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Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications

Technologies de l'information — Télécommunications et échange d'information entre systèmes — Réseaux locaux et métropolitains — Exigences spécifiques

Partie 11: Spécifications pour le contrôle d'accès au support et la couche physique

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IEEE Std 802.11i™-2003 Edition
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IEEE Std 802.11b.-1999/Cor 1-2001; and IEEE Std 802.11d.-2001)

Information technology—

Telecommunications and information exchange between systems—

Local and metropolitan area networks—
Specific requirements—

Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications

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LAN/MAN Standards Committee
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Abstract: The medium access control (MAC) and physical characteristics for wireless local area networks (LANs) are specified in this standard, which is part of a series of standards for local and metropolitan area networks. The medium access control unit in this standard is designed to support physical layer units as they may be adopted dependent on the availability of spectrum. This standard contains five physical layer units: four radio units, operating in the 2400–2500 MHz band and in the bands comprising 5.15–5.25 GHz, 5.25–5.35 GHz, and 5.725–5.825 GHz, and one baseband infrared (IR) unit. One radio unit employs the frequency-hopping spread spectrum (FHSS) technique, two employ the direct sequence spread spectrum (DSSS) technique, and another employs the orthogonal frequency division multiplexing (OFDM) technique.
Keywords: 2 GHz, 5 GHz, ad hoc network, high speed, infrared, international roaming, LAN, local area network, mobility, radio frequency, RF, wireless

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This second edition cancels and replaces the first edition (ISO/IEC 8802-11:1999), which has been technically revised. It also incorporates the amendment ISO/IEC 8802-11:1999/Amd.1:2000.

ISO/IEC 8802 consists of the following parts, under the general title *Information technology — Telecommunications and information exchange between systems — Local and metropolitan area networks — Specific requirements*:

— *Part 1: Overview of Local Area Network Standards* [Technical Report]

— *Part 2: Logical link control*

— *Part 3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specifications*

— *Part 5: Token ring access method and physical layer specifications*

— *Part 6: Distributed Queue Dual Bus (DQDB) access method and physical layer specifications*

— *Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications*



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Introduction

This introduction is not part of IEEE Std 802.11i, 2003 Edition, IEEE Standard for Information Technology—Telecommunications and Information Exchange Between Systems—Local and Metropolitan Area Networks—Specific Requirements—Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications.

IEEE Std 802.11, 2003 Edition

IEEE Std 802.11, 2003 Edition, incorporates IEEE Std 802.11, 1999 Edition; IEEE Std 802.11a-1999; IEEE Std 802.11b-1999; IEEE Std 802.11b-1999/Cor 1-2001; and IEEE Std 802.11d-2001. Minor changes have been made throughout the document.

This standard defines the protocol and compatible interconnection of data communication equipment via the air,. radio or infrared (IR), in a local area network (LAN) using the carrier sense multiple access protocol with collision avoidance (CSMA/CA) medium sharing mechanism. The medium access control (MAC) supports operation under control of an access point (AP) as well as between independent stations. The protocol includes authentication, association, and reassociation services, an optional encryption/decryption procedure,power management to reduce power consumption in mobile stations, and a point coordination function (PCF) for time-bounded transfer of data. The standard includes the definition of the management information base (MIB) using Abstract Syntax Notation 1 (ASN.1) and specifies the MAC protocol in a formal way, using the Specification and Description Language (SDL). Both ASN.1 and SDL source code are distributed with this standard.

The IR implementation of the PHY supports 1 Mbit/s data rate with an optional 2 Mbit/s extension. The radio implementations of the PHY specify frequency-hopping spread spectrum (FHSS) supporting 1 Mbit/s and optional 2 Mbit/s data rates, direct sequence spread spectrum (DSSS) supporting both 1 Mbit/s and 2 Mbit/s data rates, complementary code key (CCK) supporting both 5.5 Mbit/s and 11 Mbit/s data rates, optional packet binary convolutional code (PBCC) supporting both 5.5 Mbit/s and 11 Mbit/s data rates, and orthogonal frequency division multiplexing (OFDM) supporting 6 Mbit/s, 12 Mbit/s, and 24 Mbit/s and optional data rates of 9 Mbit/s, 18 Mbit/s, 36 Mbit/s, and 54 Mbit/s.

This standard contains state-of-the-art material. The area covered by this standard is undergoing evolution. Revisions are anticipated to this standard within the next few years to clarify existing material, to correct possible errors, and to incorporate new related material.

Conformance test methodology

An additional standards series, identified by the number 1802, has been established to identify the conformance test methodology documents for the 802 family of standards. Thus the conformance test documents for 802.3 are numbered 1802.3.

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Information technology—
Telecommunications and information exchange between systems—
Local and metropolitan area networks—
Specific requirements—

Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications

1. Overview

1.1 Scope

The scope of this standard is to develop a medium access control (MAC) and physical layer (PHY) specification for wireless connectivity for fixed, portable, and moving stations within a local area.

1.2 Purpose

The purpose of this standard is to provide wireless connectivity to automatic machinery, equipment, or stations that require rapid deployment, which may be portable or hand-held, or which may be mounted on moving vehicles within a local area. This standard also offers regulatory bodies a means of standardizing access to one or more frequency bands for the purpose of local area communication.

Specifically, this standard

— Describes the functions and services required by an IEEE 802.11™-compliant device to operate within ad hoc and infrastructure networks as well as the aspects of station mobility (transition) within those networks.
— Defines the MAC procedures to support the asynchronous MAC service data unit (MSDU) delivery services.
— Defines several PHY signaling techniques and interface functions that are controlled by the IEEE 802.11 MAC.
— Permits the operation of an IEEE 802.11-conformant device within a wireless local area network (LAN) that may coexist with multiple overlapping IEEE 802.11 wireless LANs.
— Describes the requirements and procedures to provide privacy of user information being transferred over the wireless medium (WM) and authentication of IEEE 802.11-conformant devices.

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2. Normative references

The following standards contain provisions which, through references in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards listed below.

IEEE Std 802®-1990,[1] IEEE Standards for Local and Metropolitan Area Networks: Overview and Architecture.[2] [3]

IEEE Std C95.1™-1991 (Reaff 1997), IEEE Standard Safety Levels with Respect to Human Exposure to Radio Frequency Electromagnetic Fields, 3 kHz to 300 GHz.

ISO/IEC 3166-1:1997, Codes for the representation of names of countries and their subdivisions—Part 1: Country codes.[4]

ISO/IEC 7498-1:1994, Information technology—Open Systems Interconnection—Basic Reference Model: The Basic Model.

ISO/IEC 8802-2:1998, Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Specific requirements—Part 2: Logical link control.

ISO/IEC 8824-1:1995, Information technology—Abstract Syntax Notation One (ASN.1): Specification of basic notation.

ISO/IEC 8824-2:1995, Information technology—Abstract Syntax Notation One (ASN.1): Information object specification.

ISO/IEC 8824-3:1995, Information technology—Abstract Syntax Notation One (ASN.1): Constraint specification.

ISO/IEC 8824-4:1995, Information technology—Abstract Syntax Notation One (ASN.1): Parameterization of ASN.1 specifications.

ISO/IEC 8825-1:1995, Information technology—ASN.1 encoding rules: Specification of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER).

ISO/IEC 8825-2:1996, Information technology—ASN.1 encoding rules: Specification of Packed Encoding Rules (PER).

ISO/IEC 15802-1:1995, Information technology—Telecommunications and information exchange between systems—Local and metropolitan area networks—Common specifications—Part 1: Medium Access Control (MAC) service definition.

ITU Radio Regulations, volumes 1–4.[5]

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[5]ITU-T publications are available from the International Telecommunications Union, Place des Nations, CH-1211, Geneva 20, Switzerland/Suisse (http://www.itu.int/).

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ITU-T Recommendation X.210 (11/93), Information technology—Open systems interconnection—Basic Reference Model: Conventions for the definition of OSI services (*common text with ISO/IEC*).

ITU-T Recommendation Z.100 (03/93), CCITT specification and description language (SDL).

ITU-T Recommendation Z.105 (03/95), SDL combined with ASN.1 (SDL/ASN.1).

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3. Definitions

3.1 access control: The prevention of unauthorized usage of resources.

3.2 access point (AP): Any entity that has station functionality and provides access to the distribution services, via the wireless medium (WM) for associated stations.

3.3 ad hoc network: A network composed solely of stations within mutual communication range of each other via the wireless medium (WM). An ad hoc network is typically created in a spontaneous manner. The principal distinguishing characteristic of an ad hoc network is its limited temporal and spatial extent. These limitations allow the act of creating and dissolving the ad hoc network to be sufficiently straightforward and convenient so as to be achievable by nontechnical users of the network facilities; i.e., no specialized "technical skills" are required and little or no investment of time or additional resources is required beyond the stations that are to participate in the ad hoc network. The term *ad hoc* is often used as slang to refer to an independent basic service set (IBSS).

3.4 association: The service used to establish access point/station (AP/STA) mapping and enable STA invocation of the distribution system services (DSSs).

3.5 authentication: The service used to establish the identity of one station as a member of the set of stations authorized to associate with another station.

3.6 basic service area (BSA): The conceptual area within which members of a basic service set (BSS) may communicate.

3.7 basic service set (BSS): A set of stations controlled by a single coordination function.

3.8 basic service set (BSS) basic rate set: The set of data transfer rates that all the stations in a BSS will be capable of using to receive and transmit frames from and to the wireless medium (WM). The BSS basic rate set data rates are preset for all stations in the BSS.

3.9 broadcast address: A unique multicast address that specifies all stations.

3.10 channel: An instance of medium use for the purpose of passing protocol data units (PDUs) that may be used simultaneously, in the same volume of space, with other instances of medium use (on other channels) by other instances of the same physical layer (PHY), with an acceptably low frame error ratio (FER) due to mutual interference. Some PHYs provide only one channel, whereas others provide multiple channels. Examples of channel types are as shown in the following table:

Single channel	n-channel
Narrowband radio frequency (RF) channel	Frequency division multiplexed channels
Baseband infrared (IR)	Direct sequence spread spectrum (DSSS) with code division multiple access

3.11 clear channel assessment (CCA) function: That logical function in the physical layer (PHY) that determines the current state of use of the wireless medium (WM).

3.12 confidentiality: The property of information that is not made available or disclosed to unauthorized individuals, entities, or processes.

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3.13 coordination function: The logical function that determines when a station operating within a basic service set (BSS) is permitted to transmit and may be able to receive protocol data units (PDUs) via the wireless medium (WM). The coordination function within a BSS may have one point coordination function (PCF) and will have one distributed coordination function (DCF).

3.14 coordination function pollable: A station able to (1) respond to a coordination function poll with a data frame, if such a frame is queued and able to be generated, and (2) interpret acknowledgments in frames sent to or from the point coordinator (PC).

3.15 deauthentication: The service that voids an existing authentication relationship.

3.16 directed address: *See:* **unicast frame**.

3.17 disassociation: The service that removes an existing association.

3.18 distributed coordination function (DCF): A class of coordination function where the same coordination function logic is active in every station in the basic service set (BSS) whenever the network is in operation.

3.19 distribution: The service that, by using association information, delivers medium access control (MAC) service data units (MSDUs) within the distribution system (DS).

3.20 distribution system (DS): A system used to interconnect a set of basic service sets (BSSs) and integrated local area networks (LANs) to create an extended service set (ESS).

3.21 distribution system medium (DSM): The medium or set of media used by a distribution system (DS) for communications between access points (APs) and portals of an extended service set (ESS).

3.22 distribution system service (DSS): The set of services provided by the distribution system (DS) that enable the medium access control (MAC) to transport MAC service data units (MSDUs) between stations that are not in direct communication with each other over a single instance of the wireless medium (WM). These services include transport of MSDUs between the access points (APs) of basic service sets (BSSs) within an extended service set (ESS), transport of MSDUs between portals and BSSs within an ESS, and transport of MSDUs between stations in the same BSS in cases where the MSDU has a multicast or broadcast destination address or where the destination is an individual address, but the station sending the MSDU chooses to involve DSS. DSSs are provided between pairs of IEEE 802.11 MACs.

3.23 extended rate set (ERS): The set of data transfer rates supported by a station (if any) beyond the extended service set (ESS) basic rate set. This set may include data transfer rates that will be defined in future physical layer (PHY) standards.

3.24 extended service area (ESA): The conceptual area within which members of an extended service set (ESS) may communicate. An ESA is larger than or equal to a basic service area (BSA) and may involve several basic service sets (BSSs) in overlapping, disjointed, or both configurations.

3.25 extended service set (ESS): A set of one or more interconnected basic service sets (BSSs) and integrated local area networks (LANs) that appears as a single BSS to the logical link control (LLC) layer at any station associated with one of those BSSs.

3.26 Gaussian frequency shift keying (GFSK): A modulation scheme in which the data are first filtered by a Gaussian filter in the baseband and then modulated with a simple frequency modulation.

3.27 independent basic service set (IBSS): A BSS that forms a self-contained network, and in which no access to a distribution system (DS) is available.

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3.28 infrastructure: The infrastructure includes the distribution system medium (DSM), access point (AP), and portal entities. It is also the logical location of distribution and integration service functions of an extended service set (ESS). An infrastructure contains one or more APs and zero or more portals in addition to the distribution system (DS).

3.29 integration: The service that enables delivery of medium access control (MAC) service data units (MSDUs) between the distribution system (DS) and an existing, non-IEEE 802.11 local area network (LAN) (via a portal).

3.30 medium access control (MAC) management protocol data unit (MMPDU): The unit of data exchanged between two peer MAC entities to implement the MAC management protocol.

3.31 medium access control (MAC) protocol data unit (MPDU): The unit of data exchanged between two peer MAC entities using the services of the physical layer (PHY).

3.32 medium access control (MAC) service data unit (MSDU): Information that is delivered as a unit between MAC service access points (SAPs).

3.33 minimally conformant network: An IEEE 802.11 network in which two stations in a single basic service area (BSA) are conformant with IEEE Std 802.11, 2003 Edition.

3.34 mobile station: A type of station that uses network communications while in motion.

3.35 multicast: A medium access control (MAC) address that has the group bit set. A multicast MAC service data unit (MSDU) is one with a multicast destination address. A multicast MAC protocol data unit (MPDU) or control frame is one with a multicast receiver address.

3.36 network allocation vector (NAV): An indicator, maintained by each station, of time periods when transmission onto the wireless medium (WM) will not be initiated by the station whether or not the station's clear channel assessment (CCA) function senses that the WM is busy.

3.37 point coordination function (PCF): A class of possible coordination functions in which the coordination function logic is active in only one station in a basic service set (BSS) at any given time that the network is in operation.

3.38 portable station: A type of station that may be moved from location to location, but that only uses network communications while at a fixed location.

3.39 portal: The logical point at which medium access control (MAC) service data units (MSDUs) from a non-IEEE 802.11 local area network (LAN) enter the distribution system (DS) of an extended service set (ESS).

3.40 privacy: The service used to prevent the content of messages from being read by other than the intended recipients.

3.41 reassociation: The service that enables an established association [between access point (AP) and station (STA)] to be transferred from one AP to another (or the same) AP.

3.42 station (STA): Any device that contains an IEEE 802.11-conformant medium access control (MAC) and physical layer (PHY) interface to the wireless medium (WM).

3.43 station basic rate: A data transfer rate belonging to the extended service set (ESS) basic rate set that is used by a station for specific transmissions. The station basic rate may change dynamically as frequently as

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each medium access control (MAC) protocol data unit (MPDU) transmission attempt, based on local considerations at that station.

3.44 station service (SS): The set of services that support transport of medium access control (MAC) service data units (MSDUs) between stations within a basic service set (BSS).

3.45 time unit (TU): A measurement of time equal to 1024 μs.

3.46 unauthorized disclosure: The process of making information available to unauthorized individuals, entities, or processes.

3.47 unauthorized resource use: Use of a resource not consistent with the defined security policy.

3.48 unicast frame: A frame that is addressed to a single recipient, not a broadcast or multicast frame. *Syn:* directed address.

3.49 wired equivalent privacy (WEP): The optional cryptographic confidentiality algorithm specified by IEEE 802.11 used to provide data confidentiality that is subjectively equivalent to the confidentiality of a wired local area network (LAN) medium that does not employ cryptographic techniques to enhance privacy.

3.50 wireless medium (WM): The medium used to implement the transfer of protocol data units (PDUs) between peer physical layer (PHY) entities of a wireless local area network (LAN).

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4. Abbreviations and acronyms

ACK	acknowledgment
AID	association identifier
AP	access point
ASN.1	Abstract Syntax Notation One
ATIM	announcement traffic indication message
BCC	binary convolutional code
BPSK	binary phase shift keying
BSA	basic service area
BSS	basic service set
BSSID	basic service set identification
BT	bit time
CCA	clear channel assessment
CCK	complementary code keying
CF	contention free
CFP	contention-free period
C-MPDU	coded MPDU
C-PSDU	coded PSDU
CP	contention period
CRC	cyclic redundancy code
CS	carrier sense
CSMA/CA	carrier sense multiple access with collision avoidance
CTS	clear to send
CW	contention window
DA	destination address
DBPSK	differential binary phase shift keying
DCF	distributed coordination function
DCLA	dc level adjustment
DIFS	distributed (coordination function) interframe space
DLL	data link layer
Dp	desensitization
DQPSK	differential quadrature phase shift keying
DR	data rate
DS	distribution system
DSM	distribution system medium
DSS	distribution system service
DSSS	direct sequence spread spectrum
DTIM	delivery traffic indication message
ED	energy detection
EHCC	extended hyperbolic congruence code
EIFS	extended interframe space
EIRP	equivalent isotropically radiated power
ERS	extended rate set
ESA	extended service area
ESS	extended service set

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FC	frame control
FCS	frame check sequence
FER	frame error ratio
FFT	Fast Fourier Transform
FH	frequency hopping
FHSS	frequency-hopping spread spectrum
FIFO	first in first out
FOV	field of view
GFSK	Gaussian frequency shift key or keying
GI	guard interval
HCC	hyperbolic congruence code
HEC	header error check
HR/DSSS	High Rate direct sequence spread spectrum using the Long Preamble and header
HR/DSSS/short	High Rate direct sequence spread spectrum using the optional Short Preamble and header mode
HR/DSSS/PBCC	High Rate direct sequence spread spectrum using the optional packet binary convolutional coding mode and the Long Preamble and header
HR/DSSS/PBCC/short	High Rate direct sequence spread spectrum using the optional packet binary convolutional coding mode and the optional Short Preamble and header
IBSS	independent basic service set
ICV	integrity check value
IFFT	inverse Fast Fourier Transform
IFS	interframe space
IMp	intermodulation protection
IR	infrared
IrDA	infrared data association
ISM	industrial, scientific, and medical
IUT	implementation under test
IV	initialization vector
LAN	local area network
LED	light-emitting display
LLC	logical link control
LME	layer management entity
LRC	long retry count
LSB	least significant bit
MAC	medium access control
MIB	management information base
MLME	MAC sublayer management entity
MMPDU	MAC management protocol data unit
MPDU	MAC protocol data unit
MSB	most significant bit
MSDU	MAC service data unit
N/A	not applicable
NAV	network allocation vector
OFDM	orthogonal frequency division multiplexing
OSI	Open System Interconnection
PBCC	packet binary convolutional code

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PC	point coordinator
PCF	point coordination function
PDU	protocol data unit
PER	packet error rate
PHY	physical layer
PHYCS	PHY carrier sense
PHYED	PHY energy detection
PICS	protocol implementation conformance statement
PIFS	point (coordination function) interframe space
PLCP	physical layer convergence procedure
PLME	physical layer management entity
PLW	PSDU length word
PMD	physical medium dependent
PN	pseudonoise (code sequence)
PPDU	PLCP protocol data unit
PPM	pulse position modulation
PRN	pseudo-random number
PRNG	pseudo-random number generator
PS	power save (mode)
PSDU	PLCP service data unit
PSF	PLCP Signaling field
QAM	quadrature amplitude modulation
QPSK	quadrature phase shift keying
RA	receiver address or receiving station address
RF	radio frequency
RSSI	receive signal strength indicator
RTS	request to send
RX	receive or receiver
SA	source address
SAP	service access point
SDL	specification and description language
SDU	service data unit
SFD	start frame delimiter
SIFS	short interframe space
SLRC	station long retry count
SME	station management entity
SMT	station management
SQ	signal quality (PN code correlation strength)
SRC	short retry count
SS	station service
SSID	service set identifier
SSRC	station short retry count
STA	station
SYNC	synchronization
TA	transmitter address or transmitting station address
TBTT	target beacon transmission time

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TIM	traffic indication map
TSF	timing synchronization function
TU	time unit
TX	transmit or transmitter
TXE	transmit enable
UCT	unconditional transition
U-NII	unlicensed national information infrastructure
WLAN	wireless LAN
WDS	wireless distribution system
WEP	wired equivalent privacy
WM	wireless medium

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5. General description

5.1 General description of the architecture

This subclause presents the concepts and terminology used within this standard (referred to throughout the text as IEEE 802.11). Specific terms are defined in Clause 3. Illustrations convey key IEEE 802.11 concepts and the interrelationships of the architectural components. IEEE 802.11 uses an architecture to describe functional components of an IEEE 802.11 LAN. The architectural descriptions are not intended to represent any specific physical implementation of IEEE 802.11.

5.1.1 How wireless LAN systems are different

Wireless networks have fundamental characteristics that make them significantly different from traditional wired LANs. Some countries impose specific requirements for radio equipment in addition to those specified in this standard.

5.1.1.1 Destination address does not equal destination location

In wired LANs, an address is equivalent to a physical location. This is implicitly assumed in the design of wired LANs. In IEEE 802.11, the addressable unit is a station (STA). The STA is a message destination, but not (in general) a fixed location.

5.1.1.2 The media impact the design

The PHYs used in IEEE 802.11 are fundamentally different from wired media. Thus IEEE 802.11 PHYs

a) Use a medium that has neither absolute nor readily observable boundaries outside of which stations with conformant PHY transceivers are known to be unable to receive network frames.
b) Are unprotected from outside signals.
c) Communicate over a medium significantly less reliable than wired PHYs.
d) Have dynamic topologies.
e) Lack full connectivity, and therefore the assumption normally made that every STA can hear every other STA is invalid (i.e., STAs may be “hidden” from each other).
f) Have time-varying and asymmetric propagation properties.

Because of limitations on wireless PHY ranges, wireless LANs intended to cover reasonable geographic distances may be built from basic coverage building blocks.

5.1.1.3 The impact of handling mobile stations

One of the requirements of IEEE 802.11 is to handle *mobile* as well as *portable* stations. A *portable* station is one that is moved from location to location, but that is only used while at a fixed location. *Mobile* stations actually access the LAN while in motion.

For technical reasons, it is not sufficient to handle only portable stations. Propagation effects blur the distinction between portable and mobile stations; stationary stations often appear to be mobile due to propagation effects.

Another aspect of mobile stations is that they may often be battery powered. Hence power management is an important consideration. For example, it cannot be presumed that a station’s receiver will always be powered on.

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5.1.1.4 Interaction with other IEEE 802 layers

IEEE 802.11 is required to appear to higher layers [logical link control (LLC)] as a current style IEEE 802 LAN. This requires that the IEEE 802.11 network handle station mobility within the MAC sublayer. To meet reliability assumptions (that LLC makes about lower layers), it is necessary for IEEE 802.11 to incorporate functionality that is untraditional for MAC sublayers.

5.2 Components of the IEEE 802.11 architecture

The IEEE 802.11 architecture consists of several components that interact to provide a wireless LAN that supports station mobility transparently to upper layers.

The basic service set (BSS) is the basic building block of an IEEE 802.11 LAN. Figure 1 shows two BSSs, each of which has two stations that are members of the BSS.

It is useful to think of the ovals used to depict a BSS as the coverage area within which the member stations of the BSS may remain in communication. (The concept of area, while not precise, is often good enough.) If a station moves out of its BSS, it can no longer directly communicate with other members of the BSS.

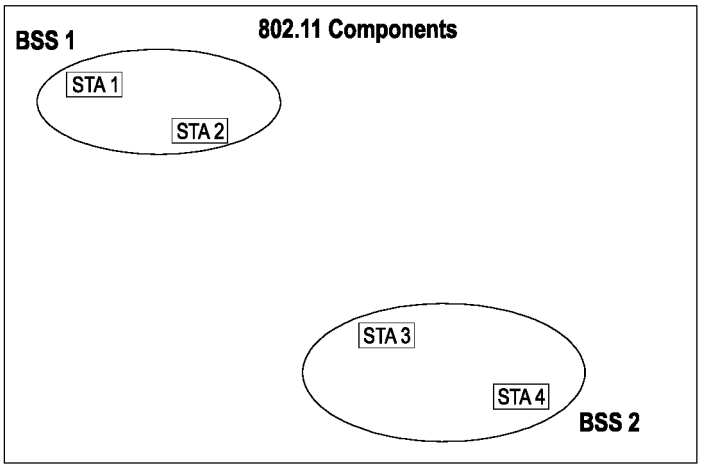

Figure 1—BSSs

5.2.1 The independent BSS (IBSS) as an ad hoc network

The IBSS is the most basic type of IEEE 802.11 LAN. A minimum IEEE 802.11 LAN may consist of only two stations.

Figure 1 shows two IBSSs. This mode of operation is possible when IEEE 802.11 stations are able to communicate directly. Because this type of IEEE 802.11 LAN is often formed without pre-planning, for only as long as the LAN is needed, this type of operation is often referred to as an *ad hoc network*.

5.2.1.1 STA to BSS association is dynamic

The association between a STA and a BSS is dynamic (STAs turn on, turn off, come within range, and go out of range). To become a member of an infrastructure BSS, a station shall become "associated." These associations are dynamic and involve the use of the distribution system service (DSS), which is described in 5.3.2.

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5.2.2 Distribution system (DS) concepts

PHY limitations determine the direct station-to-station distance that may be supported. For some networks this distance is sufficient; for other networks, increased coverage is required.

Instead of existing independently, a BSS may also form a component of an extended form of network that is built with multiple BSSs. The architectural component used to interconnect BSSs is the DS.

IEEE 802.11 logically separates the WM from the distribution system medium (DSM). Each logical medium is used for different purposes, by a different component of the architecture. The IEEE 802.11 definitions neither preclude, nor demand, that the multiple media be either the same or different.

Recognizing that the multiple media are *logically* different is key to understanding the flexibility of the architecture. The IEEE 802.11 LAN architecture is specified independently of the physical characteristics of any specific implementation.

The DS enables mobile device support by providing the logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs.

An access point (AP) is a STA that provides access to the DS by providing DS services in addition to acting as a STA.

Figure 2 adds the DS and AP components to the IEEE 802.11 architecture picture.

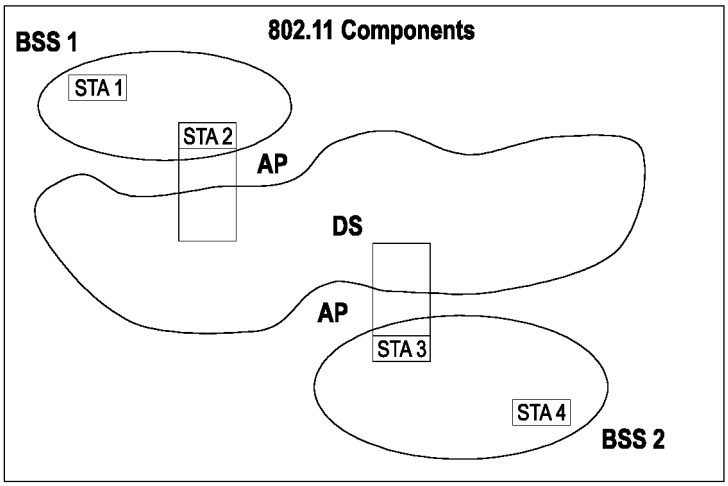

Figure 2—DSs and APs

Data move between a BSS and the DS via an AP. Note that all APs are also STAs; thus they are addressable entities. The addresses used by an AP for communication on the WM and on the DSM are not necessarily the same.

5.2.2.1 Extended service set (ESS): The large coverage network

The DS and BSSs allow IEEE 802.11 to create a wireless network of arbitrary size and complexity. IEEE 802.11 refers to this type of network as the ESS network.

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The key concept is that the ESS network appears the same to an LLC layer as an IBSS network. Stations within an ESS may communicate and mobile stations may move from one BSS to another (within the same ESS) transparently to LLC.

Nothing is assumed by IEEE 802.11 about the relative physical locations of the BSSs in Figure 3.

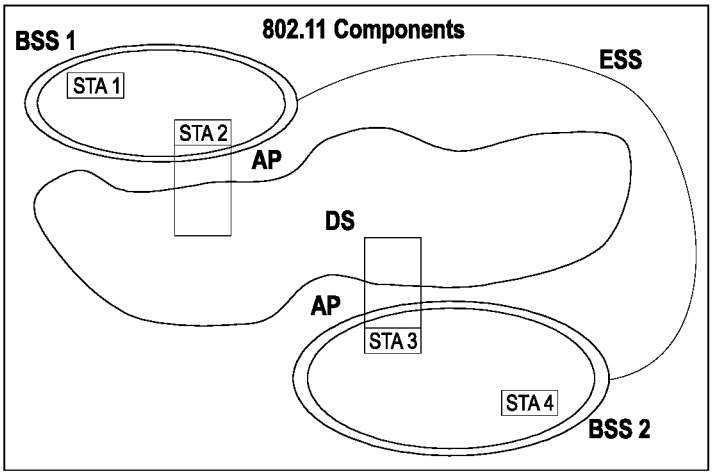

Figure 3—ESS

All of the following are possible:

a) The BSSs may partially overlap. This is commonly used to arrange contiguous coverage within a physical volume.
b) The BSSs could be physically disjointed. Logically there is no limit to the distance between BSSs.
c) The BSSs may be physically collocated. This may be done to provide redundancy.
d) One (or more) IBSS or ESS networks may be physically present in the same space as one (or more) ESS networks. This may arise for a number of reasons. Two of the most common are when an ad hoc network is operating in a location that also has an ESS network, and when physically overlapping IEEE 802.11 networks have been set up by different organizations.

5.2.3 Area concepts

For wireless PHYs, well-defined coverage areas simply do not exist. Propagation characteristics are dynamic and unpredictable. Small changes in position or direction may result in dramatic differences in signal strength. Similar effects occur whether a STA is stationary or mobile (as moving objects may impact station-to-station propagation).

Figure 4 shows a signal strength map for a simple square room with a standard metal desk and an open doorway. Figure 4 is a static snapshot; the propagation patterns change dynamically as stations and objects in the environment move. In Figure 4 the dark (solid) blocks in the lower left are a metal desk and there is a doorway at the top right of the figure. The figure indicates relative differences in field strength with different intensities and indicates the variability of field strength even in a static environment.

While the architecture diagrams show sharp boundaries for BSSs, this is an artifact of the pictorial representation, not a physical reality. Because dynamic three-dimensional field strength pictures are difficult to draw, well-defined shapes are used by IEEE 802.11 architectural diagrams to represent the coverage of a BSS.

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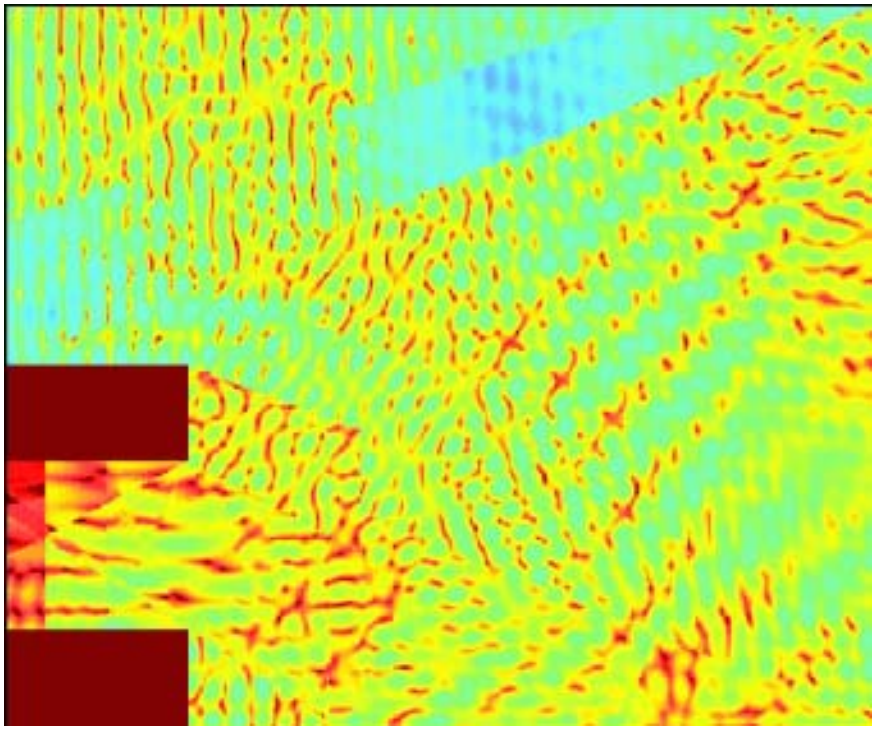

Figure 4—A representative signal intensity map

Further description difficulties arise when attempting to describe collocated coverage areas. Consider Figure 5, in which STA 6 could belong to BSS 2 or BSS 3.

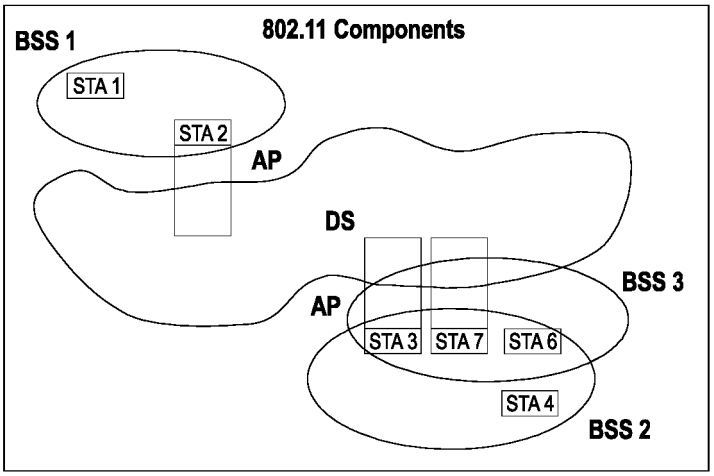

Figure 5—Collocated coverage areas

While the concept of sets of stations is correct, it is often convenient to talk about areas. For many topics the concept of area is sufficient. *Volume* is a more precise term than area, though still not technically correct. For historical reasons and convenience, this standard uses the common term *area*.

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5.2.4 Integration with wired LANs

To integrate the IEEE 802.11 architecture with a traditional wired LAN, a final *logical* architectural component is introduced—a *portal*.

A portal is the logical point at which MSDUs from an integrated non-IEEE 802.11 LAN enter the IEEE 802.11 DS. For example, a portal is shown in Figure 6 connecting to a wired IEEE 802 LAN.

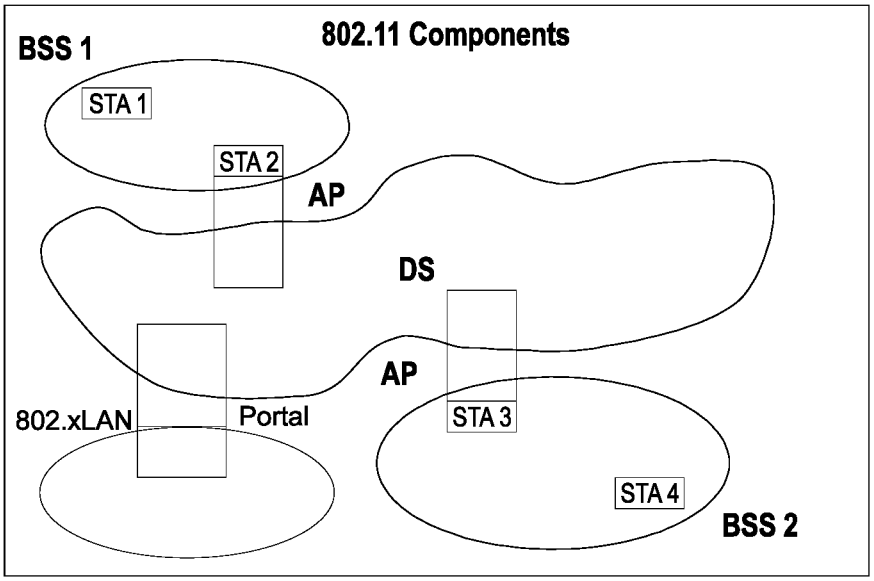

Figure 6—Connecting to other IEEE 802 LANs

All data from non-IEEE 802.11 LANs enter the IEEE 802.11 architecture via a portal. The portal provides logical integration between the IEEE 802.11 architecture and existing wired LANs. It is possible for one device to offer both the functions of an AP and a portal; this could be the case when a DS is implemented from IEEE 802 LAN components.

In IEEE 802.11, the ESS architecture (APs and the DS) provides traffic segmentation and range extension. Logical connections between IEEE 802.11 and other LANs are via the portal. Portals connect between the DSM and the LAN medium that is to be integrated.

5.3 Logical service interfaces

The IEEE 802.11 architecture allows for the possibility that the DS may not be identical to an existing wired LAN. A DS may be created from many different technologies including current IEEE 802 wired LANs. IEEE 802.11 does not constrain the DS to be either data link or network layer based. Nor does IEEE 802.11 constrain a DS to be either centralized or distributed in nature.

IEEE 802.11 explicitly does not specify the details of DS implementations. Instead, IEEE 802.11 specifies *services*. The services are associated with different components of the architecture. There are two categories of IEEE 802.11 service—the station service (SS) and the DSS. Both categories of service are used by the IEEE 802.11 MAC sublayer.

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The complete set of IEEE 802.11 architectural services are as follows:

a) Authentication
b) Association
c) Deauthentication
d) Disassociation
e) Distribution
f) Integration
g) Privacy
h) Reassociation
i) MSDU delivery

This set of services is divided into two groups: those that are part of every STA, and those that are part of a DS.

5.3.1 SS

The service provided by stations is known as the SS.

The SS is present in every IEEE 802.11 station (including APs, as APs include station functionality). The SS is specified for use by MAC sublayer entities. All conformant stations provide SS.

The SS is as follows:

a) Authentication
b) Deauthentication
c) Privacy
d) MSDU delivery

5.3.2 DSS

The service provided by the DS is known as the DSS.

These services are represented in the IEEE 802.11 architecture by arrows within the APs, indicating that the services are used to cross media and address space logical boundaries. This is the convenient place to show the services in the picture. The physical embodiment of various services may or may not be within a physical AP.

The DSSs are provided by the DS. They are accessed via a STA that also provides DSSs. A STA that is providing access to DSS is an AP.

The DSSs are as follows:

a) Association
b) Disassociation
c) Distribution
d) Integration
e) Reassociation

DSSs are specified for use by MAC sublayer entities.

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Figure 7 combines the components from previous figures with both types of services to show the complete IEEE 802.11 architecture.

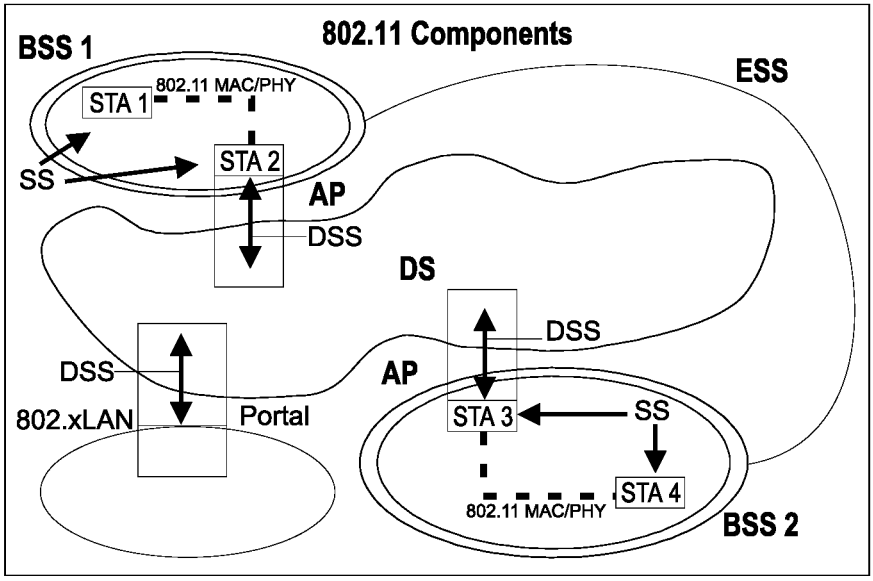

Figure 7—Complete IEEE 802.11 architecture

5.3.3 Multiple logical address spaces

Just as the IEEE 802.11 architecture allows for the possibility that the WM, DSM, and an integrated wired LAN may all be different physical media, it also allows for the possibility that each of these components may be operating within different address spaces. IEEE 802.11 only uses and specifies the use of the WM address space.

Each IEEE 802.11 PHY operates in a single medium—the WM. The IEEE 802.11 MAC operates in a single address space. MAC addresses are used on the WM in the IEEE 802.11 architecture. Therefore, it is unnecessary for the standard to explicitly specify that its addresses are "WM addresses." This is assumed throughout this standard.

IEEE 802.11 has chosen to use the IEEE 802 48-bit address space (see 7.1.3.3.1). Thus IEEE 802.11 addresses are compatible with the address space used by the IEEE 802 LAN family.

The IEEE 802.11 choice of address space implies that for many instantiations of the IEEE 802.11 architecture, the wired LAN MAC address space and the IEEE 802.11 MAC address space may be the same. In those situations where a DS that uses MAC level IEEE 802 addressing is appropriate, all three of the logical address spaces used within a system could be identical. While this is a common case, it is not the only combination allowed by the architecture. The IEEE 802.11 architecture allows for all three logical address spaces to be distinct.

A multiple address space example is one in which the DS implementation uses network layer addressing. In this case, the WM address space and the DS address space would be different.

The ability of the architecture to handle multiple logical media and address spaces is key to the ability of IEEE 802.11 to be independent of the DS implementation and to interface cleanly with network layer mobility approaches. The implementation of the DS is unspecified and is beyond the scope of this standard.

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5.4 Overview of the services

There are nine services specified by IEEE 802.11. Six of the services are used to support MSDU delivery between STAs. Three of the services are used to control IEEE 802.11 LAN access and confidentiality.

This subclause presents the services, an overview of how each service is used, and a description of how each service relates to other services and the IEEE 802.11 architecture. The services are presented in an order designed to help build an understanding of the operation of an IEEE 802.11 ESS network. As a result, the SSs and DSSs are intermixed in order (rather than being grouped by category).

Each of the services is supported by one or more MAC frame types. Some of the services are supported by MAC management messages and some by MAC data messages. All of the messages gain access to the WM via the IEEE 802.11 MAC sublayer medium access method specified in Clause 9.

The IEEE 802.11 MAC sublayer uses three types of messages—*data*, *management*, and *control* (see Clause 7). The data messages are handled via the MAC data service path.

MAC management messages are used to support the IEEE 802.11 services and are handled via the MAC management service data path.

MAC control messages are used to support the delivery of IEEE 802.11 data and management messages.

The examples here assume an ESS network environment. The differences between the ESS and the IBSS network environments are discussed separately in 5.6.

5.4.1 Distribution of messages within a DS

5.4.1.1 Distribution

This is the primary service used by IEEE 802.11 STAs. It is conceptually invoked by every data message to or from an IEEE 802.11 STA operating in an ESS (when the frame is sent via the DS). Distribution is via a DSS.

Refer to the ESS network in Figure 7 and consider a data message being sent from STA 1 to STA 4. The message is sent from STA 1 and received by STA 2 (the “input” AP). The AP gives the message to the distribution service of the DS. It is the job of the distribution service to deliver the message within the DS in such a way that it arrives at the appropriate DS destination for the intended recipient. In this example, the message is distributed to STA 3 (the “output” AP) and STA 3 accesses the WM to send the message to STA 4 (the intended destination).

How the message is distributed within the DS is not specified by IEEE 802.11. All IEEE 802.11 is required to do is to provide the DS with enough information for the DS to be able to determine the “output” point that corresponds to the desired recipient. The necessary information is provided to the DS by the three association related services (association, reassociation, and disassociation).

The previous example was a case in which the AP that invoked the distribution service was different from the AP that received the distributed message. If the message had been intended for a station that was a member of the same BSS as the sending station, then the “input” and “output” APs for the message would have been the same.

In either example, the distribution service was logically invoked. Whether the message actually had to traverse the physical DSM or not is a DS implementation matter and is not specified by this standard.

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While IEEE 802.11 does not specify DS implementations, it does recognize and support the use of the WM as the DSM. This is specifically supported by the IEEE 802.11 frame formats. (Refer to Clause 7 for details.)

5.4.1.2 Integration

If the distribution service determines that the intended recipient of a message is a member of an integrated LAN, the "output" point of the DS would be a portal instead of an AP.

Messages that are distributed to a portal cause the DS to invoke the Integration function (conceptually after the distribution service). The Integration function is responsible for accomplishing whatever is needed to deliver a message from the DSM to the integrated LAN media (including any required media or address space translations). Integration is a DSS.

Messages received from an integrated LAN (via a portal) by the DS for an IEEE 802.11 STA will invoke the Integration function before the message is distributed by the distribution service.

The details of an Integration function are dependent on a specific DS implementation and are outside the scope of this standard.

5.4.2 Services that support the distribution service

The primary purpose of a MAC sublayer is to transfer MSDUs between MAC sublayer entities. The information required for the distribution service to operate is provided by the association services. Before a data message can be handled by the distribution service, a STA shall be "associated."

To understand the concept of association, it is necessary first to understand the concept of mobility.

5.4.2.1 Mobility types

The three transition types of significance to this standard that describe the mobility of stations within a network are as follows:

a) ***No-transition:*** In this type, two subclasses that are usually indistinguishable are identified:
   1) Static—no motion.
   2) Local movement—movement within the PHY range of the communicating STAs [i.e., movement within a basic service area (BSA)].
b) ***BSS-transition:*** This type is defined as a station movement from one BSS in one ESS to another BSS within the same ESS.
c) ***ESS-transition:*** This type is defined as station movement from a BSS in one ESS to a BSS in a different ESS. This case is supported only in the sense that the STA may move. Maintenance of upper-layer connections cannot be guaranteed by IEEE 802.11; in fact, disruption of service is likely to occur.

The different association services support the different categories of mobility.

5.4.2.2 Association

To deliver a message within a DS, the distribution service needs to know which AP to access for the given IEEE 802.11 STA. This information is provided to the DS by the concept of association. Association is necessary, but not sufficient, to support BSS-transition mobility. Association is sufficient to support no-transition mobility. Association is a DSS.

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Before a STA is allowed to send a data message via an AP, it shall first become associated with the AP. The act of becoming associated invokes the association service, which provides the STA to AP mapping to the DS. The DS uses this information to accomplish its message distribution service. How the information provided by the association service is stored and managed within the DS is not specified by this standard.

At any given instant, a STA may be associated with no more than one AP. This ensures that the DS may determine a unique answer to the question, “Which AP is serving STA X?” Once an association is completed, a STA may make full use of a DS (via the AP) to communicate. Association is always initiated by the mobile STA, not the AP.

An AP may be associated with many STAs at one time.

A STA learns what APs are present and then requests to establish an association by invoking the association service. For details of how a station learns about what APs are present, see 11.1.3.

5.4.2.3 Reassociation

Association is sufficient for no-transition message delivery between IEEE 802.11 stations. Additional functionality is needed to support BSS-transition mobility. The additional required functionality is provided by the reassociation service. Reassociation is a DSS.

The reassociation service is invoked to “move” a current association from one AP to another. This keeps the DS informed of the current mapping between AP and STA as the station moves from BSS to BSS within an ESS. Reassociation also enables changing association attributes of an established association while the STA remains associated with the same AP. Reassociation is always initiated by the mobile STA.

5.4.2.4 Disassociation

The disassociation service is invoked when an existing association is to be terminated. Disassociation is a DSS.

In an ESS, this tells the DS to void existing association information. Attempts to send messages via the DS to a disassociated STA will be unsuccessful.

The disassociation service may be invoked by either party to an association (non-AP STA or AP). Disassociation is a notification, not a request. Disassociation cannot be refused by either party to the association.

APs may need to disassociate STAs to enable the AP to be removed from a network for service or for other reasons.

STAs shall attempt to disassociate when they leave a network. However, the MAC protocol does not depend on STAs invoking the disassociation service. (MAC management is designed to accommodate loss of an associated STA.)

5.4.3 Access and confidentiality control services

Two services are required for IEEE 802.11 to provide functionality equivalent to that which is inherent to wired LANs. The design of wired LANs assumes the physical attributes of wire. In particular, wired LAN design assumes the physically closed and controlled nature of wired media. The physically open medium nature of an IEEE 802.11 LAN violates those assumptions.

Two services are provided to bring the IEEE 802.11 functionality in line with wired LAN assumptions; authentication and privacy. Authentication is used instead of the wired media physical connection. Privacy is used to provide the confidential aspects of closed wired media.

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5.4.3.1 Authentication

In wired LANs, physical security can be used to prevent unauthorized access. This is impractical in wireless LANs because they have a medium without precise bounds.

IEEE 802.11 provides the ability to control LAN access via the authentication service. This service is used by all stations to establish their identity to stations with which they will communicate. This is true for both ESS and IBSS networks. If a mutually acceptable level of authentication has not been established between two stations, an association shall not be established. Authentication is an SS.

IEEE 802.11 supports several authentication processes. The IEEE 802.11 authentication mechanism also allows expansion of the supported authentication schemes. IEEE 802.11 does not mandate the use of any particular authentication scheme.

IEEE 802.11 provides link-level authentication between IEEE 802.11 STAs. IEEE 802.11 does not provide either end-to-end (message origin to message destination) or user-to-user authentication. IEEE 802.11 authentication is used simply to bring the wireless link up to the assumed physical standards of a wired link. (This use of authentication is independent of any authentication process that may be used in higher levels of a network protocol stack.) If authentication other than that described here is desired, it is recommended that IEEE Std 802.10™-1998 [B9][6] be implemented.

If desired, an IEEE 802.11 network may be operated using Open System authentication (see 8.1.1). This may violate implicit assumptions made by higher network layers. In an Open System, any station may become authenticated.

IEEE 802.11 also supports Shared Key authentication. Use of this authentication mechanism requires implementation of the wired equivalent privacy (WEP) option (see 8.2). In a Shared Key authentication system, identity is demonstrated by knowledge of a shared, secret, WEP encryption key.

Management information base (MIB) functions are provided to support the standardized authentication schemes.

IEEE 802.11 requires mutually acceptable, successful, authentication.

A STA may be authenticated with many other STAs at any given instant.

5.4.3.1.1 Preauthentication

Because the authentication process could be time-consuming (depending on the authentication protocol in use), the authentication service can be invoked independently of the association service.

Preauthentication is typically done by a STA while it is already associated with an AP (with which it previously authenticated). IEEE 802.11 does not require that STAs preauthenticate with APs. However, authentication is required before an association can be established.

If the authentication is left until reassociation time, this may impact the speed with which a STA can reassociate between APs, limiting BSS-transition mobility performance. The use of preauthentication takes the authentication service overhead out of the time-critical reassociation process.

[6]The numbers in brackets correspond to the numbers of the bibliography in Annex E.

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5.4.3.2 Deauthentication

The deauthentication service is invoked when an existing authentication is to be terminated. Deauthentication is an SS.

In an ESS, because authentication is a prerequisite for association, the act of deauthentication shall cause the station to be disassociated. The deauthentication service may be invoked by either authenticated party (non-AP STA or AP). Deauthentication is not a request; it is a notification. Deauthentication shall not be refused by either party. When an AP sends a deauthentication notice to an associated STA, the association shall also be terminated.

5.4.3.3 Privacy

In a wired LAN, only those stations physically connected to the wire may hear LAN traffic. With a wireless shared medium, this is not the case. Any IEEE 802.11-compliant STA may hear all like-PHY IEEE 802.11 traffic that is within range. Thus the connection of a single wireless link (without privacy) to an existing wired LAN may seriously degrade the security level of the wired LAN.

To bring the functionality of the wireless LAN up to the level implicit in wired LAN design, IEEE 802.11 provides the ability to encrypt the contents of messages. This functionality is provided by the privacy service. Privacy is an SS.

IEEE 802.11 specifies an optional privacy algorithm, WEP, that is designed to satisfy the goal of wired LAN "equivalent" privacy. The algorithm is not designed for ultimate security but rather to be "at least as secure as a wire." See Clause 8 for more details.

IEEE 802.11 uses the WEP mechanism (see Clause 8) to perform the actual encryption of messages. MIB functions are provided to support WEP.

Note that privacy may only be invoked for data frames and some Authentication Management frames. All stations initially start "in the clear" in order to set up the authentication and privacy services.

The default privacy state for all IEEE 802.11 STAs is "in the clear." If the privacy service is not invoked, all messages shall be sent unencrypted. If this default is not acceptable to one party or the other, data frames shall not be successfully communicated between the LLC entities. Unencrypted data frames received at a station configured for mandatory privacy, as well as encrypted data frames using a key not available at the receiving station, are discarded without an indication to LLC (or without indication to distribution services in the case of "To DS" frames received at an AP). These frames are acknowledged on the WM [if received without frame check sequence (FCS) error] to avoid wasting WM bandwidth on retries.

5.5 Relationships between services

A STA keeps two state variables for each STA with which direct communication via the WM is needed:

— *Authentication state:* The values are unauthenticated and authenticated.
— *Association state:* The values are unassociated and associated.

These two variables create three local states for each remote STA:

— *State 1:* Initial start state, unauthenticated, unassociated.
— *State 2:* Authenticated, not associated.
— *State 3:* Authenticated and associated.

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The relationships between these station state variables and the services are given in Figure 8.

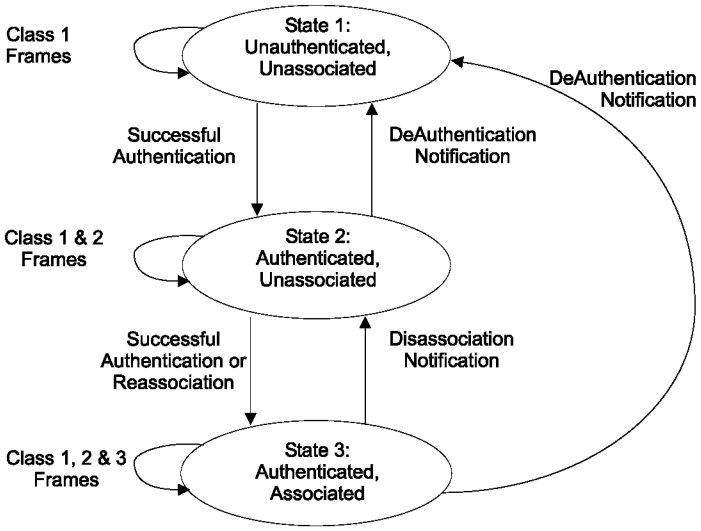

Figure 8—Relationship between state variables and services

The current state existing between the source and destination station determines the IEEE 802.11 frame types that may be exchanged between that pair of STAs (see Clause 7). The state of the sending STA given by Figure 8 is with respect to the intended receiving STA. The allowed frame types are grouped into classes and the classes correspond to the station state. In State 1, only Class 1 frames are allowed. In State 2, either Class 1 or Class 2 frames are allowed. In State 3, all frames are allowed (Classes 1, 2, and 3). The frame classes are defined as follows:

a) Class 1 frames (permitted from within States 1, 2, and 3):
   1) Control frames
      i) Request to send (RTS)
      ii) Clear to send (CTS)
      iii) Acknowledgment (ACK)
      iv) Contention-Free (CF)-End+ACK
      v) CF-End
   2) Management frames
      i) Probe request/response
      ii) Beacon
      iii) Authentication: Successful authentication enables a STA to exchange Class 2 frames. Unsuccessful authentication leaves the STA in State 1.
      iv) Deauthentication: Deauthentication notification when in State 2 or State 3 changes the STA's state to State 1. The STA shall become authenticated again prior to sending Class 2 frames.
      v) Announcement traffic indication message (ATIM)
   3) Data frames
      i) Data: Data frames with frame control (FC) bits "To DS" and "From DS" both false.
b) Class 2 frames (if and only if authenticated; allowed from within States 2 and 3 only):
   1) Management frames:
      i) Association request/response
         — Successful association enables Class 3 frames.
         — Unsuccessful association leaves STA in State 2.

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ii) Reassociation request/response
— Successful reassociation enables Class 3 frames.
— Unsuccessful reassociation leaves the STA in State 2 (with respect to the STA that was sent the reassociation message). Reassociation frames shall only be sent if the sending STA is already associated in the same ESS.

iii) Disassociation
— Disassociation notification when in State 3 changes a STA's state to State 2. This STA shall become associated again if it wishes to utilize the DS.

If STA A receives a Class 2 frame with a unicast address in the Address 1 field from STA B that is not authenticated with STA A, STA A shall send a deauthentication frame to STA B.

c) Class 3 frames (if and only if associated; allowed only from within State 3):
1) Data frames
— Data subtypes: Data frames allowed. That is, either the "To DS" or "From DS" FC bits may be set to true to utilize DSSs.
2) Management frames
— Deauthentication: Deauthentication notification when in State 3 implies disassociation as well, changing the STA's state from 3 to 1. The STA shall become authenticated again prior to another association.
3) Control frames
— Power save (PS)-Poll

If STA A receives a Class 3 frame with a unicast address in the Address 1 field from STA B that is authenticated but not associated with STA A, STA A shall send a disassociation frame to STA B.

If STA A receives a Class 3 frame with a unicast address in the Address 1 field from STA B that is not authenticated with STA A, STA A shall send a deauthentication frame to STA B.

(The use of the word "receive" in this subclause refers to a frame that meets all of the filtering criteria specified in Clause 8 and Clause 9.)

5.6 Differences between ESS and IBSS LANs

In 5.2.1 the concept of the IBSS LAN was introduced. It was noted that an IBSS is often used to support an ad hoc network. In an IBSS network, a STA communicates directly with one or more other STAs.

Consider the full IEEE 802.11 architecture as shown in Figure 9.

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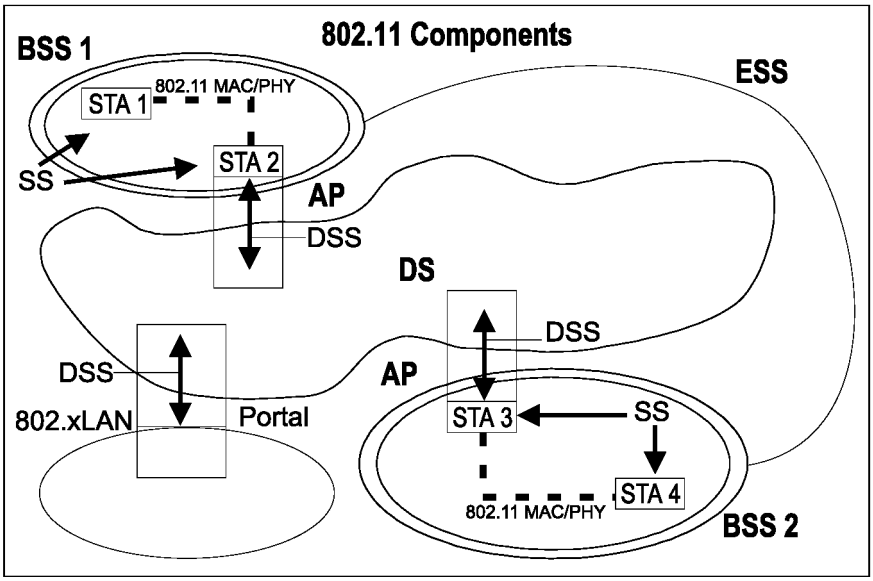

Figure 9—IEEE 802.11 architecture (again)

An IBSS consists of STAs that are directly connected. Thus there is (by definition) only one BSS. Further, because there is no physical DS, there cannot be a portal, an integrated wired LAN, or the DSSs. The logical picture reduces to Figure 10.

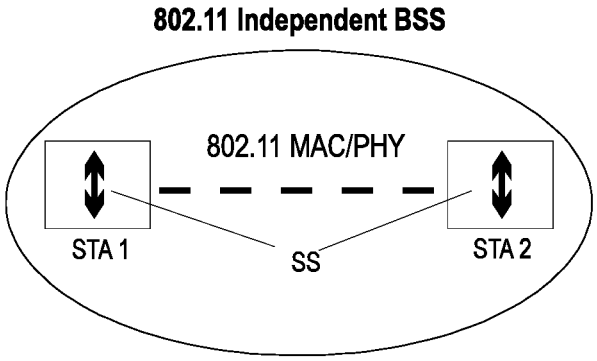

Figure 10—Logical architecture of an IBSS

Only the minimum two stations are shown in Figure 10. An IBSS may have an arbitrary number of members. In an IBSS, only Class 1 and Class 2 frames are allowed because there is no DS in an IBSS.

The services that apply to an IBSS are the SSs.

5.7 Message information contents that support the services

Each service is supported by one or more IEEE 802.11 messages. Information items are given by name; for corresponding values, see Clause 7.

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5.7.1 Data

For a STA to send data to another STA, it sends a data message, as shown below:

Data messages

— Message type: Data
— Message subtype: Data
— Information items:
  • IEEE source address of message
  • IEEE destination address of message
  • BSS identification (BSSID)
— Direction of message: From STA to STA

5.7.2 Association

For a STA to associate, the association service causes the following messages to occur:

Association request

— Message type: Management
— Message subtype: Association request
— Information items:
  • IEEE address of the STA initiating the association
  • IEEE address of the AP with which the initiating STA will associate
  • ESS ID
— Direction of message: From STA to AP

Association response

— Message type: Management
— Message subtype: Association response
— Information items:
  • Result of the requested association. This is an item with values “successful” and “unsuccessful.”
  • If the association is successful, the response shall include the association identifier (AID).
— Direction of message: From AP to STA

5.7.3 Reassociation

For a STA to reassociate, the reassociation service causes the following message to occur:

Reassociation request

— Message type: Management
— Message subtype: Reassociation request
— Information items:
  • IEEE address of the STA initiating the reassociation
  • IEEE address of the AP with which the initiating STA will reassociate
  • IEEE address of the AP with which the initiating STA is currently associated
  • ESS ID
— Direction of message:
  • From STA to AP (The AP with which the STA is requesting reassociation)

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The address of the current AP is included for efficiency. The inclusion of the current AP address facilitates MAC reassociation to be independent of the DS implementation.

Reassociation response

— Message type: Management
— Message subtype: Reassociation response
— Information items:
  • Result of the requested reassociation. This is an item with values “successful” and “unsuccessful.”
  • If the reassociation is successful, the response shall include the AID.
— Direction of message: From AP to STA

5.7.4 Disassociation

For a STA to terminate an active association, the disassociation service causes the following message to occur:

Disassociation

— Message type: Management
— Message subtype: Disassociation
— Information items:
  • IEEE address of the STA that is being disassociated. This shall be the broadcast address in the case of an AP disassociating with all associated STAs.
  • IEEE address of the AP with which the STA is currently associated.
— Direction of message: From STA to STA (e.g., STA to AP or AP to STA)

5.7.5 Privacy

For a STA to invoke the WEP privacy algorithm (as controlled by the related MIB attributes, see Clause 11), the privacy service causes MAC protocol data unit (MPDU) encryption and sets the WEP frame header bit appropriately (see Clause 7).

5.7.6 Authentication

For a STA to authenticate with another STA, the authentication service causes one or more authentication management frames to be exchanged. The exact sequence of frames and their content is dependent on the authentication scheme invoked. For all authentication schemes, the authentication algorithm is identified within the management frame body.

In an IBSS environment, either station may be the initiating STA (STA 1). In an ESS environment, STA 1 is the mobile STA, and STA 2 is the AP.

Authentication (first frame of sequence)

— Message type: Management
— Message subtype: Authentication
— Information items:
  • Authentication algorithm identification
  • Station identity assertion
  • Authentication transaction sequence number
  • Authentication algorithm dependent information
— Direction of message: First frame in the transaction sequence is always from STA 1 to STA 2.

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The first frame in an authentication sequence shall always be unencrypted.

Authentication (intermediate sequence frames)

— Message type: Management
— Message subtype: Authentication
— Information items:
  • Authentication algorithm identification
  • Authentication transaction sequence number
  • Authentication algorithm dependent information
— Direction of message:
  • Even transaction sequence numbers: From STA 2 to STA 1
  • Odd transaction sequence numbers: From STA 1 to STA 2

Authentication (final frame of sequence)

— Message type: Management
— Message subtype: Authentication
— Information items:
  • Authentication algorithm identification
  • Authentication transaction sequence number
  • Authentication algorithm dependent information
  • The result of the requested authentication. This is an item with values “successful” and “unsuccessful.”
— Direction of message: From STA 2 to STA 1

5.7.7 Deauthentication

For a STA to invalidate an active authentication, the following message is sent:

Deauthentication

— Message type: Management
— Message subtype: Deauthentication
— Information items:
  • IEEE address of the STA that is being deauthenticated
  • IEEE address of the STA with which the STA is currently authenticated
  • This shall be the broadcast address in the case of a STA deauthenticating all STAs currently authenticated.
— Direction of message: From STA to STA

5.8 Reference model

This standard presents the architectural view, emphasizing the separation of the system into two major parts: the MAC of the data link layer (DLL) and the PHY. These layers are intended to correspond closely to the lowest layers of the ISO/IEC basic reference model of Open Systems Interconnection (OSI) (ISO/IEC 7498-1: 1994[7]). The layers and sublayers described in this standard are shown in Figure 11.

[7]Information on normative references can be found in Clause 2.

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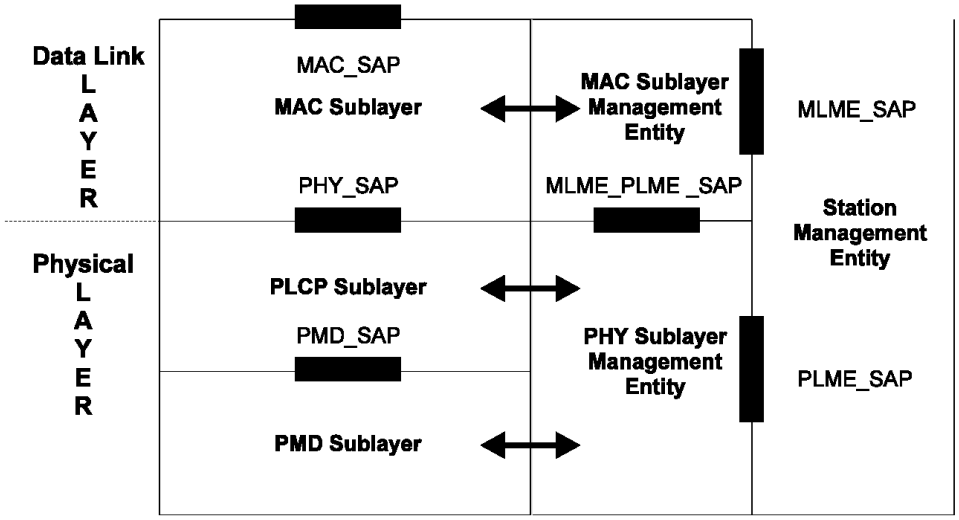

Figure 11—Portion of the ISO/IEC basic reference model covered in this standard

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6. MAC service definition

6.1 Overview of MAC services

6.1.1 Asynchronous data service

This service provides peer LLC entities with the ability to exchange MSDUs. To support this service, the local MAC uses the underlying PHY-level services to transport an MSDU to a peer MAC entity, where it will be delivered to the peer LLC. Such asynchronous MSDU transport is performed on a best-effort connectionless basis. There are no guarantees that the submitted MSDU will be delivered successfully. Broadcast and multicast transport is part of the asynchronous data service provided by the MAC. Due to the characteristics of the WM, broadcast and multicast MSDUs may experience a lower quality of service, compared to that of unicast MSDUs. All STAs will support the asynchronous data service. Because operation of certain functions of the MAC may cause reordering of some MSDUs, as discussed in more detail below, there are two service classes within the asynchronous data service. By selecting the desired service class, each LLC entity initiating the transfer of MSDUs is able to control whether MAC entities are or are not allowed to reorder those MSDUs.

6.1.2 Security services

Security services in IEEE 802.11 are provided by the authentication service and the WEP mechanism. The scope of the security services provided is limited to station-to-station data exchange. The privacy service offered by an IEEE 802.11 WEP implementation is the encryption of the MSDU. For the purposes of this standard, WEP is viewed as a logical service located within the MAC sublayer as shown in the reference model, Figure 11 (in 5.8). Actual implementations of the WEP service are transparent to the LLC and other layers above the MAC sublayer.

The security services provided by the WEP in IEEE 802.11 are as follows:

a) Confidentiality;
b) Authentication; and
c) Access control in conjunction with layer management.

During the authentication exchange, parties A and B exchange authentication information as described in Clause 8.

The MAC sublayer security services provided by WEP rely on information from nonlayer-2 management or system entities. Management entities communicate information to WEP through a set of MIB attributes.

6.1.3 MSDU ordering

The services provided by the MAC sublayer permit, and may in certain cases require, the reordering of MSDUs. The MAC does not intentionally reorder MSDUs except as may be necessary to improve the likelihood of successful delivery based on the current operational (“power management”) mode of the designated recipient station(s). The sole effect of this reordering (if any), for the set of MSDUs received at the MAC service interface of any single station, is a change in the delivery order of broadcast and multicast MSDUs, relative to directed MSDUs, originating from a single source station address. If a higher-layer protocol using the asynchronous data service cannot tolerate this possible reordering, the optional StrictlyOrdered service class should be used. MSDUs transferred between any pair of stations using the StrictlyOrdered service class are not subject to the relative reordering that is possible when the ReorderableMulticast service class is used. However, the desire to receive MSDUs sent using the StrictlyOrdered service class at a station precludes simultaneous use of the MAC power management facilities at that station.

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In order for the MAC to operate properly, the DS must meet the requirements of ISO/IEC 15802-1: 1995.

Operational restrictions that ensure the appropriate ordering of MSDUs are specified in 9.8.

6.2 Detailed service specification

6.2.1 MAC data services

The IEEE 802.11 MAC supports the following service primitives as defined in ISO/IEC 8802-2: 1998:

— MA-UNITDATA.request
— MA-UNITDATA.indication
— MA-UNITDATA-STATUS.indication

The LLC definitions of the primitives and specify parameter value restrictions imposed by IEEE 802.11 are given in 6.2.1.1 through 6.2.1.3.

6.2.1.1 MA-UNITDATA.request

6.2.1.1.1 Function

This primitive requests a transfer of an MSDU from a local LLC sublayer entity to a single peer LLC sublayer entity, or multiple peer LLC sublayer entities in the case of group addresses.

6.2.1.1.2 Semantics of the service primitive

The parameters of the primitive are as follows:

```
MA-UNITDATA.request (
                        source address,
                        destination address,
                        routing information,
                        data,
                        priority,
                        service class
                        )
```

The source address (SA) parameter specifies an individual MAC sublayer address of the sublayer entity to which the MSDU is being transferred.

The destination address (DA) parameter specifies either an individual or a group MAC sublayer entity address.

The routing information parameter specifies the route desired for the data transfer (a null value indicates source routing is not to be used). For IEEE 802.11, the routing information parameter must be null.

The data parameter specifies the MSDU to be transmitted by the MAC sublayer entity. For IEEE 802.11, the length of the MSDU must be less than or equal to 2304 octets.

The priority parameter specifies the priority desired for the data unit transfer. IEEE 802.11 allows two values: Contention or ContentionFree.

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The service class parameter specifies the service class desired for the data unit transfer. IEEE 802.11 allows two values: ReorderableMulticast or StrictlyOrdered.

6.2.1.1.3 When generated

This primitive is generated by the LLC sublayer entity when an MSDU is to be transferred to a peer LLC sublayer entity or entities.

6.2.1.1.4 Effect of receipt

The receipt of this primitive causes the MAC sublayer entity to append all MAC specified fields, including DA, SA, and all fields that are unique to IEEE 802.11, and pass the properly formatted frame to the lower layers for transfer to a peer MAC sublayer entity or entities.

6.2.1.2 MA-UNITDATA.indication

6.2.1.2.1 Function

This primitive defines the transfer of an MSDU from the MAC sublayer entity to the LLC sublayer entity, or entities in the case of group addresses. In the absence of error, the contents of the data parameter are logically complete and unchanged relative to the data parameter in the associated MA-UNITDATA.request primitive.

6.2.1.2.2 Semantics of the service primitive

The parameters of the primitive are as follows:

```
MA-UNITDATA.indication(
                        source address,
                        destination address,
                        routing information,
                        data,
                        reception status,
                        priority,
                        service class
                        )
```

The SA parameter is an individual address as specified by the SA field of the incoming frame.

The DA parameter is either an individual or a group address as specified by the DA field of the incoming frame.

The routing information parameter specifies the route that was used for the data transfer. IEEE 802.11 will always set this field to null.

The data parameter specifies the MSDU as received by the local MAC entity.

The reception status parameter indicates the success or failure of the received frame for those frames that IEEE 802.11 reports via an MA-UNITDATA.indication. This MAC only reports “success” when all failures of reception are discarded without generating MA-UNITDATA.indication.

The priority parameter specifies the receive processing priority that was used for the data unit transfer. IEEE 802.11 allows two values: Contention or ContentionFree.

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The service class parameter specifies the receive service class that was used for the data unit transfer. IEEE 802.11 allows two values: ReorderableMulticast or StrictlyOrdered.

6.2.1.2.3 When generated

The MA-UNITDATA.indication primitive is passed from the MAC sublayer entity to the LLC sublayer entity or entities to indicate the arrival of a frame at the local MAC sublayer entity. Frames are reported only if they are validly formatted at the MAC sublayer, received without error, received with valid (or null) WEP encryption, and their destination address designates the local MAC sublayer entity.

6.2.1.2.4 Effect of receipt

The effect of receipt of this primitive by the LLC sublayer is dependent on the validity and content of the frame.

6.2.1.3 MA-UNITDATA-STATUS.indication

6.2.1.3.1 Function

This primitive has local significance and provides the LLC sublayer with status information for the corresponding preceding MA-UNITDATA.request primitive.

6.2.1.3.2 Semantics of the service primitive

The parameters of the primitive are as follows:

```
MA-UNITDATA-STATUS.indication(
                                source address,
                                destination address,
                                transmission status,
                                provided priority,
                                provided service class
                                )
```

The SA parameter is an individual MAC sublayer entity address as specified in the associated MA-UNITDATA.request primitive.

The DA parameter is either an individual or group MAC sublayer entity address as specified in the associated MA-UNITDATA.request primitive.

The transmission status parameter will be used to pass status information back to the local requesting LLC sublayer entity. IEEE 802.11 specifies the following values for transmission status:

a) Successful;
b) Undeliverable (for unacknowledged directed MSDUs when the aShortRetryMax or aLongRetryMax retry limit would otherwise be exceeded);
c) Excessive data length;
d) Non-null source routing;
e) Unsupported priority (for priorities other than Contention or ContentionFree);
f) Unsupported service class (for service classes other than ReorderableMulticast or StrictlyOrdered);
g) Unavailable priority (for ContentionFree when no point coordinator (PC) is available, in which case the MSDU is transmitted with a provided priority of Contention);

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h) Unavailable service class (for StrictlyOrdered service when the station's power management mode is other than "active");

i) Undeliverable (TransmitMSDUTimer reached aMaxTransmitMSDULifetime before successful delivery);

j) Undeliverable (no BSS available);

k) Undeliverable (cannot encrypt with a null key).

The provided priority parameter specifies the priority that was used for the associated data unit transfer (Contention or ContentionFree).

The provided service class parameter specifies the class of service used for the associated data unit transfer (ReorderableMulticast or StrictlyOrdered).

6.2.1.3.3 When generated

The MA-UNITDATA-STATUS.indication primitive is passed from the MAC sublayer entity to the LLC sublayer entity to indicate the status of the service provided for the corresponding MA-UNITDATA.request primitive.

6.2.1.3.4 Effect of receipt

The effect of receipt of this primitive by the LLC sublayer is dependent upon the type of operation employed by the LLC sublayer entity.

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7. Frame formats

The format of the MAC frames is specified in this clause. All stations shall be able to properly construct frames for transmission and decode frames upon reception, as specified in this clause.

7.1 MAC frame formats

Each frame consists of the following basic components:

a) A *MAC header*, which comprises frame control, duration, address, and sequence control information;
b) A variable length *frame body*, which contains information specific to the frame *type*;
c) A *FCS*, which contains an IEEE 32-bit cyclic redundancy code (CRC).

7.1.1 Conventions

The MPDUs or frames in the MAC sublayer are described as a sequence of fields in specific order. Each figure in Clause 7 depicts the fields/subfields as they appear in the MAC frame and in the order in which they are passed to the physical layer convergence procedure (PLCP), from left to right.

In figures, all bits within fields are numbered, from 0 to k, where the length of the field is $k + 1$ bit. The octet boundaries within a field can be obtained by taking the bit numbers of the field modulo 8. Octets within numeric fields that are longer than a single octet are depicted in increasing order of significance, from lowest numbered bit to highest numbered bit. The octets in fields longer than a single octet are sent to the PLCP in order from the octet containing the lowest numbered bits to the octet containing the highest numbered bits.

Any field containing a CRC is an exception to this convention and is transmitted commencing with the coefficient of the highest-order term.

MAC addresses are assigned as ordered sequences of bits. The Individual/Group bit is always transferred first and is bit 0 of the first octet.

Values specified in decimal are coded in natural binary unless otherwise stated. The values in Table 1 are in binary, with the bit assignments shown in the table. Values in other tables are shown in decimal notation.

Reserved fields and subfields are set to 0 upon transmission and are ignored upon reception.

7.1.2 General frame format

The MAC frame format comprises a set of fields that occur in a fixed order in all frames. Figure 12 depicts the general MAC frame format. The fields Address 2, Address 3, Sequence Control, Address 4, and Frame Body are only present in certain frame types. Each field is defined in 7.1.3. The format of each of the individual frame types is defined in 7.2.

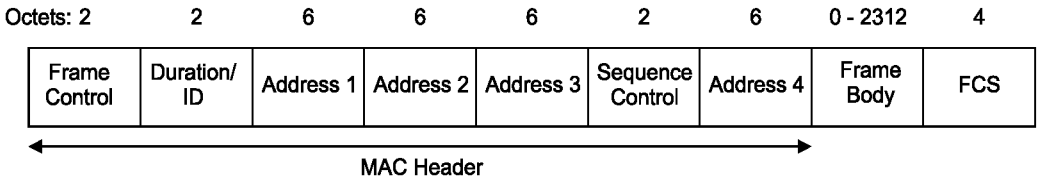

Figure 12—MAC frame format

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7.1.3 Frame fields

7.1.3.1 Frame Control field

The Frame Control field consists of the following subfields: Protocol Version, Type, Subtype, To DS, From DS, More Fragments, Retry, Power Management, More Data, WEP, and Order. The format of the Frame Control field is illustrated in Figure 13.

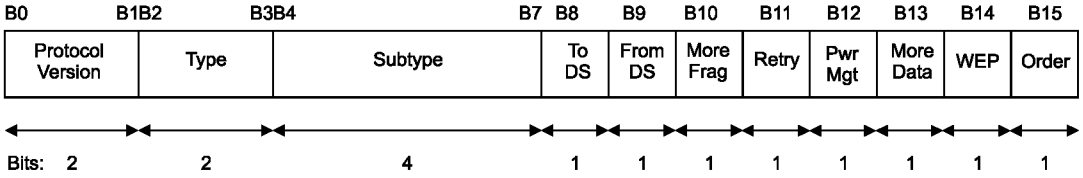

Figure 13—Frame Control field

7.1.3.1.1 Protocol Version field

The Protocol Version field is 2 bits in length and is invariant in size and placement across all revisions of this standard. For this standard, the value of the protocol version is 0. All other values are reserved. The revision level will be incremented only when a fundamental incompatibility exists between a new revision and the prior edition of the standard. A device that receives a frame with a higher revision level than it supports will discard the frame without indication to the sending station or to LLC.

7.1.3.1.2 Type and Subtype fields

The Type field is 2 bits in length, and the Subtype field is 4 bits in length. The Type and Subtype fields together identify the function of the frame. There are three frame types: control, data, and management. Each of the frame types have several defined subtypes. Table 1 defines the valid combinations of type and subtype.

7.1.3.1.3 To DS field

The To DS field is 1 bit in length and is set to 1 in data type frames destined for the DS. This includes all data type frames sent by STAs associated with an AP. The To DS field is set to 0 in all other frames.

7.1.3.1.4 From DS field

The From DS field is 1 bit in length and is set to 1 in data type frames exiting the DS. It is set to 0 in all other frames.

The permitted To/From DS bit combinations and their meanings are given in Table 2.

7.1.3.1.5 More Fragments field

The More Fragments field is 1 bit in length and is set to 1 in all data or management type frames that have another fragment of the current MSDU or current MAC management protocol data unit (MMPDU) to follow. It is set to 0 in all other frames.

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Table 1—Valid type and subtype combinations

Type value b3 b2	Type description	Subtype value b7 b6 b5 b4	Subtype description
00	Management	0000	Association request
00	Management	0001	Association response
00	Management	0010	Reassociation request
00	Management	0011	Reassociation response
00	Management	0100	Probe request
00	Management	0101	Probe response
00	Management	0110–0111	Reserved
00	Management	1000	Beacon
00	Management	1001	ATIM
00	Management	1010	Disassociation
00	Management	1011	Authentication
00	Management	1100	Deauthentication
00	Management	1101–1111	Reserved
01	Control	0000–1001	Reserved
01	Control	1010	PS-Poll
01	Control	1011	RTS
01	Control	1100	CTS
01	Control	1101	ACK
01	Control	1110	CF-End
01	Control	1111	CF-End + CF-Ack
10	Data	0000	Data
10	Data	0001	Data + CF-Ack
10	Data	0010	Data + CF-Poll
10	Data	0011	Data + CF-Ack + CF-Poll
10	Data	0100	Null function (no data)
10	Data	0101	CF-Ack (no data)
10	Data	0110	CF-Poll (no data)
10	Data	0111	CF-Ack + CF-Poll (no data)
10	Data	1000–1111	Reserved
11	Reserved	0000–1111	Reserved

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Table 2—To/From DS combinations in data type frames

To/From DS values	Meaning
To DS = 0 From DS = 0	A data frame direct from one STA to another STA within the same IBSS, as well as all management and control type frames.
To DS = 1 From DS = 0	Data frame destined for the DS.
To DS = 0 From DS = 1	Data frame exiting the DS.
To DS = 1 From DS = 1	Wireless distribution system (WDS) frame being distributed from one AP to another AP.

7.1.3.1.6 Retry field

The Retry field is 1 bit in length and is set to 1 in any data or management type frame that is a retransmission of an earlier frame. It is set to 0 in all other frames. A receiving station uses this indication to aid in the process of eliminating duplicate frames.

7.1.3.1.7 Power Management field

The Power Management field is 1 bit in length and is used to indicate the power management mode of a STA. The value of this field remains constant in each frame from a particular STA within a frame exchange sequence defined in 9.7. The value indicates the mode in which the station will be after the successful completion of the frame exchange sequence.

A value of 1 indicates that the STA will be in PS mode. A value of 0 indicates that the STA will be in active mode. This field is always set to 0 in frames transmitted by an AP.

7.1.3.1.8 More Data field

The More Data field is 1 bit in length and is used to indicate to a STA in PS mode that more MSDUs or MMPDUs are buffered for that STA at the AP. The More Data field is valid in directed data or management type frames transmitted by an AP to a STA in PS mode. A value of 1 indicates that at least one additional buffered MSDU or MMPDU is present for the same STA.

The More Data field may be set to 1 in directed data type frames transmitted by a CF-Pollable STA to the PC in response to a CF-Poll to indicate that the STA has at least one additional buffered MSDU available for transmission in response to a subsequent CF-Poll.

The More Data field is set to 0 in all other directed frames.

The More Data field is set to 1 in broadcast/multicast frames transmitted by the AP when additional broadcast/multicast MSDUs or MMPDUs remain to be transmitted by the AP during this beacon interval. The More Data field is set to 0 in broadcast/multicast frames transmitted by the AP when no more broadcast/multicast MSDUs or MMPDUs remain to be transmitted by the AP during this beacon interval and in all broadcast/multicast frames transmitted by non-AP stations.

7.1.3.1.9 WEP field

The WEP field is 1 bit in length. It is set to 1 if the Frame Body field contains information that has been processed by the WEP algorithm. The WEP field is only set to 1 within frames of type Data and frames of

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type Management, subtype Authentication. The WEP field is set to 0 in all other frames. When the WEP bit is set to 1, the Frame Body field is expanded as defined in 8.2.5.

7.1.3.1.10 Order field

The Order field is 1 bit in length and is set to 1 in any data type frame that contains an MSDU, or fragment thereof, which is being transferred using the StrictlyOrdered service class. This field is set to 0 in all other frames.

7.1.3.2 Duration/ID field

The Duration/ID field is 16 bits in length. The contents of this field are as follows:

a) In control type frames of subtype PS-Poll, the Duration/ID field carries the AID of the station that transmitted the frame in the 14 least significant bits (LSBs), with the 2 most significant bits (MSBs) both set to 1. The value of the AID is in the range 1–2007.
b) In all other frames, the Duration/ID field contains a duration value as defined for each frame type in 7.2. For frames transmitted during the contention-free period (CFP), the duration field is set to 32 768.

When the contents of the Duration/ID field are less than 32 768, the duration value is used to update the network allocation vector (NAV) according to the procedures defined in Clause 9.

The encoding of the Duration/ID field is given in Table 3.

Table 3—Duration/ID field encoding

Bit 15	Bit 14	Bits 13–0	Usage
0	0–32 767		Duration
1	0	0	Fixed value within frames transmitted during the CFP
1	0	1–16 383	Reserved
1	1	0	Reserved
1	1	1–2 007	AID in PS-Poll frames
1	1	2 008–16 383	Reserved

7.1.3.3 Address fields

There are four address fields in the MAC frame format. These fields are used to indicate the BSSID, source address (SA), destination address (DA), transmitting station address (TA), and receiving station address (RA). Certain frames may not contain some of the address fields.

Certain address field usage is specified by the relative position of the address field (1–4) within the MAC header, independent of the type of address present in that field. For example, receiver address matching is always performed on the contents of the Address 1 field in received frames, and the receiver address of CTS and ACK frames is always obtained from the Address 2 field in the corresponding RTS frame, or from the frame being acknowledged.

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7.1.3.3.1 Address representation

Each Address field contains a 48-bit address as defined in 5.2 of IEEE Std 802-1990.

7.1.3.3.2 Address designation

A MAC sublayer address is one of the following two types:

a) *Individual address.* The address associated with a particular station on the network.
b) *Group address.* A multidestination address, associated with one or more stations on a given network. The two kinds of group addresses are as follows:
    1) *Multicast-group address.* An address associated by higher level convention with a group of logically related stations.
    2) *Broadcast address.* A distinguished, predefined multicast address that always denotes the set of all stations on a given LAN. All ones in the DA field are interpreted to be the broadcast address. This group is predefined for each communication medium to consist of all stations actively connected to that medium; it is used to broadcast to all the active stations on that medium. All stations are able to recognize the broadcast address. It is not necessary that a station be capable of generating the broadcast address.

The address space is also partitioned into locally administered and universal (globally administered) addresses. The nature of a body and the procedures by which it administers these universal (globally administered) addresses is beyond the scope of this standard. See IEEE Std 802-1990 for more information.

7.1.3.3.3 BSSID field

The BSSID field is a 48-bit field of the same format as an IEEE 802 MAC address. This field uniquely identifies each BSS. The value of this field, in an infrastructure BSS, is the MAC address currently in use by the STA in the AP of the BSS.

The value of this field in an IBSS is a locally administered IEEE MAC address formed from a 46-bit random number generated according to the procedure defined in 11.1.3. The individual/group bit of the address is set to 0. The universal/local bit of the address is set to 1. This mechanism is used to provide a high probability of selecting a unique BSSID.

The value of all 1s is used to indicate the broadcast BSSID. A broadcast BSSID may only be used in the BSSID field of management frames of subtype probe request.

7.1.3.3.4 DA field

The DA field contains an IEEE MAC individual or group address that identifies the MAC entity or entities intended as the final recipient(s) of the MSDU (or fragment thereof) contained in the frame body field.

7.1.3.3.5 SA field

The SA field contains an IEEE MAC individual address that identifies the MAC entity from which the transfer of the MSDU (or fragment thereof) contained in the frame body field was initiated. The individual/group bit is always transmitted as a zero in the source address.

7.1.3.3.6 RA field

The RA field contains an IEEE MAC individual or group address that identifies the intended immediate recipient STA(s), on the WM, for the information contained in the frame body field.

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7.1.3.3.7 TA field

The TA field contains an IEEE MAC individual address that identifies the STA that has transmitted, onto the WM, the MPDU contained in the frame body field. The Individual/Group bit is always transmitted as a zero in the transmitter address.

7.1.3.4 Sequence Control field

The Sequence Control field is 16 bits in length and consists of two subfields, the Sequence Number and the Fragment Number. The format of the Sequence Control field is illustrated in Figure 14.

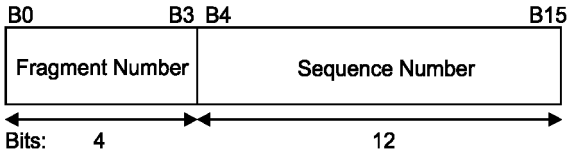

Figure 14—Sequence Control field

7.1.3.4.1 Sequence Number field

The Sequence Number field is a 12-bit field indicating the sequence number of an MSDU or MMPDU. Each MSDU or MMPDU transmitted by a STA is assigned a sequence number. Sequence numbers are assigned from a single modulo 4096 counter, starting at 0 and incrementing by 1 for each MSDU or MMPDU. Each fragment of an MSDU or MMPDU contains the assigned sequence number. The sequence number remains constant in all retransmissions of an MSDU, MMPDU, or fragment thereof.

7.1.3.4.2 Fragment Number field

The Fragment Number field is a 4-bit field indicating the number of each fragment of an MSDU or MMPDU. The fragment number is set to 0 in the first or only fragment of an MSDU or MMPDU and is incremented by one for each successive fragment of that MSDU or MMPDU. The fragment number remains constant in all retransmissions of the fragment.

7.1.3.5 Frame Body field

The Frame Body is a variable length field that contains information specific to individual frame types and subtypes. The minimum frame body is 0 octets. The maximum length frame body is defined by the maximum length (MSDU + ICV + IV), where integrity check value (ICV) and initialization vector (IV) are the WEP fields defined in 8.2.5.

7.1.3.6 FCS field

The FCS field is a 32-bit field containing a 32-bit CRC. The FCS is calculated over all the fields of the MAC header and the Frame Body field. These are referred to as the *calculation fields*.

The FCS is calculated using the following standard generator polynomial of degree 32:

$$G(x) = x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$$

The FCS is the ones complement of the sum (modulo 2) of the following:

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a) The remainder of $x^k \times (x^{31} + x^{30} + x^{29} + \ldots + x^2 + x + 1)$ divided (modulo 2) by $G(x)$, where k is the number of bits in the calculation fields, and
b) The remainder after multiplication of the contents (treated as a polynomial) of the calculation fields by x^{32} and then division by $G(x)$.

The FCS field is transmitted commencing with the coefficient of the highest-order term.

As a typical implementation, at the transmitter, the initial remainder of the division is preset to all ones and is then modified by division of the calculation fields by the generator polynomial $G(x)$. The ones complement of this remainder is transmitted, with the highest-order bit first, as the FCS field.

At the receiver, the initial remainder is preset to all ones and the serial incoming bits of the calculation fields and FCS, when divided by $G(x)$, results in the absence of transmission errors, in a unique nonzero remainder value. The unique remainder value is the polynomial:

$$x^{31} + x^{30} + x^{26} + x^{25} + x^{24} + x^{18} + x^{15} + x^{14} + x^{12} + x^{11} + x^{10} + x^8 + x^6 + x^5 + x^4 + x^3 + x + 1$$

7.2 Format of individual frame types

7.2.1 Control frames

In the following descriptions, “immediately previous” frame means a frame whose reception concluded within the prior short interframe space (SIFS) interval.

The subfields within the Frame Control field of control frames are set as illustrated in Figure 15.

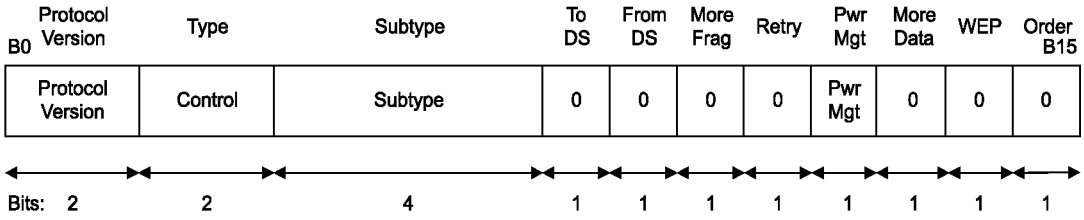

Figure 15—Frame Control field subfield values within control frames

7.2.1.1 RTS frame format

The frame format for the RTS frame is as defined in Figure 16.

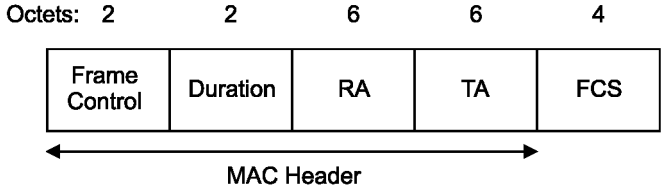

Figure 16—RTS frame

The RA field of the RTS frame is the address of the STA, on the WM, that is the intended immediate recipient of the pending directed data or management frame.

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The TA field is the address of the STA transmitting the RTS frame.

The duration value is the time, in microseconds, required to transmit the pending data or management frame, plus one CTS frame, plus one ACK frame, plus three SIFS intervals. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer.

7.2.1.2 CTS frame format

The frame format for the CTS frame is as defined in Figure 17.

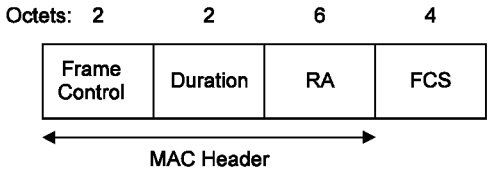

Figure 17—CTS frame

The RA field of the CTS frame is copied from the TA field of the immediately previous RTS frame to which the CTS is a response.

The duration value is the value obtained from the Duration field of the immediately previous RTS frame, minus the time, in microseconds, required to transmit the CTS frame and its SIFS interval. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer.

7.2.1.3 ACK frame format

The frame format for the ACK frame is as defined in Figure 18.

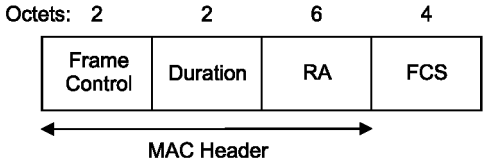

Figure 18—ACK frame

The RA field of the ACK frame is copied from the Address 2 field of the immediately previous directed data, management, or PS-Poll control frame.

If the More Fragment bit was set to 0 in the Frame Control field of the immediately previous directed data or management frame, the duration value is set to 0. If the More Fragment bit was set to 1 in the Frame Control field of the immediately previous directed data or management frame, the duration value is the value obtained from the Duration field of the immediately previous data or management frame, minus the time, in microseconds, required to transmit the ACK frame and its SIFS interval. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer.

7.2.1.4 PS-Poll frame format

The frame format for the PS-Poll frame is as defined in Figure 19.

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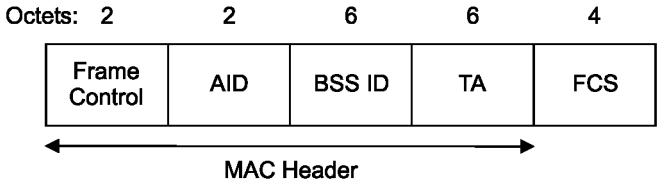

Figure 19—PS-Poll frame

The BSSID is the address of the STA contained in the AP. The TA field is the address of the STA transmitting the frame. The AID is the value assigned to the STA transmitting the frame by the AP in the association response frame that established that STA's current association.

The AID value always has its two MSBs each set to 1. All STAs, upon receipt of a PS-Poll frame, update their NAV settings as appropriate under the coordination function rules using a duration value equal to the time, in microseconds, required to transmit one ACK frame plus one SIFS interval.

7.2.1.5 CF-End frame format

The frame format for the CF-End frame is as defined in Figure 20.

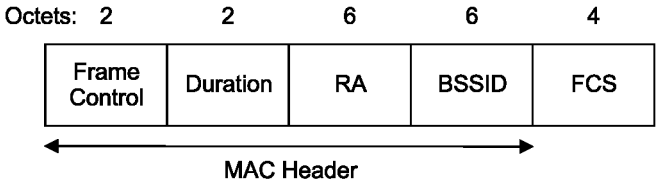

Figure 20—CF-End frame

The BSSID field is the address of the STA contained in the AP. The RA field is the broadcast group address.

The Duration field is set to 0.

7.2.1.6 CF-End+CF-Ack frame format

The frame format for the CF-End+CF-Ack frame is as defined in Figure 21.

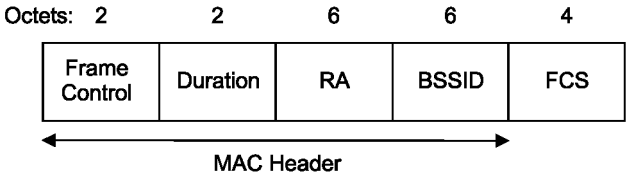

Figure 21—CF-End+CF-Ack Frame

The BSSID field is the address of the STA contained in the AP. The RA field is the broadcast group address.

The Duration field is set to 0.

7.2.2 Data frames

The frame format for a Data frame is independent of subtype and is as defined in Figure 22.

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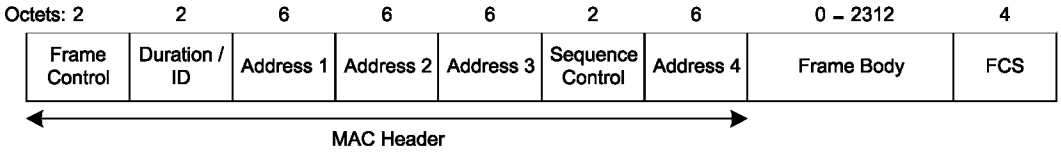

Figure 22—Data frame

The content of the Address fields of the data frame is dependent upon the values of the To DS and From DS bits and is defined in Table 4. Where the content of a field is shown as not applicable (N/A), the field is omitted. Note that Address 1 always holds the receiver address of the intended receiver (or, in the case of multicast frames, receivers), and that Address 2 always holds the address of the station that is transmitting the frame.

Table 4—Address field contents

To DS	From DS	Address 1	Address 2	Address 3	Address 4
0	0	DA	SA	BSSID	N/A
0	1	DA	BSSID	SA	N/A
1	0	BSSID	SA	DA	N/A
1	1	RA	TA	DA	SA

A station uses the contents of the Address 1 field to perform address matching for receive decisions. In cases where the Address 1 field contains a group address, the BSSID also is validated to ensure that the broadcast or multicast originated in the same BSS.

A station uses the contents of the Address 2 field to direct the acknowledgment if an acknowledgment is necessary.

The DA field is the destination of the MSDU (or fragment thereof) in the frame body field.

The SA field is the address of the MAC entity that initiated the MSDU (or fragment thereof) in the frame body field.

The RA field is the address of the STA contained in the AP in the WDS that is the next immediate intended recipient of the frame.

The TA field is the address of the STA contained in the AP in the WDS that is transmitting the frame.

The BSSID of the Data frame is determined as follows:

a) If the station is an AP or is associated with an AP, the BSSID is the address currently in use by the STA contained in the AP.
b) If the station is a member of an IBSS, the BSSID is the BSSID of the IBSS.

The frame body consists of the MSDU or a fragment thereof, and a WEP IV and ICV (if and only if the WEP subfield in the Frame Control field is set to 1). The frame body is null (0 octets in length) in data frames of Subtype Null function (no data), CF-Ack (no data), CF-Poll (no data), and CF-Ack+CF-Poll (no data).

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Within all data type frames sent during the CFP, the Duration field is set to 32 768. Within all data type frames sent during the contention period (CP), the Duration field is set according to the following rules:

— If the Address 1 field contains a group address, the duration value is set to 0.
— If the More Fragments bit is set to 0 in the Frame Control field of a frame and the Address 1 field contains an individual address, the duration value is set to the time, in microseconds, required to transmit one ACK frame, plus one SIFS interval.
— If the More Fragments bit is set to 1 in the Frame Control field of a frame, and the Address 1 field contains an individual address, the duration value is set to the time, in microseconds, required to transmit the next fragment of this data frame, plus two ACK frames, plus three SIFS intervals.

The duration value calculation for the data frame is based on the rules in 9.6 that determine the data rate at which the control frames in the frame exchange sequence are transmitted. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer. All stations process Duration field values less than or equal to 32 767 from valid data frames to update their NAV settings as appropriate under the coordination function rules.

7.2.3 Management frames

The frame format for a Management frame is independent of frame subtype and is as defined in Figure 23.

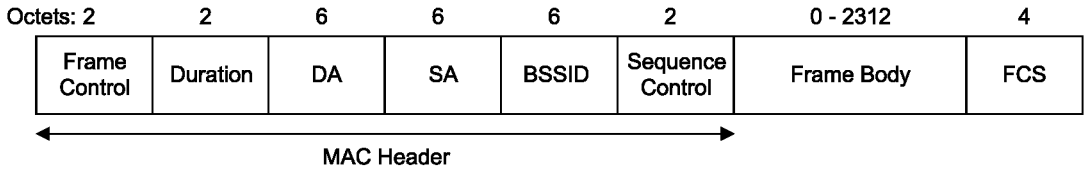

Figure 23—Management frame format

A STA uses the contents of the Address 1 field to perform the address matching for receive decisions. In the case where the Address 1 field contains a group address and the frame type is other than Beacon, the BSSID also is validated to ensure that the broadcast or multicast originated in the same BSS. If the frame type is Beacon, other address matching rules apply, as specified in 11.1.2.3.

The address fields for management frames do not vary by frame subtype.

The BSSID of the management frame is determined as follows:

a) If the station is an AP or is associated with an AP, the BSSID is the address currently in use by the STA contained in the AP.
b) If the station is a member of an IBSS, the BSSID is the BSSID of the IBSS.
c) In Management frames of subtype Probe Request, the BSSID is either a specific BSSID, or the broadcast BSSID as defined in the procedures specified in 11.1.3.

The DA field is the destination of the frame.

The SA field is the address of the station transmitting the frame.

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Within all management type frames sent during the CFP, the Duration field is set to 32 768. Within all management type frames sent during the CP, the Duration field is set according to the following rules:

— If the DA field contains a group address, the duration value is set to 0.
— If the More Fragments bit is set to 0 in the Frame Control field of a frame and the DA field contains an individual address, the duration value is set to the time, in microseconds, required to transmit one ACK frame, plus one SIFS interval.
— If the More Fragments bit is set to 1 in the Frame Control field of a frame, and the DA field contains an individual address, the duration value is set to the time, in microseconds, required to transmit the next fragment of this management frame, plus two ACK frames, plus three SIFS intervals.

The duration value calculation for the management frame is based on the rules in 9.6 that determine the data rate at which the control frames in the frame exchange sequence are transmitted. If the calculated duration includes a fractional microsecond, that value is rounded up to the next higher integer. All stations process Duration field values less than or equal to 32 767 from valid management frames to update their NAV settings as appropriate under the coordination function rules.

The frame body consists of the fixed fields and information elements defined for each management frame subtype. All fixed fields and information elements are mandatory unless stated otherwise, and they can appear only in the specified order. Stations encountering an element type they do not understand ignore that element. Element type codes not explicitly defined in this standard are reserved, and do not appear in any frames.

7.2.3.1 Beacon frame format

The frame body of a management frame of subtype Beacon contains the information shown in Table 5. If the dot11MultiDomainCapabilityEnabled attribute is true, a STA shall include a Country information element in the transmission of Beacon frames. Optionally, the Beacon frame format may also include the information described in either or both of orders 12 and 13. If the information in both orders 12 and 13 are sent, they shall describe the same hopping pattern. Note that the information described in orders 12 and 13 also may be contained in the Probe Response frame.

Table 5—Beacon frame body

Order	Information	Notes
1	Timestamp	
2	Beacon interval	
3	Capability	
4	Service Set Identifier (SSID)	
5	Supported rates	
6	Frequency-Hopping (FH) Parameter Set	The FH Parameter Set information element is present within Beacon frames generated by STAs using FH PHYs.
7	DS Parameter Set	The DS Parameter Set information element is present within Beacon frames generated by STAs using direct sequence PHYs.
8	CF Parameter Set	The CF Parameter Set information element is present only within Beacon frames generated by APs supporting a point coordination function (PCF).
9	IBSS Parameter Set	The IBSS Parameter Set information element is present only within Beacon frames generated by STAs in an IBSS.

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Table 5—Beacon frame body *(continued)*

Order	Information	Notes
10	Traffic indication map (TIM)	The TIM information element is present only within Beacon frames generated by APs.
11	Country	The Country information element shall be present when dot11MultiDomainCapabilityEnabled is true.
12	FH Parameters	FH Parameters as specified in 7.3.2.10 may be included if dot11MultiDomainCapabilityEnabled is true.
13	FH Pattern Table	FH Pattern Table information as specified in 7.3.2.11 may be included if dot11MultiDomainCapabilityEnabled is true.

7.2.3.2 IBSS ATIM frame format

The frame body of a management frame of subtype ATIM is null.

7.2.3.3 Disassociation frame format

The frame body of a management frame of subtype Disassociation contains the information shown in Table 6.

Table 6—Disassociation frame body

Order	Information
1	Reason code

7.2.3.4 Association Request frame format

The frame body of a management frame of subtype Association Request contains the information shown in Table 7.

Table 7—Association Request frame body

Order	Information
1	Capability
2	Listen interval
3	SSID
4	Supported rates

7.2.3.5 Association Response frame format

The frame body of a management frame of subtype Association Response contains the information shown in Table 8.

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Table 8—Association Response frame body

Order	Information
1	Capability
2	Status code
3	AID
4	Supported rates

7.2.3.6 Reassociation Request frame format

The frame body of a management frame of subtype Reassociation Request contains the information shown in Table 9.

Table 9—Reassociation Request frame body

Order	Information
1	Capability
2	Listen interval
3	Current AP address
4	SSID
5	Supported rates

7.2.3.7 Reassociation Response frame format

The frame body of a management frame of subtype Reassociation Response contains the information shown in Table 10.

Table 10—Reassociation Response frame body

Order	Information
1	Capability
2	Status code
3	AID
4	Supported rates

7.2.3.8 Probe Request frame format

The frame body of a management frame of subtype Probe Request contains the information shown in Table 11. If the dot11MultiDomainCapabilityEnabled attribute is true, a STA may include a Request information element in the Probe Request frame. The format of the Request information element is specified in 7.3.2.12.

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Table 11—Probe Request frame body

Order	Information	Notes
1	SSID	
2	Supported rates	
3	Request information	May be included if dot11MultiDomainCapabilityEnabled is true

7.2.3.9 Probe Response frame format

The frame body of a management frame of subtype Probe Response contains the information shown in Table 12. If the dot11MultiDomainCapabilityEnabled attribute is true, the Probe Response frame contains a Country information element and all information elements identified by the Requested Element IDs of a Request information element. Note that the information returned as a result of a Probe Request frame with a Request information element may include the FH parameters and/or the FH Pattern Table possibly replicating optional elements identified by orders 12 and 13.

A STA shall return only the information elements that it supports. In an improperly formed Request information element, a STA may ignore the first information element requested that is not ordered properly and all subsequent information elements requested. In the probe response frame, the STA shall return the requested information elements in the same order as requested in the Request information element.

Table 12—Probe Response frame body

Order	Information	Notes
1	Timestamp	
2	Beacon interval	
3	Capability	
4	SSID	
5	Supported rates	
6	FH Parameter Set	The FH Parameter Set information element is present within Probe Response frames generated by STAs using FH PHYs.
7	DS Parameter Set	The DS Parameter Set information element is present within Probe Response frames generated by STAs using direct sequence PHYs.
8	CF Parameter Set	The CF Parameter Set information element is present only within Probe Response frames generated by APs supporting a PCF.
9	IBSS Parameter Set	The IBSS Parameter Set information element is present only within Probe Response frames generated by STAs in an IBSS.
10	Country	Included if dot11MultiDomainCapabilityEnabled is true.
11	FH Parameters	FH Parameters, as specified in 7.3.2.10, may be included if dot11MultiDomainCapabilityEnabled is true.
12	FH Pattern Table	FH Pattern Table information, as specified in 7.3.2.11, may be included if dot11MultiDomainCapabilityEnabled is true.

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Table 12—Probe Response frame body *(continued)*

Order	Information	Notes
13–*n*	Requested information elements	Elements requested by the Request information element of the Probe Request frame.

7.2.3.10 Authentication frame format

The frame body of a management frame of subtype Authentication contains the information shown in Table 13.

Table 13—Authentication frame body

Order	Information	Notes
1	Authentication algorithm number	
2	Authentication transaction sequence number	
3	Status code	The status code information is reserved and set to 0 in certain Authentication frames as defined in Table 14.
4	Challenge text	The challenge text information is present only in certain Authentication frames as defined in Table 14.

Table 14—Presence of challenge text information

Authentication algorithm	Authentication transaction sequence no.	Status code	Challenge text
Open System	1	Reserved	Not present
Open System	2	Status	Not present
Shared Key	1	Reserved	Not present
Shared Key	2	Status	Present
Shared Key	3	Reserved	Present
Shared Key	4	Status	Not present

7.2.3.11 Deauthentication

The frame body of a management frame of subtype Deauthentication contains the information shown in Table 15.

Table 15—Deauthentication frame body

Order	Information
1	Reason code

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7.3 Management frame body components

Within management frames, fixed-length mandatory frame body components are defined as fixed fields; variable length mandatory and all optional frame body components are defined as information elements.

7.3.1 Fixed fields

7.3.1.1 Authentication Algorithm Number field

The Authentication Algorithm Number field indicates a single authentication algorithm. The length of the Authentication Algorithm Number field is 2 octets. The Authentication Algorithm Number field is illustrated in Figure 24. The following values are defined for authentication algorithm number:

Authentication algorithm number = 0: Open System
Authentication algorithm number = 1: Shared Key
All other values of authentication number are reserved.

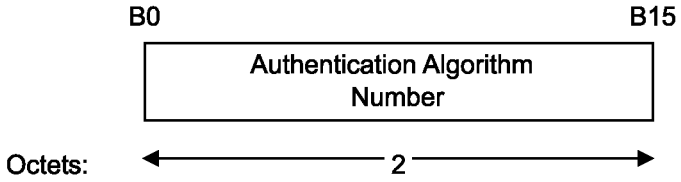

Figure 24—Authentication Algorithm Number fixed field

7.3.1.2 Authentication Transaction Sequence Number field

The Authentication Transaction Sequence Number field indicates the current state of progress through a multistep transaction. The length of the Authentication Transaction Sequence Number field is 2 octets. The Authentication Transaction Sequence Number field is illustrated in Figure 25.

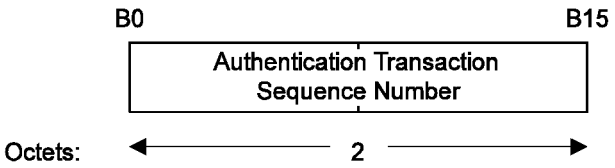

Figure 25—Authentication Transaction Sequence Number fixed field

7.3.1.3 Beacon Interval field

The Beacon Interval field represents the number of time units (TUs) between target beacon transmission times (TBTTs). The length of the Beacon Interval field is 2 octets. The Beacon Interval field is illustrated in Figure 26.

7.3.1.4 Capability Information field

The Capability Information field contains a number of subfields that are used to indicate requested or advertised capabilities.

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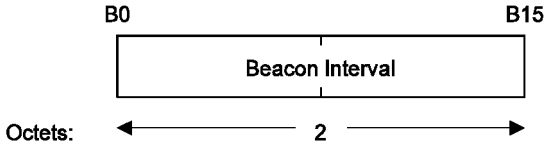

Figure 26—Beacon Interval fixed field

The length of the Capability Information field is 2 octets. The Capability Information field consists of the following subfields: ESS, IBSS, CF-Pollable, CF-Poll Request, Privacy, Short Preamble, Packet Binary Convolutional Code (PBCC), and Channel Agility. The format of the Capability Information field is illustrated in Figure 27.

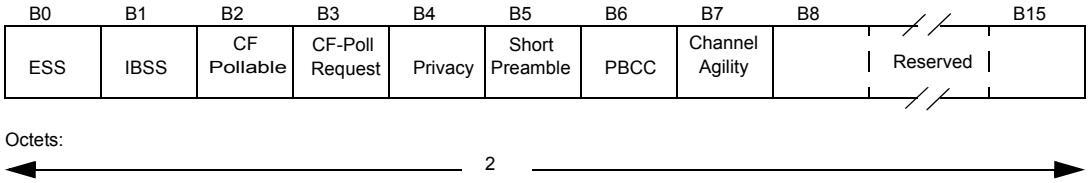

Figure 27—Capability Information fixed field

Each Capability Information subfield is interpreted only in the management frame subtypes for which the transmission rules are defined.

APs set the ESS subfield to 1 and the IBSS subfield to 0 within transmitted Beacon or Probe Response management frames. STAs within an IBSS set the ESS subfield to 0 and the IBSS subfield to 1 in transmitted Beacon or Probe Response management frames.

STAs set the CF-Pollable and CF-Poll Request subfields in Association and Reassociation Request management frames according to Table 16.

Table 16—STA usage of CF-Pollable and CF-Poll Request

CF-Pollable	CF-Poll request	Meaning
0	0	STA is not CF-Pollable
0	1	STA is CF-Pollable, not requesting to be placed on the CF-Polling list
1	0	STA is CF-Pollable, requesting to be placed on the CF-Polling list
1	1	STA is CF-Pollable, requesting never to be polled

APs set the CF-Pollable and CF-Poll Request subfields in Beacon, Probe Response, Association Response, and Reassociation Response management frames according to Table 17. An AP sets the CF-Pollable and CF-Poll Request subfield values in Association Response and Reassociation Response management frames equal to the values in the last Beacon or Probe Response frame that it transmitted.

APs set the Privacy subfield to 1 within transmitted Beacon, Probe Response, Association Response, and Reassociation Response management frames if WEP encryption is required for all data type frames exchanged within the BSS. If WEP encryption is not required, the Privacy subfield is set to 0.

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Table 17—AP usage of CF-Pollable and CF-Poll Request

CF-Pollable	CF-Poll Request	Meaning
0	0	No PC at AP
0	1	PC at AP for delivery only (no polling)
1	0	PC at AP for delivery and polling
1	1	Reserved

STAs within an IBSS set the Privacy subfield to 1 in transmitted Beacon or Probe Response management frames if WEP encryption is required for all data type frames exchanged within the IBSS. If WEP encryption is not required, the Privacy subfield is set to 0.

APs (as well as STAs in IBSSs) shall set the Short Preamble subfield to 1 in transmitted Beacon, Probe Response, Association Response, and Reassociation Response MMPDUs to indicate that the use of the Short Preamble option, as described in 18.2.2.2, is allowed within this BSS. To indicate that the use of the Short Preamble option is not allowed, the Short Preamble subfield shall be set to 0 in Beacon, Probe Response, Association Response, and Reassociation Response MMPDUs transmitted within the BSS.

STAs shall set the Short Preamble subfield to 1 in transmitted Association Request and Reassociation Request MMPDUs when the MIB attribute dot11ShortPreambleOptionImplemented is true. Otherwise, STAs shall set the Short Preamble subfield to 0 in transmitted Association Request and Reassociation Request MMPDUs.

APs (as well as STAs in IBSSs) shall set the PBCC subfield to 1 in transmitted Beacon, Probe Response, Association Response, and Reassociation Response MMPDUs to indicate that the use of the PBCC Modulation option, as described in 18.4.6.6, is allowed within this BSS. To indicate that the use of the PBCC Modulation option is not allowed, the PBCC subfield shall be set to 0 in Beacon, Probe Response, Association Response, and Reassociation Response MMPDUs transmitted within the BSS.

STAs shall set the PBCC subfield to 1 in transmitted Association Request and Reassociation Request MMPDUs when the MIB attribute dot11PBCCOptionImplemented is true. Otherwise, STAs shall set the PBCC subfield to 0 in transmitted Association Request and Reassociation Request MMPDUs.

Bit 7 of the Capabilities Information field shall be used to indicate the usage of Channel Agility by the High Rate direct sequence spread spectrum (HR/DSSS) PHY. STAs shall set the Channel Agility bit to 1 when Channel Agility is in use, and shall set it to 0 otherwise.

Bits 8–15 of the Capability Information field are reserved.

7.3.1.5 Current AP Address field

The Current AP Address field is the MAC address of the AP with which the station is currently associated. The length of the Current AP Address field is 6 octets. The Current AP Address field is illustrated in Figure 28.

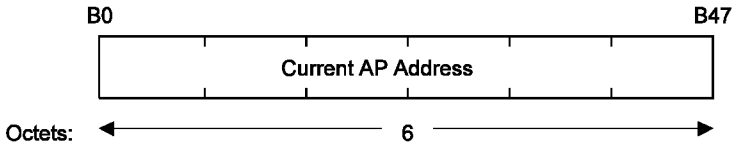

Figure 28—Current AP Address fixed field

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7.3.1.6 Listen Interval field

The Listen Interval field is used to indicate to the AP how often a STA wakes to listen to Beacon management frames. The value of this parameter is the STA's Listen Interval parameter of the MLME-ASSOCIATE.request primitive and is expressed in units of Beacon Interval. The length of the Listen Interval field is 2 octets. The Listen Interval field is illustrated in Figure 29.

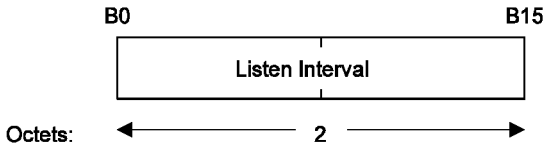

Figure 29—Listen Interval fixed field

An AP may use the Listen Interval information in determining the lifetime of frames that it buffers for a STA.

7.3.1.7 Reason Code field

This Reason Code field is used to indicate the reason that an unsolicited notification management frame of type Disassociation or Deauthentication was generated. The length of the Reason Code field is 2 octets. The Reason Code field is illustrated in Figure 30.

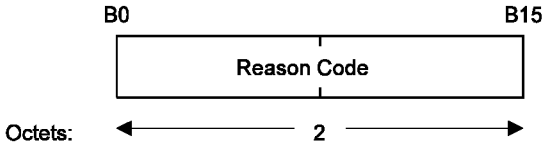

Figure 30—Reason Code fixed field

The reason codes are defined in Table 18.

Table 18—Reason codes

Reason code	Meaning
0	Reserved
1	Unspecified reason
2	Previous authentication no longer valid
3	Deauthenticated because sending station is leaving (or has left) IBSS or ESS
4	Disassociated due to inactivity
5	Disassociated because AP is unable to handle all currently associated stations
6	Class 2 frame received from nonauthenticated station
7	Class 3 frame received from nonassociated station
8	Disassociated because sending station is leaving (or has left) BSS
9	Station requesting (re)association is not authenticated with responding station
10–65 535	Reserved

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7.3.1.8 AID field

The AID field is a value assigned by an AP during association that represents the 16-bit ID of a STA. The length of the AID field is 2 octets. The AID field is illustrated in Figure 31.

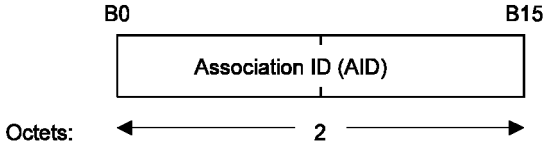

Figure 31—AID fixed field

The value assigned as the AID is in the range 1–2007 and is placed in the 14 LSBs of the AID field, with the two MSBs of the AID field each set to 1 (see 7.1.3.2).

7.3.1.9 Status Code field

The Status Code field is used in a response management frame to indicate the success or failure of a requested operation. The length of the Status Code field is 2 octets. The Status Code field is illustrated in Figure 32.

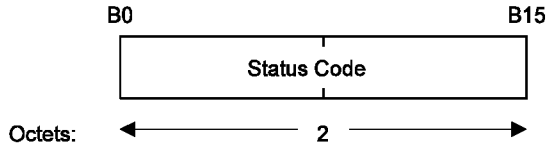

Figure 32—Status Code fixed field

If an operation is successful, then the status code is set to 0. If an operation results in failure, the status code indicates a failure cause. The failure cause codes are defined in Table 19.

Table 19—Status codes

Status code	Meaning
0	Successful
1	Unspecified failure
2–9	Reserved
10	Cannot support all requested capabilities in the Capability Information field
11	Reassociation denied due to inability to confirm that association exists
12	Association denied due to reason outside the scope of this standard
13	Responding station does not support the specified authentication algorithm
14	Received an Authentication frame with authentication transaction sequence number out of expected sequence
15	Authentication rejected because of challenge failure
16	Authentication rejected due to timeout waiting for next frame in sequence
17	Association denied because AP is unable to handle additional associated stations
18	Association denied due to requesting station not supporting all of the data rates in the BSSBasicRateSet parameter

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Table 19—Status codes *(continued)*

Status code	Meaning
19	Association denied due to requesting station not supporting the Short Preamble option
20	Association denied due to requesting station not supporting the PBCC Modulation option
21	Association denied due to requesting station not supporting the Channel Agility option
22–65 535	Reserved

7.3.1.10 Timestamp field

This field represents the value of the timing synchronization function (TSF) timer (see 11.1) of a frame's source. The length of the Timestamp field is 8 octets. The Timestamp field is illustrated in Figure 33.

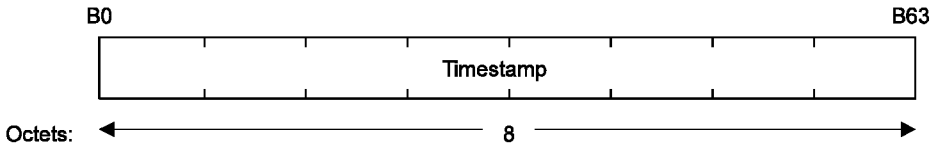

Figure 33—Timestamp fixed field

7.3.2 Information elements

Elements are defined to have a common general format consisting of a 1 octet Element ID field, a 1 octet length field, and a variable-length element-specific information field. Each element is assigned a unique Element ID as defined in this standard. The Length field specifies the number of octets in the Information field. See Figure 34.

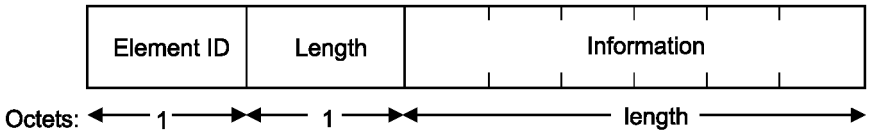

Figure 34—Element format

The set of valid elements is defined in Table 20.

Table 20—Element IDs

Information element	Element ID
SSID	0
Supported rates	1
FH Parameter Set	2
DS Parameter Set	3

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Table 20—Element IDs *(continued)*

Information element	Element ID
CF Parameter Set	4
TIM	5
IBSS Parameter Set	6
Country	7
Hopping Pattern Parameters	8
Hopping Pattern Table	9
Request	10
Reserved	11–15
Challenge text	16
Reserved for challenge text extension	17–31
Reserved	32–255

7.3.2.1 SSID element

The SSID element indicates the identity of an ESS or IBSS. See Figure 35.

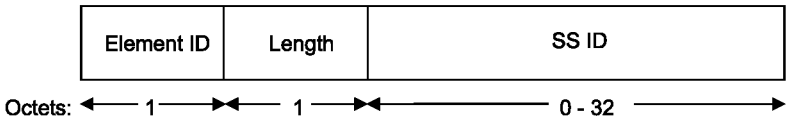

Figure 35—SSID element format

The length of the SSID information field is between 0 and 32 octets. A 0 length information field indicates the broadcast SSID.

7.3.2.2 Supported Rates element

The Supported Rates element specifies the values in the Operational-Rate-Set parameter, as described in the MLME-JOIN.request and MLME-START.request primitives. The information field is encoded as 1 to 8 octets, where each octet describes a single Supported Rate.

Within Beacon, Probe Response, Association Response, and Reassociation Response management frames, each Supported Rate belonging to the BSS basic rate set is encoded as an octet with the MSB (bit 7) set to 1 (e.g., a 1 Mbit/s rate belonging to the BSS basic rate set is encoded as X'82'). Rates not belonging to the BSS basic rate set are encoded with the MSB set to 0 (e.g., a 2 Mbit/s rate not belonging to the BSS basic rate set is encoded as X'04'). The MSB of each Supported Rate octet in other management frame types is ignored by receiving STAs.

The BSS basic rate set information in Beacon and Probe Response management frames is delivered to the management entity in a STA via the BSSBasicRateSet parameter in the MLME-SCAN.confirm primitive. It is used by the management entity in a STA to avoid associating with a BSS if the STA cannot receive and transmit all the data rates in the BSS basic rate set (see Figure 36).

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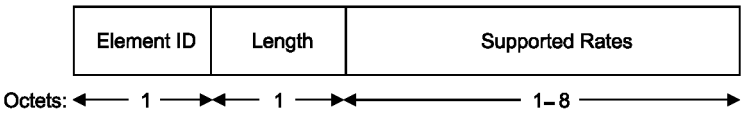

Figure 36—Supported rates element format

7.3.2.3 FH Parameter Set element

The FH Parameter Set element contains the set of parameters necessary to allow synchronization for STAs using a FH PHY. The information field contains Dwell Time, Hop Set, Hop Pattern, and Hop Index parameters. The total length of the information field is 5 octets. See Figure 37.

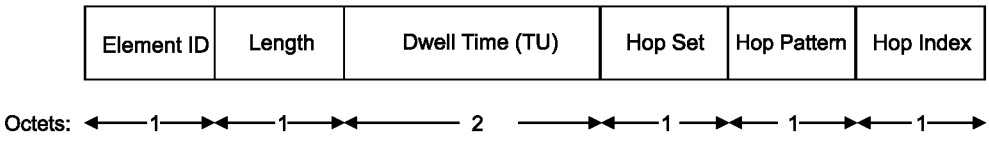

Figure 37—FH Parameter Set element format

The Dwell Time field is 2 octets in length and contains the dwell time in TU.

The Hop Set field identifies the current set (dot11CurrentSet) of hop patterns and is a single octet.

The Hop Pattern field identifies the current pattern (dot11CurrentPattern) within a set of hop patterns and is a single octet.

The Hop Index field selects the current index (dot11CurrentIndex) within a pattern and is a single octet.

The description of the attributes used in this subclause can be found in 14.8.2.

7.3.2.4 DS Parameter Set element

The DS Parameter Set element contains information to allow channel number identification for STAs using a direct sequence spread spectrum (DSSS) PHY. The information field contains a single parameter containing the dot11CurrentChannelNumber (see 15.4.6.2 for values). The length of the dot11CurrentChannelNumber parameter is 1 octet. See Figure 38.

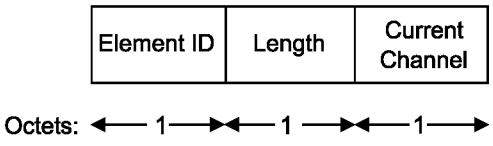

Figure 38—DS Parameter Set element format

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7.3.2.5 CF Parameter Set element

The CF Parameter Set element contains the set of parameters necessary to support the PCF. The information field contains the CFPCount, CFPPeriod, CFPMaxDuration, and CFPDurRemaining fields. The total length of the information field is 6 octets. See Figure 39.

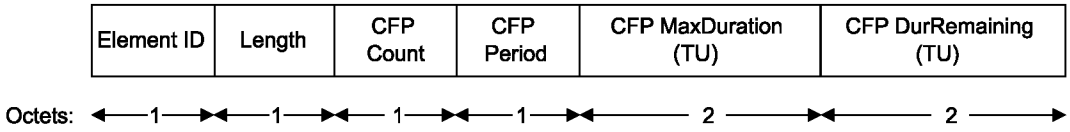

Figure 39—CF Parameter Set element format

CFPCount indicates how many delivery traffic indication messages (DTIMs) (including the current frame) appear before the next CFP start. A CFPCount of 0 indicates that the current DTIM marks the start of the CFP.

CFPPeriod indicates the number of DTIM intervals between the start of CFPs. The value is an integral number of DTIM intervals.

CFPMaxDuration indicates the maximum duration, in TU, of the CFP that may be generated by this PCF. This value is used by STAs to set their NAV at the TBTT of beacons that begin CFPs.

CFPDurRemaining indicates the maximum time, in TU, remaining in the present CFP, and is set to 0 in CFP Parameter elements of beacons transmitted during the CP. The value of CFPDurRemaining is referenced to the immediately previous TBTT. This value is used by all STAs to update their NAVs during CFPs.

7.3.2.6 TIM

The TIM element contains four fields: DTIM Count, DTIM Period, Bitmap Control, and Partial Virtual Bitmap. See Figure 40.

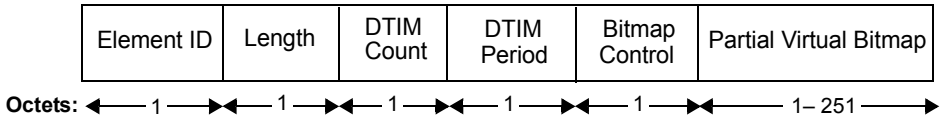

Figure 40—TIM element format

The Length field for this element indicates the length of the information field, which is constrained as described below.

The DTIM Count field indicates how many beacons (including the current frame) appear before the next DTIM. A DTIM Count of 0 indicates that the current TIM is a DTIM. The DTIM count field is a single octet.

The DTIM Period field indicates the number of Beacon intervals between successive DTIMs. If all TIMs are DTIMs, the DTIM Period field has the value 1. The DTIM Period value 0 is reserved. The DTIM period field is a single octet.

The Bitmap Control field is a single octet. Bit 0 of the field contains the Traffic Indicator bit associated with Association ID 0. This bit is set to 1 in TIM elements with a value of 0 in the DTIM Count field when one or

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more broadcast or multicast frames are buffered at the AP. The remaining 7 bits of the field form the Bitmap Offset.

The traffic-indication virtual bitmap, maintained by the AP that generates a TIM, consists of 2008 bits, and is organized into 251 octets such that bit number N ($0 \leq N \leq 2007$) in the bitmap corresponds to bit number (N mod 8) in octet number $\lfloor N / 8 \rfloor$ where the low-order bit of each octet is bit number 0, and the high order bit is bit number 7. Each bit in the traffic-indication virtual bitmap corresponds to traffic buffered for a specific station within the BSS that the AP is prepared to deliver at the time the beacon frame is transmitted. Bit number N is 0 if there are no directed frames buffered for the station whose Association ID is N. If any directed frames for that station are buffered and the AP is prepared to deliver them, bit number N in the traffic-indication virtual bitmap is 1. A PC may decline to set bits in the TIM for CF-Pollable stations it does not intend to poll (see 11.2.1.5).

The Partial Virtual Bitmap field consists of octets numbered $N1$ through $N2$ of the traffic indication virtual bitmap, where $N1$ is the largest even number such that bits numbered 1 through $(N1 \times 8) - 1$ in the bitmap are all 0 and $N2$ is the smallest number such that bits numbered $(N2 + 1) \times 8$ through 2007 in the bitmap are all 0. In this case, the Bitmap Offset subfield value contains the number $\lfloor N1/2 \rfloor$, and the Length field will be set to $(N2 - N1) + 4$.

In the event that all bits other than bit 0 in the virtual bitmap are 0, the Partial Virtual Bitmap field is encoded as a single octet equal to 0, and the Bitmap Offset subfield is 0.

7.3.2.7 IBSS Parameter Set element

The IBSS Parameter Set element contains the set of parameters necessary to support an IBSS. The information field contains the ATIM Window parameter. See Figure 41.

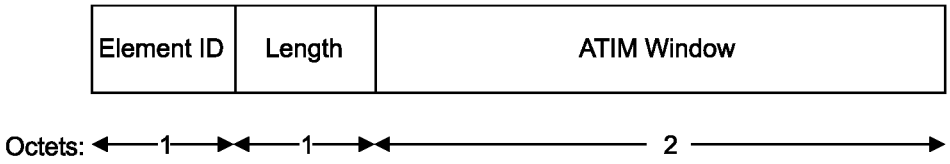

Figure 41—IBSS Parameter Set element format

The ATIM Window field is 2 octets in length and contains the ATIM Window length in TU.

7.3.2.8 Challenge Text element

The Challenge Text element contains the challenge text within Authentication exchanges. The element information field length is dependent upon the authentication algorithm and the transaction sequence number as specified in 8.1. See Figure 42.

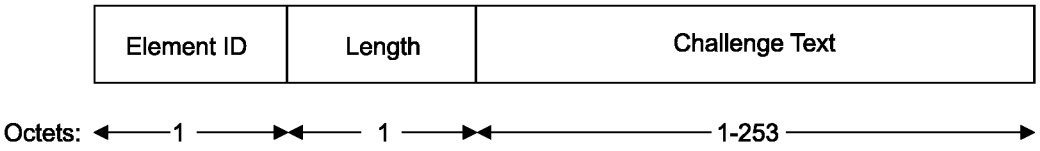

Figure 42—Challenge Text element format

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7.3.2.9 Country information element

The Country information element contains the information required to allow a station to identify the regulatory domain in which the station is located and to configure its PHY for operation in that regulatory domain. The format of this information element shall be as shown in Figure 43.

NOTE—The following text may not be necessary due to its presence in the current standard. In figures, all bits within fields are numbered, from 0 to k, where the length of the field is k + 1 bits. The octet boundaries within a field can be obtained by taking the bit-numbers of the field modulo 8. Octets within numeric fields that are longer than a single octet are depicted in increasing order of significance, from lowest numbered bit to highest numbered bit. The octets in fields longer than a single octet are sent to the PLCP in order from the octet containing the lowest numbered bits to the octet containing the highest numbered bits.

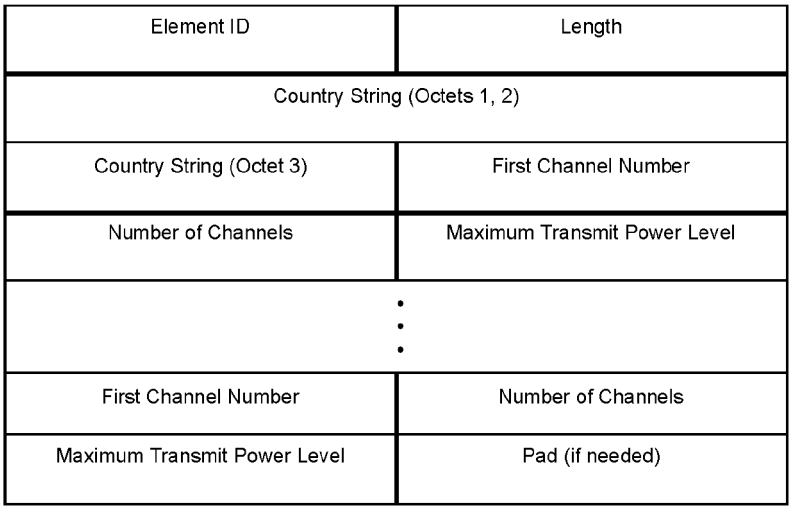

Figure 43—Country information element

The element identifier for this information element shall be 7. The length of the information element is variable, as the element may contain more than one triplet comprising the First Channel Number, Number of Channels, and Maximum Transmit Power Level fields. The minimum length of the information element is 8 octets.

The Country String field of the element shall be 3 octets in length. The AP shall set this field to the value contained in the dot11CountryString attribute before transmission in a Beacon or Probe Response frame. Upon reception of this element, a STA shall set the value of the dot11CountryString to the value contained in this field.

The First Channel Number field shall be 1 octet in length. It shall contain a positive integer value that indicates the lowest channel number in the subband described in this information element. The group of channels described by each pair of the First Channel Number and the Number of Channels fields shall not have overlapping channel identifiers. [For example, the pairs (2,4) and (5,2) overlap and shall not be used together.] The First Channel Numbers shall be monotonically increasing.

The Number of Channels field of the subelement shall be 1 octet in length.

The Maximum Transmit Power Level field is a signed number and shall be 1 octet in length. It shall indicate the maximum power, in dBm, allowed to be transmitted.

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The Pad field is 0 or 1 octet in length. The length of the Country information element shall be evenly divisible by 2. The Pad shall be used to add a single octet to the element if the length is not evenly divisible by 2. The value of the Pad field shall be 0.

7.3.2.10 Hopping Pattern Parameters information element

The Hopping Pattern Parameters information element contains the information necessary to allow a station to calculate the code family using the hyperbolic congruence code (HCC) and extended HCC (EHCC) algorithms. See 9.9.2.1 for a description of the HCC and EHCC algorithms. The format of this information element shall be as shown in Figure 44.

Element ID	Length
Prime Radix	Number of Channels

Figure 44—Hopping Pattern Parameters information element

The Element ID of this information element shall be 8. The length of this element is 4 octets.

The Prime Radix field of this element shall indicate the value to be used as the prime radix (*N*) in the HCC and EHCC algorithms. The value of this field shall be a positive integer. The size of this field is 1 octet.

The Number of Channels field of this element shall indicate the value to be used as the maximum for the family index (*a*) in the HCC and EHCC algorithms. The value of this field shall be a positive integer and shall not be less than the prime radix minus 3 (*N*–3). The size of this field is 1 octet.

7.3.2.11 Hopping Pattern Table information element

The Hopping Pattern Table information element contains the information necessary for a FH implementation to be able to create the hopping sequences necessary to operate in the regulatory domain in which the information element was received. The format of the information element shall be as shown in Figure 45.

Element ID	Length
Flag	Number of Sets
Modulus	Offset
Random Table (Octets 1, 2)	
• • •	
Random Table (Octets N–1, N)	

Figure 45—Hopping Pattern Table information element

The Element ID of this information element shall be 9. The information element is variable in length. The length of the information element is indicated by the Length field.

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The Flag field indicates that a Random Table is present when the value is 1. When the flag value is 0, it indicates that a Random Table is not present and that the hop index method is to be used to determine the hopping sequence. The size of this field is 1 octet.

The Number of Sets field indicates the total number of sets within the hopping patterns. The size of this field is 1 octet.

The Modulus and Offset fields indicate the values to be used in the equations to create a hopping sequence from the Random Table information. The size of these fields are each 1 octet.

The Random Table field is a variable length field. It is a vector of single octet values that indicate the random sequence to be followed during a hopping sequence. The size of the Random Table field is found by subtracting 4 from the value of the Length field of this element.

Two equations are used to create a hopping sequence from the information in the Frequency Hopping information element and the Hopping Pattern Table information element. Equation (1), the Random Table Method, shall be used when the value of the Flag field of the Hopping Pattern Table information element is 1. Equation (2), the Hop Index Method, shall be used when the value of the Flag field of the Hopping Pattern Table information element is 0.

$$f_x(i) = [b(i) + x] \bmod (m) + q \tag{1}$$

$$f_x(i) = [(i - 1) \times x] \bmod (m) + q \tag{2}$$

$$x = n \times p + s - 1 \tag{3}$$

where

i is the index.
m is the modulus.
q is the offset.
n is the number of sets.
p is the current pattern.
s is the current set number.

The values of *i, p,* and *s* are found in the Frequency Hopping information element. The values of *m, n,* and *q* are found in the Hopping Pattern Table information element.

7.3.2.12 Request information element

This element is placed in a Probe Request frame to request that the responding STA include the requested information in the Probe Response frame. The format of the information element shall be as shown in Figure 46.

The Element ID of this information element shall be 10. The information element is variable in length. The length of the information element is indicated in the Length field.

The Requested Element IDs are the list of elements that are to be included in the responding STA's Probe Response frame. The Requested Element IDs shall be listed in order of increasing element ID.

A STA shall return only those information elements that it supports. In an improperly formed Request information element, a STA may ignore the first information element requested that is not ordered properly and all subsequent information elements requested. In the probe response frame, the STA shall return the

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requested information elements in the same order requested in the Request information element of the probe request frame.

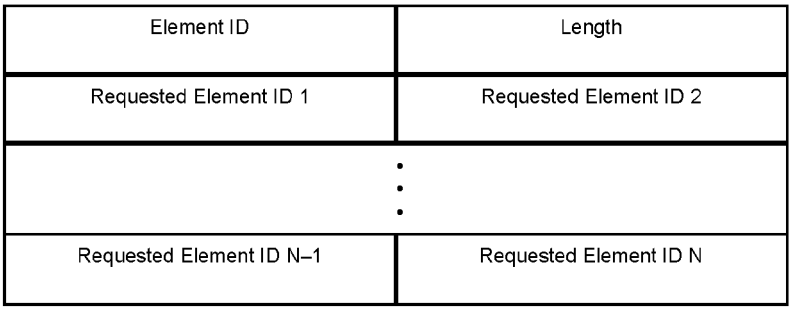

Figure 46—Request information element

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8. Authentication and privacy

8.1 Authentication services

IEEE 802.11 defines two subtypes of authentication service: *Open System* and *Shared Key*. The subtype invoked is indicated in the body of authentication management frames. Thus authentication frames are self-identifying with respect to authentication algorithm. All management frames of subtype Authentication shall be unicast frames as authentication is performed between pairs of stations (i.e., multicast authentication is not allowed). Management frames of subtype Deauthentication are advisory, and may therefore be sent as group-addressed frames.

A mutual authentication relationship shall exist between two stations following a successful authentication exchange as described below. Authentication shall be used between stations and the AP in an infrastructure BSS. Authentication may be used between two STAs in an IBSS.

8.1.1 Open System authentication

Open System authentication is the simplest of the available authentication algorithms. Essentially it is a null authentication algorithm. Any STA that requests authentication with this algorithm may become authenticated if dot11AuthenticationType at the recipient station is set to Open System authentication. Open System authentication is not required to be successful as a STA may decline to authenticate with any particular other STA. Open System authentication is the default authentication algorithm.

Open System authentication involves a two-step authentication transaction sequence. The first step in the sequence is the identity assertion and request for authentication. The second step in the sequence is the authentication result. If the result is “successful,” the STAs shall be mutually authenticated.

8.1.1.1 Open System authentication (first frame)

— Message type: Management
— Message subtype: Authentication
— Information items:
  • Authentication Algorithm Identification = “Open System”
  • Station Identity Assertion (in SA field of header)
  • Authentication transaction sequence number = 1
  • Authentication algorithm dependent information (none)
— Direction of message: From authentication initiating STA to authenticating STA

8.1.1.2 Open System authentication (final frame)

— Message type: Management
— Message subtype: Authentication
— Information items:
  • Authentication Algorithm Identification = “Open System”
  • Authentication transaction sequence number = 2
  • Authentication algorithm dependent information (none)
  • The result of the requested authentication as defined in 7.3.1.9
— Direction of message: From authenticating STA to initiating STA

If dot11AuthenticationType does not include the value “Open System,” the result code shall not take the value “successful.”

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8.1.2 Shared Key authentication

Shared Key authentication supports authentication of STAs as either a member of those who know a shared secret key or a member of those who do not. IEEE 802.11 Shared Key authentication accomplishes this without the need to transmit the secret key in the clear; however, it does require the use of the WEP privacy mechanism. Therefore, this authentication scheme is only available if the WEP option is implemented. Additionally, the Shared Key authentication algorithm shall be implemented as one of the dot11AuthenticationAlgorithms at any STA where WEP is implemented.

The required secret, shared key is presumed to have been delivered to participating STAs via a secure channel that is independent of IEEE 802.11. This shared key is contained in a write-only MIB attribute via the MAC management path. The attribute is write-only so that the key value remains internal to the MAC.

During the Shared Key authentication exchange, both the challenge and the encrypted challenge are transmitted. This facilitates unauthorized discovery of the pseudo-random number (PRN) sequence for the key/IV pair used for the exchange. Implementations should therefore avoid using the same key/IV pair for subsequent frames.

A STA shall not initiate a Shared Key authentication exchange unless its dot11PrivacyOptionImplemented attribute is “true.”

In the following description, the STA initiating the authentication exchange is referred to as the *requester*, and the STA to which the initial frame in the exchange is addressed is referred to as the *responder*.

8.1.2.1 Shared Key authentication (first frame)

— Message type: Management
— Message subtype: Authentication
— Information Items:
  • Station Identity Assertion (in SA field of header)
  • Authentication Algorithm Identification = “Shared Key”
  • Authentication transaction sequence number = 1
  • Authentication algorithm dependent information (none)
— Direction of message: From requester to responder

8.1.2.2 Shared Key authentication (second frame)

Before sending the second frame in the Shared Key authentication sequence, the responder shall use WEP to generate a string of octets that shall be used as the authentication challenge text.

— Message type: Management
— Message subtype: Authentication
— Information Items:
  • Authentication Algorithm Identification = “Shared Key”
  • Authentication transaction sequence number = 2
  • Authentication algorithm dependent information = the authentication result.
  • The result of the requested authentication as defined in 7.3.1.9

    If the status code is not “successful,” this shall be the last frame of the transaction sequence. If the status code is not “successful,” the content of the challenge text field is unspecified.

    If the status code is “successful,” the following additional information items shall have valid contents:

    Authentication algorithm dependent information = challenge text.

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This field shall be of fixed length of 128 octets. The field shall be filled with octets generated by the WEP pseudo-random number generator (PRNG). The actual value of the challenge field is unimportant, but the value shall not be a single static value. The key and IV used when generating the challenge text are unspecified because this key/IV value does not have to be shared and does not affect interoperability.

— Direction of message: From responder to requester

8.1.2.3 Shared Key authentication (third frame)

The requester shall copy the challenge text from the second frame into the third frame. The third frame shall be transmitted after encryption by WEP, as defined in 8.2.3, using the shared secret key.

— Message type: Management
— Message subtype: Authentication
— Information Items:
  • Authentication Algorithm Identification = “Shared Key”
  • Authentication transaction sequence number = 3
  • Authentication algorithm dependent information = challenge text from sequence two frame
— Direction of message: From requester to responder

This frame shall be encrypted as described below.

8.1.2.4 Shared Key authentication (final frame)

The responder shall attempt to decrypt the contents of the third frame in the authentication sequence as described below. If the WEP ICV check is successful, the responder shall then compare the decrypted contents of the Challenge Text field to the challenge text that was sent in Frame 2 of the sequence. If they are the same, then the responder shall respond with a successful status code in Frame 4 of the sequence. If the WEP ICV check fails, the responder shall respond with an unsuccessful status code in Frame 4 of the sequence as described below.

— Message type: Management
— Message subtype: Authentication
— Information Items:
  • Authentication Algorithm Identification = “Shared Key”
  • Authentication transaction sequence number = 4
  • Authentication algorithm dependent information = the authentication result
    The result of the requested authentication.
    This is a fixed length item with values “successful” and “unsuccessful.”
— Direction of message: From responder to requester

8.2 The WEP algorithm

8.2.1 Introduction

Eavesdropping is a familiar problem to users of other types of wireless technology. IEEE 802.11 specifies a wired LAN equivalent data confidentiality algorithm. WEP is defined as protecting authorized users of a wireless LAN from casual eavesdropping. This service is intended to provide functionality for the wireless LAN equivalent to that provided by the physical security attributes inherent to a wired medium.

Data confidentiality depends on an external key management service to distribute data enciphering/deciphering keys. The IEEE 802.11 standards committee specifically recommends against running an IEEE

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802.11 LAN with privacy but without authentication. While this combination is possible, it leaves the system open to significant security threats.

8.2.2 Properties of the WEP algorithm

The WEP algorithm has the following properties:

- *It is reasonably strong:* The security afforded by the algorithm relies on the difficulty of discovering the secret key through a brute-force attack. This in turn is related to the length of the secret key and the frequency of changing keys. WEP allows for the changing of the key (*k*) and frequent changing of the IV.
- *It is self-synchronizing:* WEP is self-synchronizing for each message. This property is critical for a data-link level encryption algorithm, where "best effort" delivery is assumed and packet loss rates may be high.
- *It is efficient:* The WEP algorithm is efficient and may be implemented in either hardware or software.
- *It may be exportable:* Every effort has been made to design the WEP system operation so as to maximize the chances of approval, by the U.S. Department of Commerce, of export from the U.S. of products containing a WEP implementation. However, due to the legal and political climate toward cryptography at the time of publication, no guarantee can be made that any specific IEEE 802.11 implementations that use WEP will be exportable from the USA.
- *It is optional:* The implementation and use of WEP is an IEEE 802.11 option.

8.2.3 WEP theory of operation

The process of disguising (binary) data in order to hide its information content is called *encryption* (denoted by *E)* (see Schneier [B11]). Data that is not enciphered is called *plaintext* (denoted by *P*) and data that is enciphered is called *ciphertext* (denoted by *C*). The process of turning ciphertext back into plaintext is called *decryption* (denoted by *D*). A *cryptographic algorithm*, or cipher, is a mathematical function used for enciphering or deciphering data. Modern cryptographic algorithms use a key sequence (denoted by *k*) to modify their output. The encryption function *E* operates on *P* to produce *C:*

$$E_k(P) = C$$

In the reverse process, the decryption function *D* operates on *C* to produce *P:*

$$D_k(C) = P$$

As illustrated in Figure 47, note that if the same key can be used for encryption and decryption then

$$D_k(E_k(P)) = P$$

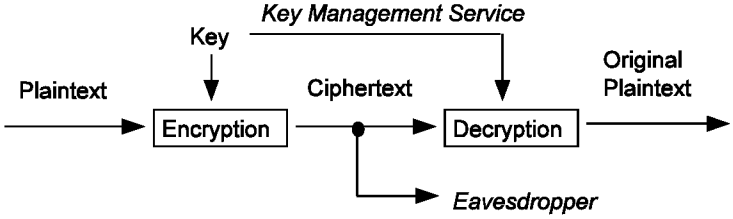

Figure 47—A confidential data channel

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The WEP algorithm is a form of electronic code book in which a block of plaintext is bitwise XORed with a pseudo-random key sequence of equal length. The key sequence is generated by the WEP algorithm.

Referring to Figure 48 and viewing from left to right, encipherment begins with a *secret key* that has been distributed to cooperating STAs by an external key management service. WEP is a symmetric algorithm in which the same key is used for encipherment and decipherment.

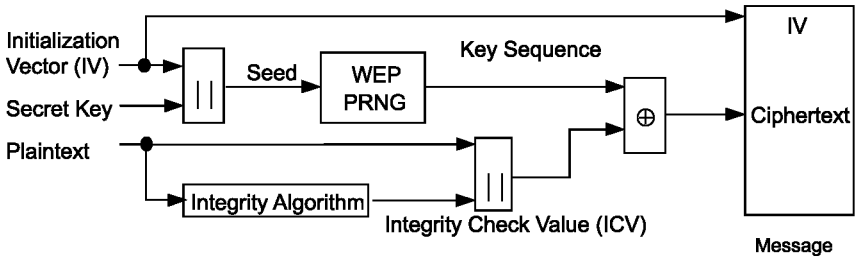

Figure 48—WEP encipherment block diagram

The secret key is concatenated with an IV and the resulting *seed* is input to a PRNG. The PRNG outputs a *key sequence k* of pseudo-random octets equal in length to the number of data octets that are to be transmitted in the expanded MPDU plus 4 (because the key sequence is used to protect the ICV as well as the data). Two processes are applied to the plaintext MPDU. To protect against unauthorized data modification, an integrity algorithm operates on *P* to produce an ICV. Encipherment is then accomplished by mathematically combining the key sequence with the plaintext concatenated with the ICV. The output of the process is a *message* containing the IV and ciphertext.

The WEP PRNG is the critical component of this process because it transforms a relatively short secret key into an arbitrarily long key sequence. This greatly simplifies the task of key distribution, as only the secret key needs to be communicated between STAs. The IV extends the useful lifetime of the secret key and provides the self-synchronous property of the algorithm. The secret key remains constant while the IV changes periodically. Each new IV results in a new seed and key sequence, thus there is a one-to-one correspondence between the IV and *k*. The IV may be changed as frequently as every MPDU; and because it travels with the message, the receiver will always be able to decipher any message. The IV is transmitted in the clear because it does not provide an attacker with any information about the secret key and because its value must be known by the recipient in order to perform the decryption.

When choosing how often to change IV values, implementers should consider that the contents of some fields in higher-layer protocol headers, as well as certain other higher-layer information, is constant or highly predictable. When such information is transmitted while encrypting with a particular key and IV, an eavesdropper can readily determine portions of the key sequence generated by that (key, IV) pair. If the same (key, IV) pair is used for successive MPDUs, this effect may substantially reduce the degree of privacy conferred by the WEP algorithm, allowing an eavesdropper to recover a subset of the user data without any knowledge of the secret key. Changing the IV after each MPDU is a simple method of preserving the effectiveness of WEP in this situation.

The WEP algorithm is applied to the frame body of an MPDU. The (IV, frame body, ICV) triplet forms the actual data to be sent in the data frame.

For WEP protected frames, the first four octets of the frame body contain the IV field for the MPDU. This field is defined in 8.2.5. The PRNG seed is 64 bits. Bits 0 through 23 of the IV correspond to bits 0 through 23 of the PRNG seed, respectively. Bits 0 through 39 of the secret key correspond to bits 24 through 63 of the PRNG seed, respectively. The bit and octet numbering conventions in 7.1.1 apply to the PRNG seed, secret key, and IV. The numbering of the octets of the PRNG seed corresponds to that of the RC4 key. The

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IV is followed by the MPDU, which is followed by the ICV. The WEP ICV is 32 bits. The WEP Integrity Check algorithm is CRC-32, as defined in 7.1.3.6.

As stated previously, WEP combines *k* with *P* using bitwise XOR.

Referring to Figure 49 and viewing from left to right, decipherment begins with the arrival of a message. The IV of the incoming message shall be used to generate the key sequence necessary to decipher the incoming message. Combining the ciphertext with the proper key sequence yields the original plaintext and ICV. Correct decipherment shall be verified by performing the integrity check algorithm on the recovered plaintext and comparing the output ICV' to the ICV transmitted with the message. If ICV' is not equal to ICV, the received MPDU is in error and an error indication is sent to MAC management. MSDUs with erroneous MPDUs (due to inability to decrypt) shall not be passed to LLC.

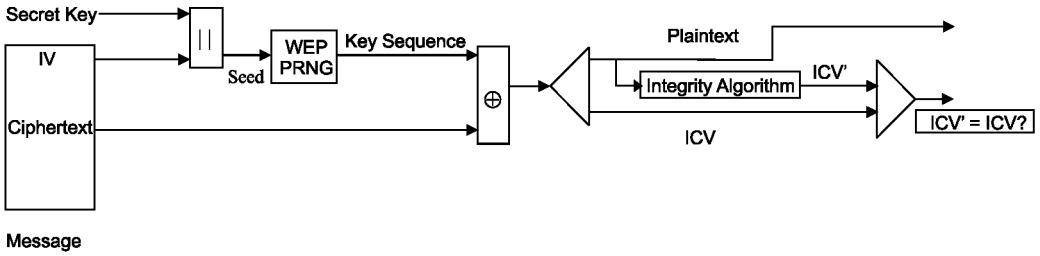


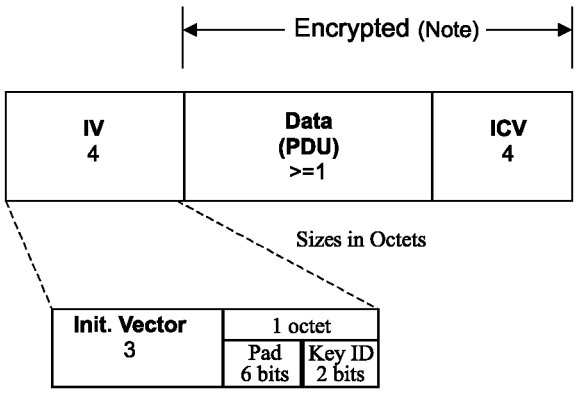
Figure 49—WEP decipherment block diagram

8.2.4 WEP algorithm specification

WEP uses the RC4 PRNG algorithm from RSA Data Security, Inc.[8]

8.2.5 WEP Frame Body expansion

Figure 50 shows the encrypted Frame Body as constructed by the WEP algorithm.



NOTE – The encypherment process has expanded the original Frame Body by 8 octets, 4 for the IV field and 4 for the ICV. The ICV is calculated on the data field only.

Figure 50—Construction of expanded WEP Frame Body

[8]Details of the RC4 algorithm are available from RSA. Contact RSA for algorithm details and the uniform RC4 licensee terms that RSA offers to anyone wishing to use RC4 for the purpose of implementing the IEEE 802.11 WEP option. If necessary, contact the IEEE Standards Department Intellectual Property Rights Administrator for details on how to communicate with RSA.

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The WEP ICV shall be a 32-bit field containing the CRC-32, as defined in 7.1.3.6 calculated over the Data (PDU) field as depicted in Figure 50. The expanded Frame Body shall include a 32-bit IV field immediately preceding the original Frame Body. This field shall contain three subfields: a three-octet field that contains the initialization vector, a 2-bit key ID field, and a 6-bit pad field. The ordering conventions defined in 7.1.1 apply to the IV fields and its subfields and to the ICV field. The key ID subfield contents select one of four possible secret key values for use in decrypting this Frame Body. Interpretation of these bits is discussed further in 8.3.2. The contents of the pad subfield shall be zero. The key ID occupies the two MSBs of the last octet of the IV field, while the pad occupies the six LSBs of this octet.

The WEP mechanism is invisible to entities outside the IEEE 802.11 MAC data path.

8.3 Security-Related MIB attributes

The IEEE 802.11 security mechanisms are controlled via the MAC management path and related MIB attributes. This subclause gives an overview of the security-related MIB attributes and how they are used. For details of the MIB attribute definitions, refer to 11.4.

8.3.1 Authentication-Related MIB attributes

The type of authentication invoked when authentication is attempted is controlled by the Authentication-Type parameter to the MLME-AUTHENTICATE.request primitive. The type of authentication request that may be accepted by a STA is controlled by the MIB attribute dot11AuthenticationType. The type of authentication is selected from the following set of values:

— Open System
— Shared Key

All other values are reserved. The numeric encoding of these values is given in 7.3.1.1.

8.3.2 Privacy-Related MIB attributes

WEP invocation is controlled by the parameters passed to the MLME-AUTHENTICATE.request primitive as well as a number of MIB attributes. An overview of the attributes and their usage is given in this subclause. All MIB attributes that hold WEP keys are externally write-only; the contents shall not be readable via MAC management service access points (SAPs). See 11.4 for the formal MIB attribute definitions.

The boolean variable dot11PrivacyInvoked shall be set to false to prevent the STA from transmitting MPDUs of type Data with the WEP subfield of the Frame Control field set to 1. It does not affect MPDU or MMPDU reception.

The default value for all WEP keys shall be null. Note that encrypting a frame using WEP with a null key is not the same as failing to encrypt the frame. Any request to encrypt a frame with a null key shall result in the MSDU being discarded and an MA-UNIDATA-STATUS.indication with a transmission status indicating that the frame may not be encrypted with a null key. Decrypting a frame whose WEP subfield is set to 1 involves stripping the IV, and checking the ICV against the calculated ICV' value computed over the data contained in the MPDU.

To support shared key configurations, the MIB contains a four-element vector called “dot11WEPDefaultKeys.” The default value for each element of this vector is null. These elements contain the default keys to be used with WEP.

An additional attribute called “dot11WEPDefaultKeyID” is an integer. When set to a value of 0, 1, 2, or 3, MPDUs transmitted with the WEP subfield of the Frame Control field set to 1 shall be encrypted using the

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first, second, third, or fourth element, respectively, from dot11WEPDefaultKeys, unless the frame has an individual receiver address and a key mapping exists for the RA field of the frame. On receive, the incoming MPDU shall be decrypted using the element from dot11WEPDefaultKeys specified by the received key ID field, unless the frame has an individual receiver address and a key mapping exists for the TA field of the frame. The value in the transmitted key ID field shall be zero in all cases except when dot11WEPDefaultKeyID is used to encrypt a frame and is set to a value of 1, 2, or 3, in which case the transmitted key ID field shall contain the value of dot11WEPDefaultKeyID.

When the boolean attribute aExcludeUnencrypted is set to true, MPDUs of type Data received by the STA with the WEP subfield of the Frame Control field equal to zero shall not be indicated at the MAC service interface. When aExcludeUnencrypted is set to true, only MSDUs that have been decrypted successfully shall be indicated at the MAC service interface.

IEEE 802.11 does not require that the same WEP key be used for all STAs. The MIB supports the ability to share a separate WEP key for each receiver address/transmitter address pair. Key mapping is supported by a MIB attribute that is an array called "dot11WEPKeyMappings." dot11WEPKeyMappings contains zero or one entry for each MAC address, up to an implementation-defined maximum number of entries identified by dot11WEPKeyMappingLength, and contains two fields for each entry: a boolean "WEPOn" and the corresponding WEPKey. In an infrastructure BSS, the AP's WEPOn value in the entry in its dot11WEPKeyMapping table corresponding to a STA's MAC address shall not be set to true for a STA if that STA has not successfully initiated and completed an authentication sequence using an authentication type other than "Open System." The default value for all WEPOn fields is false. dot11WEPKeyMappings shall be indexed by either receiver address or transmitter address (because WEP is applied only to the wireless link), as described in the decision trees that follow in this subclause. When an entry in the table exists for a particular MAC address, the values in the dot11WEPKeyMappings attribute shall be used instead of the dot11WEPDefaultKeyID and dot11WEPDefaultKeys variables.

The minimal value of dot11WEPKeyMappingLength shall be 10. This value represents a minimum capability that may be assumed for any STA implementing the WEP option.

When transmitting a frame of type Data, the values of dot11PrivacyInvoked, dot11WEPKeyMappings, dot11WEPDefaultKeys, and dot11WEPDefaultKeyID in effect at an unspecified time between receipt by the MAC of the MAUNITDATA.request primitive and the time of transmission of that frame shall be used according to the following decision tree:

```
if dot11PrivacyInvoked is "false"
        the MPDU is transmitted without encryption
else
        if (the MPDU has an individual receiver address and
         there is an entry in dot11WEPKeyMappings for that receiver address)
                if that entry has WEPOn set to false
                        the MPDU is transmitted without encryption
                else
                        if that entry contains a key that is null
                                discard the entire MSDU and generate an
                                MA-UNITDATA-STATUS.indication primitive to
                                notify LLC that the MSDU was undeliverable due to
                                a null WEP key
                        else
                                encrypt the MPDU using that entry's key, setting the keyID
                                subfield of the IV field to zero
        else
                if (the MPDU has a group receiver address and the Privacy subfield
                        of the Capability Information field in this BSS is set to 0)
```


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```
                        the MPDU is transmitted without encryption
                else
                        if dot11WEPDefaultKeys[dot11WEPDefaultKeyID] is null
                                discard the MSDU and generate an
                                MA-UNITDATA-STATUS.indication primitive to
                                notify LLC that the entire MSDU was undeliverable
                                due to a null WEP key
                        else
                                encrypt the MPDU using
                                dot11WEPDefaultKeys[dot11WEPDefaultKeyID],
                                setting the KeyID subfield of the IV field to
                                dot11WEPDefaultKeyID
```

When receiving a frame of type Data, the values of dot11PrivacyOptionImplemented, dot11WEPKeyMappings, dot11WEPDefaultKeys, dot11WEPDefaultKeyID, and aExcludeUnencrypted in effect at the time the PHY-RXSTART.indication primitive is received by the MAC shall be used according to the following decision tree:

```
if the WEP subfield of the Frame Control field is zero
        if aExcludeUnencrypted is "true"
                discard the frame body without indication to LLC and increment
                dot11WEPExcludedCount
        else
                receive the frame without decryption
else
        if dot11PrivacyOptionImplemented is "true"
                if (the MPDU has individual receiver address and
                 there is an entry in dot11WEPKeyMappings matching that transmitter address)
                        if that entry has WEPOn set to false
                                discard the frame body and increment
                                dot11WEPUndecryptableCount
                        else
                                if that entry contains a key that is null
                                        discard the frame body and increment
                                        dot11WEPUndecryptableCount
                                else
                                        attempt to decrypt with that key, incrementing
                                        dot11WEPICVErrorCount if the ICV check fails
                else
                        if dot11WEPDefaultKeys[keyID] is null
                                discard the frame body and increment
                                dot11WEPUndecryptableCount
                        else
                                attempt to decrypt with dot11WEPDefaultKeys[keyID],
                                incrementing dot11WEPICVErrorCount if the ICV check fails
        else
                discard the frame body and increment dot11WEPUndecryptableCount
```

When transmitting a frame of type Management, subtype Authentication with an Authentication Transaction Sequence Number field value of 2, the MAC shall operate according to the following decision tree:

```
if dot11PrivacyOptionImplemented is "false"
        the MMPDU is transmitted with a sequence
        of zero octets in the Challenge Text field and a Status Code value of 13
```

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else

the MMPDU is transmitted with a sequence of 128 octets generated using the WEP PRNG and a key whose value is unspecified and beyond the scope of this standard and a randomly chosen IV value (note that this will typically be selected by the same mechanism for choosing IV values for transmitted data MPDUs) in the Challenge Text field and a status code value of 0 (the IV used is immaterial and is not transmitted). Note that there are cryptographic issues involved in the choice of key/IV for this process as the challenge text is sent unencrypted and therefore provides a known output sequence from the PRNG.

When receiving a frame of type Management, subtype Authentication with an Authentication Transaction Sequence Number field value of 2, the MAC shall operate according to the following decision tree:

if the WEP subfield of the Frame Control field is one
respond with a status code value of 15
else
if dot11PrivacyOptionImplemented is "true"
if there is a mapping in dot11WEPKeyMappings matching the MSDU's transmitter address
if that key is null
respond with a frame whose Authentication Transaction Sequence Number field is 3 that contains the appropriate Authentication Algorithm Number, a status code value of 15 and no Challenge Text field, without encrypting the contents of the frame
else
respond with a frame whose Authentication Transaction Sequence Number field is 3 that contains the appropriate Authentication Algorithm Number, a status code value of 0 and the identical Challenge Text field, encrypted using that key, and setting the key ID subfield in the IV field to 0
else
if dot11WEPDefaultKeys[dot11WEPDefaultKeyID] is null
respond with a frame whose Authentication Transaction Sequence Number field is 3 that contains the appropriate Authentication Algorithm Number, a status code value of 15 and no Challenge Text field, without encrypting the contents of the frame
else
respond with a frame whose Authentication Transaction Sequence Number field is 3 that contains the appropriate Authentication Algorithm Number, a status code value of 0 and the identical Challenge Text field, encrypted using dot11WEPDefaultKeys[dot11WEPDefaultKeyID], setting the key ID subfield in the IV field to dot11WEPDefaultKeyID
else
respond with a frame whose Authentication Transaction Sequence Number field is 3 that contains the appropriate Authentication Algorithm Number, a status code value of 13 and no Challenge Text field, without encrypting the contents of the frame

When receiving a frame of type Management, subtype Authentication with an Authentication Transaction Sequence Number field value of 3, the MAC shall operate according to the following decision tree:

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```
if the WEP subfield of the Frame Control field is zero
        respond with a status code value of 15
else
        if dot11PrivacyOptionImplemented is "true"
                if there is a mapping in dot11WEPKeyMappings matching the MSDU's
                 transmitter address
                        if that key is null
                                respond with a frame whose Authentication Transaction
                                Sequence Number field is 4 that contains the appropriate
                                Authentication Algorithm Number, and a status code value
                                of 15 without encrypting the contents of the frame
                        else
                                attempt to decrypt with that key, incrementing
                                dot11WEPICVErrorCount and responding with a status code value
                                of 15 if the ICV check fails
                else
                        if dot11WEPDefaultKeys[keyID] is null
                                respond with a frame whose Authentication Transaction
                                Sequence Number field is 4 that contains the appropriate
                                Authentication Algorithm Number, and a status code value
                                of 15 without encrypting the contents of the frame
                        else
                                attempt to decrypt with dot11WEPDefaultKeys[keyID],
                                incrementing dot11WEPICVErrorCount and responding with
                                a status code value of 15 if the ICV check fails
        else
                respond with a frame whose Authentication Transaction Sequence Number
                field is 4 that contains the appropriate Authentication Algorithm Number,
                and a status code value of 15
```

The attribute dot11PrivacyInvoked shall not take the value "true" if the attribute dot11PrivacyOption-Implemented is "false." Setting the attribute dot11WEPKeyMappings to a value that includes more than dot11WEPKeyMappingLength entries is illegal and shall have an implementation-specific effect on the operation of the privacy service. Note that dot11WEPKeyMappings may contain between zero and dot11WEPKeyMappingLength entries, inclusive.

It is recommended that the values of the attributes in the aPrivacygrp not be changed during the authentication sequence as unintended operation may result.

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9. MAC sublayer functional description

The MAC functional description is presented in this clause. The architecture of the MAC sublayer, including the distributed coordination function (DCF), the PCF, and their coexistence in an IEEE 802.11 LAN are introduced in 9.1. These functions are expanded on in 9.2 and 9.3, and a complete functional description of each is provided. Fragmentation and defragmentation are covered in 9.4 and 9.5. Multirate support is addressed in 9.6. The allowable frame exchange sequences are listed in 9.7. Finally, a number of additional restrictions to limit the cases in which MSDUs are reordered or discarded are described in 9.8.

9.1 MAC architecture

The MAC architecture can be described as shown in Figure 51 as providing the PCF through the services of the DCF.

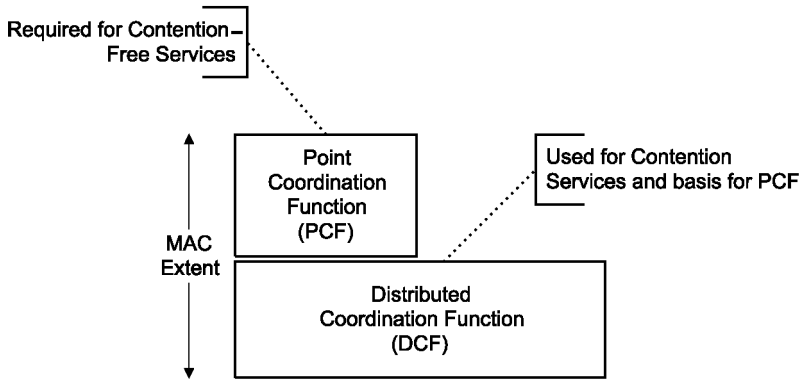

Figure 51—MAC architecture

9.1.1 DCF

The fundamental access method of the IEEE 802.11 MAC is a DCF known as *carrier sense multiple access with collision avoidance* (CSMA/CA). The DCF shall be implemented in all STAs, for use within both IBSS and infrastructure network configurations.

For a STA to transmit, it shall sense the medium to determine if another STA is transmitting. If the medium is not determined to be busy (see 9.2.1), the transmission may proceed. The CSMA/CA distributed algorithm mandates that a gap of a minimum specified duration exist between contiguous frame sequences. A transmitting STA shall ensure that the medium is idle for this required duration before attempting to transmit. If the medium is determined to be busy, the STA shall defer until the end of the current transmission. After deferral, or prior to attempting to transmit again immediately after a successful transmission, the STA shall select a random backoff interval and shall decrement the backoff interval counter while the medium is idle. A refinement of the method may be used under various circumstances to further minimize collisions—here the transmitting and receiving STA exchange short control frames (RTS and CTS frames) after determining that the medium is idle and after any deferrals or backoffs, prior to data transmission. The details of CSMA/CA, deferrals, and backoffs are described in 9.2. RTS/CTS exchanges are also presented in 9.2.

9.1.2 PCF

The IEEE 802.11 MAC may also incorporate an optional access method called a PCF, which is only usable on infrastructure network configurations. This access method uses a PC, which shall operate at the AP of the BSS, to determine which STA currently has the right to transmit. The operation is essentially that of polling,

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with the PC performing the role of the polling master. The operation of the PCF may require additional coordination, not specified in this standard, to permit efficient operation in cases where multiple point-coordinated BSSs are operating on the same channel, in overlapping physical space.

The PCF uses a virtual carrier-sense (CS) mechanism aided by an access priority mechanism. The PCF shall distribute information within Beacon management frames to gain control of the medium by setting the NAV in STAs. In addition, all frame transmissions under the PCF may use an interframe space (IFS) that is smaller than the IFS for frames transmitted via the DCF. The use of a smaller IFS implies that point-coordinated traffic shall have priority access to the medium over STAs in overlapping BSSs operating under the DCF access method.

The access priority provided by a PCF may be utilized to create a CF access method. The PC controls the frame transmissions of the STAs so as to eliminate contention for a limited period of time.

9.1.3 Coexistence of DCF and PCF

The DCF and the PCF shall coexist in a manner that permits both to operate concurrently within the same BSS. When a PC is operating in a BSS, the two access methods alternate, with a CFP followed by a CP. This is described in greater detail in 9.3.

9.1.4 Fragmentation/defragmentation overview

The process of partitioning a MSDU or a MMPDU into smaller MAC level frames, MPDUs, is called fragmentation. Fragmentation creates MPDUs smaller than the original MSDU or MMPDU length to increase reliability, by increasing the probability of successful transmission of the MSDU or MMPDU in cases where channel characteristics limit reception reliability for longer frames. Fragmentation is accomplished at each immediate transmitter. The process of recombining MPDUs into a single MSDU or MMPDU is defined as defragmentation. Defragmentation is accomplished at each immediate recipient.

Only MPDUs with a unicast receiver address shall be fragmented. Broadcast/multicast frames shall not be fragmented even if their length exceeds aFragmentationThreshold.

When a directed MSDU is received from the LLC or a directed MMPDU is received from the MAC sublayer management entity (MLME) with a length greater than aFragmentationThreshold, the MSDU or MMPDU shall be fragmented. The MSDU or MMPDU is divided into MPDUs. Each fragment is a frame no larger than aFragmentationThreshold. It is possible that any fragment may be a frame smaller than aFragmentationThreshold. An illustration of fragmentation is shown in Figure 52.

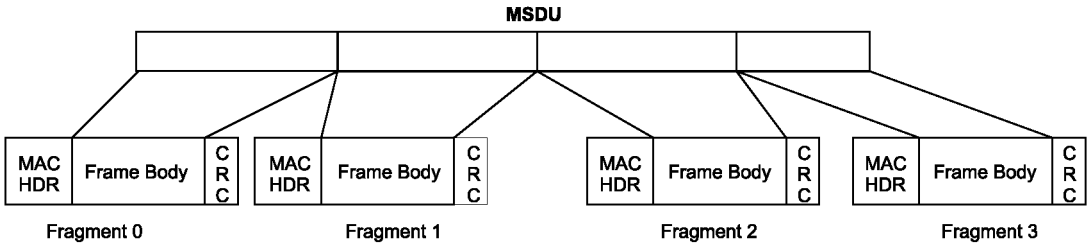

Figure 52—Fragmentation

The MPDUs resulting from the fragmentation of an MSDU or MMPDU are sent as independent transmissions, each of which is separately acknowledged. This permits transmission retries to occur per fragment, rather than per MSDU or MMPDU. Unless interrupted due to medium occupancy limitations for a given PHY, the fragments of a single MSDU or MMPDU are sent as a burst during the CP, using a single

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invocation of the DCF medium access procedure. The fragments of a single MSDU or MMPDU are sent during a CFP as individual frames obeying the rules of the PC medium access procedure.

9.1.5 MAC data service

The MAC data service shall translate MAC service requests from LLC into input signals utilized by the MAC state machines. The MAC data service shall also translate output signals from the MAC state machines into service indications to LLC. The translations are given in the MAC data service state machine defined in Annex C.

9.2 DCF

The basic medium access protocol is a DCF that allows for automatic medium sharing between compatible PHYs through the use of CSMA/CA and a random backoff time following a busy medium condition. In addition, all directed traffic uses immediate positive acknowledgment (ACK frame) where retransmission is scheduled by the sender if no ACK is received.

The CSMA/CA protocol is designed to reduce the collision probability between multiple STAs accessing a medium, at the point where collisions would most likely occur. Just after the medium becomes idle following a busy medium (as indicated by the CS function) is when the highest probability of a collision exists. This is because multiple STAs could have been waiting for the medium to become available again. This is the situation that necessitates a random backoff procedure to resolve medium contention conflicts.

CS shall be performed both through physical and virtual mechanisms.

The virtual CS mechanism is achieved by distributing reservation information announcing the impending use of the medium. The exchange of RTS and CTS frames prior to the actual data frame is one means of distribution of this medium reservation information. The RTS and CTS frames contain a Duration/ID field that defines the period of time that the medium is to be reserved to transmit the actual data frame and the returning ACK frame. All STAs within the reception range of either the originating STA (which transmits the RTS) or the destination STA (which transmits the CTS) shall learn of the medium reservation. Thus a STA can be unable to receive from the originating STA, yet still know about the impending use of the medium to transmit a data frame.

Another means of distributing the medium reservation information is the Duration/ID field in directed frames. This field gives the time that the medium is reserved, either to the end of the immediately following ACK, or in the case of a fragment sequence, to the end of the ACK following the next fragment.

The RTS/CTS exchange also performs both a type of fast collision inference and a transmission path check. If the return CTS is not detected by the STA originating the RTS, the originating STA may repeat the process (after observing the other medium-use rules) more quickly than if the long data frame had been transmitted and a return ACK frame had not been detected.

Another advantage of the RTS/CTS mechanism occurs where multiple BSSs utilizing the same channel overlap. The medium reservation mechanism works across the BSA boundaries. The RTS/CTS mechanism may also improve operation in a typical situation where all STAs can receive from the AP, but cannot receive from all other STAs in the BSA.

The RTS/CTS mechanism cannot be used for MPDUs with broadcast and multicast immediate address because there are multiple destinations for the RTS, and thus potentially multiple concurrent senders of the CTS in response. The RTS/CTS mechanism need not be used for every data frame transmission. Because the additional RTS and CTS frames add overhead inefficiency, the mechanism is not always justified, especially for short data frames.

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The use of the RTS/CTS mechanism is under control of the dot11RTSThreshold attribute. This attribute may be set on a per-STA basis. This mechanism allows STAs to be configured to use RTS/CTS either always, never, or only on frames longer than a specified length.

A STA configured not to initiate the RTS/CTS mechanism shall still update its virtual CS mechanism with the duration information contained in a received RTS or CTS frame, and shall always respond to an RTS addressed to it with a CTS.

The medium access protocol allows for stations to support different sets of data rates. All STAs shall be able to receive and transmit at all the data rates in the aBasicRateSet specified parameter of the MLME-JOIN.request and MLME-START.request primitives. To support the proper operation of the RTS/CTS and the virtual CS mechanism, all STAs shall be able to detect the RTS and CTS frames. For this reason, the RTS and CTS frames shall be transmitted at one of the rates in the BSS basic rate set. (See 9.6 for a description of multirate operation.)

Data frames sent under the DCF shall use the frame type Data and subtype Data or Null Function. STAs receiving Data type frames shall only consider the frame body as the basis of a possible indication to LLC.

9.2.1 CS mechanism

Physical and virtual CS functions are used to determine the state of the medium. When either function indicates a busy medium, the medium shall be considered busy; otherwise, it shall be considered idle.

A physical CS mechanism shall be provided by the PHY. See Clause 12 for how this information is conveyed to the MAC. The details of physical CS are provided in the individual PHY specifications.

A virtual CS mechanism shall be provided by the MAC. This mechanism is referred to as the NAV. The NAV maintains a prediction of future traffic on the medium based on duration information that is announced in RTS/CTS frames prior to the actual exchange of data. The duration information is also available in the MAC headers of all frames sent during the CP other than PS-Poll Control frames. The mechanism for setting the NAV using RTS/CTS in the DCF is described in 9.2.5.4, and use of the NAV in PCF is described in 9.3.2.2.

The CS mechanism combines the NAV state and the STA's transmitter status with physical CS to determine the busy/idle state of the medium. The NAV may be thought of as a counter, which counts down to zero at a uniform rate. When the counter is zero, the virtual CS indication is that the medium is idle; when nonzero, the indication is busy. The medium shall be determined to be busy when the STA is transmitting.

9.2.2 MAC-Level acknowledgments

The reception of some frames, as described in 9.7, 9.2.8, and 9.3.3.4, requires the receiving STA to respond with an acknowledgment, generally an ACK frame, if the FCS of the received frame is correct. This technique is known as positive acknowledgment.

Lack of reception of an expected ACK frame indicates to the source STA that an error has occurred. Note, however, that the destination STA may have received the frame correctly, and that the error may have occurred in the reception of the ACK frame. To the initiator of the frame exchange, this condition is indistinguishable from an error occurring in the initial frame.

9.2.3 IFS

The time interval between frames is called the IFS. A STA shall determine that the medium is idle through the use of the CS function for the interval specified. Four different IFSs are defined to provide priority levels

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for access to the wireless media; they are listed in order, from the shortest to the longest. Figure 53 shows some of these relationships.

a) SIFS short interframe space
b) PIFS PCF interframe space
c) DIFS DCF interframe space
d) EIFS extended interframe space

The different IFSs shall be independent of the STA bit rate. The IFS timings shall be defined as time gaps on the medium, and shall be fixed for each PHY (even in multirate-capable PHYs). The IFS values are determined from attributes specified by the PHY.

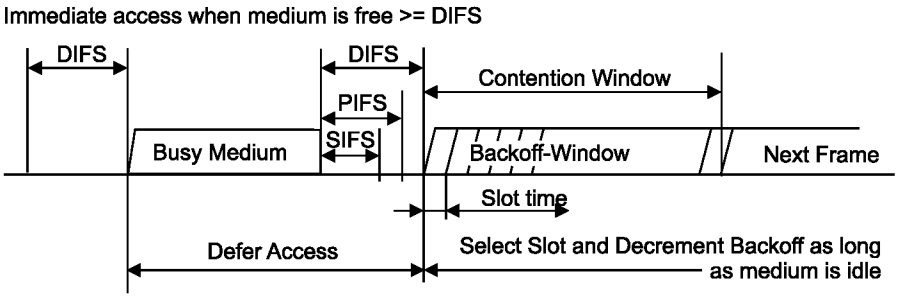

Figure 53—Some IFS relationships

9.2.3.1 SIFS

The SIFS shall be used for an ACK frame, a CTS frame, the second or subsequent MPDU of a fragment burst, and by a STA responding to any polling by the PCF. It may also be used by a PC for any types of frames during the CFP (see 9.3). The SIFS is the time from the end of the last symbol of the previous frame to the beginning of the first symbol of the preamble of the subsequent frame as seen at the air interface. The valid cases where the SIFS may or shall be used are listed in the frame exchange sequences in 9.7.

The SIFS timing shall be achieved when the transmission of the subsequent frame is started at the TxSIFS Slot boundary as specified in 9.2.10. An IEEE 802.11 implementation shall not allow the space between frames that are defined to be separated by a SIFS time, as measured on the medium, to vary from the nominal SIFS value by more than ±10% of aSlotTime for the PHY in use.

SIFS is the shortest of the IFSs. SIFS shall be used when STAs have seized the medium and need to keep it for the duration of the frame exchange sequence to be performed. Using the smallest gap between transmissions within the frame exchange sequence prevents other STAs, which are required to wait for the medium to be idle for a longer gap, from attempting to use the medium, thus giving priority to completion of the frame exchange sequence in progress.

9.2.3.2 PIFS

The PIFS shall be used only by STAs operating under the PCF to gain priority access to the medium at the start of the CFP. A STA using the PCF shall be allowed to transmit CF traffic after its CS mechanism (see 9.2.1) determines that the medium is idle at the TxPIFS slot boundary as defined in 9.2.10. The use of the PIFS by STAs operating under the PCF is described in 9.3.

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9.2.3.3 DIFS

The DIFS shall be used by STAs operating under the DCF to transmit data frames (MPDUs) and management frames (MMPDUs). A STA using the DCF shall be allowed to transmit if its CS mechanism (see 9.2.1) determines that the medium is idle at the TxDIFS slot boundary as defined in 9.2.10 after a correctly received frame, and its backoff time has expired. A STA using the DCF shall not transmit within an EIFS after it determines that the medium is idle following reception of a frame for which the PHY-RXEND.indication primitive contained an error or a frame for which the MAC FCS value was not correct. A STA may transmit after subsequent reception of an error-free frame, resynchronizing the STA. This allows the STA to transmit using the DIFS following that frame.

9.2.3.4 EIFS

The EIFS shall be used by the DCF when the PHY has indicated to the MAC that a frame transmission was begun that did not result in the correct reception of a complete MAC frame with a correct FCS value. The duration of an EIFS is defined in 9.2.10. The EIFS interval shall begin following indication by the PHY that the medium is idle after detection of the erroneous frame, without regard to the virtual CS mechanism. The EIFS is defined to provide enough time for another STA to acknowledge what was, to this STA, an incorrectly received frame before this STA commences transmission. Reception of an error-free frame during the EIFS resynchronizes the STA to the actual busy/idle state of the medium, so the EIFS is terminated and normal medium access (using DIFS and, if necessary, backoff) continues following reception of that frame.

9.2.4 Random backoff time

A STA desiring to initiate transfer of data MPDUs and/or MMPDUs shall invoke the CS mechanism (see 9.2.1) to determine the busy/idle state of the medium. If the medium is busy, the STA shall defer until the medium is determined to be idle without interruption for a period of time equal to DIFS when the last frame detected on the medium was received correctly, or after the medium is determined to be idle without interruption for a period of time equal to EIFS when the last frame detected on the medium was not received correctly. After this DIFS or EIFS medium idle time, the STA shall then generate a random backoff period for an additional deferral time before transmitting, unless the backoff timer already contains a nonzero value, in which case the selection of a random number is not needed and not performed. This process minimizes collisions during contention between multiple STAs that have been deferring to the same event.

$$\text{Backoff Time} = \text{Random}() \times \text{aSlotTime}$$

where

Random() = Pseudo-random integer drawn from a uniform distribution over the interval [0,CW], where CW is an integer within the range of values of the PHY characteristics aCWmin and aCWmax, aCWmin ≤ CW ≤ aCWmax. It is important that designers recognize the need for statistical independence among the random number streams among STAs.

aSlotTime = The value of the correspondingly named PHY characteristic.

The contention window (CW) parameter shall take an initial value of aCWmin. Every STA shall maintain a STA short retry count (SSRC) as well as a STA long retry count (SLRC), both of which shall take an initial value of zero. The SSRC shall be incremented when any short retry count (SRC) associated with any MSDU is incremented. The SLRC shall be incremented when any long retry count (LRC) associated with any MSDU is incremented. The CW shall take the next value in the series every time an unsuccessful attempt to transmit an MPDU causes either STA retry counter to increment, until the CW reaches the value of aCWmax. A retry is defined as the entire sequence of frames sent, separated by SIFS intervals, in an attempt to deliver an MPDU, as described in 9.7. Once it reaches aCWmax, the CW shall remain at the value of aCWmax until it is reset. This improves the stability of the access protocol under high-load conditions. See Figure 54.

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The CW shall be reset to aCWmin after every successful attempt to transmit an MSDU or MMPDU, when SLRC reaches aLongRetryLimit, or when SSRC reaches dot11ShortRetryLimit. The SSRC shall be reset to 0 when a CTS frame is received in response to an RTS frame, when an ACK frame is received in response to an MPDU or MMPDU transmission, or when a frame with a group address in the Address1 field is transmitted. The SLRC shall be reset to 0 when an ACK frame is received in response to transmission of an MPDU or MMPDU of length greater than dot11RTSThreshold, or when a frame with a group address in the Address1 field is transmitted.

The set of CW values shall be sequentially ascending integer powers of 2, minus 1, beginning with a PHY-specific aCWmin value, and continuing up to and including a PHY-specific aCWmax value.

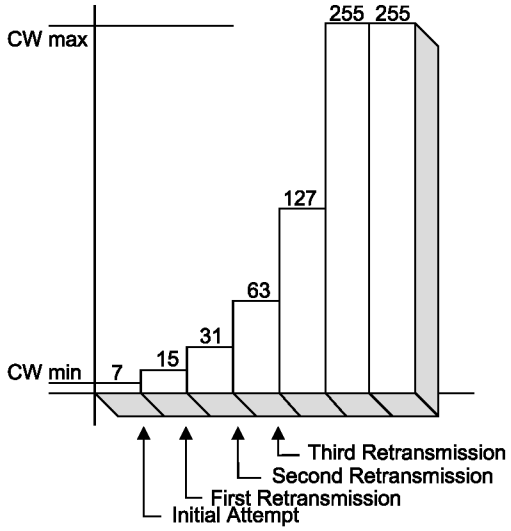

Figure 54—Example of exponential increase of CW

9.2.5 DCF access procedure

The CSMA/CA access method is the foundation of the DCF. The operational rules vary slightly between the DCF and the PCF.

9.2.5.1 Basic access

Basic access refers to the core mechanism a STA uses to determine whether it may transmit.

In general, a STA may transmit a pending MPDU when it is operating under the DCF access method, either in the absence of a PC, or in the CP of the PCF access method, when the STA determines that the medium is idle for greater than or equal to a DIFS period, or an EIFS period if the immediately preceding medium-busy event was caused by detection of a frame that was not received at this STA with a correct MAC FCS value. If, under these conditions, the medium is determined by the CS mechanism to be busy when a STA desires to initiate the initial frame of one of the frame exchanges described in 9.7, exclusive of the CF period, the random backoff algorithm described in 9.2.5.2 shall be followed. There are conditions, specified in 9.2.5.2 and 9.2.5.5, where the random backoff algorithm shall be followed even for the first attempt to initiate a frame exchange sequence.

In a STA having an FH PHY, control of the channel is lost at the dwell time boundary and the STA shall have to contend for the channel after that dwell boundary. It is required that STAs having an FH PHY complete transmission of the entire MPDU and associated acknowledgment (if required) before the dwell time

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boundary. If, when transmitting or retransmitting an MPDU, there is not enough time remaining in the dwell to allow transmission of the MPDU plus the acknowledgment (if required), the STA shall defer the transmission by selecting a random backoff time, using the present CW (without advancing to the next value in the series). The short retry counter and long retry counter for the MSDU are not affected.

The basic access mechanism is illustrated in Figure 55.

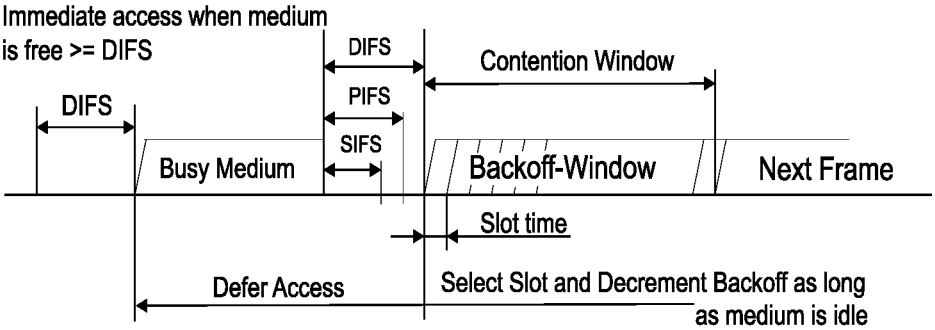

Figure 55—Basic access method

9.2.5.2 Backoff procedure

The backoff procedure shall be invoked for a STA to transfer a frame when finding the medium busy as indicated by either the physical or virtual CS mechanism (see Figure 56). The backoff procedure shall also be invoked when a transmitting STA infers a failed transmission as defined in 9.2.5.7 or 9.2.8.

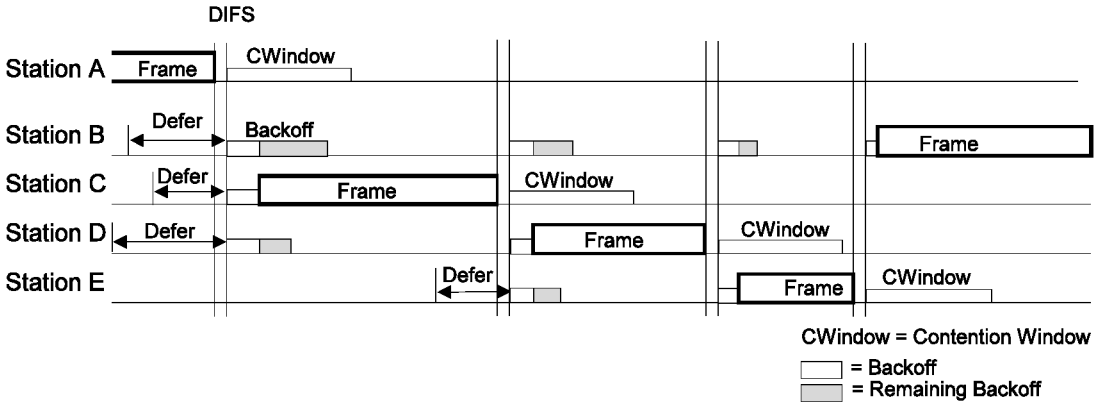

Figure 56—Backoff procedure

To begin the backoff procedure, the STA shall set its Backoff Timer to a random backoff time using the equation in 9.2.4. All backoff slots occur following a DIFS period during which the medium is determined to be idle for the duration of the DIFS period, or following an EIFS period during which the medium is determined to be idle for the duration of the EIFS period following detection of a frame that was not received correctly.

A STA performing the backoff procedure shall use the CS mechanism (see 9.2.1) to determine whether there is activity during each backoff slot. If no medium activity is indicated for the duration of a particular backoff slot, then the backoff procedure shall decrement its backoff time by aSlotTime.

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If the medium is determined to be busy at any time during a backoff slot, then the backoff procedure is suspended; that is, the backoff timer shall not decrement for that slot. The medium shall be determined to be idle for the duration of a DIFS period or EIFS, as appropriate (see 9.2.3), before the backoff procedure is allowed to resume. Transmission shall commence when the Backoff Timer reaches zero.

A backoff procedure shall be performed immediately after the end of every transmission with the More Fragments bit set to 0 of an MPDU of type Data, Management, or Control with subtype PS-Poll, even if no additional transmissions are currently queued. In the case of successful acknowledged transmissions, this backoff procedure shall begin at the end of the received ACK frame. In the case of unsuccessful transmissions requiring acknowledgment, this backoff procedure shall begin at the end of the ACK timeout interval. If the transmission is successful, the CW value reverts to aCWmin before the random backoff interval is chosen, and the SSRC and/or SLRC are updated as described in 9.2.4. This assures that transmitted frames from a STA are always separated by at least one backoff interval.

The effect of this procedure is that when multiple STAs are deferring and go into random backoff, then the STA selecting the smallest backoff time using the random function will win the contention.

In an IBSS, the backoff time for a pending nonbeacon or non-ATIM transmission shall not decrement in the period from the TBTT until the expiration of the ATIM window, and the backoff time for a pending ATIM management frame shall decrement only within the ATIM window. (See Clause 11.) Within an IBSS, a separate backoff interval shall be generated to precede the transmission of a beacon, as described in 11.1.2.2.

9.2.5.3 Recovery procedures and retransmit limits

Error recovery is always the responsibility of the STA that initiates a frame exchange sequence, as defined in 9.7. Many circumstances may cause an error to occur that requires recovery. For example, the CTS frame may not be returned after an RTS frame is transmitted. This may happen due to a collision with another transmission, due to interference in the channel during the RTS or CTS frame, or because the STA receiving the RTS frame has an active virtual CS condition (indicating a busy medium time period).

Error recovery shall be attempted by retrying transmissions for frame exchange sequences that the initiating STA infers have failed. Retries shall continue, for each failing frame exchange sequence, until the transmission is successful, or until the relevant retry limit is reached, whichever occurs first. STAs shall maintain a SRC and a LRC for each MSDU or MMPDU awaiting transmission. These counts are incremented and reset independently of each other.

After an RTS frame is transmitted, the STA shall perform the CTS procedure, as defined in 9.2.5.7. If the RTS transmission fails, the SRC for the MSDU or MMPDU and the SSRC are incremented. This process shall continue until the number of attempts to transmit that MSDU or MMPDU reaches dot11ShortRetryLimit.

After transmitting a frame that requires acknowledgment, the STA shall perform the ACK procedure, as defined in 9.2.8. The SRC for an MSDU or MMPDU and the SSRC shall be incremented every time transmission of a MAC frame of length less than or equal to dot11RTSThreshold fails for that MSDU or MMPDU. This SRC and the SSRC shall be reset when a MAC frame of length less than or equal to dot11RTSThreshold succeeds for that MSDU or MMPDU. The LRC for an MSDU or MMPDU and the SLRC shall be incremented every time transmission of a MAC frame of length greater than dot11RTSThreshold fails for that MSDU or MMPDU. This LRC and the SLRC shall be reset when a MAC frame of length greater than dot11RTSThreshold succeeds for that MSDU or MMPDU. All retransmission attempts for an MSDU or MMPDU that has failed the ACK procedure one or more times shall be made with the Retry field set to 1 in the Data or Management type frame.

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Retries for failed transmission attempts shall continue until the SRC for the MSDU or MMPDU is equal to dot11ShortRetryLimit or until the LRC for the MSDU or MMPDU is equal to aLongRetryLimit. When either of these limits is reached, retry attempts shall cease, and the MSDU or MMPDU shall be discarded.

A STA in PS mode, in an ESS, initiates a frame exchange sequence by transmitting a PS-Poll frame to request data from an AP. In the event that neither an ACK frame nor a data frame is received from the AP in response to a PS-Poll frame, then the STA shall retry the sequence, by transmitting another PS-Poll frame, at its convenience. If the AP sends a data frame in response to a PS-Poll frame, but fails to receive the ACK frame acknowledging this data frame, the next PS-Poll frame from the same STA may cause a retransmission of the last MSDU. This duplicate MSDU shall be filtered at the receiving STA using the normal duplicate frame filtering mechanism. If the AP responds to a PS-Poll by transmitting an ACK frame, then responsibility for the data frame delivery error recovery shifts to the AP because the data are transferred in a subsequent frame exchange sequence, which is initiated by the AP. The AP shall attempt to deliver one MSDU to the STA that transmitted the PS-Poll, using any frame exchange sequence valid for a directed MSDU. If the PS STA that transmitted the PS-Poll returns to Doze state after transmitting the ACK frame in response to successful receipt of this MSDU, but the AP fails to receive this ACK frame, the AP will retry transmission of this MSDU until the relevant retry limit is reached. See Clause 11 for details on filtering of extra PS-Poll frames.

9.2.5.4 Setting and resetting the NAV

STAs receiving a valid frame shall update their NAV with the information received in the Duration/ID field, but only when the new NAV value is greater than the current NAV value and only when the frame is not addressed to the receiving STA. Various additional conditions may set or reset the NAV, as described in 9.3.2.2. When the NAV is reset, a PHY-CCARESET.request shall be issued.

Figure 57 indicates the NAV for STAs that may receive the RTS frame, while other STAs may only receive the CTS frame, resulting in the lower NAV bar as shown (with the exception of the STA to which the RTS was addressed).

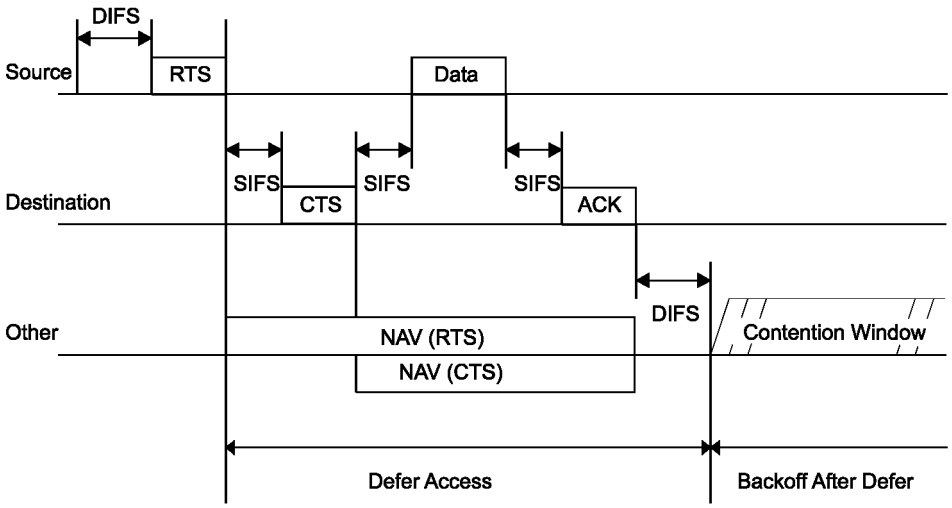

Figure 57—RTS/CTS/data/ACK and NAV setting

A STA that used information from an RTS frame as the most recent basis to update its NAV setting is permitted to reset its NAV if no PHY-RXSTART.indication is detected from the PHY during a period with a duration of (2 × aSIFSTime) + (CTS_Time) + (2 × aSlotTime) starting at the PHY-RXEND.indication corresponding to the detection of the RTS frame. The “CTS_Time” shall be calculated using the length of the CTS frame and the data rate at which the RTS frame used for the most recent NAV update was received.

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9.2.5.5 Control of the channel

The SIFS is used to provide an efficient MSDU delivery mechanism. Once the STA has contended for the channel, that STA shall continue to send fragments until either all fragments of a single MSDU or MMPDU have been sent, an acknowledgment is not received, or the STA is restricted from sending any additional fragments due to a dwell time boundary. Should the sending of the fragments be interrupted due to one of these reasons, when the next opportunity for transmission occurs the STA shall resume transmission. The algorithm by which the STA decides which of the outstanding MSDUs shall next be attempted after an unsuccessful transmission attempt is beyond the scope of this standard, but any such algorithm shall comply with the restrictions listed in 9.8.

Figure 58 illustrates the transmission of a multiple-fragment MSDU using the SIFS.

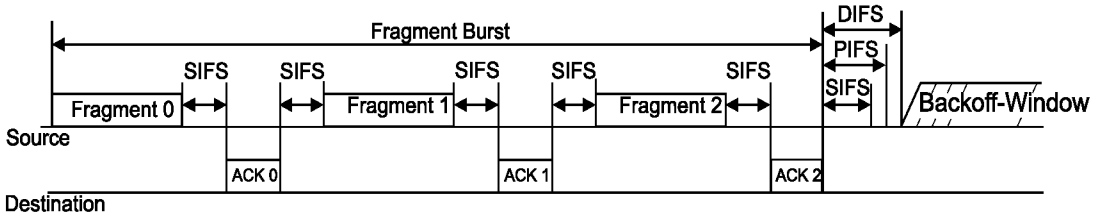

Figure 58—Transmission of a multiple-fragment MSDU using SIFS

When the source STA transmits a fragment, it shall release the channel, then immediately monitor the channel for an acknowledgment as described in 9.2.8.

When the destination STA has finished sending the acknowledgment, the SIFS following the acknowledgment shall be reserved for the source STA to continue (if necessary) with another fragment. The STA sending the acknowledgment shall not transmit on the channel immediately following the acknowledgment.

The process of sending multiple fragments after contending for the channel is defined as a fragment burst.

If the source STA receives an acknowledgment but there is not enough time to transmit the next fragment and receive an acknowledgment due to an impending dwell boundary, the source STA shall contend for the channel at the beginning of the next dwell time.

If the source STA does not receive an acknowledgment frame, it shall attempt to retransmit the failed MPDU or another eligible MPDU, as defined in 9.8, after performing the backoff procedure and the contention process.

After a STA contends for the channel to retransmit a fragment of an MSDU, it shall start with the last fragment that was not acknowledged. The destination STA shall receive the fragments in order (because the source sends them in order and they are individually acknowledged). It is possible, however, that the destination STA may receive duplicate fragments. It shall be the responsibility of the receiving STA to detect and discard duplicate fragments.

A STA shall transmit after the SIFS only under the following conditions during a fragment burst:

— The STA has just received a fragment that requires acknowledgment.
— The source STA has received an acknowledgment for a previous fragment, has more fragment(s) for the same MSDU to transmit, and there is enough time before the next dwell boundary to send the next fragment and receive its acknowledgment.

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The following rules shall also apply:

— When a STA has transmitted a frame other than an initial or intermediate fragment, that STA shall not transmit on the channel following the acknowledgment for that frame, without performing the back-off procedure.
— When an MSDU has been successfully delivered or all retransmission attempts have been exhausted, and the STA has a subsequent MSDU to transmit, then that STA shall perform a backoff procedure.
— Only unacknowledged fragments shall be retransmitted.

9.2.5.6 RTS/CTS usage with fragmentation

The following is a description of using RTS/CTS for a fragmented MSDU or MMPDU. The RTS/CTS frames define the duration of the following frame and acknowledgment. The Duration/ID field in the data and ACK frames specifies the total duration of the next fragment and acknowledgment. This is illustrated in Figure 59.

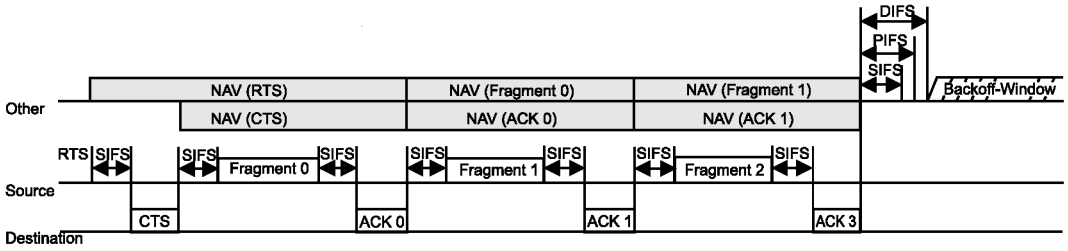

Figure 59—RTS/CTS with fragmented MSDU

Each frame contains information that defines the duration of the next transmission. The duration information from RTS frames shall be used to update the NAV to indicate busy until the end of ACK 0. The duration information from the CTS frame shall also be used to update the NAV to indicate busy until the end of ACK 0. Both Fragment 0 and ACK 0 shall contain duration information to update the NAV to indicate busy until the end of ACK 1. This shall be done by using the Duration/ID field in the Data and ACK frames. This shall continue until the last fragment, which shall have a duration of one ACK time plus one SIFS time, and its ACK, which shall have its Duration/ID field set to 0. Each fragment and ACK acts as a virtual RTS and CTS; therefore no further RTS/CTS frames need to be generated after the RTS/CTS that began the frame exchange sequence even though subsequent fragments may be larger than dot11RTSThreshold. At STAs using a FH PHY, when there is insufficient time before the next dwell boundary to transmit the subsequent fragment, the STA initiating the frame exchange sequence may set the Duration/ID field in the last data or management frame to be transmitted before the dwell boundary to the duration of one ACK time plus one SIFS time.

In the case where an acknowledgment is sent but not received by the source STA, STAs that heard the fragment, or ACK, will mark the channel busy for the next frame exchange due to the NAV having been updated from these frames. This is the worst-case situation, and it is shown in Figure 60. If an acknowledgment is not sent by the destination STA, STAs that can only hear the destination STA will not update their NAV and may attempt to access the channel when their NAV updated from the previously received frame reaches zero. All STAs that hear the source will be free to access the channel after their NAV updated from the transmitted fragment has expired.

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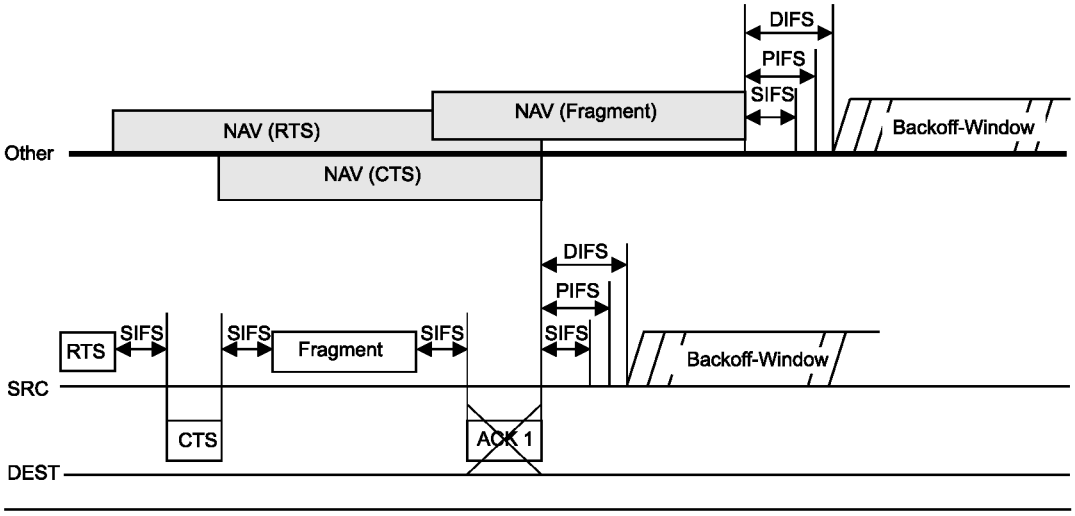

Figure 60—RTS/CTS with transmitter priority and missed acknowledgment

9.2.5.7 CTS procedure

A STA that is addressed by an RTS frame shall transmit a CTS frame after a SIFS period if the NAV at the STA receiving the RTS frame indicates that the medium is idle. If the NAV at the STA receiving the RTS indicates the medium is not idle, that STA shall not respond to the RTS frame. The RA field of the CTS frame shall be the value obtained from the TA field of the RTS frame to which this CTS frame is a response. The Duration/ID field in the CTS frame shall be the duration field from the received RTS frame, adjusted by subtraction of aSIFSTime and the number of microseconds required to transmit a CTS frame at the data rate used for the RTS frame to which this CTS frame is a response.

After transmitting an RTS frame, the STA shall wait for a CTSTimeout interval, starting at the PHY-TXEND.confirm. If a PHY-RXSTART.indication does not occur during the CTSTimeout interval, the STA shall conclude that the transmission of the RTS has failed, and this STA shall invoke its backoff procedure upon expiration of the CTSTimeout interval. If a PHY-RXSTART.indication does occur during the CTSTimeout interval, the STA shall wait for the corresponding PHY-RXEND.indication to determine whether the RTS transmission was successful. The recognition of a valid CTS frame sent by the recipient of the RTS frame, corresponding to this PHY-RXEND.indication, shall be interpreted as successful response, permitting the frame sequence to continue (see 9.7). The recognition of anything else, including any other valid frame, shall be interpreted as failure of the RTS transmission. In this instance, the STA shall invoke its backoff procedure at the PHY-RXEND.indication and may process the received frame.

9.2.6 Directed MPDU transfer procedure

A STA shall use an RTS/CTS exchange for directed frames only when the length of the MPDU is greater than the length threshold indicated by the dot11RTSThreshold attribute.

The dot11RTSThreshold attribute shall be a managed object within the MAC MIB, and its value may be set and retrieved by the MLME. The value 0 shall be used to indicate that all MPDUs shall be delivered with the use of RTS/CTS. Values of dot11RTSThreshold larger than the maximum MSDU length shall indicate that all MPDUs shall be delivered without RTS/CTS exchanges.

When an RTS/CTS exchange is used, the asynchronous data frame shall be transmitted after the end of the CTS frame and a SIFS period. No regard shall be given to the busy or idle status of the medium when transmitting this data frame.

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When an RTS/CTS exchange is not used, the asynchronous data frame shall be transmitted following the success of the basic access procedure. With or without the use of the RTS/CTS exchange procedure, the STA that is the destination of an asynchronous data frame shall follow the ACK procedure.

9.2.7 Broadcast and multicast MPDU transfer procedure

In the absence of a PCF, when broadcast or multicast MPDUs are transferred from a STA with the ToDS bit clear, only the basic access procedure shall be used. Regardless of the length of the frame, no RTS/CTS exchange shall be used. In addition, no ACK shall be transmitted by any of the recipients of the frame. Any broadcast or multicast MPDUs transferred from a STA with a ToDS bit set shall, in addition to conforming to the basic access procedure of CSMA/CA, obey the rules for RTS/CTS exchange, because the MPDU is directed to the AP. The broadcast/multicast message shall be distributed into the BSS. The STA originating the message shall receive the message as a broadcast/multicast message. Therefore, all STAs shall filter out broadcast/multicast messages that contain their address as the source address. Broadcast and multicast MSDUs shall be propagated throughout the ESS.

There is no MAC-level recovery on broadcast or multicast frames, except for those frames sent with the ToDS bit set. As a result, the reliability of this traffic is reduced, relative to the reliability of directed traffic, due to the increased probability of lost frames from interference, collisions, or time-varying channel properties.

9.2.8 ACK procedure

An ACK frame shall be generated as shown in the frame exchange sequences listed in 9.7.

Upon successful reception of a frame of a type that requires acknowledgment with the ToDS bit set, an AP shall generate an ACK frame. An ACK frame shall be transmitted by the destination STA that is not an AP, when it successfully receives a unicast frame of a type that requires acknowledgment, but not if it receives a broadcast or multicast frame of such type. After a successful reception of a frame requiring acknowledgment, transmission of the ACK frame shall commence after a SIFS period, without regard to the busy/idle state of the medium.

The source STA shall wait ACKTimeout amount of time without receiving an ACK frame before concluding that the MPDU failed. (See Figure 61.)

After transmitting an MPDU that requires an ACK frame as a response (see 9.7), the STA shall wait for an ACKTimeout interval, starting at the PHY-TXEND.confirm. If a PHY-RXSTART.indication does not occur during the ACKTimeout interval, the STA concludes that the transmission of the MPDU has failed, and this STA shall invoke its backoff procedure upon expiration of the ACKTimeout interval. If a PHY-RXSTART.indication does occur during the ACKTimeout interval, the STA shall wait for the corresponding PHY-RXEND.indication to determine whether the MPDU transmission was successful. The recognition of a valid ACK frame sent by the recipient of the MPDU requiring acknowledgment, corresponding to this PHY-RXEND.indication, shall be interpreted as successful acknowledgment, permitting the frame sequence to continue, or to end without retries, as appropriate for the particular frame sequence in progress. The recognition of anything else, including any other valid frame, shall be interpreted as failure of the MPDU transmission. In this instance, the STA shall invoke its backoff procedure at the PHY-RXEND.indication and may process the received frame. The sole exception is that recognition of a valid data frame sent by the recipient of a PS-Poll frame shall also be accepted as successful acknowledgment of the PS-Poll frame.

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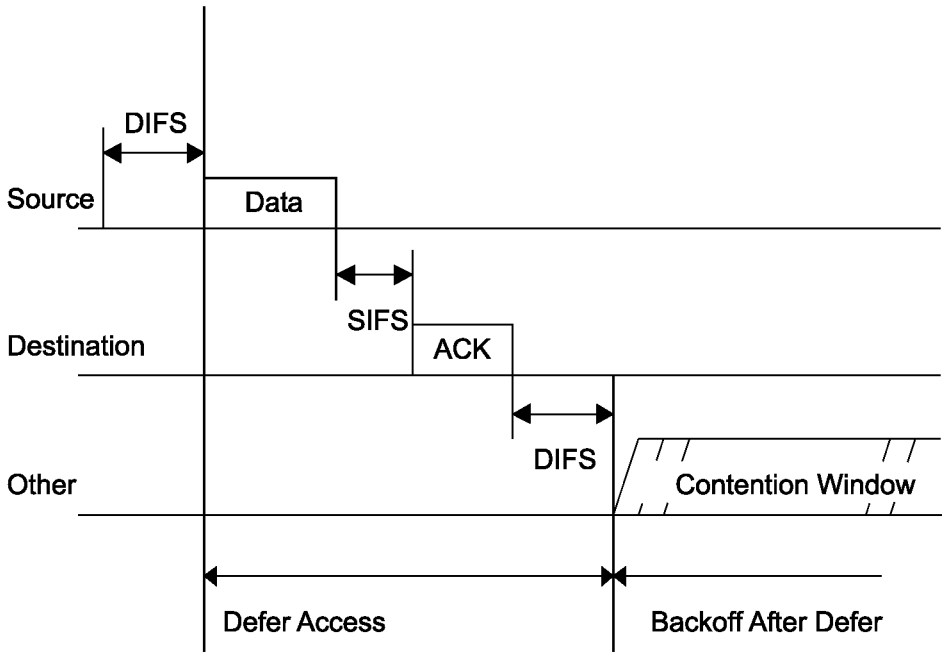

Figure 61—Directed data/ACK MPDU

9.2.9 Duplicate detection and recovery

Because MAC-level acknowledgments and retransmissions are incorporated into the protocol, there is the possibility that a frame may be received more than once. Such duplicate frames shall be filtered out within the destination MAC.

Duplicate frame filtering is facilitated through the inclusion of a Sequence Control field (consisting of a sequence number and fragment number) within data and management frames. MPDUs that are part of the same MSDU shall have the same sequence number, and different MSDUs shall (with a high probability) have a different sequence number.

The sequence number is generated by the transmitting STA as an incrementing sequence of integers.

The receiving STA shall keep a cache of recently received <Address 2, sequence-number, fragment-number> tuples. A receiving STA is required to keep only the most recent cache entry per Address 2-sequence-number pair, storing only the most recently received fragment number for that pair. A receiving STA may omit tuples obtained from broadcast/multicast or ATIM frames from the cache.

A destination STA shall reject as a duplicate frame any frame that has the Retry bit set in the Frame Control field and that matches an <Address 2, sequence-number, and fragment-number> tuple of an entry in the cache.

There is a small possibility that a frame may be improperly rejected due to such a match; however, this occurrence would be rare and simply results in a lost frame (similar to an FCS error in other LAN protocols).

The destination STA shall perform the ACK procedure on all successfully received frames requiring acknowledgment, even if the frame is discarded due to duplicate filtering.

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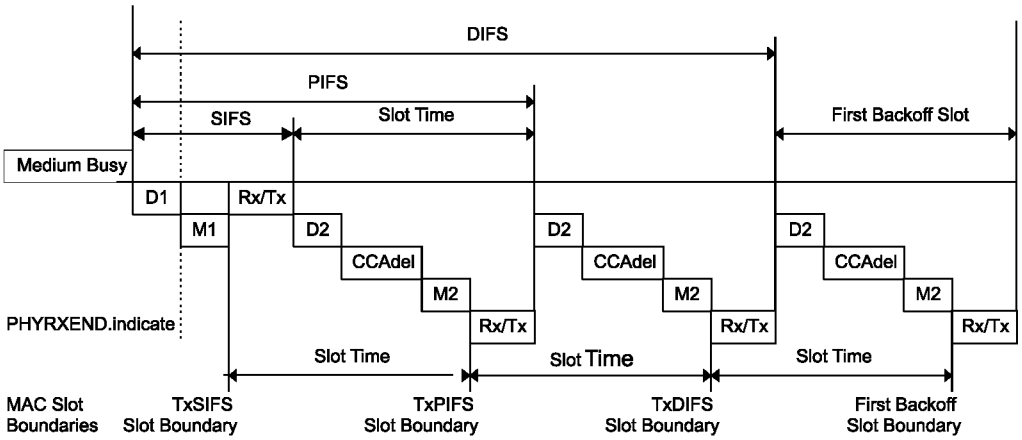
9.2.10 DCF timing relations

The relationships between the IFS specifications are defined as time gaps on the medium. The associated attributes are provided by the specific PHY. (See Figure 62.)



D1 = aRxRFDelay + aRxPLCPDelay (referenced from the end of the last symbol of a frame on the medium)
D2 = D1 + Air Propagation Time
Rx/Tx = aRXTXTurnaroundTime (begins with a PHYTXSTART.request)
M1 = M2 = aMACPrcDelay
CCAdel = aCCA Time - D1

Figure 62—DCF timing relationships

All timings that are referenced from the end of the transmission are referenced from the end of the last symbol of a frame on the medium. The beginning of transmission refers to the first symbol of the next frame on the medium.

aSIFSTime and aSlotTime are fixed per PHY.

aSIFSTime is: aRxRFDelay + aRxPLCPDelay + aMACProcessingDelay + aRxTxTurnaroundTime.

aSlotTime is: aCCATime + aRxTxTurnaroundTime + aAirPropagationTime + aMACProcessingDelay.

The PIFS and DIFS are derived by the following equations, as illustrated in Figure 62.

PIFS = aSIFSTime + aSlotTime

DIFS = aSIFSTime + 2 × aSlotTime

The EIFS is derived from the SIFS and the DIFS and the length of time it takes to transmit an ACK Control frame at 1 Mbit/s by the following equation:

EIFS = aSIFSTime + (8 × ACKSize) + aPreambleLength + aPLCPHeaderLngth + DIFS

where

ACKSize is the length, in bytes, of an ACK frame; and
(8 × ACKSize) + aPreambleLength + aPLCPHeaderLngth is expressed in microseconds required to transmit at the PHY's lowest mandatory rate.

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Figure 62 illustrates the relation between the SIFS, PIFS, and DIFS as they are measured on the medium and the different MAC slot boundaries TxSIFS, TxPIFS, and TxDIFS. These slot boundaries define when the transmitter shall be turned on by the MAC to meet the different IFS timings on the medium, after subsequent detection of the clear channel assessment (CCA) result of the previous slot time.

The following equations define the MAC Slot Boundaries, using attributes provided by the PHY, which are such that they compensate for implementation timing variations. The starting reference of these slot boundaries is again the end of the last symbol of the previous frame on the medium.

TxSIFS = SIFS – aRxTxTurnaroundTime

TxPIFS = TxSIFS + aSlotTime

TxDIFS = TxSIFS + 2 × aSlotTime.

The tolerances are specified in the physical layer management entity (PLME) SAP interface specification (see 10.4) and shall only apply to the SIFS specification so that tolerances shall not accumulate.

9.3 PCF

The PCF provides CF frame transfer. The PC shall reside in the AP. It is an option for an AP to be able to become the PC. All STAs inherently obey the medium access rules of the PCF, because these rules are based on the DCF, and they set their NAV at the beginning of each CFP. The operating characteristics of the PCF are such that all STAs are able to operate properly in the presence of a BSS in which a PC is operating, and, if associated with a point-coordinated BSS, are able to receive all frames sent under PCF control. It is also an option for a STA to be able to respond to a CF-Poll received from a PC. A STA that is able to respond to CF-Polls is referred to as being CF-Pollable, and may request to be polled by an active PC. CF-Pollable STAs and the PC do not use RTS/CTS in the CFP. When polled by the PC, a CF-Pollable STA may transmit only one MPDU, which can be to any destination (not just to the PC), and may “piggyback” the acknowledgment of a frame received from the PC using particular data frame subtypes for this transmission. If the data frame is not in turn acknowledged, the CF-Pollable STA shall not retransmit the frame unless it is polled again by the PC, or it decides to retransmit during the CP. If the addressed recipient of a CF transmission is not CF-Pollable, that STA acknowledges the transmission using the DCF acknowledgment rules, and the PC retains control of the medium. A PC may use CF frame transfer solely for delivery of frames to STAs, and never to poll non-CF-Pollable STAs.

A PC may perform a backoff on retransmission of an unacknowledged frame during the CFP. A PC that is maintaining a polling list may retry the unacknowledged frame the next time the particular AID is at the top of the polling list.

A PC may retransmit an unacknowledged frame during the CFP after a PIFS time.

When more than one point-coordinated BSS is operating on the same PHY channel in overlapping space, the potential exists for collisions between PCF transfer activities by the independent PCs. The rules under which multiple, overlapping point-coordinated BSSs may coexist are presented in 9.3.3.2. As shown in Figure 51 (in 9.1), the PCF is built on top of the CSMA/CA-based DCF, by utilizing the access priority provisions provided by this scheme. An active PC shall be located at an AP, which restricts PCF operation to infrastructure networks. PCF is activated at a PC-capable AP by setting the CFPMaxDuration parameter in the CF Parameter Set of the MLMEStart.request to a nonzero value.

Data frames sent during under the DCF shall use the data subtypes Data or Null Function. Data frames sent by, or in response to polling by, the PC during the CFP shall use the appropriate data subtypes based upon the following usage rules:

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— Data+CF-Poll, Data+CF-Ack+CF-Poll, CF-Poll, and CF-Ack+CF-Poll shall only be sent by a PC.
— Data, Data+CF-Ack, Null Function, and CF-Ack may be sent by a PC or by any CF-Pollable STA.

STAs receiving Data type frames shall only consider the frame body as the basis of a possible indication to LLC, if the frame is of subtype Data, Data+CF-Ack, Data+CF-Poll, or Data+CF-Ack+CF-Poll. CF-Pollable STAs shall interpret all subtype bits of received Data type frames for CF purposes, but shall only inspect the frame body if the frame is of subtype Data, Data+CF-Ack, Data+CF-Poll, or Data+CF-Ack+CF-Poll.

9.3.1 CFP structure and timing

The PCF controls frame transfers during a CFP. The CFP shall alternate with a CP, when the DCF controls frame transfers, as shown in Figure 63. Each CFP shall begin with a Beacon frame that contains a DTIM element (hereafter referred to as a DTIM). The CFPs shall occur at a defined repetition rate, which shall be synchronized with the beacon interval as specified in the following paragraphs.

The PC generates CFPs at the *CF repetition rate* (CFPRate), which is defined as a number of DTIM intervals. The PC shall determine the CFPRate (depicted as a repetition interval in the illustrations in Figure 63 and Figure 64) to use from the CFPRate parameter in the CF Parameter Set. This value, in units of DTIM intervals, shall be communicated to other STAs in the BSS in the CFPPeriod field of the CF Parameter Set element of Beacon frames. The CF Parameter Set element shall only be present in Beacon and Probe Response frames transmitted by STAs containing an active PC.

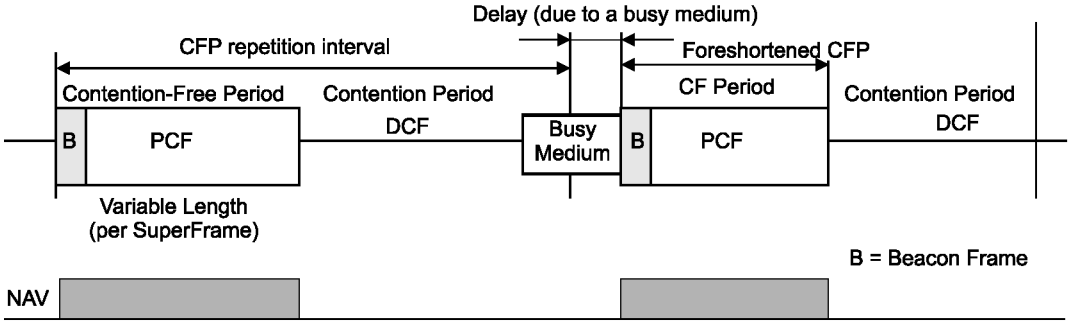

Figure 63—CFP/CP alternation

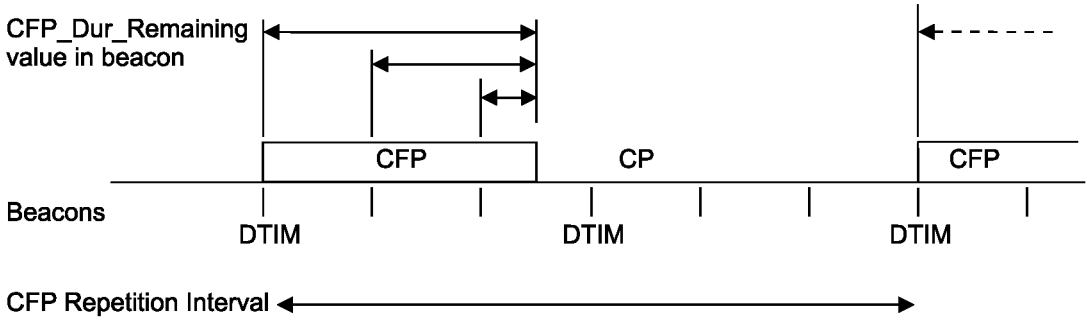

Figure 64—Beacons and CFPs

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The length of the CFP is controlled by the PC, with maximum duration specified by the value of the CFP-MaxDuration Parameter in the CF Parameter Set at the PC. Neither the maximum duration nor the actual duration (signaled by transmission of a Control frame of subtype CF-End or CF-End+ACK by the PC) is constrained to be a multiple of the beacon interval. If the CFP duration is greater than the beacon interval, the PC shall transmit beacons at the appropriate times during the CFP (subject to delay due to traffic at the nominal times, as with all beacons). The CF Parameter Set element in all beacons at the start of, or within, a CFP shall contain a nonzero value in the CFPDurRemaining field. This value, in units of TU, shall specify the maximum time from the transmission of this beacon to the end of this CFP. The value of the CFPDurRemaining field shall be zero in beacons sent during the CP. An example of these relationships is illustrated in Figure 64, which shows a case where the CFP is two DTIM intervals, the DTIM interval is three beacon intervals, and the aCFPMaxDuration value is approximately 2.5 beacon intervals.

The PC may terminate any CFP at or before the aCFPMaxDuration, based on available traffic and size of the polling list. Because the transmission of any beacon may be delayed due to a medium busy condition at the nominal beacon transmission time, a CFP may be foreshortened by the amount of the delay. In the case of a busy medium due to DCF traffic, the beacon shall be delayed for the time required to complete the current DCF frame exchange. In cases where the beacon transmission is delayed, the CFPDurRemaining value in the beacon at the beginning of the CFP shall specify a time that causes the CFP to end no later than TBTT plus the value of aCFPMaxDuration. This is illustrated in Figure 65.

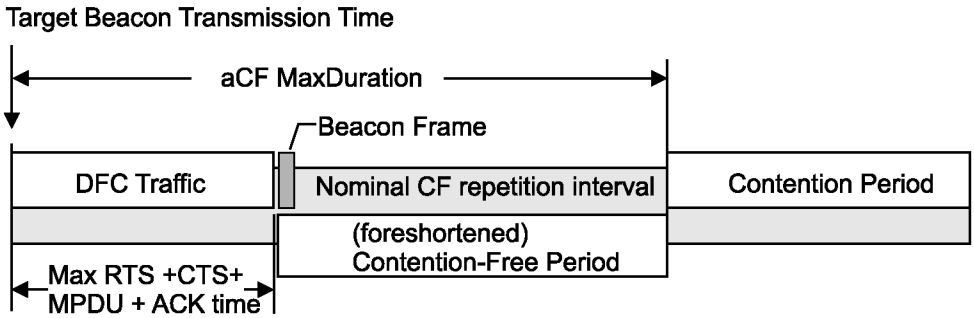

Figure 65—Example of delayed beacon and foreshortened CFP

9.3.2 PCF access procedure

The CF transfer protocol is based on a polling scheme controlled by a PC operating at the AP of the BSS. The PC gains control of the medium at the beginning of the CFP and attempts to maintain control for the entire CFP by waiting a shorter time between transmissions than the STAs using the DCF access procedure. All STAs in the BSS (other than the PC) set their NAVs to the CFPMaxDuration value at the nominal start time of each CFP. This prevents most contention by preventing nonpolled transmissions by STAs whether or not they are CF-Pollable. Acknowledgment of frames sent during the CFP may be accomplished using Data+CF-ACK, CF-ACK, Data+CF-ACK+CF-Poll (only on frames transmitted by the PC), or CF-ACK+CF-Poll (only on frames transmitted by the PC) frames in cases where a Data (or Null) frame immediately follows the frame being acknowledged, thereby avoiding the overhead of separate ACK Control frames. Non-CF-Pollable or unpolled CF-Pollable STAs acknowledge frames during the CFP using the DCF ACK procedure.

9.3.2.1 Fundamental access

At the nominal beginning of each CFP, the PC shall sense the medium. When the medium is determined to be idle for one PIFS period, the PC shall transmit a Beacon frame containing the CF Parameter Set element and a DTIM element.

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After the initial beacon frame, the PC shall wait for at least one SIFS period, and then transmit one of the following: a data frame, a CF-Poll frame, a Data+CF-Poll frame, or a CF-End frame. If the CFP is null, i.e., no traffic is buffered and no polls exist to send at the PC, a CF-End frame shall be transmitted immediately after the initial beacon.

STAs receiving directed, error-free frames from the PC are expected to respond after a SIFS period, in accordance with the transfer procedures defined in 9.3.3. If the recipient STA is not CF-Pollable, the response to receipt of an error-free data frame shall always be an ACK frame.

9.3.2.2 NAV operation during the CFP

The mechanism for handling the NAV during the CFP is designed to facilitate the operation of overlapping CFP coordinated infrastructure BSSs. The mechanism by which infrastructure BSSs coordinate their CFPs is beyond the scope of this standard.

Each STA, except the STA with the PC, shall preset its NAV to the CFPMaxDuration value (obtained from the CF Parameter Set element in beacons from this PC) at each TBTT (see Clause 11) at which a CFP is scheduled to start (based on the CFPPeriod field in the CF Parameter Set element of the Beacon frames from this PC). Each non-PC STA shall update its NAV using the CFPDurRemaining value in any error-free CF Parameter Set element of the Beacon frame that the STA receives. This includes CFPDurRemaining values in CF Parameter Set elements from Beacon frames received from other (overlapping) BSSs.

These actions prevent STAs from taking control of the medium during the CFP, which is especially important in cases where the CFP spans multiple medium-occupancy intervals, such as dwell periods of an FH PHY. This setting of the NAV also reduces the risk of hidden STAs determining the medium to be idle for a DIFS period during the CFP and possibly corrupting a transmission in progress.

A STA joining a BSS operating with a PC shall use the information in the CFPDurRemaining element of the CF parameter set of any received Beacon or Probe Response frames to update its NAV prior to initiating any transmissions.

The PC shall transmit a CF-End or CF-End+ACK frame at the end of each CFP. A STA that receives either of these frames, from any BSS, shall reset its NAV.

9.3.3 PCF transfer procedure

Frame transfers under the PCF typically consist of frames alternately sent from the AP/PC and sent to the AP/PC. During the CFP, the ordering of these transmissions, and the STA allowed to transmit frames to the PC at any given point in time, shall be controlled by the PC. Figure 66 depicts a frame transfer during a typical CFP. The rules under which this frame transfer takes place are detailed in 9.3.3.1 through 9.3.3.4.

In a STA having an FH PHY, control of the channel is lost at a dwell time boundary. It is required that the current MPDU transmission and the accompanying acknowledgment of the MPDU be transmitted before the dwell time boundary. After having been polled by the PC, if there is not enough time remaining in the dwell to allow transmission of the MPDU plus the acknowledgment, the STA shall defer the transmission of the MPDU and shall transmit a Null frame or CF-ACK frame. The short retry counter and long retry counter for the MSDU shall not be affected.

MaxMPDUTime is the time to transmit the maximum-sized MAC frame, expanded by WEP, plus the time to transmit the PHY preamble, header, trailer, and expansion bits, if any. In a STA having an FH PHY, the PC shall not transmit a CF-Poll to a STA if there is insufficient time remaining before the dwell boundary for the STA to respond with a Null frame or CF-ACK frame.

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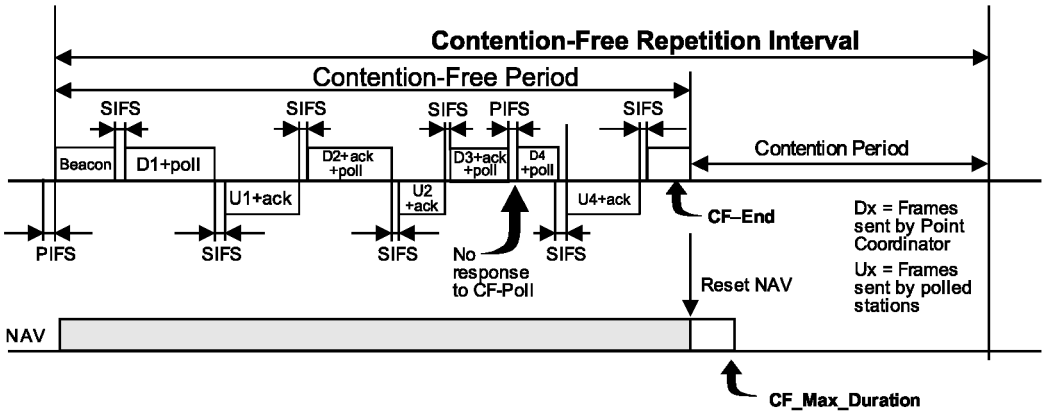

Figure 66—Example of PCF frame transfer

9.3.3.1 PCF transfers when the PCF STA is transmitter or recipient

The PC shall transmit frames between the Beacon that starts the CFP and the CF-End using the SIFS except in cases where a transmission by another STA is expected by the PC and a SIFS period elapses without the receipt of the expected transmission. In such cases the PC may send its next pending transmission as soon as one PIFS after the end of its last transmission. This permits the PC to retain control of the medium in the presence of an overlapping BSS. The PC may transmit any of the following frame types to CF-Pollable STAs:

— Data, used to send data from the PC when the addressed recipient is not being polled and there is no previous frame to acknowledge;

— Data+CF-ACK, used to send data from the PC when the addressed recipient is not being polled and the PC needs to acknowledge the receipt of a frame received from a CF-Pollable STA a SIFS period before starting this transmission;

— Data+CF-Poll, used to send data from the PC when the addressed recipient is the next STA to be permitted to transmit during this CFP and there is no previous frame to acknowledge;

— Data+CF-ACK+CF-Poll, used to send data from the PC when the addressed recipient is the next STA to be permitted to transmit during this CFP and the PC needs to acknowledge the receipt of a frame received from a CF-Pollable STA a SIFS period before starting this transmission;

— CF-Poll, used when the PC is not sending data to the addressed recipient, but the addressed recipient is the next STA to be permitted to transmit during this CFP and there is no previous frame to acknowledge;

— CF-ACK+CF-Poll, used when the PC is not sending data to the addressed recipient but the addressed recipient is the next STA to be permitted to transmit during this CFP and the PC needs to acknowledge the receipt of a frame from a CF-Pollable STA a SIFS period before starting this transmission;

— CF-ACK, used when the PC is not sending data to, or polling, the addressed recipient, but the PC needs to acknowledge receipt of a frame from a CF-Pollable STA a SIFS period before starting this transmission (useful when the next transmission by the PC is a management frame, such as a beacon); or

— Any management frame that is appropriate for the AP to send under the rules for that frame type.

The PC may transmit data or management frames to non-CF-Pollable, non-PS STAs during the CFP. These STAs shall acknowledge receipt with ACK frames after a SIFS, as with the DCF. The PC may also transmit broadcast or multicast frames during the CFP. Because the Beacon frame that initiates the CFP contains a

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DTIM element, if there are associated STAs using PS mode, the broadcasts and multicasts buffered shall be sent immediately after any beacon containing a TIM element with a DTIM count field with a value of 0.

A CF-Pollable STA that receives a directed data frame of any subtype that includes CF-Poll may transmit one data frame a SIFS period after receiving the CF-Poll. CF-Pollable STAs shall ignore, but not reset, their NAV when performing transmissions in response to a CF-Poll.

Non-CF-Pollable STAs that receive a directed frame during the CFP shall transmit an ACK, but shall not reset their NAV.

For frames that require MAC-level acknowledgment, CF-Pollable STAs that received a CF-Poll (of any type) may perform this acknowledgment using the Data+CF-ACK subtype in the response to the CF-Poll. For example, the U1 frame in Figure 66 contains the acknowledgment to the preceding D1 frame. The D2 frame contains the acknowledgment to the preceding U1 frame. The PC may use the CF-ACK subtypes to acknowledge a received frame even if the data frame sent with the CF-ACK subtype is addressed to a different STA than the one being acknowledged. CF-Pollable STAs that are expecting an acknowledgment shall interpret the subtype of the frame (if any) sent by the PC a SIFS period after that STA's transmission to the PC. If a frame that requires MAC-level acknowledgment is received by a non-CF-Pollable STA, that STA shall not interpret the CF-Poll indication (if any), and shall acknowledge the frame by sending an ACK Control frame after a SIFS period.

The lengths of the frames may be variable, only bounded by the frame and/or fragment length limitations that apply for the BSS. If a CF-Pollable STA does not respond to a CF-Poll (of any type) within the SIFS period following a transmission from the PC, or a non-CF-Pollable STA does not return the ACK frame within a SIFS period following a transmission from the PC that requires acknowledgment, then the PC shall resume control and may transmit its next frame after a PIFS period from the end of the PC's last transmission.

A CF-Pollable STA shall always respond to a CF-Poll directed to its MAC address and received without error. If the STA has no frame to send when polled, the response shall be a Null frame. If the STA has no frame to send when polled, but an acknowledgment is required for the frame that conveyed the CF-Poll, the response shall be a CF-ACK (no data) frame. The null response is required to permit a "no-traffic" situation to be distinguished from a collision between overlapping PCs.

The CFP shall end when the CFPDurRemaining time has elapsed since the Beacon frame originating the CFP or when the PC has no further frames to transmit nor STAs to poll. In either case, the end of the CFP shall be signaled by the transmission of a CF-End by the PC. If there is a received frame that requires acknowledgment at the time the CF-End is to be transmitted, the PC shall transmit a CF-End+ACK frame instead. All STAs of the BSS receiving a CF-End or CF-End+ACK shall reset their NAVs so they may attempt to transmit during the CP.

9.3.3.2 Operation with overlapping point-coordinated BSSs

Because the PCF operates without the CSMA/CA CW randomization and backoff of the DCF, there is a risk of repeated collisions if multiple, overlapping, point-coordinated BSSs are operating on the same PHY channel, and their CFP Rates and beacon intervals are approximately equal. To minimize the risk of significant frame loss due to CF collisions, the PC shall use a DIFS plus a random backoff delay (with CW in the range of 1 to aCWmin) to start a CFP when the initial beacon is delayed because of deferral due to a busy medium. The PC may optionally use this backoff during the CFP prior to retransmitting an unacknowledged, directed data or management frame.

To further reduce the susceptibility to inter-PC collisions, the PC shall require that the medium be determined as being idle for a DIFS period plus a random (over a range of 1 to aCWmin) number of slot times once every aMediumOccupancyLimit TU during the CFP. This results in loss of control of the medium to overlapping BSS or hidden STA traffic, because the STAs in this BSS are prevented from transmitting by

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their NAV setting to CFPMaxDuration or CFPDurRemaining. For operation of the PCF in conjunction with an FH PHY, aMediumOccupancyLimit shall be set equal to the dwell time. For operation in conjunction with other PHY types, aMediumOccupancyLimit may be set equal to CFPMaxDuration, unless extra protection against PCF collisions is desired. The aMediumOccupancyLimit is also useful for compliance in regulatory domains that impose limits on continuous transmission time by a single STA as part of a spectrum etiquette.

9.3.3.3 CFPMaxDuration limit

The value of CFPMaxDuration shall be limited to allow coexistence between contention and CF traffic.

The minimum value for CFPMaxDuration is two times MaxMPDUTime plus the time required to send the initial Beacon frame and the CF-End frame of the CFP. This may allow sufficient time for the AP to send one data frame to a STA, while polling that STA, and for the polled STA to respond with one data frame.

The maximum value for CFPMaxDuration is the duration of (BeaconPeriod × DTIMPeriod × CFPRate) minus [MaxMPDUTime plus (2 × aSIFSTime) plus (2 × aSlotTime) plus (8 × ACKSize)], expressed in microseconds, when operating with a CW of aCWmin. MaxMPDUTime is the time to transmit the maximum-sized MAC frame, expanded by WEP, plus the time to transmit the PHY preamble, header, trailer, and expansion bits, if any. This allows sufficient time to send at least one data frame during the CP.

9.3.3.4 CF usage rules

A PC may send broadcast or multicast frames, and directed data or management frames to any active STA, as well as to CF-Pollable PS STAs. During the CFP, CF-Pollable STAs shall acknowledge after a SIFS period, the receipt of each Data+CF-Poll frame or Data+CF-ACK+CF-Poll frame using Data+CF-Ack or CF-Ack (no data) frames, the receipt of each CF_Poll (no data) using Data or Null (no data), and the receipt of all other data and management frames using ACK Control frames. Non-CF-Pollable STAs shall acknowledge receipt of data and management frames using ACK Control frames sent after a SIFS period. This non-CF-Pollable operation is the same as that already employed by such STAs for DCF operation.

When polled by the PCF (Data+CF-Poll, Data+CF-ACK+CF-Poll, CF-Poll, or CF-ACK+CF-Poll) a CF-Pollable STA may send one data frame to any destination. Such a frame directed to or through the PC STA shall be acknowledged by the PC, using the CF-ACK indication (Data+CF-ACK, Data+CF-ACK+CF-Poll, CF-ACK, CF-ACK+CF-Poll, or CF-End+ACK) sent after a SIFS. Such a frame directed to a non-CF-Pollable STA shall be acknowledged using an ACK Control frame sent after a SIFS period. A polled CF-Pollable STA with neither a data frame nor an acknowledgment to send shall respond by transmitting a Null frame after a SIFS period. A polled CF-Pollable STA with insufficient time before the end of the CFP or current medium occupancy limit, to send its queued MPDU and receive an acknowledgment, shall respond by transmitting a Null frame, or a CF-ACK frame if polled using Data+CF-Poll or Data+CF-ACK+CF-Poll, after a SIFS period. The CF-Pollable STA may set the More Data bit in its response to permit the PC to distinguish between an empty STA queue and a response due to insufficient time to transfer an MPDU.

The PC shall not issue frames with a subtype that includes CF-Polls if insufficient time remains in the current CFP to permit the polled STA to transmit a data frame containing a minimum length MPDU.

9.3.4 CF polling list

If the PC supports use of the CFP for inbound frame transfer as well as for frame delivery, the PC shall maintain a “polling list” for use in selecting STAs that are eligible to receive CF-Polls during CFPs. The polling list functional characteristics are defined below. If the PC supports the use of the CFP solely for frame delivery, the PC does not require a polling list, and shall never generate data frames with a subtype that includes CF-Poll. The form of CF support provided by the PC is identified in the Capability Information field of Beacon, Association Response, Reassociation Response, and Probe Response management frames,

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which are sent from APs. Any such frames sent by STAs, as in noninfrastructure networks, shall always have these bits set to 0.

The polling list is used to force the polling of CF-Pollable STAs, whether or not the PC has pending traffic to transmit to those STAs. The polling list may be used to control the use of Data+CF-Poll and Data+CF-ACK+CF-Poll types for transmission of data frames being sent to CF-Pollable STAs by the PC. The polling list is a *logical* construct, which is not exposed outside of the PC. A minimum set of polling list maintenance techniques are required to ensure interoperability of arbitrary CF-Pollable STAs in BSSs controlled by arbitrary APs with active PCs. APs may also implement additional polling list maintenance techniques that are outside the scope of this standard.

9.3.4.1 Polling list processing

The PC shall send a CF-Poll to at least one STA during each CFP when there are entries in the polling list. During each CFP, the PC shall issue polls to a subset of the STAs on the polling list in order by ascending AID value.

While time remains in the CFP, all CF frames have been delivered, and all STAs on the polling list have been polled, the PC may generate one or more CF-Polls to *any* STAs on the polling list. While time remains in the CFP, all CF frames have been delivered, and all STAs on the polling list have been polled, the PC *may* send data or management frames to *any* STAs.

In order to gain maximum efficiency from the CFP, and the ability to piggyback acknowledgments on successor data frames in the opposite direction, the PC should generally use Data+CF-Poll and Data+CF-ACK+CF-Poll types for each data frame transmitted while sufficient time for the potential response to the CF-Poll remains in the CFP.

9.3.4.2 Polling list update procedure

A STA indicates its CF-Pollability using the CF-Pollable subfield of the Capability Information field of Association Request and Reassociation Request frames. If a STA desires to change the PC's record of CF-Pollability, that STA shall perform a reassociation. During association, a CF-Pollable STA may also request to be placed on the polling list for the duration of its association, or by setting the CF-Poll Request subfield in the Capability Information field. If a CF-Pollable STA desires never to be placed on the polling list, that STA shall perform Association with both the CF-Pollable subfield false and the CF-Poll Request subfield true. Never being polled is useful for CF-Pollable STAs that normally use PS mode, permitting them to receive buffered traffic during the CFP (because they have to be awake to receive the DTIM that initiated the CFP), but not requiring them to stay awake to receive CF-Polls when they have no traffic to send. If a STA desires to be removed from the polling list, that STA shall perform a reassociation.

CF-Pollable STAs that are not on the polling list, but did not request never to be polled during their most recent association, may be dynamically placed on the polling list by the PC to handle bursts of frame transfer activity by that STA.

9.4 Fragmentation

The MAC may fragment and reassemble directed MSDUs or MMPDUs. The fragmentation and defragmentation mechanisms allow for fragment retransmission.

The length of a fragment MPDU shall be an equal number of octets for all fragments except the last, which may be smaller. The length of a fragment MPDU shall always be an even number of octets, except for the last fragment of an MSDU or MMPDU, which may be either an even or an odd number of octets. The length of a fragment shall never be larger than aFragmentationThreshold unless WEP is invoked for the MPDU. If

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WEP is active for the MPDU, then the MPDU shall be expanded by IV and ICV (see 8.2.5); this may result in a fragment larger than aFragmentationThreshold.

When data are to be transmitted, the number of octets in the fragment (before WEP processing) shall be determined by aFragmentationThreshold and the number of octets in the MPDU that have yet to be assigned to a fragment at the instant the fragment is constructed for the first time. Once a fragment is transmitted for the first time, its frame body content and length shall be fixed until it is successfully delivered to the immediate receiving STA. A STA shall be capable of receiving fragments of arbitrary length.

If a fragment requires retransmission, its frame body content and length shall remain fixed for the lifetime of the MSDU or MMPDU at that STA. After a fragment is transmitted once, contents and length of that fragment are not allowed to fluctuate to accommodate the dwell time boundaries. Each fragment shall contain a Sequence Control field, which is comprised of a sequence number and fragment number. When a STA is transmitting an MSDU or MMPDU, the sequence number shall remain the same for all fragments of that MSDU or MMPDU. The fragments shall be sent in order of lowest fragment number to highest fragment number, where the fragment number value starts at zero, and increases by one for each successive fragment. The Frame Control field also contains a bit, the More Fragments bit, that is equal to zero to indicate the last (or only) fragment of the MSDU or MMPDU.

The source STA shall maintain a transmit MSDU timer for each MSDU being transmitted. The attribute aMaxTransmitMSDULifetime specifies the maximum amount of time allowed to transmit an MSDU. The timer starts on the attempt to transmit the first fragment of the MSDU. If the timer exceeds aMaxTransmitMSDULifetime, then all remaining fragments are discarded by the source STA and no attempt is made to complete transmission of the MSDU.

9.5 Defragmentation

Each fragment contains information to allow the complete MSDU or MMPDU to be reassembled from its constituent fragments. The header of each fragment contains the following information that is used by the destination STA to reassemble the MSDU or MMPDU:

- Frame type
- Address of the sender, obtained from the Address2 field
- Destination address
- *Sequence Control field:* This field allows the destination STA to check that all incoming fragments belong to the same MSDU or MMPDU, and the sequence in which the fragments should be reassembled. The sequence number within the Sequence Control field remains the same for all fragments of an MSDU or MMPDU, while the fragment number within the Sequence Control field increments for each fragment.
- *More Fragments indicator:* Indicates to the destination STA that this is not the last fragment of the MSDU or MMPDU. Only the last or sole fragment of the MSDU or MMPDU shall have this bit set to 0. All other fragments of the MSDU or MMPDU shall have this bit set to 1.

The destination STA shall reconstruct the MSDU or MMPDU by combining the fragments in order of fragment number subfield of the Sequence Control field. If WEP has been applied to the fragment, it shall be decrypted before the fragment is used for defragmentation of the MSDU or MMPDU. If the fragment with the More Fragments bit set to 0 has not yet been received, then the destination STA knows that the MSDU or MMPDU is not yet complete. As soon as the STA receives the fragment with the More Fragments bit set to 0, the STA knows that no more fragments may be received for the MSDU or MMPDU.

All STAs shall support the concurrent reception of fragments of at least three MSDUs or MMPDUs. Note that a STA receiving more than three fragmented MSDUs or MMPDUs concurrently may experience a significant increase in the number of frames discarded.

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The destination STA shall maintain a Receive Timer for each MSDU or MMPDU being received, for a minimum of three MSDUs or MMPDUs. The STA may implement additional timers to be able to receive additional concurrent MSDUs or MMPDUs. The receiving STA shall discard all fragments that are part of an MSDU or MMPDU for which a timer is not maintained. There is also an attribute, aMaxReceiveLifetime, that specifies the maximum amount of time allowed to receive an MSDU. The receive MSDU or MMPDU timer starts on the reception of the first fragment of the MSDU or MMPDU. If the receive MSDU timer exceeds aMaxReceiveLifetime, then all received fragments of this MSDU or MMPDU are discarded by the destination STA. If additional fragments of a directed MSDU or MMPDU are received after its aMaxReceiveLifetime is exceeded, those fragments shall be acknowledged and discarded.

To properly reassemble MPDUs into an MSDU or MMPDU, a destination STA shall discard any duplicated fragments received. A STA shall discard duplicate fragments as described in 9.2.9. However, an acknowledgment shall be sent in response to a duplicate fragment of a directed MSDU.

9.6 Multirate support

Some PHYs have multiple data transfer rate capabilities that allow implementations to perform dynamic rate switching with the objective of improving performance. The algorithm for performing rate switching is beyond the scope of this standard, but in order to ensure coexistence and interoperability on multirate-capable PHYs, this standard defines a set of rules that shall be followed by all STAs.

All Control frames shall be transmitted at one of the rates in the BSS basic rate set so that they will be understood by all STAs in the BSS.

All frames with multicast and broadcast receiver addresses shall be transmitted at one of the rates included in the BSS basic rate set, regardless of their type or subtype.

Data and/or management MPDUs with a unicast receiver address shall be sent on any supported data rate selected by the rate switching mechanism (whose output is an internal MAC variable called MACCurrentRate, which is used for calculating the Duration/ID field of each frame). A STA shall not transmit at a rate that is known not to be supported by the destination STA, as reported in the Supported Rates element in the management frames. For frames of type Data+CF-ACK, Data+CF-Poll+CF-ACK, and CF-Poll+CF-ACK, the rate chosen to transmit the frame must be supported by both the addressed recipient STA and the STA to which the ACK is intended.

Under no circumstances shall a STA initiate transmission of a data or management frame at a data rate higher than the greatest rate in the OperationalRateSet, a parameter of the MLME-JOIN.request primitive.

To allow the transmitting STA to calculate the contents of the Duration/ID field, the responding STA shall transmit its Control Response and Management Response frames (either CTS or ACK) at the highest rate in the BSS basic rate set that is less than or equal to the rate of the immediately previous frame in the frame exchange sequence (as defined in 9.7). In addition, the Control Response frame shall be sent using the same PHY options as the received frame.

For the HR/DSSS PHY, the time required to transmit a frame for use in the Duration/ID field is determined using the PLME-TXTIME.request primitive (see 10.4.6) and the PLME-TXTIME.confirm primitive (see 10.4.7).

For the 5 GHz PHY, the time required to transmit a frame for use in the Duration/ID field is determined using the PLME-TXTIME.request primitive and the PLME-TXTIME.confirm primitive. The calculation method of TXTIME duration is defined in 17.4.3.

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9.7 Frame exchange sequences

The allowable frame exchange sequences are summarized in Table 21 and Table 22. A legend applicable to both tables follows Table 22.

Table 21—Frame sequences

Sequence	Frames in sequence	Usage
Data(bc/mc)	1	Broadcast or multicast MSDU
Mgmt(bc)	1	Broadcast MMPDU
{RTS – CTS –} [Frag – ACK –] Last – ACK	2	Directed MSDU or MMPDU
PS-Poll – ACK	2	Deferred PS-POLL response
PS-Poll – [Frag – ACK –] Last – ACK	3	Immediate PS-POLL response
DTIM(CF) – [<CF-Sequence> –] {CF-End}	2 or more	Start of CFP
[<CF-Sequence> –] {CF-End}	2 or more	Continuation of CFP after missing ACK or medium occupancy boundary

Table 22—CF frame sequences

CF frame sequence	Frames in sequence	Usage
Beacon(CF)	1	Beacon during CFP
Data(bc/mc)	1	Broadcast or multicast MSDU
Mgmt(bc)	1 or 2	Broadcast MMPDU
Mgmt(dir) – ACK	2 or 3	Directed MMPDU
Data(dir)+CF-Poll{+CF-Ack} – Data(dir)+CF-Ack – {CF-Ack(no data)}	2	Poll and ACK sent with MPDUs
Data(dir)+CF-Poll{+CF-Ack} – CF-Ack(no data)	2	Poll of STA with empty queue, insufficient time for queued MPDU, or too little time remaining before a dwell or medium occupancy boundary to send a queued frame
CF-Poll(no data){+CF-Ack} – Data(dir) – {CF-Ack(no data)}	2	Separate poll, ACK sent with MPDU
CF-Poll(no data){+CF-Ack} – Data(dir) – ACK	3	Polled STA sends to STA in BSS
CF-Poll(no data){+CF-Ack} – Null(no data)	2	Separate poll, STA queue empty, or insufficient time for queued MPDU or too little time remaining before a dwell or medium occupancy boundary to send a queued frame
Data(dir){+CF-Ack} – ACK	2	ACK if not CF-Pollable or not polled

LEGEND (For Table 21 and Table 22)

1—Items enclosed in brackets "[…]" may occur zero or more times in the sequence.

2—Items enclosed in braces "{…}" may occur zero or one time in the sequence.

3—An isolated hyphen "-" represents a SIFS separating the pair of frames.

4—"Data(bc/mc)" represents any frame of type Data with a broadcast or multicast address in the Address1 field.

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5—“Mgmt(bc)” represents any Management type frame with a broadcast address in the DA field.

6—“RTS” represents a Control frame of subtype RTS.

7—“CTS” represents a Control frame of subtype CTS.

8—“ACK” represents a Control frame of subtype ACK.

9—“Frag” represents an MPDU of type Data or an MMPDU of type Management with an individual address in the Address1 field that has the More Fragments field set to 1.

10—“Last” represents an MPDU of type Data or an MMPDU of type Management with an individual address in the Address1 field that has the More Fragments field set to 0.

11—“PS-Poll” represents a Control frame of subtype PS-Poll.

12—“DTIM(CF)” represents a management frame of subtype Beacon that contains a DTIM information element with a nonzero value in the CFPDurRemaining field of its Parameter Set element.

13—“CF-End” represents a Control frame of type CF-End, or (if the final frame of the immediately preceding <CF-Sequence> was a directed data or management frame requiring acknowledgment by the AP) of type CF-End+Ack.

14—“Beacon(CF)” represents a management frame of subtype Beacon with a nonzero value in the CFPDurRemaining field of its CF Parameter Set element.

15—“Data(dir)” represents any MPDU of type Data with an individual address in the Address1 field.

16—“Mgmt(dir)” represents any MMPDU of type Management with an individual address in the Address1 field.

17—“CF-Ack(no data)” represents a data frame of subtype CF-ACK (no data).

18—“CF-Poll(no data)” represents a data frame of subtype CF-Poll (no data).

19—“Null(no data)” represents a data frame of subtype Null Function (no data).

20—“{+CF-Ack}” indicates that the frame may or may not include a contention-free acknowledgment.

21—“+CF-Ack” indicates that the frame includes a contention-free acknowledgment.

22—“+CF-Poll” indicates that the frame includes a contention-free poll.

23—<CF-Sequence> represents a sequence of one or more frames sent during a CFP. A valid <CF-Sequence> shall consist of one of the frame sequences shown in Table 22. The collection of sequences of frame exchanges corresponding to [<CF-Sequence>] may occur in any order within the CFP.

Individual frames within each of these sequences are separated by a SIFS.

9.8 MSDU transmission restrictions

To avoid reordering MSDUs between pairs of LLC entities and/or unnecessarily discarding MSDUs, the following restrictions shall be observed by any STA that is able to concurrently process multiple outstanding MSDUs for transmission. Note that here the term “outstanding” refers to an MSDU or MMPDU that is eligible to be transmitted at a particular time. A STA may have any number (greater than or equal to one) of eligible MSDUs outstanding concurrently, subject to the restrictions below.

The STA shall ensure that no more than one MSDU or MMPDU from a particular source address to a particular individual receiver address is outstanding at a time. Note that a simpler, more restrictive invariant to maintain is that no more than one MSDU with a particular individual receiver address may be outstanding at a time.

In a STA where the optional StrictlyOrdered service class has been implemented, that STA shall ensure that there is no group-addressed (multidestination) MSDU of the StrictlyOrdered service class outstanding from the source address of any other outstanding MSDU (either directed or group-addressed). This is because a group-addressed MSDU is implicitly addressed to a collection of peer STAs that could include any individual receiver address.

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It is recommended that the STA select a value of aMaxMSDUTransmitLifetime that is sufficiently large that the STA does not discard MSDUs due to excessive Transmit MSDU timeouts under normal operating conditions.

9.9 Operation across regulatory domains

The PHY of a wireless LAN (WLAN) is subject to regulations that can vary significantly from one geopolitical area to another. It is desirable that a mechanism exists that allows a conforming implementation to be built that is able to meet many different sets of regulations. The purpose of this clause is to allow conforming equipment to be able to operate in more than one regulatory domain over time. This clause describes the mechanism required to implement a capability in IEEE 802.11 stations that supports cross-domain mobility and operation in multiple regulatory domains, when the dot11MultiDomainCapabilityEnabled attribute is true.

NOTE—This clause does not eliminate the need to obtain type acceptance, regulatory approval, equipment authorization, or equipment certification in each of the regulatory domains in which the equipment will operate. The mechanisms described in this clause provide the information to the station to identify the regulatory domain in which it is located and to cease operation while in those domains for which it does not have type approval. It is incumbent upon the implementer to provide proof of compliance to the requirements of individual regulatory agencies.

This clause provides the framework for operation across regulatory domains. However, the method for configuring individual stations is outside the scope of this standard. A station must be properly configured for operation in a particular regulatory domain prior to beginning normal operation. Particular care must be taken when operating in an IBSS configuration.

9.9.1 Operation upon entering a regulatory domain

A STA that is enabled for operation across regulatory domains shall default to passive scanning when it has lost connectivity with its ESS. Passive scanning is performed using only the receive capabilities of the station and is, thus, compatible with regulatory requirements. The timeout for determining the loss of connectivity is system dependent and beyond the scope of this standard.

When a STA enters a regulatory domain, it shall passively scan to learn at least one valid channel, i.e., a channel upon which it detects IEEE 802.11 frames. The Beacon frame contains information on the country code, the maximum allowable transmit power, and the channels to be used for the regulatory domain. Optionally, the Beacon frame may also include, on a periodic basis, the regulatory information that would be returned in a Probe Response frame. Once the STA has acquired the information so that it is able to meet the transmit requirements of the regulatory domain, it shall transmit a Probe Request to an AP to gain the additional regulatory domain information contained in the Probe Response frame, unless the information was previously received in a Beacon frame. The STA then has sufficient information available to configure its PHY for operation in the regulatory domain.

9.9.2 Support for FH PHYs

9.9.2.1 Determination of hopping patterns

When operating in a regulatory domain that does not have a method for determining a hopping pattern described in 14.6.8 or a hopping table in Annex B, hopping patterns shall be determined by an AP using HCCs or EHCCs. The HCC hopping sequences are derived from a simple formula that uses field operations on a group. For full details of the HCC placement operator function, please see the references. The placement operator function shall be as shown in Equation (4).

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$$y_{HCC}(k;a) = \frac{a}{k} \bmod N \qquad \text{for } k, a \in J'_N \tag{4}$$

where

N is the prime radix.
a is the family index.
k is in the group J'_N.
J'_N is the group remaining when the element containing the value zero is removed from the field J_N.

Therefore, k does not take the value 0. The value $1/k$ is the multiplicative inverse of k on the field J_N. The multiplicative inverse of k on the group J_N is the integer value w, such that $(k \times w) \bmod N = 1$. The values computed for y_{HCC} are the channel numbers, a corresponds to the hopping pattern number, and k corresponds to the index into the hopping pattern. A code family is the set of N–1 hopping patterns generated for the prime radix N. There is no value equivalent to the hopping set of Clause 14. Each hopping pattern comprises N–1 channels.

As an example, consider a code family that supports 10 channels. The prime radix for such a family is 11. The code family generated by the HCC algorithm is shown below in Table 23.

Table 23—HCC family – *N* = 11; Family indices (SEQ) 1 through 10

INDEX (k) ---->										
	1	2	3	4	5	6	7	8	9	10
SEQ										
1	1	6	4	3	9	2	8	7	5	10
2	2	1	8	6	7	4	5	3	10	9
3	3	7	1	9	5	6	2	10	4	8
4	4	2	5	1	3	8	10	6	9	7
5	5	8	9	4	1	10	7	2	3	6
6	6	3	2	7	10	1	4	9	8	5
7	7	9	6	10	8	3	1	5	2	4
8	8	4	10	2	6	5	9	1	7	3
9	9	10	3	5	4	7	6	8	1	2
10	10	5	7	8	2	9	3	4	6	1

The HCC method to calculate hopping sequences only generates sequences of a length that is one less than the prime radix. The EHCC algorithm extends the original HCC algorithm to support a larger number of possible hopping sequence lengths. The EHCC algorithm works through a process known as “deletion of the diagonals.” This creates hopping patterns with N–2 and N–3 channels.

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Using the same example in Table 23, a family of codes cannot be generated for code lengths of 9 or 8 by the HCC algorithm because neither 9 or 8 is equal to a prime number minus one. However, the diagonals of the array in Table 23 represent the end points of the group. Thus, code families for code lengths 9 and 8 can be easily generated from the table simply by removing the diagonals. Table 24 shows such a code family with a code length of 9 (constructed by removing the diagonal of 10s).

Table 24—EHCC family – Code length = 9, *N* = 11; Family Indices (SEQ) 1 through 9

	INDEX (k) ---->								
	1	2	3	4	5	6	7	8	9
SEQ									
1	1	6	4	3	9	2	8	7	5
2	2	1	8	6	7	4	5	3	9
3	3	7	1	9	5	6	2	4	8
4	4	2	5	1	3	8	6	9	7
5	5	8	9	4	1	7	2	3	6
6	6	3	2	7	1	4	9	8	5
7	7	9	6	8	3	1	5	2	4
8	8	4	2	6	5	9	1	7	3
9	9	3	5	4	7	6	8	1	2

Table 24 now contains a near diagonal (upper left to lower right) consisting entirely of ones. This is a necessary mathematical property of the result of removing the initial diagonal of (p–1) in the previous operation, and will be exhibited for any prime p.

Extending the process, Table 25 shows a code family with a code length of 8 (constructed from Table 24 by removing the entry from each row that has a value of 1, subtracting 1 from each value remaining in the row, and discarding the last row).

To obtain a code family of length *N*-2, the code family of length *N*-1 calculated by the HCC algorithm shall be modified by deleting the diagonal of the code family with the value of *N*-1 and removing the row of the code family with the family coefficient of *N*-1. This results in a code family represented in a square (*N*-2) by (*N*-2) array.

To obtain a code family of length *N*–3, the code family of length *N*–1 calculated by the HCC algorithm shall be modified by deleting the diagonals of the code family with the values of 1 and *N*–1, removing the rows of the code family with the family coefficients of *N*–1 and *N*–2, and subtracting 1 from all remaining values in the code family array. This results in a code family represented in a square (*N*–3) by (*N*–3) array with array values of 1 through *N*–3.

When using hopping patterns calculated using the HCC or EHCC algorithms, the values in the FH parameter set element shall be set as follows:

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Table 25—EHCC family – Code length = 8, *N* = 11; Family indices (SEQ) 1 through 8

INDEX (k) ---->							
1	2	3	4	5	6	7	8
SEQ							
1	5	3	2	8	1	7	6	4
2	1	7	5	6	3	4	2	8
3	2	6	8	4	5	1	3	7
4	3	1	4	2	7	5	8	6
5	4	7	8	3	6	1	2	5
6	5	2	1	6	3	8	7	4
7	6	8	5	7	2	4	1	3
8	7	3	1	5	4	8	6	2

a) The Hop Set field shall be 0; the value of 0 for the Hop Set field indicates that the HCC/EHCC algorithm is in use and that the Hop Pattern field contains the HCC/EHCC family index and the Hop Index field contains the HCC/EHCC index.
b) The family index of the code being used shall be placed in the Hop Pattern field.
c) The index shall be placed in the Hop Index field.

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10. Layer management

10.1 Overview of management model

Both the MAC sublayer and PHY conceptually include management entities, called MLME and PLME, respectively. These entities provide the layer management service interfaces through which layer management functions may be invoked.

In order to provide correct MAC operation, a station management entity (SME) shall be present within each STA. The SME is a layer-independent entity that may be viewed as residing in a separate management plane or as residing "off to the side." The exact functions of the SME are not specified in this standard, but in general this entity may be viewed as being responsible for such functions as the gathering of layer-dependent status from the various layer management entities (LMEs), and similarly setting the value of layer-specific parameters. SME would typically perform such functions on behalf of general system management entities and would implement standard management protocols. Figure 11 (in 5.8) depicts the relationship among management entities.

The various entities within this model interact in various ways. Certain of these interactions are defined explicitly within this standard, via a SAP across which defined primitives are exchanged. Other interactions are not defined explicitly within this standard, such as the interfaces between MAC and MLME and between PLCP and PLME, represented as double arrows within Figure 67. The specific manner in which these MAC and PHY LMEs are integrated into the overall MAC sublayer and PHY is not specified within this standard.

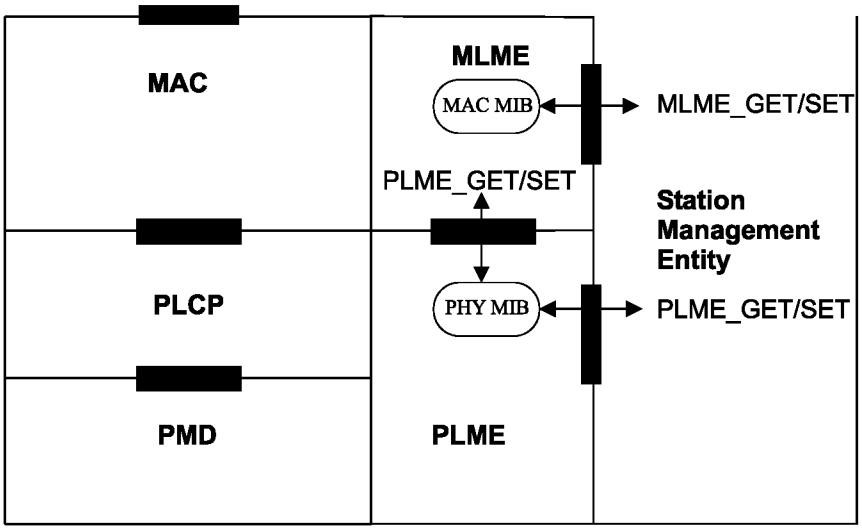

Figure 67—GET and SET operations

The management SAPs within this model are the following:

— SME-MLME SAP
— SME-PLME SAP
— MLME-PLME SAP

The latter two SAPs support identical primitives, and in fact may be viewed as a single SAP (called the PLME SAP) that may be used either directly by MLME or by SME. In this fashion, the model reflects what is anticipated to be a common implementation approach in which PLME functions are controlled by the

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MLME (on behalf of SME). In particular, PHY implementations are not required to have separate interfaces defined other than their interfaces with the MAC and MLME.

10.2 Generic management primitives

The management information specific to each layer is represented as a MIB for that layer. The MLME and PLME are viewed as "containing" the MIB for that layer. The generic model of MIB-related management primitives exchanged across the management SAPs is to allow the SAP user-entity to either GET the value of a MIB attribute, or to SET the value of a MIB attribute. The invocation of a SET.request primitive may require that the layer entity perform certain defined actions.

Figure 67 depicts these generic primitives.

The GET and SET primitives are represented as REQUESTs with associated CONFIRM primitives. These primitives are prefixed by MLME or PLME depending upon whether the MAC sublayer or PHY management SAP is involved. In the following, XX denotes MLME or PLME:

XX-GET.request(MIBattribute)
: Requests the value of the given MIBattribute.

XX-GET.confirm(status, MIBattribute, MIBattributevalue)
: Returns the appropriate MIB attribute value if status = "success," otherwise returns an error indication in the Status field. Possible error status values include "invalid MIB attribute" and "attempt to get write-only MIB attribute."

XX-SET.request(MIBattribute, MIBattributevalue)
: Requests that the indicated MIB attribute be set to the given value. If this MIBattribute implies a specific action, then this requests that the action be performed.

XX-SET.confirm(status, MIBattribute)
: If status = "success," this confirms that the indicated MIB attribute was set to the requested value, otherwise it returns an error condition in status field. If this MIBattribute implies a specific action, then this confirms that the action was performed. Possible error status values include "invalid MIB attribute" and "attempt to set read-only MIB attribute."

Additionally, there are certain requests (with associated confirms) that may be invoked across a given SAP that do not involve the setting or getting of a specific MIB attribute. One of these is supported by each SAP, as follows:

— XX-RESET.request: where XX is MLME or PLME as appropriate
— XX-RESET.confirm

This service is used to initialize the management entities, the MIBs, and the datapath entities. It may include a list of attributes for items to be initialized to nondefault values. The corresponding .confirm indicates success or failure of the request.

Other SAP-specific primitives are identified in 10.3.

10.3 MLME SAP interface

The services provided by the MLME to the SME are specified in this subclause. These services are described in an abstract way and do not imply any particular implementation or exposed interface. MLME

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SAP primitives are of the general form ACTION.request followed by ACTION.confirm. The SME uses the services provided by the MLME through the MLME SAP.

10.3.1 Power management

This mechanism supports the process of establishment and maintenance of the power management mode of a STA.

10.3.1.1 MLME-POWERMGT.request

10.3.1.1.1 Function

This primitive requests a change in the power management mode.

10.3.1.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-POWERMGT.request(
                        PowerManagementMode,
                        WakeUp,
                        ReceiveDTIMs
                        )
```

Name	Type	Valid range	Description
PowerManagementMode	Enumeration	ACTIVE, POWER_SAVE	An enumerated type that describes the desired power management mode of the STA.
WakeUp	Boolean	True, false	When true, the MAC is forced immediately into the Awake state. This parameter has no effect if the current power management mode is ACTIVE.
ReceiveDTIMs	Boolean	True, false	When true, this parameter causes the STA to awaken to receive all DTIM frames. When false, the STA is not required to awaken for every DTIM frame.

10.3.1.1.3 When generated

This primitive is generated by the SME to implement the power-saving strategy of an implementation.

10.3.1.1.4 Effect of receipt

This request sets the STA's power management parameters. The MLME subsequently issues a MLME-POWERMGT.confirm that reflects the results of the power management change request.

10.3.1.2 MLME-POWERMGT.confirm

10.3.1.2.1 Function

This primitive confirms the change in power management mode.

10.3.1.2.2 Semantics of the service primitive

The primitive parameters are as follows:

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MLME-POWERMGT.confirm(
ResultCode
)

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, NOT_SUPPORTED	Indicates the result of the MLME-POWERMGT.request.

10.3.1.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-POWERMGT.request to establish a new power management mode. It is not generated until the change has completed.

10.3.1.2.4 Effect of receipt

The SME is notified of the change of power management mode.

10.3.2 Scan

This mechanism supports the process of determining the characteristics of the available BSSs.

10.3.2.1 MLME-SCAN.request

10.3.2.1.1 Function

This primitive requests a survey of potential BSSs that the STA may later elect to try to join.

10.3.2.1.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-SCAN.request(
BSSType,
BSSID,
SSID,
ScanType,
ProbeDelay,
ChannelList,
MinChannelTime,
MaxChannelTime
)

Name	Type	Valid range	Description
BSSType	Enumeration	INFRASTRUCTURE, INDEPENDENT, ANY_BSS	Determines whether infrastructure BSS, IBSS, or both, are included in the scan.
BSSID	MACAddress	Any valid individual or broadcast MAC address	Identifies a specific or broadcast BSSID.
SSID	Octet string	0–32 octets	Specifies the desired SSID or the broadcast SSID.
ScanType	Enumeration	ACTIVE, PASSIVE	Indicates either active or passive scanning.

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Name	Type	Valid range	Description
ProbeDelay	Integer	N/A	Delay (in microseconds) to be used prior to transmitting a Probe frame during active scanning.
ChannelList	Ordered set of integers	Each channel will be selected from the valid channel range for the appropriate PHY and carrier set.	Specifies a list of channels that are examined when scanning for a BSS.
MinChannelTime	Integer	≥ ProbeDelay	The minimum time (in TU) to spend on each channel when scanning.
MaxChannelTime	Integer	≥ MinChannelTime	The maximum time (in TU) to spend on each channel when scanning.

10.3.2.1.3 When generated

This primitive is generated by the SME for a STA to determine if there are other BSSs that it may join.

10.3.2.1.4 Effect of receipt

This request initiates the scan process when the current frame exchange sequence is completed.

10.3.2.2 MLME-SCAN.confirm

10.3.2.2.1 Function

This primitive returns the descriptions of the set of BSSs detected by the scan process.

10.3.2.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-SCAN.confirm(
                        BSSDescriptionSet,
                        ResultCode
                        )
```

Name	Type	Valid range	Description
BSSDescriptionSet	Set of BSSDescriptions	N/A	The BSSDescriptionSet is returned to indicate the results of the scan request. It is a set containing zero or more instances of a BSSDescription.
ResultCode	Enumeration	SUCCESS, INVALID_ PARAMETERS	Indicates the result of the MLME-SCAN.confirm.

Each BSSDescription consists of the following elements:

Name	Type	Valid range	Description
BSSID	MACAddress	N/A	The BSSID of the found BSS.
SSID	Octet string	1–32 octets	The SSID of the found BSS.
BSSType	Enumeration	INFRASTRUC-TURE, INDEPENDENT	The type of the found BSS.

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Name	Type	Valid range	Description
Beacon Period	Integer	N/A	The Beacon period of the found BSS (in TU).
DTIM Period	Integer	As defined in frame format	The DTIM period of the BSS (in beacon periods).
Timestamp	Integer	N/A	The timestamp of the received frame (probe response/beacon) from the found BSS.
Local Time	Integer	N/A	The value of the STA's TSF timer at the start of reception of the first octet of the timestamp field of the received frame (probe response or beacon) from the found BSS.
PHY Parameter Sets	As defined in frame format	As defined in frame format	The parameter sets relevant to the PHY.
CF Parameter Set	As defined in frame format	As defined in frame format	The parameter set for the CF periods, if found BSS supports CF mode.
IBSS Parameter Set	As defined in frame format	As defined in frame format	The parameter set for the IBSS, if found BSS is an IBSS.
CapabilityInformation	As defined in frame format	As defined in frame format	The advertised capabilities of the BSS.
BSSBasicRateSet	Set of integers	1–127 inclusive (for each integer in the set)	The set of data rates that must be supported by all STAs that desire to join this BSS. The STAs must be able to receive and transmit at each of the data rates listed in the set.

10.3.2.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-SCAN.request to ascertain the operating environment of the STA.

10.3.2.2.4 Effect of receipt

The SME is notified of the results of the scan procedure.

10.3.3 Synchronization

This mechanism supports the process of selection of a peer in the authentication process.

10.3.3.1 MLME-JOIN.request

10.3.3.1.1 Function

This primitive requests synchronization with a BSS.

10.3.3.1.2 Semantics of the service primitive

The primitive parameters are as follows:

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MLME-JOIN.request(
BSSDescription,
JoinFailureTimeout,
ProbeDelay,
OperationalRateSet
)

Name	Type	Valid range	Description
BSSDescription	BSSDescription	N/A	The BSSDescription of the BSS to join. The BSSDescription is a member of the set of descriptions that was returned as a result of a MLME-SCAN.request.
JoinFailureTimeout	Integer	≥ 1	The time limit, in units of beacon intervals, after which the join procedure will be terminated.
ProbeDelay	Integer	N/A	Delay (in microseconds) to be used prior to transmitting a Probe frame during active scanning.
OperationalRateSet	Set of integers	1–127 inclusive (for each integer in the set)	The set of data rates that the STA desires to use for communication within the BSS. The STA must be able to receive at each of the data rates listed in the set. This set is a superset of the BSS basic rate set advertised by the BSS.

10.3.3.1.3 When generated

This primitive is generated by the SME for a STA to establish synchronization with a BSS.

10.3.3.1.4 Effect of receipt

This primitive initiates a synchronization procedure once the current frame exchange sequence is complete. The MLME synchronizes its timing with the specified BSS based on the elements provided in the BSSDescription parameter. The MLME subsequently issues a MLME-JOIN.confirm that reflects the results.

10.3.3.2 MLME-JOIN.confirm

10.3.3.2.1 Function

This primitive confirms synchronization with a BSS.

10.3.3.2.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-JOIN.confirm(
ResultCode
)

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, TIMEOUT	Indicates the result of the MLME-JOIN.request.

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10.3.3.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-JOIN.request to establish synchronization with a BSS.

10.3.3.2.4 Effect of receipt

The SME is notified of the results of the synchronization procedure.

10.3.4 Authenticate

This mechanism supports the process of establishing an authentication relationship with a peer MAC entity.

10.3.4.1 MLME-AUTHENTICATE.request

10.3.4.1.1 Function

This primitive requests authentication with a specified peer MAC entity.

10.3.4.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-AUTHENTICATE.request(
                                    PeerSTAAddress,
                                    AuthenticationType,
                                    AuthenticateFailureTimeout
                                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the authentication process.
AuthenticationType	Enumeration	OPEN_SYSTEM, SHARED_KEY	Specifies the type of authentication algorithm to use during the authentication process.
AuthenticationFailure-Timeout	Integer	≥ 1	Specifies a time limit (in TU) after which the authentication procedure will be terminated.

10.3.4.1.3 When generated

This primitive is generated by the SME for a STA to establish authentication with a specified peer MAC entity in order to permit Class 2 frames to be exchanged between the two STAs. During the authentication procedure, the SME may generate additional MLME-AUTHENTICATE.request primitives.

10.3.4.1.4 Effect of receipt

This primitive initiates an authentication procedure. The MLME subsequently issues a MLME-AUTHENTICATE.confirm that reflects the results.

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10.3.4.2 MLME-AUTHENTICATE.confirm

10.3.4.2.1 Function

This primitive reports the results of an authentication attempt with a specified peer MAC entity.

10.3.4.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-AUTHENTICATE.confirm(
                                    PeerSTAAddress,
                                    AuthenticationType,
                                    ResultCode
                                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the authentication process was attempted. This value must match the peer-STAAddress parameter specified in the corresponding MLME-AUTHENTICATE.request.
AuthenticationType	Enumeration	OPEN_SYSTEM, SHARED_KEY	Specifies the type of authentication algorithm that was used during the authentication process. This value must match the authenticationType parameter specified in the corresponding MLME-AUTHENTICATE.request.
ResultCode	Enumeration	SUCCESS, INVALID_ PARAMETERS, TIMEOUT, TOO_MANY_ SIMULTANEOUS_ REQUESTS, REFUSED	Indicates the result of the MLME-AUTHENTICATE.request.

10.3.4.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-AUTHENTICATE.request to authenticate with a specified peer MAC entity.

10.3.4.2.4 Effect of receipt

The SME is notified of the results of the authentication procedure.

10.3.4.3 MLME-AUTHENTICATE.indication

10.3.4.3.1 Function

This primitive reports the establishment of an authentication relationship with a specific peer MAC entity.

10.3.4.3.2 Semantics of the service primitive

The primitive parameters are as follows:

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MLME-AUTHENTICATE.indication(
PeerSTAAddress,
AuthenticationType
)

Name	Type	Valid range	Description
PeerSTAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the authentication relationship was established.
AuthenticationType	Enumeration	OPEN_SYSTEM, SHARED_KEY	Specifies the type of authentication algorithm that was used during the authentication process.

10.3.4.3.3 When generated

This primitive is generated by the MLME as a result of the establishment of an authentication relationship with a specific peer MAC entity that resulted from an authentication procedure that was initiated by that specific peer MAC entity.

10.3.4.3.4 Effect of receipt

The SME is notified of the establishment of the authentication relationship.

10.3.5 Deauthenticate

This mechanism supports the process of invalidating an authentication relationship with a peer MAC entity.

10.3.5.1 MLME-DEAUTHENTICATE.request

10.3.5.1.1 Function

This primitive requests that the authentication relationship with a specified peer MAC entity be invalidated.

10.3.5.1.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DEAUTHENTICATE.request(
PeerSTAAddress,
ReasonCode
)

Name	Type	Valid range	Description
PeerSTAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the deauthentication process.
ReasonCode	As defined in frame format	As defined in frame format	Specifies the reason for initiating the deauthentication procedure.

10.3.5.1.3 When generated

This primitive is generated by the SME for a STA to invalidate authentication with a specified peer MAC entity in order to prevent the exchange of Class 2 frames between the two STAs. During the deauthentication procedure, the SME may generate additional MLME-DEAUTHENTICATE.request primitives.

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10.3.5.1.4 Effect of receipt

This primitive initiates a deauthentication procedure. The MLME subsequently issues a MLME-DEAUTHENTICATE.confirm that reflects the results.

10.3.5.2 MLME-DEAUTHENTICATE.confirm

10.3.5.2.1 Function

This primitive reports the results of a deauthentication attempt with a specified peer MAC entity.

10.3.5.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DEAUTHENTICATE.confirm(
                                    PeerSTAAddress,
                                    ResultCode
                                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the deauthentication process was attempted.
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, TOO_MANY_SIMUL-TANEOUS_REQUESTS	Indicates the result of the MLME-DEAUTHENTICATE.request.

10.3.5.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-DEAUTHENTICATE.request to invalidate the authentication relationship with a specified peer MAC entity.

10.3.5.2.4 Effect of receipt

The SME is notified of the results of the deauthentication procedure.

10.3.5.3 MLME-DEAUTHENTICATE.indication

10.3.5.3.1 Function

This primitive reports the invalidation of an authentication relationship with a specific peer MAC entity.

10.3.5.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DEAUTHENTICATE.indication(
                                    PeerSTAAddress,
                                    ReasonCode
                                    )
```

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Name	Type	Valid range	Description
PeerSTAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the authentication relationship was invalidated.
ReasonCode	As defined in frame format.	As defined in frame format	Specifies the reason the deauthentication procedure was initiated.

10.3.5.3.3 When generated

This primitive is generated by the MLME as a result of the invalidation of an authentication relationship with a specific peer MAC entity.

10.3.5.3.4 Effect of receipt

The SME is notified of the invalidation of the specific authentication relationship.

10.3.6 Associate

The following primitives describe how a STA becomes associated with an AP.

10.3.6.1 MLME-ASSOCIATE.request

10.3.6.1.1 Function

This primitive requests association with a specified peer MAC entity that is acting as an AP.

10.3.6.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-ASSOCIATE.request(
                        PeerSTAAddress,
                        AssociateFailureTimeout,
                        CapabilityInformation,
                        ListenInterval
                        )
```

Name	Type	Valid range	Description
PeerSTAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the association process.
AssociateFailureTimeout	Integer	≥ 1	Specifies a time limit (in TU) after which the associate procedure will be terminated.
CapabilityInformation	As defined in frame format	As defined in frame format	Specifies the operational capability definitions to be used by the MAC entity.
ListenInterval	Integer	≥ 0	Specifies the number of beacon intervals that may pass before the STA awakens and listens for the next beacon.

10.3.6.1.3 When generated

This primitive is generated by the SME when a STA wishes to establish association with an AP.

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10.3.6.1.4 Effect of receipt

This primitive initiates an association procedure. The MLME subsequently issues an MLME-ASSOCIATE.confirm that reflects the results.

10.3.6.2 MLME-ASSOCIATE.confirm

10.3.6.2.1 Function

This primitive reports the results of an association attempt with a specified peer MAC entity that is acting as an AP.

10.3.6.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-ASSOCIATE.confirm(
                        ResultCode
                        )
```

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, INVALID_ PARAMETERS, TIMEOUT, REFUSED	Indicates the result of the MLME-ASSOCIATE.request.

10.3.6.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-ASSOCIATE.request to associate with a specified peer MAC entity that is acting as an AP.

10.3.6.2.4 Effect of receipt

The SME is notified of the results of the association procedure.

10.3.6.3 MLME-ASSOCIATE.indication

10.3.6.3.1 Function

This primitive reports the establishment of an association with a specific peer MAC entity.

10.3.6.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-ASSOCIATE.indication(
                        PeerSTAAddress
                        )
```

Name	Type	Valid range	Description
PeerSTAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the association was established.

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10.3.6.3.3 When generated

This primitive is generated by the MLME as a result of the establishment of an association with a specific peer MAC entity that resulted from an association procedure that was initiated by that specific peer MAC entity.

10.3.6.3.4 Effect of receipt

The SME is notified of the establishment of the association.

10.3.7 Reassociate

The following primitives describe how a STA becomes associated with another AP.

10.3.7.1 MLME-REASSOCIATE.request

10.3.7.1.1 Function

This primitive requests a change in association to a specified new peer MAC entity that is acting as an AP.

10.3.7.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-REASSOCIATE.request(
                        NewAPAddress,
                        ReassociateFailureTimeout,
                        CapabilityInformation,
                        ListenInterval
                        )
```

Name	Type	Valid range	Description
NewAPAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the reassociation process.
ReassociateFailureTimeout	Integer	≥ 1	Specifies a time limit (in TU) after which the reassociate procedure will be terminated.
CapabilityInformation	As defined in frame format	As defined in frame format	Specifies the operational capability definitions to be used by the MAC entity.
ListenInterval	Integer	≥ 0	Specifies the number of beacon intervals that may pass before the STA awakens and listens for the next beacon.

10.3.7.1.3 When generated

This primitive is generated by the SME for a STA to change association to a specified new peer MAC entity that is acting as an AP.

10.3.7.1.4 Effect of receipt

This primitive initiates a reassociation procedure. The MLME subsequently issues a MLME-REASSOCIATE.confirm that reflects the results.

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10.3.7.2 MLME-REASSOCIATE.confirm

10.3.7.2.1 Function

This primitive reports the results of a reassociation attempt with a specified peer MAC entity that is acting as an AP.

10.3.7.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-REASSOCIATE.confirm(
                                    ResultCode
                                    )
```

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, INVALID_ PARAMETERS, TIMEOUT, REFUSED	Indicates the result of the MLME-REASSOCIATE.request.

10.3.7.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-REASSOCIATE.request to reassociate with a specified peer MAC entity that is acting as an AP.

10.3.7.2.4 Effect of receipt

The SME is notified of the results of the reassociation procedure.

10.3.7.3 MLME-REASSOCIATE.indication

10.3.7.3.1 Function

This primitive reports the establishment of a reassociation with a specified peer MAC entity.

10.3.7.3.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-REASSOCIATE.indication(
                                    PeerSTAAddress
                                    )
```

Name	Type	Valid range	Description
PeerSTAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the reassociation was established.

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10.3.7.3.3 When generated

This primitive is generated by the MLME as a result of the establishment of a reassociation with a specific peer MAC entity that resulted from a reassociation procedure that was initiated by that specific peer MAC entity.

10.3.7.3.4 Effect of receipt

The SME is notified of the establishment of the reassociation.

10.3.8 Disassociate

10.3.8.1 MLME-DISASSOCIATE.request

10.3.8.1.1 Function

This primitive requests disassociation with a specified peer MAC entity that is acting as an AP.

10.3.8.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-DISASSOCIATE.request(
                                PeerSTAAddress,
                                ReasonCode
                                )
```

Name	Type	Valid range	Description
PeerSTAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which to perform the disassociation process.
ReasonCode	As defined in frame format	As defined in frame format	Specifies the reason for initiating the disassociation procedure.

10.3.8.1.3 When generated

This primitive is generated by the SME for a STA to establish disassociation with an AP.

10.3.8.1.4 Effect of receipt

This primitive initiates a disassociation procedure. The MLME subsequently issues an MLME-DISASSOCIATE.confirm that reflects the results.

10.3.8.2 MLME-DISASSOCIATE.confirm

10.3.8.2.1 Function

This primitive reports the results of a disassociation procedure with a specific peer MAC entity that is acting as an AP.

10.3.8.2.2 Semantics of the service primitive

The primitive parameters are as follows:

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MLME-DISASSOCIATE.confirm(
ResultCode
)

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS, INVALID_ PARAMETERS, TIMEOUT, REFUSED	Indicates the result of the MLME-DISASSOCIATE.request.

10.3.8.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-DISASSOCIATE.request to disassociate with a specified peer MAC entity that is acting as an AP.

10.3.8.2.4 Effect of receipt

The SME is notified of the results of the disassociation procedure.

10.3.8.3 MLME-DISASSOCIATE.indication

10.3.8.3.1 Function

This primitive reports disassociation with a specific peer MAC entity.

10.3.8.3.2 Semantics of the service primitive

The primitive parameters are as follows:

MLME-DISASSOCIATE.indication(
PeerSTAAddress,
ReasonCode
)

Name	Type	Valid range	Description
PeerSTAAddress	MACAddress	Any valid individual MAC address	Specifies the address of the peer MAC entity with which the association relationship was invalidated.
ReasonCode	As defined in frame format	As defined in frame format	Specifies the reason the disassociation procedure was initiated.

10.3.8.3.3 When generated

This primitive is generated by the MLME as a result of the invalidation of an association relationship with a specific peer MAC entity.

10.3.8.3.4 Effect of receipt

The SME is notified of the invalidation of the specific association relationship.

10.3.9 Reset

This mechanism supports the process of resetting the MAC.

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10.3.9.1 MLME-RESET.request

10.3.9.1.1 Function

This primitive requests that the MAC entity be reset.

10.3.9.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-RESET.request(
                    STAAddress,
                    SetDefaultMIB
                    )
```

Name	Type	Valid range	Description
STAAddress	MACAddress	Any valid MAC address	Specifies the MAC address that is to be used by the MAC entity that is being reset. This value may be used to provide a locally administered STA address.
SetDefaultMIB	Boolean	True, false	If true, all MIB attributes are set to their default values. The default values are implementation dependent. If false, the MAC is reset, but all MIB attributes retain the values that were in place prior to the generation of the MLME-RESET.request primitive.

10.3.9.1.3 When generated

This primitive is generated by the SME to reset the MAC to initial conditions. The MLME-RESET.request primitive must be used prior to use of the MLME-START.request primitive.

10.3.9.1.4 Effect of receipt

This primitive sets the MAC to initial conditions, clearing all internal variables to the default values. MIB attributes may be reset to their implementation-dependent default values by setting the SetDefaultMIB flag to true. The MLME subsequently issues a MLME-RESET.confirm that reflects the results.

10.3.9.2 MLME-RESET.confirm

10.3.9.2.1 Function

This primitive reports the results of a reset procedure.

10.3.9.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-RESET.confirm(
                    ResultCode
                    )
```

Name	Type	Valid range	Description
ResultCode	Enumeration	SUCCESS	Indicates the result of the MLME-RESET.request.

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10.3.9.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-RESET.request to reset the MAC entity.

10.3.9.2.4 Effect of receipt

The SME is notified of the results of the reset procedure.

10.3.10 Start

This mechanism supports the process of creating a new BSS.

10.3.10.1 MLME-START.request

10.3.10.1.1 Function

This primitive requests that the MAC entity start a new BSS.

10.3.10.1.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-START.request(
                    SSID,
                    BSSType,
                    BeaconPeriod,
                    DTIMPeriod,
                    CF parameter set,
                    PHY parameter set,
                    IBSS parameter set,
                    ProbeDelay.
                    CapabilityInformation,
                    BSSBasicRateSet,
                    OperationalRateSet
                    )
```

Name	Type	Valid range	Description
SSID	Octet string	1–32 octets	The SSID of the BSS.
BSSType	Enumeration	INFRA-STRUCTURE, INDEPEN-DENT	The type of the BSS.
Beacon Period	Integer	≥ 1	The Beacon period of the BSS (in TU).
DTIM Period	Integer	As defined in 7.3.2.6	The DTIM Period of the BSS (in beacon periods).
CF parameter set	As defined in frame format	As defined in 7.3.2.5	The parameter set for CF periods, if the BSS supports CF mode. aCFPPeriod is modified as a side effect of the issuance of an MLME-START.request primitive.
PHY parameter sets	As defined in frame format	As defined in 7.3.2.3 or 7.3.2.4	The parameter sets relevant to the PHY.
IBSS parameter set	As defined in frame format	As defined in 7.3.2.7	The parameter set for the IBSS, if BSS is an IBSS.

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Name	Type	Valid range	Description
ProbeDelay	Integer	N/A	Delay (in microseconds) to be used prior to transmitting a Probe frame during active scanning.
CapabilityInformation	As defined in frame format	As defined in 7.3.1.4	The capabilities to be advertised for the BSS.
BSSBasicRateSet	Set of integers	1–127 inclusive (for each integer in the set)	The set of data rates that must be supported by all STAs to join this BSS. The STA that is creating the BSS must be able to receive and transmit at each of the data rates listed in the set.
OperationalRateSet	Set of integers	1–127 inclusive (for each integer in the set)	The set of data rates that the STA desires to use for communication within the BSS. The STA must be able to receive at each of the data rates listed in the set. This set is a superset of the BSS basic rate set advertised by the BSS.

10.3.10.1.3 When generated

This primitive is generated by the SME to start either an infrastructure BSS (with the MAC entity acting as an AP) or an IBSS (with the MAC entity acting as the first STA in the IBSS).

The MLME-START.request primitive must be generated after an MLME-RESET.request primitive has been used to reset the MAC entity and before an MLME-JOIN.request primitive has been used to successfully join an existing infrastructure BSS or IBSS.

The MLME-START.request primitive must not be used after successful use of the MLME-START.request primitive or successful use of the MLME-JOIN.request without generating an intervening MLME-RESET.request primitive.

10.3.10.1.4 Effect of receipt

This primitive initiates the BSS initialization procedure once the current frame exchange sequence is complete. The MLME subsequently issues an MLME-START.confirm that reflects the results of the creation procedure.

10.3.10.2 MLME-START.confirm

10.3.10.2.1 Function

This primitive reports the results of a BSS creation procedure.

10.3.10.2.2 Semantics of the service primitive

The primitive parameters are as follows:

```
MLME-START.confirm(
                                    ResultCode
                                    )
```

Name	Type	Valid range	resetDescription
ResultCode	Enumeration	SUCCESS, INVALID_PARAMETERS, BSS_ALREADY_STARTED_OR_JOINED	Indicates the result of the MLME-START.request.

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10.3.10.2.3 When generated

This primitive is generated by the MLME as a result of an MLME-START.request to create a new BSS.

10.3.10.2.4 Effect of receipt

The SME is notified of the results of the BSS creation procedure.

10.4 PLME SAP interface

The PHY management service interface consists of the generic PLMEGET and PLMESET primitives on PHY MIB attributes, as described previously, together with the PLME-RESET and PLME-CHARACTERISTICS primitives and the following specific primitives.

10.4.1 PLME-RESET.request

10.4.1.1 Function

This primitive shall be a request by the LME to reset the PHY. The PHY shall be always reset to the receive state to avoid accidental data transmission.

10.4.1.2 Semantics of the service primitive

The semantics of the primitive are as follows:

PLME-RESET.request( )

This primitive has no parameters.

10.4.1.3 When generated

This primitive shall be generated at any time to reset the PHY.

10.4.1.4 Effect of receipt

Receipt of this primitive by the PHY shall cause the PHY entity to reset both the transmit and the receive state machines and place the PHY into the receive state.

10.4.2 PLME-CHARACTERISTICS.request

10.4.2.1 Function

This primitive is a request by the LME to provide the PHY operational characteristics.

10.4.2.2 Semantics of the service primitive

The semantics of the primitive are as follows:

PLME-CHARACTERISTICS.request( )

This primitive has no parameters.

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10.4.2.3 When generated

This primitive is generated by the LME, at initialization time, to request the PHY entity to provide its operational characteristics.

10.4.2.4 Effect of receipt

The effect of receipt of this primitive by the PHY entity will be to generate a PLME-CHARACTERISTICS.confirm primitive that conveys its operational characteristics.

10.4.3 PLME-CHARACTERISTICS.confirm

10.4.3.1 Function

This primitive provides the PHY operational parameters.

10.4.3.2 Semantics of the service primitive

The primitive provides the following parameters:

```
PLME-CHARACTERISTICS.confirm
                                    aSlotTime,
                                    aSIFSTime,
                                    aCCATime,
                                    aRxTxTurnaroundTime,
                                    aTxPLCPDelay,
                                    aRxPLCPDelay,
                                    aRxTxSwitchTime,
                                    aTxRampOnTime,
                                    aTxRampOffTime,
                                    aTxRFDelay,
                                    aRxRFDelay,
                                    aAirPropagationTime,
                                    aMACProcessingDelay,
                                    aPreambleLength,
                                    aPLCPHeaderLength,
                                    aMPDUDurationFactor,
                                    aMPDUMaxLength,
                                    aCWmin,
                                    aCWmax
                                    )
```

The values assigned to the parameters shall be as specified in the PLME SAP interface specification contained within each PHY subclass of this standard. The parameter aMPDUDurationFactor is not used by all PHYs defined within this standard.

Name	Type	Description
aSlotTime	integer	The Slot Time (in microseconds) that the MAC will use for defining the PIFS and DIFS periods. See 9.2.10.
aSIFSTime	integer	The nominal time (in microseconds) that the MAC and PHY will require to receive the last symbol of a frame at the air interface, process the frame, and respond with the first symbol on the air interface of the earliest possible response frame. See 9.2.10.

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Name	Type	Description
aCCATime	integer	The minimum time (in microseconds) the CCA mechanism has available to assess the medium within every time slot to determine whether the medium is busy or idle.
aRxTxTurn-aroundTime	integer	The maximum time (in microseconds) that the PHY requires to change from receiving to transmitting the start of the first symbol. The following equation is used to derive the RxTxTurnaroundTime: aTxPLCPDelay + aRxTxSwitchTime + aTxRampOnTime + aTxRFDelay.
aTxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a symbol from the MAC interface to the transmit data path of the physical medium dependent (PMD).
aRxPLCPDelay	integer	The nominal time (in microseconds) that the PLCP uses to deliver a bit from the PMD receive path to the MAC.
aRxTxSwitch-Time	integer	The nominal time (in microseconds) that the PMD takes to switch from Receive to Transmit.
aTxRampOnTime	integer	The maximum time (in microseconds) that the PMD takes to turn the Transmitter on.
aTxRampOffTime	integer	The nominal time (in microseconds) that the PMD takes to turn the Transmit Power Amplifier off.
aTxRFDelay	integer	The nominal time (in microseconds) between the issuance of a PMD_DATA.request to the PMD and the start of the corresponding symbol at the air interface. The start of a symbol is defined to be 1/2 symbol period prior to the center of the symbol for FH, or 1/2 chip period prior to the center of the first chip of the symbol for DS, or 1/2 slot time prior to the center of the corresponding slot for infrared (IR).
aRxRFDelay	integer	The nominal time (in microseconds) between the end of a symbol at the air interface to the issuance of a PMD_DATA.indicate to the PLCP. The end of a symbol is defined to be 1/2 symbol period after the center of the symbol for FH, or 1/2 chip period after the center of the last chip of the symbol for DS, or 1/2 slot time after the center of the corresponding slot for IR.
aAirPropagation-Time	integer	The anticipated time (in microseconds) it takes a transmitted signal to go from the transmitting station to the receiving station.
aMACProcess-ingDelay	integer	The nominal time (in microseconds) that the MAC uses to process a frame and prepare a response to the frame.
aPreambleLength	integer	The current PHY's Preamble Length (in microseconds). If the actual value of the length of the modulated preamble is not an integral number of microseconds, the value shall be rounded up to the next higher value.
aPLCPHeader-Length	integer	The current PHY's PLCP Header Length (in microseconds). If the actual value of the length of the modulated header is not an integral number of microseconds, the value shall be rounded up to the next higher value.
aMPDUDuration-Factor	integer	The overhead added by the PHY to the MPDU as it is transmitted through the wireless medium expressed as a scaling factor applied to the number of bits in the MPDU. The value of aMPDUDurationFactor is generated by the following equation: Truncate[((PPDUbits/PSDUbits)–1) × 10^9)]. The total time to transmit a PPDU over the air is generated by the following equation rounded up to the next integer μs: aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × PSDUoctets) / 10^9) + (8 × PSDUoctets)) / data rate where data rate is in Mbit/s. The total time (in μs) to the beginning of any octet in a PPDU from the first symbol of the preamble can be calculated using the duration factor in the following equation: Truncate[aPreambleLength + aPLCPHeaderLength + (((aMPDUDurationFactor × 8 × N) / 10^9) + (8 × N)) / data rate] + 1, where data rate is in Mbit/s and where *N* counts the number of octets in the PPDU prior to the desired octet, but does not count the number of octets in the preamble PLCP Header.
aMPDUMax-Length	integer	The maximum number of octets in an MPDU that can be conveyed by a PLCP protocol data unit (PPDU).
aCWmin	integer	The minimum size of the CW, in units of aSlotTime.
aCWmax	integer	The maximum size of the CW, in units of aSlotTime.

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10.4.3.3 When generated

This primitive will be issued by the PHY entity in response to a PLME-CHARACTERISTICS.request.

10.4.3.4 Effect of receipt

The receipt of this primitive provides the operational characteristics of the PHY entity.

10.4.4 PLME-DSSSTESTMODE.request

10.4.4.1 Function

This primitive requests that the DSSS PHY entity enter a test mode operation. The parameters associated with this primitive are considered as recommendations and are optional in any particular implementation.

10.4.4.2 Semantics of the service primitive

The primitive parameters are as follows:

PLME-DSSSTESTMODE.request(
TEST_ENABLE,
TEST_MODE,
SCRAMBLE_STATE,
SPREADING_STATE,
DATA_TYPE,
DATA_RATE;
PREAMBLE_TYPE;
MODULATION_CODE_TYPE;
)

Name	Type	Valid range	Description
TEST_ENABLE	Boolean	True, false	If true, enables the PHY test mode according to the remaining parameters.
TEST_MODE	integer	1, 2, 3	TEST_MODE selects one of three operational states: 01 = transparent receive 02 = continuous transmit 03 = 50% duty cycle
SCRAMBLE_STATE	Boolean	True, false	If true, sets the operational state of the scrambler to ON.
SPREADING_STATE	Boolean	True, false	If true, selects the operational state of the chipping.
DATA_TYPE	integer	1, 2, 3	Selects one of three data patterns to be used for the transmit portions of the tests, e.g., all ones, all zeros, and random data patterns.
DATA_RATE	integer	2, 4, 11, 12, 18, 22, 24, 36, 48, 72, 96, 108	Selects the data rate: 02 = 1 Mbit/s 04 = 2 Mbit/s 11 = 5.5 Mbit/s 12 = 6 Mbit/s 18 = 9 Mbit/s 22 = 11 Mbit/s 24 = 12 Mbit/s 36 = 18 Mbit/s 48 = 24 Mbit/s 72 = 36 Mbit/s 96 = 48 Mbit/s 108 = 54 Mbit/s

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PREAMBLE_TYPE	Boolean	null, 0, 1	Selects the preamble length: 0 = long 1 = short Can be null.
MODULATION_CODE _TYPE	Boolean	null, 0, 1	Selects the modulation code: 0 = complementary code keying (CCK) 1 = PBCC Can be null.

10.4.4.3 When generated

This primitive shall be generated at any time to enter the DSSS PHY test mode.

10.4.4.4 Effect of receipt

Receipt of this primitive by the PHY shall cause the DSSS PHY entity to enter the test mode of operation.

10.4.5 PLME-DSSSTESTOUTPUT.request

10.4.5.1 Function

This optional primitive shall be a request by the LME to enable selected test signals from the PHY. The parameters associated with this primitive are considered as recommendations and are optional in any particular implementation.

10.4.5.2 Semantics of the service primitive

The primitive parameters are as follows:

```
PLME-DSSSTESTOUTPUT.request(
                                    TEST_OUTPUT,
                                    )
```

Name	Type	Valid range	Description
TEST_OUTPUT	Boolean	True, false	If true, enables the selected test signals for testing DS PHY.

TEST_OUTPUT enables and disables selected signals for debugging and testing the PHY. Some signals that may be available for output are PHY-TXSTART.request, PHY-RXSTART.indicate(RXVECTOR), PHY-CCA.indicate, the chipping clock, the data clock, the symbol clock, transmit (TX) data, and receive (RX) data.

10.4.5.3 When generated

This primitive shall be generated at any time to enable the test outputs when in the DSSS PHY test mode.

10.4.5.4 Effect of receipt

Receipt of this primitive by the DSSS PHY shall cause the DSSS PHY entity to enable the test outputs using the modes set by the most recent PLME-DSSSTESTMODE.request primitive.

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10.4.6 PLME-TXTIME.request

10.4.6.1 Function

This primitive is a request for the PHY to calculate the time that will be required to transmit onto the WM a PPDU containing a specified length MPDU, and using a specified format, data rate, and signalling.

10.4.6.2 Semantics of the service primitive

This primitive provides the following parameters:

PLME-TXTIME.request(TXVECTOR)

The TXVECTOR represents a list of parameters that the MAC sublayer provides to the local PHY entity in order to transmit a MPDU, as further described in 12.3.4.4 and 17.4 (which defines the local PHY entity).

10.4.6.3 When generated

This primitive is issued by the MAC sublayer to the PHY entity when the MAC sublayer needs to determine the time required to transmit a particular MPDU.

10.4.6.4 Effect of receipt

The effect of receipt of this primitive by the PHY entity shall be to generate a PHY-TXTIME.confirm primitive that conveys the required transmission time.

10.4.7 PLME-TXTIME.confirm

10.4.7.1 Function

This primitive provides the time that will be required to transmit the PPDU described in the corresponding PLME-TXTIME.request.

10.4.7.2 Semantics of the service primitive

This primitive provides the following parameters:

PLME-TXTIME.confirm(TXTIME)

The TXTIME represents the time, in microseconds, required to transmit the PPDU described in the corresponding PLME-TXTIME.request. If the calculated time includes a fractional microsecond, the TXTIME value is rounded up to the next higher integer.

10.4.7.3 When generated

This primitive is issued by the local PHY entity in response to a PLME-TXTIME.request.

10.4.7.4 Effect of receipt

The receipt of this primitive provides the MAC sublayer with the PPDU transmission time.

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11. MLME

11.1 Synchronization

All STAs within a single BSS shall be synchronized to a common clock using the mechanisms defined herein.

11.1.1 Basic approach

A TSF keeps the timers for all STAs in the same BSS synchronized. All STAs shall maintain a local TSF timer.

11.1.1.1 TSF for infrastructure networks

In an infrastructure network, the AP shall be the timing master and shall perform the TSF. The AP shall initialize its TSF timer independently of any simultaneously started APs in an effort to minimize the synchronization of the TSF timers of multiple APs. The AP shall periodically transmit special frames called *beacons* that contain a copy of its TSF timer to synchronize the other STAs in a BSS. A receiving STA shall always accept the timing information in beacons sent from the AP servicing its BSS. If a STA's TSF timer is different from the timestamp in the received beacon, the receiving STA shall set its local timer to the received timestamp value.

Beacons shall be generated for transmission by the AP once every BeaconPeriod TUs.

11.1.1.2 TSF for an IBSS

The TSF in an IBSS shall be implemented via a distributed algorithm that shall be performed by all of the members of the BSS. Each STA in the BSS shall transmit beacons according to the algorithm described in this clause. Each STA in an IBSS shall adopt the timing received from any beacon or probe response that has a TSF value later than its own TSF timer.

11.1.2 Maintaining synchronization

Each STA shall maintain a TSF timer with modulus 2^{64} counting in increments of microseconds. STAs expect to receive beacons at a nominal rate. The interval between beacons is defined by the aBeaconPeriod parameter of the STA. A STA sending a beacon shall set the value of the beacon's timestamp so that it equals the value of the STA's TSF timer at the time that the first bit of the timestamp is transmitted to the PHY plus the transmitting STA's delays through its local PHY from the MAC-PHY interface to its interface with the WM [e.g., antenna, light-emitting display (LED) emission surface]. The algorithms in this clause define a mechanism that maintains the synchronization of the TSF timers in a BSS to within 4 μs plus the maximum propagation delay of the PHY for PHYs of 1 Mbit/s, or greater.

11.1.2.1 Beacon generation in infrastructure networks

The AP shall define the timing for the entire BSS by transmitting beacons according to the aBeaconPeriod attribute within the AP. This defines a series of TBTTs exactly aBeaconPeriod TUs apart. Time zero is defined to be a TBTT with the beacon being a DTIM and transmitted at the beginning of a CFP. At each TBTT, the AP shall schedule a beacon as the next frame for transmission. If the medium is determined by the CS mechanism (see 9.2.1) to be unavailable, the AP shall delay the actual transmission of a beacon according to the basic medium access rules specified in Clause 9. The beacon period is included in Beacon and Probe Response frames, and STAs shall adopt that beacon period when joining the BSS.

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NOTE—Though the transmission of a beacon may be delayed because of CSMA deferrals, subsequent beacons shall be scheduled at the nominal beacon interval. This is shown in Figure 68.

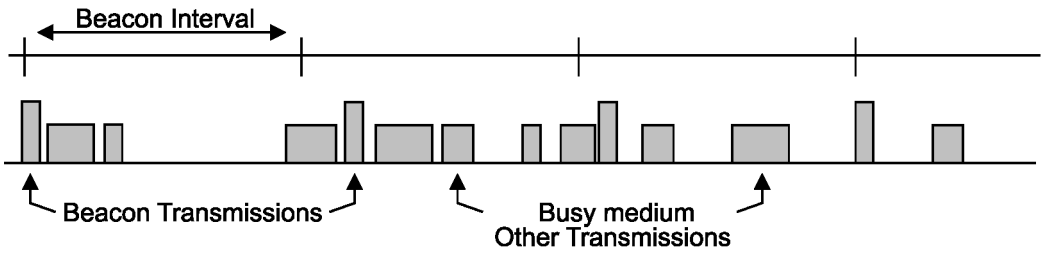

Figure 68—Beacon transmission on a busy network

11.1.2.2 Beacon generation in an IBSS

Beacon generation in an IBSS is distributed. The beacon period is included in Beacon and Probe Response frames, and STAs shall adopt that beacon period when joining the IBSS. All members of the IBSS participate in beacon generation. Each STA shall maintain its own TSF timer that is used for aBeaconPeriod timing. The beacon interval within an IBSS is established by the STA that instantiates the IBSS. This defines a series of TBTTs exactly aBeaconPeriod TUs apart. Time zero is defined to be a TBTT. At each TBTT the STA shall

a) Suspend the decrementing of the backoff timer for any pending nonbeacon or non-ATIM transmission,
b) Calculate a random delay uniformly distributed in the range between zero and twice aCWmin × aSlotTime,
c) Wait for the period of the random delay, decrementing the random delay timer using the same algorithm as for backoff,
d) Cancel the remaining random delay and the pending beacon transmission, if a beacon arrives before the random delay timer has expired, and the ATIM backoff timer shall resume decrementing.
e) Send a beacon if the random delay has expired and no beacon has arrived during the delay period.

(See Figure 69.)

The beacon transmission shall always occur during the Awake Period of STAs that are operating in a low-power mode. This is described in more detail in 11.2.

11.1.2.3 Beacon reception

STAs shall use information from the CF Parameter Set element of all received Beacon frames to update their NAV as specified in 9.3.2.2.

STAs in an infrastructure network shall only use other information in received Beacon frames, if the BSSID field is equal to the MAC address currently in use by the STA contained in the AP of the BSS.

STAs in an IBSS shall use other information in any received Beacon frame for which the IBSS subfield of the Capability field is set to 1 and the content of the SSID element is equal to the SSID of the IBSS. Use of this information is specified in 11.1.4.

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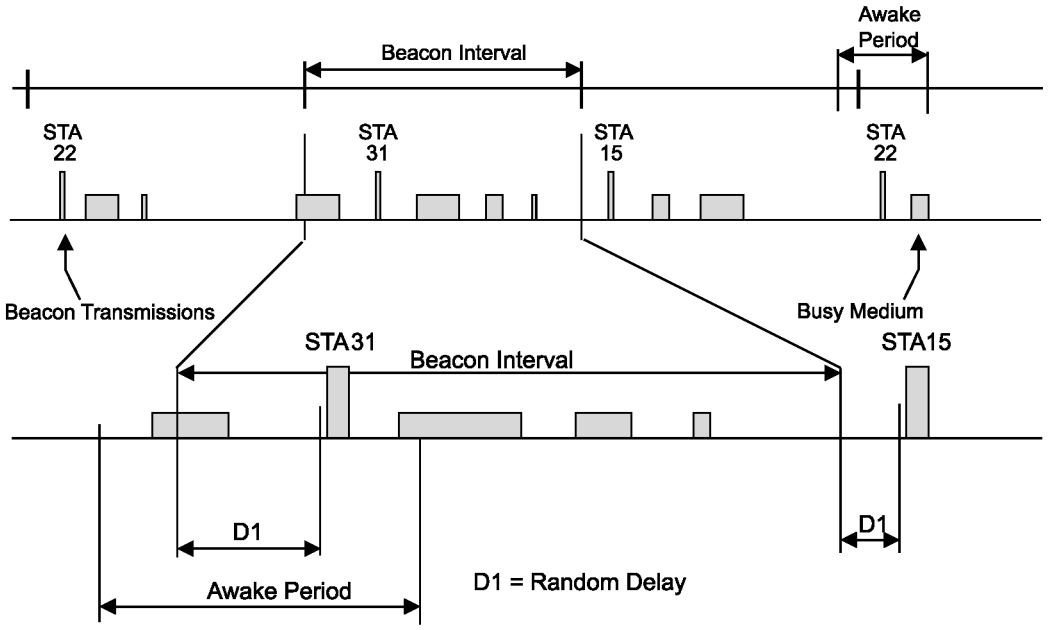

Figure 69—Beacon transmission in an IBSS

11.1.2.4 TSF timer accuracy

Upon receiving a Beacon frame with a valid FCS and BSSID or SSID, as described in 11.1.2.3, a STA shall update its TSF timer according to the following algorithm: The received timestamp value shall be adjusted by adding an amount equal to the receiving STA's delay through its local PHY components plus the time since the first bit of the timestamp was received at the MAC/PHY interface. In the case of an infrastructure BSS, the STA's TSF timer shall then be set to the adjusted value of the timestamp. In the case of an IBSS, the STA's TSF timer shall be set to the adjusted value of the received timestamp, if the adjusted value of the timestamp is later than the value of the STA's TSF timer. The accuracy of the TSF timer shall be ±0.01%.

11.1.3 Acquiring synchronization, scanning

A STA shall operate in either a Passive Scanning mode or an Active Scanning mode depending on the current value of the ScanMode parameter of the MLME-SCAN.request primitive.

Upon receipt of the MLME-SCAN.request primitive, a STA shall perform scanning. The SSID parameter indicates the SSID for which to scan. To become a member of a particular ESS using passive scanning, a STA shall scan for Beacon frames containing that ESS's SSID, returning all Beacon frames matching the desired SSID in the BSSDescriptionSet parameter of the corresponding MLME-SCAN.confirm primitive with the appropriate bits in the Capabilities Information field indicating whether the beacon came from an infrastructure BSS or IBSS. To actively scan, the STA shall transmit Probe frames containing the desired SSID. Upon completion of scanning, an MLME-SCAN.confirm is issued by the MLME indicating all of the BSS information received.

Upon receipt of an MLME-JOIN.request, the STA will join a BSS by adopting the BSSID, TSF timer value, PHY parameters, and the beacon period specified in the request.

Upon receipt of an MLME-SCAN.request with the broadcast SSID, the STA shall passively scan for any Beacon frames, or actively transmit Probe frames containing the broadcast SSID, as appropriate depending

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upon the value of ScanMode. Upon completion of scanning, an MLME-SCAN.confirm is issued by the MLME indicating all of the BSS information received.

If a STA's scanning does not result in finding a BSS with the desired SSID and of the desired type, or does not result in finding any BSS, the STA may start an IBSS upon receipt of the MLME-START.request.

A STA may start its own BSS without first scanning for a BSS to join.

When a STA starts a BSS, that STA shall determine the BSSID of the BSS. If the BSSType indicates an infrastructure BSS, then the STA shall start an infrastructure BSS and the BSSID shall be equal to the STA's dot11StationID. The value of the BSSID shall remain unchanged, even if the value of dot11StationID is changed after the completion of the MLME-START.request. If the BSSType indicates an IBSS, the STA shall start an IBSS, and the BSSID shall be an individual locally administered IEEE MAC address as defined in 5.2 of IEEE Std 802-1990. The remaining 46 bits of that MAC address shall be a number selected in a manner that minimizes the probability of STAs generating the same number, even when those STAs are subjected to the same initial conditions. The value SSID parameter shall be used as the SSID of the new BSS. It is important that designers recognize the need for statistical independence among the random number streams among STAs.

11.1.3.1 Passive scanning

If a ScanType is passive, the STA shall listen to each channel scanned for no longer than a maximum duration defined by the ChannelTime parameter.

11.1.3.2 Active scanning

Active scanning involves the generation of Probe frames and the subsequent processing of received Probe Response frames. The details of the active scanning procedures are as specified in the following subclauses.

11.1.3.2.1 Sending a probe response

STAs, subject to criteria below, receiving Probe Request frames shall respond with a probe response only if the SSID in the probe request is the broadcast SSID or matches the specific SSID of the STA. Probe Response frames shall be sent as directed frames to the address of the STA that generated the probe request. The probe response shall be sent using normal frame transmission rules. An AP shall respond to all probe requests meeting the above criteria. In an IBSS, the STA that generated the last beacon shall be the STA that responds to a probe request.

In each BSS there shall be at least one STA that is awake at any given time to respond to probe requests. A STA that sent a beacon shall remain in the Awake state and shall respond to probe requests until a Beacon frame with the current BSSID is received. If the STA is an AP, it shall always remain in the Awake state and always respond to probe requests. There may be more than one STA in an IBSS that responds to any given probe request, particularly in cases where more than one STA transmitted a Beacon frame following the most recent TBTT, either due to not receiving successfully a previous beacon or due to collisions between beacon transmissions.

11.1.3.2.2 Active scanning procedure

Upon receipt of the MLME-SCAN.request with ScanType indicating an active scan, a STA shall use the following procedure:

For each channel to be scanned,

a) Wait until the ProbeDelay time has expired or a PHYRxStart.indication has been received;

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b) Perform the Basic Access procedure as defined in 9.2.5.1;
c) Send a probe with the broadcast destination, SSID, and broadcast BSSID;
d) Clear and start a ProbeTimer;
e) If PHYCCA.indication (busy) has not been detected before the ProbeTimer reaches MinChannel-Time, then clear NAV and scan the next channel, else when ProbeTimer reaches MaxChannelTime, process all received probe responses;
f) Clear NAV and scan the next channel.

See Figure 70.

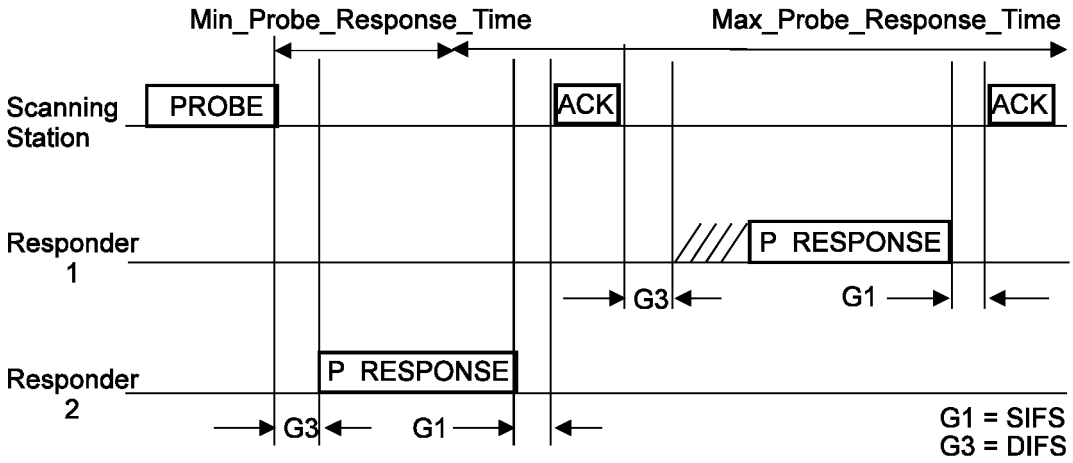

Figure 70—Probe response

When all channels in the ChannelList have been scanned, the MLME shall issue an MLME-SCAN.confirm with the BSSDescriptionSet containing all of the information gathered during the scan.

11.1.3.3 Initializing a BSS

Upon receipt of an MLME-START.request, a STA shall determine the BSS's BSSID (as described in 11.1.3), select channel synchronization information, select a beacon period, initialize and start its TSF timer, and begin transmitting beacons. If the dot11MultiDomainCapabilityEnabled attribute is true, a STA shall not start a BSS, neither an infrastructure BSS nor an IBSS, unless a properly formed Beacon frame including a Country information element can be constructed, and the dot11CountryString attribute has been set.

11.1.3.4 Synchronizing with a BSS

Upon receipt of an MLME-JOIN.request, a STA shall adopt the BSSID, channel synchronization information, and TSF timer value of the parameters in the request. Upon receipt of a Beacon frame from the BSS, the MLME shall issue an MLME-JOIN.confirm indicating the operation was successful. If the JoinFailure-Timeout expires prior to the receipt of a Beacon frame from the BSS, the MLME shall issue an MLME-JOIN.confirm indicating the operation was unsuccessful. If the dot11MultiDomainCapabilityEnabled attribute is true, a STA receiving a Beacon or Probe Response frame containing a Country information element shall adopt the parameters included in that element when joining a BSS. If a Hopping Pattern Parameters element is present in the Beacon or Probe Response frame, and if the dot11MultiDomainCapability-Enabled attribute is true, a STA shall adopt the pattern parameters in the element and calculate the hopping patterns using one of the algorithms defined in 7.3.2.10 or 7.3.2.11. Using the appropriate pattern, set, and index values from the FH Parameter Set element, the STA shall adopt the values in use by the BSS when

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joining. The dot11RegDomainsSupportEntry shall be set to Other when the STA is operating using country code settings.

11.1.4 Adjusting STA timers

In the infrastructure network, STAs shall always adopt the timer in a beacon or probe response coming from the AP in their BSS.

In an IBSS, a STA shall always adopt the information in the contents of a Beacon or Probe Response frame when that frame contains a matching SSID and the value of the time stamp is later than the STA's TSF timer. In response to an MLME-JOIN.request, a STA shall initialize its TSF timer to 0 and shall not transmit a beacon or probe response until it hears a beacon or probe response from a member of the IBSS with a matching SSID.

All Beacon and Probe Response frames carry a Timestamp field. A STA receiving such a frame from another STA in an IBSS with the same SSID shall compare the Timestamp field with its own TSF time. If the Timestamp field of the received frame is later than its own TSF time, the STA shall adopt all parameters contained in the Beacon frame.

11.1.5 Timing synchronization for FH PHYs

NOTE—This subclause pertains only to STAs using an FH PHY.

The TSF described here provides a mechanism for STAs in an FH system to synchronize their transitions from one channel to another (their "hops"). Every STA shall maintain a table of all of the hopping sequences that are used in the system. All of the STAs in a BSS shall use the same hopping sequence. Each beacon and probe response includes the channel synchronization information necessary to determine the hop pattern and timing for the BSS.

STAs shall use their TSF timer to time the aCurrentDwellTime. The aCurrentDwellTime is the length of time that STAs shall stay on each frequency in their hopping sequence. Once STAs are synchronized, they have the same TSF timer value.

STAs in the BSS shall issue an appropriate PLME service primitive for the PHY in use to tune to the next frequency in the hopping sequence when

TSF timer MOD aCurrentDwellTime = 0

11.2 Power management

11.2.1 Power management in an infrastructure network

STAs changing Power Management mode shall inform the AP of this fact using the Power Management bits within the Frame Control field of transmitted frames. The AP shall not arbitrarily transmit MSDUs to STAs operating in a PS mode, but shall buffer MSDUs and only transmit them at designated times.

The STAs that currently have buffered MSDUs within the AP are identified in a TIM, which shall be included as an element within all beacons generated by the AP. A STA shall determine that an MSDU is buffered for it by receiving and interpreting a TIM.

STAs operating in PS modes shall periodically listen for beacons, as determined by the STA's ListenInterval and ReceiveDTIMs parameters of the MLME-POWERMGT.request primitive.

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In a BSS operating under the DCF, or during the CP of a BSS using the PCF, upon determining that an MSDU is currently buffered in the AP, a STA operating in the *PS mode* shall transmit a short PS-Poll frame to the AP, which shall respond with the corresponding buffered MSDU immediately, or acknowledge the PS-Poll and respond with the corresponding MSDU at a later time. If the TIM indicating the buffered MSDU is sent during a CFP, a CF-Pollable STA operating in the PS mode does not send a PS-Poll frame, but remains active until the buffered MSDU is received (or the CFP ends). If any STA in its BSS is in PS mode, the AP shall buffer all broadcast and multicast MSDUs and deliver them to all STAs immediately following the next Beacon frame containing a DTIM transmission.

A STA shall remain in its current Power Management mode until it informs the AP of a Power Management mode change via a successful frame exchange. Power Management mode shall not change during any single frame exchange sequence, as described in 9.7.

11.2.1.1 STA Power Management modes

A STA may be in one of two different power states:

— *Awake:* STA is fully powered.
— *Doze:* STA is not able to transmit or receive and consumes very low power.

The manner in which a STA transitions between these two power states shall be determined by the STA's Power Management mode. These modes are summarized in Table 26.

The Power Management mode of a STA is selected by the PowerManagementMode parameter of the MLME-POWERMGT.request. Once the STA updates its Power Management mode, the MLME shall issue an MLME-POWERMGT.confirm indicating the success of the operation.

Table 26—Power Management modes

Active mode or AM	STA may receive frames at any time. In Active mode, a STA shall be in the Awake state. A STA on the polling list of a PCF shall be in Active mode for the duration of the CFP.
PS	STA listens to selected beacons (based upon the ListenInterval parameter of the MLME-ASSOCIATE.request primitive) and sends PS-Poll frames to the AP if the TIM element in the most recent beacon indicates a directed MSDU buffered for that STA. The AP shall transmit buffered directed MSDUs to a PS STA only in response to a PS-Poll from that STA, or during the CFP in the case of a CF-Pollable PS STA. In PS mode, a STA shall be in the Doze state and shall enter the Awake state to receive selected beacons, to receive broadcast and multicast transmissions following certain received beacons, to transmit, and to await responses to transmitted PS-Poll frames or (for CF-Pollable STAs) to receive CF transmissions of buffered MSDUs.

To change Power Management modes, a STA shall inform the AP through a successful frame exchange initiated by the STA. The Power Management bit in the Frame Control field of the frame sent by the STA in this exchange indicates the Power Management mode that the STA shall adopt upon successful completion of the entire frame exchange.

A STA that is changing from Doze to Awake in order to transmit shall perform CCA until a frame sequence is detected by which it can correctly set its NAV, or until a period of time equal to the ProbeDelay has transpired.

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11.2.1.2 AP TIM transmissions

The TIM shall identify the STAs for which traffic is pending and buffered in the AP. This information is coded in a *partial virtual bitmap*, as described in 7.3.2.6. In addition, the TIM contains an indication whether broadcast/multicast traffic is pending. Every STA is assigned an AID by the AP as part of the association process. AID 0 (zero) is reserved to indicate the presence of buffered broadcast/multicast MSDUs. The AP shall identify those STAs for which it is prepared to deliver buffered MSDUs by setting bits in the TIM's partial virtual bitmap that correspond to the appropriate SIDs.

11.2.1.3 TIM types

Two different TIM types are distinguished: TIM and DTIM. After a DTIM, the AP shall send out the buffered broadcast/multicast MSDUs using normal frame transmission rules, before transmitting any unicast frames.

The AP shall transmit a TIM with every beacon. Every DTIMPeriod, a TIM of type *DTIM* is transmitted within a beacon, rather than an ordinary TIM.

Figure 71 illustrates the AP and STA activity under the assumption that a DTIM is transmitted once every three TIMs. The top line in Figure 71 represents the time axis, with the beacon interval shown together with a DTIM Interval of three beacon intervals. The second line depicts AP activity. The AP schedules beacons for transmission every beacon interval, but the beacons may be delayed if there is traffic at the TBTT. This is indicated as "busy medium" on the second line. For the purposes of this figure, the important fact about beacons is that they contain TIMs, some of which may be DTIMs. Note that the second STA with ReceiveDTIMs set to false does not power-on its receiver for all DTIMs.

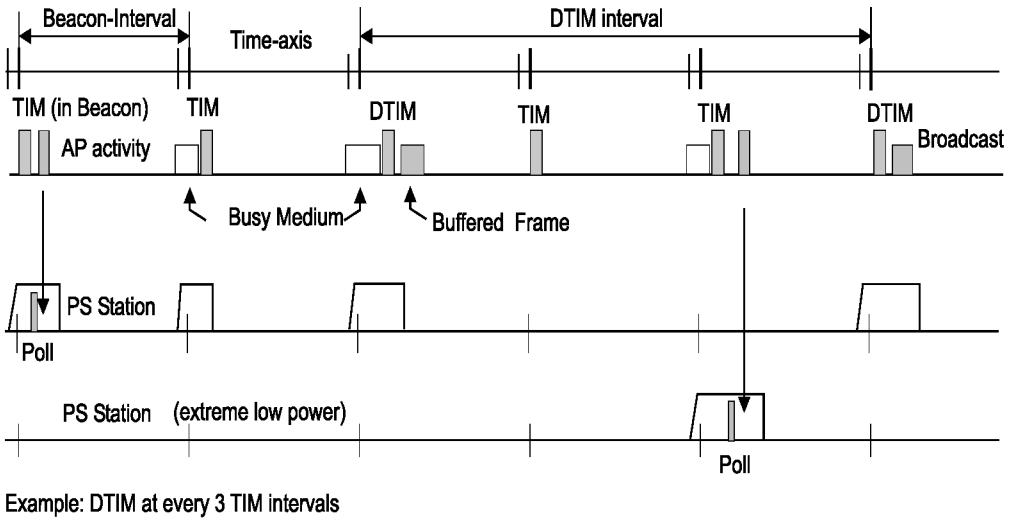

Figure 71—Infrastructure power management operation (no PCF operating)

The third and fourth lines in Figure 71 depict the activity of two STAs operating with different power management requirements. Both STAs power-on their receivers when they need to listen for a TIM. This is indicated as a ramp-up of the receiver power prior to the TBTT. The first STA, for example, powers up its receiver and receives a TIM in the first beacon; that TIM indicates the presence of a buffered MSDU for the receiving STA. The receiving STA then generates a PS-Poll frame, which elicits the transmission of the buffered data MSDU from the AP. Broadcast and multicast MSDUs are sent by the AP subsequent to the

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transmission of a beacon containing a DTIM. The DTIM is indicated by the DTIM count field of the TIM element having a value of 0.

11.2.1.4 AP operation during the CP

APs shall maintain a Power Management status for each currently associated STA that indicates in which Power Management mode the STA is currently operating. An AP shall, depending on the Power Management mode of the STA, temporarily buffer the MSDU or management frame destined to the STA. No MSDUs or management frames received for STAs operating in the Active mode shall be buffered for power management reasons.

a) MSDUs, or management frames destined for PS STAs, shall be temporarily buffered in the AP. The algorithm to manage this buffering is beyond the scope of this standard.
b) MSDUs, or management frames destined for STAs in the Active mode, shall be directly transmitted.
c) At every beacon interval, the AP shall assemble the partial virtual bitmap containing the buffer status per destination for STAs in the PS mode, and shall send this out in the TIM field of the beacon. The bit for AID 0 (zero) shall be set when broadcast or multicast traffic is buffered.
d) All broadcast/multicast MSDUs, with the Order bit in the Frame Control field clear, shall be buffered if any associated STAs are in PS mode.
e) Immediately after every DTIM, the AP shall transmit all buffered broadcast/multicast MSDUs. The More Data field of each broadcast/multicast frame shall be set to indicate the presence of further buffered broadcast/multicast MSDUs. If the AP is unable to transmit all of the buffered broadcast/multicast MSDUs before the TBTT following the DTIM, the AP shall indicate that it will continue to deliver the broadcast/multicast MSDUs by setting the bit for AID 0 (zero) of the TIM element of every Beacon frame, until all buffered broadcast/multicast frames have been transmitted.
f) A single buffered MSDU or management frame for a STA in the PS mode shall be forwarded to the STA after a PS-Poll has been received from that STA. The More Data field shall be set to indicate the presence of further buffered MSDUs or management frames for the polling STA. Further PS-Poll frames from the same STA shall be acknowledged and ignored until the MSDU or management frame has either been successfully delivered, or presumed failed due to maximum retries being exceeded. This prevents a retried PS-Poll from being treated as a new request to deliver a buffered frame.
g) An AP shall have an aging function to delete pending traffic when it is buffered for an excessive time period.
h) When an AP is informed that a STA changes to the Active mode, then the AP shall send buffered MSDUs and management frames (if any exist) to that STA without waiting for a PS-Poll.

11.2.1.5 AP operation during the CFP

APs shall maintain a Power Management status for each currently associated CF-Pollable STA that indicates in which Power Management mode the STA is currently operating. An AP shall, for STAs in PS mode, temporarily buffer the MSDU destined to the STA.

a) MSDUs destined for PS STAs shall be temporarily buffered in the AP. The algorithm to manage this buffering is beyond the scope of this standard.
b) MSDUs destined to STAs in the Active mode shall be transmitted as defined in Clause 9.
c) Prior to every CFP, and at each beacon interval within the CFP, the AP shall assemble the partial virtual bitmap containing the buffer status per destination for STAs in the PS mode, set the bits in the partial virtual bitmap for STAs the PC is intending to poll during this CFP, and shall send this out in the TIM field of the DTIM. The bit for AID 0 (zero) shall be set when broadcast or multicast traffic is buffered.
d) All broadcast and multicast MSDUs, with the Order bit in the Frame Control field clear, shall be buffered if any associated STAs are in the PS mode, whether or not those STAs are CF-Pollable.

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e) Immediately after every DTIM (Beacon frame with DTIM Count field of the TIM element equal to zero), the AP shall transmit all buffered broadcast and multicast frames. The More Data field shall be set to indicate the presence of further buffered broadcast/multicast MSDUs. If the AP is unable to transmit all of the buffered broadcast/multicast MSDUs before the TBTT following the DTIM, the AP shall indicate that it will continue to deliver the broadcast/multicast MSDUs by setting the bit for AID 0 (zero) of the TIM element of every Beacon frame, until all buffered broadcast/multicast frames have been transmitted.
f) Buffered MSDUs or management frames for STAs in the PS mode shall be forwarded to the CF-Pollable STAs under control of the PC. Transmission of these buffered MSDUs or management frames shall begin immediately after transmission of buffered broadcast and multicast frames (if any), and shall occur in order by increasing AID of CF-Pollable STAs. A CF-Pollable STA for which the TIM element of the most recent beacon indicated buffered MSDUs or management frames shall be in the Awake state at least until the receipt of a directed frame from the AP in which the Frame Control field does not indicate the existence of more buffered MSDUs or management frames. After acknowledging the last of the buffered MSDUs or management frames, the CF-Pollable STA operating in the PS mode may enter the Doze state until the next DTIM is expected.
g) An AP shall have an aging function to delete pending traffic buffered for an excessive time period. The exact specification of the aging function is beyond the scope of this standard.
h) When an AP detects that a CF-Pollable STA has changed from the PS mode to the Active mode, then the AP shall queue any buffered frames addressed to that STA for transmission to that CF-Pollable STA as directed by the AP's PCF.

11.2.1.6 Receive operation for STAs in PS mode during the CP

STAs in PS mode shall operate as follows to receive an MSDU or management frame from the AP when no PC is operating and during the CP when a PC is operating.

a) STAs shall wake up early enough to be able to receive the next scheduled beacon after ListenInterval from the last TBTT.
b) When a STA detects that the bit corresponding to its AID is set in the TIM, the STA shall issue a PS-Poll to retrieve the buffered MSDU or management frame. If more than one bit is set in the TIM, the PS-Poll shall be transmitted after a random delay uniformly distributed between zero and aCWmin.
c) The STA shall remain in the Awake state until it receives the response to its poll, or it receives another beacon whose TIM indicates that the AP does not have any MSDUs or management frames buffered for this STA. If the bit corresponding to the STA's AID is set in the subsequent TIM, the STA shall issue another PS-Poll to retrieve the buffered MSDU or management frame(s).
d) If the More Data field in the received MSDU or management frame indicates that more traffic for that STA is buffered, the STA, at its convenience, shall Poll until no more MSDUs or management frames are buffered for that STA.
e) When ReceiveDTIMs is true, the STA shall wake up early enough to be able to receive every DTIM. A STA receiving broadcast/multicast MSDUs shall remain awake until the More Data field of the broadcast/multicast MSDUs indicates there are no further buffered broadcast/multicast MSDUs, or until a TIM is received indicating there are no more buffered broadcast/multicast MSDUs.

11.2.1.7 Receive operation for STAs in PS mode during the CFP

STAs in PS mode that are associated as CF-Pollable shall operate as follows in a BSS with an active PC to receive MSDUs or management frames from the AP during the CFP:

a) STAs shall enter the Awake state so as to receive the Beacon frame (which contains a DTIM) at the start of each CFP.
b) To receive broadcast/multicast MSDUs, the STA shall wake up early enough to be able to receive every DTIM that may be sent during the CFP. A STA receiving broadcast/multicast MSDUs shall remain awake until the More Data field of the broadcast/multicast MSDUs indicates there are no

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further buffered broadcast/multicast MSDUs, or until a TIM is received indicating there are no more broadcast/multicast MSDUs buffered.

c) When a STA detects that the bit corresponding to its AID is set in the DTIM at the start of the CFP (or in a subsequent TIM during the CFP), the STA shall remain in the Awake state for at least that portion of the CFP through the time that the STA receives a directed MSDU or management frame from the AP with the More Data field in the Frame Control field indicating that no further traffic is buffered.

d) If the More Data field in the Frame Control field of the last MSDU or management frame received from the AP indicates that more traffic for the STA is buffered, then, when the CFP ends, the STA may remain in the Awake state and transmit PS-Poll frames during the CP to request the delivery of additional buffered MSDU or management frames, or may enter the Doze state during the CP (except at TBTTs for DTIMs expected during the CP), awaiting the start of the next CFP.

11.2.1.8 STAs operating in the Active mode

A STA operating in this mode shall have its receiver activated continuously; it does not need to interpret the traffic announcement part of the beacons.

11.2.1.9 AP aging function

The AP shall have an aging function to delete buffered traffic when it has been buffered for an excessive period of time. That function shall be based on the ListenInterval parameter of the MLME-ASSOCIATE.request primitive of the STA for which the traffic is buffered. The AP aging function shall not cause the buffered traffic to be discarded after any period that is shorter than the ListenInterval of the STA for which the traffic is buffered. The exact specification of the aging function is beyond the scope of this standard.

11.2.2 Power management in an IBSS

This subclause specifies the power management mechanism for use within an IBSS.

11.2.2.1 Basic approach

The basic approach is similar to the infrastructure case in that the STAs are synchronized, and multicast MSDUs and those MSDUs that are to be transmitted to a power-conserving STA are first announced during a period when all STAs are awake. The announcement is done via an ad hoc ATIM. A STA in the PS mode shall listen for these announcements to determine if it needs to remain in the awake state.

When an MSDU is to be transmitted to a destination STA that is in a PS mode, the transmitting STA first transmits an ATIM frame during the ATIM Window, in which all the STAs including those operating in a PS mode are awake. The ATIM Window is defined as a specific period of time, defined by aATIMWindow, following a TBTT, during which only Beacon or ATIM frames shall be transmitted. ATIM transmission times are randomized, after a Beacon frame is either transmitted or received by the STA, using the backoff procedure with the CW equal to aCWminx. Directed ATIMs shall be acknowledged. If a STA transmitting a directed ATIM does not receive an acknowledgment, the STA shall execute the backoff procedure for retransmission of the ATIM. Multicast ATIMs shall not be acknowledged.

If a STA receives a directed ATIM frame during the ATIM Window, it shall acknowledge the directed ATIM and stay awake for the entire beacon interval waiting for the announced MSDU(s) to be received. If a STA does not receive an ATIM, it may enter the Doze state at the end of the ATIM Window. Transmissions of MSDUs announced by ATIMs are randomized after the ATIM Window, using the backoff procedure described in Clause 9.

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It is possible that an ATIM may be received from more than one STA, and that a STA that receives an ATIM may receive more than a single MSDU from the transmitting STA. ATIM frames are only addressed to the destination STA of the MSDU.

An ATIM for a broadcast or multicast MSDU shall have a destination address identical to that of the MSDU.

After the ATIM interval, only those directed MSDUs that have been successfully announced with an acknowledged ATIM, and broadcast/multicast MSDUs that have been announced with an ATIM, shall be transmitted to STAs in the PS mode. Transmission of these frames shall be done using the normal DCF access procedure.

Figure 72 illustrates the basic PS operation.

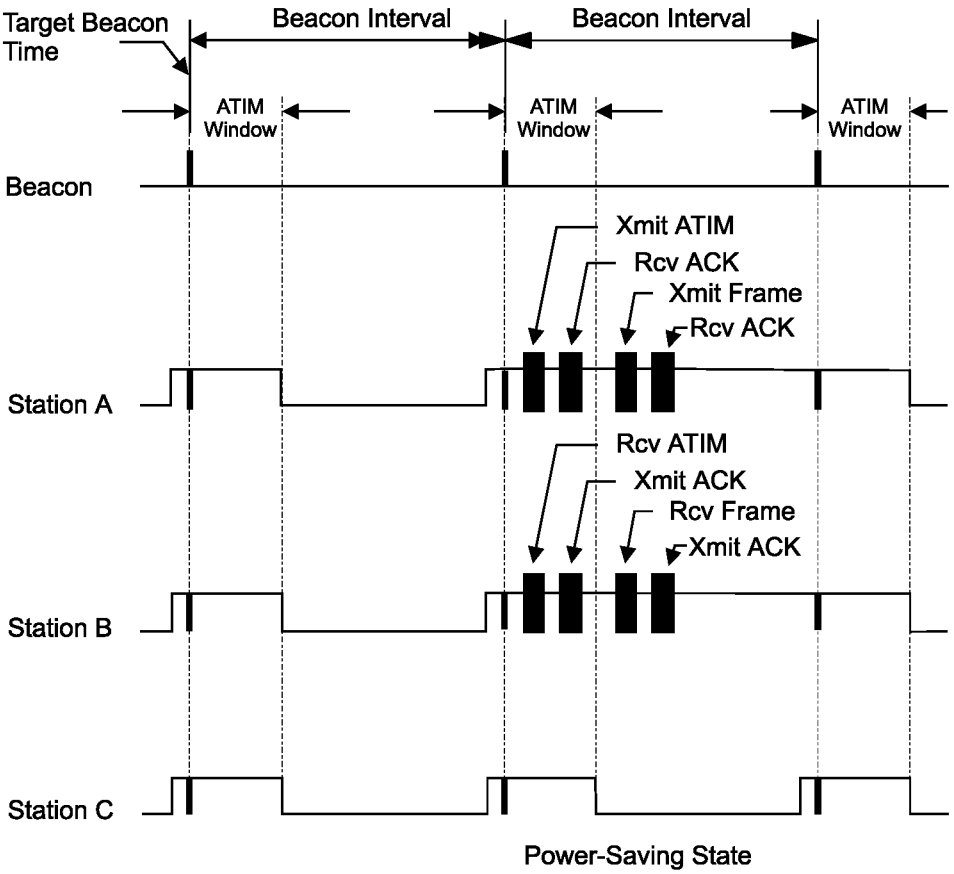

Figure 72—Power management in an IBSS—basic operation

The estimated power-saving state of another STA may be based on the power management information transmitted by that STA and on additional information available locally, such as a history of failed transmission attempts. The use of RTS/CTS in an IBSS may reduce the number of transmissions to a STA that is in PS mode. If an RTS is sent and a CTS is not received, the transmitting STA may assume that the destination STA is in PS mode. The method of estimating the power management state of other STAs in the IBSS is outside the scope of this standard.

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11.2.2.2 Initialization of power management within an IBSS

The following procedure shall be used to initialize power management within a new IBSS, or to learn about the power management being used within an existing IBSS.

a) A STA joining an existing IBSS by the procedure in 11.1.3.3 shall update its ATIM Window with the value contained in the ATIM Window field of the IBSS Parameter Set element within the Beacon or Probe Response management frame received during the scan procedure.
b) A STA creating a new IBSS by the procedure in 11.1.3.3 shall set the value of the ATIM Window field of the IBSS Parameter Set element within the Beacon management frames transmitted to the value of its ATIM Window.
c) The start of the ATIM Window shall be the TBTT, defined in 11.1.2.2. The end of the ATIM Window shall be defined as

   TSF timer MOD BeaconInterval = ATIMWindow.
d) The ATIM Window period shall be static during the lifetime of the IBSS.
e) An ATIM Window value of zero shall indicate that power management is not in use within the IBSS.

11.2.2.3 STA power state transitions

A STA may enter PS mode if and only if the value of the ATIM Window in use within the IBSS is greater than zero. A STA shall set the Power Management subfield in the Frame Control field of MSDUs that it transmits according to the procedure in 7.1.3.1.7.

A STA in PS mode shall transition between Awake and Doze states according to the following rules:

a) If a STA is operating in PS mode, it shall enter the Awake state prior to each TBTT.
b) If a STA receives a directed ATIM management frame containing its individual address, or a multicast ATIM management frame during the ATIM Window it shall remain in the Awake state until the end of the next ATIM Window.
c) If a STA transmits a Beacon or an ATIM management frame, it shall remain in the Awake state until the end of the next ATIM Window regardless of whether an acknowledgment is received for the ATIM.
d) If the STA has not transmitted an ATIM and does not receive either a directed ATIM management frame containing its individual address, or a multicast ATIM management frame during the ATIM Window, it may return to the Doze state following the end of the current ATIM Window.

11.2.2.4 ATIM and frame transmission

If power management is in use within an IBSS, all STAs shall buffer MSDUs for STAs that are known to be in PS mode. The algorithm used for the estimation of the power management state of STAs within the IBSS is outside the scope of this standard. MSDUs may be sent to STAs in Active mode at any valid time.

a) Following the reception or transmission of the beacon, during the ATIM Window, the STA shall transmit a directed ATIM management frame to each STA for which it has one or more buffered unicast MSDUs. If the STA has one or more buffered multicast MSDUs, with the Strictly Ordered bit clear, it shall transmit an appropriately addressed multicast ATIM frame. A STA transmitting an ATIM management frame shall remain awake for the entire current beacon interval.
b) All STAs shall use the backoff procedure defined in 9.2.5.2 for transmission of the first ATIM following the beacon. All remaining ATIMs shall be transmitted using the conventional DCF access procedure.
c) ATIM management frames shall only be transmitted during the ATIM Window.

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d) A STA shall transmit no frame types other than RTS, CTS, and ACK Control frames and Beacon and ATIM management frames during the ATIM Window.
e) Directed ATIM management frames shall be acknowledged. If no acknowledgment is received, the ATIM shall be retransmitted using the conventional DCF access procedure. Multicast ATIM management frames shall not be acknowledged.
f) If a STA is unable to transmit an ATIM during the ATIM Window, for example due to contention with other STAs, the STA shall retain the buffered MSDU(s) and attempt to transmit the ATIM during the next ATIM Window.
g) Immediately following the ATIM Window, a STA shall begin transmission of buffered broadcast/multicast frames for which an ATIM was previously transmitted. Following the transmission of any broadcast/multicast frames, any MSDUs and management frames addressed to STAs for which an acknowledgment for a previously transmitted ATIM frame was received shall be transmitted. All STAs shall use the backoff procedure defined in 9.2.5.2 for transmission of the first frame following the ATIM Window. All remaining frames shall be transmitted using the conventional DCF access procedure.
h) A buffered MSDU may be transmitted using fragmentation. If an MSDU has been partially transmitted when the next beacon frame is sent, the STA shall retain the buffered MSDU and announce the remaining fragments by transmitting an ATIM during the next ATIM Window.
i) If a STA is unable to transmit a buffered MSDU during the beacon interval in which it was announced, for example due to contention with other STAs, the STA shall retain the buffered MSDU and announce the MSDU again by transmitting an ATIM during the next ATIM Window.
j) Following the transmission of all buffered MSDUs, a STA may transmit MSDUs without announcement to STAs that are known to be in the Awake state for the current beacon interval due to an appropriate ATIM management or Beacon frame having been transmitted or received.
k) A STA may discard frames buffered for later transmission to power-saving STAs if the STA determines that the frame has been buffered for an excessive amount of time or if other conditions internal to the STA implementation make it desirable to discard buffered frames (e.g., buffer starvation). In no case shall a frame be discarded that has been buffered for less than aBeaconPeriod. The algorithm to manage this buffering is beyond the scope of this standard.

11.3 Association and reassociation

This subclause defines how a STA associates and reassociates with an AP.

11.3.1 STA association procedures

Upon receipt of an MLME-ASSOCIATE.request, a STA shall associate with an AP via the following procedure:

a) The STA shall transmit an association request to an AP with which that STA is authenticated.
b) If an Association Response frame is received with a status value of “successful,” the STA is now associated with the AP and the MLME shall issue an MLME-ASSOCIATE.confirm indicating the successful completion of the operation.
c) If an Association Response frame is received with a status value other than “successful” or the AssociateFailureTimeout expires, the STA is not associated with the AP and the MLME shall issue an MLME-ASSOCIATE.confirm indicating the failure of the operation.

11.3.2 AP association procedures

An AP shall operate as follows in order to support the association of STAs.

a) When an Association Request frame is received from a STA and the STA is authenticated, the AP shall transmit an association response with a status code as defined in 7.3.1.9. If the status value is

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"successful," the Association ID assigned to the STA shall be included in the response. If the STA is not authenticated, the AP shall transmit a Deauthentication frame to the STA.

b) When the association response with a status value of "successful" is acknowledged by the STA, the STA is considered to be associated with this AP.
c) The AP shall inform the DS of the association and the MLME shall issue an MLME-ASSOCIATE.indication.

11.3.3 STA reassociation procedures

Upon receipt of an MLME-REASSOCIATE.request, a STA shall reassociate with an AP via the following procedure:

a) The STA shall transmit a Reassociation Request frame to an AP.
b) If a Reassociation Response frame is received with a status value of "successful," the STA is now associated with the AP and the MLME shall issue an MLME-REASSOCIATE.confirm indicating the successful completion of the operation.
c) If a Reassociation Response frame is received with a status value other than "successful" or the ReassociateFailureTimeout expires, the STA is not associated with the AP and the MLME shall issue an MLME-REASSOCIATE.confirm indicating the failure of the operation.

11.3.4 AP reassociation procedures

An AP shall operate as follows in order to support the reassociation of STAs.

a) When a Reassociation Request frame is received from a STA and the STA is authenticated, the AP shall transmit a reassociation response with a status value as defined in 7.3.1.9. If the status value is "successful," the Association ID assigned to the STA shall be included in the response. If the STA is not authenticated, the AP shall transmit a Deauthentication frame to the STA.
b) When the reassociation response with a status value of "successful" is acknowledged by the STA, the STA is considered to be associated with this AP.
c) The AP shall inform the DS of the reassociation and the MLME shall issue an MLME-REASSOCIATE.indication.

11.4 MIB definitions

The MIB comprises the managed objects, attributes, actions, and notifications required to manage a station. The definition of these managed objects, attributes, actions, and notifications, as well as their structure, is presented in Annex D.

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12. PHY service specification

12.1 Scope

The PHY services provided to the IEEE 802.11 wireless LAN MAC are described in this clause. Different PHYs are defined as part of the IEEE 802.11 standard. Each PHY can consist of two protocol functions as follows:

a) A PHY convergence function, which adapts the capabilities of the PMD system to the PHY service. This function is supported by the PLCP, which defines a method of mapping the IEEE 802.11 MPDUs into a framing format suitable for sending and receiving user data and management information between two or more STAs using the associated PMD system.
b) A PMD system, whose function defines the characteristics of, and method of transmitting and receiving data through, a WM between two or more STAs.

Each PMD sublayer may require the definition of a unique PLCP. If the PMD sublayer already provides the defined PHY services, the PHY convergence function might be null.

12.2 PHY functions

The protocol reference model for the IEEE 802.11 architecture is shown in Figure 11 (in 5.8). Most PHY definitions contain three functional entities: the PMD function, the PHY convergence function, and the layer management function.

The PHY service is provided to the MAC entity at the STA through a SAP, called the PHY-SAP, as shown in Figure 11. A set of primitives might also be defined to describe the interface between the PLCP sublayer and the PMD sublayer, called the PMD_SAP.

12.3 Detailed PHY service specifications

12.3.1 Scope and field of application

The services provided by the PHY to the IEEE 802.11 MAC are specified in this subclause. These services are described in an abstract way and do not imply any particular implementation or exposed interface.

12.3.2 Overview of the service

The PHY function as shown in Figure 11 is separated into two sublayers: the PLCP sublayer and the PMD sublayer. The function of the PLCP sublayer is to provide a mechanism for transferring MPDUs between two or more STAs over the PMD sublayer.

12.3.3 Overview of interactions

The primitives associated with communication between the IEEE 802.11 MAC sublayer and the IEEE 802.11 PHY fall into two basic categories:

a) Service primitives that support MAC peer-to-peer interactions;
b) Service primitives that have local significance and support sublayer-to-sublayer interactions.

12.3.4 Basic service and options

All of the service primitives described here are considered mandatory unless otherwise specified.

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12.3.4.1 PHY-SAP peer-to-peer service primitives

Table 27 indicates the primitives for peer-to-peer interactions.

Table 27—PHY-SAP peer-to-peer service primitives

Primitive	Request	Indicate	Confirm
PHY-DATA	X	X	X

12.3.4.2 PHY-SAP sublayer-to-sublayer service primitives

Table 28 indicates the primitives for sublayer-to-sublayer interactions.

Table 28—PHY-SAP sublayer-to-sublayer service primitives

Primitive	Request	Indicate	Confirm
PHY-TXSTART	X		X
PHY-TXEND	X		X
PHY-CCARESET	X		X
PHY-CCA		X	
PHY-RXSTART		X	
PHY-RXEND		X	

12.3.4.3 PHY-SAP service primitives parameters

Table 29 shows the parameters used by one or more of the PHY-SAP service primitives.

Table 29—PHY-SAP service primitive parameters

Parameter	Associated primitive	Value
DATA	PHY-DATA.request PHY-DATA.indication	Octet value X'00'–X'FF'
TXVECTOR	PHY-TXSTART.request	A set of parameters
STATUS	PHY-CCA.indication	BUSY, IDLE
RXVECTOR	PHY-RXSTART.indication	A set of parameters
RXERROR	PHY-RXEND.indication	NoError, FormatViolation, Carrier-Lost, UnsupportedRate

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12.3.4.4 Vector descriptions

Several service primitives include a parameter vector. This vector is a list of parameters that may vary depending on the PHY type. Table 30 lists the parameter values required by the MAC or PHY in each of the parameter vectors. Parameters in the vectors that are management rather than MAC may be specific to the PHY and are listed in the clause covering that PHY.

Table 30—Vector descriptions

Parameter	Associate vector	Value
DATARATE	TXVECTOR, RXVECTOR	PHY dependent. The name of the field used to specify the Tx data rate and report the Rx data rate may vary for different PHYs.
LENGTH	TXVECTOR, RXVECTOR	PHY dependent

12.3.5 PHY-SAP detailed service specification

The following subclause describes the services provided by each PHY primitive.

12.3.5.1 PHY-DATA.request

12.3.5.1.1 Function

This primitive defines the transfer of an octet of data from the MAC sublayer to the local PHY entity.

12.3.5.1.2 Semantics of the service primitive

The primitive provides the following parameters:

PHY-DATA.request(DATA)

The DATA parameter is an octet of value X'00' through X'FF'.

12.3.5.1.3 When generated

This primitive is generated by the MAC sublayer to transfer an octet of data to the PHY entity. This primitive can only be issued following a transmit initialization response (PHY-TXSTART.confirm) from the PHY.

12.3.5.1.4 Effect of receipt

The receipt of this primitive by the PHY entity causes the PLCP transmit state machine to transmit an octet of data. When the PHY entity receives the octet, it will issue a PHY-DATA.confirm to the MAC sublayer.

12.3.5.2 PHY-DATA.indication

12.3.5.2.1 Function

This primitive indicates the transfer of data from the PHY to the local MAC entity.

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12.3.5.2.2 Semantics of the service primitive

The primitive provides the following parameters:

PHY-DATA.indication (DATA)

The DATA parameter is an octet of value X'00' through X'FF'.

12.3.5.2.3 When generated

The PHY-DATA.indication is generated by a receiving PHY entity to transfer the received octet of data to the local MAC entity. The time between receipt of the last bit of the provided octet from the WM and the receipt of this primitive by the MAC entity will be the sum of aRXRFDelay + aRxPLCPDelay.

12.3.5.2.4 Effect of receipt

The effect of receipt of this primitive by the MAC is unspecified.

12.3.5.3 PHY-DATA.confirm

12.3.5.3.1 Function

This primitive is issued by the PHY to the local MAC entity to confirm the transfer of data from the MAC entity to the PHY.

12.3.5.3.2 Semantics of the service primitive

The semantics of the primitive are as follows:

PHY-DATA.confirm

This primitive has no parameters.

12.3.5.3.3 When generated

This primitive will be issued by the PHY to the MAC entity when the PLCP has completed the transfer of data from the MAC entity to the PHY. The PHY will issue this primitive in response to every PHY-DATA.request primitive issued by the MAC sublayer.

12.3.5.3.4 Effect of receipt

The receipt of this primitive by the MAC will cause the MAC to start the next MAC entity request.

12.3.5.4 PHY-TXSTART.request

12.3.5.4.1 Function

This primitive is a request by the MAC sublayer to the local PHY entity to start the transmission of an MPDU.

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12.3.5.4.2 Semantics of the service primitive

The primitive provides the following parameters:

PHY-TXSTART.request(TXVECTOR)

The TXVECTOR represents a list of parameters that the MAC sublayer provides to the local PHY entity in order to transmit an MPDU. This vector contains both PLCP and PHY management parameters. The required PHY parameters are listed in 12.3.4.4.

12.3.5.4.3 When generated

This primitive will be issued by the MAC sublayer to the PHY entity when the MAC sublayer needs to begin the transmission of an MPDU.

12.3.5.4.4 Effect of receipt

The effect of receipt of this primitive by the PHY entity will be to start the local transmit state machine.

12.3.5.5 PHY-TXSTART.confirm

12.3.5.5.1 Function

This primitive is issued by the PHY to the local MAC entity to confirm the start of a transmission. The PHY will issue this primitive in response to every PHY-TXSTART.request primitive issued by the MAC sublayer.

12.3.5.5.2 Semantics of the service primitive

The semantics of the primitive are as follows:

PHY-TXSTART.confirm

This primitive has no parameters.

12.3.5.5.3 When generated

This primitive will be issued by the PHY to the MAC entity when the PHY has received a PHY-TXSTART.request from the MAC entity and is ready to begin receiving data octets.

12.3.5.5.4 Effect of receipt

The receipt of this primitive by the MAC entity will cause the MAC to start the transfer of data octets.

12.3.5.6 PHY-TXEND.request

12.3.5.6.1 Function

This primitive is a request by the MAC sublayer to the local PHY entity that the current transmission of the MPDU be completed.

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12.3.5.6.2 Semantics of the service primitive

The semantics of the primitive are as follows:

PHY-TXEND.request

This primitive has no parameters.

12.3.5.6.3 When generated

This primitive will be generated when the MAC sublayer has received the last PHY-DATA.confirm from the local PHY entity for the MPDU currently being transferred.

12.3.5.6.4 Effect of receipt

The effect of receipt of this primitive by the local PHY entity will be to stop the transmit state machine.

12.3.5.7 PHY-TXEND.confirm

12.3.5.7.1 Function

This primitive is issued by the PHY to the local MAC entity to confirm the completion of a transmission. The PHY issues this primitive in response to every PHY-TXEND.request primitive issued by the MAC sublayer.

12.3.5.7.2 Semantics of the service primitive

The semantics of the primitive are as follows:

PHY-TXEND.confirm

This primitive has no parameters.

12.3.5.7.3 When generated

This primitive will be issued by the PHY to the MAC entity when the PHY has received a PHY-TXEND.request immediately after transmitting the end of the last bit of the last data octet indicating that the last data octet has been transferred.

12.3.5.7.4 Effect of receipt

The receipt of this primitive by the MAC entity provides the time reference for the contention backoff protocol.

12.3.5.8 PHY-CCARESET.request

12.3.5.8.1 Function

This primitive is a request by the MAC sublayer to the local PHY entity to reset the CCA state machine.

12.3.5.8.2 Semantics of the service primitive

The semantics of the primitives are as follows:

PHY-CCARESET.request

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This primitive has no parameters.

12.3.5.8.3 When generated

This primitive is generated by the MAC sublayer for the local PHY entity at the end of a NAV timer. This request can be used by some PHY implementations that may synchronize antenna diversity with slot timings.

12.3.5.8.4 Effect of receipt

The effect of receipt of this primitive by the PHY entity is to reset the PLCP CS/CCA timers to the state appropriate for the end of a received frame.

12.3.5.9 PHY-CCARESET.confirm

12.3.5.9.1 Function

This primitive is issued by the PHY to the local MAC entity to confirm that the PHY has reset the CCA state machine.

12.3.5.9.2 Semantics of the service primitive

The semantics of the primitives are as follows:

PHY-CCARESET.request

This primitive has no parameters.

12.3.5.9.3 When generated

This primitive is issued by the PHY to the MAC entity when the PHY has received a PHY-CCARESET.request.

12.3.5.9.4 Effect of receipt

The effect of receipt of this primitive by the MAC is unspecified.

12.3.5.10 PHY-CCA.indication

12.3.5.10.1 Function

This primitive is an indication by the PHY to the local MAC entity of the current state of the medium.

12.3.5.10.2 Semantics of the service primitive

The primitive provides the following parameter:

PHY-CCA.indication (STATE)

The STATE parameter can be one of two values: BUSY or IDLE. The parameter value is BUSY if the channel assessment by the PHY determines that the channel is not available. Otherwise, the value of the parameter is IDLE.

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12.3.5.10.3 When generated

This primitive is generated every time the status of the channel changes from channel idle to channel busy or from channel busy to channel idle. This includes the period of time when the PHY is receiving data. The PHY maintains the channel busy indication until the period indicated by the LENGTH field in a valid PLCP Header has expired.

12.3.5.10.4 Effect of receipt

The effect of receipt of this primitive by the MAC is unspecified.

12.3.5.11 PHY-RXSTART.indication

12.3.5.11.1 Function

This primitive is an indication by the PHY to the local MAC entity that the PLCP has received a valid start frame delimiter (SFD) and PLCP Header.

12.3.5.11.2 Semantics of the service primitive

The primitive provides the following parameter:

PHY-RXSTART.indication (RXVECTOR)

The RXVECTOR represents a list of parameters that the PHY provides the local MAC entity upon receipt of a valid PLCP Header. This vector may contain both MAC and MAC management parameters. The required parameters are listed in 12.3.4.4.

12.3.5.11.3 When generated

This primitive is generated by the local PHY entity to the MAC sublayer when the PHY has successfully validated the PLCP header error check (HEC) CRC at the start of a new PPDU.

12.3.5.11.4 Effect of receipt

The effect of receipt of this primitive by the MAC is unspecified.

12.3.5.12 PHY-RXEND.indication

12.3.5.12.1 Function

This primitive is an indication by the PHY to the local MAC entity that the MPDU currently being received is complete.

12.3.5.12.2 Semantics of the service primitive

The primitive provides the following parameter:

PHY-RXEND.indication (RXERROR)

The RXERROR parameter can convey one or more of the following values: NoError, FormatViolation, CarrierLost, or UnsupportedRate. A number of error conditions may occur after the PLCP's receive state machine has detected what appears to be a valid preamble and SFD. The following describes the parameter returned for each of those error conditions.

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— *NoError.* This value is used to indicate that no error occurred during the receive process in the PLCP.
— *FormatViolation.* This value is used to indicate that the format of the received PPDU was in error.
— *CarrierLost.* This value is used to indicate that during the reception of the incoming MPDU, the carrier was lost and no further processing of the MPDU can be accomplished.
— *UnsupportedRate.* This value is used to indicate that during the reception of the incoming PPDU, a nonsupported date rate was detected.

12.3.5.12.3 When generated

This primitive is generated by the PHY for the local MAC entity to indicate that the receive state machine has completed a reception with or without errors.

12.3.5.12.4 Effect of receipt

The effect of receipt of this primitive by the MAC is unspecified.

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13. PHY management

The MIB comprises the managed objects, attributes, actions, and notifications required to manage a station. The definition of these managed objects, attributes, actions, and notifications, as well as their structure, is presented in Annex D.

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14. Frequency-Hopping spread spectrum (FHSS) PHY specification for the 2.4 GHz industrial, scientific, and medical (ISM) band

14.1 Overview

14.1.1 Overview of FHSS PHY

The PHY services provided to the IEEE 802.11 wireless LAN MAC for the 2.4 GHz frequency-hopping spread spectrum (FHSS) system are described in this clause. The FHSS PHY consists of the following two protocol functions:

a) A PHY convergence function, which adapts the capabilities of the PMD system to the PHY service. This function is supported by the PLCP, which defines a method of mapping the IEEE 802.11 MPDUs into a framing format suitable for sending and receiving user data and management information between two or more STAs using the associated PMD system.
b) A PMD system, whose function defines the characteristics of, and method of transmitting and receiving data through, a WM between two or more STAs.

14.1.2 FHSS PHY functions

The 2.4 GHz FHSS PHY architecture is shown in Figure 11 (in 5.8). The FHSS PHY contains three functional entities: the PMD function, the PHY convergence function, and the PHY management function. Each of these functions is described in detail in 14.1.2.1 through 14.1.2.3.

The FHSS PHY service is provided to the MAC entity at the STA through a SAP, called the PHY-SAP, as shown in Figure 11. A set of primitives might also be defined that describe the interface between the PLCP sublayer and the PMD sublayer, called the PMD_SAP.

14.1.2.1 PLCP sublayer

To allow the IEEE 802.11 MAC to operate with minimum dependence on the PMD sublayer, a PHY convergence sublayer is defined. This function simplifies provision of a PHY service interface to the IEEE 802.11 MAC services.

14.1.2.2 PLME

The PLME performs management of the local PHY functions in conjunction with the MLME.

14.1.2.3 PMD sublayer

The PMD sublayer provides a transmission interface used to send and receive data between two or more STAs.

14.1.3 Service specification method and notation

The models represented by state diagrams in the following subclauses are intended as the primary specifications of the functions provided. It is important to distinguish, however, between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, while any realistic implementation may place heavier emphasis on efficiency and suitability to a particular implementation technology.

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The service of a layer or sublayer is the set of capabilities that it offers to a user in the next higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition of service is independent of any particular implementation.

14.2 FHSS PHY-specific service parameter lists

14.2.1 Overview

The architecture of the IEEE 802.11 MAC is intended to be PHY independent. Some PHY implementations require medium management state machines running in the MAC sublayer in order to meet certain PMD requirements. These PHY-dependent MAC state machines reside in a sublayer defined as the MLME. The MLME in certain PMD implementations may need to interact with the PLME as part of the normal PHY-SAP primitives. These interactions are defined by the PLME parameter list currently defined in the PHY Service Primitives as TXVECTOR and RXVECTOR. The list of these parameters and the values they may represent are defined in the specific PHY specifications for each PMD. This subclause addresses the TXVECTOR and RXVECTOR for the FHSS PHY.

All of the values included in the TXVECTOR or RXVECTOR described in this subclause are considered mandatory unless otherwise specified. The 1 Mbit/s and 2 Mbit/s data rates are the only rates currently supported. Other indicated data rates are for possible future use.

14.2.2 TXVECTOR parameters

The parameters in Table 31 are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request service primitive.

Table 31—TXVECTOR parameters

Parameter	Associate primitive	Value
LENGTH	PHY-TXSTART.request(TXVECTOR)	1–4095
DATARATE	PHY-TXSTART.request(TXVECTOR)	1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5

14.2.2.1 TXVECTOR LENGTH

The LENGTH parameter has the value of 1 to 4095. This parameter is used to indicate the number of octets in the MPDU that the MAC is currently requesting the PHY to transmit. This value is used by the PHY to determine the number of octet transfers that will occur between the MAC and the PHY after receiving a request to start a transmission.

14.2.2.2 TXVECTOR DATARATE

The DATARATE parameter describes the bit rate at which the PLCP should transmit the PLCP service data unit (PSDU). Its value can be any of the rates as defined in Table 31, and supported by the conformant FH PHY.

14.2.3 RXVECTOR parameters

The parameters in Table 32 are defined as part of the RXVECTOR parameter list in the PHY-RXSTART.indicate service primitive.

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Table 32—RXVECTOR parameters

Parameter	Associate primitive	Value
LENGTH	PHY-RXSTART.indicate(RXVECTOR)	1–4095
Receive signal strength indicator (RSSI)	PHY-RXSTART.indicate(RXVECTOR)	0–RSSI Max
DATARATE	PHY-RXSTART.request(RXVECTOR)	1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5

14.2.3.1 TRXVECTOR LENGTH

The LENGTH parameter has the value of 1 to 4095. This parameter is used to indicate the value contained in the LENGTH field that the PLCP has received in the PLCP Header. The MAC and PLCP will use this value to determine the number of octet transfers that will occur between the two sublayers during the transfer of the received PSDU.

14.2.3.2 RXVECTOR RSSI

The RSSI is an optional parameter that has a value of 0 through RSSI Max. This parameter is a measure by the PHY of the energy observed at the antenna used to receive the current PPDU. RSSI shall be measured between the beginning of the SFD and the end of the PLCP HEC. RSSI is intended to be used in a relative manner. Absolute accuracy of the RSSI reading is not specified.

14.3 FHSS PLCP sublayer

14.3.1 Overview

This subclause provides a convergence procedure to map MPDUs into a frame format designed for FHSS radio transceivers. The procedures for transmission, CS, and reception are defined for single and multiple antenna diversity radios.

14.3.1.1 State diagram notation

The operation of the procedures can be described by state diagrams. Each diagram represents the domain and consists of a group of connected, mutually exclusive states. Only one state is active at any given time. Each state is represented by a rectangle as shown in Figure 73. These are divided into two parts by a horizontal line. In the upper part the state is identified by a name. The lower part contains the name of any signal that is generated. Actions described by short phrases are enclosed in brackets.

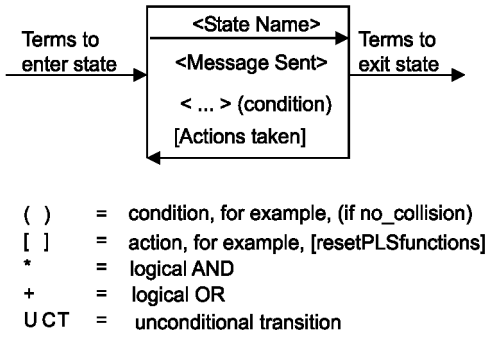

Figure 73—State diagram notation example

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Each permissible transition between the states is represented graphically by an arrow from the initial to the terminal state. A transition that is global in nature (e.g., an exit condition from all states to the IDLE or RESET state) is indicated by an open arrow. Labels on transitions are qualifiers that must be fulfilled before the transition will be taken. The label UCT designates an unconditional transition. Qualifiers described by short phrases are enclosed in parentheses.

State transitions and sending and receiving of messages occur instantaneously. When a state is entered and the condition to leave that state is not immediately fulfilled, the state executes continuously, sending the messages and executing the actions contained in the state in a continuous manner.

Some devices described in this standard are allowed to have two or more ports. State diagrams capable of describing the operation of devices with an unspecified number of ports require qualifier notation that allows testing for conditions at multiple ports. The notation used is a term that includes a description in parentheses of which ports must meet the term for the qualifier to be satisfied (e.g., ANY and ALL). It is also necessary to provide for term-assignment statements that assign a name to a port that satisfies a qualifier. The following convention is used to describe a term-assignment statement that is associated with a transition:

a) The character ":" (colon) is a delimiter used to denote that a term assignment statement follows.
b) The character "<" (left arrow) denotes assignment of the value following the arrow to the term preceding the arrow.

The state diagrams contain the authoritative statement of the procedures they depict; when apparent conflicts between descriptive text and state diagrams arise, the state diagrams are to take precedence. This does not, however, override any explicit description in the text that has no parallel in the state diagrams.

The models presented by state diagrams are intended as the primary specifications to be provided. It is important to distinguish, however, between a model and a real implementation. The models are optimized for simplicity and clarity of presentation, while any realistic implementation may place heavier emphasis on efficiency and suitability to a particular implementation technology. It is the functional behavior of any unit that must match the standard, not its internal structure. The internal details of the model are useful only to the extent that they specify the external behavior clearly and precisely.

14.3.2 PLCP frame format

The PPDU frame format provides for the asynchronous transfer of MAC sublayer MPDUs from any transmitting STA to all receiving STAs within the wireless LAN's BSS. The PPDU illustrated in Figure 74 consists of three parts: a PLCP Preamble, a PLCP Header, and a PSDU. The PLCP Preamble provides a period of time for several receiver functions. These functions include antenna diversity, clock and data recovery, and field delineation of the PLCP Header and the PSDU. The PLCP Header is used to specify the length of the whitened PSDU field and support any PLCP management information. The PPDU contains the PLCP Preamble, the PLCP Header, and the PSDU modified by the PPDU data whitener.

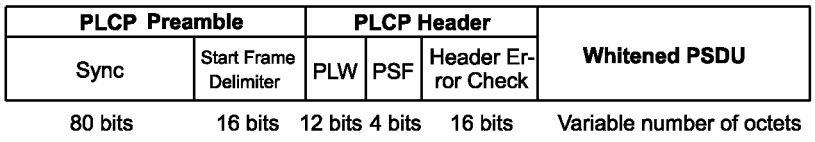

Figure 74—PLCP frame format

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14.3.2.1 PLCP Preamble

The PLCP Preamble contains two separate subfields, the Preamble Synchronization (SYNC) field and the SFD, to allow the PHY circuitry to reach steady-state demodulation and synchronization of bit clock and frame start.

14.3.2.1.1 Preamble SYNC field

The Preamble SYNC field is an 80-bit field containing an alternating zero-one pattern, transmitted starting with zero and ending with one, to be used by the PHY to detect a potentially receivable signal, select an antenna if diversity is utilized, and reach steady-state frequency offset correction and synchronization with the received packet timing.

14.3.2.1.2 SFD

The SFD consists of the 16-bit binary pattern 0000 1100 1011 1101 (transmitted leftmost bit first). The first bit of the SFD follows the last bit of the sync pattern. The SFD defines the frame timing.

14.3.2.2 PLCP Header field

The PLCP Header field contains three separate subfields: a 12-bit PSDU Length Word (PLW), a 4-bit PLCP Signaling field (PSF), and a 16-bit PLCP HEC field.

14.3.2.2.1 PLW

The PLW is passed from the MAC as a parameter within the PHY-TXSTART.request primitive. The PLW specifies the number of octets contained in the PSDU. Its valid values are X'001'–X'FFF', representing counts of one to 4095 octets. The PLW is transmitted LSB first and MSB last. The PLW is used by the receiving STA, in combination with the 32/33 coding algorithm specified in this clause, to determine the last bit in the packet.

14.3.2.2.2 PSF

The 4-bit PSF is defined in Table 33. The PSF is transmitted bit 0 first and bit 3 last.

Table 33—PSF bit descriptions

Bit	Parameter name	Parameter values	Description
0	Reserved	Default = 0	Reserved
1:3	PLCP_BITRATE	b1 b2 b3 = Data Rate 0 0 0 = 1.0 Mbit/s, 0 0 1 = 1.5 Mbit/s, 0 1 0 = 2.0 Mbit/s, 0 1 1 = 2.5 Mbit/s, 1 0 0 = 3.0 Mbit/s, 1 0 1 = 3.5 Mbit/s, 1 1 0 = 4.0 Mbit/s, 1 1 1 = 4.5 Mbit/s	This field indicates the data rate of the whitened PSDU from 1 Mbit/s to 4.5 Mbit/s in 0.5 Mbit/s increments.

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14.3.2.2.3 HEC field

The HEC field is a 16-bit CRC-16 error detection field. The HEC uses the CRC-16 generator polynomial $G(x)$ as follows:

$$G(x) = x^{16}+x^{12}+x^5+1$$

The HEC shall be the ones complement of the sum (modulo 2) of the following:

a) The remainder of $x^k \times (x^{15} + x^{14} + \ldots + x^2 + x^1 + 1)$ divided (modulo 2) by $G(x)$, where k is the number of bits in the PSF and PLW fields of the PLCP Header;
b) The remainder after multiplication by x^{16} and then division (modulo 2) by $G(x)$ of the content (treated as a polynomial) of the PSF and PLW fields.

The HEC shall be transmitted with the coefficient of the highest term first.

As a typical implementation, at the transmitter, the initial remainder of the division is preset to all ones and is then modified by division of the PSF and PLW fields by the generator polynomial, $G(x)$. The ones complement of this remainder is inserted in the HEC field with the MSB transmitted first.

At the receiver, the initial remainder of the division is again preset to all ones. The division of the received PSF, PLW, and HEC fields by the generator polynomial, $G(x)$, results, in the absence of transmission errors, in a unique nonzero value, which is the following polynomial $R(x)$:

$$R(x) = x^{12} + x^{11} + x^{10} + x^8 + x^3 + x^2 + x^1 + 1$$

14.3.2.3 PLCP data whitener

The PLCP data whitener uses a length-127 frame-synchronous scrambler followed by a 32/33 bias-suppression encoding to randomize the data and to minimize the data dc bias and maximum run lengths. Data octets are placed in the transmit serial bit stream LSB first and MSB last. The frame synchronous scrambler uses the generator polynomial $S(x)$ as follows:

$$S(x) = x^7+x^4+1$$

and is illustrated in Figure 75. The 127-bit sequence generated repeatedly by the scrambler is (leftmost bit used first) 00001110 11110010 11001001 00000010 00100110 00101110 10110110 00001100 11010100 11100111 10110100 00101010 11111010 01010001 10111000 1111111. The same scrambler is used to scramble transmit data and to descramble receive data. The data whitening starts with the first bit of the PSDU, which follows the last bit of the PLCP Header. The specific bias suppression encoding and decoding method used is defined in Figure 79 and Figure 84. The format of the packet after data whitening is as shown in Figure 76.

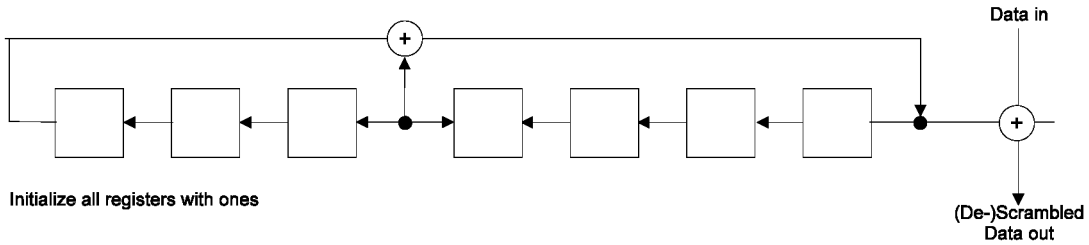

Figure 75—Frame synchronous scrambler/descrambler

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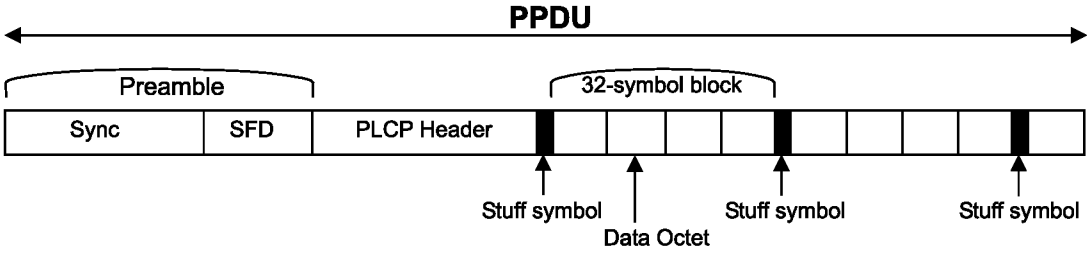

Figure 76—PLCP data whitener format

14.3.3 PLCP state machines

The PLCP consists of three state machines, as illustrated in the overview diagram of Figure 77: the TX, the CS/CCA, and the RX state machines. The three PLCP state machines are defined in the subclauses below; Figure 77 is not a state diagram itself. Execution of the PLCP state machines normally is initiated by the FH PLME state machine and begins at the CS/CCA state machine. The PLCP returns to the FH PLME state machine upon interrupt to service a PLME service request, e.g., PLME-SET, PLME-RESET.

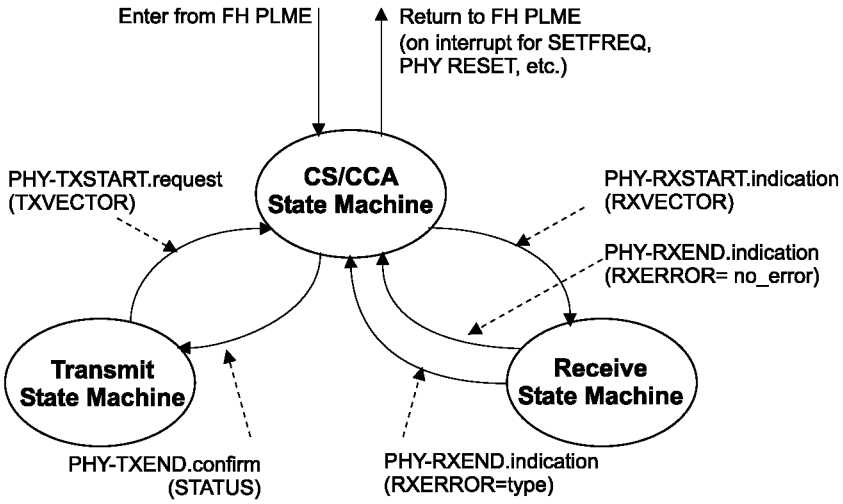

Figure 77—PLCP top-level state diagram

14.3.3.1 Transmit PLCP

The transmit PLCP is invoked by the CS/CCA procedure immediately upon receiving a PHY-TXSTART.request(TXVECTOR) from the MAC sublayer. The CSMA/CA protocol is performed by the MAC with the PHY PLCP in the CS/CCA procedure prior to executing the transmit procedure.

14.3.3.1.1 Transmit state machine

The PLCP transmit state machine illustrated in Figure 78 includes functions that must be performed prior to, during, and after PPDU data transmission. Upon entering the transmit procedure in response to a PHY-TXSTART.request(TXVECTOR) from the MAC, the PLCP shall switch the PHY PMD circuitry from receive to transmit state; ramp on the transmit power amplifier in the manner prescribed in 14.6; and

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transmit the preamble sync pattern and SFD. The PLCP shall generate the PLCP Header as defined in 14.3.2.2 in sufficient time to send the bits at their designated bit slot time. The PLCP shall add the PLCP Header to the start of the PSDU data.

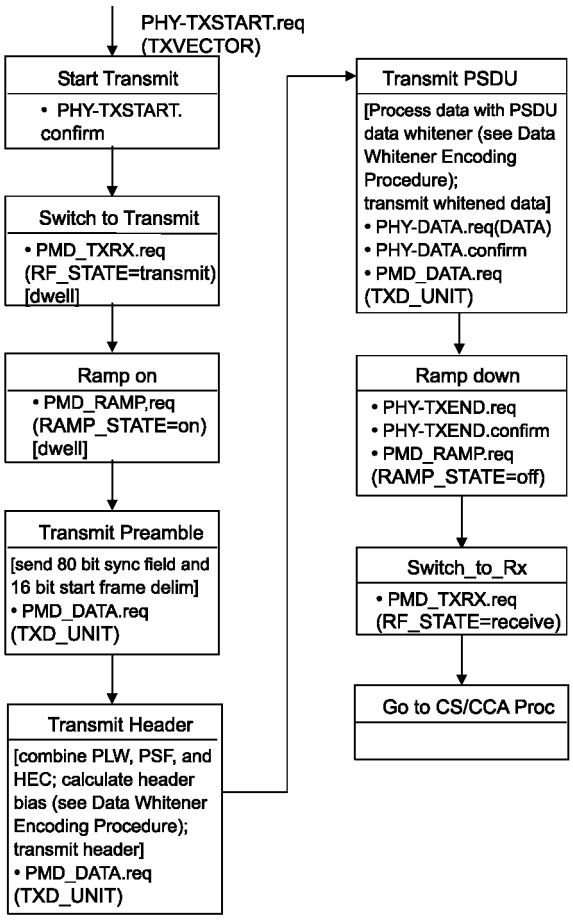

Figure 78—Transmit state machine

Prior to transmitting the first PSDU data bit, the PLCP shall send a PHY-TXSTART.confirm message to the MAC indicating that the PLCP is ready to receive an MPDU data octet. The MAC will pass an MPDU data octet to the PHY with a PHY-DATA.request(DATA), which the PHY will respond to with a PHY-DATA.confirm. This sequence of PHY-DATA.request(DATA) and PHY-DATA.confirm shall be executed until the last data octet is passed to the PLCP. During transmission of the PSDU data, each bit of the PSDU shall be processed by the data whitener algorithm defined in Figure 79 and described in 14.3.2.3. Each PSDU data octet is processed and transmitted LSB first and MSB last.

After the last MPDU octet is passed to the PLCP, the MAC will indicate the end of the frame with a *PHY-TXEND.request*. After the last bit of the PSDU data has completed propagation through the radio and been transmitted on the air, the PLCP shall complete the transmit procedure by sending a *PHY-TXEND.confirm* to the MAC sublayer, ramp off the power amplifier in the manner prescribed in 14.6, and switch the PHY PMD circuitry from transmit to receive state. The execution shall then return to the CS/CCA procedure.

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Data whitener encoding algorithm:

```
/*      If MSB of stuff symbol = 1 then the next block is inverted; 0 = not inverted */
/*      Accumulate PLCP Header; begin stuffing on first bit of the PSDU */

/********* Calculate number of 32-symbol BSE blocks required to send PSDU;
            no padding is necessary when the number of symbols is not a multiple of 32 *********/
Input parameter: number_of_PSDU_octets, rate;          /* rate is 1 or 2*/
number_of_symbols= (number_of_PSDU_octets *8) /rate;
number_of_blocks_in_packet = truncate{(number_of_symbols + 31) / 32)};

/********* Accumulate the bias in the header to use in calculating the inversion state of the first
            block of PSDU data *********/
Read in header {b(1),...,b(32)};          /* b(1) is first bit in */
header_bias = Sum{weight(b(1)),...,weight(b(32))};
                  /* calculate bias in header; weights are defined in Table 31*/
Transmit {b(1),...,b(32)};                /* no stuffing on header */
accum=header_bias;                        /* initialize accum */
Initialize scrambler to all ones;

/********* Whiten the PSDU data with scrambler and BSE encoder *********/
For n = 1 to number_of_blocks_in_packet
{
        b(0) = 0 for 1 Mbit/s; b(0)=00 for 2 Mbit/s;          /* b(0) is the stuff symbol */
        N = min(32, number_of_symbols);                       /* N= block size in symbols */
        Read in next symbol block {b(1),...,b(N)};            /* b(n) = {0,1} or {0,1,2,3};
        1 - 8 octets, use PHY-DATA.req(DATA), PHY-DATA.confirm for each octet*/
        Scramble {b(1),...,b(N)};                                   /* see 14.3.2.3*/
        bias_next_block = Sum{weight(b(0)),...,weight(b(N))};       /* calculate bias with b(0)=0 */

        /***** if accum and bias of next block has the same sign, then invert block;
                if accum=0 or bias_next_block=0, don't invert *****/
        If {[accum * bias_next_block > 0] then
        {
                Invert {b(0),...,b(N)};     /* Invert deviation, or, negate MSB of symbol */
                bias_next_block = - bias_next_block;
        }

        accum = accum + bias_next_block;
        transmit {b(0),...,b(N)};                   /* b(0) is first symbol out */
        number_of_symbols = number_of_symbols - N
}
```

Figure 79—Data whitener encoding procedure

The weights assigned to each value of the symbols are defined in Table 34 for the 1 Mbit/s [two-level Gaussian frequency shift keying (2GFSK)] and 2 Mbit/s [four-level GFSK (4GFSK)] symbols.

Table 34—PLCP field bit descriptions

2GFSK	4GFSK	Weight
—	10	3
1	—	2
—	11	1
Center	Center	0
—	01	–1
0	—	–2
—	00	–3

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14.3.3.1.2 Transmit state timing

The transmit timing illustrated in Figure 80 is defined from the instant that the *PHY-TXSTART.request(TXVECTOR)* is received from the MAC sublayer. The PLCP shall switch the PMD circuitry from receive to transmit, turn on and settle the transmitter, and begin transmitting the first bit of the preamble at the antenna within a maximum of 20 μs of receiving the *PHY-TXSTART.request(TXVECTOR)*. The PLCP Preamble shall be transmitted at 1 Mbit/s and be completed in 96 μs. The PLCP Header shall be transmitted at 1 Mbit/s and be completed in 32 μs. The variable length PSDU shall be transmitted at the selected data rate. After the last bit of the PSDU data has completed propagation through the radio and been transmitted on the air, the PLCP shall send the *PHY-TXEND.confirm* to the MAC sublayer. The PLCP shall turn off the transmitter, reducing the output energy to less than the specified off-mode transmit power within the time specified in 14.6. At the end of the power amplifier ramp down period, the PLCP shall switch the PMD circuitry from transmit to receive.

14.3.3.2 CS/CCA procedure

The CS/CCA procedure is executed while the receiver is turned on and the STA is not currently receiving or transmitting a packet. The CS/CCA procedure is used for two purposes: to detect the start of a network signal that can be received (CS) and to determine whether the channel is clear prior to transmitting a packet (CCA).

14.3.3.2.1 CS/CCA state machine

Timing for priority (PIFS, DIFS), contention backoff (slot times), and CS/CCA windows is defined relative to the end of the last bit of the last packet on the air. The CS/CCA state machine is shown in Figure 81. The PLCP shall perform a CS/CCA on a minimum of one antenna within a MAC contention backoff slot time of 50 μs. The PLCP shall be capable of detecting within the slot time an FH-PHY-conformant signal that is received at the selected antenna up to 22 μs after the start of the slot time with the synchronous detection performance specified in 14.6.15.3. Detection performance with zero-one sync patterns and with random data patterns is specified in 14.6.15.3. If a start of a transmission is asynchronous with the BSS and arrives after the start of the slot but at least 16 μs prior to the end of the slot, the PLCP shall indicate a busy channel prior to the end of the slot time with the asynchronous detection performance specified in 14.6.15.3. The CCA indication immediately prior to transmission shall be performed on an antenna with essentially the same free space gain and gain pattern as the antenna to be used for transmission. The method of determining CS/CCA is unspecified except for the detection performance of a conformant method as specified in 14.6.15.3.

If a *PHY-TXSTART.request(TXVECTOR)* is received, the CS/CCA procedure shall exit to the transmit procedure within 1 μs. If a *PHY-CCARESET.request* is received, the PLCP shall reset the CS/CCA state machine to the state appropriate for the end of a complete received frame. This service primitive is generated by the MAC at the end of a NAV period. The PHY shall indicate completion of the request by sending a *PHY-CCARESET.confirm* to the MAC.

If a CS/CCA returns a channel idle result, the PHY shall send a *PHY-CCA.indicate(STATUS=idle)* to the MAC.

If a CS/CCA returns a channel busy result, the PHY shall send a *PHY-CCA.indicate(STATUS=busy)* to the MAC. Upon a channel busy assessment, the PLCP shall stop any antenna switching prior to the earliest possible arrival time of the SFD and detect a valid SFD and PLCP Header if received. A valid PLCP Header is defined as containing valid PLW and PSF values and a valid HEC field. If a valid SFD/PLCP Header is detected, the CS/CCA procedure shall send a PHY-RXSTART.indicate(RXVECTOR) message to the MAC sublayer and exit to the receive procedure. The PLCP shall dwell and search for the SFD/PLCP Header for a minimum period longer than the latest possible arrival time of the SFD/PLCP Header. Indication of a busy channel does not necessarily lead to the successful reception of a frame.

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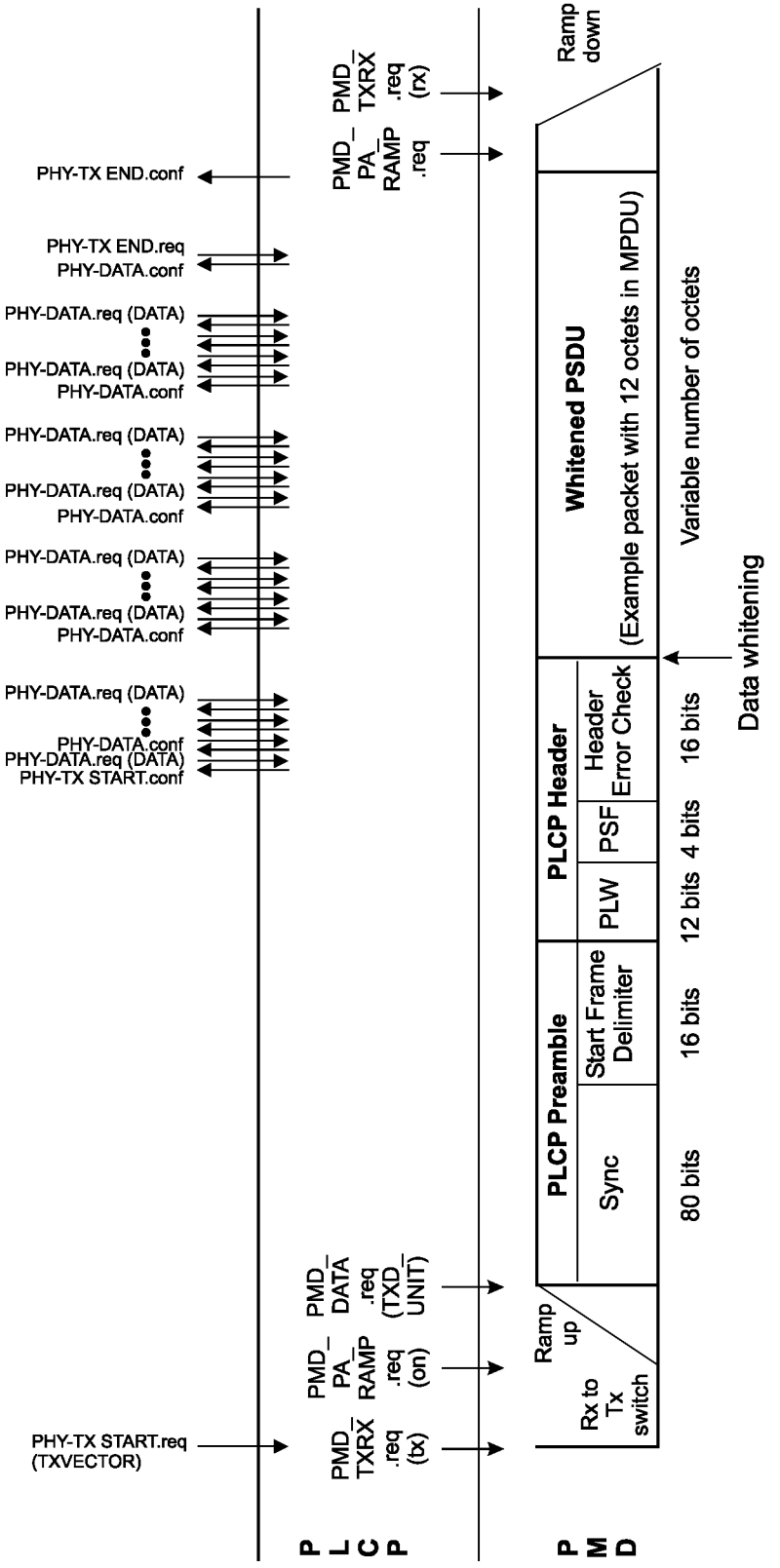

Figure 80—Transmit state timing

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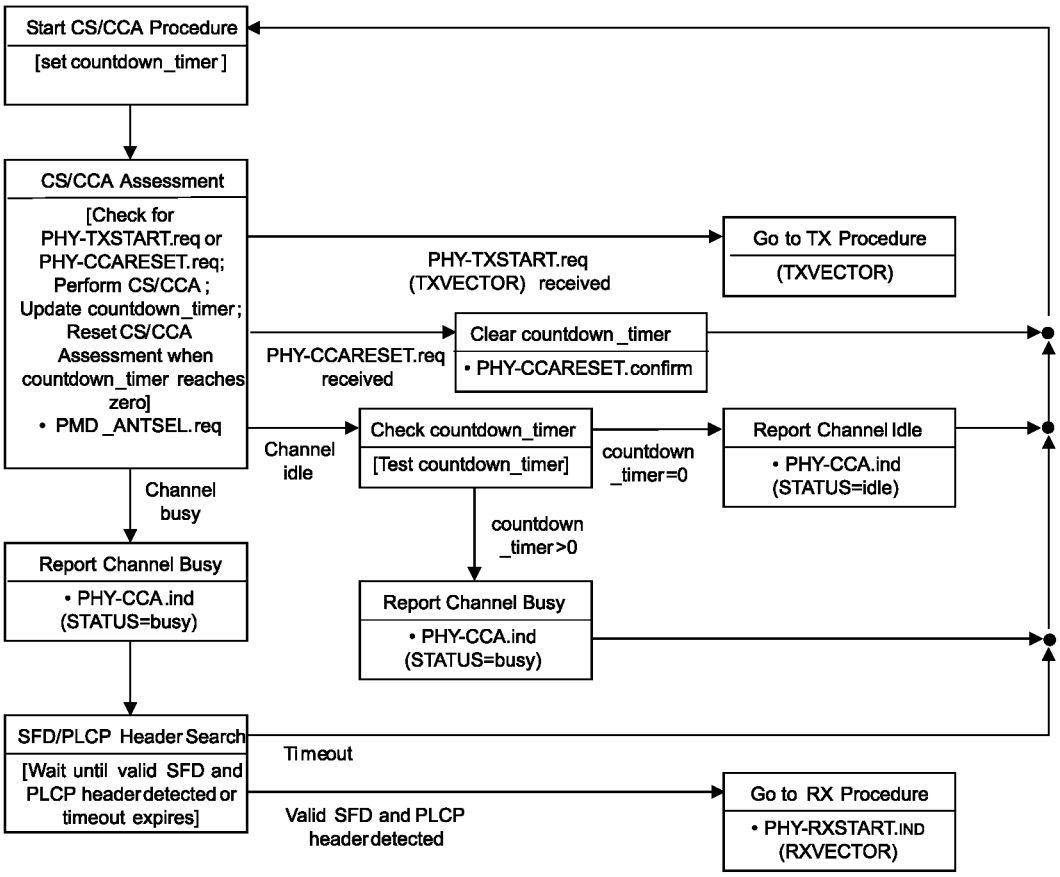

Figure 81—CS/CCA state machine

The octet/bit count remaining may be a nonzero value when returning from the receive procedure if a signal in the process of being received was lost prior to the end as determined from the LENGTH field of a valid PLCP Header. The countdown timer shall be set to the octet/bit count and used to force the CS/CCA indication to remain in the BUSY state until the predicted end of the frame regardless of actual CS/CCA indications.

However, if the CS/CCA procedure indicates the start of a new frame within the countdown timer period, it is possible to transition to the receive procedure prior to the end of the countdown timer period. If the PHY transitions to receive under these conditions, the countdown timer shall be reset to the longer of

— The remaining time of the current frame or
— The length of the new frame.

When a nonzero countdown timer reaches zero, the PLCP shall reset the CS/CCA state machine to the state appropriate for the end of a complete received frame and the CS/CCA indication shall reflect the state of the channel.

If the receive procedure encountered an unsupported rate error, the PLCP shall keep the CS/CCA state at Busy for the duration of the frame by setting the countdown timer to the value corresponding to the calculated time based on the information in the PLCP Header and the 33/32 expansion factor.

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14.3.3.2.2 CS/CCA state timing

Timing for priority (PIFS, DIFS), contention backoff (slot times), and CS/CCA windows is defined relative to the end of the last bit of the last packet on the air. The PLCP shall perform a CS/CCA on a minimum of one antenna within a slot time. The appropriate CS/CCA indication shall be available prior to the end of each 50 μs slot time with the performance specified in 14.6. See Figure 82.

If a STA has not successfully received the previous packet, the perceived packet end time and slot boundary times will have a higher uncertainty for that STA.

14.3.3.3 Receive PLCP

The receive PLCP is invoked by the CS/CCA procedure upon detecting a portion of the preamble sync pattern followed by a valid SFD and PLCP Header.

14.3.3.3.1 Receive state machine

The receive PLCP shown in Figure 83 includes functions that must be performed while the PPDU is being received. The receive PLCP begins upon detection of a valid SFD and PLCP Header in the CS/CCA procedure. The PLCP shall set a PPDU octet/bit counter to indicate the last bit of the packet, receive the PPDU bits, and perform the data whitening decoding procedure shown in Figure 84 on each PPDU bit. The PLCP shall pass correctly received data octets to the MAC with a series of *PHY-DATA.indicate(DATA)*. After the last PPDU bit is received and the last octet is passed to the MAC, the PLCP shall send a *PHY-RXEND.indicate(RXERROR=no_error)* to the MAC sublayer. Upon error-free completion of a packet reception, the PLCP shall exit the receive procedure and return to the CS/CCA procedure with the octet/bit count set to 0.

If the PLCP Header was decoded without a CRC error but encountered an unsupported rate, then the PLCP shall immediately complete the receive procedure with a *PHY-RXEND.indicate(RXERROR = unsupported_rate)* to the MAC, and return to the CS/CCA procedure with the octet/bit count remaining and the data rate value contained in the PLCP Header.

If an error was detected during the reception of the PPDU, the PLCP shall immediately complete the receive procedure with a *PHY-RXEND.indicate(RXERROR=carrier_lost)* to the MAC, and return to the CS/CCA procedure with the octet/bit count remaining and the data rate value contained in the PLCP Header.

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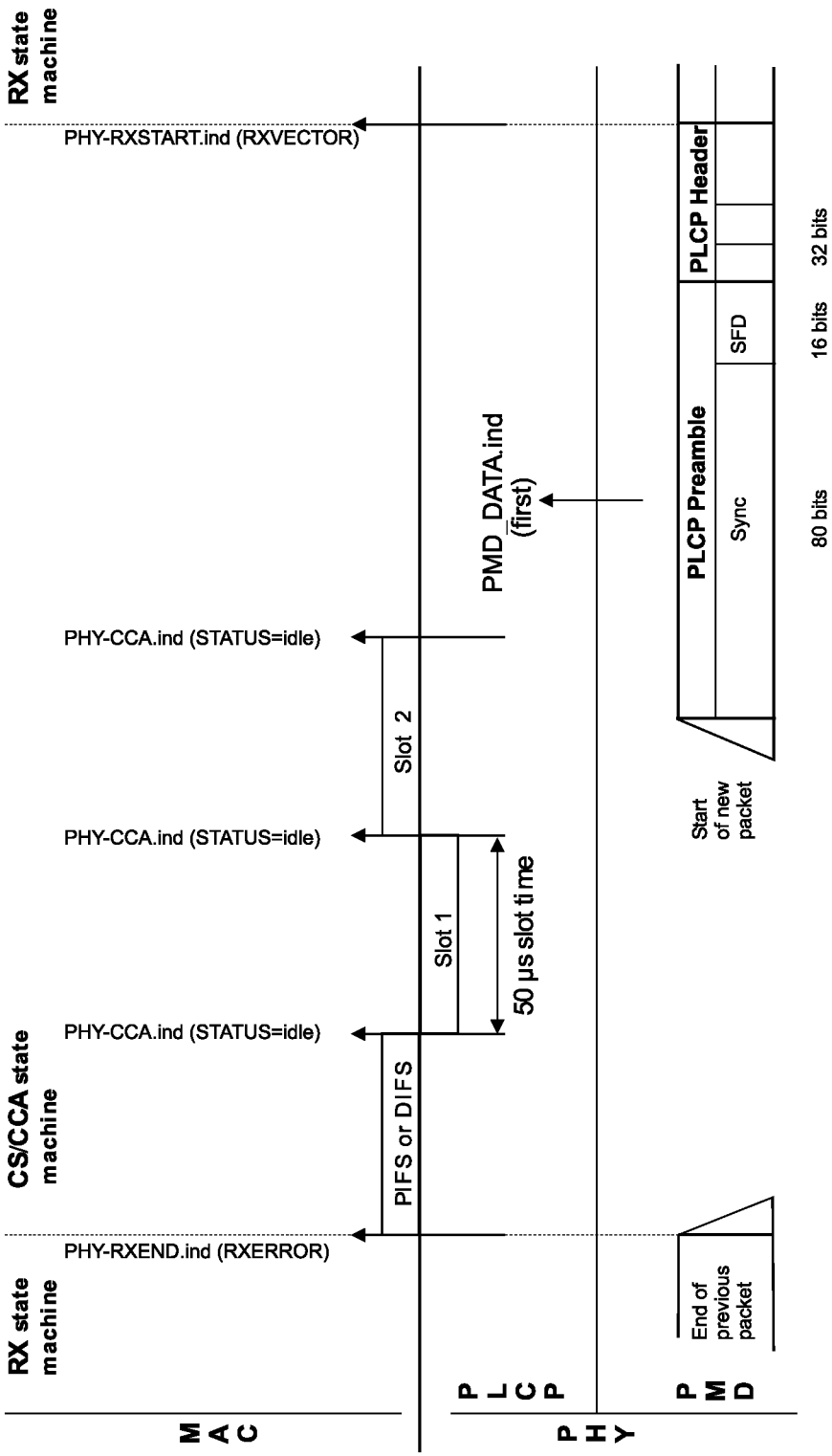

Figure 82—CS/CCA state timing

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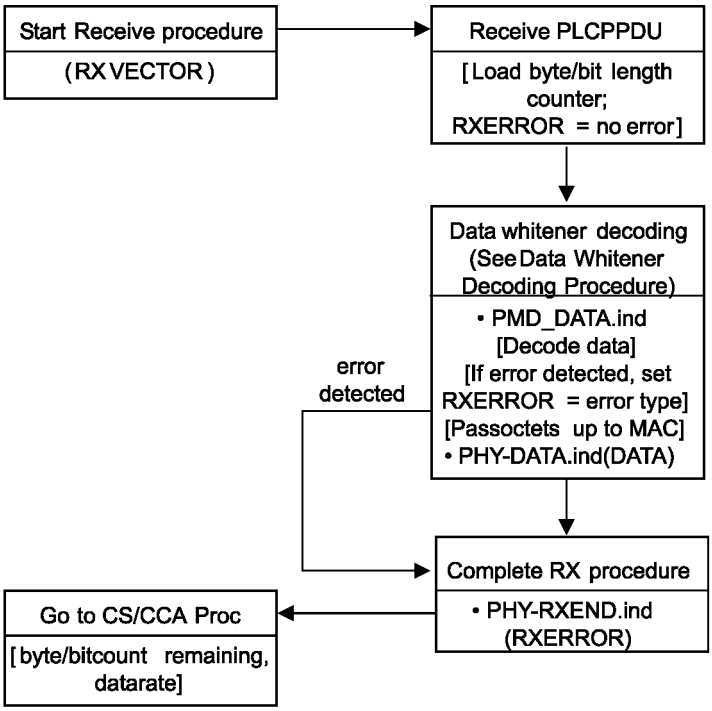

Figure 83—Receive state machine

Data whitener decoding algorithm:

```
/*      If MSB of stuff symbol = 1 then the next block is inverted; 0 = not inverted */
/*      Stuffing begins on first symbol of PLCP Header following the SFD */
/*      Algorithm begins after verifying validity of header with HEC */

/********* Read header *********/
Read in header {b(1),...,b(32)};                          /* b(1) is first bit in */

Get number_of_PSDU_octets, rate from header;              /* rate is 1 or 2 */
number_of_symbols = (number_of_PSDU_octets*8)/rate
number_of_blocks_in_packet = truncate{(number_of_symbols + 31) / 32};
Initialize scrambler to all ones;

/********* De-whiten the PPDU data with BSE decoder and de-scrambler *********/
For n = 1 to number_of_blocks_in_packet
{
        N = min(32, # of symbols remaining);      /* N= block size in symbols */
        Read in next block {b(0),...,b(N)};/                * b(n) = {0,1} or {0,1,2,3} */

        If {[MSB of b(0)=1] then Invert {b(1),...,b(N)};      /* if invert bit=true */
        Descramble {b(1),...,b(N)};               /* see 14.3.2.3*/
        Send {b(1),...,b(N)} to MAC
                                  /* 1 - 8 octets; use PHY-DATA.ind(DATA) for each octet. */
}
```

Figure 84—Data whitener decoding procedure

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14.3.3.3.2 Receive state timing

The receive state timing shown in Figure 85 is defined to begin upon detection of a valid SFD and PLCP Header in the CS/CCA procedure. The PLCP shall begin receiving the variable length whitened PSDU immediately after the end of the last bit of the PLCP Header. The PLCP shall send a *PHY-RXEND.indicate(RXERROR)* after receiving the last PPDU data bit.

If any error was detected during the reception of the PPDU, the PLCP may send a PHY-RXEND.indicate(RXERROR) and terminate the receive procedure before the last bit arrives.

14.4 PLME SAP layer management

14.4.1 Overview

This subclause describes the services provided by the FHSS PLME to the upper LMEs. The PLME/PMD services are defined in terms of service primitives. These primitives are abstract representations of the services and are not intended to restrict implementations.

14.4.2 FH PHY specific MLME procedures

14.4.2.1 Overview

The specific MLME procedures required for operating the FHSS PHY are specified in this portion of the subclause. The relationship between the MLME and FH PLME procedures is also described.

14.4.2.2 FH synchronization

The MLME of a compliant FH PHY STA shall perform the FH time synchronization procedure as defined in 11.1.5. This procedure provides for synchronized FH for all compliant FH PHY STAs within a single BSS or ad hoc network. The FH PLME accepts PLME-SET.request commands from the MLME to change the tune frequency at the time determined by the MLME. The tune frequency is changed by updating any combination of the Set, Pattern, and Index PHY MIB parameters.

14.4.3 FH PLME state machines

14.4.3.1 Overview

This portion of this subclause describes the FH PLME state machines to turn the PMD on/off, reset the PLCP state machine, and change the frequency hop channel.

14.4.3.2 PLME state machine

The PLME state machine in Figure 86 begins with a *PLME-SET.request(dot11CurrentPowerState= ON)*, which turns on the PHY circuitry, resets the PLME and PLCP state machines, and sends a *PLME-SET.confirm*. The MAC then sends a series of three *PLME-SET.request* primitives to update the dot11CurrentSet, dot11CurrentPattern, and dot11CurrentIndex PHY MIB parameters, which together tune the PMD to the selected channel. The PLME then transfers execution to the PLCP state machine as defined in 14.3.3.

Upon receiving a PLME request from a higher level LME, the PLCP shall return execution to the PLME state machine and process the request. A *PLME-RESET.request* shall cause a reset to the PLME and PLCP state machines. A *PLME-SET.request* updating the dot11CurrentIndex or a combination of the dot11CurrentSet, dot11CurrentPattern, and dot11CurrentIndex shall cause the PLCP to terminate a receive or CS/CCA process and change frequency before returning to the PLCP state machine. A

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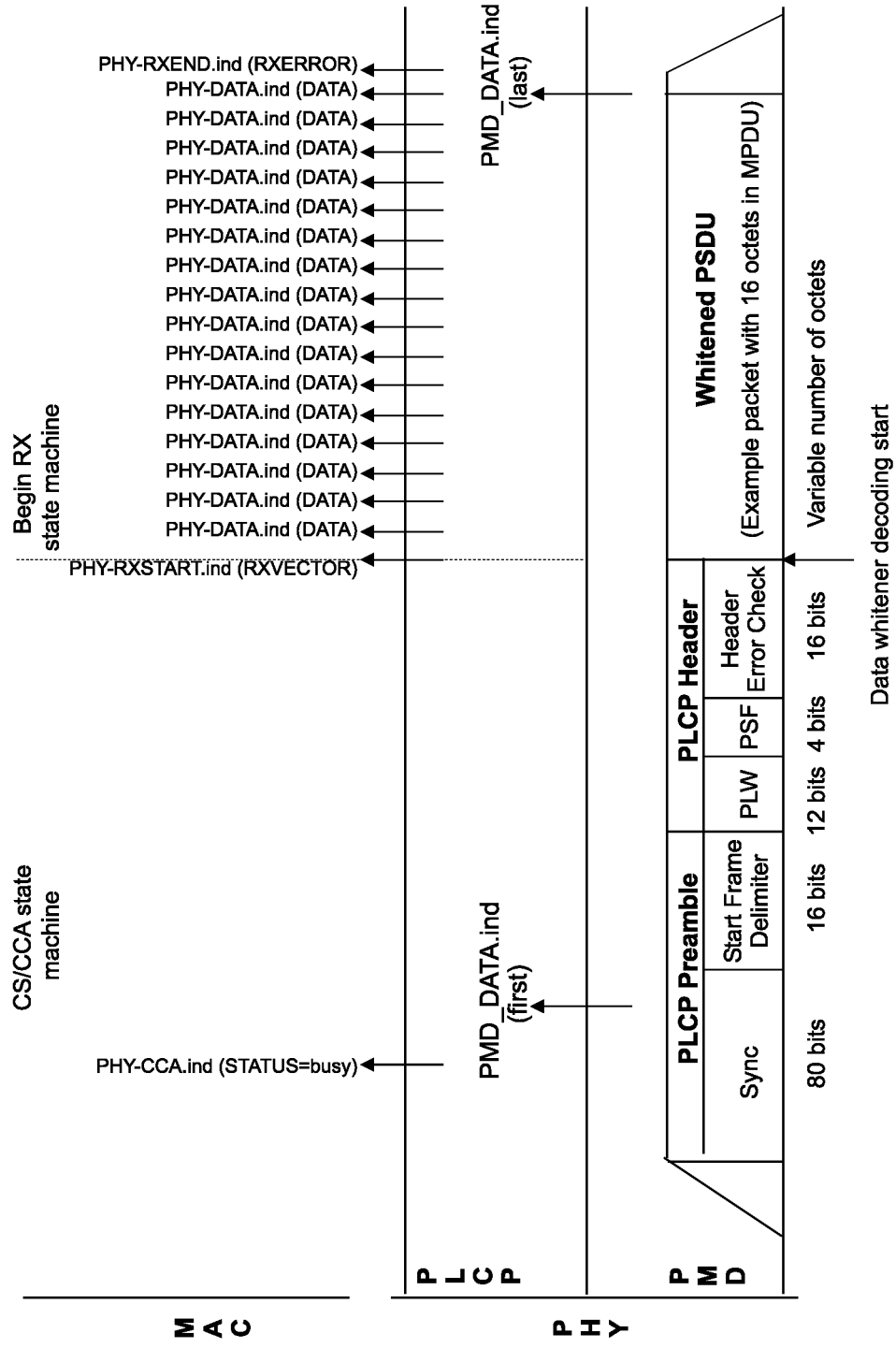

Figure 85—Receive timing

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PLME-SET.request(dot11CurrentPowerState=OFF) shall cause the PLCP to terminate a receive or CS/CCA process, power-down the PMD circuitry, and return the PLME state machine to the idle state. *PLME-SET.request*s to any parameter other than the ones identified within this paragraph shall be executed and control shall be returned to the PLCP state machine. The MAC should not send a PLME request while the PLCP is in the transmit state.

All *PLME-GET.request*s shall be processed in parallel and with no interruption to the execution of any state machine in process.

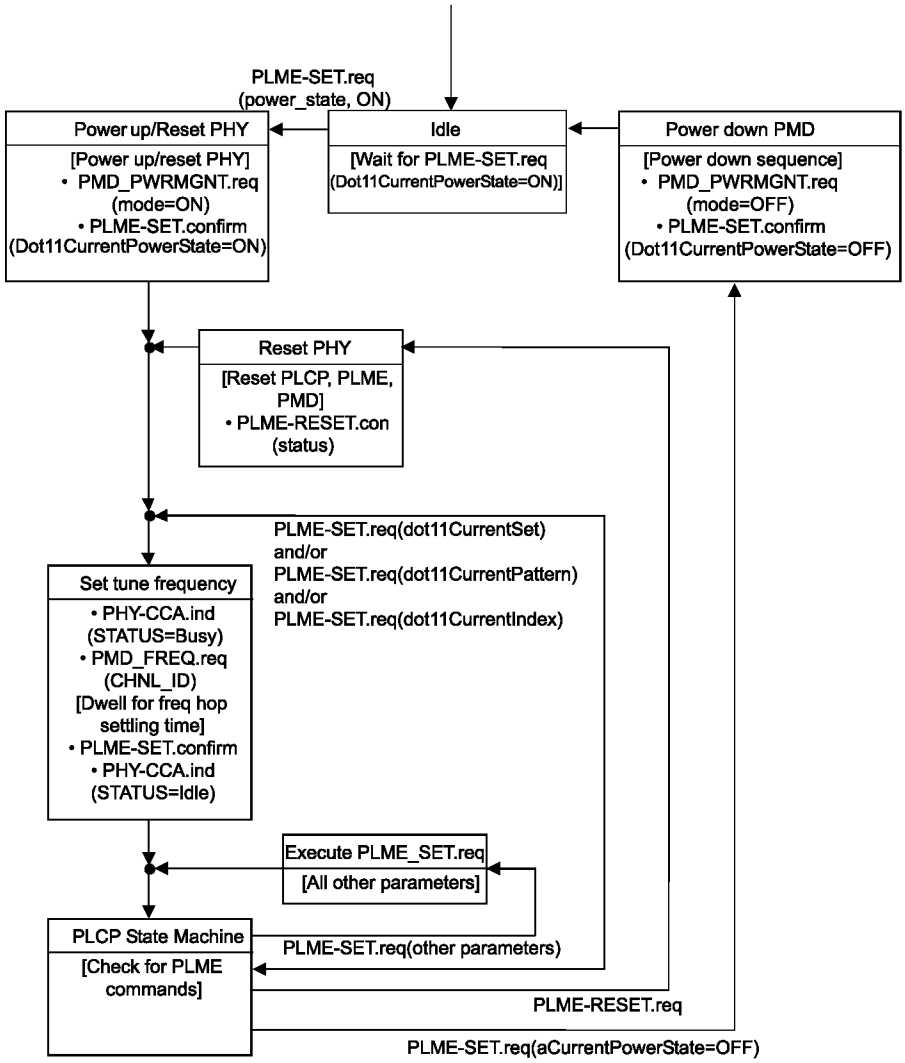

Figure 86—PLME state machine

14.4.3.3 PLME management primitives

The FH PLME uses the generic management primitives defined in 10.2 to manage all FH PHY parameters.

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14.5 FHSS PMD sublayer services

14.5.1 Scope and field of application

The PMD services provided to the PLCP for the FHSS PHY are described in this subclause. Also defined in this subclause are the functional, electrical, and radio frequency (RF) characteristics required for interoperability of implementations conforming to this specification. The relationship of this specification to the entire FHSS PHY is shown in Figure 87.

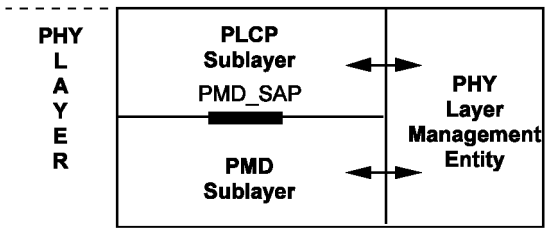

Figure 87—PMD layer reference model

14.5.2 Overview of services

In general, the FHSS PMD sublayer accepts PLCP sublayer service primitives and provides the actual means by which the signals required by these primitives are imposed onto the medium. In the FHSS PMD sublayer at the receiver the process is reversed. The combined function of the transmitting and receiving FHSS PMD sublayers results in a data stream, timing information, and receive parameter information being delivered to the receiving PLCP sublayer.

14.5.3 Overview of interactions

The primitives associated with the IEEE 802.11 PLCP sublayer to the FHSS PMD sublayer fall into the following two basic categories:

a) Service primitives that support PLCP peer-to-peer interactions;
b) Service primitives that have local significance and support sublayer-to-sublayer interactions.

14.5.4 Basic service and options

All of the service primitives described in this subclause are considered mandatory unless otherwise specified.

14.5.4.1 PMD_SAP peer-to-peer service primitives

Table 35 indicates the primitives for peer-to-peer interactions.

Table 35—PMD_SAP peer-to-peer service primitives

Primitive	Request	Indicate	Confirm	Response
PMD_DATA	X	X	—	—

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14.5.4.2 PMD_SAP sublayer-to-sublayer service primitives

Table 36 indicates the primitives for sublayer-to-sublayer interactions.

Table 36—PMD_SAP sublayer-to-sublayer service primitives

Primitive	Request	Indicate	Confirm	Response
PMD_TXRX	X	—	—	—
PMD_PA_RAMP	X	—	—	—
PMD_ANTSEL	X	—	—	—
PMD_TXPWRLVL	X	—	—	—
PMD_FREQ	X	—	—	—
PMD_RSSI	—	X	—	—
PMD_PWRMGMT	X	—	—	—

14.5.4.3 PMD_SAP service primitives parameters

Table 37 shows the parameters used by one or more of the PMD_SAP service primitives.

Table 37—List of parameters for PMD primitives

Parameter	Associate primitive	Value
TXD_UNIT	PMD_DATA.request	1 Mbit/s: 0, 1 2 Mbit/s: 0, 1, 2, 3
RXD_UNIT	PMD_DATA.indicate	1 Mbit/s: 0, 1 2 Mbit/s: 0, 1, 2, 3
RF_STATE	PMD_TXRX.request	TRANSMIT, RECEIVE
RAMP_STATE	PMD_PA_RAMP.request	ON, OFF
ANTENNA_STATE	PMD_ANTSEL.request	1 to 255
TXPWR_LEVEL	PMD_TXPWRLVL.request	LEVEL1, LEVEL2, LEVEL3, LEVEL4
CHNL_ID	PMD_FREQ.request	2–80 inclusive
STRENGTH	PMD_RSSI.indicate	0 to RSSI Max
MODE	PMD_PWRMGMT.request	ON, OFF

14.5.5 PMD_SAP detailed service specification

This subclause describes the services provided by each PMD primitive.

14.5.5.1 PMD_DATA.request

14.5.5.1.1 Function

This primitive defines the transfer of data from the PLCP sublayer to the PMD entity.

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14.5.5.1.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_DATA.request(TXD_UNIT)

The TXD_UNIT parameter can take on one of two values: one or zero. This parameter represents a single data bit. The effect of this parameter is that the PMD will properly modulate the medium to represent ones or zeros as defined in the FHSS PMD modulation specifications for a given data rate.

14.5.5.1.3 When generated

This primitive is generated by the PLCP sublayer to request the transmission of a single data bit on the PMD sublayer. The bit clock is assumed to be resident or part of the PLCP and this primitive is issued at every clock edge once the PLCP has begun transmitting data.

14.5.5.1.4 Effect of receipt

The receipt of this primitive will cause the PMD entity to encode and transmit a single data bit.

14.5.5.2 PMD_DATA.indicate

14.5.5.2.1 Function

This primitive defines the transfer of data from the PMD entity to the PLCP sublayer.

14.5.5.2.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_DATA.indicate(RXD_UNIT)

The RXD_UNIT parameter can take on one of two values: one or zero. This parameter represents the current state of the medium as determined by the FHSS PMD modulation specifications for a given data rate.

14.5.5.2.3 When generated

The PMD_DATA.indicate is generated to all receiving PLCP entities in the network after a PMD_DATA.request is issued.

14.5.5.2.4 Effect of receipt

The effect of receipt of this primitive by the PLCP is unspecified in this standard.

14.5.5.3 PMD_TXRX.request

14.5.5.3.1 Function

This primitive is used to place the PMD entity into the transmit or receive function.

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14.5.5.3.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_TXRX.request(RF_STATE)

The RF_STATE parameter can take on one of two values: TRANSMIT or RECEIVE. When the value of the primitive is TRANSMIT, the RF state of the radio is transmit. If the value of the primitive is RECEIVE, the RF state of the radio is receive.

14.5.5.3.3 When generated

This primitive is generated when the mode of the radio needs to be set or when changing from transmit to receive or receive to transmit.

14.5.5.3.4 Effect of receipt

The receipt of this primitive by the PMD entity will cause the mode of the radio to be in either transmit or receive.

14.5.5.4 PMD_PA_RAMP.request

14.5.5.4.1 Function

This primitive defines the start of the ramp up or ramp down of the radio transmitter's power amplifier.

14.5.5.4.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_PA_RAMP.request(RAMP_STATE)

The RAMP_STATE parameter can take on one of two values: ON or OFF. When the value of the primitive is ON, the state of the transmit power amplifier is "on." If the value of the primitive is OFF, the state of the transmit power amplifier is "off."

14.5.5.4.3 When generated

This primitive is issued only during transmit and to establish the initial state. It is generated by the PLCP at the start of the transmit function to turn the transmitter's power amplifier "on." A power amplifier ramp-up period follows the change of state from "off" to "on." After the PLCP has transferred all required data to the PMD entity, this primitive again will be issued by the PLCP to place the transmit power amplifier back into the "off" state. A power amplifier ramp-down period follows the change of state from "on" to "off."

14.5.5.4.4 Effect of receipt

The receipt of this primitive by the PMD entity will cause the transmit power amplifier to turn on or off.

14.5.5.5 PMD_ANTSEL.request

14.5.5.5.1 Function

This primitive is used to select which antenna the PMD entity will use to transmit or receive data.

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14.5.5.5.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_ANTSEL.request(ANTENNA_STATE)

The ANTENNA_STATE parameter can take on values from one to *N* (where *N* is the number of antennas supported). When the value of the primitive is a ONE, the PMD will switch to antenna 1 for receive or transmit; if the value of the primitive is TWO, the PMD entity will switch to antenna 2 for receive or transmit, etc.

14.5.5.5.3 When generated

This primitive is generated at various times by the PLCP entity to select an antenna. During receive, this primitive can be used to manage antenna diversity. During transmit, this primitive can be use to select a transmit antenna. This primitive will also be used during CCA.

14.5.5.5.4 Effect of receipt

The receipt of this primitive by the PMD entity will cause the radio to select the antenna specified.

14.5.5.6 PMD_TXPWRLVL.request

14.5.5.6.1 Function

This primitive defines the power level the PMD entity will use to transmit data.

14.5.5.6.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_TXPWRLVL.request(TXPOWER_LEVEL)

The TXPOWER_LEVEL parameter can be one of the values listed in Table 38.

Table 38—Transmit power levels

TXPWR_LEVEL	Level description
LEVEL1	Defined as TxPowerLevel1 in MIB
LEVEL2	Defined as TxPowerLevel2 in MIB
LEVEL3	Defined as TxPowerLevel3 in MIB
LEVEL4	Defined as TxPowerLevel4 in MIB
LEVEL5	Defined as TxPowerLevel5 in MIB
LEVEL6	Defined as TxPowerLevel6 in MIB
LEVEL7	Defined as TxPowerLevel7 in MIB
LEVEL8	Defined as TxPowerLevel8 in MIB

14.5.5.6.3 When generated

This primitive is generated as part of the transmit sequence.

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14.5.5.6.4 Effect of receipt

The receipt of this primitive by the PMD entity will cause the transmit power level to be modify.

14.5.5.7 PMD_FREQ.request

14.5.5.7.1 Function

This primitive defines the frequency the PMD entity will use to receive or transmit data. Because changing the RF is not an immediate function, this primitive serves also as an indication of the start of this process. The completion of this process is dictated by other PMD specifications.

14.5.5.7.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_FREQ.request(CHANNEL_ID)

The CHANNEL_ID parameter can be one of the values listed in Table 42, Table 43, Table 44, or Table 45 (in 14.6.5).

14.5.5.7.3 When generated

This primitive is generated by the PLCP when a change to a new frequency is required.

14.5.5.7.4 Effect of receipt

The receipt of this primitive by the PMD entity will cause the radio to change to a new frequency defined by the value of the CHNL_ID.

14.5.5.8 PMD_RSSI.indicate

14.5.5.8.1 Function

This primitive transfers a receiver signal strength indication of the physical medium from the PMD sublayer to the PLCP sublayer. This value will be used by the PLCP to perform any diversity or CCA functions required by the PLCP or other sublayers.

14.5.5.8.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_RSSI.indicate(STRENGTH)

The STRENGTH parameter can be a value from 0 to 15. This parameter is an indication by the PMD sublayer of the magnitude of the energy observed at the selected antenna. This reported value is used to generate the RSSI term in the PHY-RXSTART.ind(RXVECTOR) primitive and might also be used by any diversity function. Because RSSI is only used in a relative manner by the MAC sublayer, this parameter is defined to have no more than 16 values, ranging from 0 through RSSI_Max. The value zero is the weakest signal strength, while RSSI_Max is the strongest signal strength.

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14.5.5.8.3 When generated

This primitive is generated continually by the PMD entity to transfer a RSSI to the PLCP.

14.5.5.8.4 Effect of receipt

The effect of receipt of this primitive by the PLCP is unspecified in this standard.

14.5.5.9 PMD_PWRMGMT.request

14.5.5.9.1 Function

This primitive is used by the higher layer entities to manage or control the power consumption of the PMD when not in use. This allows higher layer entities to put the radio into a sleep or standby mode when receipt or sending of any data is not expected.

14.5.5.9.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_PWRMGMT.request(MODE)

The MODE parameter can have one of two values: ON or OFF. When the value of the parameter is ON, the PMD entity will enter into a fully functional mode that allows it to send or receive data. When the value of the parameter is OFF, the PMD entity will place itself in a standby or power-saving mode. In the low-power mode, the PMD entity is not expected to be able to perform any request by the PLCP, nor is it expected to indicate any change in PMD state or status.

14.5.5.9.3 When generated

This primitive is delivered by the PLCP but actually is generated by a higher level LME.

14.5.5.9.4 Effect of receipt

Upon receipt of this primitive, the PMD entity will enter a fully functional or low power consumption state depending on the value of the primitive's parameter.

14.6 FHSS PMD sublayer, 1.0 Mbit/s

14.6.1 1 Mbit/s PMD operating specifications, general

In general, the PMD accepts convergence layer service primitives and provides the actual means by which the signals required by these primitives are imposed on the medium. In the PMD sublayer at the receiver, the process is reversed. The combined function of the transmitting and receiving PMD sublayers results in a data stream, timing information, and receive parameter information being delivered to the receiving convergence sublayer.

14.6.2 Regulatory requirements

Wireless LANs implemented in accordance with this standard are subject to equipment certification and operating requirements established by regional and national regulatory administrations. The PMD specification establishes minimum technical requirements for interoperability, based upon established regulations for Europe, Japan, and North America at the time this standard was issued. These regulations are subject to

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revision, or may be superseded. Requirements that are subject to local geographic regulations are annotated within the PMD specification. Regulatory requirements that do not affect interoperability are not addressed within this standard. Implementers are referred to the following regulatory sources for further information. Operation in countries within Europe, or other regions outside Japan or North America, may be subject to additional or alternative national regulations.

The documents listed in Table 39 specify the current regulatory requirements for various geographic areas at the time this standard was developed. They are provided for information only and are subject to change or revision at any time.

Table 39—Regulatory requirements for various geographic areas

Geographic area	Approval standards	Documents	Approval authority
Europe	European Telecommunications Standards Institute (ETSI)	ETS 300-328 [B4], ETS 300-339 [B5]	National type approval authorities
France	Règle technique applicable aux équipements radioélectriques de transmission de données à large bande fonctionnant dans la bande de fréquences à 2,4 GHz et utilisant la technique de l'étalement de spectre (Édition février 1995)	SP/DGPT/ATAS/23, ETS 300-328 [B4], ETS 300-339 [B5]	Direction Générale des Postes et Télécommunications (DGPT)
Japan	Association of Radio Industries and Businesses (ARIB)	RCR STD-33 [B2]	Ministry of Telecommunications (MKK)
North America Canada United States	 Industry Canada (IC) Federal Communications Commission (FCC)	 GL-36 [B7] CFR47 [B6], Part 15, Sections 15.205, 15.209, 15.247	 IC FCC
Spain	Supplemento Del Numero 164 Del Boletin Oficial Del Estado (Published 10 July 1991, Revised 25 June 1993)	ETS 300-328 [B4], ETS 300-339 [B5]	Cuadro Nacional De Atribucion De Frecuesias

14.6.3 Operating frequency range

A conformant PMD implementation shall be able to select the carrier frequency (F_c) from the full geographic-specific set of available carrier frequencies. Table 40 summarizes these frequencies for a number of geographic locations.

Table 40—Operating frequency range

Lower Limit	Upper limit	Regulatory range	Geography
2.402 GHz	2.480 GHz	2.400–2.4835 GHz	North America
2.402 GHz	2.480 GHz	2.400–2.4835 GHz	Europe[a]
2.473 GHz	2.495 GHz	2.471–2.497 GHz	Japan
2.447 GHz	2.473 GHz	2.445–2.475 GHz	Spain
2.448 GHz	2.482 GHz	2.4465–2.4835 GHz	France
NOTE—The frequency ranges in this table are subject to the geographic-specific regulatory authorities.			

[a]Excluding Spain and France.

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14.6.4 Number of operating channels

The number of transmit and receive frequency channels used for operating the PMD entity is 79 for the United States and Europe, and 23 for Japan. Table 41 summarizes these frequencies for a number of geographic locations. This is more fully defined in Table 42 through Table 45.

Table 41—Number of operating channels

Minimum	Hopping set	Geography
75	79	North America
20	79	Europe[a]
N/A	23	Japan
20	27	Spain
20	35	France
NOTE—The number of required hopping channels is subject to the geographic-specific regulatory authorities.		

[a]Excluding Spain and France.

14.6.5 Operating channel center frequency

The channel center frequency is defined in sequential 1.0 MHz steps beginning with the first channel, channel 2.402 GHz for the United States and Europe excluding Spain and France, as listed in Table 42. The channel centers for Japan, starting at 2.473 GHz with 1 MHz increments, are listed in Table 43. The channel centers for Spain and France are listed in Table 44 and Table 45, respectively.

Table 42—Requirements in North America and Europe (excluding Spain and France; values specified in GHz)

Channel #	Value	Channel #	Value	Channel #	Value
2	2.402	28	2.428	54	2.454
3	2.403	29	2.429	55	2.455
4	2.404	30	2.430	56	2.456
5	2.405	31	2.431	57	2.457
6	2.406	32	2.432	58	2.458
7	2.407	33	2.433	59	2.459
8	2.408	34	2.434	60	2.460
9	2.409	35	2.435	61	2.461
10	2.410	36	2.436	62	2.462
11	2.411	37	2.437	63	2.463
12	2.412	38	2.438	64	2.464
13	2.413	39	2.439	65	2.465

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Table 42—Requirements in North America and Europe *(continued)*
(excluding Spain and France; values specified in GHz)

Channel #	Value	Channel #	Value	Channel #	Value
14	2.414	40	2.440	66	2.466
15	2.415	41	2.441	67	2.467
16	2.416	42	2.442	68	2.468
17	2.417	43	2.443	69	2.469
18	2.418	44	2.444	70	2.470
19	2.419	45	2.445	71	2.471
20	2.420	46	2.446	72	2.472
21	2.421	47	2.447	73	2.473
22	2.422	48	2.448	74	2.474
23	2.423	49	2.449	75	2.475
24	2.424	50	2.450	76	2.476
25	2.425	51	2.451	77	2.477
26	2.426	52	2.452	78	2.478
27	2.427	53	2.453	79	2.479
—	—	—	—	80	2.480

Table 43—Requirements in Japan
(values specified in GHz)

Channel #	Value	Channel #	Value	Channel #	Value
73	2.473	81	2.481	89	2.489
74	2.474	82	2.482	90	2.490
75	2.475	83	2.483	91	2.491
76	2.476	84	2.484	92	2.492
77	2.477	85	2.485	93	2.493
78	2.478	86	2.486	94	2.494
79	2.479	87	2.487	95	2.495
80	2.480	88	2.488	—	—

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Table 44—Requirements in Spain (values specified in GHz)

Channel #	Value	Channel #	Value	Channel #	Value
47	2.447	56	2.456	65	2.465
48	2.448	57	2.457	66	2.466
49	2.449	58	2.458	67	2.467
50	2.450	59	2.459	68	2.468
51	2.451	60	2.460	69	2.469
52	2.452	61	2.461	70	2.470
53	2.453	62	2.462	71	2.471
54	2.454	63	2.463	72	2.472
55	2.455	64	2.464	73	2.473

Table 45—Requirements in France (values specified in GHz)

Channel #	Value	Channel #	Value	Channel #	Value
48	2.448	60	2.460	72	2.472
49	2.449	61	2.461	73	2.473
50	2.450	62	2.462	74	2.474
51	2.451	63	2.463	75	2.475
52	2.452	64	2.464	76	2.476
53	2.453	65	2.465	77	2.477
54	2.454	66	2.466	78	2.478
55	2.455	67	2.467	79	2.479
56	2.456	68	2.468	80	2.480
57	2.457	69	2.469	81	2.481
58	2.458	70	2.470	82	2.482
59	2.459	71	2.471	—	—

14.6.6 Occupied channel bandwidth

Occupied channel bandwidth shall meet all applicable local geographic regulations for 1 MHz channel spacing. The rate at which the PMD entity will hop is governed by the MAC. The hop rate is an attribute with a maximum dwell time subject to local geographic regulations.

14.6.7 Minimum hop rate

The minimum hop rate shall be governed by the regulatory authorities.

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14.6.8 Hop sequences

The hopping sequence of an individual PMD entity is used to create a pseudo-random hopping pattern utilizing uniformly the designated frequency band. Sets of hopping sequences are used to co-locate multiple PMD entities in similar networks in the same geographic area and to enhance the overall efficiency and throughput capacity of each individual network.

An FH pattern, F_x, consists of a permutation of all frequency channels defined in Table 42 and Table 43. For a given pattern number, x, the hopping sequence can be written as follows:

$$F_x = \{f_x(1), f_x(2), \ldots f_x(p)\} \quad (5)$$

where

$f_x(i)$ is the channel number (as defined in 14.6.4) for i^{th} frequency in x^{th} hopping pattern;
p is the number of frequency channels in hopping pattern (79 for North America and most of Europe, 23 for Japan, 35 for France, 27 for Spain).

Given the hopping pattern number, x, and the index for the next frequency, i (in the range 1 to p), the channel number shall be defined to be as follows:

$f_x(i) = [b(i) + x] \bmod (79) + 2$ in North America and most of Europe, with $b(i)$ defined in Table 46.
$= [(i - 1) \times x] \bmod (23) + 73$ in Japan.
$= [b(i) + x] \bmod (27) + 47$ in Spain with $b(i)$ defined in Table 47.
$= [b(i) + x] \bmod (35) + 48$ in France with $b(i)$ defined in Table 48.

Table 46—Base-Hopping sequence *b(i)* for North America and most of Europe

i	*b(i)*	*i*	*b(i)*	*i*	*b(i)*	*i*	*b(i)*	*i*	*b(i)*	*i*	*b(i)*	*i*	*b(i)*	*i*	*b(i)*
1	0	11	76	21	18	31	34	41	14	51	20	61	48	71	55
2	23	12	29	22	11	32	66	42	57	52	73	62	15	72	35
3	62	13	59	23	36	33	7	43	41	53	64	63	5	73	53
4	8	14	22	24	71	34	68	44	74	54	39	64	17	74	24
5	43	15	52	25	54	35	75	45	32	55	13	65	6	75	44
6	16	16	63	26	69	36	4	46	70	56	33	66	67	76	51
7	71	17	26	27	21	37	60	47	9	57	65	67	49	77	38
8	47	18	77	28	3	38	27	48	58	58	50	68	40	78	30
9	19	19	31	29	37	39	12	49	78	59	56	69	1	79	46
10	61	20	2	30	10	40	25	50	45	60	42	70	28	—	—

The sequences are designed to ensure some minimum distance in frequency between contiguous hops. The minimum hop size is 6 MHz for North America and Europe, including Spain and France, and 5 MHz for Japan.

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Table 47—Base-Hopping sequence *b(i)* for Spain

i	*b(i)*	*i*	*b(i)*	*i*	*b(i)*
1	13	10	19	19	14
2	4	11	8	20	1
3	24	12	23	21	20
4	18	13	15	22	7
5	5	14	22	23	16
6	12	15	9	24	2
7	3	16	21	25	11
8	10	17	0	26	17
9	25	18	6	27	26

Table 48—Base-Hopping sequence *b(i)* for France

i	*b(i)*	*i*	*b(i)*	*i*	*b(i)*
1	17	13	31	25	15
2	5	14	20	26	3
3	18	15	29	27	11
4	32	16	22	28	30
5	23	17	12	29	24
6	7	18	6	30	9
7	16	19	28	31	27
8	4	20	14	32	19
9	13	21	25	33	2
10	33	22	0	34	21
11	26	23	8	35	34
12	10	24	1	—	—

The hopping pattern numbers *x* are divided into three sets. The sets are designed to avoid prolonged collision periods between different hopping sequences in a set. Hopping sequence sets contain 26 sequences for North America and Europe, and 4 sequences per set for Japan:

For North America and most of Europe:

x = {0,3,6,9,12,15,18,21,24,27,30,33,36,39,42,45,48,51,54,57,60,63,66,69,72,75} Set 1
x = {1,4,7,10,13,16,19,22,25,28,31,34,37,40,43,46,49,52,55,58,61,64,67,70,73,76} Set 2
x = {2,5,8,11,14,17,20,23,26,29,32,35,38,41,44,47,50,53,56,59,62,65,68,71,74,77} Set 3

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For Japan:

x = {6,9,12,15} Set 1
x = {7,10,13,16} Set 2
x = {8,11,14,17} Set 3

For Spain:

x = {0,3,6,9,12,15,18,21,24} Set 1
x = {1,4,7,10,13,16,19,22,25} Set 2
x = {2,5,8,11,14,17,20,23,26} Set 3

For France:

x = {0,3,6,9,12,15,18,21,24,27,30} Set 1
x = {1,4,7,10,13,16,19,22,25,28,31} Set 2
x = {2,5,8,11,14,17,20,23,26,29,32} Set 3

The three sets of hopping sequences for North America and most of Europe, of 26 patterns each, are listed in Table B.1, Table B.2, and Table B.3. Similarly, there are three sets for Japan of four patterns each. The three sets for Spain have nine patterns each. The three sets for France have 11 patterns each. The channel numbers listed under each pattern refer to the actual frequency values listed in Table 42 and Table 43.

14.6.9 Unwanted emissions

Conformant PMD implementations shall limit the emissions that fall outside of the operating frequency range, defined in Table 40, to the geographically applicable limits**.**

14.6.10 Modulation

The minimum set of requirements for a PMD to be compliant with the IEEE 802.11 FHSS PHY shall be as follows.

The PMD shall be capable of operating using 2GFSK modulation with a nominal bandwidth bit time (BT) = 0.5. The PMD shall accept symbols from the set {{1},{0}} from the PLCP. The symbol {1} shall be encoded with a peak deviation of ($+f_d$), giving a peak transmit frequency of (F_c+f_d), which is greater than the carrier center frequency (F_c). The symbol {0} shall be encoded with a peak frequency deviation of ($–f_d$), giving a peak transmit frequency of ($F_c–f_d$).

An incoming bit stream at 1 Mbit/s will be converted to symbols at *Fclk* = 1 *M*symbols/s, as shown in Table 49.

Table 49—Symbol encoding into carrier deviation (1 Mbit/s, 2GFSK)

Symbol	Carrier deviation
1	1/2 × h2 × Fclk
0	–1/2 × h2 × Fclk
NOTE—These deviation values are measured using the center symbol of 7 consecutive symbols of the same value. The instantaneous deviation will vary due to Gaussian pulse shaping.	

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The deviation factor h2 for 2GFSK (measured as difference between frequencies measured in the middle of 0000 and 1111 patterns encountered in the SFD, divided by 1 MHz) will nominally be 0.32.

The minimum frequency deviation, as shown in Figure 88, shall be greater than 110 kHz relative to the nominal center frequency F_c. F_d is the average center frequency of the last 8 bits of the Preamble Sync field, measured as the deviation at the midsymbol. Midsymbol is defined as the point that is midway between the zero crossings derived from a best fit to the last 8 bits of the Sync field. Maximum deviation is not specified, but modulation is subject to the occupied bandwidth limits of 14.6.5.

The zero crossing error shall be less than ±1/8 of a symbol period. The zero crossing error is the time difference between the ideal symbol periods and measured crossings of F_c. This is illustrated in Figure 88.

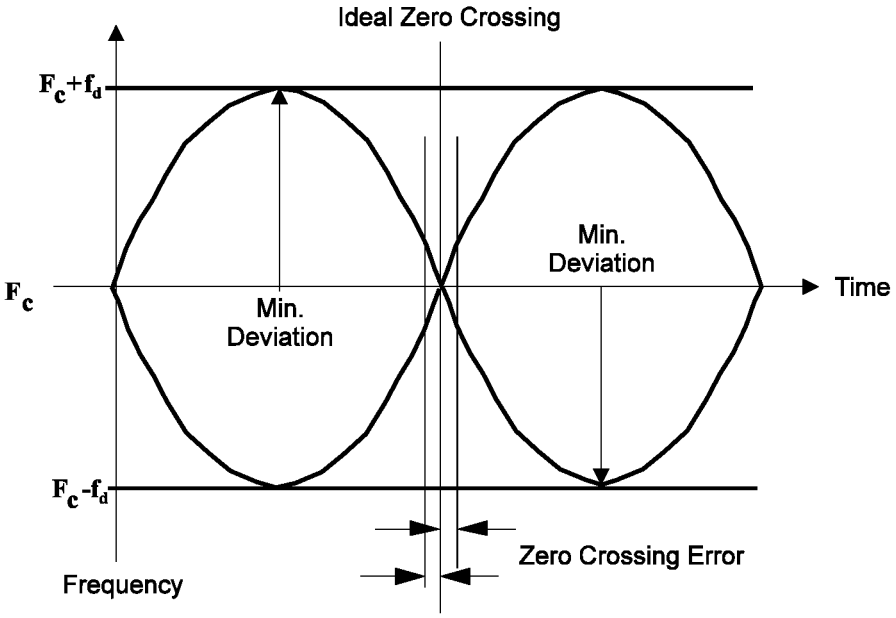

Figure 88—Transmit modulation mask

14.6.11 Channel data rate

A compliant IEEE 802.11 FHSS PMD shall be capable of transmitting and receiving at a nominal data rate of 1.0 Mbit/s ±50 ppm.

14.6.12 Channel switching/settling time

The time to change from one operating channel frequency, as specified in 14.6.3, is defined as 224 μs. A conformant PMD meets this switching time specification when the operating channel center frequency has settled to within ±60 kHz of the nominal channel center frequency as outlined in 14.6.3.

14.6.13 Receive to transmit switch time

The maximum time for a conformant PMD to switch the radio from the receive state to the transmit state and place the start of the first bit on the air shall be 19 μs. At the end of this 19 μs, the RF carrier shall be within the nominal transmit power level range, and within the described modulation specifications.

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14.6.14 PMD transmit specifications

The following portion of this subclause describes the transmit functions and parameters associated with the PMD sublayer. In general, these are specified by primitives from the PLCP, and the transmit PMD entity provides the actual means by which the signals required by the PLCP primitives are imposed onto the medium.

14.6.14.1 Nominal transmit power

The nominal transmit power of a frame is defined as the power averaged between the start of the first symbol in the PLCP Header to the end of the last symbol in the PLCP Header. When in the transmit state, the transmit power shall be within 2 dB of the nominal transmit power from the start of the Preamble SYNC field to the last symbol at the end of the frame.

14.6.14.2 Transmit power levels

Unless governed by more stringent local geographic regulations, the radiated emissions from compliant devices shall meet IEEE Std C95.1-1991 limits for controlled or uncontrolled environments, in accordance with their intended usage. In addition, all conformant PMD implementations shall support at least one power level with a minimum equivalent isotropically radiated power (EIRP) of 10 mW.

14.6.14.3 Transmit power level control

If a conformant PMD implementation has the ability to transmit in a manner that results in the EIRP of the transmit signal exceeding the level of 100 mW, at least one level of transmit power control shall be implemented. This transmit power control shall be such that the level of the emission is reduced to a level at or below 100 mW under the influence of said power control.

14.6.14.4 Transmit spectrum shape

Within the operational frequency band the transmitter shall pass a spectrum mask test. The duty cycle between Tx and Rx is nominally 50% and the transmit frame length is nominally 400 μs. The adjacent channel power is defined as the sum of the power measured in a 1 MHz band. For a pseudo-random data pattern, the adjacent channel power shall be a function of the offset between channel number *N* and the assigned transmitter channel *M*, where *M* is the actual transmitted center frequency and *N* is a channel separated from it by an integer number of megahertz.

Channel offset:

$|N-M|=2$ –20 dBm or –40 dBc, whichever is the lower power.
$|N-M|\geq 3$ –40 dBm or –60 dBc, whichever is the lower power.

The levels given in dBc are measured relative to the transmitter power measured in a 1 MHz channel centered on the transmitter center frequency. The adjacent channel power and the transmitter power for this subclause of the specification shall be measured with a resolution bandwidth of 100 kHz, a video bandwidth of 300 kHz, and a peak detector, and with the measurement device set to maximum hold.

For any transmit center frequency M, two exceptions to the spectrum mask requirements are permitted within the operational frequency band, provided the exceptions are less than –50 dBc, where each offset channel exceeded counts as a separate exception. An exception occurs when the total energy within a given 1 MHz channel as defined in 14.6.5 exceeds the levels specified in 14.6.14.1 through 14.6.14.4.

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14.6.14.5 Transmit center frequency tolerance

The PMD transmit center frequency shall be within ±60 kHz of the nominal center frequency as specified in 14.6.5.

14.6.14.6 Transmitter ramp periods

The transmitter shall go from off to within 2 dB of the nominal transmit power in 8 μs or less. The transmitter shall go from within 2 dB of the nominal transmit power to off (less than –50 dBm) in 8 μs or less.

14.6.15 PMD receiver specifications

The following portion of this subclause describes the receive functions and parameters associated with the PMD sublayer. In general, these are specified by primitives from the PLCP. The Receive PMD entity provides the actual means by which the signals required by the PLCP primitives are recovered from the medium. The PMD sublayer monitors signals on the medium and will return symbols from the set {{1},{0}} to the PLCP sublayer.

14.6.15.1 Input signal range

The PMD shall be capable of recovering a conformant PMD signal from the medium, as described in related subclauses, with a frame error ratio (FER) ≤ 3% for PSDUs of 400 octets generated with pseudo-random data, for receiver input signal levels in the range from –20 dBm to the receiver sensitivity (as specified in 14.6.15.4), across the frequency band of operation.

14.6.15.2 Receive center frequency acceptance range

An IEEE 802.11 FHSS-compliant PMD shall meet all specifications with an input signal having a center frequency range of ±60 kHz from nominal.

14.6.15.3 CCA power threshold

In the presence of any IEEE 802.11-compliant 1 Mbit/s FH PMD signal above –85 dBm that starts synchronously with respect to slot times as specified in 14.3.3.2.1, the PHY shall signal busy, with a 90% probability of detection, during the preamble within the CCA window. In the presence of any IEEE 802.11-compliant 1 Mbit/s FH PMD signal above –85 dBm that starts asynchronously with respect to slot times as specified in 14.3.3.2.1, the PHY shall signal busy, with a 70% probability of detection, during the preamble within the CCA window. In the presence of any IEEE 802.11-compliant 1 Mbit/s FH PMD signal above –65 dBm, the PHY shall signal busy, with a 70% probability of detection, during random data within the CCA window. This specification applies to a PMD operating with a nominal EIRP of < 100 mW. A compliant PMD operating at a nominal output power greater than 100 mW shall use the following equation to define the CCA threshold, where P_t represents transmit power.

$$\text{CCA threshold (preamble)} = -85\ \text{dBm} - \left[5 \times \log_{10}\left(\frac{P_t}{100\ \text{mW}}\right)\right]\ \text{dBm}$$

CCA threshold (random data) = CCA threshold (preamble) + 20 dB

14.6.15.4 Receiver sensitivity

The sensitivity is defined as the minimum signal level required for an FER of 3% for PSDUs of 400 octets generated with pseudo-random data. The sensitivity shall be less than or equal to –80 dBm. The reference sensitivity is defined as –80 dBm for the 1 Mbit/s FH PHY specifications.

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14.6.15.5 Intermodulation

Intermodulation protection (IMp) is defined as the ratio of the minimum amplitude of one of two equal interfering signals to the desired signal amplitude, where the interfering signals are spaced 4 MHz and 8 MHz removed from the center frequency of the desired signal, both on the same side of center frequency. The IMp ratio is established at the interfering signal level that causes the FER of the receiver to be increased to 3% for PSDUs of 400 octets generated with pseudo-random data, when the desired signal is –77 dBm. Each interfering signal is modulated with the FH PMD modulation uncorrelated in time to each other or the desired signal. The PMD shall have the IMp for the interfering signal at 4 MHz and 8 MHz be ≥ 30 dB.

14.6.15.6 Desensitization (Dp)

Desensitization (Dp) is defined as the ratio to measured sensitivity of the minimum amplitude of an interfering signal that causes the FER at the output of the receiver to be increased to 3% for PSDUs of 400 octets generated with pseudo-random data, when the desired signal is –77 dBm. The interfering signal shall be modulated with the FHSS PMD modulation uncorrelated in time to the desired signal. The minimum Dp shall be as given in Table 50. The spectral purity of the interferer shall be sufficient to ensure that the measurement is limited by the receiver performance.

Table 50—1 Mbit/s Dp

Interferer frequency[a]	Dp minimum
$M = N \pm 2$	30 dB
$M = N \pm 3$ or more	40 dB

[a]Where M is the interferer frequency and N is the desired channel frequency.

14.6.15.7 Receiver radiation

The signal leakage when receiving shall not exceed –50 dBm EIRP in the operating frequency range. The FHSS PHY shall conform with out-of-band spurious emissions by regulatory bodies.

14.6.16 Operating temperature range

Two temperature ranges for full operation compliance to the FH PHY are specified. Type 1 is defined as 0 °C to 40 °C and is designated for office environments. Type 2 is defined as –30 °C to +70 °C and is designated for industrial environments.

14.7 FHSS PMD sublayer, 2.0 Mbit/s

14.7.1 Overview

This subclause details the RF specification differences of the optional 2 Mbit/s operation from the baseline 1 Mbit/s PMD as contained in 14.6. Unless otherwise specified in this subclause, the compliant PMD shall also meet all requirements of 14.6 when transmitting at 2 Mbit/s. When implementing the 2 Mbit/s option, the preamble and PHY Header shall be transmitted at 1 Mbit/s. STAs implementing the 2 Mbit/s option shall also be capable of transmitting and receiving PPDUs at 1 Mbit/s.

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14.7.2 4GFSK modulation

For an FHSS 2 Mbit/s PMD, the modulation scheme shall be 4GFSK, with a nominal symbol-period bandwidth product (BT) of 0.5. The four-level deviation factor, defined as the frequency separation of adjacent symbols divided by symbol rate, h4, shall be related to the deviation factor of the 2GFSK modulation, h2, by the following equation:

$h4/h2 = 0.45 \pm 0.01$

An incoming bit stream at 2 Mbit/s will be converted to 2-bit words or symbols, with a rate of Fclk = 1 Msymbol/s. The first received bit will be encoded as the LMB of the symbol in Table 51. The bits will be encoded into symbols as shown in Table 51.

Table 51—Symbol encoding into carrier deviation

1 Mbit/s, 2GFSK	
Symbol	**Carrier deviation**
1	$1/2 \times h2 \times Fclk$
0	$-1/2 \times h2 \times Fclk$
2 Mbit/s, 4GFSK	
Symbol	**Carrier deviation**
10	$3/2 \times h4 \times Fclk$
11	$1/2 \times h4 \times Fclk$
01	$-1/2 \times h4 \times Fclk$
00	$-3/2 \times h4 \times Fclk$
NOTE—These deviation values are measured using the center symbol of 7 consecutive symbols of the same value. The instantaneous deviation will vary due to Gaussian pulse shaping.	

The deviation factor h2 for 2GFSK (measured as the difference between frequencies measured in the middle of 0000 and 1111 patterns encountered in the SFD, divided by 1 MHz) will nominally be 0.32. The deviation factor h2 will be no less than 0.30 (with maximum dictated by regulatory bandwidth requirement). Accordingly, h4 (measured as a difference between the outermost frequencies, divided by 3, divided by 1 MHz) is nominally $0.45 \times 0.32 = 0.144$, and it will be no less than $0.45 \times 0.3 = 0.135$.

The modulation error shall be less than ±15 kHz at the midsymbol time for 4GFSK, from the frequency deviations specified above, for a symbol surrounded by identical symbols, and less than ±25 kHz for any symbol. The deviation is relative to the actual center frequency of the RF carrier. For definition purposes, the actual center frequency is the midfrequency between symbols 11 and 01. The actual center frequency shall be within ±60 kHz of the nominal channel center frequency defined in 14.6.5 and shall not vary by more than ±10 kHz/ms, from the start to end of the PPDU. The peak-to-peak variation of the actual center frequency over the PPDU shall not exceed 15 kHz. Symbols and terms used within this subclause are illustrated in Figure 89.

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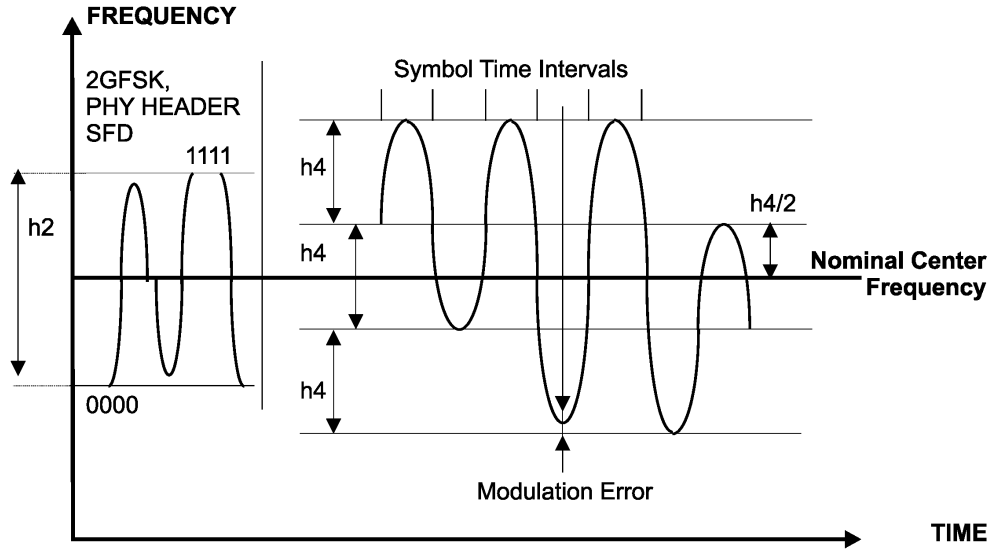

Figure 89—4GFSK transmit modulation

14.7.2.1 Frame structure for HS FHSS PHY

The high rate FHSS PPDU consists of PLCP Preamble, PLCP Header, and whitened PSDU. The PLCP Preamble and PLCP Header format are identical to the 1 Mbit/s PHY, as described in 14.3.2. The whitened PSDU is transmitted in 2GFSK, 4GFSK, or potentially a higher-rate format, according to the rate chosen. The rate is indicated in a 3-bit field in a PLCP Header, having a value of 1 or 2 bits/symbol (or Mbit/s).

The PPDU is transmitted as four-level symbols, with the amount determined by number_of_symbols = (number_of_PSDU_octets × 8)/rate.

The input bits are scrambled according to the method in 14.3.2.3.

The scrambled bit stream is divided into groups of rate (1 or 2) consecutive bits. The bits are mapped into symbols according to Table 51.

A bias suppression algorithm is applied to the resulting symbol stream. The bias suppression algorithm is defined in 14.3.2.3, Figure 76, and Figure 79. A polarity control symbol is inserted prior to each block of 32 symbols (or less for the last block). The polarity control signals are 4GFSK symbols 10 or 00. The algorithm is equivalent to the case of 2GFSK, with the polarity symbol 2GFSK "1" replaced with 4GFSK symbol "10," and the 2GFSK polarity symbol "0" replaced with a 4GFSK symbol "00."

14.7.3 Channel data rate

The data rate for the whitened PSDU at the optional rate shall be 2.0 Mbit/s ±50 ppm.

14.7.3.1 Input dynamic range

The PMD shall be capable of recovering a conformant PMD signal from the medium, as described in related subclauses, with an FER ≤ 3% for PSDUs of 400 octets generated with pseudo-random data, for receiver input signal levels in the range from –20 dBm to the receiver sensitivity (as specified in 14.7.3.2), across the frequency band of operation.

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14.7.3.2 Receiver sensitivity

The sensitivity is defined as the minimum signal level required for an FER of 3% for PSDUs of 400 octets generated with pseudo-random data. The sensitivity shall be less than or equal to –75 dBm. The reference sensitivity is defined as –75 dBm for the 2 Mbit/s FH PHY specifications.

14.7.3.3 IMp

IMp is defined as the ratio to –77 dBm of the minimum amplitude of one of the two equal-level interfering signals at 4 MHz and 8 MHz removed from center frequency, both on the same side of center frequency, that cause the FER of the receiver to be increased to 3% for PSDUs of 400 octets generated with pseudo-random data, when the desired signal is –72 dBm (3 dB above the specified sensitivity specified in 14.7.3.2). Each interfering signal is modulated with the FH 1 Mbit/s PMD modulation uncorrelated in time to each other or the desired signal. The FHSS optional 2 Mbit/s rate IMp shall be ≥ 25 dB.

14.7.3.4 Dp

Dp is defined as the ratio to measured sensitivity of the minimum amplitude of an interfering signal that causes the FER of the receiver to be increased to 3% for PSDUs of 400 octets generated with pseudo-random data, when the desired signal is –72 dB (3 dB above sensitivity specified in 14.7.3.2). The interfering signal shall be modulated with the FHSS PMD modulation uncorrelated in time to the desired signal. The minimum Dp shall be as given in Table 52.

Table 52—2 Mbit/s Dp

Interferer frequency[a]	DP minimum
$M = N \pm 2$	20 dB
$M = N \pm 3$ or more	30 dB

[a]Where M is the interferer frequency and N is the desired channel frequency.

14.8 FHSS PHY MIB

14.8.1 FH PHY attributes

This subclause defines the attributes for the FHSS MIB. Table 53 lists these attributes and the default values. A description of each attribute is given in 14.8.2.

Table 53—FHSS PHY attributes

Attribute	Default value	Operational semantics	Operational behavior
dot11PHYType	FHSS = X'01'	Static	Identical for all FH PHYs
dot11RegDomainsSupported	FCC = X'10' IC = X'20' ETSI = X'30' Spain = X'31' France = X'32' MKK = X'40' Other = X'00'	Static	Implementation dependent
dot11CurrentRegDomain	X'00'	Dynamic LME	Implementation dependent

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Table 53—FHSS PHY attributes *(continued)*

Attribute	Default value	Operational semantics	Operational behavior
dot11TempType	Type 1 = X'01' Type 2 = X'02' Type 3 = X'03'	Static	Implementation dependent
dot11SupportedDataRatesTX	1 Mbit/s = X'02' mandatory 2 Mbit/s = X'04' optional	Static	Identical for all FH PHYs
dot11SupportedDataRatesRX	1 Mbit/s = X'02' mandatory 2 Mbit/s = X'04' optional	Static	Identical for all FH PHYs
dot11SupportedTxAntennas	Ant 1 = X'01' Ant 2 = X'02' Ant 3 = X'03' Ant n = n	Static	Implementation dependent
dot11CurrentTxAntenna	Ant 1 = default	Dynamic LME	Implementation dependent
dot11SupportedRxAntennas	Ant 1 = X'01' Ant 2 = X'02' Ant 3 = X'03' Ant n = n	Static	Implementation dependent
dot11DiversitySupport	Available = X'01' Not avail. = X'02' Control avail. = X'03'	Static	Implementation dependent
dot11DiversitySelectionRx	Ant 1 = X'01' Ant 2 = X'02' Ant 3 = X'03' Ant 4 = X'04' Ant 5 = X'05' Ant 6 = X'06' Ant 7 = X'07' Ant 8 = X'08'	Dynamic LME	Implementation dependent
dot11NumberSupportedPowerLevels	Lvl1 = X'01' Lvl2 = X'02' Lvl3 = X'03' Lvl4 = X'04' Lvl5 = X'05' Lvl6 = X'06' Lvl7 = X'07' Lvl8 = X'08'	Static	Implementation dependent
dot11TxPowerLevel1	Factory default	Static	Implementation dependent
dot11TxPowerLevel2	Factory default	Static	Implementation dependent
dot11TxPowerLevel3	Factory default	Static	Implementation dependent
dot11TxPowerLevel4	Factory def.	Static	Implementation dependent
dot11TxPowerLevel5	Factory def.	Static	Implementation dependent
dot11TxPowerLevel6	Factory def.	Static	Implementation dependent
dot11TxPowerLevel7	Factory def.	Static	Implementation dependent
dot11TxPowerLevel8	Factory def.	Static	Implementation dependent
dot11CurrentTxPowerLevel	TxPowerLevel1	Dynamic LME	Implementation dependent
dot11HopTime	224 μs	Static	Identical for all FH PHYs
dot11CurrentChannelNumber	X'00'	Dynamic PLME	
dot11MaxDwellTime	390 TU	Static	Regulatory domain dependent
dot11CurrentSet	X'00'	Dynamic PLME	
dot11CurrentPattern	X'00'	Dynamic PLME	
dot11CurrentIndex	X'00'	Dynamic PLME	

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Table 53—FHSS PHY attributes *(continued)*

Attribute	Default value	Operational semantics	Operational behavior
dot11CurrentPowerState	X'01' off X'02' on	Dynamic LME	
NOTE—The column titled "Operational semantics" contains two types: static and dynamic. Static MIB attributes are fixed and cannot be modified for a given PHY implementation. MIB attributes defined as dynamic can be modified by some management entity. When an attribute is defined as dynamic, the column also shows which entity has control over the attribute. LME refers to the MLME, while PHY refers to the PLME.			

14.8.2 FH PHY attribute definitions

14.8.2.1 dot11PHYType

The dot11PHYType is FHSS. The LME uses this attribute to determine what PLCP and PMD are providing services to the MAC. It also is used by the MAC to determine what MAC sublayer management state machines must be invoked to support the PHY. The value of this attribute is defined as the integer 01 to indicate the FHSS PHY.

14.8.2.2 dot11RegDomainsSupported

Operational requirements for FHSS PHY are defined by agencies representing certain geographical regulatory domains. These regulatory agencies may define limits on various parameters that differ from region to region. This parameters may include dot11TxPowerLevels, and dot11MaxDwellTime, as well as the total number of frequencies in the hopping pattern. The values shown in Table 54 indicate regulatory agencies supported by this document.

Table 54—Regulatory domain codes

Code point	Regulatory agency	Region
X'10'	FCC	United States
X'20'	IC	Canada
X'30'	ETSI	Most of Europe
X'31'	Spain	Spain
X'32'	France	France
X'40'	MKK	Japan

Because a PLCP and PMD might be designed to support operation in more than one regulatory domain, this attribute can actually represent a list of agencies. This list can be one or more of the above agencies and must be terminated using the null terminator. Upon activation of the PLCP and PMD, the information in this list must be used to set the value of the dot11CurrentRegDomain attribute.

14.8.2.3 dot11CurrentRegDomain

The dot11CurrentRegDomain attribute for the FHSS PHY is defined as the regulatory domain under which the PMD is currently operating. This value must be one of the values listed in the dot11RegDomainsSupported list. This MIB attribute is managed by the LME.

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14.8.2.4 dot11TempType

The parameter dot11TempType defines the temperature range supported by the PHY. Type 1 equipment (X'01') supports a temperature range of 0 °C to 40 °C. Type 2 equipment (X'02') supports a temperature range of –20 °C to +55 °C. Type 3 equipment (X'03') supports a temperature range of –30 °C to +70 °C.

14.8.2.5 dot11CurrentPowerState

The dot11CurrentPowerState attribute for the FHSS PHY allows the MLME to control the power state of the PHY. This attribute can be updated using the PLMESET.request. The permissible values are ON and OFF.

14.8.2.6 dot11SupportedDataRatesTX

The dot11SupportedDataRatesTX attribute for the FHSS PHY is defined as a null terminated list of supported data rates in the transmit mode for this implementation. Table 55 shows the possible values appearing in the list.

Table 55—Supported data rate codes (dot11SupportedDataRatesTX)

Code point	Data rate
X'02'	1 Mbit/s
X'04'	2 Mbit/s
X'00'	Null terminator

14.8.2.7 dot11SupportedDataRatesRX

The dot11SupportedDataRatesRX attribute for the FHSS PHY is defined as a null terminated list of supported data rates in the receive mode for this implementation. Table 56 shows the possible values appearing in the list.

Table 56—Supported data rate codes (dot11SupportedDataRatesRX)

Code point	Data rate
X'02'	1 Mbit/s
X'04'	2 Mbit/s
X'00'	Null terminator

14.8.2.8 aMPDUMaxLength

The aMPDUMaximumLength attribute for the FHSS PHY is defined as the maximum PSDU, in octets, that the PHY shall ever be capable of accepting. This value for the FHSS PHY is set at 4095 octets. The recommended value for maximum PSDU length in an FHSS PHY system is 400 octets at 1 Mbit/s and 800 octets at 2 Mbit/s, which corresponds to a frame duration less than 3.5 ms. These values are optimized to achieve high performance in a variety of RF channel conditions, particularly with respect to indoor multi-path, channel stability for moving STAs, and interference in the 2.4 GHz band.

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14.8.2.9 dot11SupportedTxAntennas

The dot11SupportedTxAntennas attribute for the FHSS PHY is defined as a null terminated list of antennas that this implementation can use to transmit data. Table 57 shows the possible values appearing in the list, where $N \leq 255$.

Table 57—Number of transmit antennas

Code point	Antenna number
X'01'	Tx Antenna 1
X'02'	Tx Antenna 2
X'03'	Tx Antenna 3
…	…
N	Tx Antenna *N*
X'00'	Null terminator

14.8.2.10 dot11CurrentTxAntenna

The dot11CurrentTxAntenna attribute for the FHSS PHY is used to describe the current antenna the implementation is using for transmission. This value should represent one of the antennas appearing in the dot11SupportedTxAntennas list.

14.8.2.11 dot11SupportedRxAntenna

The dot11SupportedRxAntennas attribute for the FHSS PHY is defined as a null terminated list of antennas that this implementation can use to receive data. In the FHSS PHY primitives, one of these values is passed as part of the PHY-RXSTART.indicate to the MAC sublayer for every received packet. Table 58 shows the possible values appearing in the list, where $N \leq 255$.

Table 58—Number of receive antennas

Code point	Antenna number
X'01'	Rx Antenna 1
X'02'	Rx Antenna 2
X'03'	Rx Antenna 3
…	…
N	Rx Antenna *N*
X'00'	Null terminator

14.8.2.12 dot11DiversitySupport

The dot11DiversitySupport attribute for the FHSS PHY is used to describe the implementation's diversity support. Table 59 shows the possible values appearing in the list.

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Table 59—Diversity support codes

Code point	Diversity support
X'01'	Diversity available
X'02'	No diversity
X'03'	Control available

The value X'01' indicates that this implementation uses two or more antennas for diversity. The value X'02' indicates that the implementation has no diversity support. The value X'03' indicates that the choice of antennas used during diversity is programmable. (See 14.8.2.13.)

14.8.2.13 dot11DiversitySelectionRx

The dot11DiversitySelectionRx attribute for the FHSS PHY is a null terminated list describing the receive antenna or antennas currently in use during diversity and packet reception. Table 60 shows the possible values appearing in the list, where $N \leq 255$.

Table 60—Diversity select antenna codes

Code point	Antenna number
X'01'	Rx Antenna 1
X'02'	Rx Antenna 2
X'03'	Rx Antenna 3
…	…
N	Rx Antenna *N*
X'00'	Null terminator

The null terminated list can consist of one or more of the receive antennas listed in the dot11SupportedRxAntennas attribute. This attribute can be changed dynamically by the LME.

14.8.2.14 dot11NumberSupportedPowerLevels

The dot11NumberSupportedPowerLevels attribute for the FHSS PHY describes the number of power levels this implementation supports. This attribute can be an integer of value 1 through 8, inclusive.

14.8.2.15 dot11TxPowerLevel1-8

Some implementations may provide up to eight different transmit power levels. The dot11TxPowerLevels attribute for the FHSS PHY is a list of up to eight power levels supported. Table 61 describes the list.

14.8.2.16 dot11CurrentTxPowerLevel

The dot11CurrentTxPowerLevel attribute for the FHSS PHY is defined as the current transmit output power level. This level shall be one of the levels implemented in the list of attributes called dot11TxPowerLevel*N* (where *N* is 1–8). This MIB attribute is also used to define the sensitivity of the CCA mechanism when the output power exceeds 100 mW. This MIB attribute is managed by the LME.

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Table 61—Transmit power levels

Attribute	Power level
TxPowerLevel1	Default setting
TxPowerLevel2	Level 2
TxPowerLevel3	Level 3
TxPowerLevel4	Level 4
TxPowerLevel5	Level 5
TxPowerLevel6	Level 6
TxPowerLevel7	Level 7
TxPowerLevel8	Level 8

14.8.2.17 dot11HopTime

The dot11HopTime attribute for the FHSS PHY describes the time allocated for the PHY to change to a new frequency. For the FHSS PHY, this time period is 224 μs.

14.8.2.18 dot11CurrentChannelNumber

The dot11CurrentChannelNumber attribute for the FHSS PHY is defined as the current operating channel number of the PMD. The values of this attribute correspond to the values shown in Table 42. This MIB attribute is managed by the PLME and is updated as the result of a PLMESET.request to dot11CurrentSet, dot11CurrentPattern, or dot11CurrentIndex.

14.8.2.19 dot11MaxDwellTime

The dot11MaxDwellTime attribute for the FHSS PHY is defined as the maximum time the PMD can dwell on a channel and meet the requirements of the current regulatory domain. For the FCC regulatory domain, this number is 390 TU (FCC = 400 ms). The recommended dwell time for the FHSS PHY is 19 TU.

14.8.2.20 dot11CurrentSet

The FHSS PHY contains three sets of hopping patterns. The dot11CurrentSet attribute for the FHSS PHY defines what set the STA is using to determine the hopping pattern. Its value can be 1, 2, or 3. This attribute is managed by the PLME. When dot11MultiDomainOperationImplemented is true, this value may also be 0. A value of 0 indicates that the hopping pattern is to be obtained from the Hopping Pattern Table information element most recently received in a beacon or Probe Response frame.

14.8.2.21 dot11CurrentPattern

There are up to 78 patterns in each hopping set used by the FHSS PHY. The dot11CurrentPattern attribute for the FHSS PHY defines the *x* value used in Equation (5) in 14.6.8 to calculate the current channel number. Its value has various ranges, always within the overall range of 0 to 77, depending on the dot11CurrentRegDomain. This attribute is managed by the PLME.

14.8.2.22 dot11CurrentIndex

The FHSS PHY addresses each channel in the selected hopping pattern through an index. The dot11CurrentIndex attribute for the FHSS PHY defines the *i* value used in the equation for $f_x(i)$ in 14.6.8 to

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calculate the current channel number. Its value has various ranges, always within the overall range of 1 to 79, depending on the dot11CurrentRegDomain. This attribute is managed by the PLME.

14.8.2.23 dot11CurrentPowerState

The parameter dot11CurrentPowerState defines the operational state of the FHSS PHY. When this attribute has a value of X'01', the PHY is "OFF." When this attribute has a value of X'02', the PHY is "ON." This attribute is managed by the PLME.

14.9 FH PHY characteristics

Table 62 gives the static FH PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive. The definitions of these characteristics are in 10.4.3.

Table 62—FH PHY characteristics

Characteristic	Value	Notes
aSlotTime	50 μs	—
aSIFSTime	28 μs	In order to account for variations between implementations, this value has a tolerance as specified in 9.2.3.1.
aCCATime	27 μs	This period includes the aRxRFDelay and the aRxPLCPDelay.
aRxTxTurnaroundTime	20 μs	—
aTxPLCPDelay	1 μs	Implementers may choose to increase or decrease this delay as long as the requirements of aRxTxTurnaroundTime are met.
aRxPLCPDelay	2 μs	Implementers may choose to increase or decrease this delay as long as the requirements of aSIFSTime and aCCATime are met.
aRxTxSwitchTime	10 μs	Implementers may choose to increase or decrease this delay as long as the requirements of aRxTxTurnaroundTime are met.
aTxRampOnTime	8 μs	Implementers may choose to increase or decrease this delay as long as the requirements of aRxTxTurnaroundTime are met.
aTxRampOffTime	8 μs	—
aTxRFDelay	1 μs	Implementers may choose to increase or decrease this delay as long as the requirements of aRxTxTurnaroundTime are met.
aRxRFDelay	4 μs	Implementers may choose to increase or decrease this delay as long as the requirements of aSIFSTime and aCCATime are met.
aAirPropagationTime	1 μs	Variations in the actual propagation time are accounted for in the allowable range of aSIFSTime.
aMACProcessingDelay	2 μs	Implementers may choose to increase or decrease this delay as long as the requirements of aSIFSTime are met.
aPreambleLength	96 μs	—
aPLCPHeaderLength	32 μs	—
aMPDUDurationFactor	31250000	This factor is calculated as $[(33/32) - 1] \times 10^9$ to account for the expansion due to the data whitener encoding algorithm.

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Table 62—FH PHY characteristics *(continued)*

Characteristic	Value	Notes
aMPDUMaxLength	4095	The recommended value for maximum PSDU length in an FHSS PHY system is 400 octets at 1 Mbit/s and 800 octets at 2 Mbit/s, which corresponds to a frame duration less than 3.5 ms. These values are optimized to achieve high performance in a variety of RF channel conditions, particularly with respect to indoor multipath, channel stability for moving STAs, and interference in the 2.4 GHz band.
aCWmin	15	—
aCWmax	1023	—

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15. DSSS PHY specification for the 2.4 GHz band designated for ISM applications

15.1 Overview

The PHY for the DSSS system is described in this clause. The RF LAN system is initially aimed for the 2.4 GHz band designated for ISM applications as provided in the United States according to Section 15.247 of FCC CFR47 [B6], in Europe by ETS 300-328 [B4], and in other countries according to 15.4.6.2.

The DSSS system provides a wireless LAN with both a 1 Mbit/s and a 2 Mbit/s data payload communication capability. According to the FCC regulations, the DSSS system shall provide a processing gain of at least 10 dB. This shall be accomplished by chipping the baseband signal at 11 MHz with an 11-chip pseudonoise (PN) code. The DSSS system uses baseband modulations of differential binary phase shift keying (DBPSK) and differential quadrature phase shift keying (DQPSK) to provide the 1 Mbit/s and 2 Mbit/s data rates, respectively.

15.1.1 Scope

The PHY services provided to the IEEE 802.11 wireless LAN MAC by the 2.4 GHz DSSS system are described in this clause. The DSSS PHY consists of two protocol functions:

a) A PHY convergence function, which adapts the capabilities of the PMD system to the PHY service. This function shall be supported by the PLCP, which defines a method of mapping the IEEE 802.11 MPDUs into a framing format suitable for sending and receiving user data and management information between two or more STAs using the associated PMD system.
b) A PMD system, whose function defines the characteristics of, and method of transmitting and receiving data through, a WM between two or more STAs each using the DSSS system.

15.1.2 DSSS PHY functions

The 2.4 GHz DSSS PHY architecture is depicted in the reference model shown in Figure 11 (in 5.8). The DSSS PHY contains three functional entities: the PMD function, the PHY convergence function, and the layer management function. Each of these functions is described in detail in the following subclauses.

The DSSS PHY service shall be provided to the MAC through the PHY service primitives described in Clause 12.

15.1.2.1 PLCP sublayer

To allow the IEEE 802.11 MAC to operate with minimum dependence on the PMD sublayer, a PLCP sublayer is defined. This function simplifies the PHY service interface to the IEEE 802.11 MAC services.

15.1.2.2 PMD sublayer

The PMD sublayer provides a means to send and receive data between two or more STAs. This clause is concerned with the 2.4 GHz ISM bands using direct sequence modulation.

15.1.2.3 PLME

The PLME performs management of the local PHY functions in conjunction with the MLME.

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15.1.3 Service specification method and notation

The models represented by figures and state diagrams are intended to be illustrations of functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation; the actual method of implementation is left to the discretion of the IEEE 802.11 DSSS-PHY-compliant developer.

The service of a layer or sublayer is a set of capabilities that it offers to a user in the next-higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

15.2 DSSS PLCP sublayer

15.2.1 Overview

This clause provides a convergence procedure in which MPDUs are converted to and from PPDUs. During transmission, the MPDU shall be prepended with a PLCP Preamble and Header to create the PPDU. At the receiver, the PLCP Preamble and Header are processed to aid in demodulation and delivery of the MPDU.

15.2.2 PLCP frame format

Figure 90 shows the format for the PPDU including the DSSS PLCP Preamble, the DSSS PLCP Header, and the MPDU. The PLCP Preamble contains the following fields: SYNC and SFD. The PLCP Header contains the following fields: IEEE 802.11 Signaling (SIGNAL), IEEE 802.11 Service (SERVICE), length (LENGTH), and CRC-16 (CRC). Each of these fields is described in detail in 15.2.3.

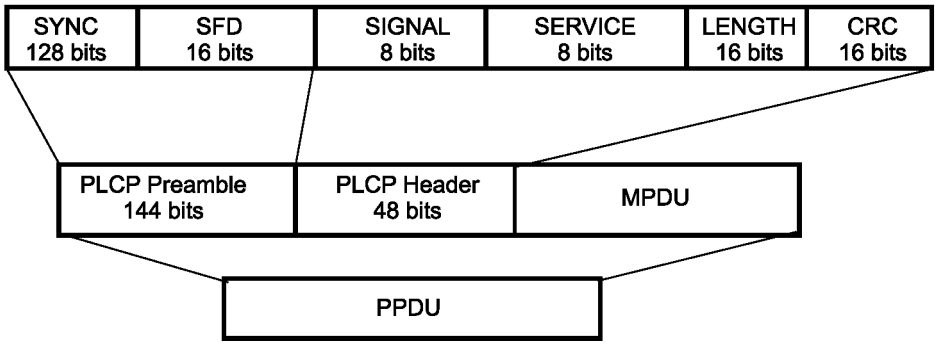

Figure 90—PLCP frame format

15.2.3 PLCP field definitions

The entire PLCP Preamble and Header shall be transmitted using the 1 Mbit/s DBPSK modulation described in 15.4.7. All transmitted bits shall be scrambled using the feedthrough scrambler described in 15.2.4.

15.2.3.1 PLCP SYNC field

The SYNC field shall consist of 128 bits of scrambled ones. This field shall be provided so that the receiver can perform the necessary operations for synchronization.

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15.2.3.2 PLCP SFD

The SFD shall be provided to indicate the start of PHY-dependent parameters within the PLCP Preamble. The SFD shall be a 16-bit field, X'F3A0' (MSB to LSB). The LSB shall be transmitted first in time.

15.2.3.3 PLCP IEEE 802.11 SIGNAL field

The 8-bit IEEE 802.11 SIGNAL field indicates to the PHY the modulation that shall be used for transmission (and reception) of the MPDU. The data rate shall be equal to the signal field value multiplied by 100 kbit/s. The DSSS PHY currently supports two mandatory modulation services given by the following 8-bit words, where the LSB shall be transmitted first in time:

a) X'0A' (MSB to LSB) for 1 Mbit/s DBPSK
b) X'14' (MSB to LSB) for 2 Mbit/s DQPSK

The DSSS PHY rate change capability is described in 15.2.5. This field shall be protected by the CRC-16 FCS described in 15.2.3.6.

15.2.3.4 PLCP IEEE 802.11 SERVICE field

The 8-bit IEEE 802.11 SERVICE field shall be reserved for future use. The value of X'00' signifies IEEE 802.11 device compliance. The LSB shall be transmitted first in time. This field shall be protected by the CRC-16 FCS described in 15.2.3.6.

15.2.3.5 PLCP LENGTH field

The PLCP LENGTH field shall be an unsigned 16-bit integer that indicates the number of microseconds (16 to 2^{16}–1 as defined by aMPDUMaxLength) required to transmit the MPDU. The transmitted value shall be determined from the LENGTH parameter in the TXVECTOR issued with the PHY-TXSTART.request primitive described in 12.3.5.4. The LENGTH field provided in the TXVECTOR is in bytes and is converted to microseconds for inclusion in the PLCP LENGTH field. The LSB shall be transmitted first in time. This field shall be protected by the CRC-16 FCS described in 15.2.3.6.

15.2.3.6 PLCP CRC field

The IEEE 802.11 SIGNAL, IEEE 802.11 SERVICE, and LENGTH fields shall be protected with a CRC-16 FCS. The CRC-16 FCS shall be the ones complement of the remainder generated by the modulo 2 division of the protected PLCP fields by the polynomial:

$$x^{16} + x^{12} + x^5 + 1$$

The protected bits shall be processed in transmit order. All FCS calculations shall be made prior to data scrambling.

As an example, the SIGNAL, SERVICE, and LENGTH fields for a DBPSK signal with a packet length of 192 μs (24 bytes) would be given by the following:

0101 0000 0000 0000 0000 0011 0000 0000 (leftmost bit transmitted first in time)

The ones complement FCS for these protected PLCP Preamble bits would be the following:

0101 1011 0101 0111 (leftmost bit transmitted first in time)

Figure 91 depicts this example.

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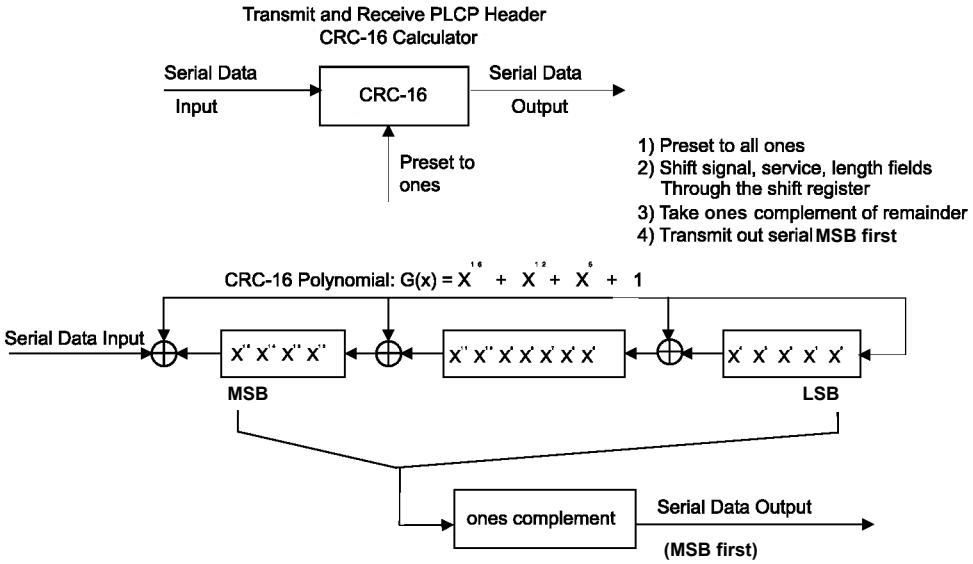

Figure 91—CRC-16 implementation

An illustrative example of the CRC-16 FCS using the information from Figure 91 follows in Figure 92.

Data	CRC registers MSB LSB	
	1111111111111111	; initialize preset to ones
0	1110111111011111	
1	1101111110111110	
0	1010111101011101	
1	0101111010111010	
0	1011110101110100	
0	0110101011001001	
0	1101010110010010	
0	1011101100000101	
0	0110011000101011	
0	1100110001010110	
0	1000100010001101	
0	0000000100111011	
0	0000001001110110	
0	0000010011101100	
0	0000100111011000	
0	0001001110110000	
0	0010011101100000	
0	0100111011000000	
0	1001110110000000	
0	0010101100100001	
0	0101011001000010	
0	1010110010000100	
1	0101100100001000	
1	1010001000110001	
0	0101010001000011	
0	1010100010000110	
0	0100000100101101	
0	1000001001011010	
0	0001010010010101	
0	0010100100101010	
0	0101001001010100	
0	1010010010101000	
	0101101101010111	; ones complement, result = CRC FCS parity

Figure 92—Example CRC calculation

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15.2.4 PLCP/DSSS PHY data scrambler and descrambler

The polynomial $G(z) = z^{-7} + z^{-4} + 1$ shall be used to scramble all bits transmitted by the DSSS PHY. The feedthrough configuration of the scrambler and descrambler is self-synchronizing, which requires no prior knowledge of the transmitter initialization of the scrambler for receive processing. Figure 93 and Figure 94 show typical implementations of the data scrambler and descrambler, but other implementations are possible.

The scrambler should be initialized to any state except all ones when transmitting.

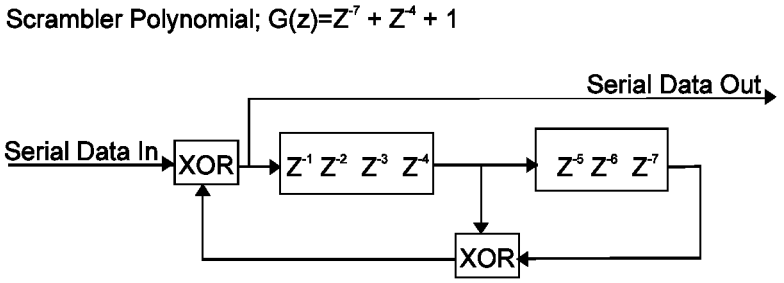

Figure 93—Data scrambler

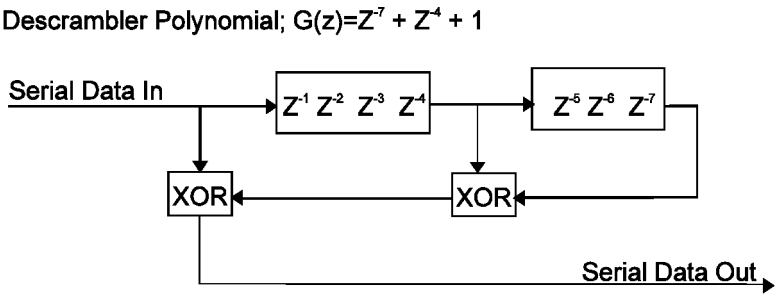

Figure 94—Data descrambler

15.2.5 PLCP data modulation and modulation rate change

The PLCP Preamble shall be transmitted using the 1 Mbit/s DBPSK modulation. The IEEE 802.11 SIGNAL field shall indicate the modulation that shall be used to transmit the MPDU. The transmitter and receiver shall initiate the modulation indicated by the IEEE 802.11 SIGNAL field starting with the first symbol (1 bit for DBPSK or 2 bits for DQPSK) of the MPDU. The MPDU transmission rate shall be set by the DATA-RATE parameter in the TXVECTOR issued with the PHY-TXSTART.request primitive described in 15.4.4.1.

15.2.6 Transmit PLCP

The transmit PLCP is shown in Figure 95.

In order to transmit data, PHY-TXSTART.request shall be enabled so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate channel through station management via the PLME. Other transmit parameters such as DATARATE, TX antenna, and TX power are set via the PHY-SAP with the PHY-TXSTART.request(TXVECTOR) as described in 15.4.4.2.

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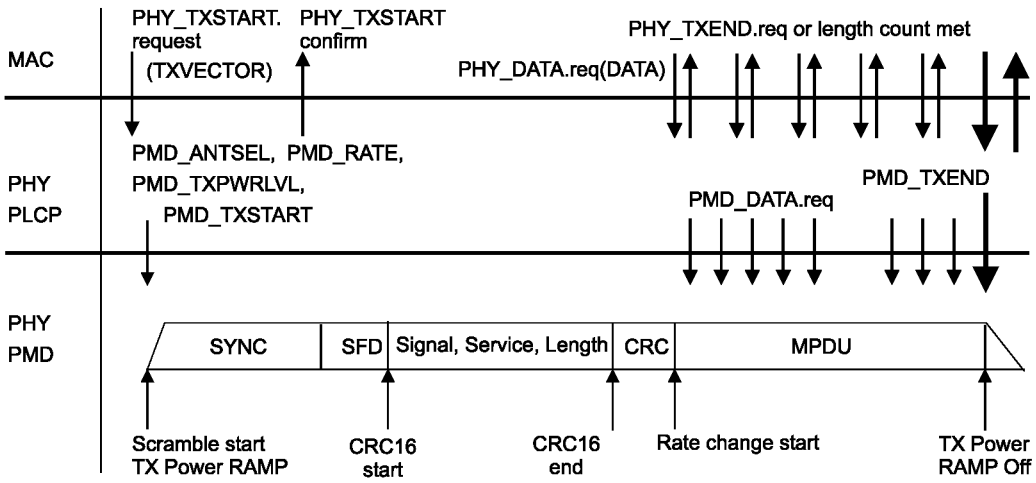

Figure 95—Transmit PLCP

Based on the status of CCA indicated by PHY-CCA.indicate, the MAC will assess that the channel is clear. A clear channel shall be indicated by PHY-CCA.indicate(IDLE). If the channel is clear, transmission of the PPDU shall be initiated by issuing the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR elements for the PHY-TXSTART.request are the PLCP Header parameters SIGNAL (DATARATE), SERVICE, and LENGTH, and the PMD parameters of TX_ANTENNA and TXPWR_LEVEL. The PLCP Header parameter LENGTH is calculated from the TXVECTOR element by multiplying by 8 for 1 Mbit/s and by 4 for 2 Mbit/s.

The PLCP shall issue PMD_ANTSEL, PMD_RATE, and PMD_TXPWRLVL primitives to configure the PHY. The PLCP shall then issue a PMD_TXSTART.request and the PHY entity shall immediately initiate data scrambling and transmission of the PLCP Preamble based on the parameters passed in the PHY-TXSTART.request primitive. The time required for transmit power-on ramp described in 15.4.7.7 shall be included in the PLCP SYNC field. Once the PLCP Preamble transmission is complete, data shall be exchanged between the MAC and the PHY by a series of PHY-DATA.request(DATA) primitives issued by the MAC and PHY-DATA.confirm primitives issued by the PHY. The modulation rate change, if any, shall be initiated with the first data symbol of the MPDU as described in 15.2.5. The PHY proceeds with MPDU transmission through a series of data octet transfers from the MAC. At the PMD layer, the data octets are sent in LSB-to-MSB order and presented to the PHY through PMD_DATA.request primitives. Transmission can be prematurely terminated by the MAC through the primitive PHY-TXEND.request. PHY-TXSTART shall be disabled by the issuance of the PHY-TXEND.request. Normal termination occurs after the transmission of the final bit of the last MPDU octet according to the number supplied in the DSSS PHY preamble LENGTH field. The packet transmission shall be completed and the PHY entity shall enter the receive state (i.e., PHY-TXSTART shall be disabled). It is recommended that chipping continue during power-down. Each PHY-TXEND.request is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

A typical state machine implementation of the transmit PLCP is provided in Figure 96.

15.2.7 Receive PLCP

The receive PLCP is shown in Figure 97.

In order to receive data, PHY-TXSTART.request shall be disabled so that the PHY entity is in the receive state. Further, through station management via the PLME, the PHY is set to the appropriate channel and the CCA method is chosen. Other receive parameters such as RSSI, signal quality (SQ), and indicated DATARATE may be accessed via the PHY-SAP.

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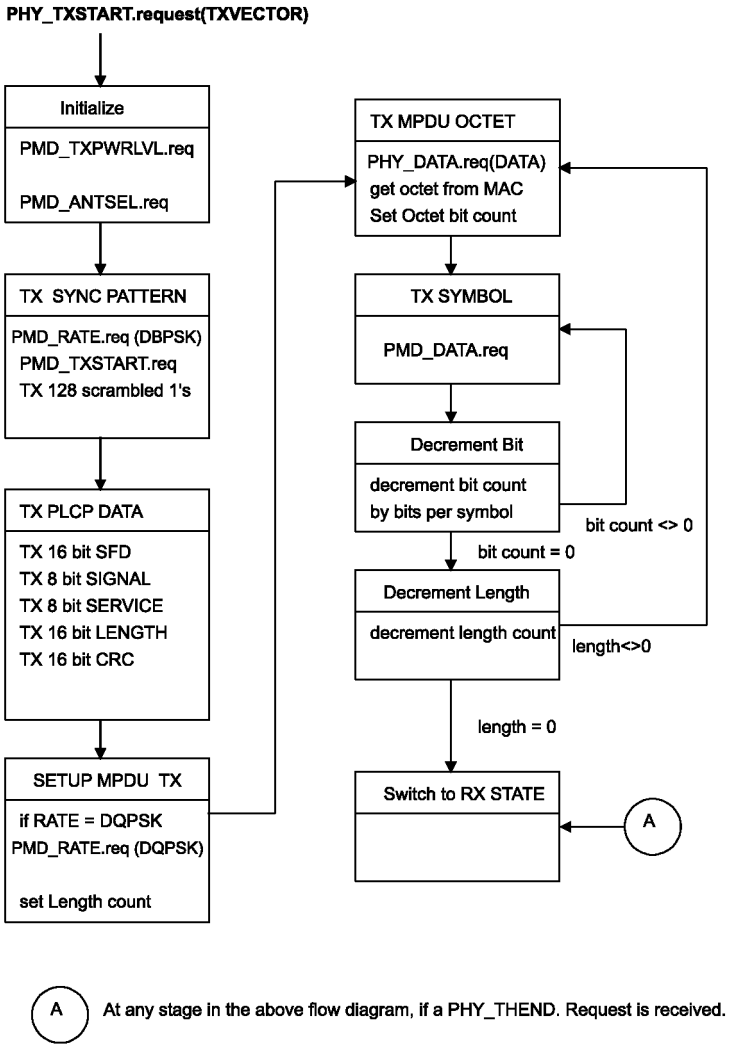

Figure 96—PLCP transmit state machine

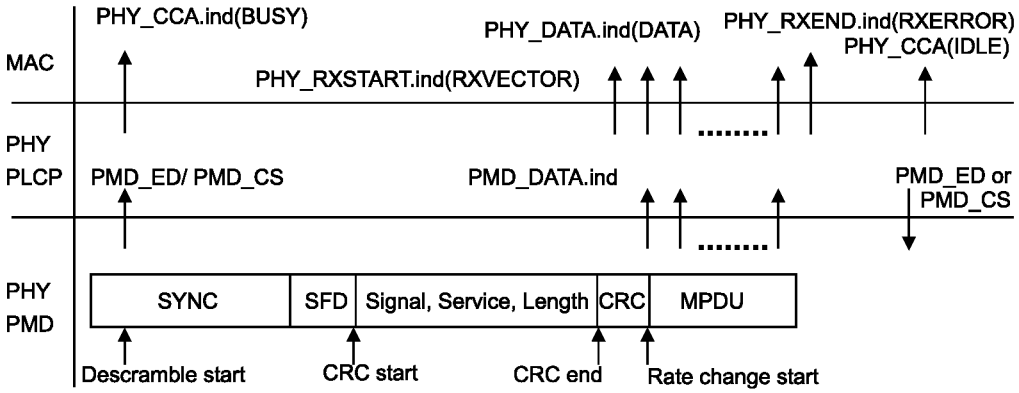

Figure 97—Receive PLCP

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Upon receiving the transmitted energy, according to the selected CCA mode, the PMD_ED shall be enabled (according to 15.4.8.4) as the RSSI reaches the ED_THRESHOLD and/or PMD_CS shall be enabled after code lock is established. These conditions are used to indicate activity to the MAC via PHY-CCA.indicate according to 15.4.8.4. PHY-CCA.indicate(BUSY) shall be issued for energy detection (ED) and/or code lock prior to correct reception of the PLCP frame. The PMD primitives PMD_SQ and PMD_RSSI are issued to update the RSSI and SQ parameters reported to the MAC.

After PHY-CCA.indicate is issued, the PHY entity shall begin searching for the SFD field. Once the SFD field is detected, CRC-16 processing shall be initiated and the PLCP IEEE 802.11 SIGNAL, IEEE 802.11 SERVICE and LENGTH fields are received. The CRC-16 FCS shall be processed. If the CRC-16 FCS check fails, the PHY receiver shall return to the RX IDLE state as depicted in Figure 98. Should the status of CCA return to the IDLE state during reception prior to completion of the full PLCP processing, the PHY receiver shall return to the RX IDLE state.

If the PLCP Header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY-RXSTART.indicate(RXVECTOR) shall be issued. The RXVECTOR associated with this primitive includes the SIGNAL field, the SERVICE field, the MPDU length in bytes (calculated from the LENGTH field in microseconds), the antenna used for receive (RX_ANTENNA), RSSI, and SQ.

The received MPDU bits are assembled into octets and presented to the MAC using a series of PHY-DATA.indicate(DATA) primitive exchanges. The rate change indicated in the IEEE 802.11 SIGNAL field shall be initiated with the first symbol of the MPDU as described in 15.2.5. The PHY proceeds with MPDU reception. After the reception of the final bit of the last MPDU octet indicated by the PLCP Preamble LENGTH field, the receiver shall be returned to the RX IDLE state as shown in Figure 98. A PHY-RXEND.indicate(NoError) primitive shall be issued. A PHY-CCA.indicate(IDLE) primitive shall be issued following a change in PHY carrier sense (PHYCS) and/or PHY energy detection (PHYED) according to the selected CCA method.

In the event that a change in PHYCS or PHYED would cause the status of CCA to return to the IDLE state before the complete reception of the MPDU as indicated by the PLCP LENGTH field, the error condition PHY-RXEND.indicate(CarrierLost) shall be reported to the MAC. The DSSS PHY will ensure that the CCA will indicate a busy medium for the intended duration of the transmitted packet.

If the PLCP Header is successful, but the indicated rate in the SIGNAL field is not receivable, a PHY-RXSTART.indicate will not be issued. The PHY shall issue the error condition PHY-RXEND.indicate(UnsupportedRate). If the PLCP Header is successful, but the SERVICE field is out of IEEE 802.11 DSSS specification, a PHY-RXSTART.indicate will not be issued. The PHY shall issue the error condition PHY-RXEND.indicate(FormatViolation). Also, in both cases, the DSSS PHY will ensure that the CCA shall indicate a busy medium for the intended duration of the transmitted frame as indicated by the LENGTH field. The intended duration is indicated by the LENGTH field (length $\times 1$ μs).

A typical state machine implementation of the receive PLCP is provided in Figure 98.

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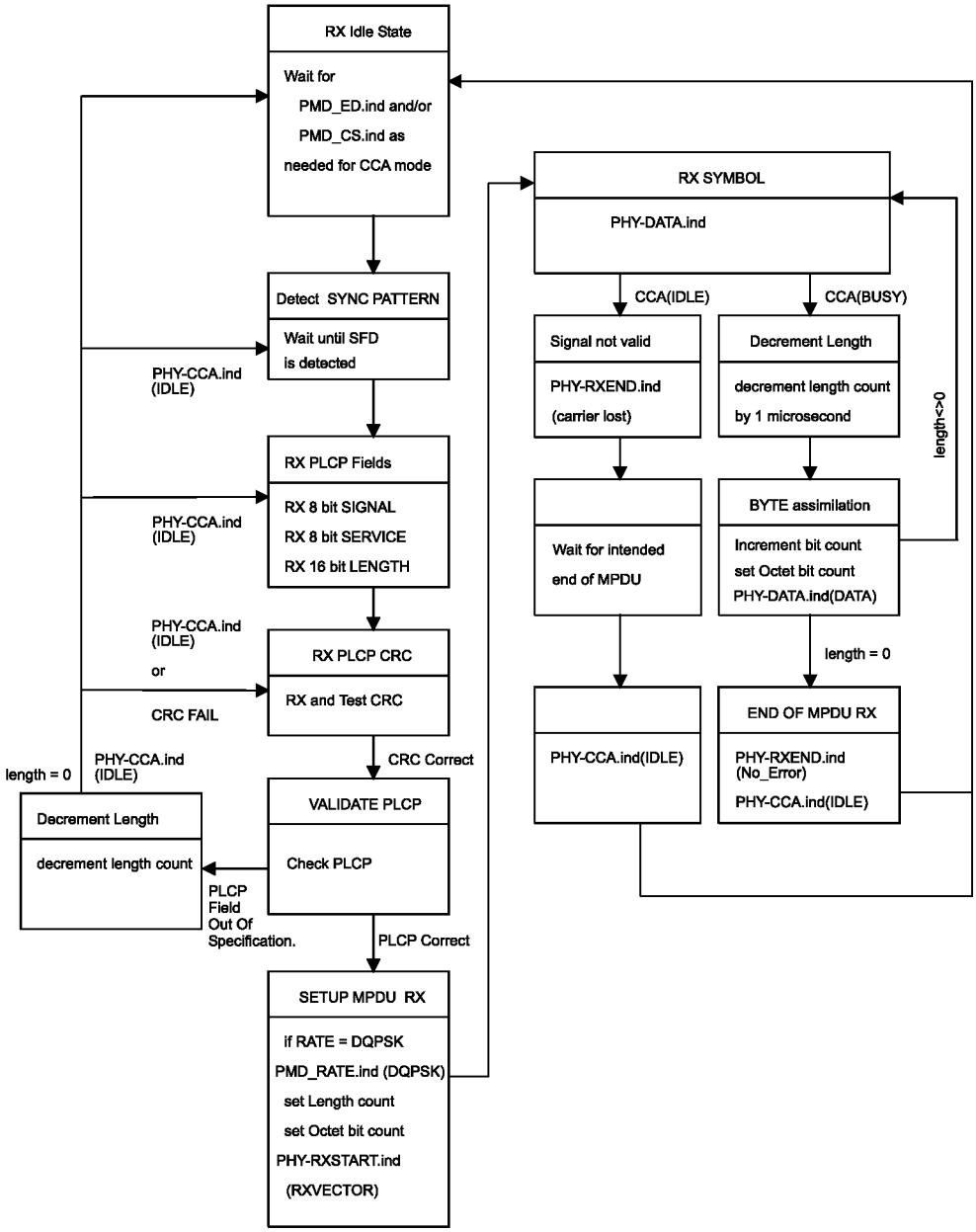

Figure 98—PLCP receive state machine

15.3 DSSS PLME

15.3.1 PLME_SAP sublayer management primitives

Table 63 lists the MIB attributes that may be accessed by the PHY entities and intralayer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, and PLME-RESET primitives defined in Clause 10.

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15.3.2 DSSS PHY MIB

All DSSS PHY MIB attributes are defined in Clause 12, with specific values defined in Table 63.

Table 63—MIB attribute default values/ranges

Managed object	Default value/range	Operational semantics
dot11PhyOperationComplianceGroup		
dot11PHYdot11TempType	DSSS–2.4 (02)	Static
dot11TempType	Implementation dependent	Static
dot11RegDomainsSupported	Implementation dependent	Static
dot11CurrentRegDomain	Implementation dependent	Static
dot11PhyRateGroup		
dot11SupportedDataRatesTx	X'02', X'04'	Static
dot11SupportedDataRatesRx	X'02', X'04'	Static
dot11PhyAntennaComplianceGroup		
dot11CurrentTxAntenna	Implementation dependent	Dynamic
dot11DiversitySupport	Implementation dependent	Static
dot11CurrentRxAntenna	Implementation dependent	Dynamic
dot11PhyTxPowerComplianceGroup		
dot11NumberSupportedPowerLevels	Implementation dependent	Static
dot11TxPowerLevel1	Implementation dependent	Static
dot11TxPowerLevel2	Implementation dependent	Static
dot11TxPowerLevel3	Implementation dependent	Static
dot11TxPowerLevel4	Implementation dependent	Static
dot11TxPowerLevel5	Implementation dependent	Static
dot11TxPowerLevel6	Implementation dependent	Static
dot11TxPowerLevel7	implementation dependent	Static
dot11TxPowerLevel8	Implementation dependent	Static
dot11CurrentTxPowerLevel	Implementation dependent	Dynamic
dot11PhyDSSSComplianceGroup		
dot11CurrentChannel	Implementation dependent	Dynamic
dot11CCAModeSupported	Implementation dependent	Static
dot11CurrentCCAMode	Implementation dependent	Dynamic
dot11EDThreshold	Implementation dependent	Dynamic
dot11AntennasListGroup		
dot11SupportedTxAntenna	Implementation dependent	Static
dot11SupportedRxAntenna	Implementation dependent	Static
dot11DiversitySelectionRx	Implementation dependent	Dynamic
NOTE—The column titled “Operational semantics” contains two types: static and dynamic. Static MIB attributes are fixed and cannot be modified for a given PHY implementation. MIB attributes defined as dynamic can be modified by some management entities.		

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15.3.3 DS PHY characteristics

The static DS PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 64. The definitions of these characteristics are in 10.4.3.

Table 64—DS PHY characteristics

Characteristic	Value
aSlotTime	20 μs
aSIFSTime	10 μs
aCCATime	≤ 15 μs
aRxTxTurnaroundTime	≤ 5 μs
aTxPLCPDelay	Implementers may choose any value for this delay as long as the requirements of aRxTxTurnaroundTime are met.
aRxPLCPDelay	Implementers may choose any value for this delay as long as the requirements of aSIFSTime and aCCATime are met.
aRxTxSwitchTime	≤ 5 μs
aTxRampOnTime	Implementers may choose any value for this delay as long as the requirements of aRxTxTurnaroundTime are met.
aTxRampOffTime	Implementers may choose any value for this delay as long as the requirements of aSIFSTime are met.
aTxRFDelay	Implementers may choose any value for this delay as long as the requirements of aRxTxTurnaroundTime are met.
aRxRFDelay	Implementers may choose any value for this delay as long as the requirements of aSIFSTime and aCCATime are met.
aAirPropagationTime	1 μs
aMACProcessingDelay	0 (N/A)
aPreambleLength	144 μs
aPLCPHeaderLength	48 μs
aMPDUDurationFactor	0
aMPDUMaxLength	$4 \le x \le (2^{13} - 1)$
aCWmin	31
aCWmax	1023

15.4 DSSS PMD sublayer

15.4.1 Scope and field of application

This subclause describes the PMD services provided to the PLCP for the DSSS PHY. Also defined in this subclause are the functional, electrical, and RF characteristics required for interoperability of implementations conforming to this standard. The relationship of this standard to the entire DSSS PHY is shown in Figure 99.

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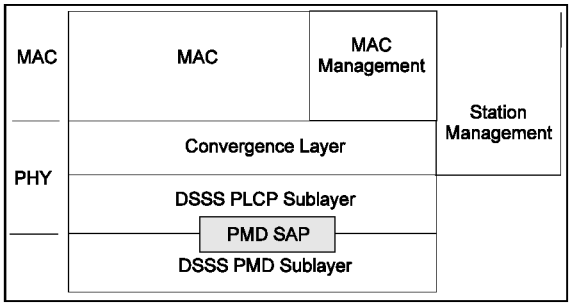

Figure 99—PMD layer reference model

15.4.2 Overview of service

The DSSS PMD sublayer accepts PLCP sublayer service primitives and provides the actual means by which data shall be transmitted or received from the medium. The combined function of DSSS PMD sublayer primitives and parameters for the receive function results in a data stream, timing information, and associated receive signal parameters being delivered to the PLCP sublayer. A similar functionality shall be provided for data transmission.

15.4.3 Overview of interactions

The primitives associated with the IEEE 802.11 PLCP sublayer to the DSSS PMD fall into two basic categories:

a) Service primitives that support PLCP peer-to-peer interactions, and
b) Service primitives that have local significance and that support sublayer-to-sublayer interactions.

15.4.4 Basic service and options

All of the service primitives described in this clause are considered mandatory unless otherwise specified.

15.4.4.1 PMD_SAP peer-to-peer service primitives

Table 65 indicates the primitives for peer-to-peer interactions.

Table 65—PMD_SAP peer-to-peer service primitives

Primitive	Request	Indicate	Confirm	Response
PHY-RXSTART		X		—
PHY-RXEND		X		—
PHY-CCA		X		—
PHY-TXSTART	X		X	—
PHY-TXEND	X		X	—
PHY-DATA	X	X	X	—

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15.4.4.2 PMD_SAP peer-to-peer service primitive parameters

Several service primitives include a parameter vector. This vector shall be a list of parameters that may vary depending on PHY type. Table 66 indicates the parameters required by the MAC or DSSS PHY in each of the parameter vectors used for peer-to-peer interactions.

Table 66—DSSS PMD_SAP peer-to-peer service primitives

Parameter	Associated primitive	Value
LENGTH	RXVECTOR, TXVECTOR	0 to $2^{13} - 1$
DATARATE	RXVECTOR, TXVECTOR	1, 2 Mbit/s
SERVICE	RXVECTOR, TXVECTOR	1, 2 Mbit/s
TXPWR_LEVEL	TXVECTOR	1, 2 Mbit/s
TX_ANTENNA	TXVECTOR	1, 2 Mbit/s
RSSI	RXVECTOR	1, 2 Mbit/s
SQ	RXVECTOR	1, 2 Mbit/s
RX_ANTENNA	RXVECTOR	1, 2 Mbit/s

15.4.4.3 PMD_SAP sublayer-to-sublayer service primitives

Table 67 indicates the primitives for sublayer-to-sublayer interactions.

Table 67—PMD_SAP sublayer-to-sublayer service primitives

Primitive	Request	Indicate	Confirm	Response
PMD_TXSTART	X		—	—
PMD_TXEND	X		—	—
PMD_ANTSEL	X	X	—	—
PMD_TXPWRLVL	X		—	—
PMD_RATE	X	X	—	—
PMD_RSSI		X	—	—
PMD_SQ		X	—	—
PMD_CS		X	—	—
PMD_ED	X	X	—	—

15.4.4.4 PMD_SAP service primitive parameters

Table 68 indicates the parameters for the PMD primitives.

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Table 68—List of parameters for the PMD primitives

Parameter	Associate primitive	Value
DATA	PHY-DATA.request PHY-DATA.indicate	Octet value: X'00'–X'FF'
TXVECTOR	PHY-DATA.request	A set of parameters
RXVECTOR	PHY-DATA.indicate	A set of parameters
TXD_UNIT	PMD_DATA.request	1, 0: DBPSK dibit combinations 00,01,11,10: DQPSK
RXD_UNIT	PMD_DATA.indicate	1, 0: DBPSK dibit combinations 00,01,11,10: DQPSK
RF_STATE	PMD_TXE.request	Receive, Transmit
ANT_STATE	PMD_ANTSEL.indicate PMD_ANTSEL.request	1 to 256
TXPWR_LEVEL	PHY-TXSTART	0, 1, 2, 3 (max of 4 levels)
RATE	PMD_RATE.indicate PMD_RATE.request	X'0A' for 1 Mbit/s DBPSK X'14' for 2 Mbit/s DQPSK
RSSI	PMD_RSSI.indicate	0–8 bits of RSSI
SQ	PMD_SQ.indicate	0–8 bits of SQ

15.4.5 PMD_SAP detailed service specification

The services provided by each PMD primitive are described in 15.4.5.1 through 15.4.5.15.

15.4.5.1 PMD_DATA.request

15.4.5.1.1 Function

This primitive defines the transfer of data from the PLCP sublayer to the PMD entity.

15.4.5.1.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_DATA.request(TXD_UNIT)

The TXD_UNIT parameter takes on the value of either 1 or 0 for DBPSK modulation or the dibit combination 00, 01, 11, or 10 for DQPSK modulation. This parameter represents a single block of data, which, in turn, shall be used by the PHY to be differentially encoded into a DBPSK or DQPSK transmitted symbol. The symbol itself shall be spread by the PN code prior to transmission.

15.4.5.1.3 When generated

This primitive shall be generated by the PLCP sublayer to request transmission of a symbol. The data clock for this primitive shall be supplied by the PMD layer based on the PN code repetition.

15.4.5.1.4 Effect of receipt

The PMD performs the differential encoding, PN code modulation, and transmission of the data.

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15.4.5.2 PMD_DATA.indicate

15.4.5.2.1 Function

This primitive defines the transfer of data from the PMD entity to the PLCP sublayer.

15.4.5.2.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_DATA.indicate(RXD_UNIT)

The RXD_UNIT parameter takes on the value of 1 or 0 for DBPSK modulation or as the dibit 00, 01, 11, or 10 for DQPSK modulation. This parameter represents a single symbol that has been demodulated by the PMD entity.

15.4.5.2.3 When generated

This primitive, which is generated by the PMD entity, forwards received data to the PLCP sublayer. The data clock for this primitive shall be supplied by the PMD layer based on the PN code repetition.

15.4.5.2.4 Effect of receipt

The PLCP sublayer either interprets the bit or bits that are recovered as part of the PLCP or passes the data to the MAC sublayer as part of the MPDU.

15.4.5.3 PMD_TXSTART.request

15.4.5.3.1 Function

This primitive, which is generated by the PHY PLCP sublayer, initiates PPDU transmission by the PMD layer.

15.4.5.3.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_TXSTART.request

15.4.5.3.3 When generated

This primitive shall be generated by the PLCP sublayer to initiate the PMD layer transmission of the PPDU. The PHY-DATA.request primitive shall be provided to the PLCP sublayer prior to issuing the PMD_TXSTART command.

15.4.5.3.4 Effect of receipt

PMD_TXSTART initiates transmission of a PPDU by the PMD sublayer.

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15.4.5.4 PMD_TXEND.request

15.4.5.4.1 Function

This primitive, which is generated by the PHY PLCP sublayer, ends PPDU transmission by the PMD layer.

15.4.5.4.2 Semantics of the service primitive

The semantics of the primitive are as follows:

PMD_TXEND.request

15.4.5.4.3 When generated

This primitive shall be generated by the PLCP sublayer to terminate the PMD layer transmission of the PPDU.

15.4.5.4.4 Effect of receipt

PMD_TXEND terminates transmission of a PPDU by the PMD sublayer.

15.4.5.5 PMD_ANTSEL.request

15.4.5.5.1 Function

This primitive, which is generated by the PHY PLCP sublayer, selects the antenna used by the PHY for transmission or reception (when diversity is disabled).

15.4.5.5.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_ANTSEL.request(ANT_STATE)

ANT_STATE selects which of the available antennas should be used for transmit. The number of available antennas shall be determined from the MIB table parameters aSuprtRxAntennas and aSuprtTxAntennas.

15.4.5.5.3 When generated

This primitive shall be generated by the PLCP sublayer to select a specific antenna for transmission or reception (when diversity is disabled).

15.4.5.5.4 Effect of receipt

PMD_ANTSEL immediately selects the antenna specified by ANT_STATE.

15.4.5.6 PMD_ANTSEL.indicate

15.4.5.6.1 Function

This primitive, which is generated by the PHY PLCP sublayer, reports the antenna used by the PHY for reception of the most recent packet.

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15.4.5.6.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_ANTSEL.indicate(ANT_STATE)

ANT_STATE reports which of the available antennas was used for reception of the most recent packet.

15.4.5.6.3 When generated

This primitive shall be generated by the PLCP sublayer to report the antenna used for the most recent packet reception.

15.4.5.6.4 Effect of receipt

PMD_ANTSEL immediately reports the antenna specified by ANT_STATE.

15.4.5.7 PMD_TXPWRLVL.request

15.4.5.7.1 Function

This primitive, which is generated by the PHY PLCP sublayer, selects the power level used by the PHY for transmission.

15.4.5.7.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_TXPWRLVL.request(TXPWR_LEVEL)

TXPWR_LEVEL selects which of the optional transmit power levels should be used for the current packet transmission. The number of available power levels shall be determined by the MIB parameter dot11NumberSupportedPowerLevels. See 15.4.7.3 for further information on the optional DSSS PHY power-level-control capabilities.

15.4.5.7.3 When generated

This primitive shall be generated by the PLCP sublayer to select a specific transmit power. This primitive shall be applied prior to setting PMD_TXSTART to the transmit state.

15.4.5.7.4 Effect of receipt

PMD_TXPWRLVL immediately sets the transmit power level given by TXPWR_LEVEL.

15.4.5.8 PMD_RATE.request

15.4.5.8.1 Function

This primitive, which is generated by the PHY PLCP sublayer, selects the modulation rate that shall be used by the DSSS PHY for transmission.

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15.4.5.8.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_RATE.request(RATE)

The RATE parameter selects which of the DSSS PHY data rates shall be used for MPDU transmission. Subclause 15.4.6.4 provides further information on the DSSS PHY modulation rates. The DSSS PHY rate change capability is fully described in 15.2.

15.4.5.8.3 When generated

This primitive shall be generated by the PLCP sublayer to change or set the current DSSS PHY modulation rate used for the MPDU portion of a PPDU.

15.4.5.8.4 Effect of receipt

The receipt of PMD_RATE selects the rate that shall be used for all subsequent MPDU transmissions. This rate shall be used for transmission only. The DSSS PHY shall still be capable of receiving all the required DSSS PHY modulation rates.

15.4.5.9 PMD_RATE.indicate

15.4.5.9.1 Function

This primitive, which is generated by the PMD sublayer, indicates which modulation rate was used to receive the MPDU portion of the PPDU. The modulation shall be indicated in the PSF.

15.4.5.9.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_RATE.indicate(RATE)

In receive mode, the RATE parameter informs the PLCP layer which of the DSSS PHY data rates was used to process the MPDU portion of the PPDU. Subclause 15.4.6.4 provides further information on the DSSS PHY modulation rates. The DSSS PHY rate change capability is fully described in 15.2.

15.4.5.9.3 When generated

This primitive shall be generated by the PMD sublayer when the PSF has been properly detected.

15.4.5.9.4 Effect of receipt

This parameter shall be provided to the PLCP layer for information only.

15.4.5.10 PMD_RSSI.indicate

15.4.5.10.1 Function

This optional primitive, which is generated by the PMD sublayer, provides to the PLCP and MAC entity the receive signal strength.

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15.4.5.10.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_RSSI.indicate(RSSI)

The RSSI shall be a measure of the RF energy received by the DSSS PHY. RSSI indications of up to 8 bits (256 levels) are supported.

15.4.5.10.3 When generated

This primitive shall be generated by the PMD when the DSSS PHY is in the receive state. It shall be continuously available to the PLCP, which, in turn, provides the parameter to the MAC entity.

15.4.5.10.4 Effect of receipt

This parameter shall be provided to the PLCP layer for information only. The RSSI may be used in conjunction with SQ as part of a CCA scheme.

15.4.5.11 PMD_SQ.indicate

15.4.5.11.1 Function

This optional primitive, which is generated by the PMD sublayer, provides to the PLCP and MAC entity the SQ of the DSSS PHY PN code correlation. The SQ shall be sampled when the DSSS PHY achieves code lock and shall be held until the next code lock acquisition.

15.4.5.11.2 Semantics of the service primitive

The primitive shall provide the following parameter:

PMD_SQ.indicate(SQ)

The SQ shall be a measure of the PN code correlation quality received by the DSSS PHY. SQ indications of up to 8 bits (256 levels) are supported.

15.4.5.11.3 When generated

This primitive shall be generated by the PMD when the DSSS PHY is in the receive state and code lock is achieved. It shall be continuously available to the PLCP, which, in turn, provides the parameter to the MAC entity.

15.4.5.11.4 Effect of receipt

This parameter shall be provided to the PLCP layer for information only. The SQ may be used in conjunction with RSSI as part of a CCA scheme.

15.4.5.12 PMD_CS.indicate

15.4.5.12.1 Function

This primitive, which is generated by the PMD, shall indicate to the PLCP layer that the receiver has acquired (locked) the PN code and data are being demodulated.

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15.4.5.12.2 Semantics of the service primitive

The PMD_CS (carrier sense) primitive in conjunction with PMD_ED provides CCA status through the PLCP layer PHYCCA primitive. PMD_CS indicates a binary status of ENABLED or DISABLED. PMD_CS shall be ENABLED when the correlator SQ indicated in PMD_SQ is greater than the CS_THRESHOLD parameter. PMD_CS shall be DISABLED when the PMD_SQ falls below the correlation threshold.

15.4.5.12.3 When generated

This primitive shall be generated by the PHY when the DSSS PHY is receiving a PPDU and the PN code has been acquired.

15.4.5.12.4 Effect of receipt

This indicator shall be provided to the PLCP for forwarding to the MAC entity for information purposes through the PHYCCA indicator. This parameter shall indicate that the RF medium is busy and occupied by a DSSS PHY signal. The DSSS PHY should not be placed into the transmit state when PMD_CS is ENABLED.

15.4.5.13 PMD_ED.indicate

15.4.5.13.1 Function

This optional primitive, which is generated by the PMD, shall indicate to the PLCP layer that the receiver has detected RF energy indicated by the PMD_RSSI primitive that is above a predefined threshold.

15.4.5.13.2 Semantics of the service primitive

The PMD_ED (energy detect) primitive, along with the PMD_SQ, provides CCA status at the PLCP layer through the PHYCCA primitive. PMD_ED indicates a binary status of ENABLED or DISABLED. PMD_ED shall be ENABLED when the RSSI indicated in PMD_RSSI is greater than the ED_THRESHOLD parameter. PMD_ED shall be DISABLED when the PMD_RSSI falls below the energy detect threshold.

15.4.5.13.3 When generated

This primitive shall be generated by the PHY when the PHY is receiving RF energy from any source that exceeds the ED_THRESHOLD parameter.

15.4.5.13.4 Effect of receipt

This indicator shall be provided to the PLCP for forwarding to the MAC entity for information purposes through the PMD_ED indicator. This parameter shall indicate that the RF medium may be busy with an RF energy source that is not DSSS PHY compliant. If a DSSS PHY source is being received, the PMD_CS function shall be enabled shortly after the PMD_ED function is enabled.

15.4.5.14 PMD_ED.request

15.4.5.14.1 Function

This optional primitive, which is generated by the PHY PLCP, sets the energy detect ED_THRESHOLD value.

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15.4.5.14.2 Semantics of the service primitive

The primitive shall provide the following parameters:

PMD_ED.request(ED_THRESHOLD)

ED_THRESHOLD is the value that the RSSI indicated shall exceed for PMD_ED to be enabled.

15.4.5.14.3 When generated

This primitive shall be generated by the PLCP sublayer to change or set the current DSSS PHY energy detect threshold.

15.4.5.14.4 Effect of receipt

The receipt of PMD_ED immediately changes the ED threshold as set by the ED_THRESHOLD parameter.

15.4.5.15 PHY-CCA.indicate

15.4.5.15.1 Function

This primitive, which is generated by the PMD, indicates to the PLCP layer that the receiver has detected RF energy that adheres to the CCA algorithm.

15.4.5.15.2 Semantics of the service primitive

The PHY-CCA primitive provides CCA status at the PLCP layer to the MAC.

15.4.5.15.3 When generated

This primitive shall be generated by the PHY when the PHY is receiving RF energy from any source that exceeds the ED_THRESHOLD parameter (PMD_ED is active), and optionally is a valid correlated DSSS PHY signal whereby PMD_CS would also be active.

15.4.5.15.4 Effect of receipt

This indicator shall be provided to the PLCP for forwarding to the MAC entity for information purposes through the PHY-CCA indicator. This parameter indicates that the RF medium may be busy with an RF energy source that may or may not be DSSS PHY compliant. If a DSSS PHY source is being received, the PMD_CS function shall be enabled shortly after the PMD_ED function is enabled.

15.4.6 PMD operating specifications, general

The following subclauses provide general specifications for the DSSS PMD sublayer. These specifications apply to both the Receive and the Transmit functions and general operation of a DSSS PHY.

15.4.6.1 Operating frequency range

The DSSS PHY shall operate in the frequency range of 2.4 GHz to 2.4835 GHz as allocated by regulatory bodies in the United States and Europe or in the 2.471 GHz to 2.497 GHz frequency band as allocated by regulatory authority in Japan.

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15.4.6.2 Number of operating channels

The channel center frequencies and CHNL_ID numbers shall be as shown in Table 69. The FCC (United States), IC (Canada), and ETSI (Europe) specify operation from 2.4 GHz to 2.4835 GHz. For MKK (Japan), operation is specified as 2.471 GHz to 2.497 GHz. France allows operation from 2.4465 GHz to 2.4835 GHz, and Spain allows operation from 2.445 GHz to 2.475 GHz. For each supported regulatory domain, all channels in Table 69 marked with "X" shall be supported.

Table 69—DSSS PHY frequency channel plan

CHNL_ID	Frequency	Regulatory domains					
		X'10' FCC	X'20' IC	X'30' ETSI	X'31' Spain	X'32' France	X'40' MKK
1	2412 MHz	X	X	X	—	—	—
2	2417 MHz	X	X	X	—	—	—
3	2422 MHz	X	X	X	—	—	—
4	2427 MHz	X	X	X	—	—	—
5	2432 MHz	X	X	X	—	—	—
6	2437 MHz	X	X	X	—	—	—
7	2442 MHz	X	X	X	—	—	—
8	2447 MHz	X	X	X	—	—	—
9	2452 MHz	X	X	X	—	—	—
10	2457 MHz	X	X	X	X	X	—
11	2462 MHz	X	X	X	X	X	—
12	2467 MHz	—	—	X	—	X	—
13	2472 MHz	—	—	X	—	X	—
14	2484 MHz	—	—	—	—	—	X

In a multiple cell network topology, overlapping and/or adjacent cells using different channels can operate simultaneously without interference if the distance between the center frequencies is at least 30 MHz. Channel 14 shall be designated specifically for operation in Japan.

15.4.6.3 Spreading sequence

The following 11-chip Barker sequence shall be used as the PN code sequence:

+1, –1, +1, +1, –1, +1, +1, +1, –1, –1, –1

The leftmost chip shall be output first in time. The first chip shall be aligned at the start of a transmitted symbol. The symbol duration shall be exactly 11 chips long.

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15.4.6.4 Modulation and channel data rates

Two modulation formats and data rates are specified for the DSSS PHY: a *basic access rate* and an *enhanced access rate*. The basic access rate shall be based on 1 Mbit/s DBPSK modulation. The DBPSK encoder is specified in Table 70. The enhanced access rate shall be based on 2 Mbit/s DQPSK. The DQPSK encoder is specified in Table 71. (In the tables, $+j\omega$ shall be defined as counterclockwise rotation.)

Table 70—1 Mbit/s DBPSK encoding table

Bit input	Phase change ($+j\omega$)
0	0
1	π

Table 71—2 Mbit/s DQPSK encoding table

Dibit pattern (d0,d1) d0 is first in time	Phase change ($+j\omega$)
00	0
01	$\pi/2$
11	π
10	$3\pi/2$ ($-\pi/2$)

15.4.6.5 Transmit and receive in-band and out-of-band spurious emissions

The DSSS PHY shall conform with in-band and out-of-band spurious emissions as set by regulatory bodies. For the United States, refer to Sections 15.205, 15.209, and 15.247 of FCC CFR47 [B6]. For Europe, refer to ETS 300-328 [B4].

15.4.6.6 TX-to-RX turnaround time

The TX-to-RX turnaround time shall be less than 10 μs, including the power-down ramp specified in 15.4.7.7.

The TX-to-RX turnaround time shall be measured at the air interface from the trailing edge of the last transmitted symbol to valid CCA detection of the incoming signal. The CCA should occur within 25 μs (10 μs for turnaround time plus 15 μs for energy detect) or by the next slot boundary occurring after 25 μs has elapsed (refer to 15.4.8.4). A receiver input signal 3 dB above the ED threshold described in 15.4.8.4 shall be present at the receiver.

15.4.6.7 RX-to-TX turnaround time

The RX-to-TX turnaround time shall be measured at the MAC/PHY interface, using PHYTXSTART.request and shall be ≤ 5 μs. This includes the transmit power-on ramp described in 15.4.7.7.

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15.4.6.8 Slot time

The slot time for the DSSS PHY shall be the sum of the RX-to-TX turnaround time (5 μs) and the energy detect time (15 μs specified in 15.4.8.4). The propagation delay shall be regarded as being included in the energy detect time.

15.4.6.9 Transmit and receive antenna port impedance

The impedance of the transmit and receive antenna port(s) shall be 50 Ω if the port is exposed.

15.4.6.10 Transmit and receive operating temperature range

Three temperature ranges for full operation compliance to the DSSS PHY are specified in Clause 13. Type 1 shall be defined as 0 °C to 40 °C, and is designated for office environments. Type 2 shall be defined as –20 °C to +50 °C, and Type 3 shall be defined as –30 °C to +70 °C. Types 2 and 3 are designated for industrial environments.

15.4.7 PMD transmit specifications

The transmit functions and parameters associated with the PMD sublayer are described in 15.4.7.1 through 15.4.7.9.

15.4.7.1 Transmit power levels

The maximum allowable output power as measured in accordance with practices specified by the regulatory bodies is shown in Table 72. In the United States, the radiated emissions should also conform with the IEEE uncontrolled radiation emission standard (IEEE Std C95.1-1991).

Table 72—Transmit power levels

Maximum output power	Geographic location	Compliance document
1000 mW	United States	Section 15.247 of FCC CFR47 [B6]
100 mW (EIRP)	Europe	ETS 300-328 [B4]
10 mW/MHz	Japan	MPT ordinance for Regulating Radio Equipment, Article 49-20

15.4.7.2 Minimum transmitted power level

The minimum transmitted power shall be no less than 1 mW.

15.4.7.3 Transmit power level control

Power control shall be provided for transmitted power greater than 100 mW. A maximum of four power levels may be provided. At a minimum, a radio capable of transmission greater than 100 mW shall be capable of switching power back to 100 mW or less.

15.4.7.4 Transmit spectrum mask

The transmitted spectral products shall be less than –30 dBr (dB relative to the SINx/x peak) for f_c – 22 MHz $< f < f_c$ –11 MHz, f_c +11 MHz $< f < f_c$ + 22 MHz, –50 dBr for $f < f_c$ –22 MHz, and $f > f_c$ + 22 MHz, where f_c

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is the channel center frequency. The transmit spectral mask is shown in Figure 100. The measurements shall be made using 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

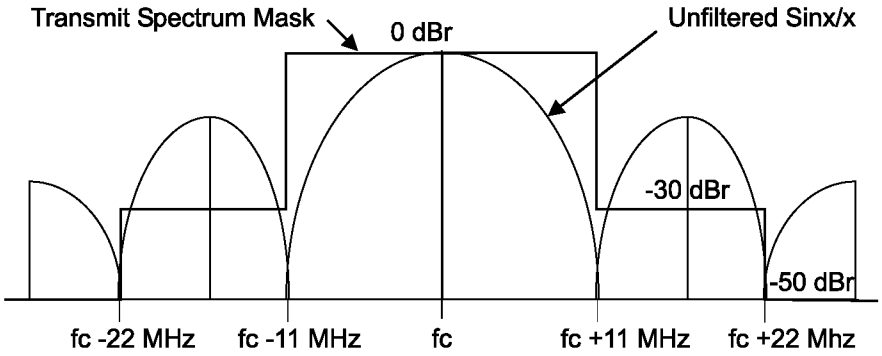

Figure 100—Transmit spectrum mask

15.4.7.5 Transmit center frequency tolerance

The transmitted center frequency tolerance shall be ±25 ppm maximum.

15.4.7.6 Chip clock frequency tolerance

The PN code chip clock frequency tolerance shall be better than ±25 ppm maximum.

15.4.7.7 Transmit power-on and power-down ramp

The transmit power-on ramp for 10% to 90% of maximum power shall be no greater than 2 μs. The transmit power-on ramp is shown in Figure 101.

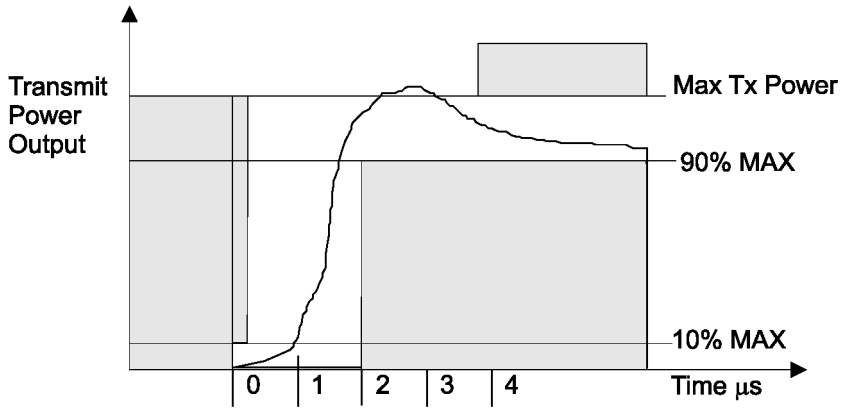

Figure 101—Transmit power-on ramp

The transmit power-down ramp for 90% to 10% maximum power shall be no greater than 2 μs. The transmit power-down ramp is shown in Figure 102.

The transmit power ramps shall be constructed such that the DSSS PHY emissions conform with the spurious frequency product specification defined in 15.4.6.5.

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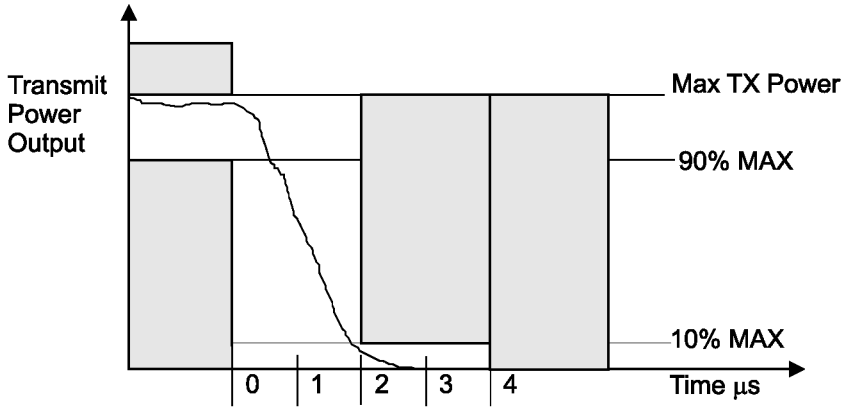

Figure 102—Transmit power-down ramp

15.4.7.8 RF carrier suppression

The RF carrier suppression, measured at the channel center frequency, shall be at least 15 dB below the peak SIN(x)/x power spectrum. The RF carrier suppression shall be measured while transmitting a repetitive 01 data sequence with the scrambler disabled using DQPSK modulation. A 100 kHz resolution bandwidth shall be used to perform this measurement.

15.4.7.9 Transmit modulation accuracy

The transmit modulation accuracy requirement for the DSSS PHY shall be based on the difference between the actual transmitted waveform and the ideal signal waveform. Modulation accuracy shall be determined by measuring the peak vector error magnitude measured during each chip period. Worst-case vector error magnitude shall not exceed 0.35 for the normalized sampled chip data. The ideal complex I and Q constellation points associated with DQPSK modulation (0.707, 0.707), (0.707, –0.707), (–0.707, 0.707), (–0.707, –0.707) shall be used as the reference. These measurements shall be from baseband I and Q sampled data after recovery through a reference receiver system.

Figure 103 illustrates the ideal DQPSK constellation points and range of worst-case error specified for modulation accuracy.

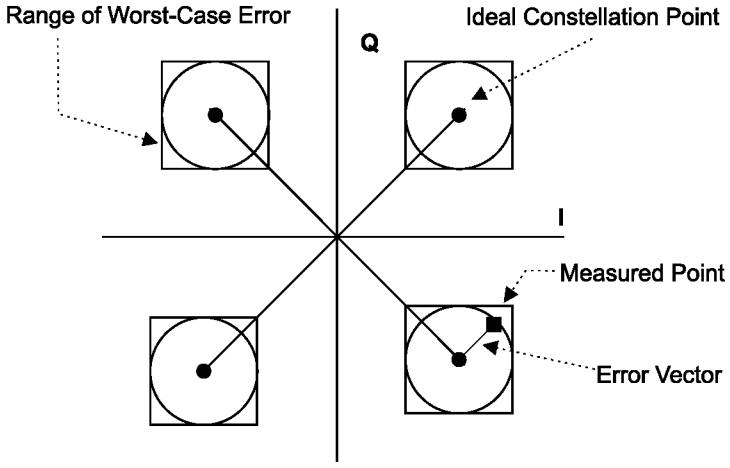

Figure 103—Modulation accuracy measurement example

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Error vector measurement requires a reference receiver capable of carrier lock. All measurements shall be made under carrier lock conditions. The distortion induced in the constellation by the reference receiver shall be calibrated and measured. The test data error vectors described below shall be corrected to compensate for the reference receiver distortion.

The IEEE 802.11 vendor compatible radio shall provide an exposed TX chip clock, which shall be used to sample the I and Q outputs of the reference receiver.

The measurement shall be made under the conditions of continuous DQPSK transmission using scrambled all ones.

The eye pattern of the I channel shall be used to determine the *I* and *Q* sampling point. The chip clock provided by the vendor radio shall be time delayed such that the samples fall at a 1/2 chip period offset from the mean of the zero crossing positions of the eye (see Figure 104). This is the ideal center of the eye and may not be the point of maximum eye opening.

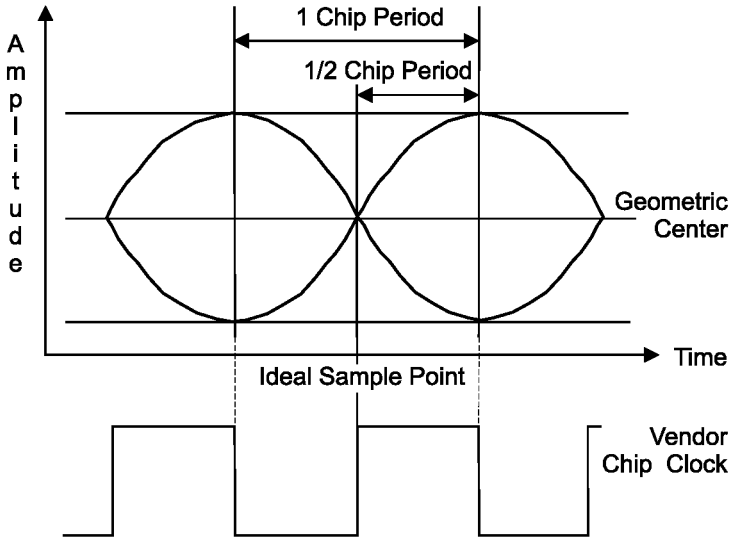

Figure 104—Chip clock alignment with baseband eye pattern

Using the aligned chip clock, 1000 samples of the *I* and *Q* baseband outputs from the reference receiver are captured. The vector error magnitudes shall be calculated as follows:

Calculate the dc offsets for *I* and *Q* samples.

$$I_{\text{mean}} = \sum_{n=1}^{1000} |I(n)| / 1000$$

$$Q_{\text{mean}} = \sum_{n=1}^{1000} |Q(n)| / 1000$$

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Calculate the dc corrected I and Q samples for all n =1000 sample pairs.

$$I_{dc}(n) = I(n) - I_{mean}$$

$$Q_{dc}(n) = Q(n) - Q_{mean}$$

Calculate the average magnitude of I and Q samples.

$$I_{mag} = \sum_{n=1}^{1000} |I_{dc}(n)| / 1000$$

$$Q_{mag} = \sum_{n=1}^{1000} |Q_{dc}(n)| / 1000$$

Calculate the normalized error vector magnitude for the $I_{dc}(n)/Q_{dc}(n)$ pairs.

$$V_{err}(n) = \left[\frac{1}{2} \times (\{|I_{dc}(n)| / I_{mag}\}^2 + \{|Q_{dc}(n)| / Q_{mag}\}^2)\right]^{\frac{1}{2}} - V_{correction}$$

with $V_{correction}$ = error induced by the reference receiver system.

A vendor DSSS PHY implementation shall be compliant if for all n =1000 samples the following condition is met:

$$V_{err}(n) < 0.35$$

15.4.8 PMD receiver specifications

The receive functions and parameters associated with the PMD sublayer are described in 15.4.8.1 through 15.4.8.4.

15.4.8.1 Receiver minimum input level sensitivity

The FER shall be less than 8×10^{-2} at an MPDU length of 1024 bytes for an input level of –80 dBm measured at the antenna connector. This FER shall be specified for 2 Mbit/s DQPSK modulation. The test for the minimum input level sensitivity shall be conducted with the ED threshold set ≤ –80 dBm.

15.4.8.2 Receiver maximum input level

The receiver shall provide a maximum FER of 8×10^{-2} at an MPDU length of 1024 bytes for a maximum input level of –4 dBm measured at the antenna. This FER shall be specified for 2 Mbit/s DQPSK modulation.

15.4.8.3 Receiver adjacent channel rejection

Adjacent channel rejection is defined between any two channels with ≥ 30 MHz separation in each channel group defined in 15.4.6.2.

The adjacent channel rejection shall be ≥ 35 dB with an FER of 8×10^{-2} using 2 Mbit/s DQPSK modulation described in 15.4.6.4 and an MPDU length of 1024 bytes.

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The adjacent channel rejection shall be measured using the following method:

Input a 2 Mbit/s DQPSK modulated signal at a level 6 dB greater than specified in 15.4.8.1. In an adjacent channel (≥ 30 MHz separation as defined by the channel numbering), input a signal modulated in a similar fashion that adheres to the transmit mask specified in 15.4.7.4 to a level 41 dB above the level specified in 15.4.8.1. The adjacent channel signal shall be derived from a separate signal source. It cannot be a frequency shifted version of the reference channel. Under these conditions, the FER shall be no worse than 8×10^{-2}.

15.4.8.4 CCA

The DSSS PHY shall provide the capability to perform CCA according to at least one of the following three methods:

— *CCA Mode 1:* Energy above threshold. CCA shall report a busy medium upon detection of any energy above the ED threshold.
— *CCA Mode 2:* CS only. CCA shall report a busy medium only upon detection of a DSSS signal. This signal may be above or below the ED threshold.
— *CCA Mode 3:* CS with energy above threshold. CCA shall report a busy medium upon detection of a DSSS signal with energy above the ED threshold.

The ED status shall be given by the PMD primitive, PMD_ED. The CS status shall be given by PMD_CS. The status of PMD_ED and PMD_CS is used in the PLCP to indicate activity to the MAC through the PHY interface primitive PHY-CCA.indicate.

A busy channel shall be indicated by PHY-CCA.indicate of class BUSY.

A clear channel shall be indicated by PHY-CCA.indicate of class IDLE.

The PHY MIB attribute dot11CCAModeSupported shall indicate the appropriate operation modes. The PHY shall be configured through the PHY MIB attribute dot11CurrentCCAMode.

The CCA shall be TRUE if there is no energy detect or CS. The CCA parameters are subject to the following criteria:

a) The ED threshold shall be ≤ –80 dBm for TX power > 100 mW, –76 dBm for 50 mW < TX power ≤ 100 mW, and –70 dBm for TX power ≤ 50 mW.
b) With a valid signal (according to the CCA mode of operation) present at the receiver antenna within 5 μs of the start of a MAC slot boundary, the CCA indicator shall report channel busy before the end of the slot time. This implies that the CCA signal is available as an exposed test point. Refer to Figure 62 (in 9.2.10) for a definition of slot time boundary.
c) In the event that a correct PLCP Header is received, the DSSS PHY shall hold the CCA signal inactive (channel busy) for the full duration as indicated by the PLCP LENGTH field. Should a loss of CS occur in the middle of reception, the CCA shall indicate a busy medium for the intended duration of the transmitted packet.

Conformance to DSSS PHY CCA shall be demonstrated by applying a DSSS-compliant signal, above the appropriate ED threshold (item a), so that all conditions described in item b and item c are demonstrated.

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16. Infrared (IR) PHY specification

16.1 Overview

The PHY for the infrared (IR) system is specified in this clause. The IR PHY uses near-visible light in the 850 nm to 950 nm range for signaling. This is similar to the spectral usage of both common consumer devices such as IR remote controls, as well as other data communications equipment, such as IR data association (IrDA) devices.

Unlike many other IR devices, however, the IR PHY is not directed. That is, the receiver and transmitter do not have to be aimed at each other and do not need a clear line-of-sight. This permits the construction of a true LAN system, whereas with an aimed system, it would be difficult or impossible to install a LAN because of physical constraints.

A pair of conformant IR devices would be able to communicate in a typical environment at a range up to about 10 m. This standard allows conformant devices to have more sensitive receivers, and this may increase range up to about 20 m.

The IR PHY relies on both reflected IR energy as well as line-of-sight IR energy for communications. Most designs anticipate that *all* of the energy at the receiver is reflected energy. This reliance on reflected IR energy is called *diffuse IR* transmission.

This standard specifies the transmitter and receiver in such a way that a conformant design will operate well in most environments where there is no line-of-sight path from the transmitter to the receiver. However, in an environment that has few or no reflecting surfaces, and where there is no line-of-sight, an IR PHY system may suffer reduced range.

The IR PHY will operate only in indoor environments. IR radiation does not pass through walls, and is significantly attenuated passing through most exterior windows. This characteristic can be used to "contain" an IR PHY in a single physical room, like a classroom or conference room. Different LANs using the IR PHY can operate in adjacent rooms separated only by a wall without interference, and without the possibility of eavesdropping.

At the time of this standard's preparation, the only known regulatory standards that apply to the use of IR radiation are safety regulations, such as IEC 60825-1:1993 [B8] and ANSI Z136.1-1993 [B1]. While a conformant IR PHY device can be designed to also comply with these safety standards, conformance with this standard does not ensure conformance with other standards.

Worldwide, no frequency allocation or bandwidth allocation regulatory restrictions currently exist on IR emissions.

Emitter (typically LED) and detector (typically PIN diode) devices for IR communications are relatively inexpensive at the IR wavelengths specified in the IR PHY, and at the electrical operating frequencies required by this PHY.

While many other devices in common use also use IR emissions in the same optical band, these devices usually transmit IR intermittently and do not interfere with the proper operation of a compliant IR PHY. If such a device does interfere, by transmitting continuously and with a very strong signal, it can be physically isolated (placing it in a different room) from the IEEE 802.11 LAN.

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16.1.1 Scope

The PHY services provided to the IEEE 802.11 wireless LAN MAC by the IR system are described in this clause. The IR PHY consists of two protocol functions as follows:

a) A PHY convergence function, which adapts the capabilities of the PMD system to the PHY service. This function is supported by the PLCP, which defines a method of mapping the IEEE 802.11 MPDUs into a framing format suitable for sending and receiving user data and management information between two or more STAs using the associated PMD system.
b) A PMD system, whose function defines the characteristics of, and method of transmitting and receiving data through, the WM between two or more STAs.

16.1.2 IR PHY functions

The IR PHY contains three functional entities: the PMD function, the PHY convergence function, and the layer management function. Each of these functions is described in detail below.

The IR PHY service is provided to the MAC entity at the STA through a SAP as described in Clause 12. For a visual guide to the relationship of the IR PHY to the remainder of the system, refer to Figure 11 (in 5.8).

16.1.2.1 PLCP sublayer

To allow the IEEE 802.11 MAC to operate with minimum dependence on the PMD sublayer, a PLCP sublayer is defined. This function simplifies the PHY service interface to the IEEE 802.11 MAC services. The PHY-specific preamble is normally associated with this convergence layer.

16.1.2.2 PMD sublayer

The PMD sublayer provides a CCA mechanism, transmission mechanism, and reception mechanism that are used by the MAC via the PLCP to send or receive data between two or more STAs.

16.1.2.3 PLME

The PLME performs management of the local PHY functions in conjunction with the MLME. See 16.4 for the MIB variables that may be accessed by the PHY entities and intralayer of higher level LMEs. These variables are accessed via the PLME-GET, PLME-SET, and PLME-RESET primitives defined in Clause 10.

16.1.3 Service specification method and notation

The models represented by figures and state diagrams are intended as illustrations of functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation; the actual method of implementation is left to the discretion of the IEEE 802.11 IR-PHY-compliant developer. Conformance to this standard is not dependent on following the model, and an implementation that follows the model closely may not be conformant.

Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation. In particular, the PHY-SAP operations are defined and described as instantaneous; however, this may be difficult to achieve in an implementation.

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16.2 IR PLCP sublayer

While the PLCP sublayer and the PMD sublayer are described separately, the separation and distinction between these sublayers is artificial, and is not meant to imply that the implementation must separate these functions. This distinction is made primarily to provide a point of reference from which to describe certain functional components and aspects of the PMD. The functions of the PLCP can be subsumed by a PMD sublayer; in this case, the PMD will incorporate the PHY-SAP as its interface, and will not offer a PMD_SAP.

16.2.1 Overview

A convergence procedure is provided by which MPDUs are converted to and from PPDUs. During transmission, the MPDU (PSDU) is prepended with a PLCP Preamble and PLCP Header to create the PPDU. At the receiver, the PLCP Preamble is processed and the internal data fields are processed to aid in demodulation and delivery of the MPDU (PSDU).

16.2.2 PLCP frame format

Figure 105 shows the format for the PPDU including the PLCP Preamble, the PLCP Header, and the PSDU. The PLCP Preamble contains the following fields: SYNC and SFD. The PLCP Header contains the following fields: data rate (DR), dc level adjustment (DCLA), length (LENGTH), and CRC. Each of these fields is described in detail in 16.2.4.

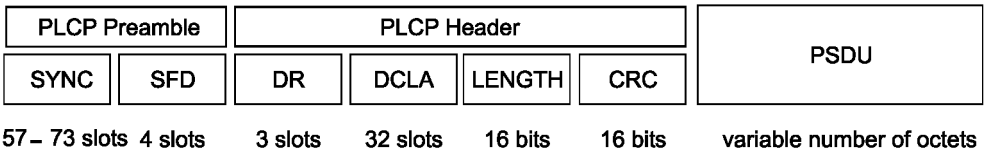

Figure 105—PPDU frame format

16.2.3 PLCP modulation and rate change

The PLCP Preamble shall be transmitted using the basic pulse defined in 16.3.3.2. The PSDU, LENGTH, and CRC fields shall be transmitted using pulse position modulation (PPM). PPM maps bits in the octet into symbols: 16-PPM maps four bits into a 16-position symbol, and 4-PPM maps two bits into a 4-position symbol. The basic L-PPM TU is the slot. A slot corresponds to one of the L positions of a symbol and has a 250 ns duration. The PSDU, LENGTH, and CRC fields are transmitted at one of two bit rates: 1 Mbit/s or 2 Mbit/s. The DR field indicates the data rate that will be used to transmit the PSDU, LENGTH, and CRC fields. The 1 Mbit/s data rate uses 16-PPM (basic access rate), and the 2 Mbit/s data rate uses 4-PPM (enhanced access rate). The transmitter and receiver will initiate the modulation or demodulation indicated by the DR field starting with the first 4 bits (in 16-PPM) or 2 bits (in 4-PPM) of the LENGTH field. The PSDU transmission rate is set by the DATARATE parameter in the PHY-TXSTART.request primitive. Any conformant IR PHY shall be capable of receiving at 1 Mbit/s and 2 Mbit/s. Transmission at 2 Mbit/s is optional.

A PHY-TXSTART.request that specifies a data rate that is not supported by a PHY instance will cause the PHY to indicate an error to its MAC instance. A PHY is not permitted under any circumstance to transmit at a different rate than the requested rate.

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16.2.4 PLCP field definitions

16.2.4.1 PLCP SYNC field

The SYNC field consists of a sequence of alternated presence and absence of a pulse in consecutive slots. The SYNC field has a minimum length of 57 L-PPM slots and a maximum length of 73 L-PPM slots and shall terminate with the absence of a pulse in the last slot. This field is provided so that the receiver can perform clock recovery (slot synchronization), automatic gain control (optional), signal-to-noise ratio estimation (optional), and diversity selection (optional).

The SYNC field is not modulated using L-PPM, but instead consists of transitions in L-PPM slots that would otherwise constitute an illegal symbol. See 16.3.2.1 for legal symbols.

16.2.4.2 PLCP SFD field

The SFD field length is four L-PPM slots and consists of the binary sequence 1001, where 1 indicates a pulse in the L-PPM slot and 0 indicates no pulse in the L-PPM slot. The leftmost bit shall be transmitted first. The SFD field is provided to indicate the start of the PLCP Preamble and to perform bit and symbol synchronization.

The SFD field is not modulated using L-PPM, but instead consists of transitions in L-PPM slots that would otherwise constitute an illegal symbol.

16.2.4.3 PLCP DR field

The DR field indicates to the PHY the data rate that shall be used for the transmission or reception of the PSDU, LENGTH, and CRC fields. The transmitted value shall be provided by the PHY-TXSTART.request primitive as described in Clause 12. The DR field has a length of three L-PPM slots. The leftmost bit, as shown below, shall be transmitted first. The IR PHY currently supports two data rates defined by the slot pattern shown for the three L-PPM slots following the SFD, where 1 indicates a pulse in the L-PPM slot and 0 indicates no pulse in the L-PPM slot:

1 Mbit/s:000
2 Mbit/s:001

The DR field is not modulated using L-PPM, but instead consists of transitions in L-PPM slots that would otherwise constitute an illegal symbol.

16.2.4.4 PLCP DCLA field

The DCLA field is required to allow the receiver to stabilize the dc level after the SYNC, SFD, and DR fields. The leftmost bit, as shown below, shall be transmitted first. The length of the DCLA field is 32 L-PPM slots and consists of the contents shown, where 1 indicates a pulse in the L-PPM slot and 0 indicates no pulse in the L-PPM slot:

1 Mbit/s: 00000000100000000000000010000000
2 Mbit/s: 00100010001000100010001000100010

The DCLA field is not modulated using L-PPM, but instead consists of transitions in L-PPM slots that would otherwise constitute an illegal symbol.

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16.2.4.5 PLCP LENGTH field

The LENGTH field is an unsigned 16-bit integer that indicates the number of octets to be transmitted in the PSDU. The transmitted value shall be provided by the PHYTXSTART.request primitive as described in Clause 12. The LSB shall be transmitted first. This field is modulated and sent in L-PPM format. This field is protected by the CRC described in 16.2.4.6.

16.2.4.6 PLCP CRC field

The LENGTH field shall be protected by a 16-bit CRC. The CRC is the ones complement of the remainder generated by the modulo 2 division of the LENGTH field by the polynomial:

$$x^{16} + x^{12} + x^5 + 1$$

The protected bits will be processed in transmit order. The MSB of the 16-bit CRC shall be transmitted first. This field shall be modulated and sent in L-PPM format. All CRC calculations shall be made prior to L-PPM encoding on transmission and after L-PPM decoding on reception.

16.2.4.7 PSDU field

This field is composed of a variable number of octets. The minimum is 0 (zero) and the maximum is 2500. The LSB of each octet shall be transmitted first. All the octets of this field shall be modulated and sent in L-PPM format.

16.2.5 PLCPs

16.2.5.1 Transmit PLCP

All commands issued by the MAC require that a confirmation primitive be issued by the PHY. The confirmation primitives provide flow control between the MAC and the PHY.

The transmit PLCP is as follows:

a) Based on the status of CCA, the MAC shall determine whether the channel is clear.
b) If the channel is clear, transmission of the PSDU shall be initiated by a PHY-TXSTART.request with parameters LENGTH and DATARATE.
c) The PHY entity shall immediately initiate transmission of the PLCP Preamble and PLCP Header based on the LENGTH and DATARATE parameters passed in the PHY-TXSTART.request. Once the PLCP Preamble and PLCP Header transmission is completed, the PHY entity shall issue a PHY-TXSTART.confirm.
d) Each octet of the PSDU is passed from the MAC to the PHY by a single PHY-DATA.request primitive. Each PHY-DATA.request shall be confirmed by the PHY with a PHY-DATA.confirm before the next request can be made.
e) At the PHY each PSDU octet shall be divided into symbols of 2 bits or 4 bits each. The symbols shall be modulated using L-PPM and transmitted into the medium.
f) Transmission is terminated by the MAC through the primitive PHY-TXEND.request. The PHY shall confirm the resulting end of transmission with a PHY-TXEND.confirm.

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16.2.5.2 Receive PLCP

The receive PLCP is as follows:

a) CCA is provided to the MAC via the PHY-CCA.indicate primitive. When the PHY senses activity on the medium, it shall indicate that the medium is busy with a PHY-CCA.indicate with a value of BUSY. This will normally occur during the SYNC field of the PLCP Preamble.

b) The PHY entity shall begin searching for the SFD field. Once the SFD field is detected, the PHY entity shall attempt to receive the PLCP Header. After receiving the DR and DCLA fields, the PHY shall initiate processing of the received CRC and LENGTH fields. The data rate indicated in the DR field applies to all symbols in the latter part of the received PSDU, commencing with the first symbol of the LENGTH field. The CRC shall be checked for correctness immediately after its reception.

c) If the CRC check fails, or the value received in the DR field is not one supported by the PHY, then a PHY-RXSTART.indicate shall not be issued to the MAC. When the medium is again free, the PHY shall issue a PHY-CCA.indicate with a value of IDLE.

d) If the PLCP Preamble and PLCP Header reception is successful, the PHY shall send a PHY-RXSTART.indicate to the MAC; this includes the parameters DATARATE and LENGTH.

   In the absence of errors, the receiving PHY shall report the same length to its local MAC, in the RXVECTOR parameter of the PHY-RXSTART.indicate primitive, that the peer MAC presented to its local PHY entity in the TXVECTOR parameter of its respective PHY-TXSTART.request.

e) The received PSDU L-PPM symbols shall be assembled into octets and presented to the MAC using a series of PHY-DATA.indicate primitives, one per octet.

f) Reception shall be terminated after the reception of the final symbol of the last PSDU octet indicated by the PLCP Header's LENGTH field. After the PHY-DATA.indicate for that octet is issued, the PHY shall issue a PHY-RXEND.indicate primitive to its MAC.

g) After issuing the PHY-RXEND.indicate primitive, and when the medium is no longer busy, the PHY shall issue a PHY-CCA.indicate primitive with a value of IDLE.

16.2.5.3 CCA procedure

CCA is provided to the MAC via the PHY-CCA.indicate primitive.

The CCA procedure is as follows:

a) When the PHY senses activity on the medium, a PHY-CCA.indicate primitive with a value of BUSY shall be issued. This will normally occur during reception of the SYNC field of the PLCP Preamble.

b) When the PHY senses that the medium is free, a PHY-CCA.indicate primitive with a value of IDLE shall be issued.

c) At any time, the MAC may issue a PHY-CCARESET.request primitive, which will reset the PHY's internal CCA detection mechanism to the medium not-busy (IDLE) state. This primitive will be acknowledged with a PHY-CCARESET.confirm primitive.

16.2.5.4 PMD_SAP peer-to-peer service primitive parameters

Several service primitives include a parameter vector. This vector shall be a list of parameters that may vary depending on PHY type. Table 73 indicates the parameters required by the MAC or IR PHY in each of the parameter vectors used for peer-to-peer interactions.

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Table 73—IR PMD_SAP peer-to-peer service primitives

Parameter	Associated primitive	Value
LENGTH	RXVECTOR, TXVECTOR	4 to $2^{16} - 1$
DATARATE	RXVECTOR, TXVECTOR	PHY dependent

16.3 IR PMD sublayer

The IR PMD sublayer does not define PMD SAPs. The mechanism for communications between the PLCP and PMD sublayers, as well as the distinction between these two sublayers, if any, is left to implementers. In particular, it is possible to design and implement, in a conformant way, a single sublayer that subsumes the functions of both the PLCP and PMD, presenting only the PHY-SAP.

16.3.1 Overview

The PMD functional, electrical, and optical characteristics required for interoperability of implementations conforming to this specification are described in this subclause. The relationship of this specification to the entire IR PHY is shown in Figure 11 (in 5.8).

16.3.2 PMD operating specifications, general

General specifications for the IR PMD sublayer are provided in this subclause. These specifications apply to both the receive and transmit functions and general operation of a compliant IR PHY.

16.3.2.1 Modulation and channel data rates

Two modulation formats and data rates are specified for the IR PHY: a *basic access rate* and an *enhanced access rate*. The basic access rate is based on 1 Mbit/s 16-PPM modulation. The 16-PPM encoding is specified in Table 74. Each group of 4 data bits is mapped to one of the 16-PPM symbols. The enhanced access rate is based on 2 Mbit/s 4-PPM. The 4-PPM encoding is specified in Table 75. Each group of 2 data bits is mapped to one of the 4-PPM symbols. Transmission order of the symbol slots is from left to right, as shown in the table, where a one indicates in-band energy in the slot, and a zero indicates the absence of in-band energy in the slot.

The data in Table 74 and Table 75 have been arranged (Gray coded) so that a single out-of-position-by-one error in the medium, caused, for example, by intersymbol interference, results in only a single bit error in the received data, rather than in a multiple bit error.

Table 74—Sixteen-PPM basic rate mapping

Data	16-PPM symbol
0000	0000000000000001
0001	0000000000000010
0011	0000000000000100
0010	0000000000001000
0110	0000000000010000
0111	0000000000100000
0101	0000000001000000
0100	0000000010000000

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Table 74—Sixteen-PPM basic rate mapping *(continued)*

Data	16-PPM symbol
1100	0000000100000000
1101	0000001000000000
1111	0000010000000000
1110	0000100000000000
1010	0001000000000000
1011	0010000000000000
1001	0100000000000000
1000	1000000000000000

Table 75—Four-PPM enhanced rate mapping

Data	4-PPM symbol
00	0001
01	0010
11	0100
10	1000

16.3.2.2 Octet partition and PPM symbol generation procedure

Because PPM is a block modulation method, with the block size less than a full octet, octets have to be partitioned prior to modulation (mapping into PPM symbols).

Octet partition depends on the PPM order being used.

Assume an octet is formed by eight bits numbered 7 6 5 4 3 2 1 0, where bit 0 is the LSB. Partition the octet as follows:

For 16-PPM, create two PPM symbols:

— The symbol using bits 3 2 1 0 shall be transmitted onto the medium first.
— The symbol using bits 7 6 5 4 shall be transmitted onto the medium last.

For 4-PPM, create four PPM symbols:

— The symbol using bits 1 0 shall be transmitted onto the medium first.
— The symbol using bits 3 2 shall be transmitted onto the medium second.
— The symbol using bits 5 4 shall be transmitted onto the medium third.
— The symbol using bits 7 6 shall be transmitted onto the medium last.

16.3.2.3 Operating environment

The IR PHY will operate only in indoor environments. IR PHY interfaces cannot be exposed to direct sunlight. The IR PHY relies on reflected IR energy and does not require a line-of-sight between emitter and receiver in order to work properly. The range and bit error rate of the system may vary with the geometry of the environment and with natural and artificial illumination conditions.

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16.3.2.4 Operating temperature range

The temperature range for full operation compliance with the IR PHY is specified as 0 °C to 40 °C.

16.3.3 PMD transmit specifications

The following subclauses describe the transmit functions and parameters associated with the PMD sublayer.

16.3.3.1 Transmitted peak optical power

The peak optical power of an emitted pulse shall be as specified in Table 76.

Table 76—Peak optical power as a function of emitter radiation pattern mask

Emitter radiation pattern mask	Peak optical power
Mask 1	2 W ±20%
Mask 2	0.55 W ±20%

16.3.3.2 Basic pulse shape and parameters

The basic pulse width, measured between the 50% amplitude points, shall be 250 ±10 ns. The pulse rise time, measured between the 10% and 90% amplitude points, shall be no more than 40 ns. The pulse fall time, measured between the 10% and 90% amplitude points, shall be no more than 40 ns. The edge jitter, defined as the absolute deviation of the edge from its correct position, shall be no more than 10 ns. The basic pulse shape is shown in Figure 106.

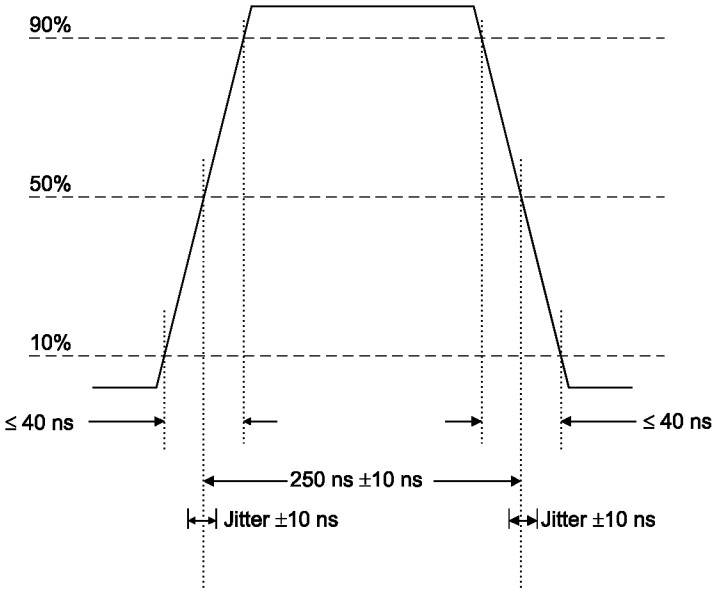

Figure 106—Basic pulse shape

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16.3.3.3 Emitter radiation pattern mask

The standard contains two emitter radiation pattern masks. Mask 1 is defined in Table 77 and illustrated in Figure 107. Mask 2 is defined in Table 78 and illustrated in Figure 108.

Table 77—Definition of the emitter radiation pattern mask 1

Declination angle	Normalized irradiance
$\alpha \leq 60°$	$> 3.5 \times 10^{-6}$
$\alpha \leq 29°$	$\leq 2.2 \times 10^{-5}$
$29° < \alpha \leq 43°$	$\leq -1.06 \times 10^{-4} + (0.44 \times 10^{-5})\ \alpha$
$43° < \alpha \leq 57°$	$\leq 1.15 \times 10^{-4} - (7.1 \times 10^{-7})\ \alpha$
$57° < \alpha \leq 74°$	$\leq 2.98 \times 10^{-4} - (3.9 \times 10^{-6})\ \alpha$
$74° < \alpha \leq 90°$	$\leq 4.05 \times 10^{-5} - (4.5 \times 10^{-7})\ \alpha$

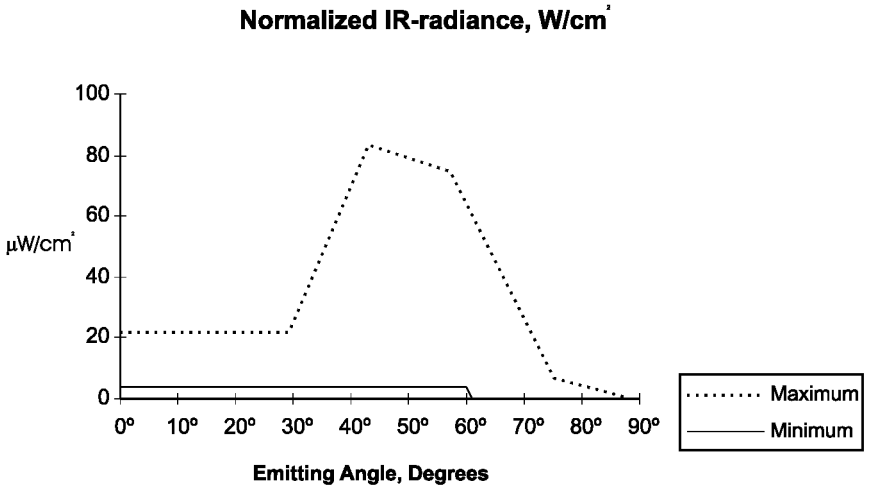

Figure 107—Emitter radiation pattern mask 1

Following is a description of how to interpret the Mask 1 table and figure. Position the conformant Mask 1 device in its recommended attitude. Define the conformant Mask 1 device axis as the axis passing through the emitter center and having the direction perpendicular to the floor. The mask represents the irradiance normalized to the total peak emitted power, as a function of the angle between the conformant Mask 1 device axis and the axis from the emitter center to the test receiver center (declination angle). The distance between emitter and test receiver is 1 m. The test receiver normal is always aimed at the emitter center. The azimuth angle is a rotation angle on the conformant device axis.

A device is conformant if for any azimuth angle its radiation pattern as a function of declination angle falls within the pattern mask.

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Table 78—Definition of emitter radiation pattern mask 2

Declination angle	Pitch angle	Normalized irradiance
$\alpha \leq 60$	$\alpha = 0$	0.05 ±15%
$\alpha \leq 90$	$\alpha = 0$	0.025 ±15%
$\alpha \geq 100$	$\alpha = 0$	≤ 0.015
$0 \leq \alpha \leq 60$	$0 \leq \alpha \leq 10$	$0.035 \leq I \leq 0.055$
$0 \leq \alpha \leq 60$	$10 \leq \alpha \leq 20$	$0.0225 \leq I \leq 0.05$
$0 \leq \alpha \leq 60$	$\alpha \geq 30$	≤ 0.015

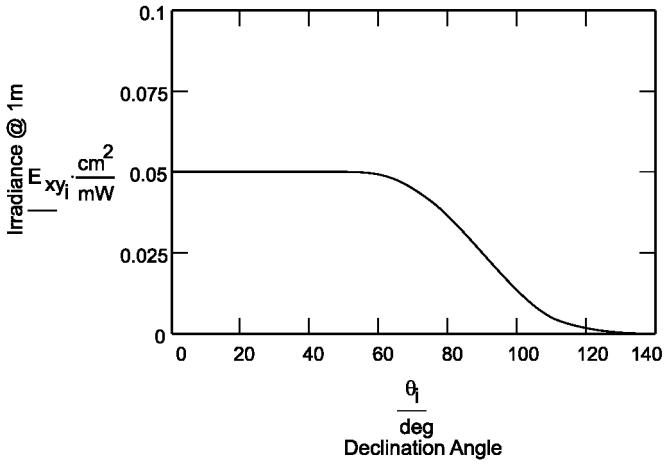

Figure 108—Emitter radiation pattern mask 2

Figure 109 is a description of how to interpret the Mask 2 table with reference to Figure 108.

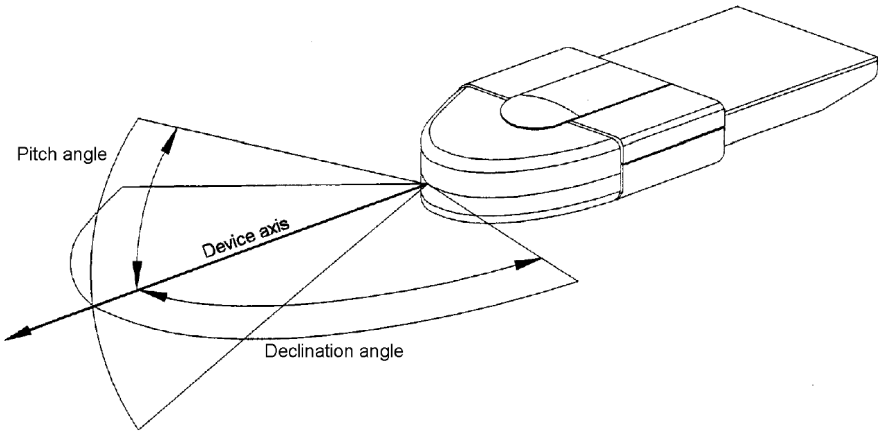

Figure 109—Mask 2 device orientation drawing

Position the conformant Mask 2 device in its recommended attitude. Define the conformant Mask 2 device axis as passing through the emitter center and having the direction relative to the device as defined by the

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manufacturer. The declination angle plane is as defined by the manufacturer. The mask represents the irradiance normalized to the peak emitted power on the conformant Mask 2 device axis, as a function of the angle between the conformant device axis and the axis from the emitter center to the test receiver center (declination angle) in the declination plane. The distance between emitter and test receiver is 1 m. The test receiver normal is always aimed at the emitter center. The pitch angle is an angle relative to the conformant device axis which is perpendicular to the declination plane.

The device is conformant if, for a pitch angle of 0 degrees, at any declination angle from 0 to 100 degrees, and if, for any declination angle from 0 to 60 degrees, at any pitch angle from 0 to 20 degrees, its radiation pattern as a function of angle falls within the pattern mask.

Other radiation patterns are for future study.

16.3.3.4 Optical emitter peak wavelength

The optical emitter peak wavelength shall be between 850 nm and 950 nm.

16.3.3.5 Transmit spectrum mask

Define the transmit spectrum of a transmitter as the Fourier Transform, or equivalent, of a voltage (or current) signal whose amplitude, as a function of time, is proportional to the transmitted optical power.

The transmit spectrum of a conformant transmitter shall be 20 dB below its maximum for all frequencies above 15 MHz. The transmit spectrum mask is shown in Figure 110.

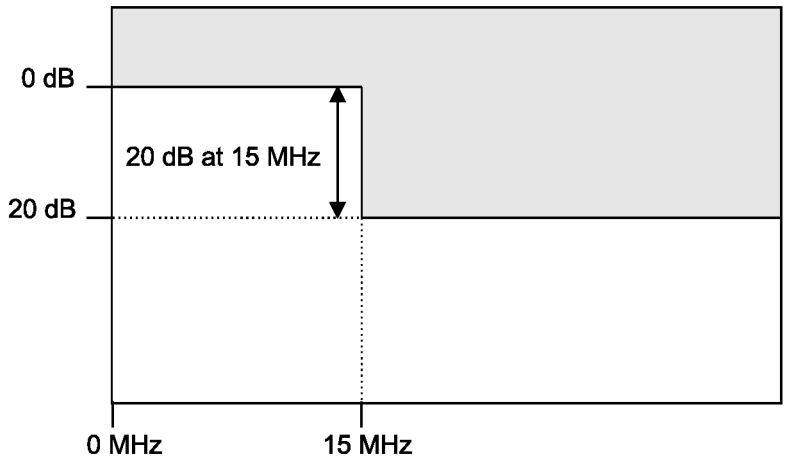

Figure 110—Transmit spectrum mask

16.3.4 PMD receiver specifications

The following subclauses describe the receive functions and parameters associated with the PMD sublayer.

16.3.4.1 Receiver sensitivity

The receiver sensitivity, defined as the minimum irradiance (in mW/cm^2) at the photodetector plane required for a FER of 4×10^{-5} with a PSDU of 512 octets and with an unmodulated background IR source between 800 nm and 1000 nm with a level of 0.1 mW/cm^2, shall be

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1 Mbit/s: 2×10^{-5}mW/cm^2
2 Mbit/s: 8×10^{-5}mW/cm^2

16.3.4.2 Receiver dynamic range

The receiver dynamic range, defined as the ratio between the maximum and minimum irradiance at the plane normal to the receiver axis that assures an FER lower than or equal to 4×10^{-5} with a PSDU of 512 octets and with an unmodulated background IR source between 800 nm and 1000 nm with a level of 0.1 mW/cm^2, shall be ≥ 30 dB.

16.3.4.3 Receiver field of view (FOV)

The receiver axis is defined as the direction of incidence of the optical signal at which the received optical power is maximum.

The received optical power shall be greater than the values given in Table 79, at the angles indicated, where "angle of incidence" is the angle of the optical signal relative to the receiver axis, and "received power" is the received optical power as a percentage of that measured at the receiver axis.

Table 79—Definition of the receiver FOV

Angle of incidence	Received power
$\alpha \leq 20°$	≥ 65%
$\alpha \leq 40°$	≥ 55%
$\alpha \leq 60°$	≥ 35%
$\alpha \leq 80°$	≥ 10%

16.3.5 ED, CS, and CCA definitions

16.3.5.1 ED signal

The ED signal shall be set true when IR energy variations in the band between 1 MHz and 10 MHz exceed 0.001 mW/cm^2.

The ED shall operate independently of the CS. The ED shall not be asserted at the minimum signal level specified in 16.3.4.1, which is below the level specified in this subclause.

This signal is not directly available to the MAC.

16.3.5.2 CS signal

The CS shall be asserted by the PHY when it detects and locks onto an incoming PLCP Preamble signal. Conforming PHYs shall assert this condition within the first 12 μs of signal reception, at the minimum signal level equal to the receiver sensitivity specified in 16.3.4.1, with a background IR level as specified in 16.3.4.1.

The CS shall be deasserted by the PHY when the receiving conformant device loses carrier lock.

NOTE—The 12 μs specification is somewhat less than the minimum length of the PLCP SYNC interval, which is 14.25 μs.

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The CS shall operate independently of the ED and shall not require a prior ED before the acquisition and assertion of CS. This permits reception of signals at the minimum signal level specified in 16.3.4.1, even though these signals fall below the ED level.

This signal is not directly available to the MAC.

16.3.5.3 CCA

CCA shall be asserted IDLE by the PHY when the CS and the ED are both false, or when ED has been continuously asserted for a period of time defined by the product of dot11CCAWatchdogTimerMax and dot11CCAWatchdogCountMax without CS becoming active. When either CS or ED go true, CCA is indicated as BUSY to the MAC via the primitive PHY-CCA.indicate. CS and ED behavior are defined in 16.3.5.2.

Normally, CCA will be held BUSY throughout the period of the PLCP Header. After receiving the last PLCP bit and the first data octet, the PHY shall signal PHY-RXSTART.indicate with the parameters LENGTH and RATE. CCA shall be held BUSY until the number of octets specified in the decoded PLCP Header are received. At that time the PHY shall signal PHY-RXEND.indicate. The CCA may remain BUSY after the end of data if some form of energy is still being detected. The PHY will signal PHY-CCA.indicate with a value of IDLE only when the CCA goes CLEAR.

The transition of CCA from BUSY to IDLE is indicated to the MAC via the primitive PHY-CCA.indicate.

If CS and ED go false before the PHY signals PHY-RXSTART.indicate, CCA is set to IDLE and *immediately* signaled to the MAC via PHY-CCA.indicate with a value of IDLE. If CS and ED go false after the PHY has signaled PHY-RXSTART.indicate, implying that the PLCP Header has been properly decoded, then the PHY shall not signal a change in state of CCA until the proper interval has passed for the number of octets indicated by the received PLCP LENGTH field. At that time, the PHY shall signal PHY-RXEND.indicate with an RXERROR parameter of CarrierLost followed by PHY-CCA.indicate with a value of IDLE.

The transition of CCA from CLEAR to BUSY resets the CCA watchdog timer and CCA watchdog counter. dot11CCAWatchdogTimerMax and dot11CCAWatchdogCountMax are parameters available via MIB entries and can be read and set via the LME.

Rise and fall times of CCA relative to the OR'ing of the CS and ED signals shall be less than 30 ns. CS and ED are both internal signals to the PHY and are not available directly to the MAC, nor are they defined at any exposed interface.

16.3.5.4 CHNL_ID

For the IR PHY, CHNL_ID = X'01' is defined as the baseband modulation method. All other values are not defined.

16.4 PHY attributes

PHY attributes have allowed values and default values that are PHY dependent. Table 80 and Table 81 describe those values, and further specify whether they are permitted to vary from implementation to implementation.

Table 80 does not provide the definition of the attributes, but only provides the IR PHY-specific values for the attributes whose definitions are in Clause 13.

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Table 80—IR PHY MIB attributes

PHY MIB object	Default value	Operational semantics	Operational behavior
dot11CCAWatchdogTimerMax	Implementation dependent	Dynamic	A conformant PHY may set this via the LME
dot11CCAWatchdogCountMax	Implementation dependent	Dynamic	A conformant PHY may set this via the LME
dot11CCAWatchdogTimerMin	22 μs	Static	Identical for all conformant PHYs
dot11CCAWatchdogCountMin	1	Static	Identical for all conformant PHYs
dot11SupportedDataRatesTx	Implementation dependent	Static	All conformant PHYs must include the value X'02' (1 Mbit/s).
dot11SupportedDataRatesRx	Implementation dependent	Static	All conformant PHYs must include the values X'02' (1 Mbit/s) and X'04' (2 Mbit/s).
dot11PhyType	03	Static	Identical for all conformant PHYs
dot11PhyTempType	X'01'	Static	Identical for all conformant PHYs

The static IR PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 81. The definitions of these characteristics are in 10.4.3.

Table 81—IR PHY characteristics

Characteristic	Value
aSlotTime	8 μs
aSIFSTime	10 μs
aCCATime	5 μs
aRxTxTurnaroundTime	0 μs
aTxPLCPDelay	Implementers may choose any value for this delay as long as the requirements of aRxTxTurnaroundTime are met.
aRxPLCPDelay	1 μs
aRxTxSwitchTime	0 μs
aTxRampOnTime	0 μs
aTxRampOffTime	0 μs
aTxRFDelay	Implementers may choose any value for this delay as long as the requirements of aRxTxTurnaroundTime are met.
aRxRFDelay	Implementers may choose any value for this delay as long as the requirements of aSIFSTime and aCCATime are met.
aAirPropagationTime	1 μs
aMACProcessingDelay	2 μs
aPreambleLength	16 μs (1 Mbit/s) 20 μs (2 Mbit/s)
aPLCPHeaderLength	41 μs (1 Mbit/s) 25 μs (2 Mbit/s)
aMPDUDurationFactor	0
aMPDUMaxLength	2500
aCWmin	63
aCWmax	1023

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17. Orthogonal frequency division multiplexing (OFDM) PHY specification for the 5 GHz band

17.1 Introduction

This clause specifies the PHY entity for an orthogonal frequency division multiplexing (OFDM) system. The RF LAN system is initially aimed for the 5.15–5.25, 5.25–5.35 and 5.725–5.825 GHz unlicensed national information structure (U-NII) bands, as regulated in the United States by the Code of Federal Regulations, Title 47, Section 15.407. The OFDM system provides a wireless LAN with data payload communication capabilities of 6, 9, 12, 18, 24, 36, 48, and 54 Mbit/s. The support of transmitting and receiving at data rates of 6, 12, and 24 Mbit/s is mandatory. The system uses 52 subcarriers that are modulated using binary or quadrature phase shift keying (BPSK or QPSK) or using 16- or 64-quadrature amplitude modulation (16-QAM or 64-QAM). Forward error correction coding (convolutional coding) is used with a coding rate of 1/2, 2/3, or 3/4.

17.1.1 Scope

This subclause describes the PHY services provided to the IEEE 802.11 wireless LAN MAC by the 5 GHz (bands) OFDM system. The OFDM PHY consists of two protocol functions, as follows:

a) A PHY convergence function, which adapts the capabilities of the PMD system to the PHY service. This function is supported by the PLCP, which defines a method of mapping the IEEE 802.11 PSDUs into a framing format suitable for sending and receiving user data and management information between two or more stations using the associated PMD system.

b) A PMD system whose function defines the characteristics and method of transmitting and receiving data through a WM between two or more stations, each using the OFDM system.

17.1.2 OFDM PHY functions

The 5 GHz OFDM PHY architecture is depicted in the reference model shown in Figure 11 (in 5.8). The OFDM PHY contains three functional entities: the PMD function, the PHY convergence function, and the layer management function. Each of these functions is described in detail in 17.1.2.1 through 17.1.2.4.

The OFDM PHY service is provided to the MAC through the PHY service primitives described in Clause 12.

17.1.2.1 PLCP sublayer

In order to allow the IEEE 802.11 MAC to operate with minimum dependence on the PMD sublayer, a PHY convergence sublayer is defined. This function simplifies the PHY service interface to the IEEE 802.11 MAC services.

17.1.2.2 PMD sublayer

The PMD sublayer provides a means to send and receive data between two or more stations. This clause is concerned with the 5 GHz band using OFDM modulation.

17.1.2.3 PLME

The PLME performs management of the local PHY functions in conjunction with the MLME.

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17.1.2.4 Service specification method

The models represented by figures and state diagrams are intended to be illustrations of the functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation; the actual method of implementation is left to the discretion of the IEEE 802.11 OFDM-PHY-compliant developer.

The service of a layer or sublayer is the set of capabilities that it offers to a user in the next higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

17.2 OFDM PHY specific service parameter list

17.2.1 Introduction

The architecture of the IEEE 802.11 MAC is intended to be PHY independent. Some PHY implementations require medium management state machines running in the MAC sublayer in order to meet certain PMD requirements. These PHY-dependent MAC state machines reside in a sublayer defined as the MLME. In certain PMD implementations, the MLME may need to interact with the PLME as part of the normal PHY-SAP primitives. These interactions are defined by the PLME parameter list currently defined in the PHY service primitives as TXVECTOR and RXVECTOR. The list of these parameters, and the values they may represent, are defined in the specific PHY specifications for each PMD. This subclause addresses the TXVECTOR and RXVECTOR for the OFDM PHY.

17.2.2 TXVECTOR parameters

The parameters in Table 82 are defined as part of the TXVECTOR parameter list in the PHY-TXSTART.request service primitive.

Table 82—TXVECTOR parameters

Parameter	Associate primitive	Value
LENGTH	PHY-TXSTART.request (TXVECTOR)	1–4095
DATATRATE	PHY-TXSTART.request (TXVECTOR)	6, 9, 12, 18, 24, 36, 48, and 54 (Support of 6, 12, and 24 data rates is mandatory.)
SERVICE	PHY-TXSTART.request (TXVECTOR)	Scrambler initialization; 7 null bits + 9 reserved null bits
TXPWR_LEVEL	PHY-TXSTART.request (TXVECTOR)	1–8

17.2.2.1 TXVECTOR LENGTH

The allowed values for the LENGTH parameter are in the range of 1 to 4095. This parameter is used to indicate the number of octets in the MPDU which the MAC is currently requesting the PHY to transmit. This value is used by the PHY to determine the number of octet transfers that will occur between the MAC and the PHY after receiving a request to start the transmission.

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17.2.2.2 TXVECTOR DATARATE

The DATARATE parameter describes the bit rate at which the PLCP shall transmit the PSDU. Its value can be any of the rates defined in Table 82. Data rates of 6, 12, and 24 shall be supported; other rates may also be supported.

17.2.2.3 TXVECTOR SERVICE

The SERVICE parameter consists of 7 null bits used for the scrambler initialization and 9 null bits reserved for future use.

17.2.2.4 TXVECTOR TXPWR_LEVEL

The allowed values for the TXPWR_LEVEL parameter are in the range from 1 to 8. This parameter is used to indicate which of the available TxPowerLevel attributes defined in the MIB shall be used for the current transmission.

17.2.3 RXVECTOR parameters

The parameters listed in Table 83 are defined as part of the RXVECTOR parameter list in the PHY-RXSTART.indicate service primitive.

Table 83—RXVECTOR parameters

Parameter	Associate primitive	Value
LENGTH	PHY-RXSTART.indicate	1–4095
RSSI	PHY-RXSTART.indicate (RXVECTOR)	0–RSSI maximum
DATARATE	PHY-RXSTART.request (RXVECTOR)	6, 9, 12, 18, 24, 36, 48, and 54
SERVICE	PHY-RXSTART.request (RXVECTOR)	Null

17.2.3.1 RXVECTOR LENGTH

The allowed values for the LENGTH parameter are in the range from 1–4095. This parameter is used to indicate the value contained in the LENGTH field which the PLCP has received in the PLCP header. The MAC and PLCP will use this value to determine the number of octet transfers that will occur between the two sublayers during the transfer of the received PSDU.

17.2.3.2 RXVECTOR RSSI

The allowed values for the RSSI parameter are in the range from 0 through RSSI maximum. This parameter is a measure by the PHY of the energy observed at the antenna used to receive the current PPDU. RSSI shall be measured during the reception of the PLCP preamble. RSSI is intended to be used in a relative manner, and it shall be a monotonically increasing function of the received power.

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17.2.3.3 DATARATE

DATARATE shall represent the data rate at which the current PPDU was received. The allowed values of the DATARATE are 6, 9, 12, 18, 24, 36, 48, or 54.

17.2.3.4 SERVICE

The SERVICE field shall be null.

17.3 OFDM PLCP sublayer

17.3.1 Introduction

This subclause provides a convergence procedure in which PSDUs are converted to and from PPDUs. During transmission, the PSDU shall be provided with a PLCP preamble and header to create the PPDU. At the receiver, the PLCP preamble and header are processed to aid in demodulation and delivery of the PSDU.

17.3.2 PLCP frame format

Figure 111 shows the format for the PPDU including the OFDM PLCP preamble, OFDM PLCP header, PSDU, tail bits, and pad bits. The PLCP header contains the following fields: LENGTH, RATE, a reserved bit, an even parity bit, and the SERVICE field. In terms of modulation, the LENGTH, RATE, reserved bit, and parity bit (with 6 zero tail bits appended) constitute a separate single OFDM symbol, denoted SIGNAL, which is transmitted with the most robust combination of BPSK modulation and a coding rate of R = 1/2. The SERVICE field of the PLCP header and the PSDU (with 6 zero tail bits and pad bits appended), denoted as DATA, are transmitted at the data rate described in the RATE field and may constitute multiple OFDM symbols. The tail bits in the SIGNAL symbol enable decoding of the RATE and LENGTH fields immediately after the reception of the tail bits. The RATE and LENGTH fields are required for decoding the DATA part of the packet. In addition, the CCA mechanism can be augmented by predicting the duration of the packet from the contents of the RATE and LENGTH fields, even if the data rate is not supported by the station. Each of these fields is described in detail in 17.3.3, 17.3.4, and 17.3.5.

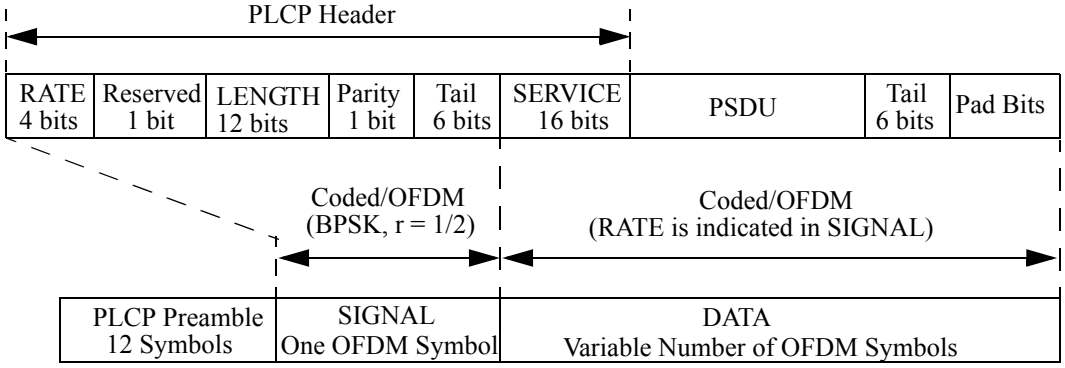

Figure 111—PPDU frame format

17.3.2.1 Overview of the PPDU encoding process

The encoding process is composed of many detailed steps, which are described fully in later subclauses, as noted below. The following overview intends to facilitate understanding the details of the convergence procedure:

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a) Produce the PLCP preamble field, composed of 10 repetitions of a "short training sequence" (used for AGC convergence, diversity selection, timing acquisition, and coarse frequency acquisition in the receiver) and two repetitions of a "long training sequence" (used for channel estimation and fine frequency acquisition in the receiver), preceded by a guard interval (GI). Refer to 17.3.3 for details.

b) Produce the PLCP header field from the RATE, LENGTH, and SERVICE fields of the TXVECTOR by filling the appropriate bit fields. The RATE and LENGTH fields of the PLCP header are encoded by a convolutional code at a rate of R = 1/2, and are subsequently mapped onto a single BPSK encoded OFDM symbol, denoted as the SIGNAL symbol. In order to facilitate a reliable and timely detection of the RATE and LENGTH fields, 6 zero tail bits are inserted into the PLCP header. The encoding of the SIGNAL field into an OFDM symbol follows the same steps for convolutional encoding, interleaving, BPSK modulation, pilot insertion, Fourier transform, and prepending a GI as described subsequently for data transmission at 6 Mbit/s. The contents of the SIGNAL field are not scrambled. Refer to 17.3.4 for details.

c) Calculate from RATE field of the TXVECTOR the number of data bits per OFDM symbol (N_{DBPS}), the coding rate (R), the number of bits in each OFDM subcarrier (N_{BPSC}), and the number of coded bits per OFDM symbol (N_{CBPS}). Refer to 17.3.2.2 for details.

d) Append the PSDU to the SERVICE field of the TXVECTOR. Extend the resulting bit string with zero bits (at least 6 bits) so that the resulting length will be a multiple of N_{DBPS}. The resulting bit string constitutes the DATA part of the packet. Refer to 17.3.5.3 for details.

e) Initiate the scrambler with a pseudo-random nonzero seed, generate a scrambling sequence, and XOR it with the extended string of data bits. Refer to 17.3.5.4 for details.

f) Replace the six scrambled zero bits following the data with six nonscrambled zero bits. (Those bits return the convolutional encoder to the zero state and are denoted as tail bits.) Refer to 17.3.5.2 for details.

g) Encode the extended, scrambled data string with a convolutional encoder (R = 1/2). Omit (puncture) some of the encoder output string (chosen according to "puncturing pattern") to reach the desired "coding rate." Refer to 17.3.5.5 for details.

h) Divide the encoded bit string into groups of N_{CBPS} bits. Within each group, perform an "interleaving" (reordering) of the bits according to a rule corresponding to the desired RATE. Refer to 17.3.5.6 for details.

i) Divide the resulting coded and interleaved data string into groups of N_{CBPS} bits. For each of the bit groups, convert the bit group into a complex number according to the modulation encoding tables. Refer to 17.3.5.7 for details.

j) Divide the complex number string into groups of 48 complex numbers. Each such group will be associated with one OFDM symbol. In each group, the complex numbers will be numbered 0 to 47 and mapped hereafter into OFDM subcarriers numbered –26 to –22, –20 to –8, –6 to –1, 1 to 6, 8 to 20, and 22 to 26. The subcarriers –21, –7, 7, and 21 are skipped and, subsequently, used for inserting pilot subcarriers. The 0 subcarrier, associated with center frequency, is omitted and filled with zero value. Refer to 17.3.5.9 for details.

k) Four subcarriers are inserted as pilots into positions –21, –7, 7, and 21. The total number of the subcarriers is 52 (48 + 4). Refer to 17.3.5.8 for details.

l) For each group of subcarriers –26 to 26, convert the subcarriers to time domain using inverse Fourier transform. Prepend to the Fourier-transformed waveform a circular extension of itself thus forming a GI, and truncate the resulting periodic waveform to a single OFDM symbol length by applying time domain windowing. Refer to 17.3.5.9 for details.

m) Append the OFDM symbols one after another, starting after the SIGNAL symbol describing the RATE and LENGTH fields. Refer to 17.3.5.9 for details.

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n) Up-convert the resulting "complex baseband" waveform to an RF according to the center frequency of the desired channel and transmit. Refer to 17.3.2.4 and 17.3.8.1 for details.

An illustration of the transmitted frame and its parts appears in Figure 114 (in 17.3.3).

17.3.2.2 RATE-dependent parameters

The modulation parameters dependent on the data rate used shall be set according to Table 84.

Table 84—Rate-dependent parameters

Data rate (Mbit/s)	Modulation	Coding rate (R)	Coded bits per subcarrier (N_{BPSC})	Coded bits per OFDM symbol (N_{CBPS})	Data bits per OFDM symbol (N_{DBPS})
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

17.3.2.3 Timing related parameters

Table 85 is the list of timing parameters associated with the OFDM PLCP.

Table 85—Timing-related parameters

Parameter	Value
N_{SD}: Number of data subcarriers	48
N_{SP}: Number of pilot subcarriers	4
N_{ST}: Number of subcarriers, total	52 ($N_{SD} + N_{SP}$)
Δ_F: Subcarrier frequency spacing	0.3125 MHz (=20 MHz/64)
T_{FFT}: Inverse Fast Fourier Transform (IFFT) / Fast Fourier Transform (FFT) period	3.2 μs ($1/\Delta_F$)
$T_{PREAMBLE}$: PLCP preamble duration	16 μs ($T_{SHORT} + T_{LONG}$)
T_{SIGNAL}: Duration of the SIGNAL BPSK-OFDM symbol	4.0 μs ($T_{GI} + T_{FFT}$)
T_{GI}: GI duration	0.8 μs ($T_{FFT}/4$)
T_{GI2}: Training symbol GI duration	1.6 μs ($T_{FFT}/2$)

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Table 85—Timing-related parameters *(continued)*

Parameter	Value
T_{SYM}: Symbol interval	4 μs ($T_{GI} + T_{FFT}$)
T_{SHORT}: Short training sequence duration	8 μs ($10 \times T_{FFT}/4$)
T_{LONG}: Long training sequence duration	8 μs ($T_{GI2} + 2 \times T_{FFT}$)

17.3.2.4 Mathematical conventions in the signal descriptions

The transmitted signals will be described in a complex baseband signal notation. The actual transmitted signal is related to the complex baseband signal by the following relation:

$$r_{(RF)}(t) = Re\{r(t)\exp(j2\pi f_c t)\} \tag{6}$$

where

$Re(.)$ represents the real part of a complex variable;
f_c denotes the carrier center frequency.

The transmitted baseband signal is composed of contributions from several OFDM symbols.

$$r_{PACKET}(t) = r_{PREAMBLE}(t) + r_{SIGNAL}(t - t_{SIGNAL}) + r_{DATA}(t - t_{DATA}) \tag{7}$$

The subframes of which Equation (7) are composed are described in 17.3.3, 17.3.4, and 17.3.5.9. The time offsets $t_{SUBFRAME}$ determine the starting time of the corresponding subframe; t_{SIGNAL} is equal to 16 μs, and t_{DATA} is equal to 20 μs.

All the subframes of the signal are constructed as an inverse Fourier transform of a set of coefficients, C_k, with C_k defined later as data, pilots, or training symbols in 17.3.3 through 17.3.5.

$$r_{SUBFRAME}(t) = w_{TSUBFRAME}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} C_k \exp(j2\pi k\Delta_f)(t - T_{GUARD}) \tag{8}$$

The parameters Δ_F and N_{ST} are described in Table 85. The resulting waveform is periodic with a period of $T_{FFT} = 1/\Delta_F$. Shifting the time by T_{GUARD} creates the "circular prefix" used in OFDM to avoid ISI from the previous frame. Three kinds of T_{GUARD} are defined: for the short training sequence (= 0 μs), for the long training sequence (= T_{GI2}), and for data OFDM symbols (= T_{GI}). (Refer to Table 85.) The boundaries of the subframe are set by a multiplication by a time-windowing function, $w_{TSUBFRAME}(t)$, which is defined as a rectangular pulse, $w_T(t)$, of duration T, accepting the value $T_{SUBFRAME}$. The time-windowing function, $w_T(t)$, depending on the value of the duration parameter, T, may extend over more than one period, T_{FFT}. In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble. Figure 112 illustrates the possibility of extending the windowing function over more than one period, T_{FFT}, and additionally shows smoothed transitions by application of a windowing function, as exemplified in Equation (9). In particular, window functions that extend over multiple periods of the FFT are utilized in the definition of the preamble.

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$$w_T(t) = \begin{cases} \sin^2\left(\frac{\pi}{2}(0.5 + t/T_{TR})\right) & (-T_{TR}/2 < t < T_{TR}/2) \\ 1 & (T_{TR}/2 \le t < T - T_{TR}/2) \\ \sin^2\left(\frac{\pi}{2}(0.5 - (t-T)/T_{TR})\right) & (T - T_{TR}/2 \le t < T + T_{TR}/2) \end{cases} \quad (9)$$

In the case of vanishing T_{TR}, the windowing function degenerates into a rectangular pulse of duration T. The normative specifications of generating the transmitted waveforms shall utilize the rectangular pulse shape. In implementation, higher T_{TR} is typically implemented in order to smooth the transitions between the consecutive subsections. This creates a small overlap between them, of duration T_{TR}, as shown in Figure 112. The transition time, T_{TR}, is about 100 ns. Smoothing the transition is required in order to reduce the spectral sidelobes of the transmitted waveform. However, the binding requirements are the spectral mask and modulation accuracy requirements, as detailed in 17.3.9.2 and 17.3.9.6. Time domain windowing, as described here, is just one way to achieve those objectives. The implementer may use other methods to achieve the same goal, such as frequency domain filtering. Therefore, the transition shape and duration of the transition are informative parameters.

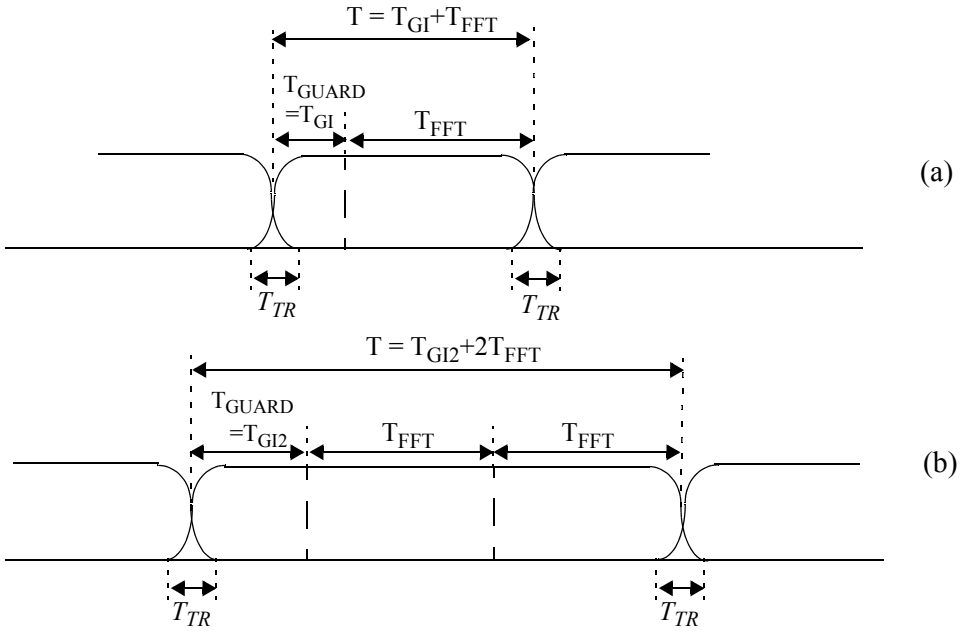

Figure 112—Illustration of OFDM frame with cyclic extension and windowing for (a) single reception or (b) two receptions of the FFT period

17.3.2.5 Discrete time implementation considerations

The following descriptions of the discrete time implementation are informational.

In a typical implementation, the windowing function will be represented in discrete time. As an example, when a windowing function with parameters T = 4.0 μs and a T_{TR} = 100 ns is applied, and the signal is sampled at 20 Msample/s, it becomes

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$$w_T[n] = w_T(nT_S) = \begin{Bmatrix} 1 & 1 \le n \le 79 \\ 0.5 & 0, 80 \\ 0 & otherwise \end{Bmatrix} \quad (10)$$

The common way to implement the inverse Fourier transform, as shown in Equation (8), is by an IFFT algorithm. If, for example, a 64-point IFFT is used, the coefficients 1 to 26 are mapped to the same numbered IFFT inputs, while the coefficients –26 to –1 are copied into IFFT inputs 38 to 63. The rest of the inputs, 27 to 37 and the 0 (dc) input, are set to 0. This mapping is illustrated in Figure 113. After performing an IFFT, the output is cyclically extended to the desired length.

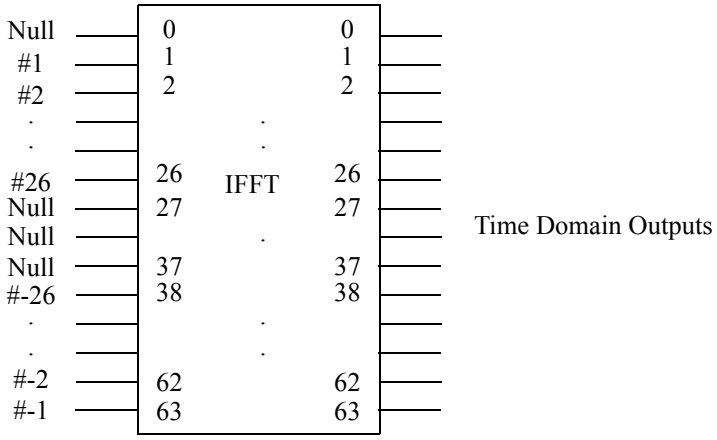

Figure 113—Inputs and outputs of inverse Fourier transform

17.3.3 PLCP preamble (SYNC)

The PLCP preamble field is used for synchronization. It consists of 10 short symbols and two long symbols that are shown in Figure 114 and described in this subclause.

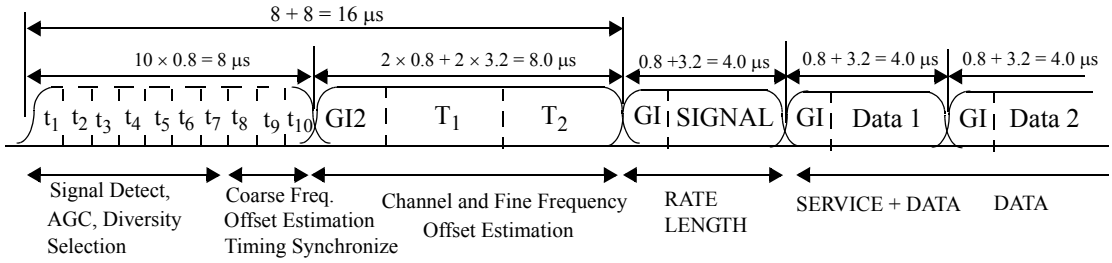

Figure 114—OFDM training structure

Figure 114 shows the OFDM training structure (PLCP preamble), where t_1 to t_{10} denote short training symbols and T_1 and T_2 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA. The total training length is 16 µs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier transform.

A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by

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$$S_{-26,26} = \sqrt{(13/6)} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0,$$

$$0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0,0\} \quad (11)$$

The multiplication by a factor of $\sqrt{(13/6)}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers.

The signal shall be generated according to the following equation:

$$r_{SHORT}(t) = w_{TSHORT}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} S_k \exp(j2\pi k\Delta_F t) \quad (12)$$

The fact that only spectral lines of $S_{-26:26}$ with indices that are a multiple of 4 have nonzero amplitude results in a periodicity of $T_{FFT}/4 = 0.8$ μs. The interval T_{SHORT} is equal to ten 0.8 μs periods (i.e., 8 μs).

Generation of the short training sequence is illustrated in Table G.2.

A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence L, given by

$$L_{-26,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 0,$$

$$1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\} \quad (13)$$

A long OFDM training symbol shall be generated according to the following equation:

$$r_{LONG}(t) = w_{TLONG}(t) \sum_{k=-N_{ST}/2}^{N_{ST}/2} L_k \exp(j2\pi k\Delta_F (t - T_{G12})) \quad (14)$$

where

$T_{G12} = 1.6$ μs.

Two periods of the long sequence are transmitted for improved channel estimation accuracy, yielding $T_{LONG} = 1.6 + 2 \times 3.2 = 8$ μs.

An illustration of the long training sequence generation is given in Table G.5.

The sections of short repetitions and long repetitions shall be concatenated to form the preamble

$$r_{PREAMBLE}(t) = r_{SHORT}(t) + r_{LONG}(t - T_{SHORT}) \quad (15)$$

17.3.4 SIGNAL field

The OFDM training symbols shall be followed by the SIGNAL field, which contains the RATE and the LENGTH fields of the TXVECTOR. The RATE field conveys information about the type of modulation and the coding rate as used in the rest of the packet. The encoding of the SIGNAL single OFDM symbol shall be performed with BPSK modulation of the subcarriers and using convolutional coding at R = 1/2. The encoding procedure, which includes convolutional encoding, interleaving, modulation mapping processes, pilot

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insertion, and OFDM modulation, follows the steps described in 17.3.5.5, 17.3.5.6, and 17.3.5.8, as used for transmission of data at a 6 Mbit/s rate. The contents of the SIGNAL field are not scrambled.

The SIGNAL field shall be composed of 24 bits, as illustrated in Figure 115. The four bits 0 to 3 shall encode the RATE. Bit 4 shall be reserved for future use. Bits 5–16 shall encode the LENGTH field of the TXVECTOR, with the LSB being transmitted first.

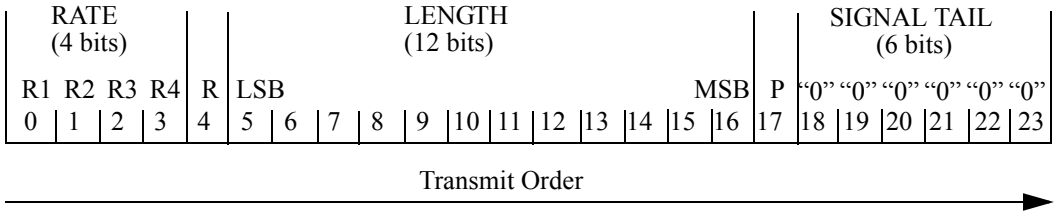

Figure 115—SIGNAL field bit assignment

The process of generating the SIGNAL OFDM symbol is illustrated in G.4.

17.3.4.1 RATE field

The bits R1–R4 shall be set, dependent on RATE, according to the values in Table 86.

Table 86—Contents of the SIGNAL field

Rate (Mbit/s)	R1–R4
6	1101
9	1111
12	0101
18	0111
24	1001
36	1011
48	0001
54	0011

17.3.4.2 PLCP LENGTH field

The PLCP LENGTH field shall be an unsigned 12-bit integer that indicates the number of octets in the PSDU that the MAC is currently requesting the PHY to transmit. This value is used by the PHY to determine the number of octet transfers that will occur between the MAC and the PHY after receiving a request to start transmission. The transmitted value shall be determined from the LENGTH parameter in the TXVECTOR issued with the PHY-TXSTART.request primitive described in 12.3.5.4. The LSB shall be transmitted first in time. This field shall be encoded by the convolutional encoder described in 17.3.5.5.

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17.3.4.3 Parity (P), Reserved (R), and SIGNAL TAIL fields

Bit 4 shall be reserved for future use. Bit 17 shall be a positive parity (even parity) bit for bits 0–16. The bits 18–23 constitute the SIGNAL TAIL field, and all 6 bits shall be set to 0.

17.3.5 DATA field

The DATA field contains the SERVICE field, the PSDU, the TAIL bits, and the PAD bits, if needed, as described in 17.3.5.2 and 17.3.5.3. All bits in the DATA field are scrambled, as described in 17.3.5.4.

17.3.5.1 SERVICE field

The IEEE 802.11 SERVICE field has 16 bits, which shall be denoted as bits 0–15. The bit 0 shall be transmitted first in time. The bits from 0–6 of the SERVICE field, which are transmitted first, are set to zeros and are used to synchronize the descrambler in the receiver. The remaining 9 bits (7–15) of the SERVICE field shall be reserved for future use. All reserved bits shall be set to 0. Refer to Figure 116.

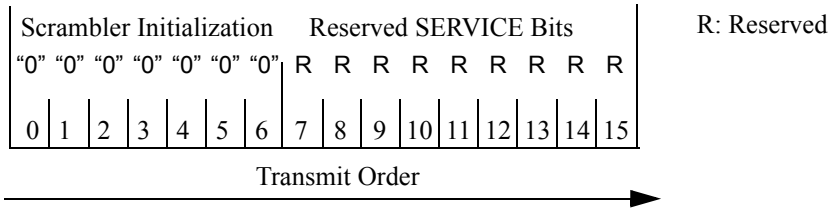

Figure 116—SERVICE field bit assignment

17.3.5.2 PPDU TAIL field

The PPDU TAIL field shall be six bits of zero, which are required to return the convolutional encoder to the zero state. This procedure improves the error probability of the convolutional decoder, which relies on future bits when decoding and which may be not be available past the end of the message. The PLCP tail bit field shall be produced by replacing six scrambled zero bits following the message end with six nonscrambled zero bits.

17.3.5.3 Pad bits (PAD)

The number of bits in the DATA field shall be a multiple of N_{CBPS}, the number of coded bits in an OFDM symbol (48, 96, 192, or 288 bits). To achieve that, the length of the message is extended so that it becomes a multiple of N_{DBPS}, the number of data bits per OFDM symbol. At least 6 bits are appended to the message, in order to accommodate the TAIL bits, as described in 17.3.5.2. The number of OFDM symbols, N_{SYM}; the number of bits in the DATA field, N_{DATA}; and the number of pad bits, N_{PAD}, are computed from the length of the PSDU (LENGTH) as follows:

$$N_{SYM} = \text{Ceiling}((16 + 8 \times \text{LENGTH} + 6)/N_{DBPS}) \quad (16)$$

$$N_{DATA} = N_{SYM} \times N_{DBPS} \quad (17)$$

$$N_{PAD} = N_{DATA} - (16 + 8 \times \text{LENGTH} + 6) \quad (18)$$

The function ceiling (.) is a function that returns the smallest integer value greater than or equal to its argument value. The appended bits ("pad bits") are set to zeros and are subsequently scrambled with the rest of the bits in the DATA field.

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An example of a DATA field that contains the SERVICE field, DATA, tail, and pad bits is given in G.5.1.

17.3.5.4 PLCP DATA scrambler and descrambler

The DATA field, composed of SERVICE, PSDU, tail, and pad parts, shall be scrambled with a length-127 frame-synchronous scrambler. The octets of the PSDU are placed in the transmit serial bit stream, bit 0 first and bit 7 last. The frame synchronous scrambler uses the generator polynomial *S(x)* as follows, and is illustrated in Figure 117:

$$S(x) = x^7 + x^4 + 1 \tag{19}$$

The 127-bit sequence generated repeatedly by the scrambler shall be (leftmost used first), 00001110 11110010 11001001 00000010 00100110 00101110 10110110 00001100 11010100 11100111 10110100 00101010 11111010 01010001 10111000 1111111, when the all ones initial state is used. The same scrambler is used to scramble transmit data and to descramble receive data. When transmitting, the initial state of the scrambler will be set to a pseudo-random nonzero state. The seven LSBs of the SERVICE field will be set to all zeros prior to scrambling to enable estimation of the initial state of the scrambler in the receiver.

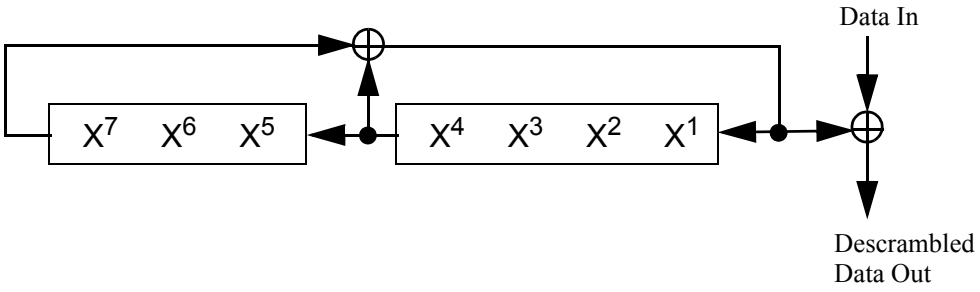

Figure 117—Data scrambler

An example of the scrambler output is illustrated in G.5.2.

17.3.5.5 Convolutional encoder

The DATA field, composed of SERVICE, PSDU, tail, and pad parts, shall be coded with a convolutional encoder of coding rate R = 1/2, 2/3, or 3/4, corresponding to the desired data rate. The convolutional encoder shall use the industry-standard generator polynomials, $g_0 = 133_8$ and $g_1 = 171_8$, of rate R = 1/2, as shown in Figure 118. The bit denoted as "A" shall be output from the encoder before the bit denoted as "B." Higher rates are derived from it by employing "puncturing." Puncturing is a procedure for omitting some of the encoded bits in the transmitter (thus reducing the number of transmitted bits and increasing the coding rate) and inserting a dummy "zero" metric into the convolutional decoder on the receive side in place of the omitted bits. The puncturing patterns are illustrated in Figure 119. Decoding by the Viterbi algorithm is recommended.

An example of encoding operation is shown in G.6.1.

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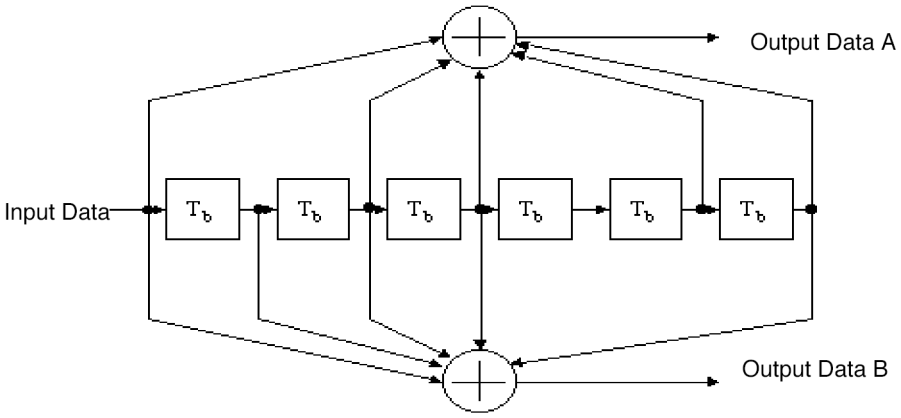

Figure 118—Convolutional encoder (k = 7)

17.3.5.6 Data interleaving

All encoded data bits shall be interleaved by a block interleaver with a block size corresponding to the number of bits in a single OFDM symbol, N_{CBPS}. The interleaver is defined by a two-step permutation. The first permutation ensures that adjacent coded bits are mapped onto nonadjacent subcarriers. The second ensures that adjacent coded bits are mapped alternately onto less and more significant bits of the constellation and, thereby, long runs of low reliability (LSB) bits are avoided.

The index of the coded bit before the first permutation shall be denoted by *k*; *i* shall be the index after the first and before the second permutation; and *j* shall be the index after the second permutation, just prior to modulation mapping.

The first permutation is defined by the rule

$$i = (N_{CBPS}/16)\,(k \bmod 16) + \text{floor}(k/16) \qquad k = 0,1,\ldots,N_{CBPS} - 1 \tag{20}$$

The function floor (.) denotes the largest integer not exceeding the parameter.

The second permutation is defined by the rule

$$j = s \times \text{floor}(i/s) + (i + N_{CBPS} - \text{floor}(16 \times i/N_{CBPS})) \bmod s \qquad i = 0,1,\ldots N_{CBPS} - 1 \tag{21}$$

The value of s is determined by the number of coded bits per subcarrier, N_{BPSC}, according to

$$s = \max(N_{BPSC}/2,1) \tag{22}$$

The deinterleaver, which performs the inverse relation, is also defined by two permutations.

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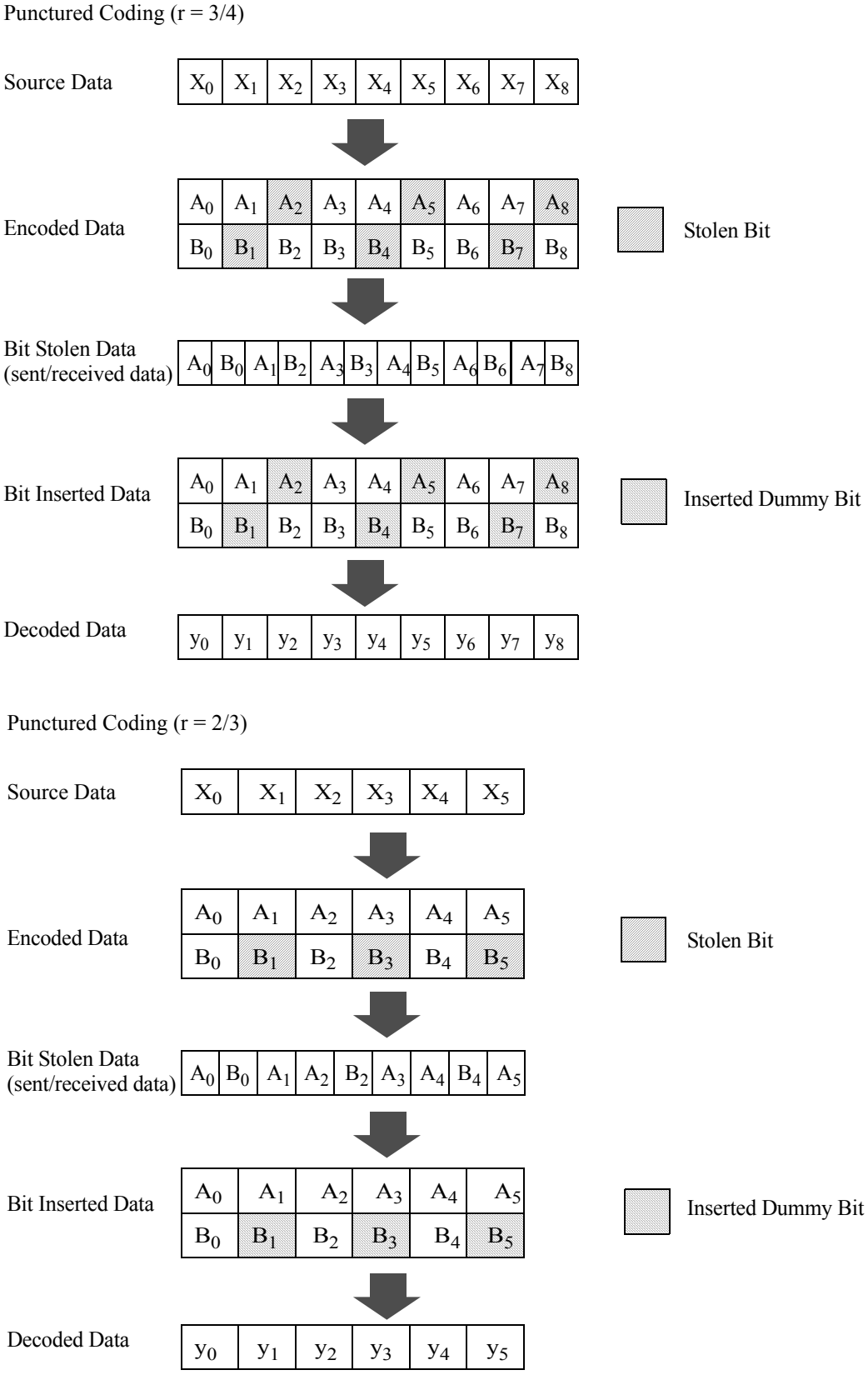

Figure 119—Example of the bit-stealing and bit-insertion procedure (r = 3/4, 2/3)

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Here the index of the original received bit before the first permutation shall be denoted by j; i shall be the index after the first and before the second permutation; and k shall be the index after the second permutation, just prior to delivering the coded bits to the convolutional (Viterbi) decoder.

The first permutation is defined by the rule

$$i = s \times \text{floor}(j/s) + (j + \text{floor}(16 \times j/N_{CBPS})) \bmod s \qquad j = 0,1,\ldots N_{CBPS} - 1 \tag{23}$$

where

s is defined in Equation (22).

This permutation is the inverse of the permutation described in Equation (21).

The second permutation is defined by the rule

$$k = 16 \times i - (N_{CBPS} - 1)\text{floor}(16 \times i/N_{CBPS}) \qquad i = 0,1,\ldots N_{CBPS} - 1 \tag{24}$$

This permutation is the inverse of the permutation described in Equation (20).

An example of interleaving operation is illustrated in G.6.2.

17.3.5.7 Subcarrier modulation mapping

The OFDM subcarriers shall be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM, depending on the RATE requested. The encoded and interleaved binary serial input data shall be divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion shall be performed according to Gray-coded constellation mappings, illustrated in Figure 120, with the input bit, b_0, being the earliest in the stream. The output values, d, are formed by multiplying the resulting (I+jQ) value by a normalization factor K_{MOD}, as described in Equation (25).

$$d = (I + jQ) \times K_{MOD} \tag{25}$$

The normalization factor, K_{MOD}, depends on the base modulation mode, as prescribed in Table 87. Note that the modulation type can be different from the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Figure 111. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in 17.3.9.6.

Table 87—Modulation-dependent normalization factor K_{MOD}

Modulation	K_{MOD}
BPSK	1
QPSK	$1/\sqrt{2}$
16-QAM	$1/\sqrt{10}$
64-QAM	$1/\sqrt{42}$

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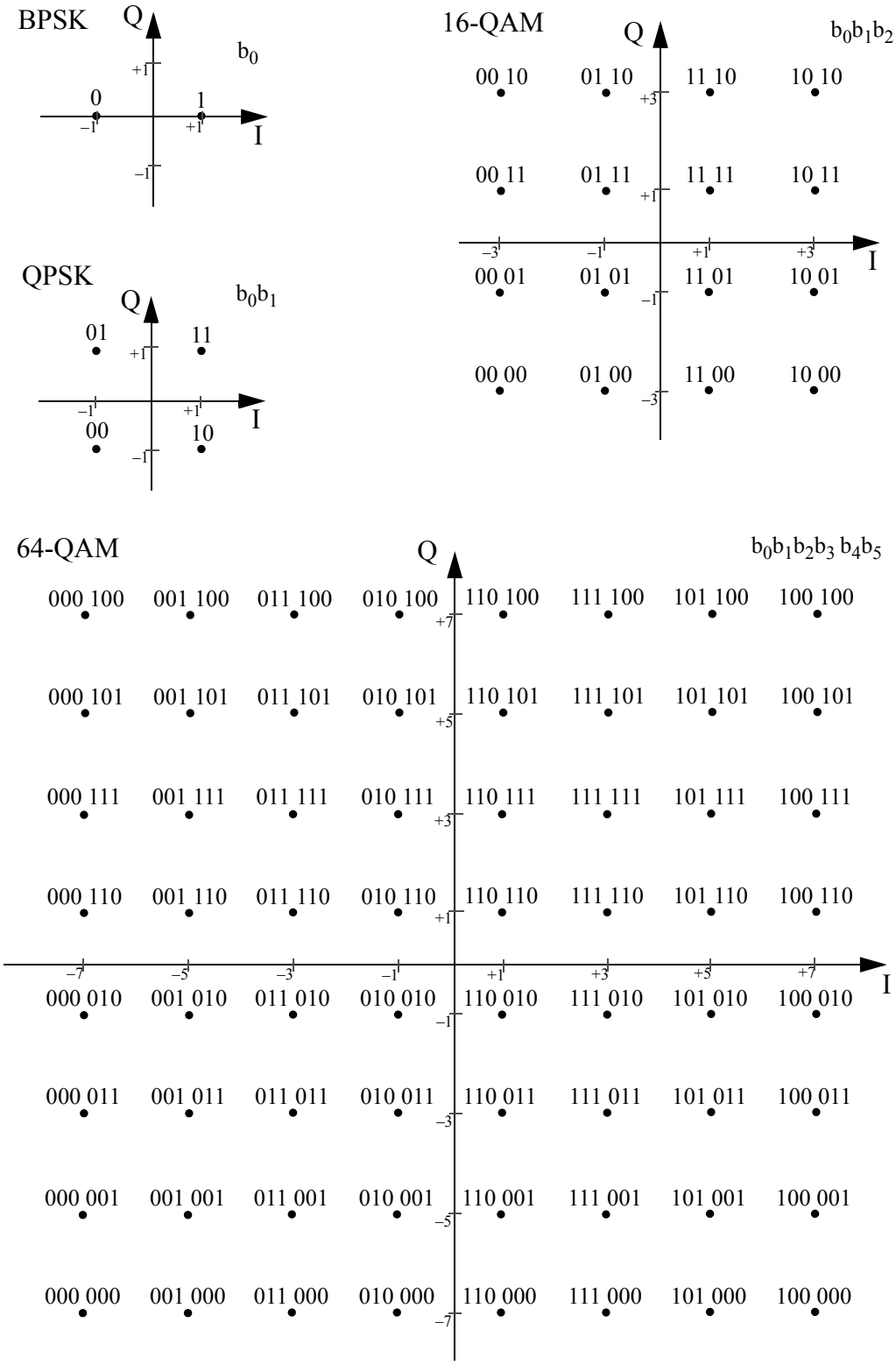

Figure 120—BPSK, QPSK, 16-QAM, and 64-QAM constellation bit encoding

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For BPSK, b_0 determines the I value, as illustrated in Table 88. For QPSK, b_0 determines the I value and b_1 determines the Q value, as illustrated in Table 89. For 16-QAM, b_0b_1 determines the I value and b_2b_3 determines the Q value, as illustrated in Table 90. For 64-QAM, $b_0b_1b_2$ determines the I value and $b_3b_4b_5$ determines the Q value, as illustrated in Table 91.

Table 88—BPSK encoding table

Input bit (b_0)	I-out	Q-out
0	–1	0
1	1	0

Table 89—QPSK encoding table

Input bit (b_0)	I-out
0	–1
1	1

Input bit (b_1)	Q-out
0	–1
1	1

Table 90—16-QAM encoding table

Input bits (b_0 b_1)	I-out
00	–3
01	–1
11	1
10	3

Input bits (b_2 b_3)	Q-out
00	–3
01	–1
11	1
10	3

Table 91—64-QAM encoding table

Input bits (b_0 b_1 b_2)	I-out
000	–7
001	–5
011	–3
010	–1
110	1
111	3
101	5
100	7

Input bits (b_3 b_4 b_5)	Q-out
000	–7
001	–5
011	–3
010	–1
110	1
111	3
101	5
100	7

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17.3.5.8 Pilot subcarriers

In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals shall be put in subcarriers –21, –7, 7, and 21. The pilots shall be BPSK modulated by a pseudo-binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in 17.3.5.9.

17.3.5.9 OFDM modulation

The stream of complex numbers is divided into groups of $N_{SD} = 48$ complex numbers. This shall be denoted by writing the complex number $d_{k,n}$, which corresponds to subcarrier k of OFDM symbol n, as follows:

$$d_{k,n} \equiv d_{k+N_{SD}\times n}, \qquad k = 0, \ldots N_{SD} - 1,\ n = 0, \ldots N_{SYM} - 1 \tag{26}$$

The number of OFDM symbols, N_{SYM}, was introduced in 17.3.5.3.

An OFDM symbol, $r_{DATA,n}(t)$, is defined as

$$r_{DATA,n}(t) = w_{TSYM}(t)\left(\sum_{k=0}^{N_{SD}-1} d_{k,n}\exp((j2\pi M(k)\Delta_F(t-T_{GI})) + p_{n+1}\sum_{k=-N_{ST}/2}^{N_{ST}/2} P_k\exp(j2\pi k\Delta_F(t-T_{GI}))\right) \tag{27}$$

where the function, $M(k)$, defines a mapping from the logical subcarrier number 0 to 47 into frequency offset index -26 to 26, while skipping the pilot subcarrier locations and the 0th (dc) subcarrier.

$$M(k) = \begin{cases} k-26 & 0 \le k \le 4 \\ k-25 & 5 \le k \le 17 \\ k-24 & 18 \le k \le 23 \\ k-23 & 24 \le k \le 29 \\ k-22 & 30 \le k \le 42 \\ k-21 & 43 \le k \le 47 \end{cases} \tag{28}$$

The contribution of the pilot subcarriers for the nth OFDM symbol is produced by inverse Fourier transform of sequence P, given by

$$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{29}$$

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The polarity of the pilot subcarriers is controlled by the sequence, p_n, which is a cyclic extension of the 127 elements sequence and is given by

$$p_{0..126v} = \{1,1,1,1,\ -1,-1,-1,1,\ -1,-1,-1,-1,\ 1,1,-1,1,\ -1,-1,1,1,\ -1,1,1,-1,\ 1,1,1,1,\ 1,1,-1,1,$$
$$1,1,-1,1,\ 1,-1,-1,1,\ 1,1,-1,1,\ -1,-1,-1,1,\ -1,1,-1,-1,\ 1,-1,-1,1,\ 1,1,1,1,\ -1,-1,1,1,$$
$$-1,-1,1,-1,\ 1,-1,1,1,\ -1,-1,-1,1,\ 1,-1,-1,-1,\ -1,1,-1,-1,\ 1,-1,1,1,\ 1,1,-1,1,\ -1,1,-1,1,$$
$$-1,-1,-1,-1,\ -1,1,-1,1,\ 1,-1,1,-1,\ 1,1,1,-1,\ -1,1,-1,-1,\ -1,1,1,1,\ -1,-1,-1,-1,\ -1,-1,-1\} \quad (30)$$

The sequence p_n can be generated by the scrambler defined by Figure 117 when the all ones initial state is used, and by replacing all 1's with –1 and all 0's with 1. Each sequence element is used for one OFDM symbol. The first element, p_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from p_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Figure 121. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used.

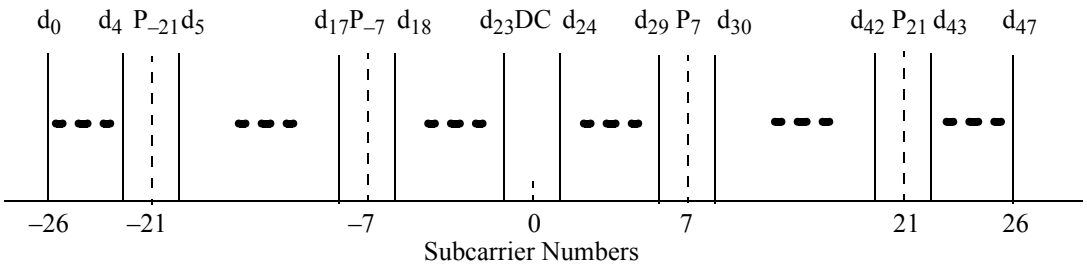

Figure 121—Subcarrier frequency allocation

The concatenation of N_{SYM} OFDM symbols can now be written as

$$r_{DATA}(t) = \sum_{n=0}^{N_{SYM}-1} r_{DATA,n}(t - nT_{SYM}) \quad (31)$$

An example of mapping into symbols is shown in G.6.3, as well as the scrambling of the pilot signals (see G.7. The final output of these operations is also shown in G.8.

17.3.6 CCA

PLCP shall provide the capability to perform CCA and report the result to the MAC. The CCA mechanism shall detect a "medium busy" condition with a performance specified in 17.3.10.5. This medium status report is indicated by the primitive PHY_CCA.indicate.

17.3.7 PLCP data modulation and modulation rate change

The PLCP preamble shall be transmitted using an OFDM modulated fixed waveform. The IEEE 802.11 SIGNAL field, BPSK-OFDM modulated at 6 Mbit/s, shall indicate the modulation and coding rate that shall be used to transmit the MPDU. The transmitter (receiver) shall initiate the modulation (demodulation) constellation and the coding rate according to the RATE indicated in the SIGNAL field. The MPDU transmission rate shall be set by the DATARATE parameter in the TXVECTOR, issued with the PHY-TXSTART.request primitive described in 17.2.2.

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17.3.8 PMD operating specifications (general)

General specifications for the BPSK OFDM, QPSK OFDM, 16-QAM OFDM, and 64-QAM OFDM PMD sublayers are provided in 17.3.8.1 through 17.3.8.8. These specifications apply to both the receive and transmit functions and general operation of the OFDM PHY.

17.3.8.1 Outline description

The general block diagram of the transmitter and receiver for the OFDM PHY is shown in Figure 122. Major specifications for the OFDM PHY are listed in Table 92.

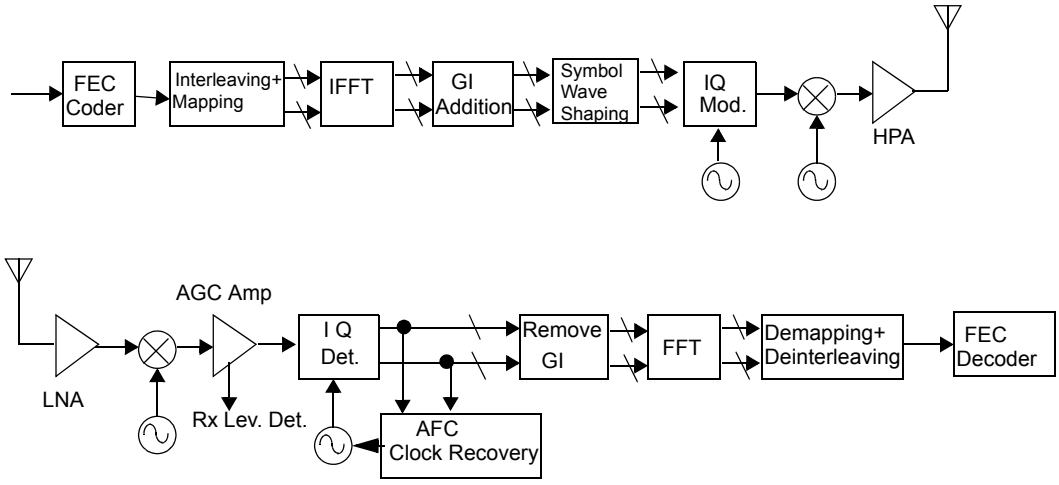

Figure 122—Transmitter and receiver block diagram for the OFDM PHY

Table 92—Major parameters of the OFDM PHY

Information data rate	6, 9, 12, 18, 24, 36, 48 and 54 Mbit/s (6, 12 and 24 Mbit/s are mandatory)
Modulation	BPSK OFDM QPSK OFDM 16-QAM OFDM 64-QAM OFDM
Error correcting code	K = 7 (64 states) convolutional code
Coding rate	1/2, 2/3, 3/4
Number of subcarriers	52
OFDM symbol duration	4.0 μs
GI	0.8 μs[a] (T_{GI})
Occupied bandwidth	16.6 MHz

[a]Refer to 17.3.2.4.

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17.3.8.2 Regulatory requirements

Wireless LANs implemented in accordance with this standard are subject to equipment certification and operating requirements established by regional and national regulatory administrations. The PMD specification establishes minimum technical requirements for interoperability, based upon established regulations at the time this standard was issued. These regulations are subject to revision, or may be superseded. Requirements that are subject to local geographic regulations are annotated within the PMD specification. Regulatory requirements that do not affect interoperability are not addressed in this standard. Implementers are referred to the regulatory sources in Table 93 for further information. Operation in countries within defined regulatory domains may be subject to additional or alternative national regulations.

The documents listed in Table 93 specify the current regulatory requirements for various geographic areas at the time this standard was developed. They are provided for information only, and are subject to change or revision at any time.

Table 93—Regulatory requirement list

Geographic area	Approval standards	Documents	Approval authority
United States	Federal Communications Commission (FCC)	CFR47 [B6], Part 15, Sections 15.205, 15.209, and 15.247; and Subpart E, Sections 15.401–15.407	FCC
Japan	Ministry of Post and Telecommunication (MPT)	MPT Ordinance for Regulating Radio Equipment, Article 49.20	MPT

17.3.8.3 Operating channel frequencies

17.3.8.3.1 Operating frequency range

The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region. Spectrum allocation in the 5 GHz band is subject to authorities responsible for geographic-specific regulatory domains (e.g., global, regional, and national). The particular channelization to be used for this standard is dependent on such allocation, as well as the associated regulations for use of the allocations. These regulations are subject to revision, or may be superseded. In the United States, the FCC is the agency responsible for the allocation of the 5 GHz U-NII bands.

In some regulatory domains, several frequency bands may be available for OFDM PHY-based wireless LANs. These bands may be contiguous or not, and different regulatory limits may be applicable. A compliant OFDM PHY shall support at least one frequency band in at least one regulatory domain. The support of specific regulatory domains, and bands within the domains, shall be indicated by PLME attributes dot11 RegDomainsSupported and dot11 FrequencyBandsSupported.

17.3.8.3.2 Channel numbering

Channel center frequencies are defined at every integral multiple of 5 MHz above 5 GHz. The relationship between center frequency and channel number is given by Equation (32):

$$\text{Channel center frequency} = 5000 + 5 \times n_{ch} \text{ (MHz)} \quad (32)$$

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where

$n_{ch} = 0,1,\ldots 200.$

This definition provides a unique numbering system for all channels with 5 MHz spacing from 5 GHz to 6 GHz, as well as the flexibility to define channelization sets for all current and future regulatory domains.

17.3.8.3.3 Channelization

The set of valid operating channel numbers by regulatory domain is defined in Table 94.

Table 94—Valid operating channel numbers by regulatory domain and band

Regulatory domain	Band (GHz)	Operating channel numbers	Channel center frequencies (MHz)
United States	U-NII lower band (5.15–5.25)	36 40 44 48	5180 5200 5220 5240
United States	U-NII middle band (5.25–5.35)	52 56 60 64	5260 5280 5300 5320
United States	U-NII upper band (5.725–5.825)	149 153 157 161	5745 5765 5785 5805

Figure 123 shows the channelization scheme for this standard, which shall be used with the FCC U-NII frequency allocation. The lower and middle U-NII sub-bands accommodate eight channels in a total bandwidth of 200 MHz. The upper U-NII band accommodates four channels in a 100 MHz bandwidth. The centers of the outermost channels shall be at a distance of 30 MHz from the band's edges for the lower and middle U-NII bands, and 20 MHz for the upper U-NII band.

The OFDM PHY shall operate in the 5 GHz band, as allocated by a regulatory body in its operational region.

The center frequency is indicated in Figure 123; however, no subcarrier is allocated on the center frequency as described in Figure 121.

In a multiple cell network topology, overlapping and/or adjacent cells using different channels can operate simultaneously.

17.3.8.4 Transmit and receive in-band and out-of-band spurious emissions

The OFDM PHY shall conform to in-band and out-of-band spurious emissions as set by regulatory bodies. For the United States, refer to Section 15.407 of FCC CFR47.

17.3.8.5 TX RF delay

The TX RF delay time shall be defined as the time between the issuance of a PMD.DATA.request to the PMD and the start of the corresponding symbol at the air interface.

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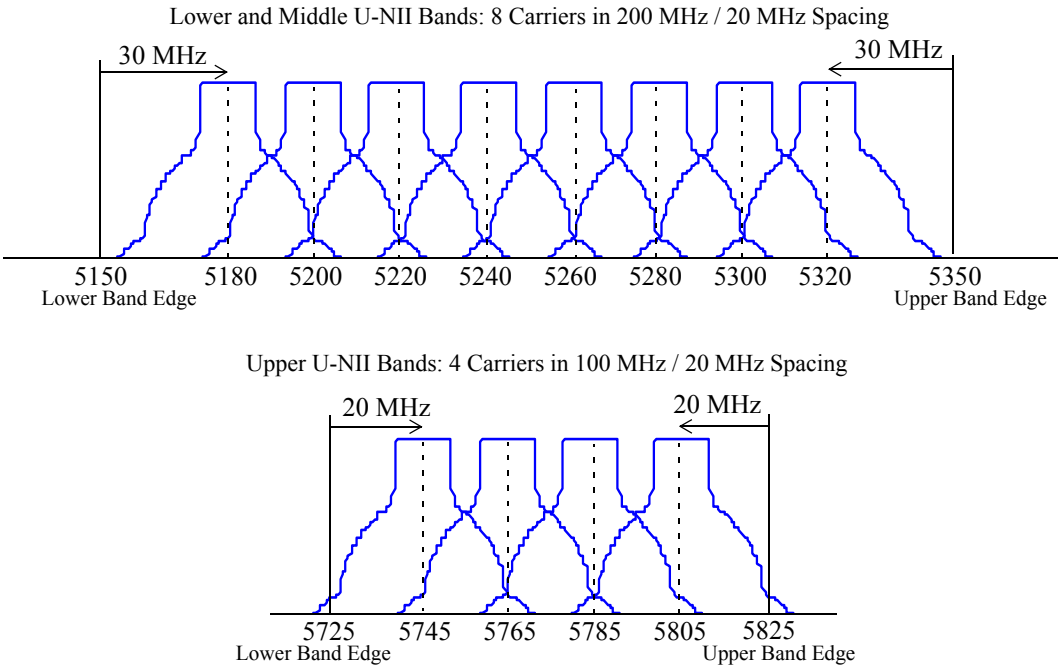

Figure 123—OFDM PHY frequency channel plan for the United States

17.3.8.6 Slot time

The slot time for the OFDM PHY shall be 9 μs, which is the sum of the RX-to-TX turnaround time, MAC processing delay, and CCA detect time (< 4 μs). The propagation delay shall be regarded as being included in the CCA detect time.

17.3.8.7 Transmit and receive antenna port impedance

The transmit and receive antenna port(s) impedance shall be 50 Ω if the port is exposed.

17.3.8.8 Transmit and receive operating temperature range

Three temperature ranges for full operation compliance to the OFDM PHY are specified in Clause 13. Type 1, defined as 0 °C to 40 °C, is designated for office environments. Type 2, defined as –20 °C to 50 °C, and Type 3, defined as –30 °C to 70 °C, are designated for industrial environments.

17.3.9 PMD transmit specifications

The transmit specifications associated with the PMD sublayer are described in 17.3.9.1 through 17.3.9.7. In general, these are specified by primitives from the PLCP, and the transmit PMD entity provides the actual means by which the signals required by the PLCP primitives are imposed onto the medium.

17.3.9.1 Transmit power levels

The maximum allowable output power according to FCC regulations is shown in Table 95.

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Table 95—Transmit power levels for the United States

Frequency band (GHz)	Maximum output power with up to 6 dBi antenna gain (mW)
5.15–5.25	40 (2.5 mW/MHz)
5.25–5.35	200 (12.5 mW/MHz)
5.725–5.825	800 (50 mW/MHz)

17.3.9.2 Transmit spectrum mask

The transmitted spectrum shall have a 0 dBr (dB relative to the maximum spectral density of the signal) bandwidth not exceeding 18 MHz, –20 dBr at 11 MHz frequency offset, –28 dBr at 20 MHz frequency offset and –40 dBr at 30 MHz frequency offset and above. The transmitted spectral density of the transmitted signal shall fall within the spectral mask, as shown in Figure 124. The measurements shall be made using a 100 kHz resolution bandwidth and a 30 kHz video bandwidth.

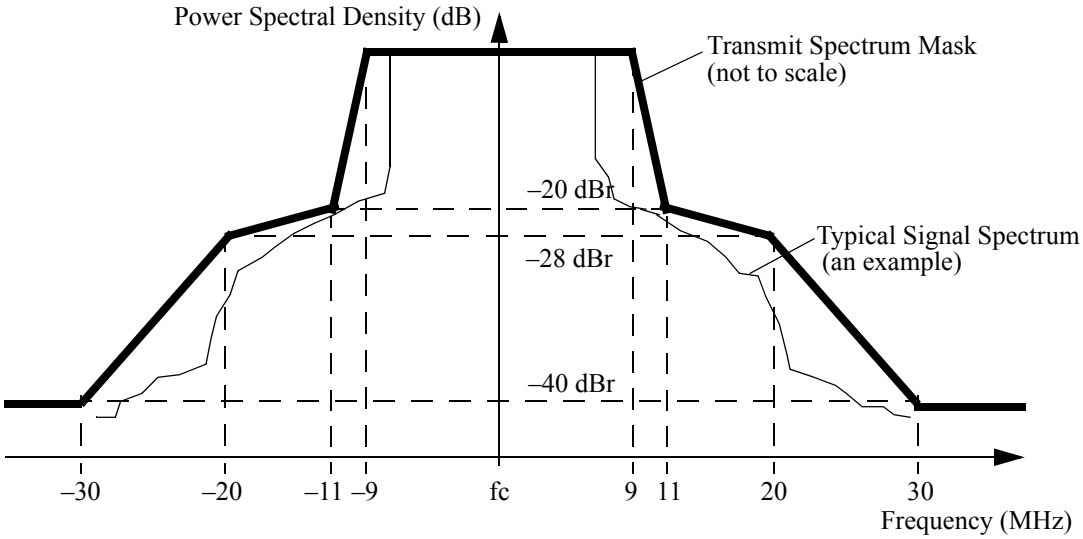

Figure 124—Transmit spectrum mask

17.3.9.3 Transmission spurious

Spurious transmissions from compliant devices shall conform to national regulations.

17.3.9.4 Transmit center frequency tolerance

The transmitted center frequency tolerance shall be ±20 ppm maximum. The transmit center frequency and the symbol clock frequency shall be derived from the same reference oscillator.

17.3.9.5 Symbol clock frequency tolerance

The symbol clock frequency tolerance shall be ±20 ppm maximum. The transmit center frequency and the symbol clock frequency shall be derived from the same reference oscillator.

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17.3.9.6 Modulation accuracy

Transmit modulation accuracy specifications are described in this subclause. The test method is described in 17.3.9.7.

17.3.9.6.1 Transmitter center frequency leakage

Certain transmitter implementations may cause leakage of the center frequency component. Such leakage (which manifests itself in a receiver as energy in the center frequency component) shall not exceed -15 dB relative to overall transmitted power or, equivalently, +2 dB relative to the average energy of the rest of the subcarriers. The data for this test shall be derived from the channel estimation phase.

17.3.9.6.2 Transmitter spectral flatness

The average energy of the constellations in each of the spectral lines –16.. –1 and +1.. +16 will deviate no more than ± 2 dB from their average energy. The average energy of the constellations in each of the spectral lines –26.. –17 and +17.. +26 will deviate no more than +2/–4 dB from the average energy of spectral lines –16.. –1 and +1.. +16. The data for this test shall be derived from the channel estimation step.

17.3.9.6.3 Transmitter constellation error

The relative constellation RMS error, averaged over subcarriers, OFDM frames, and packets, shall not exceed a data-rate dependent value according to Table 96.

Table 96—Allowed relative constellation error versus data rate

Data rate (Mbit/s)	Relative constellation error (dB)
6	–5
9	–8
12	–10
18	–13
24	–16
36	–19
48	–22
54	–25

17.3.9.7 Transmit modulation accuracy test

The transmit modulation accuracy test shall be performed by instrumentation capable of converting the transmitted signal into a stream of complex samples at 20 Msample/s or more, with sufficient accuracy in terms of I/Q arm amplitude and phase balance, dc offsets, phase noise, etc. A possible embodiment of such a setup is converting the signal to a low IF frequency with a microwave synthesizer, sampling the signal with a digital oscilloscope and decomposing it digitally into quadrature components.

The sampled signal shall be processed in a manner similar to an actual receiver, according to the following steps, or an equivalent procedure:

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a) Start of frame shall be detected.

b) Transition from short sequences to channel estimation sequences shall be detected, and fine timing (with one sample resolution) shall be established.

c) Coarse and fine frequency offsets shall be estimated.

d) The packet shall be derotated according to estimated frequency offset.

e) The complex channel response coefficients shall be estimated for each of the subcarriers.

f) For each of the data OFDM symbols: transform the symbol into subcarrier received values, estimate the phase from the pilot subcarriers, derotate the subcarrier values according to estimated phase, and divide each subcarrier value with a complex estimated channel response coefficient.

g) For each data-carrying subcarrier, find the closest constellation point and compute the Euclidean distance from it.

h) Compute the RMS average of all errors in a packet. It is given by

$$Error_{RMS} = \frac{\sum_{i=1}^{N_f} \sqrt{\frac{\sum_{j=1}^{L_P} \left[\sum_{k=1}^{52} \{(I(i,j,k) - I_0(i,j,k))^2 + (Q(i,j,k) - Q_0(i,j,k))^2\} \right]}{52 L_P \times P_0}}}{N_f} \quad (33)$$

where

L_P is the length of the packet;

N_f is the number of frames for the measurement;

$(I_0(i,j,k), Q_0(i,j,k))$ denotes the ideal symbol point of the ith frame, j^{th} OFDM symbol of the frame, k^{th} subcarrier of the OFDM symbol in the complex plane;

$(I(i,j,k), Q(i,j,k))$ denotes the observed point of the ith frame, j^{th} OFDM symbol of the frame, k^{th} subcarrier of the OFDM symbol in the complex plane (see Figure 125);

P_0 is the average power of the constellation.

The vector error on a phase plane is shown in Figure 125.

The test shall be performed over at least 20 frames (N_f), and the RMS average shall be taken. The packets under test shall be at least 16 OFDM symbols long. Random data shall be used for the symbols.

17.3.10 PMD receiver specifications

The receive specifications associated with the PMD sublayer are described in 17.3.10.1 through 17.3.10.5.

17.3.10.1 Receiver minimum input level sensitivity

The packet error rate (PER) shall be less than 10% at a PSDU length of 1000 bytes for rate-dependent input levels shall be the numbers listed in Table 97 or less. The minimum input levels are measured at the antenna connector (NF of 10 dB and 5 dB implementation margins are assumed).

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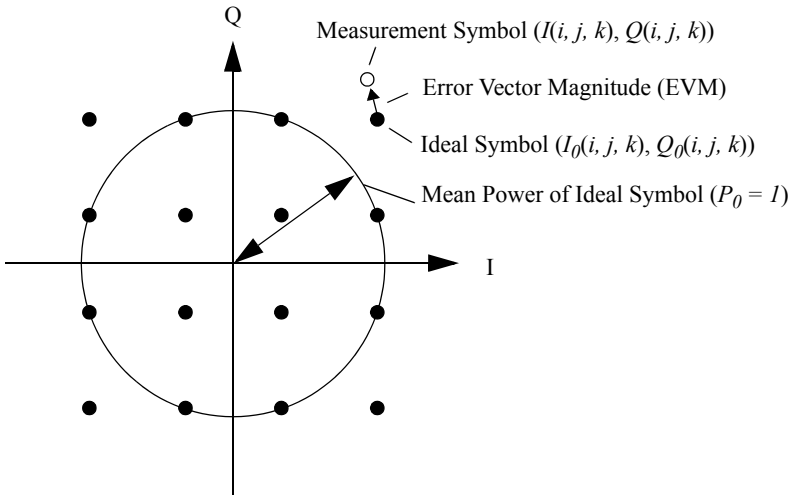

Figure 125—Constellation error

Table 97—Receiver performance requirements

Data rate (Mbit/s)	Minimum sensitivity (dBm)	Adjacent channel rejection (dB)	Alternate adjacent channel rejection (dB)
6	–82	16	32
9	–81	15	31
12	–79	13	29
18	–77	11	27
24	–74	8	24
36	–70	4	20
48	–66	0	16
54	–65	–1	15

17.3.10.2 Adjacent channel rejection

The adjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 97 and raising the power of the interfering signal until 10% PER is caused for a PSDU length of 1000 bytes. The power difference between the interfering and the desired channel is the corresponding adjacent channel rejection. The interfering signal in the adjacent channel shall be a conformant OFDM signal, unsynchronized with the signal in the channel under test. For a conformant OFDM PHY the corresponding rejection shall be no less than specified in Table 97.

17.3.10.3 Nonadjacent channel rejection

The nonadjacent channel rejection shall be measured by setting the desired signal's strength 3 dB above the rate-dependent sensitivity specified in Table 97, and raising the power of the interfering signal until a 10%

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PER occurs for a PSDU length of 1000 bytes. The power difference between the interfering and the desired channel is the corresponding nonadjacent channel rejection. The interfering signal in the nonadjacent channel shall be a conformant OFDM signal, unsynchronized with the signal in the channel under test. For a conformed OFDM PHY, the corresponding rejection shall be no less than specified in Table 97.

17.3.10.4 Receiver maximum input level

The receiver shall provide a maximum PER of 10% at a PSDU length of 1000 bytes, for a maximum input level of –30 dBm measured at the antenna for any baseband modulation.

17.3.10.5 CCA sensitivity

The start of a valid OFDM transmission at a receive level equal to or greater than the minimum 6 Mbit/s sensitivity (–82 dBm) shall cause CCA to indicate busy with a probability > 90% within 4 μs. If the preamble portion was missed, the receiver shall hold the CS signal busy for any signal 20 dB above the minimum 6 Mbit/s sensitivity (–62 dBm).

17.3.11 Transmit PLCP

The transmit PLCP is shown in Figure 126. In order to transmit data, PHY-TXSTART.request shall be enabled so that the PHY entity shall be in the transmit state. Further, the PHY shall be set to operate at the appropriate frequency through station management via the PLME. Other transmit parameters, such as DATARATE and TX power, are set via the PHY-SAP with the PHY-TXSTART.request(TXVECTOR), as described in 17.2.2.

A clear channel shall be indicated by PHY-CCA.indicate(IDLE). The MAC considers this indication before issuing the PHY-TXSTART.request. Transmission of the PPDU shall be initiated after receiving the PHY-TXSTART.request(TXVECTOR) primitive. The TXVECTOR elements for the PHY-TXSTART.request are the PLCP header parameters DATARATE, SERVICE, and LENGTH, and the PMD parameter TXPWR_LEVEL.

The PLCP shall issue PMD_TXPWRLVL and PMD_RATE primitives to configure the PHY. The PLCP shall then issue a PMD_TXSTART.request, and transmission of the PLCP preamble and PLCP header, based on the parameters passed in the PHY-TXSTART.request primitive. Once PLCP preamble transmission is started, the PHY entity shall immediately initiate data scrambling and data encoding. The scrambled and encoded data shall then be exchanged between the MAC and the PHY through a series of PHY-DATA.request(DATA) primitives issued by the MAC, and PHY-DATA.confirm primitives issued by the PHY. The modulation rate change, if any, shall be initiated from the SERVICE field data of the PLCP header, as described in 17.3.2.

The PHY proceeds with PSDU transmission through a series of data octet transfers from the MAC. The PLCP header parameter, SERVICE, and PSDU are encoded by the convolutional encoder with the bit-stealing function described in 17.3.5.5. At the PMD layer, the data octets are sent in bit 0–7 order and presented to the PHY through PMD_DATA.request primitives. Transmission can be prematurely terminated by the MAC through the primitive PHY-TXEND.request. PHY-TXSTART shall be disabled by the issuance of the PHY-TXEND.request. Normal termination occurs after the transmission of the final bit of the last PSDU octet, according to the number supplied in the OFDM PHY preamble LENGTH field.

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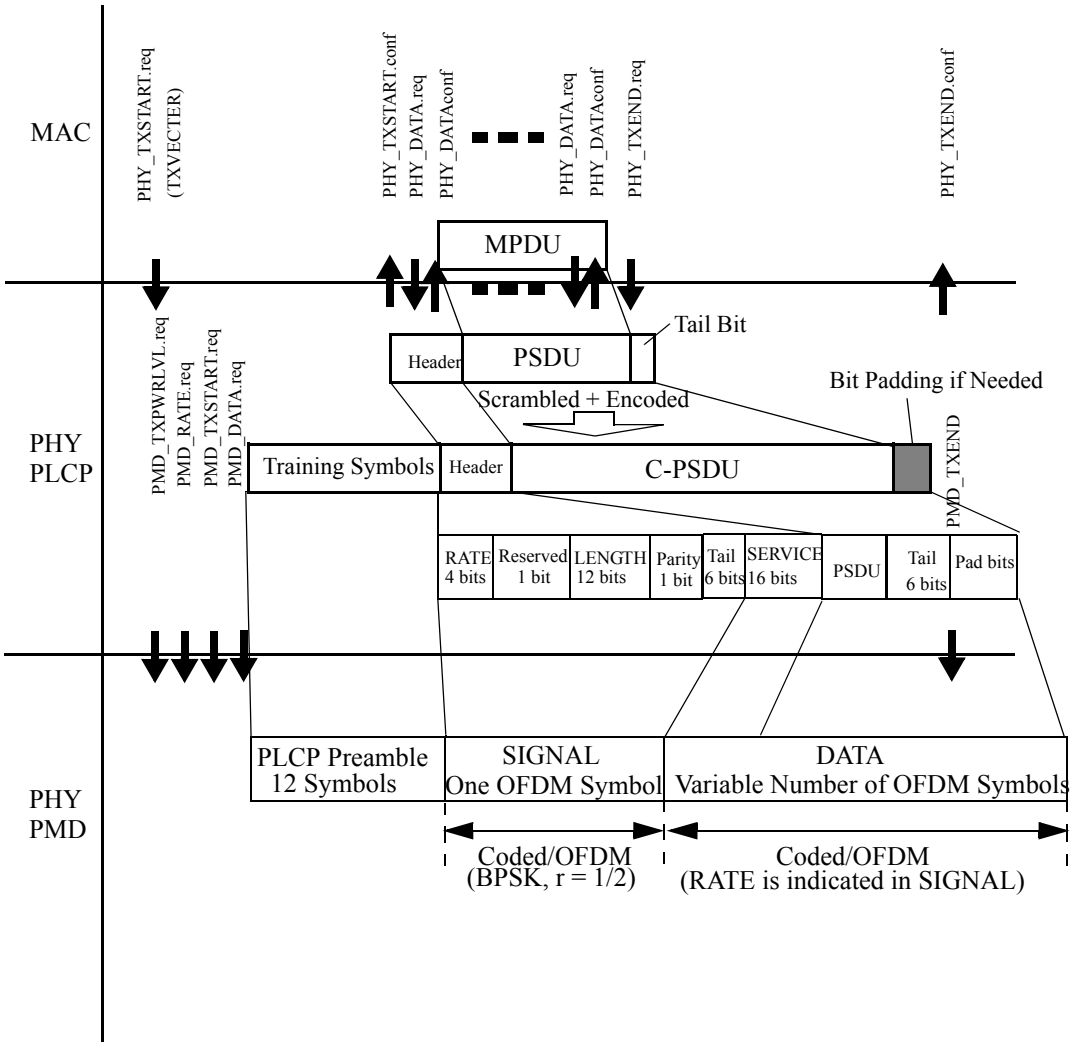

Figure 126—Transmit PLCP

The packet transmission shall be completed and the PHY entity shall enter the receive state (i.e., PHY-TXSTART shall be disabled). Each PHY-TXEND.request is acknowledged with a PHY-TXEND.confirm primitive from the PHY. If the coded PSDU (C-PSDU) is not multiples of the OFDM symbol, bits shall be stuffed to make the C-PSDU length multiples of the OFDM symbol.

In the PMD, the GI shall be inserted in every OFDM symbol as a countermeasure against severe delay spread.

A typical state machine implementation of the transmit PLCP is provided in Figure 127. Requests (.req) and confirmations(.confirm) are issued once with designated states.

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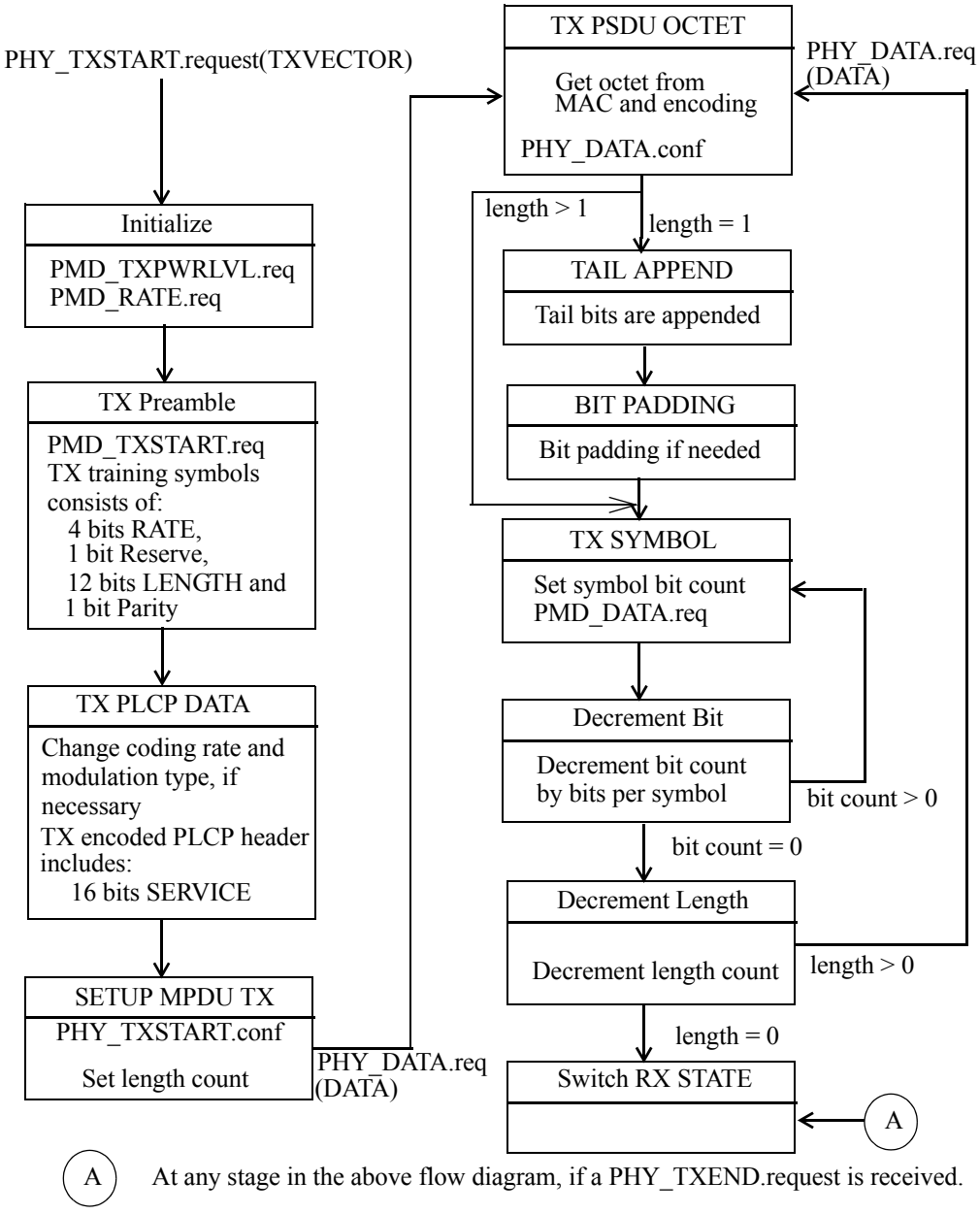

Figure 127—PLCP transmit state machine

17.3.12 Receive PLCP

The receive PLCP is shown in Figure 128. In order to receive data, PHY-TXSTART.request shall be disabled so that the PHY entity is in the receive state. Further, through station management (via the PLME) the PHY is set to the appropriate frequency. Other receive parameters, such as RSSI and indicated DATARATE, may be accessed via the PHY-SAP.

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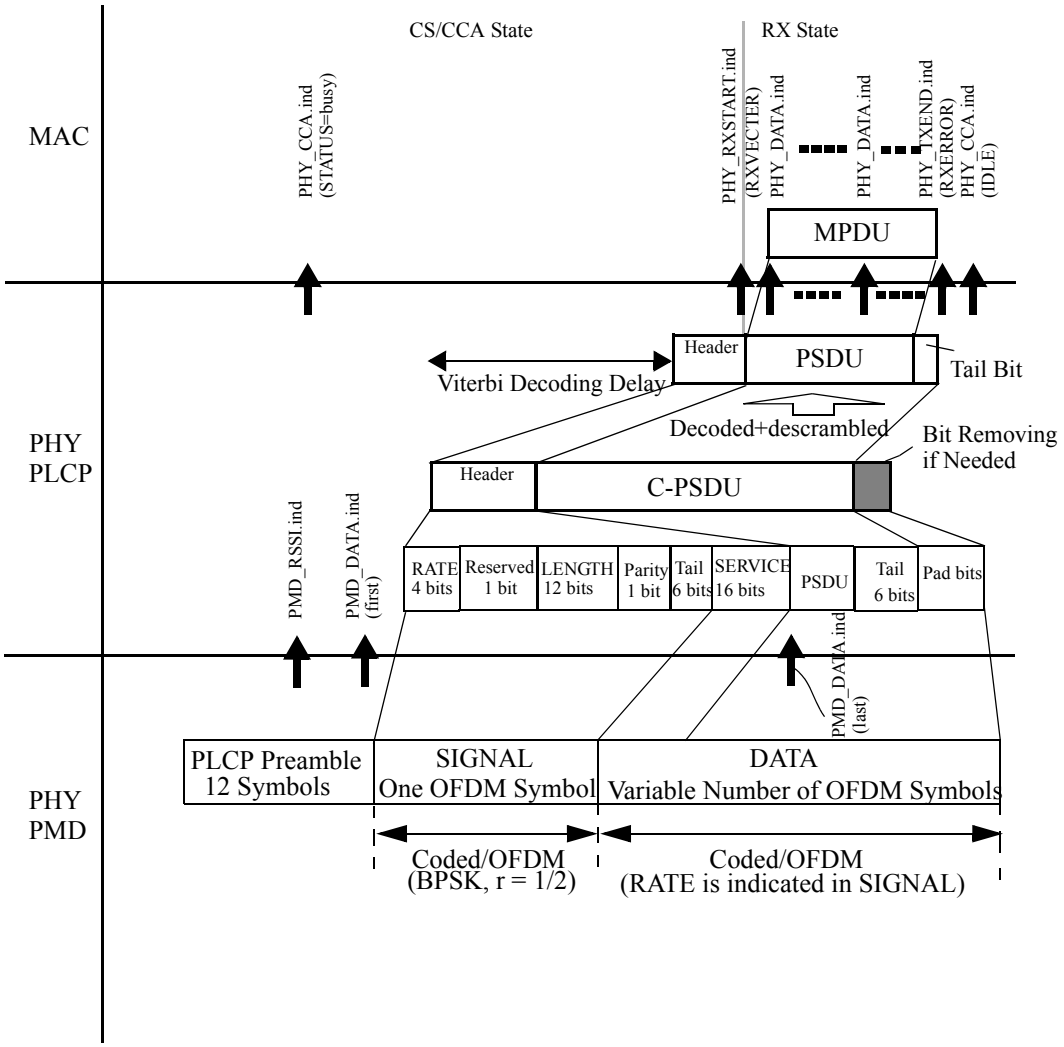

Figure 128—Receive PLCP

Upon receiving the transmitted PLCP preamble, PMD_RSSI.indicate shall report a significant received signal strength level to the PLCP. This indicates activity to the MAC via PHY_CCA.indicate. PHY_CCA.indicate(BUSY) shall be issued for reception of a signal prior to correct reception of the PLCP frame. The PMD primitive PMD_RSSI is issued to update the RSSI and parameter reported to the MAC.

After PHY-CCA.indicate is issued, the PHY entity shall begin receiving the training symbols and searching for the SIGNAL in order to set the length of the data stream, the demodulation type, and the decoding rate. Once the SIGNAL is detected, without any errors detected by a single parity (even), FEC decode shall be initiated and the PLCP IEEE 802.11 SERVICE fields and data shall be received, decoded (a Viterbi decoder is recommended), and checked by ITU-T CRC-32. If the FCS by the ITU-T CRC-32 check fails, the PHY receiver shall return to the RX IDLE state, as depicted in Figure 128. Should the status of CCA return to the IDLE state during reception prior to completion of the full PLCP processing, the PHY receiver shall return to the RX IDLE state.

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If the PLCP header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY-RXSTART.indicate(RXVECTOR) shall be issued. The RXVECTOR associated with this primitive includes the SIGNAL field, the SERVICE field, the PSDU length in bytes, and the RSSI. Also, in this case, the OFDM PHY will ensure that the CCA shall indicate a busy medium for the intended duration of the transmitted frame, as indicated by the LENGTH field.

The received PSDU bits are assembled into octets, decoded, and presented to the MAC using a series of PHY-DATA.indicate(DATA) primitive exchanges. The rate change indicated in the IEEE 802.11 SIGNAL field shall be initiated from the SERVICE field data of the PLCP header, as described in 17.3.2. The PHY shall proceed with PSDU reception. After the reception of the final bit of the last PSDU octet indicated by the PLCP preamble LENGTH field, the receiver shall be returned to the RX IDLE state, as shown in Figure 128. A PHY-RXEND.indicate(NoError) primitive shall be issued.

In the event that a change in the RSSI causes the status of the CCA to return to the IDLE state before the complete reception of the PSDU, as indicated by the PLCP LENGTH field, the error condition PHY-RXEND.indicate(CarrierLost) shall be reported to the MAC. The OFDM PHY will ensure that the CCA indicates a busy medium for the intended duration of the transmitted packet.

If the indicated rate in the SIGNAL field is not receivable, a PHY-RXSTART.indicate will not be issued. The PHY shall issue the error condition PHY-RXEND.indicate(UnsupportedRate). If the PLCP header is receivable, but the parity check of the PLCP header is not valid, a PHY-RXSTART.indicate will not be issued. The PHY shall issue the error condition PHY-RXEND.indicate(FormatViolation).

Any data received after the indicated data length are considered pad bits (to fill out an OFDM symbol) and should be discarded.

A typical state machine implementation of the receive PLCP is given in Figure 129.

17.4 OFDM PLME

17.4.1 PLME_SAP sublayer management primitives

Table 98 lists the MIB attributes that may be accessed by the PHY entities and the intralayer of higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, PLME-RESET, and PLME-CHARACTERISTICS primitives defined in 10.4.

17.4.2 OFDM PHY MIB

All OFDM PHY MIB attributes are defined in Clause 13, with specific values defined in Table 98. The column titled “Operational semantics” in Table 98 contains two types: static and dynamic. Static MIB attributes are fixed and cannot be modified for a given PHY implementation. Dynamic MIB attributes can be modified by some management entity.

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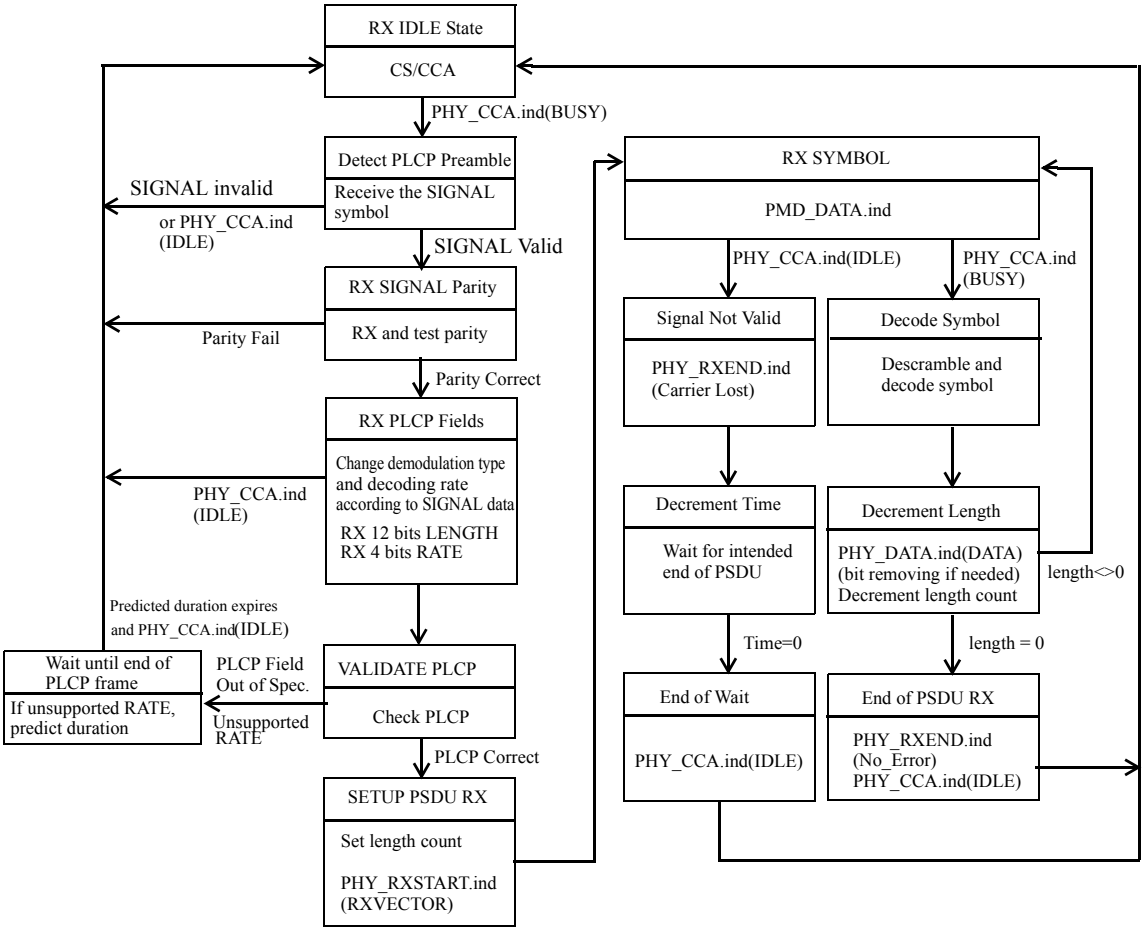

Figure 129—PLCP receive state machine

Table 98—MIB attribute default values/ranges

Managed object	Default value/range	Operational semantics
dot11 PHY Operation Table		
dot11 PHY type	OFDM-5. (04)	Static
dot11 Current reg domain	Implementation dependent	Static
dot11 Current frequency band	Implementation dependent	Dynamic
dot11 Temp type	Implementation dependent	Static
dot11 PHY Antenna Table		
dot11 Current Tx antenna	Implementation dependent	Dynamic
dot11 Diversity support	Implementation dependent	Static
dot11 Current Rx antenna	Implementation dependent	Dynamic

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Table 98—MIB attribute default values/ranges *(continued)*

Managed object	Default value/range	Operational semantics
dot11 PHY Tx Power Table		
dot11 Number supported power levels	Implementation dependent	Static
dot11 Tx power level 1	Implementation dependent	Static
dot11 Tx power level 2	Implementation dependent	Static
dot11 Tx power level 3	Implementation dependent	Static
dot11 Tx power level 4	Implementation dependent	Static
dot11 Tx power level 5	Implementation dependent	Static
dot11 Tx power level 6	Implementation dependent	Static
dot11 Tx power level 7	Implementation dependent	Static
dot11 Tx power level 8	Implementation dependent	Static
dot11 current Tx Power Level	Implementation dependent	Dynamic
dot11 Reg Domains Supported Table		
dot11 Reg domains supported	Implementation dependent	Static
dot11 Frequency bands supported	Implementation dependent	Static
dot11 PHY Antennas List Table		
dot 11 Supported Tx antenna	Implementation dependent	Static
dot11 Supported Rx antenna	Implementation dependent	Static
dot 11 Diversity selection Rx	Implementation dependent	Dynamic
dot11 Supported Data Rates Tx Table		
dot11 Supported data rates Tx value	6, 9, 12, 18, 24, 36, 48, and 54 Mbit/s Mandatory rates: 6, 12, and 24	Static
dot11SupportedDataRatesRxTable		
dot11 Supported data rates Rx value	6, 9, 12, 18, 24, 36, 48, and 54 Mbit/s Mandatory rates: 6, 12, and 24	Static
dot11 PHY OFDM Table		
dot11 Current frequency	Implementation dependent	Dynamic
dot11 TI threshold	Implementation dependent	Dynamic

17.4.3 OFDM TXTIME calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated according to the following equation:

$$TXTIME = T_{PREAMBLE} + T_{SIGNAL} + T_{SYM} \times Ceiling((16 + 8 \times LENGTH + 6)/N_{DBPS}) \quad (34)$$

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where

N_{DBPS} is derived from the DATARATE parameter. (Ceiling is a function that returns the smallest integer value greater than or equal to its argument value.)

N_{SYM} is given by Equation (16).

A simplified equation may be used.

$$TXTIME = T_{PREAMBLE} + T_{SIGNAL} + (16 + 8 \times LENGTH + 6)/DATARATE + T_{SYM}/2 \quad (35)$$

Equation (35) does not include the effect of rounding to the next OFDM symbol and may be in error by ±2 μs.

17.4.4 OFDM PHY characteristics

The static OFDM PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 99. The definitions for these characteristics are given in 10.4.

Table 99—OFDM PHY characteristics

Characteristics	Value
aSlotTime	9 μs
aSIFSTime	16 μs
aCCATime	< 4 μs
aRxTxTurnaroundTime	< 2 μs
aTxPLCPDelay	Implementation dependent
aRxPLCPDelay	Implementation dependent
aRxTxSwitchTime	<< 1 μs
aTxRampOnTime	Implementation dependent
aTxRampOffTime	Implementation dependent
aTxRFDelay	Implementation dependent
aRxRFDelay	Implementation dependent
aAirPropagationTime	<< 1 μs
aMACProcessingDelay	< 2 μs
aPreambleLength	20 μs
aPLCPHeaderLength	4 μs
aMPDUMaxLength	4095
aCWmin	15
aCWmax	1023

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17.5 OFDM PMD sublayer

17.5.1 Scope and field of application

This subclause describes the PMD services provided to the PLCP for the OFDM PHY. Also defined in this subclause are the functional, electrical, and RF characteristics required for interoperability of implementations conforming to this specification. The relationship of this specification to the entire OFDM PHY is shown in Figure 130.

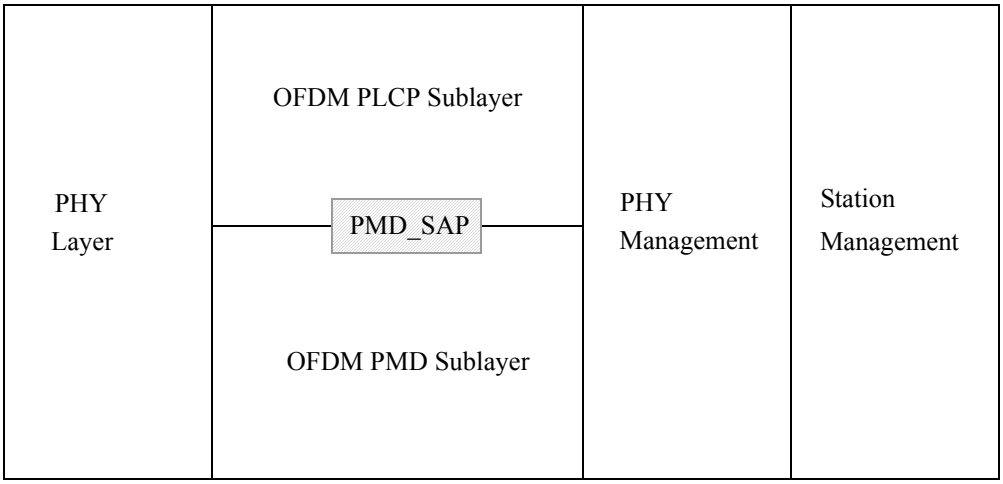

Figure 130—PMD layer reference model

17.5.2 Overview of service

The OFDM PMD sublayer accepts PLCP sublayer service primitives and provides the actual means by which data are transmitted or received from the medium. The combined function of the OFDM PMD sublayer primitives and parameters for the receive function results in a data stream, timing information, and associated receive signal parameters being delivered to the PLCP sublayer. A similar functionality shall be provided for data transmission.

17.5.3 Overview of interactions

The primitives associated with the IEEE 802.11 PLCP sublayer to the OFDM PMD fall into two basic categories

a) Service primitives that support PLCP peer-to-peer interactions;
b) Service primitives that have local significance and support sublayer-to-sublayer interactions.

17.5.4 Basic service and options

All of the service primitives described in this subclause are considered mandatory, unless otherwise specified.

17.5.4.1 PMD_SAP peer-to-peer service primitives

Table 100 indicates the primitives for peer-to-peer interactions.

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Table 100—PMD_SAP peer-to-peer service primitives

Primitive	Request	Indicate	Confirm	Response
PMD_DATA	X	X	—	—

17.5.4.2 PMD_SAP sublayer-to-sublayer service primitives

Table 101 indicates the primitives for sublayer-to-sublayer interactions.

Table 101—PMD_SAP sublayer-to-sublayer service primitives

Primitive	Request	Indicate	Confirm	Response
PMD_TXSTART	X	—	—	—
PMD_TXEND	X	—	—	—
PMD_TXPWRLVL	X	—	—	—
PMD_RATE	X	—	—	—
PMD_RSSI	—	X	—	—

17.5.4.3 PMD_SAP service primitive parameters

Table 102 shows the parameters used by one or more of the PMD_SAP service primitives.

Table 102—List of parameters for the PMD primitives

Parameter	Associate primitive	Value
TXD_UNIT	PMD_DATA.request	One(1), Zero(0): one OFDM symbol value
RXD_UNIT	PMD_DATA.indicate	One(1), Zero(0): one OFDM symbol value
TXPWR_LEVEL	PMD_TXPWRLVL.request	1–8 (max of 8 levels)
RATE	PMD_RATE.request	12 Mbit/s (for BPSK) 24 Mbit/s (for QPSK) 48 Mbit/s (for 16-QAM) 72 Mbit/s (for 64-QAM)
RSSI	PMD_RSSI.indicate	0–8 bits of RSSI

17.5.5 PMD_SAP detailed service specification

This subclause describes the services provided by each PMD primitive.

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17.5.5.1 PMD_DATA.request

17.5.5.1.1 Function

This primitive defines the transfer of data from the PLCP sublayer to the PMD entity.

17.5.5.1.2 Semantic of the service primitive

This primitive shall provide the following parameters:

PMD_DATA.request(TXD_UNIT)

The TXD_UNIT parameter shall be the n-bit combination of 0 and 1 for one symbol of OFDM modulation. If the length of a coded MPDU (C-MPDU) is shorter than n bits, 0 bits are added to form an OFDM symbol. This parameter represents a single block of data which, in turn, shall be used by the PHY to be encoded into an OFDM transmitted symbol.

17.5.5.1.3 When generated

This primitive shall be generated by the PLCP sublayer to request transmission of one OFDM symbol. The data clock for this primitive shall be supplied by the PMD layer based on the OFDM symbol clock.

17.5.5.1.4 Effect of receipt

The PMD performs transmission of the data.

17.5.5.2 PMD_DATA.indicate

17.5.5.2.1 Function

This primitive defines the transfer of data from the PMD entity to the PLCP sublayer.

17.5.5.2.2 Semantic of the service primitive

This primitive shall provide the following parameters:

PMD_DATA.indicate(RXD_UNIT)

The RXD_UNIT parameter shall be 0 or 1, and shall represent either a signal field bit or a data field bit after the decoding of the convolutional code by the PMD entity.

17.5.5.2.3 When generated

This primitive, generated by the PMD entity, forwards received data to the PLCP sublayer. The data clock for this primitive shall be supplied by the PMD layer based on the OFDM symbol clock.

17.5.5.2.4 Effect of receipt

The PLCP sublayer interprets the bits that are recovered as part of the PLCP or passes the data to the MAC sublayer as part of the MPDU.

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17.5.5.3 PMD_TXSTART.request

17.5.5.3.1 Function

This primitive, generated by the PHY PLCP sublayer, initiates PPDU transmission by the PMD layer.

17.5.5.3.2 Semantic of the service primitive

This primitive shall provide the following parameters:

PMD_TXSTART.request

17.5.5.3.3 When generated

This primitive shall be generated by the PLCP sublayer to initiate the PMD layer transmission of the PPDU. The PHY-TXSTART.request primitive shall be provided to the PLCP sublayer prior to issuing the PMD_TXSTART command.

17.5.5.3.4 Effect of receipt

PMD_TXSTART initiates transmission of a PPDU by the PMD sublayer.

17.5.5.4 PMD_TXEND.request

17.5.5.4.1 Function

This primitive, generated by the PHY PLCP sublayer, ends PPDU transmission by the PMD layer.

17.5.5.4.2 Semantic of the service primitive

This primitive shall provide the following parameters:

PMD_TXEND.request

17.5.5.4.3 When generated

This primitive shall be generated by the PLCP sublayer to terminate the PMD layer transmission of the PPDU.

17.5.5.4.4 Effect of receipt

PMD_TXEND terminates transmission of a PPDU by the PMD sublayer.

17.5.5.5 PMD_TXPWRLVL.request

17.5.5.5.1 Function

This primitive, generated by the PHY PLCP sublayer, selects the power level used by the PHY for transmission.

17.5.5.5.2 Semantic of the service primitive

This primitive shall provide the following parameters:

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PMD_TXPWRLVL.request(TXPWR_LEVEL)

TXPWR_LEVEL selects which of the transmit power levels should be used for the current packet transmission. The number of available power levels shall be determined by the MIB parameter aNumberSupportedPowerLevels. See 17.3.9.1 for further information on the OFDM PHY power level control capabilities.

17.5.5.5.3 When generated

This primitive shall be generated by the PLCP sublayer to select a specific transmit power. This primitive shall be applied prior to setting PMD_TXSTART into the transmit state.

17.5.5.5.4 Effect of receipt

PMD_TXPWRLVL immediately sets the transmit power level to that given by TXPWR_LEVEL.

17.5.5.6 PMD_RATE.request

17.5.5.6.1 Function

This primitive, generated by the PHY PLCP sublayer, selects the modulation rate that shall be used by the OFDM PHY for transmission.

17.5.5.6.2 Semantic of the service primitive

This primitive shall provide the following parameters:

PMD_RATE.request(RATE)

RATE selects which of the OFDM PHY data rates shall be used for MPDU transmission. See 17.3.8.6 for further information on the OFDM PHY modulation rates. The OFDM PHY rate change capability is described in detail in 17.3.7.

17.5.5.6.3 When generated

This primitive shall be generated by the PLCP sublayer to change or set the current OFDM PHY modulation rate used for the MPDU portion of a PPDU.

17.5.5.6.4 Effect of receipt

The receipt of PMD_RATE selects the rate that shall be used for all subsequent MPDU transmissions. This rate shall be used for transmission only. The OFDM PHY shall still be capable of receiving all the required OFDM PHY modulation rates.

17.5.5.7 PMD_RSSI.indicate

17.5.5.7.1 Function

This primitive, generated by the PMD sublayer, provides the receive signal strength to the PLCP and MAC entity.

17.5.5.7.2 Semantic of the service primitive

This primitive shall provide the following parameters:

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PMD_RSSI.indicate(RSSI)

The RSSI shall be a measure of the RF energy received by the OFDM PHY. RSSIs of up to 8 bits (256 levels) are supported.

17.5.5.7.3 When generated

This primitive shall be generated by the PMD when the OFDM PHY is in the receive state. It shall be available continuously to the PLCP which, in turn, shall provide the parameter to the MAC entity.

17.5.5.7.4 Effect of receipt

This parameter shall be provided to the PLCP layer for information only. The RSSI may be used as part of a CCA scheme.

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18. High Rate direct sequence spread spectrum (HR/DSSS) PHY specification

18.1 Overview

This clause specifies the High Rate extension of the PHY for the DSSS system (see Clause 15), hereinafter known as the High Rate PHY for the 2.4 GHz band designated for ISM applications.

This extension of the DSSS system builds on the data rate capabilities, as described in Clause 15, to provide 5.5 Mbit/s and 11 Mbit/s payload data rates in addition to the 1 Mbit/s and 2 Mbit/s rates. To provide the higher rates, 8-chip complementary code keying (CCK) is employed as the modulation scheme. The chipping rate is 11 MHz, which is the same as the DSSS system described in Clause 15, thus providing the same occupied channel bandwidth. The basic new capability described in this clause is called HR/DSSS. The basic High Rate PHY uses the same PLCP preamble and header as the DSSS PHY, so both PHYs can coexist in the same BSS and can use the rate switching mechanism as provided.

In addition to providing higher speed extensions to the DSSS system, a number of optional features allow the performance of the RF LAN system to be improved as technology allows the implementation of these options to become cost effective.

An optional mode replacing the CCK modulation with HR/DSSS/PBCC is provided.

Another optional mode is provided that allows data throughput at the higher rates (2, 5.5, and 11 Mbit/s) to be significantly increased by using a shorter PLCP preamble. This mode is called HR/DSSS/short, or HR/DSSS/PBCC/short. This Short Preamble mode can coexist with DSSS, HR/DSSS, or HR/DSSS/PBCC under limited circumstances, such as on different channels or with appropriate CCA mechanisms.

An optional capability for Channel Agility is also provided. This option allows an implementation to overcome some inherent difficulty with static channel assignments (a tone jammer), without burdening all implementations with the added cost of this capability. This option can also be used to implement IEEE 802.11-compliant systems that are interoperable with both FH and DS modulations. See Annex F for more details.

18.1.1 Scope

This clause specifies the PHY entity for the HR/DSSS extension and the changes that have to be made to the base standard to accommodate the High Rate PHY.

The High Rate PHY consists of the following two protocol functions:

a) A PHY convergence function, which adapts the capabilities of the PMD system to the PHY service. This function is supported by the PLCP, which defines a method for mapping the MPDUs into a framing format suitable for sending and receiving user data and management information between two or more STAs using the associated PMD system. The PHY exchanges PPDUs that contain PSDUs. The MAC uses the PHY service, so each MPDU corresponds to a PSDU that is carried in a PPDU.
b) A PMD system, whose function defines the characteristics of, and method of transmitting and receiving data through, a WM between two or more STAs, each using the High Rate PHY system.

18.1.2 High Rate PHY functions

The 2.4 GHz High Rate PHY architecture is depicted in the ISO/IEC basic reference model shown in Figure 141. The High Rate PHY contains three functional entities: the PMD function, the PHY convergence

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function, and the layer management function. Each of these functions is described in detail in 18.1.2.1, 18.1.2.2, and 18.1.2.3. For the purposes of MAC and MAC management, when Channel Agility is both present and enabled (see 18.3.2 and Annex C), the High Rate PHY shall be interpreted to be both a High Rate and a FH PHY.

The High Rate PHY service shall be provided to the MAC through the PHY service primitives described in Clause 12.

18.1.2.1 PLCP sublayer

To allow the MAC to operate with minimum dependence on the PMD sublayer, a PLCP sublayer is defined. This function simplifies the PHY service interface to the MAC services.

18.1.2.2 PMD sublayer

The PMD sublayer provides a means and method of transmitting and receiving data through a WM between two or more STAs, each using the High Rate system.

18.1.2.3 PLME

The PLME performs management of the local PHY functions in conjunction with the MLME.

18.1.3 Service specification method and notation

The models represented by figures and state diagrams are intended to be illustrations of functions provided. It is important to distinguish between a model and a real implementation. The models are optimized for simplicity and clarity of presentation; the actual method of implementation is left to the discretion of the High-Rate-PHY-compliant developer.

The service of a layer or sublayer is a set of capabilities that it offers to a user in the next-higher layer (or sublayer). Abstract services are specified here by describing the service primitives and parameters that characterize each service. This definition is independent of any particular implementation.

18.2 High Rate PLCP sublayer

18.2.1 Overview

This subclause provides a convergence procedure for the 2 Mbit/s, 5.5 Mbit/s, and 11 Mbit/s specification, in which PSDUs are converted to and from PPDUs. During transmission, the PSDU shall be appended to a PLCP preamble and header to create the PPDU. Two different preambles and headers are defined: the mandatory supported Long Preamble and header, which interoperates with the current 1 Mbit/s and 2 Mbit/s DSSS specification, and an optional Short Preamble and header. At the receiver, the PLCP preamble and header are processed to aid in demodulation and delivery of the PSDU.

The optional Short Preamble and header is intended for applications where maximum throughput is desired and interoperability with legacy and nonshort-preamble capable equipment is not a consideration. That is, it is expected to be used only in networks of like equipment, which can all handle the optional mode.

18.2.2 PPDU format

Two different preambles and headers are defined: the mandatory supported Long Preamble and header, which is interoperable with the current 1 Mbit/s and 2 Mbit/s DSSS specification, and an optional Short Preamble and header.

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18.2.2.1 Long PPDU format

Figure 131 shows the format for the interoperable (long) PPDU, including the High Rate PLCP preamble, the High Rate PLCP header, and the PSDU. The PLCP preamble contains the following fields: SYNC and SFD. The PLCP header contains the following fields: signaling (SIGNAL), service (SERVICE), length (LENGTH), and CRC-16. Each of these fields is described in detail in 18.2.3. The format for the PPDU, including the long High Rate PLCP preamble, the long High Rate PLCP header, and the PSDU, does not differ from the format for 1Mbit/s and 2 Mbit/s. The only exceptions are

a) The encoding of the rate in the SIGNAL field;
b) The use of a bit in the SERVICE field to resolve an ambiguity in PSDU length in octets, when the length is expressed in whole microseconds;
c) The use of a bit in the SERVICE field to indicate if the optional PBCC mode is being used;
d) The use of a bit in the SERVICE field to indicate that the transit frequency and bit clocks are locked.

.

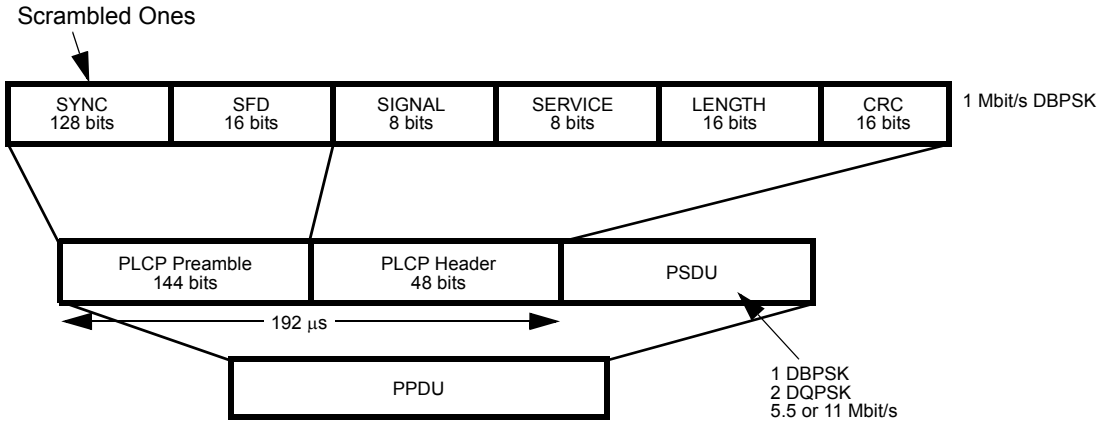

Figure 131—Long PPDU format

18.2.2.2 Short PPDU format (optional)

The short PLCP preamble and header (HR/DSSS/short) is defined as optional. The Short Preamble and header may be used to minimize overhead and, thus, maximize the network data throughput. The format of the PPDU, with HR/DSSS/short, is depicted in Figure 132.

A transmitter using the short PLCP will only be interoperable with another receiver that is also capable of receiving this short PLCP. To interoperate with a receiver that is not capable of receiving a Short Preamble and header, the transmitter shall use the long PLCP preamble and header. The short PLCP preamble uses the 1 Mbit/s Barker code spreading with DBPSK modulation. The short PLCP header uses the 2 Mbit/s Barker code spreading with DQPSK modulation, and the PSDU is transmitted at 2Mbit/s, 5.5 Mbit/s, or 11 Mbit/s.

Stations not implementing this option that do active scanning will get a response even when the network is using Short Preambles, because all management traffic is returned with the same type preamble as received.

18.2.3 PPDU field definitions

In the PLCP field definition subclauses (18.2.3.1 through 18.2.3.14), the definitions of the long (Clause 15) PLCP fields are given first, followed by the definitions of the short PLCP. The names for the short PLCP fields are preceded by the term *short*.

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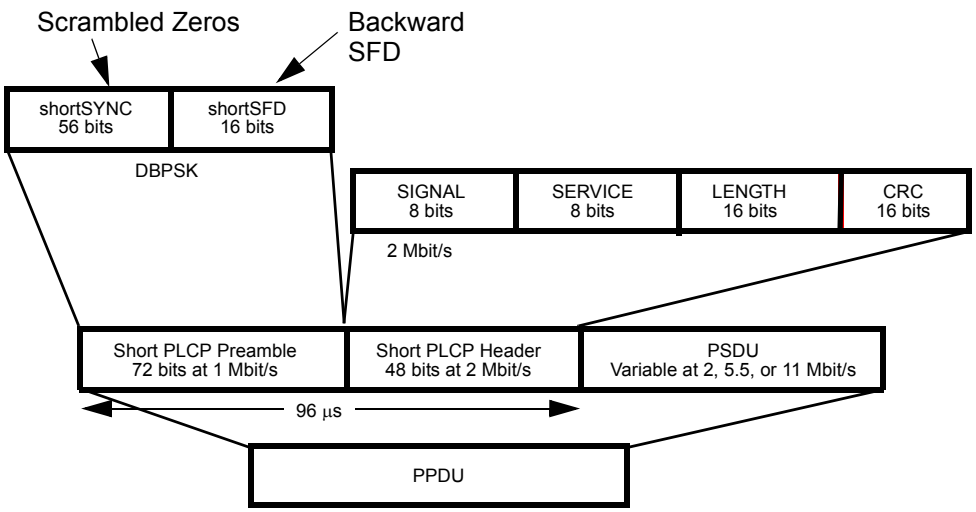

Figure 132—Short PPDU format

18.2.3.1 Long PLCP SYNC field

The SYNC field shall consist of 128 bits of scrambled 1 bits. This field is provided so the receiver can perform the necessary synchronization operations. The initial state of the scrambler (seed) shall be [1101100], where the leftmost bit specifies the value to put in the first delay element (Z^1) in Figure 135 (in 18.2.4), and the rightmost bit specifies the value to put in the last delay element in the scrambler.

To support the reception of DSSS signals generated with implementations based on Clause 15, the receiver shall also be capable of synchronization on a SYNC field derived from any nonzero scrambler initial state.

18.2.3.2 Long PLCP SFD

The SFD shall be provided to indicate the start of PHY-dependent parameters within the PLCP preamble. The SFD shall be a 16-bit field, [1111 0011 1010 0000], where the rightmost bit shall be transmitted first in time.

18.2.3.3 Long PLCP SIGNAL field

The 8-bit SIGNAL field indicates to the PHY the modulation that shall be used for transmission (and reception) of the PSDU. The data rate shall be equal to the SIGNAL field value multiplied by 100 kbit/s. The High Rate PHY supports four mandatory rates given by the following 8-bit words, which represent the rate in units of 100 kbit/s, where the LSB shall be transmitted first in time:

a) X'0A' (MSB to LSB) for 1 Mbit/s;
b) X'14' (MSB to LSB) for 2 Mbit/s;
c) X'37' (MSB to LSB) for 5.5 Mbit/s;
d) X'6E' (MSB to LSB) for 11 Mbit/s.

The High Rate PHY rate change capability is described in 18.2.3.14. This field shall be protected by the CRC-16 FCS described in 18.2.3.6.

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18.2.3.4 Long PLCP SERVICE field

Three bits have been defined in the SERVICE field to support the High Rate extension. The rightmost bit (bit 7) shall be used to supplement the LENGTH field described in 18.2.3.5. Bit 3 shall be used to indicate whether the modulation method is CCK <0> or PBCC <1>, as shown in Table 103. Bit 2 shall be used to indicate that the transmit frequency and symbol clocks are derived from the same oscillator. This locked clocks bit shall be set by the PHY based on its implementation configuration. The SERVICE field shall be transmitted b0 first in time, and shall be protected by the CRC-16 FCS described in 18.2.3.6. An IEEE 802.11-compliant device shall set the values of the bits b0, b1, b4, b5, and b6 to 0.

Table 103—SERVICE field definitions

b0	b1	b2	b3	b4	b5	b6	b7
Reserved	Reserved	Locked clocks bit 0 = not 1 = locked	Mod. selection bit 0 = CCK 1 = PBCC	Reserved	Reserved	Reserved	Length extension bit

18.2.3.5 Long PLCP LENGTH field

The PLCP LENGTH field shall be an unsigned 16-bit integer that indicates the number of microseconds required to transmit the PSDU. The transmitted value shall be determined from the LENGTH and DATARATE parameters in the TXVECTOR issued with the PHY-TXSTART.request primitive described in 18.4.4.2.

The LENGTH field provided in the TXVECTOR is in octets and is converted to microseconds for inclusion in the PLCP LENGTH field. The LENGTH field is calculated as follows. Because there is an ambiguity in the number of octets that is described by a length in integer microseconds for any data rate over 8 Mbit/s, a length extension bit shall be placed at bit position b7 in the SERVICE field to indicate when the smaller potential number of octets is correct.

a) 5.5 Mbit/s CCK Length = number of octets × 8/5.5, rounded up to the next integer.
b) 11 Mbit/s CCK Length = number of octets × 8/11, rounded up to the next integer; the service field (b7) bit shall indicate a 0 if the rounding took less than 8/11 or a 1 if the rounding took more than or equal to 8/11.
c) 5.5 Mbit/s PBCC Length = (number of octets + 1) × 8/5.5, rounded up to the next integer.
d) 11 Mbit/s PBCC Length = (number of octets + 1) × 8/11, rounded up to the next integer; the service field (b7) bit shall indicate a 0 if the rounding took less than 8/11 or a 1 if the rounding took more than or equal to 8/11.

At the receiver, the number of octets in the MPDU is calculated as follows:

a) 5.5 Mbit/s CCK Number of octets = Length × 5.5/8, rounded down to the next integer.
b) 11 Mbit/s CCK Number of octets = Length × 11/8, rounded down to the next integer, minus 1 if the service field (b7) bit is a 1.
c) 5.5 Mbit/s PBCC Number of octets = (Length × 5.5/8) –1, rounded down to the next integer.
d) 11 Mbit/s PBCC Number of octets = (Length × 11/8) –1, rounded down to the next integer, minus 1 if the service field (b7) bit is a 1.

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An example for an 11 Mbit/s calculation described in psuedocode form is shown below. At the transmitter, the values of the LENGTH field and length extension bit are calculated as follows:

LENGTH' = ((number of octets + P) × 8) / R

LENGTH = Ceiling (LENGTH')

If

(R = 11) and ((LENGTH–LENGTH') ≥ 8/11)

then

Length Extension = 1

else

Length Extension = 0

where

R	is the data rate in Mbit/s;
P	is 0 for CCK;
P	is 1 for PBCC;
Ceiling (X)	returns the smallest integer value greater than or equal to X.

At the receiver, the number of octets in the MPDU is calculated as follows:

Number of octets = Floor(((Length × R) / 8) – P) – Length Extension

where

R	is the data rate in Mbit/s;
P	is 0 for CCK;
P	is 1 for PBCC;
Floor (X)	returns the largest integer value less than or equal to X.

Table 104 shows an example calculation for several packet lengths of CCK at 11 Mbit/s.

Table 104—Example of LENGTH calculations for CCK

TX octets	Octets (× 8/11)	LENGTH	Length extension bit	LENGTH (× 11/8)	Floor (X)	RX octets
1023	744	744	0	1023	1023	1023
1024	744.7273	745	0	1024.375	1024	1024
1025	745.4545	746	0	1025.75	1025	1025
1026	746.1818	747	1	1027.125	1027	1026

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Table 105 shows an example calculation for several packet lengths of PBCC at 11 Mbit/s.

Table 105—Example of LENGTH calculations for PBCC

TX octets	(Octets × 8/11) + 1	LENGTH	Length extension bit	(LENGTH × 11/8) – 1	Floor (X)	RX octets
1023	744.7273	745	0	1023.375	1023	1023
1024	745.4545	746	0	1024.750	1024	1024
1025	746.1818	747	1	1026.125	1026	1025
1026	746.9091	747	0	1026.125	1026	1026

This example illustrates why normal rounding or truncation of the number will not produce the right result. The LENGTH field is defined in units of microseconds and must correspond to the actual length, and the number of octets must be exact.

The LSB shall be transmitted first in time. This field shall be protected by the CRC-16 FCS described in 18.2.3.6.

18.2.3.6 PLCP CRC (CRC-16) field

The SIGNAL, SERVICE, and LENGTH fields shall be protected with a CRC-16 FCS. The CRC-16 FCS shall be the ones complement of the remainder generated by the modulo 2 division of the protected PLCP fields by the polynomial

$$x^{16} + x^{12} + x^5 + 1$$

The protected bits shall be processed in transmit order. All FCS calculations shall be made prior to data scrambling. A schematic of the processing is shown in Figure 133.

As an example, the SIGNAL, SERVICE, and LENGTH fields for a DBPSK signal with a PPDU length of 192 μs (24 octets) would be given by the following:

0101 0000 0000 0000 0000 0011 0000 0000 [leftmost bit (b0) transmitted first in time]
b0.....b48

The ones complement FCS for these protected PLCP preamble bits would be the following:

0101 1011 0101 0111 [leftmost bit (b0) transmitted first in time]
b0.....b16

Figure 133 depicts this example.

An illustrative example of the CRC-16 FCS using the information from Figure 133 is shown in Figure 134.

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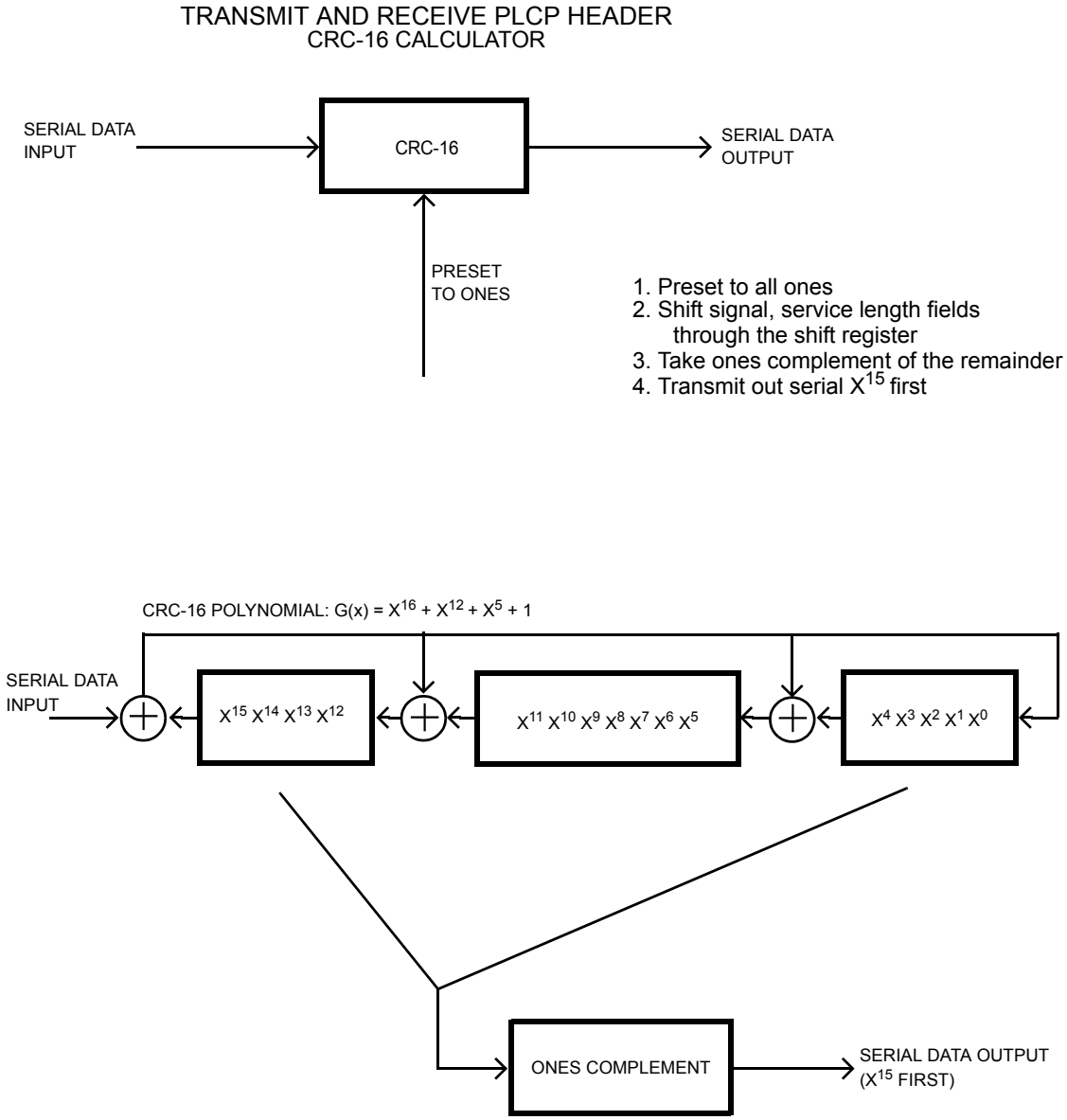

Figure 133—CRC-16 implementation

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```
Data        CRC Registers
            MSB          LSB

            1111111111111111        ; Initialize preset to ones
  0         1110111111011111
  1         1101111110111110
  0         1010111101011101
  1         0101111010111010
  0         1011110101110100
  0         0110101011001001
  0         1101010110010010
  0         1011101100000101
  0         0110011000101011
  0         1100110001010110
  0         1000100010001101
  0         0000000100111011
  0         0000001001110110
  0         0000010011101100
  0         0000100111011000
  0         0001001110110000
  0         0010011101100000
  0         0100111011000000
  0         1001110110000000
  0         0010101100100001
  0         0101011001000010
  0         1010110010000100
  1         0101100100001000
  1         1010001000110001
  0         0101010001000011
  0         1010100010000110
  0         0100000100101101
  0         1000001001011010
  0         0001010010010101
  0         0010100100101010
  0         0101001001010100
  0         1010010010101000
            0101101101010111        ; ones complement, result = CRC FCS parity
```

Figure 134—Example of CRC calculation

18.2.3.7 Long PLCP data modulation and modulation rate change

The long PLCP preamble and header shall be transmitted using the 1 Mbit/s DBPSK modulation. The SIGNAL and SERVICE fields combined shall indicate the modulation that shall be used to transmit the PSDU. The SIGNAL field indicates the rate, and the SERVICE field indicates the modulation. The transmitter and receiver shall initiate the modulation and rate indicated by the SIGNAL and SERVICE fields, starting with the first octet of the PSDU. The PSDU transmission rate shall be set by the DATARATE parameter in the TXVECTOR, issued with the PHY-TXSTART.request primitive described in 18.4.4.1.

18.2.3.8 Short PLCP synchronization (shortSYNC)

The shortSYNC field shall consist of 56 bits of scrambled 0 bits. This field is provided so the receiver can perform the necessary synchronization operations. The initial state of the scrambler (seed) shall be [001 1011], where the left end bit specifies the value to place in the first delay element (Z^1) in Figure 135 (in 18.2.4), and the right end bit specifies the value to place in the last delay element (Z^7).

18.2.3.9 Short PLCP SFD field (shortSFD)

The shortSFD shall be a 16-bit field and be the time reverse of the field of the SFD in the long PLCP preamble (18.2.3.2). The field is the bit pattern 0000 0101 1100 1111. The right end bit shall be transmitted first in time. A receiver not configured to use the short header option will not detect this SFD.

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18.2.3.10 Short PLCP SIGNAL field (shortSIGNAL)

The 8-bit SIGNAL field of the short header indicates to the PHY the data rate that shall be used for transmission (and reception) of the PSDU. A PHY operating with the HR/DSSS/short option supports three mandatory rates given by the following 8-bit words, where the LSB shall be transmitted first in time and the number represents the rate in units of 100 kBit/s:

a) X'14' (MSB to LSB) for 2 Mbit/s;
b) X'37'(MSB to LSB) for 5.5 Mbit/s;
c) X'6E' (MSB to LSB) for 11 Mbit/s.

18.2.3.11 Short PLCP SERVICE field (shortSERVICE)

The SERVICE field in the short header shall be the same as the SERVICE field described in 18.2.3.4.

18.2.3.12 Short PLCP LENGTH field (shortLENGTH)

The LENGTH field in the short header shall be the same as the LENGTH field described in 18.2.3.5.

18.2.3.13 Short CRC-16 field (shortCRC)

The CRC in the short header shall be the same as the CRC field defined in 18.2.3.6. The CRC-16 is calculated over the shortSIGNAL, shortSERVICE, and shortLENGTH fields.

18.2.3.14 Short PLCP data modulation and modulation rate change

The short PLCP preamble shall be transmitted using the 1 Mbit/s DBPSK modulation. The short PLCP header shall be transmitted using the 2 Mbit/s modulation. The SIGNAL and SERVICE fields combined shall indicate the modulation that shall be used to transmit the PSDU. The SIGNAL field indicates the rate, and the SERVICE field indicates the modulation. The transmitter and receiver shall initiate the modulation and rate indicated by the SIGNAL and SERVICE fields, starting with the first octet of the PSDU. The PSDU transmission rate shall be set by the DATARATE parameter in the TXVECTOR, issued with the PHY-TXSTART.request primitive described in 18.4.4.1.

18.2.4 PLCP/High Rate PHY data scrambler and descrambler

The polynomial $G(z) = z^{-7} + z^{-4} + 1$ shall be used to scramble all bits transmitted. The feedthrough configuration of the scrambler and descrambler is self-synchronizing, which requires no prior knowledge of the transmitter initialization of the scrambler for receive processing. Figure 135 and Figure 136 show typical implementations of the data scrambler and descrambler, but other implementations are possible.

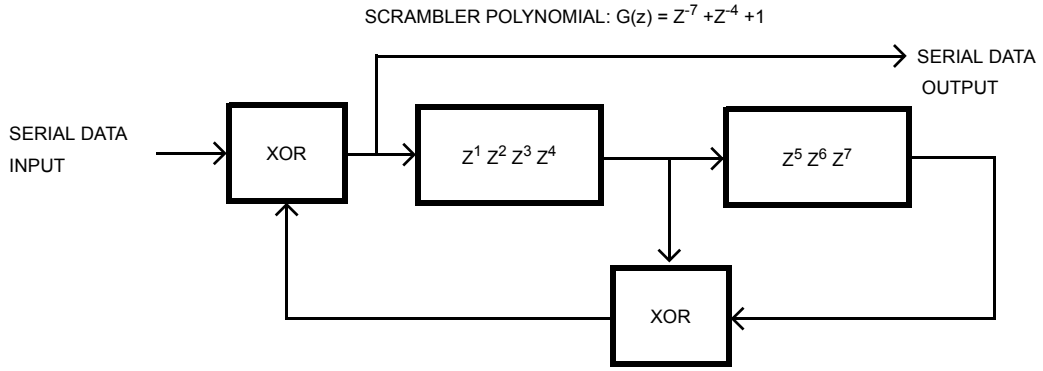

Figure 135—Data scrambler

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The scrambler shall be initialized as specified in 18.2.3.8 for the short PLCP and 18.2.3.1 for the long PLCP. For a Long Preamble, this shall result in the scrambler registers Z^1 through Z^7 in Figure 135 having the data pattern [1101100] (i.e., Z^1= 1... Z^7= 0) when the scrambler is first started. The scrambler shall be initialized with the reverse pattern [0011011] when transmitting the optional Short Preamble.

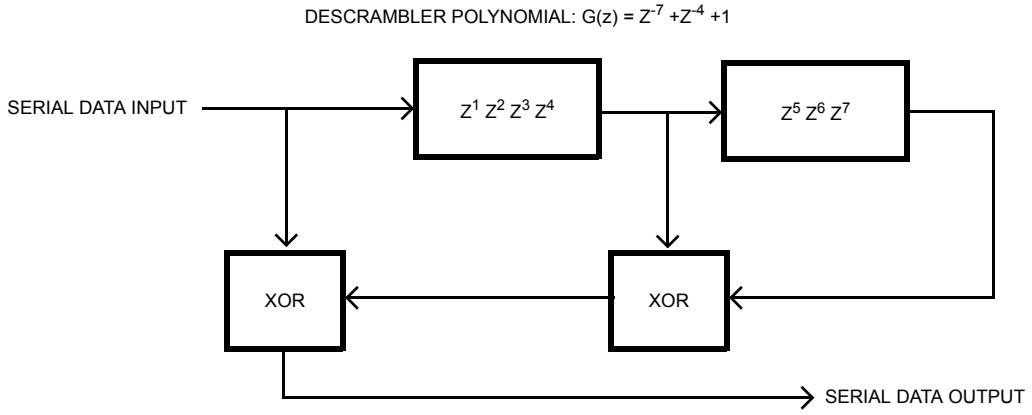

Figure 136—Data descrambler

18.2.5 Transmit PLCP

The transmit procedures for a High Rate PHY using the long PLCP preamble and header are the same as the transmit procedures described in 15.2.6 and 15.2.7 and do not change apart from the ability to transmit 5.5 Mbit/s and 11 Mbit/s.

The procedures for a transmitter employing HR/DSSS/short and HR/DSSS/PBCC/short are the same except for length and rate changes. The decision to use a long or short PLCP is beyond the scope of this standard.

The transmit PLCP is shown in Figure 137.

A PHY-TXSTART.request(TXVECTOR) primitive will be issued by the MAC to start the transmission of a PPDU. In addition to parameters DATARATE and LENGTH, other transmit parameters such as PREAMBLE_TYPE and MODULATION are set via the PHY-SAP with the PHY-TXSTART.request(TXVECTOR), as described in 18.3.5. The SIGNAL, SERVICE, and LENGTH fields of the PLCP header are calculated as described in 18.2.3.

The PLCP shall issue PMD_ANTSEL, PMD_RATE, and PMD_TXPWRLVL primitives to configure the PHY. The PLCP shall then issue a PMD_TXSTART.request, and the PHY entity shall immediately initiate data scrambling and transmission of the PLCP preamble based on the parameters passed in the PHY-TXSTART.request primitive. The time required for transmit power-on ramp, described in 18.4.7.6, shall be included in the PLCP SYNC field. Once the PLCP preamble transmission is complete, data shall be exchanged between the MAC and the PHY by a series of PHY-DATA.request(DATA) primitives issued by the MAC and PHY-DATA.confirm primitives issued by the PHY. The modulation and rate change, if any, shall be initiated with the first data symbol of the PSDU, as described in 18.2.3.7 and 18.2.3.14. The PHY proceeds with PSDU transmission through a series of data octet transfers from the MAC. At the PMD layer, the data octets are sent in LSB-to-MSB order and presented to the PHY through PMD_DATA.request primitives. Transmission can be prematurely terminated by the MAC through the primitive PHY-TXEND.request. PHY-TXSTART shall be disabled by the issuance of the PHY-TXEND.request. Normal termination occurs after the transmission of the final bit of the last PSDU octet, calculated from the number supplied in the PHY preamble LENGTH and SERVICE fields using the equations specified in 18.2.3.5. The PPDU transmission shall be completed and the PHY entity shall enter the receive state (i.e., PHY-TXSTART shall be disabled).

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It is recommended that modulation continue during power-down to prevent radiating a continuous wave carrier. Each PHY-TXEND.request is acknowledged with a PHY-TXEND.confirm primitive from the PHY.

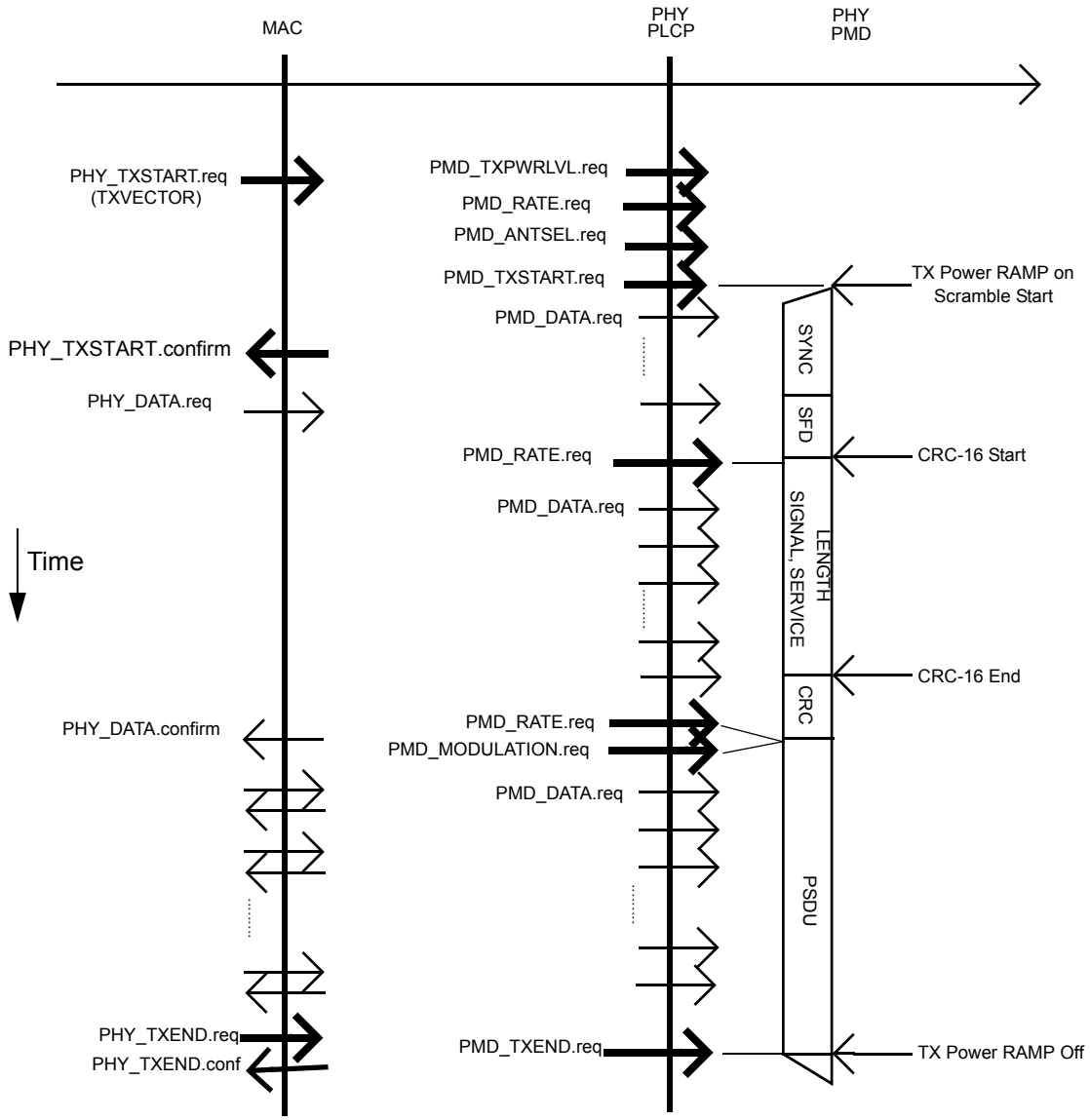

Figure 137—Transmit PLCP

A typical state machine implementation of the transmit PLCP is provided in Figure 138.

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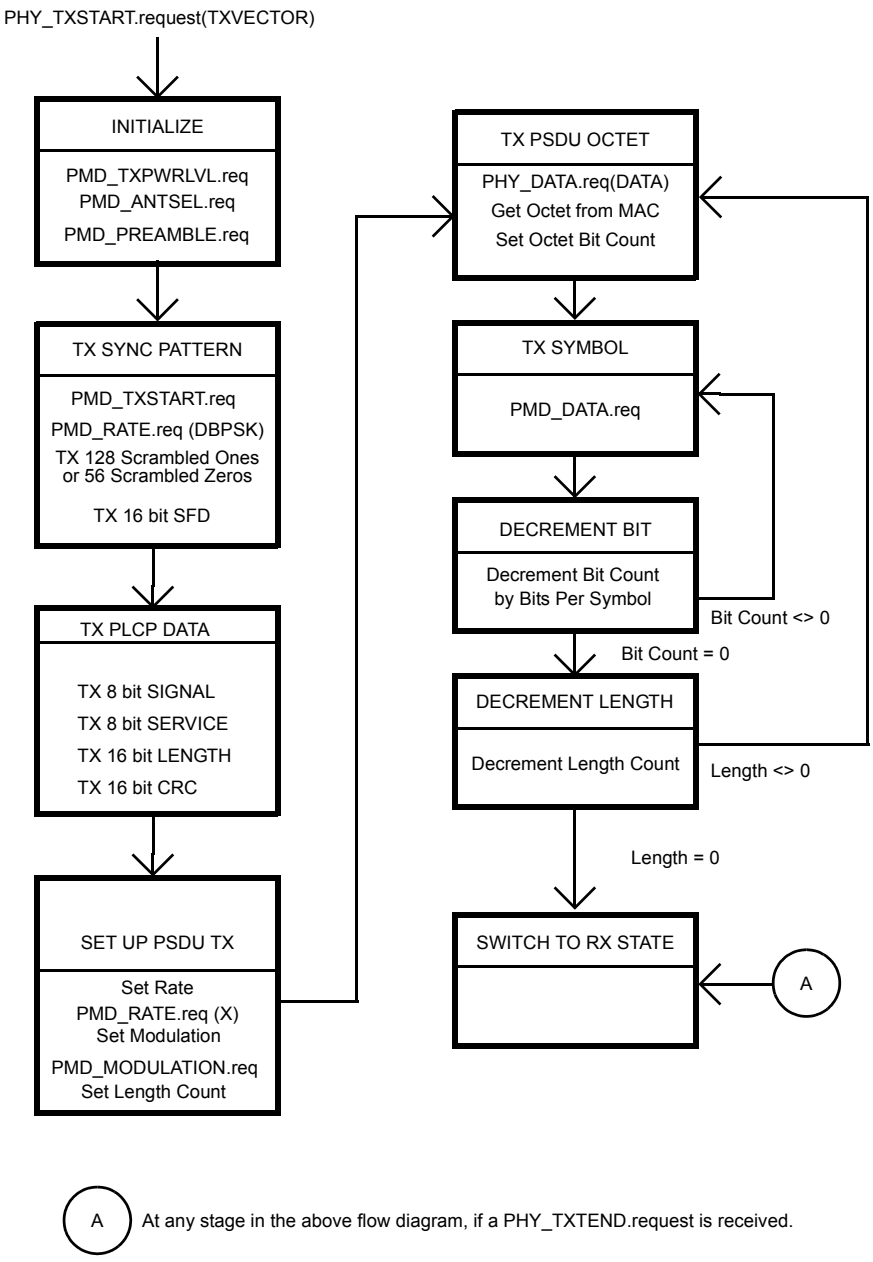

Figure 138—PLCP transmit state machine

18.2.6 Receive PLCP

The receive procedures for receivers configured to receive the mandatory and optional PLCPs, rates, and modulations are described in this subclause. A receiver that supports this High Rate extension of the standard is capable of receiving 5.5 Mbit/s and 11 Mbit/s, in addition to 1 Mbit/s and 2 Mbit/s. If the PHY implements the Short Preamble option, it shall detect both short and Long Preamble formats and indicate which type of preamble was received in the RXVECTOR. If the PHY implements the PBCC Modulation option, it shall detect either CCK or PBCC Modulations, as indicated in the SIGNAL field, and shall report the type of modulation used in the RXVECTOR.

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The receiver shall implement the CCA procedure as defined in 18.4.8.4. Upon receiving a PPDU, the receiver shall distinguish between a long and short header format by the value of the SFD, as specified in 18.2.2. The receiver shall demodulate a long PLCP header using BPSK at 1 Mbit/s. The receiver shall demodulate a short PLCP header using QPSK at 2 Mbit/s. The receiver shall use the SIGNAL and SERVICE fields of the PLCP header to determine the data rate and modulation of the PSDU.

The receive PLCP is shown in Figure 139 In order to receive data, the PHY-TXSTART.request shall be disabled so that the PHY entity is in the receive state. Further, through station management via the PLME, the PHY shall be set to the appropriate channel and the CCA method chosen. Other receive parameters, such as RSSI, SQ, and indicated DATARATE, may be accessed via the PHY-SAP.

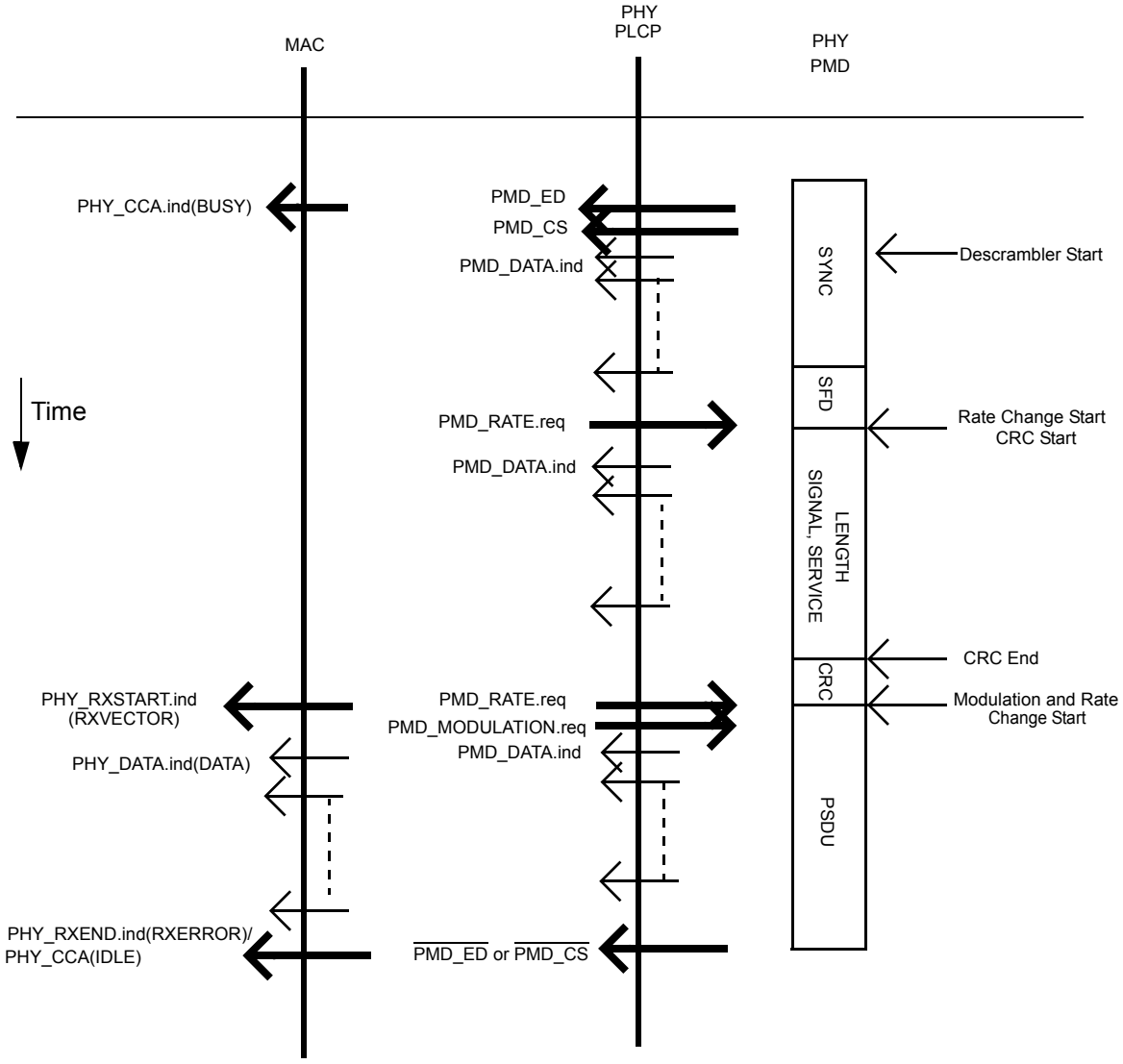

Figure 139—Receive PLCP

Upon receiving the transmitted energy, according to the selected CCA mode, the PMD_ED shall be enabled (according to 18.4.8.4) as the RSSI reaches the ED_THRESHOLD, and/or PMD_CS shall be enabled after code lock is established. These conditions are used to indicate activity to the MAC via PHY-CCA.indicate,

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according to 18.4.8.4. PHY-CCA.indicate(BUSY) shall be issued for ED and/or code lock prior to correct reception of the PLCP header. The PMD primitives, PMD_SQ and PMD_RSSI, are issued to update the RSSI and SQ parameters reported to the MAC.

After PHY-CCA.indicate is issued, the PHY entity shall begin searching for the SFD field. Once the SFD field is detected, CRC-16 processing shall be initiated and the PLCP SIGNAL, SERVICE, and LENGTH fields shall be received. The CRC-16 FCS shall be processed. If the CRC-16 FCS check fails, the PHY receiver shall return to the RX IDLE state, as depicted in Figure 140. Should the status of CCA return to the IDLE state during reception prior to completion of the full PLCP processing, the PHY receiver shall return to the RX IDLE state.

If the PLCP header reception is successful (and the SIGNAL field is completely recognizable and supported), a PHY-RXSTART.indicate(RXVECTOR) shall be issued. The RXVECTOR associated with this primitive includes

a) The SIGNAL field;
b) The SERVICE field;
c) The PSDU length in octets (calculated from the LENGTH field in microseconds and the DATARATE in Mbit/s, in accordance with the formula in 18.2.3.5);
d) RXPREAMBLE_TYPE (which is an enumerated type taking on values SHORTPREAMBLE or LONGPREAMBLE);
e) The antenna used for receive (RX_ANTENNA), RSSI, and SQ.

The received PSDU bits are assembled into octets and presented to the MAC using a series of PHY-DATA.indicate(DATA) primitive exchanges. The rate and modulation change indicated in the SIGNAL field shall be initiated with the first symbol of the PSDU, as described in 18.2.5. The PHY proceeds with PSDU reception. After reception of the final bit of the last PSDU octet, indicated by the PLCP preamble LENGTH field, the receiver shall be returned to the RX IDLE state shown in Figure 140.

A PHY-RXEND.indicate(NoError) primitive shall be issued. A PHY-CCA.indicate(IDLE) primitive shall be issued following a change in PHYCS and/or PHYED according to the selected CCA method.

In the event that a change in PHYCS or PHYED would cause the status of CCA to return to the IDLE state before the complete reception of the PSDU, as indicated by the PLCP LENGTH field, the error condition PHY-RXEND.indicate(CarrierLost) shall be reported to the MAC. The High Rate PHY shall ensure that the CCA indicates a busy medium for the intended duration of the transmitted PPDU.

If the PLCP header is successful, but the indicated rate or modulation in the SIGNAL and SERVICE fields is not within the capabilities of the receiver, a PHY-RXSTART.indicate shall not be issued. The PHY shall issue the error condition PHY-RXEND.indicate(UnsupportedRate). If the PLCP header is invalid, a PHY-RXSTART.indicate shall not be issued, and the PHY shall issue the error condition PHY-RXEND.indicate(FormatViolation). Also, in both cases, the High Rate PHY shall ensure that the CCA indicates a busy medium for the intended duration of the transmitted PSDU, as indicated by the LENGTH field. The intended duration is indicated by the LENGTH field (LENGTH × 1 μs).

A typical state machine implementation of the receive PLCP is shown in Figure 140.

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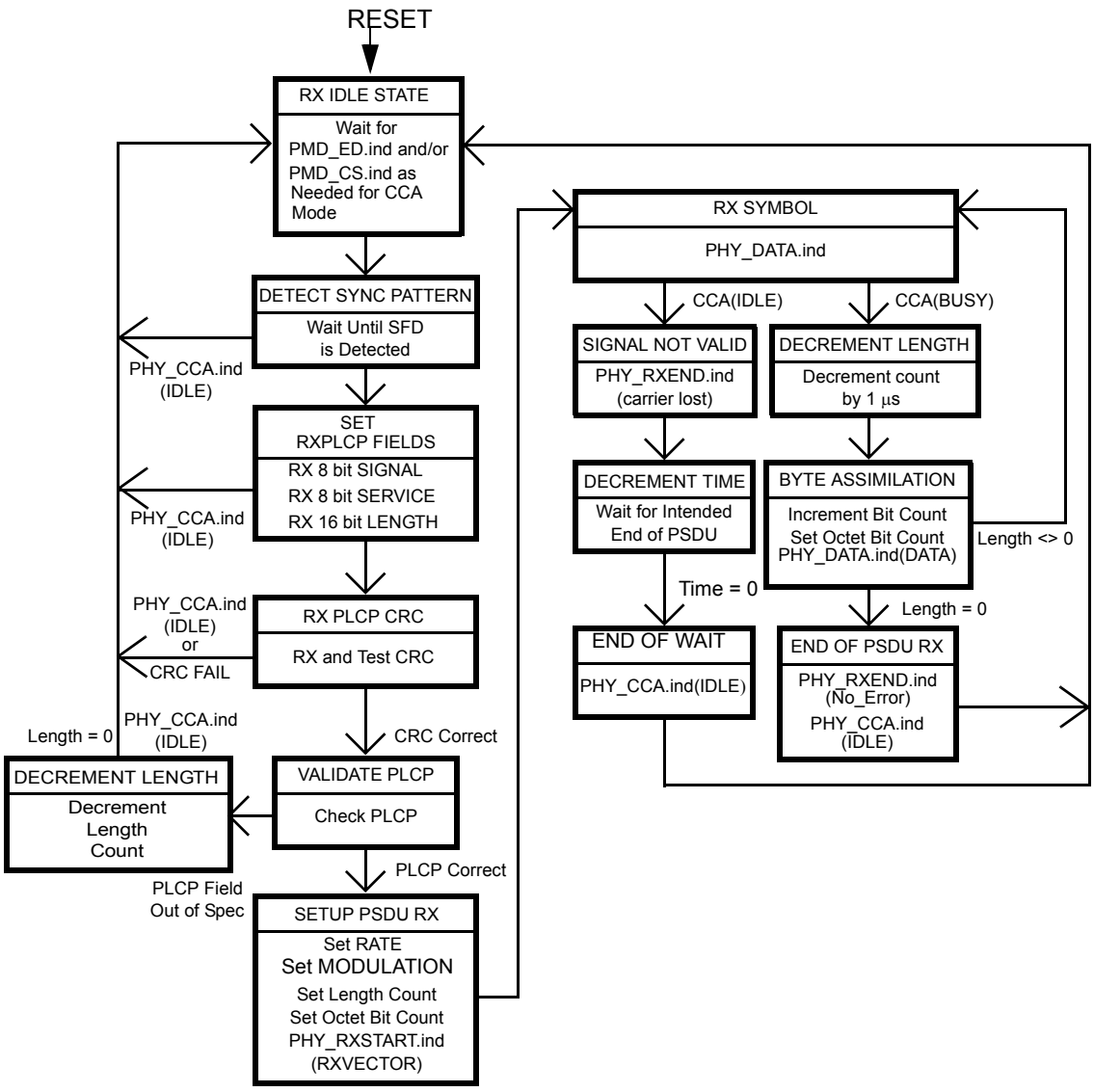

Figure 140—PLCP receive state machine

18.3 High Rate PLME

18.3.1 PLME_SAP sublayer management primitives

Table 106 lists the MIB attributes that may be accessed by the PHY entities and intralayer or higher level LMEs. These attributes are accessed via the PLME-GET, PLME-SET, and PLME-RESET primitives defined in Clause 10.

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18.3.2 High Rate PHY MIB

All High Rate PHY MIB attributes are defined in Annex D, with specific values defined in Table 106.

Table 106—MIB attribute default values/ranges

Managed object	Default value/range	Operational semantics
dot11PhyOperationTable		
dot11PHYType	High Rate–2.4 (X'05')	Static
dot11TempType	Implementation dependent	Static
dot11CurrentRegDomain	Implementation dependent	Static
dot11ShortPreambleOptionImplemented	Implementation dependent	Static
dot11PBCCOptionImplemented	Implementation dependent	Static
dot11ChannelAgility Present	Implementation dependent	Static
dot11ChannelAgilityEnabled	False/Boolean	Dynamic
dot11PhyAntennaTable		
dot11CurrentTxAntenna	Implementation dependent	Dynamic
dot11DiversitySupport	Implementation dependent	Static
dot11CurrentRxAntenna	Implementation dependent	Dynamic
dot11PhyTxPowerTable		
dot11NumberSupportedPowerLevels	Implementation dependent	Static
dot11TxPowerLevel1	Implementation dependent	Static
dot11TxPowerLevel2	Implementation dependent	Static
dot11TxPowerLevel3	Implementation dependent	Static
dot11TxPowerLevel4	Implementation dependent	Static
dot11TxPowerLevel5	Implementation dependent	Static
dot11TxPowerLevel6	Implementation dependent	Static
dot11TxPowerLevel7	Implementation dependent	Static
dot11TxPowerLevel8	Implementation dependent	Static
dot11CurrentTxPowerLevel	Implementation dependent	Dynamic
dot11PhyDSSSTable		
dot11CurrentChannel	Implementation dependent	Dynamic
dot11CCAModeSupported	Implementation dependent	Static
dot11CurrentCCAMode	Implementation dependent	Dynamic
dot11EDThreshold	Implementation dependent	Dynamic
dot11AntennasListTable		
dot11SupportTxAntenna	Implementation dependent	Static
dot11SupportRxAntenna	Implementation dependent	Static
dot11DiversitySelectionRx	Implementation dependent	Dynamic

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Table 106—MIB attribute default values/ranges *(continued)*

Managed object	Default value/range	Operational semantics
dot11RegDomainsSupportedTable		
dot11RegDomainsSupported	Implementation dependent	Static
dot11SupportedDataRatesTx	Table Tx X'02', X'04', X'0B', X'16'	Static
dot11SupportedDataRatesRx	Table Rx X'02', X'04', 'X'0B', X'16'	Static
NOTE—The column titled "Operational semantics" contains two types: static and dynamic. Static MIB attributes are fixed and cannot be modified for a given PHY implementation. Dynamic MIB attributes can be modified by some management entities.		

18.3.3 DS PHY characteristics

The static DS PHY characteristics, provided through the PLME-CHARACTERISTICS service primitive, are shown in Table 107. The definitions of these characteristics are in 10.4.3.

Table 107—High Rate PHY characteristics

Characteristic	Value
aSlotTime	20 μs
aSIFSTime	10 μs
aCCATime	$\leq$ 15 μs
aRxTxTurnaroundTime	$\leq$ 5 μs
aTxPLCPDelay	Implementers may choose any value for this delay as long as the requirements of aRxTxTurnaroundTime are met.
aRxPLCPDelay	Implementers may choose any value for this delay as long as the requirements of aSIFSTime and aCCATime are met.
aRxTxSwitchTime	$\leq$ 5 μs
aTxRampOnTime	Implementers may choose any value for this delay as long as the requirements of aRxTxTurnaroundTime are met.
aTxRampOffTime	Implementers may choose any value for this delay as long as the requirements of aSIFSTime are met.
aTxRFDelay	Implementers may choose any value for this delay as long as the requirements of aRxTxTurnaroundTime are met.
aRxRFDelay	Implementers may choose any value for this delay as long as the requirements of aSIFSTime and aCCATime are met.
aAirPropagationTime	1 μs
aMACProcessingDelay	0 (N/A)
aPreambleLength	144 μs
aPLCPHeaderLength	48 bits
aMPUMaxLength	$14 \leq x \leq (2^{12} - 1)$
aCWmin	31
aCWmax	1023

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18.3.4 High Rate TXTIME calculation

The value of the TXTIME parameter returned by the PLME-TXTIME.confirm primitive shall be calculated according to the following equation:

TXTIME = PreambleLength + PLCPHeaderTime + Ceiling(((LENGTH+PBCC) × 8) / DATARATE)

where

LENGTH and DATARATE	are values from the TXVECTOR parameter of the corresponding PLME-TXTIME.request primitive;
LENGTH	is in units of octets;
DATARATE	is in units of Mbit/s;
Ceiling	is a function that returns the smallest integer value greater than or equal to its argument value;
PBCC	has a value of 1 if the SIGNAL value from the TXVECTOR parameter specifies PBCC and has a value of 0 otherwise;
The value of PreambleLength	is 144 μs if the TXPREAMBLE_TYPE value from the TXVECTOR parameter indicates "LONGPREAMBLE," or 72 μs if the TXPREAMBLE_TYPE value from the TXVECTOR parameter indicates "SHORTPREAMBLE";
The value of PLCPHeaderTime	is 48 μs if the TXPREAMBLE_TYPE value from the TXVECTOR parameter indicates "LONGPREAMBLE," or 24 μs if the TXPREAMBLE_TYPE value from the TXVECTOR parameter indicates "SHORTPREAMBLE."

18.3.5 Vector descriptions

Several service primitives include a parameter vector. These vectors are a list of parameters as described in Table 108. DATARATE and LENGTH are described in 12.3.4.4. The remaining parameters are considered to be management parameters and are specific to this PHY.

Table 108—Parameter vectors

Parameter	Associated vector	Value
DATARATE	RXVECTOR, TXVECTOR	The rate used to transmit the PSDU in Mbit/s.
LENGTH	RXVECTOR, TXVECTOR	The length of the PSDU in octets.
PREAMBLE_TYPE	RXVECTOR, TXVECTOR	The preamble used for the transmission of this PPDU. This is an enumerated type that can take the value SHORTPREAMBLE or LONGPREAMBLE.
MODULATION	RXVECTOR, TXVECTOR	The modulation used for the transmission of this PSDU. This is an integer where 0 means CCK and 1 means PBCC.

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18.4 High Rate PMD sublayer

18.4.1 Scope and field of application

The PMD services provided to the PLCP for the High Rate PHY are described in 18.4. Also defined in 18.4 are the functional, electrical, and RF characteristics required for interoperability of implementations conforming to this specification. The relationship of this specification to the entire High Rate PHY is shown in Figure 141.

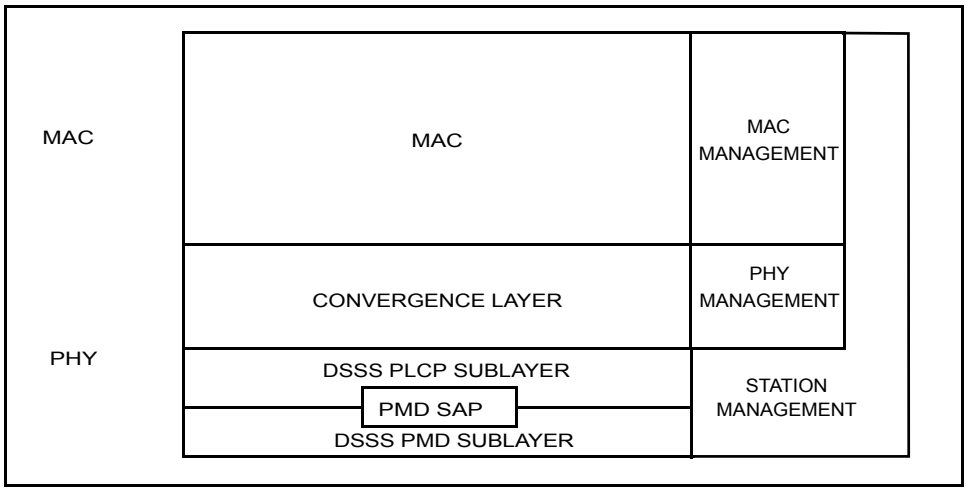

Figure 141—Layer reference model

18.4.2 Overview of service

The High Rate PMD sublayer accepts PLCP sublayer service primitives and provides the actual means by which data are transmitted or received from the medium. The combined functions of the High Rate PMD sublayer primitives and parameters for the receive function result in a data stream, timing information, and associated receive signal parameters being delivered to the PLCP sublayer. A similar functionality is provided for data transmission.

18.4.3 Overview of interactions

The primitives associated with the PLCP sublayer to the High Rate PMD fall into two basic categories

a) Service primitives that support PLCP peer-to-peer interactions;
b) Service primitives that have local significance and that support sublayer-to-sublayer interactions.

18.4.4 Basic service and options

All of the service primitives described in this subclause are considered mandatory, unless otherwise specified.

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18.4.4.1 PMD_SAP peer-to-peer service primitives

Table 109 indicates the primitives for peer-to-peer interactions.

Table 109—PMD_SAP peer-to-peer service primitives

Primitive	Request	Indicate	Confirm	Response
PMD_DATA	X	X	—	—

18.4.4.2 PMD_SAP sublayer-to-sublayer service primitives

Table 110 indicates the primitives for sublayer-to-sublayer interactions.

Table 110—PMD_SAP sublayer-to-sublayer service primitives

Primitive	Request	Indicate	Confirm	Response
PMD_TXSTART	X	—	—	—
PMD_TXEND	X	—	—	—
PMD_ANTSEL	X	X	—	—
PMD_TXPWRLVL	X	—	—	—
PMD_MODULATION	X	X	—	—
PMD_PREAMBLE	X	X	—	—
PMD_RATE	X	X	—	—
PMD_RSSI	—	X	—	—
PMD_SQ	—	X	—	—
PMD_CS	—	X	—	—
PMD_ED	X	X	—	—

18.4.5 PMD_SAP detailed service specification

The services provided by each PMD primitive are described in 18.4.5.1 through 18.4.5.15.

18.4.5.1 PMD_DATA.request

18.4.5.1.1 Function

This primitive defines the transfer of data from the PLCP sublayer to the PMD entity.

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18.4.5.1.2 Semantics of the service primitive

This primitive provides the following parameters.

Parameter	Associated primitive	Value (Mbit/s)	Description
TXD_UNIT	PMD_DATA.request	0,1: 1 00,01,11,10:2 X'0'–X'F': 5.5 X'00'–X'FF': 11	This parameter represents a single block of data, which, in turn, is used by the PMD to be differentially encoded into a transmitted symbol. The symbol itself is spread by the PN code prior to transmission.

18.4.5.1.3 When generated

This primitive is generated by the PLCP sublayer to request transmission of a symbol. The data clock for this primitive is supplied by the PMD layer based on the PN code repetition.

18.4.5.1.4 Effect of receipt

The PMD performs the differential encoding, PN code modulation, and transmission of data.

18.4.5.2 PMD_DATA.indicate

18.4.5.2.1 Function

This primitive defines the transfer of data from the PMD entity to the PLCP sublayer.

18.4.5.2.2 Semantics of the service primitive

This primitive provides the following parameters.

Parameter	Associated primitive	Value (Mbit/s)	Description
RXD_UNIT	PMD_DATA.indicate	0,1: 1 00,01,11,10:2 X'0' - X'F': 5.5 X'00' - X'FF': 11	This parameter represents a single symbol that has been demodulated by the PMD entity.

18.4.5.2.3 When generated

This primitive, which is generated by the PMD entity, forwards received data to the PLCP sublayer. The data clock for this primitive is supplied by the PMD layer based on the PN code repetition.

18.4.5.2.4 Effect of receipt

The PLCP sublayer either interprets the bit or bits that are recovered as part of the PLCP or passes the data to the MAC sublayer as part of the PSDU.

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18.4.5.3 PMD_MODULATION.request

18.4.5.3.1 Function

This primitive, which is generated by the PHY PLCP sublayer, selects the modulation code that is used by the High Rate PHY for transmission.

18.4.5.3.2 Semantics of the service primitive

This primitive provides the following parameters.

Parameter	Associated primitive	Value	Description
MODULATION	PMD_MODULATION.request PMD_MODULATION.indicate	1 MbBarker, 2 MbBarker, 5.5 CCK, 11 CCK, 5.5 PBCC, or 11 PBCC	In Receive mode, the MODULATION parameter informs the PLCP layer which PHY data modulation was used to process the PSDU portion of the PPDU. See 18.4.6.3 for further information on the High Rate PHY modulation codes.

18.4.5.3.3 When generated

This primitive is generated by the PLCP sublayer to change or set the current High Rate PHY modulation code used for the PSDU portion of a PPDU. The PMD_MODULATION.request primitive is normally issued prior to issuing the PMD_TXSTART command.

18.4.5.3.4 Effect of receipt

The receipt of PMD_MODULATION selects the modulation that is used for all subsequent PSDU transmissions. This code is used for transmission only. The High Rate PHY shall still be capable of receiving all the required High Rate PHY modulations. This primitive, which is generated by the PMD entity, sets the state of the PHY for demodulation of the appropriate modulation.

18.4.5.4 PMD_PREAMBLE.request

18.4.5.4.1 Function

This primitive, which is generated by the PHY PLCP sublayer, selects the preamble mode that is used by the High Rate PHY for transmission.

18.4.5.4.2 Semantics of the service primitive

This primitive provides the following parameters.

Parameter	Associated primitive	Value	Description
PREAMBLE	PMD_PREAMBLE.request	0 for long 1 for short	PREAMBLE selects which of the High Rate PHY preamble types is used for PLCP transmission. See 18.2.2 for further information on the High Rate PHY preamble modes.

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18.4.5.4.3 When generated

This primitive is generated by the PLCP sublayer to change or set the current High Rate PHY preamble mode used for the PLCP portion of a PPDU. The PMD_PREAMBLE.request primitive is normally issued prior to issuing the PMD_TXSTART command.

18.4.5.4.4 Effect of receipt

The receipt of PMD_PREAMBLE selects the preamble mode that is used for all subsequent PSDU transmissions. This mode is used for transmission only. The High Rate PHY shall still be capable of receiving all the required High Rate PHY preambles. This primitive sets the state of the PHY for modulation of the appropriate mode.

18.4.5.5 PMD_PREAMBLE.indicate

18.4.5.5.1 Function

This primitive, which is generated by the PMD sublayer, indicates which preamble mode was used to receive the PLCP portion of the PPDU.

18.4.5.5.2 Semantics of the service primitive

This primitive provides the following parameters.

Parameter	Associated primitive	Value	Description
PREAMBLE	PMD_PREAMBLE.indicate	0 for long 1 for short	In RECEIVE mode, the PREAMBLE parameter informs the PLCP layer which of the High Rate PHY preamble modes was used to send the PLCP portion of the PPDU.

18.4.5.5.3 When generated

This primitive is generated by the PMD sublayer when the PLCP preamble has been properly detected.

18.4.5.5.4 Effect of receipt

This parameter is provided to the PLCP layer for information only.

18.4.5.6 PMD_TXSTART.request

18.4.5.6.1 Function

As a result of receiving a PHY_DATA.request from the MAC, the PLCP issues this primitive, which initiates PPDU transmission by the PMD layer.

18.4.5.6.2 Semantics of the service primitive

This primitive has no parameters.

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18.4.5.6.3 When generated

This primitive is generated by the PLCP sublayer to initiate the PMD layer transmission of the PPDU. The PHY-DATA.request primitive is provided to the PLCP sublayer prior to issuing the PMD_TXSTART command.

18.4.5.6.4 Effect of receipt

PMD_TXSTART initiates transmission of a PPDU by the PMD sublayer.

18.4.5.7 PMD_TXEND.request

18.4.5.7.1 Function

This primitive, which is generated by the PHY PLCP sublayer, ends PPDU transmission by the PMD layer.

18.4.5.7.2 Semantics of the service primitive

This primitive has no parameters.

18.4.5.7.3 When generated

This primitive is generated by the PLCP sublayer to terminate the PMD layer transmission of the PPDU.

18.4.5.7.4 Effect of receipt

PMD_TXEND terminates transmission of a PPDU by the PMD sublayer.

18.4.5.8 PMD_ANTSEL.request

18.4.5.8.1 Function

This primitive, which is generated by the PHY PLCP sublayer, selects the antenna used by the PHY for transmission or reception (when diversity is disabled).

18.4.5.8.2 Semantics of the service primitive

This primitive provides the following parameters.

Parameter	Associated primitive	Value	Description
ANT_STATE	PMD_ANTSEL.request PMD_ANTSEL.indicate	1 to 256	ANT_STATE selects which of the available antennas should be used for transmit. The number of available antennas is determined from the MIB table parameters, aSuprtRxAntennas and aSuprtTxAntennas.

18.4.5.8.3 When generated

This primitive is generated by the PLCP sublayer to select a specific antenna for transmission (or reception when diversity is disabled).

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18.4.5.8.4 Effect of receipt

PMD_ANTSEL immediately selects the antenna specified by ANT_STATE.

18.4.5.9 PMD_TXPWRLVL.request

18.4.5.9.1 Function

This primitive, which is generated by the PHY PLCP sublayer, selects the power level used by the PHY for transmission.

18.4.5.9.2 Semantics of the service primitive

This primitive provides the following parameters.

Parameter	Associated primitive	Value	Description
TXPWR_LEVEL	PHY-TXPWR_LEVEL.request	0, 1, 2, 3 (maximum of 4 levels)	TXPWR_LEVEL selects which of the optional transmit power levels should be used for the current PPDU transmission. The number of available power levels is determined by the MIB parameter dot11NumberSupportedPowerLevels. See 18.4.7.2 for further information on the optional High Rate PHY power-level control capabilities.

18.4.5.9.3 When generated

This primitive is generated by the PLCP sublayer to select a specific transmit power. This primitive is applied prior to setting PMD_TXSTART to the transmit state.

18.4.5.9.4 Effect of receipt

PMD_TXPWRLVL immediately sets the transmit power level given by TXPWR_LEVEL.

18.4.5.10 PMD_RATE.request

18.4.5.10.1 Function

This primitive, which is generated by the PHY PLCP sublayer, selects the data rate that shall be used by the High Rate PHY for transmission.

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18.4.5.10.2 Semantics of the service primitive

This primitive provides the following parameters.

Parameter	Associated primitive	Value (Mbit/s)	Description
RATE	PMD_RATE.indicate PMD_RATE.request	X'0A' or 1 X'14' for 2 X'37' for 5.5 X'6E' for 11	RATE selects which of the High Rate PHY data rates is used for PSDU transmission. See 18.4.6.3 for further information on the High Rate PHY data rates. The High Rate PHY rate change capability is described in 18.2.

18.4.5.10.3 When generated

This primitive is generated by the PLCP sublayer to change or set the current High Rate PHY data rate used for the PSDU portion of a PPDU.

18.4.5.10.4 Effect of receipt

The receipt of PMD_RATE selects the rate that is used for all subsequent PSDU transmissions. This rate is used for transmission only. The High Rate PHY shall still be capable of receiving all the required High Rate PHY data rates.

18.4.5.11 PMD_RSSI.indicate

18.4.5.11.1 Function

This optional primitive may be generated by the PMD to provide the receive signal strength to the PLCP.

18.4.5.11.2 Semantics of the service primitive

This primitive provides the following parameters.

Parameter	Associated primitive	Value	Description
RSSI	PMD_RSSI.indicate	0–8 bits of RSSI	The RSSI is a measure of the RF energy received by the High Rate PHY.

18.4.5.11.3 When generated

This primitive is generated by the PMD when the High Rate PHY is in the receive state. It is continuously available to the PLCP, which, in turn, provides the parameter to the MAC entity.

18.4.5.11.4 Effect of receipt

This parameter is provided to the PLCP layer for information only. The RSSI may be used in conjunction with SQ as part of a CCA scheme.

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18.4.5.12 PMD_SQ.indicate

18.4.5.12.1 Function

This optional primitive may be generated by the PMD to provide an indication of the SQ of the High Rate PHY PN code correlation to the PLCP. SQ is a measure of the quality of BARKER code lock, providing an effective measure during the full reception of a PLCP preamble and header.

18.4.5.12.2 Semantics of the service primitive

This primitive provides the following parameters

Parameter	Associated primitive	Value	Description
SQ	PMD_SQ.indicate	0–8 bits of SQ	This primitive is a measure of the SQ received by the HR/ DSSS PHY.

18.4.5.12.3 When generated

This primitive is generated by the PMD when the High Rate PHY is in the receive state and Barker code lock is achieved. It is continuously available to the PLCP, which, in turn, provides the parameter to the MAC entity.

18.4.5.12.4 Effect of receipt

This parameter is provided to the PLCP layer for information only. The SQ may be used in conjunction with RSSI as part of a CCA scheme.

18.4.5.13 PMD_CS.indicate

This primitive, which is generated by the PMD, shall indicate to the PLCP layer that the receiver has acquired (locked) the Barker code and data are being demodulated.

18.4.5.13.1 Function

This primitive, which is generated by the PMD, shall indicate to the PLCP layer that the receiver has acquired (locked) the Barker code and data are being demodulated.

18.4.5.13.2 Semantics of the service primitive

This primitive provides the following parameters.

Parameter	Associated primitive	Value	Description
PMD_CS	PMD_CS.indicate	0 for DISABLED 1 for ENABLED	The PMD_CS (carrier sense) primitive, in conjunction with PMD_ED, provide CCA status through the PLCP layer PHYCCA primitive. PMD_CS indicates a binary status of ENABLED or DISABLED. PMD_CS is ENABLED when the correlator SQ indicated in PMD_SQ is greater than the correlation threshold. PMD_CS is DISABLED when the PMD_SQ falls below the correlation threshold.

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18.4.5.13.3 When generated

This primitive is generated by the PMD sublayer when the High Rate PHY is receiving a PPDU and the PN code has been acquired.

18.4.5.13.4 Effect of receipt

This indicator is provided to the PLCP for forwarding to the MAC entity for information purposes through the PHYCCA indicator. This parameter shall indicate that the RF medium is busy and occupied by a High Rate PHY signal. The High Rate PHY should not be placed into the transmit state when PMD_CS is ENABLED.

18.4.5.14 PMD_ED.indicate

18.4.5.14.1 Function

This optional primitive may be generated by the PMD to provide an indication that the receiver has detected RF energy indicated by the PMD_RSSI primitive that is above a predefined threshold.

18.4.5.14.2 Semantics of the service primitive

This primitive provides the following parameters.

Parameter	Associated primitive	Value	Description
PMD_ED	PMD_ED.indicate	0 for DISABLED 1 for ENABLED	The PMD_ED (energy detect) primitive, along with the PMD_SQ, provides CCA status at the PLCP layer through the PHYCCA primitive. PMD_ED indicates a binary status of ENABLED or DISABLED. PMD_ED is ENABLED when the RSSI in PMD_RSSI is greater than the ED_THRESHOLD parameter. PMD_ED is DISABLED when the PMD_RSSI falls below the energy detect threshold.

18.4.5.14.3 When generated

This primitive is generated by the PHY when the PHY is receiving RF energy from any source that exceeds the ED_THRESHOLD parameter.

18.4.5.14.4 Effect of receipt

This indicator is provided to the PLCP for forwarding to the MAC entity for information purposes through the PMD_ED indicator. This parameter shall indicate that the RF medium may be busy with an RF energy source that is not High Rate PHY compliant. If a High Rate PHY source is being received, the PMD_CS function is enabled shortly after the PMD_ED function is enabled.

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18.4.5.15 PMD_ED.request

18.4.5.15.1 Function

This optional primitive may be generated by the PLCP to set a set a value for the energy detect ED_THRESHOLD.

18.4.5.15.2 Semantics of the service primitive

This primitive provides the following parameters.

Parameter	Associated primitive	Value	Description
PMD_ED	PMD_ED.request	ED_THRESHOLD	ED_THRESHOLD is the threshold that the RSSI should be greater than in order for PMD_ED to be enabled. PMD_ED is DISABLED when the PMD_RSSI falls below the energy detect threshold.

18.4.5.15.3 When generated

This primitive is generated by the PLCP sublayer to change or set the current High Rate PHY energy detect threshold.

18.4.5.15.4 Effect of receipt

The receipt of PMD_ED immediately changes the energy detect threshold as set by the ED_THRESHOLD parameter.

18.4.6 PMD operating specifications, general

General specifications for the High Rate PMD sublayer are provided in 18.4.6.1 through 18.4.6.14. These specifications apply to both the receive and transmit functions and general operation of a High Rate PHY.

Wireless LANs implemented in accordance with this standard are subject to equipment certification and operation requirements established by regional and national regulatory administrations. The PMD specification establishes minimum technical requirements for interoperability, based upon established regulations at the time this standard was issued. These regulations are subject to revision, or may be superseded. Requirements that are subject to local geographic regulations are annotated within the PMD specification. Regulatory requirements that do not affect interoperability are not addressed in this standard. Implementers are referred to the following regulatory sources for further information. Operation in countries within defined regulatory domains may be subject to additional regulations.

The documents listed in 14.6.2 and in Table 111 specify the current regulatory requirements for various geographic areas at the time the standard was developed. They are provided for information only and are subject to change or revision at any time.

18.4.6.1 Operating frequency range

The High Rate PHY shall operate in the 2.4–2.4835 GHz frequency range, as allocated by regulatory bodies in the United States, Europe, and Japan, or in the 2.471–2.497 GHz frequency range, as allocated by regulatory authority in Japan.

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Table 111—Additional regulatory requirement list

Geographic area	Approval standards	Documents	Approval authority
Japan	Ministry of Public Management, Home Affairs, Post and Telecommunication (MPHPT)	MPHPT Ordinance for Regulating Radio Equipment, Article 49-20	MPHPT

18.4.6.2 Number of operating channels

The channel center frequencies and CHNL_ID numbers shall be as shown in Table 112. The FCC (United States), IC (Canada), MPHPT (Japan), and ETSI (Europe) specify operation from 2.4 GHZ to 2.4835 GHz. For Japan, operation is additionally specified as 2.471 GHz to 2.497 GHz. France allows operation from 2.4465 GHz to 2.4835 GHz, and Spain allows operation from 2.445 GHz to 2.475 GHz. For each supported regulatory domain, all channels in Table 112 marked with "X" shall be supported.

Table 112—High Rate PHY frequency channel plan

		Regulatory domains						
CHNL_ID	Frequency (MHz)	X'10' FCC	X'20' IC	X'30' ETSI	X'31' Spain	X'32 France	X'40' Japan	X'41' Japan
1	2412	X	X	X	—	—	—	X
2	2417	X	X	X	—	—	—	X
3	2422	X	X	X	—	—	—	X
4	2427	X	X	X	—	—	—	X
5	2432	X	X	X	—	—	—	X
6	2437	X	X	X	—	—	—	X
7	2442	X	X	X	—	—	—	X
8	2447	X	X	X	—	—	—	X
9	2452	X	X	X	—	—	—	X
10	2457	X	X	X	X	X	—	X
11	2462	X	X	X	X	X	—	X
12	2467	—	—	X	—	X	—	X
13	2472	—	—	X	—	X	—	X
14	2484	—	—	—	—	—	X	—

In a multiple cell network topology, overlapping and/or adjacent cells using different channels can operate simultaneously without interference if the distance between the center frequencies is at least 25 MHz. Channel 14 shall be designated specifically for operation in Japan.

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18.4.6.3 Modulation and channel data rates

Four modulation formats and data rates are specified for the High Rate PHY. The basic access rate shall be based on 1 Mbit/s DBPSK modulation. The enhanced access rate shall be based on 2 Mbit/s DQPSK. The extended direct sequence specification defines two additional data rates. The High Rate access rates shall be based on the CCK modulation scheme for 5.5 Mbit/s and 11 Mbit/s. An optional PBCC mode is also provided for potentially enhanced performance.

18.4.6.4 Spreading sequence and modulation for 1 and 2 Mbit/s

The following 11-chip Barker sequence shall be used as the PN code sequence for the 1 and 2 Mbit/s modulation:

+1, –1, +1, +1, –1, +1, +1, +1, –1, –1, –1

The leftmost chip shall be output first in time. The first chip shall be aligned at the start of a transmitted symbol. The symbol duration shall be exactly 11 chips long.

The DBPSK encoder for the basic access rate is specified in Table 113. The DQPSK encoder is specified in Table 114. (In these tables, +jω shall be defined as counterclockwise rotation.)

Table 113—1 Mbit/s DBPSK encoding table

Bit input	Phase change (+jω)
0	0
1	π

Table 114—2 Mbit/s DQPSK encoding table

Dibit pattern (d0,d1) (d0 is first in time)	Phase change (+jω)
00	0
01	π/2
11	π
10	3π/2 (–π/2)

18.4.6.5 Spreading sequences and modulation for CCK modulation at 5.5 Mbit/s and 11 Mbit/s

For the CCK modulation modes, the spreading code length is 8 and is based on complementary codes. The chipping rate is 11 Mchip/s. The symbol duration shall be exactly 8 complex chips long.

The following formula shall be used to derive the CCK code words that shall be used for spreading both 5.5 Mbit/s and 11 Mbit/s

$$c = \{e^{j(\varphi_1+\varphi_2+\varphi_3+\varphi_4)}, e^{j(\varphi_1+\varphi_3+\varphi_4)}, e^{j(\varphi_1+\varphi_2+\varphi_4)}, -e^{j(\varphi_1+\varphi_4)}, e^{j(\varphi_1+\varphi_2+\varphi_3)}, e^{j(\varphi_1+\varphi_3)}, -e^{j(\varphi_1+\varphi_2)}, e^{j\varphi_1}\} \quad (36)$$

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where C is the code word

C = {c0 to c7}

The terms φ1, φ2, φ3, and φ4 are defined in 18.4.6.5.2 for 5.5 Mbit/s and 18.4.6.5.3 for 11 Mbit/s.

This formula creates 8 complex chips (c0 to c7), where c0 is transmitted first in time.

This is a form of the generalized Hadamard transform encoding, where φ1 is added to all code chips, φ2 is added to all odd code chips, φ3 is added to all odd pairs of code chips, and φ4 is added to all odd quads of code chips.

The term φ1 modifies the phase of all code chips of the sequence and shall be DQPSK encoded for 5.5 Mbit/s and 11 Mbit/s. This shall take the form of rotating the whole symbol by the appropriate amount relative to the phase of the preceding symbol. Note that the chip c7 of the symbol defined above is the chip that indicates the symbol's phase and is transmitted last.

18.4.6.5.1 Cover code for CCK

The fourth and seventh chips are rotated 180° by a cover sequence to optimize the sequence correlation properties and minimize dc offsets in the codes. This can be seen by the minus sign on the fourth and seventh terms in Equation (36).

18.4.6.5.2 CCK 5.5 Mbit/s modulation

At 5.5 Mbit/s 4 bits (d0 to d3; d0 first in time) are transmitted per symbol.

The data bits d0 and d1 encode φ1 based on DQPSK. The DQPSK encoder is specified in Table 114. (In the table, +jω shall be defined as counterclockwise rotation.) The phase change for φ1 is relative to the phase φ1 of the preceding symbol. For the header to PSDU transition, the phase change for φ1 is relative to the phase of the preceding DQPSK (2 Mbit/s) symbol. That is, the phase of the last symbol of the CRC-16 is the reference phase for the first symbol generated from the PSDU octets. (See the definition in 18.4.6.4 for the reference phase of this Barker coded symbol.) A "+1" chip in the Barker code shall represent the same carrier phase as a "+1" chip in the CCK code.

All odd-numbered symbols generated from the PSDU octets shall be given an extra 180 degree (π) rotation, in addition to the standard DQPSK modulation as shown in Table 115. The symbols of the PSDU shall be numbered starting with 0 for the first symbol, for the purposes of determining odd and even symbols. That is, the PSDU transmission starts on an even-numbered symbol.

Table 115—DQPSK encoding table

Dibit pattern (d0, d1) (d0 is first in time)	Even symbols phase change (+jω)	Odd symbols phase change (+jω)
00	0	π
01	π/2	3π/2 (–π/2)
11	π	0
10	3π/2 (–π/2)	π/2

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The data dibits d2 and d3 CCK encode the basic symbol, as specified in Table 116. This table is derived from the formula above by setting $\varphi 2 = (d2 \times \pi) + \pi/2$, $\varphi 3 = 0$, and $\varphi 4 = d3 \times \pi$. In this table, d2 and d3 are in the order shown, and the complex chips are shown c0 to c7 (left to right), with c0 transmitted first in time.

Table 116—5.5 Mbit/s CCK encoding table

d2, d3	c1	c2	c3	c4	c5	c6	c7	c8
00	1j	1	1j	–1	1j	1	–1j	1
01	–1j	–1	–1j	1	1j	1	–1j	1
10	–1j	1	–1j	–1	–1j	1	1j	1
11	1j	–1	1j	1	–1j	1	1j	1

18.4.6.5.3 CCK 11 Mbit/s modulation

At 11 Mbit/s, 8 bits (d0 to d7; d0 first in time) are transmitted per symbol.

The first dibit (d0, d1) encodes φ1 based on DQPSK. The DQPSK encoder is specified in Table 114. The phase change for φ1 is relative to the phase φ1 of the preceding symbol. In the case of header to PSDU transition, the phase change for φ1 is relative to the phase of the preceding DQPSK symbol. All odd-numbered symbols of the PSDU are given an extra 180 degree (π) rotation, in accordance with the DQPSK modulation shown in Table 114. Symbol numbering starts with 0 for the first symbol of the PSDU.

The data dibits (d2, d3), (d4, d5), and (d6, d7) encode φ2, φ3, and φ4, respectively, based on QPSK as specified in Table 117. Note that this table is binary (not Gray) coded.

Table 117—QPSK encoding table

Dibit pattern [di, d(i+1)] (di is first in time)	Phase
00	0
01	π/2
10	π
11	3π/2 (–π/2)

18.4.6.6 DSSS/PBCC data modulation and modulation rate (optional)

This optional coding scheme uses a binary convolutional coding with a 64-state binary convolutional code (BCC) and a cover sequence. The output of the BCC is encoded jointly onto the I and Q channels, as described in this subclause.

The encoder for this scheme is shown in Figure 142. Incoming data are first encoded with a binary convolutional code. A cover code is applied to the encoded data prior to transmission through the channel.

The BCC that is used is a 64-state, rate ½ code. The generator matrix for the code is given as

$$G = [D^6 + D^4 + D^3 + D + 1, \quad D^6 + D^5 + D^4 + D^3 + D^2 + 1]$$

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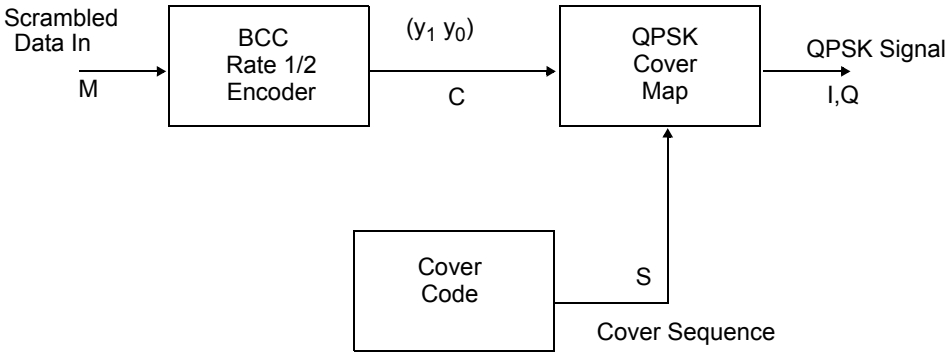

Figure 142—PBCC modulator scheme

or in octal notation, it is given by

$$G = [133, \quad 175]$$

Because the system is frame (PPDU) based, the encoder shall be in state zero (i.e., all memory elements contain zero at the beginning of each PPDU). The encoder must also be placed in a known state at the end of each PPDU to prevent the data bits near the end of the PPDU from being substantially less reliable than those early on in the PPDU. To place the encoder in a known state at the end of a PPDU, at least six deterministic bits must be input immediately following the last data bit input to the convolutional encoder. This is achieved by appending one octet containing all zeros to the end of the PPDU prior to transmission, and discarding the final octet of each received PPDU. In this manner, the decoding process can be completed reliably on the last data bits.

An encoder block diagram is shown in Figure 143. It consists of six memory elements. For every data bit input, two output bits are generated.

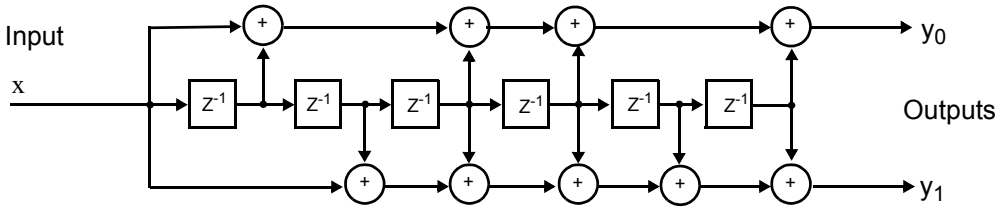

Figure 143—PBCC convolutional encoder

The output of the binary convolutional code described above is mapped to a constellation using one of two possible rates. The 5.5 Mbit/s rate uses BPSK, and the 11 Mbit/s rate uses QPSK. In QPSK mode, each pair of output bits from the binary convolutional code is used to produce one symbol; in BPSK mode, each

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pair of bits from the BCC is taken serially (y_0 first) and used to produce two BPSK symbols. This yields a throughput of one bit per symbol in QPSK mode and one-half a bit per symbol in BPSK mode.

The phase of the first complex chip of the PSDU shall be defined with respect to the phase of the last chip of the PCLP header (i.e., the last chip of the CRC check). The bits (y_1 y_0) = (0, 0) shall indicate the same phase as the last chip of the CRC check. The other three combinations of (y_1 y_0) shall be defined with respect to this reference phase, as shown in Figure 144.

The mapping from BCC outputs to PSK constellation points in BPSK and QPSK modes is determined by a pseudo-random cover sequence. This is shown for both modes in Figure 144. Note that this is an absolute phase table, not differential as in CCK.

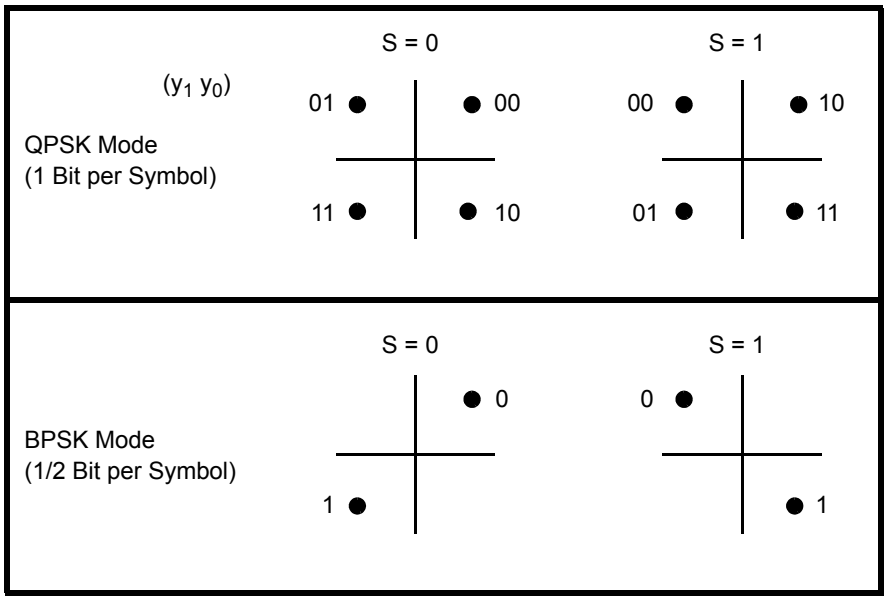

Figure 144—Cover code mapping

The pseudo-random cover sequence is generated from a seed sequence. The 16-bit seed sequence is 0011001110001011, where the first bit of the sequence in time is the leftmost bit. This sequence in octal notation is given as 150714, where the LSB is the first in time. This seed sequence is used to generate the 256-bit pseudo-random cover sequence, which is used in the mapping of the current PSK symbol. It is the current binary value of this sequence at every given point in time that is taken as S in Figure 144.

This sequence of 256 bits is produced by taking the first sixteen bits of the sequence as the seed sequence, the second sixteen bits as the seed sequence cyclically left rotated by three, the third sixteen bits as the seed sequence cyclically left rotated by six, etc. If c*i* is the ith bit of the seed sequence, where $0 \le I \le 15$, then the sequence that is used to cover the data is given row-wise as follows:

c0 c1 c2 c3 c4 c5 c6 c7 c8 c9 c10 c11 c12 c13 c14 c15
c3 c4 c5 c6 c7 c8 c9 c10 c11 c12 c13 c14 c15 c0 c1 c2
c6 c7 c8 c9 c10 c11 c12 c13 c14 c15 c0 c1 c2 c3 c4 c5
c9 c10 c11 c12 c13 c14 c15 c0 c1 c2 c3 c4 c5 c6 c7 c8
c12 c13 c14 c15 c0 c1 c2 c3 c4 c5 c6 c7 c8 c9 c10 c11
c15 c0 c1 c2 c3 c4 c5 c6 c7 c8 c9 c10 c11 c12 c13 c14

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c2 c3 c4 c5 c6 c7 c8 c9 c10 c11 c12 c13 c14 c15 c0 c1
c5 c6 c7 c8 c9 c10 c11 c12 c13 c14 c15 c0 c1 c2 c3 c4
c8 c9 c10 c11 c12 c13 c14 c15 c0 c1 c2 c3 c4 c5 c6 c7
c11 c12 c13 c14 c15 c0 c1 c2 c3 c4 c5 c6 c7 c8 c9 c10
c14 c15 c0 c1 c2 c3 c4 c5 c6 c7 c8 c9 c10 c11 c12 c13
c1 c2 c3 c4 c5 c6 c7 c8 c9 c10 c11 c12 c13 c14 c15 c0
c4 c5 c6 c7 c8 c9 c10 c11 c12 c13 c14 c15 c0 c1 c2 c3
c7 c8 c9 c10 c11 c12 c13 c14 c15 c0 c1 c2 c3 c4 c5 c6
c10 c11 c12c13 c14 c15 c0 c1 c2 c3 c4 c5 c6 c7 c8 c9
c13 c14 c15 c0 c1 c2 c3 c4 c5 c6 c7 c8 c9 c10 c11 c12

For PPDUs with more than 256 data bits, this sequence of 256 bits is simply repeated.

18.4.6.7 Channel Agility (optional)

This Channel Agility option allows an implementation to overcome some inherent difficulty with static channel assignments (a tone jammer), without burdening all implementations with the added cost of this capability. When the Channel Agility option is enabled, the PHY shall meet the requirements on channel switching and settling time, as described in 18.4.6.12, and the hop sequences described below. This option can also be used to implement IEEE 802.11-compliant systems that are interoperable between both FH and DS modulations. Annex F contains a description of the expected behavior when such networks are employed.

18.4.6.7.1 Hop sequences

The hop sequences for each of the specified geographical areas are defined with two sets. High Rate frequency channels referred to in this subclause are defined in Table 112.

The first set (Figure 145 and Figure 147) uses nonoverlapping frequency channels to allow the High Rate systems to minimize interference degradation. The synchronization of FH is performed by the MLME, as defined in 11.1.5 for the FH PHY. The PLME SAP service primitives used to command a new frequency channel are defined in 10.4.

The second set (Figure 146 and Figure 148) uses half overlapping frequency channels, with 10 MHz center frequency spacing, to enable interoperability with 1 Mbit/s and 2 Mbit/s FH systems hopping with the approved IEEE 802.11 hop sequences. The High Rate hop frequency is calculated from the specific 1 MHz channel chosen for a given hop by picking the closest High Rate channel within the set. Where there is a choice of two DSSS channels, the lower one shall be the one chosen. Therefore, the chosen channel shall be no more than ±5 MHz of the channel center of the FH channel. When operating on the FH channels beyond ±5 MHz of the closest High Rate channel specified in the set, the High Rate mode shall not be used and all FH transmissions shall occur at the 1 Mbit/s or 2 Mbit/s rate.

18.4.6.7.2 Operating channels

The operating channels for specified geographical areas are defined in Table 118 and Table 119.

Table 118—North American operating channels

Set	Number of channels	HR/DSSS channel numbers
1	3	1, 6, 11
2	6	1, 3, 5, 7, 9, 11

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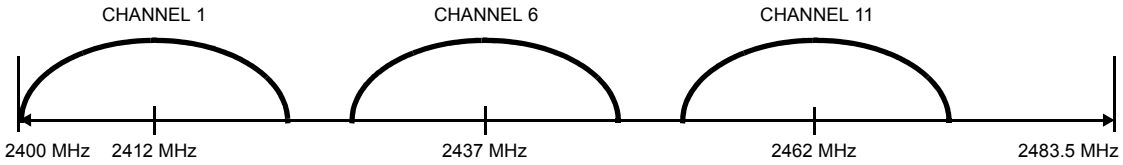

Figure 145—North American channel selection—nonoverlapping

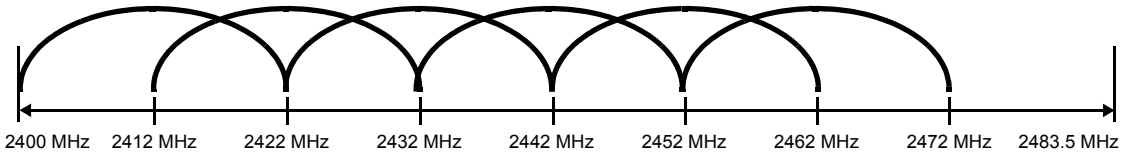

Figure 146—North American channel selection—overlapping

Table 119—European operating channels (except France and Spain)

Set	Number of channels	HR/DSS channel numbers
1	3	1, 7, 13
2	7	1, 3, 5, 7, 9, 11, 13

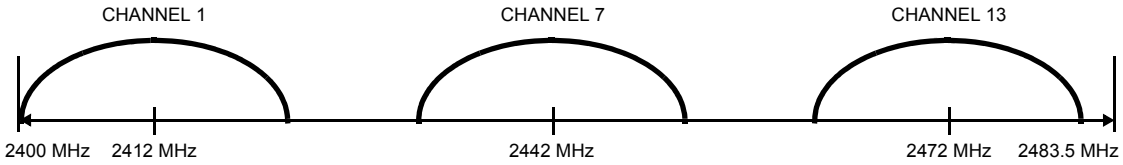

Figure 147—European channel selection—nonoverlapping

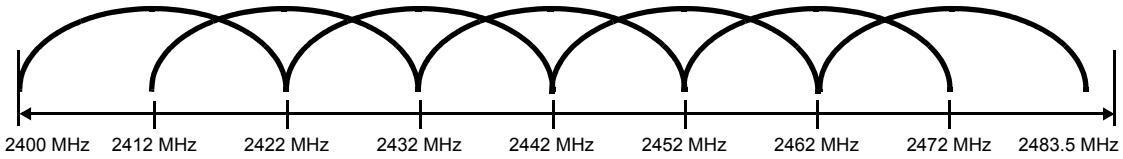

Figure 148—European channel selection—overlapping

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18.4.6.7.3 Hop patterns

A FH pattern, Fx, consists of a permutation of all frequency channels defined in Table 118 and Table 119. For a given pattern number *x*, the hopping sequence can be written as

$$Fx = \{fx(1), fx(2), ..., fx(p)\}$$

where

fx (*i*) is the channel number (as defined in 14.6.4) for i^{th} frequency in the xth hopping pattern;

p is the number of hops in pseudo-random hopping pattern before repeating sequence (79 for North America and most of Europe).

The FH patterns for Set 1 of each geographic area are based on the hop patterns in Table 120 and Table 121.

The FH patterns for Set 2 of each geographic area are defined by the 1/2 Mbit/s FH PHY hop sequences, as described in the FH PHY (14.6.8). Given the hopping pattern number *x*, and the index for the next frequency, *i* (in the range 1 to p), the DS channel number (as defined in 18.4.6.2) shall be selected with the following algorithm:

North America

$f'x(i) = fx(i)$ for $1 \le fx(i) \le 11$;
$f'x(i)$ = null for $fx(i) < 1$ and $fx(i) > 11$;
$f'x(i) = 2 \times \text{Int}[(\{[b(i) + x] \bmod (79) + 2\} - 6) / 10] - 1$;
with $b(i)$ defined in Table 42 (in 14.6.8).

Most of Europe

$f'x(i) = fx(i)$ for $1 \le fx(i) \le 13$;
$f'x(i)$ = null for $fx(i) < 1$ and $fx(i) > 13$;
$f'x(i) = 2 \times \text{Int}[(\{[b(i) + x] \bmod (79) + 2\} - 6) / 10] - 1$;
with $b(i)$ defined in Table 42 (in 14.6.8).

Table 120—North American Set 1 hop patterns

Index	Pattern 1	Pattern 2
1	1	1
2	6	11
3	11	6

Table 121—European Set 1 hop patterns (except France and Spain)

Index	Pattern 1	Pattern 2
1	1	1
2	7	13
3	13	7

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18.4.6.8 Transmit and receive in-band and out-of-band spurious emissions

The High Rate PHY conforms with in-band and out-of-band spurious emissions as set by regulatory bodies. For the United States, refer to Sections 15.205, 15.209, and 15.247 of FCC CFR47 [B6]. For Europe, refer to ETS 300–328 [B4]. For Japan, refer to MPT ordinance for Regulating Radio Equipment, Article 7.

18.4.6.9 TX-to-RX turnaround time

The TX-to-RX turnaround time shall be less than 10 μs, including the power-down ramp specified in 18.4.7.6.

The TX-to-RX turnaround time shall be measured at the air interface from the trailing edge of the last transmitted symbol to the valid CCA detection of the incoming signal. The CCA should occur within 25 μs (10 μs for turnaround time, plus 15 μs for energy detect), or by the next slot boundary occurring after the 25 μs has elapsed (see 18.4.8.4). A receiver input signal 3 dB above the ED threshold described in 18.4.8.4 shall be present at the receiver.

18.4.6.10 RX-to-TX turnaround time

The RX-to-TX turnaround time shall be measured at the MAC/PHY interface using PHYTXSTART.request, and shall be 5 μs. This includes the transmit power-on ramp described in 18.4.7.6.

18.4.6.11 Slot time

The slot time for the High Rate PHY shall be the sum of the RX-to-TX turnaround time (5 μs) and the energy detect time (15 μs specified in 18.4.8.4). The propagation delay shall be regarded as being included in the energy detect time.

18.4.6.12 Channel switching/settling time

When the Channel Agility option is enabled, the time to change from one operating channel frequency to another, as specified in 18.4.6.2, is 224 μs. A conformant PMD meets this switching time specification when the operating channel center frequency has settled to within ±60 kHz of the nominal channel center. Stations shall not transmit until after the channel change settling time.

18.4.6.13 Transmit and receive antenna port impedance

The impedance of the transmit and receive antenna port(s) shall be 50 Ω if the port is exposed.

18.4.6.14 Transmit and receive operating temperature range

Two temperature ranges are specified for full operation compliance to the High Rate PHY. Type 1 shall be defined as 0 °C to 40 °C, and is designated for office environments. Type 2 shall be defined as –30 °C to +70 °C, and is designated for industrial environments.

18.4.7 PMD transmit specifications

The transmit functions and parameters associated with the PMD sublayer are described in 18.4.7.1 through 18.4.7.8.

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18.4.7.1 Transmit power levels

The maximum allowable output power, as measured in accordance with practices specified by the appropriate regulatory bodies, is shown in Table 122. In the United States, the radiated emissions should also conform with the ANSI uncontrolled radiation emission standards (IEEE Std C95.1-1999).

Table 122—Transmit power levels

Maximum output power	Geographic location	Compliance document
1000 mW	United States	FCC CFR47 [B6]: Section 15.247
100 mW (EIRP)	Europe	ETS 300-328 [B4]
See Table 123	Japan	MPT ordinance for Regulating Radio Equipment, Article 49-20

Table 123—Transmit Power Levels in Japan

Maximum output power	Modulation/Frequency range	Compliance document
10 mW/MHz	for FH-SS or DS-SS modulation and operation in 2.471–2.497 GHz range	MPHPT ordinance for Regulating Radio Equipment, Article 49-20
10 mW/MHz	for DS-SS modulation and operation in 2.400–2.4835 GHz range	
3 mW/MHz	for FH-SS modulation and operation in 2.400–2.4835 GHz range	

18.4.7.2 Transmit power level control

Power control shall be provided for transmitted power greater than 100 mW. A maximum of four power levels may be provided. As a minimum, a radio capable of transmission greater than 100 mW shall be capable of switching power back to 100 mW or less.

18.4.7.3 Transmit spectrum mask

The transmitted spectral products shall be less than –30 dBr (dB relative to the SINx/x peak) for

$f_c - 22\ \text{MHz} < f < f_c - 11\ \text{MHz}$; and
$f_c + 11\ \text{MHz} < f < f_c + 22\ \text{MHz}$;

and shall be less than –50 dBr for

$f < f_c - 22\ \text{MHz}$; and
$f > f_c + 22\ \text{MHz}$.

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where

f_c is the channel center frequency.

The transmit spectral mask is shown in Figure 149. The measurements shall be made using a 100 kHz resolution bandwidth and a 100 kHz video bandwidth.

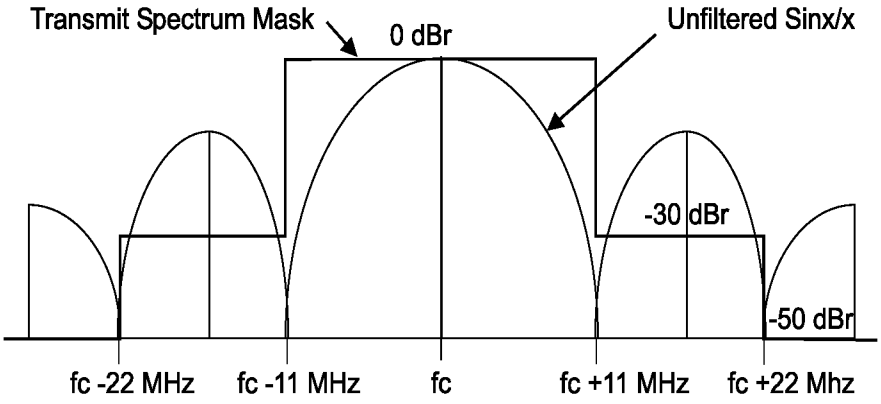

Figure 149—Transmit spectrum mask

18.4.7.4 Transmit center frequency tolerance

The transmitted center frequency tolerance shall be ±25 ppm maximum.

18.4.7.5 Chip clock frequency tolerance

The PN code chip clock frequency tolerance shall be better than ±25 ppm maximum. It is highly recommended that the chip clock and the transmit frequency be locked (coupled) for optimum demodulation performance. If these clocks are locked, it is recommended that bit 2 of the SERVICE field be set to 1, as indicated in 18.2.3.4.

18.4.7.6 Transmit power-on and power-down ramp

The transmit power-on ramp for 10% to 90% of maximum power shall be no greater than 2 μs. The transmit power-on ramp is shown in Figure 150.

The transmit power-down ramp for 90% to 10% maximum power shall be no greater than 2 μs. The transmit power-down ramp is shown in Figure 151.

The transmit power ramps shall be constructed such that the High Rate PHY emissions conform with spurious frequency product specification defined in 18.4.6.8.

18.4.7.7 RF carrier suppression

The RF carrier suppression, measured at the channel center frequency, shall be at least 15 dB below the peak SIN(x)/x power spectrum. The RF carrier suppression shall be measured while transmitting a repetitive 01 data sequence with the scrambler disabled using DQPSK modulation. A 100 kHz resolution bandwidth shall be used to perform this measurement.

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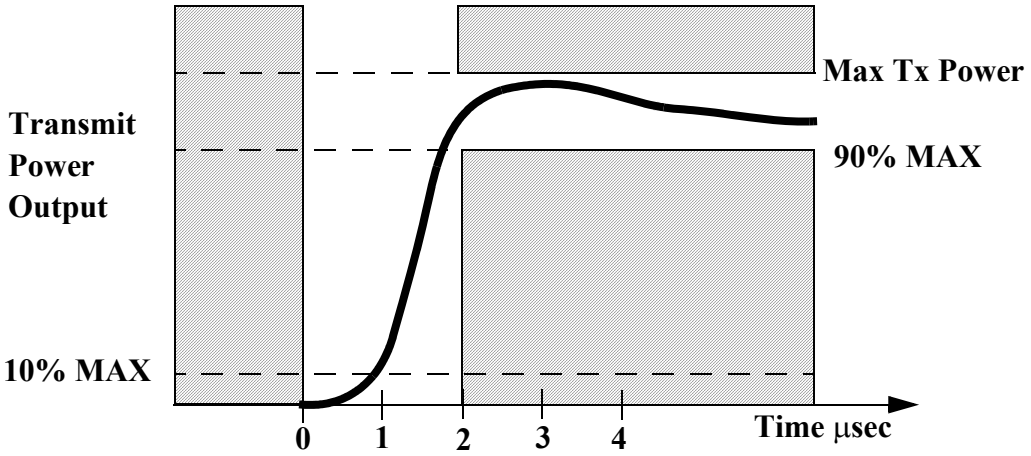

Figure 150—Transmit power-on ramp

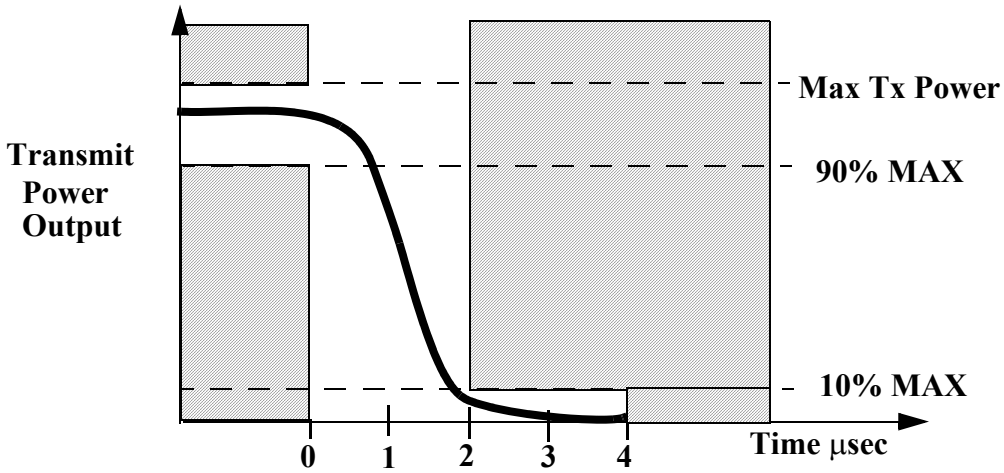

Figure 151—Transmit power-down ramp

18.4.7.8 Transmit modulation accuracy

The transmit modulation accuracy requirement for the High Rate PHY shall be based on the difference between the actual transmitted waveform and the ideal signal waveform. Modulation accuracy shall be determined by measuring the peak vector error magnitude during each chip period. Worst-case vector error magnitude shall not exceeded 0.35 for the normalized sampled chip data. The ideal complex I and Q constellation points associated with DQPSK modulation, (0.707, 0.707), (0.707, –0.707), (–0.707, 0.707), (–0.707, –0.707), shall be used as the reference. These measurements shall be from baseband I and Q sampled data after recovery through a reference receiver system.

Figure 152 illustrates the ideal DQPSK constellation points and range of worst-case error specified for modulation accuracy.

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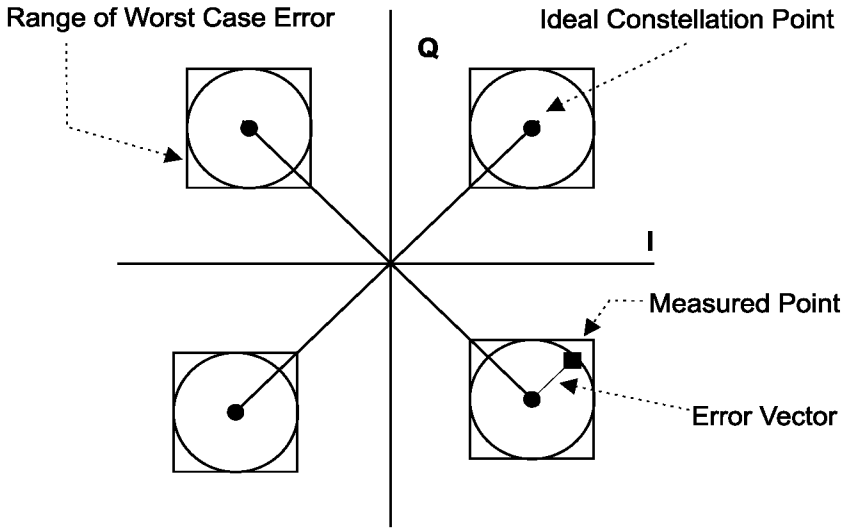

Figure 152—Modulation accuracy measurement example

Error vector measurement requires a reference receiver capable of carrier lock. All measurements shall be made under carrier lock conditions. The distortion induced in the constellation by the reference receiver shall be calibrated and measured. The test data error vectors described below shall be corrected to compensate for the reference receiver distortion.

The IEEE 802.11-compatible radio shall provide an exposed TX chip clock, which shall be used to sample the I and Q outputs of the reference receiver.

The measurement shall be made under the conditions of continuous DQPSK transmission using scrambled all ones.

The eye pattern of the I channel shall be used to determine the I and Q sampling point. The chip clock provided by the vendor radio shall be time delayed, such that the samples fall at a 1/2 chip period offset from the mean of the zero crossing positions of the eye (see Figure 153). This is the ideal center of the eye and may not be the point of maximum eye opening.

Using the aligned chip clock, 1000 samples of the I and Q baseband outputs from the reference receiver are captured. The vector error magnitudes shall be calculated as follows:

Calculate the dc offsets for I and Q samples

$$I_{\text{mean}} = \sum_{n=0}^{999} I(n) / 1000$$

$$Q_{\text{mean}} = \sum_{n=0}^{999} Q(n) / 1000$$

Calculate the dc corrected I and Q samples for all n = 1000 sample pairs

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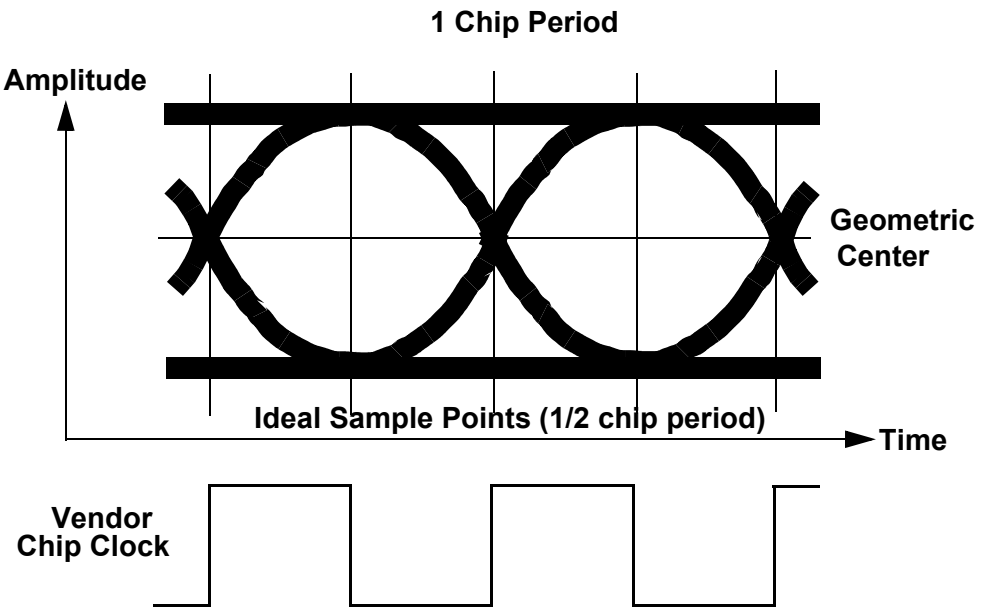

Figure 153—Chip clock alignment with baseband eye pattern

$I_{dc}(n) = I(n) - I_{mean}$

$Q_{dc}(n) = Q(n) - Q_{mean}$

Calculate the average magnitude of I and Q samples

$$I_{mag} = \sum_{n=0}^{999} |I_{dc}(n)| / 1000$$

$$Q_{mag} = \sum_{n=0}^{999} |Q_{dc}(n)| / 1000$$

Calculate the normalized error vector magnitude for the $I_{dc}(n)/Q_{dc}(n)$ pairs

$$V_{err}(n) = \left[\frac{1}{2} \times (\{|I_{dc}(n)| - I_{mag}\}^2 + \{|Q_{dc}(n)| - Q_{mag}\}^2)\right]^{\frac{1}{2}} - V_{correction}$$

where

$V_{correction}$ is the error induced by the reference receiver system.

A vendor High Rate PHY implementation shall be compliant if for all n = 1000 samples, the following condition is met:

$V_{err}(n) < 0.35$

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18.4.8 PMD receiver specifications

The receive functions and parameters associated with the PMD sublayer are described in 18.4.8.1 through 18.4.8.4.

18.4.8.1 Receiver minimum input level sensitivity

The FER shall be less than 8×10^{-2} at a PSDU length of 1024 octets for an input level of –76 dBm measured at the antenna connector. This FER shall be specified for 11 Mbit/s CCK modulation. The test for the minimum input level sensitivity shall be conducted with the ED threshold set less than or equal to –76 dBm.

18.4.8.2 Receiver maximum input level

The receiver shall provide a maximum FER of 8×10^{-2} at a PSDU length of 1024 octets for a maximum input level of –10 dBm measured at the antenna. This FER shall be specified for 11 Mbit/s CCK modulation.

18.4.8.3 Receiver adjacent channel rejection

Adjacent channel rejection is defined between any two channels with ≥ 25 MHz separation in each channel group, as defined in 18.4.6.2.

The adjacent channel rejection shall be equal to or better than 35 dB, with an FER of 8×10^{-2} using 11 Mbit/s CCK modulation described in 18.4.6.3 and a PSDU length of 1024 octets.

The adjacent channel rejection shall be measured using the following method.

Input an 11 Mbit/s CCK modulated signal at a level 6 dB greater than specified in 18.4.8.1. In an adjacent channel (≥ 25 MHz separation as defined by the channel numbering), input a signal modulated in a similar fashion, which adheres to the transmit mask specified in 18.4.7.3, to a level 41 dB above the level specified in 18.4.8.1. The adjacent channel signal shall be derived from a separate signal source. It cannot be a frequency shifted version of the reference channel. Under these conditions, the FER shall be no worse than 8×10^{-2}.

18.4.8.4 CCA

The High Rate PHY shall provide the capability to perform CCA according to at least one of the following three methods:

— CCA Mode 1: Energy above threshold. CCA shall report a busy medium upon detecting any energy above the ED threshold.
— CCA Mode 4: CS with timer. CCA shall start a timer whose duration is 3.65 ms and report a busy medium only upon the detection of a High Rate PHY signal. CCA shall report an IDLE medium after the timer expires and no High Rate PHY signal is detected. The 3.65 ms timeout is the duration of the longest possible 5.5 Mbit/s PSDU.
— CCA Mode 5: A combination of CS and energy above threshold. CCA shall report busy at least while a High Rate PPDU with energy above the ED threshold is being received at the antenna.

The ED status shall be given by the PMD primitive, PMD_ED. The CS status shall be given by PMD_CS. The status of PMD_ED and PMD_CS is used in the PLCP to indicate activity to the MAC through the PHY interface primitive, PHY-CCA.indicate.

A busy channel shall be indicated by PHY-CCA.indicate of class BUSY. A clear channel shall be indicated by PHY-CCA.indicate of class IDLE.

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The PHY MIB attribute, dot11CCAModeSupported, shall indicate the appropriate operation modes. The PHY shall be configured through the PHY MIB attribute, dot11CurrentCCAMode.

The CCA shall indicate TRUE if there is no energy detect or CS. The CCA parameters are subject to the following criteria:

a) If a valid High Rate signal is detected during its preamble within the CCA window, the ED threshold shall be less than or equal to –76 dBm for TX power > 100 mW; –73 dBm for 50 mW < TX power $\leq$ 100 mW; and –70 dBm for TX power $\leq$ 50 mW.
b) With a valid signal (according to the CCA mode of operation) present at the receiver antenna within 5 μs of the start of a MAC slot boundary, the CCA indicator shall report channel busy before the end of the slot time. This implies that the CCA signal is available as an exposed test point. Refer to Figure 62 (in 9.2.10) for a slot time boundary definition.
c) In the event that a correct PLCP header is received, the High Rate PHY shall hold the CCA signal inactive (channel busy) for the full duration, as indicated by the PLCP LENGTH field. Should a loss of CS occur in the middle of reception, the CCA shall indicate a busy medium for the intended duration of the transmitted PPDU. Upon reception of a correct PLCP header, the timer of CCA Mode 2 shall be overridden by this requirement.

Conformance to the High Rate PHY CCA shall be demonstrated by applying an equivalent High-Rate-compliant signal above the appropriate ED threshold (item a) so that all conditions described in item b and item c are demonstrated.

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Annex A

(normative)

Protocol Implementation Conformance Statement (PICS) proforma

A.1 Introduction

The supplier of a protocol implementation that is claimed to conform to IEEE Std 802.11, 2003 Edition, shall complete the following protocol implementation conformance statement (PICS) proforma.

A completed PICS proforma is the PICS for the implementation in question. The PICS is a statement of which capabilities and options of the protocol have been implemented. The PICS can have a number of uses, including use

a) By the protocol implementer, as a checklist to reduce the risk of failure to conform to the standard through oversight;
b) By the supplier and acquirer, or potential acquirer, of the implementation, as a detailed indication of the capabilities of the implementation, stated relative to the common basis for understanding provided by the standard PICS proforma;
c) By the user, or potential user, of the implementation, as a basis for initially checking the possibility of interworking with another implementation (note that, while interworking can never be guaranteed, failure to interwork can often be predicted from incompatible PICS proformas);
d) By a protocol tester, as the basis for selecting appropriate tests against which to assess the claim for conformance of the implementation.

A.2 Abbreviations and special symbols

A.2.1 Symbols for Status column

M	mandatory
O	optional
O.<n>	optional, but support of at least one of the group of options labeled by the same numeral <n> is required
pred:	conditional symbol, including predicate identification

A.2.2 General abbreviations for Item and Support columns

N/A	not applicable
AD	address function capability
CF	implementation under test (IUT) configuration
DS	direct sequence
FR	medium access control (MAC) frame capability
FS	frame sequence capability
FT	frame transmission
HRDS	High Rate direct sequence
MD	multidomain
PC	protocol capability

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A.3 Instructions for completing the PICS proforma

A.3.1 General structure of the PICS proforma

The first parts of the PICS proforma, Implementation identification and Protocol summary, are to be completed as indicated with the information necessary to identify fully both the supplier and the implementation.

The main part of the PICS proforma is a fixed questionnaire, divided into subclauses, each containing a number of individual items. Answers to the questionnaire items are to be provided in the rightmost column, either by simply marking an answer to indicate a restricted choice (usually Yes or No) or by entering a value or a set or a range of values. (Note that there are some items where two or more choices from a set of possible answers may apply. All relevant choices are to be marked in these cases.)

Each item is identified by an item reference in the first column. The second column contains the question to be answered. The third column contains the reference or references to the material that specifies the item in the main body of this standard. The remaining columns record the status of each item, i.e., whether support is mandatory, optional, or conditional, and provide the space for the answers (see also A.3.4). Marking an item as supported is to be interpreted as a statement that all relevant requirements of the subclauses and normative annexes, cited in the References column for the item, are met by the implementation.

A supplier may also provide, or be required to provide, further information, categorized as either Additional Information or Exception Information. When present, each kind of further information is to be provided in a further subclause of items labeled A<*I*> or X<*I*>, respectively, for cross-referencing purposes, where <*I*> is any unambiguous identification for the item (e.g., simply a numeral). There are no other restrictions on its format or presentation.

The PICS proforma for a station consists of A.4.1 through A.4.4 inclusive, and at least one of A.4.5, A.4.6, or A.4.7 corresponding to the physical layer (PHY) implemented.

A completed PICS proforma, including any Additional Information and Exception Information, is the PICS for the implementation in question.

NOTE—Where an implementation is capable of being configured in more than one way, a single PICS may be able to describe all such configurations. However, the supplier has the choice of providing more than one PICS, each covering some subset of the implementation's capabilities, if this makes for easier and clearer presentation of the information.

A.3.2 Additional information

Items of Additional Information allow a supplier to provide further information intended to assist in the interpretation of the PICS. It is not intended or expected that a large quantity of information will be supplied, and a PICS can be considered complete without any such information. Examples of such Additional Information might be an outline of the ways in which an (single) implementation can be set up to operate in a variety of environments and configurations, or information about aspects of the implementation that are outside the scope of this standard but have a bearing upon the answers to some items.

References to items of Additional Information may be entered next to any answer in the questionnaire, and may be included in items of Exception Information.

A.3.3 Exception information

It may happen occasionally that a supplier will wish to answer an item with mandatory status (after any conditions have been applied) in a way that conflicts with the indicated requirement. No preprinted answer will

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be found in the Support column for this. Instead, the supplier shall write the missing answer into the Support column, together with an X<*I*> reference to an item of Exception Information, and shall provide the appropriate rationale in the Exception Information item itself.

An implementation for which an Exception Information item is required in this way does not conform to this standard.

NOTE—A possible reason for the situation described above is that a defect in this standard has been reported, a correction for which is expected to change the requirement not met by the implementation.

A.3.4 Conditional status

The PICS proforma contains a number of conditional items. These are items for which both the applicability of the item itself, and its status if it does apply, mandatory or optional, are dependent upon whether or not certain other items are supported.

Where a group of items is subject to the same condition for applicability, a separate preliminary question about the condition appears at the head of the group, with an instruction to skip to a later point in the questionnaire if the N/A answer is selected. Otherwise, individual conditional items are indicated by a conditional symbol in the Status column.

A conditional symbol is of the form "<pred>:<S>", where "<pred>" is a predicate as described below, and "<S>" is one of the status symbols M or O.

If the value of the predicate is true, the conditional item is applicable, and its status is given by S: the support column is to be completed in the usual way. Otherwise, the conditional item is not relevant and the N/A answer is to be marked.

A predicate is one of the following:

a) An item-reference for an item in the PICS proforma: the value of the predicate is true if the item is marked as supported, and is false otherwise.
b) A boolean expression constructed by combining item-references using the boolean operator OR: the value of the predicate is true if one or more of the items is marked as supported, and is false otherwise.

Each item referenced in a predicate, or in a preliminary question for grouped conditional items, is indicated by an asterisk in the Item column.

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A.4 PICS proforma—IEEE Std 802.11, 2003 Edition[9]

A.4.1 Implementation identification

Supplier	
Contact point for queries about the PICS	
Implementation Name(s) and Version(s)	
Other information necessary for full identification, e.g., name(s) and version(s) of the machines and/or operating systems(s), system names	

NOTES

1—Only the first three items are required for all implementations. Other information may be completed as appropriate in meeting the requirement for full identification.

2—The terms Name and Version should be interpreted appropriately to correspond with a supplier's terminology (e.g., Type, Series, Model).

A.4.2 Protocol summary

Identification of protocol standard	IEEE Std 802.11, 2003 Edition
Identification of amendments and corrigenda to this PICS proforma that have been completed as part of this PICS	Amd. : Corr. : Amd. : Corr. :
Have any exception items been required? (See A.3.3; the answer Yes means that the implementation does not conform to IEEE Std 802.11, 2003 Edition.)	Yes ❑ No ❑

Date of statement (dd/mm/yy)	

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A.4.3 IUT configuration

Item	IUT configuration	References	Status	Support
	What is the configuration of the IUT?			
* CF1	Access point (AP)	5.2	O.1	Yes ❑ No ❑
* CF2	Independent station (*not* an AP)	5.2	O.1	Yes ❑ No ❑
* CF3	Frequency-hopping spread spectrum (FHSS) PHY for the 2.4 GHz band	—	O.2	Yes ❑ No ❑
* CF4	Direct sequence spread spectrum (DSSS) PHY for the 2.4 GHz band	—	O.2	Yes ❑ No ❑
* CF5	Infrared (IR) PHY	—	O.2	Yes ❑ No ❑
* CF6	Orthogonal frequency division multiplexing (OFDM) PHY for the 5 GHz band	—	O.2	Yes ❑ No ❑
* CF7	High-speed PHY	—	O.2	Yes ❑ No ❑
* CF8	Is multidomain operation capability implemented?	7.3.2.10, 7.3.2.11, 9.9, 11.1.3.4	O.3	Yes ❑ No ❑

A.4.4 MAC protocol

A.4.4.1 MAC protocol capabilities

Item	Protocol capability	References	Status	Support
	Are the following MAC protocol capabilities supported?			
PC1	Authentication service	5.4.3.1, 5.4.3.2, 5.7.6, 5.7.7, 8.1, Annex C	M	Yes ❑ No ❑
PC1.1	Authentication state	5.5	M	Yes ❑ No ❑
PC1.2	Open System authentication	8.1.1	M	Yes ❑ No ❑
PC1.3	Shared Key authentication	8.1.2, 8.3	PC2:M	Yes ❑ No ❑ N/A ❑
* PC2	Wired equivalent privacy (WEP) algorithm	5.4.3.3, 8.2, Annex C	O	Yes ❑ No ❑
PC2.1	WEP Encryption procedure	8.2.3, 8.2.4, 8.2.5	PC2:M	Yes ❑ No ❑ N/A ❑
PC2.2	WEP Decryption procedure	8.2.3, 8.2.4, 8.2.5	PC2:M	Yes ❑ No ❑ N/A ❑
PC2.3	Security services management	8.3	M	Yes ❑ No ❑
PC3	Distributed coordination function (DCF)	9.1, 9.2, Annex C	M	Yes ❑ No ❑
PC3.1	Network allocation vector (NAV) function	9.2.1, 9.2.5, 9.3.2.2	M	Yes ❑ No ❑
PC3.2	Interframe space usage and timing	9.2.3, 9.2.5, 9.2.10	M	Yes ❑ No ❑
PC3.3	Random Backoff function	9.2.4	M	Yes ❑ No ❑

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A.4.4.1 MAC protocol capabilities *(continued)*

Item	Protocol capability	References	Status	Support
PC3.4	DCF Access procedure	9.2.5.1, 9.2.5.5	M	Yes ❑ No ❑
PC3.5	Random Backoff procedure	9.2.5.2	M	Yes ❑ No ❑
PC3.6	Recovery procedures and retransmit limits	9.2.5.3	M	Yes ❑ No ❑
PC3.7	Request to send (RTS)/clear to send (CTS) procedure	9.2.5.4, 9.2.5.6, 9.2.5.7	M	Yes ❑ No ❑
PC3.8	Directed MAC protocol data unit (MPDU) transfer	9.2.6	M	Yes ❑ No ❑
PC3.9	Broadcast and multicast MPDU transfer	9.2.7	M	Yes ❑ No ❑
PC3.10	MAC level acknowledgment	9.2.2, 9.2.8	M	Yes ❑ No ❑
PC3.11	Duplicate detection and recovery	9.2.9	M	Yes ❑ No ❑
* PC4	Point coordinator (PC)	9.1, 9.3, Annex C	CF1:O	Yes ❑ No ❑ N/A ❑
PC4.1	Maintenance of contention-free period (CFP) structure and timing	9.3.1, 9.3.2	PC4:M	Yes ❑ No ❑ N/A ❑
PC4.2	Point coordination function (PCF) MPDU transfer from PC	9.3.3	PC4:M	Yes ❑ No ❑ N/A ❑
* PC4.3	PCF MPDU transfer to PC	9.3.3	PC4:O	Yes ❑ No ❑ N/A ❑
PC4.4	Overlapping PC provisions	9.3.3.2	PC4:M	Yes ❑ No ❑ N/A ❑
PC4.5	Polling list maintenance	9.3.4	PC4.3:M	Yes ❑ No ❑ N/A ❑
* PC5	Contention-free (CF)-Pollable	9.1, 9.3, Annex C	CF2:O	Yes ❑ No ❑ N/A ❑
PC5.1	Interpretation of CFP structure and timing	9.3.1, 9.3.2	PC5:M	Yes ❑ No ❑ N/A ❑
PC5.2	PCF MPDU transfer to/from and CF-Pollable station (STA)	9.3.3	PC5:M	Yes ❑ No ❑ N/A ❑
PC5.3	Polling list update	9.3.4	PC5:M	Yes ❑ No ❑ N/A ❑
PC6	Fragmentation	9.2, 9.4, Annex C	M	Yes ❑ No ❑
PC7	Defragmentation	9.2, 9.5, Annex C	M	Yes ❑ No ❑
PC8	MAC data service	9.1.5, 9.8, Annex C	M	Yes ❑ No ❑
PC8.1	Reorderable-Multicast service class	9.8	M	Yes ❑ No ❑
PC8.2	StrictlyOrdered service class	9.8	O	Yes ❑ No ❑
PC9	Multirate support	9.6, Annex C	M	Yes ❑ No ❑
* PC10	Multiple outstanding MAC service data unit (MSDU) support	9.8, Annex C	O	Yes ❑ No ❑
PC10.1	Multiple outstanding MSDU transmission restrictions	9.8	PC10:M	Yes ❑ No ❑ N/A ❑
PC11	Timing synchronization function (TSF)	11.1, Annex C	M	Yes ❑ No ❑
PC11.1	Timing in an infrastructure network	11.1.1.1, 11.1.4	CF1:M	Yes ❑ No ❑ N/A ❑

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A.4.4.1 MAC protocol capabilities *(continued)*

Item	Protocol capability	References	Status	Support
PC11.2	Timing in an independent basic service set (IBSS)	11.1.1.2, 11.1.4	CF2:M	Yes ❑ No ❑ N/A ❑
PC11.3	Beacon Generation function	11.1.2	M	Yes ❑ No ❑ N/A ❑
PC11.4	TSF synchronization and accuracy	11.1.2	M	Yes ❑ No ❑
PC11.5	Infrastructure basic service set (BSS) initialization	11.1.3	CF1:M	Yes ❑ No ❑ N/A ❑
PC11.6	IBSS initialization	11.1.3	CF2:M	Yes ❑ No ❑ N/A ❑
PC11.7	Passive scanning	11.1.3	CF2:M	Yes ❑ No ❑ N/A ❑
PC11.8	Active scanning	11.1.3	CF2:M	Yes ❑ No ❑ N/A ❑
PC11.9	Probe response	11.1.3	M	Yes ❑ No ❑
PC11.10	Hop Synchronization function	11.1.5	CF3:M	Yes ❑ No ❑ N/A ❑
PC12	Infrastructure power management	11.2.1, Annex C	M	Yes ❑ No ❑
PC12.1	Station power management modes	11.2.1.1, 11.2.1.8	CF2:M	Yes ❑ No ❑ N/A ❑
PC12.2	Traffic indication map (TIM) transmission	11.2.1.2, 11.2.1.3	CF1:M	Yes ❑ No ❑ N/A ❑
PC12.3	AP function during contention period (CP)	11.2.1.4	CF1:M	Yes ❑ No ❑ N/A ❑
PC12.4	AP function during CFP	11.2.1.5	PC4:M	Yes ❑ No ❑ N/A ❑
PC12.5	Receive function during CP	11.2.1.6	CF2:M	Yes ❑ No ❑ N/A ❑
PC12.6	Receive function during CFP	11.2.1.7	PC5:M	Yes ❑ No ❑ N/A ❑
PC12.7	Aging function	11.2.1.9	CF1:M	Yes ❑ No ❑ N/A ❑
PC13	IBSS power management	11.2.2, Annex C	CF2:M	Yes ❑ No ❑ N/A ❑
PC13.1	Initialization of power management	11.2.2.2	CF2:M	Yes ❑ No ❑ N/A ❑
PC13.2	STA power state transitions	11.2.2.3	CF2:M	Yes ❑ No ❑ N/A ❑
PC13.3	Announcement traffic indication message (ATIM) and frame transmission	11.2.2.4	CF2:M	Yes ❑ No ❑ N/A ❑
PC14	Association and reassociation	5.4, 5.7, 11.3, Annex C	M	Yes ❑ No ❑
PC14.1	Association state	5.5	M	Yes ❑ No ❑
PC14.2	STA association procedure	11.3.1	CF2:M	Yes ❑ No ❑ N/A ❑
PC14.3	AP association procedure	11.3.2	CF1:M	Yes ❑ No ❑ N/A ❑
PC14.4	STA reassociation procedure	11.3.3	CF2:M	Yes ❑ No ❑ N/A ❑
PC14.5	AP reassociation procedure	11.3.4	CF1:M	Yes ❑ No ❑ N/A ❑
PC15	Management information base (MIB)	Annex D	M	Yes ❑ No ❑
PC15.1	dot11SMTbase, dot11SmtAuthenticationAlgorithms	Annex D	M	Yes ❑ No ❑
* PC15.2	dot11SMTprivacy	Annex D	PC2:M	Yes ❑ No ❑ N/A ❑
PC15.3	dot11MACbase, dot11CountersGroup, dot11MacGroupAddresses	Annex D	M	Yes ❑ No ❑

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A.4.4.1 MAC protocol capabilities *(continued)*

Item	Protocol capability	References	Status	Support
* PC15.4	dot11MACStatistics	Annex D	O	Yes ❑ No ❑
PC15.5	dot11ResourceTypeID	Annex D	M	Yes ❑ No ❑

A.4.4.2 MAC frames

Item	MAC frame	References	Status	Support
	Is transmission of the following MAC frames supported?	Clause 7, Annex C		
FT1	Association request	Clause 7	CF2:M	Yes ❑ No ❑ N/A ❑
FT2	Association response	Clause 7	CF1:M	Yes ❑ No ❑ N/A ❑
FT3	Reassociation request	Clause 7	CF2:M	Yes ❑ No ❑ N/A ❑
FT4	Reassociation response	Clause 7	CF1:M	Yes ❑ No ❑ N/A ❑
FT5	Probe request	Clause 7	CF2:M	Yes ❑ No ❑ N/A ❑
FT6	Probe response	Clause 7	M	Yes ❑ No ❑
FT7	Beacon	Clause 7	M	Yes ❑ No ❑
FT8	ATIM	Clause 7	CF2:M	Yes ❑ No ❑ N/A ❑
FT9	Disassociation	Clause 7	M	Yes ❑ No ❑
FT10	Authentication	Clause 7	M	Yes ❑ No ❑
FT11	Deauthentication	Clause 7	M	Yes ❑ No ❑
FT12	Power save (PS)-Poll	Clause 7	CF2:M	Yes ❑ No ❑ N/A ❑
FT13	RTS	Clause 7	M	Yes ❑ No ❑
FT14	CTS	Clause 7	M	Yes ❑ No ❑
FT15	Acknowledgment (ACK)	Clause 7	M	Yes ❑ No ❑
FT16	CF-End	Clause 7	PC4:M	Yes ❑ No ❑ N/A ❑
FT17	CF End+CF-Ack	Clause 7	PC4:M	Yes ❑ No ❑ N/A ❑
FT18	Data	Clause 7	M	Yes ❑ No ❑
FT19	Data + CF-Ack	Clause 7	(PC4 OR PC5):M	Yes ❑ No ❑ N/A ❑
FT20	Data + CF-Poll	Clause 7	PC4.3:M	Yes ❑ No ❑ N/A ❑
FT21	Data + CF-Ack+CF-Poll	Clause 7	PC4.3:M	Yes ❑ No ❑ N/A ❑
FT22	Null	Clause 7	M	Yes ❑ No ❑
FT23	CF-Ack (no data)	Clause 7	(PC4 OR PC5):M	Yes ❑ No ❑ N/A ❑
FT24	CF-Poll (no data)	Clause 7	PC4.3:M	Yes ❑ No ❑ N/A ❑
FT25	CF-Ack+CF-Poll (no data)	Clause 7	PC4.3:M	Yes ❑ No ❑ N/A ❑
	Is reception of the following MAC frames supported?	Clause 7, Annex C		
FR1	Association request	Clause 7	CF1:M	Yes ❑ No ❑ N/A ❑
FR2	Association response	Clause 7	CF2:M	Yes ❑ No ❑ N/A ❑
FR3	Reassociation request	Clause 7	CF1:M	Yes ❑ No ❑ N/A ❑
FR4	Reassociation response	Clause 7	CF2:M	Yes ❑ No ❑ N/A ❑

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A.4.4.2 MAC frames *(continued)*

Item	MAC frame	References	Status	Support
FR5	Probe request	Clause 7	M	Yes ❑ No ❑
FR6	Probe response	Clause 7	M	Yes ❑ No ❑
FR7	Beacon	Clause 7	M	Yes ❑ No ❑
FR8	ATIM	Clause 7	CF2:M	Yes ❑ No ❑ N/A ❑
FR9	Disassociation	Clause 7	M	Yes ❑ No ❑
FR10	Authentication	Clause 7	M	Yes ❑ No ❑
FR11	Deauthentication	Clause 7	M	Yes ❑ No ❑
FR12	PS-Poll	Clause 7	CF1:M	Yes ❑ No ❑ N/A ❑
FR13	RTS	Clause 7	M	Yes ❑ No ❑
FR14	CTS	Clause 7	M	Yes ❑ No ❑
FR15	ACK	Clause 7	M	Yes ❑ No ❑
FR16	CF-End	Clause 7	M	Yes ❑ No ❑
FR17	CF End+CF-Ack	Clause 7	M	Yes ❑ No ❑
FR18	Data	Clause 7	M	Yes ❑ No ❑
FR19	Data + CF-Ack	Clause 7	M	Yes ❑ No ❑
FR20	Data + CF-Poll	Clause 7	PC5:M	Yes ❑ No ❑ N/A ❑
FR21	Data + CF-Ack+CF-Poll	Clause 7	PC5:M	Yes ❑ No ❑ N/A ❑
FR22	Null	Clause 7	M	Yes ❑ No ❑
FR23	CF-Ack (no data)	Clause 7	(PC4 OR PC5):M	Yes ❑ No ❑ N/A ❑
FR24	CF-Poll (no data)	Clause 7	PC5:M	Yes ❑ No ❑ N/A ❑
FR25	CF-Ack+CF-Poll (no data)	Clause 7	PC5:M	Yes ❑ No ❑ N/A ❑

A.4.4.3 Frame exchange sequences

Item	Frame exchange sequence	References	Status	Support
	Are the following frame sequences supported?			
FS1	Basic frame sequences	9.7, Annex C	M	Yes ❑ No ❑
FS2	CF-Frame sequences	9.7, Annex C	(PC4 OR PC5):M	Yes ❑ No ❑ N/A ❑

A.4.4.4 MAC addressing functions

Item	MAC Address function	References	Status	Support
	Are the following MAC Addressing functions supported?			
AD1	STA universal individual IEEE 802 address	5.3.3, 7.1.3.3	M	Yes ❑ No ❑

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A.4.4.4 MAC addressing functions

Item	MAC Address function	References	Status	Support
AD2	BSS identification (BSSID) generation	7.1.3.3, 11.1.3, Annex C	M	Yes ❑ No ❑
AD3	Receive address matching	7.1.3.3, 7.2.2, Annex C	M	Yes ❑ No ❑ N/A ❑

A.4.5 Frequency hopping (FH) PHY functions

Item	Protocol feature	References	Status	Support
	Which requirements and options does the PHY support?			
FH1	PHY service primitive parameters			
FH1.1	TXVECTOR parameter: LENGTH	14.2.2.1	M	Yes ❑ No ❑
FH1.2	TXVECTOR parameter: PLCPBITRATE	14.2.2.2	M	Yes ❑ No ❑
FH1.2.1	PLCPBITRATE = X'00' (1.0 Mbit/s)	14.2.2.2	M	Yes ❑ No ❑
* FH1.2.2	PLCPBITRATE = X'02' (2.0 Mbit/s)	14.2.2.2	O	Yes ❑ No ❑
FH1.3	RXVECTOR parameter: LENGTH	14.2.3.1	M	Yes ❑ No ❑
FH1.4	RXVECTOR parameter: Receive signal strength indicator (RSSI)	14.2.3.2	O	Yes ❑ No ❑
FH2	Physical layer convergence procedure (PLCP) frame format			
FH2.1	PLCP Preamble: Sync	14.3.2.1.1	M	Yes ❑ No ❑
FH2.2	PLCP Preamble: Start frame delimiter (SFD)	14.3.2.1.2	M	Yes ❑ No ❑
FH2.3	PLCP Header: PSDU length word (PLW)	14.3.2.2.1	M	Yes ❑ No ❑
FH2.4	PLCP Header: PLCP Signaling field (PSF)	14.3.2.2.2	M	Yes ❑ No ❑
FH2.5	PLCP Header: Header error check (HEC)	14.3.2.2.3	M	Yes ❑ No ❑
FH2.6	PLCP Data Whitener: Scrambling and bias suppression encoding	14.3.2.3, 14.3.3.1.1	M	Yes ❑ No ❑
FH3	Transmit PLCP			
FH3.1	Transmit: transmit on MAC request	14.3.3.1.1	M	Yes ❑ No ❑
FH3.2	Transmit: format and whiten frame	14.3.3.1.1	M	Yes ❑ No ❑
FH3.3	Transmit: Timing	14.3.3.1.1	M	Yes ❑ No ❑
FH4	Carrier sense (CS)/clear channel assessment (CCA) procedure			
FH4.1	CS/CCA: perform on a minimum of one antenna	14.3.3.2.1	M	Yes ❑ No ❑
FH4.2.	CS/CCA: Detect preamble starting up to 20 μs after start of slot time	14.3.3.2.1	M	Yes ❑ No ❑
FH4.3	CS/CCA: Detect preamble starting at least 16 μs prior to end of slot time	14.3.3.2.1	M	Yes ❑ No ❑
FH4.4	CS/CCA: Detect random data	14.3.3.2.1	M	Yes ❑ No ❑

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A.4.5 Frequency hopping (FH) PHY functions *(continued)*

Item	Protocol feature	References	Status	Support
FH4.5	CS/CCA: Perform on antenna with essentially same gain and pattern as transmit antenna	14.3.3.2.1	M	Yes ❑ No ❑
FH4.6	CS/CCA: Detect valid SFD and PLCP header	14.3.3.2.1	M	Yes ❑ No ❑
FH4.7	CS/CCA: Maintain BUSY indication until end of length contained in valid PLCP header	14.3.3.2.1	M	Yes ❑ No ❑
FH5	Receive PLCP			
FH5.1	Receive: Receive and dewhiten frame	14.3.3.3.1	M	Yes ❑ No ❑
FH6	Physical layer management entity (PLME)			
FH6.1	PLME: Support FH sync	14.4.2.2	M	Yes ❑ No ❑
FH6.2	PLME: Support PLME primitives	14.4.3.2	O	Yes ❑ No ❑
FH7	Geographic area specific requirements			
* FH7.1	Geographic areas			
FH7.1.1	North America	14.6.2	O.1	Yes ❑ No ❑
FH7.1.2	Most of Europe	14.6.2	O.1	Yes ❑ No ❑
FH7.1.3	Japan	14.6.2	O.1	Yes ❑ No ❑
FH7.1.4	Spain	14.6.2	O.1	Yes ❑ No ❑
FH7.1.5	France	14.6.2	O.1	Yes ❑ No ❑
FH7.2	Operating frequency range	14.6.3	FH7.1:M	Yes ❑ No ❑
FH7.3	Number of operating channels	14.6.4	FH7.1:M	Yes ❑ No ❑
FH7.4	Operating channel frequencies	14.6.5	FH7.1:M	Yes ❑ No ❑
FH7.5	Occupied channel bandwidth	14.6.6	FH7.1:M	Yes ❑ No ❑
FH7.6	Minimum hop rate	14.6.7	FH7.1:M	Yes ❑ No ❑
FH7.7	Hop sequences	14.6.8	FH7.1:M	Yes ❑ No ❑
FH7.8	Unwanted emissions	14.6.9	FH7.1:M	Yes ❑ No ❑
FH8	1 Mbit/s physical medium dependent (PMD)			
FH8.1	Modulation 2GFSK, bit time (BT) = 0.5, 1 = positive frequency deviation, 0 = negative frequency deviation	14.6.10	M	Yes ❑ No ❑
FH8.2	Peak frequency deviation	14.6.10	M	Yes ❑ No ❑
FH8.3	Zero-Crossing error	14.6.10	M	Yes ❑ No ❑
FH8.4	Nominal channel data rate	14.6.11	M	Yes ❑ No ❑
FH8.5	Channel switching/settling time	14.6.12	M	Yes ❑ No ❑
FH8.6	Receive to transmit switch time	14.6.13	M	Yes ❑ No ❑
FH8.7	Nominal transmit power	14.6.14.1	M	Yes ❑ No ❑
FH8.8	Transmit power levels	14.6.14.2	M	Yes ❑ No ❑
FH8.9	Transmit power level control to < 100 mW	14.6.14.3	M	Yes ❑ No ❑
FH8.10	Transmit spectrum shape	14.6.14.4	M	Yes ❑ No ❑
FH8.11	Transmit center frequency tolerance	14.6.14.5	M	Yes ❑ No ❑

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A.4.5 Frequency hopping (FH) PHY functions *(continued)*

Item	Protocol feature	References	Status	Support
FH8.12	Transmitter ramp periods	14.6.14.6	M	Yes ❑ No ❑
FH8.13	Receiver input dynamic range	14.6.15.1	M	Yes ❑ No ❑
FH8.14	Receiver center frequency acceptance range	14.6.15.2	M	Yes ❑ No ❑
FH8.15	CCA power threshold for a probability of detection of 90% (preamble)/70% (random data) for 100 mW units	14.6.15.3	M	Yes ❑ No ❑
FH8.16	CCA power threshold for units > 100 mW; sensitivity threshold is 1/2 dB lower for every dB above 20 dBm	14.6.15.3	M	Yes ❑ No ❑
FH8.17	Minimum receiver sensitivity at frame error ratio (FER) = 3% with 400 octet frames	14.6.15.4	M	Yes ❑ No ❑
FH8.18	Intermodulation protection (IMp)	14.6.15.5	M	Yes ❑ No ❑
FH8.19	Desensitization (Dp)	14.6.15.6	M	Yes ❑ No ❑
FH8.20	Operating temperature range	14.6.16	M	Yes ❑ No ❑
FH8.20.1	Temperature type 1	14.6.16	O	Yes ❑ No ❑
FH8.20.2	Temperature type 2	14.6.16	O	Yes ❑ No ❑
FH8.20.3	Temperature type 3	14.6.16	O	Yes ❑ No ❑
FH9	2 Mbit/s PMD			
FH9.1	All 1M PMD requirements	14.7.1	FH1.2.2:M	Yes ❑ No ❑ N/A ❑
FH9.2	Modulation 4GFSK, BT = 0.5	14.7.2	FH1.2.2:M	Yes ❑ No ❑ N/A ❑
FH9.3	Frame structure for 2M PHY	14.7.2.1	FH1.2.2:M	Yes ❑ No ❑ N/A ❑
FH9.4	Nominal channel data rate	14.7.3	FH1.2.2:M	Yes ❑ No ❑ N/A ❑
FH9.5	Input dynamic range	14.7.4	FH1.2.2:M	Yes ❑ No ❑ N/A ❑
FH9.6	Minimum receiver sensitivity at FER = 3% with 400 octet frames	14.7.5	FH1.2.2:M	Yes ❑ No ❑ N/A ❑
FH9.7	IMp	14.7.6	FH1.2.2:M	Yes ❑ No ❑ N/A ❑
FH9.8	Dp	14.7.7	FH1.2.2:M	Yes ❑ No ❑ N/A ❑
FH10	MIB	13.1, 14.8, Annex D	M	Yes ❑ No ❑
FH10.1	dot11PhyFHSSComplianceGroup, dot11PhyRegDomainsSupportGroup, and dot11PhyOperationComplianceGroup	13.1,14.8	M	Yes ❑ No ❑

A.4.6 Direct sequence PHY functions

Item	PHY feature	References	Status	Support
	PLCP sublayer procedures	15.2		
DS1	Preamble prepend on transmit (TX)	15.2.1	M	Yes ❑ No ❑
DS1.1	PLCP frame format	15.2.2, 15.2.3	M	Yes ❑ No ❑
DS1.2	PLCP integrity check generation	15.2.3, 15.2.3.6	M	Yes ❑ No ❑
DS1.3	TX rate change capability	15.2.3.3, 15.2.5	M	Yes ❑ No ❑

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A.4.6 Direct sequence PHY functions *(continued)*

Item	PHY feature	References	Status	Support
DS1.4	Supported data rates	15.1, 15.2.3.3	M	Yes ❑ No ❑
DS1.5	Data whitener scrambler	15.2.4	M	Yes ❑ No ❑
DS1.6	Scrambler initialization	15.2.4	M	Yes ❑ No ❑
DS2	Preamble process on receive (RX)	15.2.1		
DS2.1	PLCP frame format	15.2.2, 15.2.3	M	Yes ❑ No ❑
DS2.2	PLCP integrity check verify	15.2.3, 15.2.3.6	M	Yes ❑ No ❑
DS2.3	RX Rate change capability	15.2.3.3, 15.2.5	M	Yes ❑ No ❑
DS2.4	Data whitener descrambler	15.2.4	M	Yes ❑ No ❑
DS3	Pseudonoise (PN) code sequence	15.4.6.3	M	Yes ❑ No ❑
DS4	Chipping continue on power-down	15.2.6	O	Yes ❑ No ❑
*DS5	Operating channel capability	15.2.6, 15.4.6.2		
* DS5.1	North America (FCC)	15.2.6, 15.4.6.2	DS5:O.1	Yes ❑ No ❑ N/A ❑
DS5.1.1	Channel 1	15.2.6, 15.4.6.2	DS5.1:M	Yes ❑ No ❑ N/A ❑
DS5.1.2	Channel 2	15.2.6, 15.4.6.2	DS5.1:M	Yes ❑ No ❑ N/A ❑
DS5.1.3	Channel 3	15.2.6, 15.4.6.2	DS5.1:M	Yes ❑ No ❑ N/A ❑
DS5.1.4	Channel 4	15.2.6, 15.4.6.2	DS5.1:M	Yes ❑ No ❑ N/A ❑
DS5.1.5	Channel 5	15.2.6, 15.4.6.2	DS5.1:M	Yes ❑ No ❑ N/A ❑
DS5.1.6	Channel 6	15.2.6, 15.4.6.2	DS5.1:M	Yes ❑ No ❑ N/A ❑
DS5.1.7	Channel 7	15.2.6, 15.4.6.2	DS5.1:M	Yes ❑ No ❑ N/A ❑
DS5.1.8	Channel 8	15.2.6, 15.4.6.2	DS5.1:M	Yes ❑ No ❑ N/A ❑
DS5.1.9	Channel 9	15.2.6, 15.4.6.2	DS5.1:M	Yes ❑ No ❑ N/A ❑
DS5.1.10	Channel 10	15.2.6, 15.4.6.2	DS5.1:M	Yes ❑ No ❑ N/A ❑
DS5.1.11	Channel 11	15.2.6, 15.4.6.2	DS5.1:M	Yes ❑ No ❑ N/A ❑
* DS5.2	Canada (IC)	15.2.6, 15.4.6.2	DS5:O.1	Yes ❑ No ❑ N/A ❑
DS5.2.1	Channel 1	15.2.6, 15.4.6.2	DS5.2:M	Yes ❑ No ❑ N/A ❑
DS5.2.2	Channel 2	15.2.6, 15.4.6.2	DS5.2:M	Yes ❑ No ❑ N/A ❑
DS5.2.3	Channel 3	15.2.6, 15.4.6.2	DS5.2:M	Yes ❑ No ❑ N/A ❑
DS5.2.4	Channel 4	15.2.6, 15.4.6.2	DS5.2:M	Yes ❑ No ❑ N/A ❑
DS5.2.5	Channel 5	15.2.6, 15.4.6.2	DS5.2:M	Yes ❑ No ❑ N/A ❑
DS5.2.6	Channel 6	15.2.6, 15.4.6.2	DS5.2:M	Yes ❑ No ❑ N/A ❑
DS5.2.7	Channel 7	15.2.6, 15.4.6.2	DS5.2:M	Yes ❑ No ❑ N/A ❑
DS5.2.8	Channel 8	15.2.6, 15.4.6.2	DS5.2:M	Yes ❑ No ❑ N/A ❑
DS5.2.9	Channel 9	15.2.6, 15.4.6.2	DS5.2:M	Yes ❑ No ❑ N/A ❑
DS5.2.10	Channel 10	15.2.6, 15.4.6.2	DS5.2:M	Yes ❑ No ❑ N/A ❑
DS5.2.11	Channel 11	15.2.6, 15.4.6.2	DS5.2:M	Yes ❑ No ❑ N/A ❑
* DS5.3	Europe (ETSI)	15.2.6, 15.4.6.2	DS5:O.1	Yes ❑ No ❑ N/A ❑
DS5.3.1	Channel 1	15.2.6, 15.4.6.2	DS5.3:M	Yes ❑ No ❑ N/A ❑
DS5.3.2	Channel 2	15.2.6, 15.4.6.2	DS5.3:M	Yes ❑ No ❑ N/A ❑
DS5.3.3	Channel 3	15.2.6, 15.4.6.2	DS5.3:M	Yes ❑ No ❑ N/A ❑
DS5.3.4	Channel 4	15.2.6, 15.4.6.2	DS5.3:M	Yes ❑ No ❑ N/A ❑

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A.4.6 Direct sequence PHY functions *(continued)*

Item	PHY feature	References	Status	Support
DS5.3.5	Channel 5	15.2.6, 15.4.6.2	DS5.3:M	Yes ❑ No ❑ N/A ❑
DS5.3.6	Channel 6	15.2.6, 15.4.6.2	DS5.3:M	Yes ❑ No ❑ N/A ❑
DS5.3.7	Channel 7	15.2.6, 15.4.6.2	DS5.3:M	Yes ❑ No ❑ N/A ❑
DS5.3.8	Channel 8	15.2.6, 15.4.6.2	DS5.3:M	Yes ❑ No ❑ N/A ❑
DS5.3.9	Channel 9	15.2.6, 15.4.6.2	DS5.3:M	Yes ❑ No ❑ N/A ❑
DS5.3.10	Channel 10	15.2.6, 15.4.6.2	DS5.3:M	Yes ❑ No ❑ N/A ❑
DS5.3.11	Channel 11	15.2.6, 15.4.6.2	DS5.3:M	Yes ❑ No ❑ N/A ❑
DS5.3.12	Channel 12	15.2.6, 15.4.6.2	DS5.3:M	Yes ❑ No ❑ N/A ❑
DS5.3.13	Channel 13	15.2.6, 15.4.6.2	DS5.3:M	Yes ❑ No ❑ N/A ❑
* DS5.4	France	15.2.6, 15.4.6.2	DS5:O.1	Yes ❑ No ❑ N/A ❑
DS5.4.1	Channel 10	15.2.6, 15.4.6.2	DS5.4:M	Yes ❑ No ❑ N/A ❑
DS5.4.2	Channel 11	15.2.6, 15.4.6.2	DS5.4:M	Yes ❑ No ❑ N/A ❑
DS5.4.3	Channel 12	15.2.6, 15.4.6.2	DS5.4:M	Yes ❑ No ❑ N/A ❑
DS5.4.4	Channel 13	15.2.6, 15.4.6.2	DS5.4:M	Yes ❑ No ❑ N/A ❑
* DS5.5	Spain	15.2.6, 15.4.6.2	DS5:O.1	Yes ❑ No ❑ N/A ❑
DS5.5.1	Channel 10	15.2.6, 15.4.6.2	DS5.5:M	Yes ❑ No ❑ N/A ❑
DS5.5.2	Channel 11	15.2.6, 15.4.6.2	DS5.5:M	Yes ❑ No ❑ N/A ❑
* DS5.6	Japan	15.2.6, 15.4.6.2	DS5:O.1	Yes ❑ No ❑ N/A ❑
DS6	Bits to symbol mapping	15.4.6.4		
DS6.1	1 Mbit/s	15.4.6.4	M	Yes ❑ No ❑
DS6.2	2 Mbit/s	15.4.6.4	M	Yes ❑ No ❑
*DS7	CCA functionality	15.4.8.4		
DS7.1	Energy Only (RSSI above threshold)	15.4.8.4	DS7:O.2	Yes ❑ No ❑
DS7.2	IEEE 802.11 DSSS correlation	15.4.8.4	DS7:O.2	Yes ❑ No ❑
DS7.3	Both methods	15.4.8.4	DS7:O.2	Yes ❑ No ❑
DS7.4	Hold CCA busy for packet duration of a correctly received PLCP but carrier lost during reception of MPDU	15.2.7	M	Yes ❑ No ❑
DS7.5	Hold CCA busy for packet duration of a correctly received but out of specification PLCP	15.2.7	M	Yes ❑ No ❑
DS8	Transmit antenna selection	15.4.5.5, 15.4.5.6	O	Yes ❑ No ❑
DS9	Receive antenna diversity	15.4.5.5, 15.4.5.6, 15.4.5.7	O	Yes ❑ No ❑
*DS10	Antenna port(s) availability	15.4.6.9	O	Yes ❑ No ❑
DS10.1	50 ¾ impedance	15.4.6.9	DS10:M	Yes ❑ No ❑ N/A ❑
*DS11	Transmit power level support	15.4.5.8, 15.4.7.3	O	Yes ❑ No ❑
DS11.1	If greater than 100 mW capability	15.4.7.3	DS11:M	Yes ❑ No ❑ N/A ❑

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A.4.6 Direct sequence PHY functions *(continued)*

Item	PHY feature	References	Status	Support
*DS12	Radio type (temperature range)	15.4.6.10		
DS12.1	Type 1	15.4.6.10	DS12:O.3	Yes ❑ No ❑ N/A ❑
DS12.2	Type 2	15.4.6.10	DS12:O.3	Yes ❑ No ❑ N/A ❑
DS13	Spurious emissions conformance	15.4.6.5	M	Yes ❑ No ❑
DS14	TX-to-RX turnaround time	15.4.6.6	M	Yes ❑ No ❑
DS15	RX-to-TX turnaround time	15.4.6.7	M	Yes ❑ No ❑
DS16	Slot time	15.4.6.8	M	Yes ❑ No ❑
DS17	Energy detection (ED) reporting time	15.4.6.8, 15.4.8.4	M	Yes ❑ No ❑
DS18	Minimum transmit power level	15.4.7.2	M	Yes ❑ No ❑
DS19	Transmit spectral mask conformance	15.4.7.4	M	Yes ❑ No ❑
DS20	Transmitted center frequency tolerance	15.4.7.5	M	Yes ❑ No ❑
DS21	Chip clock frequency tolerance	15.4.7.6	M	Yes ❑ No ❑
DS22	Transmit power-on ramp	15.4.7.7	M	Yes ❑ No ❑
DS23	Transmit power-down ramp	15.4.7.7	M	Yes ❑ No ❑
DS24	Radio frequency (RF) carrier suppression	15.4.7.8	M	Yes ❑ No ❑
DS25	Transmit modulation accuracy	15.4.7.9	M	Yes ❑ No ❑
DS26	Receiver minimum input level sensitivity	15.4.8.1	M	Yes ❑ No ❑
DS27	Receiver maximum input level	15.4.8.2	M	Yes ❑ No ❑
DS28	Receiver adjacent channel rejection	15.4.8.3	M	Yes ❑ No ❑
DS29	MIB	13.1, 15.3.2, Annex D	M	Yes ❑ No ❑
DS29.1	dot11PhyDSSSComplianceGroup, dot11PhyRegDomainsSupportGroup, and dot11PhyOperationComplianceGroup	13.1, 15.3.2	M	Yes ❑ No ❑

A.4.7 IR baseband PHY functions

Item	Feature	References	Status	Support
IR1	Is the transmitted synchronization (SYNC) field length in the range of required number of pulse position modulation (PPM) slots, with the absence of a pulse in the last slot of the field?	16.2.4.1	M	Yes ❑
IR2	Is the transmitted SYNC field entirely populated by alternating presence and absence of pulses in consecutive PPM slots, with the absence of a pulse in the last slot of the field?	16.2.4.1	M	Yes ❑

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A.4.7 IR baseband PHY functions *(continued)*

Item	Feature	References	Status	Support
IR3	Is the transmitted SFD field the binary sequence 1001, where 1 indicates a pulse in the PPM slot and 0 indicates no pulse in the PPM slot?	16.2.4.2	M	Yes ❑
IR4	Is the transmitted data rate (DR) field pulse sequence equal to the correct value for the data rate provided by the TXVECTOR parameter PLCP BITRATE, where 1 indicates a pulse in the PPM slot and 0 indicates no pulse in the PPM slot?	16.2.4.3	M	Yes ❑
IR5	Is the transmitted dc level adjustment (DCLA) field 32 PPM slots long with the specified sequence for 1 Mbit/s, where 1 indicates a pulse in the PPM slot and 0 indicates no pulse in the PPM slot? 1 Mbit/s: 00000000100000000000000010000000	16.2.4.4	M	Yes ❑
* IR5a	Does the unit support 2 Mbit/s transmission?	16.2.4.4	O	Yes ❑ No ❑
IR5b	If the unit supports 2 Mbit/s transmission, is the transmitted DCLA field 32 PPM slots long with the specified sequence for 2 Mbit/s, where 1 indicates a pulse in the PPM slot and 0 indicates no pulse in the PPM slot? 2 Mbit/s: 00100010001000100010001000100010	16.2.4.4	IR5a:M	Yes ❑ No ❑ N/A ❑
IR6	Is the transmitted LENGTH field the correct PPM representation of the unsigned 16-bit binary integer, least significant bit (LSB) transmitted first, equal to the correct value provided by the TXVECTOR parameter LENGTH?	16.2.4.5	M	Yes ❑
IR7	Is the transmitted cyclic redundancy code (CRC) field the correct PPM representation of the CRC value calculated as per reference subclause, transmitted LSB first?	16.2.4.6	M	Yes ❑
IR8	Is the transmitted PLCP service data unit (PSDU) field the correct PPM representation of the PSDU, transmitted LSB first?	16.2.4.7	M	Yes ❑
IR9	When the CCA is false does transmission begin based on PHYTXSTART.request?	16.2.5.1	M	Yes ❑
IR10	Does the PHY issue a PHYTXSTART.confirm after the transmission of the PLCP header?	16.2.5.1	M	Yes ❑
IR11	Does the PHY accept each octet of the PSDU in a PHYDATA.request and answer with a PHYDATA.confirm?	16.2.5.1	M	Yes ❑
IR12	Does the PHY cease transmission in response to a PHYTXEND.request and answer with a PHYTXEND.confirm?	16.2.5.1	M	Yes ❑
IR13	Does the PHY of a receiving STA send a PHY-CCA.indicate during reception of the SYNC field?	16.2.5.2	M	Yes ❑

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A.4.7 IR baseband PHY functions *(continued)*

Item	Feature	References	Status	Support
IR14	Does the PHY of a receiving STA properly receive a transmission that changes data rate according to the DR field?	16.2.5.2	M	Yes ❑
IR15	Does the PHY of a receiving STA properly reject an incorrect CRC?	16.2.5.2	M	Yes ❑
IR16	Does the PHY of a receiving STA properly reject a DR field other than those specified in reference subclause?	16.2.5.2, 16.2.4.3	M	Yes ❑
IR17	Does the PHY of a receiving STA send PHYRXSTART.indicate with correct RATE and LENGTH parameters after proper reception of PLCP preamble and PLCP header?	16.2.5.2	M	Yes ❑
IR18	Does the PHY of a receiving STA forward receive octets in PHYDATA.indicate primitives?	16.2.5.2	M	Yes ❑
IR19	Does the PHY of a receiving STA send a PHYRXEND.indicate after the final octet indicated by the LENGTH field?	16.2.5.2	M	Yes ❑
IR20	Does the PHY of a receiving STA send a PHY-CCA.indicate with a state value of IDLE after the PHYRXEND.indicate?	16.2.5.2	M	Yes ❑
IR21	Does the PHY reset its CCA detection mechanism upon receiving a PHYC-CARST.request, and respond with a PHYCCARST.indicate?	16.2.5.3	M	Yes ❑
IR22	When transmitting at 1 Mbit/s does the PHY transmit PPM symbols according to the 16-PPM Basic Rate Mapping table, transmitting from left to right?	16.3.2.1, 16.3.2.2	M	Yes ❑
IR23	When transmitting at 2 Mbit/s does the PHY transmit PPM symbols according to the 4-PPM Enhanced Rate Mapping table, transmitting from left to right?	16.3.2.1, 16.3.2.2	IR5a:M	Yes ❑
IR24	Does the PHY operate over a temperature range of 0 °C to 40 °C?	16.3.2.4	M	Yes ❑
* IR25	If the unit is conformant to emitter radiation mask 1, is the peak optical power of an emitted pulse within the specification range averaged over the pulse width?	16.3.3.1	O.1	Yes ❑ No ❑ N/A ❑
* IR26	If the unit is conformant to emitter radiation mask 2, is the peak optical power of an emitted pulse within the specification range averaged over the pulse width?	16.3.3.1	O.1	Yes ❑ No ❑ N/A ❑
IR27	Does the transmitted pulse shape conform to the description of the reference subclause?	16.3.3.2	M	Yes ❑
IR28	Does the emitter radiation pattern as a function of angle conform to the requirements of the reference subclause as applicable based on conformance to emitter radiation mask 1?	16.3.3.3	IR25:M	Yes ❑ No ❑ N/A ❑

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A.4.7 IR baseband PHY functions *(continued)*

Item	Feature	References	Status	Support
IR28a	Does the emitter radiation pattern as a function of angle conform to the requirements of the reference subclause as applicable based on conformance to emitter radiation mask 2?	16.3.3.3	IR26:M	Yes ❑ No ❑ N/A ❑
IR29	Is the peak emitter optical output as a function of wavelength in the range specified?	16.3.3.4	M	Yes ❑
IR30	Does the spectrum of the transmit signal amplitude as a voltage or current meet the requirements of the reference subclause?	16.3.3.5	M	Yes ❑
IR31	Does the receiver sensitivity meet the requirements of the reference subclause for receive signals of both 1 Mbit/s and 2 Mbit/s?	16.3.4.1	M	Yes ❑
IR32	Does the receiver exhibit a dynamic range as specified in reference subclause?	16.3.4.2	M	Yes ❑
IR33	Does the receiver field of view (FOV) conform to the requirements of the reference subclause?	16.3.4.3	M	Yes ❑
IR34	When it is known that the conditions are such that the Carrier Detect Signal and the Energy Detect Signal are false is the CCA asserted IDLE?	16.3.5.1	M	Yes ❑
IR35	When the conditions are such that Energy Detect is true for greater than the time defined in reference subclause, does CCA become IDLE?	16.3.5.1	M	Yes ❑
IR36	When conditions are such that either Carrier Detect or Energy Detect go true, does CCA go BUSY?	16.3.5.1	M	Yes ❑
IR37	Are these compliance groups implemented? dot11PhyIRComplianceGroup, dot11PhyRegDomainsSupportGroup, and dot11PhyOperationComplianceGroup	16.4	M	Yes ❑

A.4.8 OFDM PHY functions

Item	Feature	References	Status	Support
OF1: OFDM PHY Specific Service Parameters				
OF1.1	TXVECTOR parameter: LENGTH	17.2.2.1	M	Yes ❑ No ❑
OF1.2	TXVECTOR parameter: DATARATE	17.2.2.2	M	Yes ❑ No ❑
OF1.2.1	DATARATE = 6.0 Mbit/s	17.2.2.2	M	Yes ❑ No ❑
*OF1.2.2	DATARATE = 9.0 Mbit/s	17.2.2.2	O	Yes ❑ No ❑
OF1.2.3	DATARATE = 12.0 Mbit/s	17.2.2.2	M	Yes ❑ No ❑
*OF1.2.4	DATARATE = 18.0 Mbit/s	17.2.2.2	O	Yes ❑ No ❑
OF1.2.5	DATARATE = 24.0 Mbit/s	17.2.2.2	M	Yes ❑ No ❑
*OF1.2.6	DATARATE = 36.0 Mbit/s	17.2.2.2	O	Yes ❑ No ❑
*OF1.2.7	DATARATE = 48.0 Mbit/s	17.2.2.2	O	Yes ❑ No ❑

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A.4.8 OFDM PHY functions *(continued)*

Item	Feature	References	Status	Support
*OF1.2.8	DATARATE = 54.0 Mbit/s	17.2.2.2	O	Yes ❑ No ❑
OF1.3	TXVECTOR parameter: SERVICE	17.2.2.3	M	Yes ❑ No ❑
OF1.4	TXVECTOR parameter: TXPWR_LEVEL	17.2.2.4	M	Yes ❑ No ❑
OF1.5	RXVECTOR parameter: LENGTH	17.2.3.1	M	Yes ❑ No ❑
OF1.6	RXVECTOR parameter: RSSI	17.2.3.2	M	Yes ❑ No ❑
OF2: OFDM PLCP Sublayer				
OF2.1	RATE-dependent parameters	17.3.2.2	M	Yes ❑ No ❑
OF2.2	Timing related parameters	17.3.2.3	M	Yes ❑ No ❑
OF2.3	PLCP Preamble: SYNC	17.3.3	M	Yes ❑ No ❑
OF2.4	PLCP header: SIGNAL	17.3.4	M	Yes ❑ No ❑
OF2.5	PLCP header: LENGTH	17.3.4.1	M	Yes ❑ No ❑
OF2.6	PLCP header: RATE	17.3.4.2	M	Yes ❑ No ❑
OF2.7	PLCP header: parity, reserve	17.3.4.3	M	Yes ❑ No ❑
OF2.8	PLCP header: SIGNAL TAIL	17.3.4.3	M	Yes ❑ No ❑
OF2.9	PLCP header: SERVICE	17.3.5.1	M	Yes ❑ No ❑
OF2.10	PLCP protocol data unit (PPDU): TAIL	17.3.5.2	M	Yes ❑ No ❑
OF2.11	PPDU: PAD	17.3.5.3	M	Yes ❑ No ❑
OF2.12	PLCP/OFDM PHY data scrambler and descrambler	17.3.5.4	M	Yes ❑ No ❑
OF2.13	Convolutional encoder	17.3.5.5	M	Yes ❑ No ❑
OF2.13.1	Rate R = 1/2	17.3.5.5	M	Yes ❑ No ❑
OF2.13.2	Punctured coding R = 2/3	17.3.5.5	OF1.2.7:M	Yes ❑ No ❑ N/A ❑
OF2.13.3	Punctured coding R = 3/4	17.3.5.5	OF1.2.2 OR OF1.2.4 OR OF1.2.6 OR OF1.2.8:M	Yes ❑ No ❑ N/A ❑
OF2.14	Data interleaving	17.3.5.6	M	Yes ❑ No ❑
OF2.15	Subcarrier modulation mapping	17.3.5.7	M	Yes ❑ No ❑
OF2.15.1	Binary phase shift keying (BPSK)	17.3.5.7	M	Yes ❑ No ❑
OF2.15.2	Quadrature phase shift keying (QPSK)	17.3.5.7	M	Yes ❑ No ❑
OF2.15.3	16-quadrature amplitude modulation (QAM)	17.3.5.7	M	Yes ❑ No ❑
OF2.15.4	64-QAM	17.3.5.7	OF1.2.7 OR OF1.2.8:M	Yes ❑ No ❑ N/A ❑
OF2.16	Pilot subcarriers	17.3.5.8	M	Yes ❑ No ❑
OF2.17	OFDM modulation	17.3.5.9	M	Yes ❑ No ❑
OF2.18	Packet duration calculation	17.3.5.10	M	Yes ❑ No ❑

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A.4.8 OFDM PHY functions *(continued)*

Item	Feature	References	Status	Support
OF2.19	CCA			
OF2.19.1	CCA: RSSI	17.3.6	M	Yes ❑ No ❑
OF2.19.2	CCA: indication to MAC sublayer	17.3.6	M	Yes ❑ No ❑
OF2.20	PLCP data modulation and modulation rate change	17.3.7	M	Yes ❑ No ❑
OF3: PDM Operating Specification General				
OF3.1	Occupied channel bandwidth	17.3.8.1	M	Yes ❑ No ❑
OF3.2	Operating frequency range	17.3.8.2	M	Yes ❑ No ❑
OF3.3	Channelization	17.3.8.3	M	Yes ❑ No ❑
*OF3.3.1	Lower unlicensed national information infrastructure (U-NII) subband (5.15–5.25 GHz)	17.3.8.3	O.1	Yes ❑ No ❑
*OF3.3.2	Middle U-NII subband (5.25–5.35 GHz)	17.3.8.3	O.1	Yes ❑ No ❑
*OF3.3.3	Upper U-NII subband (5.725–5.825 GHz)	17.3.8.3	O.1	Yes ❑ No ❑
OF3.4	Number of operating channels	17.3.8.3	M	Yes ❑ No ❑
OF3.5	Operating channel frequencies	17.3.8.3	M	Yes ❑ No ❑
OF3.6	Transmit and receive in band and out of band spurious emission	17.3.8.4	M	Yes ❑ No ❑
OF3.7	TX RF delay	17.3.8.5	M	Yes ❑ No ❑
OF3.8	Slot time	17.3.8.6	M	Yes ❑ No ❑
OF3.9	Transmit and receive antenna port impedance	17.3.8.7	M	Yes ❑ No ❑
OF3.10	Transmit and receive operating temperature range	17.3.8.8	M	Yes ❑ No ❑
OF3.10.1	Type 1 (0 °C to 40 °C)	17.3.8.8	M	Yes ❑ No ❑
OF3.10.2	Type 2 (–20 °C to 50 °C)	17.3.8.8	O	Yes ❑ No ❑
OF3.10.3	Type 3 (–30 °C to 70 °C)	17.3.8.8	O	Yes ❑ No ❑
OF4: PMD Transmit Specification				
OF4.1	Transmit power levels		M	Yes ❑ No ❑
OF4.1.1	Power level (5.15–5.25 GHz)	17.3.9.1	OF3.3.1:M	Yes ❑ No ❑ N/A ❑
OF4.1.2	Power level (5.25–5.35 GHz)	17.3.9.1	OF3.3.2:M	Yes ❑ No ❑ N/A ❑
OF4.1.3	Power level (5.725–5.825 GHz)	17.3.9.1	OF3.3.3:M	Yes ❑ No ❑ N/A ❑
OF4.2	Spectrum mask	17.3.9.2	M	Yes ❑ No ❑
OF4.3	Spurious	17.3.9.3	M	Yes ❑ No ❑
OF4.4	Center frequency tolerance	17.3.9.4	M	Yes ❑ No ❑
OF4.5	Clock frequency tolerance	17.3.9.5	M	Yes ❑ No ❑
OF4.6	Modulation accuracy			Yes ❑ No ❑
OF4.6.1	Center frequency leakage	17.3.9.6.1	M	Yes ❑ No ❑
OF4.6.2	Spectral flatness	17.3.9.6.2	M	Yes ❑ No ❑
OF4.6.3	Transmitter constellation error < –5 dB	17.3.9.6.3	M	Yes ❑ No ❑
OF4.6.4	Transmitter constellation error < –8 dB	17.3.9.6.3	OF1.2.2:M	Yes ❑ No ❑ N/A ❑

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A.4.8 OFDM PHY functions *(continued)*

Item	Feature	References	Status	Support
OF4.6.5	Transmitter constellation error < –10 dB	17.3.9.6.3	M	Yes ❑ No ❑
OF4.6.6	Transmitter constellation error < –13 dB	17.3.9.6.3	OF1.2.4:M	Yes ❑ No ❑ N/A ❑
OF4.6.7	Transmitter constellation error < –16 dB	17.3.9.6.3	M	Yes ❑ No ❑
OF4.6.8	Transmitter constellation error < –19 dB	17.3.9.6.3	OF1.2.6:M	Yes ❑ No ❑ N/A ❑
OF4.6.9	Transmitter constellation error < –22 db	17.3.9.6.3	OF1.2.7:M	Yes ❑ No ❑ N/A ❑
OF4.6.10	Transmitter constellation error < –25 dB	17.3.9.6.3	OF1.2.8:M	Yes ❑ No ❑ N/A ❑
OF5: PMD Receiver Specifications				
OF5.1	Minimum input level sensitivity at packet error rate (PER) = 10% with 1000 octet frames			
OF5.1.1	–82 dBm for 6 Mbit/s	17.3.10.1	M	Yes ❑ No ❑
OF5.1.2	–81 dBm for 9 Mbit/s	17.3.10.1	OF1.2.2:M	Yes ❑ No ❑ N/A ❑
OF5.1.3	–79 dBm for 12 Mbit/s	17.3.10.1	M	Yes ❑ No ❑
OF5.1.4	–77 dBm for 18 Mbit/s	17.3.10.1	OF1.2.4:M	Yes ❑ No ❑ N/A ❑
OF5.1.5	–74 dBm for 24 Mbit/s	17.3.10.1	M	Yes ❑ No ❑
OF5.1.6	–70 dBm for 36 Mbit/s	17.3.10.1	OF1.2.6:M	Yes ❑ No ❑ N/A ❑
OF5.1.7	–66 dBm for 48 Mbit/s	17.3.10.1	OF1.2.7:M	Yes ❑ No ❑ N/A ❑
OF5.1.8	–65 dBm for 54 Mbit/s	17.3.10.1	OF1.2.8:M	Yes ❑ No ❑ N/A ❑
OF5.2	Adjacent channel rejection	17.3.10.2	M	Yes ❑ No ❑
OF5.3	Nonadjacent channel rejection	17.3.10.3	M	Yes ❑ No ❑
OF5.4	Maximum input level	17.3.10.4	M	Yes ❑ No ❑
OF5.5	CCA sensitivity	17.3.10.5	M	Yes ❑ No ❑
OF6: Transmit PLCP				
OF6.1	Transmit: transmit on MAC request	17.3.13	M	Yes ❑ No ❑
OF6.2	Transmit: format and data encoding	17.3.13	M	Yes ❑ No ❑
OF6.3	Transmit: timing	17.3.13	M	Yes ❑ No ❑
OF7: Receive PLCP				
OF7.1	Receive: receive and data decoding	17.3.14	M	Yes ❑ No ❑
OF8: PLME				
OF8.1	PLME: support PLME_SAP management primitives	17.4.1	M	Yes ❑ No ❑
OF8.2	PLME: support PHY management information base	17.4.2	M	Yes ❑ No ❑
OF8.3	PLME: support PHY characteristics	17.4.3	M	Yes ❑ No ❑
OF9: OFDM PMD Sublayer				
OF9.1	PMD: support PMD_SAP peer-to-peer service primitives	17.5.4.1, 17.5.5.1, 17.5.5.2	M	Yes ❑ No ❑

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A.4.8 OFDM PHY functions *(continued)*

Item	Feature	References	Status	Support
OF9.2	PMD: support PMD_SAP sublayer-to-sublayer service primitives	17.5.4.2, 17.5.5.3, 17.5.5.4, 17.5.5.5, 17.5.5.6, 17.5.5.7	M	Yes ❑ No ❑
OF9.3	PMD_SAP service primitive parameters			
OF9.3.1	Parameter: TXD_UNIT	17.5.4.3	M	Yes ❑ No ❑
OF9.3.2	Parameter: RXD_UNIT	17.5.4.3	M	Yes ❑ No ❑
OF9.3.3	Parameter: TXPWR_LEVEL	17.5.4.3	M	Yes ❑ No ❑
OF9.3.4	Parameter: RATE (12 Mbit/s)	17.5.4.3	M	Yes ❑ No ❑
OF9.3.5	Parameter: RATE (24 Mbit/s)	17.5.4.3	M	Yes ❑ No ❑
OF9.3.6	Parameter: RATE (48 Mbit/s)	17.5.4.3	M	Yes ❑ No ❑
OF9.3.7	Parameter: RATE (72 Mbit/s)	17.5.4.3	O	Yes ❑ No ❑
OF9.3.8	Parameter: RSSI	17.5.4.3	M	Yes ❑ No ❑
OF10: Geographic Area Specific Requirements				
*OF10.1	Geographic areas	17.3.8.2, 17.3.8.3, 17.3.8.4, 17.3.9.3	M	Yes ❑ No ❑

A.4.9 High Rate, direct sequence PHY functions

Item	PHY feature	References	Status	Support
	Are the following PHY features supported?			
HRDS1	Long preamble and header procedures	18.2	M	Yes ❑ No ❑
HRDS1.1	Long direct sequence preamble prepended on TX	18.2.1	M	Yes ❑ No ❑
HRDS1.2	Long PLCP integrity check generation	18.2.3, 18.2.3.6	M	Yes ❑ No ❑
HRDS1.3	TX rate change capability	18.2.3.3	M	Yes ❑ No ❑
HRDS1.4	Supported data rates	18.1, 18.2.3.3	M	Yes ❑ No ❑
HRDS1.5	Data scrambler	18.2.4	M	Yes ❑ No ❑
HRDS1.6	Scrambler initialization	18.2.4	M	Yes ❑ No ❑
*HRDS2	Channel Agility option	18.3.2	O	Yes ❑ No ❑
*HRDS3	Short Preamble and header procedures	18.2	O	Yes ❑ No ❑
HRDS3.1	Short Preamble prepended on TX	18.2.2	HRDS3:M	Yes ❑ No ❑ N/A ❑
HRDS3.2	Short header transmission	18.2.3.8, 18.2.3.9, 18.2.3.10, 18.2.3.11, 18.2.3.12, 18.2.3.13, 18.2.3.14	HRDS3:M	Yes ❑ No ❑ N/A ❑

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A.4.9 High Rate, direct sequence PHY functions *(continued)*

Item	PHY feature	References	Status	Support
HRDS4	Long Preamble process on RX	18.2.6	M	Yes ❑ No ❑
HRDS4.1	PLCP format	18.2.6	M	Yes ❑ No ❑
HRDS4.2	PLCP integrity check verify	18.2.6	M	Yes ❑ No ❑
HRDS4.3	RX Rate change capability	18.2.6	M	Yes ❑ No ❑
HRDS4.4	Data whitener descrambler	18.2.6	M	Yes ❑ No ❑
*HRDS5	Short Preamble process on RX	18.2.6	HRDS3:M	Yes ❑ No ❑ N/A ❑
HRDS5.1	PLCP format	18.2.6	HRDS5:M	Yes ❑ No ❑ N/A ❑
HRDS5.2	PLCP integrity check verify	18.2.6	HRDS5:M	Yes ❑ No ❑ N/A ❑
HRDS5.3	RX rate change capability	18.2.6	HRDS5:M	Yes ❑ No ❑ N/A ❑
HRDS5.4	Data whitener descrambler	18.2.6	HRDS5:M	Yes ❑ No ❑ N/A ❑
*HRDS6	Operating channel capability	—	—	—
*HRDS6.1	North America (FCC)	18.4.6.2	HRDS6:O.3	Yes ❑ No ❑ N/A ❑
HRDS6.1.1	Channel 1	18.4.6.2	HRDS6.1:M	Yes ❑ No ❑ N/A ❑
HRDS6.1.2	Channel 2	18.4.6.2	HRDS6.1:M	Yes ❑ No ❑ N/A ❑
HRDS6.1.3	Channel 3	18.4.6.2	HRDS6.1:M	Yes ❑ No ❑ N/A ❑
HRDS6.1.4	Channel 4	18.4.6.2	HRDS6.1:M	Yes ❑ No ❑ N/A ❑
HRDS6.1.5	Channel 5	18.4.6.2	HRDS6.1:M	Yes ❑ No ❑ N/A ❑
HRDS6.1.6	Channel 6	18.4.6.2	HRDS6.1:M	Yes ❑ No ❑ N/A ❑
HRDS6.1.7	Channel 7	18.4.6.2	HRDS6.1:M	Yes ❑ No ❑ N/A ❑
HRDS6.1.8	Channel 8	18.4.6.2	HRDS6.1:M	Yes ❑ No ❑ N/A ❑
HRDS6.1.9	Channel 9	18.4.6.2	HRDS6.1:M	Yes ❑ No ❑ N/A ❑
HRDS6.1.10	Channel 10	18.4.6.2	HRDS6.1:M	Yes ❑ No ❑ N/A ❑
HRDS6.1.11	Channel 11	18.4.6.2	HRDS6.1:M	Yes ❑ No ❑ N/A ❑
*HRDS6.2	Canada (IC)	18.4.6.2	HRDS6:O.3	Yes ❑ No ❑ N/A ❑
HRDS6.2.1	Channel 1	18.4.6.2	HRDS6.2:M	Yes ❑ No ❑ N/A ❑
HRDS6.2.2	Channel 2	18.4.6.2	HRDS6.2:M	Yes ❑ No ❑ N/A ❑

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A.4.9 High Rate, direct sequence PHY functions *(continued)*

Item	PHY feature	References	Status	Support
HRDS6.2.3	Channel 3	18.4.6.2	HRDS6.2:M	Yes ❑ No ❑ N/A ❑
HRDS6.2.4	Channel 4	18.4.6.2	HRDS6.2:M	Yes ❑ No ❑ N/A ❑
HRDS6.2.5	Channel 5	18.4.6.2	HRDS6.2:M	Yes ❑ No ❑ N/A ❑
HRDS6.2.6	Channel 6	18.4.6.2	HRDS6.2:M	Yes ❑ No ❑ N/A ❑
HRDS6.2.7	Channel 7	18.4.6.2	HRDS6.2:M	Yes ❑ No ❑ N/A ❑
HRDS6.2.8	Channel 8	18.4.6.2	HRDS6.2:M	Yes ❑ No ❑ N/A ❑
HRDS6.2.9	Channel 9	18.4.6.2	HRDS6.2:M	Yes ❑ No ❑ N/A ❑
HRDS6.2.10	Channel 10	18.4.6.2	HRDS6.2:M	Yes ❑ No ❑ N/A ❑
HRDS6.2.11	Channel 11	18.4.6.2	HRDS6.2:M	Yes ❑ No ❑ N/A ❑
*HRDS6.3	Europe (ETSI)	18.4.6.2	HRDS6:O.3	Yes ❑ No ❑ N/A ❑
HRDS6.3.1	Channel 1	18.4.6.2	HRDS6.3:M	Yes ❑ No ❑ N/A ❑
HRDS6.3.2	Channel 2	18.4.6.2	HRDS6.3:M	Yes ❑ No ❑ N/A ❑
HRDS6.3.3	Channel 3	18.4.6.2	HRDS6.3:M	Yes ❑ No ❑ N/A ❑
HRDS6.3.4	Channel 4	18.4.6.2	HRDS6.3:M	Yes ❑ No ❑ N/A ❑
HRDS6.3.5	Channel 5	18.4.6.2	HRDS6.3:M	Yes ❑ No ❑ N/A ❑
HRDS6.3.6	Channel 6	18.4.6.2	HRDS6.3:M	Yes ❑ No ❑ N/A ❑
HRDS6.3.7	Channel 7	18.4.6.2	HRDS6.3:M	Yes ❑ No ❑ N/A ❑
HRDS6.3.8	Channel 8	18.4.6.2	HRDS6.3:M	Yes ❑ No ❑ N/A ❑
HRDS6.3.9	Channel 9	18.4.6.2	HRDS6.3:M	Yes ❑ No ❑ N/A ❑
HRDS6.3.10	Channel 10	18.4.6.2	HRDS6.3:M	Yes ❑ No ❑ N/A ❑
HRDS6.3.11	Channel 11	18.4.6.2	HRDS6.3:M	Yes ❑ No ❑ N/A ❑
HRDS6.3.12	Channel 12	18.4.6.2	HRDS6.3:M	Yes ❑ No ❑ N/A ❑
HRDS6.3.13	Channel 13	18.4.6.2	HRDS6.3:M	Yes ❑ No ❑ N/A ❑

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A.4.9 High Rate, direct sequence PHY functions *(continued)*

Item	PHY feature	References	Status	Support
*HRDS6.4	France	18.4.6.2	HRDS6:O.3	Yes ❑ No ❑ N/A ❑
HRDS6.4.1	Channel 10	18.4.6.2	HRDS6.4:M	Yes ❑ No ❑ N/A ❑
HRDS6.4.2	Channel 11	18.4.6.2	HRDS6.4:M	Yes ❑ No ❑ N/A ❑
HRDS6.4.3	Channel 12	18.4.6.2	HRDS6.4:M	Yes ❑ No ❑ N/A ❑
HRDS6.4.4	Channel 13	18.4.6.2	HRDS6.4:M	Yes ❑ No ❑ N/A ❑
*HRDS6.5	Spain	18.4.6.2	HRDS6:O.3	Yes ❑ No ❑ N/A ❑
HRDS6.5.1	Channel 10	18.4.6.2	HRDS6.5:M	Yes ❑ No ❑ N/A ❑
HRDS6.5.2	Channel 11	18.4.6.2	HRDS6.5:M	Yes ❑ No ❑ N/A ❑
*HRDS6.6	Japan	18.4.6.2	HRDS6:O.3	Yes ❑ No ❑ N/A ❑
HRDS6.6.1	Channel 1	18.4.6.2	HRDS6.6:M	Yes ❑ No ❑ N/A ❑
HRDS6.6.2	Channel 2	18.4.6.2	HRDS6.6:M	Yes ❑ No ❑ N/A ❑
HRDS6.6.3	Channel 3	18.4.6.2	HRDS6.6:M	Yes ❑ No ❑ N/A ❑
HRDS6.6.4	Channel 4	18.4.6.2	HRDS6.6:M	Yes ❑ No ❑ N/A ❑
HRDS6.6.5	Channel 5	18.4.6.2	HRDS6.6:M	Yes ❑ No ❑ N/A ❑
HRDS6.6.6	Channel 6	18.4.6.2	HRDS6.6:M	Yes ❑ No ❑ N/A ❑
HRDS6.6.7	Channel 7	18.4.6.2	HRDS6.6:M	Yes ❑ No ❑ N/A ❑
HRDS6.6.8	Channel 8	18.4.6.2	HRDS6.6:M	Yes ❑ No ❑ N/A ❑
HRDS6.6.9	Channel 9	18.4.6.2	HRDS6.6:M	Yes ❑ No ❑ N/A ❑
HRDS6.6.10	Channel 10	18.4.6.2	HRDS6.6:M	Yes ❑ No ❑ N/A ❑
HRDS6.6.11	Channel 11	18.4.6.2	HRDS6.6:M	Yes ❑ No ❑ N/A ❑
HRDS6.6.12	Channel 12	18.4.6.2	HRDS6.6:M	Yes ❑ No ❑ N/A ❑
HRDS6.6.13	Channel 13	18.4.6.2	HRDS6.6:M	Yes ❑ No ❑ N/A ❑
HRDS6.6.14	Channel 14	18.4.6.2	HRDS6.6:M	Yes ❑ No ❑ N/A ❑

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A.4.9 High Rate, direct sequence PHY functions *(continued)*

Item	PHY feature	References	Status	Support
HRDS7	Hop sequences		HRDS2:M	Yes ❑ No ❑ N/A ❑
HRDS8	Complementary code keying (CCK) bits to symbol mapping			
HRDS8.1	5.5 Mbit/s	18.4.6.5	M	Yes ❑ No ❑
HRDS8.2	11 Mbit/s	18.4.6.5	M	Yes ❑ No ❑
*HRDS9	Packet binary convolutional code (PBCC) bits to symbol mappings	18.4.6.6	O	
HRDS9.1	5.5 Mbit/s	18.4.6.6	HRDS9:M	Yes ❑ No ❑
HRDS9.2	11 Mbit/s	18.4.6.6	HRDS9:M	Yes ❑ No ❑
*HRDS10	CCA functionality	18.4.8.4		
HRDS10.1	CCA Mode 1, energy only (RSSI above threshold)	18.4.8.4	HRDS10:O.4	Yes ❑ No ❑
HRDS10.2	CCA Mode 4, CS with timer	18.4.8.4	HRDS10:O.4	Yes ❑ No ❑
HRDS10.3	CCA Mode 5, energy detect with High Rate CS	18.4.8.4	HRDS10:O.4	Yes ❑ No ❑
HRDS10.4	Hold CCA busy for packet duration of a correctly received PLCP, but carrier lost during reception of MPDU.	18.2.6	M	Yes ❑ No ❑
HRDS10.5	Hold CCA busy for packet duration of a correctly received, but out of spec, PLCP.	18.2.6	M	Yes ❑ No ❑
HRDS11	Transmit antenna selection	18.4.5.8	O	Yes ❑ No ❑
HRDS12	Receive antenna diversity	18.4.5.8, 18.4.5.9	O	Yes ❑ No ❑
*HRDS13	Antenna port(s) availability	18.4.6.8	O	Yes ❑ No ❑
HRDS13.1	If available (50 ¾ impedance)	18.4.6.8	HRDS13:M	Yes ❑ No ❑ N/A ❑
*HRDS14	Transmit power level support	18.4.5.9, 18.4.7.2	O	Yes ❑ No ❑
HRDS14.1	If greater than 100 mW capability	18.4.7.2	HRDS14:M	Yes ❑ No ❑ N/A ❑
*HRDS15	Radio type (temperature range)	18.4.6.14		
HRDS15.1	Type 1	18.4.6.14	HRDS15:O.5	Yes ❑ No ❑ N/A ❑
HRDS15.2	Type 2	18.4.6.14	HRDS15:O.5	Yes ❑ No ❑ N/A ❑
HRDS16	Spurious emissions conformance	18.4.6.8	M	Yes ❑ No ❑
HRDS17	TX-to-RX turnaround time	18.4.6.9	M	Yes ❑ No ❑
HRDS18	RX-to-TX turnaround time	18.4.6.10	M	Yes ❑ No ❑
HRDS19	Slot time	18.4.6.11	M	Yes ❑ No ❑
HRDS20	ED reporting time	18.4.6.10, 18.4.8.4	M	Yes ❑ No ❑
HRDS21	Minimum transmit power level	18.4.7.2	M	Yes ❑ No ❑
HRDS22	Transmit spectral mask conformance	18.4.7.3	M	Yes ❑ No ❑
HRDS23	Transmitted center frequency tolerance	18.4.7.4	M	Yes ❑ No ❑

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A.4.9 High Rate, direct sequence PHY functions *(continued)*

Item	PHY feature	References	Status	Support
HRDS24	Chip clock frequency tolerance	18.4.7.5	M	Yes ❑ No ❑
HRDS25	Transmit power-on ramp	18.4.7.6	M	Yes ❑ No ❑
HRDS26	Transmit power-down ramp	18.4.7.6	M	Yes ❑ No ❑
HRDS27	RF carrier suppression	18.4.7.7	M	Yes ❑ No ❑
HRDS28	Transmit modulation accuracy	18.4.7.8	M	Yes ❑ No ❑
HRDS29	Receiver minimum input level sensitivity	18.4.8.1	M	Yes ❑ No ❑
HRDS30	Receiver maximum input level	18.4.8.2	M	Yes ❑ No ❑
HRDS31	Receiver adjacent channel rejection	18.4.8.3	M	Yes ❑ No ❑
HRDS32	MIB	13.1, 18.3.2, Annex C	M	Yes ❑ No ❑
HRDS32.1	PHY object class	13.1, 18.3.3	M	Yes ❑ No ❑

A.4.10 Regulatory Domain Extensions

Item	Protocol capability	References	Status	Support
MD1	Country information element dot11MultiDomainCapability-Enabled attribute dot11MultiDomainCapability-Enabled Length CountryString FieldChannel Number First Channel Number Maximum Transmit Power Level Number of Channels	7.2.3.1, 7.2.3.9 7.3.2.9	CF8:M	Yes ❑ No ❑ N/A ❑
MD2	Inclusion of the Request information in the Probe Request frame	7.2.3.8	CF8:O	Yes ❑ No ❑ N/A ❑
MD3	Hopping Pattern Parameters Element ID Prime Radix Number of Channels	7.3.2.10	(CF3 or (CF7 and HRDS2)) and CF8:M	Yes ❑ No ❑ N/A ❑
MD4	Hopping Pattern information element Format Element ID Random table method	7.3.2.11	(CF3 or (CF7 and HRDS2)) and CF8:M	Yes ❑ No ❑ N/A ❑

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A.4.10 Regulatory Domain Extensions *(continued)*

Item	Protocol capability	References	Status	Support
MD5	Request information element Format Element ID Order of the Requested Elemented IDs	7.3.2.12	CF8:M	Yes ❑ No ❑ N/A ❑
MD6	Entering a Regulatory Domain Lost Connectivity with its extended service set (ESS) Passive Scanning to learn Beacon information Transmit Probe Request	9.9.1	CF8:M	Yes ❑ No ❑ N/A ❑
MD7	Determination of the Hopping Patterns [Hop Index Method without table, Hop Index Method with table, and hyperbolic congruence code (HCC)/extended HCC (EHCC)]	7.3.2.11, 9.9.2.1,	(CF3 or (CF7 and HRDS2)) and CF8:M	Yes ❑ No ❑ N/A ❑
MD8	Roaming requires Beacon frame with country information element	11.1.3.3	CF8:M	Yes ❑ No ❑ N/A ❑
MD9	Actions to be taken upon the receipt of the beacon	11.1.3.4	CF8:M	Yes ❑ No ❑ N/A ❑
MD10	Ignore improperly formed Request information element	7.2.3.9	CF8:O	Yes ❑ No ❑ N/A ❑
MD11	Hopping Pattern set attribute	14.8.2.20	(CF3 or (CF7 and HRDS2)) and CF8:M	Yes ❑ No ❑ N/A ❑

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Annex B

(informative)

Hopping sequences

The following tables pertain to the hopping sequences for North America and ETSI.

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Table B.1—Hopping sequence set 1

index	0	3	6	9	12	15	18	21	24	27	30	33	36
1	2	5	8	11	14	17	20	23	26	29	32	35	38
2	25	28	31	34	37	40	43	46	49	52	55	58	61
3	64	67	70	73	76	79	3	6	9	12	15	18	21
4	10	13	16	19	22	25	28	31	34	37	40	43	46
5	45	48	51	54	57	60	63	66	69	72	75	78	2
6	18	21	24	27	30	33	36	39	42	45	48	51	54
7	73	76	79	3	6	9	12	15	18	21	24	27	30
8	49	52	55	58	61	64	67	70	73	76	79	3	6
9	21	24	27	30	33	36	39	42	45	48	51	54	57
10	63	66	69	72	75	78	2	5	8	11	14	17	20
11	78	2	5	8	11	14	17	20	23	26	29	32	35
12	31	34	37	40	43	46	49	52	55	58	61	64	67
13	61	64	67	70	73	76	79	3	6	9	12	15	18
14	24	27	30	33	36	39	42	45	48	51	54	57	60
15	54	57	60	63	66	69	72	75	78	2	5	8	11
16	65	68	71	74	77	80	4	7	10	13	16	19	22
17	28	31	34	37	40	43	46	49	52	55	58	61	64
18	79	3	6	9	12	15	18	21	24	27	30	33	36
19	33	36	39	42	45	48	51	54	57	60	63	66	69
20	4	7	10	13	16	19	22	25	28	31	34	37	40
21	20	23	26	29	32	35	38	41	44	47	50	53	56
22	13	16	19	22	25	28	31	34	37	40	43	46	49
23	38	41	44	47	50	53	56	59	62	65	68	71	74
24	74	77	80	4	7	10	13	16	19	22	25	28	31
25	56	59	62	65	68	71	74	77	80	4	7	10	13
26	71	74	77	80	4	7	10	13	16	19	22	25	28
27	23	26	29	32	35	38	41	44	47	50	53	56	59
28	5	8	11	14	17	20	23	26	29	32	35	38	41
29	39	42	45	48	51	54	57	60	63	66	69	72	75
30	12	15	18	21	24	27	30	33	36	39	42	45	48
31	36	39	42	45	48	51	54	57	60	63	66	69	72
32	68	71	74	77	80	4	7	10	13	16	19	22	25
33	9	12	15	18	21	24	27	30	33	36	39	42	45
34	70	73	76	79	3	6	9	12	15	18	21	24	27
35	77	80	4	7	10	13	16	19	22	25	28	31	34
36	6	9	12	15	18	21	24	27	30	33	36	39	42
37	62	65	68	71	74	77	80	4	7	10	13	16	19
38	29	32	35	38	41	44	47	50	53	56	59	62	65
39	14	17	20	23	26	29	32	35	38	41	44	47	50

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Table B.1—Hopping sequence set 1 *(continued)*

index	0	3	6	9	12	15	18	21	24	27	30	33	36
40	27	30	33	36	39	42	45	48	51	54	57	60	63
41	16	19	22	25	28	31	34	37	40	43	46	49	52
42	59	62	65	68	71	74	77	80	4	7	10	13	16
43	43	46	49	52	55	58	61	64	67	70	73	76	79
44	76	79	3	6	9	12	15	18	21	24	27	30	33
45	34	37	40	43	46	49	52	55	58	61	64	67	70
46	72	75	78	2	5	8	11	14	17	20	23	26	29
47	11	14	17	20	23	26	29	32	35	38	41	44	47
48	60	63	66	69	72	75	78	2	5	8	11	14	17
49	80	4	7	10	13	16	19	22	25	28	31	34	37
50	47	50	53	56	59	62	65	68	71	74	77	80	4
51	22	25	28	31	34	37	40	43	46	49	52	55	58
52	75	78	2	5	8	11	14	17	20	23	26	29	32
53	66	69	72	75	78	2	5	8	11	14	17	20	23
54	41	44	47	50	53	56	59	62	65	68	71	74	77
55	15	18	21	24	27	30	33	36	39	42	45	48	51
56	35	38	41	44	47	50	53	56	59	62	65	68	71
57	67	70	73	76	79	3	6	9	12	15	18	21	24
58	52	55	58	61	64	67	70	73	76	79	3	6	9
59	58	61	64	67	70	73	76	79	3	6	9	12	15
60	44	47	50	53	56	59	62	65	68	71	74	77	80
61	50	53	56	59	62	65	68	71	74	77	80	4	7
62	17	20	23	26	29	32	35	38	41	44	47	50	53
63	7	10	13	16	19	22	25	28	31	34	37	40	43
64	19	22	25	28	31	34	37	40	43	46	49	52	55
65	8	11	14	17	20	23	26	29	32	35	38	41	44
66	69	72	75	78	2	5	8	11	14	17	20	23	26
67	51	54	57	60	63	66	69	72	75	78	2	5	8
68	42	45	48	51	54	57	60	63	66	69	72	75	78
69	3	6	9	12	15	18	21	24	27	30	33	36	39
70	30	33	36	39	42	45	48	51	54	57	60	63	66
71	57	60	63	66	69	72	75	78	2	5	8	11	14
72	37	40	43	46	49	52	55	58	61	64	67	70	73
73	55	58	61	64	67	70	73	76	79	3	6	9	12
74	26	29	32	35	38	41	44	47	50	53	56	59	62
75	46	49	52	55	58	61	64	67	70	73	76	79	3
76	53	56	59	62	65	68	71	74	77	80	4	7	10
77	40	43	46	49	52	55	58	61	64	67	70	73	76
78	32	35	38	41	44	47	50	53	56	59	62	65	68
79	48	51	54	57	60	63	66	69	72	75	78	2	5

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Table B.1—Hopping sequence set 1 *(continued)*

index	39	42	45	48	51	54	57	60	63	66	69	72	75
1	41	44	47	50	53	56	59	62	65	68	71	74	77
2	64	67	70	73	76	79	3	6	9	12	15	18	21
3	24	27	30	33	36	39	42	45	48	51	54	57	60
4	49	52	55	58	61	64	67	70	73	76	79	3	6
5	5	8	11	14	17	20	23	26	29	32	35	38	41
6	57	60	63	66	69	72	75	78	2	5	8	11	14
7	33	36	39	42	45	48	51	54	57	60	63	66	69
8	9	12	15	18	21	24	27	30	33	36	39	42	45
9	60	63	66	69	72	75	78	2	5	8	11	14	17
10	23	26	29	32	35	38	41	44	47	50	53	56	59
11	38	41	44	47	50	53	56	59	62	65	68	71	74
12	70	73	76	79	3	6	9	12	15	18	21	24	27
13	21	24	27	30	33	36	39	42	45	48	51	54	57
14	63	66	69	72	75	78	2	5	8	11	14	17	20
15	14	17	20	23	26	29	32	35	38	41	44	47	50
16	25	28	31	34	37	40	43	46	49	52	55	58	61
17	67	70	73	76	79	3	6	9	12	15	18	21	24
18	39	42	45	48	51	54	57	60	63	66	69	72	75
19	72	75	78	2	5	8	11	14	17	20	23	26	29
20	43	46	49	52	55	58	61	64	67	70	73	76	79
21	59	62	65	68	71	74	77	80	4	7	10	13	16
22	52	55	58	61	64	67	70	73	76	79	3	6	9
23	77	80	4	7	10	13	16	19	22	25	28	31	34
24	34	37	40	43	46	49	52	55	58	61	64	67	70
25	16	19	22	25	28	31	34	37	40	43	46	49	52
26	31	34	37	40	43	46	49	52	55	58	61	64	67
27	62	65	68	71	74	77	80	4	7	10	13	16	19
28	44	47	50	53	56	59	62	65	68	71	74	77	80
29	78	2	5	8	11	14	17	20	23	26	29	32	35
30	51	54	57	60	63	66	69	72	75	78	2	5	8
31	75	78	2	5	8	11	14	17	20	23	26	29	32
32	28	31	34	37	40	43	46	49	52	55	58	61	64
33	48	51	54	57	60	63	66	69	72	75	78	2	5
34	30	33	36	39	42	45	48	51	54	57	60	63	66
35	37	40	43	46	49	52	55	58	61	64	67	70	73
36	45	48	51	54	57	60	63	66	69	72	75	78	2
37	22	25	28	31	34	37	40	43	46	49	52	55	58
38	68	71	74	77	80	4	7	10	13	16	19	22	25
39	53	56	59	62	65	68	71	74	77	80	4	7	10

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Table B.1—Hopping sequence set 1 *(continued)*

index	39	42	45	48	51	54	57	60	63	66	69	72	75
40	66	69	72	75	78	2	5	8	11	14	17	20	23
41	55	58	61	64	67	70	73	76	79	3	6	9	12
42	19	22	25	28	31	34	37	40	43	46	49	52	55
43	3	6	9	12	15	18	21	24	27	30	33	36	39
44	36	39	42	45	48	51	54	57	60	63	66	69	72
45	73	76	79	3	6	9	12	15	18	21	24	27	30
46	32	35	38	41	44	47	50	53	56	59	62	65	68
47	50	53	56	59	62	65	68	71	74	77	80	4	7
48	20	23	26	29	32	35	38	41	44	47	50	53	56
49	40	43	46	49	52	55	58	61	64	67	70	73	76
50	7	10	13	16	19	22	25	28	31	34	37	40	43
51	61	64	67	70	73	76	79	3	6	9	12	15	18
52	35	38	41	44	47	50	53	56	59	62	65	68	71
53	26	29	32	35	38	41	44	47	50	53	56	59	62
54	80	4	7	10	13	16	19	22	25	28	31	34	37
55	54	57	60	63	66	69	72	75	78	2	5	8	11
56	74	77	80	4	7	10	13	16	19	22	25	28	31
57	27	30	33	36	39	42	45	48	51	54	57	60	63
58	12	15	18	21	24	27	30	33	36	39	42	45	48
59	18	21	24	27	30	33	36	39	42	45	48	51	54
60	4	7	10	13	16	19	22	25	28	31	34	37	40
61	10	13	16	19	22	25	28	31	34	37	40	43	46
62	56	59	62	65	68	71	74	77	80	4	7	10	13
63	46	49	52	55	58	61	64	67	70	73	76	79	3
64	58	61	64	67	70	73	76	79	3	6	9	12	15
65	47	50	53	56	59	62	65	68	71	74	77	80	4
66	29	32	35	38	41	44	47	50	53	56	59	62	65
67	11	14	17	20	23	26	29	32	35	38	41	44	47
68	2	5	8	11	14	17	20	23	26	29	32	35	38
69	42	45	48	51	54	57	60	63	66	69	72	75	78
70	69	72	75	78	2	5	8	11	14	17	20	23	26
71	17	20	23	26	29	32	35	38	41	44	47	50	53
72	76	79	3	6	9	12	15	18	21	24	27	30	33
73	15	18	21	24	27	30	33	36	39	42	45	48	51
74	65	68	71	74	77	80	4	7	10	13	16	19	22
75	6	9	12	15	18	21	24	27	30	33	36	39	42
76	13	16	19	22	25	28	31	34	37	40	43	46	49
77	79	3	6	9	12	15	18	21	24	27	30	33	36
78	71	74	77	80	4	7	10	13	16	19	22	25	28
79	8	11	14	17	20	23	26	29	32	35	38	41	44

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Table B.2—Hopping sequence set 2

index	1	4	7	10	13	16	19	22	25	28	31	34	37
1	3	6	9	12	15	18	21	24	27	30	33	36	39
2	26	29	32	35	38	41	44	47	50	53	56	59	62
3	65	68	71	74	77	80	4	7	10	13	16	19	22
4	11	14	17	20	23	26	29	32	35	38	41	44	47
5	46	49	52	55	58	61	64	67	70	73	76	79	3
6	19	22	25	28	31	34	37	40	43	46	49	52	55
7	74	77	80	4	7	10	13	16	19	22	25	28	31
8	50	53	56	59	62	65	68	71	74	77	80	4	7
9	22	25	28	31	34	37	40	43	46	49	52	55	58
10	64	67	70	73	76	79	3	6	9	12	15	18	21
11	79	3	6	9	12	15	18	21	24	27	30	33	36
12	32	35	38	41	44	47	50	53	56	59	62	65	68
13	62	65	68	71	74	77	80	4	7	10	13	16	19
14	25	28	31	34	37	40	43	46	49	52	55	58	61
15	55	58	61	64	67	70	73	76	79	3	6	9	12
16	66	69	72	75	78	2	5	8	11	14	17	20	23
17	29	32	35	38	41	44	47	50	53	56	59	62	65
18	80	4	7	10	13	16	19	22	25	28	31	34	37
19	34	37	40	43	46	49	52	55	58	61	64	67	70
20	5	8	11	14	17	20	23	26	29	32	35	38	41
21	21	24	27	30	33	36	39	42	45	48	51	54	57
22	14	17	20	23	26	29	32	35	38	41	44	47	50
23	39	42	45	48	51	54	57	60	63	66	69	72	75
24	75	78	2	5	8	11	14	17	20	23	26	29	32
25	57	60	63	66	69	72	75	78	2	5	8	11	14
26	72	75	78	2	5	8	11	14	17	20	23	26	29
27	24	27	30	33	36	39	42	45	48	51	54	57	60
28	6	9	12	15	18	21	24	27	30	33	36	39	42
29	40	43	46	49	52	55	58	61	64	67	70	73	76
30	13	16	19	22	25	28	31	34	37	40	43	46	49
31	37	40	43	46	49	52	55	58	61	64	67	70	73
32	69	72	75	78	2	5	8	11	14	17	20	23	26
33	10	13	16	19	22	25	28	31	34	37	40	43	46
34	71	74	77	80	4	7	10	13	16	19	22	25	28
35	78	2	5	8	11	14	17	20	23	26	29	32	35
36	7	10	13	16	19	22	25	28	31	34	37	40	43
37	63	66	69	72	75	78	2	5	8	11	14	17	20
38	30	33	36	39	42	45	48	51	54	57	60	63	66
39	15	18	21	24	27	30	33	36	39	42	45	48	51

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Table B.2—Hopping sequence set 2 *(continued)*

index	1	4	7	10	13	16	19	22	25	28	31	34	37
40	28	31	34	37	40	43	46	49	52	55	58	61	64
41	17	20	23	26	29	32	35	38	41	44	47	50	53
42	60	63	66	69	72	75	78	2	5	8	11	14	17
43	44	47	50	53	56	59	62	65	68	71	74	77	80
44	77	80	4	7	10	13	16	19	22	25	28	31	34
45	35	38	41	44	47	50	53	56	59	62	65	68	71
46	73	76	79	3	6	9	12	15	18	21	24	27	30
47	12	15	18	21	24	27	30	33	36	39	42	45	48
48	61	64	67	70	73	76	79	3	6	9	12	15	18
49	2	5	8	11	14	17	20	23	26	29	32	35	38
50	48	51	54	57	60	63	66	69	72	75	78	2	5
51	23	26	29	32	35	38	41	44	47	50	53	56	59
52	76	79	3	6	9	12	15	18	21	24	27	30	33
53	67	70	73	76	79	3	6	9	12	15	18	21	24
54	42	45	48	51	54	57	60	63	66	69	72	75	78
55	16	19	22	25	28	31	34	37	40	43	46	49	52
56	36	39	42	45	48	51	54	57	60	63	66	69	72
57	68	71	74	77	80	4	7	10	13	16	19	22	25
58	53	56	59	62	65	68	71	74	77	80	4	7	10
59	59	62	65	68	71	74	77	80	4	7	10	13	16
60	45	48	51	54	57	60	63	66	69	72	75	78	2
61	51	54	57	60	63	66	69	72	75	78	2	5	8
62	18	21	24	27	30	33	36	39	42	45	48	51	54
63	8	11	14	17	20	23	26	29	32	35	38	41	44
64	20	23	26	29	32	35	38	41	44	47	50	53	56
65	9	12	15	18	21	24	27	30	33	36	39	42	45
66	70	73	76	79	3	6	9	12	15	18	21	24	27
67	52	55	58	61	64	67	70	73	76	79	3	6	9
68	43	46	49	52	55	58	61	64	67	70	73	76	79
69	4	7	10	13	16	19	22	25	28	31	34	37	40
70	31	34	37	40	43	46	49	52	55	58	61	64	67
71	58	61	64	67	70	73	76	79	3	6	9	12	15
72	38	41	44	47	50	53	56	59	62	65	68	71	74
73	56	59	62	65	68	71	74	77	80	4	7	10	13
74	27	30	33	36	39	42	45	48	51	54	57	60	63
75	47	50	53	56	59	62	65	68	71	74	77	80	4
76	54	57	60	63	66	69	72	75	78	2	5	8	11
77	41	44	47	50	53	56	59	62	65	68	71	74	77
78	33	36	39	42	45	48	51	54	57	60	63	66	69
79	49	52	55	58	61	64	67	70	73	76	79	3	6

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Table B.2—Hopping sequence set 2 *(continued)*

index	40	43	46	49	52	55	58	61	64	67	70	73	76
1	42	45	48	51	54	57	60	63	66	69	72	75	78
2	65	68	71	74	77	80	4	7	10	13	16	19	22
3	25	28	31	34	37	40	43	46	49	52	55	58	61
4	50	53	56	59	62	65	68	71	74	77	80	4	7
5	6	9	12	15	18	21	24	27	30	33	36	39	42
6	58	61	64	67	70	73	76	79	3	6	9	12	15
7	34	37	40	43	46	49	52	55	58	61	64	67	70
8	10	13	16	19	22	25	28	31	34	37	40	43	46
9	61	64	67	70	73	76	79	3	6	9	12	15	18
10	24	27	30	33	36	39	42	45	48	51	54	57	60
11	39	42	45	48	51	54	57	60	63	66	69	72	75
12	71	74	77	80	4	7	10	13	16	19	22	25	28
13	22	25	28	31	34	37	40	43	46	49	52	55	58
14	64	67	70	73	76	79	3	6	9	12	15	18	21
15	15	18	21	24	27	30	33	36	39	42	45	48	51
16	26	29	32	35	38	41	44	47	50	53	56	59	62
17	68	71	74	77	80	4	7	10	13	16	19	22	25
18	40	43	46	49	52	55	58	61	64	67	70	73	76
19	73	76	79	3	6	9	12	15	18	21	24	27	30
20	44	47	50	53	56	59	62	65	68	71	74	77	80
21	60	63	66	69	72	75	78	2	5	8	11	14	17
22	53	56	59	62	65	68	71	74	77	80	4	7	10
23	78	2	5	8	11	14	17	20	23	26	29	32	35
24	35	38	41	44	47	50	53	56	59	62	65	68	71
25	17	20	23	26	29	32	35	38	41	44	47	50	53
26	32	35	38	41	44	47	50	53	56	59	62	65	68
27	63	66	69	72	75	78	2	5	8	11	14	17	20
28	45	48	51	54	57	60	63	66	69	72	75	78	2
29	79	3	6	9	12	15	18	21	24	27	30	33	36
30	52	55	58	61	64	67	70	73	76	79	3	6	9
31	76	79	3	6	9	12	15	18	21	24	27	30	33
32	29	32	35	38	41	44	47	50	53	56	59	62	65
33	49	52	55	58	61	64	67	70	73	76	79	3	6
34	31	34	37	40	43	46	49	52	55	58	61	64	67
35	38	41	44	47	50	53	56	59	62	65	68	71	74
36	46	49	52	55	58	61	64	67	70	73	76	79	3
37	23	26	29	32	35	38	41	44	47	50	53	56	59
38	69	72	75	78	2	5	8	11	14	17	20	23	26
39	54	57	60	63	66	69	72	75	78	2	5	8	11

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Table B.2—Hopping sequence set 2 *(continued)*

index	40	43	46	49	52	55	58	61	64	67	70	73	76
40	67	70	73	76	79	3	6	9	12	15	18	21	24
41	56	59	62	65	68	71	74	77	80	4	7	10	13
42	20	23	26	29	32	35	38	41	44	47	50	53	56
43	4	7	10	13	16	19	22	25	28	31	34	37	40
44	37	40	43	46	49	52	55	58	61	64	67	70	73
45	74	77	80	4	7	10	13	16	19	22	25	28	31
46	33	36	39	42	45	48	51	54	57	60	63	66	69
47	51	54	57	60	63	66	69	72	75	78	2	5	8
48	21	24	27	30	33	36	39	42	45	48	51	54	57
49	41	44	47	50	53	56	59	62	65	68	71	74	77
50	8	11	14	17	20	23	26	29	32	35	38	41	44
51	62	65	68	71	74	77	80	4	7	10	13	16	19
52	36	39	42	45	48	51	54	57	60	63	66	69	72
53	27	30	33	36	39	42	45	48	51	54	57	60	63
54	2	5	8	11	14	17	20	23	26	29	32	35	38
55	55	58	61	64	67	70	73	76	79	3	6	9	12
56	75	78	2	5	8	11	14	17	20	23	26	29	32
57	28	31	34	37	40	43	46	49	52	55	58	61	64
58	13	16	19	22	25	28	31	34	37	40	43	46	49
59	19	22	25	28	31	34	37	40	43	46	49	52	55
60	5	8	11	14	17	20	23	26	29	32	35	38	41
61	11	14	17	20	23	26	29	32	35	38	41	44	47
62	57	60	63	66	69	72	75	78	2	5	8	11	14
63	47	50	53	56	59	62	65	68	71	74	77	80	4
64	59	62	65	68	71	74	77	80	4	7	10	13	16
65	48	51	54	57	60	63	66	69	72	75	78	2	5
66	30	33	36	39	42	45	48	51	54	57	60	63	66
67	12	15	18	21	24	27	30	33	36	39	42	45	48
68	3	6	9	12	15	18	21	24	27	30	33	36	39
69	43	46	49	52	55	58	61	64	67	70	73	76	79
70	70	73	76	79	3	6	9	12	15	18	21	24	27
71	18	21	24	27	30	33	36	39	42	45	48	51	54
72	77	80	4	7	10	13	16	19	22	25	28	31	34
73	16	19	22	25	28	31	34	37	40	43	46	49	52
74	66	69	72	75	78	2	5	8	11	14	17	20	23
75	7	10	13	16	19	22	25	28	31	34	37	40	43
76	14	17	20	23	26	29	32	35	38	41	44	47	50
77	80	4	7	10	13	16	19	22	25	28	31	34	37
78	72	75	78	2	5	8	11	14	17	20	23	26	29
79	9	12	15	18	21	24	27	30	33	36	39	42	45

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Table B.3—Hopping sequence set 3

index	2	5	8	11	14	17	20	23	26	29	32	35	38
1	4	7	10	13	16	19	22	25	28	31	34	37	40
2	27	30	33	36	39	42	45	48	51	54	57	60	63
3	66	69	72	75	78	2	5	8	11	14	17	20	23
4	12	15	18	21	24	27	30	33	36	39	42	45	48
5	47	50	53	56	59	62	65	68	71	74	77	80	4
6	20	23	26	29	32	35	38	41	44	47	50	53	56
7	75	78	2	5	8	11	14	17	20	23	26	29	32
8	51	54	57	60	63	66	69	72	75	78	2	5	8
9	23	26	29	32	35	38	41	44	47	50	53	56	59
10	65	68	71	74	77	80	4	7	10	13	16	19	22
11	80	4	7	10	13	16	19	22	25	28	31	34	37
12	33	36	39	42	45	48	51	54	57	60	63	66	69
13	63	66	69	72	75	78	2	5	8	11	14	17	20
14	26	29	32	35	38	41	44	47	50	53	56	59	62
15	56	59	62	65	68	71	74	77	80	4	7	10	13
16	67	70	73	76	79	3	6	9	12	15	18	21	24
17	30	33	36	39	42	45	48	51	54	57	60	63	66
18	2	5	8	11	14	17	20	23	26	29	32	35	38
19	35	38	41	44	47	50	53	56	59	62	65	68	71
20	6	9	12	15	18	21	24	27	30	33	36	39	42
21	22	25	28	31	34	37	40	43	46	49	52	55	58
22	15	18	21	24	27	30	33	36	39	42	45	48	51
23	40	43	46	49	52	55	58	61	64	67	70	73	76
24	76	79	3	6	9	12	15	18	21	24	27	30	33
25	58	61	64	67	70	73	76	79	3	6	9	12	15
26	73	76	79	3	6	9	12	15	18	21	24	27	30
27	25	28	31	34	37	40	43	46	49	52	55	58	61
28	7	10	13	16	19	22	25	28	31	34	37	40	43
29	41	44	47	50	53	56	59	62	65	68	71	74	77
30	14	17	20	23	26	29	32	35	38	41	44	47	50
31	38	41	44	47	50	53	56	59	62	65	68	71	74
32	70	73	76	79	3	6	9	12	15	18	21	24	27
33	11	14	17	20	23	26	29	32	35	38	41	44	47
34	72	75	78	2	5	8	11	14	17	20	23	26	29
35	79	3	6	9	12	15	18	21	24	27	30	33	36
36	8	11	14	17	20	23	26	29	32	35	38	41	44
37	64	67	70	73	76	79	3	6	9	12	15	18	21
38	31	34	37	40	43	46	49	52	55	58	61	64	67
39	16	19	22	25	28	31	34	37	40	43	46	49	52

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Table B.3—Hopping sequence set 3 *(continued)*

index	2	5	8	11	14	17	20	23	26	29	32	35	38
40	29	32	35	38	41	44	47	50	53	56	59	62	65
41	18	21	24	27	30	33	36	39	42	45	48	51	54
42	61	64	67	70	73	76	79	3	6	9	12	15	18
43	45	48	51	54	57	60	63	66	69	72	75	78	2
44	78	2	5	8	11	14	17	20	23	26	29	32	35
45	36	39	42	45	48	51	54	57	60	63	66	69	72
46	74	77	80	4	7	10	13	16	19	22	25	28	31
47	13	16	19	22	25	28	31	34	37	40	43	46	49
48	62	65	68	71	74	77	80	4	7	10	13	16	19
49	3	6	9	12	15	18	21	24	27	30	33	36	39
50	49	52	55	58	61	64	67	70	73	76	79	3	6
51	24	27	30	33	36	39	42	45	48	51	54	57	60
52	77	80	4	7	10	13	16	19	22	25	28	31	34
53	68	71	74	77	80	4	7	10	13	16	19	22	25
54	43	46	49	52	55	58	61	64	67	70	73	76	79
55	17	20	23	26	29	32	35	38	41	44	47	50	53
56	37	40	43	46	49	52	55	58	61	64	67	70	73
57	69	72	75	78	2	5	8	11	14	17	20	23	26
58	54	57	60	63	66	69	72	75	78	2	5	8	11
59	60	63	66	69	72	75	78	2	5	8	11	14	17
60	46	49	52	55	58	61	64	67	70	73	76	79	3
61	52	55	58	61	64	67	70	73	76	79	3	6	9
62	19	22	25	28	31	34	37	40	43	46	49	52	55
63	9	12	15	18	21	24	27	30	33	36	39	42	45
64	21	24	27	30	33	36	39	42	45	48	51	54	57
65	10	13	16	19	22	25	28	31	34	37	40	43	46
66	71	74	77	80	4	7	10	13	16	19	22	25	28
67	53	56	59	62	65	68	71	74	77	80	4	7	10
68	44	47	50	53	56	59	62	65	68	71	74	77	80
69	5	8	11	14	17	20	23	26	29	32	35	38	41
70	32	35	38	41	44	47	50	53	56	59	62	65	68
71	59	62	65	68	71	74	77	80	4	7	10	13	16
72	39	42	45	48	51	54	57	60	63	66	69	72	75
73	57	60	63	66	69	72	75	78	2	5	8	11	14
74	28	31	34	37	40	43	46	49	52	55	58	61	64
75	48	51	54	57	60	63	66	69	72	75	78	2	5
76	55	58	61	64	67	70	73	76	79	3	6	9	12
77	42	45	48	51	54	57	60	63	66	69	72	75	78
78	34	37	40	43	46	49	52	55	58	61	64	67	70
79	50	53	56	59	62	65	68	71	74	77	80	4	7

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Table B.3—Hopping sequence set 3 *(continued)*

index	41	44	47	50	53	56	59	62	65	68	71	74	77
1	43	46	49	52	55	58	61	64	67	70	73	76	79
2	66	69	72	75	78	2	5	8	11	14	17	20	23
3	26	29	32	35	38	41	44	47	50	53	56	59	62
4	51	54	57	60	63	66	69	72	75	78	2	5	8
5	7	10	13	16	19	22	25	28	31	34	37	40	43
6	59	62	65	68	71	74	77	80	4	7	10	13	16
7	35	38	41	44	47	50	53	56	59	62	65	68	71
8	11	14	17	20	23	26	29	32	35	38	41	44	47
9	62	65	68	71	74	77	80	4	7	10	13	16	19
10	25	28	31	34	37	40	43	46	49	52	55	58	61
11	40	43	46	49	52	55	58	61	64	67	70	73	76
12	72	75	78	2	5	8	11	14	17	20	23	26	29
13	23	26	29	32	35	38	41	44	47	50	53	56	59
14	65	68	71	74	77	80	4	7	10	13	16	19	22
15	16	19	22	25	28	31	34	37	40	43	46	49	52
16	27	30	33	36	39	42	45	48	51	54	57	60	63
17	69	72	75	78	2	5	8	11	14	17	20	23	26
18	41	44	47	50	53	56	59	62	65	68	71	74	77
19	74	77	80	4	7	10	13	16	19	22	25	28	31
20	45	48	51	54	57	60	63	66	69	72	75	78	2
21	61	64	67	70	73	76	79	3	6	9	12	15	18
22	54	57	60	63	66	69	72	75	78	2	5	8	11
23	79	3	6	9	12	15	18	21	24	27	30	33	36
24	36	39	42	45	48	51	54	57	60	63	66	69	72
25	18	21	24	27	30	33	36	39	42	45	48	51	54
26	33	36	39	42	45	48	51	54	57	60	63	66	69
27	64	67	70	73	76	79	3	6	9	12	15	18	21
28	46	49	52	55	58	61	64	67	70	73	76	79	3
29	80	4	7	10	13	16	19	22	25	28	31	34	37
30	53	56	59	62	65	68	71	74	77	80	4	7	10
31	77	80	4	7	10	13	16	19	22	25	28	31	34
32	30	33	36	39	42	45	48	51	54	57	60	63	66
33	50	53	56	59	62	65	68	71	74	77	80	4	7
34	32	35	38	41	44	47	50	53	56	59	62	65	68
35	39	42	45	48	51	54	57	60	63	66	69	72	75
36	47	50	53	56	59	62	65	68	71	74	77	80	4
37	24	27	30	33	36	39	42	45	48	51	54	57	60
38	70	73	76	79	3	6	9	12	15	18	21	24	27
39	55	58	61	64	67	70	73	76	79	3	6	9	12

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Table B.3—Hopping sequence set 3 *(continued)*

index	41	44	47	50	53	56	59	62	65	68	71	74	77
40	68	71	74	77	80	4	7	10	13	16	19	22	25
41	57	60	63	66	69	72	75	78	2	5	8	11	14
42	21	24	27	30	33	36	39	42	45	48	51	54	57
43	5	8	11	14	17	20	23	26	29	32	35	38	41
44	38	41	44	47	50	53	56	59	62	65	68	71	74
45	75	78	2	5	8	11	14	17	20	23	26	29	32
46	34	37	40	43	46	49	52	55	58	61	64	67	70
47	52	55	58	61	64	67	70	73	76	79	3	6	9
48	22	25	28	31	34	37	40	43	46	49	52	55	58
49	42	45	48	51	54	57	60	63	66	69	72	75	78
50	9	12	15	18	21	24	27	30	33	36	39	42	45
51	63	66	69	72	75	78	2	5	8	11	14	17	20
52	37	40	43	46	49	52	55	58	61	64	67	70	73
53	28	31	34	37	40	43	46	49	52	55	58	61	64
54	3	6	9	12	15	18	21	24	27	30	33	36	39
55	56	59	62	65	68	71	74	77	80	4	7	10	13
56	76	79	3	6	9	12	15	18	21	24	27	30	33
57	29	32	35	38	41	44	47	50	53	56	59	62	65
58	14	17	20	23	26	29	32	35	38	41	44	47	50
59	20	23	26	29	32	35	38	41	44	47	50	53	56
60	6	9	12	15	18	21	24	27	30	33	36	39	42
61	12	15	18	21	24	27	30	33	36	39	42	45	48
62	58	61	64	67	70	73	76	79	3	6	9	12	15
63	48	51	54	57	60	63	66	69	72	75	78	2	5
64	60	63	66	69	72	75	78	2	5	8	11	14	17
65	49	52	55	58	61	64	67	70	73	76	79	3	6
66	31	34	37	40	43	46	49	52	55	58	61	64	67
67	13	16	19	22	25	28	31	34	37	40	43	46	49
68	4	7	10	13	16	19	22	25	28	31	34	37	40
69	44	47	50	53	56	59	62	65	68	71	74	77	80
70	71	74	77	80	4	7	10	13	16	19	22	25	28
71	19	22	25	28	31	34	37	40	43	46	49	52	55
72	78	2	5	8	11	14	17	20	23	26	29	32	35
73	17	20	23	26	29	32	35	38	41	44	47	50	53
74	67	70	73	76	79	3	6	9	12	15	18	21	24
75	8	11	14	17	20	23	26	29	32	35	38	41	44
76	15	18	21	24	27	30	33	36	39	42	45	48	51
77	2	5	8	11	14	17	20	23	26	29	32	35	38
78	73	76	79	3	6	9	12	15	18	21	24	27	30
79	10	13	16	19	22	25	28	31	34	37	40	43	46

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Annex C

(normative)

Formal description of MAC operation

This annex contains formal descriptions of the behavior of MAC STA and AP entities. These descriptions also describe the frame formats and the generation and interpretation of information encoded in MAC frames, in the parameters of service primitives supported by the MAC, and in MIB attributes used or generated by the MAC. The MAC is described using the 1992 version of the ITU Specification and Description Language (SDL-92). SDL-92 is defined in ITU-T Recommendation Z.100 (03/93). An update to Z.100 was approved in 1996 (SDL-96), but none of the SDL facilities used in this annex were modified. An introduction to the MAC formal description is provided in C.1. Definitions of the data types and operators used by the MAC state machines are provided in C.2. An SDL system describing MAC operation at an IEEE 802.11 station is contained in C.3. Finally, a subset of an SDL system describing the aspects of MAC operation at an IEEE 802.11 AP that differ from operation at a non-AP station is provided in C.4.

In Annex D, the MAC and PHY MIBs are described in Abstract Syntax Notation One (ASN.1), defined in ISO/IEC 8824-1:1995, ISO/IEC 8824-2:1995, ISO/IEC 8824-3:1995, ISO/IEC 8824-4:1995, ISO/IEC 8825-1:1995, and ISO/IEC 8825-2:1996. ITU-T Recommendation Z.105 (03/95) defines the use of SDL in conjunction with ASN.1, allowing system behavior to be defined using SDL and data types to be defined using ASN.1. Incomplete tool support precluded the use of ITU-T Recommendation Z.105 in this annex. However, within the limits of ITU-T Recommendation Z.100 (referred to subsequently as Z.100), the data types in C.2 are defined in a similar manner to ITU-T Recommendation Z.105 (referred to subsequently as Z.105). Annex E contains a listing of available documentation.

NOTES

1—The SDL definitions in this annex should be usable with any SDL tool that supports the 1993 version or 1996 update of ITU-T Recommendation Z.100. Software for generating, analyzing, verifying, and simulating SDL system descriptions is available from several sources.

2—The SDL code in this annex was generated using *SDT/PC version 3.02*; from Telelogic AB, Malmo, Sweden (+46-40-174700; internet: telelogic.se); USA office in Princeton, NJ (+1-609-520-1935; internet: telelogic.com). Telelogic offers SDT for several workstation platforms in addition to SDT/PC.

3— The use of Telelogic's product to prepare this annex does not constitute an endorsement of SDT by the IEEE LAN MAN Standards Committee or by the IEEE.

4—The diagrams on the next two pages show most of the symbols of SDL graphical syntax (SDL-GR) used in the MAC formal description. The symbols in these diagrams have labels and comments that explain their meanings. These diagrams are intended to serve as a legend for the SDL-GR symbols that comprise most of the process interaction and state transition diagrams. These diagrams are neither a complete SDL system, nor a complete presentation of SDL-GR symbology. Also, this state machine fragment exists to illustrate the SDL graphical syntax and does not describe any useful behavior.

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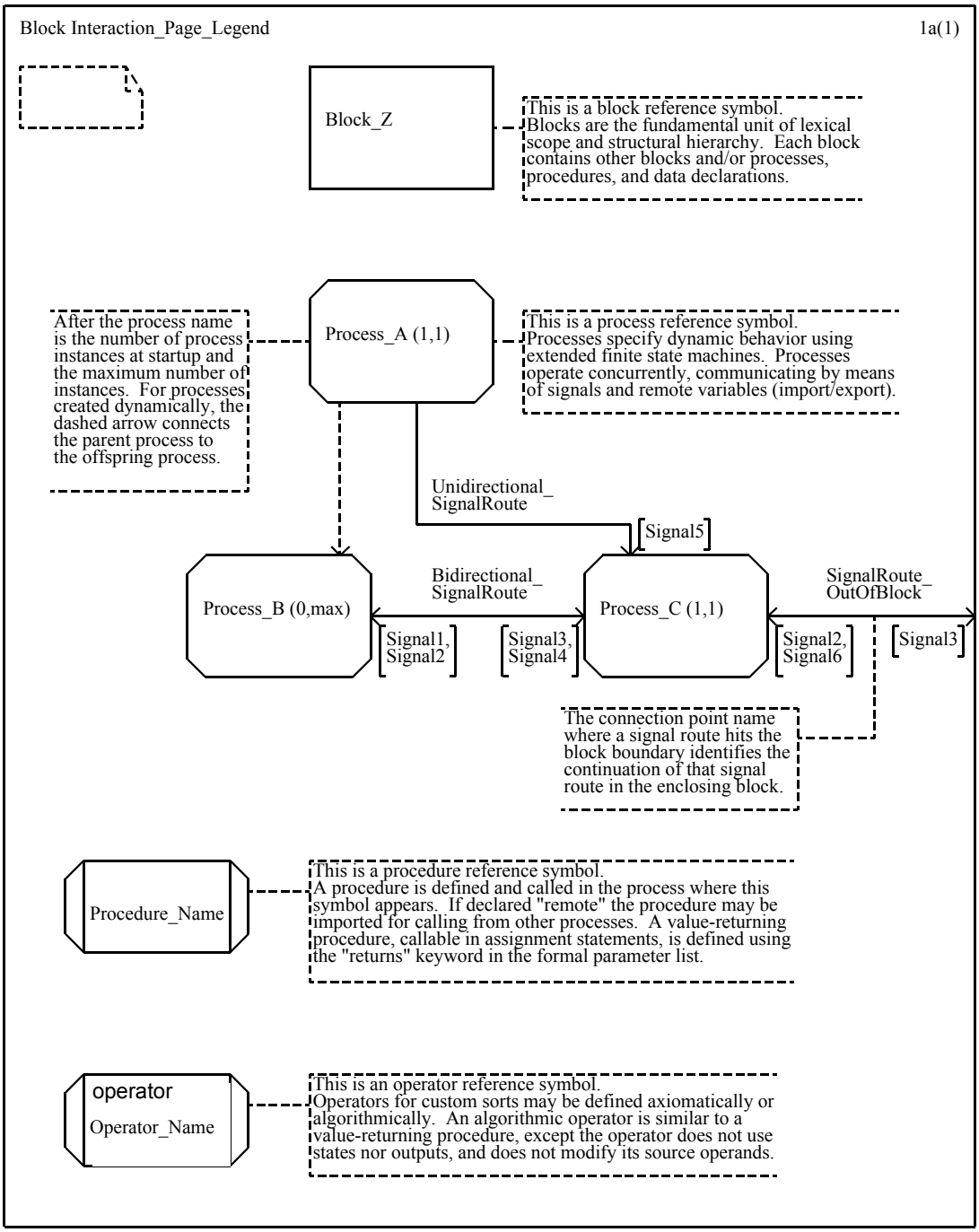

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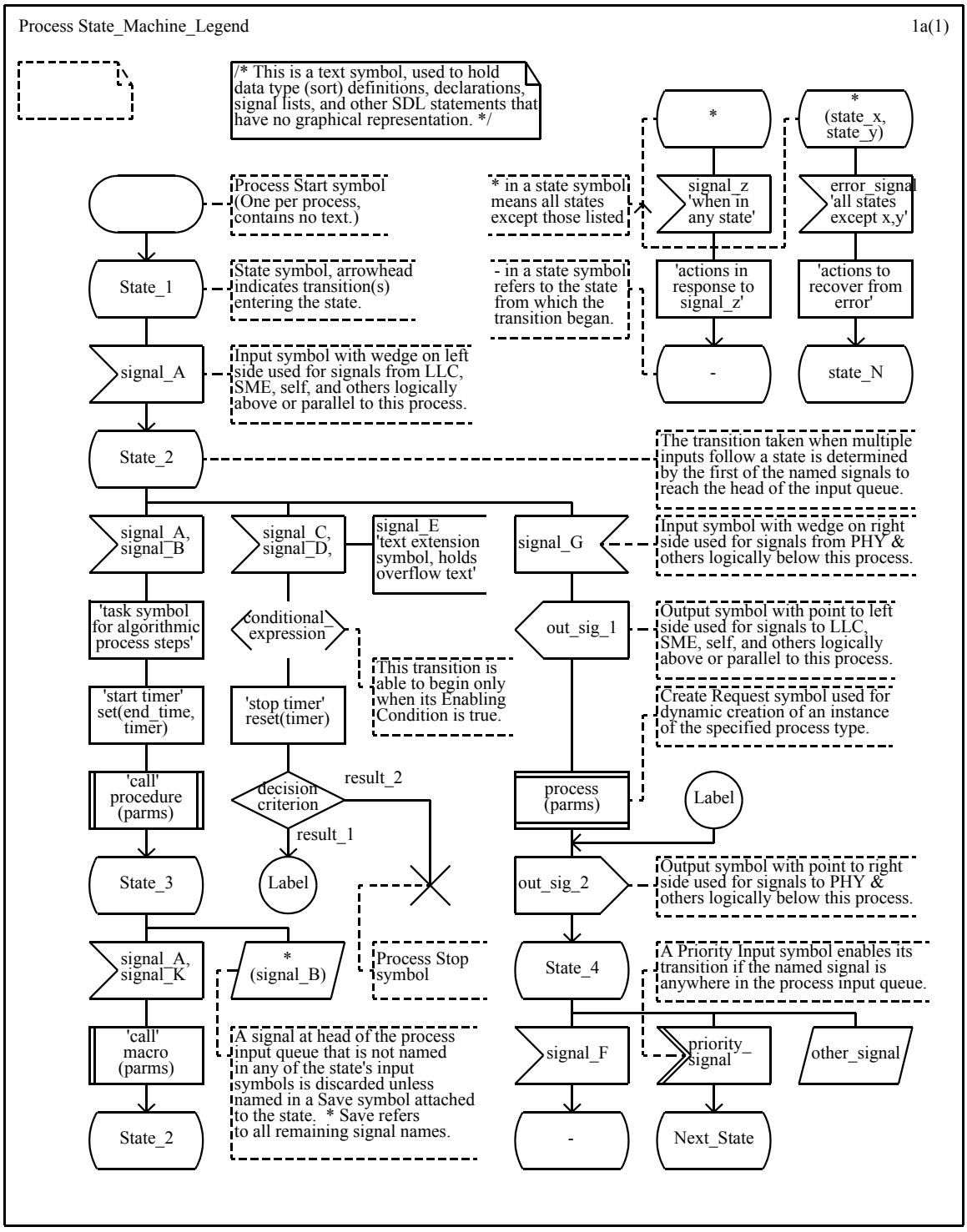

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C.1 Introduction to the MAC formal description

This formal description defines the behavior of IEEE 802.11 MAC entities. The MAC protocol functional decomposition used herein facilitates explicit description of the reference points and durations of the various timed intervals; the bases for generation and/or validation of header fields, service parameters, and MIB attributes; and the interpretation of each value in cases where enumerated data types are used in service parameters.

C.1.1 Fundamental assumptions

The MAC protocol is described as an SDL system, which is a set of extended finite state machines. Each state machine is a set of independent processes, all of which operate concurrently. All variable data-holding entities and procedures exist solely within the context of a single process. In SDL all interprocess communication is done with signals (there are no global variables). Signals may be sent and received explicitly, using SDL's output and input symbols, or implicitly, using SDL's export/import mechanism (only if the variables or procedures are declared "remote"). By default, signals incur delays when traversing channels between blocks; however, only nondelaying channels and signal routes are used in the MAC state machines, and all remote variables and procedures are declared with the "nodelay" property.

State transitions, procedure calls, and tasks (assignment statements and other algorithmic processing steps) are assumed to require zero time. This permits the time intervals that are part of the normative MAC behavior to be defined explicitly, using SDL timers. One unit of system time (a 1.0 change in the value of "now") is assumed to represent 1 μs of real time. Usec (microsecond) and TU data types are defined, with operators to convert Usec and TU values to SDL time or duration when necessary.

The SDL system boundary encloses the MAC entities. The LLC, SME, PHY, and DS are part of the environment. SDL generally assumes that entities in the environment operate as specified; however, the MAC state machines that communicate with the various SAPs attempt to validate inputs from the environment, and to handle cases where a pair of communicating entities, one within the system and the other outside the system boundary, have different local views of the medium, station, or service state. All stations in an IEEE 802.11 service set are assumed to exhibit the behaviors described herein. Nevertheless, because of the open nature of the WM, the MAC state machines check for error cases that can arise only when an entity on the WM is transmitting IEEE 802.11 protocol data units (PDUs), but is not obeying the communication protocols specified by this standard.

C.1.2 Notation conventions

When practical, names used in the clauses of this standard are spelled identically in this annex. The principal exceptions are those names that conflict with one of SDL's reserved words (such as power management mode "active," which is renamed "sta_active" in SDL). To help fit the SDL text into the graphic symbols, acronyms with multiple, sequential capital letters are written with only the first letter capitalized (e.g., "MSDU" is written "Msdu" and "MLMEJoin.request" is written "MlmeJoin.request").

SDL reserved words and the names of variables and synonyms (named constants) begin with lowercase letters. The names of sorts (data types), signals, signal routes, channels, blocks, and processes begin with uppercase letters. The names of certain groups of variables and/or synonyms begin with a particular lowercase letter, followed by the remainder of the name, beginning with an uppercase letter. These groups are

"aNameOfAttribute"PHY operational parameters.
"cNameOfCapability"Capability bits, also used for internal values exported as MIB counters.
"dNameOfDuration"Duration (relative time) values, declared as Usec, TU, or Duration.
"dot11NameOfAttribute"MIB attributes.

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"eNameOfElement"Element ID values.
"mNameOfVariable"Remote variables used for intra-MAC communication, but not part of the MIB. Most of these variables are exported from the MLME block.
"sNameOfStaticValue"Synonyms for static data values used within the MAC.
"tNameOfTime"Time (absolute time) values, declared as Usec, TU, or Time. The names of timers begin with "T."

C.1.3 Modeling techniques

State machines are grouped according to defined function sets that are visible, directly or indirectly, at an exposed interface. The emphasis in the organization of the state machines is explicitly to show initiation of and response to events at the exposed interfaces, and time-related actions, including those dependent on the absence of external events (e.g., response timeouts) and intervals measured in derived units (e.g., backoff "time" in units of slots during which the WM is idle). The operations associated with the various state transitions emphasize communication functions. Most of the details regarding insertion, extraction, and encoding of information in fields of the PDUs is encapsulated with the definitions of those fields. This approach, which relies heavily on SDL's abstract data type and inheritance mechanisms, permits the behavior of the data-holding entities to be precisely defined, without obscuring process flow by adding in-line complexity to the individual state transitions.

The modeling of PDUs and service data units (SDUs) requires sorts such as octet strings, and operators such as bitwise boolean functions, which are not predefined in SDL. These sorts and operators are defined in Package macsorts, which appears in C.2.

PDU and SDU sorts are based on the **Bit** sort. Bit is a subtype of SDL's predefined Boolean sort. As a result, Bit literals 0 and 1 are alternative names for "false" and "true" and have no numeric significance. To use 0 or 1 as integer values requires a conversion operation. Items of the **Bitstring** sort are 0-origin, variable-length strings of Bits. With Bitstring operands, operators "and," "or," "xor," and "not" operate bitwise, with the length of the result equal to the length of the longest (or only) source string. The **Octet** sort is a subtype of Bitstring that adds conversion operators to and from Integer. Each item of the Octet sort has length=8 {by usage convention in Z.100, enforced in Z.105}. Items of the **Octetstring** sort are 0-origin, variable-length strings of Octets. The **Frame** sort is a subtype of Octetstring that adds operators to extract and to modify all MAC header fields and most other MAC frame fields and elements. Most MAC fields and elements that contain named values with specific value assignments or enumerations are defined as subtypes of Frame, Octetstring, or Bitstring with the names added as literals or synonyms, so that the state machines can refer to the names without introducing ambiguity about the value encodings.

Where communication at a SAP or between processes is strictly first in first out (FIFO), the (implicit) input queue of the SDL processes is used. When more sophisticated queue management is needed, a queue whose entries are instances of one, specified sort is created using the **Queue** generator. Entries on Queue sorts may be added and removed at either the tail or the head, and the number of queue entries may be determined. The contents of a Queue may also be searched to locate entries with particular parameter values.

In C.2 is an SDL-92 Package (a named collection of SDL definitions that can be included by reference into an SDL System specification), which is a formal description of the formats and data encodings used in IEEE 802.11 SDUs, PDUs, and the parameters of the service primitives used at each of the SAPs supported by the IEEE 802.11 MAC. This package also contains definitions for some data structures and operators used internally by one or more of the MAC state machines.

The behaviors of many intra-MAC operators are part of the normative description of the MAC protocol because results of the specified operations are visible, directly or indirectly, at exposed interfaces. For example, custom operators are used to define the generation of the CRC-32 value used in the FCS field (operator crc32, page 424), the calculation of frame transmission time used as part of the value in the Duration/ID

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field in certain types of frames (operator calcDur, page 440), the comparison of the values of particular fields of a received MAC header with cached data values as part of the procedure for detecting duplicate frames (operator searchTupleCache, page 412), and numerous other aspects of frame formats and information encoding. On the other hand, data structures used solely for intra-MAC storage or for transferring of information between different state machines of a single station or AP, are only normative to the extent that they define items of internal state and the temporal sequence necessary for proper operation of the MAC protocol. The specific structures and encodings used for internal data storage and communication functions in this formal description do *not* constrain MAC implementations, provided those implementations exhibit the specified behaviors at the defined SAPs and, in conjunction with an appropriate PHY, on the WM.

C.2 Data type and operator definitions for the MAC state machines

This clause is in SDL/PR (phrase notation), with the exception of procedural operators, which are defined in SDL/GR (graphic notation). Package macsorts contains the definitions of the sorts (data types with associated operators and literals) and synonyms (named constants) used by the MAC state machines. Package macmib defines data types for attributes in the MAC MIB, and portions of the PHY MIB, accessed by the MAC state machines. Package macmib exists solely to satisfy SDL's strong type checking in the absence of an SDL tool that fully supports Z.105 (the combined use of SDL with ASN.1).

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Package macsorts 3101_d\MacEnum(31)



```
/*     PACKAGE MACSORTS     */
/* This package contains definitions of the custom sorts (data types), operators,
   literals, and synonyms (named constants) used by the MAC state machines. */
```

```
/*************************************************************************
 *       Enumerated types used within the MAC state machines
 *************************************************************************/
newtype ChangeType    /* type of change due at the next boundary */
  literals  dwell,    /* dwell (only with FH PHY) */
            mocp;     /* medium occupancy (only with PCF) */
endnewtype ChangeType;
newtype Imed    /* priority for queuing MMPDUs, relative to MSDUs */
  literals  head,    /* place MMPDU at head of transmit queue */
            norm;    /* place MMPDU at tail of transmit queue */
endnewtype Imed;
newtype NavSrc    /* source of duration in SetNav & ClearNav signals */
  literals  rts,    /* RTS frame */
            cfpBss,  cfendBss,    /* start/end of CFP in own BSS */
            cfpOther,  cfendOther,    /* start/end of CFP in other BSS */
            cswitch,    /* channel switch */
            misc,    /* durId from other frame types */
            nosrc;    /* nonreception events */
endnewtype NavSrc;
newtype PsMode    /* power save mode of a station (PsResponse signal) */
  literals  sta_active,  power_save,  unknown;   endnewtype PsMode;
newtype PsState    /* power save state of this station */
  literals  awake,  doze;   endnewtype PsState;
newtype StateErr    /* requests disasoc or deauth (MmIndicate signal) */
  literals  noerr,  class2,  class3;   endnewtype StateErr;
newtype StationState    /* asoc/auth state of sta (SsResponse signal) */
  literals  not_auth,  auth_open,  auth_key,  asoc,  dis_asoc;
endnewtype StationState;
newtype TxResult    /* transmission attempt status (PduConfirm signal) */
  literals  successful,  partial,  retryLimit,  txLifetime,
  atimAck,  atimNak;   endnewtype TxResult;
```

```
/*************************************************************************
 *       Enumerated types used in PHY service primitives
 *************************************************************************/
newtype CcaStatus    /* <state> parameter of PhyCca.indication */
  literals  busy,  idle;   endnewtype CcaStatus;
newtype PhyRxStat    /* <rxerror> parameter of PhyRxEnd.indication */
  literals  no_error,  fmt_violation,  carrier_lost,  unsupt_rate;
endnewtype PhyRxStat;
```

```
/*************************************************************************
 *       Placeholders for Mlme/Plme Get/Set Parameter Values
 *************************************************************************/
   /* MibAtrib (placeholder in MlmeGet/Set definitions) */
syntype MibAtrib = Charstring   endsyntype MibAtrib;
   /* MibValue (placeholder in MlmeGet/Set definitions) */
syntype MibValue = Integer   endsyntype MibValue;
```

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Package macsorts 3102_d\LmeEnum(31)



```
/*****************************************************************
 *       Enumerated types used in Mac and Mlme service primitives
 *****************************************************************/
newtype AuthType    /* <authentication type> parm in Mlme primitives */
  inherits Octetstring  operators all;
  adding  literals open_system,  shared_key;
  axioms  open_system == mkOS(0, 2);  shared_key == mkOS(1, 2);
endnewtype AuthType;
newtype AuthTypeSet  powerset( AuthType);   endnewtype AuthTypeSet;
newtype BssType    /* <BSS type> parameter & BSS description element */
  literals infrastructure,  independent,  any_bss;   endnewtype BssType;
newtype BssTypeSet  powerset( BssType);   endnewtype BssTypeSet;
newtype CfPriority    /* <priority> parameter of various requests */
  literals  contention,  contentionFree;   endnewtype CfPriority;
newtype MibStatus    /* <status> parm of Mlme/Plme Get/Set.confirm */
  literals  success,   invalid,   write_only,   read_only;
endnewtype MibStatus;
newtype MlmeStatus    /* <status> parm of Mlme operation confirm */
  literals  success,  invalid,  timeout,  refused,
          tomany_req,  already_bss;   endnewtype MlmeStatus;
newtype PwrSave    /* <power save mode> parameter of MlmePowerMgt */
  literals  sta_active,  power_save;   endnewtype PwrSave;
newtype Routing    /* <routing info> parameter for MAC data service */
  literals  null_rt;   endnewtype Routing;
newtype RxStatus    /* <reception status> parm of MaUnitdata indication */
  literals  rx_success,  rx_failure;   endnewtype RxStatus;
newtype ScanType    /* <scan type> parameter of MlmeScan.request */
  literals  active_scan,  passive_scan;   endnewtype ScanType;
newtype ServiceClass    /* <service class> parameter for MaUnitdata */
  literals  reorderable,  strictlyOrdered;   endnewtype ServiceClass;
newtype TxStatus    /* <transmission status> parm of MaUnitdataStatus */
  literals  successful,   retryLimit,   txLifetime,   noBss,
     excessiveDataLength,  nonNullSourceRouting,
     unsupportedPriority,  unavailablePriority,
     unsupportedServiceClass,  unavailableServiceClass,
     unavailableKeyMapping;  endnewtype TxStatus;
```


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Package macsorts 3103_e\IntraMac(31)



```
/*****************************************************************
 *       Intra-MAC remote variables (names of form mXYZ)
 *****************************************************************/
remote mActingAsAp Boolean nodelay;    /* =true if STA started BSS */
remote mAId  AsocId nodelay;    /* AID assigned to STA by AP */
remote mAssoc  Boolean nodelay;    /* =true if STA associated w/BSS */
remote mAtimW  Boolean nodelay;    /* =true if ATIM window in prog */
remote mBkIP  Boolean nodelay;    /* =true if backoff in prog */
remote mBrates Ratestring nodelay;    /* basic rate set for this sta */
remote mBssId  MacAddr nodelay;    /* identifier of current (I)BSS */
remote mCap  Octetstring nodelay;    /* capability info from MlmeJoin */
remote mCfp  Boolean nodelay;    /* =true if CF period in progress */
remote mDisable  Boolean nodelay;    /* =true if not in any BSS; then */
     /* TX only sends probe_req; RX only accepts beacon, probe_rsp */
remote mDtimCount  Integer nodelay;    /* =0 at Tbtt of Beacon with DTIM */
remote mFxIP  Boolean nodelay;    /* =true during frame exchange seq */
remote mIbss  Boolean nodelay;    /* =true if STA is member of IBSS */
remote mListenInt  Integer nodelay;    /* beacons between wake up @TBTT */
remote mNavEnd  Time nodelay;    /* NAV end Time, <=now when idle */
remote mNextBdry  Time nodelay;    /* next boundary Time; =0 if none */
remote mNextTbtt  Time nodelay;    /* Time next beacon due to occur */
remote mPcAvail  Boolean nodelay;    /* =true if point coord in BSS */
remote mPcDlvr  Boolean nodelay;    /* =true if CF delivery only */
remote mPcPoll  Boolean nodelay;    /* =true if CF delivery & polling */
remote mPdly  Usec nodelay;    /* probe delay from start or join */
remote mPss  PsState nodelay;    /* power save state of STA */
remote mReceiveDTIMs Boolean nodelay;  /* =true if DTIMs received */
remote mRxA  Boolean nodelay;    /* =true if RX indicated by PHY */
remote mSsId  Octetstring nodelay;    /* name of the current (I)BSS */
remote procedure TSF nodelay;    /* read & update 64-bit TSF timer */
   fpar Integer, Boolean;   returns Integer;
```

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Package macsorts 3104_d\StaticData(31)



```
/*****************************************************************
 *       Named static data values    (names of form sXYZ)
 *****************************************************************/
synonym sMaxMsduLng Integer = 2304;    /* max octets in an MSDU */
synonym sMacHdrLng  Integer = 24;    /* octets in data header, no WEP */
synonym sWepHdrLng  Integer = 28;    /* octets in data header with WEP */
synonym sWepAddLng  Integer = 8;    /* octets added for WEP */
synonym sWdsAddLng  Integer = 6;    /* octets added for WDS (addr4) */
synonym sCrcLng  Integer = 4;    /* octets for crc32 (FCS, ICV) */
synonym sMaxMpduLng  Integer =        /* max octets in an MPDU */
   (sMaxMsduLng + sMacHdrLng + sWdsAddLng + sWepAddLng + sCrcLng);
syntype FrameIndexRange = Integer    /* index range for octets in MPDU */
   constants 0 : sMaxMpduLng   endsyntype FrameIndexRange;
synonym sTsOctet  Integer = 24;    /* first octet of Timestamp field */
synonym sMinFragLng Integer = 256;    /* min value for aMpduMaxLength */
synonym sMaxFragNum Integer =        /* maximum fragment number */
   (sMaxMsduLng / (sMinFragLng - sMacHdrLng - sCrcLng));
synonym sAckCtsLng Integer = 112;  /* bits in ACK and CTS frames */
```

```
/*****************************************************************
 *       Station configuration flags (static, supplementary to MIB)
 *****************************************************************/
synonym sVersion  Integer = 0;    /* supported Protocol Version */
synonym sCanBeAp  Boolean = false;    /* =true if STA can operate as AP */
synonym sCanBePc  Boolean = false;    /* =true if AP can be Point Coord */
synonym sCfPollable Boolean =true;    /* =true if responds to CF-polls */
```


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Package macsorts 3105_d\Usec_TU(31)



```
/*****************************************************************
 *       Discrete microsecond and Time Unit sorts
 *****************************************************************/
/* SDL does not define the relationship between its concept */
/* of Time and physical time in the system being described. */
/* An abstraction is needed to establish this relationship, */
/* because Time in SDL uses the semantics of Real, whereas */
/* time in the MAC protocol is discrete, with the semantics */
/* of Natural and a step size (resolution) of 1 micosecond. */
/* Most MAC times are defined using the subtypes of Integer */
/* Usec and TU.  These have operators for explicit conversion */
/* to SDL Time (tUsec, tTU), SDL Duration (dUsec, dTU), and */
/* from SDL Time (uTime, tuTime) as needed to comply with SDL's */
/* strong type checking.  Where the MAC state machines need to */
/* access the contents of the TSF timer, SDL's 'now' (current */
/* time) is used.  This yields readable time-dependent code, */
/* but the value of 'now' cannot be modified by an SDL program, */
/* so adopting the TSF time from timestamps in received Beacons */
/* or Probe Responses is shown as an informal task symbol. */
/* Microsecond sort -- also has operators tmin and tmax */
newtype Usec   inherits Integer   operators all;
  adding  operators
    dUsec : Usec -> Duration;
    tUsec : Usec -> Time;
    uTime : Time -> Usec;
    tmax  : Usec, Usec -> Usec;
    tmin  : Usec, Usec -> Usec;
  axioms    for all u, w in Usec(
      u >= w ==> tmax(u, w) == u;      u < w ==> tmax(u, w) == w;
      u >= w ==> tmin(u, w) == w;      u < w ==> tmin(u, w) == u;
      for all t in Time(     for all r in Real(
          r = float(u) ==> tUsec(u) == Time!(Duration!(r));
          t = Time!(Duration!(r)) and u = fix(r) ==> u == uTime(t);));
      for all d in Duration(     for all r in Real(
          r = float(u) ==> dUsec(u) == Duration!(r); )));
  constants >= 0 /* constrain value range to be non-negative */
endnewtype Usec;
/* Time Unit sort -- (1 * TU) = (1024 * Usec) */
newtype TU  inherits Integer  operators all;
  adding  operators
    dTU    : TU -> Duration;
    tTU    : TU -> Time;
    tuTime : Time -> TU;
    u2TU   : Usec -> TU;
    tu2U   : TU -> Usec;
  axioms    for all k in TU(   for all t in Time(   for all r in Real(
          r = float(k) ==> tTU(k) == Time!(Duration!(1024 * r));
          t = Time!(Duration!(r)) and k = (fix(r) / 1024) ==> k == tuTime(t);));
      for all d in Duration(   for all r in Real(
          r = float(k) ==> dTU(k) == Duration!(1024 * r);));
      for all u in Usec(   u2TU(u) == u / 1024;   tu2U(k) == k * 1024; ));
  constants >= 0 /* constrain value range to be non-negative */
endnewtype TU;
```

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Package macsorts

3106_d\String0(31)



```
/*****************************************************************
 *       Generator for 0-origin String sorts (adapted from Z.105, Annex A)
 *****************************************************************/
/* String0(sort, nullSymbol) can define strings of any sort. */
/* These strings are indexed starting from 0 rather than 1. */
/* Sorts defined by String0 have the normal String operators, plus */
/* Tail (all but first item), Head (all but last item), and */
/* aggregators S2, S3, S4, S6, S8 (make fixed length strings). */
generator String0(type Item, literal Emptystring)
  literals Emptystring;
  operators
    MkString : Item -> String0;    /* make a string from an item */
    Length  : String0 -> Integer;    /* length of string */
    First  : String0 -> Item;    /* first item in string */
    Tail  : String0 -> String0;    /* all but first item in string */
    Last  : String0 -> Item;    /* last item in string */
    head  : String0 -> String0;    /* all but last item in string */
    "//"  : String0, String0 -> String0;    /* concatenation */
    Extract! : String0, Integer -> Item;    /* get item from string */
    Modify!  : String0, Integer, Item -> String0;  /* modify string */
    SubStr  : String0, Integer, Integer -> String0;
       /* SubStr(s,i,j) is string0 of length j starting at string0(i) */
    S2 : Item, Item -> String0;     S3 : Item, Item, Item -> String0;
    S4 : Item, Item, Item, Item -> String0;
    S6 : Item, Item, Item, Item, Item, Item -> String0;
    S8 : Item, Item, Item, Item, Item, Item, Item, Item -> String0;
 /* axioms  continued on next page... */

endgenerator String0;
```


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Package macsorts 3107_a\String0(31)



```
/* String0 axioms  */
/*   for all item0,item1,item2,item3,item4,item5,item6,item7 in Item(
     for all s, s1, S2, S3 in String0(     for all i, j in Integer(
     constructors are Emptystring, MkString, and "//";
      equalities between constructor terms
        s // Emptystring == s;          Emptystring // s == s;
        (s1 // S2) // S3 == s1 // (S2 // S3);
      definition of Length by applying it to all constructors
          type String Length(Emptystring) == 0;
          type String Length(MkString(item0)) == 1;
          type String Length(s1 // S2) == Length(s1) + Length(S2);
      definition of Extract! by applying it to all constructors,
        Extract!(MkString(item0), 0) == item0;
        i < Length(s1) ==> Extract!(s1 // S2, i) == Extract!(s1, i);
        i >= Length(s1) ==> Extract!(s1 // S2, i) == Extract!(S2, i - Length(s1));
        i < 0 or i >= Length(s) ==> Extract!(s, i) == error!;
      definition of First and Last by other operations
        First(s) == Extract!(s, 0);
        Last(s) == Extract!(s, Length(s) - 1);
      definition of substr(s,i,j) by induction on j,
        i >= 0 and i <= Length(s) ==> SubStr(s, i, 0) == Emptystring;
        i >= 0 and j > 0 and i + j <= Length(s) ==> SubStr(s, i, j) ==
                SubStr(s, i, j - 1) // MkString(Extract!(s, i + j - 1));
        i < 0 or j < 0 or i + j > Length(s) ==> SubStr(s, i, j) == error!;
      definition of Modify!, Head, Tail, Sx by other operations
        Modify!(s, i, item0) == SubStr(s, 0, i) // MkString(item0) //
            SubStr(s, i + 1, Length(s) - i - 1);
        head(s) == SubStr(s, 0, Length(s) - 1);
        Tail(s) == SubStr(s, 1, Length(s) - 1);
        S2(item0, item1) == MkString(item0) // MkString(item1);
        S3(item0, item1, item2) ==
          MkString(item0) // MkString(item1) // MkString(item2);
        S4(item0, item1, item2, item3) ==
          MkString(item0) // MkString(item1) // MkString(item2) //
            MkString(item3);
        S6(item0, item1, item2, item3, item4, item5) ==
          MkString(item0) // MkString(item1) // MkString(item2) //
            MkString(item3) // MkString(item4) // MkString(item5);
        S8(item0, item1, item2, item3, item4, item5, item6, item7) ==
          MkString(item0) // MkString(item1) // MkString(item2) //
            MkString(item3) // MkString(item4) // MkString(item5) //
            MkString(item6) // MkString(item7); )));
*/
```

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Package macsorts 3108_d\Bitstring(31)



```
/*****************************************************************
 *       ASN.1-style BIT sort    (from Z.105, Annex A)
 *****************************************************************/
   /* Bit is a subtype of Boolean -- bit values 0 and 1 are
   /* not numerals and cannot be used with Integer operators */
newtype Bit   inherits Boolean
   literals  0 = false,  1 = true;   operators all;   endnewtype Bit;
```

```
/*****************************************************************
 *       ASN.1-style BIT STRING sort    (adapted from Z.105, Annex A)
 *****************************************************************/
/* Bitstrings are 0-origin strings of Bit.  Z.105 uses ASN.1-style */
/* literals in binary ('1011'B) or hexadecimal ('D3'H), but this */
/* syntax is not accepted for Z.100 string literals.  Therefore, */
/* this version provides only hexadecimal literals 0x00-0xFF. */
/* Bitstring operators '=>', 'not', 'and', 'or', and 'xor' act */
/* bitwise, with the length of the result string equal to the */
/* length of the longest (or only) source string. */
newtype Bitstring String0(Bit, '')
  adding  literals     macro Hex_Literals;
  operators
    "not" : Bitstring -> Bitstring;
    "and" : Bitstring, Bitstring -> Bitstring;
    "or"  : Bitstring, Bitstring -> Bitstring;
    "xor" : Bitstring, Bitstring -> Bitstring;
    "=>"  : Bitstring, Bitstring -> Bitstring;     noequality;
  axioms     macro Hex_Axioms;
    for all s, s1, S2, S3 in Bitstring(
      s = s == true;      s1 = S2 == S2 = s1;
      s1 /= S2 == not (s1 = S2);      s1 = S2 == true ==> s1 == S2;
      ((s1 = S2) and (S2 = S3)) ==> s1 = S3 == true;
      ((s1 = S2) and (S2 /= S3)) ==> s1 = S3 == false;
      for all b, b1, b2 in Bit(
        not ('') == '';
        not (MkString(b) // s) == MkString(not (b)) // not (s);
        '' and '' == '';
        Length(s) > 0 ==> '' and s == MkString(0) and s;
        Length(s) > 0 ==> s and '' == s and MkString(0);
        (MkString(b1) // s1) and (MkString(b2) // S2) ==
          MkString(b1 and b2) // (s1 and S2);
        s1 or S2 == not (not s1 and not S2);
        s1 xor S2 == (s1 or S2) and not (s1 and S2);
        s1 => S2 == not (not s1 and S2);));
  map  for all b1, b2 in Bitstring literals(
     for all bs1, bs2 in Charstring literals(
/* connection to the String generator */
       for all b in Bit literals(
          spelling(b1) = "" // bs1 // bs2 // "",
         spelling(b2) = "" // bs2 // "",  spelling(b) = bs1
           ==> b1 == MkString(b) // b2; )));
endnewtype Bitstring;
```


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Package macsorts 3109_d\Octetstring(31)



```
/*****************************************************************
 *       OCTET sort    (influenced by Z.105, Annex A)
 *****************************************************************/
/* Octet is a subtype of Bitstring where length always =8. */
/* Z.105 adds a "size" keyword to SDL and defines Octet with */
/* "... constants size (8) ..." to impose this length constraint. */
/* Here Octet relies on proper use maintain lengths as multiples */
/* of 8.  Proper length strings are created by the hexadecimal */
/* Bitstring literals (e.g. 0xD5) and operator mkOctet: */
/*    o:= mkOctet(i)    converts a non-negative Integer (mod 256) */
/*                              to an Octet (exactly 8 bits) */
/*    i:= octetVal(o)    converts an Octet to an Integer (0:255) */
/*    o:= flip(o)    reverses bit order of the Octet */
/*                              (0<-->7, 1<-->6, 2<-->5, 3<-->4) */
newtype Octet   inherits Bitstring   operators all;
  adding  operators
    mkOctet  : Integer -> Octet;
    octetVal : Octet -> Integer;
    flip     : Octet -> Octet;
  axioms
    for all i in Integer(     for all z in Octet(
        i = 0 ==> mkOctet(i) == S8(0, 0, 0, 0, 0, 0, 0, 0);
        i = 1 ==> mkOctet(i) == S8(1, 0, 0, 0, 0, 0, 0, 0);
        i > 1 and i <= 255 ==> mkOctet(i) ==
           SubStr((First(mkOctet(i mod 2)) // mkOctet(i / 2)), 0, 8);
        i > 255 ==> mkOctet(i) == mkOctet(i mod 256);
        i < 0 ==> mkOctet(i) == error!;
        z = MkString(0) ==> octetVal(z) == 0;
        z = MkString(1) ==> octetVal(z) == 1;
        Length(z) > 1 and Length(z) <= 8 ==>
           octetVal(z) == octetVal(First(z)) +
              (2 * (octetVal(SubStr(z, 1, Length(z) - 1))));
        Length(z) > 8 ==> octetVal(z) == error!;
        flip(z) == S8(z(7),z(6),z(5),z(4),z(3),z(2),z(1),z(0)); ));
endnewtype Octet;
```

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Package macsorts 3109.1_a\Octetstring(31)



```
/*****************************************************************
 *       OCTET STRING sort    (somewhat influenced by Z.105, Annex A)
 *****************************************************************/
/* Octetstrings are 0-ORIGIN strings of Octet, NOT 1-ORIGIN */
/* strings like Octet_String in Z.105 (hence the name change). */
/* Octetstring has conversion operators to and from Bitstring, */
/* and integer to Octetstring.  Octetstring literals are "null" */
/* and 1-4, 6, 8 item 0x00 strings O1, O2, O3, O4, O6, O8. */
newtype Octetstring String0(Octet, null)
 adding  literals O1, O2, O3, O4, O6, O8;
 operators
   B_S  : Octetstring -> Bitstring;    /* name changed from Z.105 */
   O_S  : Bitstring -> Octetstring;    /* name changed from Z.105 */
   mkOS : Integer,Integer -> Octetstring; /* mkOS(i1,i2) returns */
                  /* mkstring(mkOctet(i1)) padded (0x00) to length i2 */
   mk2octets : Integer -> Octetstring;    /* 16-bit int to 2-octets */
 axioms
   for all b, b1, b2 in Bitstring(
     for all s in Octetstring(     for all o in Octet(
        B_S(null) == null;          O_S(null) == null;
        B_S(MkString(o) // s) == o // B_S(s);
        Length(b1) > 0, Length(b1) < 8 ==>
          O_S(b1) == MkString(b1 or 0x00);  /* expand b1 to 8 bits */
        b == b1 // b2, Length(b1) = 8 ==>
          O_S(b) == MkString(b1) // O_S(b2);
        for all i, k in Integer(
          k = 1 ==> mkOS(i, k) == MkString(mkOctet(i));
          k > 1 ==> mkOS(i, k) == mkOS(i, k - 1) // MkString(0x00);
          k <= 0 ==> error!;
          mk2octets(i) == MkString(mkOctet(i mod 256)) //
            MkString(mkOctet(i / 256)); );
        O1 == MkString(0x00);     O2 == O1 // O1;
        O3 == O2 // O1;           O4 == O2 // O2;
        O6 == O4 // O2;           O8 == O4 // O4; )));
 map  for all O1, O2 in Octetstring literals(
     for all b1, b2 in Bitstring literals(
        spelling(O1) =  spelling(b1),  spelling(O2) =  spelling(b2)
         ==> O1 = O2 == b1 = b2; ));
endnewtype Octetstring;
```


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Package macsorts 3110_d\MacAddr(31)



```
/*********************************************************************
 *       MAC Address sorts
 *********************************************************************/
/* MacAddr is a subtype of Octetstring with added operators: */
/*    isGroup(m) =true if given a group address */
/*    isBcst(m)  =true if given the broadcast address */
/*    isLocal(m) =true if given a locally-administered address */
/*    adrOs(m)   converts MacAddr to Octetstring */
/* MAC addresses must be defined to be exactly 6 octets long, */
/* typically using the S6 operator or nullAddr synonym. */
newtype MacAddr   inherits Octetstring   operators all;
  adding  operators
    isGroup : MacAddr -> Boolean;
    isBcst  : MacAddr -> Boolean;
    isLocal : MacAddr -> Boolean;
    adrOs   : MacAddr -> Octetstring;
  axioms
    for all m in MacAddr(
      (Length(m) = 6) and ((Extract!(m,0) and 0x01) = 0x01) ==> isGroup(m) == true;
      (Length(m) = 6) and ((Extract!(m,0) and 0x01) = 0x00) ==> isGroup(m) == false;
      (Length(m) = 6) and (m = S6(0xFF,0xFF,0xFF,0xFF,0xFF,0xFF)) ==> isBcst == true;
      (Length(m) = 6) and (m /= S6(0xFF,0xFF,0xFF,0xFF,0xFF,0xFF)) ==> isBcst == false;
      (Length(m) = 6) and ((Extract!(m,0) and 0x02) = 0x02) ==> isLocal == true;
      (Length(m) = 6) and ((Extract!(m,0) and 0x02) = 0x00) ==> isLocal == false;
      Length(m) /= 6 ==> error! /* common error! term */;
      for all o in Octetstring(m = MacAddr!(o) == adrOs(m) = o; ));
endnewtype MacAddr;
newtype MacAddrSet   powerset( MacAddr)   endnewtype MacAddrSet;
synonym bcstAddr  MacAddr =    /* Broadcast Address */
          <<type MacAddr>>  S6(0xFF,0xFF,0xFF,0xFF,0xFF,0xFF);
synonym nullAddr  MacAddr =    /* Null Address */
          << type MacAddr>>  S6(0x00,0x00,0x00,0x00,0x00,0x00);
```

```
/*********************************************************************
 *       BSS description sorts
 *********************************************************************/
   /* BssDscr is used with MlmeScan.confirm and MlmeJoin.request */
newtype BssDscr  struct
   bdBssId    MacAddr;
   bdSsId    Octetstring;    /* 1 <= length <= 32 */
   bdType    BssType;
   bdBcnPer    TU;    /* beacon period in Time Units */
   bdDtimPer    Integer;    /* DTIM period in beacon periods */
   bdTstamp    Octetstring;    /* 8 Octets from ProbeRsp/Beacon */
   bdStartTs    Octetstring;    /* 8 Octets TSF when rx Tstamp */
   bdPhyParms    PhyParms;    /* empty if not needed by PHY */
   bdCfParms    CfParms;    /* empty if not CfPollable/no PCF */
   bdIbssParms    IbssParms;    /* empty if infrastructure BSS */
   bdCap    Capability;    /* capability information */
   bdBrates    Ratestring;    /* BSS basic rate set */
endnewtype BssDscr;
newtype BssDscrSet   powerset( BssDscr)   endnewtype BssDscrSet;
```

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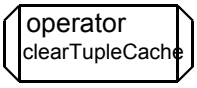
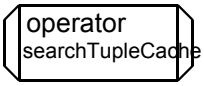
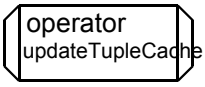
Package macsorts 3111_d\TupleCache(31)



```
/*****************************************************************
 *       Duplicate filtering support sorts
 *****************************************************************/
syntype FragNum = Integer    /* Range of possible fragment numbers */
       constants 0:sMaxFragNum  endsyntype FragNum;
syntype SeqNum = Integer    /* Range of possible sequence numbers */
       constants 0:4095  endsyntype SeqNum;
newtype Tuple  struct    /* for duplicate filtering & defragmentation */
   full    Boolean;    /* =true if Tuple contains valid info */
   ta    MacAddr;    /* transmitting station address (Addr2) */
   sn    SeqNum;    /* Msdu/Mmpdu sequence number */
   fn    FragNum;    /* most recent Mpdu fragment number */
   tRx    Time;    /* reception time (endRx of fragment) */
  default (. false, nullAddr, 0, 0, 0 .);
endnewtype Tuple;
```








```
/*****************************************************************
 *       TupleCache support sorts
 *****************************************************************/
   /* Number of TupleCache entries and associated index range */
synonym tupleCacheSize Integer = 32;    /* this value is an example,
                    TupleCache size is implementation dependent */
syntype CacheIndex = Integer  constants 1:tupleCacheSize
  endsyntype CacheIndex;
/* TupleCache array */
/*    cache:= ClearTupleCache(cache)  to initialize cache */
/*    cache:= UpdateTupleCache(cache, addr, seq, frag, endRx) */
/*       if <addr,seq> is already cached, updates frag */
/*       if <addr,seq> not cached, fills an empty entry */
/*             or replaces an entry using an unspecified algorithm */
/*    SearchTupleCache(cache, addr, seq, frag) */
/*             returns true if specified <addr,seq,frag> in cache */
newtype TupleCache  Array( CacheIndex, Tuple);
  adding  operators
    ClearTupleCache  : TupleCache -> TupleCache;
    SearchTupleCache : TupleCache, MacAddr, SeqNum, FragNum -> Boolean;
    UpdateTupleCache : TupleCache, MacAddr, SeqNum, FragNum, Time ->
       TupleCache;
  operator ClearTupleCache;
    fpar cache TupleCache;  returns TupleCache;  referenced;
  operator SearchTupleCache;
    fpar cache TupleCache,  taddr MacAddr,  tseq SeqNum,  tfrag FragNum;
    returns Boolean;  referenced;
  operator UpdateTupleCache;
    fpar cache TupleCache,  taddr MacAddr,  tseq SeqNum,  tfrag FragNum,
    tnow Time;  returns TupleCache;  referenced;
endnewtype TupleCache;
```

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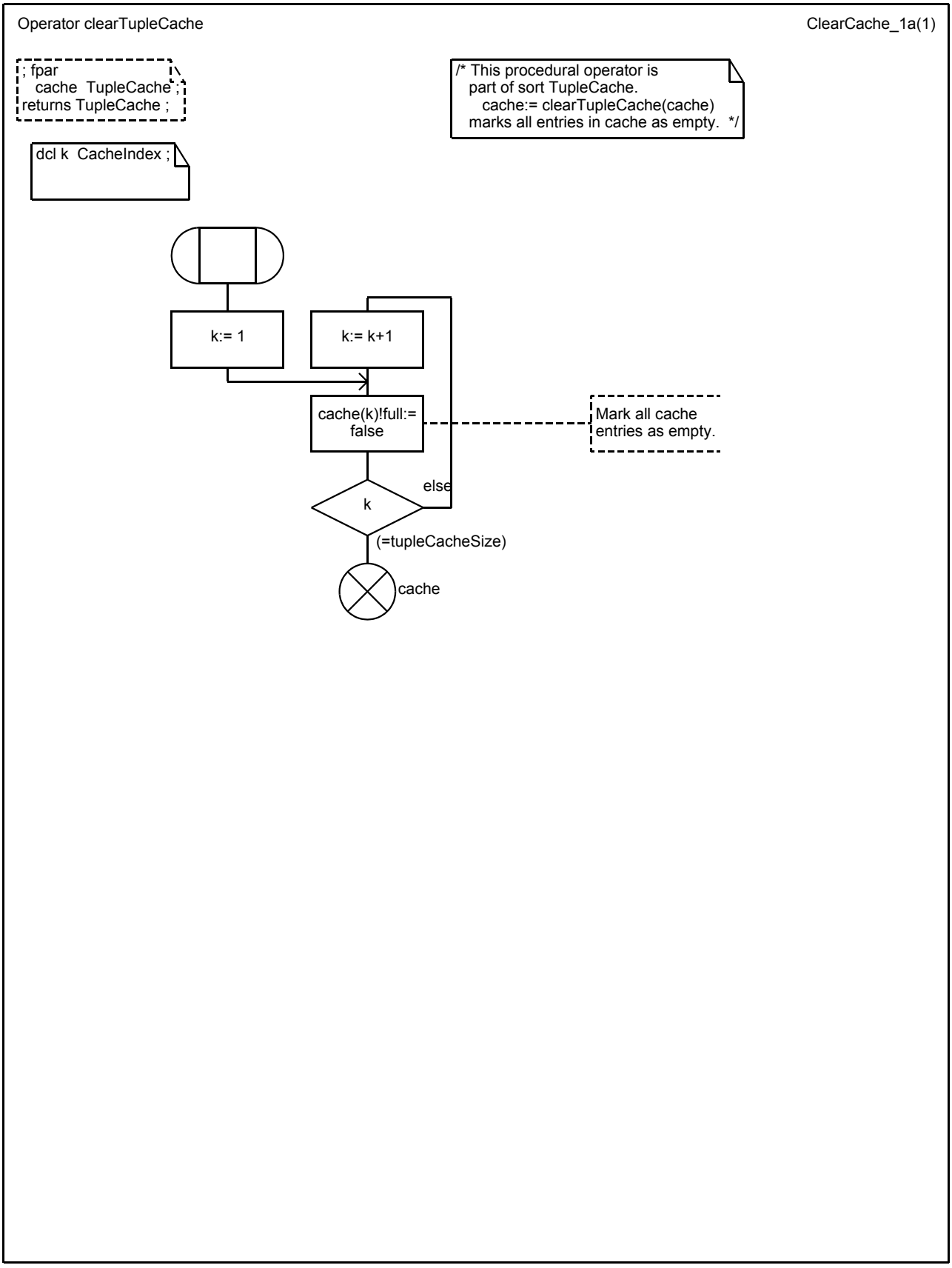

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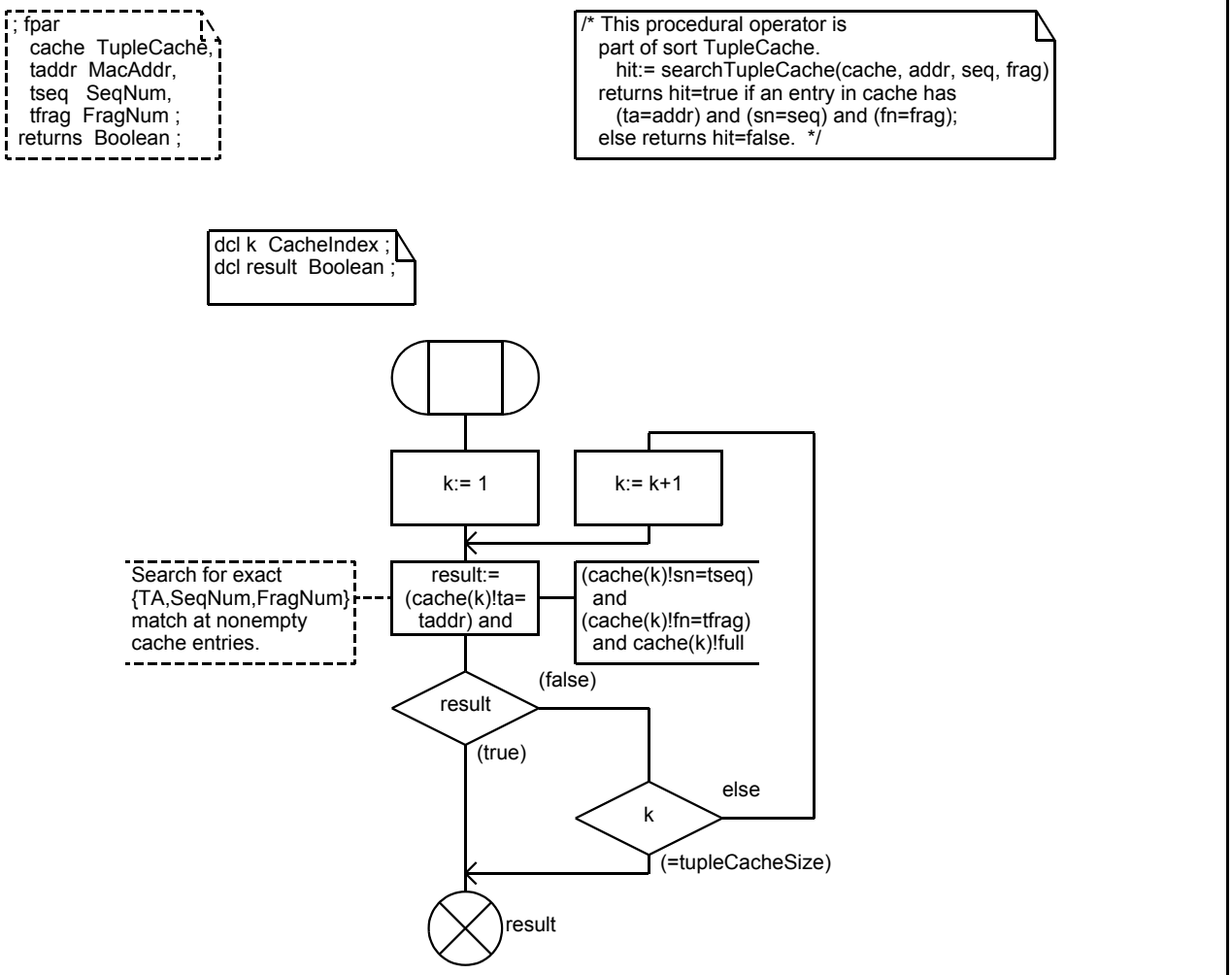
Operator searchTupleCache SearchCache_1a(1)



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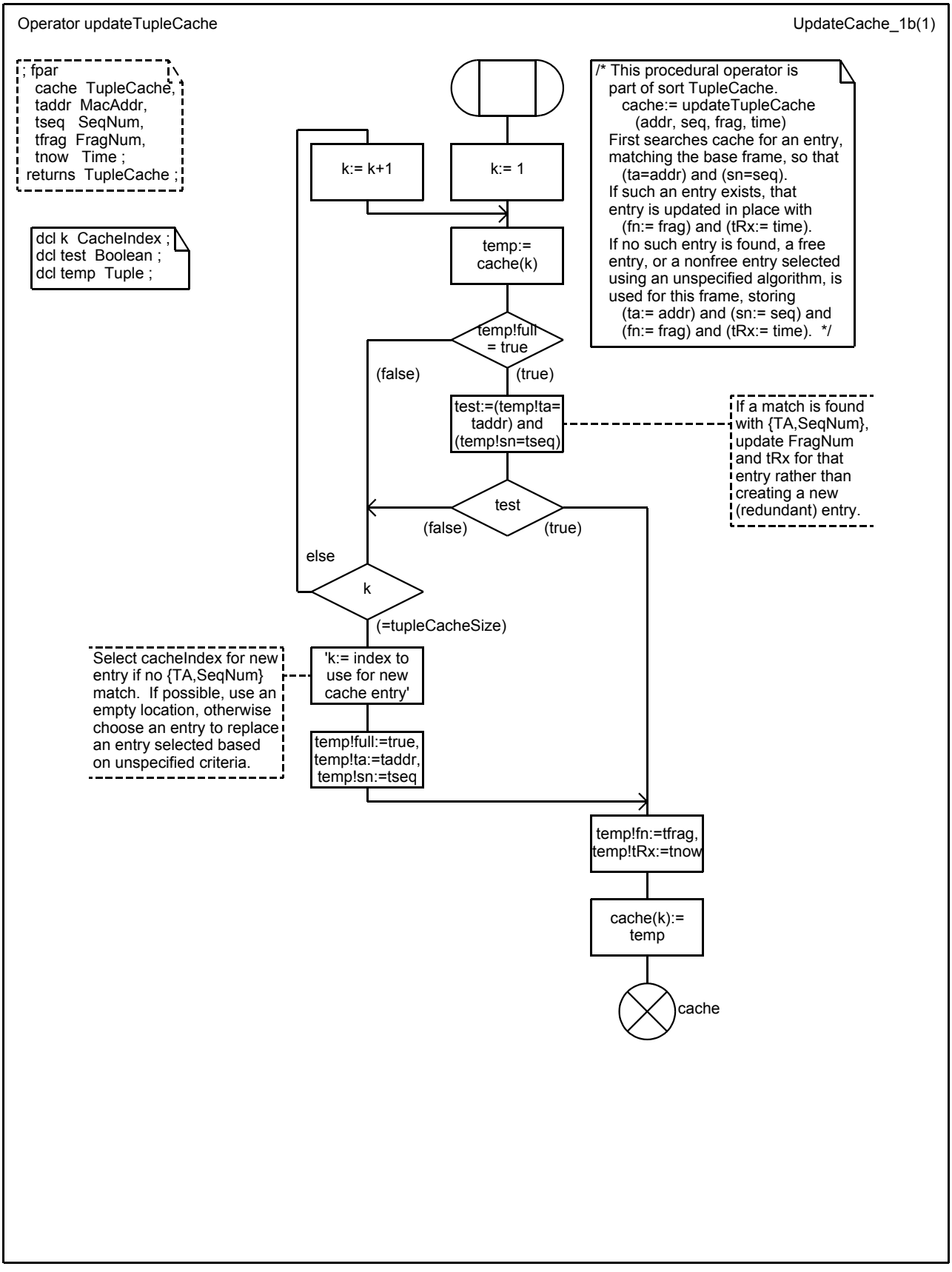

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Package macsorts 3112_d\Counter(31)



```
/*****************************************************************
 *        32-bit Counter sort and Integer string sort
 *****************************************************************/
/* This sort used for MIB counters, needed because SDL Integers */
/* have no specified maximum value.  inc(counter) increments the */
/* counter value by 1, with wraparound from (2^32)-1 to 0. */

newtype Counter32   inherits Integer   operators all;
  adding  operators
    inc : Counter32 -> Counter32;
  axioms
    for all c in Counter32 (
      c < 4294967295 ==> inc(c) == c + 1;
      c >= 4294967295 ==> inc(c) == 0; );
endnewtype Counter32;
       /* String (1-origin) of Integer */
newtype Intstring   String( Integer, noInt);   endnewtype Intstring;
```

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Package macsorts 3113_d\Queue(31)



```
/*****************************************************************
 *       Generator for Queue sorts
 *****************************************************************/
/* The Queue generator is derived from the String0 generator */
/* to create Queues of any sort.  Queues operators are: */
/*    Qfirst(queue,item)  adds item as the first queue element */
/*    Qlast(queue,item)   adds item as the last queue element */
/* and the String0 operators Length, //, First, Last, Head, Tail */
/* Because operators can only return a single value, removing an */
/* element from a queue is a 2-step process: */
/*    dequeue first:  item:=First(queue);  queue:=Tail(queue); */
/*    dequeue last:   item:=Last(queue);   queue:=Head(queue); */
generator Queue(type Item, literal Emptyqueue)
 literals Emptyqueue;
 operators
   MkQ  : Item -> Queue;    /* make a queue from an item */
   Length  : Queue -> Integer;    /* number of items on queue */
   First  : Queue -> Item;    /* first item on queue */
   Qfirst  : Queue,Item -> Queue;    /* add item as first on queue */
   Tail  : Queue -> Queue;    /* all but first item on queue */
   Last  : Queue -> Item;    /* last item on queue */
   Qlast  : Queue,Item -> Queue;    /* add item as last on queue */
   head  : Queue -> Queue;    /* all but last item on queue */
    "//"  : Queue, Queue -> Queue;    /* concatenation */
   Extract! : Queue,Integer -> Item;    /* copy item from queue */
   Modify!  : Queue,Integer,Item -> Queue; /* modify item in queue */
   SubQ  : Queue,Integer,Integer -> Queue;
          /* SubQ(q,i,j) queue of length j starting from queue(i) */
 axioms
   for all item0 in Item(     for all q, q1, q2, q3 in Queue(
      for all i, j in Integer(
   /* constructors are Emptyqueue, MkQueue, and "//"; */
   /* equalities between constructor terms */
        q // Emptyqueue == q;          Emptyqueue // q == q;
        (q1 // q2) // q3 == q1 // (q2 // q3);
   /* definition of Length by applying it to all constructors */
         type Queue Length(Emptyqueue) == 0;
         type Queue Length(MkQueue(item0)) == 1;
         type Queue Length(q1 // q2) == Length(q1) + Length(q2);
   /* definition of Extract! by applying it to all constructors, */
        Extract!(MkQueue(item0), 0) == item0;
        i < Length(q1) ==> Extract!(q1 // q2, i) == Extract!(q1, i);
        i >= Length(q1) ==> Extract!(q1 // q2, i) == Extract!(q2, i - Length(q1));
        i < 0 or i >= Length(q) ==> Extract!(q, i) == error!;
   /* definition of First and Last by other operations */
        First(q) == Extract!(q, 0);     Last(q) == Extract!(q, Length(q) - 1);
   /* definition of SubQ(q,i,j) by induction on j, */
        i >= 0 and i <= Length(q) ==> SubQ(q, i, 0) == Emptyqueue;
        i >= 0 and j > 0 and i + j <= Length(q) ==> SubQ(q, i, j) ==
           SubQ(q, i, j - 1) // MkQueue(Extract!(q, i + j - 1));
        i < 0 or j < 0 or i + j > Length(q) ==> SubQ(q,i,j) == error!;
   /* define Modify!, Head, Tail, Qfirst, Qlast by other ops */
        Modify!(q, i, item0) == SubQ(q, 0, I) //
           MkQueue(item0) // SubQ(q, i + 1, Length(q) - i - 1);
        head(q) == SubQ(q, 0, Length(q) - 1);
        Tail(q) == SubQ(q, 1, Length(q) - 1);
        Qfirst(q, item0) == MkQueue(item0) // q;
        Qlast(q, item0) == q // MkQueue(item0); )));
endgenerator Queue;
```

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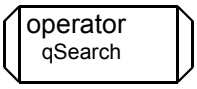
Package macsorts 3114_d\Fragment(31)






```
/*****************************************************************
 *       Fragmentation support sorts
 *****************************************************************/
/* Array to hold up to FragNum fragments of an Msdu/Mmpdu */
newtype FragArray  Array(FragNum, Frame);   endnewtype FragArray;
/* FragSdu structure is for OUTGOING MSDUs/MMPDUs (called SDUs) */
/* Each SDU, even if not fragmented, is held in an instance of */
/* this structure awaiting its (re)transmission attempt(s). */
/* Transmit queue(s) are ordered lists of FragSdu instances. */
newtype FragSdu struct
   fTot    FragNum;    /* number of fragments in pdus FragArray */
   fCur    FragNum;    /* next fragment number to send */
   fAnc    FragNum;    /* next fragment to announce in ATIM or TIM
                          when fAnc > fCur, pdus(fCur)+ may be sent */
   eol    Time;    /* set to (now + dUsec(aMaxTxMsduLifetime))
                          when the entry is created */
   sqf    SeqNum;    /* SDU sequence number, set at 1st Tx attempt */
   src    Integer;    /* short retry counter for this SDU */
   lrc    Integer;    /* long retry counter for this SDU */
   dst    MacAddr;    /* destinaton address */
   grpa    Boolean;    /* =true if RA (not DA) is a group address */
   psm    Boolean;    /* =true if RA (not DA) may be in pwr_save */
   resume    Boolean;    /* =true if fragment burst being resumed */
   cnfTo    PId;    /* address to which confirmation is sent */
   txrate    Rate;    /* data rate used for initial fragment */
   cf    CfPriority;    /* requested priority (from LLC) */
   pdus    FragArray;    /* array of Frame to hold fragments */
endnewtype FragSdu;
/* Queue of FragSdu */
/* for power save buffers, etc., searchable with Qsearch operator: */
/*    index:= Qsearch(queue, addr)     where queue is an SduQueue, */
/* index identifies the first queue entry at which */
/* entry!dst = addr; or as -1 if no match (or queue empty). */
newtype SduQueue Queue(FragSdu, emptyQ);
  adding  operators
    qSearch : SduQueue, MacAddr -> Integer;
  operator qSearch;
    fpar que SduQueue,  val MacAddr;  returns Integer; referenced;
endnewtype SduQueue;
```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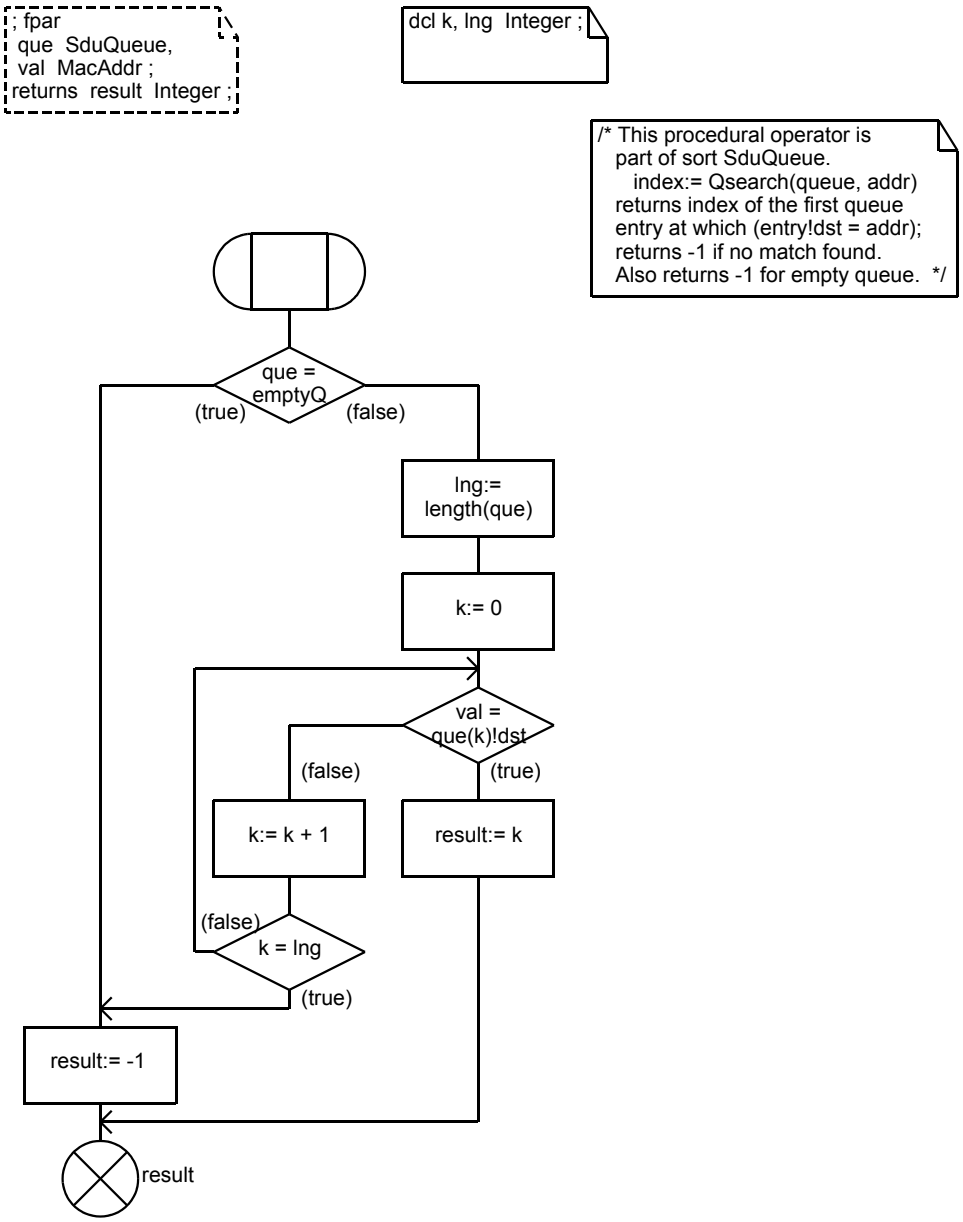
Operator Qsearch Qsearch_1a(1)



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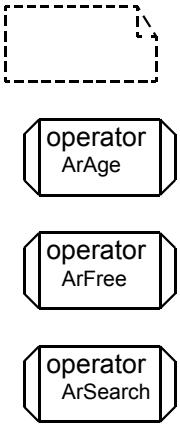
Package macsorts 3115_d\Defragment(31)




```
/*********************************************************************
 *       Defragmentation support sorts
 *********************************************************************/
/* The PartialSdu structure is for INCOMPLETE MSDUs/MMPDUs */
/* (generically SDUs) for which at least 1 fragment has been */
/* received.  Unfragmented SDUs are reported upward immediately, */
/* and are never stored in instances of this structure.  */
newtype PartialSdu struct
    inUse    Boolean;    /* =true if this instance holds any fragments */
    rta    MacAddr;    /* transmitting station (Addr2) */
    rsn    SeqNum;    /* SDU sequence number */
    rCur    FragNum;    /* fragment number of most recent Mpdu */
    reol    Time;    /* (now+dUsec(aMaxReceiveLifetime) @ 1st Mpdu */
    rsdu    Frame;    /* buffer where Mpdus are concatenated */
  default (. false, nullAddr, 0, 0, 0, null .);
endnewtype PartialSdu;
newtype PartialSduKeys struct  /* if aPrivacyOptionImplemented=true */
    wDefKeys    KeyVector;    /* default keys when 1st frag received */
    wKeyMap    KeyMapArray;    /* key mappings when 1st frag received */
    wExclude    Boolean;    /* aExcludeUnencrypted @ 1st frag rx */
endnewtype PartialSduKeys;
/* Number of entries in defragmentation array at this station. */
/* The value is implementation dependent (min=3, see 9.5). */
synonym defragSize Integer = 6;
syntype defragIndex = Integer   constants 1:defragSize
endsyntype defragIndex;
/* Array of PartialSdu for use defragmenting Msdus and Mmpdus. */
/* Searchable using the ArSearch operator */
/*    index:= ArSearch(array, addr, seq, frag) */
/* where index is returned to identify the first element for which */
/* ((inUse = true) and (entry!rta = addr) and (entry!rsn = seq) */
/*  and (entry!rCur = (frag-1));   or as =1 if no match found. */
/*    index:= ArFree(array)    returns the index of a free entry, */
/* or -1 if no entries free.  May free an entry, selected using */
/* an unspecified algorithm, to avoid returning -1. */
/*    array:= ArAge(array, age) */
/* frees where (entry!eol < age), also used to clear array. */
newtype DefragArray  Array( defragIndex, PartialSdu);
  adding  operators
    ArSearch : DefragArray, MacAddr, SeqNum, FragNum -> Integer;
    ArFree   : DefragArray -> Integer;
    ArAge    : DefragArray, Time -> DefragArray;
  operator ArSearch;
    fpar  ar DefragArray,   adr MacAddr,   seq SeqNum,   frg FragNum;
    returns Integer; referenced;
  operator ArFree;  fpar  ar DefragArray;   returns Integer; referenced;
  operator ArAge;  fpar  ar DefragArray,   age Time;
    returns DefragArray; referenced;
endnewtype DefragArray;
newtype DefragKeysArray  Array( defragIndex, PartialSduKeys);
endnewtype DefragKeysArray;
```

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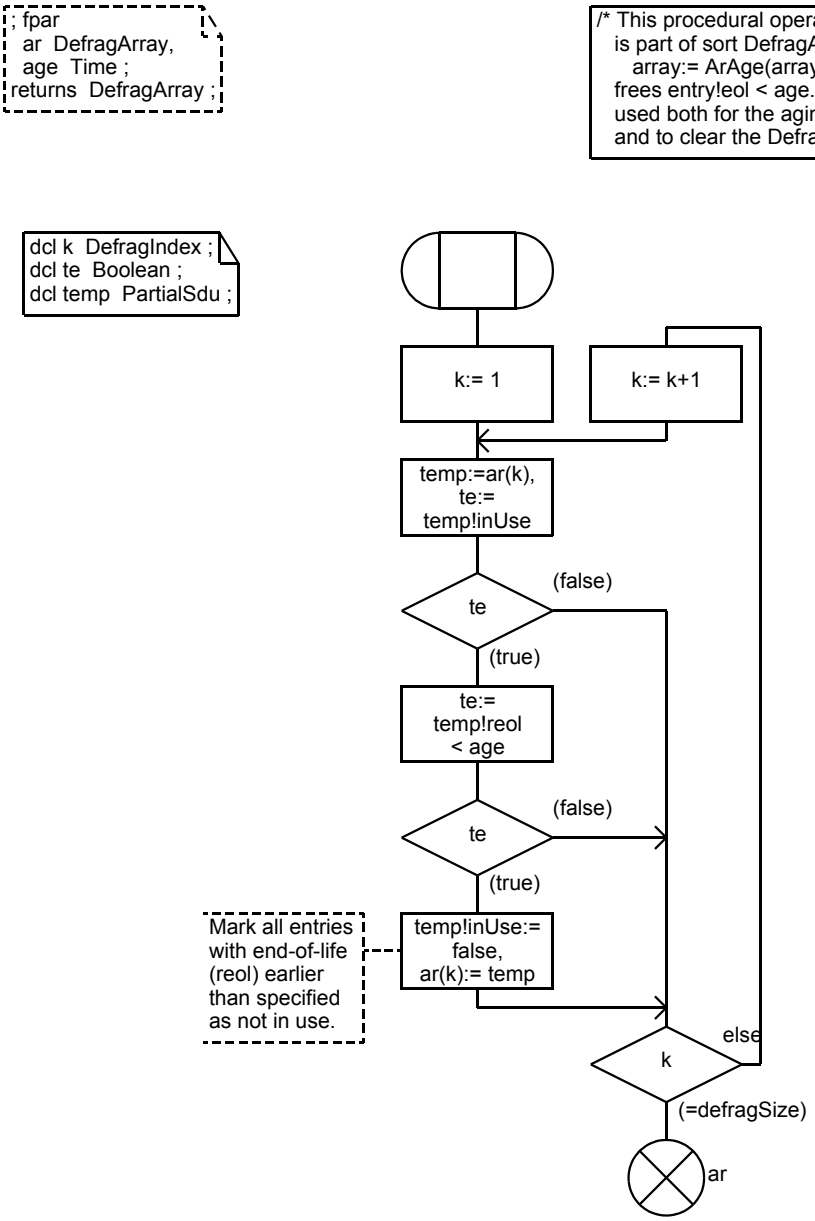
Operator ArAge ArAge_1a(1)



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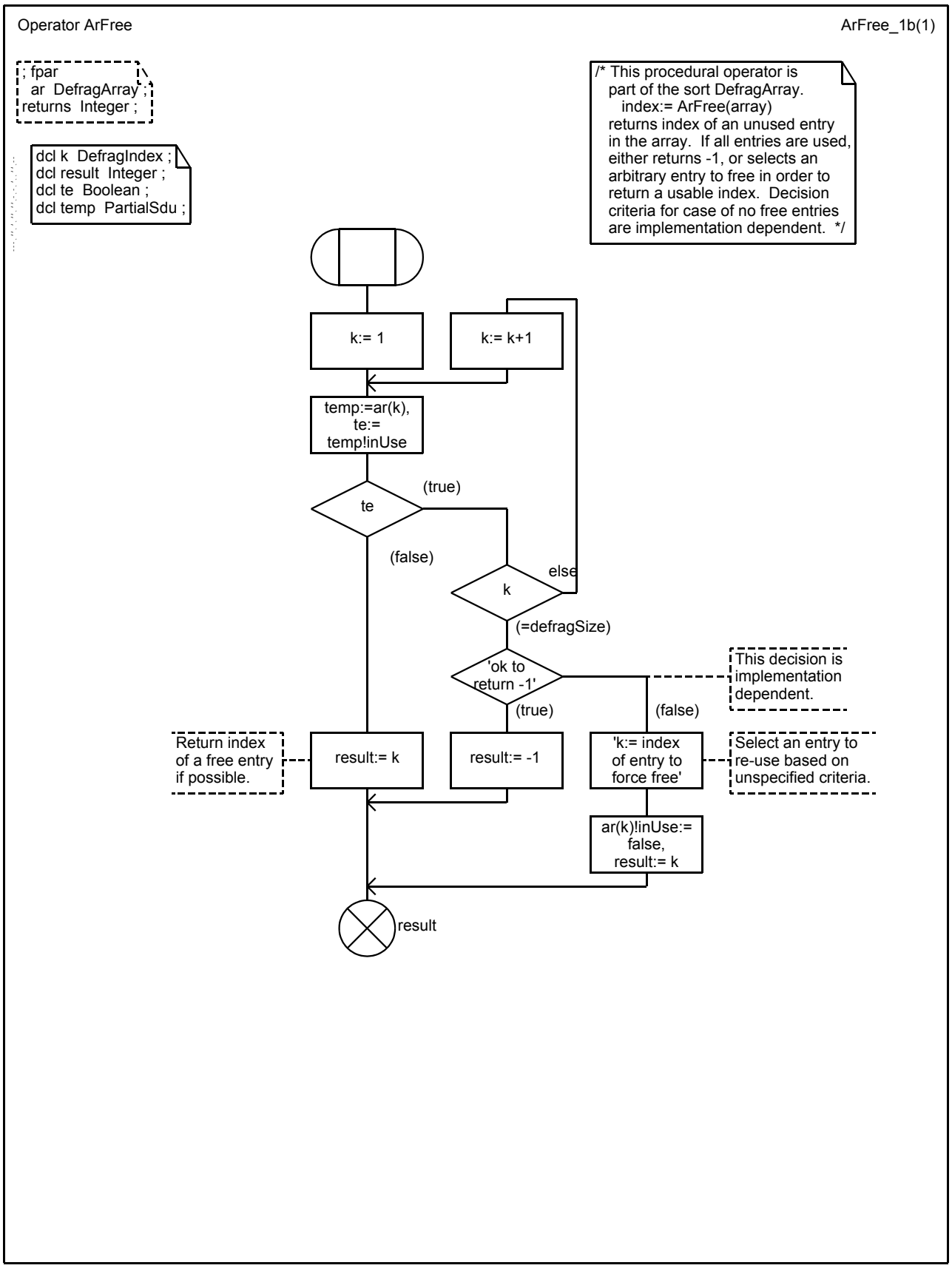

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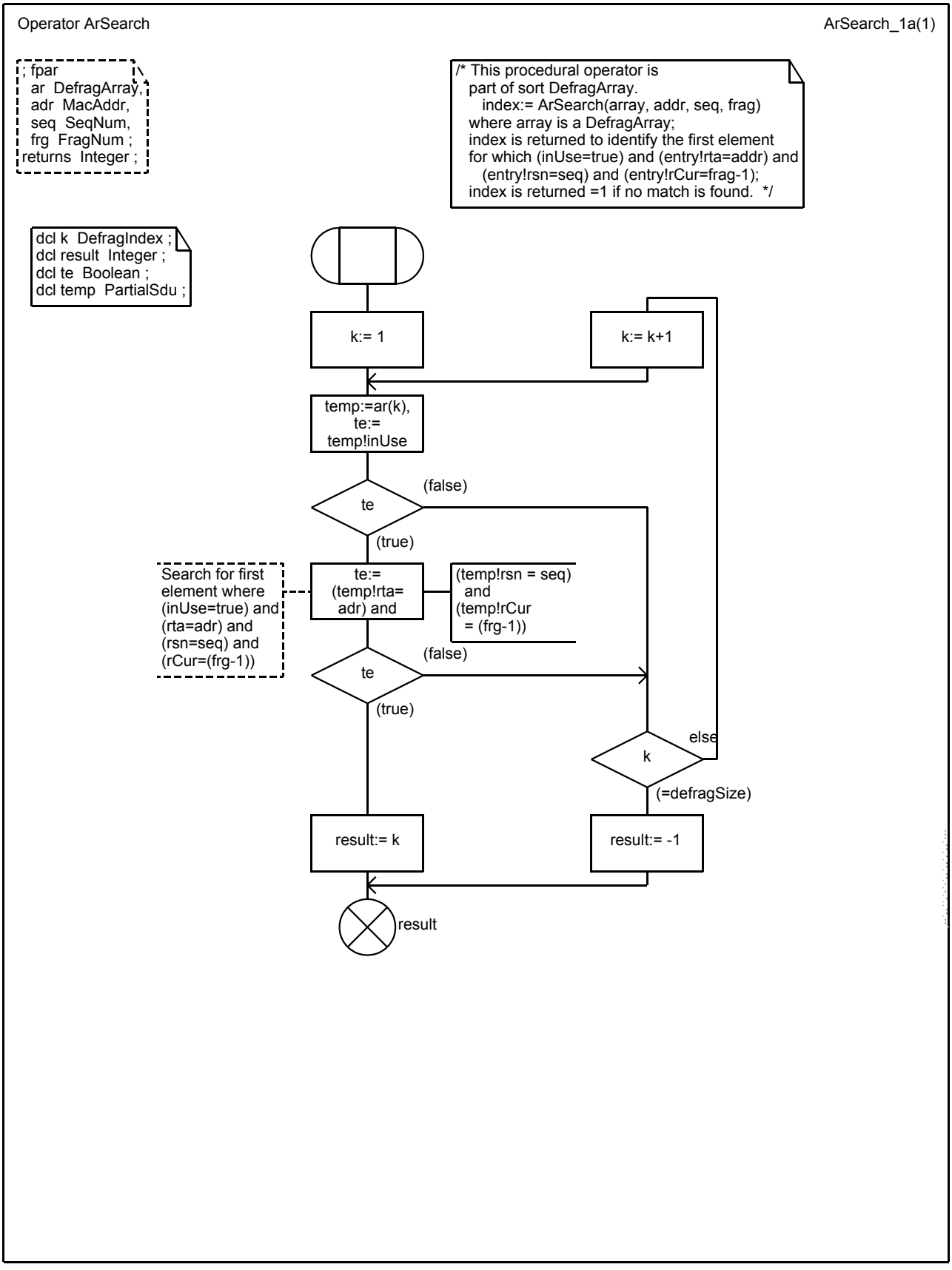

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Package macsorts 3116_d\Crc_Wep(31)



operator
crc32

```
/*********************************************************************
 *       CRC-32 sorts (for FCS and ICV)
 *********************************************************************/
/* Crc is a subtype of Octetstring with added operators: */
/*    crc:= Crc32(crc,octet) */
/* updates the crc value to include the new octet, and */
/*    Mirror(crc), which returns a Crc value with the order */
/* of the octets, and of the bits in each octet, reversed for */
/* MSb-first transmission (see 7.1.1).  Crc variables must have */
/* exactly 4 octets, which is done using initCrc or S4. */
newtype Crc   inherits Octetstring   operators all;
  adding  operators
    Crc32  : Crc, Octet -> Crc;
    mirror : Crc -> Octetstring;
  operator Crc32;  fpar crcin Crc, val Octet;  returns Crc;  referenced;
  axioms     for all c in Crc(
      mirror(c) == S4(flip(c(3)),flip(c(2)),flip(c(1)), flip(c(0))); );
endnewtype Crc;
synonym initCrc Crc =    /* Initial Crc value (all 1s) */
          << type Crc>> S4(0xFF,0xFF,0xFF,0xFF);
synonym goodCrc Crc =    /* Unique remainder for valid CRC-32 */
          << type Crc>> S4(0x7B,0xDD,0x04,0xC7);
```

operator
keyLookup

```
/*********************************************************************
 *    WEP support sorts
 *********************************************************************/
syntype KeyIndex = Integer   constants 0:3   endsyntype KeyIndex;
newtype PrngKey inherits Octetstring   operators all;
  adding literals nullKey;  /* nullKey is not any of 2^40 key values */
  axioms nullKey == null;   default nullKey;   endnewtype PrngKey;
newtype KeyVector  /* vector of default WEP keys */
  Array( KeyIndex, PrngKey);   endnewtype KeyVector;
    /* Number of entries in aWepKeyMappings array at this station.
    /* implementation dependent value, minimum=10 (see 8.3.2). */
synonym sWepKeyMappingLength Integer = 10;
syntype KeyMappingRange = Integer
    constants 1:sWepKeyMappingLength   endsyntype KeyMappingRange;
newtype KeyMap  struct    /* structure used for entries in KeyMapArray */
    mappedAddr    MacAddr;
    wepOn    Boolean;
    wepKey    PrngKey;
endnewtype KeyMap;
/* KeyMapArray -- used for aWepKeyMapping table; */
/* an array of KeyMap indexed by KeyMappingRange, with operator */
/*    KeyMap := keyLookup(addr, keyMapArray, keyMapArrayLength) */
/* returns the KeyMap entry for the specified addr, or */
/* (. nullAddr, false, nullKey .) if no mapping for addr. */
newtype KeyMapArray  Array( KeyMappingRange, KeyMap);
  adding  operators
    keyLookup : MacAddr, KeyMapArray, Integer -> KeyMap;
  operator keyLookup;
    fpar  luadr MacAddr,   kma KeyMapArray,   kml Integer;
    returns KeyMap; referenced;
endnewtype KeyMapArray;
```


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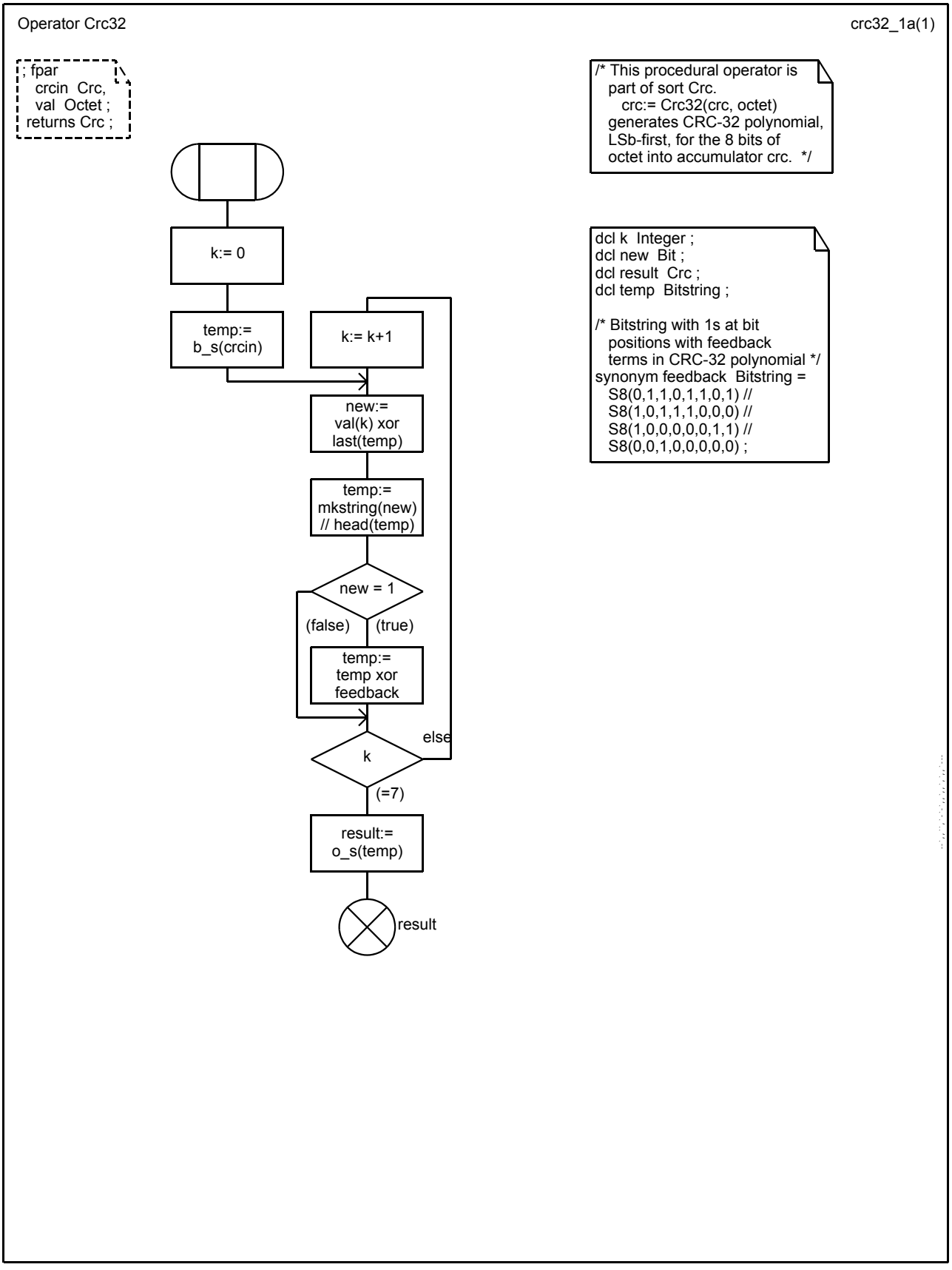
Operator Crc32 crc32_1a(1)



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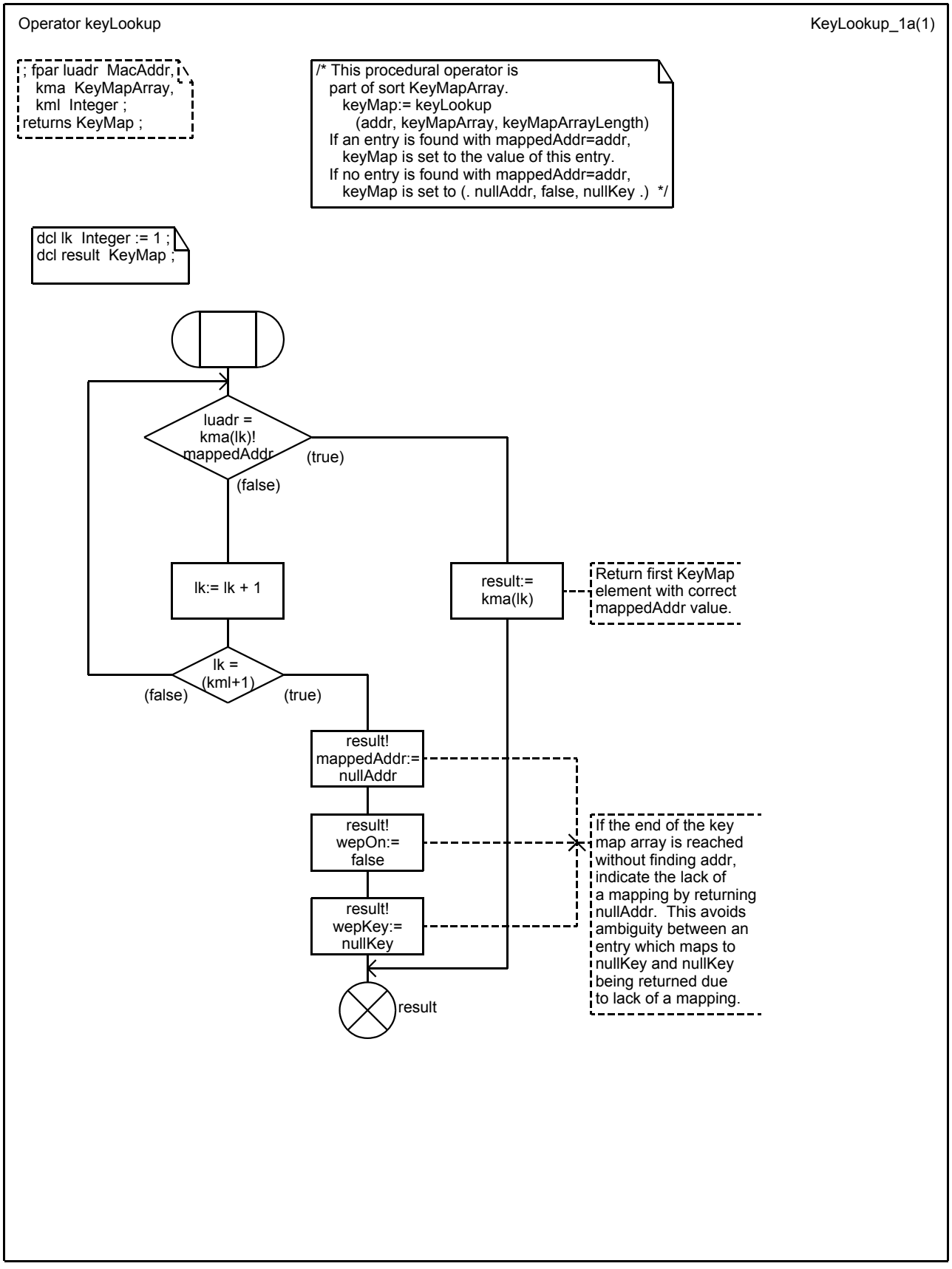

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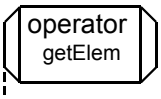
Package macsorts

3117_d\Frame_1(31)



```
/*****************************************************************
 *       FRAME sort (the basic definition of fields in MAC frames)
 *****************************************************************/
/* Frame is a subtype of Octetstring with operators for creating
/* MAC headers, extracting each of the header fields and some
/* management frame fields, and modifying most of these fields.
/* There are operators to create and extract management frame
/* elements, but no operators for the frame body, IV, ICV, and FCS
/* fields, which are handled directly as Octetstrings. */
newtype Frame   inherits Octetstring   operators all;
 adding  operators
   mkFrame  : TypeSubtype, MacAddr, MacAddr, Octetstring -> Frame;
   mkCtl  : TypeSubtype, Octetstring, MacAddr -> Frame;
   protocolVer  : Frame -> Integer;   /* Protocol version (2 bits) */
   basetype  : Frame -> BasicType;    /* Type field (2 bits) */
   ftype  : Frame -> TypeSubtype;    /* Type & Subtype (6 bits) */
   setFtype  : Frame, TypeSubtype -> Frame;
   toDs  : Frame -> Bit;    /* To DS bit (1 bit) */
   setToDs  : Frame, Bit -> Frame;
   frDs  : Frame -> Bit;    /* From DS bit (1 bit) */
   setFrDs  : Frame, Bit -> Frame;
   moreFrag  : Frame -> Bit;    /* More Fragments bit (1 bit) */
   setMoreFrag  : Frame, Bit -> Frame;
   retryBit  : Frame -> Bit;    /* Retry bit (1 bit) */
   setRetryBit  : Frame, Bit -> Frame;
   pwrMgt   : Frame -> Bit;    /* Power Management bit (1 bit) */
   setPwrMgt  : Frame, Bit -> Frame;
   moreData  : Frame -> Bit;    /* More Data bit (1 bit) */
   setMoreData  : Frame, Bit -> Frame;
   wepBit  : Frame -> Bit;    /* WEP bit (1 bit) */
   setWepBit  : Frame, Bit -> Frame;
   orderBit  : Frame -> Bit;    /* {strictly}Order{ed} (1 bit) */
   setOrderBit  : Frame, Bit -> Frame;
   durId  : Frame -> Integer;    /* Duration/ID field (2) */
   setDurId  : Frame, Integer -> Frame;
   addr1  : Frame -> MacAddr;    /* Address 1 [DA/RA] field (6) */
   setAddr1  : Frame, MacAddr -> Frame;
   addr2  : Frame -> MacAddr;    /* Address 2 [SA/TA] field (6) */
   setAddr2  : Frame, MacAddr -> Frame;
   addr3  : Frame -> MacAddr;    /* Address 3 [Bss/DA/SA] field */
   setAddr3  : Frame, MacAddr -> Frame;
   addr4  : Frame -> MacAddr;    /* Address 4 [WDS-SA] field (6) */
   insAddr4  : Frame, MacAddr -> Frame;
   seq  : Frame -> SeqNum;    /* Sequence Number (12 bits) */
   setSeq  : Frame, SeqNum -> Frame;
   frag  : Frame -> FragNum;    /* Fragment Number (4 bits) */
   setFrag  : Frame, FragNum -> Frame;
   ts  : Frame -> Time;    /* Timestamp field (8) */
   setTs  : Frame, Time -> Frame;
   mkElem  : ElementID, Octetstring -> Frame;    /* make element */
   GetElem  : Frame, ElementID -> Frame;    /* get element if aval */
   status  : Frame -> StatusCode;    /* Status Code field (2) */
   setStatus  : Frame, StatusCode -> Frame;
   authStat  : Frame -> StatusCode;    /* Status Code in Auth frame */
   reason  : Frame -> ReasonCode;    /* Reason Code field (2) */

/* Frame operators continued on next page ...*/
```



Gets element from body of Management frame. If the target element is not present an Octetstring of length zero is returned.

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Package macsorts 3118_d\Frame_2(31)



```
/* ...Frame Sort Operators continued */
  authSeqNum  : Frame -> Integer;    /* Auth Sequence Number (2) */
  authAlg  : Frame -> AuthType;    /* Auth Algorithm field (2) */
  beaconInt  : Frame -> TU;    /* Beacon Interval field (2) */
  listenInt  : Frame -> TU;    /* Listen Interval field (2) */
  AId  : Frame -> AsocId;    /* Association ID field (2) */
  setAId  : Frame, AsocId -> Frame;
  curApAddr  : Frame -> MacAddr;    /* Current AP Addr field (6) */
  capA  : Frame, Capability -> Bit;    /* Capability (Re)Asoc */
  setCapA  : Frame, Capability, Bit -> Frame;
  capB  : Frame, Capability -> Bit;    /* Capability Bcn/Probe */
  setCapB  : Frame, Capability, Bit -> Frame;
  keyId  : Frame -> KeyIndex;    /* Key ID subfield (2 bits) */
  setKeyId  : Frame, KeyIndex -> Frame;
 operator GetElem;
  fpar   fr Frame,   el ElementID;   returns Frame;   referenced;
```

```
/* Frame Sort Axioms  */
 axioms
   for all f in Frame(     for all a, sa, da, ra, ta, bssa in MacAddr(
    for all body, dur, sid, info in Octetstring(
     addr1(f) == SubStr(f,4,6);
     setAddr1(f,a) == SubStr(f,0,4) // a // SubStr(f,10,Length(f)-10);
     addr2(f) == SubStr(f,10,6);
     setAddr2(f,a) == SubStr(f,0,10) // a // SubStr(f,16,Length(f)-16);
     addr3(f) == SubStr(f,16,6);
     setAddr3(f,a) == SubStr(f,0,16) // a // SubStr(f,22,Length(f)-22);
     addr4(f) == SubStr(f,24,6);
     insAddr4(f,a) == SubStr(f,0,24) // a // SubStr(f,24,Length(f)-24);
     curApAddr(f) == SubStr(f,28,6);
      for all ft in TypeSubtype(
        mkFrame(ft, da, bssa, body) ==
           ft // O3 // da // dot11MacAddress // bssa // O2 // body;
        (ft = rts) ==> mkCtl(ft, dur, ra) ==
           ft // O1 // dur // ra // aStationID;
        (ft = ps_poll) ==> mkCtl(ft, sid, bssa) ==
           ft // O1 // sid // bssa // aStationID;
        (ft = cts) or (ft = ack) ==> mkCtl(ft, dur, ra) ==
           ft // O1 // dur // ra;
        (ft = cfend) or (ft = cfend_ack) ==> mkCtl(ft, bssa, ra) ==
           ft // O3 // ra // bssa;
        ftype(f) == MkString(f(0) and 0xFC);
        setFtype(f, ft) == Modify!(f, 0, MkString((f(0) and 0x03) or
           ft)); );
      for all bt in BasicType(   basetype(f) == f(0) and 0x0C;   );
      for all i in Integer(
        protocolVer(f) == octetVal(f(0) and 0x03);
        authSeqNum(f) == octetVal(f(26)) + (octetVal(f(27)) * 256);
        durId(f) == octetVal(f(2)) + (octetVal(f(3)) * 256);
        setDurId(f, i) == SubStr(f, 0, 2) // mkOS(i mod 256, 1) //
           mkOS(i / 256, 1) // SubStr(f, 4, Length(f) - 4); );
      for all e in ElementID(
        mkElem(e, info) == e // mkOS(Length(info) + 2, 1) // info; );

/* Frame Sort Axioms continued on next page ... */
```


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Package macsorts 3119_d\Frame_3(31)



```
/*  ... Frame Sort  Axioms continued */
      for all b in Bit(
        toDs(f) == if (f(1) and 0x01) then 1 else 0 fi;
        setToDs(f, b) ==
            Modify!(f, 1, (f(1) and 0xFE) or S8(0,0,0,0,0,0,0,b));
        frDs(f) == if (f(1) and 0x02) then 1 else 0 fi;
        setFrDs(f, b) ==
            Modify!(f, 1, (f(1) and 0xFD) or S8(0,0,0,0,0,0,b,0));
        moreFrag(f) == if (f(1) and 0x04) then 1 else 0 fi;
        setMoreFrag(f, b) ==
            Modify!(f, 1, (f(1) and 0xFB) or S8(0,0,0,0,0,b,0,0));
        retryBit(f) == if (f(1) and 0x08) then 1 else 0 fi;
       setRetryBit(f, b) ==
            Modify!(f, 1, (f(1) and 0xF7) or S8(0,0,0,0,b,0,0,0));
        pwrMgt(f) == if (f(1) and 0x10) then 1 else 0 fi;
        setPwrMgt(f, b) ==
            Modify!(f, 1, (f(1) and 0xFB) or S8(0,0,0,b,0,0,0,0));
        moreData(f) == if (f(1) and 0x20) then 1 else 0 fi;
        setMoreData(f, b) ==
            Modify!(f, 1, (f(1) and 0xFB) or S8(0,0,b,0,0,0,0,0));
        wepBit(f) == if (f(1) and 0x40) then 1 else 0 fi;
        setWepBit(f, b) ==
            Modify!(f, 1, (f(1) and 0xFB) or S8(0,b,0,0,0,0,0,0));
        orderBit(f) == if (f(1) and 0x80) then 1 else 0 fi;
        setOrderBit(f, b) ==
            Modify!(f, 1, (f(1) and 0xFB) or S8(b,0,0,0,0,0,0,0));
        for all c in Capability(
         capA(f,c) == if (B_S(SubStr(f,24,2)) and c) then 1 else 0 fi;
         setCapA(f,c,b) == SubStr(f,0,24) // (B_S(SubStr(f,24,2) and
             (not c)) or (if b then c else O2 fi)) //
             SubStr(f,26,Length(f) - 26);
        capB(f,c) == if (B_S(SubStr(f,34,2)) and c) then 1 else 0 fi;
         setCapB(f,c,b) == SubStr(f,0,34) // (B_S(SubStr(f,34,2) and
             (not c)) or (if b then c else O2 fi)) //
             SubStr(f,36,Length(f) - 36); ));
      for all sq in SeqNum(
        seq(f) == (octetVal(f(22) and 0xF0)/16)+(octetVal(f(23)*16));
        setSeq(f, sq) == SubStr(f, 0, 22) // MkString((f(22) and 0x0F)
            or mkOctet((sq mod 16) * 16)) // mkOS(sq / 16, 1) //
            SubStr(f, 24, Length(f) - 24); );
      for all fr in FragNum(
        frag(f) == octetVal(f(22) and 0x0F);
        setFrag(f, fr) ==
            SubStr(f, 0, 22) // MkString((f(22) and 0xF0) or
            mkOctet(fr)) // SubStr(f, 23, Length(f) - 23); );
      for all tm in Time(
        ts(f) == tUsec( Usec!(octetVal(f(24)) +
            (256 * (octetVal(f(25)) +
              (256 * (octetVal(f(26)) +
                (256 * (octetVal(f(27)) +
                  (256 * (octetVal(f(28)) +
                    (256 * (octetVal(f(29)) +
                      (256 * (octetVal(f(30)) +
                        (256 * octetVal(f(31))))))))))))))) ) );

/*  Frame Sort Axioms continued on next page ... */
```

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Package macsorts 3120_d\Frame_4(31)



```
/*  ... Frame Sort Axioms continued  */
        setTs(f, tm) == SubStr(f, 0, 24) // mkOS(fix(tm), 1) //
            mkOS((fix(tm) / 256), 1) // mkOS((fix(tm) / 65536), 1) //
            mkOS((fix(tm) / 16777216), 1) //
            mkOS((fix(tm) / 4294967296), 1) //
            mkOS(((fix(tm) / 4294967296) / 256), 1) //
            mkOS(((fix(tm) / 4294967296) / 65536), 1) //
            mkOS(((fix(tm) / 4294967296) / 16777216), 1) //
            SubStr(f, 32, Length(f) - 32); );
      for all stat in StatusCode(
        status(f) == SubStr(f, 26, 2);
        setStatus(f, stat) ==
            SubStr(f, 0, 26) // stat // SubStr(f, 28, Length(f) - 28);
        authStat(f) == SubStr(f, 28, 2); );
      for all rea in ReasonCode(   reason(f) == SubStr(f, 24, 2);   );
      for all alg in AuthType(   AuthType(f) == SubStr(f, 24, 2);   );
     for all u in TU(
        beaconInt(f) == octetVal(f(32)) + (octetVal(f(33)) * 256);
        listenInt(f) == octetVal(f(26)) + (octetVal(f(27)) * 256); );
      for all sta in AssocId(
        AId(f) == octetVal(f(28)) + (octetVal(f(29)) * 256);
        setAId(f, sta) == SubStr(f, 0, 28) // mkOS(sta mod 256, 1) //
            mkOS(sta / 256, 1) // SubStr(f, 30, Length(f) - 30); );
      for all kid in KeyIndexRange(
        keyId(f) == octetVal(f(27)) / 64;
        setKeyId(f, kid) == Modify!(f, 27, mkOS(kid * 64)); );   )));
endnewtype Frame;
```

```
/*************************************************************************
 *       ReasonCode sort
 *************************************************************************/
newtype ReasonCode   inherits Octetstring   operators all;
 adding  literals unspec_reason,   auth_not_valid,   deauth_lv_ss,
   inactivity,   ap_overload,   class2_err,   class3_err,
   disas_lv_ss,   asoc_not_auth;
 axioms
   unspec_reason == mkOS(1, 2);    auth_not_valid == mkOS(2, 2);
   deauth_lv_ss == mkOS(3, 2);    inactivity == mkOS(4, 2);
   ap_overload == mkOS(5, 2);    class2_err == mkOS(6, 2);
   class3_err == mkOS(7, 2);    disas_lv_ss == mkOS(8, 2);
   asoc_not_auth == mkOS(9, 2);
endnewtype ReasonCode;
```

```
/*************************************************************************
 *       StatusCode sort
 *************************************************************************/
newtype StatusCode   inherits Octetstring   operators all;
 adding  literals successful,   unspec_fail,   unsup_cap,
   reasoc_no_asoc,   fail_other, unsupt_alg, auth_seq_fail,
   chlng_fail,   auth_timeout,   ap_full,   unsup_rate;
 axioms
   successful == mkOS(0, 2);    unspec_failure == mkOS(1, 2);
   unsup_cap == mkOS(10, 2);    reasoc_no_asoc == mkOS(11, 2);
   fail_other == mkOS(12, 2);    unsupt_alg == mkOS(13, 2);
   auth_seq_fail == mkOS(14, 2);    chlng_fail == mkOS(15, 2);
   auth_timeout == mkOS(16, 2);    ap_full == mkOS(17, 2);
   unsup_rate == mkOS(18, 2);
   no_short_preamble == mkOS(19, 2);
   no_Pbcc == mkOS(20, 2);
   no_agility == mkOS(21, 2);
endnewtype StatusCode;
```


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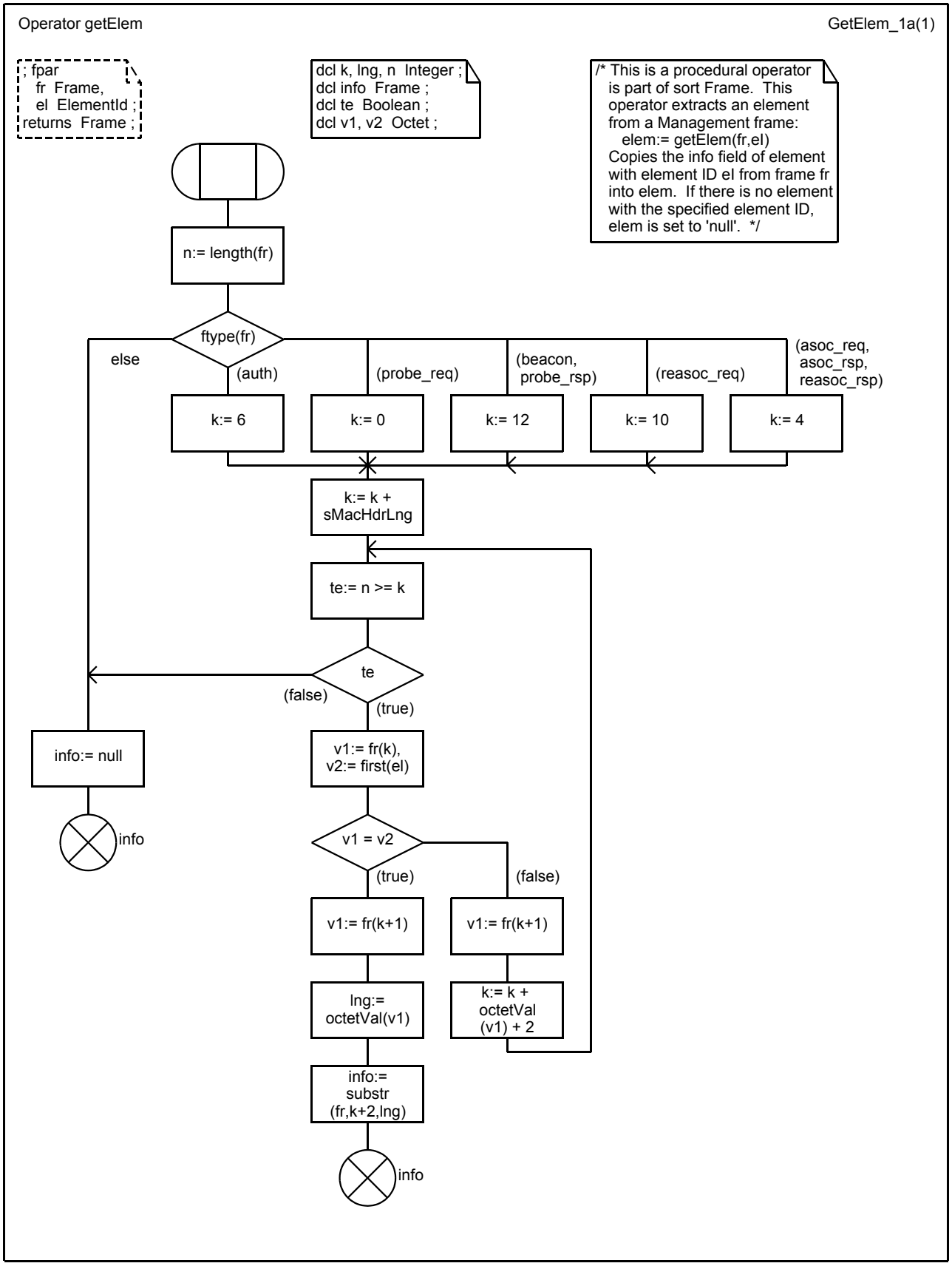

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Package macsorts 3121_d\FrameType(31)



```
/*****************************************************************
 *       Frame Type sorts
 *****************************************************************/
/* TypeSubtype defines the full, 6-bit frame type identifiers. */
/* These values are useful with ftype operator of Frame sort. */
newtype TypeSubtype   inherits Octetstring   operators all;
 adding  literals  asoc_req,  asoc_rsp,  reasoc_req,  reasoc_rsp,
   probe_req,  probe_rsp,  beacon,  atim,  disasoc,  auth,  deauth,
   ps_poll,  rts,  cts,  ack,  cfend,  cfend_ack,  data,  data_ack,
   data_poll,  data_poll_ack,  null_frame,  cfack,  cfpoll,  cfpoll_ack;
 axioms
   asoc_req == MkString(S8(0,0,0,0,0,0,0,0));
   asoc_rsp == MkString(S8(0,0,0,0,1,0,0,0));
   reasoc_req == MkString(S8(0,0,0,0,0,1,0,0));
   reasoc_rsp == MkString(S8(0,0,0,0,1,1,0,0));
   probe_req == MkString(S8(0,0,0,0,0,0,1,0));
   probe_rsp == MkString(S8(0,0,0,0,1,0,1,0));
   beacon == MkString(S8(0,0,0,0,0,0,0,1));
   atim == MkString(S8(0,0,0,0,1,0,0,1));
   disasoc == MkString(S8(0,0,0,0,0,1,0,1));
   auth == MkString(S8(0,0,0,0,1,1,0,1));
   deauth == MkString(S8(0,0,0,0,0,0,1,1));
   ps_poll == MkString(S8(0,0,1,0,0,1,0,1));
   rts == MkString(S8(0,0,1,0,1,1,0,1));
   cts == MkString(S8(0,0,1,0,0,0,1,1));
   ack == MkString(S8(0,0,1,0,1,0,1,1));
   cfend == MkString(S8(0,0,1,0,0,1,1,1));
   cfend_ack == MkString(S8(0,0,1,0,1,1,1,1));
   data == MkString(S8(0,0,0,1,0,0,0,0));
   data_ack == MkString(S8(0,0,0,1,1,0,0,0));
   data_poll == MkString(S8(0,0,0,1,0,1,0,0));
   data_poll_ack == MkString(S8(0,0,0,1,1,1,0,0));
   null_frame == MkString(S8(0,0,0,1,0,0,1,0));
   cfack == MkString(S8(0,0,0,1,1,0,1,0));
   cfpoll == MkString(S8(0,0,0,1,0,1,1,0));
   cfpoll_ack == MkString(S8(0,0,0,1,1,1,1,0));
endnewtype TypeSubtype;
/* BasicTypes defines the 2-bit frame type groups */
newtype BasicType   inherits Bitstring   operators all;
 adding  literals   control,   data,   management,   reserved;
 axioms
   control == S8(0,0,1,0,0,0,0,0);    data == S8(0,0,0,1,0,0,0,0);
   management == S8(0,0,0,0,0,0,0,0);    reserved == S8(0,0,1,1,0,0,0,0);
endnewtype BasicType;
```

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Package macsorts 3122_d\MgmtFields(31)



```
/*********************************************************************
 *       ElementID sort
 *********************************************************************/
newtype ElementID   inherits Octetstring   operators all;
 adding  literals eSsId,  eSupRates,  eFhParms,  eDsParms,
   eCfParms,  eTim,  eIbParms,  eCtext;
 axioms
   eSsId == mkOS(0, 1);  /* service set identifier (0:32) */
   eSupRates == mkOS(1, 1);  /* supported rates (1:8) */
   eFhParms == mkOS(2, 1);  /* FH parameter set (5) */
   eDsParms == mkOS(3, 1);  /* DS parameter set (1) */
   eCfParms == mkOS(4, 1);  /* CF parameter set (6) */
   eTim == mkOS(5, 1);  /* Traffic Information Map (4:254) */
   eIbParms == mkOS(6, 1);  /* IBSS parameter set (2) */
   eCtext == mkOS(16, 1); /* challenge text (128, see 8.1.2.2) */
   eCountry == mkOS(7, 1); /* Country Information (8:254) */
   eHopParm == mkOS(8, 1); /* FH Hopping Parameters (4) */
   eHopTable == mkOS(9, 1); /* FH Hopping Table (6:254) */
   eRequest == mkOS(10, 1); /* Request (3:254) */
endnewtype ElementID;
```

```
/*********************************************************************
 *       Capability field bit assignments sort
 *********************************************************************/
newtype Capability   inherits Bitstring   operators all;
 adding  literals cEss, cIbss, cPollable, cPollReq, cPrivacy;
 axioms
   cEss == S8(1,0,0,0,0,0,0,0) // 0x00;    /* ESS capability */
   cIbss == S8(0,1,0,0,0,0,0,0) // 0x00;    /* IBSS capability */
   cPollable == S8(0,0,1,0,0,0,0,0) // 0x00;    /* CF-pollable (sta), PC present (ap) */
   cPollReq == S8(0,0,0,1,0,0,0,0) // 0x00;    /* not CF poll req (sta), PC polls (ap) */
   cPrivacy == S8(0,0,0,0,1,0,0,0) // 0x00;    /* WEP required */
   cShortPreamble == S8(0,0,0,0,0,1,0,0) // 0x00;    /* Short Preamble */
   cPBCC == S8(0,0,0,0,0,0,1,0) // 0x00;    /* PBCC */
   cChannelAgility == S8(0,0,0,0,0,0,0,1) // 0x00;    /* Channel Agility */
   cShortPreamble == S8(0,0,0,0,0,0,1,0,0) // 0x00;    /* Short Preamble */
endnewtype Capability;
```

```
/*********************************************************************
 *       IBSS parameter set sort
 *********************************************************************/
newtype IbssParms   inherits Octetstring   operators all;
 adding  operators
   atimWin : IbssParms -> TU;
   setAtimWin : IbssParms, TU -> IbssParms;
 axioms
   for all ib in IbssParms(     for all u in TU(
      atimWin(ib) == octetVal(ib(0)) + (octetVal(ib(1)) * 256);
      setAtimWin(ib, u) == mkOS(u mod 256, 1) // mkOS(u / 256, 1); ));
endnewtype IbssParms;
```

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Package macsorts 3123_d\CF_And_AsocParams(31)



```
/*****************************************************************
 *       CF parameter set sort
 *****************************************************************/
newtype CfParms   inherits Octetstring   operators all;
 adding  operators
   cfpCount  : CfParms -> Integer; /* CfpCount field (1) */
   setCfpCount  : CfParms, Integer -> CfParms;
   cfpPeriod  : CfParms -> Integer; /* CfpPeriod field (1) */
   setCfpPeriod  : CfParms, Integer -> CfParms;
   cfpMaxDur  : CfParms -> TU;    /* CfpMaxDuration field (2) */
   setCfpMaxDur  : CfParms, TU -> CfParms;
   cfpDurRem  : CfParms -> TU;    /* CfpDurRemaining field (2) */
   setCfpDurRem  : CfParms, TU -> CfParms;
 axioms   for all cf in CfParms(   for all i in Integer(   for all u in TU(
        cfpCount(cf) == octetVal(cf(0));
        setCfpCount(cf, i) == mkOS(i, 1) // Tail(cf);
        cfpPeriod(cf) == octetVal(cf(1));
        setCfpPeriod(cf, i) == cf(0) // mkOS(i, 1) // SubStr(cf,2,4);
        cfpMaxDur(cf) == octetVal(cf(2)) + (octetVal(cf(3)) * 256);
        setCfpMaxDur(cf, u) == SubStr(cf, 0, 2) // mkOS(u mod 256, 1)
           // mkOS(u / 256, 1) // SubStr(cf, 4, 2);
        cfpDurRem(cf) == octetVal(cf(4)) + (octetVal(cf(5)) * 256);
        setCfpDurRem(cf, u) == SubStr(cf, 0, 4) // mkOS(u mod 256, 1)
           // mkOS(u / 256, 1); )));
endnewtype CfParms;
```

operator
AIdLookup

```
/*****************************************************************
 *       Sorts for association management at AP
 *****************************************************************/
synonym sMaxAId Integer = 2007;  /* 2007 is largest allowable value */
                          /* implementation limit may be lower */
syntype AsocId = Integer   constants 0:sMaxAId   endsyntype AsocId;
      /* Station Association Record -- only used at APs */
newtype AsocData struct
   adAddr    MacAddr;    /* address of associated station */
   adPsm     PwrSave;    /* power save mode of the station */
   adCfPoll  Boolean;    /* true if station is CfPollable */
   adPollRq  Boolean;    /* true if station requested polling */
   adNoPoll  Boolean;    /* true if station requested no polling */
   adMsduIP  Boolean;    /* true if partial Msdu outstanding to sta */
   adAuth    AuthType;   /* authentication type used by station */
   adRates   RateSet;    /* supported rates from association request */
   adAge     Time;    /* time of association */
endnewtype AsocData;
/* Association table -- array of AsocData, only used at APs */
/*    index:= AIdLookup(table, addr) */
/* returns the index of location where table(x)!adAddr=addr */
/* or 0 if no such location found. */
newtype AIdTable   Array(AsocId, AsocData);
 adding  operators
   AIdLookup : AIdTable, MacAddr -> AsocId;
 operator AIdLookup;
   fpar tbl AIdTable,   val MacAddr;   returns AsocId;   referenced;
endnewtype AIdTable;
```

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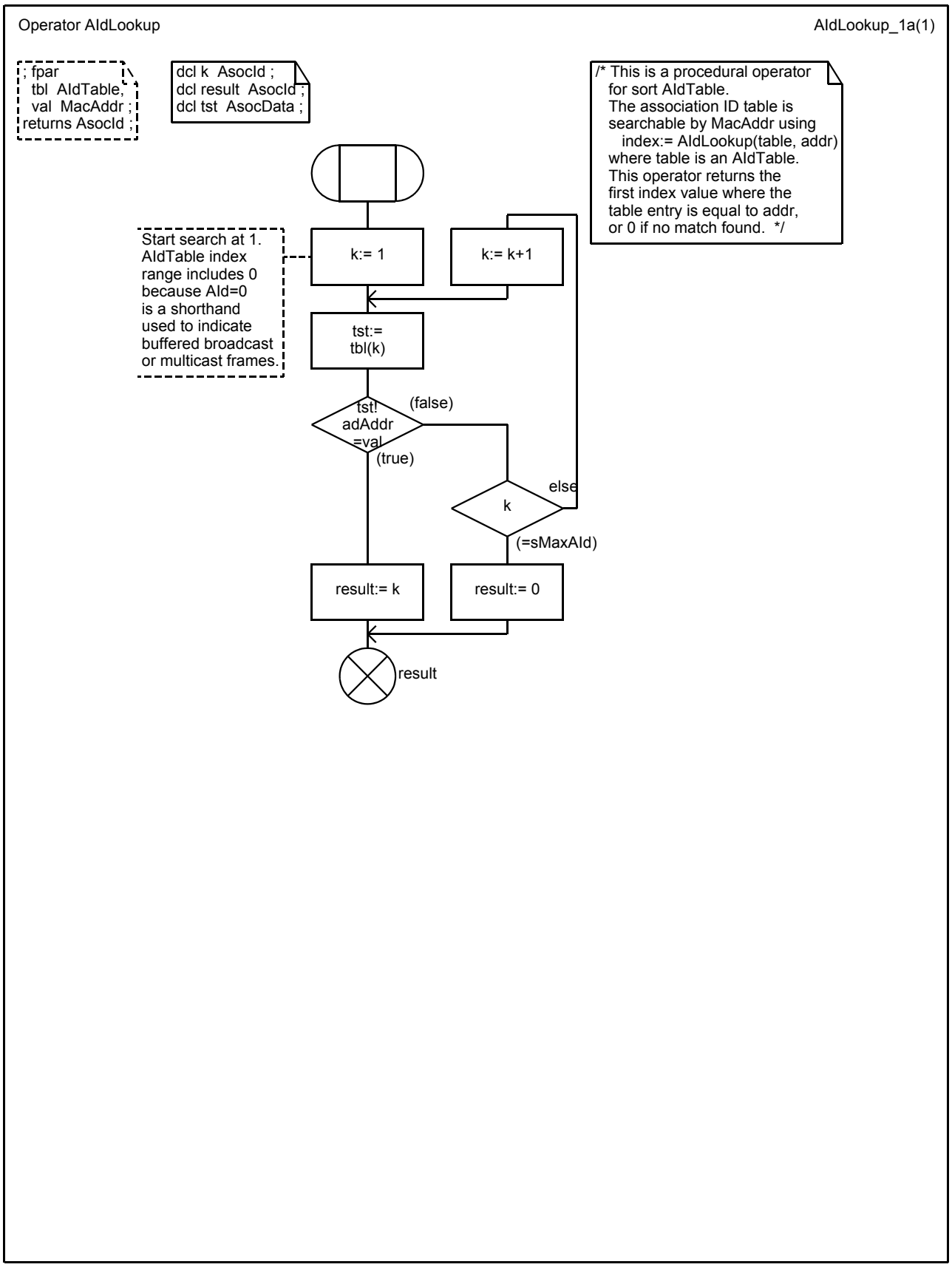

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Package macsorts 3124_d\TIM(31)



operator
mkTim

operator
nextAId

```
/*****************************************************************
 *       Traffic Information Map (TIM) support sorts
 *****************************************************************/
/* TrafficMap is an Array of Bit indexed by AId. */
/* Bits =1 in TrafficMap denote the presence of buffered frame(s) */
/* for the station assigned that AId.  TrafficMap operators are: */
/*    mkTim(trafficMap, dtimCnt, dtimPer, lowAId, highAId, bcst) */
/* returns Octetstring to use as the info field of a TIM element */
/* The TIM will contain bits =1 for TrafficMap locations in the */
/* range (lowAId):(highAId).  Buffered broadcasts and multicasts */
/* (AId 0) are indicated if dtimCnt=0 and if bcst=true. */
/*    nextAId(trafficMap, currentAId) */
/* returns index greater than currentAId at which TrafficMap=1. */
/* If no locations before sMaxAId are =1, returns 0. */
newtype TrafficMap  Array( AsocId, Bit);
 adding  operators
   mkTim : TrafficMap, Integer, Integer, AsocId, AsocId, Boolean -> Octetstring;
   nextAId : TrafficMap, AsocId -> AsocId;
 operator mkTim;
   fpar trf TrafficMap,  dtc Integer,  dtp Integer,  xlo AsocId,
   xhi AsocId,  bc Boolean;  returns Octetstring;  referenced;
 operator nextAId;
   fpar trf TrafficMap,  x AsocId;  returns AsocId;  referenced;
endnewtype TrafficMap;
/* TIM is a subtype of Octetstring with operators: */
/*    bufFrame(tim,AId)   returns true if the TIM info field */
/*       (obtained using getElem) is =1 at tim(AId). */
/*    bufBcst(tim)   returns true if the TIM info field */
/*       indicates buffered broadcast/multicast traffic */
/*    dtCount(tim)   returns DTIM count value from TIM */
/*    dtPeriod(tim)  returns DTIM period value from TIM */
newtype TIM   inherits Octetstring   operators all;
 adding  operators
   bufFrame : TIM, AsocId -> Boolean;
   bufBcst  : TIM -> Boolean;
   dtCount  : TIM -> Integer;
   dtPeriod : TIM -> Integer;
 axioms
   for all el in TIM(     for all a in AsocId(
     bufFrame(el, a) ==
       if a < (octetVal(el(2) and 0xFE) * 8) then false
         else
         if a >= ((octetVal(el(2) and 0xFE)*8) + ((Length(el)-3)*8))
           then false
           else
             Extract!(B_S(el), (a-(octetVal(el(2) and 0xFE)*8)+24)) = 1
         fi fi;
     bufBcst(el) == (el(2) and 0x01) = 0x01;
     dtCount(el) == octetVal(el(0));
     dtPeriod(el) == octetVal(el(1)); ));
endnewtype TIM;
```


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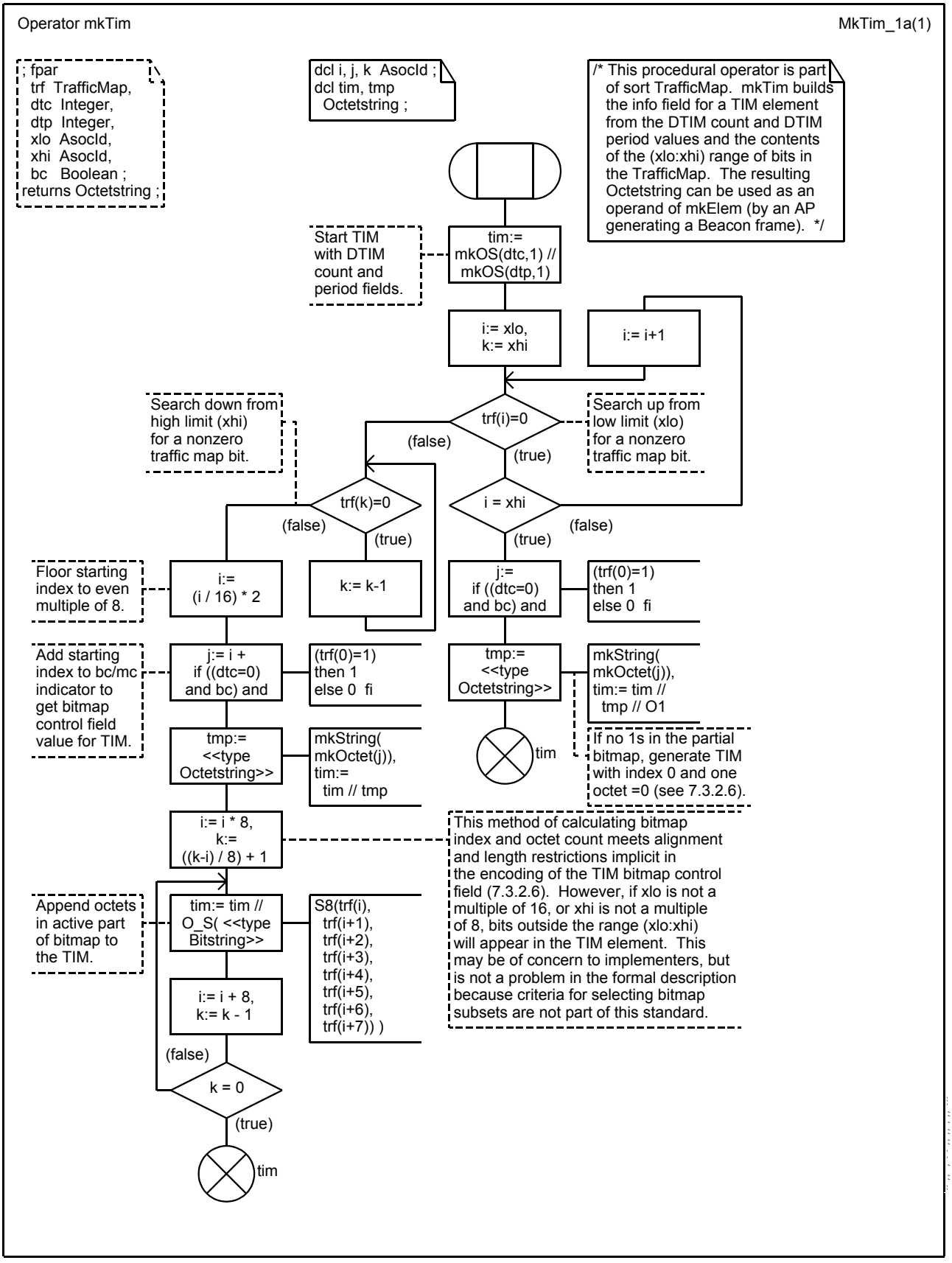

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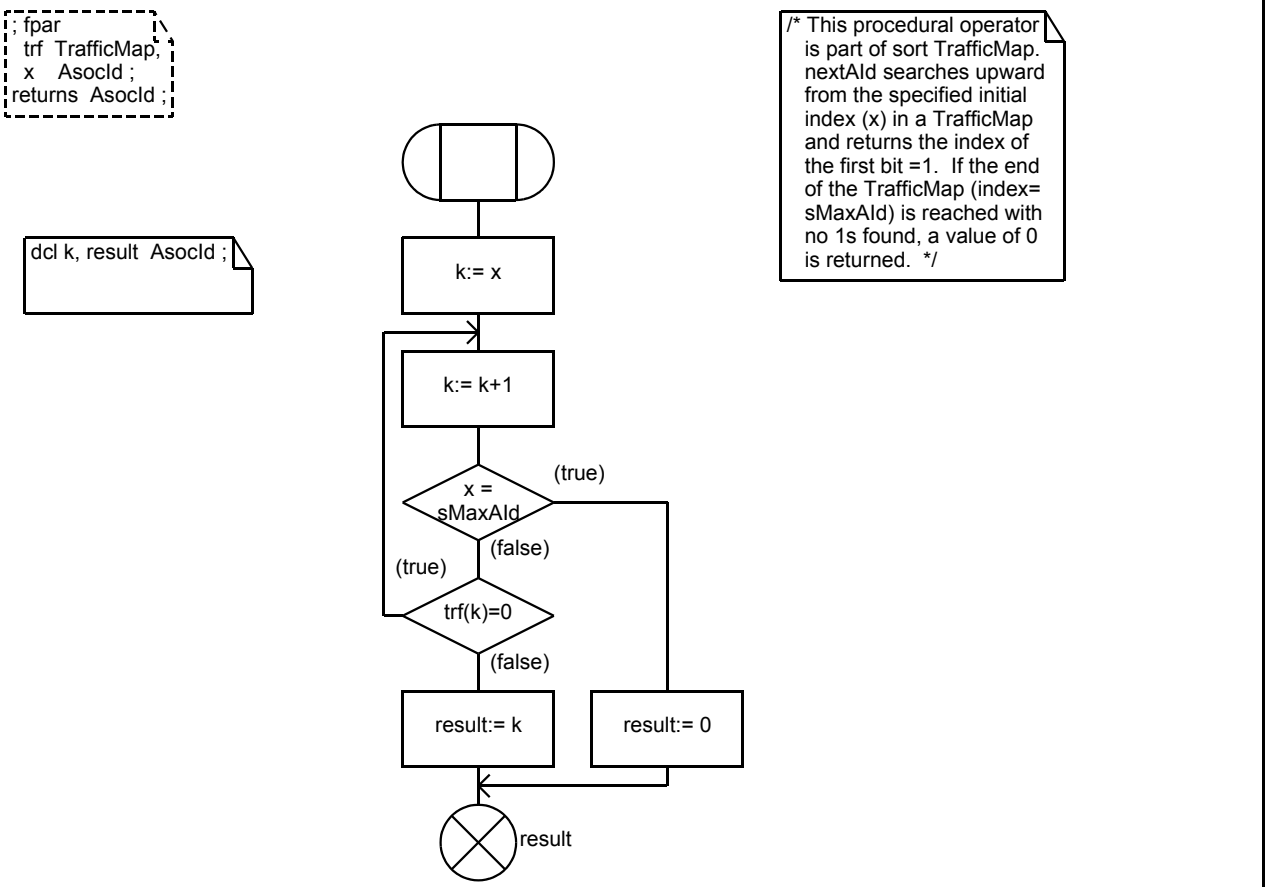
Operator nextAId NextAId_1a(1)



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Package macsorts 3125_d\RateAndDurationSorts(31)



```
/*****************************************************************
 *       Multi-rate support sorts
 *****************************************************************/
newtype Rate   inherits Octet   operators all;
  adding  operators
    calcDur : Rate, Integer -> Integer; /* converts (rate,bitCount) to integer usec */
    rateVal : Rate -> Rate; /* clears high-order bit */
    basicRate : Rate -> Rate; /* sets high-order bit */
    isBasic : Rate -> Boolean; /* true if high-order bit set */
  axioms
    for all r in Rate(    for all i in Integer(    for all b in Boolean(
          calcDur(r, i) == ((((10000000 + (octetVal(r and 0x7F) - 1)) /
              (500 * octetVal(r and 0x7F))) * i) + 9999) / 10000;
          rateVal(r) == r and 0x7F;          basicRate(r) == r or 0x80;
          isBasic(r) == (r and 0x80) = 0x80; )));
endnewtype Rate;
syntype RateString = Octetstring   endsyntype RateString;
```

```
/*****************************************************************
 *       MPDU duration factor support sort
 *****************************************************************/
/* These operators support the encoding used to allow */
/* an Integer to represent the value of aMpduDurationFactor. */
/*    calcDF(PlcpBits, MpduBits)  returns an Integer which is */
/* the fractional part of ((PlcpBits/MpduBits)-1)*(1e9). */
/*    stuff(durFactor, MpduBits)  returns the number of PlcpBits */
/* which result from MpduBits at the specified durFactor. */
newtype DurFactor   inherits Integer   operators all;
  adding  operators
    calcDF : Integer, Integer -> DurFactor;
    stuff  : DurFactor, Integer -> Integer;
  axioms
    for all df in DurFactor(     for all mb, pb in Integer(
        calcDF(pb, mb) == ((pb * 1000000000) / mb) - 1000000000;
        stuff(df, mb) == ((mb * df) + (mb - 1)) / 1000000000; ));
endnewtype DurFactor;
```

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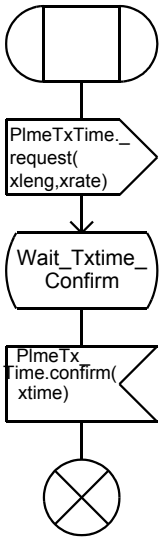
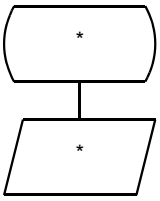
Operator calcDur

;fpar
in/out xtime Integer,
in xleng Integer,
in xrate Rate;

/* This procedural operator calcDur is used by the high-rate PHYs to calculate the duration of PPDU. For the high-rate PHYs, this operator replaces the axiomatic definition of calcDur given on page 439. In the case of the high-rate PHY, calculations of PPDU duration are performed by the PHY through the PLME-TXTIME primitives. These calculations are dependent on PHY options. Note: To maintain consistency with the alternate axiomatic definition of calcDur, the PHY options are not shown in calls to this operator. These values are passed implicitly. */





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Package macsorts 3126_d\FH_DS_Params(31)



```
/*****************************************************************
 *       FH parameter set sort
 *****************************************************************/
newtype FhParms   inherits Octetstring   operators all;
 adding  operators
   dwellTime  : FhParms -> TU;    /* Dwell Time field (2) */
   setDwellTime  : FhParms, TU -> FhParms;
   hopSet  : FhParms -> Integer; /* Hop Set field (1) */
   setHopSet  : FhParms, Integer -> FhParms;
   hopPattern  : FhParms -> Integer; /* Hop Pattern field (1) */
   setHopPattern  : FhParms, Integer -> FhParms;
   hopIndex  : FhParms -> Integer; /* Hop Index field (1) */
   setHopIndex  : FhParms, Integer -> FhParms;
 axioms
   for all fh in FhParms(   for all i in Integer(   for all u in TU(
     dwellTime(fh) == octetVal(fh(0)) + (octetVal(fh(1)) * 256);
     setDwellTime(fh, u) == mkOS(u mod 256, 1) // mkOS(u / 256, 1) // SubStr(fh, 2, 3);
     hopSet(fh) == octetVal(fh(2));
     setHopSet(fh,i) == SubStr(fh,0,2) // mkOS(i,1) // SubStr(fh,3,2);
     hopPattern(fh) == octetVal(fh(3));
     setHopPattern(fh, i) == SubStr(fh,0,3) // mkOS(i,1) // Last(fh);
     hopIndex(fh) == octetVal(fh(4));
     setHopIndex(fh, i) == SubStr(fh, 0, 4) // mkOS(i, 1);)));
endnewtype FhParms;
```

```
/*****************************************************************
 *       DS parameter set sort
 *****************************************************************/
newtype DsParms   inherits Octetstring   operators all;
 adding  operators
   curChannel  : DsParms -> Integer; /* Current Channel (1) */
   setCurChannel  : DsParms, Integer -> DsParms;
 axioms
   for all ds in DsParms(     for all i in Integer(
       curChannel(ds) == octetVal(ds(0));
       setCurChannel(ds, i) == mkOS(i); ));
endnewtype DsParms;
```

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Package macsorts 3127_e\PHY_Params(31)



```
/*****************************************************************
 *       Generic PHY Parameter Set sort
 *****************************************************************/
/* Generic PHY parameter element for signals related to Beacons */
/* and Probe Responses that are PHY-type independent. */
syntype PhyParms = Octetstring   endsyntype PhyParms;
```

```
NEWTYPE PhyChrstcs struct
  aSlotTime Usec;
  aSifsTime Usec;
  aCCATime Usec;
  aRxTxTurnaroundTime Usec;
  aTxPLCPDelay Usec;
  aRxPLCPDelay Usec;
  aRxTxSwitchTime Usec;
  aTxRampOnTime Usec;
  aTxRampOffTime Usec;
  aTxRFDelay Usec;
  aRxRFDelay Usec;
  aAirPropagationTime Usec;
  aMACProcessingDelay Usec;
  aPreambleLength Usec;
  aPLCPHeaderLength Usec;
  aMPDUMaxLength Integer;
  aCWmin Integer;
  aCWmax Integer;
EndNewType PhyChrstcs;
```


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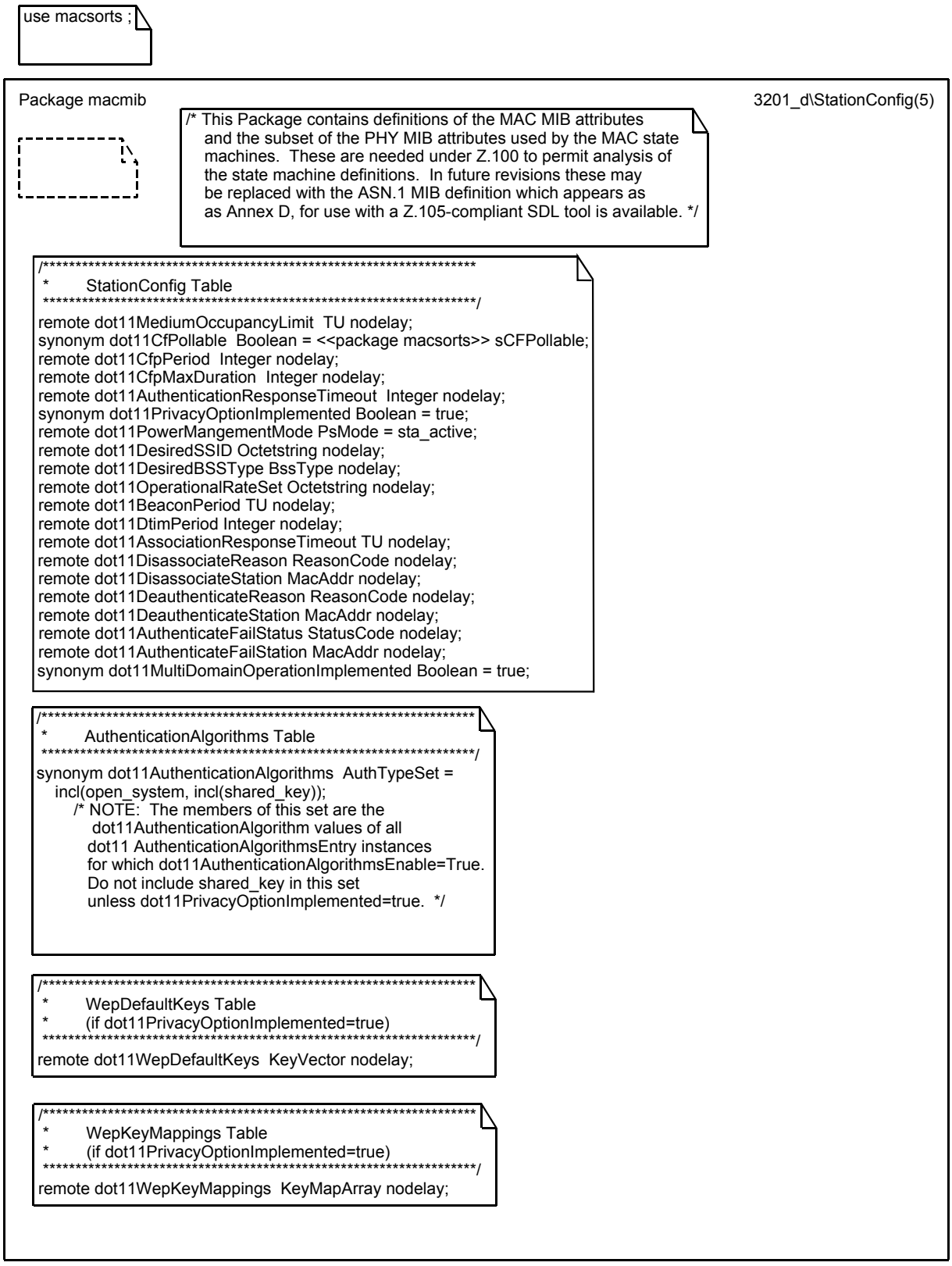

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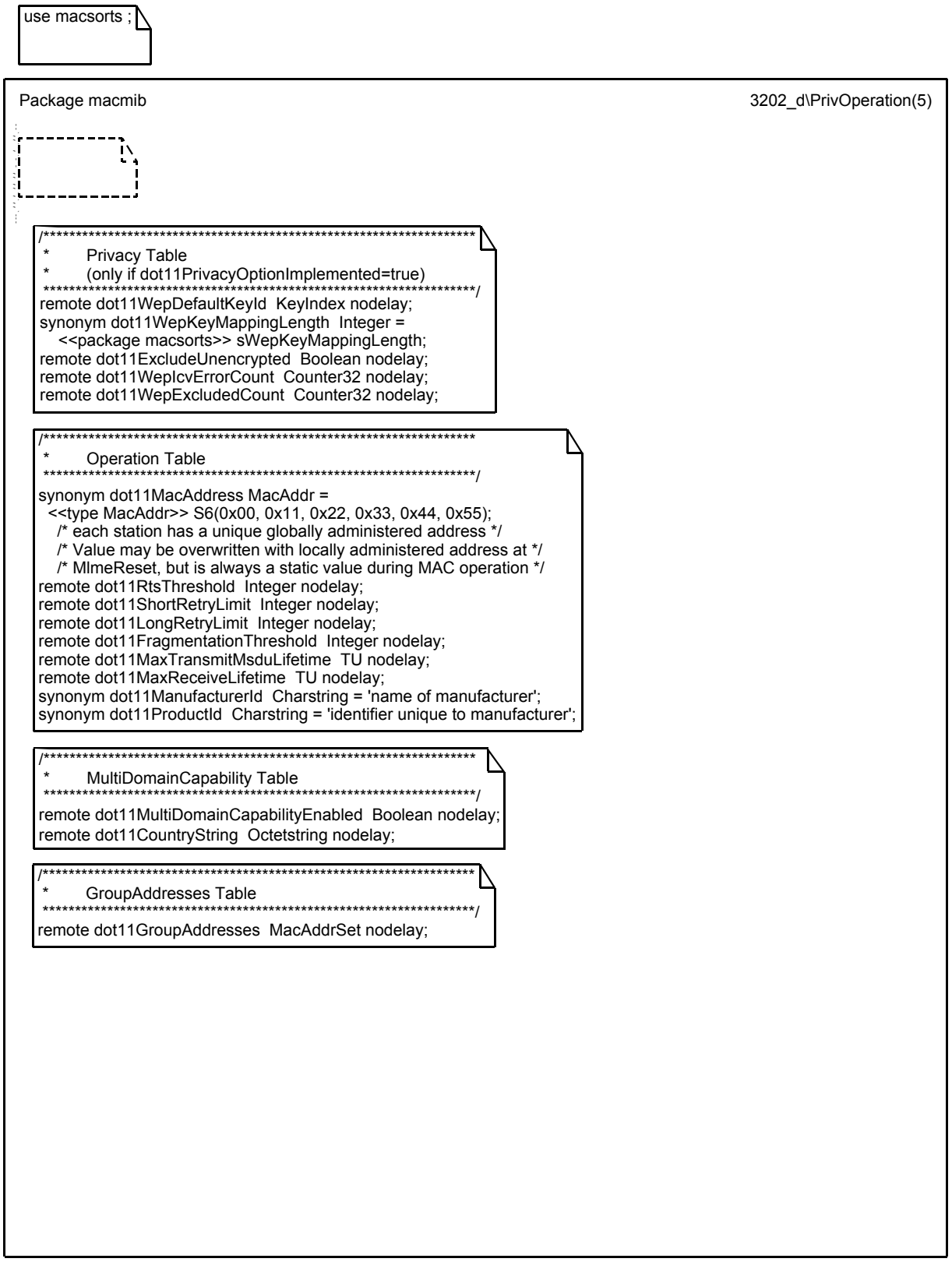

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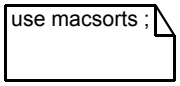

Package macmib 3203_d\Counters(5)



```
/*******************************************************************
 *       Counters Table
 *******************************************************************/
remote dot11TransmittedFragmentCount  Counter32 nodelay;
remote dot11MulticastTransmittedFrameCount  Counter32 nodelay;
remote dot11FailedCount  Counter32 nodelay;
remote dot11RetryCount Counter32 nodelay;
remote dot11MultipleRetryCount  Counter32 nodelay;
remote dot11RtsSuccessCount  Counter32 nodelay;
remote dot11RtsFailureCount  Counter32 nodelay;
remote dot11AckFailureCount  Counter32 nodelay;
remote dot11ReceivedFragmentCount  Counter32 nodelay;
remote dot11MulticastReceivedFrameCount  Counter32 nodelay;
remote dot11FcsErrorCount  Counter32 nodelay;
remote dot11FrameDuplicateCount  Counter32 nodelay;
```

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use macsorts ;

Package macmib

3204_e\PhyOperation(5)

```
/*************************************************************************
 *       PhyOperation Table
 *       (values shown are mostly for FH PHY)
 *************************************************************************/
synonym FHphy Integer = 01; /* enumerated dot11PHYType value */
synonym DSphy Integer = 02; /* enumerated dot11PHYType value */
synonym IRPhy Integer = 03; /* enumerated dot11PHYType value */
synonym dot11PHYType  Integer = FHphy;
remote dot11CurrentRegDomain  Integer nodelay;
synonym dot11TempType Integer = 01;

/*****************************************************************************************
*  PhyCharacteristic Parameters (values shown are mostly for FH PHY )
*****************************************************************************************/
/* NOTE:  The PhyCharacteristics are defined as synonyms because
   their values are static during MAC operation.  It is assumed
   that , during each initialization of MAC operation, current
   values for each of these parameters are obtained from the
   PHY using the PlmeCharacteristics primitive. */
remote procedure TxTime;  returns Integer;
synonym aSlotTime  Usec = (aCcaTime + aRxTxTurnaroundTime +
    aAirPropagationTime + aMacProcessingTime);
synonym aCcaTime  Usec = 27;
synonym aRxTxTurnaroundTime Usec = (aTxPlcpDelay + aRxTxSwitchTime +
    aTxRampOnTime + aTxRfDelay);
synonym aTxPlcpDelay  Usec = 1;
synonym aRxTxSwitchTime  Usec = 10;
synonym aTxRampOnTime  Usec = 8;
synonym aTxRfDelay  Usec = 1;
synonym aSifsTime Usec = (aRxRfDelay + aRxPlcpDelay +
    aMacProcessingTime + aRxTxTurnaroundTime);
synonym aRxRfDelay  Usec = 4;
synonym aRxPlcpDelay  Usec = 2;
synonym aMacProcessingTime  Usec = 2;
synonym aTxRampOffTime  Usec = 8;
synonym aPreambleLength  Usec = 96;
synonym aPlcpHeaderLength  Usec = 32;
synonym aMpduMaxLength Integer = 4095;
synonym aAirPropagationTime  Usec = 1;
synonym aCWmax  Integer = 1023;
synonym aCWmin  Integer = 15;
```


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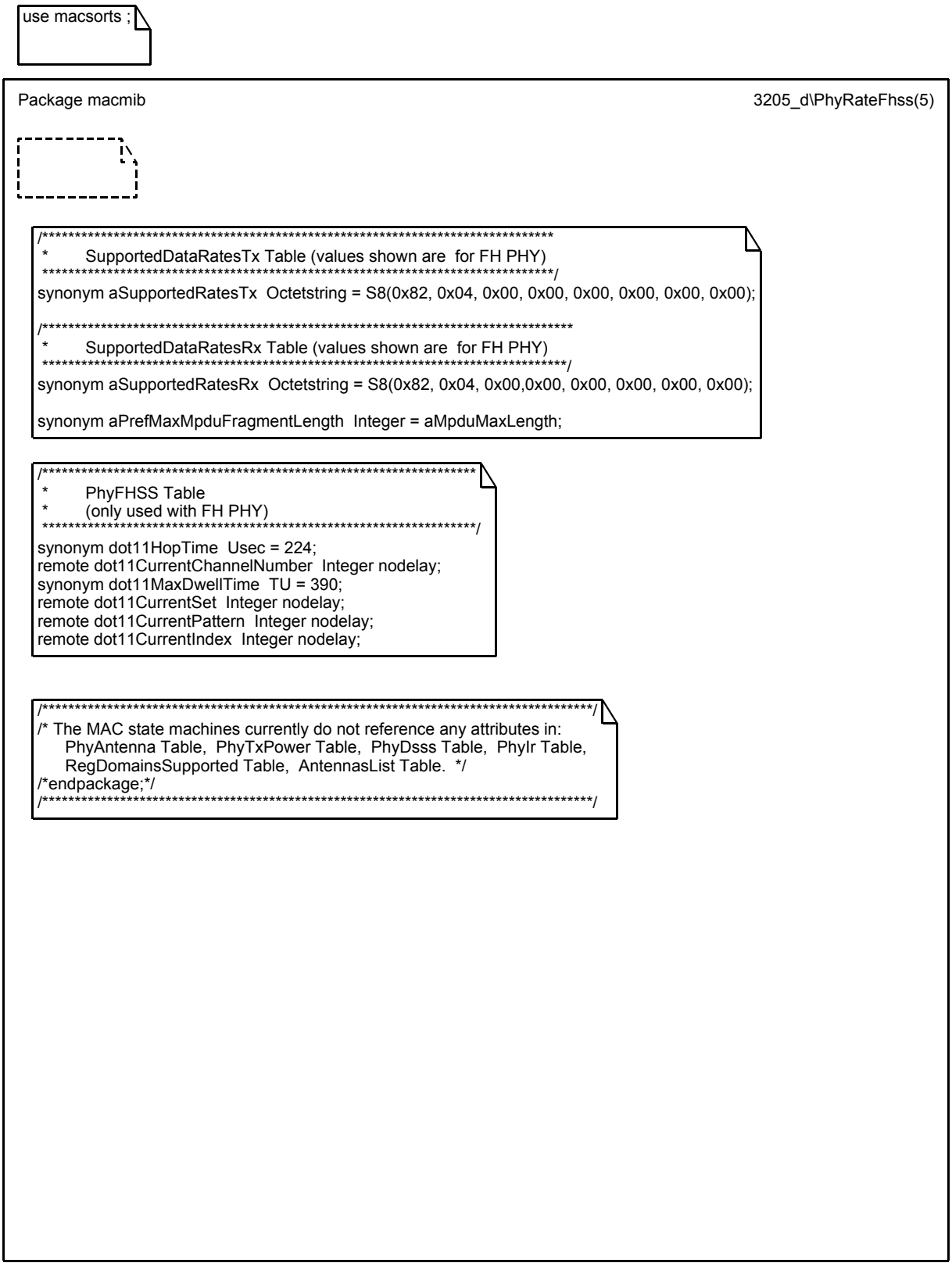

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C.3 State machines for MAC stations

The following SDL-92 system specification defines operation of the MAC protocol at an IEEE 802.11 STA. Many aspects of STA operation also apply to AP operation. These are defined in blocks and processes referenced from both the STA and AP system specifications. Blocks and processes used in both STA and AP are identifiable by the SDL comment /* for STA & AP */ below the block or process name. Blocks and processes specific to STA operation are identifiable by the SDL comment /* station version */ below the block or process name. The definitions of all blocks and processes referenced in the station system specification appear in C.3.

The remainder of C.3 is the formal description, in SDL/GR, of an IEEE 802.11 STA.

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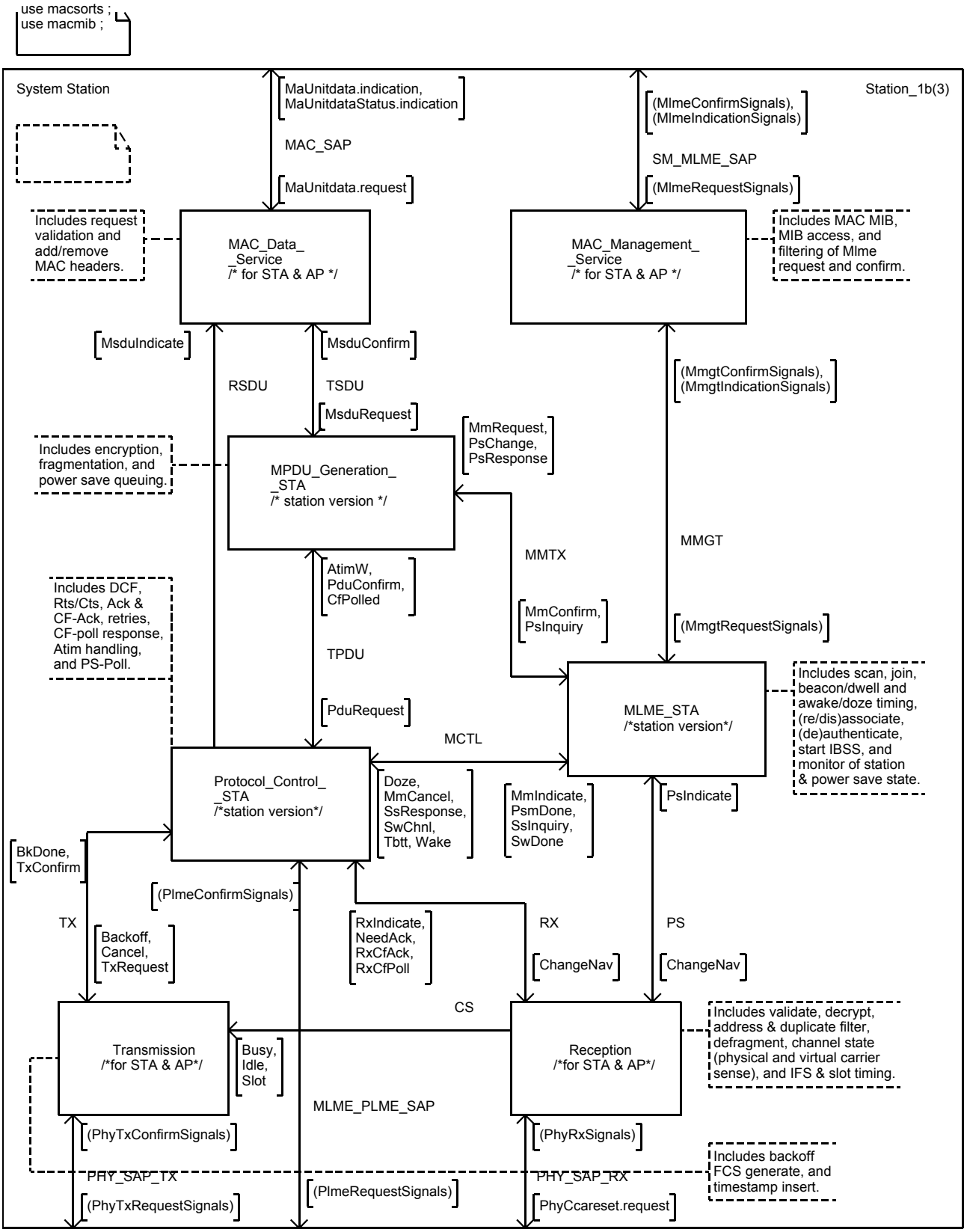

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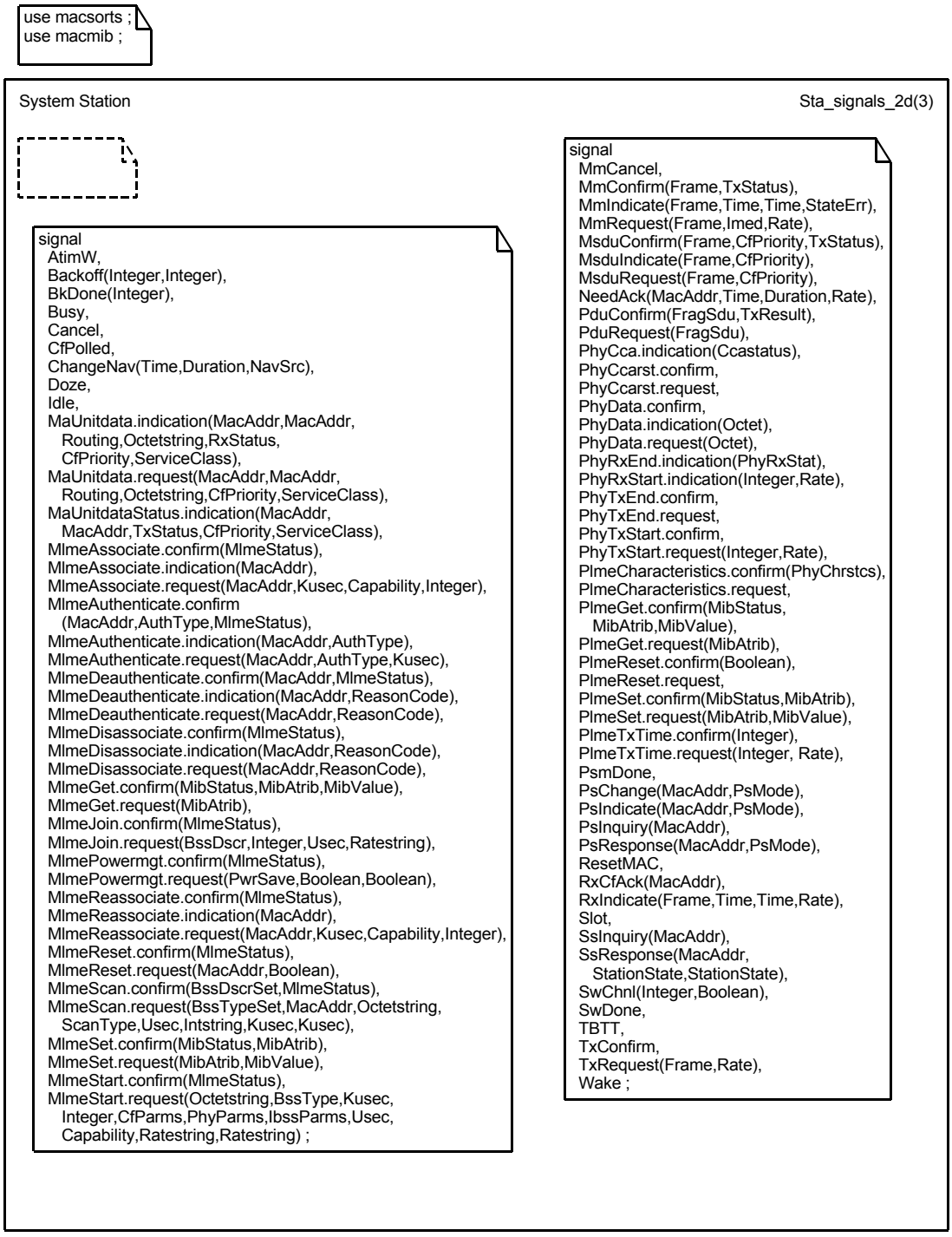

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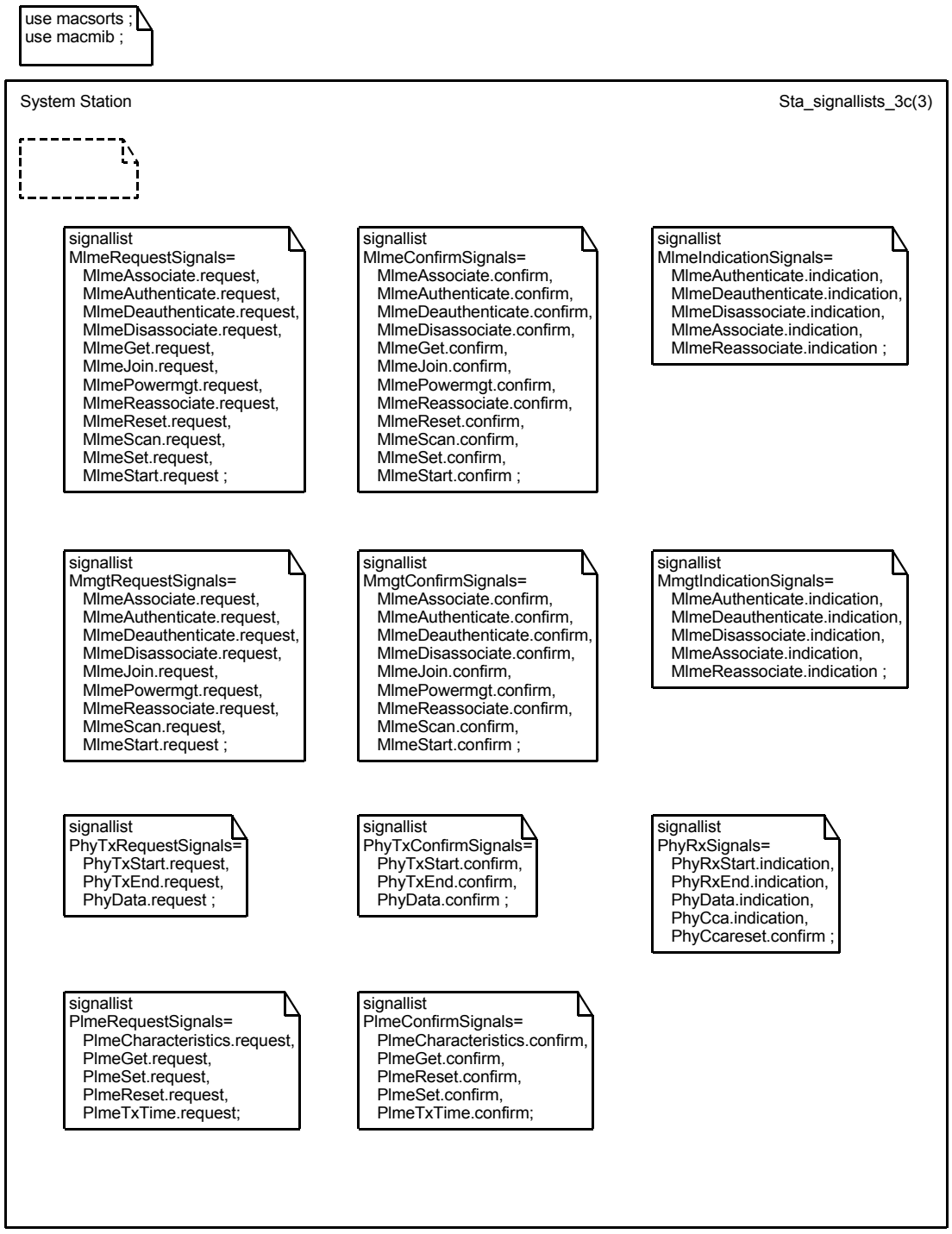

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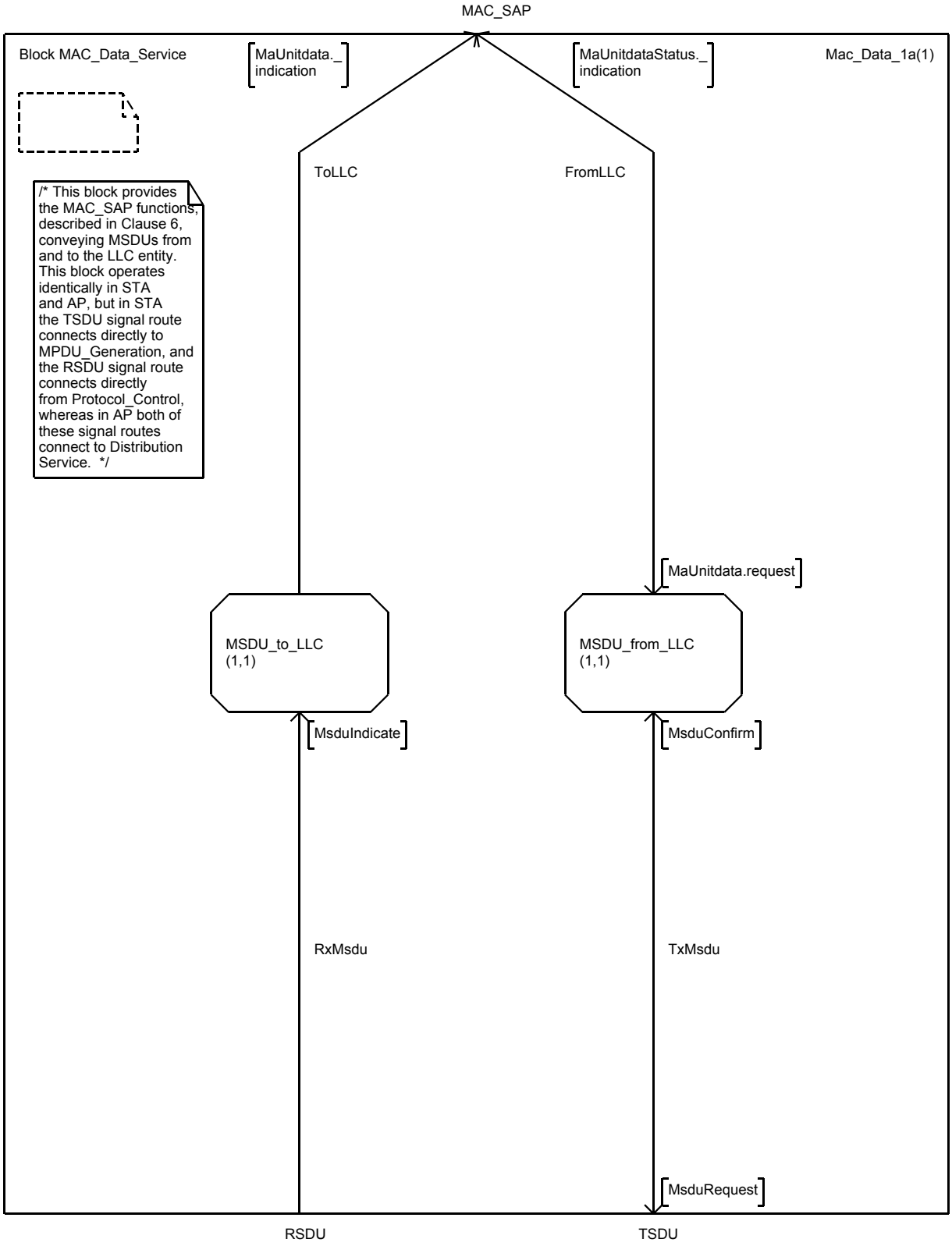

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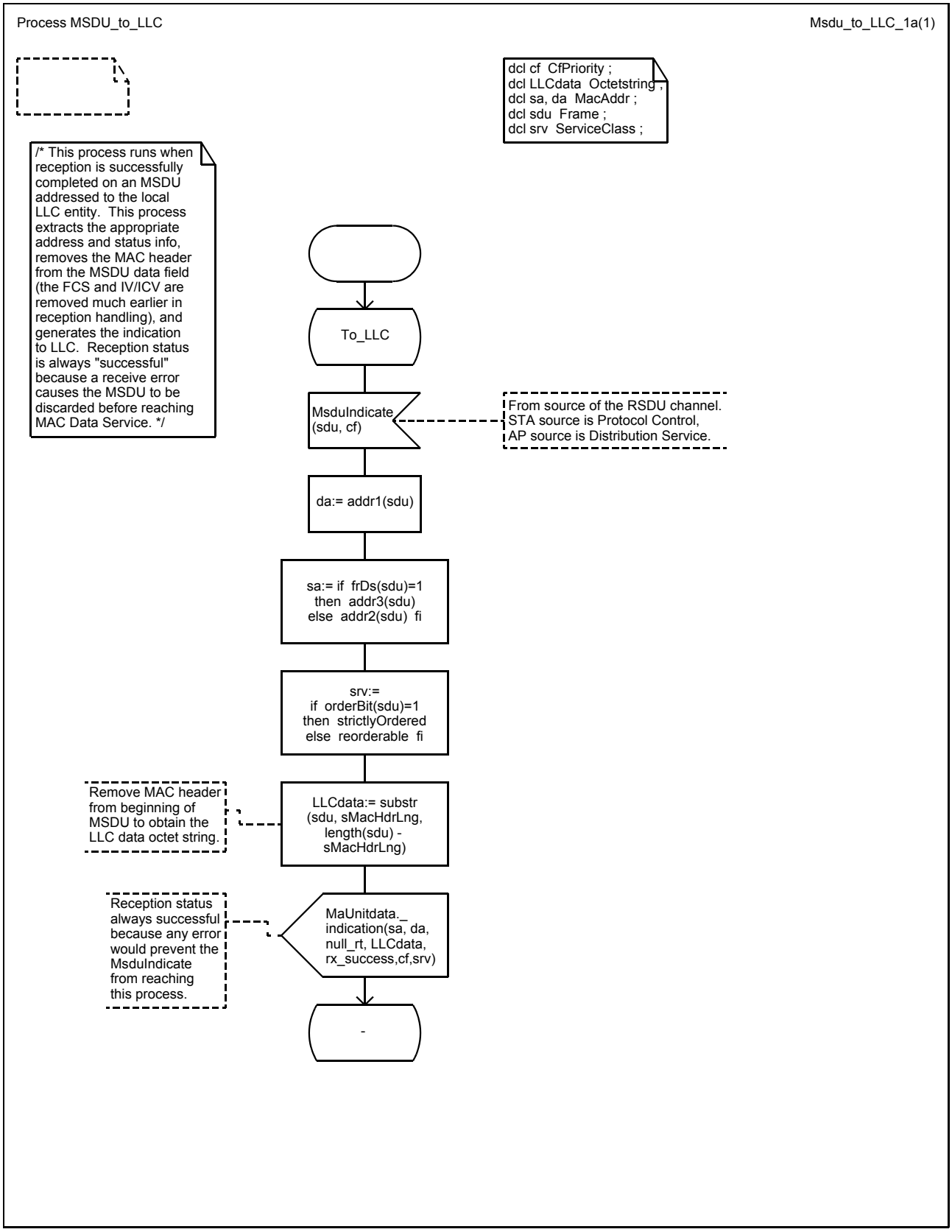

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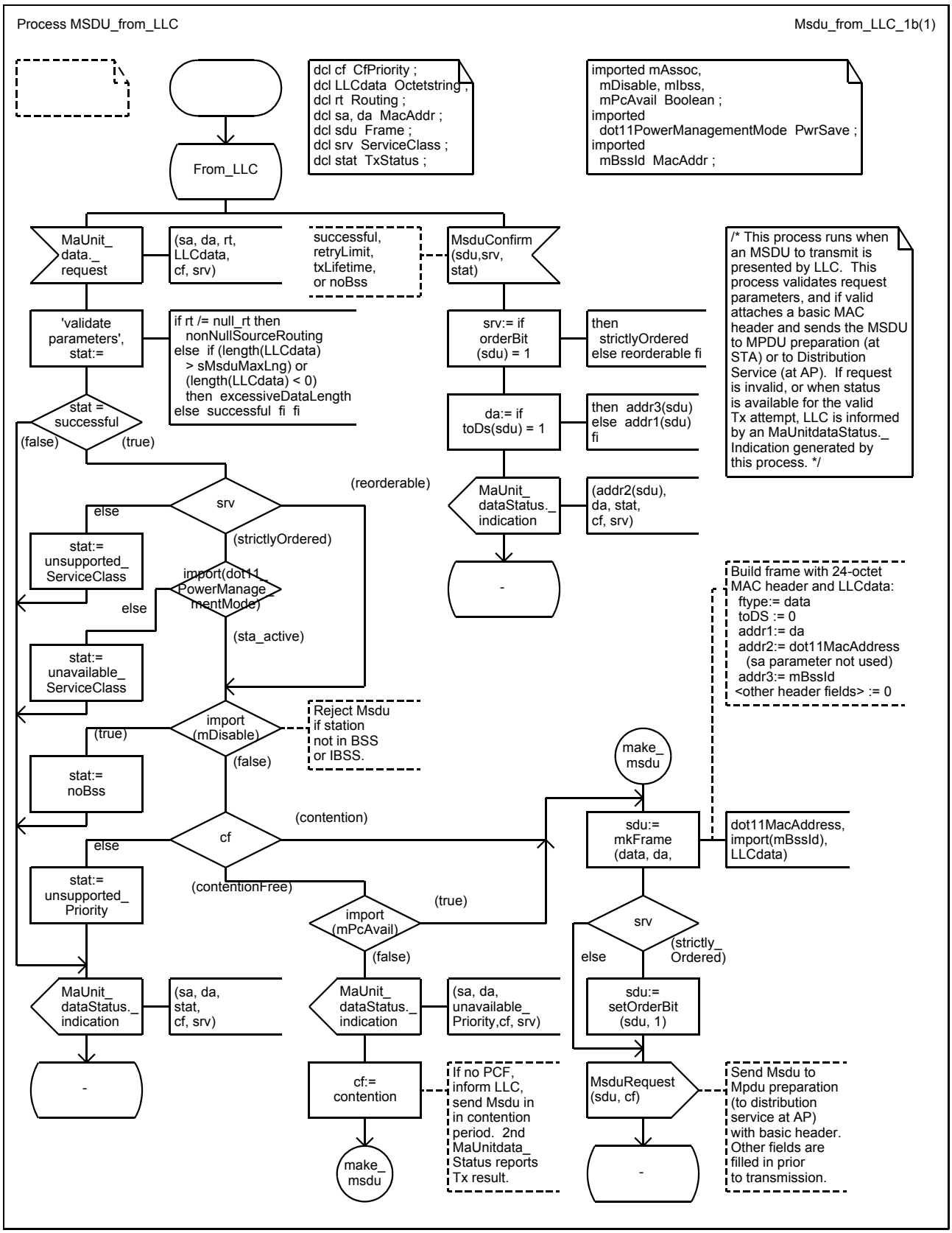

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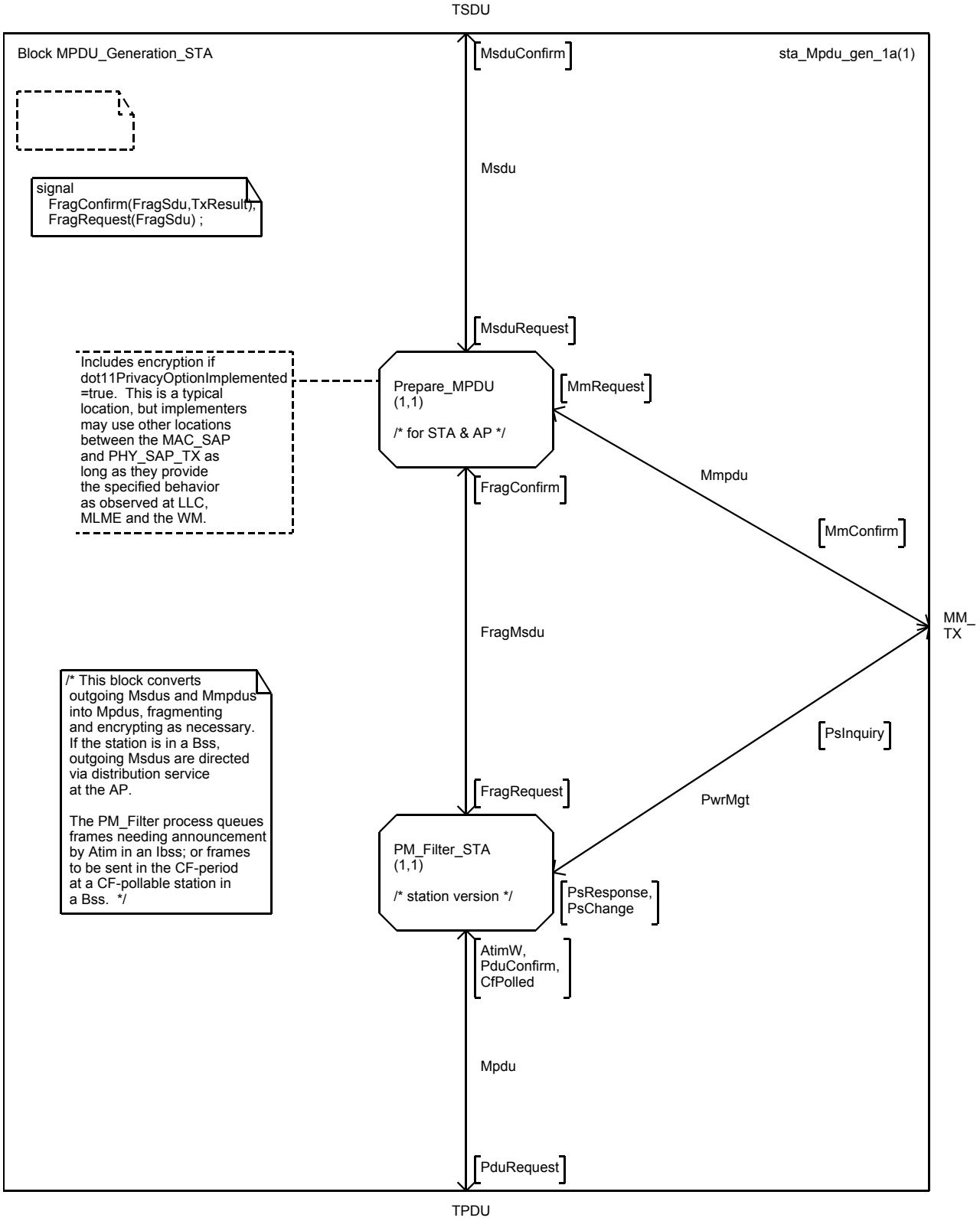

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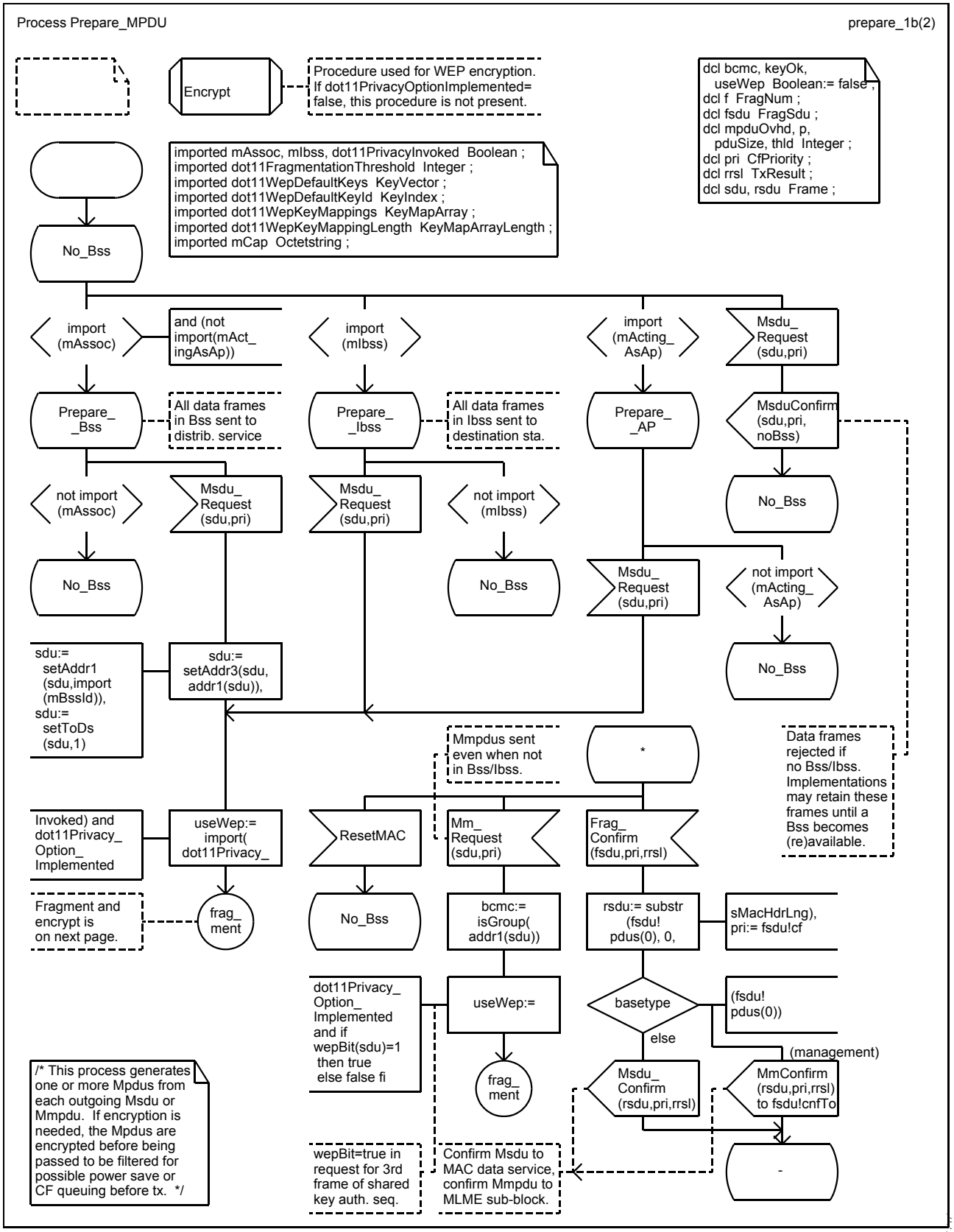

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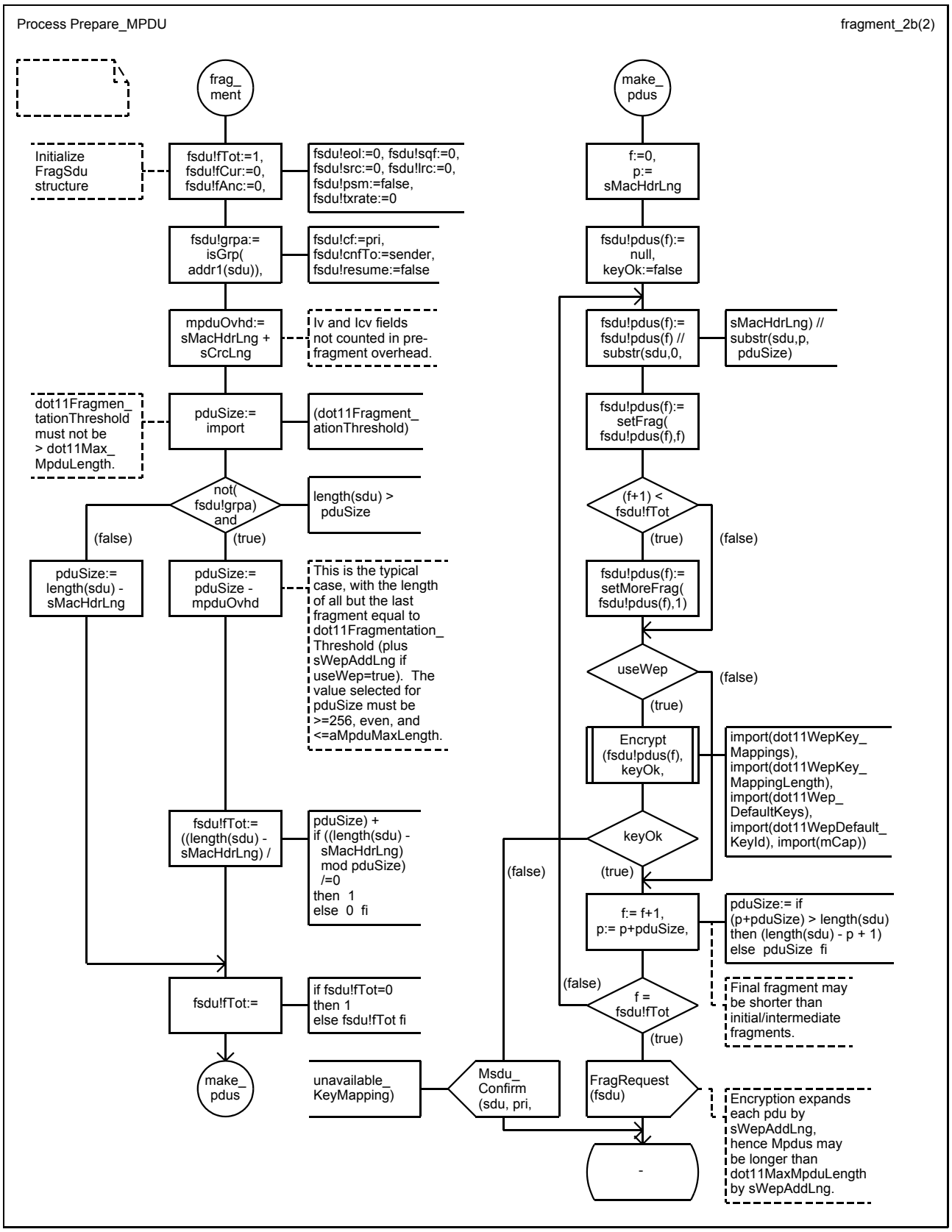

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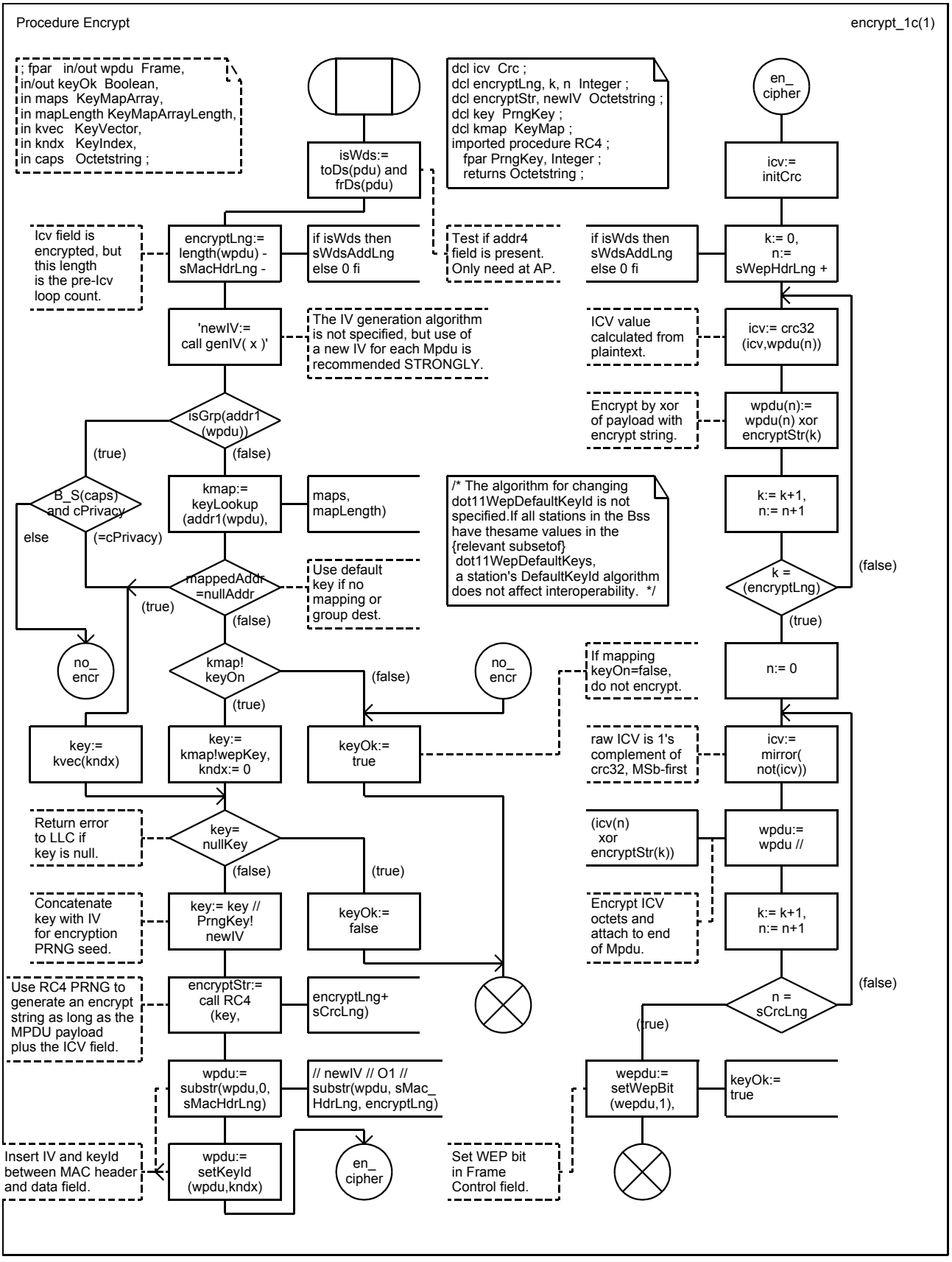

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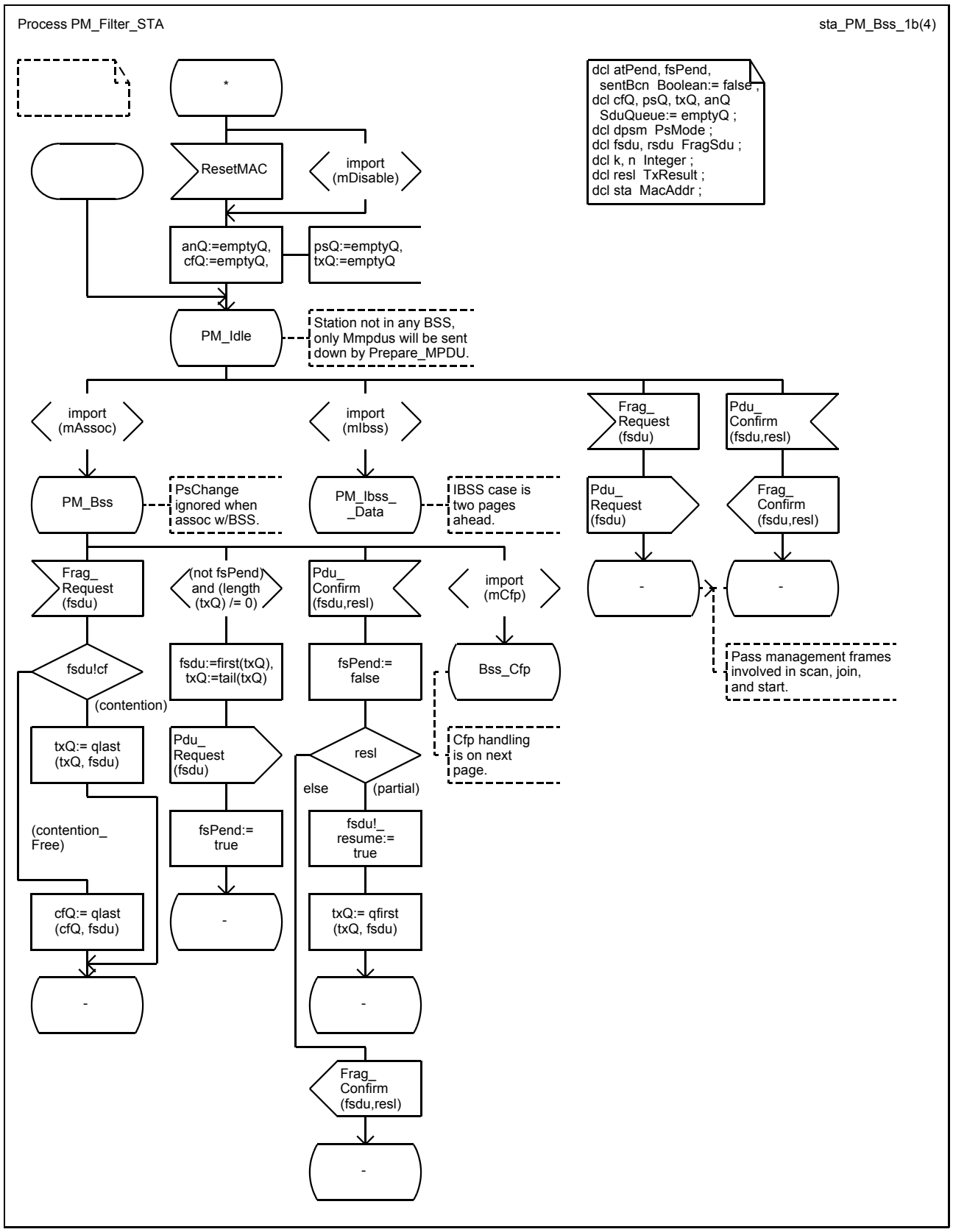

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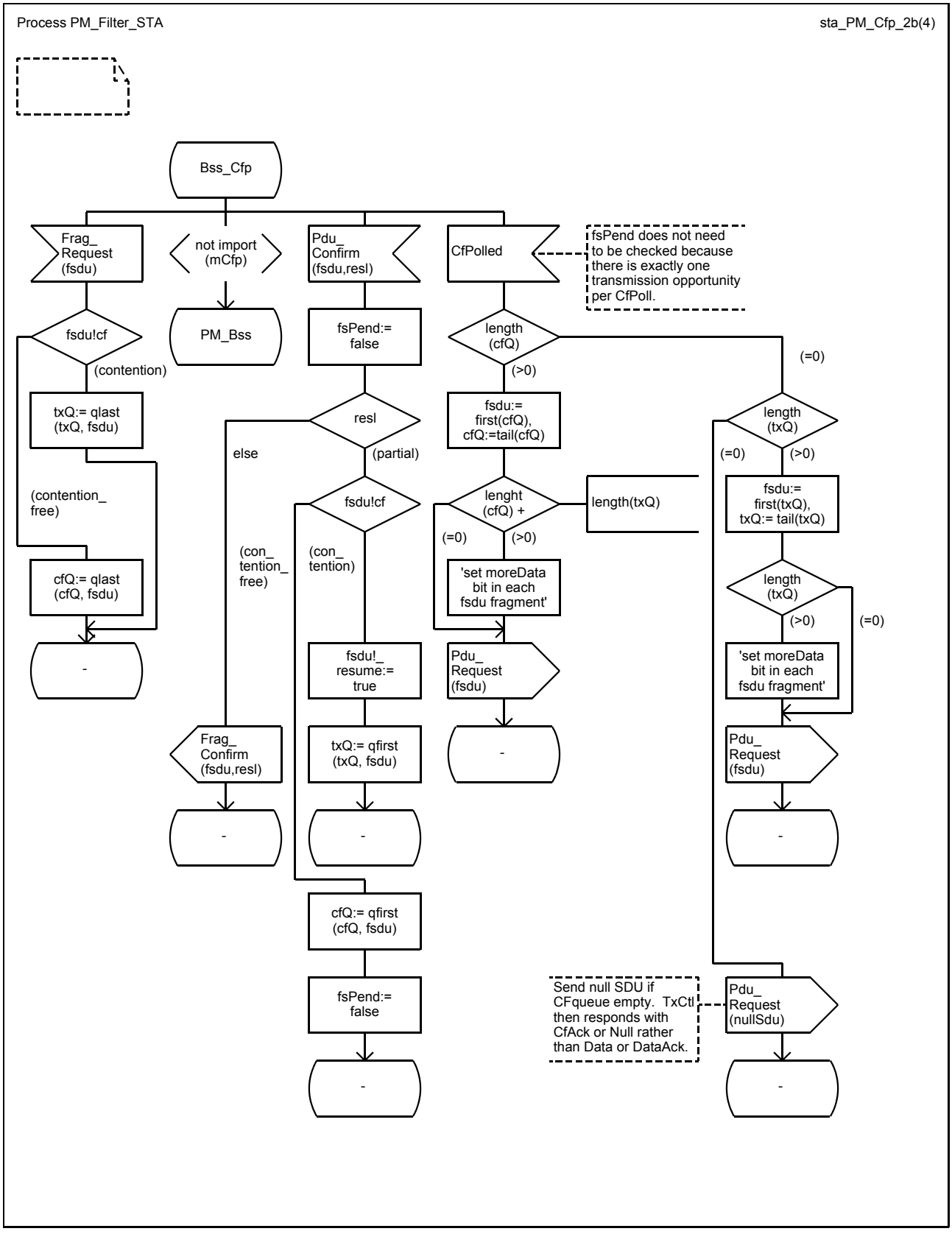

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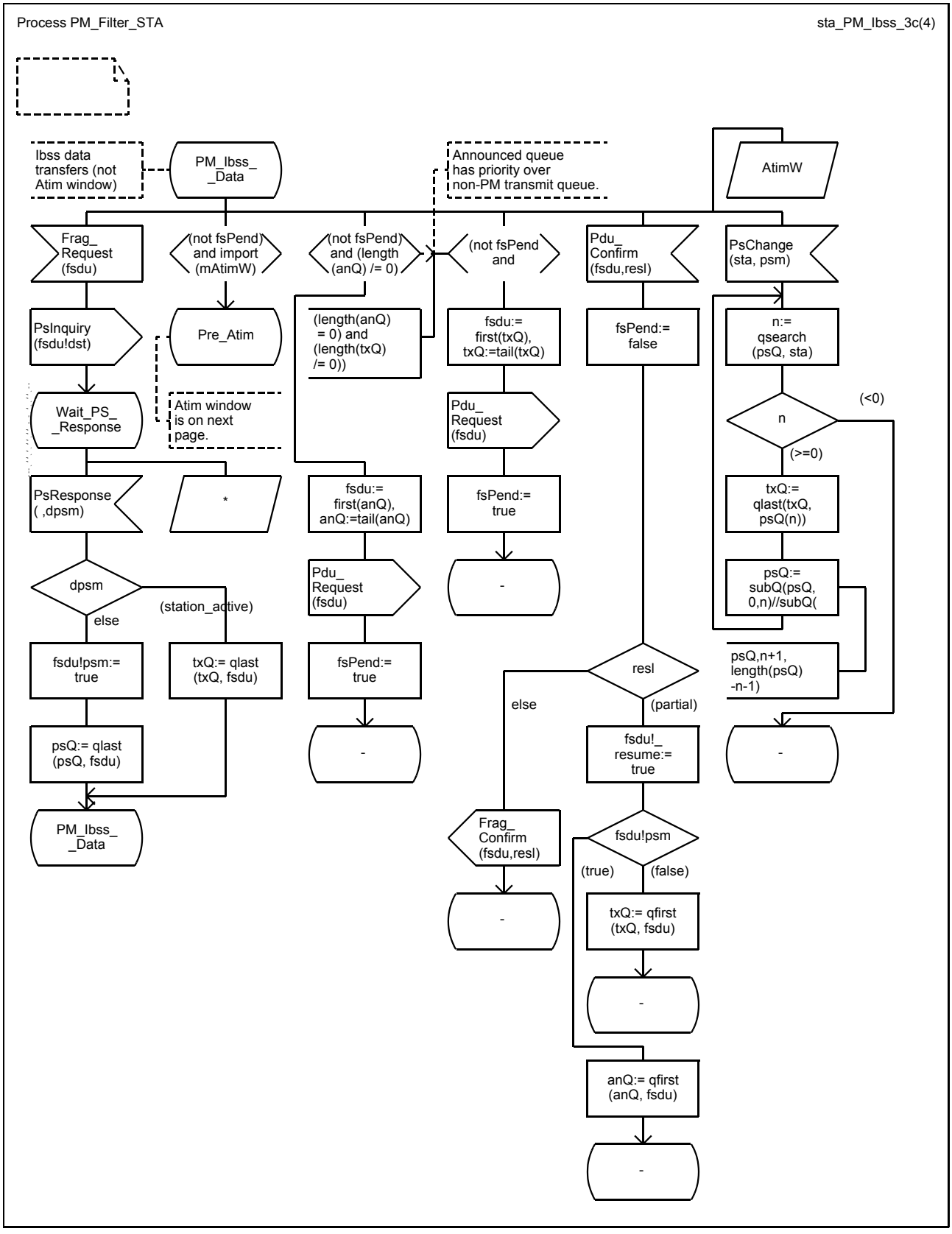

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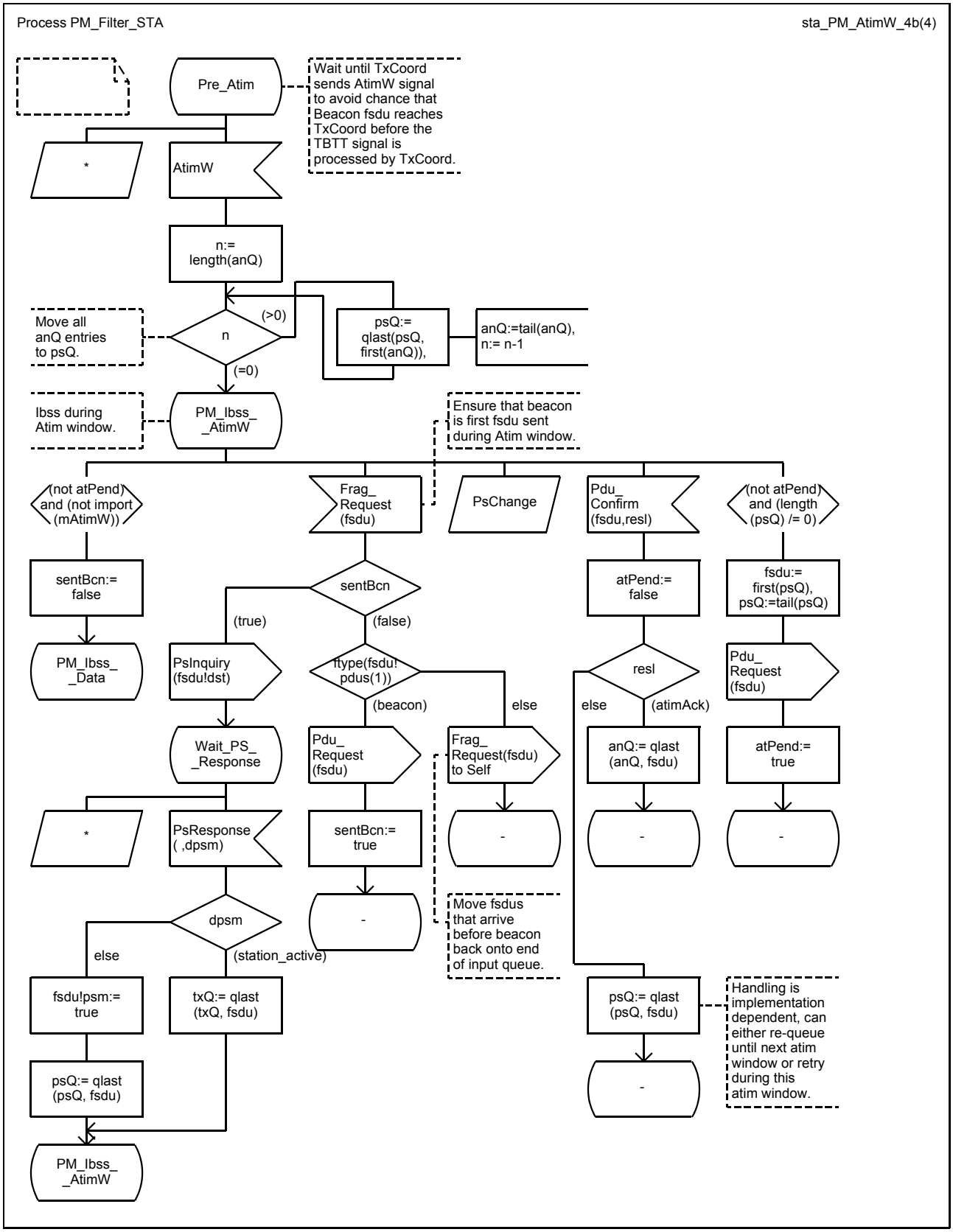

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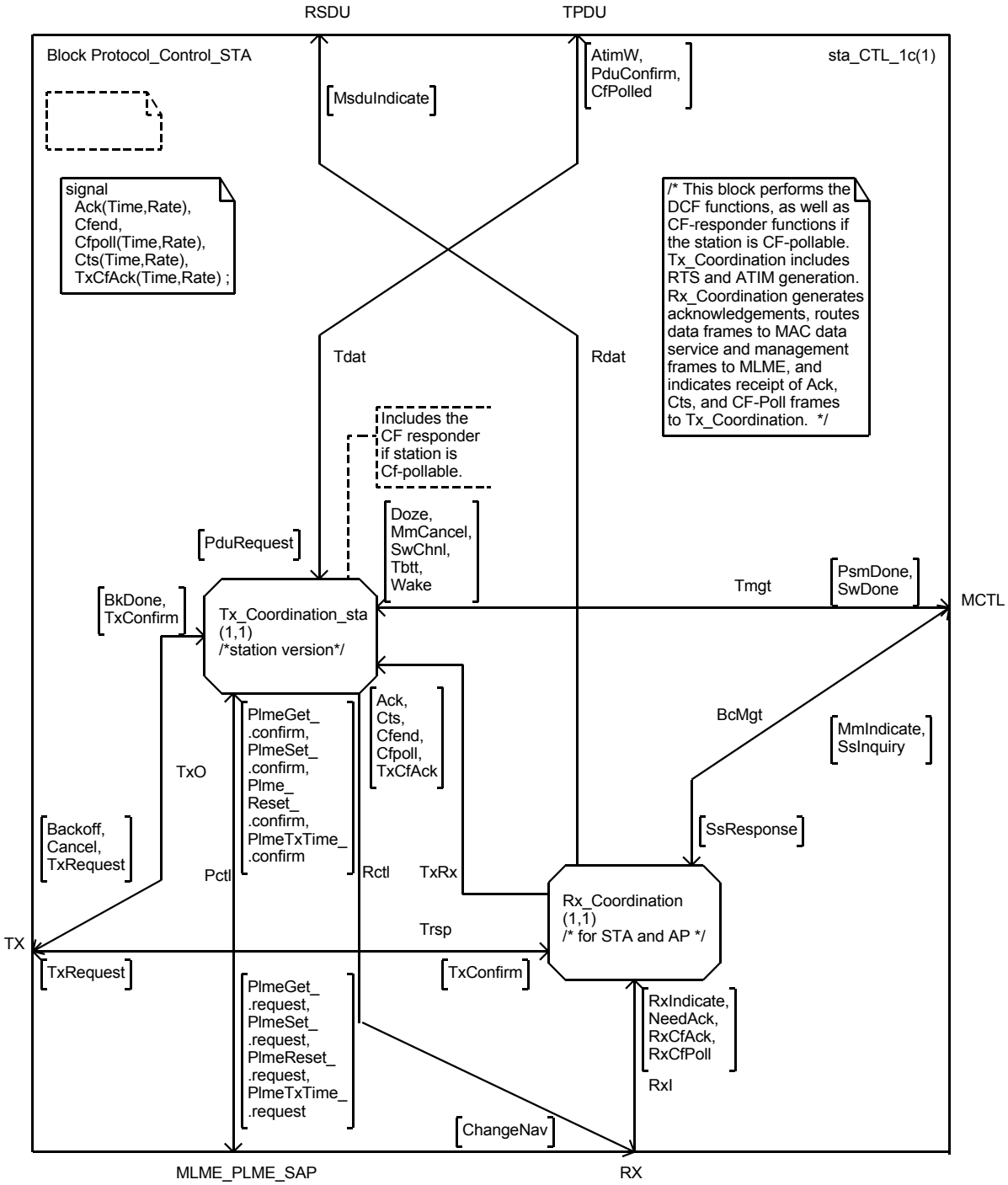

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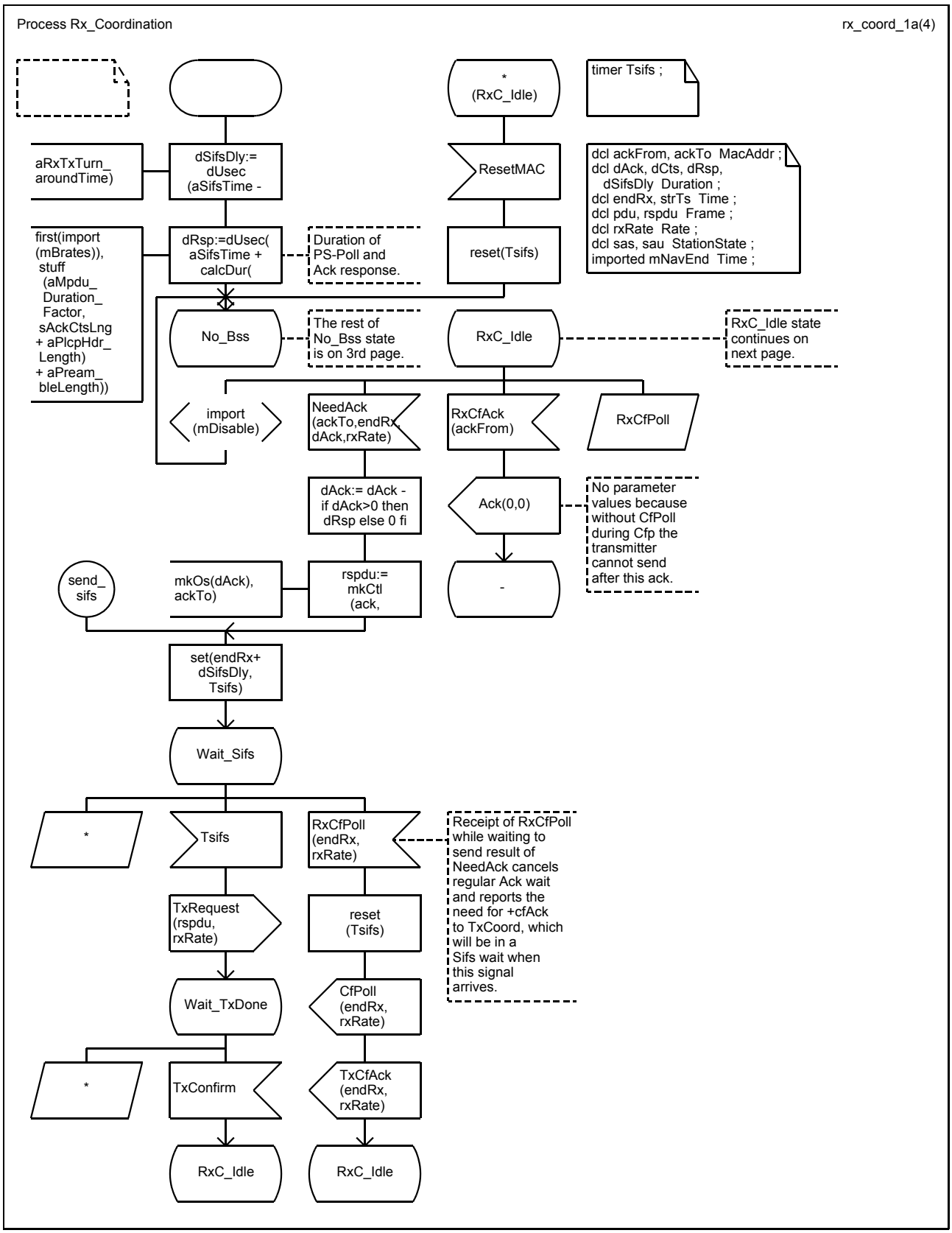

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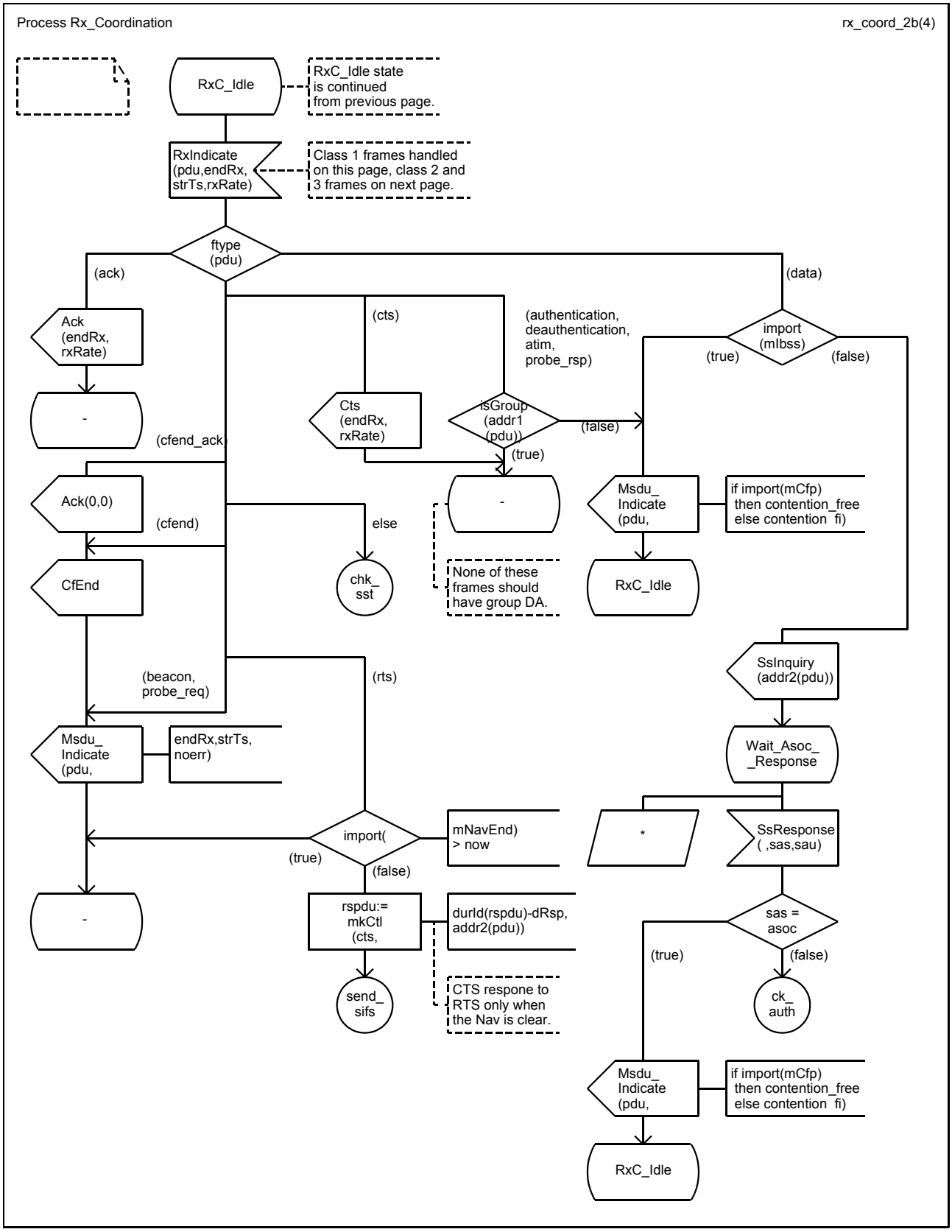

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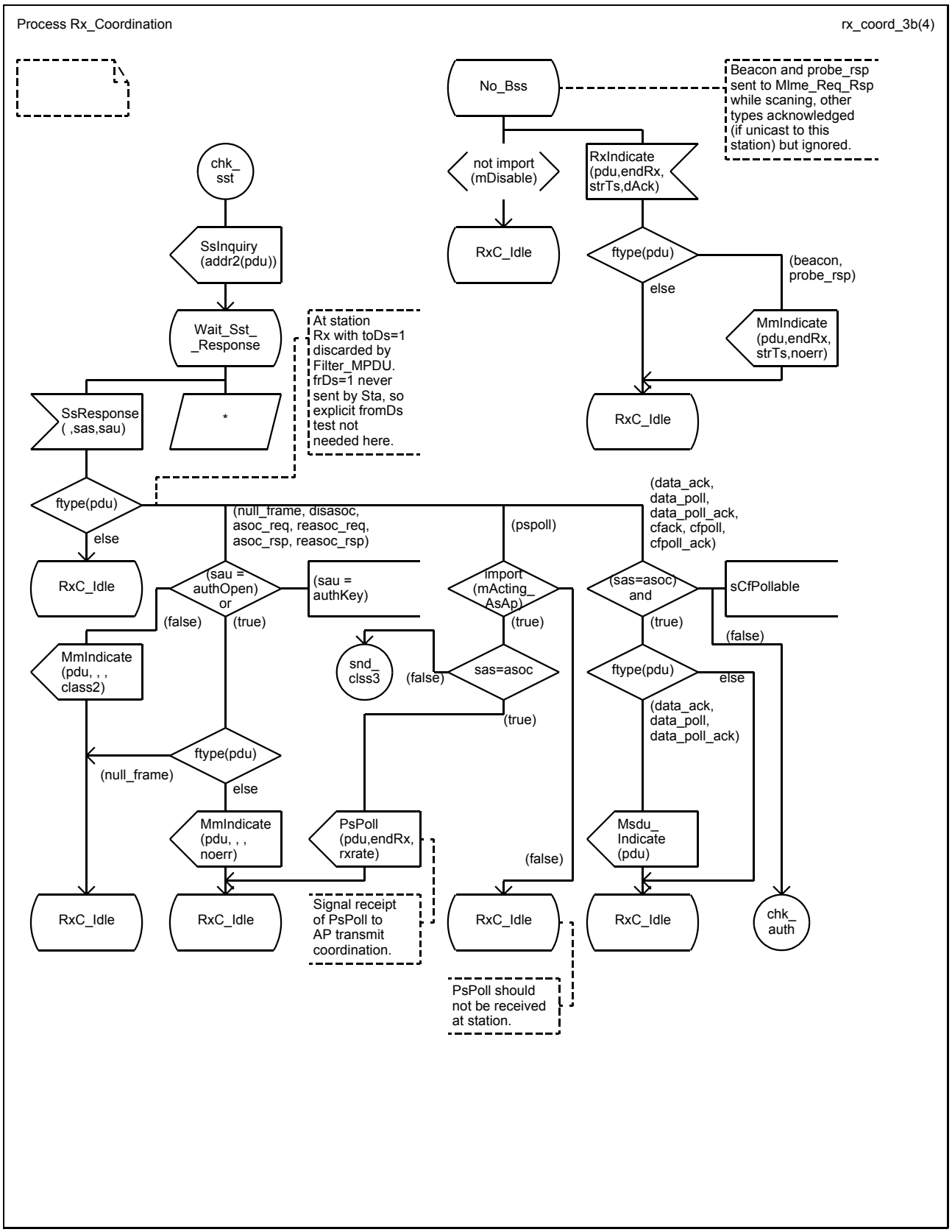

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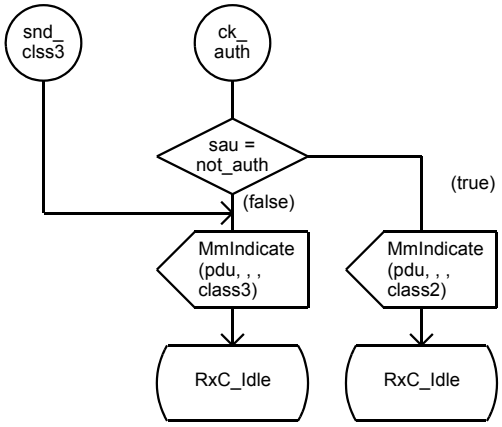
Process Rx_Coordination rx_coord_3.1a(4)





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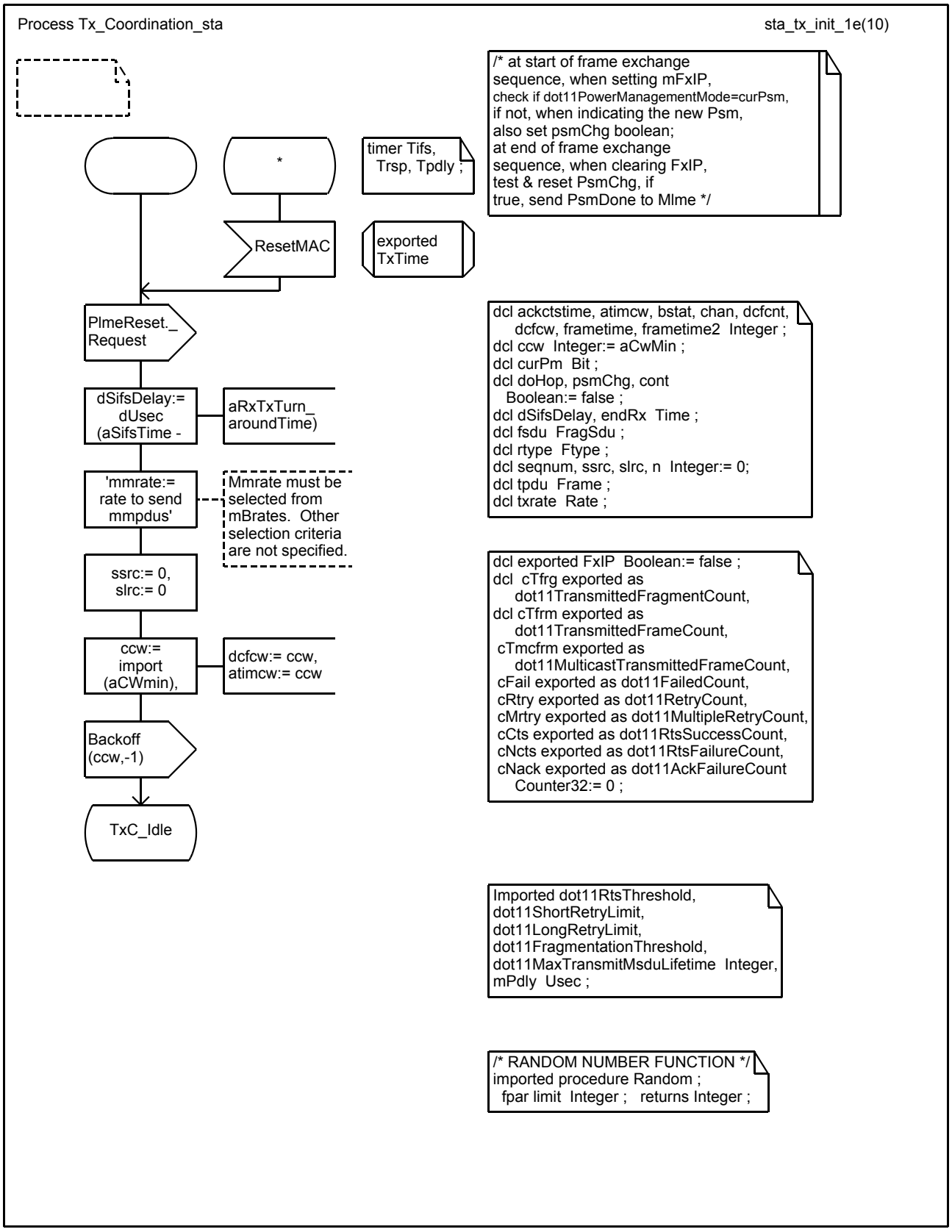

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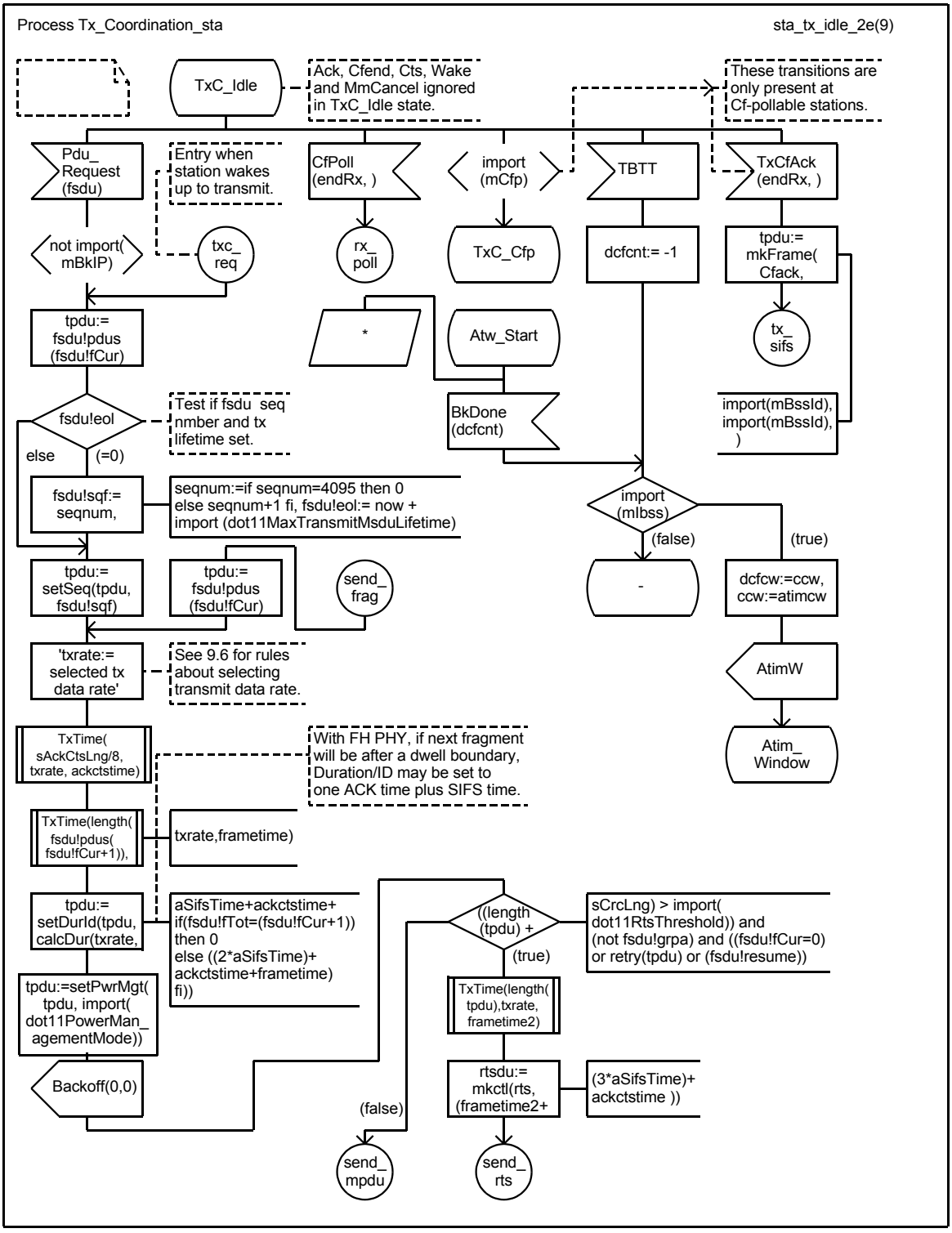

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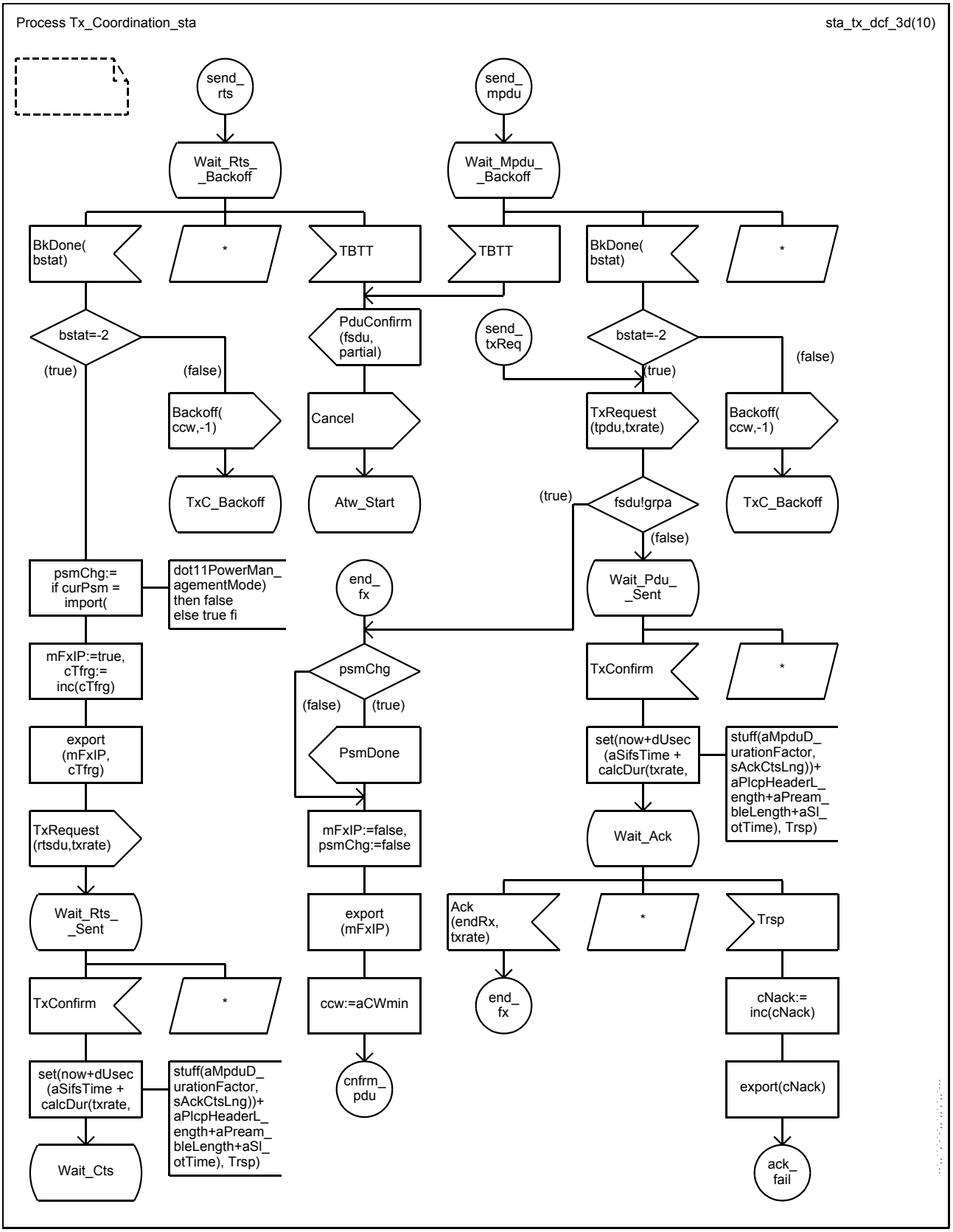

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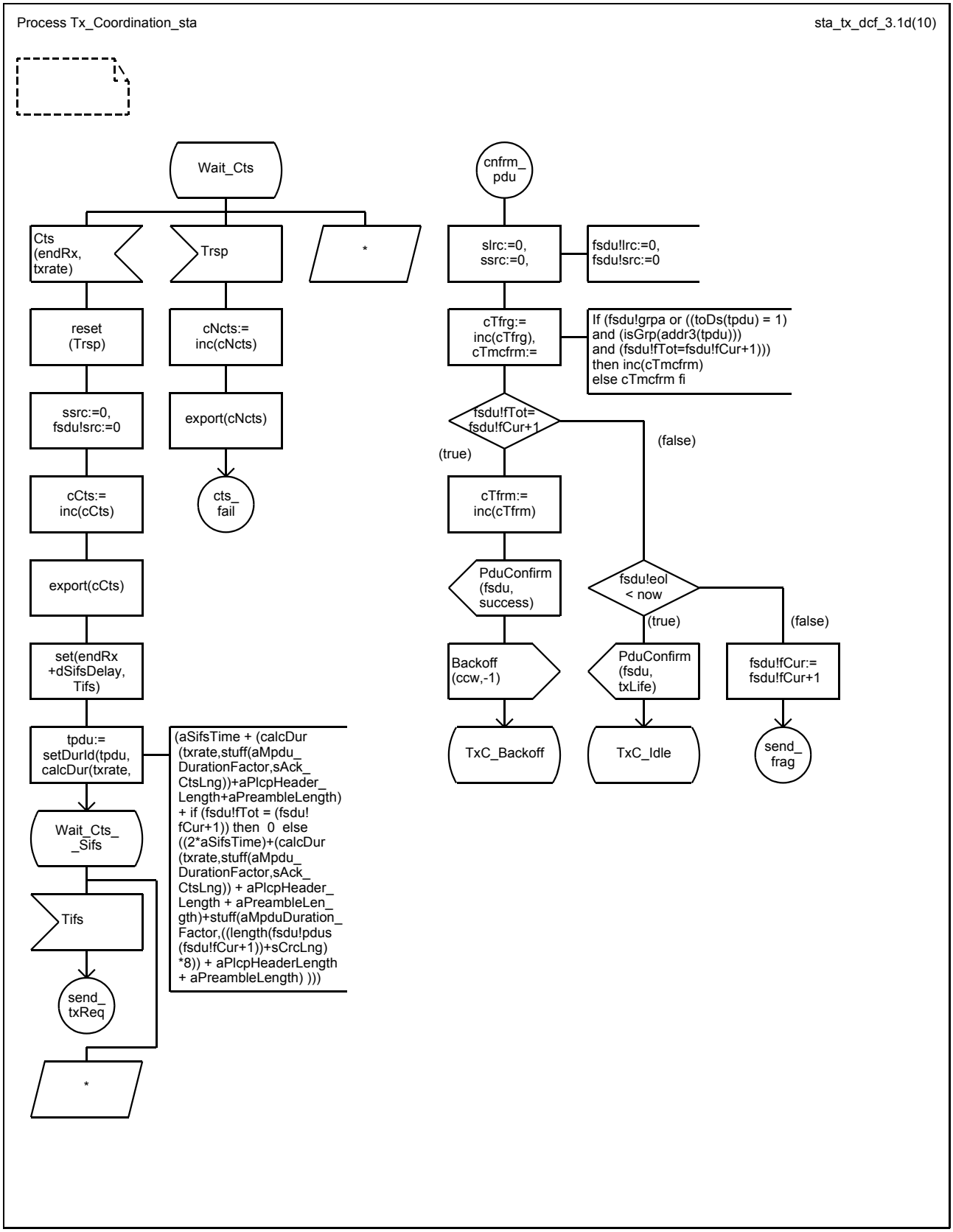

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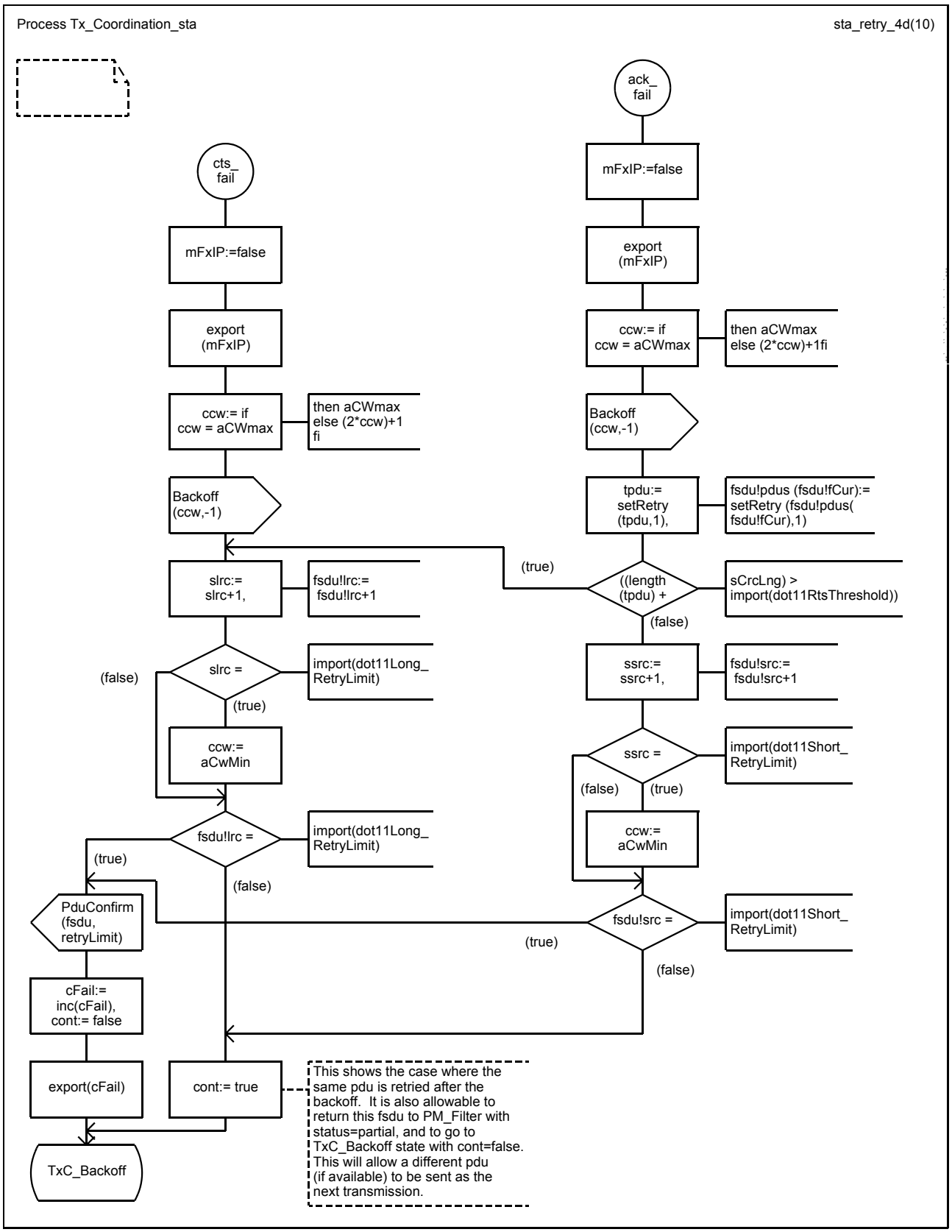

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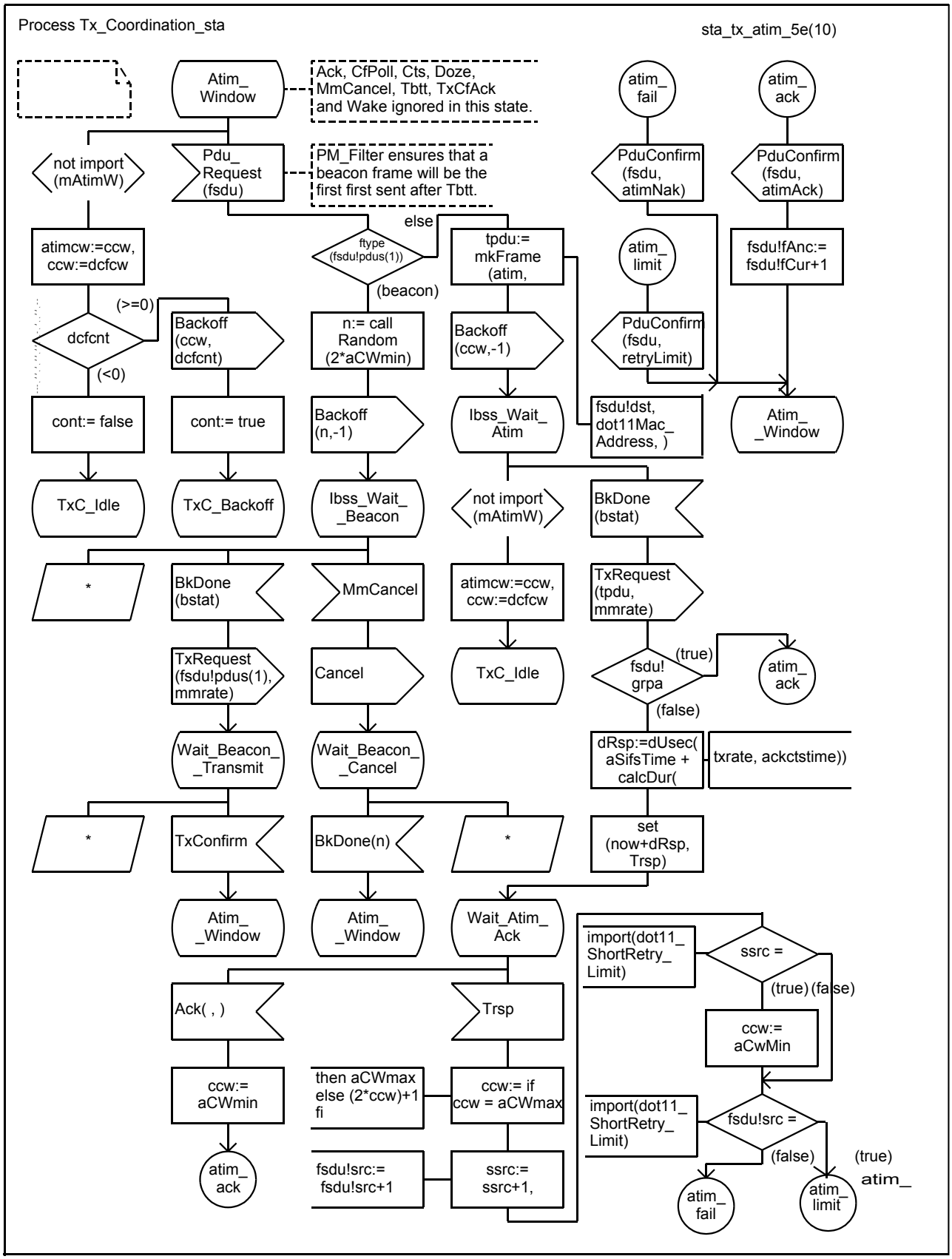

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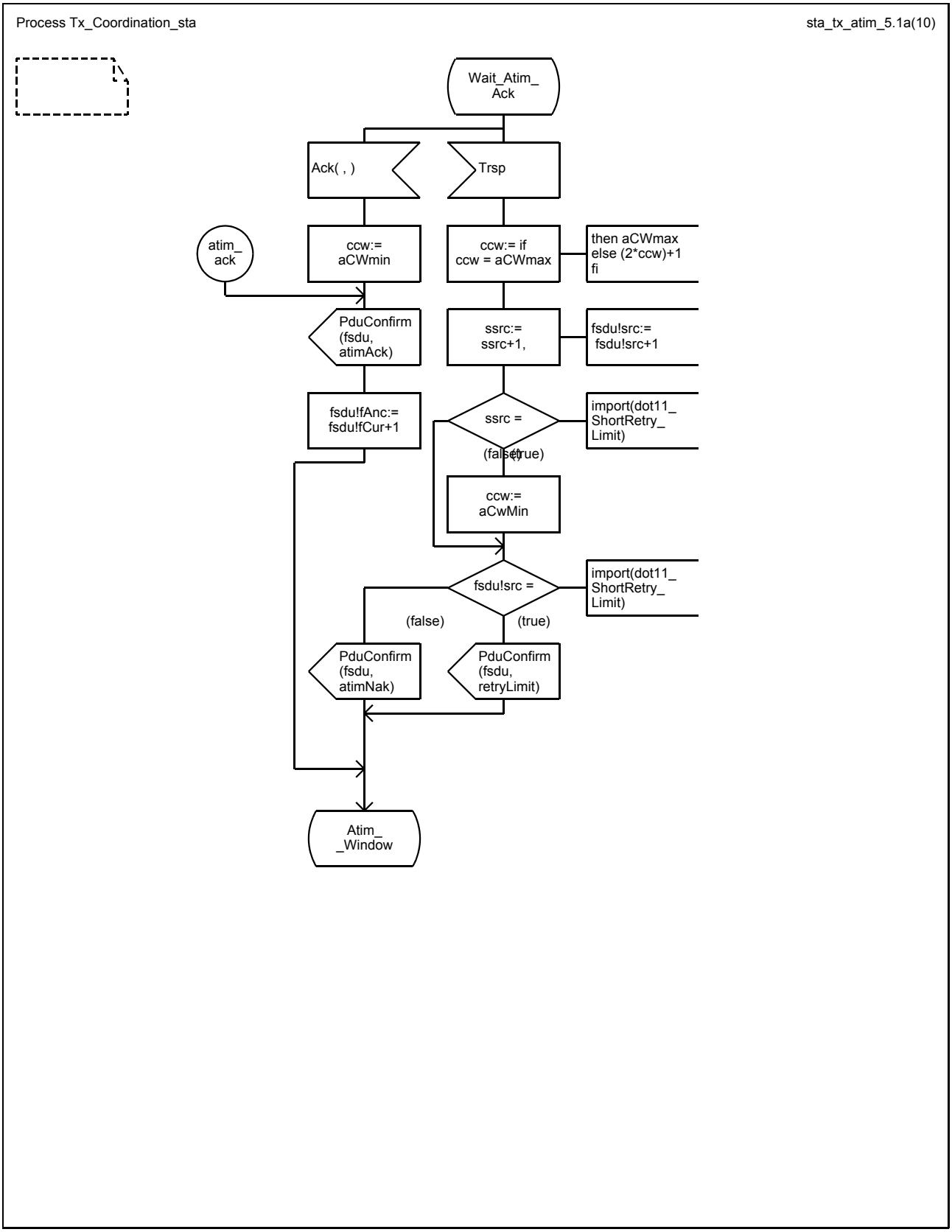

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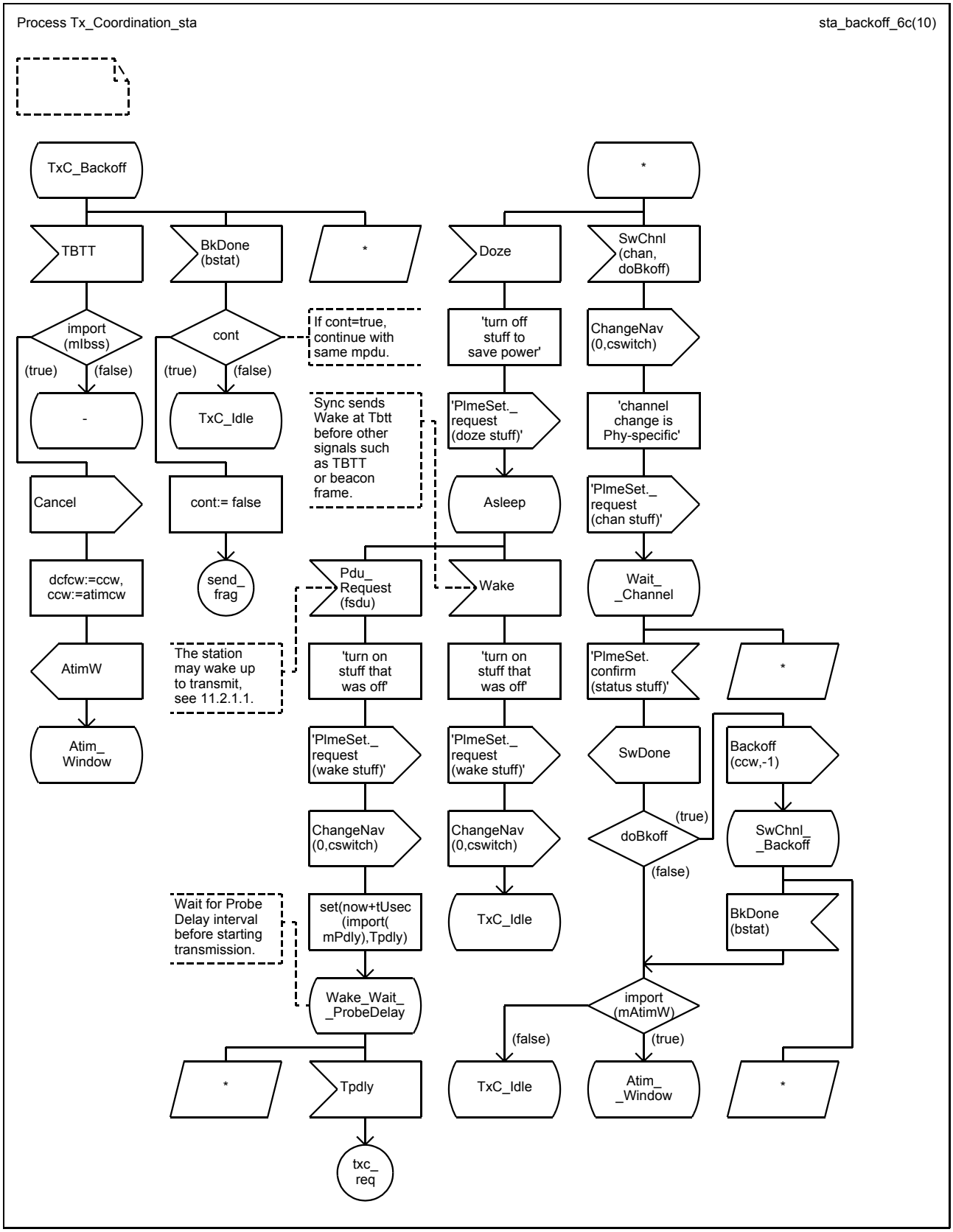

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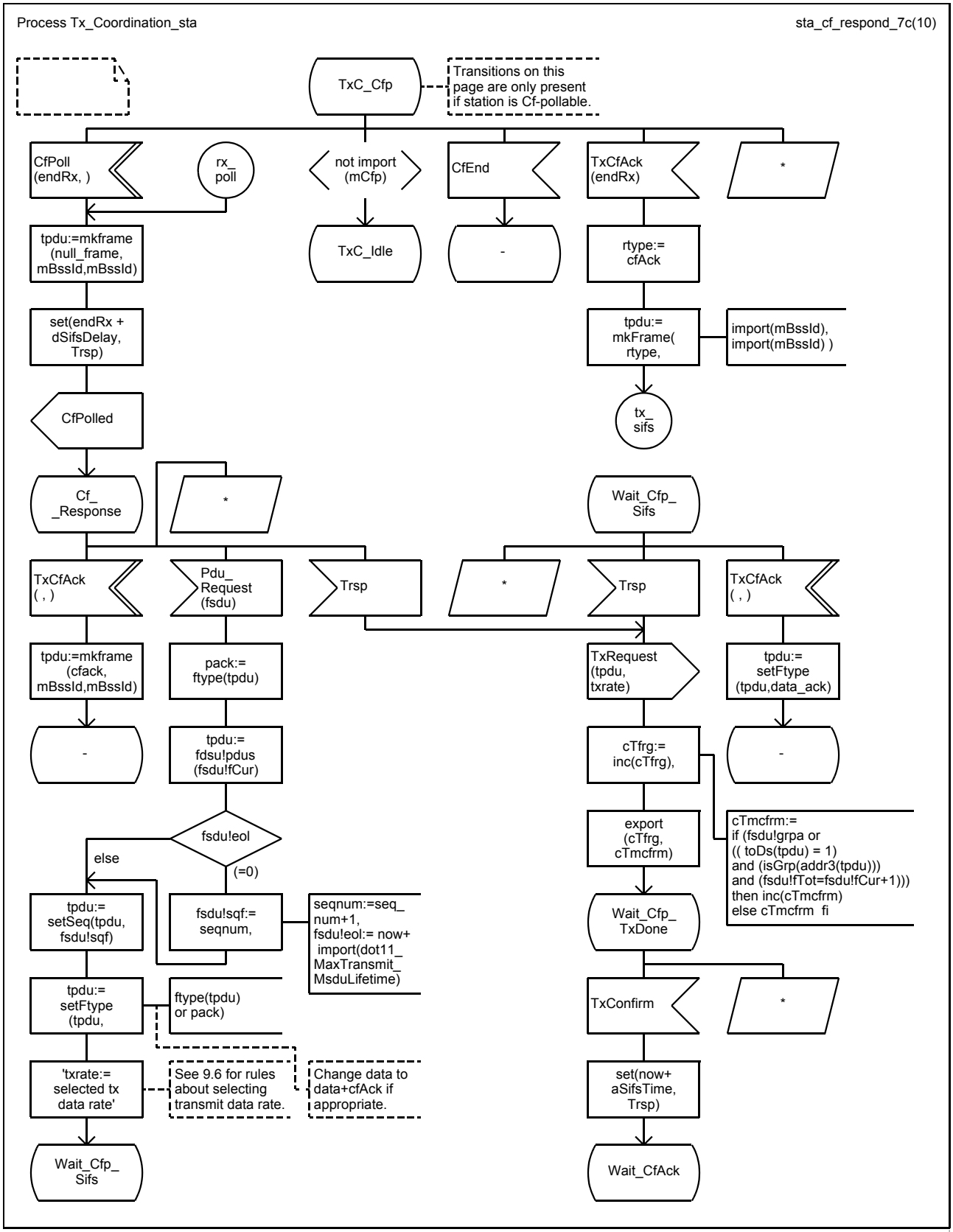

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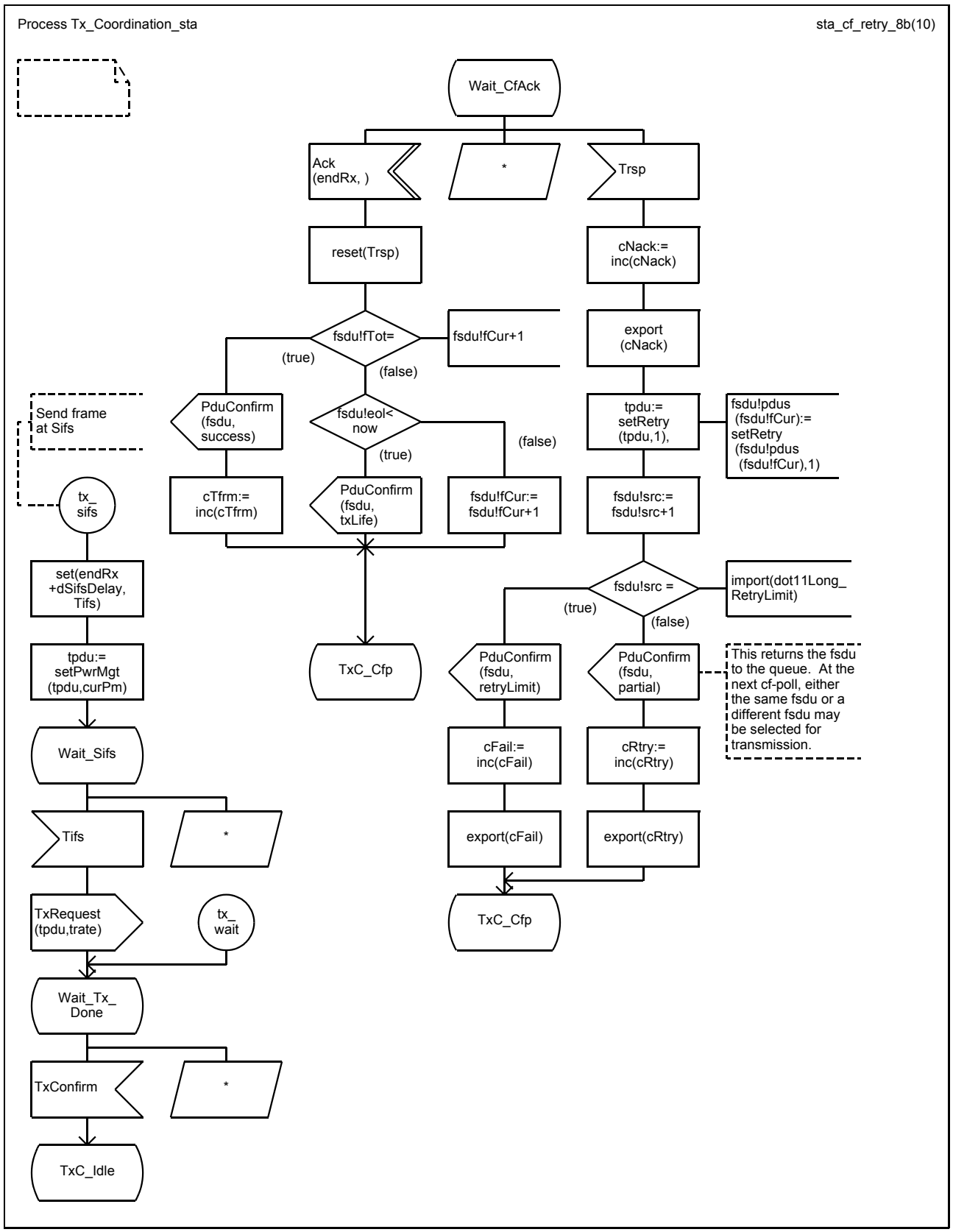

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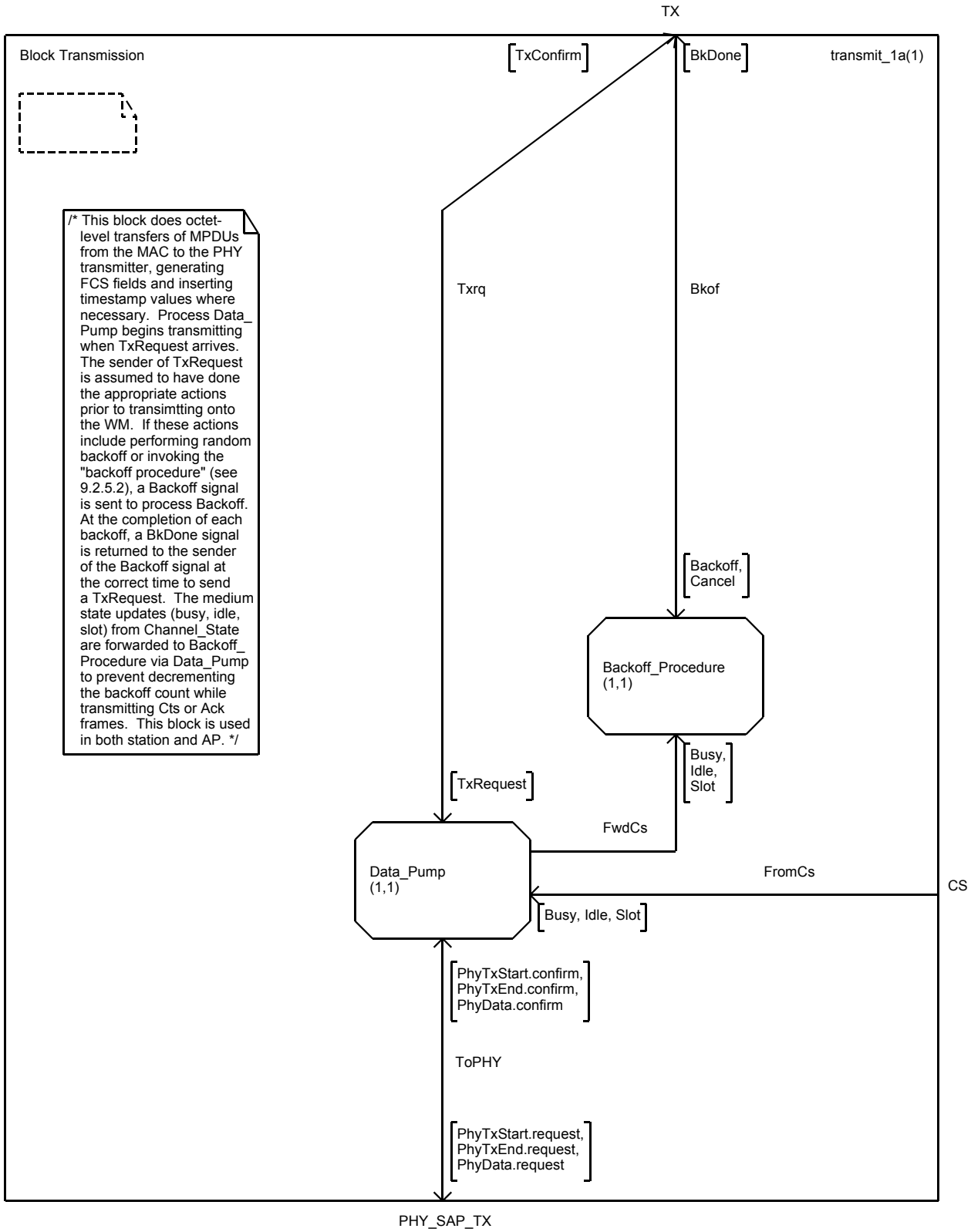

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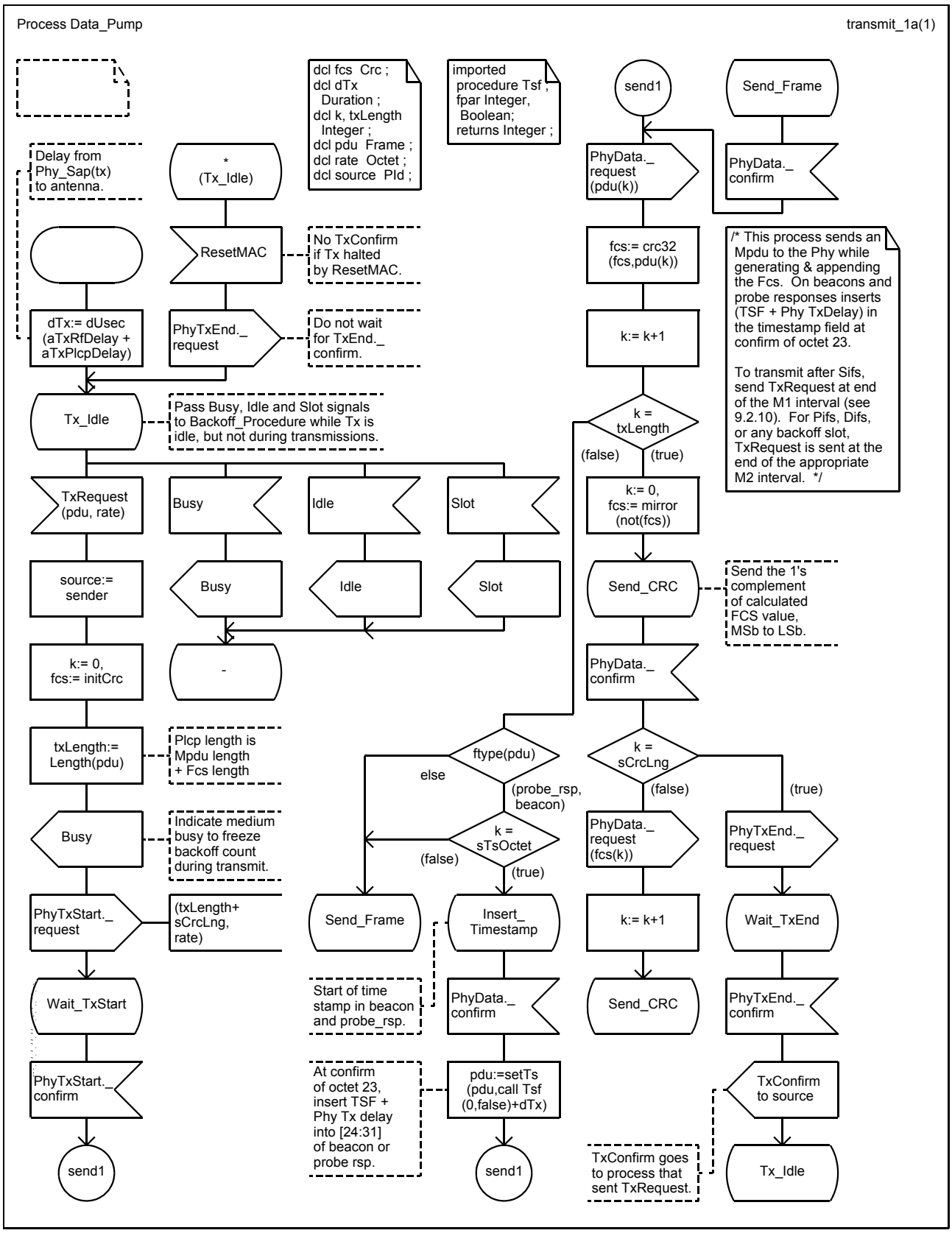

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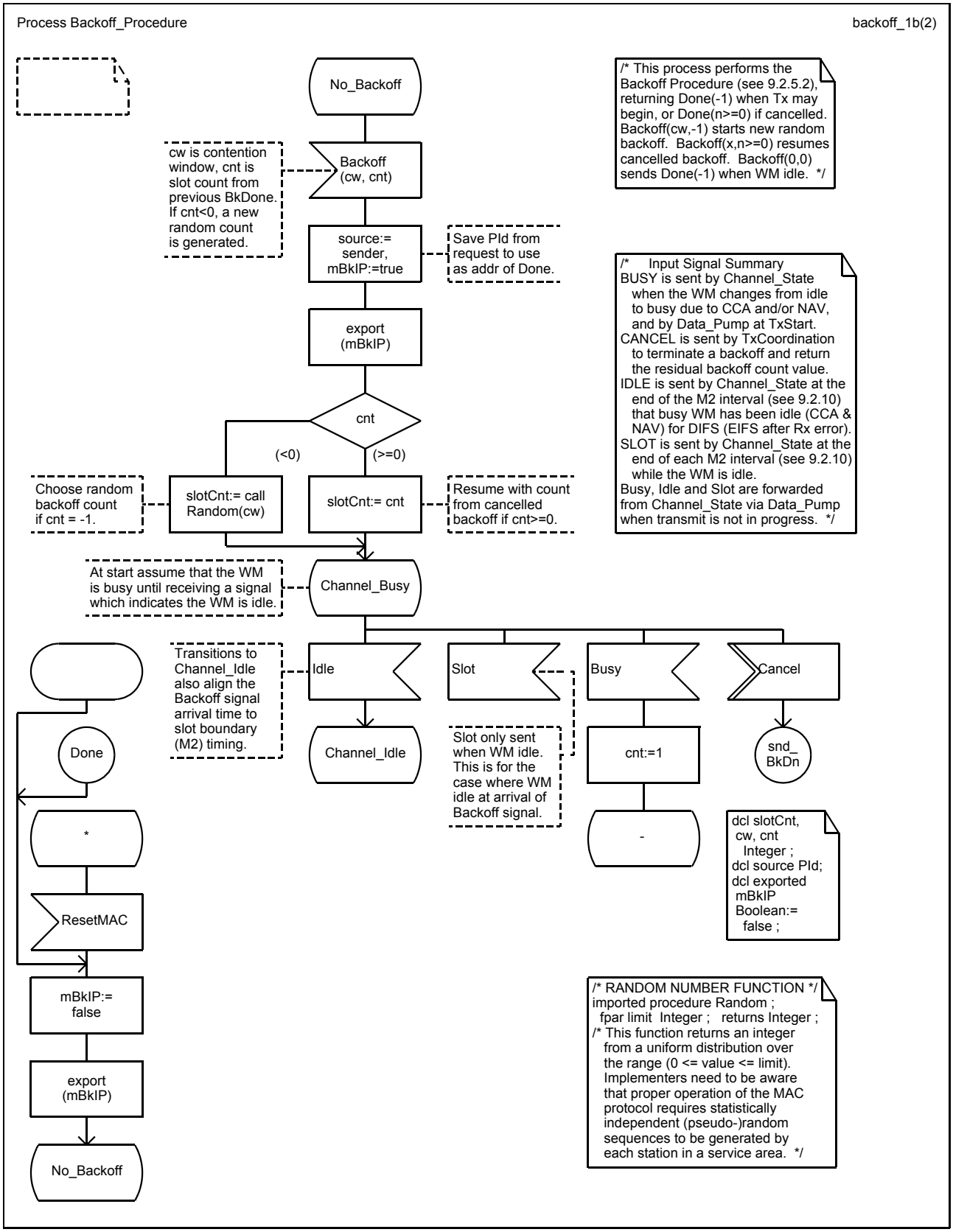

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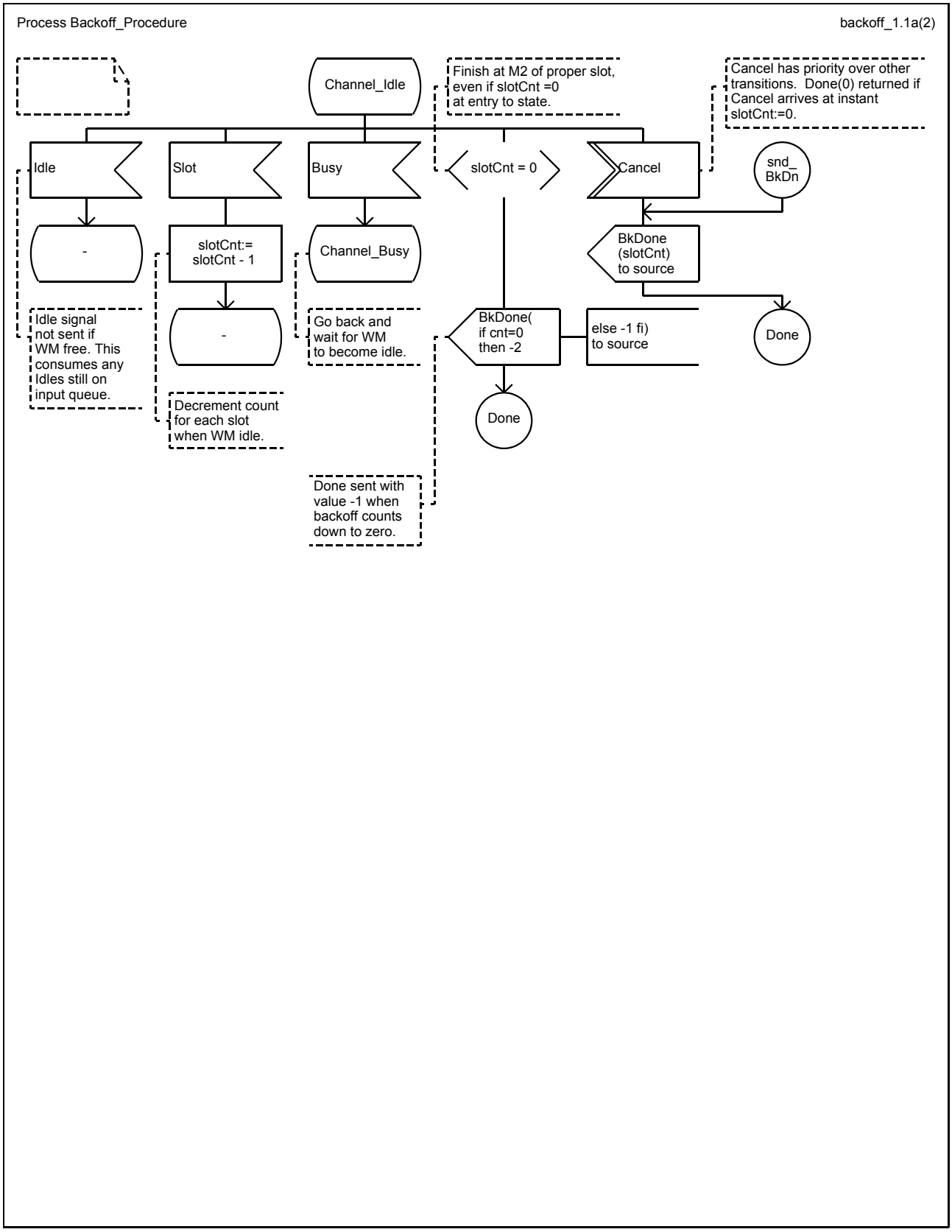

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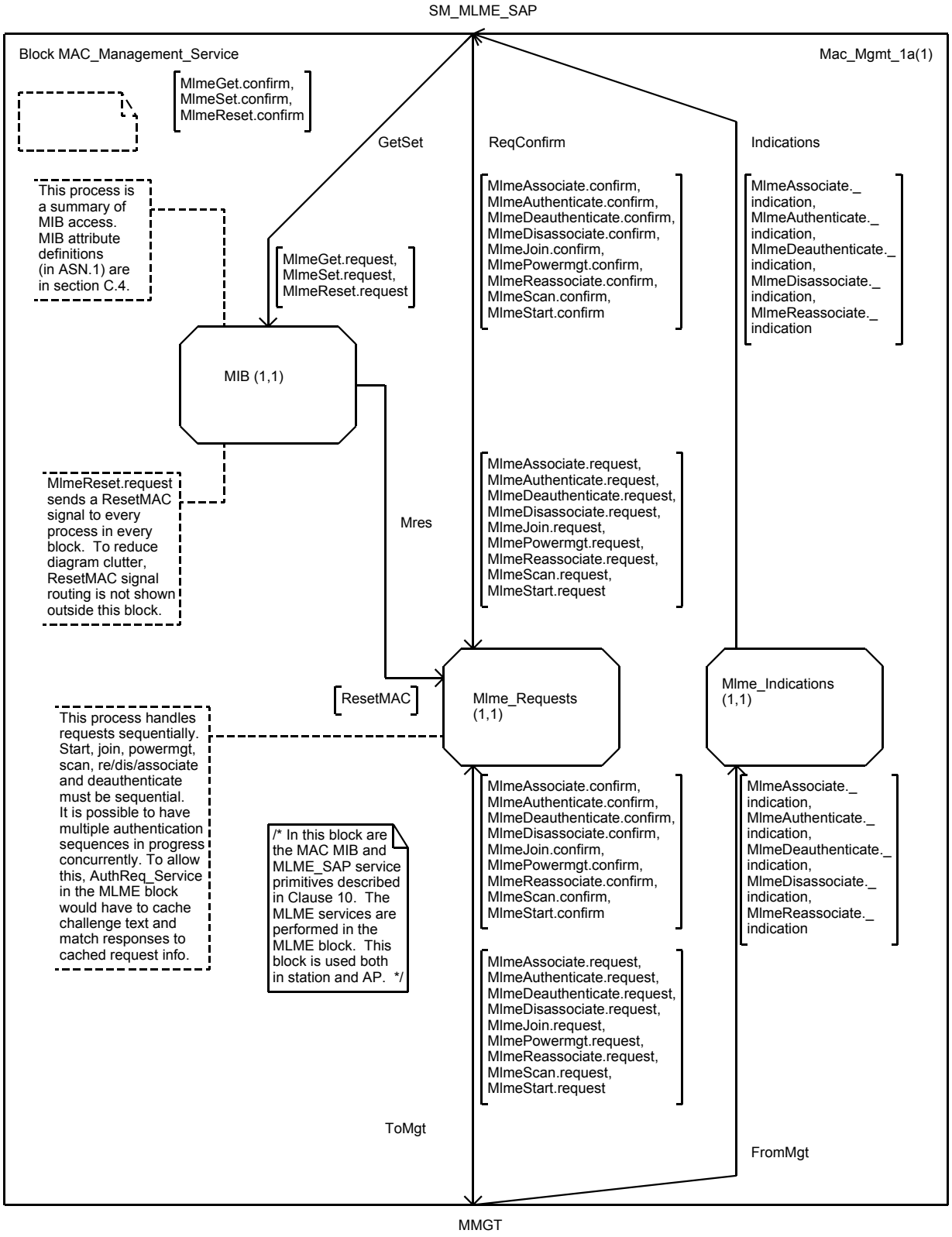

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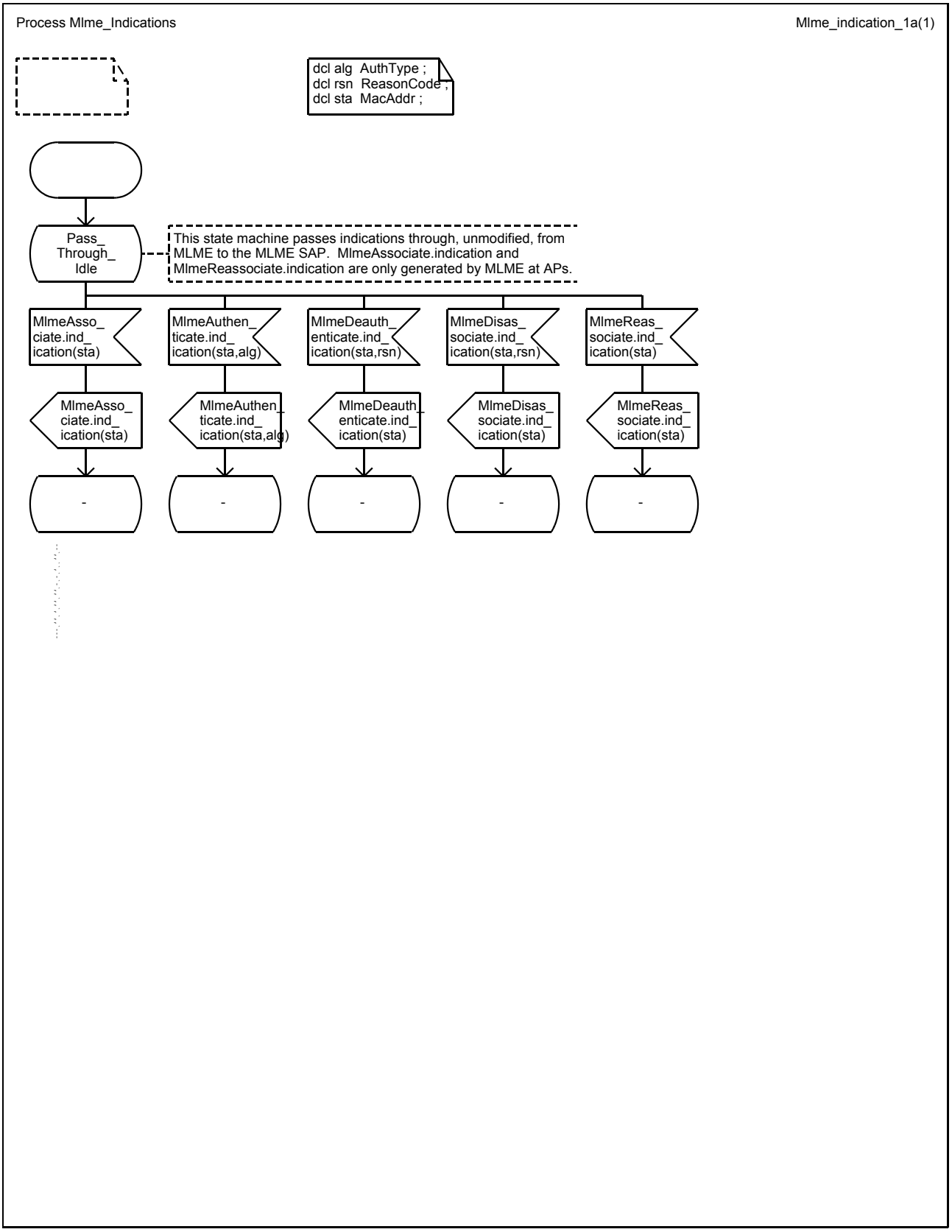

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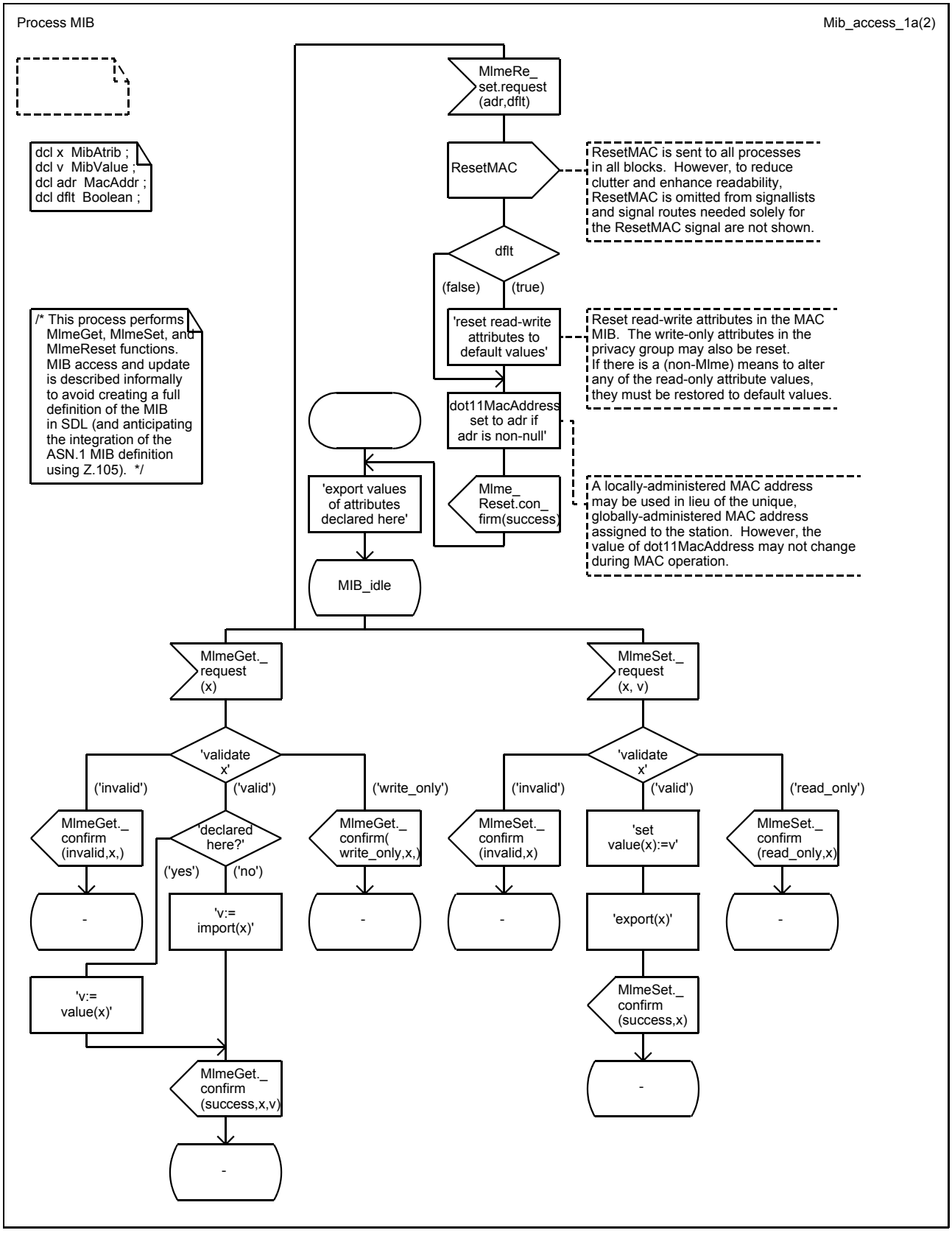

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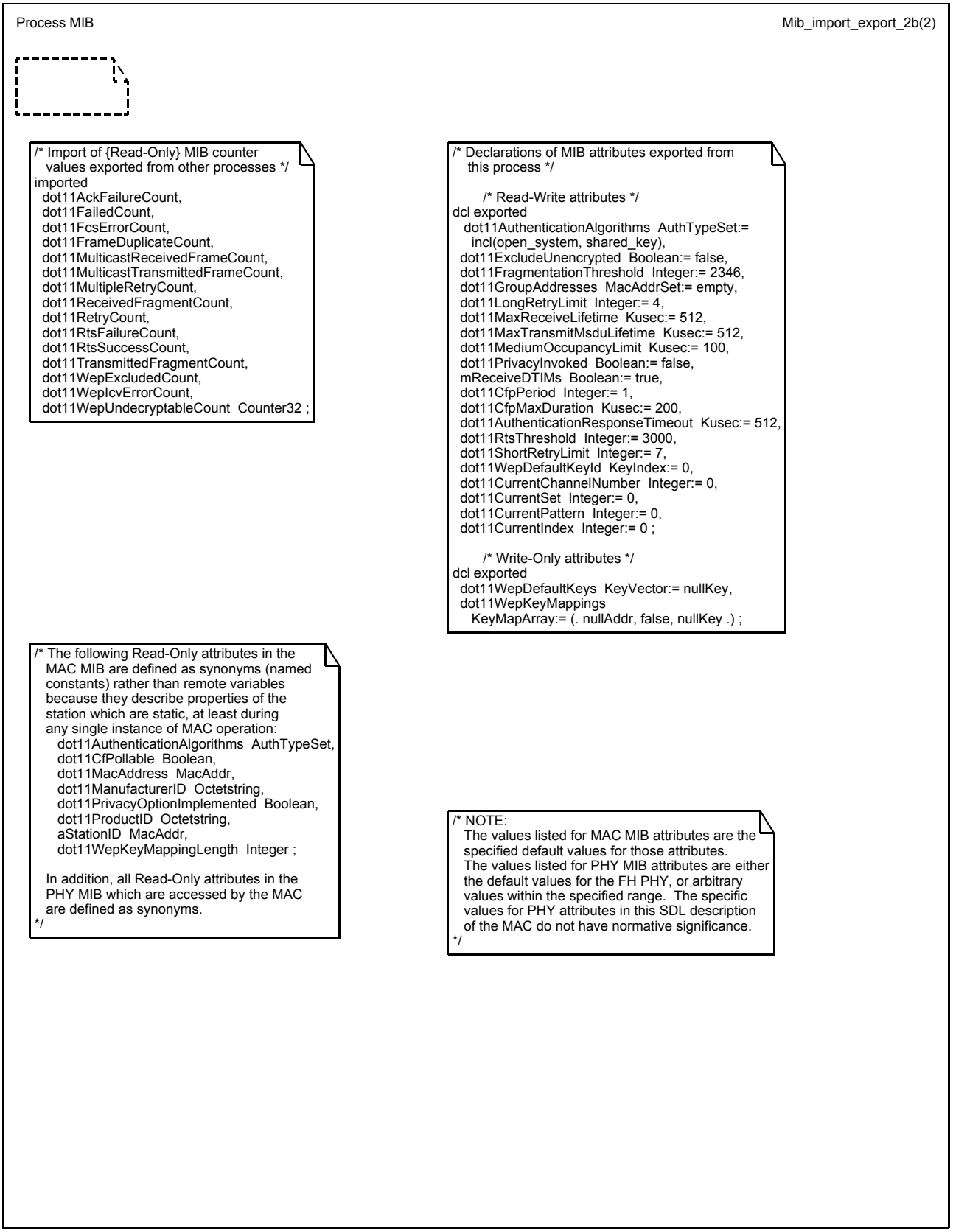

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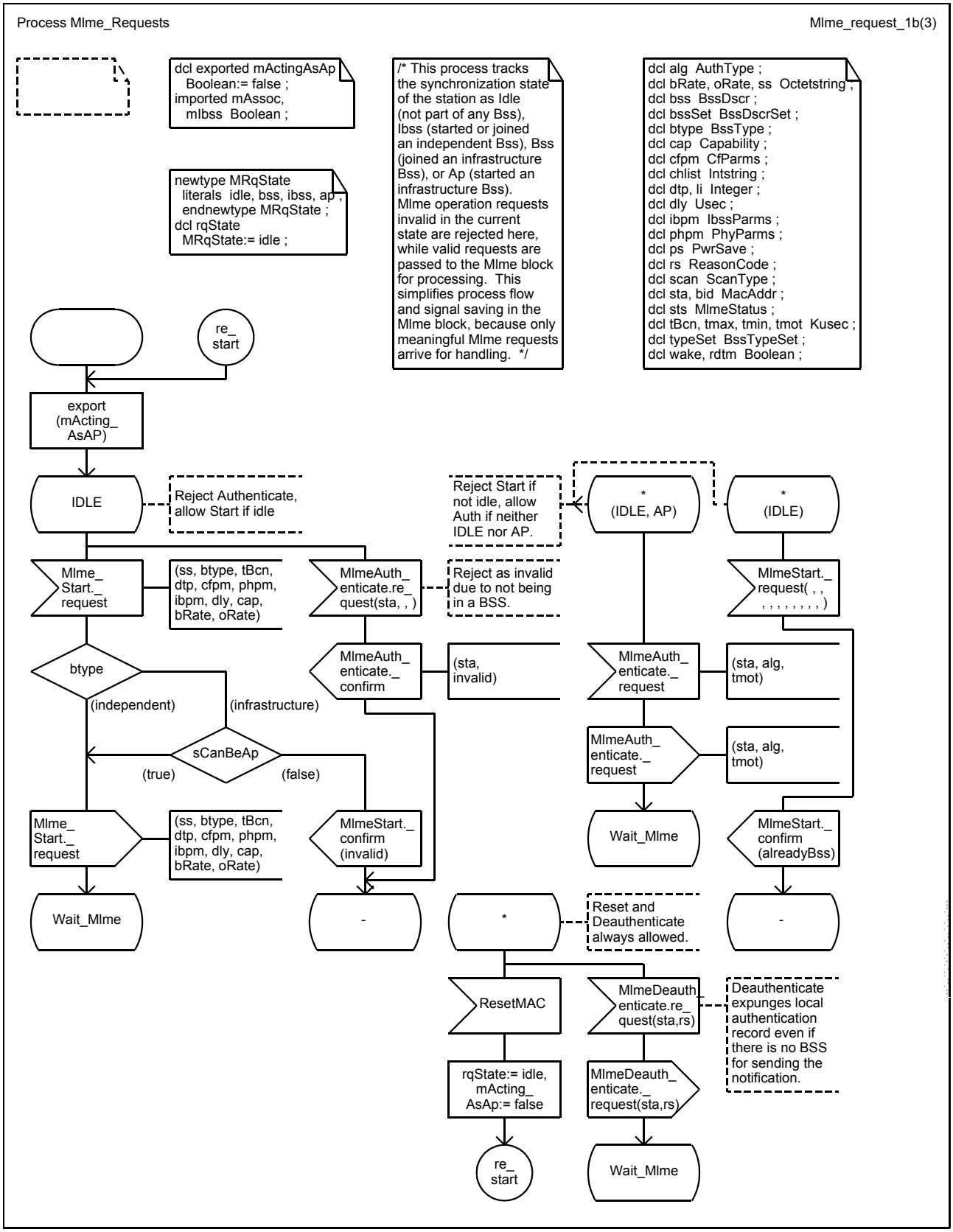

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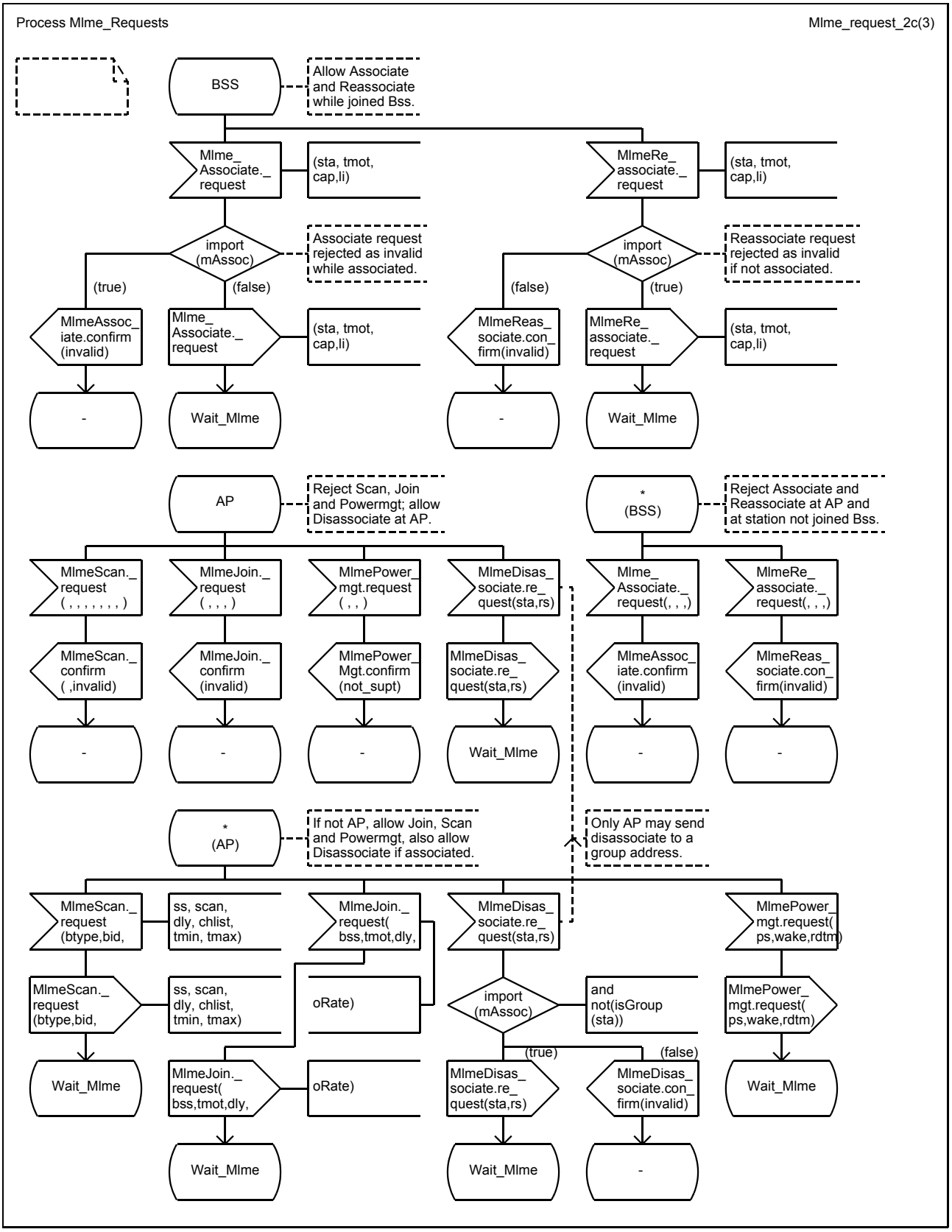

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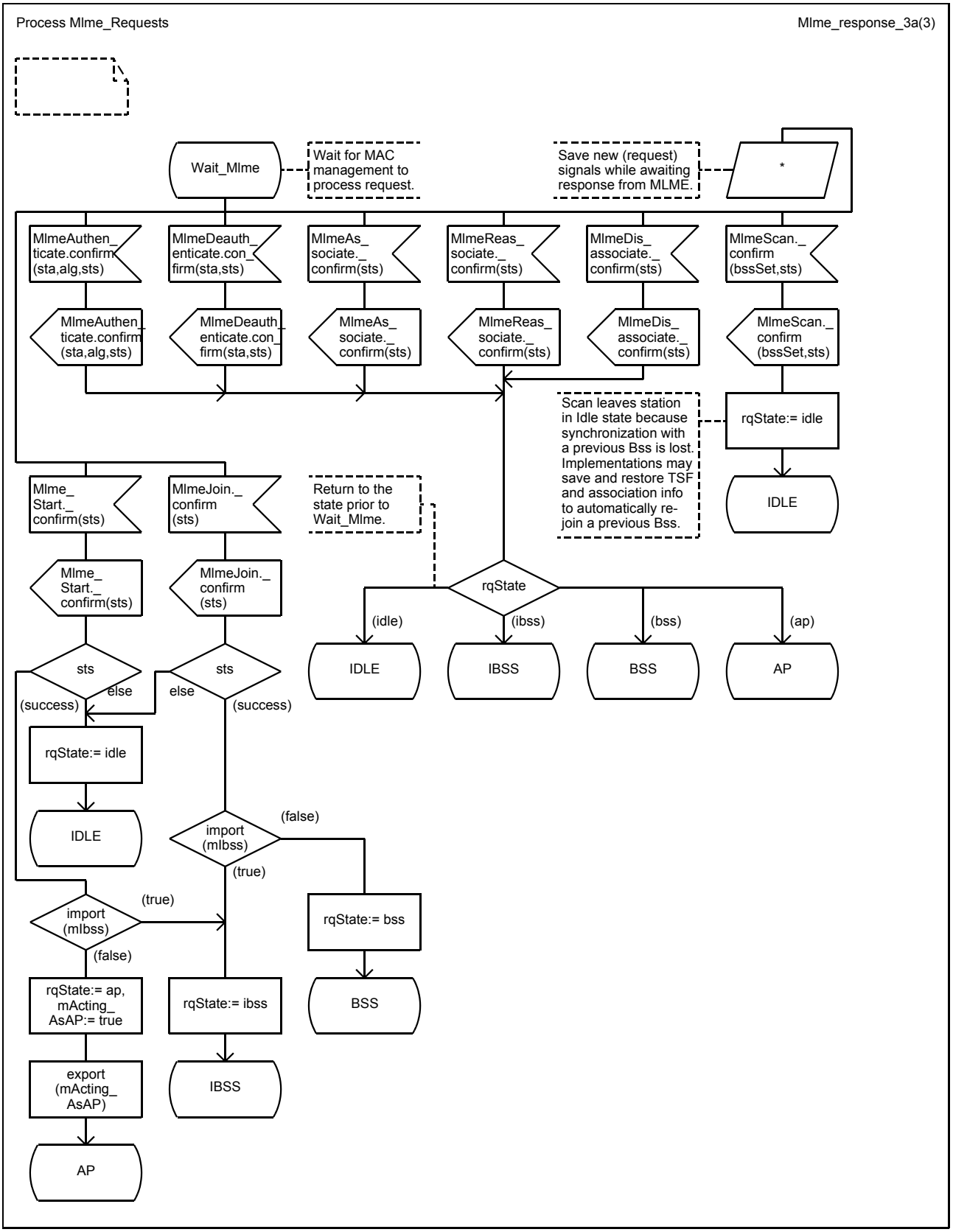

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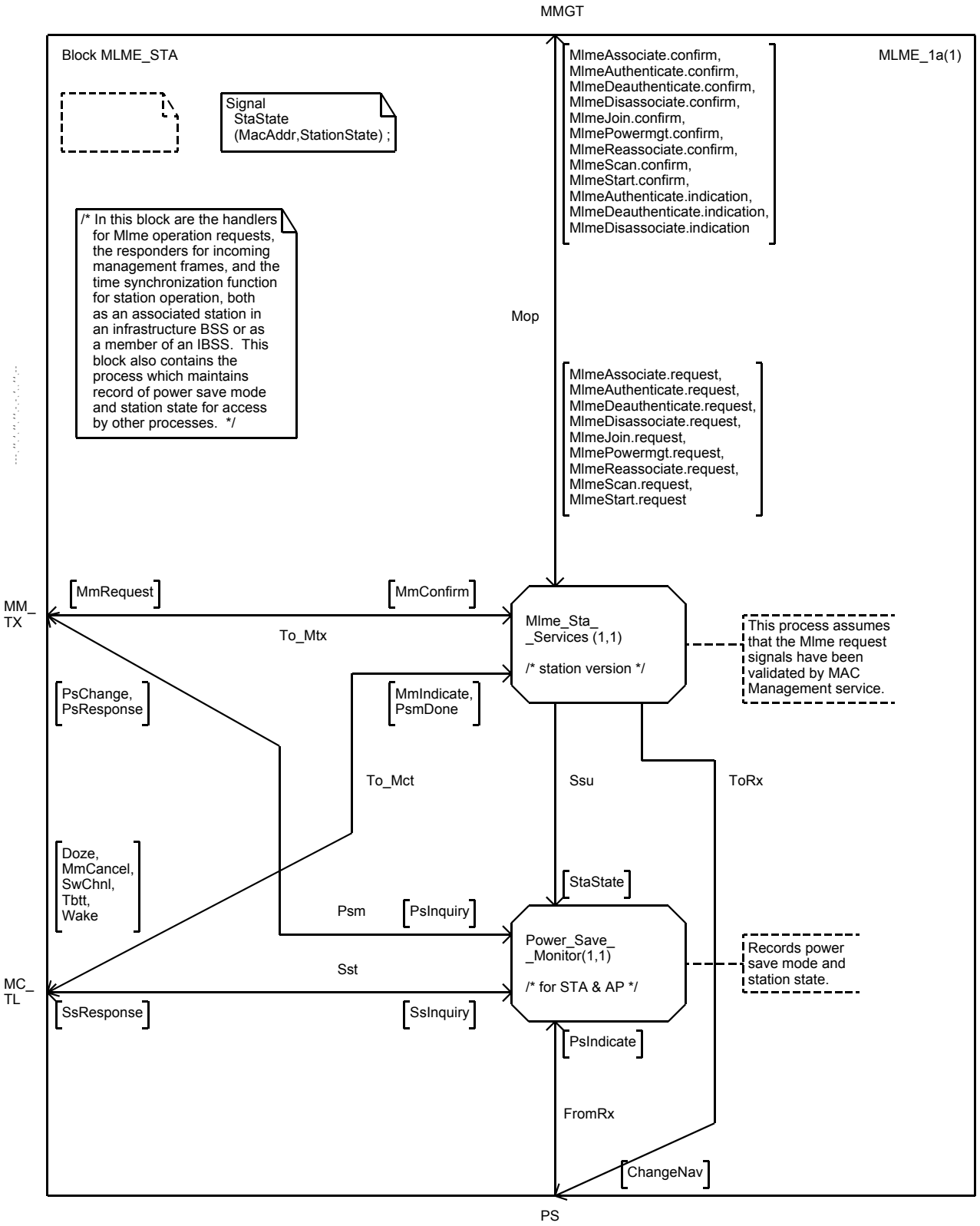

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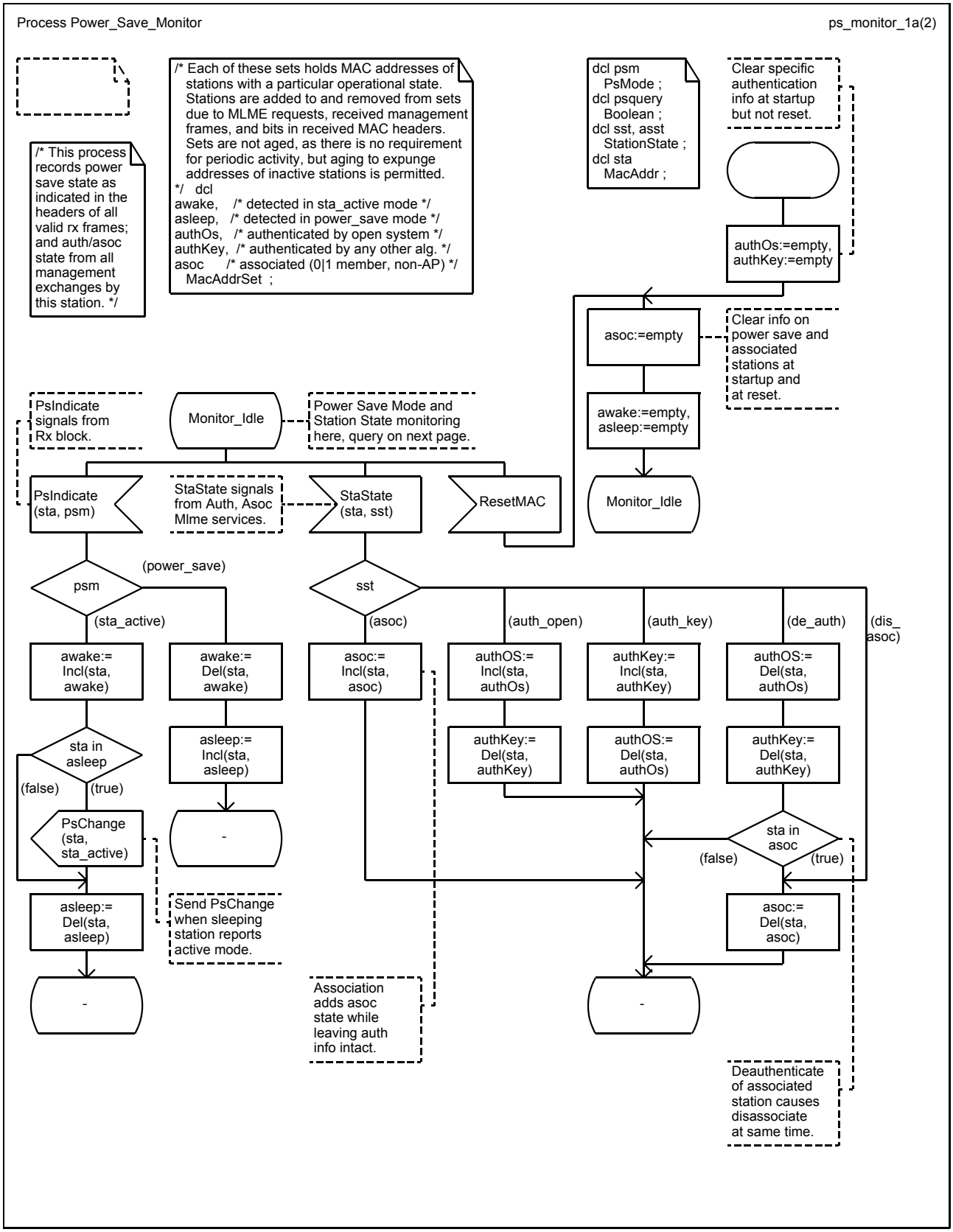

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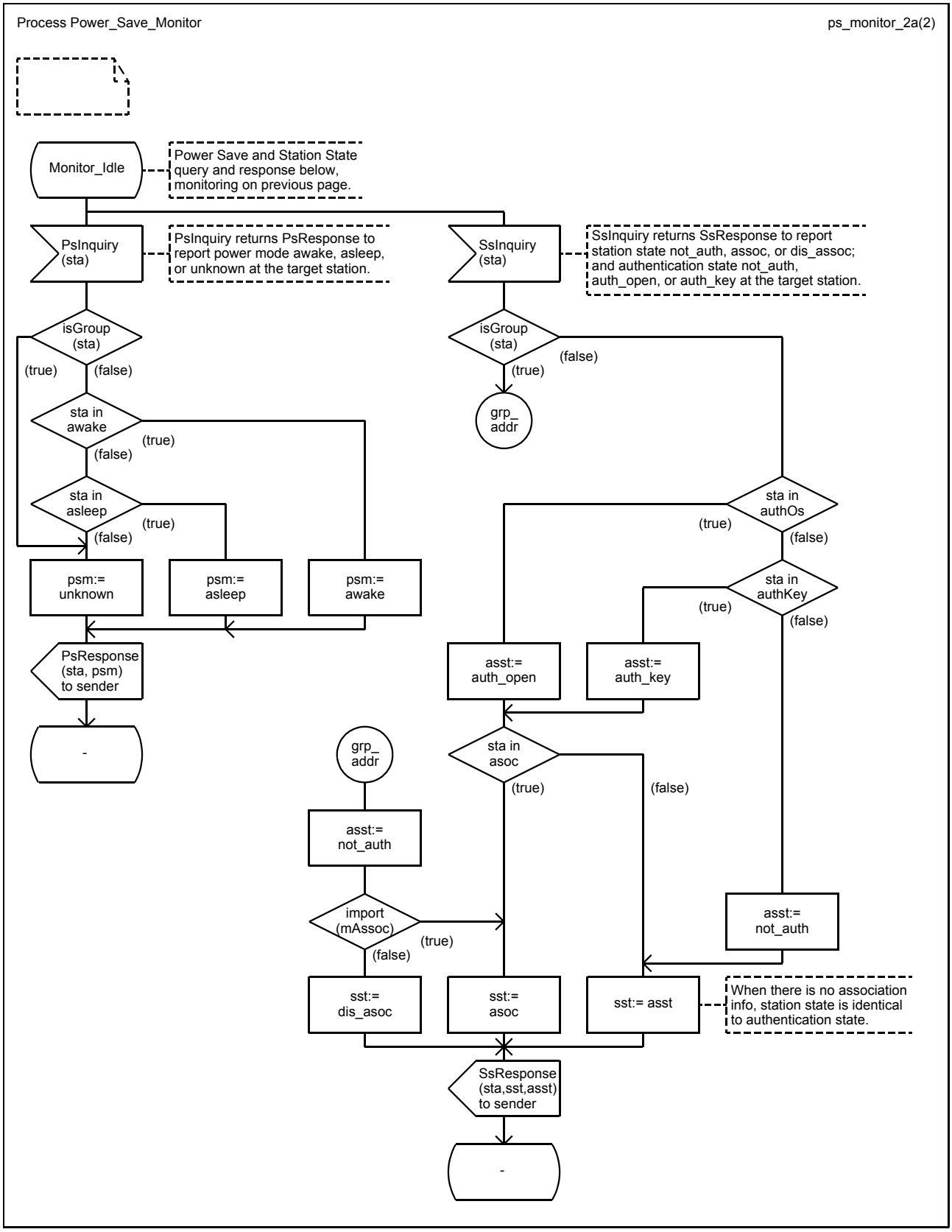

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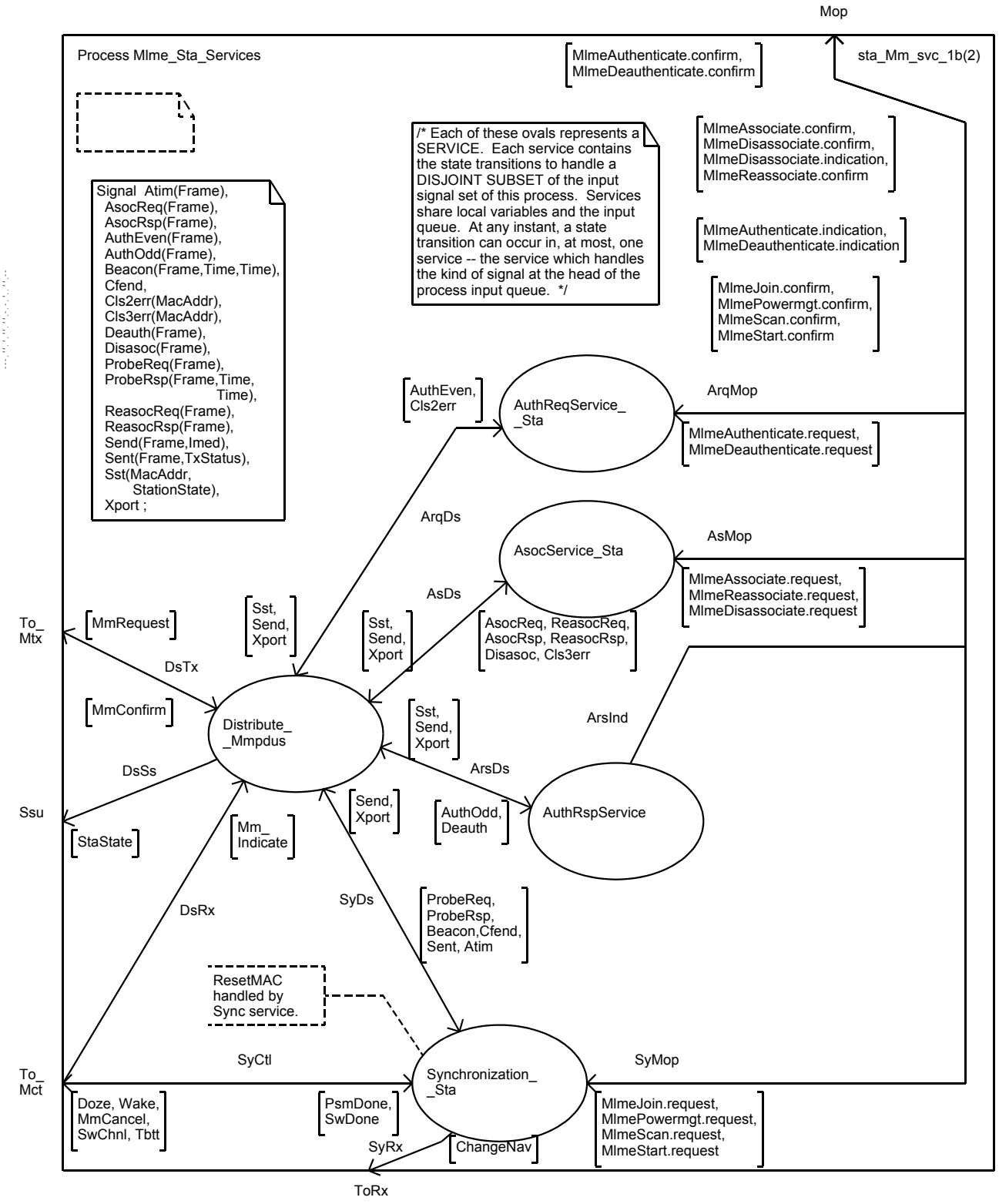

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Process MIme_Sta_Services sta_Mm_svc_1.1b(2)



```
Timer Tasoc,
  Tauth, Tchal,
  Tbcn, Tatim ;
```

```
/* Intra-MAC remote variables */
dcl exported
dot11PowerManagementMode  PwrSave:= sta_active,
dot11DesiredSsid  Octetstring,
dot11DesiredBssType,
dot11OperationalRateSet  Ratestring:= mkOS(2,1),
dot11BeaconPeriod  TU,
dot11DtimPeriod  Integer:= 1,
dot11AssociationResponseTimeOut  TU,
dot11MultiDomainCapabilityEnabled  Boolean:= false,
mAId  AsocId:= 0,
mAssoc  Boolean:= false,
mAtimW  Boolean:= false,
mBrates Ratestring:= mkOS(2,1),
mBssId  MacAddr:= nullAddr,
mCap  Octetstring:= O2,
mCfp  Boolean:= false,
mDisable  Boolean:= true,
mDtimCount  Integer:= 1,
mIbss  Boolean:= false,
mNextBdry  Time:= 0,
mNextTbtt  Time:= 0,
mPcAvail  Boolean:= false,
mPcPoll  Boolean:= false,
mPdly  Usec:= 0,
mPss  PsState:= awake,
mSsId  Octetstring:= null;
```


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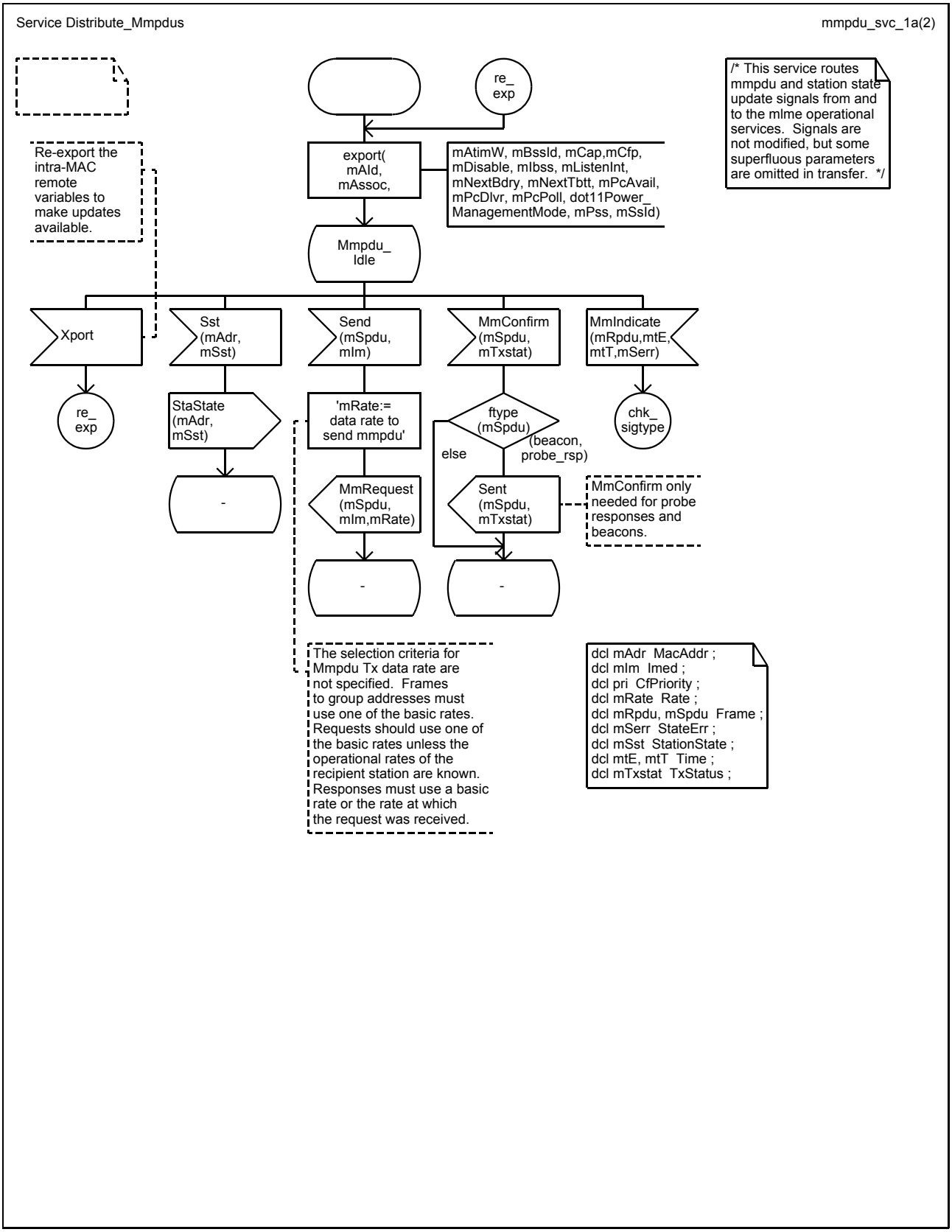

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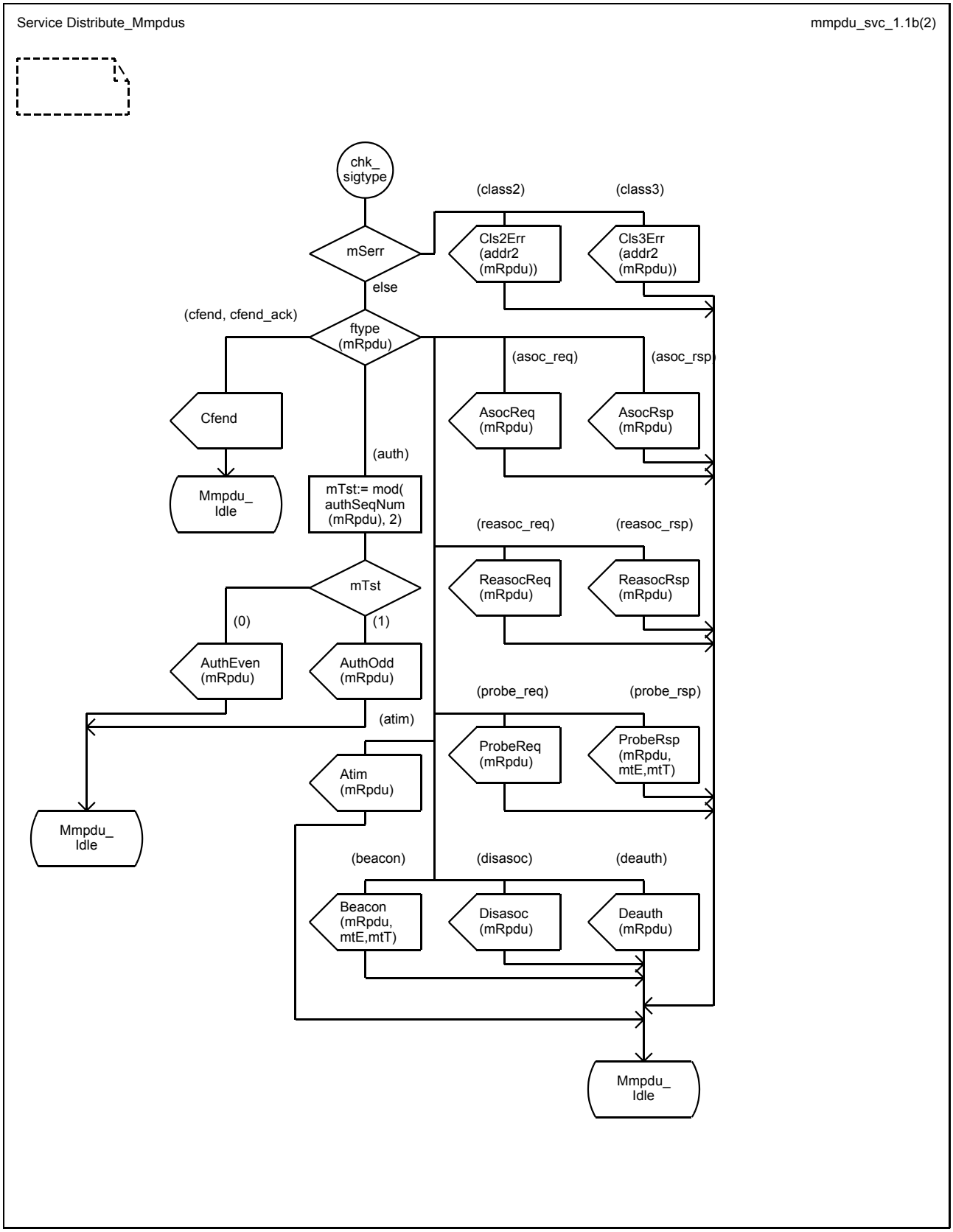

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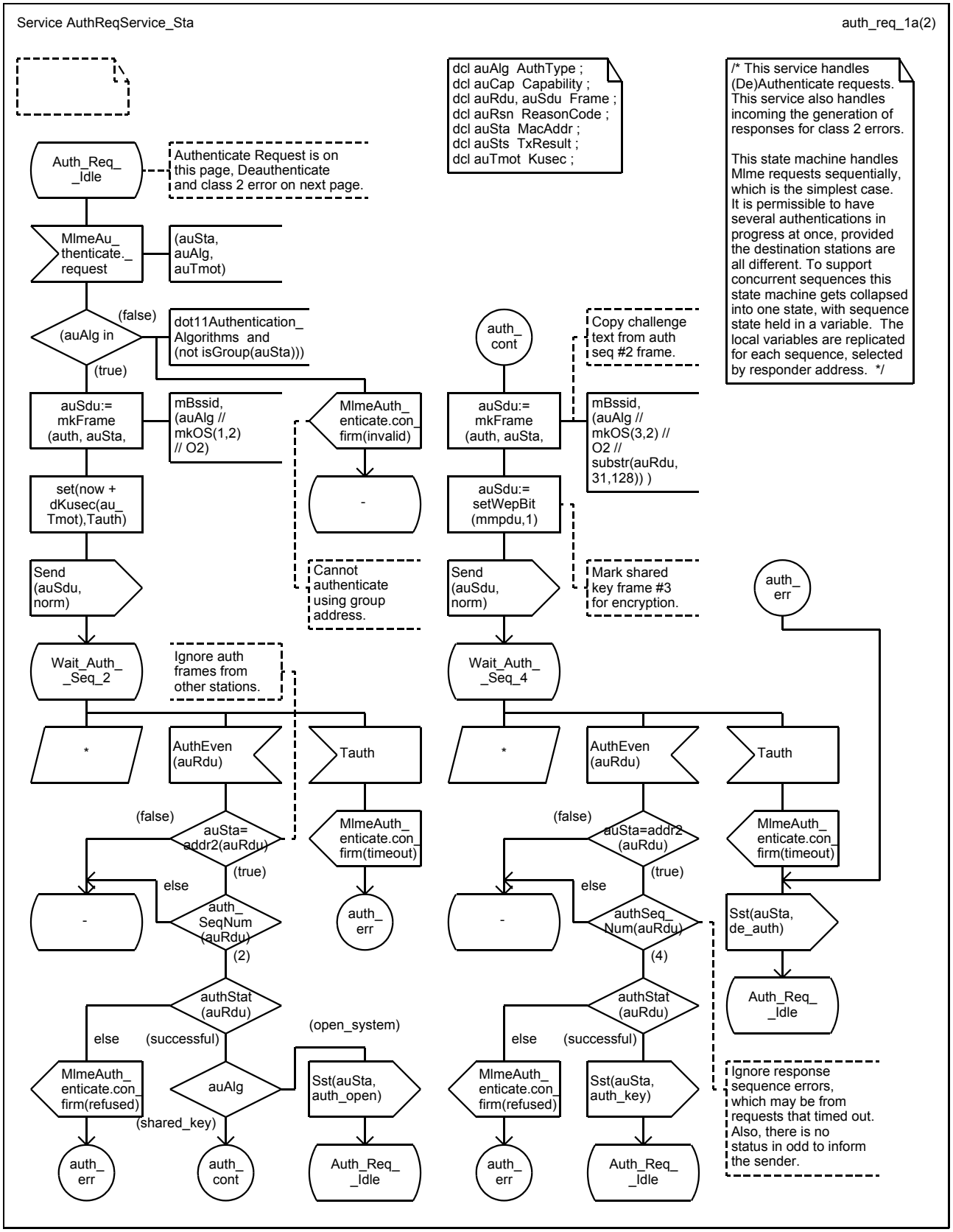

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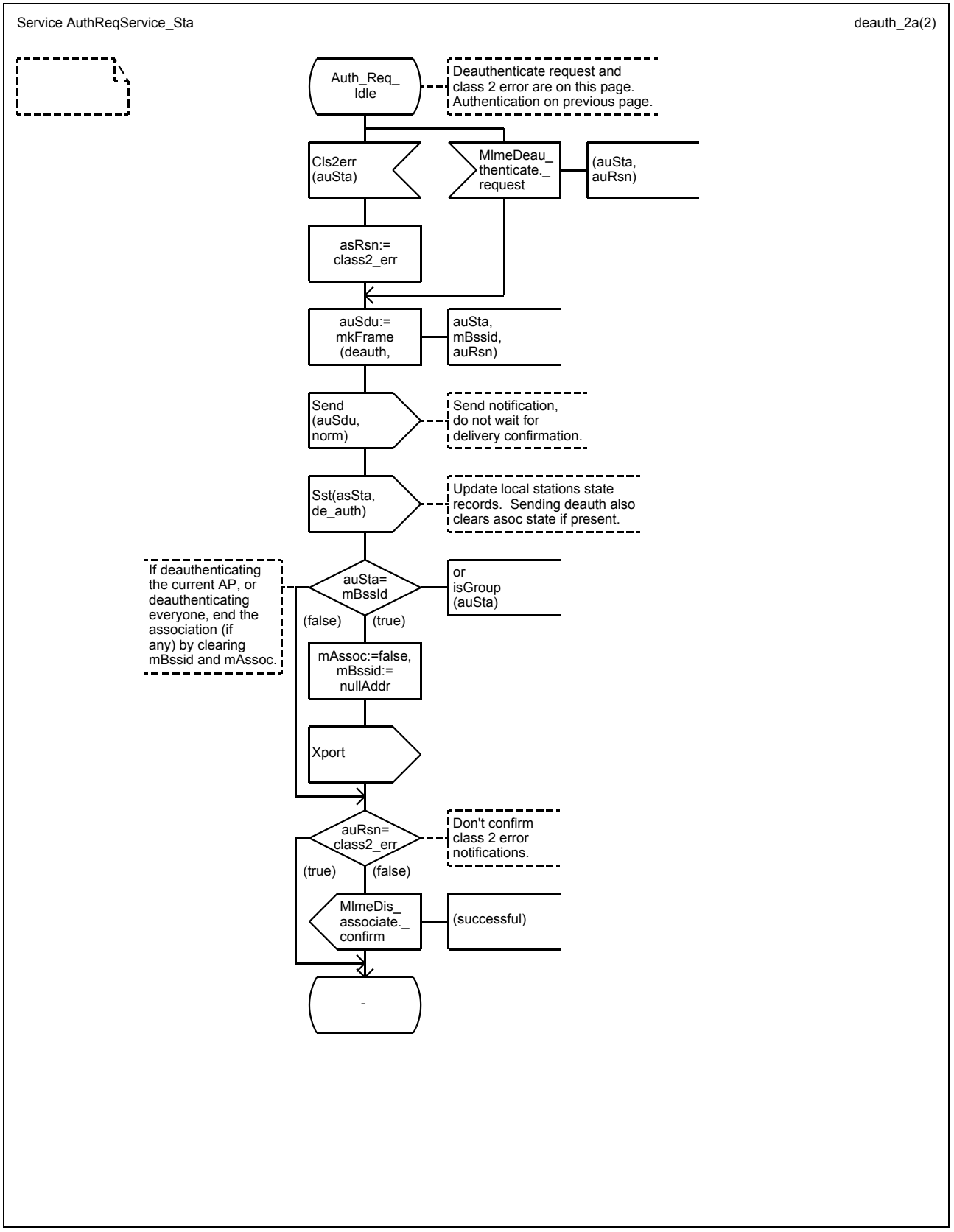

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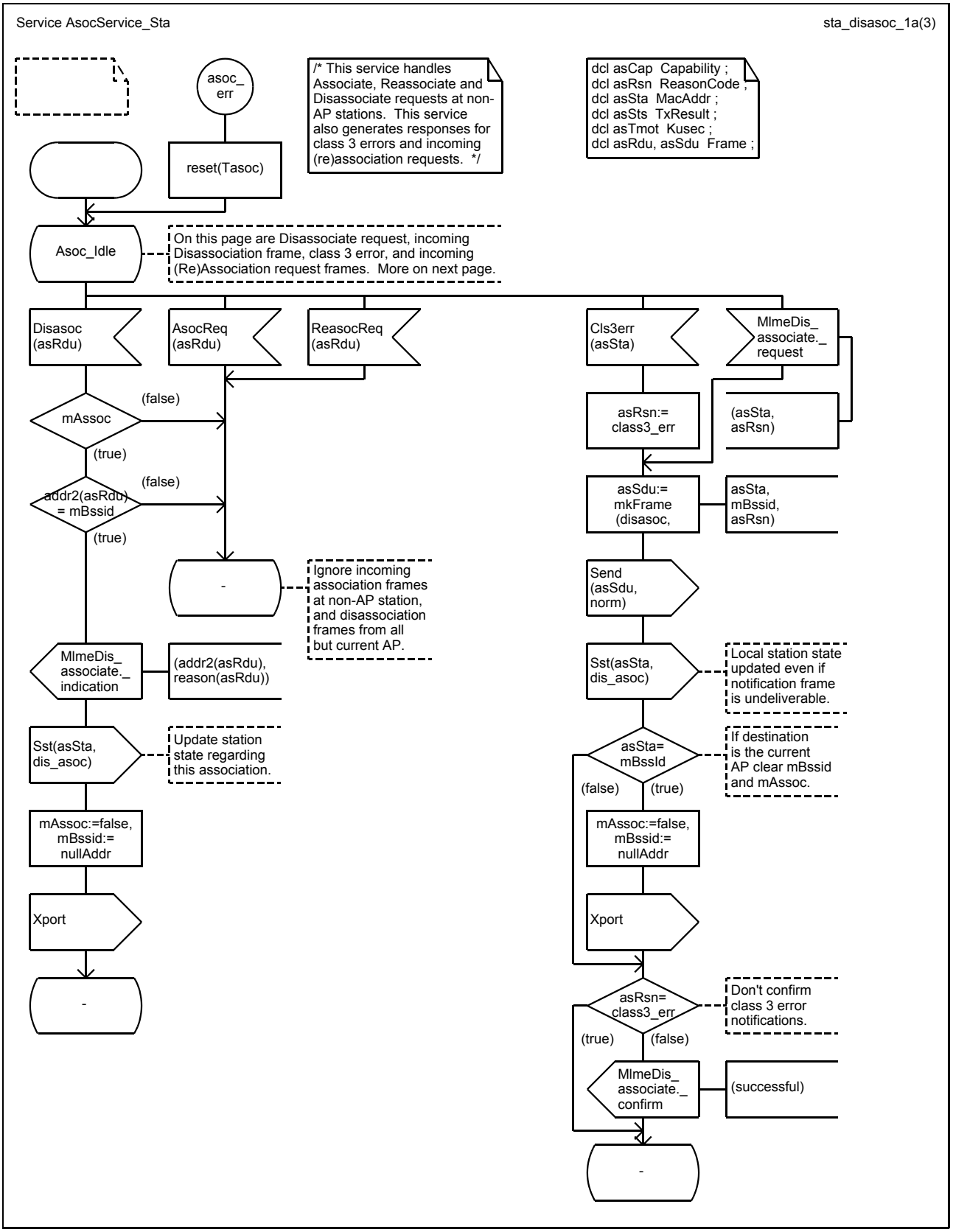

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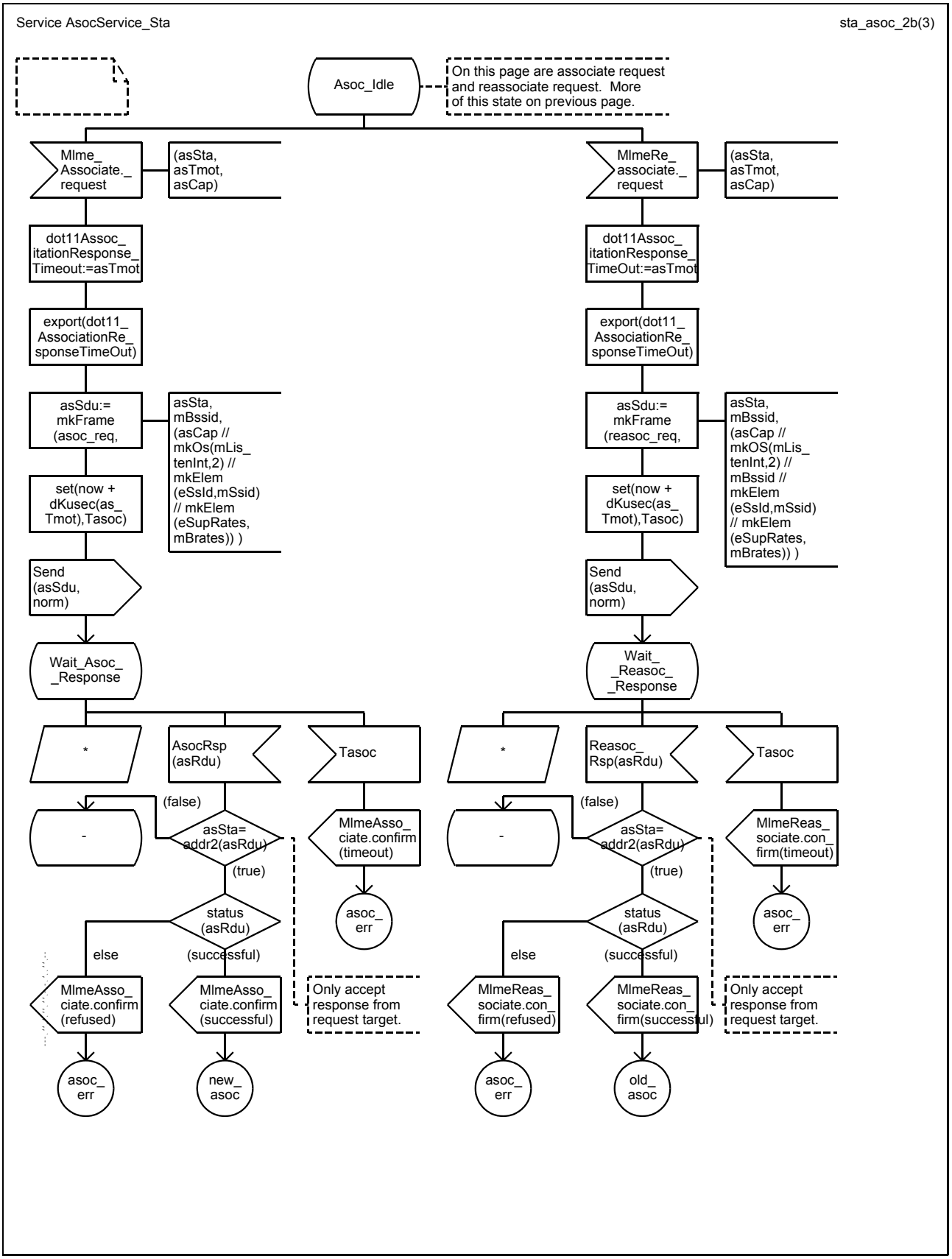

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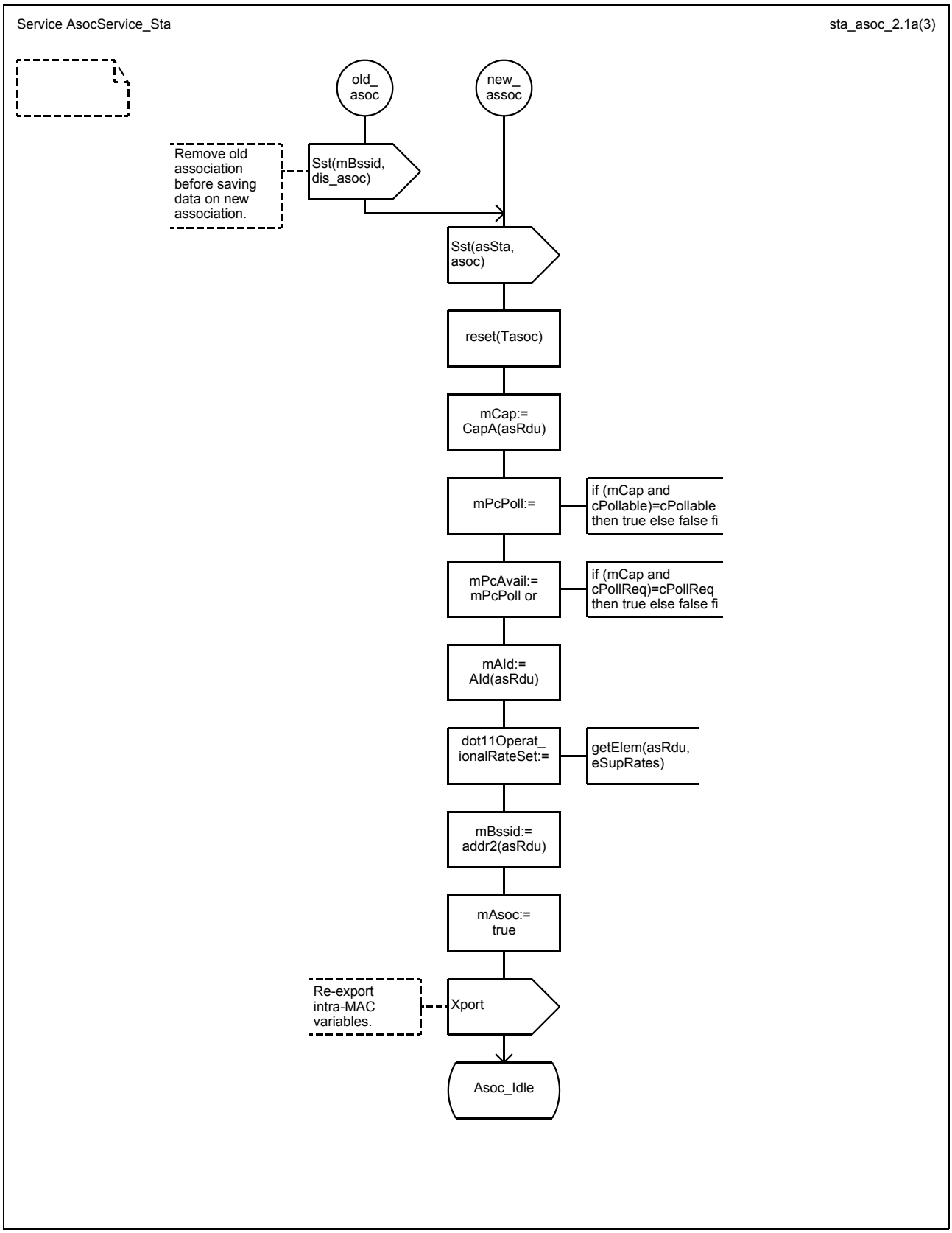

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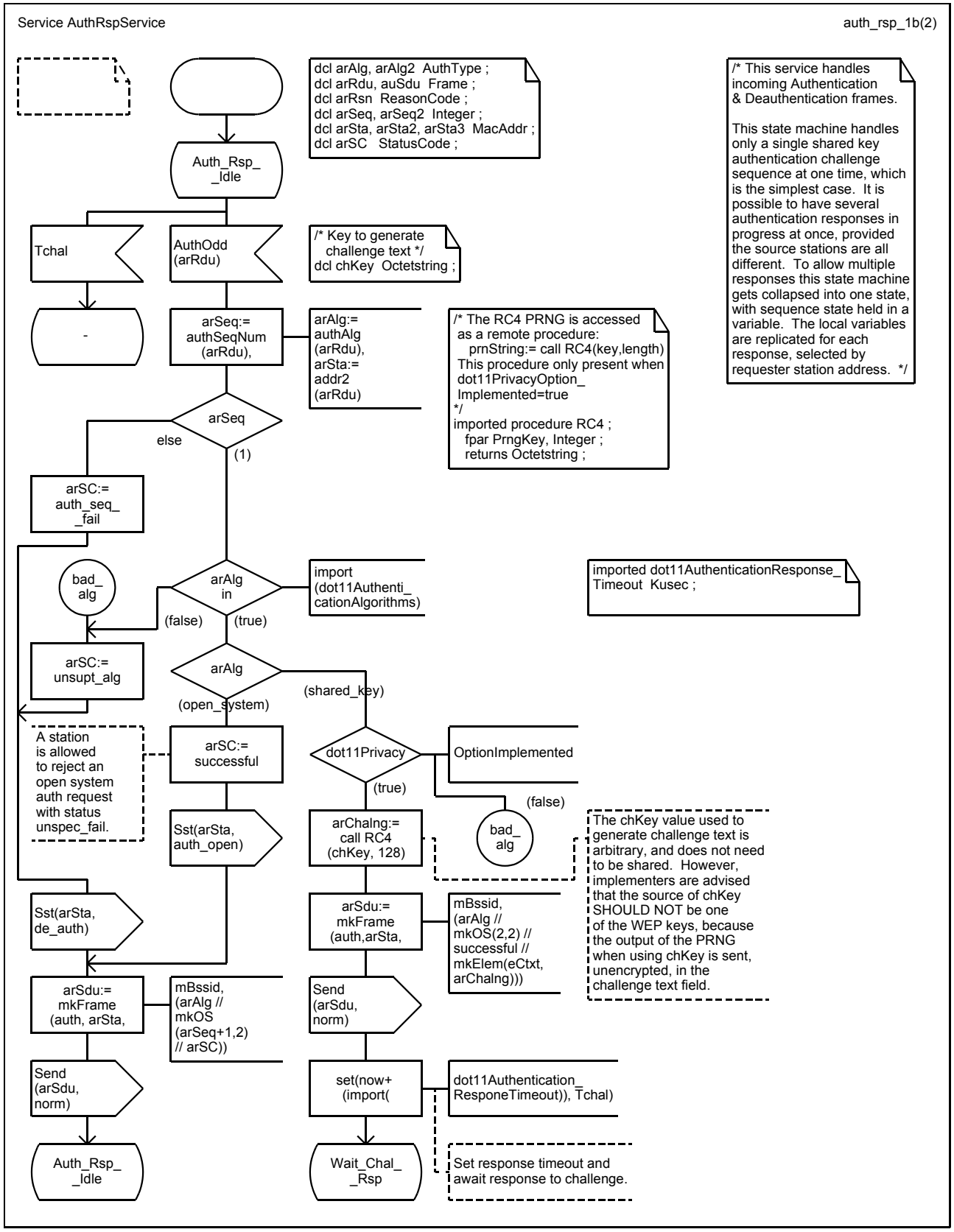

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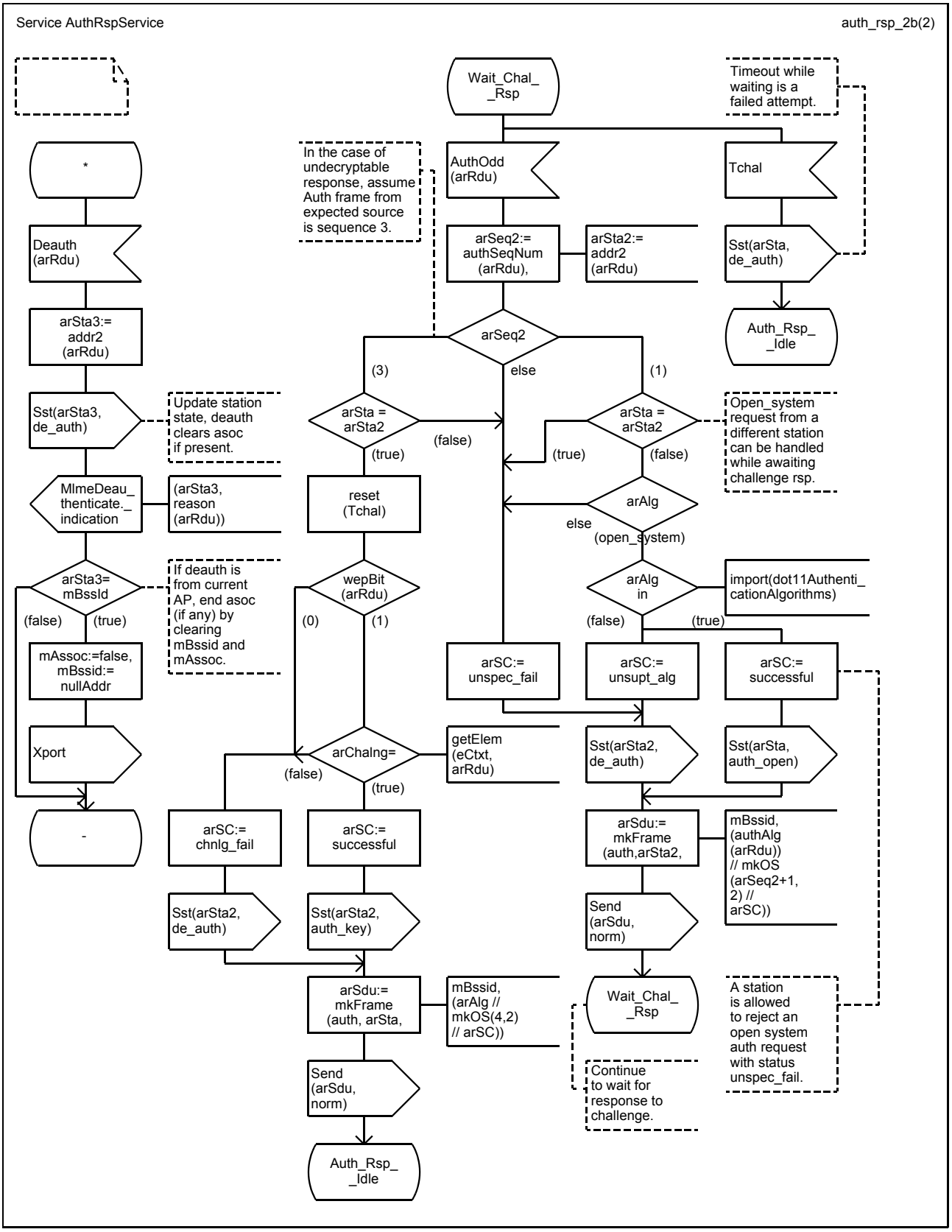

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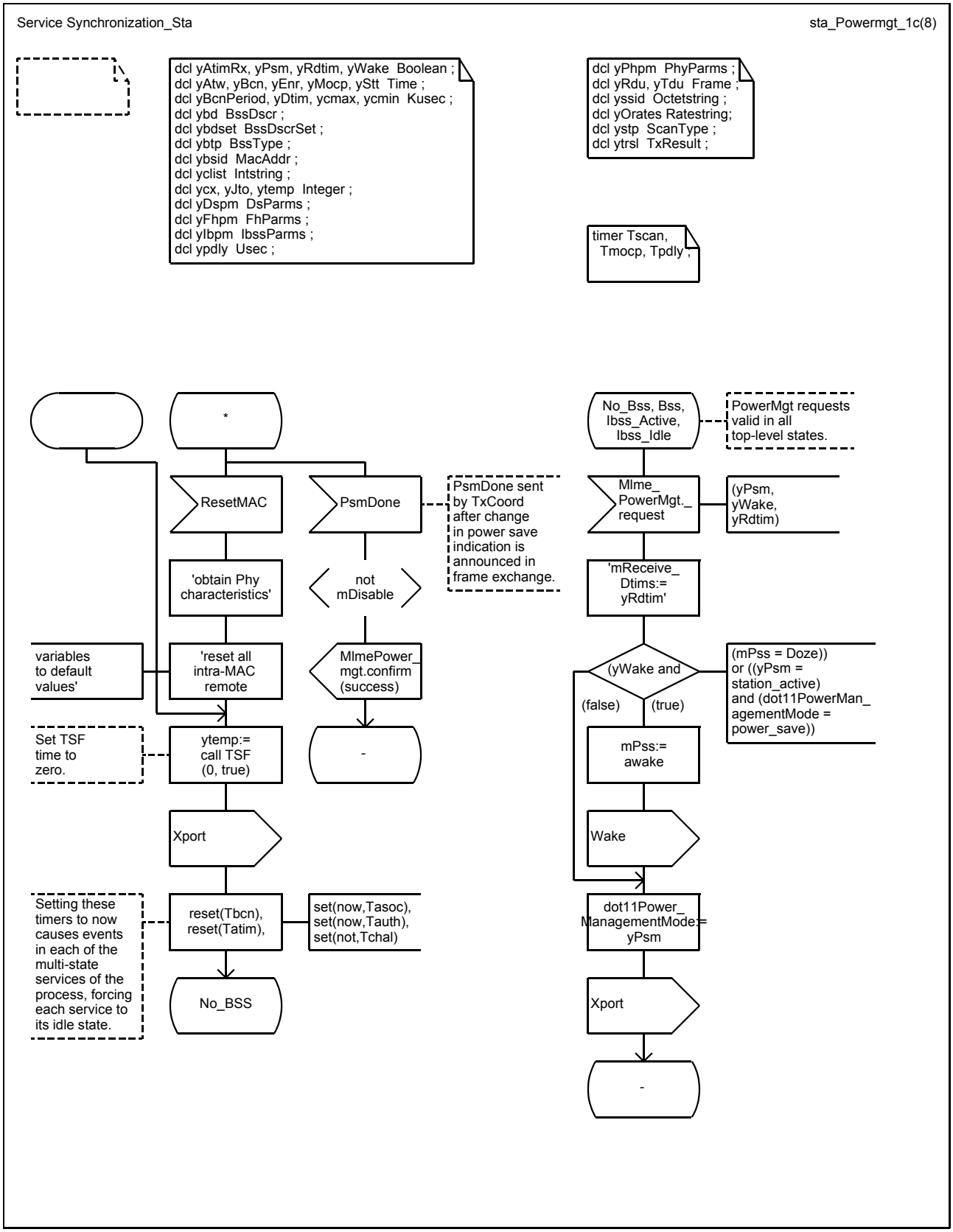

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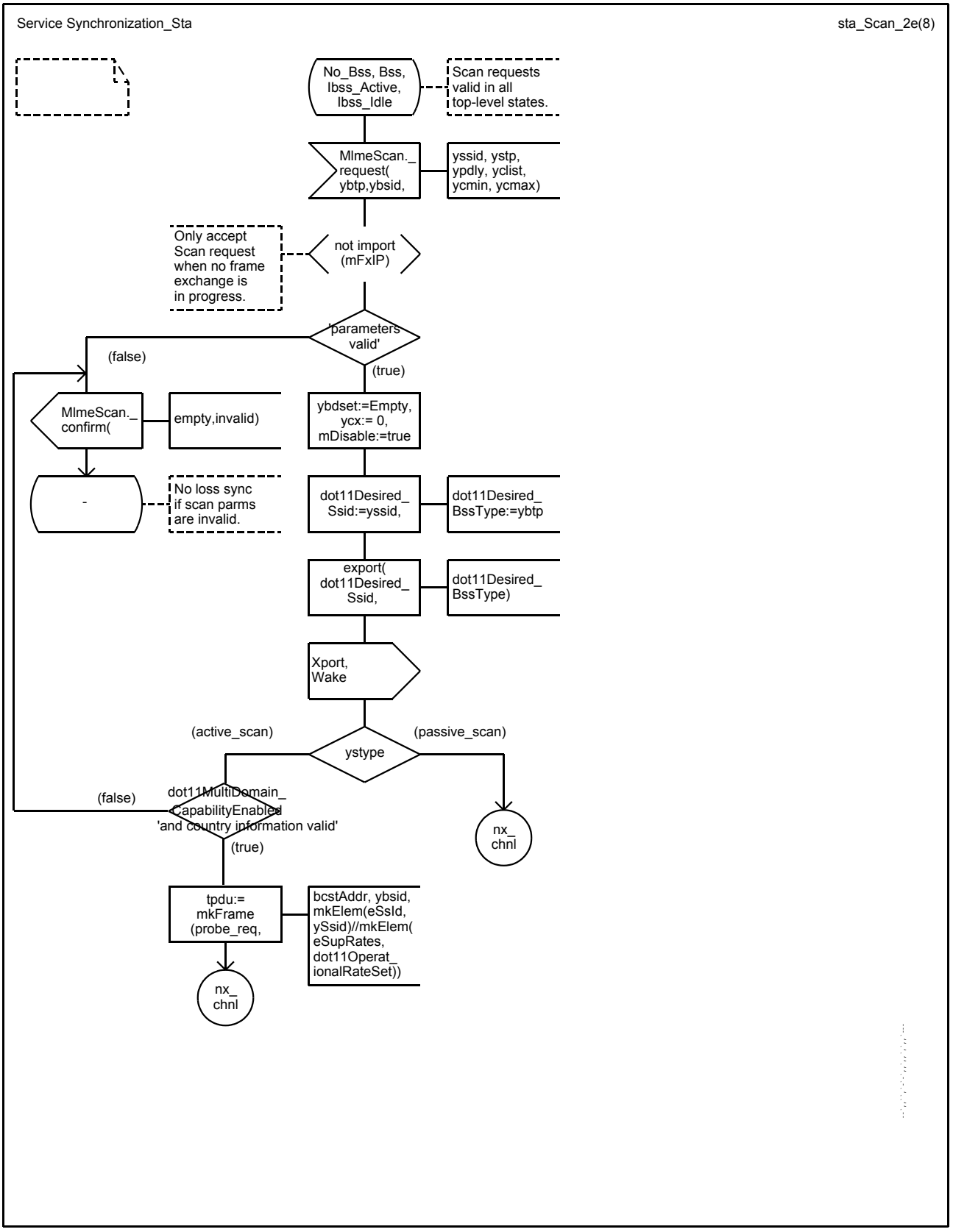

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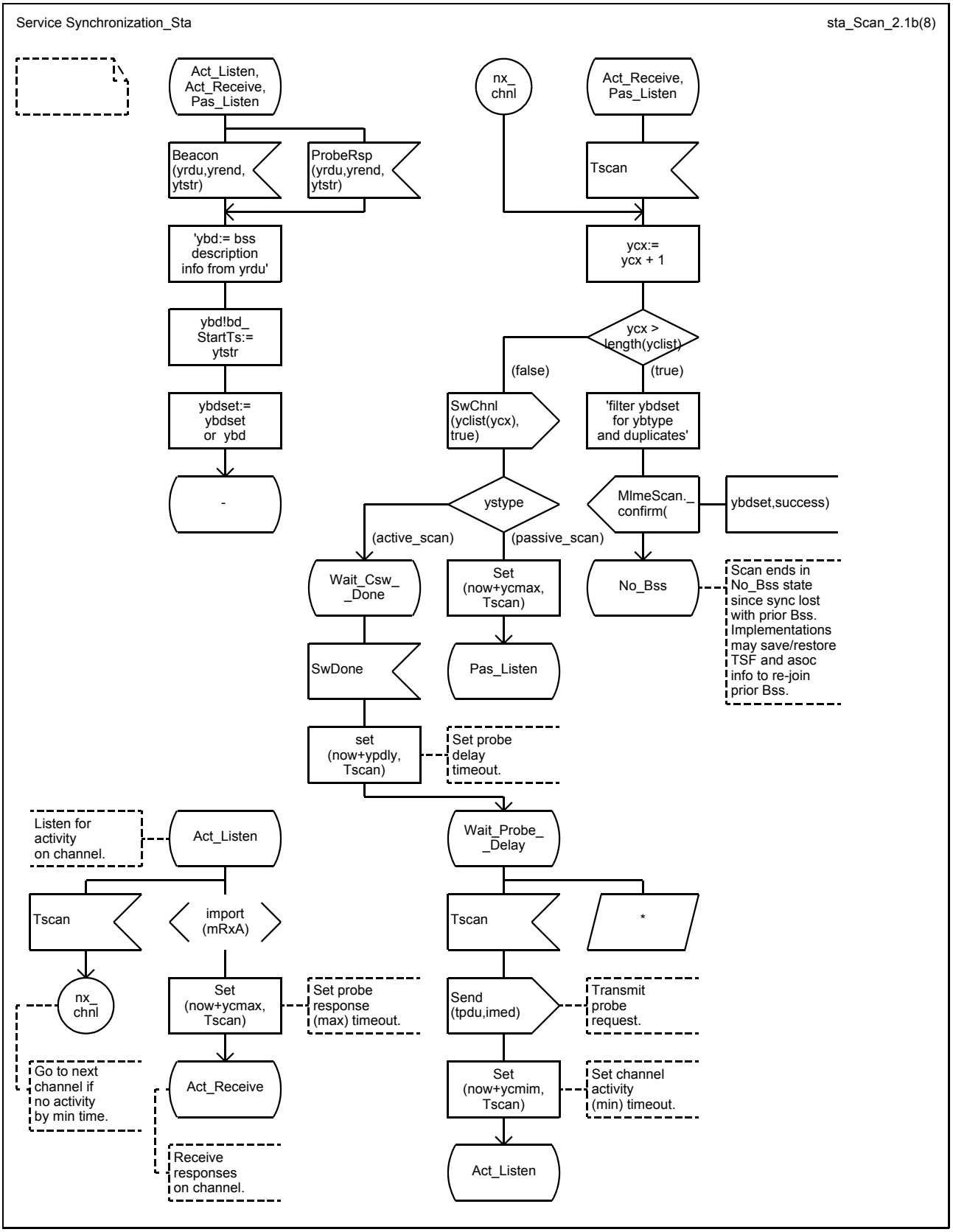

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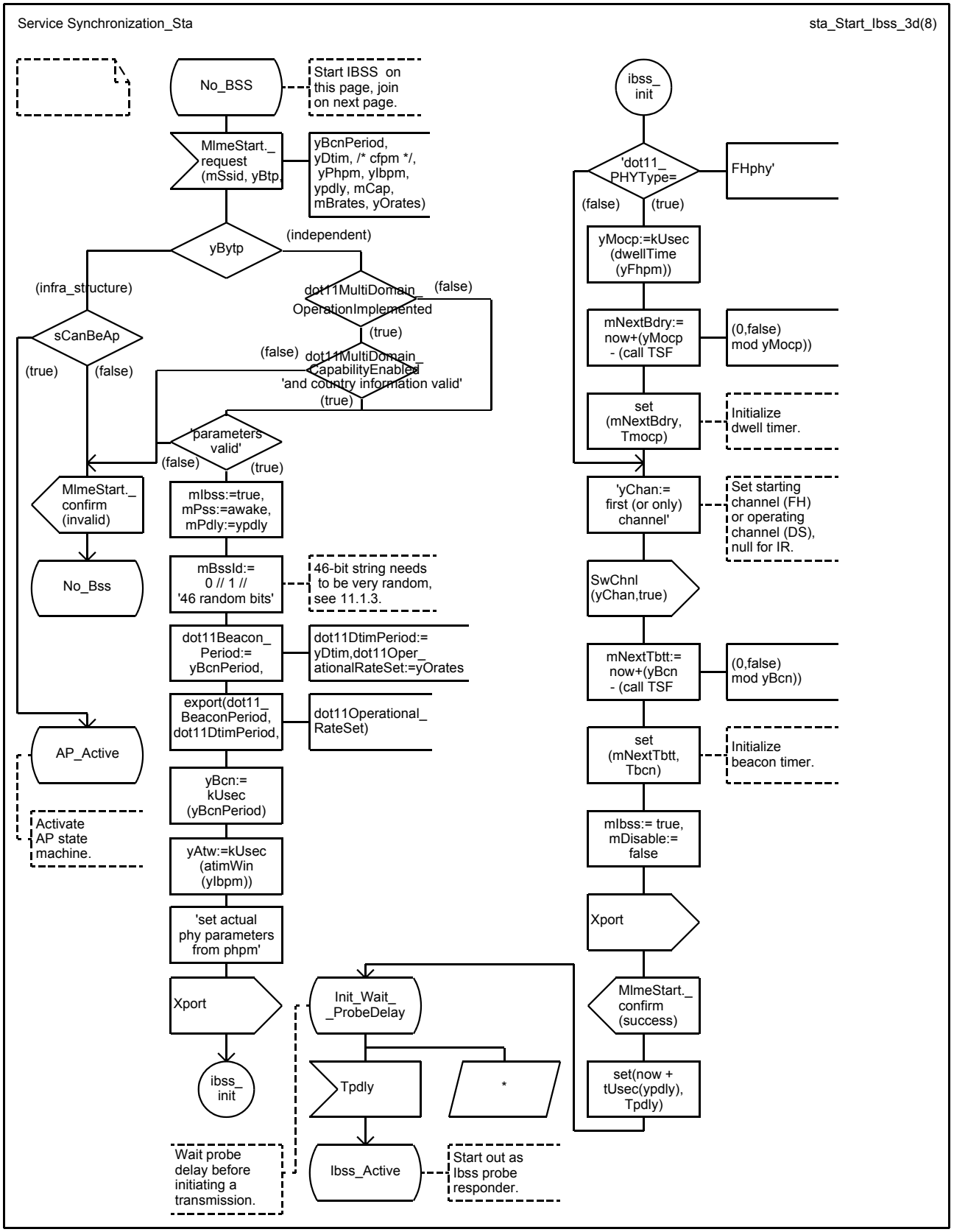

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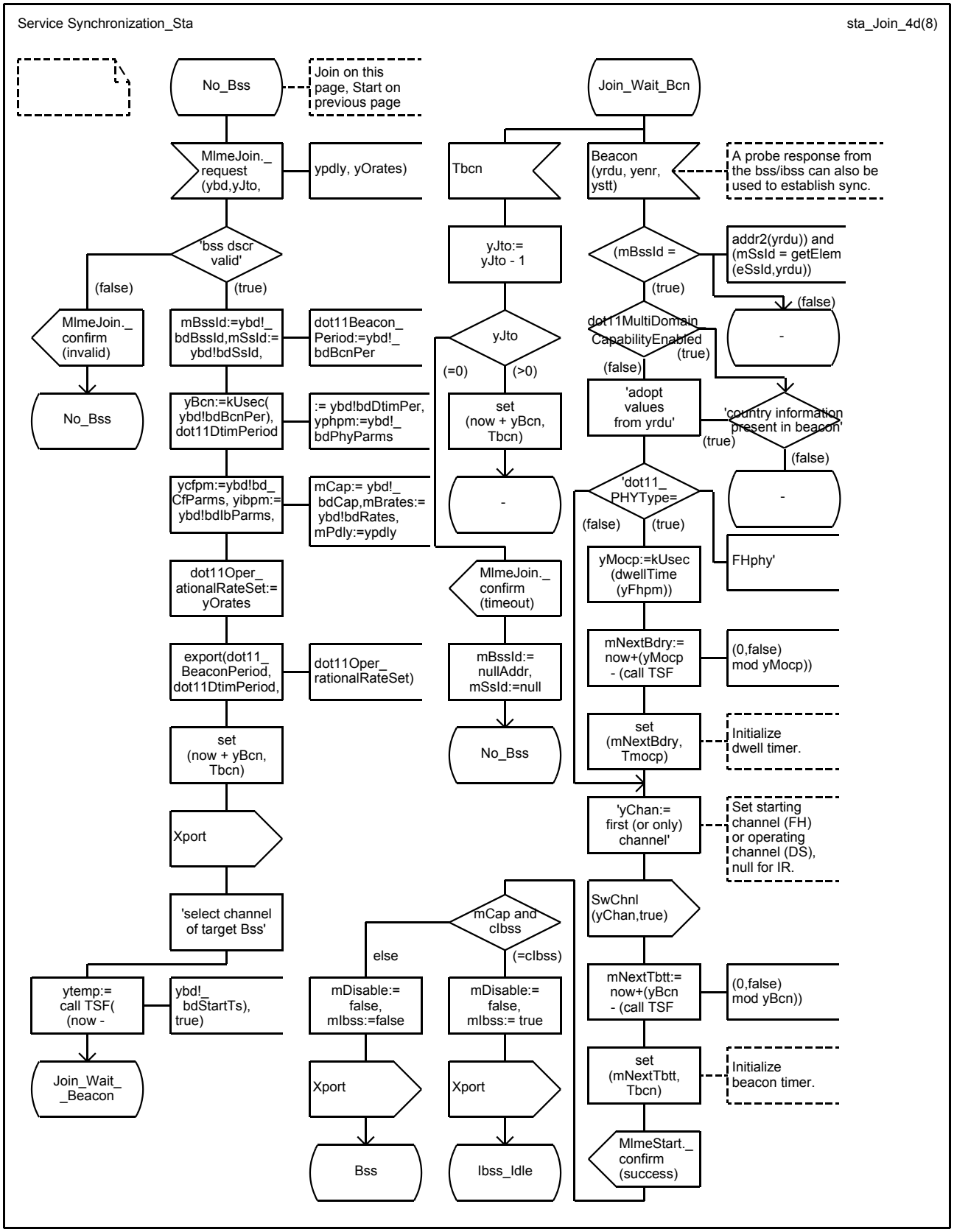

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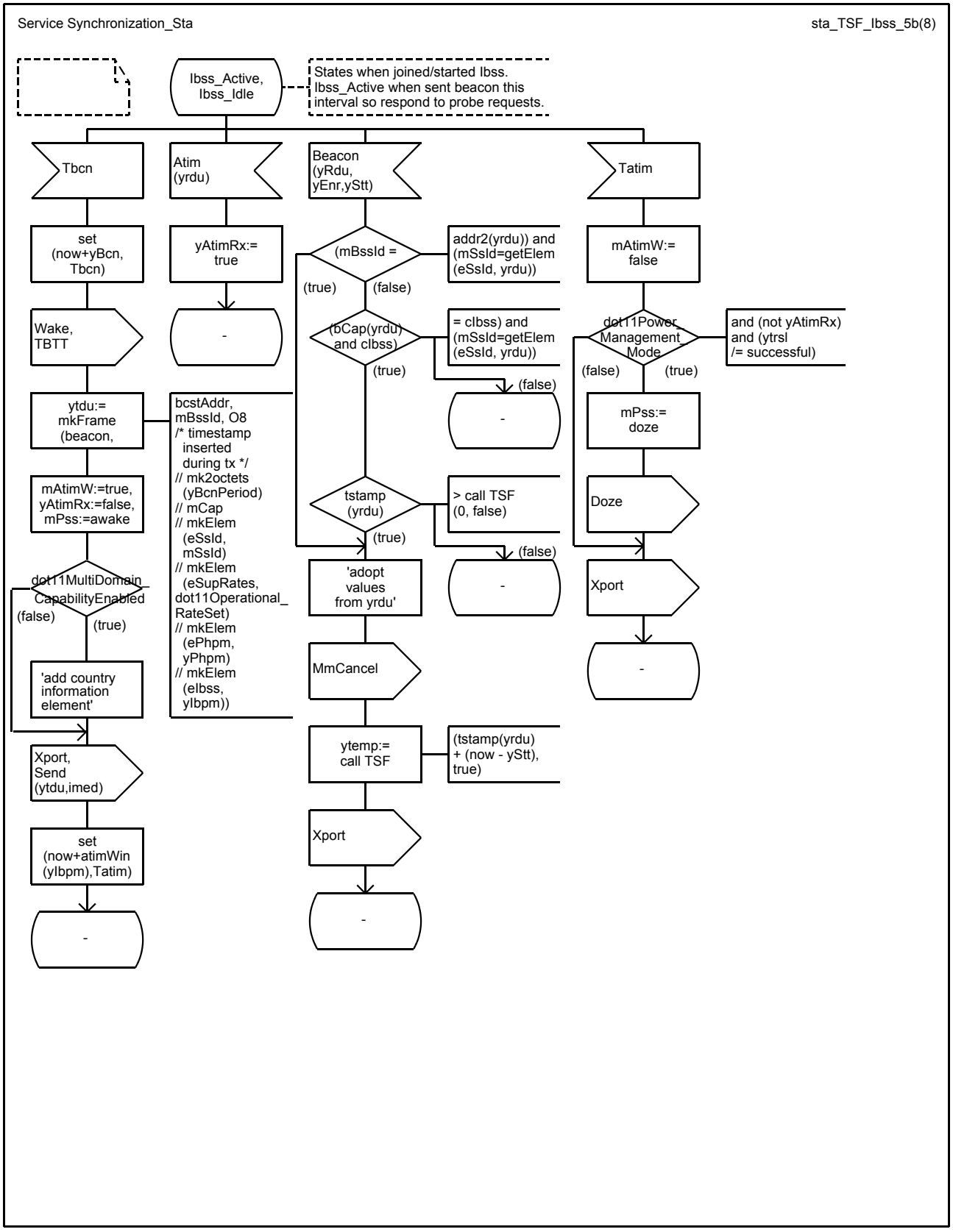

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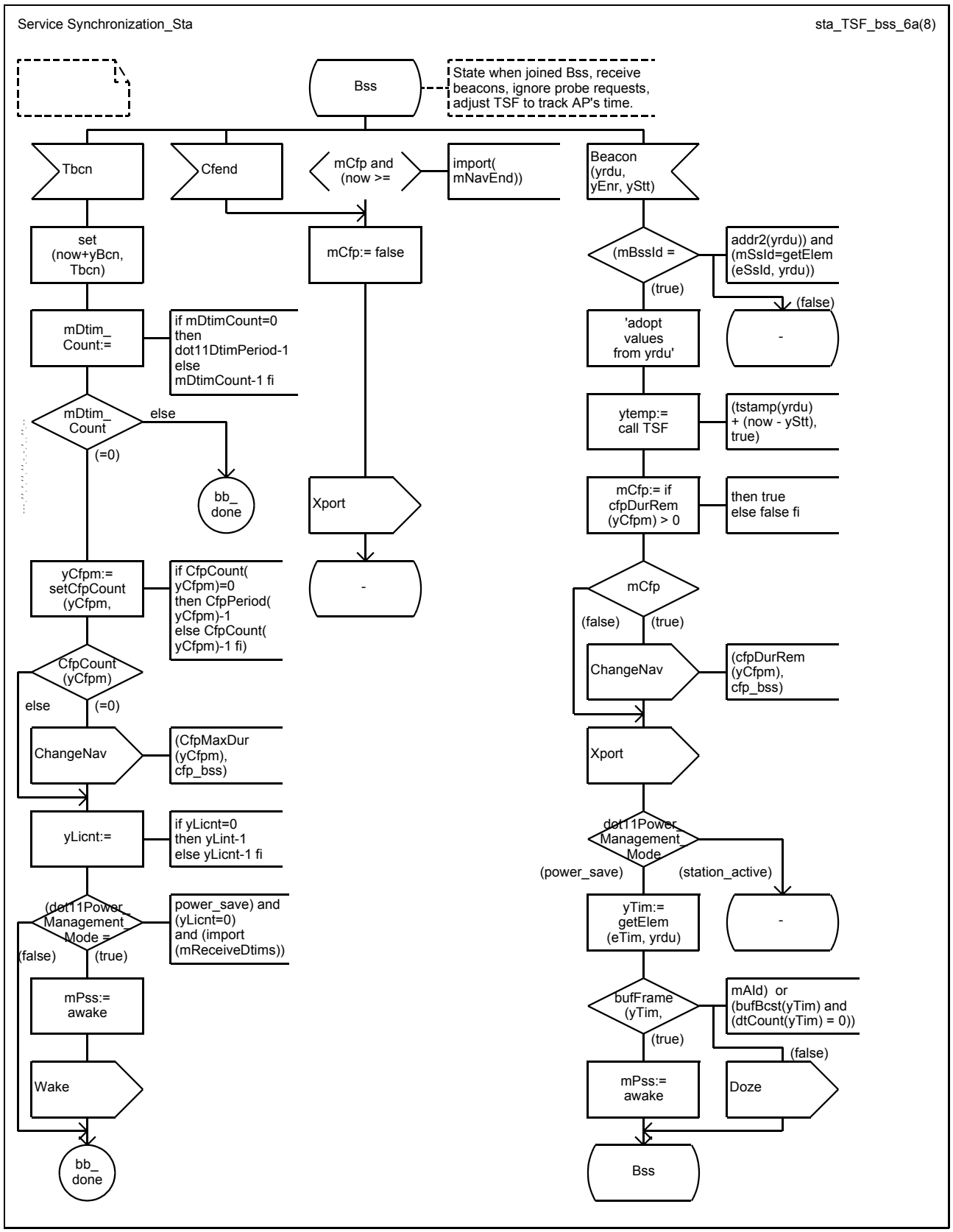

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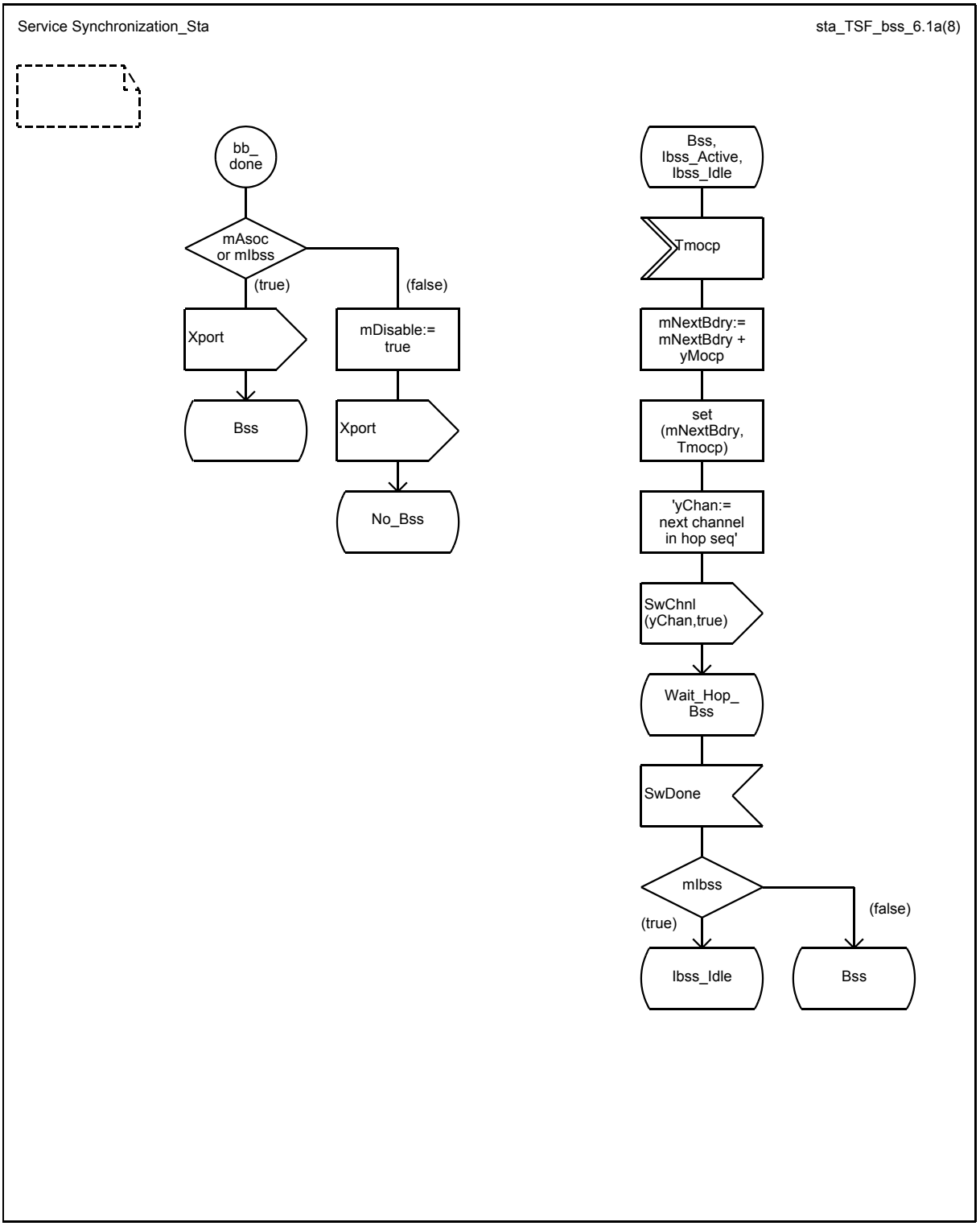

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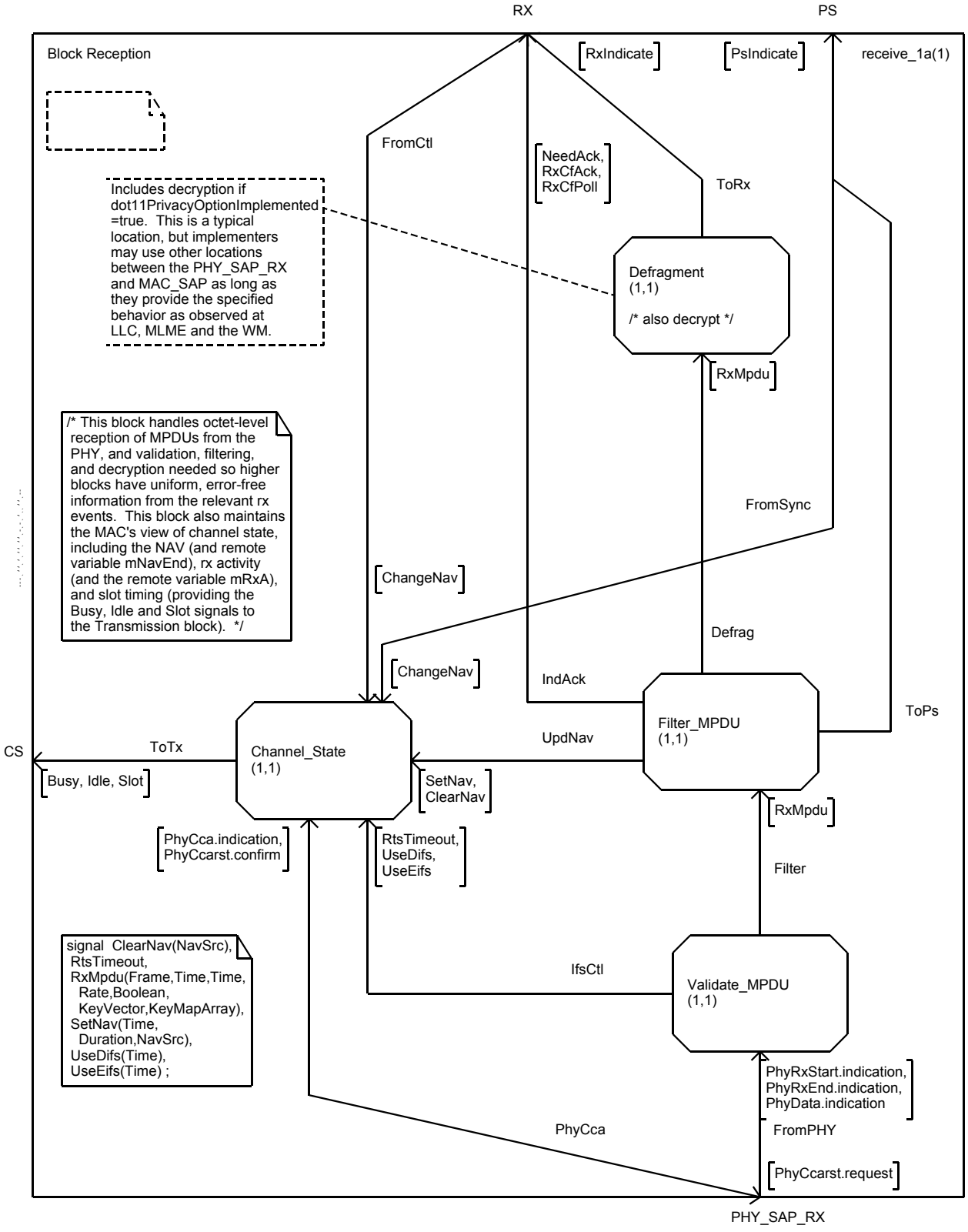

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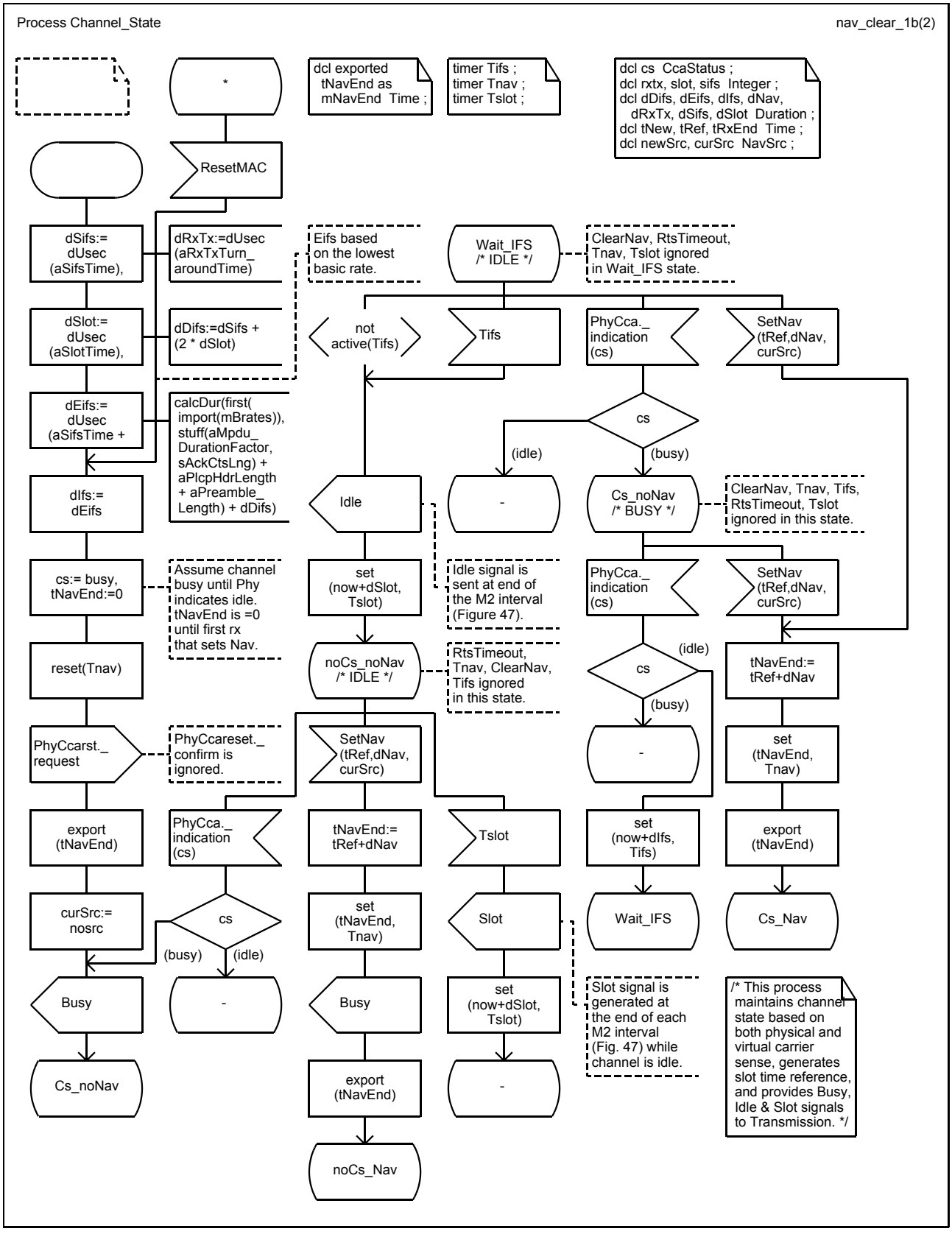

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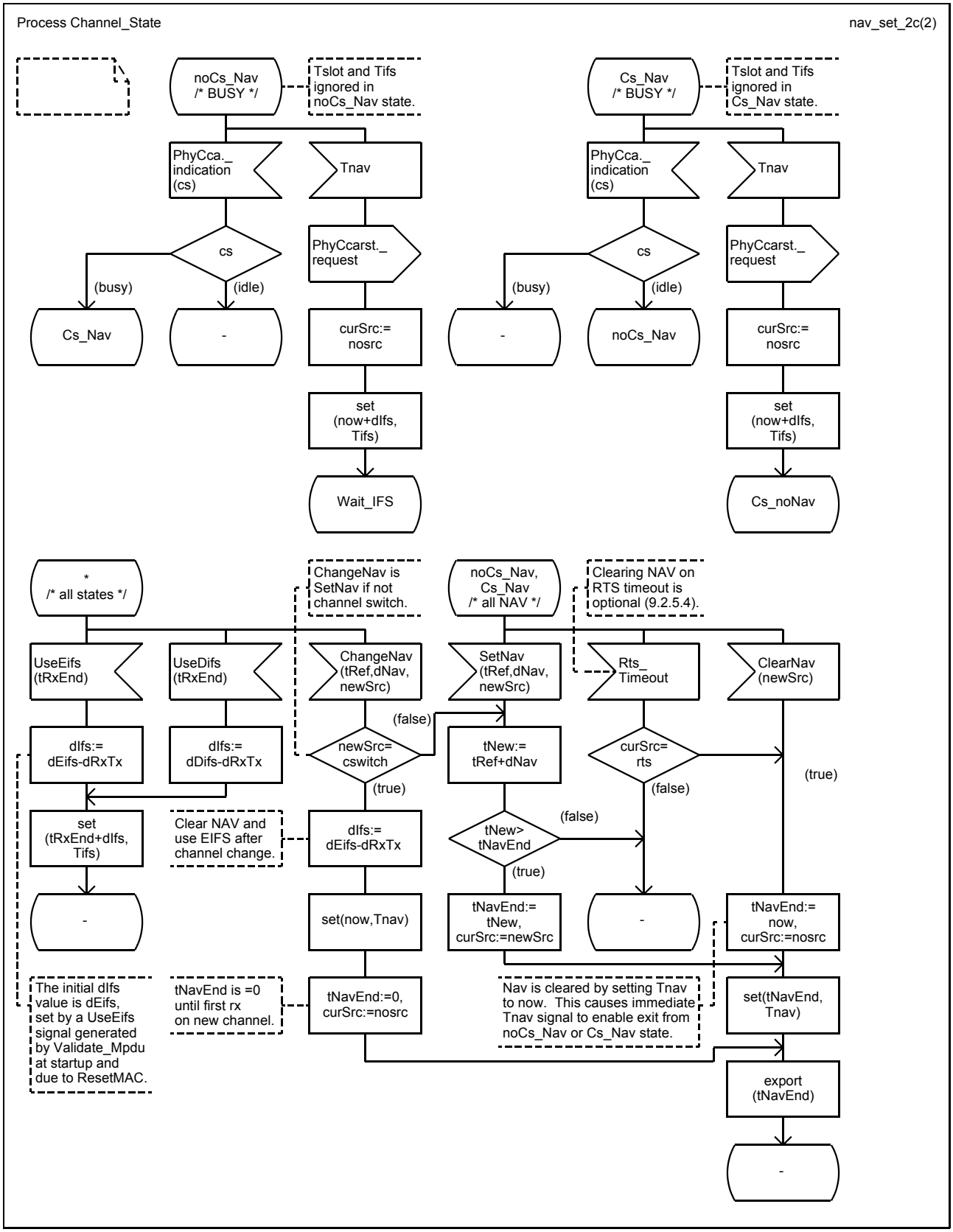

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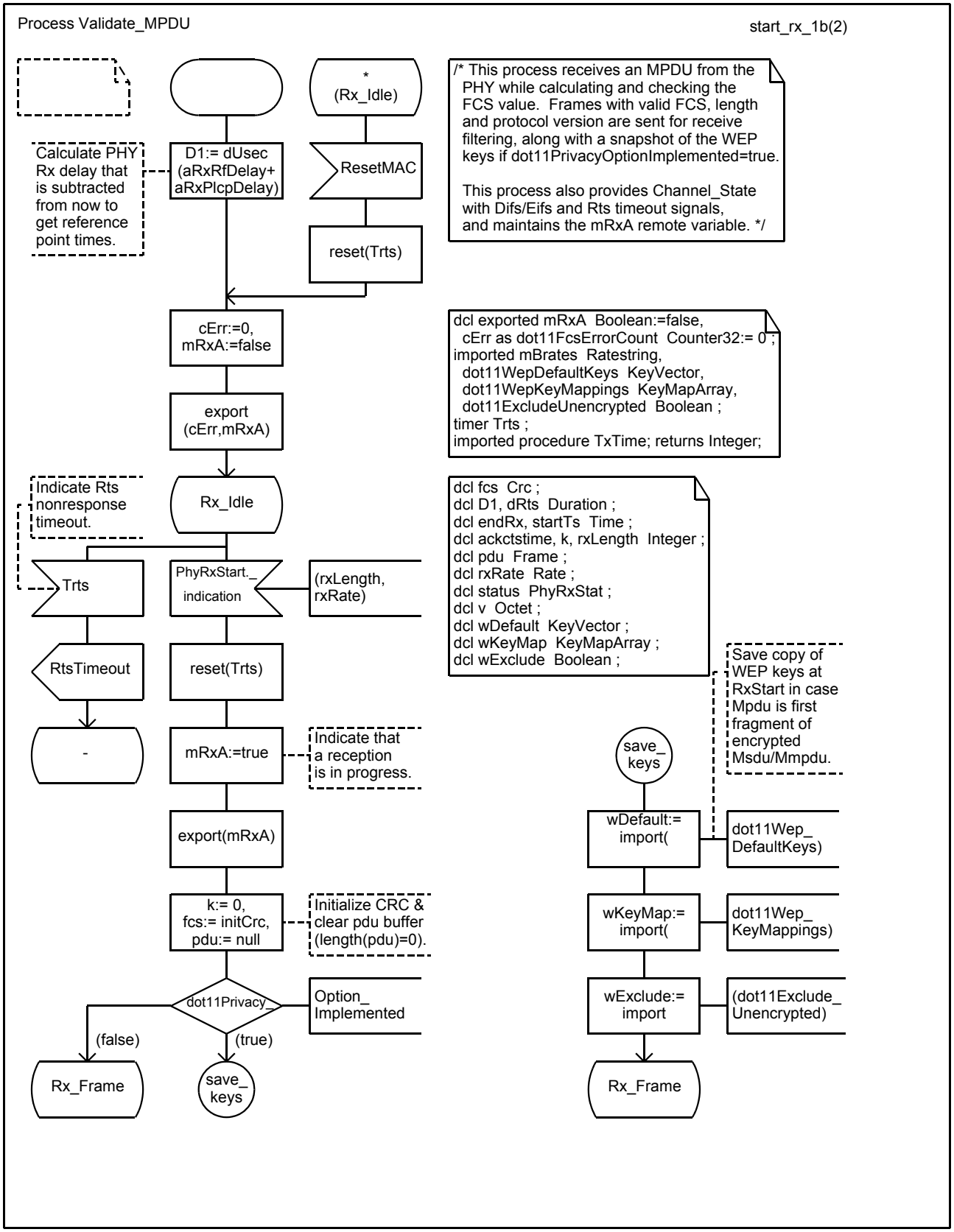

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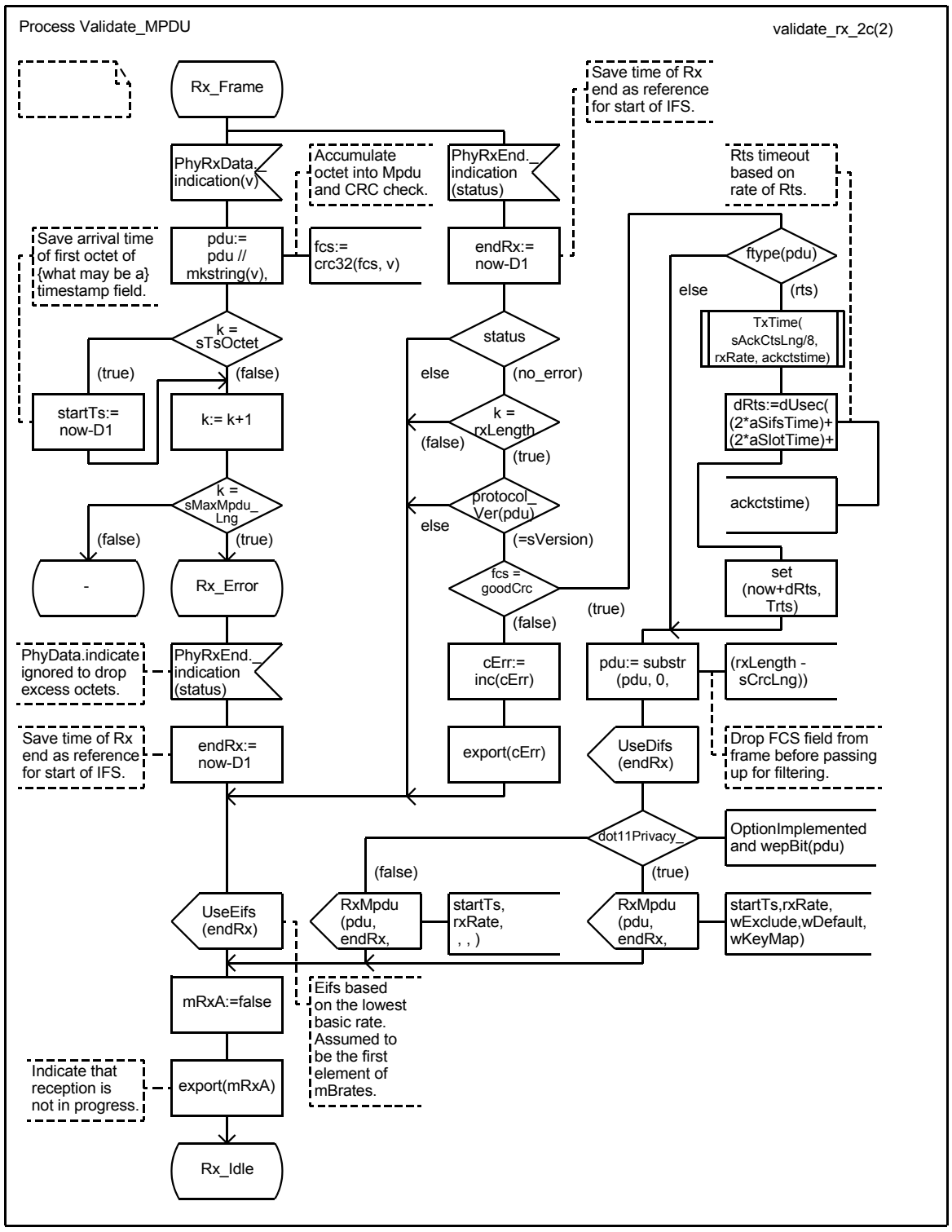

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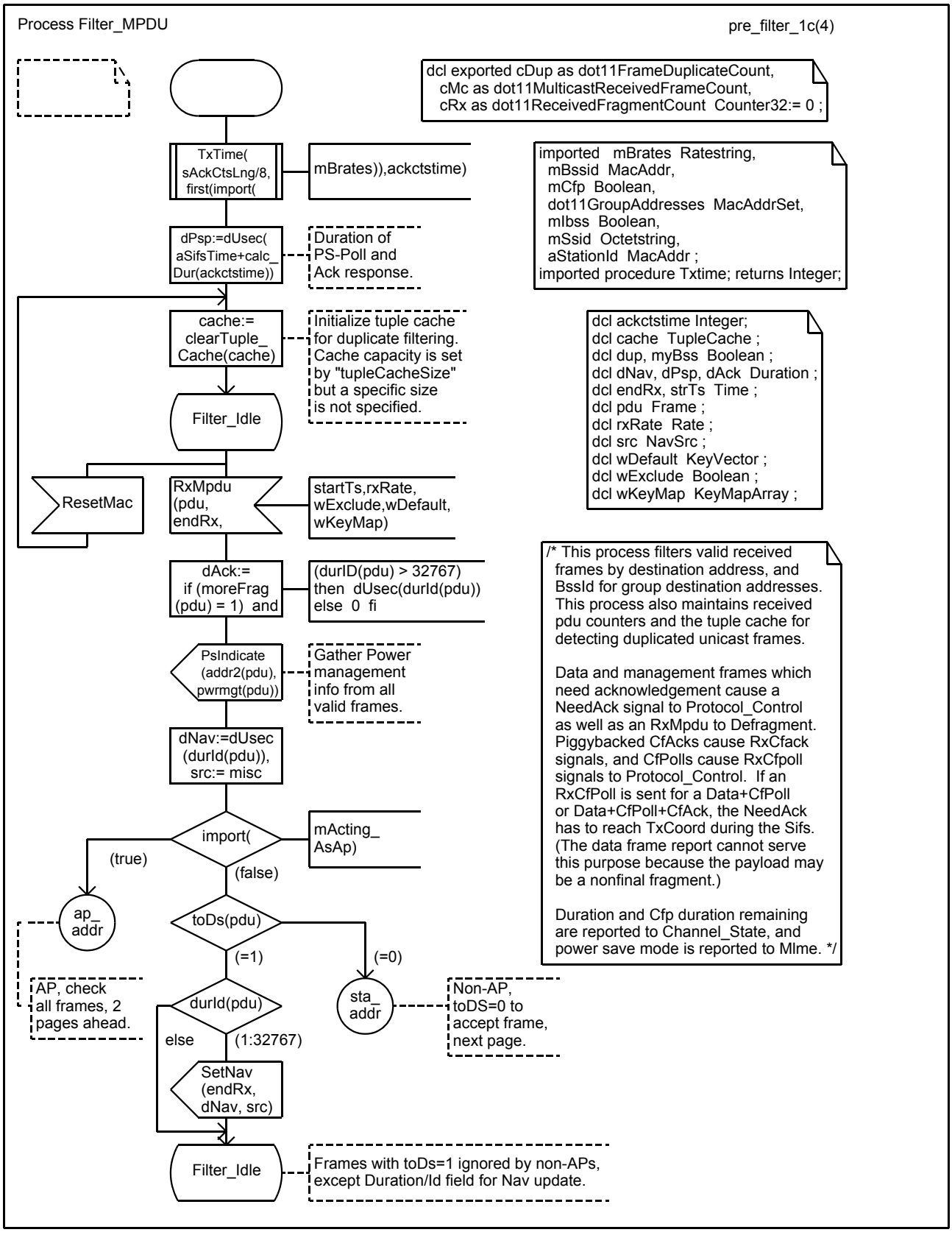

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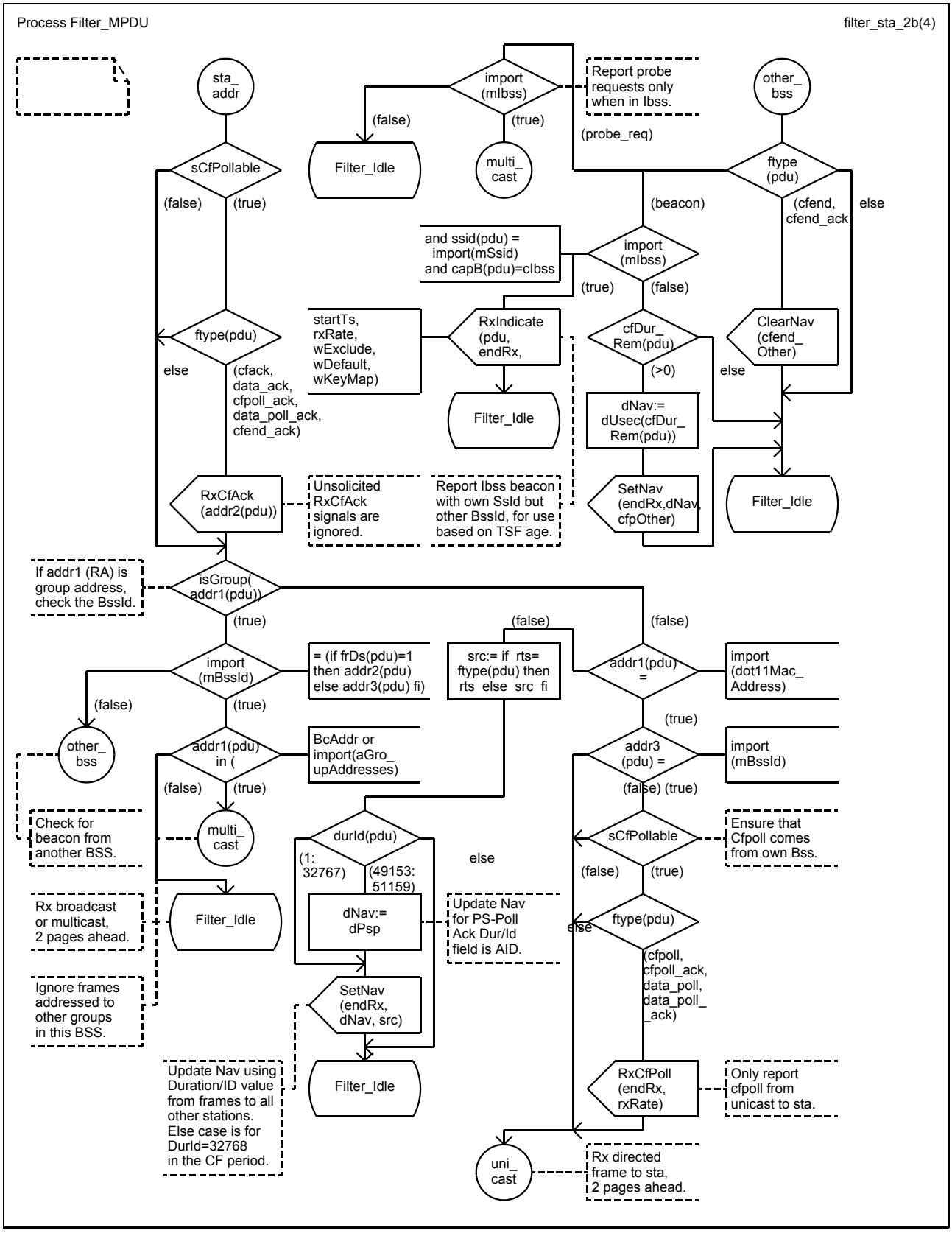

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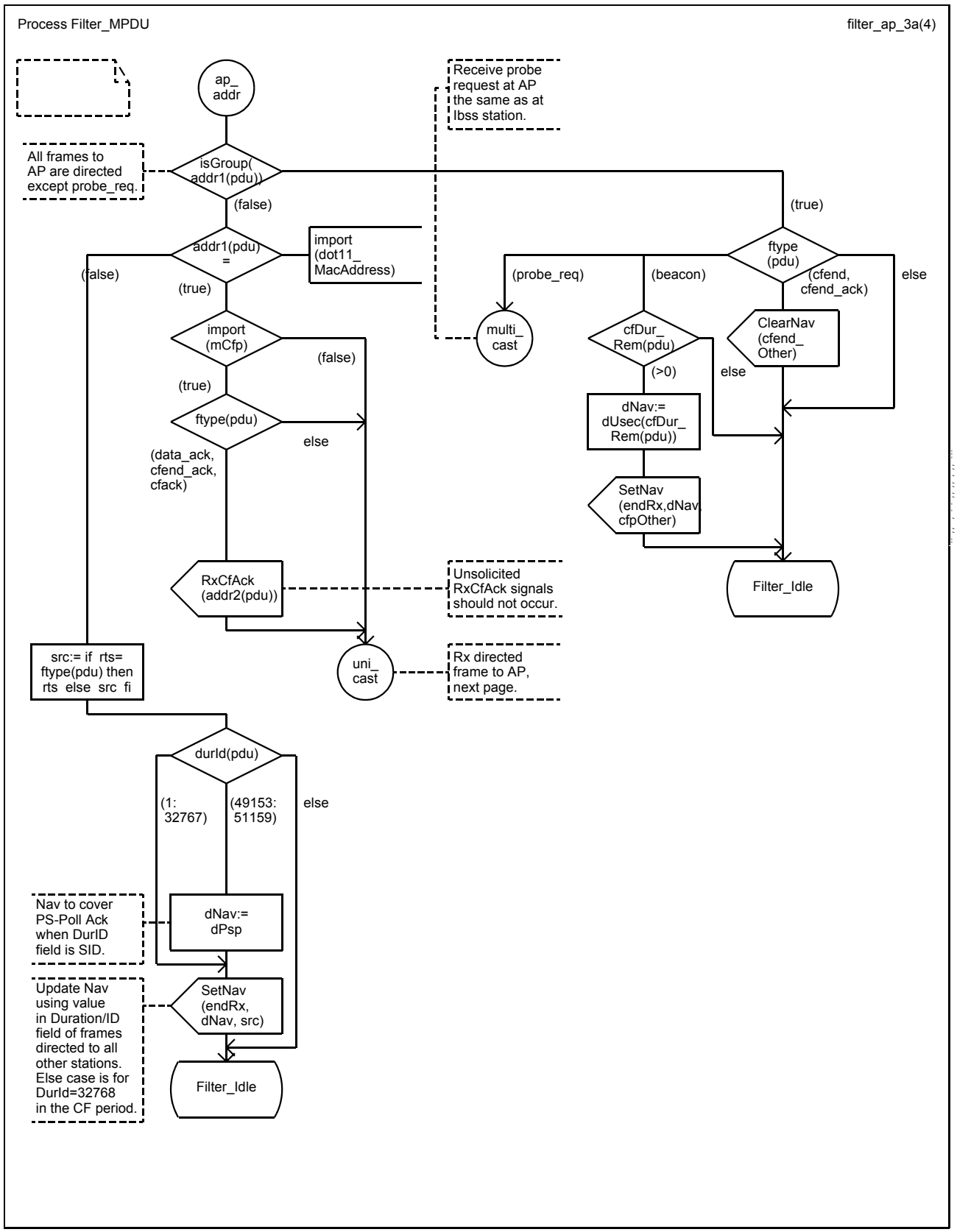

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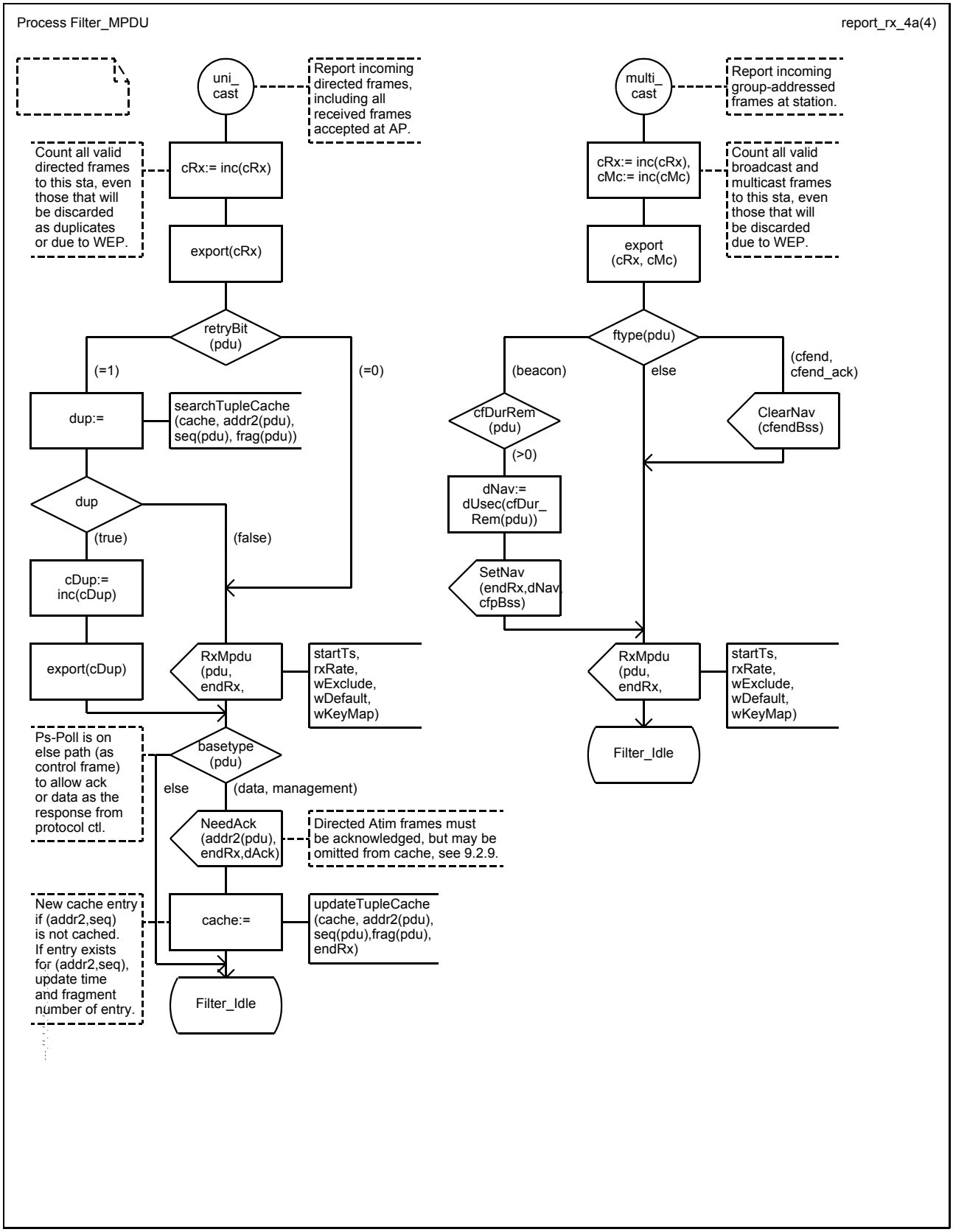

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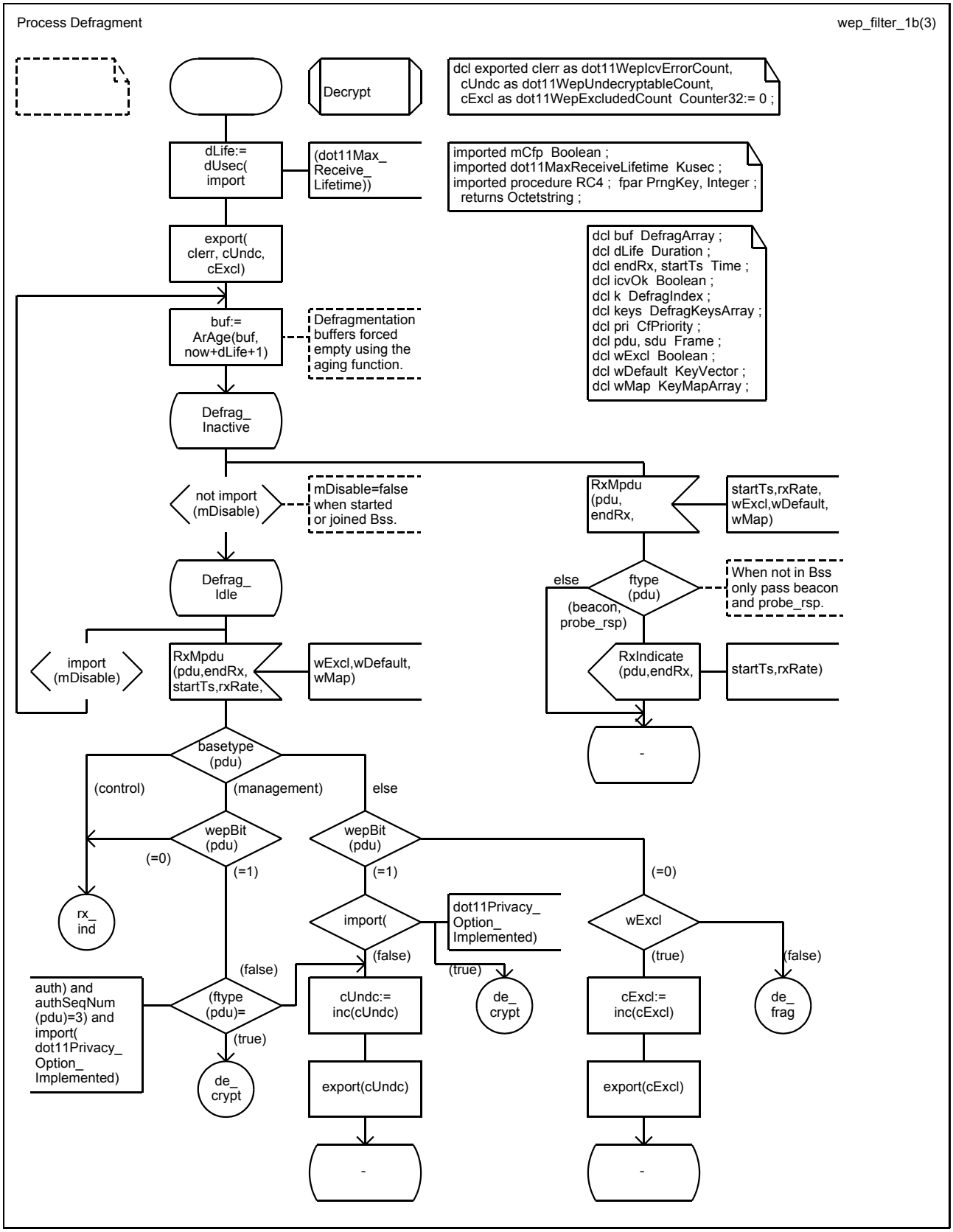

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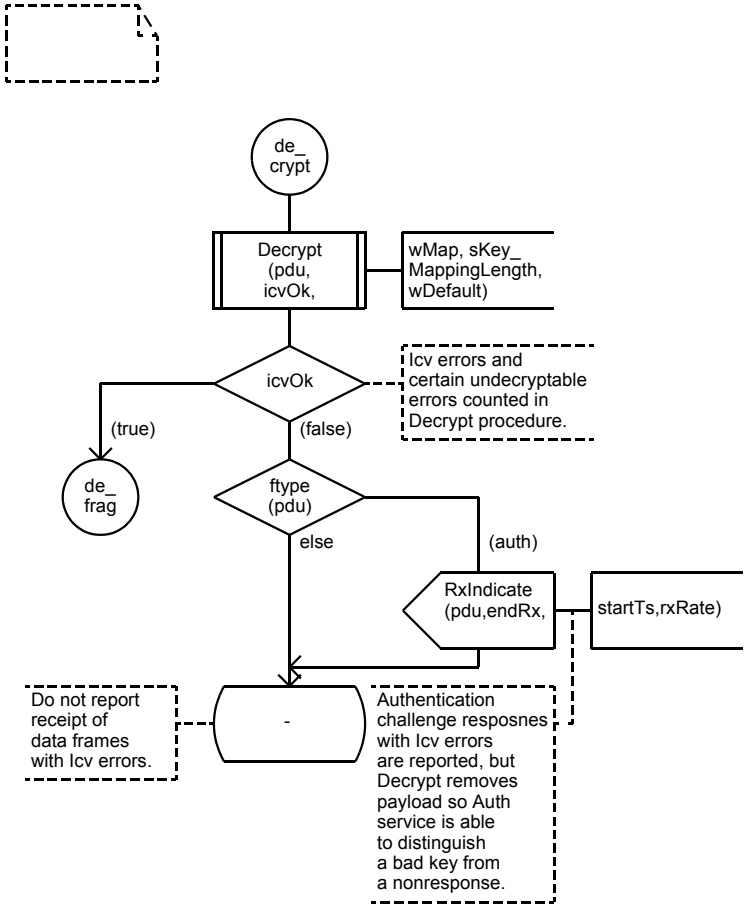

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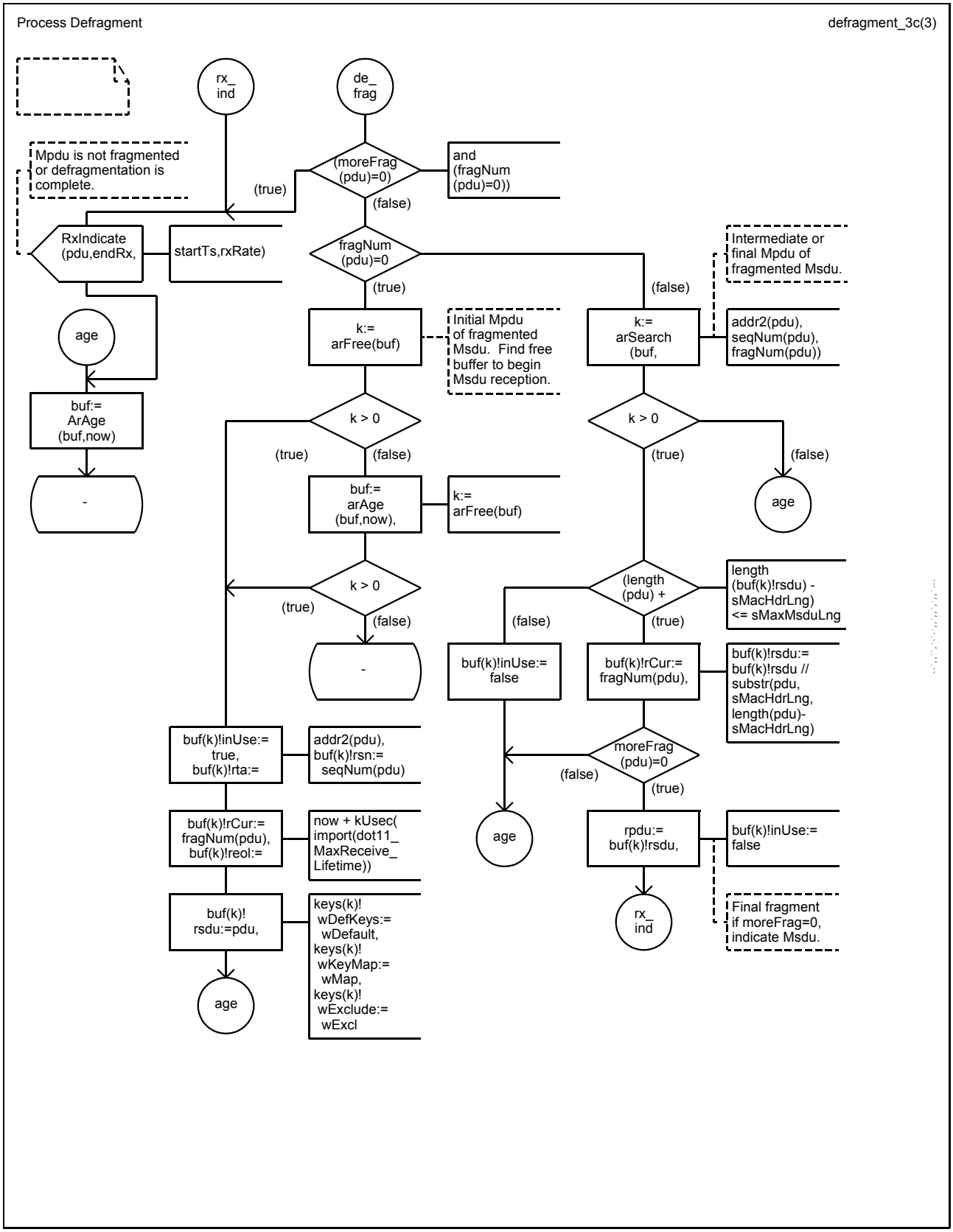

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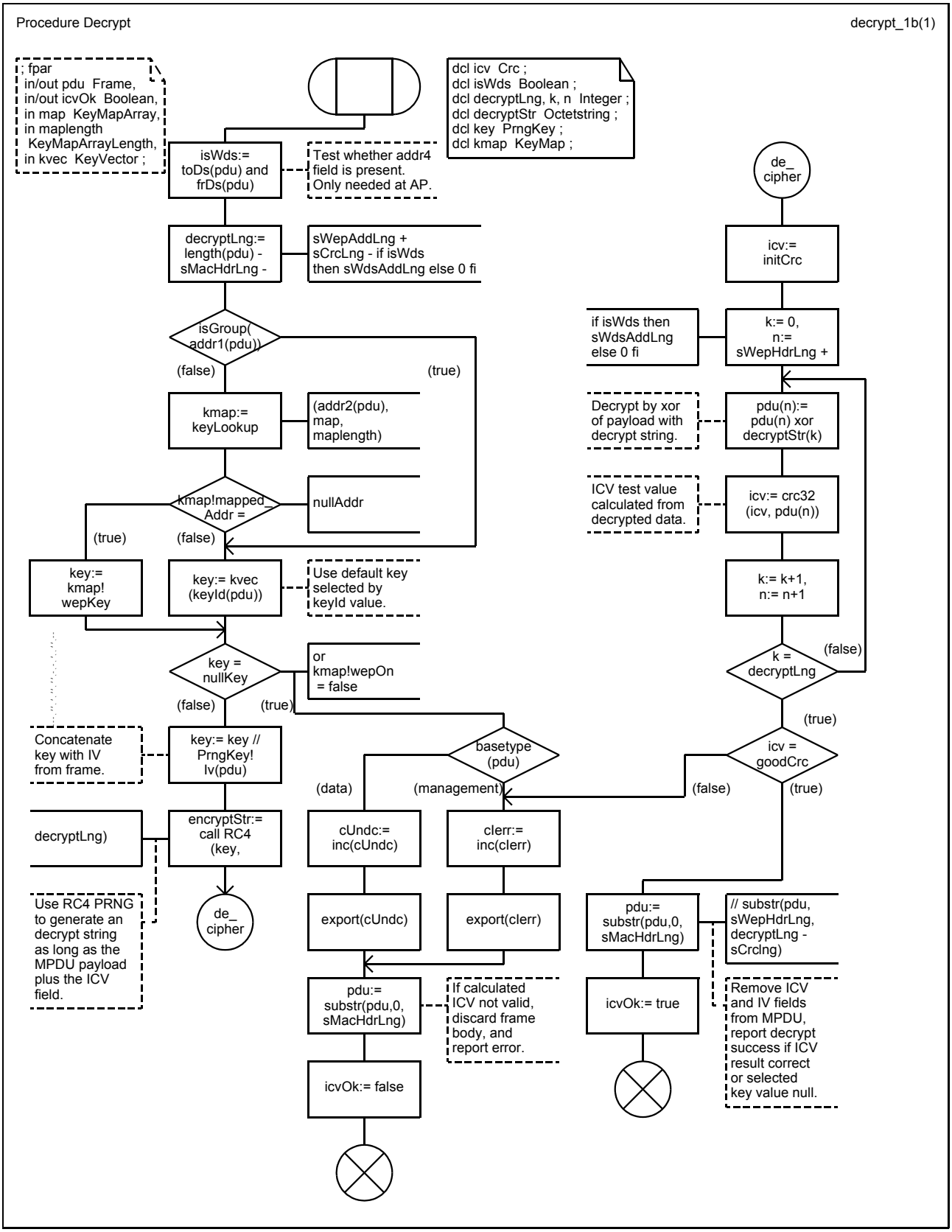

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C.4 State machines for MAC AP

The following SDL-92 system specification defines operation of the MAC protocol at an IEEE 802.11 AP. Many aspects of AP operation are identical to the STA operation. These are defined in blocks and processes referenced from both the STA and AP system specifications. Blocks and processes used in both STA and AP are identifiable by the SDL comment /* for STA & AP */ below the block or process name. Blocks and processes specific to AP operation are identifiable by the SDL comment /* AP version */ below the block or process name. Definitions for the /* AP version */ and the /* STA & AP */ blocks and processes appear in this subclause.

The remainder of this clause is the formal description, in SDL/GR, of an IEEE 802.11 AP.

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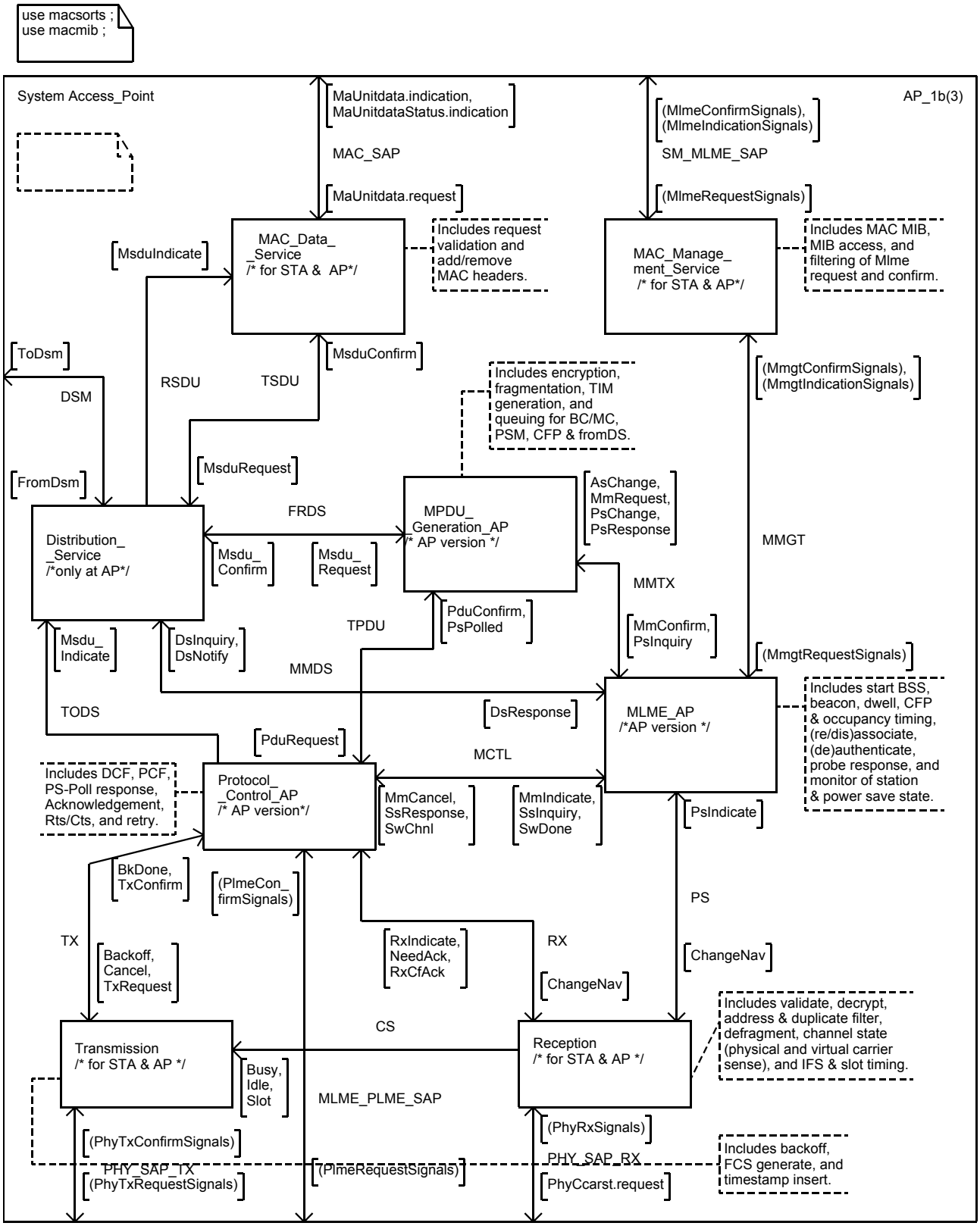

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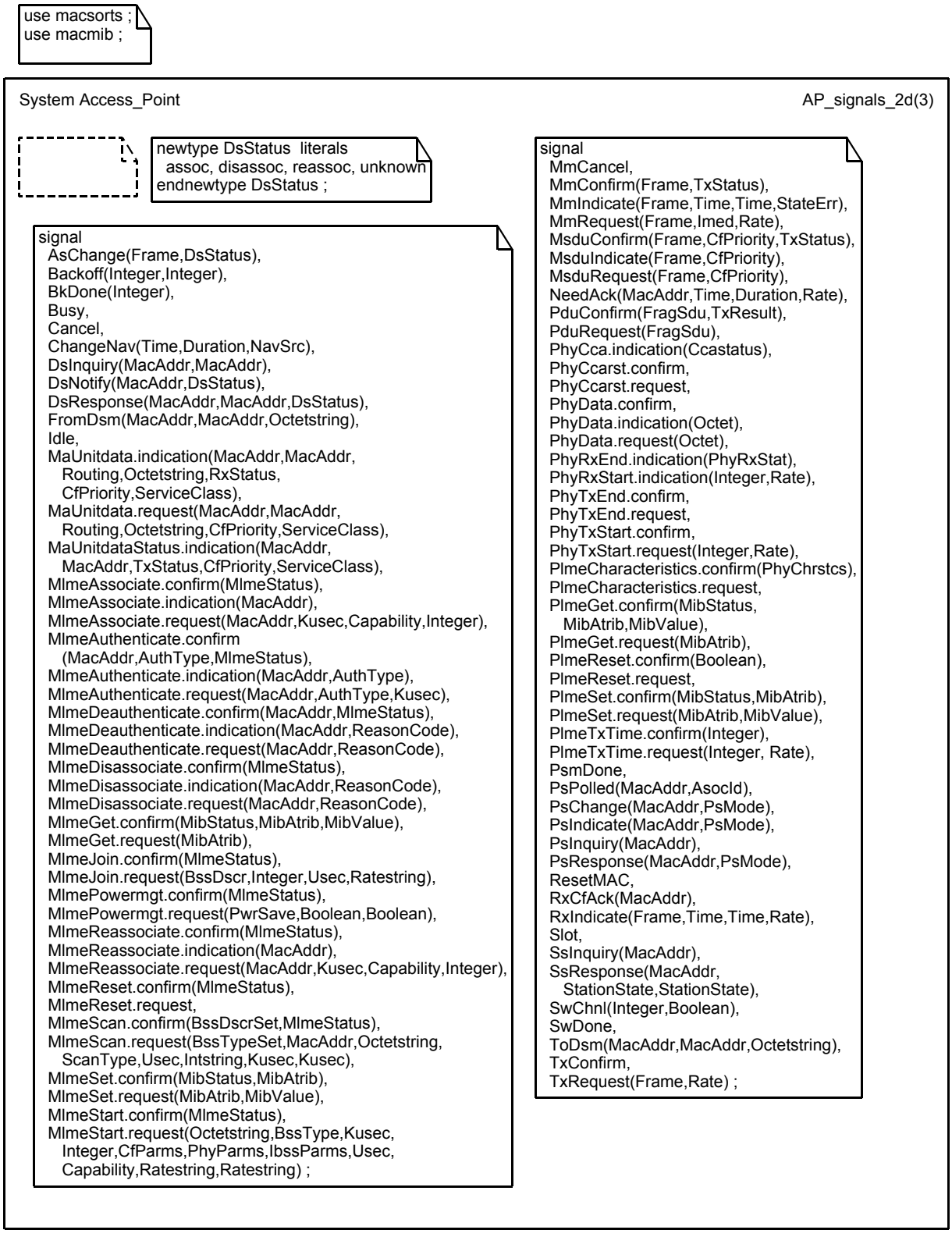

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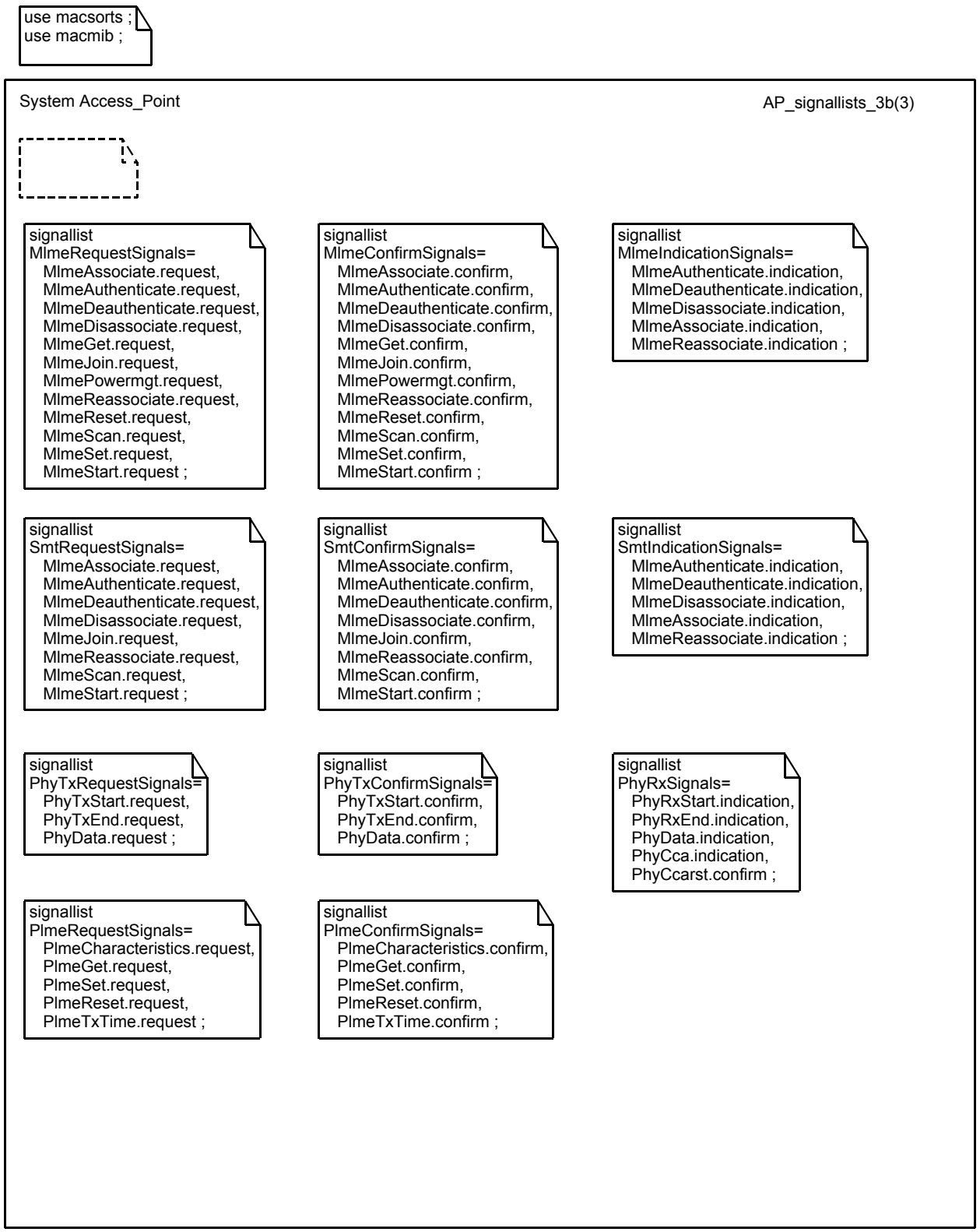

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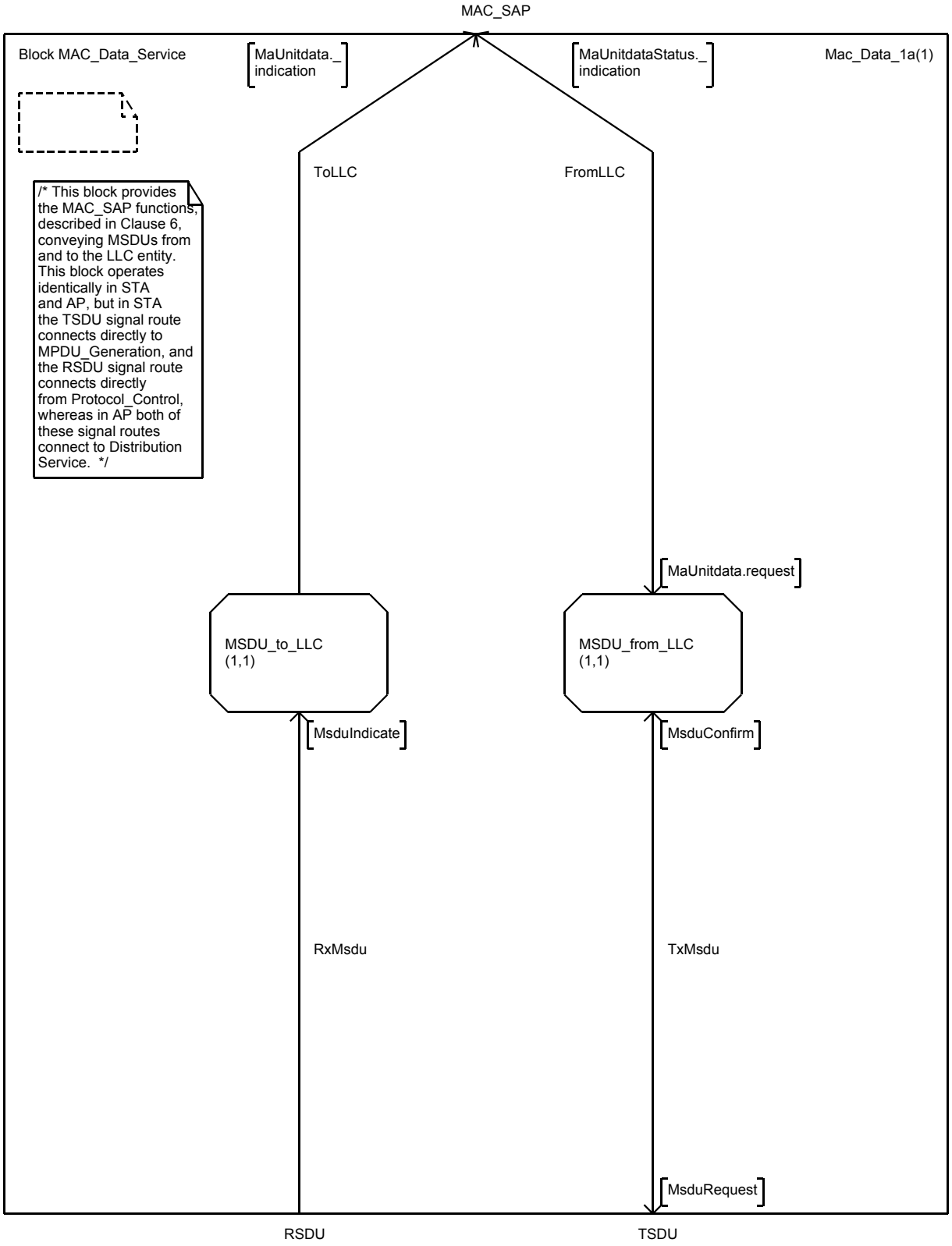

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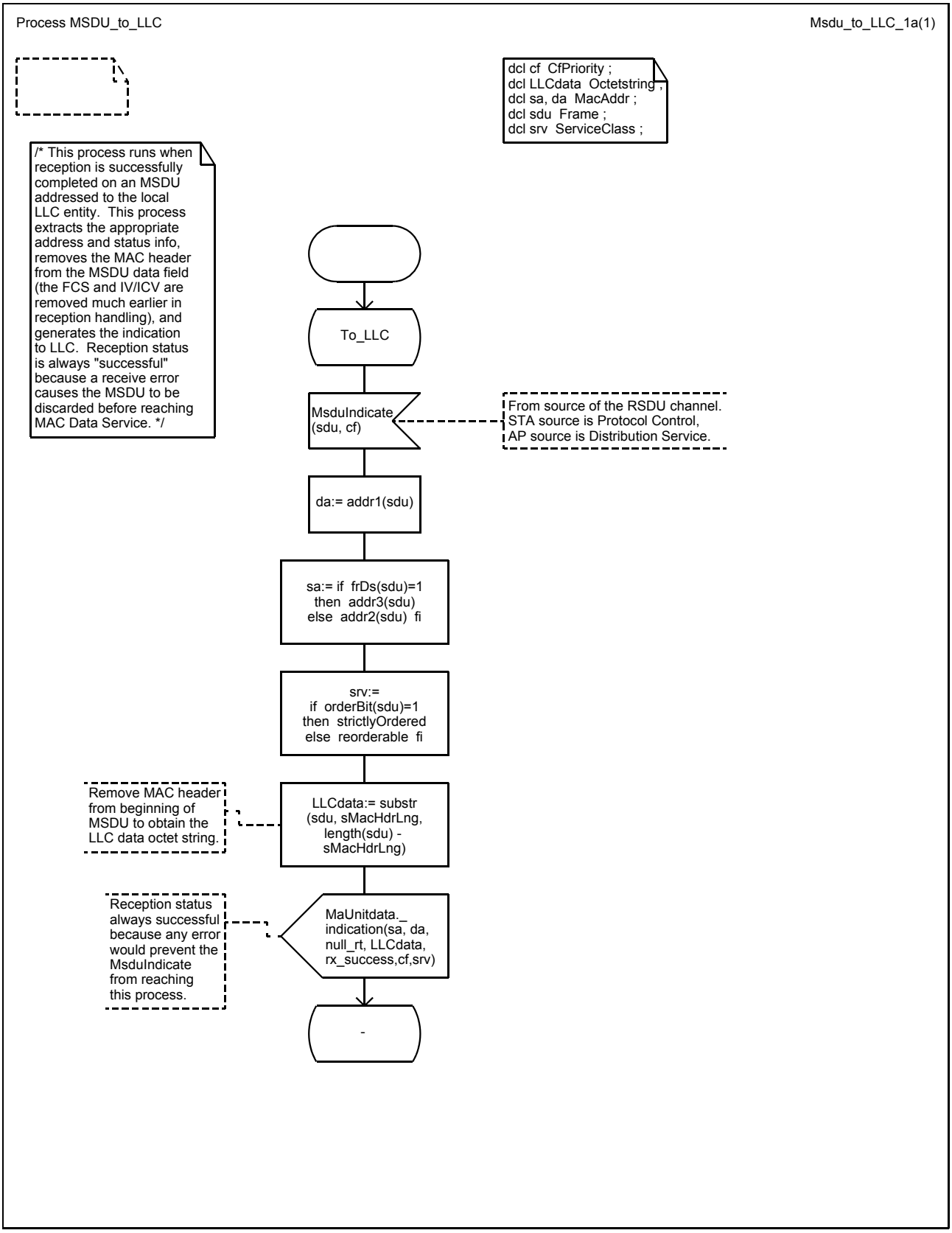

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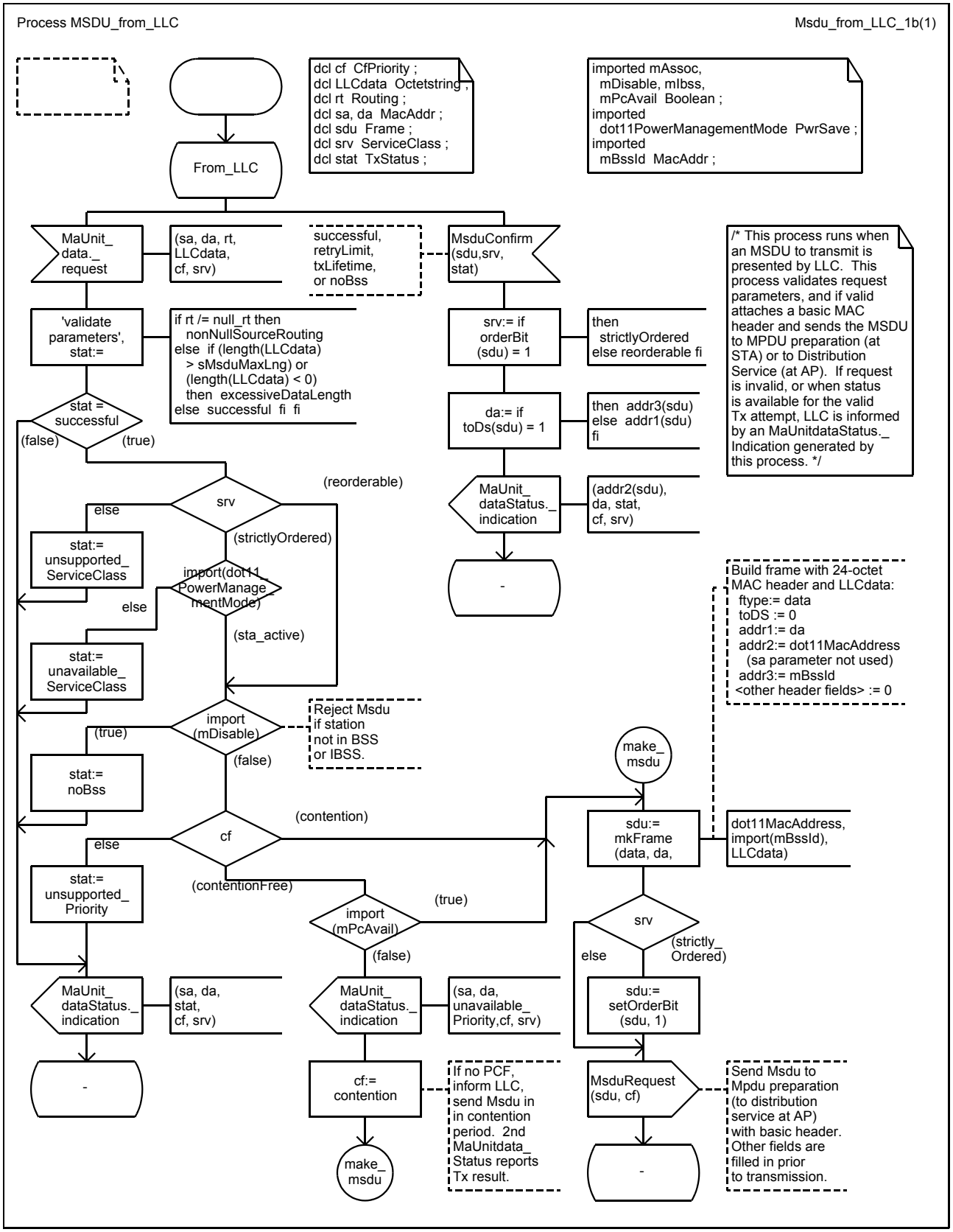

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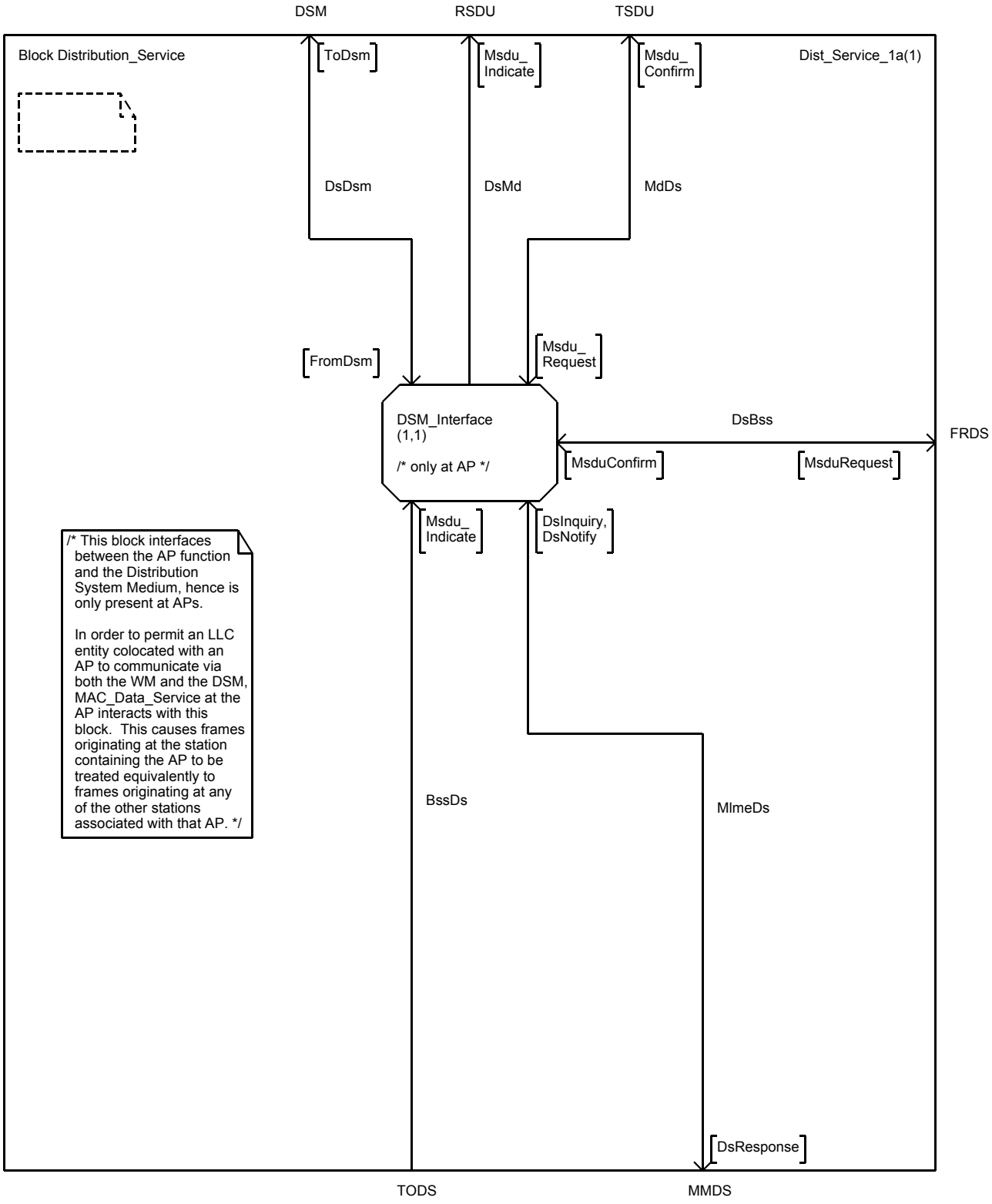

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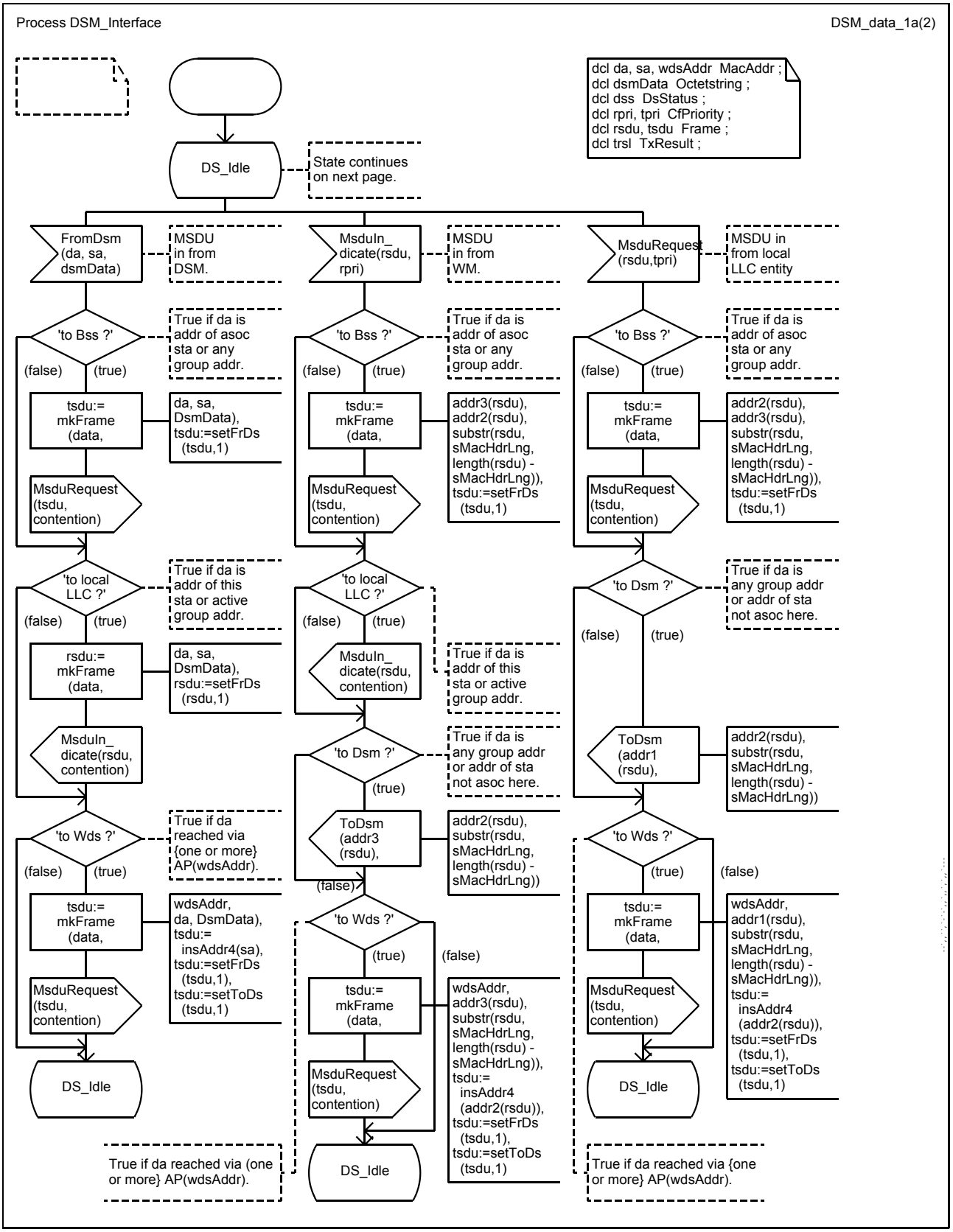

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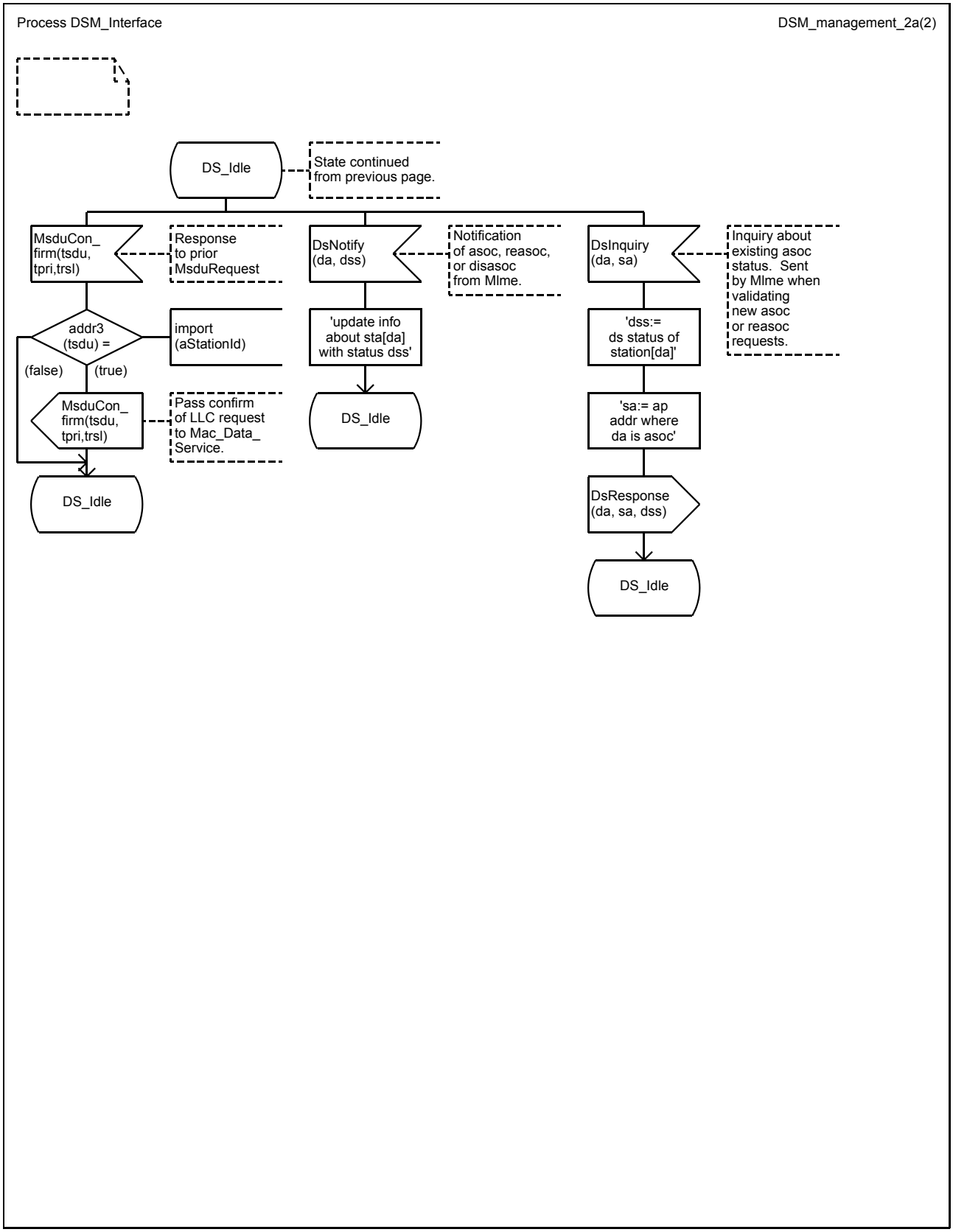

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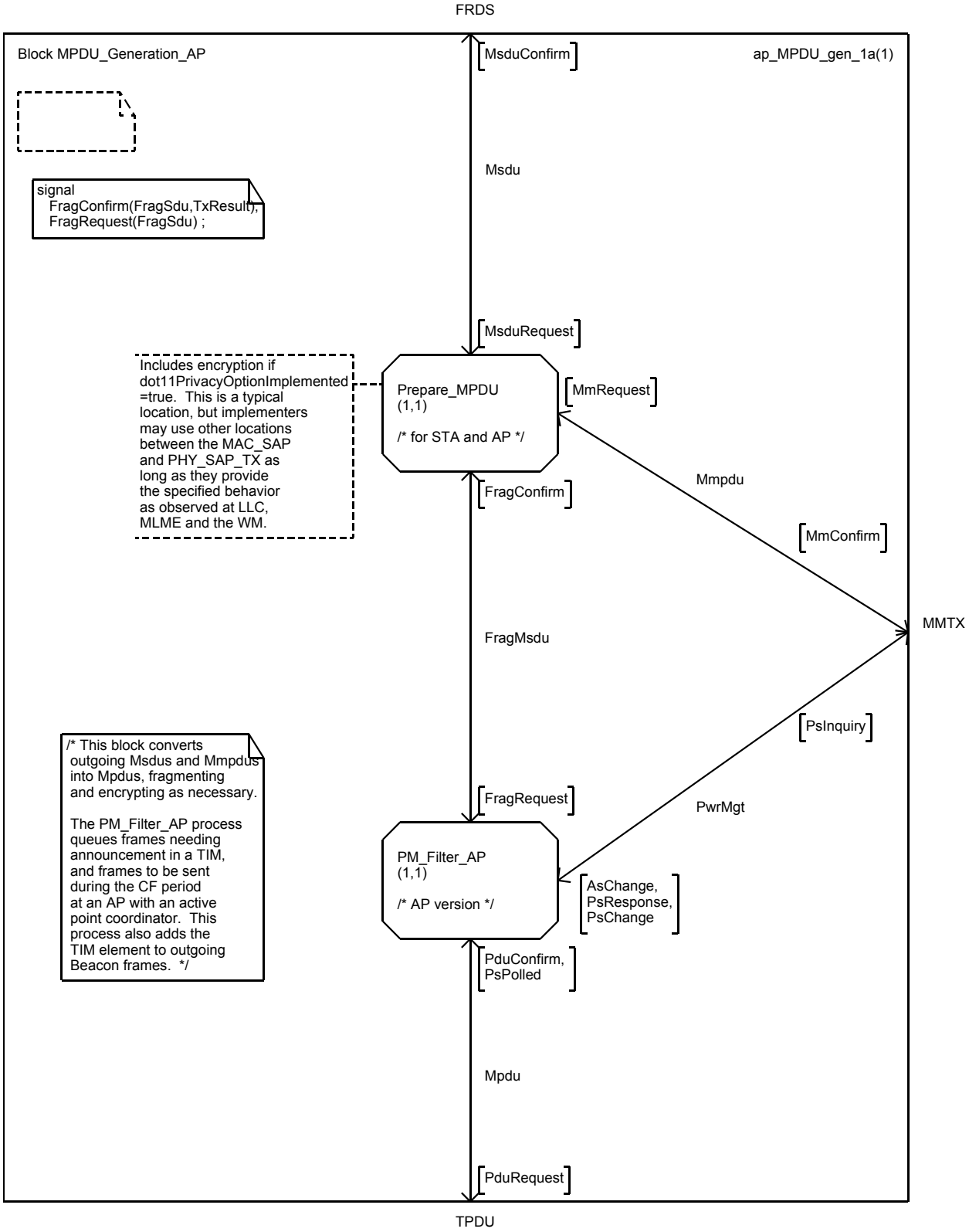

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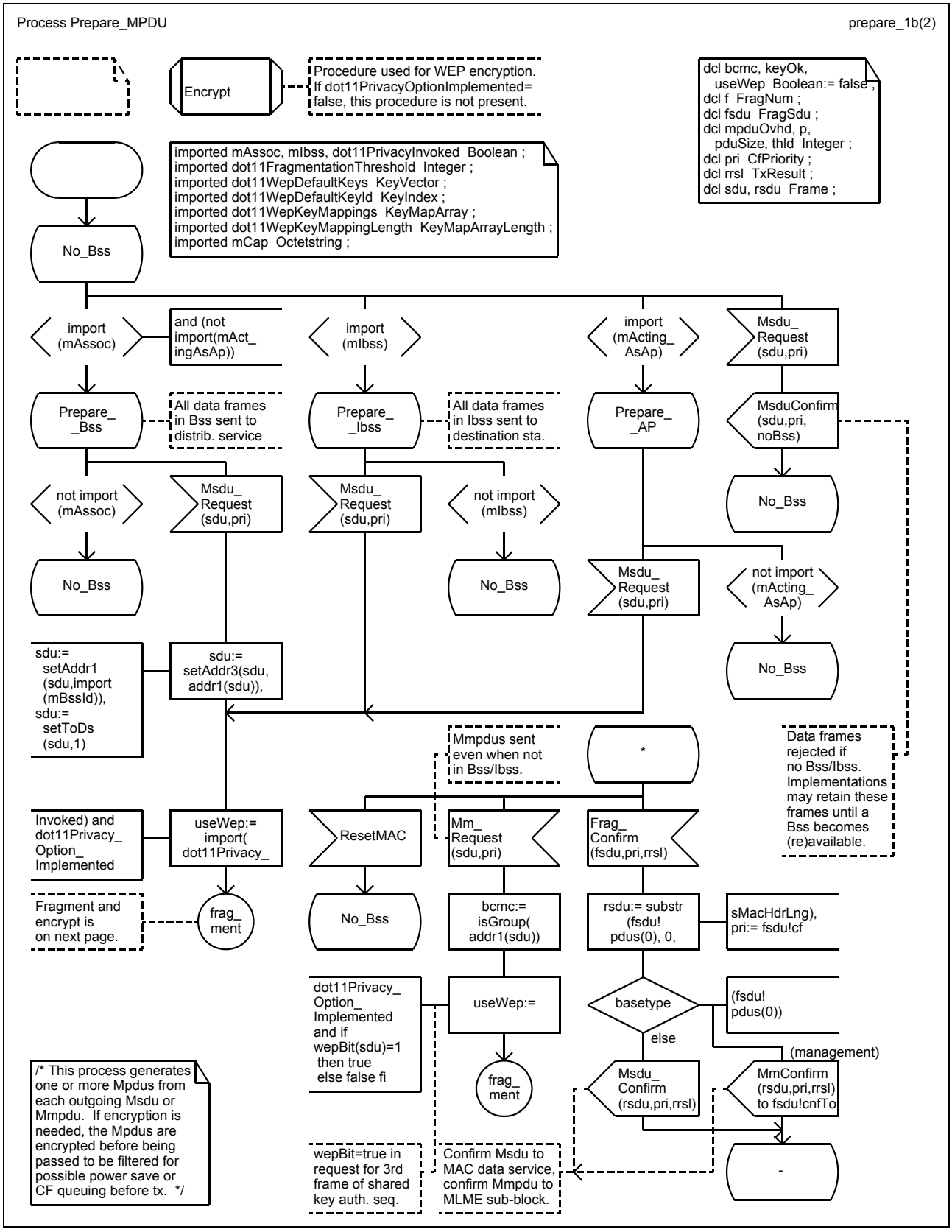

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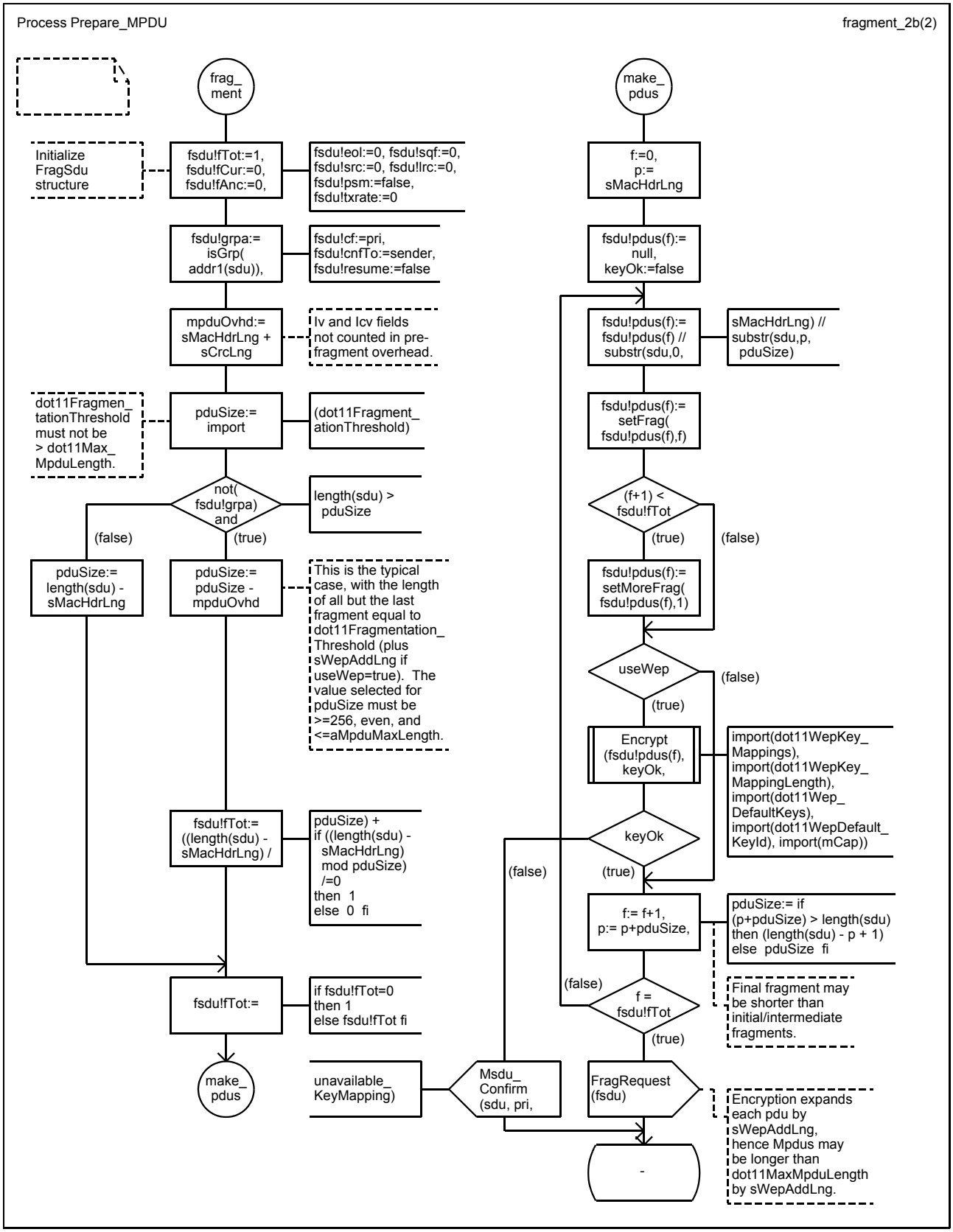

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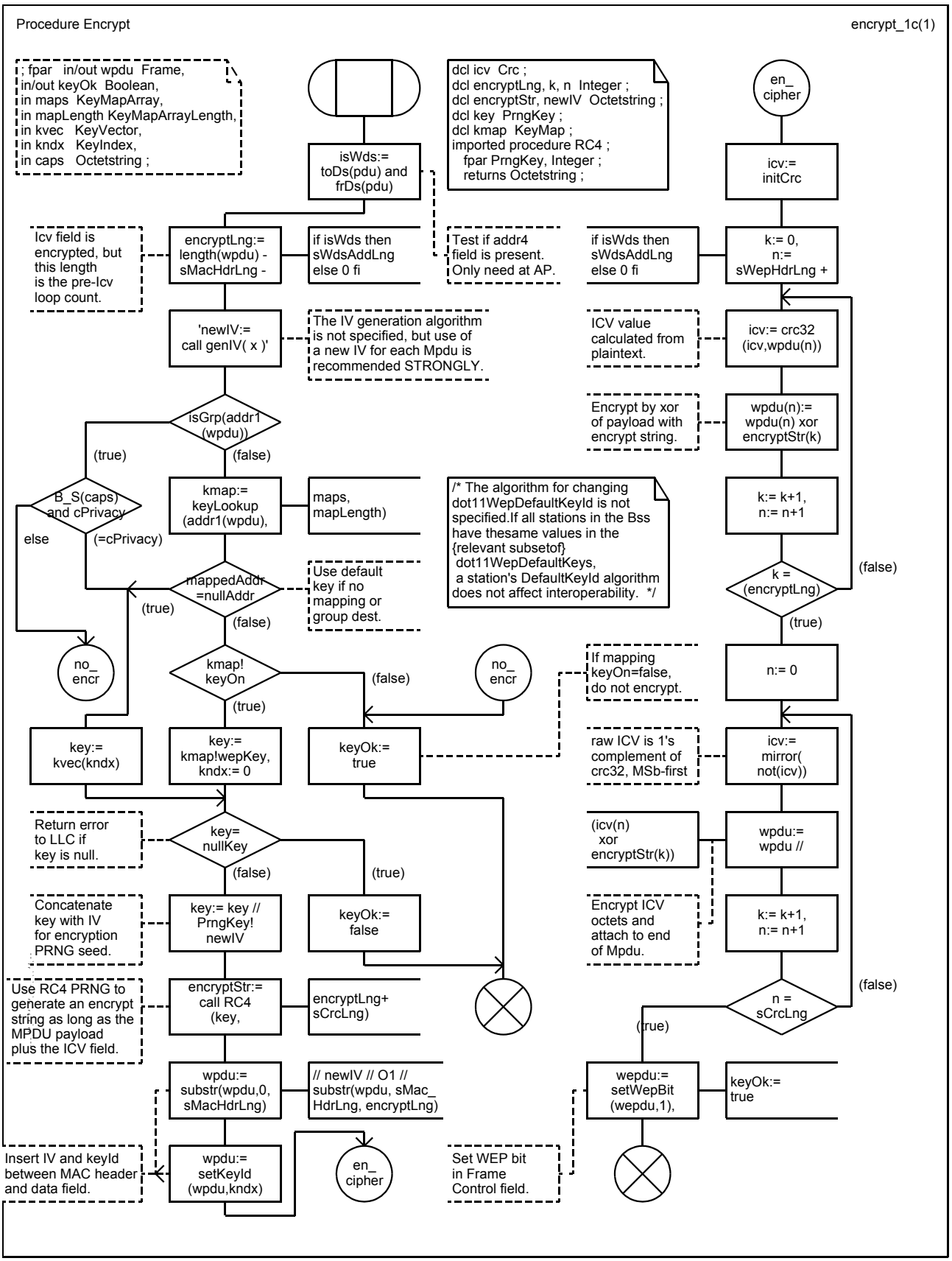

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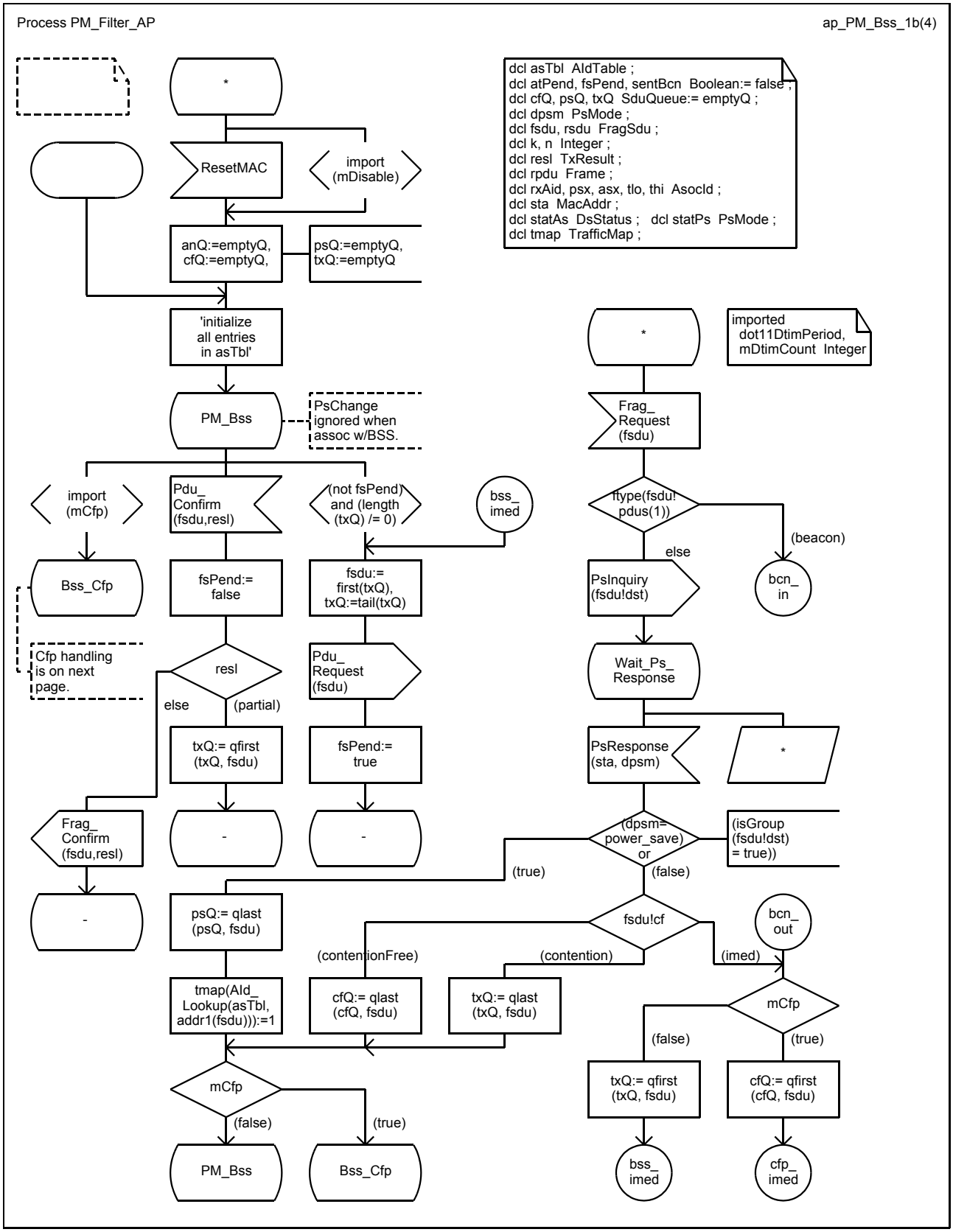

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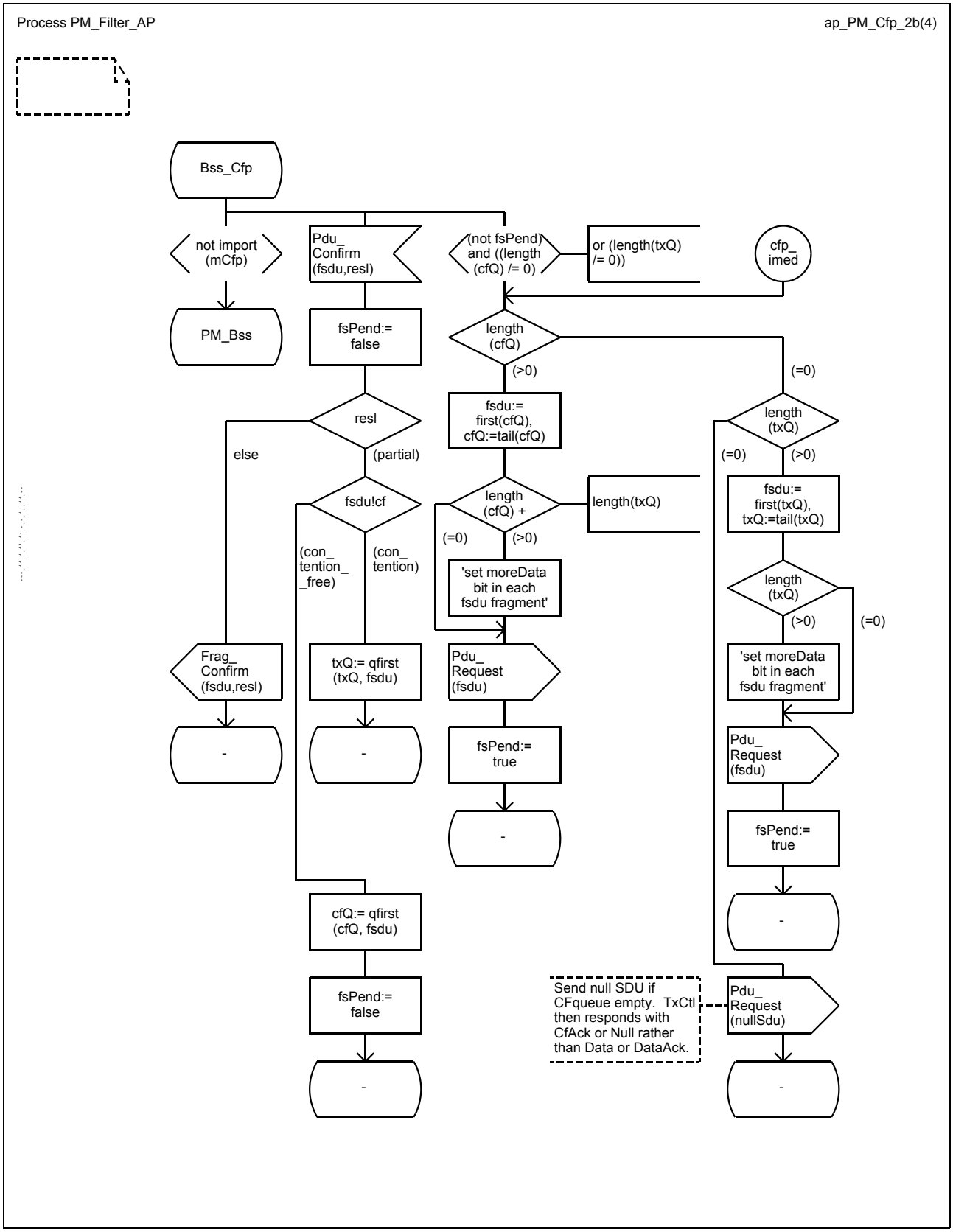

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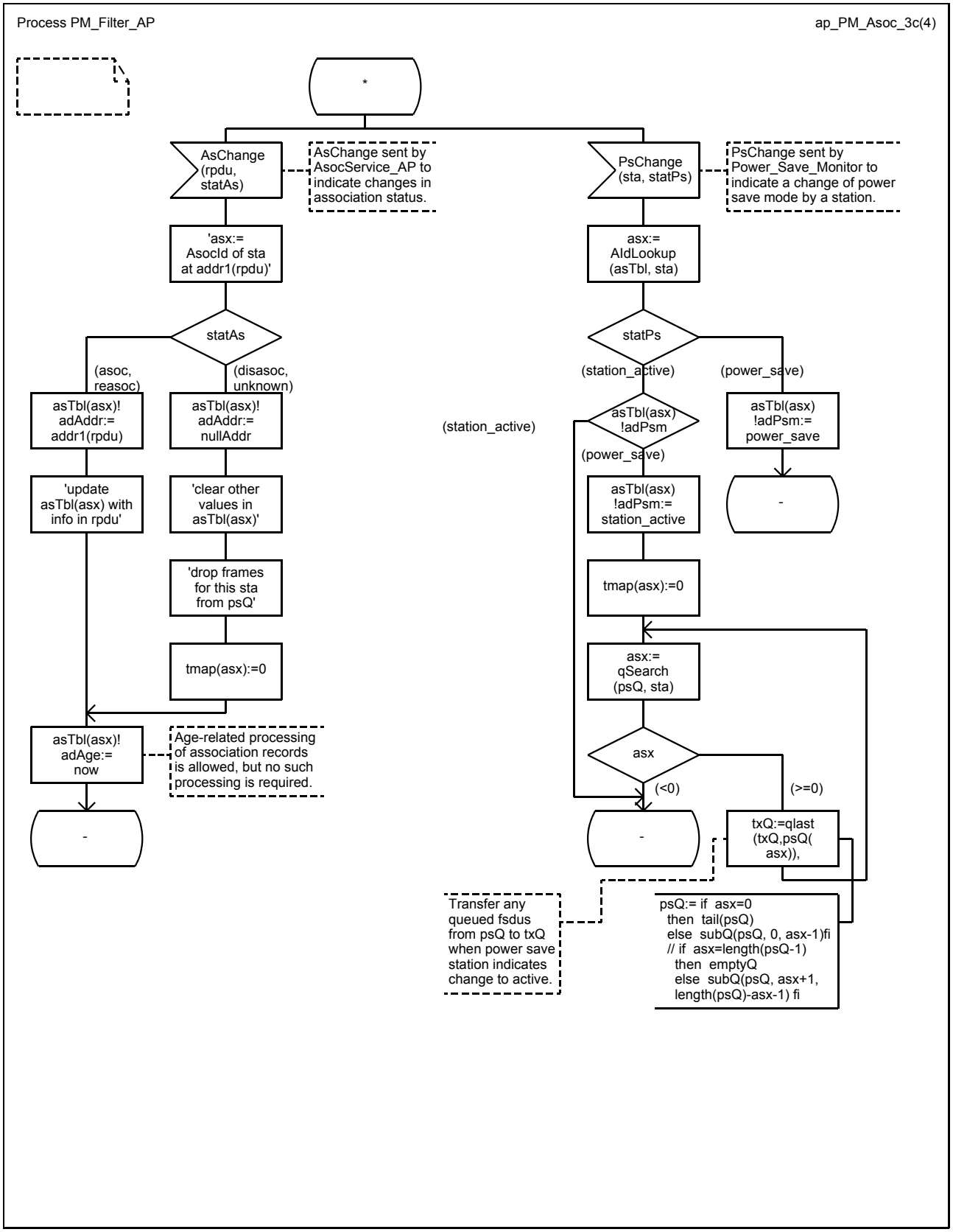

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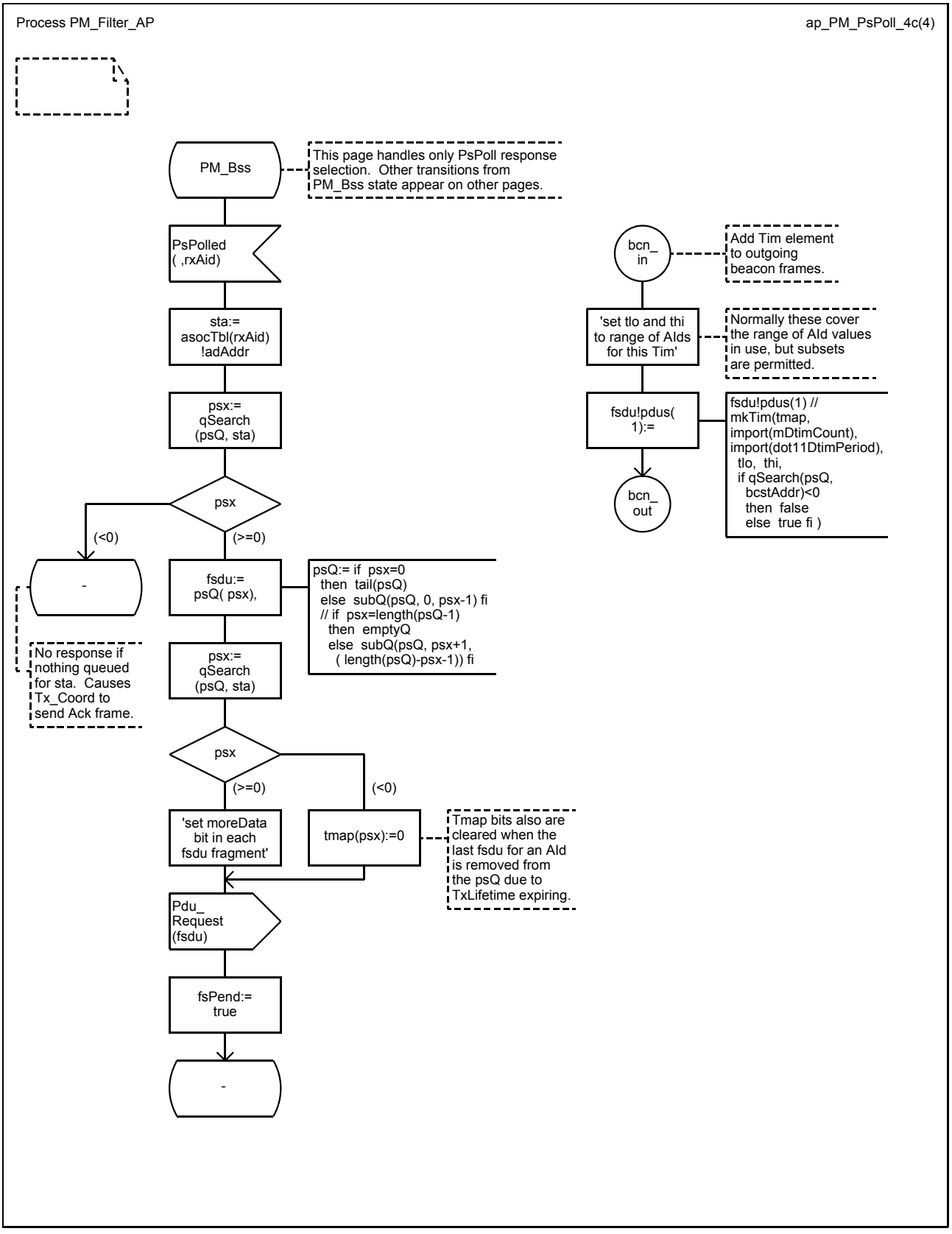

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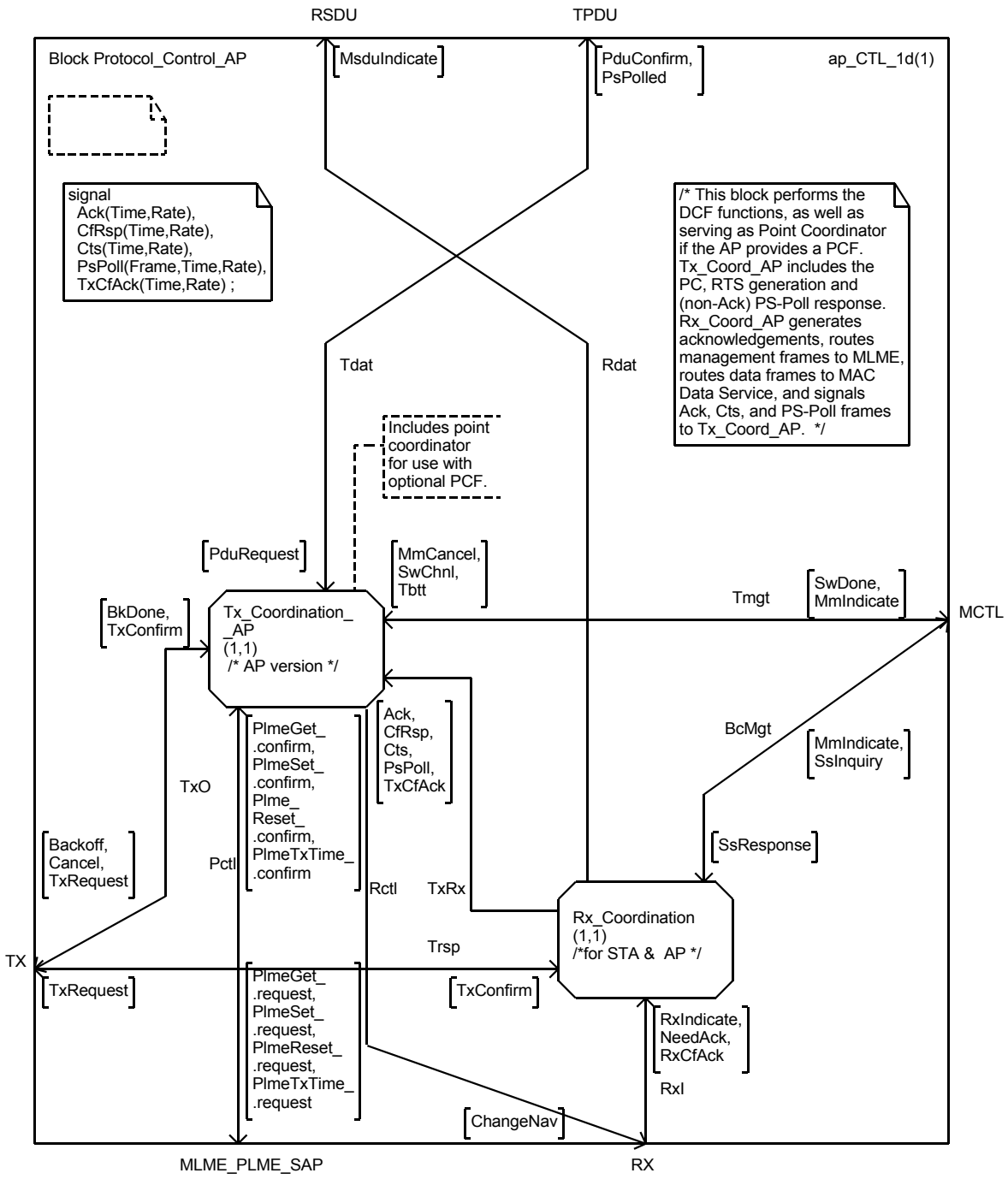

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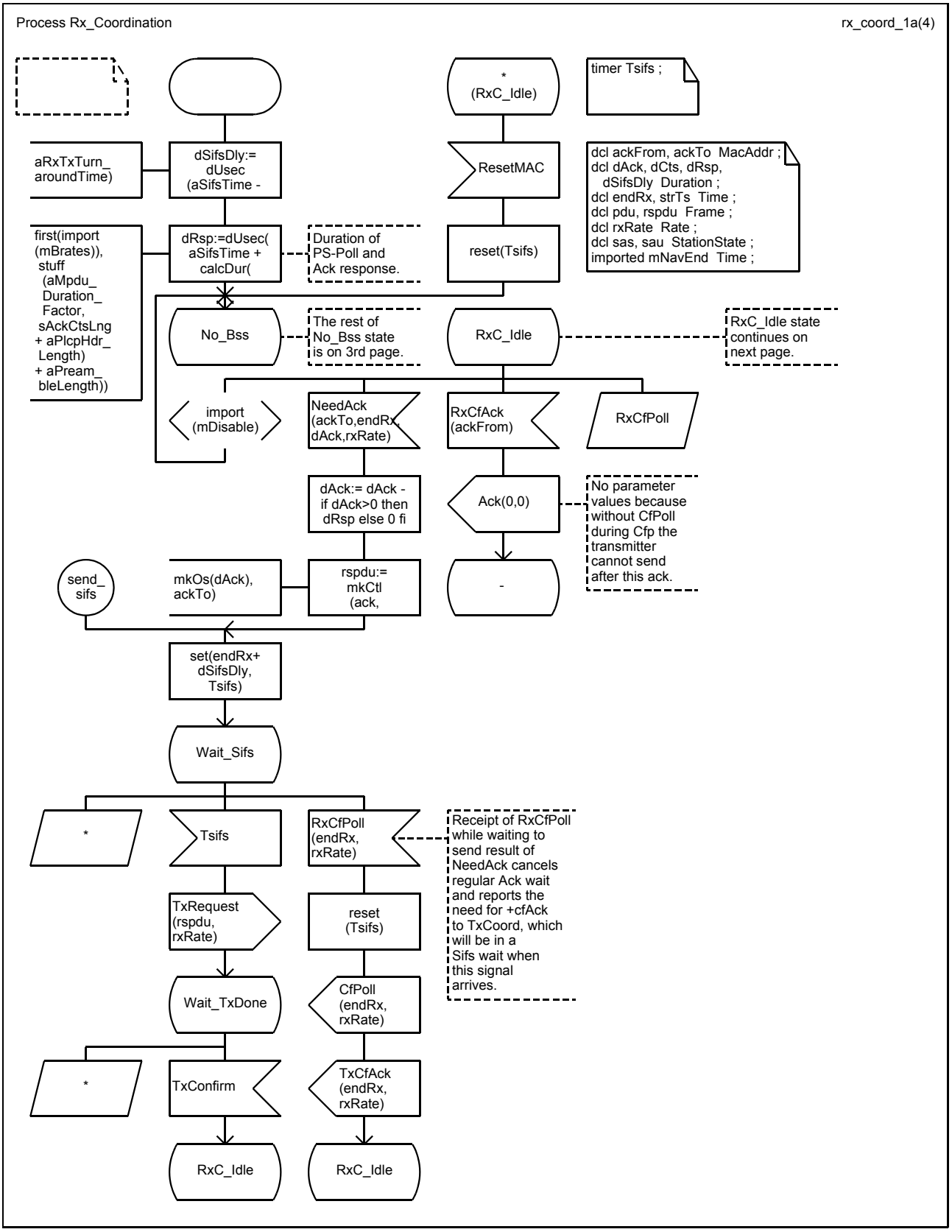

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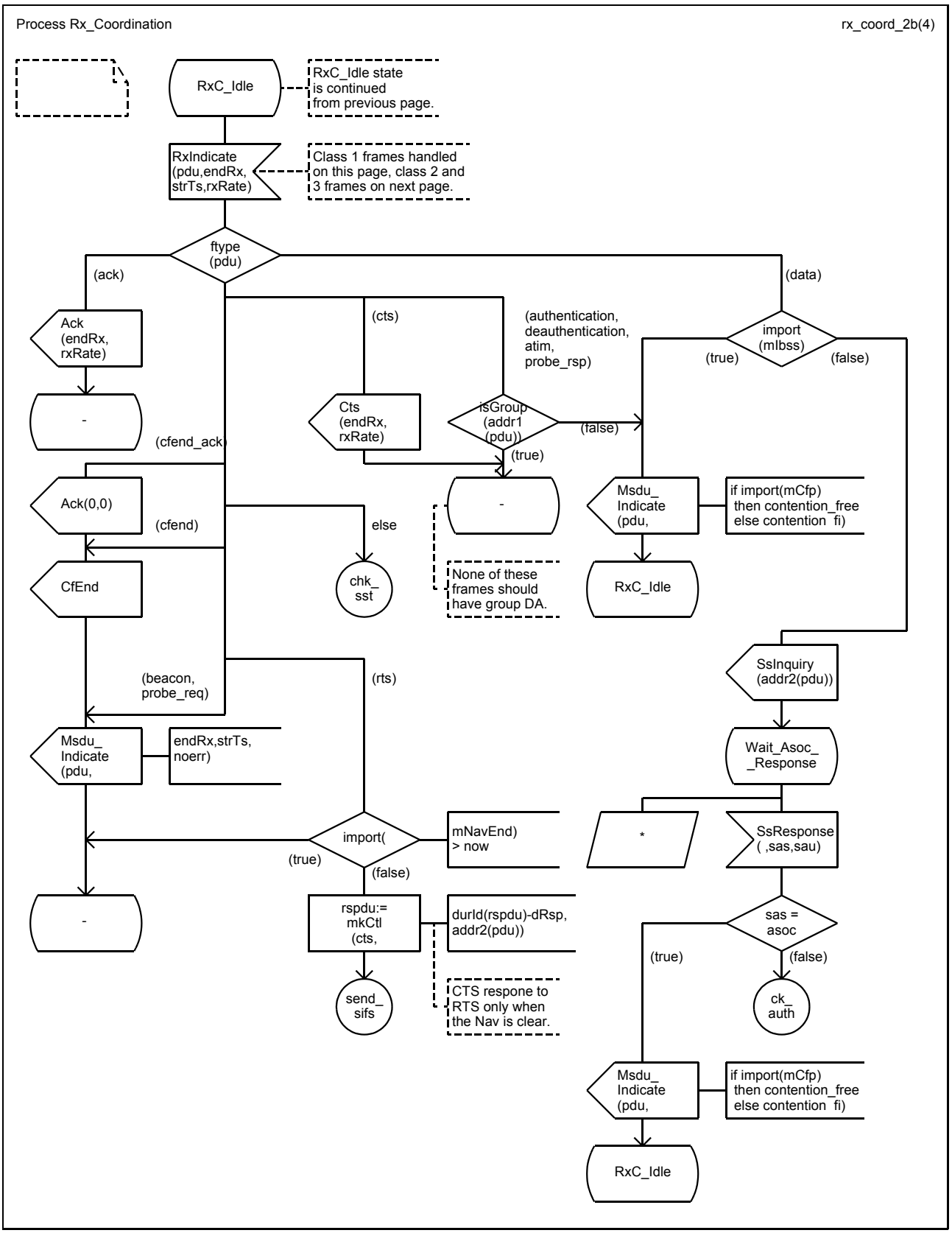

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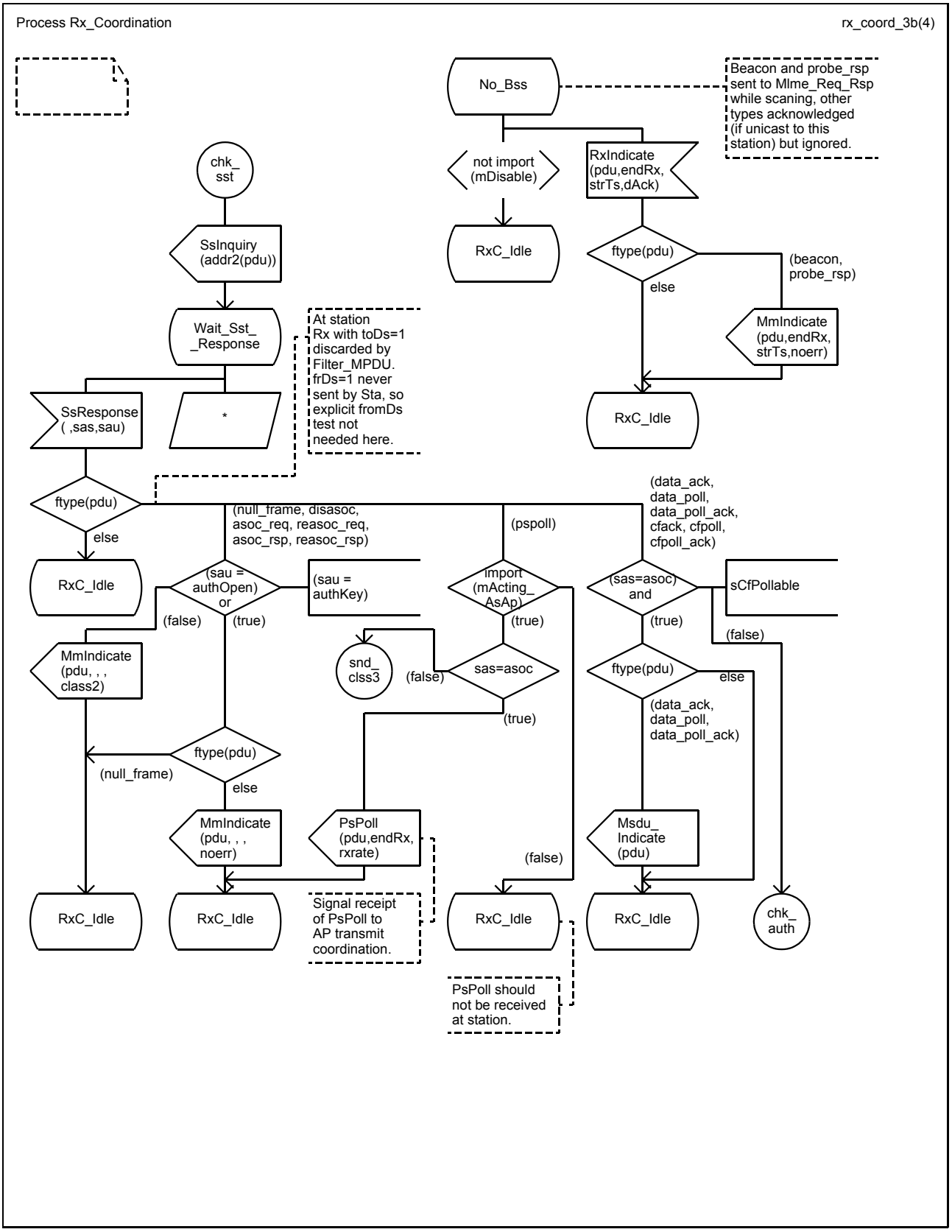

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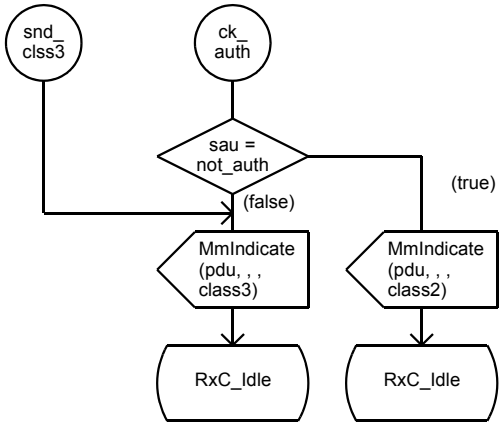
Process Rx_Coordination rx_coord_3.1a(4)





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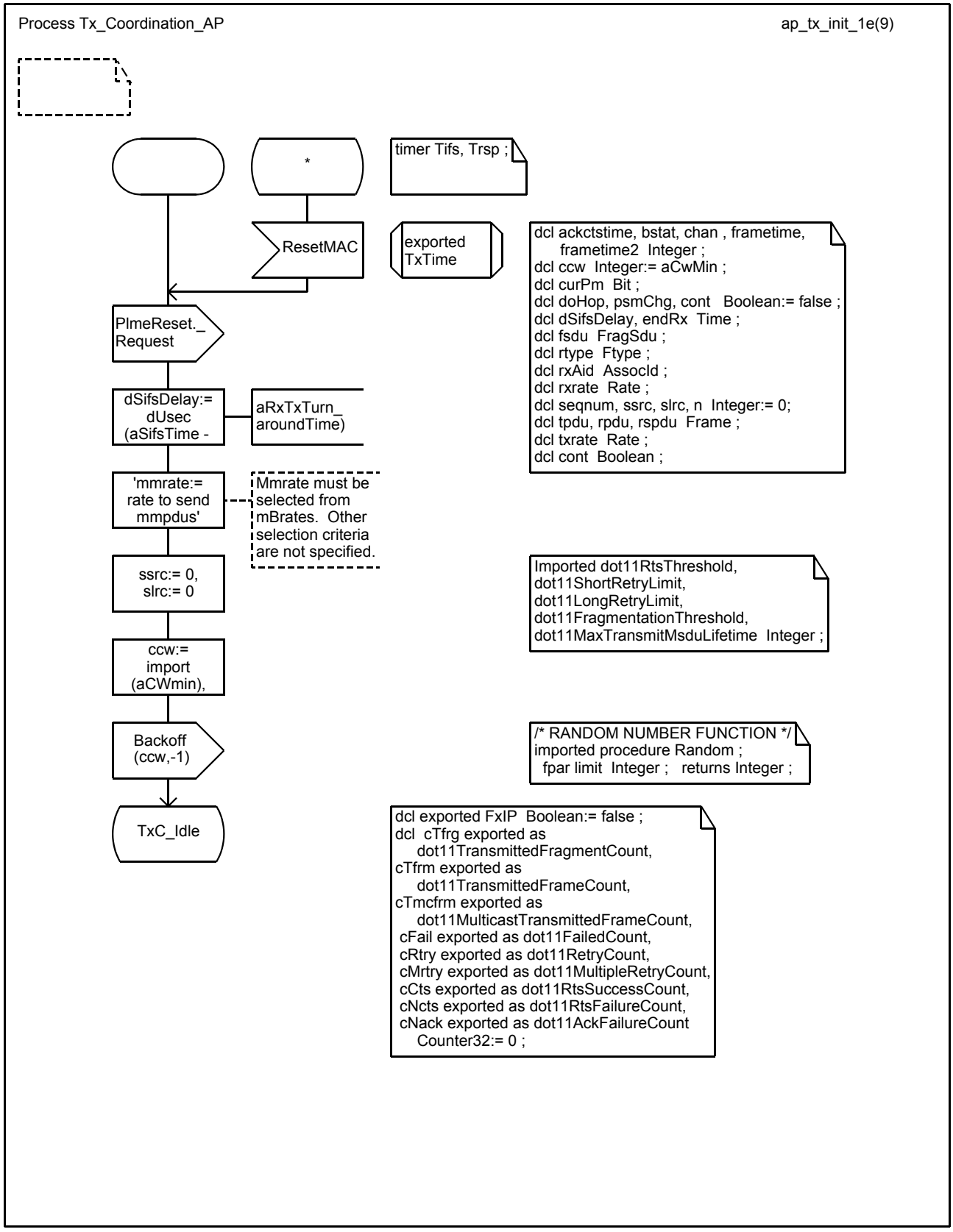

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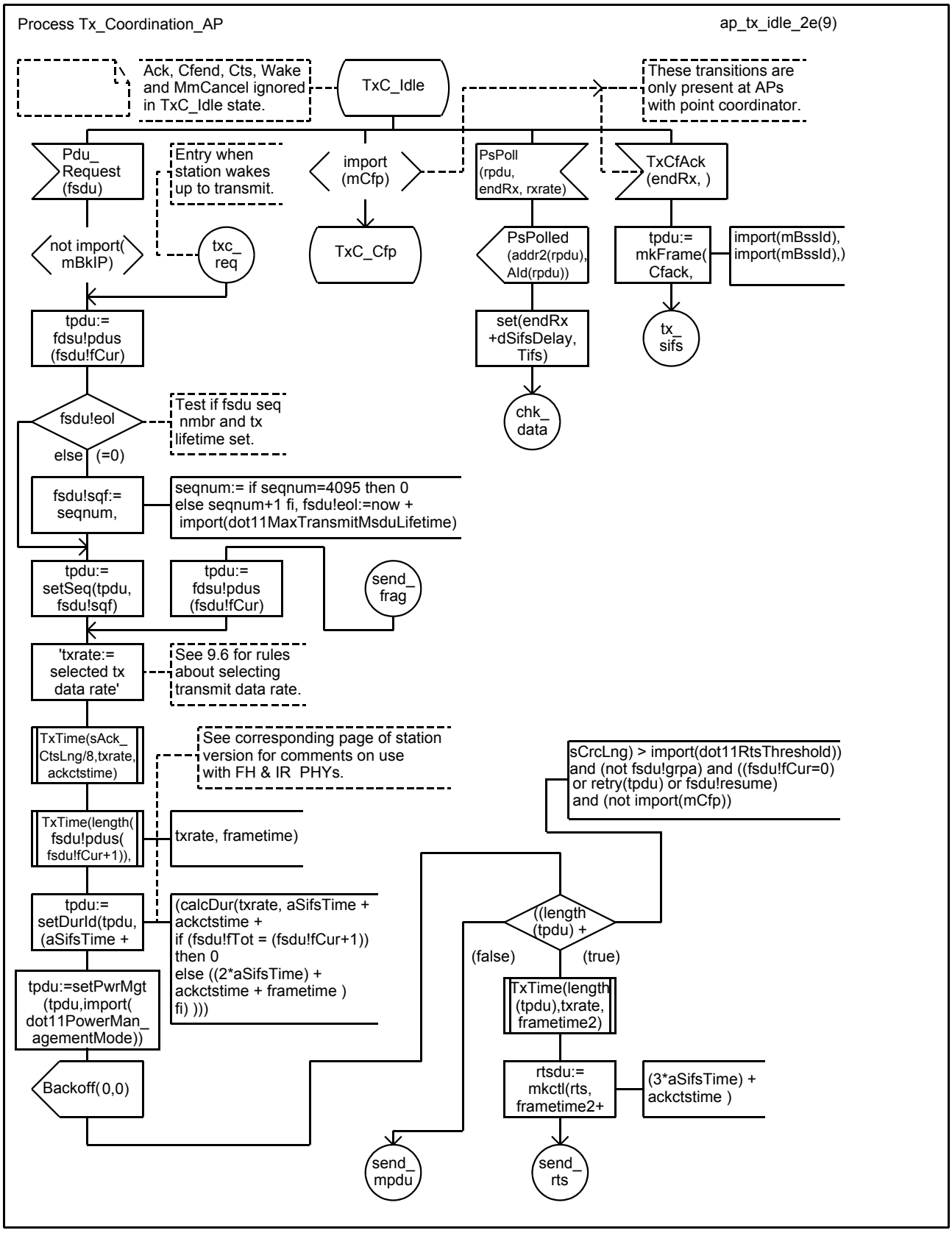

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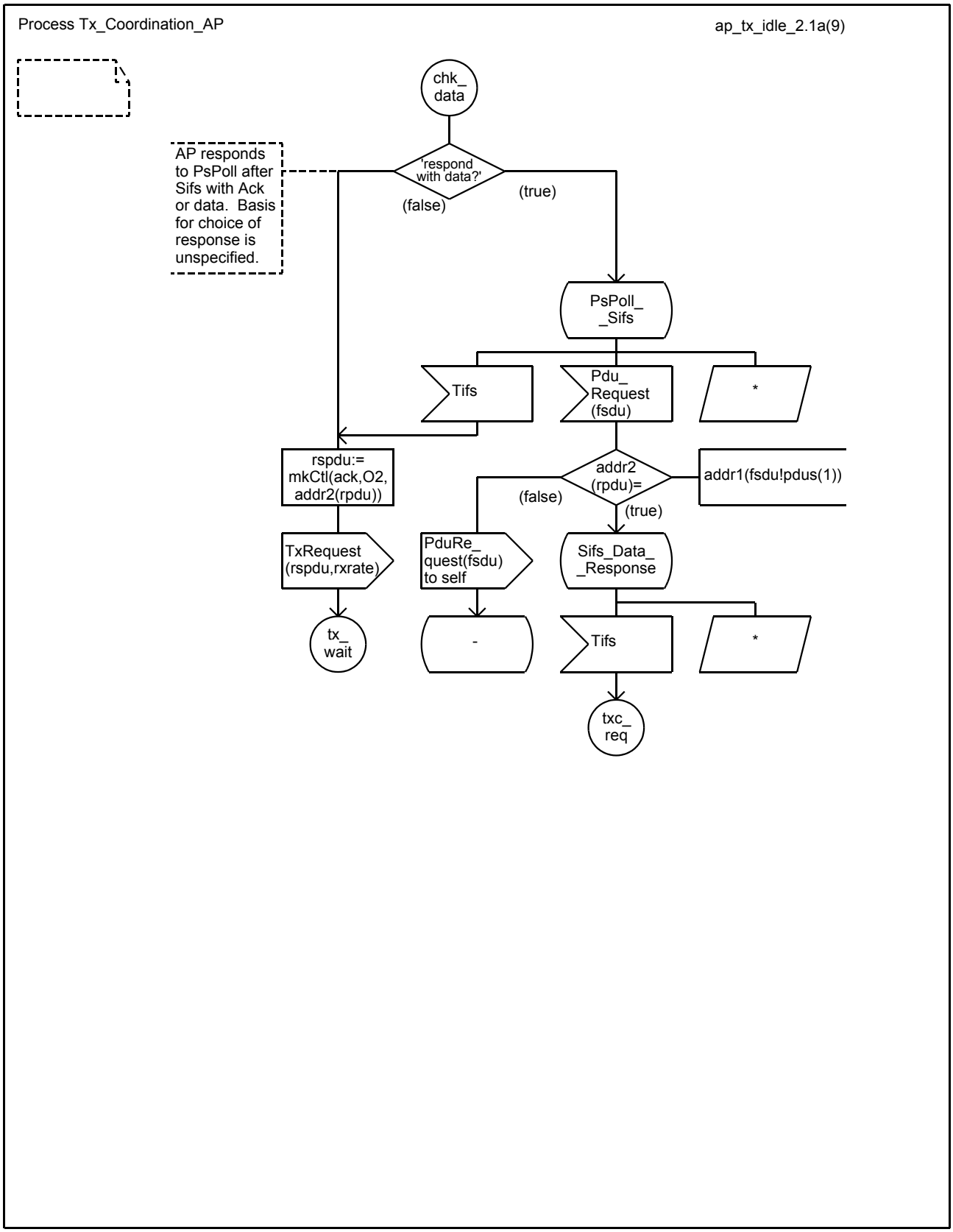

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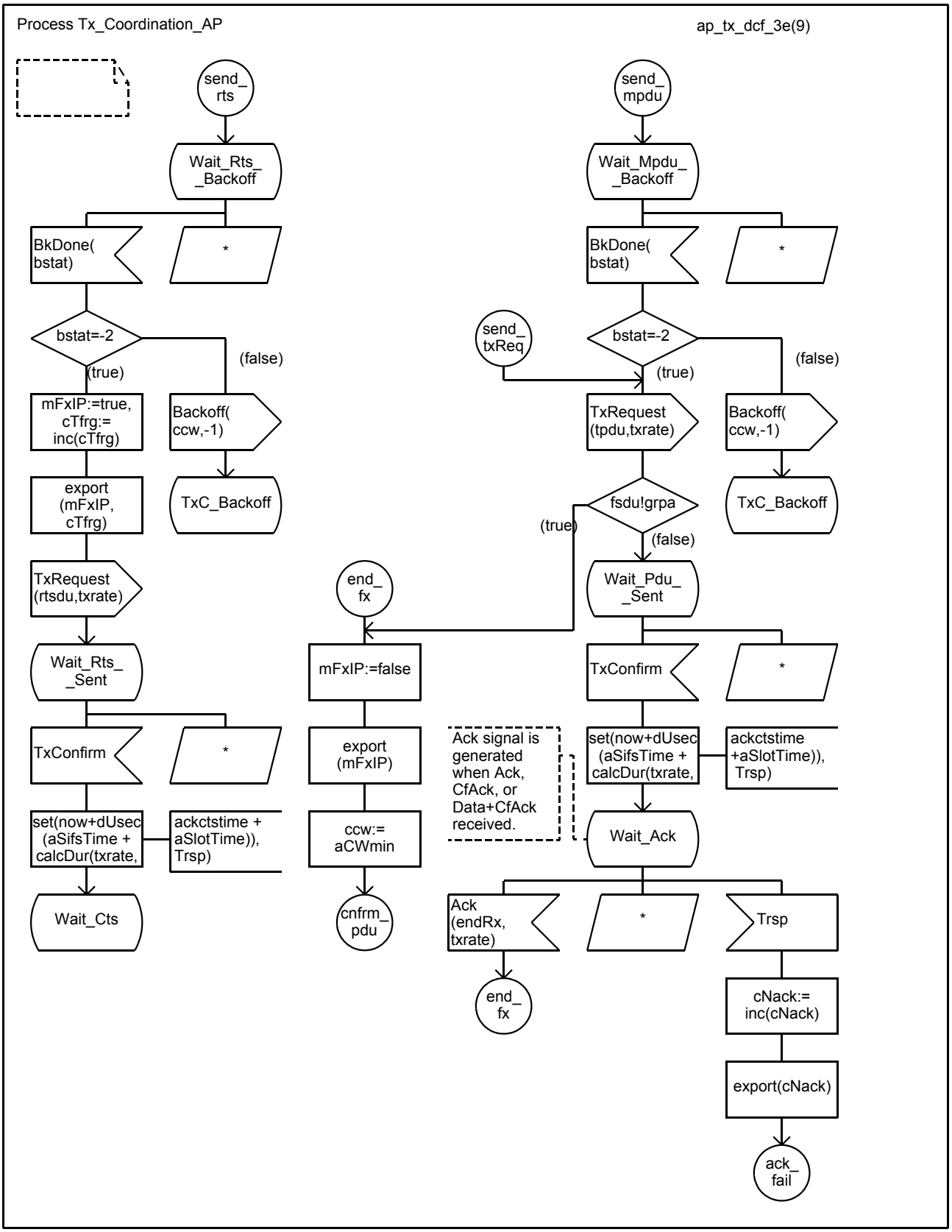

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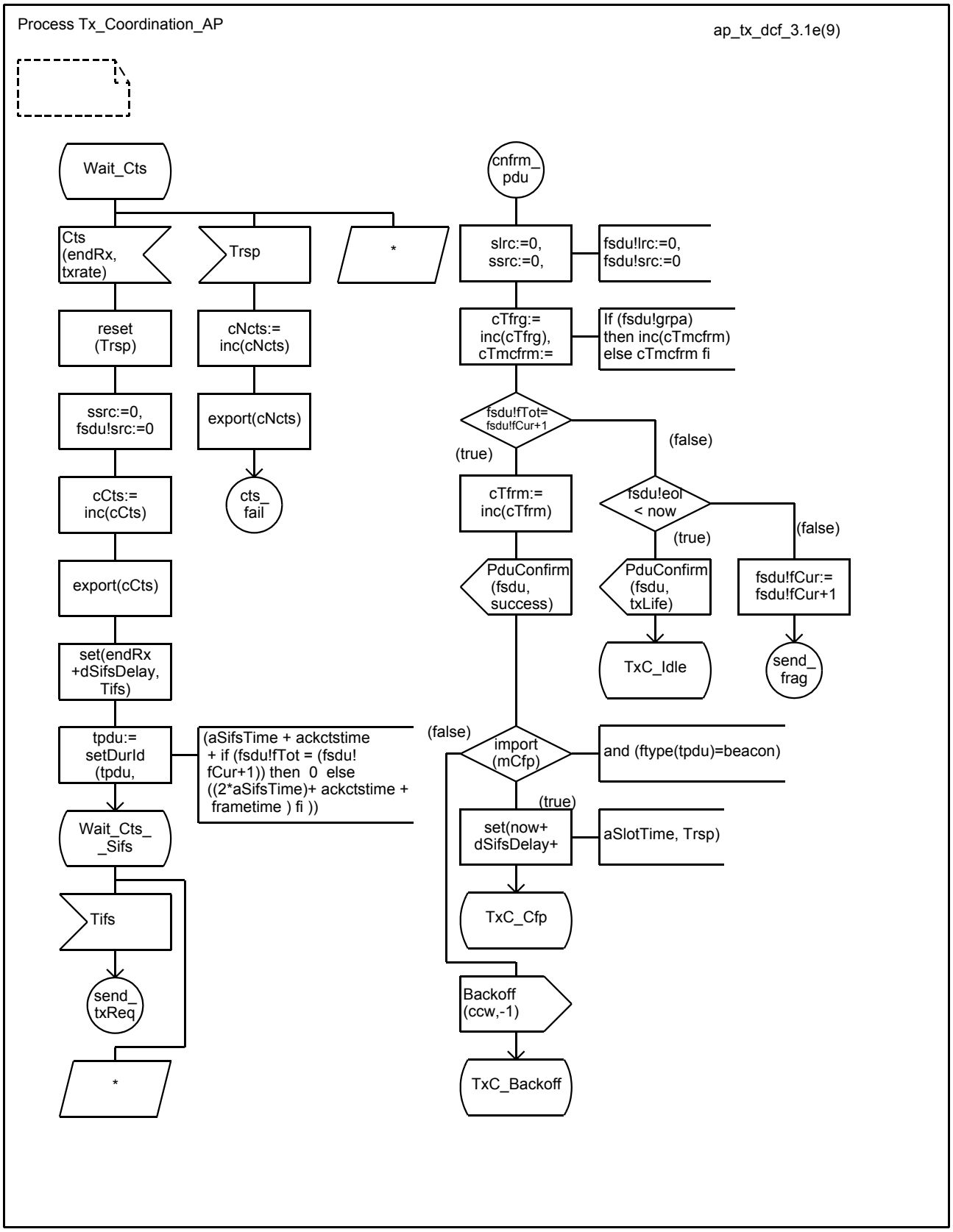

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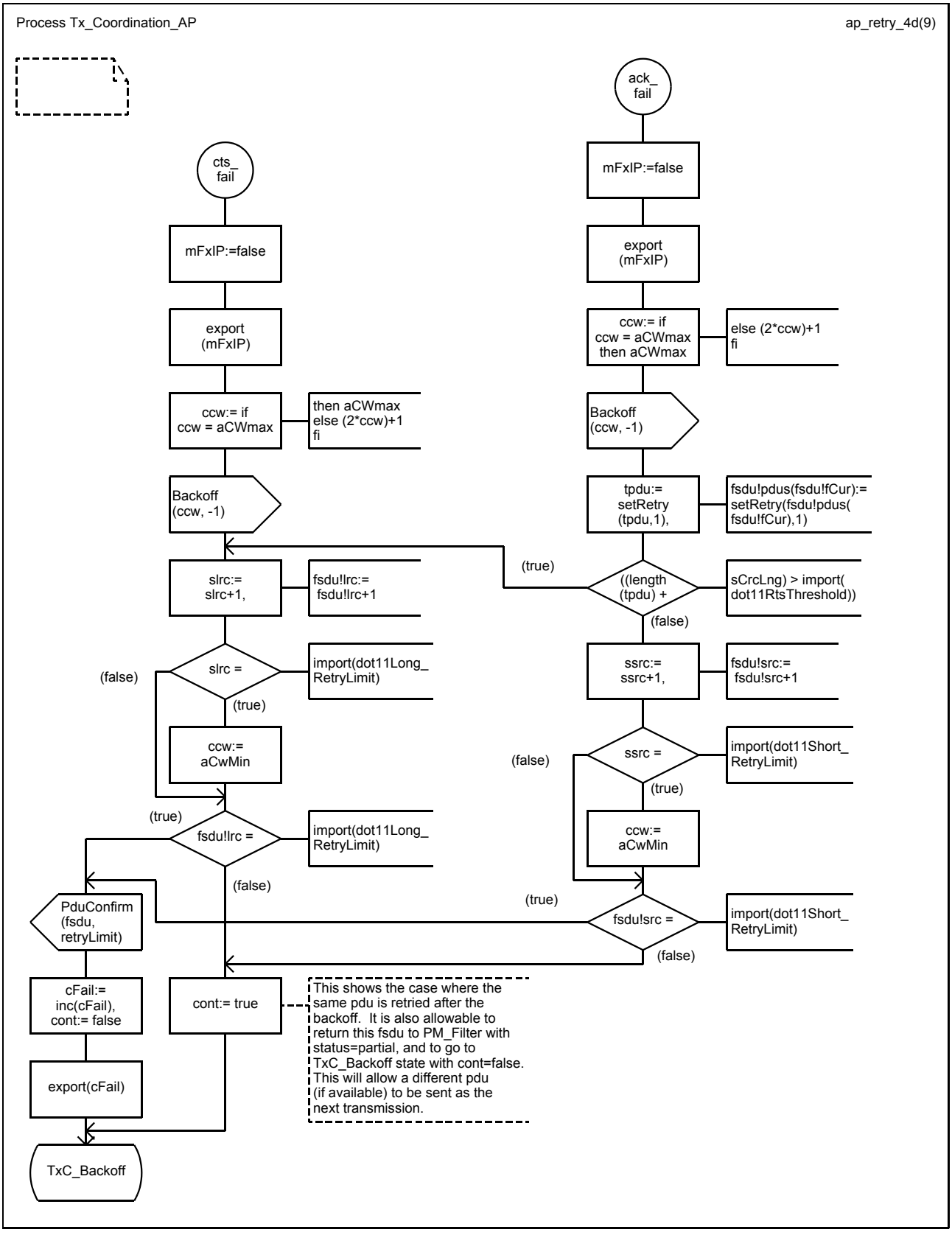

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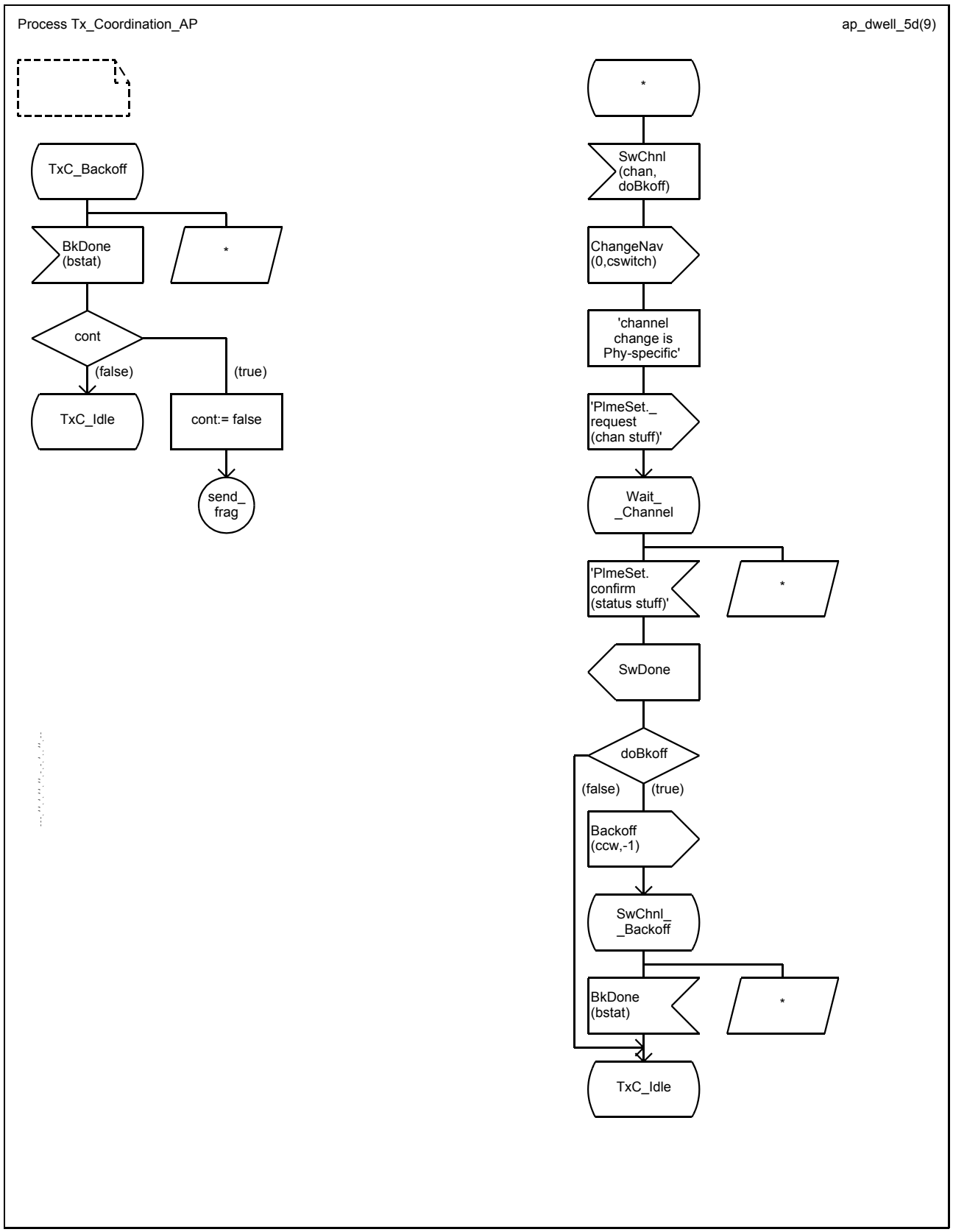

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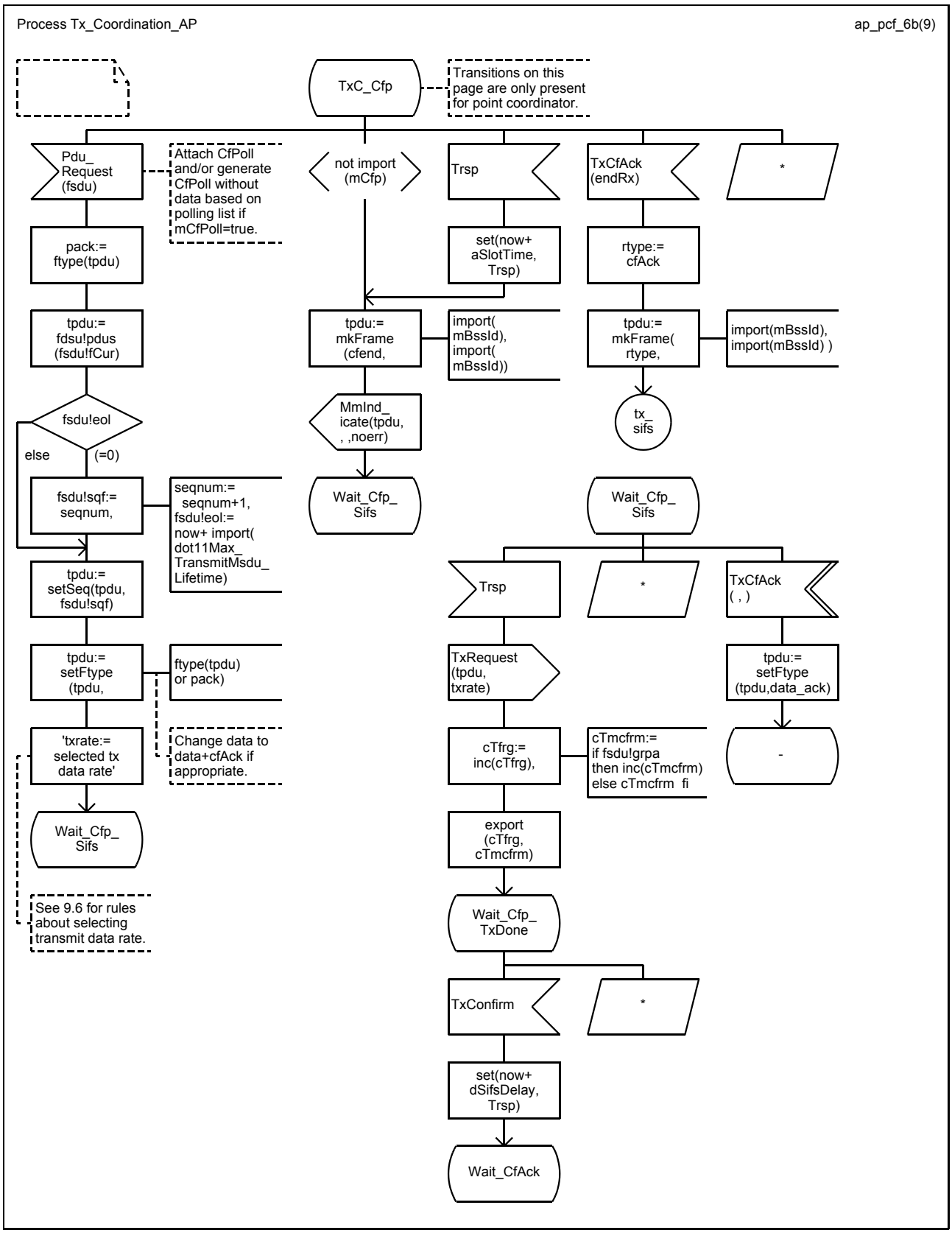

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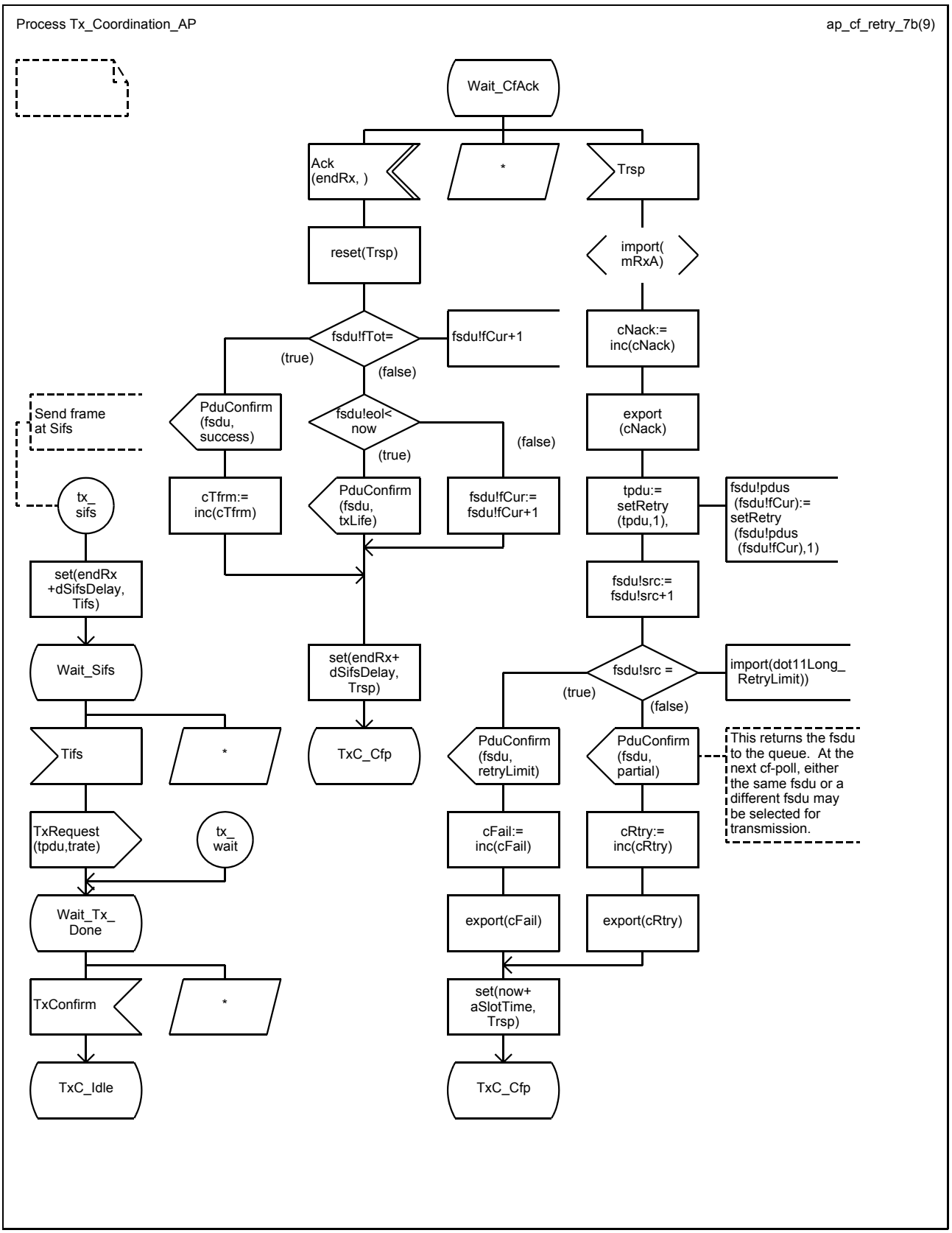

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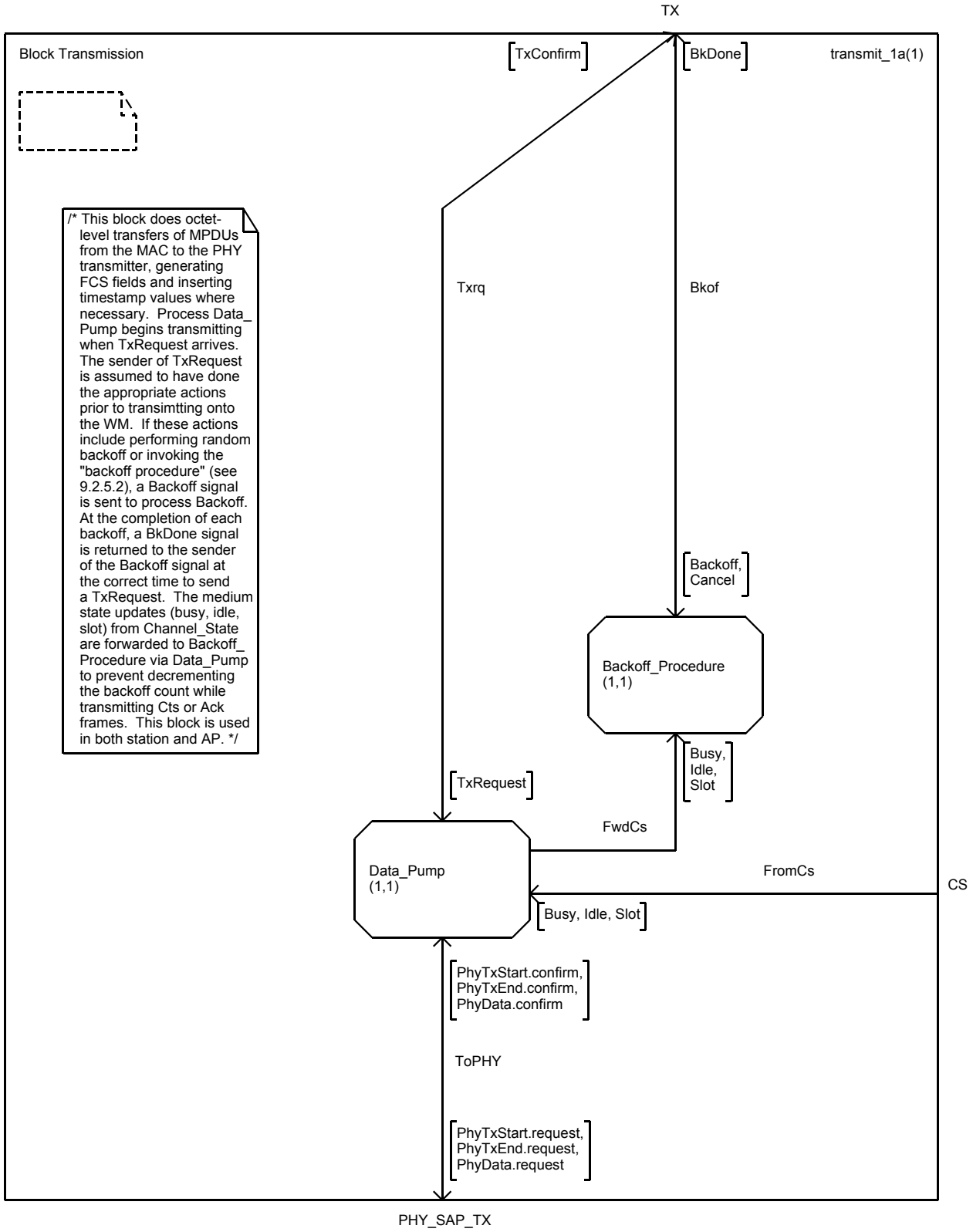

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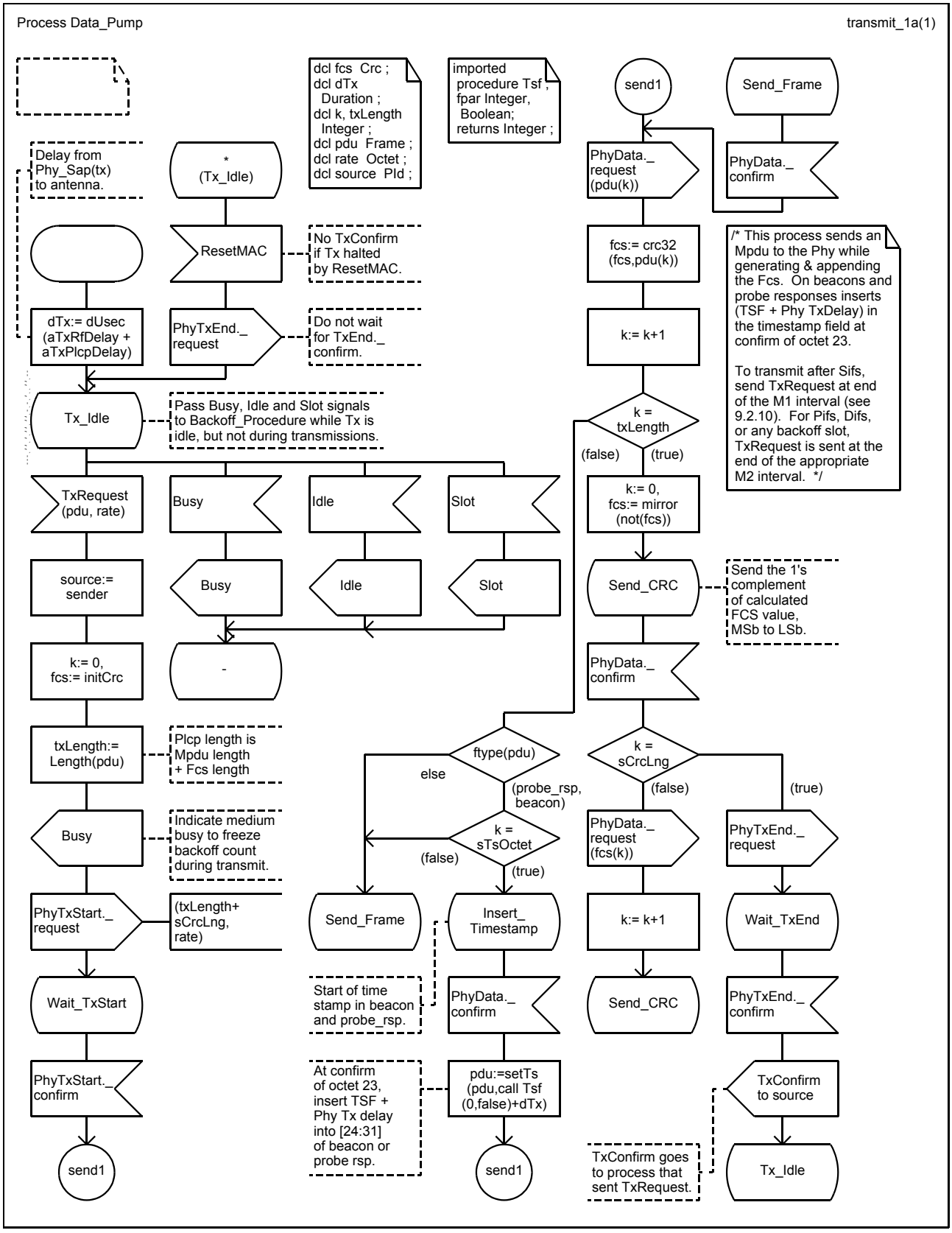

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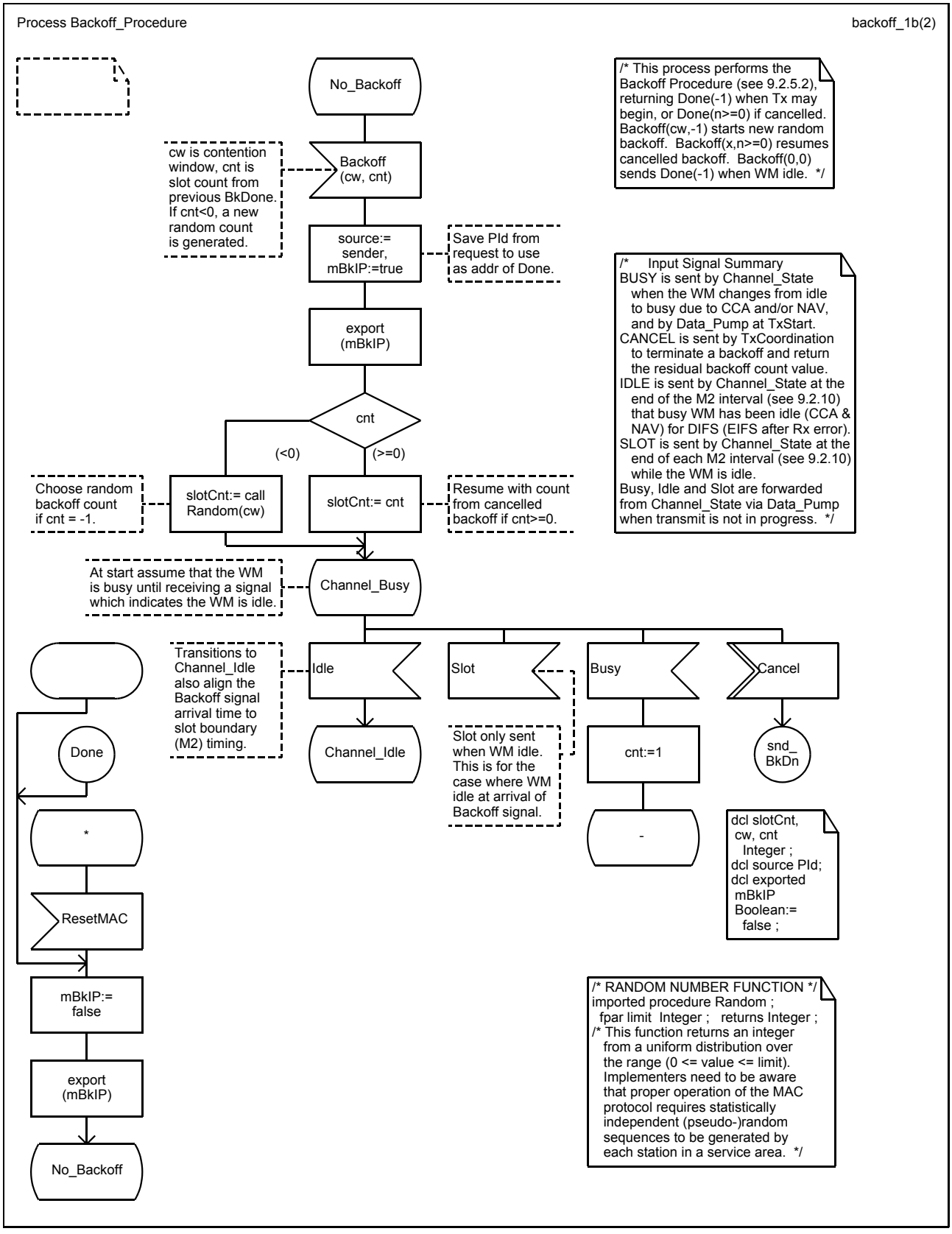

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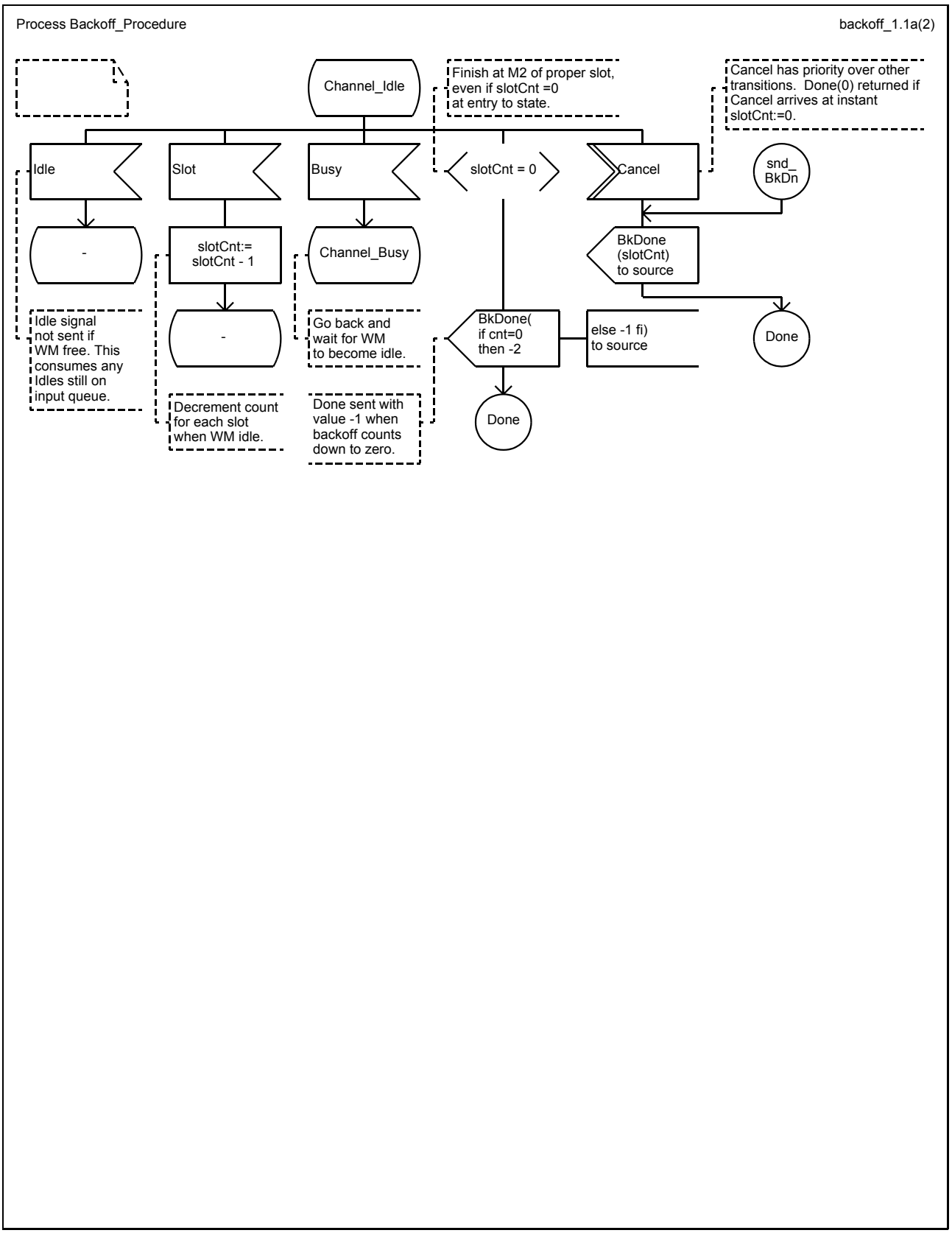

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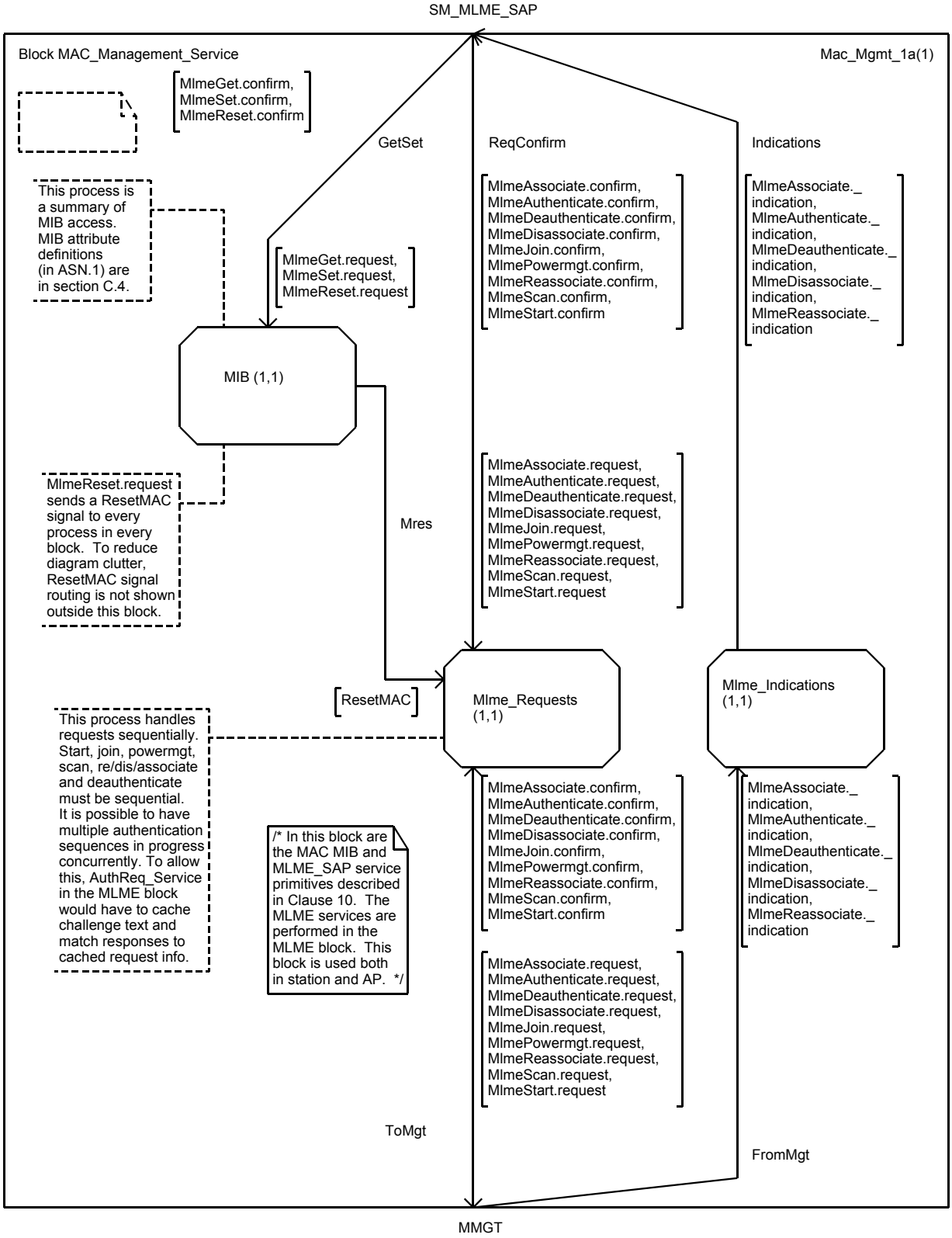

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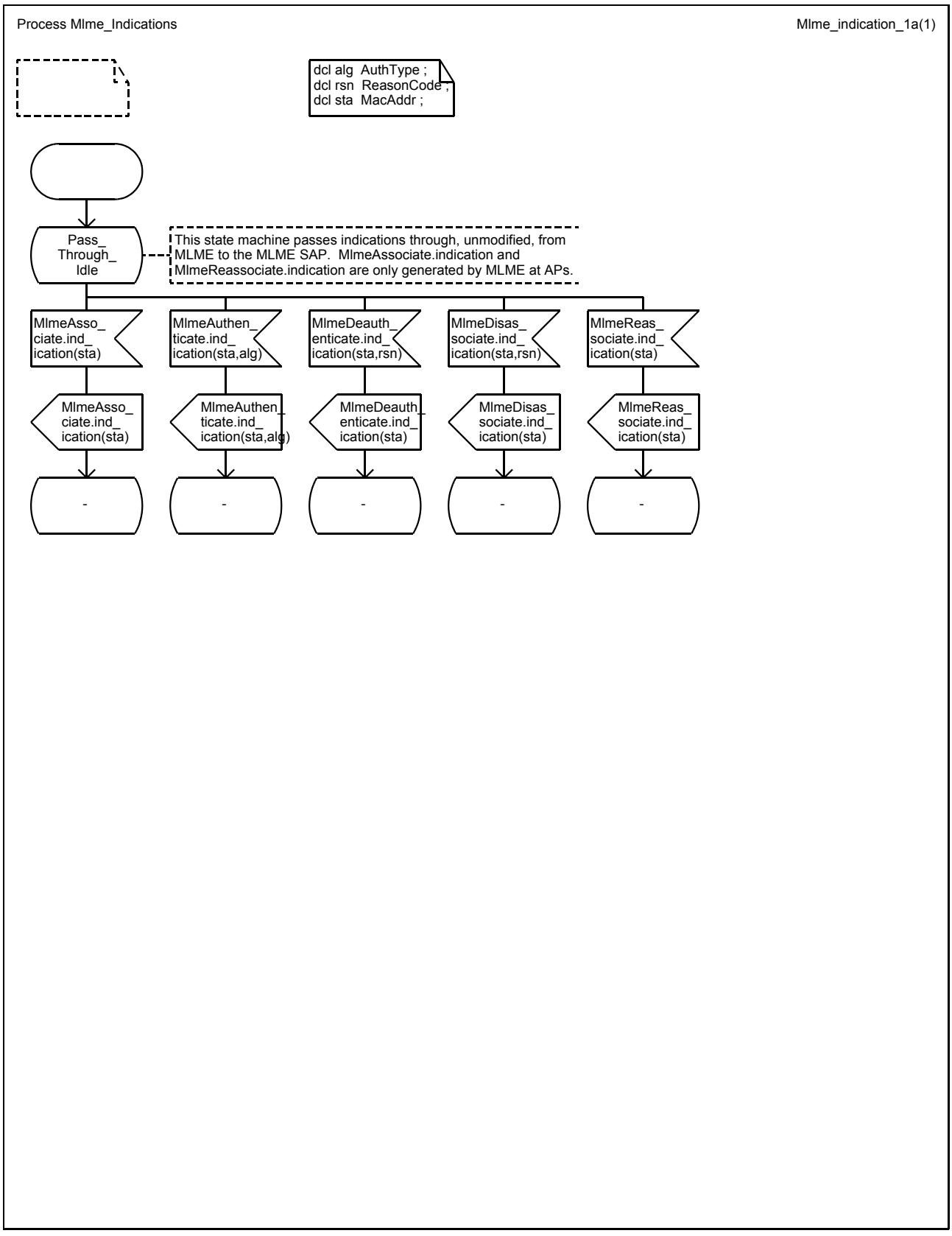

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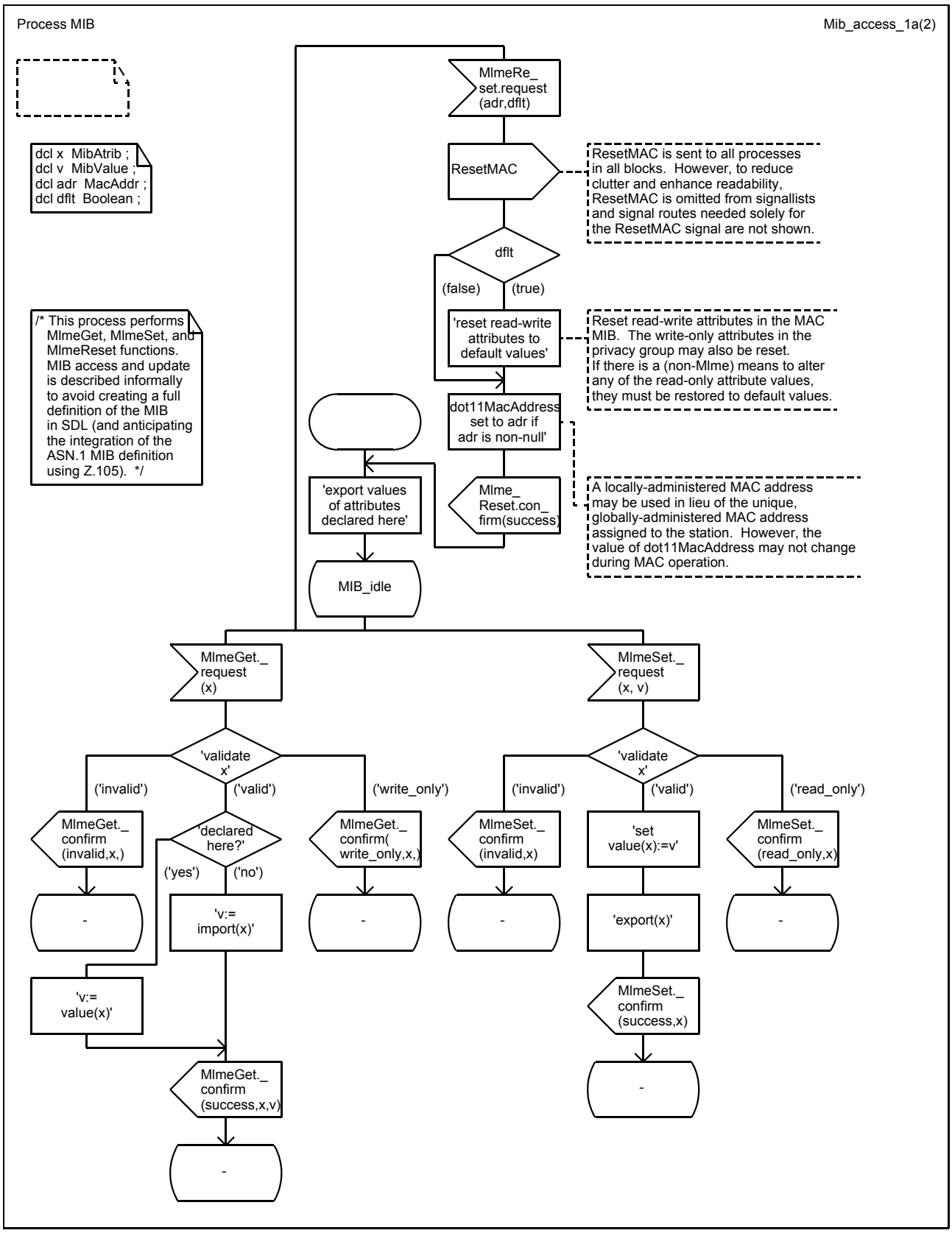

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Process MIB Mib_import_export_2b(2)

```
/* Import of {Read-Only} MIB counter
   values exported from other processes */
imported
  dot11AckFailureCount,
  dot11FailedCount,
  dot11FcsErrorCount,
  dot11FrameDuplicateCount,
  dot11MulticastReceivedFrameCount,
  dot11MulticastTransmittedFrameCount,
  dot11MultipleRetryCount,
  dot11ReceivedFragmentCount,
  dot11RetryCount,
  dot11RtsFailureCount,
  dot11RtsSuccessCount,
  dot11TransmittedFragmentCount,
  dot11WepExcludedCount,
  dot11WepIcvErrorCount,
  dot11WepUndecryptableCount  Counter32 ;
```

```
/* Declarations of MIB attributes exported from
    this process */

       /* Read-Write attributes */
dcl exported
   dot11AuthenticationAlgorithms  AuthTypeSet:=
     incl(open_system, shared_key),
  dot11ExcludeUnencrypted  Boolean:= false,
  dot11FragmentationThreshold  Integer:= 2346,
  dot11GroupAddresses  MacAddrSet:= empty,
  dot11LongRetryLimit  Integer:= 4,
  dot11MaxReceiveLifetime  Kusec:= 512,
  dot11MaxTransmitMsduLifetime  Kusec:= 512,
  dot11MediumOccupancyLimit  Kusec:= 100,
  dot11PrivacyInvoked  Boolean:= false,
  mReceiveDTIMs  Boolean:= true,
  dot11CfpPeriod  Integer:= 1,
  dot11CfpMaxDuration  Kusec:= 200,
  dot11AuthenticationResponseTimeout  Kusec:= 512,
  dot11RtsThreshold  Integer:= 3000,
  dot11ShortRetryLimit  Integer:= 7,
  dot11WepDefaultKeyId  KeyIndex:= 0,
  dot11CurrentChannelNumber  Integer:= 0,
  dot11CurrentSet  Integer:= 0,
  dot11CurrentPattern  Integer:= 0,
  dot11CurrentIndex  Integer:= 0 ;

       /* Write-Only attributes */
dcl exported
  dot11WepDefaultKeys  KeyVector:= nullKey,
  dot11WepKeyMappings
    KeyMapArray:= (. nullAddr, false, nullKey .) ;
```

```
/* The following Read-Only attributes in the
   MAC MIB are defined as synonyms (named
   constants) rather than remote variables
   because they describe properties of the
   station which are static, at least during
   any single instance of MAC operation:
      dot11AuthenticationAlgorithms  AuthTypeSet,
      dot11CfPollable  Boolean,
      dot11MacAddress  MacAddr,
      dot11ManufacturerID  Octetstring,
      dot11PrivacyOptionImplemented  Boolean,
      dot11ProductID  Octetstring,
      aStationID  MacAddr,
      dot11WepKeyMappingLength  Integer ;

   In addition, all Read-Only attributes in the
   PHY MIB which are accessed by the MAC
   are defined as synonyms.
*/
```

```
/* NOTE:
   The values listed for MAC MIB attributes are the
   specified default values for those attributes.
   The values listed for PHY MIB attributes are either
   the default values for the FH PHY, or arbitrary
   values within the specified range.  The specific
   values for PHY attributes in this SDL description
   of the MAC do not have normative significance.
*/
```


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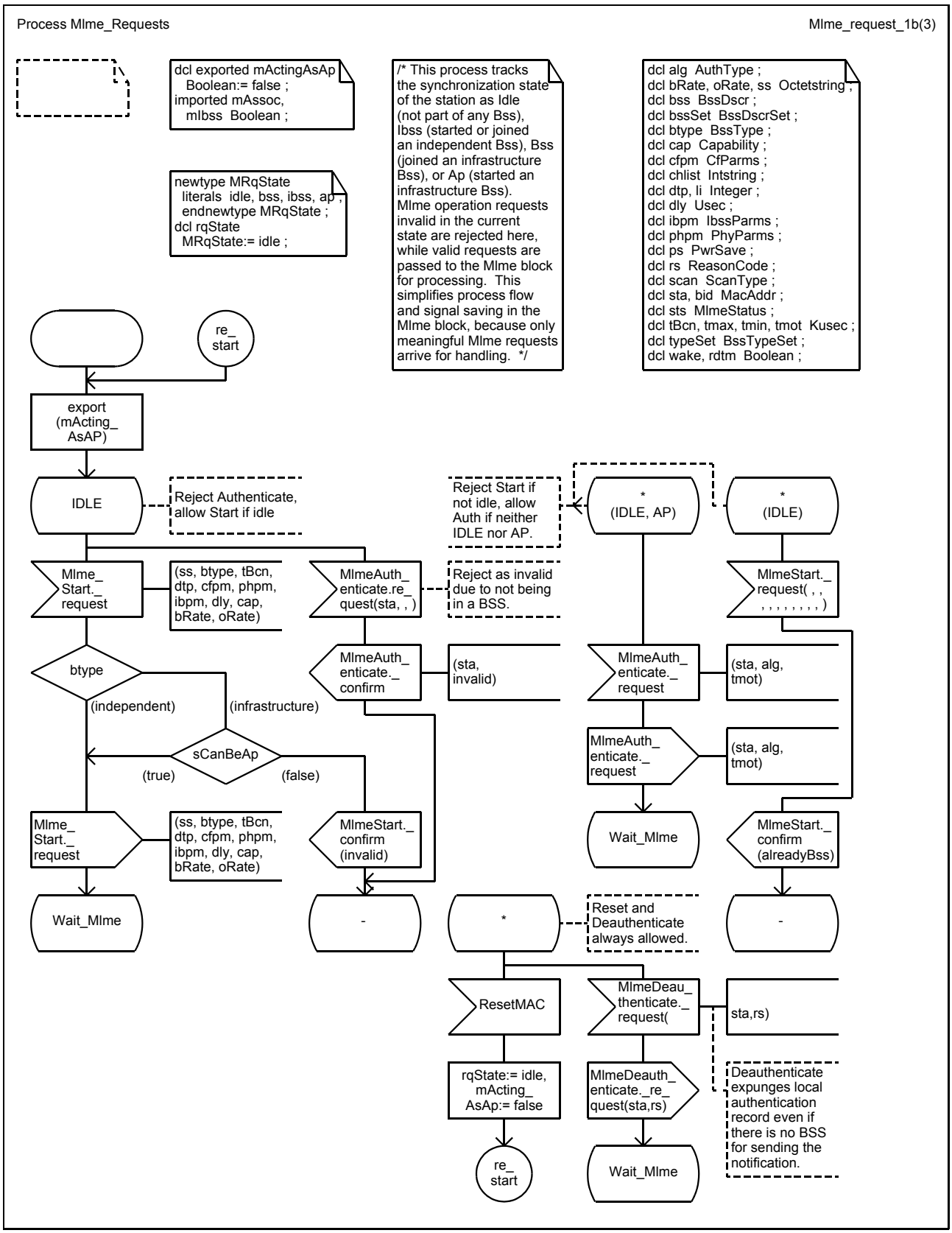

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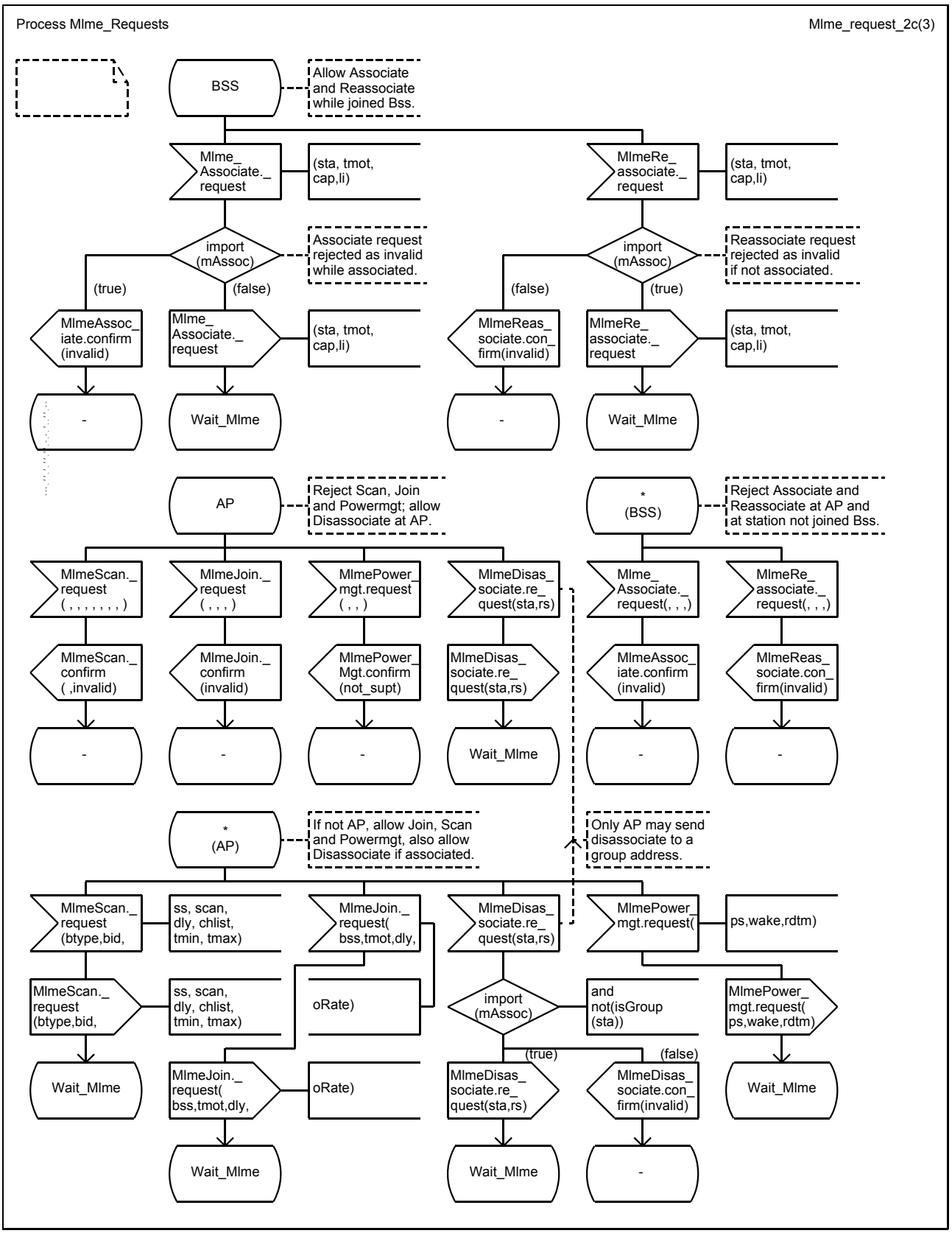

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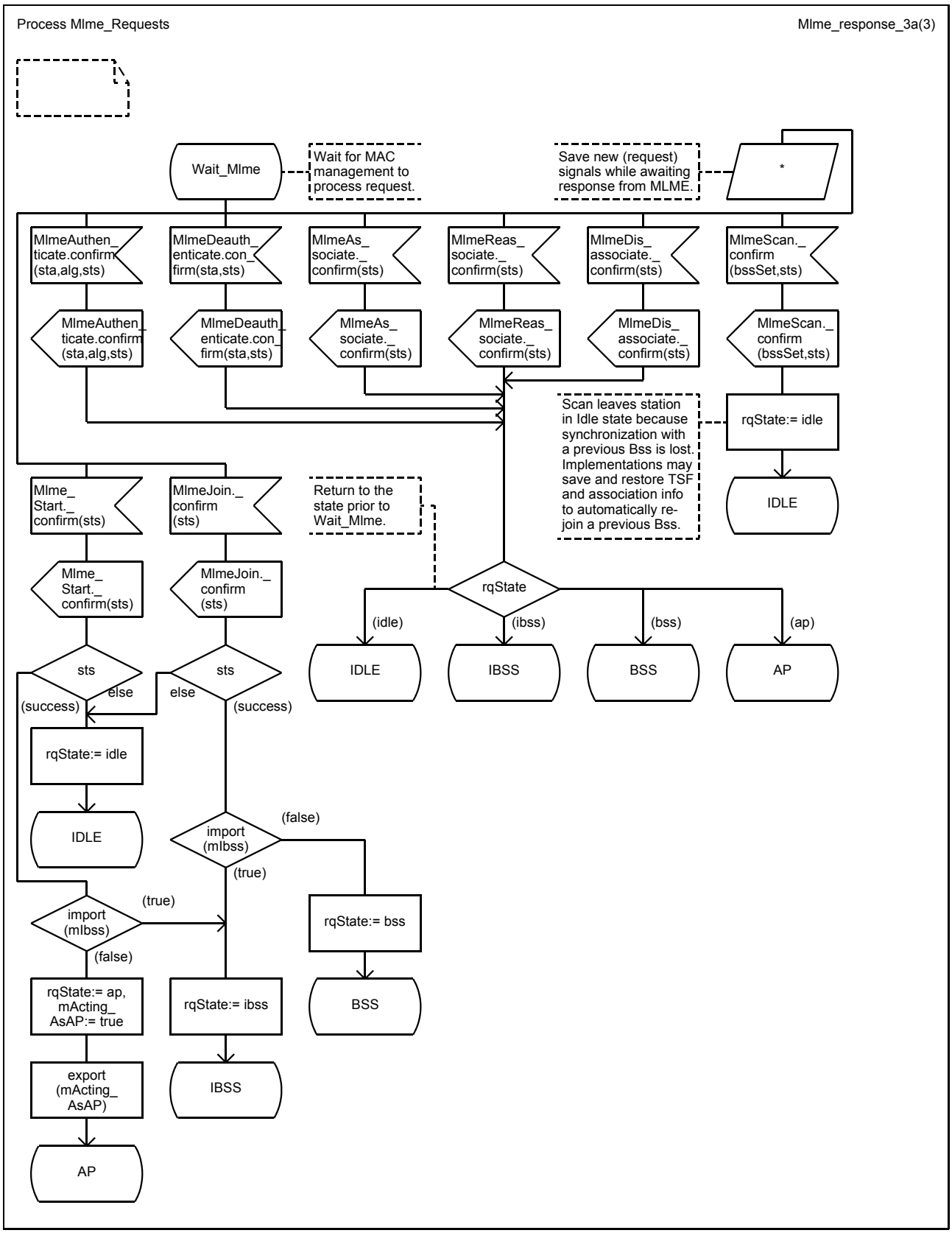

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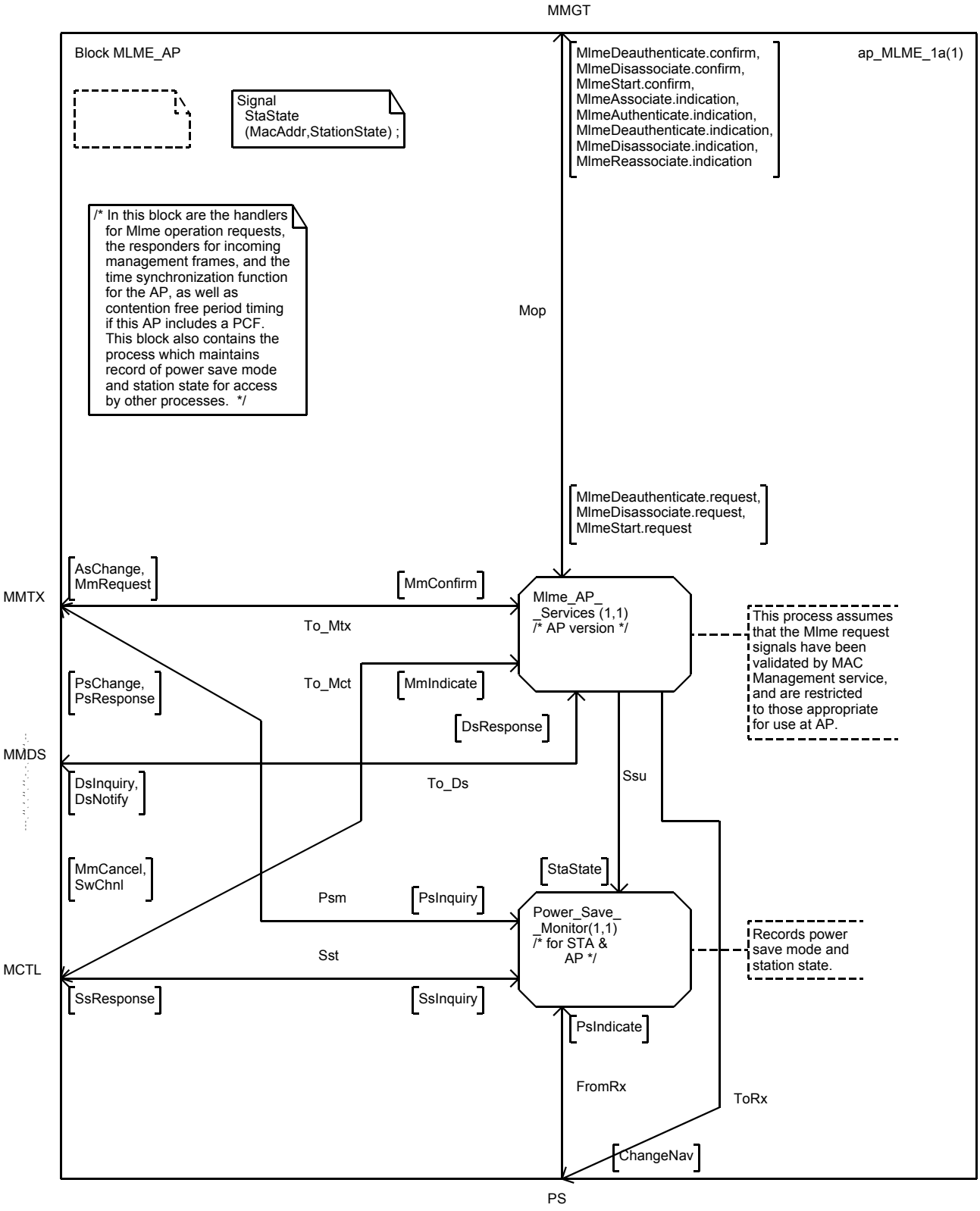

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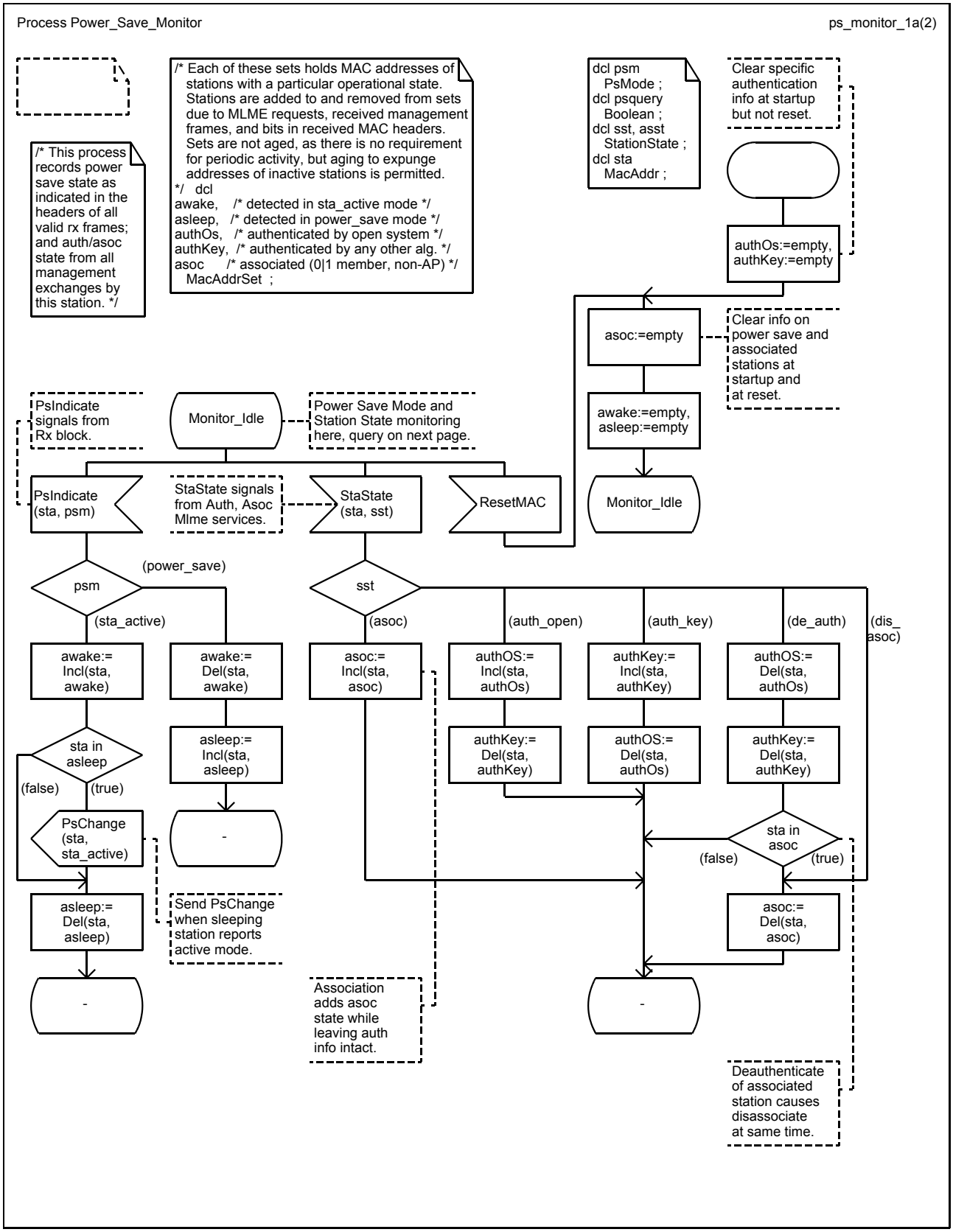

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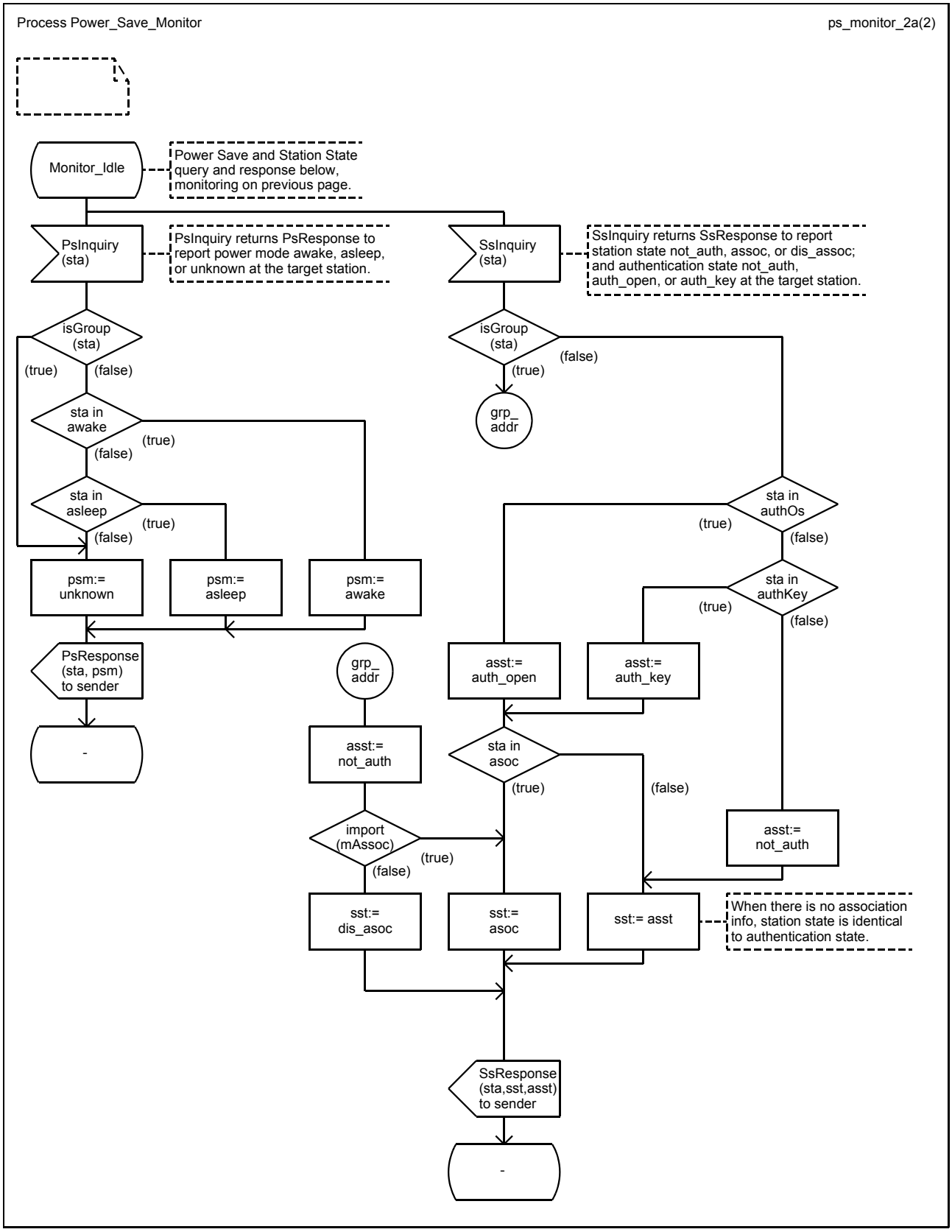

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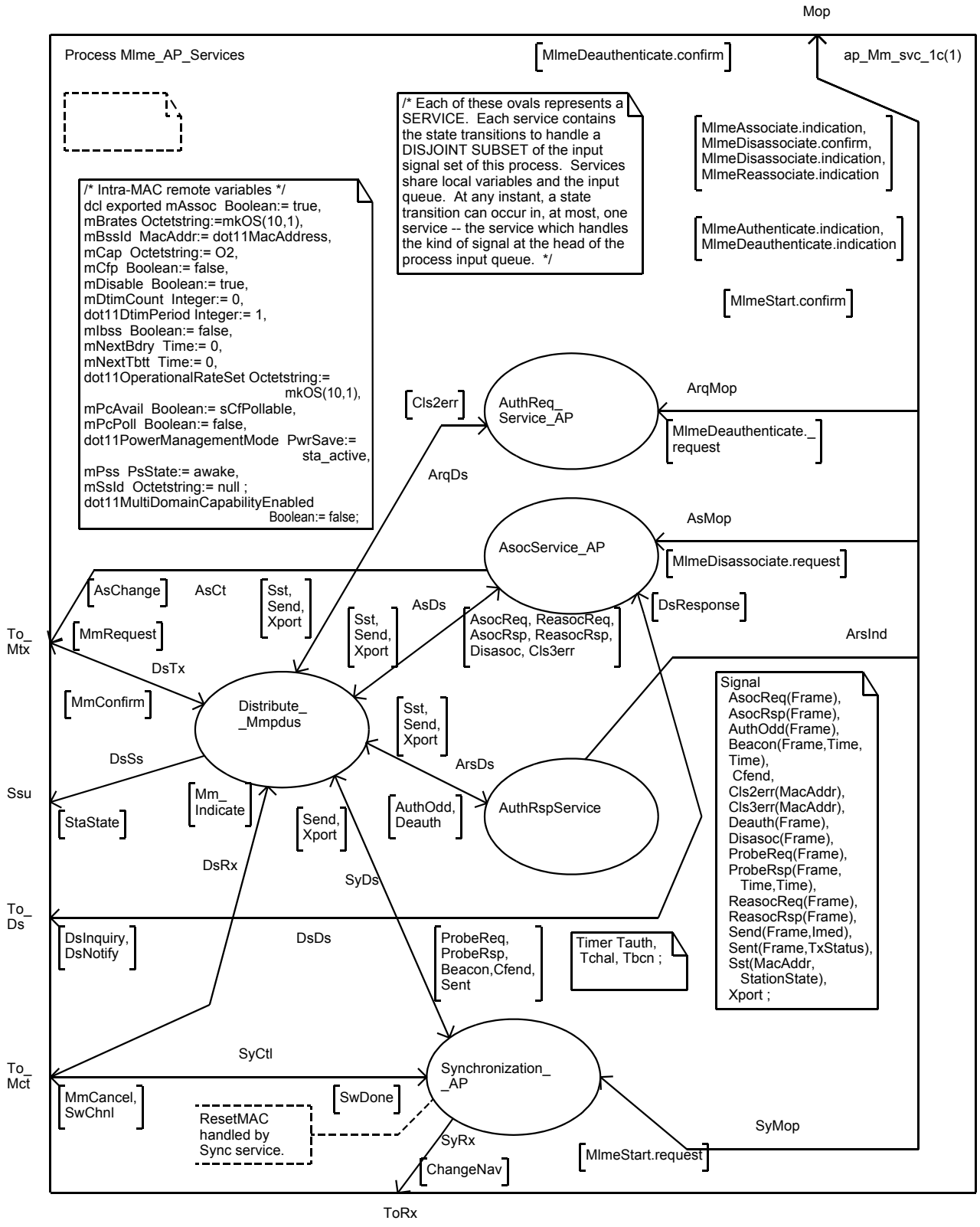

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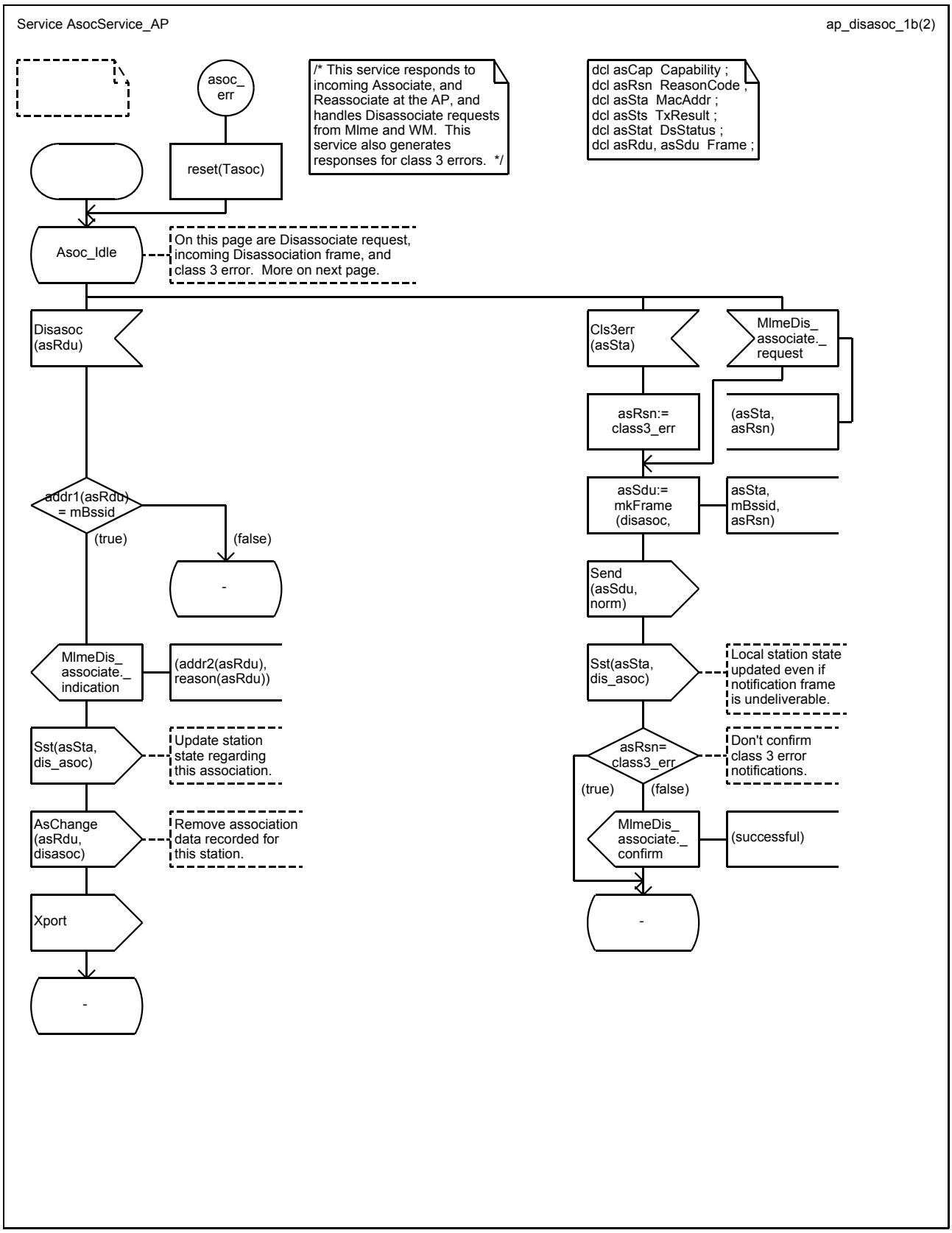

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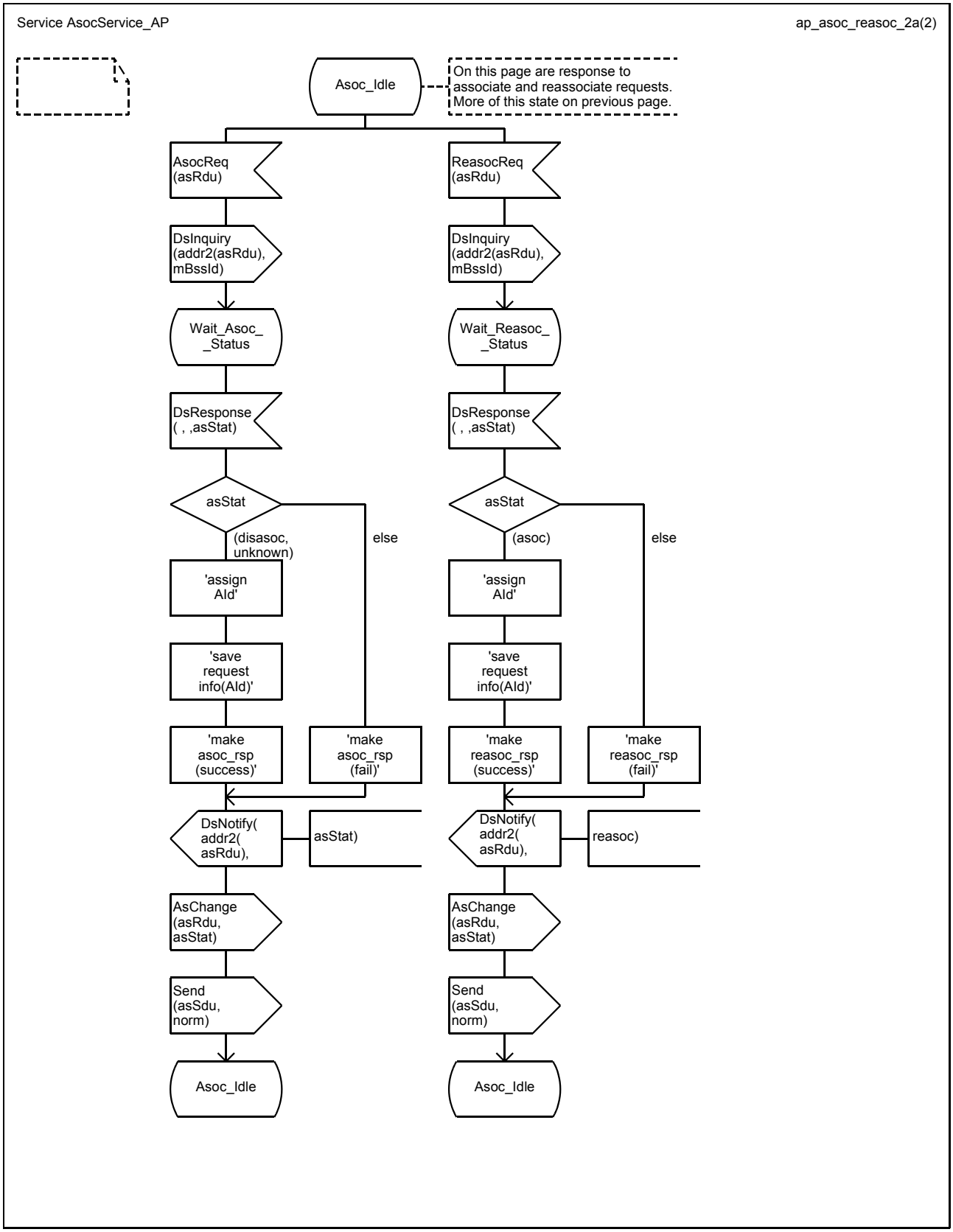

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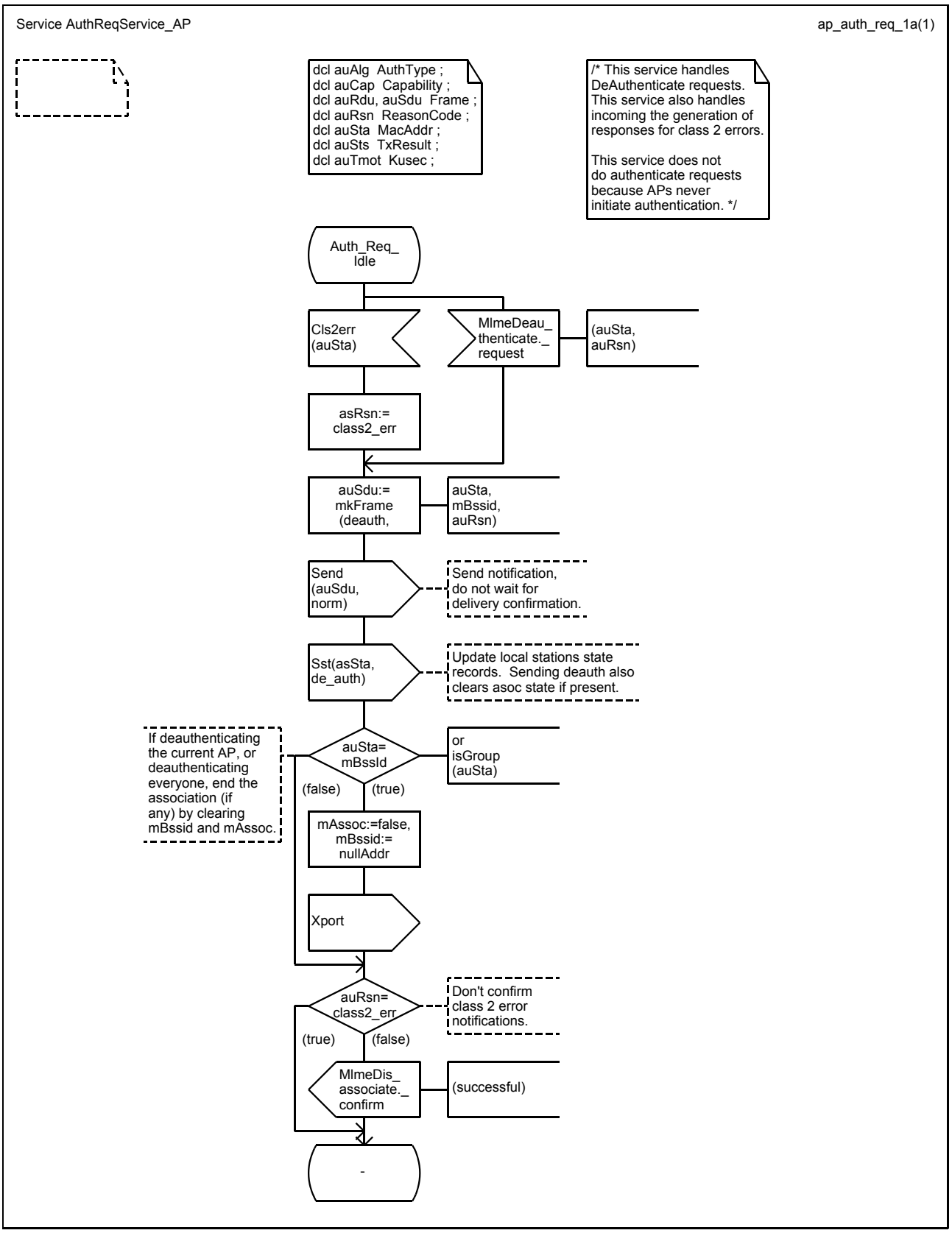

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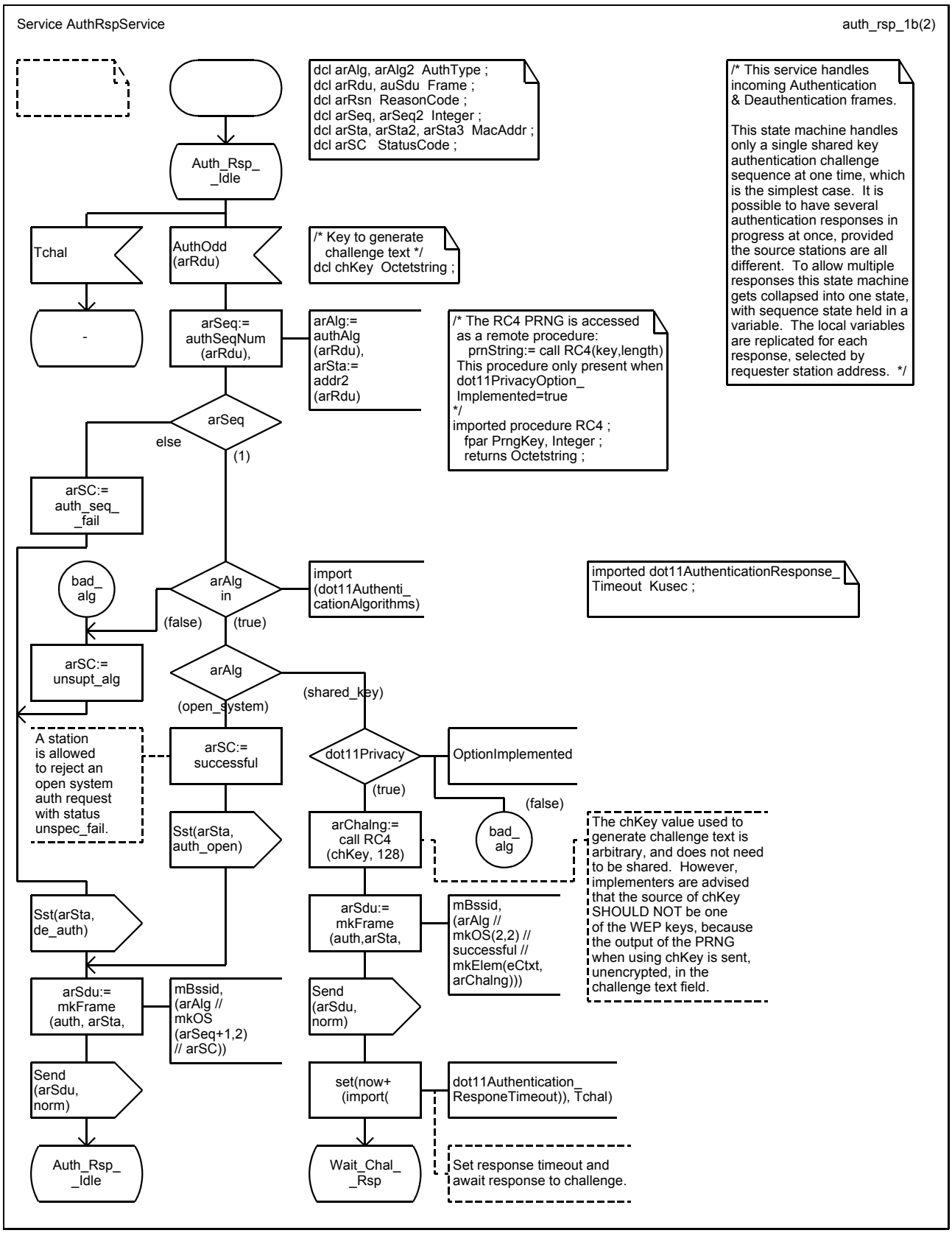

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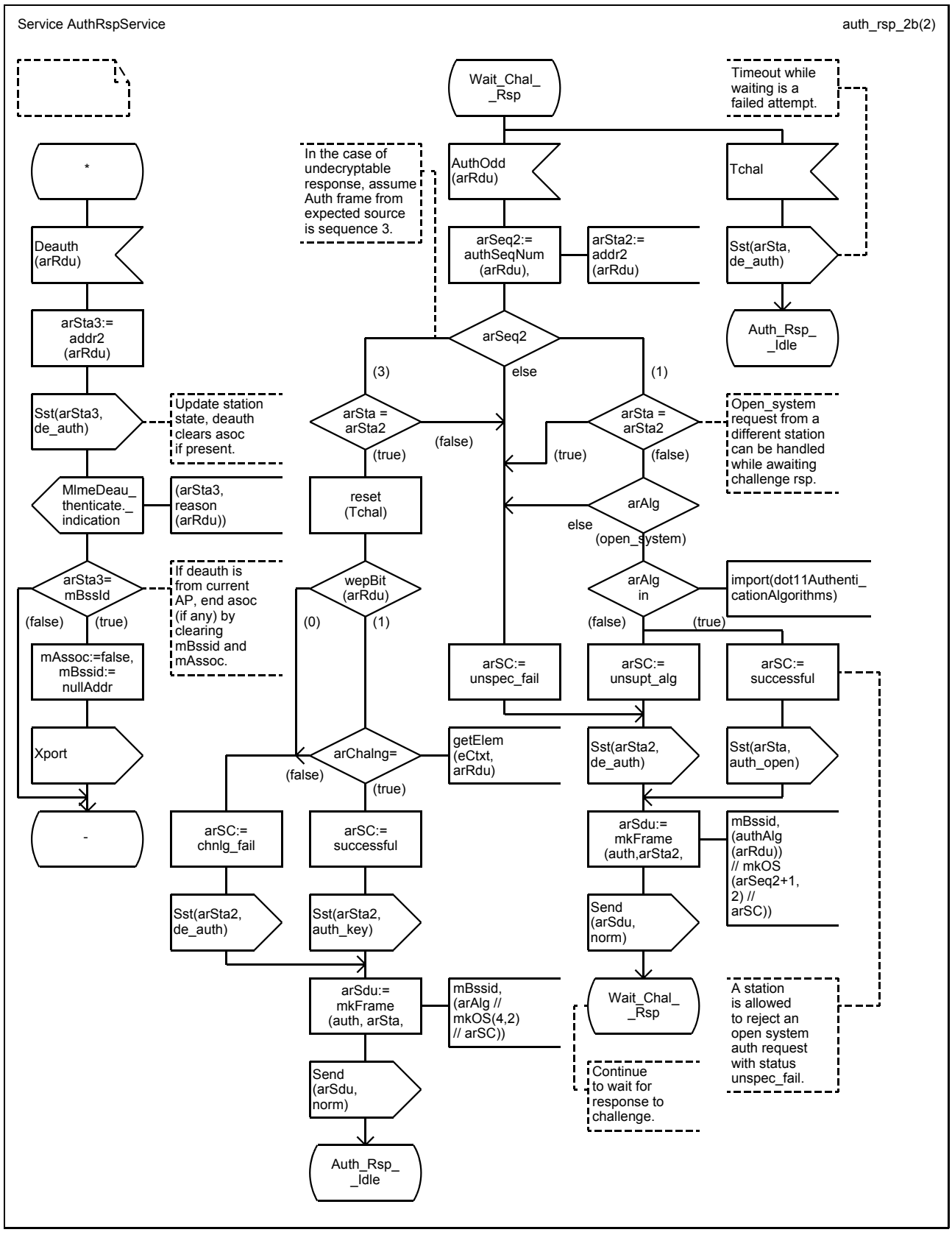

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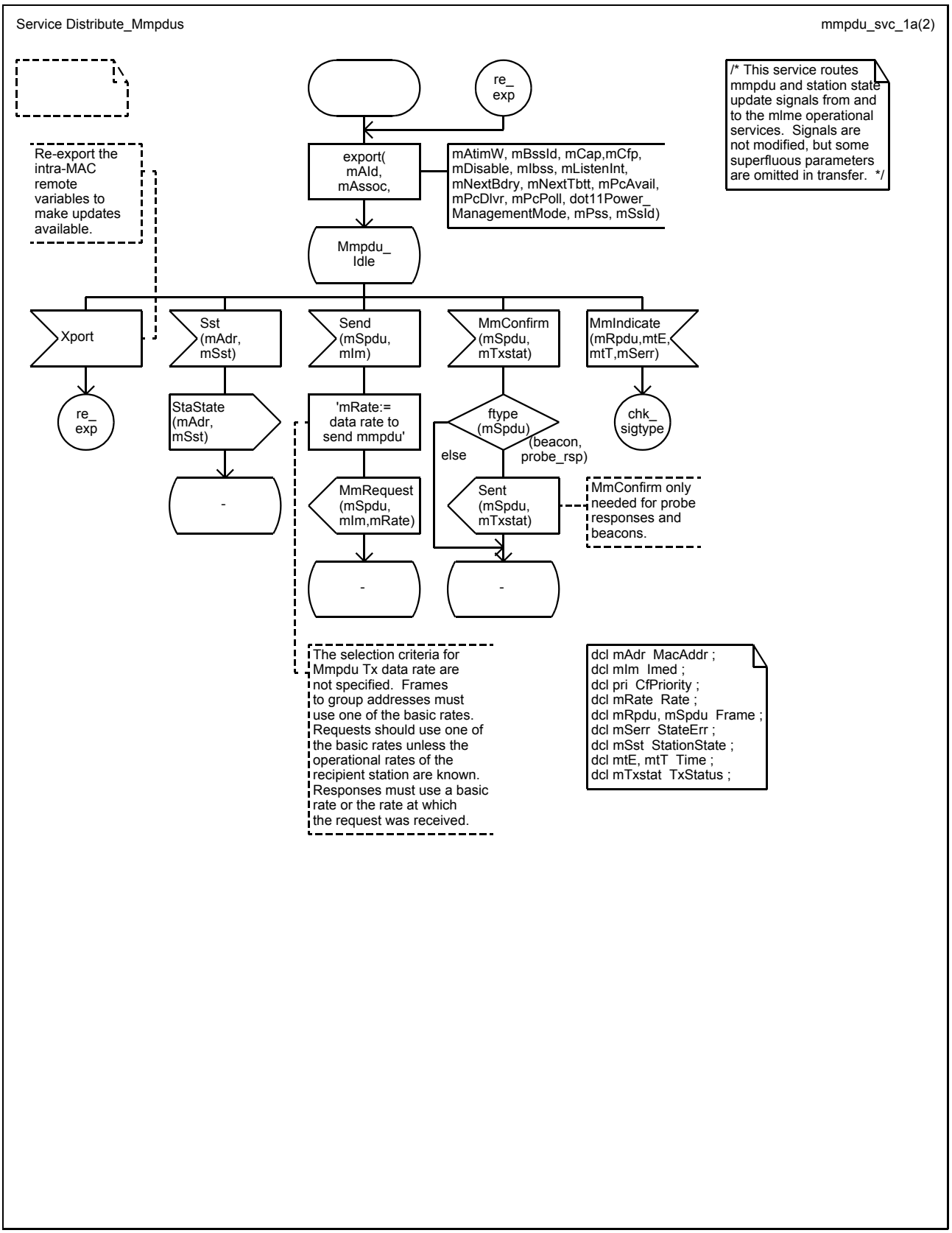

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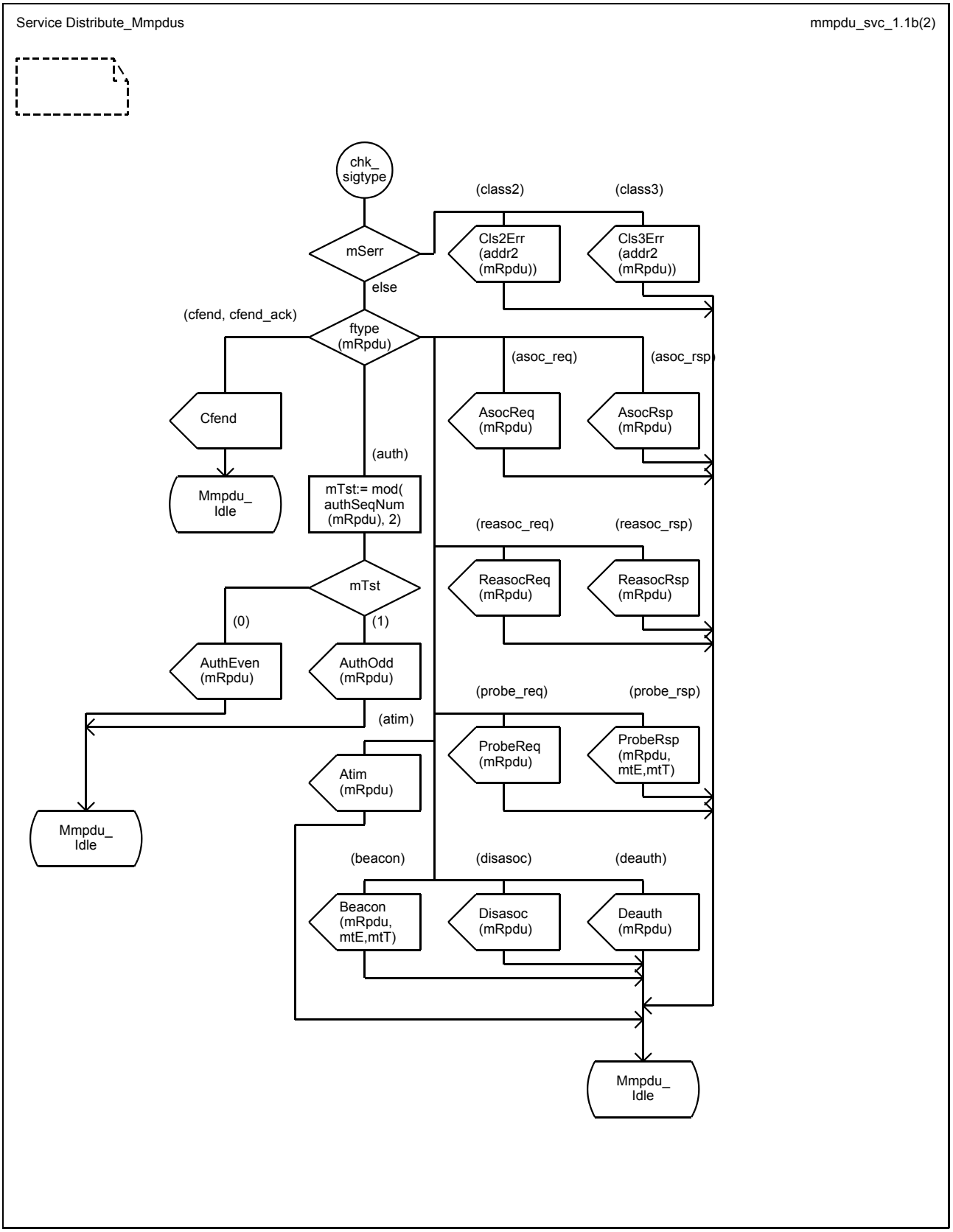

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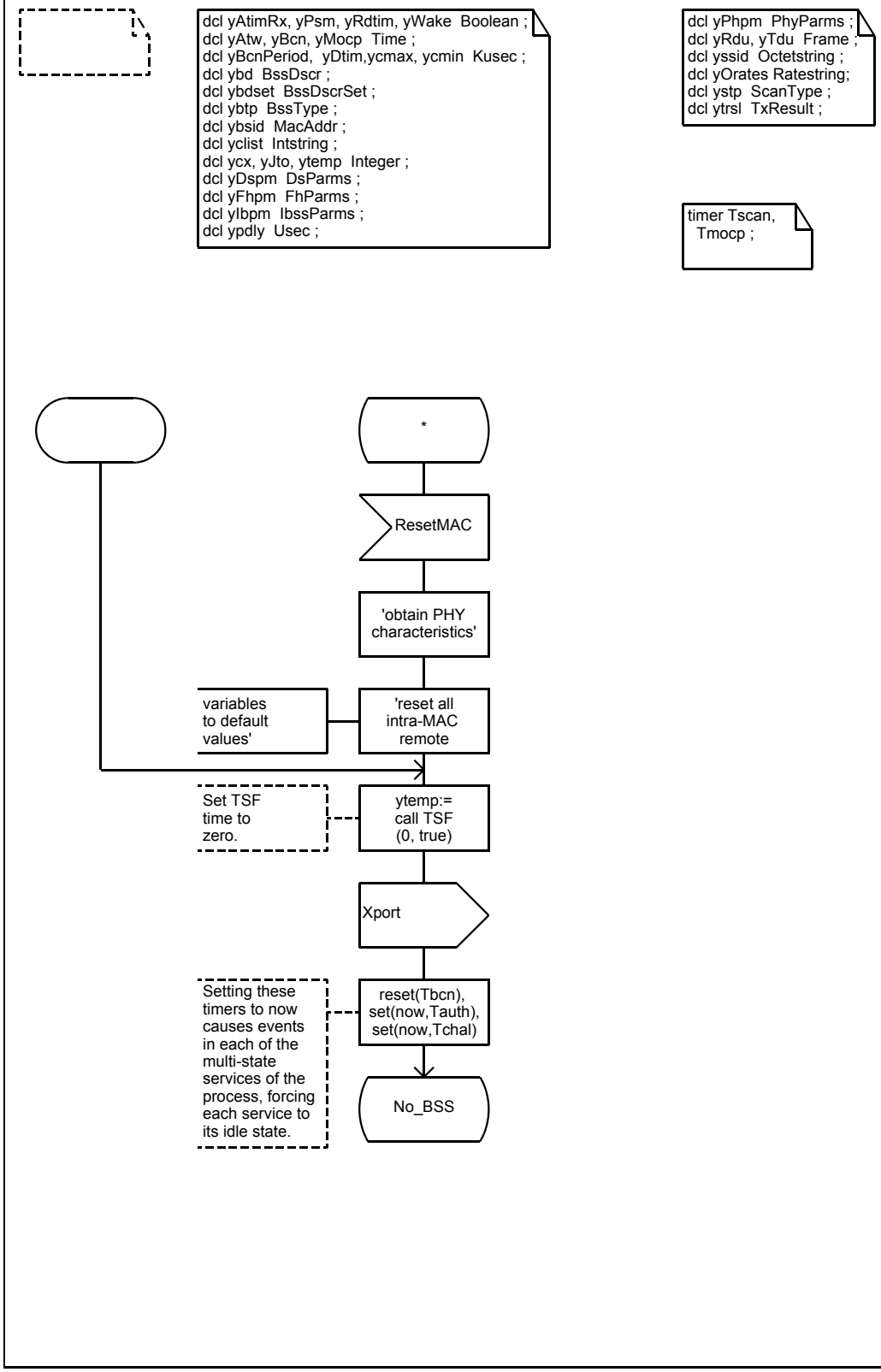

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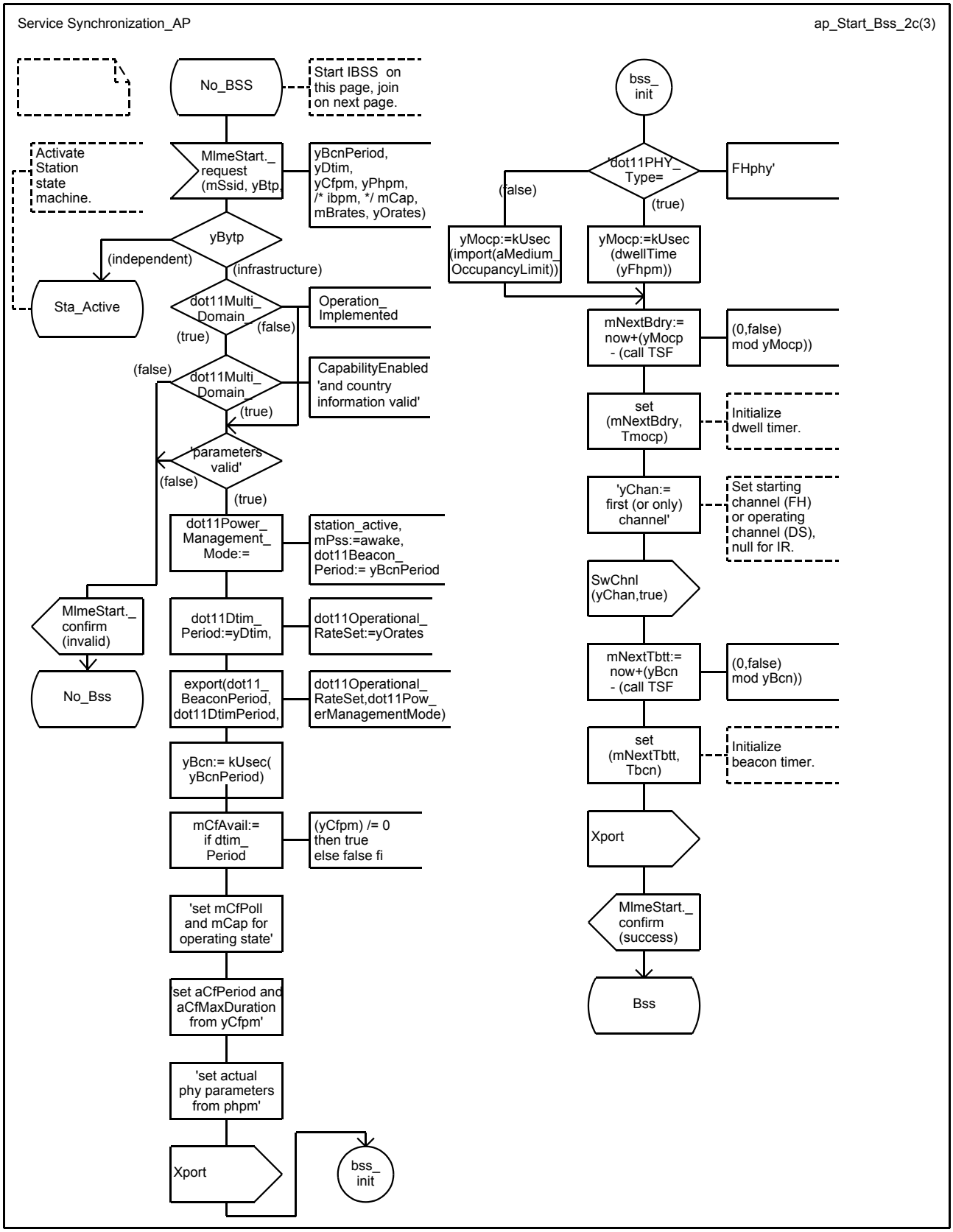

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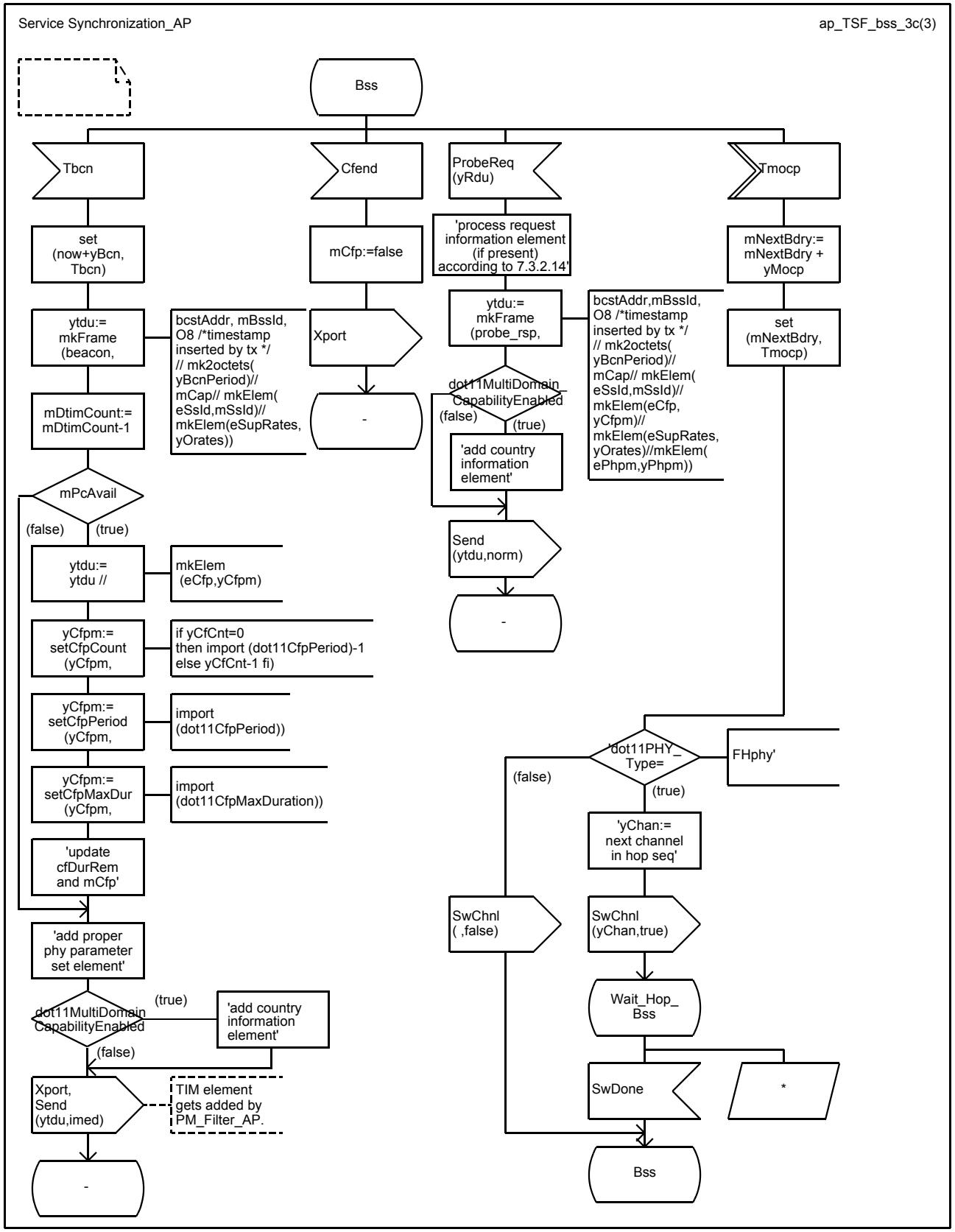

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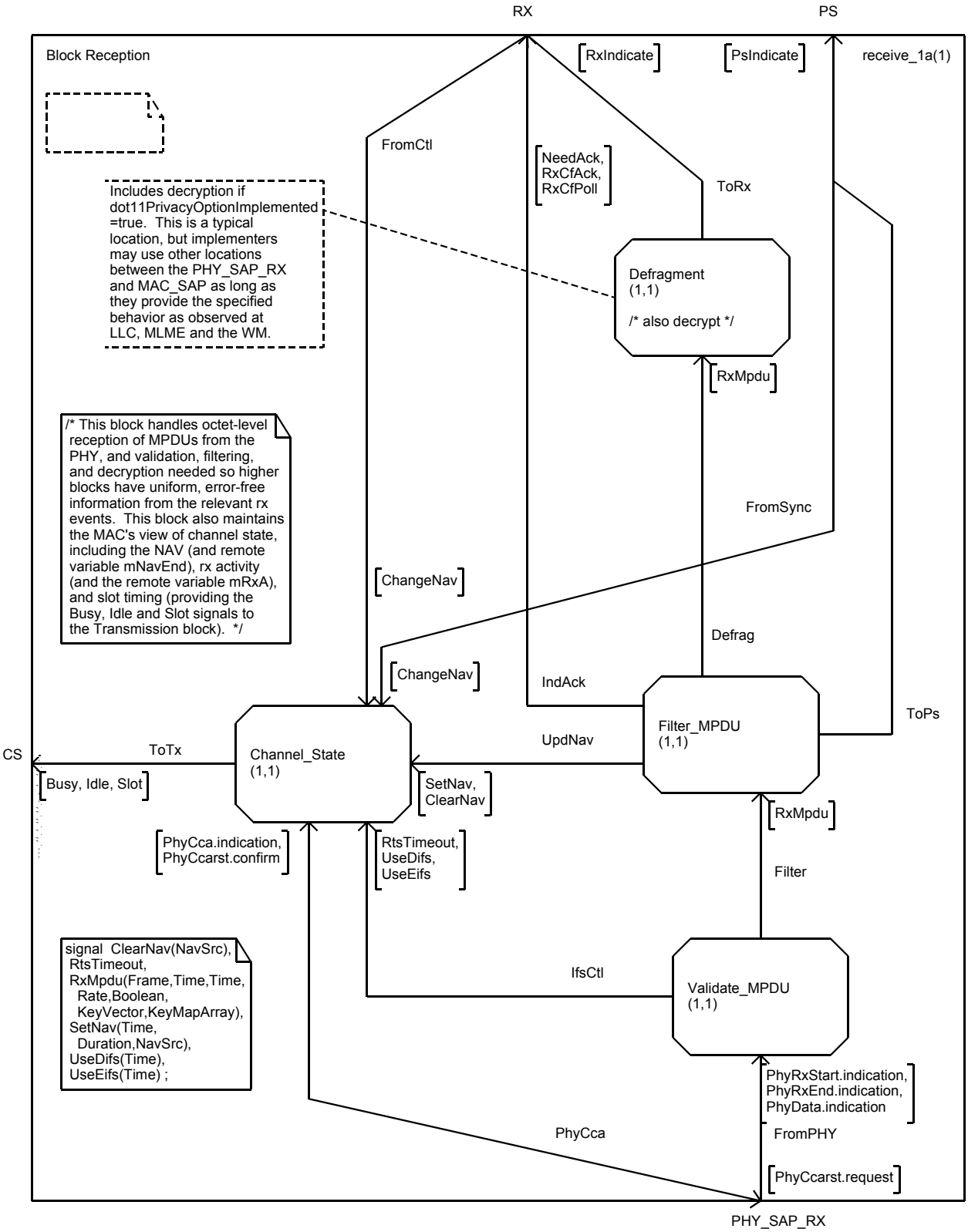

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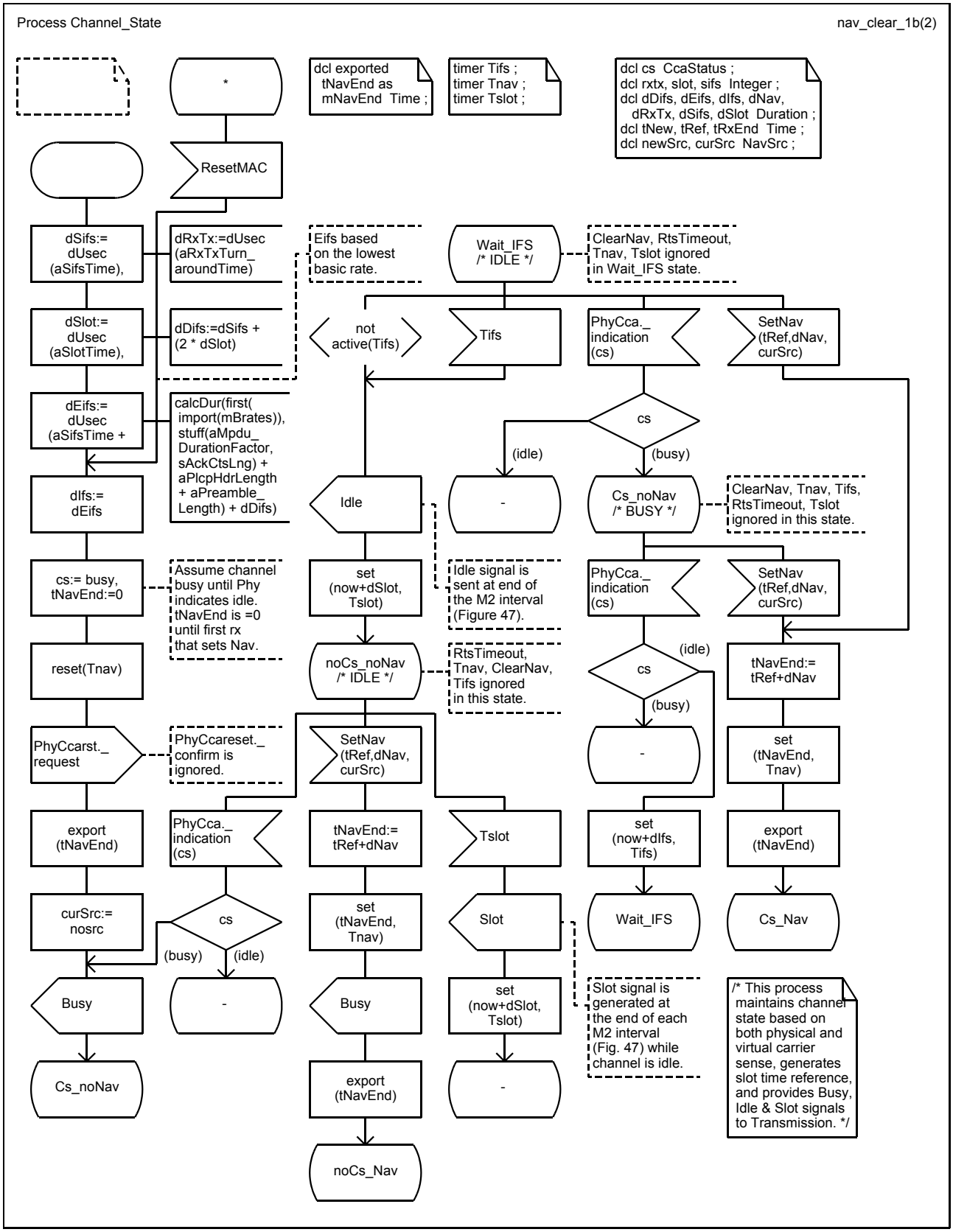

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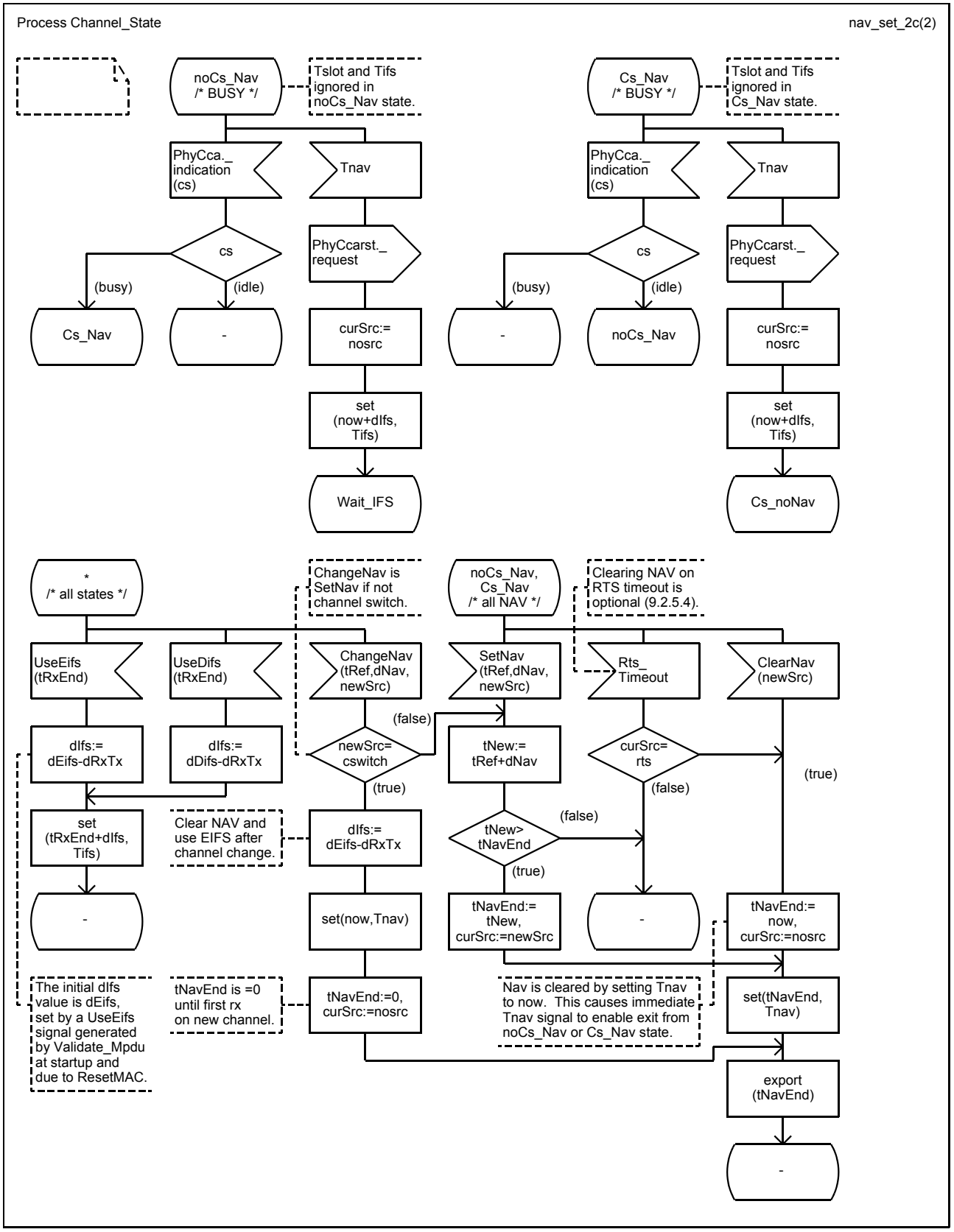

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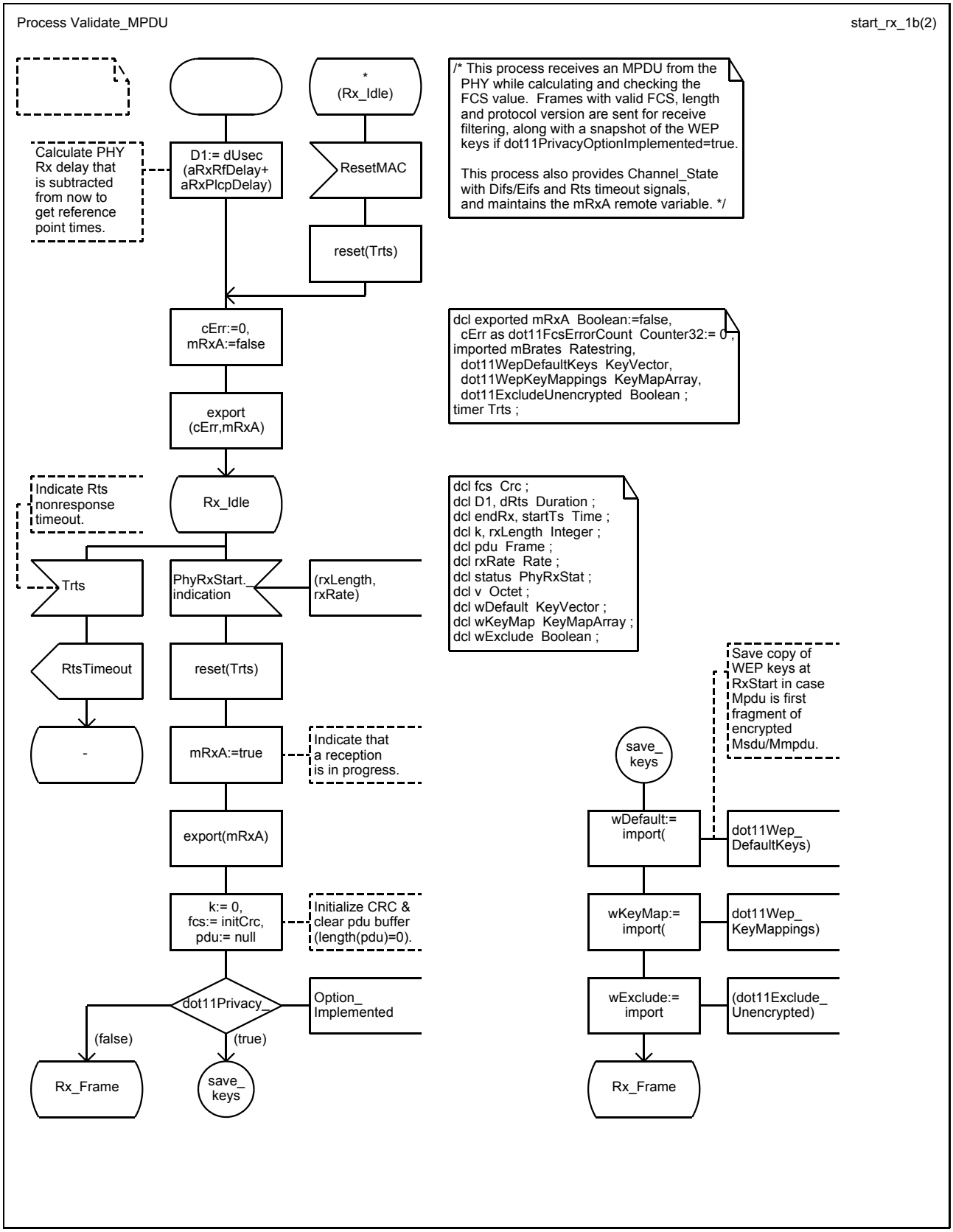

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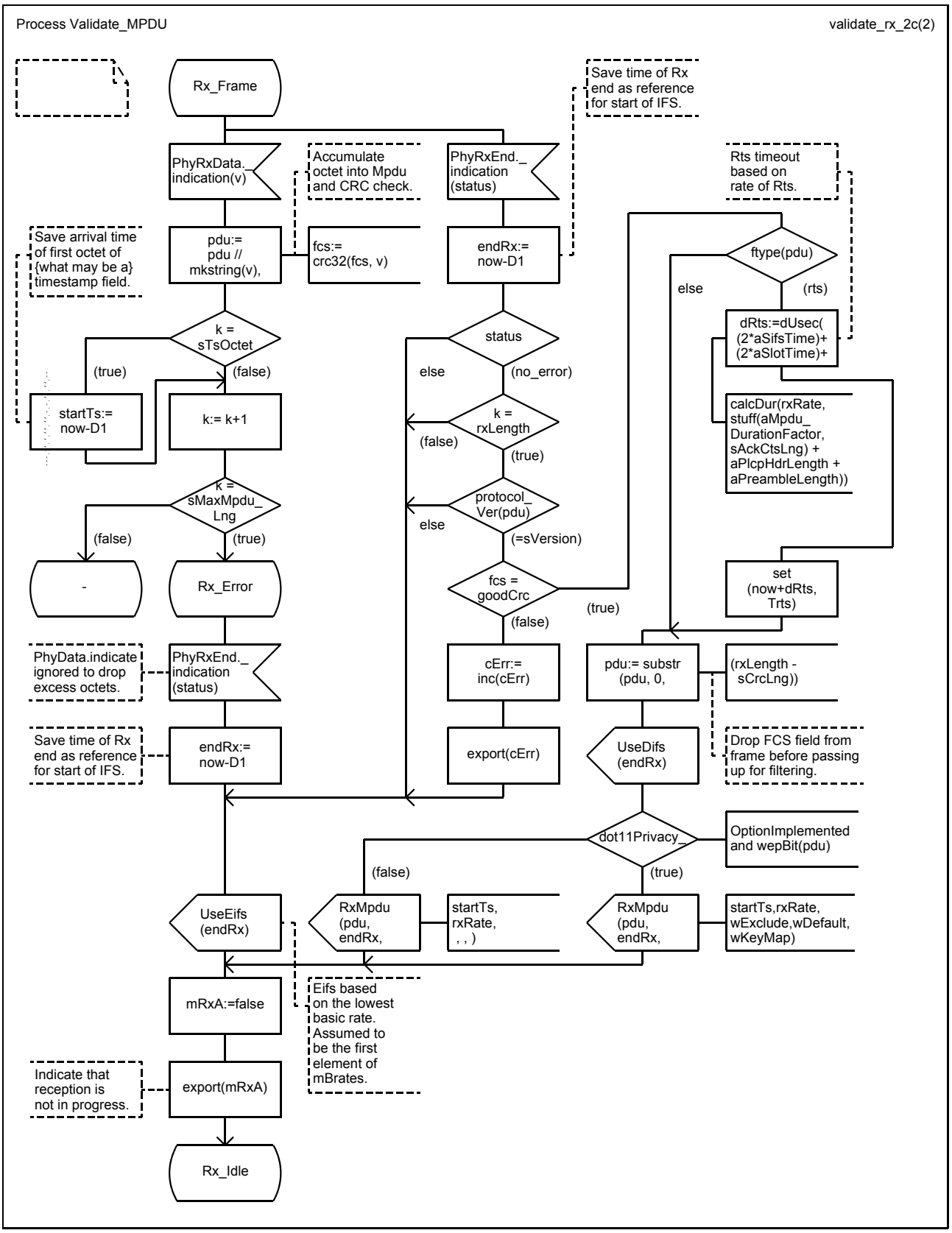

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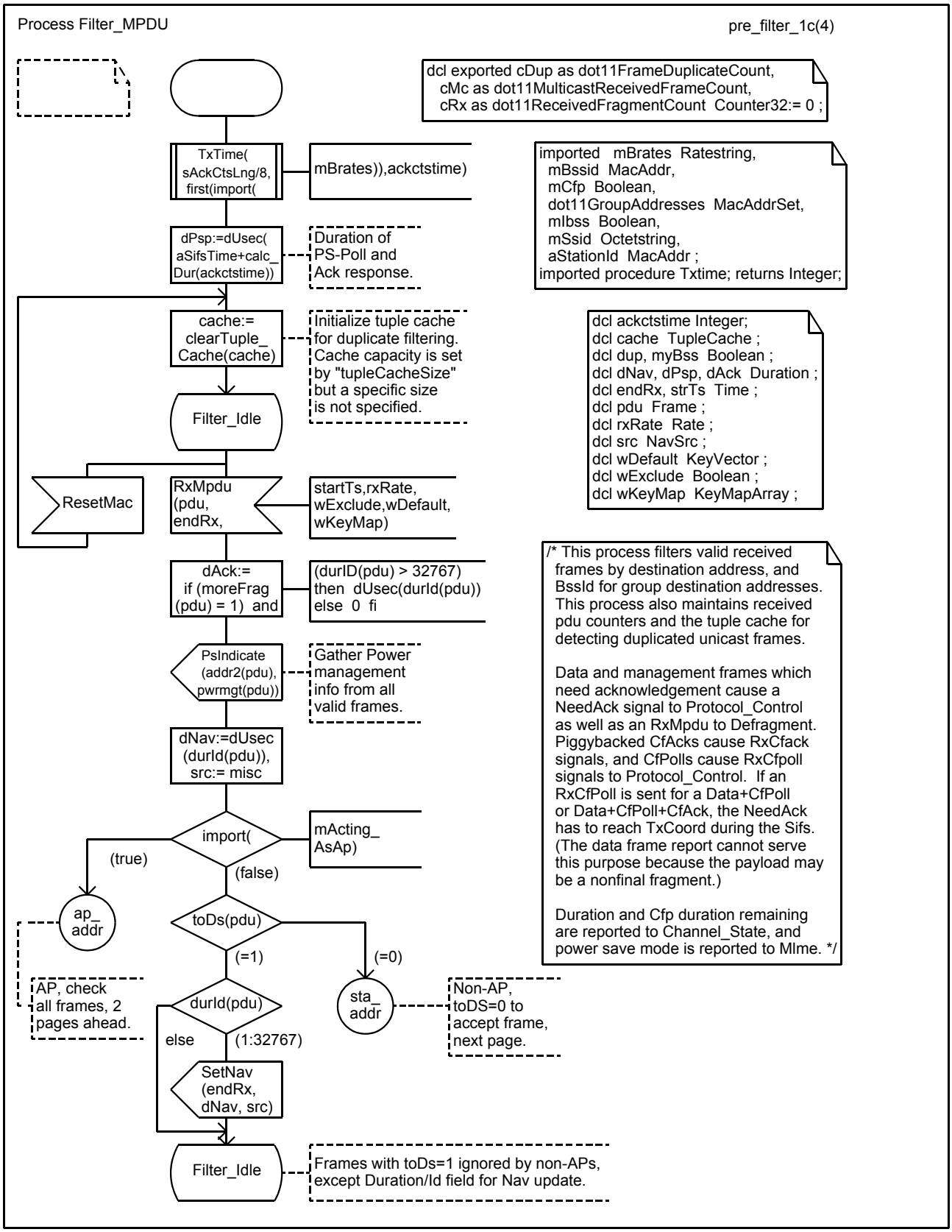

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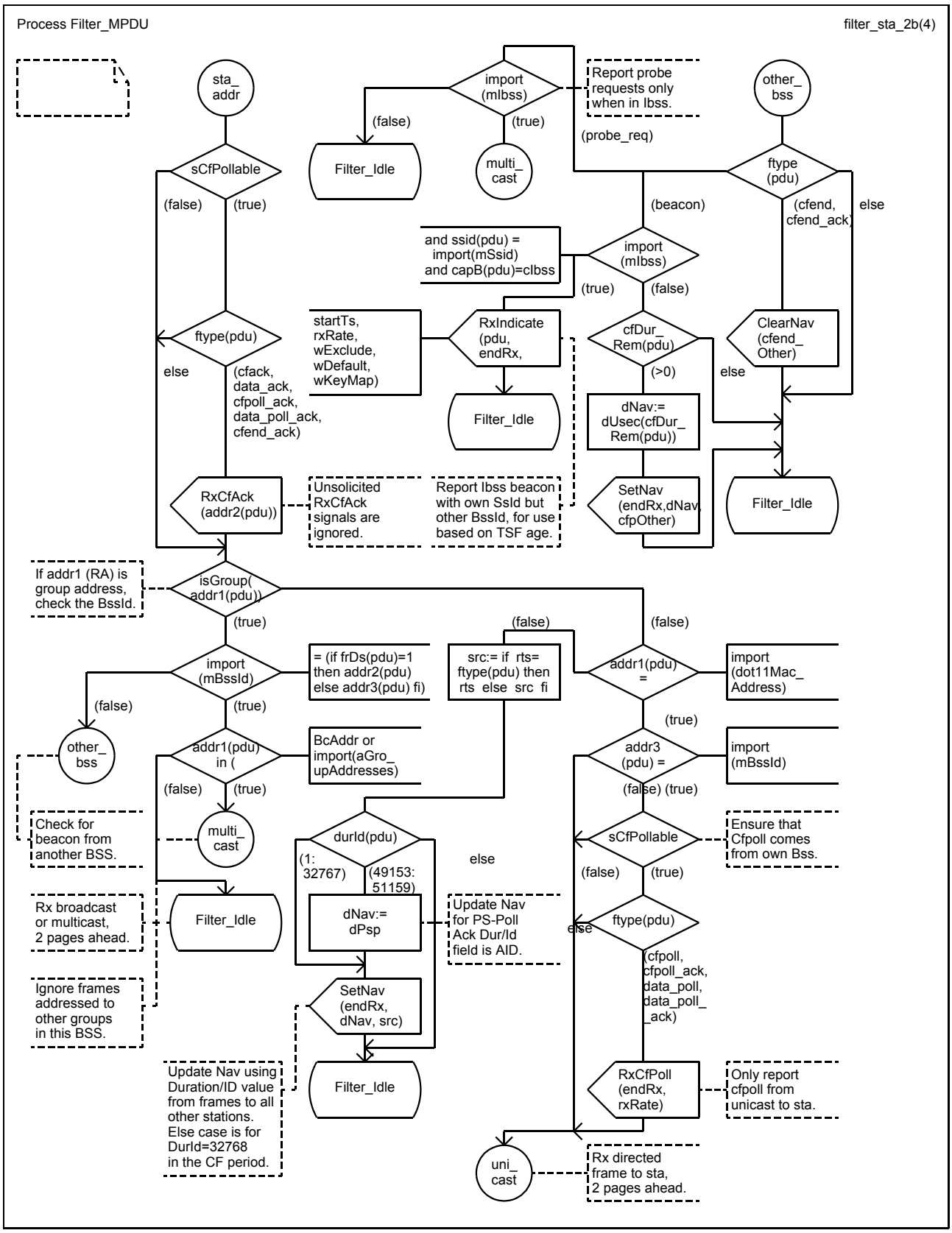

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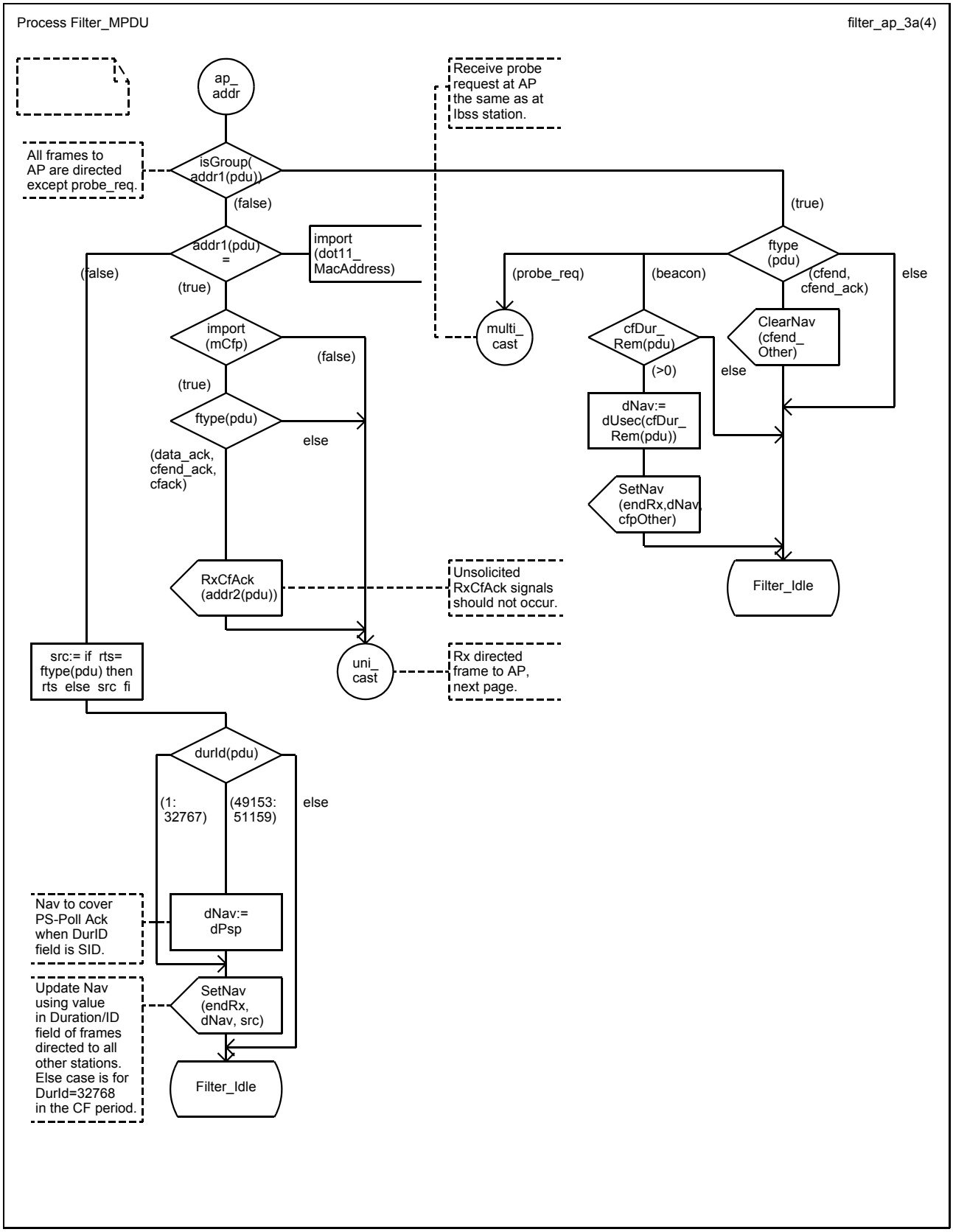

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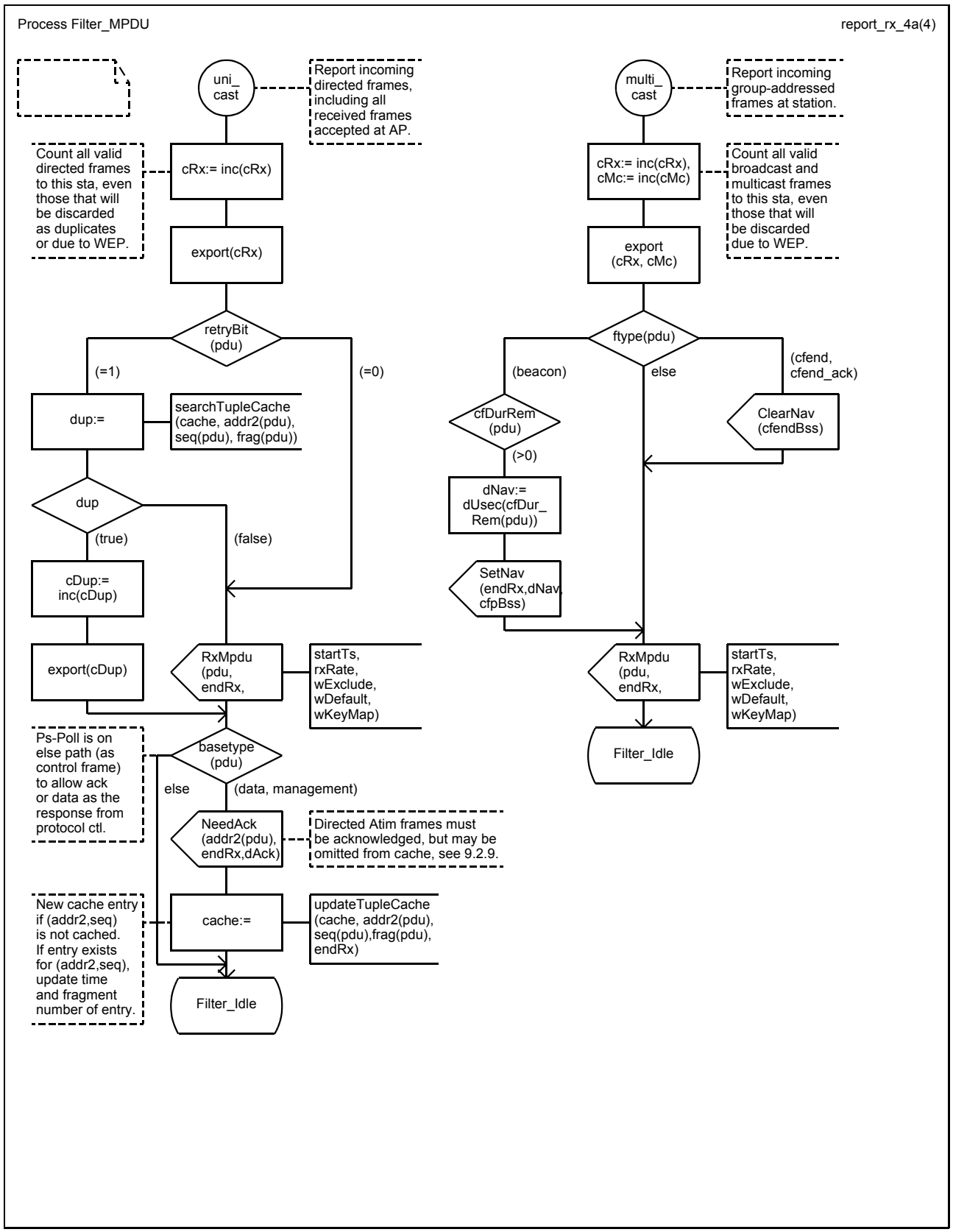

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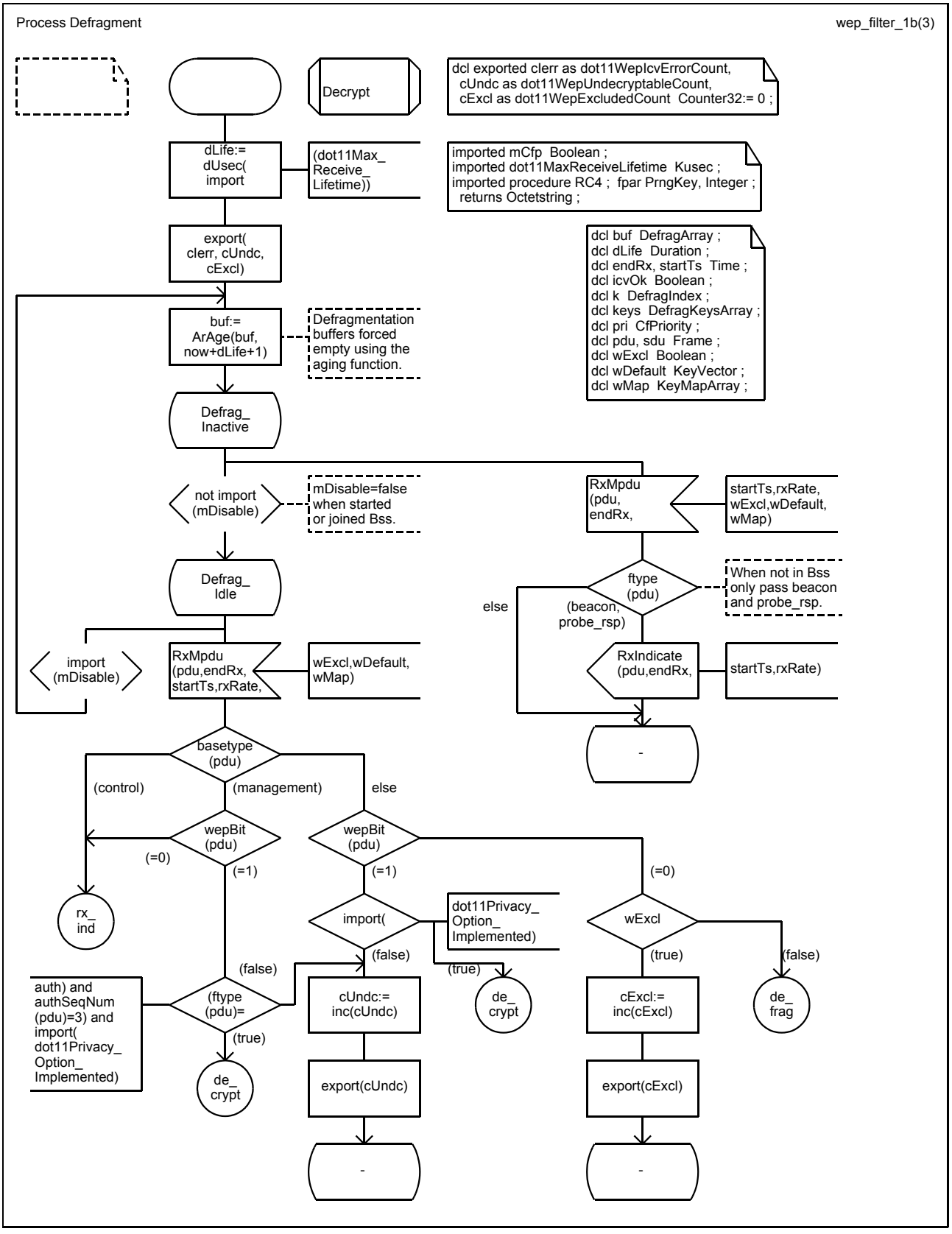

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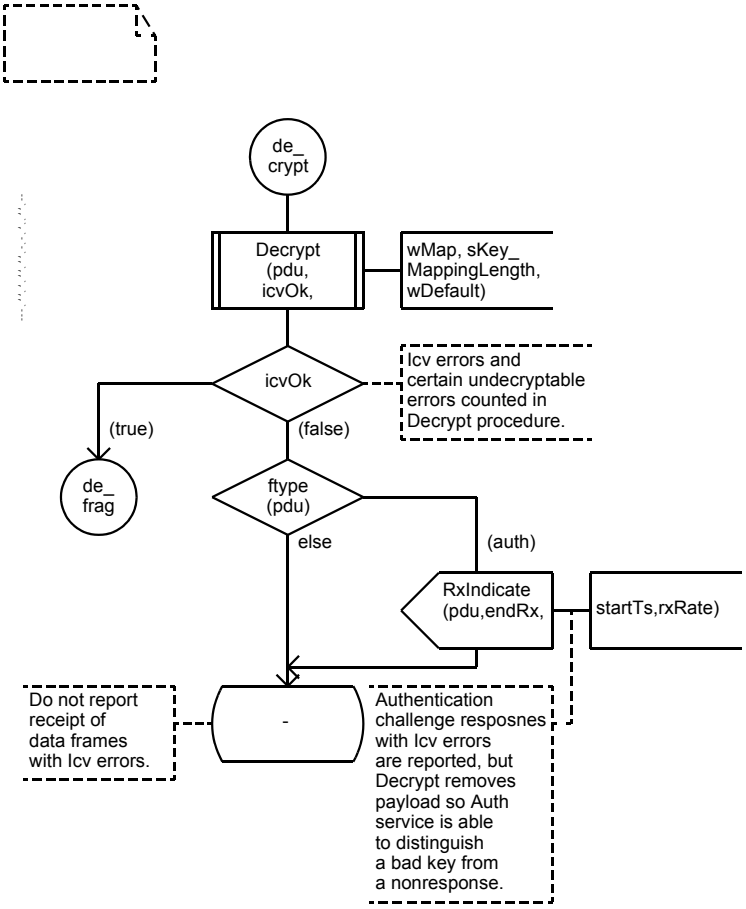
Process Defragment wep_decrypt_2b(3)



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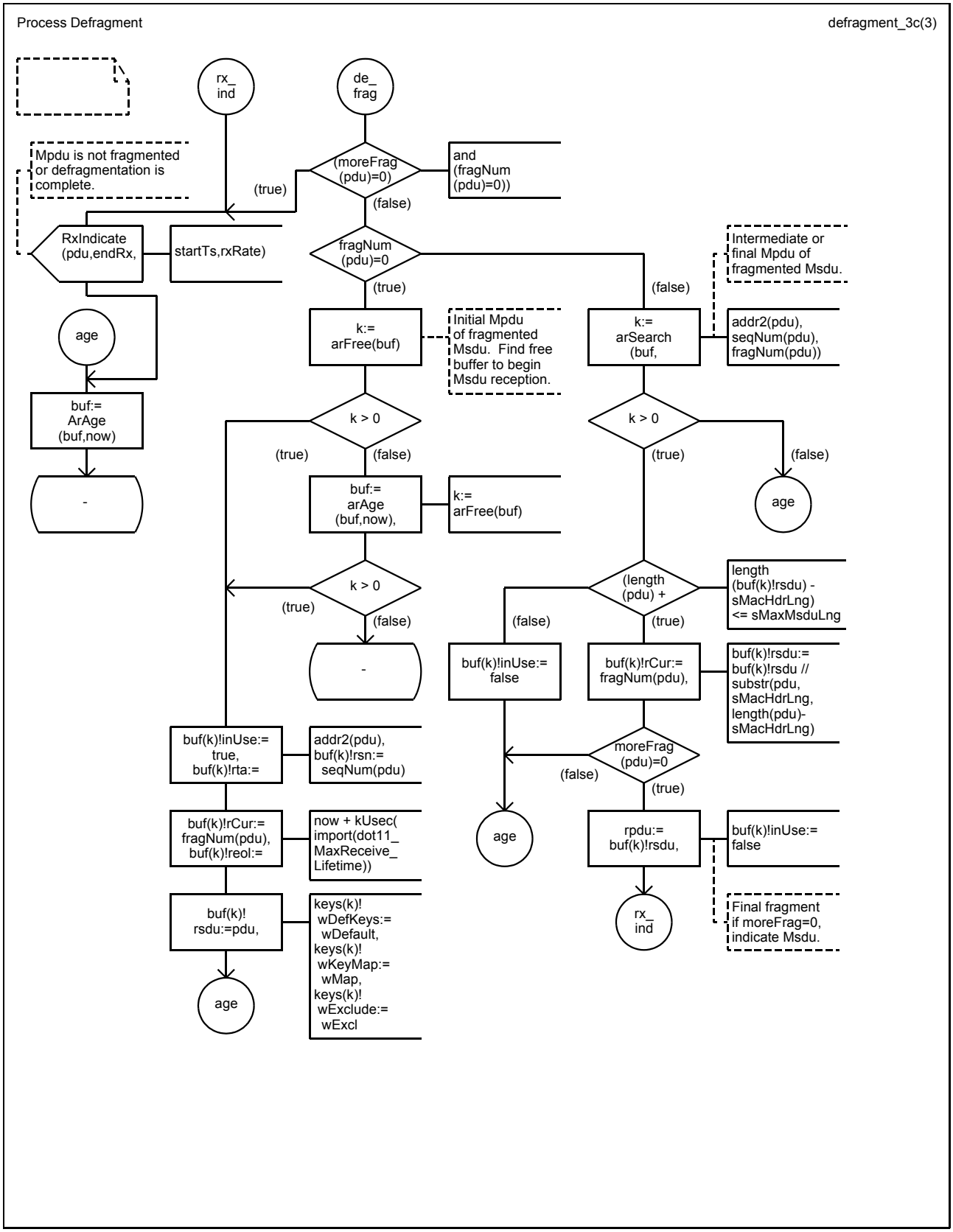

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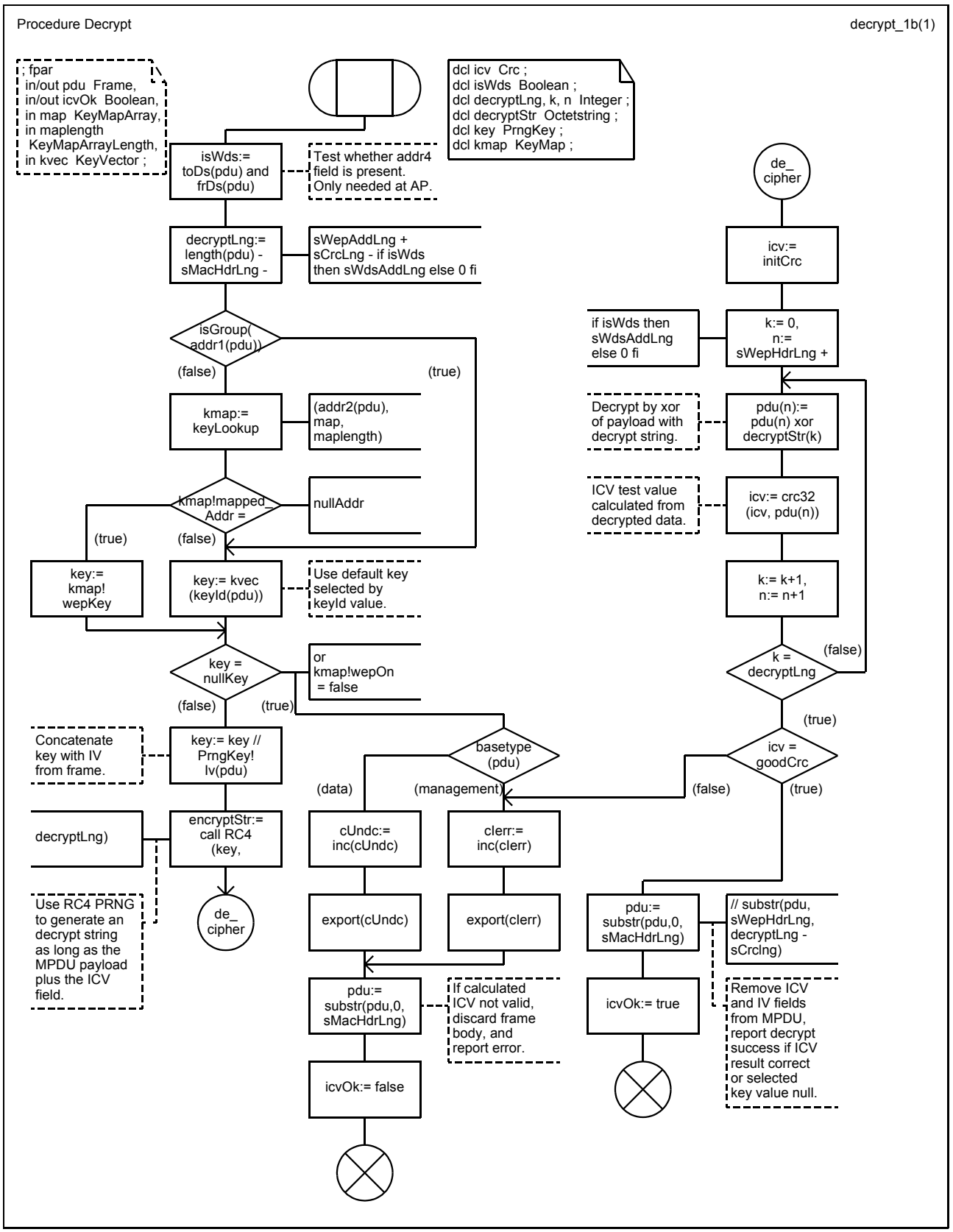

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Annex D

(normative)

ASN.1 encoding of the MAC and PHY MIB

```
-- ************************************************************************
-- * IEEE 802.11 MIB
-- ************************************************************************

IEEE802dot11-MIB DEFINITIONS ::= BEGIN

    IMPORTS
        MODULE-IDENTITY, OBJECT-TYPE,
        NOTIFICATION-TYPE,Integer32, Counter32,
        Unsigned32                              FROM SNMPv2-SMI

        DisplayString , MacAddress, RowStatus,
        TruthValue                              FROM SNMPv2-TC

        MODULE-COMPLIANCE, OBJECT-GROUP,
        NOTIFICATION-GROUP                      FROM SNMPv2-CONF

        ifIndex                                 FROM RFC1213-MIB;

-- ************************************************************************
-- *  Tree Definition
-- ************************************************************************

    member-body     OBJECT IDENTIFIER ::= { iso 2 }
    us              OBJECT IDENTIFIER ::= { member-body 840 }

-- ************************************************************************
-- *  MODULE IDENTITY
-- ************************************************************************

ieee802dot11 MODULE-IDENTITY
    LAST-UPDATED "0208300000Z"
    ORGANIZATION "IEEE 802.11"
    CONTACT-INFO
           "WG E-mail: stds-802-11@ieee.org

                Chair: Stuart J. Kerry
                Postal: Philips Semiconductors, Inc.
                        1109 McKay Drive
                        M/S 48 SJ
                        San Jose, CA 95130-1706  USA
                   Tel: +1 408 474 7356
                   Fax: +1 408 474 7247
                E-mail: stuart.kerry@philips.com

                Editor: Terry L. Cole
                Postal: AMD, M/S PCS4
                        5900 E. Ben White Blvd.
                        Austin, TX  78741 USA
                   Tel: +1 512 602 2454
                   Fax: +1 512 602 5051
```

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```
                E-mail: terry.cole@amd.com"
    DESCRIPTION
        "The MIB module for IEEE 802.11 entities.
        iso(1).member-body(2).us(840).ieee802dot11(10036)"
    ::= { us 10036 }

-- ****************************************************************
-- *  Major sections
-- ****************************************************************

--  Station ManagemenT (SMT) Attributes
    --  DEFINED AS "The SMT object class provides the necessary support
    --  at the station to manage the processes in the station such that
    --  the station may work cooperatively as a part of an IEEE 802.11
    --  network."

    dot11smt OBJECT IDENTIFIER ::= { ieee802dot11 1 }

        --  dot11smt GROUPS
        --  dot11StationConfigTable            ::= { dot11smt 1 }
        --  dot11AuthenticationAlgorithmsTable ::= { dot11smt 2 }
        --  dot11WEPDefaultKeysTable           ::= { dot11smt 3 }
        --  dot11WEPKeyMappingsTable           ::= { dot11smt 4 }
        --  dot11PrivacyTable                  ::= { dot11smt 5 }
        --  dot11SMTnotification               ::= { dot11smt 6 }
        --  dot11MultiDomainCapabilityTable    ::= { dot11smt 7 }

--  MAC Attributes
    --  DEFINED AS "The MAC object class provides the necessary support
    --  for the access control, generation, and verification of frame
    --  check sequences (FCSs), and proper delivery of valid data to
    --  upper layers."

    dot11mac OBJECT IDENTIFIER ::= { ieee802dot11 2 }

      --  MAC GROUPS
      --  reference IEEE Std 802.1f-1993
         --  dot11OperationTable          ::= { dot11mac 1 }
         --  dot11CountersTable           ::= { dot11mac 2 }
         --  dot11GroupAddressesTable     ::= { dot11mac 3 }

--  Resource Type ID
    dot11res          OBJECT IDENTIFIER ::= { ieee802dot11 3 }
    dot11resAttribute OBJECT IDENTIFIER ::= { dot11res 1 }

--  PHY Attributes
    --  DEFINED AS "The PHY object class provides the necessary support
    --  for required PHY operational information that may vary from PHY
    --  to PHY and from STA to STA to be communicated to upper layers."

    dot11phy OBJECT IDENTIFIER ::= { ieee802dot11 4 }

    --  PHY GROUPS
       --  dot11PhyOperationTable        ::= { dot11phy 1 }
       --  dot11PhyAntennaTable          ::= { dot11phy 2 }
       --  dot11PhyTxPowerTable          ::= { dot11phy 3 }
       --  dot11PhyFHSSTable             ::= { dot11phy 4 }
       --  dot11PhyDSSSTable             ::= { dot11phy 5 }
       --  dot11PhyIRTable               ::= { dot11phy 6 }
```


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```
       --  dot11RegDomainsSupportedTable       ::= { dot11phy 7 }
       --  dot11AntennasListTable              ::= { dot11phy 8 }
       --  dot11SupportedDataRatesTxTable      ::= { dot11phy 9 }
       --  dot11SupportedDataRatesRxTable      ::= { dot11phy 10 }
       --  dot11PhyOFDMTable                   ::= { dot11phy 11 }
       --  dot11PhyHRDSSSTable                 ::= { dot11phy 12 }
       --  dot11EHCCHoppingPatternTable        ::= { dot11phy 13 }

-- ****************************************************************
-- *  Textual conventions from 802 definitions
-- ****************************************************************

    WEPKeytype ::= OCTET STRING (SIZE (5))

-- ****************************************************************
-- *  MIB attribute OBJECT-TYPE definitions follow
-- ****************************************************************

-- ****************************************************************
-- *  SMT Station Config  Table
-- ****************************************************************

dot11StationConfigTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11StationConfigEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "Station Configuration attributes.  In tablular form to
            allow for multiple instances on an agent."
    ::= { dot11smt 1 }

dot11StationConfigEntry OBJECT-TYPE
        SYNTAX Dot11StationConfigEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An entry in the dot11StationConfigTable.  It is
            possible for there to be multiple IEEE 802.11 interfaces
            on one agent, each with its unique MAC address. The
            relationship between an IEEE 802.11 interface and an
            interface in the context of the Internet-standard MIB is
            one-to-one.  As such, the value of an ifIndex object
            instance can be directly used to identify corresponding
            instances of the objects defined herein.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
        INDEX { ifIndex }
    ::= { dot11StationConfigTable 1 }

Dot11StationConfigEntry ::=
         SEQUENCE {
             dot11StationID                          MacAddress,
             dot11MediumOccupancyLimit               INTEGER,
             dot11CFPollable                         TruthValue,
             dot11CFPPeriod                          INTEGER,
             dot11CFPMaxDuration                     INTEGER,
             dot11AuthenticationResponseTimeOut      Unsigned32,
```

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```
            dot11PrivacyOptionImplemented           TruthValue,
            dot11PowerManagementMode                INTEGER,
            dot11DesiredSSID                        OCTET STRING,
            dot11DesiredBSSType                     INTEGER,
            dot11OperationalRateSet                 OCTET STRING,
            dot11BeaconPeriod                       INTEGER,
            dot11DTIMPeriod                         INTEGER,
            dot11AssociationResponseTimeOut         Unsigned32,
            dot11DisassociateReason                 INTEGER,
            dot11DisassociateStation                MacAddress,
            dot11DeauthenticateReason               INTEGER,
            dot11DeauthenticateStation              MacAddress,
            dot11AuthenticateFailStatus             INTEGER,
            dot11AuthenticateFailStation            MacAddress,
            dot11MultiDomainCapabilityImplemented   TruthValue,
            dot11MultiDomainCapabilityEnabled       TruthValue,
            dot11CountryString                      OCTET STRING }

dot11StationID OBJECT-TYPE
        SYNTAX MacAddress
        MAX-ACCESS read-write
        STATUS deprecated
        DESCRIPTION
            "The purpose of dot11StationID is to allow a manager to
            identify a station for its own purposes.  This attribute
            provides for that eventuality while keeping the true MAC
            address independent.  Its syntax is MAC address, and the
            default value is the station's assigned, unique
            MAC address."
    ::= { dot11StationConfigEntry 1 }

dot11MediumOccupancyLimit OBJECT-TYPE
        SYNTAX INTEGER (0..1000)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "This attribute shall indicate the maximum amount of time,
            in TU, that a point coordinator (PC) may control the usage
            of the wireless medium (WM) without relinquishing control
            for long enough to allow at least one instance of DCF access
            to the medium.  The default value of this attribute shall
            be 100, and the maximum value shall be 1000."
    ::= { dot11StationConfigEntry 2 }

dot11CFPollable OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
               "When this attribute is true, it shall indicate that
               the STA is able to respond to a CF-Poll with a data frame
               within a SIFS time. This attribute shall be false if
               the STA is not able to respond to a CF-Poll with a data
               frame within a SIFS time."
    ::= { dot11StationConfigEntry 3 }

dot11CFPPeriod OBJECT-TYPE
        SYNTAX INTEGER (0..255)
        MAX-ACCESS read-write
```


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```
        STATUS current
        DESCRIPTION
            "The attribute shall describe the number of DTIM intervals
            between the start of CFPs.  It is modified by
            MLME-START.request primitive."
    ::= { dot11StationConfigEntry 4 }

dot11CFPMaxDuration OBJECT-TYPE
        SYNTAX INTEGER (0..65535)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
               "The attribute shall describe the maximum duration of
               the CFP in TU that may be generated by the PCF. It is
               modified by MLME-START.request primitive."
    ::= { dot11StationConfigEntry 5 }

dot11AuthenticationResponseTimeOut OBJECT-TYPE
        SYNTAX Unsigned32 (1..4294967295)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "This attribute shall specify the number of time units (TUs)
             that a responding STA should wait for the next frame in the
            authentication sequence."
    ::= { dot11StationConfigEntry 6 }

dot11PrivacyOptionImplemented OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "This attribute, when true, shall indicate that the IEEE
            802.11 WEP option is implemented.  The default value of
            this attribute shall be false."
    ::= { dot11StationConfigEntry 7 }

dot11PowerManagementMode OBJECT-TYPE
             SYNTAX INTEGER { active(1), powersave(2) }
             MAX-ACCESS read-write
             STATUS current
             DESCRIPTION
                    "This attribute shall specify the power management
                    mode of the STA. When set to active, it shall
                    indicate that the station is not in power-save
                    (PS) mode. When set to powersave, it shall indicate
                    that the station is in power-save mode. The power
                    management mode is transmitted in all frames
                    according to the rules in  7.1.3.1.7."
       ::= { dot11StationConfigEntry 8 }

dot11DesiredSSID OBJECT-TYPE
             SYNTAX OCTET STRING (SIZE(0..32))
             MAX-ACCESS read-write
             STATUS current
             DESCRIPTION
                    "This attribute reflects the Service Set ID (SSID)
                    used in the DesiredSSID parameter of the most recent
                    MLME-SCAN.request.  This value may be modified
```

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```
                    by an external management entity and used by the
                    local SME to make decisions about the Scanning
                    process."
        ::= { dot11StationConfigEntry 9 }

dot11DesiredBSSType OBJECT-TYPE
              SYNTAX INTEGER { infrastructure(1), independent(2), any(3) }
              MAX-ACCESS read-write
              STATUS current
              DESCRIPTION
                    "This attribute shall specify the type of BSS the
                    station shall use when scanning for a BSS with
                    which to synchronize. This value is used to filter
                    Probe Response frames and Beacons. When set to
                    infrastructure, the station shall only synchronize
                    with a BSS whose Capability Information field has
                    the ESS subfield set to 1. When set to independent,
                    the station shall only synchronize with a BSS whose
                    Capability Information field has the IBSS subfield
                    set to 1. When set to any, the station may
                    synchronize to either type of BSS."
        ::= { dot11StationConfigEntry 10 }

dot11OperationalRateSet OBJECT-TYPE
              SYNTAX OCTET STRING (SIZE(1..126))
              MAX-ACCESS read-write
              STATUS current
              DESCRIPTION
                    "This attribute shall specify the set of data
                    rates at which the station may transmit data.
                    Each octet contains a value representing a rate.
                    Each rate shall be within the range from 2 to 127,
                    corresponding to data rates in increments of
                    500 kbit/s from 1 Mbit/s to 63.5 Mbit/s, and shall
                    be supported (as indicated in the supported rates
                    table) for receiving data. This value is reported in
                    transmitted Beacon, Probe Request, Probe Response,
                    Association Request, Association Response,
                    Reassociation Request, and Reassociation Response
                    frames, and is used to determine whether a BSS
                    with which the station desires to synchronize is
                    suitable. It is also used when starting a BSS,
                    as specified in  10.3."
        ::= { dot11StationConfigEntry 11 }

dot11BeaconPeriod OBJECT-TYPE
              SYNTAX INTEGER (1..65535)
              MAX-ACCESS read-write
              STATUS current
              DESCRIPTION
                    "This attribute shall specify the number of TUs that
                    a station shall use for scheduling Beacon
                    transmissions. This value is transmitted in Beacon
                    and Probe Response frames."
        ::= { dot11StationConfigEntry 12 }

dot11DTIMPeriod OBJECT-TYPE
              SYNTAX INTEGER(1..255)
              MAX-ACCESS read-write
```


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```
                STATUS current
                DESCRIPTION
                        "This attribute shall specify the number of beacon
                        intervals that shall elapse between transmission of
                        Beacons frames containing a TIM element whose DTIM
                        Count field is 0. This value is transmitted in
                        the DTIM Period field of Beacon frames."
        ::= { dot11StationConfigEntry 13 }

dot11AssociationResponseTimeOut OBJECT-TYPE
                SYNTAX Unsigned32 (1..4294967295)
                MAX-ACCESS read-write
                STATUS current
                DESCRIPTION
                        "This attribute shall specify the number of TU that a
                        requesting STA should wait for a response to a
                        transmitted association-request MMPDU."
        ::= { dot11StationConfigEntry 14 }

dot11DisassociateReason OBJECT-TYPE
                SYNTAX INTEGER(0..65535)
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                        "This attribute holds the most recently
                        transmitted Reason Code in a Disassociation
                        frame.  If no Disassociation frame has been
                        transmitted, the value of this attribute shall
                        be 0."
         REFERENCE "IEEE Std 802.11, 1999 Edition, 7.3.1.7"
        ::= { dot11StationConfigEntry 15 }

dot11DisassociateStation OBJECT-TYPE
                SYNTAX MacAddress
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                        "This attribute holds the MAC address from the
                        Address 1 field of the most recently transmitted
                        Disassociation frame.  If no Disassociation
                        frame has been transmitted, the value of this
                        attribute shall be 0."
        ::= { dot11StationConfigEntry 16 }

dot11DeauthenticateReason OBJECT-TYPE
                SYNTAX INTEGER(0..65535)
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                        "This attribute holds the most recently
                        transmitted Reason Code in a Deauthentication
                        frame.  If no Deauthentication frame has been
                        transmitted, the value of this attribute shall
                        be 0."
         REFERENCE "IEEE Std 802.11, 1999 Edition, 7.3.1.7"
        ::= { dot11StationConfigEntry 17 }

dot11DeauthenticateStation OBJECT-TYPE
                SYNTAX MacAddress
```

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```
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                        "This attribute holds the MAC address from the
                        Address 1 field of the most recently transmitted
                        Deauthentication frame.  If no Deauthentication
                        frame has been transmitted, the value of this
                        attribute shall be 0."
        ::= { dot11StationConfigEntry 18 }

dot11AuthenticateFailStatus OBJECT-TYPE
                SYNTAX INTEGER(0..65535)
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                        "This attribute holds the most recently
                        transmitted Status Code in a failed
                        Authentication frame.  If no failed
                        Authentication frame has been transmitted, the
                        value of this attribute shall be 0."
         REFERENCE "IEEE Std 802.11, 1999 Edition, 7.3.1.9"
        ::= { dot11StationConfigEntry 19 }

dot11AuthenticateFailStation OBJECT-TYPE
                SYNTAX MacAddress
                MAX-ACCESS read-only
                STATUS current
                DESCRIPTION
                        "This attribute holds the MAC address from the
                        Address 1 field of the most recently transmitted
                        failed Authentication frame.  If no failed
                        Authentication frame has been transmitted, the
                        value of this attribute shall be 0."
        ::= { dot11StationConfigEntry 20 }

dot11MultiDomainCapabilityImplemented OBJECT-TYPE
                SYNTAX TruthValue
                MAX-ACCESS read-write
                STATUS current
                DESCRIPTION
                        "This attribute, when TRUE, indicates that the
                        station implementation is capable of supporting
                        multiple regulatory domains.  The capability is
                        disabled, otherwise.  The default value of this
                        attribute is FALSE."
        ::= { dot11StationConfigEntry 21 }

dot11MultiDomainCapabilityEnabled OBJECT-TYPE
                SYNTAX TruthValue
                MAX-ACCESS read-write
                STATUS current
                DESCRIPTION
                        "This attribute, when TRUE, indicates that the
                        capability of the station to operate in multiple
                        regulatory domains is enabled.  The capability is
                        disabled, otherwise.  The default value of this
                        attribute is FALSE."
        ::= { dot11StationConfigEntry 22 }
```


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```
dot11CountryString OBJECT-TYPE
             SYNTAX OCTET STRING (SIZE(3))
             MAX-ACCESS read-only
             STATUS current
             DESCRIPTION
                    "This attribute identifies the country in which the
                    station is operating. The first two octets of this
                    string is the two character country code as described
                    in document ISO/IEC 3166-1.  The third octet shall
                    be one of the following:

                    1. an ASCII space character, if the regulations under
                    which the station is operating encompass all
                    environments in the country,

                    2. an ASCII 'O' character, if the regulations under
                    which the station is operating are for an Outdoor
                    environment only, or

                    3. an ASCII 'I' character, if the regulations under
                    which the station is operating are for an Indoor
                    environment only."
       ::= { dot11StationConfigEntry 23 }

-- ****************************************************************
-- *    End of dot11StationConfig  TABLE
-- ****************************************************************

-- ****************************************************************
-- *    AuthenticationAlgorithms  TABLE
-- ****************************************************************

dot11AuthenticationAlgorithmsTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11AuthenticationAlgorithmsEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "This (conceptual) table of attributes shall be a set of
            all the authentication algorithms supported by the
            stations.  The following are the default values and the
            associated algorithm:
                Value = 1: Open System
                Value = 2: Shared Key"
        REFERENCE "IEEE Std 802.11, 1999 Edition, 7.3.1.1"
    ::= { dot11smt 2 }

dot11AuthenticationAlgorithmsEntry OBJECT-TYPE
        SYNTAX Dot11AuthenticationAlgorithmsEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An Entry (conceptual row) in the Authentication
            Algorithms Table.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
        INDEX { ifIndex,
                dot11AuthenticationAlgorithmsIndex }
```

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```
    ::= { dot11AuthenticationAlgorithmsTable  1 }

Dot11AuthenticationAlgorithmsEntry ::=
         SEQUENCE { dot11AuthenticationAlgorithmsIndex      Integer32,
                    dot11AuthenticationAlgorithm            INTEGER,
                    dot11AuthenticationAlgorithmsEnable     TruthValue }

dot11AuthenticationAlgorithmsIndex OBJECT-TYPE
        SYNTAX Integer32
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "The auxiliary variable used to identify instances
            of the columnar objects in the Authentication Algorithms Table."
    ::= { dot11AuthenticationAlgorithmsEntry 1 }

dot11AuthenticationAlgorithm OBJECT-TYPE
        SYNTAX INTEGER { openSystem(1), sharedKey(2) }
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "This attribute shall be a set of all the authentication
            algorithms supported by the STAs. The following are the
            default values and the associated algorithm.
                     Value = 1: Open System
                     Value = 2: Shared Key"
    ::= { dot11AuthenticationAlgorithmsEntry 2 }

dot11AuthenticationAlgorithmsEnable  OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "This attribute, when true at a station, shall enable the acceptance
            of the authentication algorithm described in the corresponding table
            entry in authentication frames received by the station that have odd
            authentication sequence numbers.  The default value of this attribute
            shall be 1 for the Open System table entry and 2 for all other table
            entries."
    ::= { dot11AuthenticationAlgorithmsEntry 3 }

-- ************************************************************************
-- *    End of AuthenticationAlgorithms  TABLE
-- ************************************************************************

-- ************************************************************************
-- *    WEPDefaultKeys  TABLE
-- ************************************************************************

dot11WEPDefaultKeysTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11WEPDefaultKeysEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "Conceptual table for WEP default keys.  This table shall
            contain the four WEP default secret key values
            corresponding to the four possible KeyID values.  The WEP
            default secret keys are logically WRITE-ONLY.  Attempts to
            read the entries in this table shall return unsuccessful
```


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```
            status and values of null or zero.  The default value of
            each WEP default key shall be null."
        REFERENCE "IEEE Std 802.11, 1999 Edition, 8.3.2"
    ::= { dot11smt 3 }

dot11WEPDefaultKeysEntry OBJECT-TYPE
        SYNTAX Dot11WEPDefaultKeysEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An Entry (conceptual row) in the WEP Default Keys Table.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
       INDEX { ifIndex,
               dot11WEPDefaultKeyIndex }
    ::= { dot11WEPDefaultKeysTable  1 }

Dot11WEPDefaultKeysEntry ::=
         SEQUENCE { dot11WEPDefaultKeyIndex     INTEGER,
                    dot11WEPDefaultKeyValue     WEPKeytype }

dot11WEPDefaultKeyIndex OBJECT-TYPE
        SYNTAX INTEGER (1..4)
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "The auxiliary variable used to identify instances
            of the columnar objects in the WEP Default Keys Table.
            The value of this variable is equal to the WEPDefaultKeyID + 1"
    ::= { dot11WEPDefaultKeysEntry 1 }

dot11WEPDefaultKeyValue OBJECT-TYPE
        SYNTAX WEPKeytype
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "A WEP default secret key value."
    ::= { dot11WEPDefaultKeysEntry 2 }

-- ************************************************************************
-- *    End of WEPDefaultKeys  TABLE
-- ************************************************************************

-- ************************************************************************
-- *    WEPKeyMappings  TABLE
-- ************************************************************************

dot11WEPKeyMappingsTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11WEPKeyMappingsEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "Conceptual table for WEP Key Mappings.  The MIB supports
            the ability to share a separate WEP key for each RA/TA
            pair.  The Key Mappings Table contains zero or one entry
            for each MAC address and contains two fields for each
            entry: WEPOn and the corresponding WEP key.  The WEP key
```

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```
            mappings are logically WRITE-ONLY.  Attempts to read the
            entries in this table shall return unsuccessful status and
            values of null or zero.  The default value for all WEPOn
            fields is false."
        REFERENCE "IEEE Std 802.11, 1999 Edition, 8.3.2"
    ::= { dot11smt 4 }

dot11WEPKeyMappingsEntry OBJECT-TYPE
        SYNTAX Dot11WEPKeyMappingsEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An Entry (conceptual row) in the WEP Key Mappings Table.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
        INDEX { ifIndex,
                dot11WEPKeyMappingIndex }
    ::= { dot11WEPKeyMappingsTable  1 }

Dot11WEPKeyMappingsEntry ::=
        SEQUENCE { dot11WEPKeyMappingIndex     Integer32,
                   dot11WEPKeyMappingAddress   MacAddress,
                   dot11WEPKeyMappingWEPOn     TruthValue,
                   dot11WEPKeyMappingValue     WEPKeytype,
                   dot11WEPKeyMappingStatus    RowStatus }

dot11WEPKeyMappingIndex OBJECT-TYPE
        SYNTAX Integer32
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "The auxiliary variable used to identify instances
            of the columnar objects in the WEP Key Mappings Table."
    ::= { dot11WEPKeyMappingsEntry 1 }

dot11WEPKeyMappingAddress OBJECT-TYPE
        SYNTAX MacAddress
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "The MAC address of the STA for which the values from this
            key mapping entry are to be used."
    ::= { dot11WEPKeyMappingsEntry 2 }

dot11WEPKeyMappingWEPOn OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "Boolean as to whether WEP is to be used when communicating
            with the dot11WEPKeyMappingAddress STA."
    ::= { dot11WEPKeyMappingsEntry 3 }

dot11WEPKeyMappingValue OBJECT-TYPE
        SYNTAX WEPKeytype
        MAX-ACCESS read-create
        STATUS current
```


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```
        DESCRIPTION
            "A WEP secret key value."
    ::= { dot11WEPKeyMappingsEntry 4 }

dot11WEPKeyMappingStatus OBJECT-TYPE
        SYNTAX RowStatus
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "The status column used for creating, modifying, and
            deleting instances of the columnar objects in the WEP key
            mapping Table."
        DEFVAL { active }
    ::= { dot11WEPKeyMappingsEntry 5 }

-- ****************************************************************
-- *    End of WEPKeyMappings  TABLE
-- ****************************************************************

-- ****************************************************************
-- *    dot11PrivacyTable  TABLE
-- ****************************************************************

dot11PrivacyTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11PrivacyEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "Group containing attributes concerned with IEEE 802.11
            Privacy.  Created as a table to allow multiple
            instantiations on an agent."
    ::= { dot11smt 5 }

dot11PrivacyEntry OBJECT-TYPE
        SYNTAX Dot11PrivacyEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An entry in the dot11PrivacyTable Table.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
        INDEX { ifIndex }
    ::= { dot11PrivacyTable 1 }

Dot11PrivacyEntry ::=
        SEQUENCE { dot11PrivacyInvoked         TruthValue,
                   dot11WEPDefaultKeyID        INTEGER,
                   dot11WEPKeyMappingLength    Unsigned32,
                   dot11ExcludeUnencrypted     TruthValue,
                   dot11WEPICVErrorCount       Counter32,
                   dot11WEPExcludedCount       Counter32 }

dot11PrivacyInvoked OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
```

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```
                "When this attribute is true, it shall indicate that the IEEE
                802.11 WEP mechanism is used for transmitting frames of type
                Data. The default value of this attribute shall be false."
    ::= { dot11PrivacyEntry 1 }

dot11WEPDefaultKeyID  OBJECT-TYPE
        SYNTAX INTEGER (0..3)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "This attribute shall indicate the use of the first,
            second, third, or fourth element of the WEPDefaultKeys
            array when set to values of zero, one, two, or three.  The
            default value of this attribute shall be 0."
        REFERENCE "IEEE Std 802.11, 1999 Edition, 8.3.2"
    ::= { dot11PrivacyEntry 2 }

dot11WEPKeyMappingLength  OBJECT-TYPE
        SYNTAX Unsigned32 (10..4294967295)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "The maximum number of tuples that dot11WEPKeyMappings can hold."
        REFERENCE "IEEE Std 802.11, 1999 Edition, 8.3.2"
    ::= { dot11PrivacyEntry 3 }

dot11ExcludeUnencrypted  OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
               "When this attribute is true, the STA shall not indicate at
               the MAC service interface received MSDUs that have the WEP
               subfield of the Frame Control field equal to zero. When this
               attribute is false, the STA may accept MSDUs that have the WEP
               subfield of the Frame Control field equal to zero. The default
               value of this attribute shall be false."
    ::= { dot11PrivacyEntry 4 }

dot11WEPICVErrorCount  OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "This counter shall increment when a frame is received with the
            WEP subfield of the Frame Control field set to one and the value
            of the ICV as received in the frame does not match the ICV value
            that is calculated for the contents of the received frame."
    ::= { dot11PrivacyEntry 5 }

dot11WEPExcludedCount  OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "This counter shall increment when a frame is received with the
            WEP subfield of the Frame Control field set to zero and the value
            of dot11ExcludeUnencrypted causes that frame to be discarded."
    ::= { dot11PrivacyEntry 6 }
```


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```
-- ****************************************************************
-- *    End of dot11Privacy  TABLE
-- ****************************************************************

-- ****************************************************************
-- *    SMT notification Objects
-- ****************************************************************

dot11SMTnotification OBJECT IDENTIFIER ::= { dot11smt 6 }

dot11Disassociate NOTIFICATION-TYPE
        OBJECTS { ifIndex, dot11DisassociateReason, dot11DisassociateStation }
        STATUS current
        DESCRIPTION
             "The disassociate notification shall be sent when the STA
             sends a Disassociation frame. The value of the notification
             shall include the MAC address of the MAC to which the Disassociation
             frame was sent and the reason for the disassociation.

             ifIndex - Each IEEE 802.11 interface is represented by an
             ifEntry.  Interface tables in this MIB module are indexed
             by ifIndex."
    ::= { dot11SMTnotification 0 1 }

dot11Deauthenticate NOTIFICATION-TYPE
       OBJECTS { ifIndex, dot11DeauthenticateReason, dot11DeauthenticateStation }
       STATUS current
       DESCRIPTION
            "The deauthenticate notification shall be sent when the STA
            sends a Deauthentication frame. The value of the notification
            shall include the MAC address of the MAC to which the Deauthentication
            frame was sent and the reason for the deauthentication.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
    ::= { dot11SMTnotification 0 2 }

dot11AuthenticateFail NOTIFICATION-TYPE
        OBJECTS { ifIndex, dot11AuthenticateFailStatus,
dot11AuthenticateFailStation }
        STATUS current
        DESCRIPTION
            "The authenticate failure notification shall be sent when the STA
            sends an Authentication frame with a status code other than
            'successful'. The value of the notification
            shall include the MAC address of the MAC to which the Authentication
            frame was sent and the reason for the authentication failure.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
    ::= { dot11SMTnotification 0 3 }

-- ****************************************************************
-- *    End of SMT notification Objects
-- ****************************************************************
```

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```
-- ************************************************************************
-- * dot11MultiDomainCapability TABLE
-- ************************************************************************

dot11MultiDomainCapabilityTable OBJECT-TYPE
       SYNTAX SEQUENCE OF Dot11MultiDomainCapabilityEntry
       MAX-ACCESS not-accessible
       STATUS current
       DESCRIPTION
              "This (conceptual) table of attributes for
              cross-domain mobility."
     ::= { dot11smt 7 }

dot11MultiDomainCapabilityEntry OBJECT-TYPE
       SYNTAX Dot11MultiDomainCapabilityEntry
       MAX-ACCESS not-accessible
       STATUS current
       DESCRIPTION
              "An entry (conceptual row) in the Multiple Domain
              Capability Table.

              IfIndex - Each IEEE 802.11 interface is represented
              by an ifEntry. Interface tables in this MIB are
              indexed by ifIndex."
       INDEX { ifIndex,
               dot11MultiDomainCapabilityIndex }
     ::= { dot11MultiDomainCapabilityTable 1 }

Dot11MultiDomainCapabilityEntry ::=
      SEQUENCE { dot11MultiDomainCapabilityIndex     Integer32,
                 dot11FirstChannelNumber             Integer32,
                 dot11NumberofChannels               Integer32,
                 dot11MaximumTransmitPowerLevel      Integer32 }

dot11MultiDomainCapabilityIndex OBJECT-TYPE
       SYNTAX Integer32
       MAX-ACCESS not-accessible
       STATUS current
       DESCRIPTION
              "The auxiliary variable used to identify instances of
              the columnar objects in the Multi Domain Capability Table."
     ::= { dot11MultiDomainCapabilityEntry 1 }

dot11FirstChannelNumber OBJECT-TYPE
       SYNTAX Integer32
       MAX-ACCESS read-write
       STATUS current
       DESCRIPTION
              "This attribute shall indicate the value of the lowest
              channel number in the subband for the associated domain
              country string. The default value of this attribute
              shall be zero."
     ::= { dot11MultiDomainCapabilityEntry 2 }

dot11NumberofChannels OBJECT-TYPE
       SYNTAX Integer32
       MAX-ACCESS read-write
       STATUS current
       DESCRIPTION
```


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```
                "This attribute shall indicate the value of the total
                number of channels allowed in the subband for the
                associated domain country string. The default value of
                this attribute shall be zero."
        ::= { dot11MultiDomainCapabilityEntry 3 }

dot11MaximumTransmitPowerLevel OBJECT-TYPE
        SYNTAX Integer32
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
                "This attribute shall indicate the maximum transmit power,
                in dBm, allowed in the subband for the associated domain
                country string. The default value of this attribute shall
                be zero."
        ::= { dot11MultiDomainCapabilityEntry 4 }

-- ****************************************************************
-- * End of dot11MultiDomainCapability TABLE
-- ****************************************************************

-- ****************************************************************
-- *    MAC Attribute Templates
-- ****************************************************************

-- ****************************************************************
-- *    dot11OperationTable  TABLE
-- ****************************************************************

dot11OperationTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11OperationEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "Group contains MAC attributes pertaining to the operation
            of the MAC.  This has been implemented as a table in order
            to allow for multiple instantiations on an agent."
    ::= { dot11mac 1 }

dot11OperationEntry OBJECT-TYPE
        SYNTAX Dot11OperationEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An entry in the dot11OperationEntry Table.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
        INDEX { ifIndex }
    ::= { dot11OperationTable 1 }

Dot11OperationEntry ::=
        SEQUENCE { dot11MACAddress                MacAddress,
                   dot11RTSThreshold              INTEGER,
                   dot11ShortRetryLimit           INTEGER,
                   dot11LongRetryLimit            INTEGER,
                   dot11FragmentationThreshold    INTEGER,
                   dot11MaxTransmitMSDULifetime   Unsigned32,
```

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```
                    dot11MaxReceiveLifetime         Unsigned32,
                    dot11ManufacturerID             DisplayString,
                    dot11ProductID                  DisplayString }

dot11MACAddress OBJECT-TYPE
        SYNTAX MacAddress
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
             "Unique MAC Address assigned to the STA."
    ::= { dot11OperationEntry 1 }

dot11RTSThreshold OBJECT-TYPE
        SYNTAX INTEGER (0..2347)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
               "This attribute shall indicate the number of octets in an MPDU,
               below which an RTS/CTS handshake shall not be performed. An
               RTS/CTS handshake shall be performed at the beginning of any
               frame exchange sequence where the MPDU is of type Data or
               Management, the MPDU has an individual address in the Address1
               field, and the length of the MPDU is greater than
               this threshold. (For additional details, refer to Table 21 in
               9.7.) Setting this attribute to be larger than the maximum
               MSDU size shall have the effect of turning off the RTS/CTS
               handshake for frames of Data or Management type transmitted by
               this STA. Setting this attribute to zero shall have the effect
               of turning on the RTS/CTS handshake for all frames of Data or
               Management type transmitted by this STA. The default value of
               this attribute shall be 2347."
    ::= { dot11OperationEntry 2 }

dot11ShortRetryLimit OBJECT-TYPE
        SYNTAX INTEGER (1..255)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
               "This attribute shall indicate the maximum number of
               transmission attempts of a frame, the length of which is less
               than or equal to dot11RTSThreshold, that shall be made before a
               failure condition is indicated. The default value of this
               attribute shall be 7."
    ::= { dot11OperationEntry 3 }

dot11LongRetryLimit OBJECT-TYPE
        SYNTAX INTEGER (1..255)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
               "This attribute shall indicate the maximum number of
               transmission attempts of a frame, the length of which is
               greater than dot11RTSThreshold, that shall be made before a
               failure condition is indicated. The default value of this
               attribute shall be 4."
    ::= { dot11OperationEntry 4 }

dot11FragmentationThreshold OBJECT-TYPE
        SYNTAX INTEGER (256..2346)
```


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```
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
              "This attribute shall specify the current maximum size, in
              octets, of the MPDU that may be delivered to the PHY. An MSDU
              shall be broken into fragments if its size exceeds the value
              of this attribute after adding MAC headers and trailers. An MSDU
              or MMPDU shall be fragmented when the resulting frame has an
              individual address in the Address1 field, and the length of the
              frame is larger than this threshold. The default value for this
              attribute shall be the lesser of 2346 or the aMPDUMaxLength of
              the attached PHY and shall never exceed the lesser of 2346 or
              the  aMPDUMaxLength of the attached PHY. The value of this
              attribute shall never be less than 256. "
    ::= { dot11OperationEntry 5 }

dot11MaxTransmitMSDULifetime OBJECT-TYPE
        SYNTAX Unsigned32 (1..4294967295)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
              "The MaxTransmitMSDULifetime shall be the elapsed time in TU,
              after the initial transmission of an MSDU, after which further
              attempts to transmit the MSDU shall be terminated. The default
              value of this attribute shall be 512."
    ::= { dot11OperationEntry 6 }

dot11MaxReceiveLifetime OBJECT-TYPE
        SYNTAX Unsigned32 (1..4294967295)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "The MaxReceiveLifetime shall be the elapsed time in TU,
            after the initial reception of a fragmented MMPDU or MSDU,
            after which further attempts to reassemble the MMPDU or
            MSDU shall be terminated. The default value shall be
            512."
    ::= { dot11OperationEntry 7 }

dot11ManufacturerID OBJECT-TYPE
        SYNTAX DisplayString (SIZE(0..128))
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "The ManufacturerID shall include, at a minimum, the name
            of the manufacturer.  It may include additional
            information at the manufacturer's discretion.  The default
            value of this attribute shall be null."
    ::= { dot11OperationEntry 8 }

dot11ProductID OBJECT-TYPE
        SYNTAX DisplayString (SIZE(0..128))
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "The ProductID shall include, at a minimum, an identifier
            that is unique to the manufacturer.  It may include
            additional information at the manufacturer's discretion.
            The default value of this attribute shall be null."
```

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```
    ::= { dot11OperationEntry 9 }

-- ****************************************************************
-- *    End of dot11OperationEntry  TABLE
-- ****************************************************************

-- ****************************************************************
-- *    dot11Counters TABLE
-- ****************************************************************

dot11CountersTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11CountersEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "Group containing attributes that are MAC counters.
            Implemented as a table to allow for multiple
            instantiations on an agent."
    ::= { dot11mac 2 }

dot11CountersEntry OBJECT-TYPE
        SYNTAX Dot11CountersEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An entry in the dot11CountersEntry Table.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
        INDEX { ifIndex }
    ::= { dot11CountersTable 1 }

Dot11CountersEntry ::=
        SEQUENCE { dot11TransmittedFragmentCount       Counter32,
                   dot11MulticastTransmittedFrameCount Counter32,
                   dot11FailedCount                    Counter32,
                   dot11RetryCount                     Counter32,
                   dot11MultipleRetryCount             Counter32,
                   dot11FrameDuplicateCount            Counter32,
                   dot11RTSSuccessCount                Counter32,
                   dot11RTSFailureCount                Counter32,
                   dot11ACKFailureCount                Counter32,
                   dot11ReceivedFragmentCount          Counter32,
                   dot11MulticastReceivedFrameCount    Counter32,
                   dot11FCSErrorCount                  Counter32,
                   dot11TransmittedFrameCount          Counter32,
                   dot11WEPUndecryptableCount          Counter32 }

dot11TransmittedFragmentCount OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "This counter shall be incremented for an acknowledged MPDU
            with an individual address in the address 1 field or an MPDU
            with a multicast address in the address 1 field of type Data
            or Management."
    ::= { dot11CountersEntry 1 }
```


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```
dot11MulticastTransmittedFrameCount OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "This counter shall increment only when the multicast bit
            is set in the destination MAC address of a successfully
            transmitted MSDU.  When operating as a STA in an ESS, where
            these frames are directed to the AP, this implies having
            received an acknowledgment to all associated MPDUs."
    ::= { dot11CountersEntry 2 }

dot11FailedCount OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
               "This counter shall increment when an MSDU is not transmitted
               successfully due to the number of transmit attempts exceeding
               either the  dot11ShortRetryLimit or dot11LongRetryLimit."
    ::= { dot11CountersEntry 3 }

dot11RetryCount OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "This counter shall increment when an MSDU is successfully
            transmitted after one or more retransmissions."
    ::= { dot11CountersEntry 4 }

dot11MultipleRetryCount OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "This counter shall increment when an MSDU is successfully
            transmitted after more than one retransmission."
    ::= { dot11CountersEntry 5 }

dot11FrameDuplicateCount  OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "This counter shall increment when a frame is received
            that the Sequence Control field indicates is a
            duplicate."
    ::= { dot11CountersEntry 6 }

dot11RTSSuccessCount OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "This counter shall increment when a CTS is received in
            response to an RTS."
    ::= {  dot11CountersEntry 7 }
```

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```
dot11RTSFailureCount OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
               "This counter shall increment when a CTS is not received in
               response to an RTS."
    ::= { dot11CountersEntry 8 }

dot11ACKFailureCount OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "This counter shall increment when an ACK is not received
            when expected."
    ::= {  dot11CountersEntry 9 }

dot11ReceivedFragmentCount OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "This counter shall be incremented for each successfully
            received MPDU of type Data or Management."
    ::= { dot11CountersEntry 10 }

dot11MulticastReceivedFrameCount OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "This counter shall increment when a MSDU is received
            with the multicast bit set in the destination
            MAC address."
    ::= { dot11CountersEntry 11 }

dot11FCSErrorCount OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "This counter shall increment when an FCS error is
            detected in a received MPDU."
    ::= { dot11CountersEntry 12 }

dot11TransmittedFrameCount OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
              "This counter shall increment for each successfully transmitted
              MSDU."
    ::= { dot11CountersEntry 13 }

dot11WEPUndecryptableCount OBJECT-TYPE
        SYNTAX Counter32
        MAX-ACCESS read-only
```


--`,,`,`-`-`,,`,,`,`,,`---
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```
        STATUS current
        DESCRIPTION
              "This counter shall increment when a frame is received with
              the WEP subfield of the Frame Control field set to one and the
              WEPOn value for the key mapped to the transmitter's MAC address
              indicates that the frame should not have been encrypted or
              that frame is discarded due to the receiving STA not
              implementing the privacy option."
    ::= { dot11CountersEntry 14 }

-- ****************************************************************
-- *    End of dot11CountersEntry  TABLE
-- ****************************************************************

-- ****************************************************************
-- *    GroupAddresses  TABLE
-- ****************************************************************

dot11GroupAddressesTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11GroupAddressesEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "A conceptual table containing a set of MAC addresses
            identifying the multicast addresses for which this STA
            will receive frames.  The default value of this attribute
            shall be null."
    ::= { dot11mac 3 }

dot11GroupAddressesEntry OBJECT-TYPE
        SYNTAX Dot11GroupAddressesEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An Entry (conceptual row) in the Group Addresses Table.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
        INDEX { ifIndex,
                dot11GroupAddressesIndex }
    ::= { dot11GroupAddressesTable  1 }

Dot11GroupAddressesEntry ::=
        SEQUENCE { dot11GroupAddressesIndex    Integer32,
                   dot11Address                MacAddress,
                   dot11GroupAddressesStatus   RowStatus }

dot11GroupAddressesIndex OBJECT-TYPE
        SYNTAX Integer32
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "The auxiliary variable used to identify instances
            of the columnar objects in the Group Addresses Table."
    ::= { dot11GroupAddressesEntry 1 }

dot11Address OBJECT-TYPE
        SYNTAX MacAddress
```

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```
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "MAC address identifying multicast addresses
            from which this STA will receive frames."
    ::= { dot11GroupAddressesEntry 2 }

dot11GroupAddressesStatus OBJECT-TYPE
        SYNTAX RowStatus
        MAX-ACCESS read-create
        STATUS current
        DESCRIPTION
            "The status column used for creating, modifying, and
            deleting instances of the columnar objects in the Group
            Addresses Table."
        DEFVAL { active }
    ::= { dot11GroupAddressesEntry 3 }

-- ****************************************************************
-- *    End of GroupAddress  TABLE
-- ****************************************************************

-- ****************************************************************
-- *    Resource Type Attribute Templates
-- ****************************************************************

dot11ResourceTypeIDName OBJECT-TYPE
        SYNTAX DisplayString (SIZE(4))
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "Contains the name of the Resource Type ID managed object.
            The attribute is read-only and always contains the value
            RTID.  This attribute value shall not be used as a naming
            attribute for any other managed object class."
        REFERENCE "IEEE Std 802.1F-1993,  A.7"
        DEFVAL { "RTID" }
    ::= { dot11resAttribute 1 }

-- ****************************************************************
-- *    dot11ResourceInfo  TABLE
-- ****************************************************************

dot11ResourceInfoTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11ResourceInfoEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "Provides a means of indicating, in data readable from a
            managed object, information that identifies the source of
            the implementation."
        REFERENCE "IEEE Std 802.1F-1993,  A.7"
    ::= { dot11resAttribute 2 }

dot11ResourceInfoEntry OBJECT-TYPE
        SYNTAX Dot11ResourceInfoEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
```


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```
            "An entry in the dot11ResourceInfo Table.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
        INDEX { ifIndex }
    ::= { dot11ResourceInfoTable 1 }

Dot11ResourceInfoEntry ::=
        SEQUENCE { dot11manufacturerOUI             OCTET STRING,
                   dot11manufacturerName            DisplayString,
                   dot11manufacturerProductName     DisplayString,
                   dot11manufacturerProductVersion  DisplayString }

dot11manufacturerOUI OBJECT-TYPE
        SYNTAX OCTET STRING (SIZE(3))
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "Takes the value of an organizationally unique identifier."
    ::= { dot11ResourceInfoEntry 1 }

dot11manufacturerName OBJECT-TYPE
        SYNTAX DisplayString (SIZE(0..128))
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "A printable string used to identify the manufacturer of the
            resource.  Maximum string length is 128 octets."
    ::= { dot11ResourceInfoEntry 2 }

dot11manufacturerProductName OBJECT-TYPE
        SYNTAX DisplayString (SIZE(0..128))
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "A printable string used to identify the manufacturer's product
            name of the resource.  Maximum string length is 128 octets."
    ::= { dot11ResourceInfoEntry 3 }

dot11manufacturerProductVersion OBJECT-TYPE
        SYNTAX DisplayString (SIZE(0..128))
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "Printable string used to identify the manufacturer's product
            version of the resource.  Maximum string length is 128 octets."
    ::= { dot11ResourceInfoEntry 4 }

-- ****************************************************************
-- *    End of dot11ResourceInfo  TABLE
-- ****************************************************************

-- ****************************************************************
-- *   PHY Attribute Templates
-- ****************************************************************
```

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```
-- ************************************************************************
-- *    dot11PhyOperation  TABLE
-- ************************************************************************

dot11PhyOperationTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11PhyOperationEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
               "PHY level attributes concerned with
               operation.  Implemented as a table indexed on
               ifIndex to allow for multiple instantiations on an
               Agent."
    ::= { dot11phy 1 }

dot11PhyOperationEntry OBJECT-TYPE
        SYNTAX Dot11PhyOperationEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An entry in the dot11PhyOperation Table.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
        INDEX { ifIndex }
    ::= { dot11PhyOperationTable 1 }

Dot11PhyOperationEntry ::=
        SEQUENCE { dot11PHYType            INTEGER,
                   dot11CurrentRegDomain   Integer32,
                   dot11TempType           INTEGER }

dot11PHYType OBJECT-TYPE
        SYNTAX INTEGER { fhss(1), dsss(2), irbaseband(3), ofdm(4),
                         hrdsss(5) }
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
               "This is an 8-bit integer value that identifies the PHY type
               supported by the attached PLCP and PMD. Currently defined
               values and their corresponding PHY types are:

               FHSS 2.4 GHz = 01 , DSSS 2.4 GHz = 02, IR Baseband = 03,
               OFDM 5GHz = 04, HRDSSS = 05"
    ::= { dot11PhyOperationEntry 1 }

dot11CurrentRegDomain OBJECT-TYPE
        SYNTAX Integer32
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "The current regulatory domain this instance of the PMD is
            supporting.  This object corresponds to one of the
            RegDomains listed in dot11RegDomainsSupported."
    ::= { dot11PhyOperationEntry 2 }

dot11TempType OBJECT-TYPE
        SYNTAX INTEGER { tempType1(1), tempType2(2) }
```


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```
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
              "There are different operating temperature requirements
              dependent on the anticipated environmental conditions. This
              attribute describes the current PHY's operating temperature
              range capability. Currently defined values and their
              corresponding temperature ranges are:

              Type 1 = X'01'-Commercial range of 0 to 40 degrees C,

              Type 2 = X'02'-Industrial range of -30 to 70 degrees C."
    ::= { dot11PhyOperationEntry 3 }

-- ****************************************************************
-- *    End of dot11PhyOperation  TABLE
-- ****************************************************************

-- ****************************************************************
-- *    dot11PhyAntenna  TABLE
-- ****************************************************************

dot11PhyAntennaTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11PhyAntennaEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "Group of attributes for PhyAntenna.  Implemented as a
            table indexed on ifIndex to allow for multiple instances on
            an agent."
    ::= { dot11phy 2}

dot11PhyAntennaEntry OBJECT-TYPE
        SYNTAX Dot11PhyAntennaEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An entry in the dot11PhyAntenna Table.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
        INDEX { ifIndex }
    ::= { dot11PhyAntennaTable 1 }

Dot11PhyAntennaEntry ::=
        SEQUENCE { dot11CurrentTxAntenna  Integer32,
                   dot11DiversitySupport  INTEGER,
                   dot11CurrentRxAntenna  Integer32 }

dot11CurrentTxAntenna OBJECT-TYPE
        SYNTAX Integer32 (1..255)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
             "The current antenna being used to transmit.  This value
             is one of the values appearing in dot11SupportedTxAntenna. This
             may be used by a management agent to control which antenna is
             used for transmission. "
```

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```
    ::= { dot11PhyAntennaEntry 1 }

dot11DiversitySupport OBJECT-TYPE
        SYNTAX INTEGER { fixedlist(1), notsupported(2), dynamic(3) }
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
           "This implementation's support for diversity, encoded as:

               X'01'-diversity is available and is performed over the fixed
                   list of antennas defined in dot11DiversitySelectionRx.

               X'02'-diversity is not supported.

               X'03'-diversity is supported and control of diversity is also
                   available, in which case the attribute
                   dot11DiversitySelectionRx can be dynamically modified by the
                   LME."
    ::= { dot11PhyAntennaEntry 2 }

dot11CurrentRxAntenna OBJECT-TYPE
        SYNTAX Integer32 (1..255)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
             "The current antenna being used to receive, if the dot11
             DiversitySupport indicates that diversity is not supported.
             The selected antenna shall be one of the antennae marked
             for receive in the dot11AntennasListTable."
    ::= { dot11PhyAntennaEntry 3 }

-- ****************************************************************
-- *    End of dot11PhyAntenna  TABLE
-- ****************************************************************

-- ****************************************************************
-- *    dot11PhyTxPower  TABLE
-- ****************************************************************

dot11PhyTxPowerTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11PhyTxPowerEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "Group of attributes for dot11PhyTxPowerTable.  Implemented
            as a table indexed on STA ID to allow for multiple
            instances on an Agent."
    ::= { dot11phy 3}

dot11PhyTxPowerEntry OBJECT-TYPE
        SYNTAX Dot11PhyTxPowerEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An entry in the dot11PhyTxPower Table.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
```


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```
        INDEX { ifIndex }
    ::= { dot11PhyTxPowerTable 1 }

Dot11PhyTxPowerEntry ::=
        SEQUENCE { dot11NumberSupportedPowerLevels  INTEGER,
                   dot11TxPowerLevel1               INTEGER,
                   dot11TxPowerLevel2               INTEGER,
                   dot11TxPowerLevel3               INTEGER,
                   dot11TxPowerLevel4               INTEGER,
                   dot11TxPowerLevel5               INTEGER,
                   dot11TxPowerLevel6               INTEGER,
                   dot11TxPowerLevel7               INTEGER,
                   dot11TxPowerLevel8               INTEGER,
                   dot11CurrentTxPowerLevel         INTEGER }

dot11NumberSupportedPowerLevels OBJECT-TYPE
        SYNTAX INTEGER (1..8)
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "The number of power levels supported by the PMD.
            This attribute can have a value of 1 to 8."
    ::= { dot11PhyTxPowerEntry 1 }

dot11TxPowerLevel1 OBJECT-TYPE
        SYNTAX INTEGER (0..10000)
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "The transmit output power for LEVEL1 in mW.
            This is also the default power level."
    ::= { dot11PhyTxPowerEntry 2 }

dot11TxPowerLevel2 OBJECT-TYPE
        SYNTAX INTEGER (0..10000)
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "The transmit output power for LEVEL2 in mW."
    ::= { dot11PhyTxPowerEntry 3 }

dot11TxPowerLevel3 OBJECT-TYPE
        SYNTAX INTEGER (0..10000)
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "The transmit output power for LEVEL3 in mW."
    ::= { dot11PhyTxPowerEntry 4 }

dot11TxPowerLevel4 OBJECT-TYPE
        SYNTAX INTEGER (0..10000)
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "The transmit output power for LEVEL4 in mW."
    ::= { dot11PhyTxPowerEntry 5 }

dot11TxPowerLevel5 OBJECT-TYPE
        SYNTAX INTEGER (0..10000)
```

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```
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "The transmit output power for LEVEL5 in mW."
    ::= { dot11PhyTxPowerEntry 6 }

dot11TxPowerLevel6 OBJECT-TYPE
        SYNTAX INTEGER (0..10000)
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "The transmit output power for LEVEL6 in mW."
    ::= { dot11PhyTxPowerEntry 7 }

dot11TxPowerLevel7 OBJECT-TYPE
        SYNTAX INTEGER (0..10000)
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "The transmit output power for LEVEL7 in mW."
    ::= { dot11PhyTxPowerEntry 8 }

dot11TxPowerLevel8 OBJECT-TYPE
        SYNTAX INTEGER (0..10000)
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "The transmit output power for LEVEL8 in mW."
    ::= { dot11PhyTxPowerEntry 9 }

dot11CurrentTxPowerLevel OBJECT-TYPE
        SYNTAX INTEGER (1..8)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "The TxPowerLevel N currently being used to transmit data.
            Some PHYs also use this value to determine the receiver
            sensitivity requirements for CCA."
    ::= { dot11PhyTxPowerEntry 10 }

-- ****************************************************************
-- *    End of dot11PhyTxPower  TABLE
-- ****************************************************************

-- ****************************************************************
-- *    dot11PhyFHSS  TABLE
-- ****************************************************************

dot11PhyFHSSTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11PhyFHSSEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "Group of attributes for dot11PhyFHSSTable.  Implemented as a
            table indexed on STA ID to allow for multiple instances on
            an Agent."
    ::= { dot11phy 4 }
```


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```
dot11PhyFHSSEntry OBJECT-TYPE
        SYNTAX Dot11PhyFHSSEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An entry in the dot11PhyFHSS Table.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
        INDEX { ifIndex }
    ::= { dot11PhyFHSSTable 1 }

Dot11PhyFHSSEntry ::=
        SEQUENCE { dot11HopTime                              INTEGER,
                   dot11CurrentChannelNumber                 INTEGER,
                   dot11MaxDwellTime                         INTEGER,
                   dot11CurrentDwellTime                     INTEGER,
                   dot11CurrentSet                           INTEGER,
                   dot11CurrentPattern                       INTEGER,
                   dot11CurrentIndex                         INTEGER,
                   dot11EHCCPrimeRadix                       Integer32,
                   dot11EHCCNumberofChannelsFamilyIndex      Integer32,
                   dot11EHCCCapabilityImplemented            TruthValue,
                   dot11EHCCCapabilityEnabled                TruthValue,
                   dot11HopAlgorithmAdopted                  INTEGER,
                   dot11RandomTableFlag                      TruthValue,
                   dot11NumberofHoppingSets                  Integer32,
                   dot11HopModulus                           Integer32,
                   dot11HopOffset                            Integer32 }

dot11HopTime OBJECT-TYPE
        SYNTAX INTEGER (224)
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "The time in microseconds for the PMD to change from
            channel 2 to channel 80."
    ::= { dot11PhyFHSSEntry 1 }

dot11CurrentChannelNumber OBJECT-TYPE
        SYNTAX INTEGER (0..200)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
           "The current channel number of the frequency output by the RF
           synthesizer."
    ::= { dot11PhyFHSSEntry 2 }

dot11MaxDwellTime OBJECT-TYPE
        SYNTAX INTEGER (1..65535)
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "The maximum time in TU that the transmitter
            is permitted to operate on a single channel."
    ::= { dot11PhyFHSSEntry 3 }
```

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```
dot11CurrentDwellTime OBJECT-TYPE
        SYNTAX INTEGER (1..65535)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "The current time in TU that the transmitter shall operate
            on a single channel, as set by the MAC.  Default is 19 TU."
    ::= { dot11PhyFHSSEntry 4 }

dot11CurrentSet OBJECT-TYPE
        SYNTAX INTEGER (1..255)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
           "The current set of patterns the PLME
           is using to determine the hopping sequence. "
    ::= { dot11PhyFHSSEntry 5 }

dot11CurrentPattern OBJECT-TYPE
        SYNTAX INTEGER (0..255)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "The current pattern the PLME is
            using to determine the hop sequence."
    ::= { dot11PhyFHSSEntry 6 }

dot11CurrentIndex OBJECT-TYPE
        SYNTAX INTEGER (1..255)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "The current index value the PLME is using to determine
            the CurrentChannelNumber."
    ::= { dot11PhyFHSSEntry 7 }

dot11EHCCPrimeRadix OBJECT-TYPE
       SYNTAX Integer32
       MAX-ACCESS read-write
       STATUS current
       DESCRIPTION
            "This attribute indicates the value to be
            used as the prime radix (N) in the HCC and
            EHCC algorithms."
    ::= { dot11PhyFHSSEntry 8 }

dot11EHCCNumberofChannelsFamilyIndex OBJECT-TYPE
       SYNTAX Integer32
       MAX-ACCESS read-write
       STATUS current
       DESCRIPTION
            "This attribute indicates the value to be
            used as the maximum for the family index (a)
            in the HCC and EHCC algorithms. The value of
            this field shall not be less than the prime
            radix minus 3 (N - 3). The valid range of
            allowed values is (N - 1), (N - 2), and (N - 3)."
    ::= { dot11PhyFHSSEntry 9 }
```


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```
dot11EHCCCapabilityImplemented OBJECT-TYPE
       SYNTAX TruthValue
       MAX-ACCESS read-write
       STATUS current
       DESCRIPTION
            "This attribute, when TRUE, indicates that the
            station implementation is capable of generating
            the HCC or EHCC algorithms for determining Hopping
            patterns.  The capability is disabled, otherwise.
            The default value of this attribute is FALSE."
    ::= { dot11PhyFHSSEntry 10 }

dot11EHCCCapabilityEnabled OBJECT-TYPE
       SYNTAX TruthValue
       MAX-ACCESS read-write
       STATUS current
       DESCRIPTION
            "This attribute, when TRUE, indicates that the
            capability of the station to operate using the HCC
            or EHCC algorithms for determining Hopping Patterns
            is enabled.  The capability is disabled, otherwise.
            The default value of this attribute is FALSE."
    ::= { dot11PhyFHSSEntry 11 }

dot11HopAlgorithmAdopted OBJECT-TYPE
       SYNTAX INTEGER { crnt(1), hopindex(2), hcc(3) }
       MAX-ACCESS read-write
       STATUS current
       DESCRIPTION
            "This attribute, indicates which of the algorithms
            will be used to generate the Hopping Patterns.
            Valid values are:

            1 - hopping patterns as defined in clause 14
            2 - hop index method (with or without table)
            3 - HCC/EHCC method"
    ::= { dot11PhyFHSSEntry 12 }

dot11RandomTableFlag OBJECT-TYPE
       SYNTAX TruthValue
       MAX-ACCESS read-write
       STATUS current
       DESCRIPTION
            "This attribute, indicates that a Random Table is
            present when the value is True. When the value is
            False it indicates that a Random Table is not
            present and that the hop index method is to be
            used to determine the hopping sequence. The default
            value of this attribute is True."
    ::= { dot11PhyFHSSEntry 13 }

dot11NumberofHoppingSets OBJECT-TYPE
       SYNTAX Integer32
       MAX-ACCESS read-only
       STATUS current
       DESCRIPTION
            "The Number of Sets field indicates the total
            number of sets within the hopping patterns."
    ::= { dot11PhyFHSSEntry 14 }
```

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```
dot11HopModulus OBJECT-TYPE
       SYNTAX Integer32
       MAX-ACCESS read-only
       STATUS current
       DESCRIPTION
            "The number of allowed channels for the hopping
            set. This is defined by the governing regulatory
            agency for the country code of the country
            in which this device is operating."
    ::= { dot11PhyFHSSEntry 15 }

dot11HopOffset OBJECT-TYPE
       SYNTAX Integer32
       MAX-ACCESS read-write
       STATUS current
       DESCRIPTION
            "The next position in the hopping set."
    ::= { dot11PhyFHSSEntry 16 }

-- ****************************************************************
-- *    End of dot11PhyFHSS  TABLE
-- ****************************************************************

-- ****************************************************************
-- *    dot11PhyDSSSEntry  TABLE
-- ****************************************************************

dot11PhyDSSSTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11PhyDSSSEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "Entry of attributes for dot11PhyDSSSEntry.  Implemented as a
            table indexed on ifIndex to allow for multiple instances on
            an Agent."
    ::= { dot11phy 5 }

dot11PhyDSSSEntry OBJECT-TYPE
        SYNTAX Dot11PhyDSSSEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An entry in the dot11PhyDSSSEntry Table.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
        INDEX { ifIndex }
    ::= { dot11PhyDSSSTable 1 }

Dot11PhyDSSSEntry ::=
        SEQUENCE { dot11CurrentChannel    INTEGER,
                   dot11CCAModeSupported  INTEGER,
                   dot11CurrentCCAMode    INTEGER,
                   dot11EDThreshold       Integer32 }

dot11CurrentChannel OBJECT-TYPE
        SYNTAX INTEGER (1..14)
```


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```
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "The current operating frequency channel of the DSSS
            PHY. Valid channel numbers are as defined in 15.4.6.2"
    ::= { dot11PhyDSSSEntry 1 }

dot11CCAModeSupported OBJECT-TYPE
        SYNTAX INTEGER (1..7)
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
             "dot11CCAModeSupported is a bit-significant value,
             representing all of the CCA modes supported by the PHY.
             Valid values are:

                energy detect only (ED_ONLY) = 01,
                carrier sense only (CS_ONLY) = 02,
                carrier sense and energy detect (ED_and_CS)= 04

             or the logical sum of any of these values.  This
             attribute shall not be used to indicate the CCA modes
             supported by a higher rate extension PHY.  Rather, the
             dot11HRCCAModeSupported attribute shall be used to
             indicate the CCA modes of the higher rate extension PHY."
    ::= { dot11PhyDSSSEntry 2 }

dot11CurrentCCAMode OBJECT-TYPE
        SYNTAX INTEGER { edonly(1), csonly(2), edandcs(4), cswithtimer(8),
                         hrcsanded(16) }
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "The current CCA method in operation.   Valid values are:
                energy detect only (edonly) = 01,
                carrier sense only (csonly) = 02,
                carrier sense and energy detect (edandcs)= 04
                carrier sense with timer (cswithtimer)= 08
                high rate carrier sense and energy detect (hrcsanded)=16."
    ::= { dot11PhyDSSSEntry 3 }

dot11EDThreshold OBJECT-TYPE
        SYNTAX Integer32
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "The current Energy Detect Threshold being used by the DSSS PHY."
    ::= { dot11PhyDSSSEntry 4 }

-- ****************************************************************
-- *    End of dot11PhyDSSSEntry  TABLE
-- ****************************************************************

-- ****************************************************************
-- *    dot11PhyIR  TABLE
-- ****************************************************************

dot11PhyIRTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11PhyIREntry
```

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```
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "Group of attributes for dot11PhyIRTable.  Implemented as a
            table indexed on ifIndex to allow for multiple instances on
            an Agent."
    ::= { dot11phy 6 }

dot11PhyIREntry OBJECT-TYPE
        SYNTAX Dot11PhyIREntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An entry in the dot11PhyIR Table.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
        INDEX { ifIndex }
    ::= { dot11PhyIRTable 1 }

Dot11PhyIREntry ::=
        SEQUENCE { dot11CCAWatchdogTimerMax       Integer32,
                   dot11CCAWatchdogCountMax       Integer32,
                   dot11CCAWatchdogTimerMin       Integer32,
                   dot11CCAWatchdogCountMin       Integer32 }

dot11CCAWatchdogTimerMax OBJECT-TYPE
        SYNTAX Integer32
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "This parameter, together with CCAWatchdogCountMax,
            determines when energy detected in the channel can be
            ignored."
    ::= { dot11PhyIREntry 1 }

dot11CCAWatchdogCountMax OBJECT-TYPE
        SYNTAX Integer32
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "This parameter, together with CCAWatchdogTimerMax,
            determines when energy detected in the channel can be
            ignored."
    ::= { dot11PhyIREntry 2 }

dot11CCAWatchdogTimerMin OBJECT-TYPE
        SYNTAX Integer32
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "The minimum value to which CCAWatchdogTimerMax can be
            set."
    ::= { dot11PhyIREntry 3 }

dot11CCAWatchdogCountMin OBJECT-TYPE
        SYNTAX Integer32
        MAX-ACCESS read-write
```


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```
        STATUS current
        DESCRIPTION
            "The minimum value to which CCAWatchdogCount can be set."
    ::= { dot11PhyIREntry 4 }

-- ****************************************************************
-- *    End of dot11PhyIR  TABLE
-- ****************************************************************

-- ****************************************************************
-- *    dot11RegDomainsSupported  TABLE
-- ****************************************************************

dot11RegDomainsSupportedTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11RegDomainsSupportedEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "There are different operational requirements dependent on
            the regulatory domain.  This attribute list describes the
            regulatory domains the PLCP and PMD support in this
            implementation.  Currently defined values and their
            corresponding Regulatory Domains are:

            FCC (USA) = X'10', DOC (Canada) = X'20', ETSI (most of
            Europe) = X'30', Spain = X'31', France = X'32', MKK
            (Japan) = X'40', Other = X'00' "
    ::= { dot11phy 7}

dot11RegDomainsSupportedEntry OBJECT-TYPE
        SYNTAX Dot11RegDomainsSupportedEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An entry in the dot11RegDomainsSupportedTable.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
        INDEX { ifIndex,
                dot11RegDomainsSupportedIndex }
    ::= { dot11RegDomainsSupportedTable 1 }

Dot11RegDomainsSupportedEntry ::=
        SEQUENCE { dot11RegDomainsSupportedIndex    Integer32,
                   dot11RegDomainsSupportedValue    INTEGER }

dot11RegDomainsSupportedIndex OBJECT-TYPE
        SYNTAX Integer32
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "The auxiliary variable used to identify instances
            of the columnar objects in the RegDomainsSupport Table."
    ::= { dot11RegDomainsSupportedEntry 1 }

dot11RegDomainsSupportedValue OBJECT-TYPE
        SYNTAX INTEGER { fcc(16), doc(32), etsi(48), spain (49), france(50),
                         mkk (64) }
```

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```
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "There are different operational requirements dependent on
            the regulatory domain.  This attribute list describes the
            regulatory domains the PLCP and PMD support in this
            implementation.  Currently defined values and their
            corresponding Regulatory Domains are:

            FCC (USA) = X'10', DOC (Canada) = X'20', ETSI (most of
            Europe) = X'30', Spain = X'31', France = X'32', MKK
            (Japan) = X'40' "
    ::= { dot11RegDomainsSupportedEntry 2 }

-- ****************************************************************
-- *    End of dot11RegDomainsSupported  TABLE
-- ****************************************************************

-- ****************************************************************
-- *    dot11AntennasList  TABLE
-- ****************************************************************

dot11AntennasListTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11AntennasListEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
           "This table represents the list of antennae.  An antenna can be
           marked to be capable of transmitting, receiving, and/or for
           participation in receive diversity.  Each entry in this table
           represents a single antenna with its properties.  The maximum
           number of antennae that can be contained in this table is 255."
    ::= { dot11phy 8 }

dot11AntennasListEntry OBJECT-TYPE
        SYNTAX Dot11AntennasListEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An entry in the dot11AntennasListTable, representing the properties
            of a single antenna.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
        INDEX { ifIndex,
                dot11AntennaListIndex }
    ::= { dot11AntennasListTable 1 }

Dot11AntennasListEntry ::=
        SEQUENCE { dot11AntennaListIndex     Integer32,
                   dot11SupportedTxAntenna   TruthValue,
                   dot11SupportedRxAntenna   TruthValue,
                   dot11DiversitySelectionRx TruthValue }

dot11AntennaListIndex OBJECT-TYPE
        SYNTAX Integer32 (1..255)
        MAX-ACCESS not-accessible
        STATUS current
```


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```
        DESCRIPTION
           "The unique index of an antenna which is used to identify the columnar
            objects in the dot11AntennasList Table."
    ::= { dot11AntennasListEntry 1 }

dot11SupportedTxAntenna OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "When true, this object indicates that the antenna represented by
            dot11AntennaIndex can be used as a transmit antenna."
    ::= { dot11AntennasListEntry 2 }

dot11SupportedRxAntenna OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
           "When true, this object indicates that the antenna represented by the
            dot11AntennaIndex can be used as a receive antenna."
    ::= { dot11AntennasListEntry 3 }

dot11DiversitySelectionRx OBJECT-TYPE
        SYNTAX TruthValue
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "When true, this object indicates that the antenna represented by
            dot11AntennaIndex can be used for receive diversity.  This object
            may only be true if the antenna can be used as a receive antenna,
            as indicated by dot11SupportedRxAntenna."
    ::= { dot11AntennasListEntry 4 }

-- ****************************************************************
-- *    End of dot11AntennasList  TABLE
-- ****************************************************************

-- ****************************************************************
-- *    SupportedDataRatesTx  TABLE
-- ****************************************************************

dot11SupportedDataRatesTxTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11SupportedDataRatesTxEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "The Transmit bit rates supported by the PLCP and PMD,
            represented by a count from X'02-X'7f, corresponding to data
            rates in increments of 500kbit/s from 1 Mbit/s to 63.5 Mbit/s subject
            to limitations of each individual PHY."
    ::= { dot11phy 9 }

dot11SupportedDataRatesTxEntry OBJECT-TYPE
        SYNTAX Dot11SupportedDataRatesTxEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An Entry (conceptual row) in the dot11SupportedDataRatesTx
```

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```
            Table.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
        INDEX { ifIndex,
                dot11SupportedDataRatesTxIndex }
    ::= { dot11SupportedDataRatesTxTable  1 }

Dot11SupportedDataRatesTxEntry ::=
        SEQUENCE { dot11SupportedDataRatesTxIndex  Integer32,
                   dot11SupportedDataRatesTxValue  Integer32 }

dot11SupportedDataRatesTxIndex OBJECT-TYPE
        SYNTAX Integer32 (1..8)
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "Index object which identifies which data rate to access.
            Range is 1..8."
    ::= { dot11SupportedDataRatesTxEntry 1 }

dot11SupportedDataRatesTxValue OBJECT-TYPE
        SYNTAX Integer32 (2..127)
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "The Transmit bit rates supported by the PLCP and PMD,
            represented by a count from X'02-X'7f, corresponding to data
            rates in increments of 500kbit/s from 1 Mbit/s to 63.5 Mbit/s subject
            to limitations of each individual PHY."
    ::= { dot11SupportedDataRatesTxEntry 2 }

-- ****************************************************************
-- *    End of dot11SupportedDataRatesTx  TABLE
-- ****************************************************************

-- ****************************************************************
-- *    SupportedDataRatesRx  TABLE
-- ****************************************************************

dot11SupportedDataRatesRxTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11SupportedDataRatesRxEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "The receive bit rates supported by the PLCP and PMD,
            represented by a count from X'002-X'7f, corresponding to data
            rates in increments of 500kbit/s from 1 Mbit/s to 63.5 Mbit/s."
    ::= { dot11phy 10 }

dot11SupportedDataRatesRxEntry OBJECT-TYPE
        SYNTAX Dot11SupportedDataRatesRxEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An Entry (conceptual row) in the dot11SupportedDataRatesRx Table.

            ifIndex - Each IEEE 802.11 interface is represented by an
```


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```
            ifEntry.  Interface tables in this MIB module are indexed
            by ifIndex."
        INDEX { ifIndex,
                dot11SupportedDataRatesRxIndex }
    ::= { dot11SupportedDataRatesRxTable  1 }

Dot11SupportedDataRatesRxEntry ::=
        SEQUENCE { dot11SupportedDataRatesRxIndex  Integer32,
                   dot11SupportedDataRatesRxValue  Integer32 }

dot11SupportedDataRatesRxIndex OBJECT-TYPE
        SYNTAX Integer32 (1..8)
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "Index object which identifies which data rate to access.
            Range is 1..8."
    ::= { dot11SupportedDataRatesRxEntry 1 }

dot11SupportedDataRatesRxValue OBJECT-TYPE
        SYNTAX Integer32 (2..127)
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "The receive bit rates supported by the PLCP and PMD,
            represented by a count from X'02-X'7f, corresponding to data
            rates in increments of 500kbit/s from 1 Mbit/s to 63.5 Mbit/s."
    ::= { dot11SupportedDataRatesRxEntry 2 }

-- ****************************************************************
-- *    End of dot11SupportedDataRatesRx  TABLE
-- ****************************************************************

--****************************************************************
-- * dot11PhyOFDM TABLE
--****************************************************************

dot11PhyOFDMTable OBJECT-TYPE
        SYNTAX SEQUENCE OF Dot11PhyOFDMEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "Group of attributes for dot11PhyOFDMTable. Implemented as a
            table indexed on ifindex to allow for multiple instances on
            an Agent."
    ::= { dot11phy 11 }

dot11PhyOFDMEntry OBJECT-TYPE
        SYNTAX Dot11PhyOFDMEntry
        MAX-ACCESS not-accessible
        STATUS current
        DESCRIPTION
            "An entry in the dot11PhyOFDM Table.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry. Interface tables in this MIB module are indexed
            by ifIndex."
        INDEX { ifIndex }
    ::= { dot11PhyOFDMTable 1 }
```

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```
Dot11PhyOFDMEntry ::=
        SEQUENCE { dot11CurrentFrequency        INTEGER,
                   dot11TIThreshold             Integer32,
                   dot11FrequencyBandsSupported INTEGER }

dot11CurrentFrequency OBJECT-TYPE
        SYNTAX INTEGER (0..200)
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
            "The number of the current operating frequency channel of the OFDM
            PHY."
    ::= { dot11PhyOFDMEntry 1 }

dot11TIThreshold OBJECT-TYPE
        SYNTAX Integer32
        MAX-ACCESS read-write
        STATUS current
        DESCRIPTION
             "The Threshold being used to detect a busy medium (frequency).
             CCA shall report a busy medium upon detecting the RSSI above
            this threshold."
    ::= { dot11PhyOFDMEntry 2 }

dot11FrequencyBandsSupported OBJECT-TYPE
        SYNTAX INTEGER (1..7)
        MAX-ACCESS read-only
        STATUS current
        DESCRIPTION
            "The capability of the OFDM PHY implementation to operate in
            the three U-NII bands. Coded as an integer value of a three
            bit field as follows:
                 bit 0 .. capable of operating in the lower (5.15-5.25 GHz)
                     U-NII band
                 bit 1 .. capable of operating in the middle (5.25-5.35 GHz)
                     U-NII band
                 bit 2 .. capable of operating in the upper (5.725-5.825 GHz)
                     U-NII band
            For example, for an implementation capable of operating in the
            lower and mid bands this attribute would take the value 3."
    ::= { dot11PhyOFDMEntry 3 }

-- ************************************************************************
-- * End of dot11PhyOFDM TABLE
-- ************************************************************************

-- ************************************************************************
-- *   dot11PhyHRDSSSEntry TABLE
-- ************************************************************************

dot11PhyHRDSSSTable OBJECT-TYPE
       SYNTAX SEQUENCE OF Dot11PhyHRDSSSEntry
       MAX-ACCESS not-accessible
       STATUS current
       DESCRIPTION
            "Entry of attributes for dot11PhyHRDSSSEntry.
            Implemented as a table indexed on ifIndex to allow for
            multiple instances on an Agent."
```


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```
    ::= { dot11phy 12 }

dot11PhyHRDSSSEntry OBJECT-TYPE
       SYNTAX Dot11PhyHRDSSSEntry
       MAX-ACCESS not-accessible
       STATUS current
       DESCRIPTION
            "An entry in the dot11PhyHRDSSSEntry Table.

            ifIndex - Each IEEE 802.11 interface is represented by an
            ifEntry. Interface tables in this MIB module are indexed
            by ifIndex."
       INDEX { ifIndex }
    ::= { dot11PhyHRDSSSTable 1 }

Dot11PhyHRDSSSEntry ::=
        SEQUENCE { dot11ShortPreambleOptionImplemented      TruthValue,
                   dot11PBCCOptionImplemented               TruthValue,
                   dot11ChannelAgilityPresent               TruthValue,
                   dot11ChannelAgilityEnabled               TruthValue,
                   dot11HRCCAModeSupported                  INTEGER }

dot11ShortPreambleOptionImplemented OBJECT-TYPE
       SYNTAX TruthValue
       MAX-ACCESS read-only
       STATUS current
       DESCRIPTION
            "This attribute, when true, shall indicate that the
            short preamble option as defined in subclause 18.2.2.2
            is implemented.  The default value of this attribute
            shall be false."
    ::= { dot11PhyHRDSSSEntry 1 }

dot11PBCCOptionImplemented OBJECT-TYPE
       SYNTAX TruthValue
       MAX-ACCESS read-only
       STATUS current
       DESCRIPTION
            "This attribute, when true, shall indicate that the PBCC
            modulation option as defined in subclause 18.4.6.6 is
            implemented.  The default value of this attribute shall
            be false."
    ::= { dot11PhyHRDSSSEntry 2 }

dot11ChannelAgilityPresent OBJECT-TYPE
       SYNTAX TruthValue
       MAX-ACCESS read-only
       STATUS current
       DESCRIPTION
            "This attribute indicates that the PHY is capable of
            channel agility."
    ::= { dot11PhyHRDSSSEntry 3 }

dot11ChannelAgilityEnabled OBJECT-TYPE
       SYNTAX TruthValue
       MAX-ACCESS read-only
       STATUS current
       DESCRIPTION
            "This attribute indicates that the PHY channel agility
```

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```
            functionality is enabled."
    ::= { dot11PhyHRDSSSEntry 4 }

dot11HRCCAModeSupported OBJECT-TYPE
       SYNTAX INTEGER (1..31)
       MAX-ACCESS read-only
       STATUS current
       DESCRIPTION
            "dot11HRCCAModeSupported is a bit-significant value,
            representing all of the CCA modes supported by the PHY.
            Valid values are:
                  energy detect only (ED_ONLY) = 01,
                  carrier sense only (CS_ONLY) = 02,
                  carrier sense and energy detect (ED_and_CS)= 04,
                  carrier sense with timer (CS_and_Timer)= 08,
                  high rate carrier sense and energy detect
                     (HRCS_and_ED)= 16
            or the logical sum of any of these values.  In
            the high rate extension PHY, this attribute shall
            be used in preference to the dot11CCAModeSupported
            attribute."
    ::= { dot11PhyHRDSSSEntry 5 }

-- ****************************************************************
-- * End of dot11PhyHRDSSSEntry TABLE
-- ****************************************************************

-- ****************************************************************
-- * dot11 Hopping Pattern TABLE
-- ****************************************************************

dot11HoppingPatternTable OBJECT-TYPE
       SYNTAX SEQUENCE OF Dot11HoppingPatternEntry
       MAX-ACCESS not-accessible
       STATUS current
       DESCRIPTION
            "The (conceptual) table of attributes necessary for
            a frequency hopping implementation to be able to
            create the hopping sequences necessary to operate
            in the subband for the associated domain country string."
    ::= { dot11phy 13 }

dot11HoppingPatternEntry OBJECT-TYPE
       SYNTAX Dot11HoppingPatternEntry
       MAX-ACCESS not-accessible
       STATUS current
       DESCRIPTION
            "An entry (conceptual row) in the Hopping Pattern Table
            that indicates the random hopping sequence to be followed.

            IfIndex - Each IEEE 802.11 interface is represented
            by an ifEntry. Interface tables in this MIB are indexed
            by ifIndex."
       INDEX { ifIndex,
                dot11HoppingPatternIndex }
    ::= { dot11HoppingPatternTable 1 }
```


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```
Dot11HoppingPatternEntry ::=
            SEQUENCE { dot11HoppingPatternIndex      Integer32,
                       dot11RandomTableFieldNumber   Integer32 }

dot11HoppingPatternIndex OBJECT-TYPE
       SYNTAX Integer32
       MAX-ACCESS not-accessible
       STATUS current
       DESCRIPTION
            "The auxiliary variable used to identify instances of
            the columnar objects in the Hopping Pattern Table."
    ::= { dot11HoppingPatternEntry 1 }

dot11RandomTableFieldNumber OBJECT-TYPE
       SYNTAX Integer32
       MAX-ACCESS read-write
       STATUS current
       DESCRIPTION
            "This attribute shall indicate the value of the
            starting channel number in the hopping sequence of
            the subband for the associated domain country string.
            The default value of this attribute shall be zero."
    ::= { dot11HoppingPatternEntry 2 }

-- ****************************************************************
-- * End of dot11 Hopping Pattern TABLE
-- ****************************************************************

-- ****************************************************************
-- * Conformance Information
-- ****************************************************************

dot11Conformance    OBJECT IDENTIFIER ::= { ieee802dot11 5 }
dot11Groups         OBJECT IDENTIFIER ::= { dot11Conformance 1 }
dot11Compliances    OBJECT IDENTIFIER ::= { dot11Conformance 2 }

-- ****************************************************************
-- * Compliance Statements
-- ****************************************************************

dot11Compliance MODULE-COMPLIANCE
        STATUS  current
        DESCRIPTION
            "The compliance statement for SNMPv2 entities
            that implement the IEEE 802.11 MIB."
       MODULE  -- this module
       MANDATORY-GROUPS {
              dot11SMTbase2,
              dot11MACbase, dot11CountersGroup,
              dot11SmtAuthenticationAlgorithms,
              dot11ResourceTypeID, dot11PhyOperationComplianceGroup }

   GROUP dot11PhyDSSSComplianceGroup
        DESCRIPTION
           "Implementation of this group is required when object
           dot11PHYType has the value of dsss.  This group is
           mutually exclusive with the groups dot11PhyIRComplianceGroup,
           dot11PhyFHSSComplianceGroup, dot11PhyOFDMComplianceGroup
           and dot11PhyHRDSSSComplianceGroup."
```

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```
    GROUP dot11PhyIRComplianceGroup
        DESCRIPTION
            "Implementation of this group is required when object
            dot11PHYType has the value of irbaseband.  This group is
            mutually exclusive with the groups dot11PhyDSSSComplianceGroup,
            dot11PhyFHSSComplianceGroup, dot11PhyOFDMComplianceGroup
            and dot11PhyHRDSSSComplianceGroup."

    GROUP dot11PhyFHSSComplianceGroup
        DESCRIPTION
            "Implementation of this group is required when object
            dot11PHYType has the value of fhss.  This group is
            mutually exclusive with the groups dot11PhyDSSSComplianceGroup,
            dot11PhyIRComplianceGroup, dot11PhyOFDMComplianceGroup
            and dot11PhyHRDSSSComplianceGroup."

    GROUP dot11PhyOFDMComplianceGroup
        DESCRIPTION
            "Implementation of this group is required when object
            dot11PHYType has the value of ofdm. This group is
            mutually exclusive with the groups dot11PhyDSSSComplianceGroup,
            dot11PhyIRComplianceGroup, dot11PhyFHSSComplianceGroup
            and dot11PhyHRDSSSComplianceGroup."

    GROUP dot11PhyHRDSSSComplianceGroup
        DESCRIPTION
            "Implementation of this group is required when object
            dot11PHYType has the value of hrdsss. This group is
            mutually exclusive with the groups
            dot11PhyDSSSComplianceGroup, dot11PhyIRComplianceGroup,
            dot11PhyFHSSComplianceGroup and dot11PhyOFDMComplianceGroup."

    -- OPTIONAL-GROUPS { dot11SMTprivacy, dot11MACStatistics,
    --    dot11PhyAntennaComplianceGroup, dot11PhyTxPowerComplianceGroup,
    --    dot11PhyRegDomainsSupportGroup,
    --    dot11PhyAntennasListGroup, dot11PhyRateGroup,
    --    dot11SMTbase3, dot11MultiDomainCapabilityGroup,
    --    dot11PhyFHSSComplianceGroup2 }
    --

    ::= { dot11Compliances 1 }

-- ****************************************************************
-- *   Groups - units of conformance
-- ****************************************************************

dot11SMTbase OBJECT-GROUP
       OBJECTS { dot11StationID, dot11MediumOccupancyLimit,
                 dot11CFPollable,
                 dot11CFPPeriod,
                 dot11CFPMaxDuration,
                 dot11AuthenticationResponseTimeOut,
                 dot11PrivacyOptionImplemented,
                 dot11PowerManagementMode,
                 dot11DesiredSSID, dot11DesiredBSSType,
                 dot11OperationalRateSet,
                 dot11BeaconPeriod, dot11DTIMPeriod,
                 dot11AssociationResponseTimeOut }
```


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```
        STATUS deprecated
        DESCRIPTION
            "The SMT object class provides the necessary support at the
            STA to manage the processes in the STA such that the STA may
            work cooperatively as a part of an IEEE 802.11 network."
    ::= { dot11Groups 1 }

dot11SMTprivacy OBJECT-GROUP
       OBJECTS { dot11PrivacyInvoked,
                 dot11WEPKeyMappingLength, dot11ExcludeUnencrypted,
                 dot11WEPICVErrorCount , dot11WEPExcludedCount ,
                 dot11WEPDefaultKeyID,
                 dot11WEPDefaultKeyValue,
                 dot11WEPKeyMappingWEPOn,
                 dot11WEPKeyMappingValue , dot11WEPKeyMappingAddress,
                 dot11WEPKeyMappingStatus }
        STATUS current
        DESCRIPTION
            "The SMTPrivacy package is a set of attributes that shall be
            present if WEP is implemented in the STA."
    ::= { dot11Groups 2 }

dot11MACbase OBJECT-GROUP
       OBJECTS { dot11MACAddress, dot11Address,
                 dot11GroupAddressesStatus,
                 dot11RTSThreshold, dot11ShortRetryLimit,
                 dot11LongRetryLimit, dot11FragmentationThreshold,
                 dot11MaxTransmitMSDULifetime,
                 dot11MaxReceiveLifetime, dot11ManufacturerID,
                 dot11ProductID }
        STATUS current
        DESCRIPTION
            "The MAC object class provides the necessary support for the
            access control, generation, and verification of frame check
            sequences (FCSs), and proper delivery of valid data to upper
            layers."
    ::= { dot11Groups 3 }

dot11MACStatistics OBJECT-GROUP
       OBJECTS { dot11RetryCount, dot11MultipleRetryCount,
                 dot11RTSSuccessCount, dot11RTSFailureCount,
                 dot11ACKFailureCount, dot11FrameDuplicateCount }
        STATUS current
        DESCRIPTION
            "The MACStatistics package provides extended statistical
            information on the operation of the MAC.  This
            package is completely optional."
    ::= { dot11Groups 4 }

dot11ResourceTypeID OBJECT-GROUP
       OBJECTS { dot11ResourceTypeIDName, dot11manufacturerOUI,
                 dot11manufacturerName, dot11manufacturerProductName,
                 dot11manufacturerProductVersion }
        STATUS current
        DESCRIPTION
            "Attributes used to identify a STA, its manufacturer,
            and various product names and versions."
    ::= { dot11Groups 5 }
```

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```
dot11SmtAuthenticationAlgorithms OBJECT-GROUP
       OBJECTS { dot11AuthenticationAlgorithm,
                 dot11AuthenticationAlgorithmsEnable }
        STATUS current
        DESCRIPTION
            "Authentication Algorithm Table."
    ::= { dot11Groups 6 }

dot11PhyOperationComplianceGroup OBJECT-GROUP
       OBJECTS { dot11PHYType, dot11CurrentRegDomain, dot11TempType }
        STATUS current
        DESCRIPTION
            "PHY layer operations attributes."
    ::= { dot11Groups 7 }

dot11PhyAntennaComplianceGroup OBJECT-GROUP
       OBJECTS { dot11CurrentTxAntenna, dot11DiversitySupport,
                 dot11CurrentRxAntenna }
        STATUS current
        DESCRIPTION
            "Attributes for Data Rates for IEEE 802.11."
    ::= { dot11Groups 8 }

dot11PhyTxPowerComplianceGroup OBJECT-GROUP
       OBJECTS { dot11NumberSupportedPowerLevels, dot11TxPowerLevel1,
                 dot11TxPowerLevel2, dot11TxPowerLevel3, dot11TxPowerLevel4,
                 dot11TxPowerLevel5, dot11TxPowerLevel6, dot11TxPowerLevel7,
                 dot11TxPowerLevel8, dot11CurrentTxPowerLevel }
        STATUS current
        DESCRIPTION
            "Attributes for Control and Management of transmit power."
    ::= { dot11Groups 9 }

dot11PhyFHSSComplianceGroup OBJECT-GROUP
       OBJECTS { dot11HopTime, dot11CurrentChannelNumber, dot11MaxDwellTime,
                 dot11CurrentDwellTime, dot11CurrentSet, dot11CurrentPattern,
                 dot11CurrentIndex }
        STATUS current
        DESCRIPTION
            "Attributes that configure the Frequency Hopping for IEEE
            802.11."
    ::= { dot11Groups 10 }

dot11PhyDSSSComplianceGroup OBJECT-GROUP
       OBJECTS { dot11CurrentChannel, dot11CCAModeSupported,
                 dot11CurrentCCAMode, dot11EDThreshold }
        STATUS current
        DESCRIPTION
            "Attributes that configure the DSSS for IEEE 802.11."
    ::= { dot11Groups 11 }

dot11PhyIRComplianceGroup OBJECT-GROUP
       OBJECTS { dot11CCAWatchdogTimerMax, dot11CCAWatchdogCountMax,
                 dot11CCAWatchdogTimerMin, dot11CCAWatchdogCountMin }
        STATUS current
        DESCRIPTION
            "Attributes that configure the baseband IR for IEEE 802.11."
    ::= { dot11Groups 12 }
```


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```
dot11PhyRegDomainsSupportGroup OBJECT-GROUP
        OBJECTS { dot11RegDomainsSupportedTable }
        STATUS current
        DESCRIPTION
            "Attributes that specify the supported Regulation Domains."
    ::= { dot11Groups 13 }

dot11PhyAntennasListGroup OBJECT-GROUP
       OBJECTS { dot11SupportedTxAntenna,
                 dot11SupportedRxAntenna, dot11DiversitySelectionRx }
        STATUS current
        DESCRIPTION
            "Attributes that specify the supported Regulation Domains."
    ::= { dot11Groups 14 }

dot11PhyRateGroup OBJECT-GROUP
       OBJECTS { dot11SupportedDataRatesTxValue,
                 dot11SupportedDataRatesRxValue }
        STATUS current
        DESCRIPTION
            "Attributes for Data Rates for IEEE 802.11."
    ::= { dot11Groups 15 }

dot11CountersGroup OBJECT-GROUP
       OBJECTS { dot11TransmittedFragmentCount,
                 dot11MulticastTransmittedFrameCount,
                 dot11FailedCount, dot11ReceivedFragmentCount,
                 dot11MulticastReceivedFrameCount,
                 dot11FCSErrorCount,
                 dot11WEPUndecryptableCount,
                 dot11TransmittedFrameCount }
        STATUS current
        DESCRIPTION
            "Attributes from the dot11CountersGroup that are not described
            in the dot11MACStatistics group.  These objects are
            mandatory."
    ::= { dot11Groups 16 }

dot11NotificationGroup NOTIFICATION-GROUP
       NOTIFICATIONS { dot11Disassociate,
                       dot11Deauthenticate,
                       dot11AuthenticateFail }
       STATUS current
       DESCRIPTION
            "IEEE 802.11 notifications"
     ::= { dot11Groups 17 }

dot11SMTbase2 OBJECT-GROUP
       OBJECTS { dot11MediumOccupancyLimit,
                 dot11CFPollable,
                 dot11CFPPeriod,
                 dot11CFPMaxDuration,
                 dot11AuthenticationResponseTimeOut,
                 dot11PrivacyOptionImplemented,
                 dot11PowerManagementMode,
                 dot11DesiredSSID, dot11DesiredBSSType,
                 dot11OperationalRateSet,
                 dot11BeaconPeriod, dot11DTIMPeriod,
                 dot11AssociationResponseTimeOut,
```

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```
                dot11DisassociateReason,
                dot11DisassociateStation,
                dot11DeauthenticateReason,
                dot11DeauthenticateStation,
                dot11AuthenticateFailStatus,
                dot11AuthenticateFailStation }
        STATUS current
        DESCRIPTION
            "The SMTbase2 object class provides the necessary support at the
            STA to manage the processes in the STA such that the STA may
            work cooperatively as a part of an IEEE 802.11 network."
    ::= { dot11Groups 18 }

dot11PhyOFDMComplianceGroup OBJECT-GROUP
       OBJECTS { dot11CurrentFrequency,
                 dot11TIThreshold,
                 dot11FrequencyBandsSupported }
        STATUS current
        DESCRIPTION
            "Attributes that configure the OFDM for IEEE 802.11."
    ::= { dot11Groups 19 }

dot11SMTbase3 OBJECT-GROUP
       OBJECTS { dot11MediumOccupancyLimit,
                 dot11CFPollable,
                 dot11CFPPeriod,
                 dot11CFPMaxDuration,
                 dot11AuthenticationResponseTimeOut,
                 dot11PrivacyOptionImplemented,
                 dot11PowerManagementMode,
                 dot11DesiredSSID, dot11DesiredBSSType,
                 dot11OperationalRateSet,
                 dot11BeaconPeriod, dot11DTIMPeriod,
                 dot11AssociationResponseTimeOut,
                 dot11DisassociateReason,
                 dot11DisassociateStation,
                 dot11DeauthenticateReason,
                 dot11DeauthenticateStation,
                 dot11AuthenticateFailStatus,
                 dot11AuthenticateFailStation,
                 dot11MultiDomainCapabilityImplemented,
                 dot11MultiDomainCapabilityEnabled,
                 dot11CountryString }
        STATUS current
        DESCRIPTION
            "The SMTbase3 object class provides the necessary support at the
            STA to manage the processes in the STA such that the STA may
            work cooperatively as a part of an IEEE 802.11 network, when the STA
            is capable of multi-domain operation. This object group should be
            implemented when the multi-domain capability option is implemented."
    ::= { dot11Groups 20 }

dot11MultiDomainCapabilityGroup OBJECT-GROUP
       OBJECTS { dot11FirstChannelNumber,
                 dot11NumberofChannels,
                 dot11MaximumTransmitPowerLevel }
       STATUS current
       DESCRIPTION
            "The dot11MultiDomainCapabilityGroup object class provides
```


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```
            the objects necessary to manage the channels usable by a STA,
            when the multi-domain capability option is implemented."
     ::= { dot11Groups 21 }

dot11PhyFHSSComplianceGroup2 OBJECT-GROUP
       OBJECTS { dot11HopTime, dot11CurrentChannelNumber, dot11MaxDwellTime,
                 dot11CurrentDwellTime, dot11CurrentSet, dot11CurrentPattern,
                 dot11CurrentIndex, dot11EHCCPrimeRadix,
                 dot11EHCCNumberofChannelsFamilyIndex,
                 dot11EHCCCapabilityImplemented, dot11EHCCCapabilityEnabled,
                 dot11HopAlgorithmAdopted, dot11RandomTableFlag,
                 dot11NumberofHoppingSets, dot11HopModulus,
                 dot11HopOffset, dot11RandomTableFieldNumber }
        STATUS current
        DESCRIPTION
            "Attributes that configure the Frequency Hopping for IEEE
            802.11 when multi-domain capability option is implemented."
    ::= { dot11Groups 22 }

dot11PhyHRDSSSComplianceGroup OBJECT-GROUP
       OBJECTS { dot11CurrentChannel, dot11CCAModeSupported,
                 dot11CurrentCCAMode, dot11EDThreshold,
                 dot11ShortPreambleOptionImplemented,
                 dot11PBCCOptionImplemented, dot11ChannelAgilityPresent,
                 dot11ChannelAgilityEnabled, dot11HRCCAModeSupported }
        STATUS current
        DESCRIPTION
           "Attributes that configure the HRDSSS for IEEE 802.11."
    ::= { dot11Groups 23 }

-- ****************************************************************
-- *   End of 802.11 MIB
-- ****************************************************************

END
```

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Annex E

(informative)

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E.1 General

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[B3] Engwer, D., and Zweig, J., "Algorithmically Derived Hop Sequences," submission 99/195 to the IEEE P802.11 Working Group, Sept. 1999.

[B4] ETS 300-328/A1 ed.2 (1997-07), Radio Equipment and Systems (RES); Wideband transmission systems; Technical characteristics and test conditions for data transmission equipment operating in the 2,4 GHz ISM band and using spread spectrum modulation techniques.[12]

[B5] ETS 300-339 V1.1.1 (1998-06), Electromagnetic compatibility and Radio spectrum Matters (ERM); General ElectroMagnetic Compatibility (EMC) for radio communications equipment.

[B6] FCC CFR47, Title 47 of the Code of Federal Regulations, Federal Communication Commission, October 2001.[13]

[B7] IC GL-36, Technical Requirements for Low Power Devices in the 2400–2483.5 MHz Band, Industry Canada (IC), August 1999.[14]

[B8] IEC 60825-1:1993, Safety of laser products—Part 1: Equipment classification, requirements and user's guide.[15]

[B9] IEEE Std 802.10-1998, IEEE Standards for Local and Metropolitan Area Networks: Interoperable LAN/MAN Security (SILS).[16, 17]

[B10] Maric, S. V., and Titlebaum, E. L., "A Class of Frequency Hop Codes with Nearly Ideal Characteristics for Use in Multiple-Access Spread-Spectrum Communications and Radar and Sonar Systems," *IEEE Transactions on Communications*, vol. 40, no. 9, pp. 1442-1447, Sept. 1992.

[10]ANSI publications are available from the Sales Department, American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).

[11]ARIB publications are available from the Association of Radio Industries and Businesses (www.arib.or.jp)

[12]ETSI publications are available from the European Telecommunications Standards Institute (www.etsi.org).

[13]FCC publications are available from the Government Printing Office (GPO, www.gpo.gov). Updates are published in the FCC Register (also published by the GPO) and are available online (www.fcc.gov).

[14]IC publications are available from Industry Canada (www.strategic.ic.gc.ca).

[15]IEC publications are available from the Sales Department of the International Electrotechnical Commission, Case Postale 131, 3, rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (http://www.iec.ch/). IEC publications are also available in the United States from the Sales Department, American National Standards Institute, 11 West 42nd Street, 13th Floor, New York, NY 10036, USA.

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[B15] Olsen, A., Faergemand, O., Moller-Pedersen, B., Reed, R., and Smith, T. R. W., *Systems Engineering Using SDL-92.* Amsterdam, the Netherlands: Elsevier Science B.V., 1994.[21]

[18]An introductory text on SDL, also useful as a language reference (for SDL-88).

[19]A recently published book, which appears to be the most comprehensive single-volume introduction and reference for SDL-92, including its object-oriented extensions.

[20]This provides a summary of the changes from SDL-88 to SDL-92.

[21]A detailed guide to using SDL-92, including a thorough explanation of abstract data type mechanism and SDL combined with ASN.1 (ITU-T Recommendation Z.105).

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Annex F

(informative)

High Rate PHY/FH interoperability

The Channel Agility option described in 18.4.6.7 provides for IEEE 802.11 FH PHY interoperability with the High Rate PHY. The FH patterns, as defined within this annex, enable synchronization with an FH-PHY-compliant BSS in North America and most of Europe. In addition, CCA requirements on a High Rate station using this mode provide for CCA detection of 1 MHz wide FH signals within the wideband DS channel selected. FH PHY stations operating in mixed mode FH/DS environments are advised to use similar cross PHY CCA mechanisms. The FH (Channel Agility) and cross CCA mechanisms provide the basic mechanisms to enable coexistence and interoperability.

The MAC elements include both DS and FH elements in beacons and probe responses when the Channel Agility option is turned on. Added capability fields indicate the ability to support the Channel Agility option and to indicate whether the option is turned on. These fields allow synchronization to the hopping sequence and timing, identification of what modes are being used within a BSS when joining on either High Rate or FHSS sides, and rejection of an association request in some cases.

Interoperability within an infrastructure BSS can be achieved, as an example, using a virtual dual AP. A virtual dual AP is defined, for purposes of discussion, as two logically separate APs that exist within a single physical AP with a single radio (one transmit and one receive path). Both FHSS and High Rate logical APs send out their own beacons, DTIMs, and other nondirected packets. The two sides interact in the sharing of the medium and the AP's processor and radio. Addressing and association issues may be handled in one of several ways and are left as an implementation choice.

Minimal interoperability with a nonhopping High Rate or legacy DSSS is provided by the use of a channel at least 1/7 or more of the time. While throughput would be significantly reduced by having a channel only 1/7 of the time, connection and minimal throughput can be provided.

F.1 Additional CCA recommendations

When the FH option is utilized, the HR/DSSS PHY should provide the CCA capability to detect 1 MHz wide FH PHY signals operating within the wideband DS channel at levels 10 dB higher than that specified in 18.4.8.4 for wideband HR/DSSS signals. This is in addition to the primary CCA requirements in 18.4.8.4. A timeout mechanism to avoid excessive deferral to constant CW or other non-IEEE 802.11 type signals is allowed.

FH PHY stations operating in mixed environments should provide similar CCA mechanisms to detect wideband DSSS signals at levels specified in 18.4.8.4, but measured within a 1 MHz bandwidth. Signal levels measured in a full DSSS channel will be generally 10 dB or higher.

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Annex G

(informative)

An example of encoding a frame for OFDM PHY

G.1 Introduction

The purpose of this annex is to show an example of encoding a frame for the OFDM PHY, as described in Clause 17. This example covers all the encoding details defined by the base standard.

The encoding illustration goes through the following stages:

a) Generating the short training sequence section of the preamble;
b) Generating the long preamble sequence section of the preamble;
c) Generating the SIGNAL field bits;
d) Coding and interleaving the SIGNAL field bits;
e) Mapping the SIGNAL field into frequency domain;
f) Pilot insertion;
g) Transforming into time domain;
h) Delineating the data octet stream into a bit stream;
i) Prepending the SERVICE field and adding the pad bits, thus forming the DATA;
j) Scrambling and zeroing the tail bits;
k) Encoding the DATA with a convolutional encoder and puncturing;
l) Mapping into complex 16-QAM symbols;
m) Pilot insertion;
n) Transforming from frequency to time and adding a circular prefix;
o) Concatenating the OFDM symbols into a single, time-domain signal.

In the description of time domain waveforms, a complex baseband signal at 20 Msample/s shall be used.

This example uses the 36 Mbit/s data rate and a message of 100 octets. These parameters are chosen in order to illustrate as many nontrivial aspects of the processing as possible.

a) Use of several bits per symbol (4 in this case);
b) Puncturing of the convolutional code;
c) Interleaving, which uses the LSB–MSB swapping stage;
d) Scrambling of the pilot subcarriers.

G.2 The message

The message being encoded consists of the first 72 characters of the well-known “Ode to Joy” by F. Schiller:

Joy, bright spark of divinity,
Daughter of Elysium,
Fire-insired we tread
Thy sanctuary.
Thy magic power re-unites
All that custom has divided,

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All men become brothers
Under the sway of thy gentle wings…

The message is converted to ASCII; then it is prepended with an appropriate MAC header and a CRC32 is added. The resulting 100 octets PSDU is shown in Table G.1.

Table G.1—The message

##	Val	Val	Val	Val	Val
1…5	04	02	00	2e	00
6…10	60	08	cd	37	a6
11…15	00	20	d6	01	3c
16…20	f1	00	60	08	ad
21…25	3b	af	00	00	4a
26…30	6f	79	2c	20	62
31…35	72	69	67	68	74
36…45	20	73	70	61	72
41…45	6b	20	6f	66	20
46…50	64	69	76	69	6e
51…55	69	74	79	2c	0a
56…60	44	61	75	67	68
61…55	74	65	72	20	6f
66…60	66	20	45	6c	79
71…55	73	69	75	6d	2c
76…60	0a	46	69	72	65
81…55	2d	69	6e	73	69
86…60	72	65	64	20	77
91…55	65	20	74	72	65
96…100	61	da	57	99	ed

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G.3 Generation of the preamble

G.3.1 Generation of the short sequences

The short sequences section of the preamble is described by its frequency domain representation, given in Table G.2.

Table G.2—Frequency domain representation of the short sequences

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
–32	0.0	0.0	–16	1.472	1.472	0	0.0	0.0	16	1.472	1.472
–31	0.0	0.0	–15	0.0	0.0	1	0.0	0.0	17	0.0	0.0
–30	0.0	0.0	–14	0.0	0.0	2	0.0	0.0	18	0.0	0.0
–29	0.0	0.0	–13	0.0	0.0	3	0.0	0.0	19	0.0	0.0
–28	0.0	0.0	–12	–1.472	–1.472	4	–1.472	–1.472	20	1.472	1.472
–27	0.0	0.0	–11	0.0	0.0	5	0.0	0.0	21	0.0	0.0
–26	0.0	0.0	–10	0.0	0.0	6	0.0	0.0	22	0.0	0.0
–25	0.0	0.0	–9	0.0	0.0	7	0.0	0.0	23	0.0	0.0
–24	1.472	1.472	–8	–1.472	–1.472	8	–1.472	–1.472	24	1.472	1.472
–23	0.0	0.0	–7	0.0	0.0	9	0.0	0.0	25	0.0	0.0
–22	0.0	0.0	–6	0.0	0.0	10	0.0	0.0	26	0.0	0.0
–21	0.0	0.0	–5	0.0	0.0	11	0.0	0.0	27	0.0	0.0
–20	–1.472	–1.472	–4	1.472	1.472	12	1.472	1.472	28	0.0	0.0
–19	0.0	0.0	–3	0.0	0.0	13	0.0	0.0	29	0.0	0.0
–18	0.0	0.0	–2	0.0	0.0	14	0.0	0.0	30	0.0	0.0
–17	0.0	0.0	–1	0.0	0.0	15	0.0	0.0	31	0.0	0.0

One period of the IFFT on the contents of Table G.2 is given in Table G.3.

Table G.3—One period of IFFT of the short sequences

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
0	0.046	0.046	1	–0.132	0.002	2	–0.013	–0.079	3	0.143	–0.013
4	0.092	0.000	5	0.143	–0.013	6	–0.013	–0.079	7	–0.132	0.002
8	0.046	0.046	9	0.002	–0.132	10	–0.079	–0.013	11	–0.013	0.143
12	0.000	0.092	13	–0.013	0.143	14	–0.079	–0.013	15	0.002	–0.132
16	0.046	0.046	17	–0.132	0.002	18	–0.013	–0.079	19	0.143	–0.013
20	0.092	0.000	21	0.143	–0.013	22	–0.013	–0.079	23	–0.132	0.002

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Table G.3—One period of IFFT of the short sequences *(continued)*

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
24	0.046	0.046	25	0.002	–0.132	26	–0.079	–0.013	27	–0.013	0.143
28	0.000	0.092	29	–0.013	0.143	30	–0.079	–0.013	31	0.002	–0.132
32	0.046	0.046	33	–0.132	0.002	34	–0.013	–0.079	35	0.143	–0.013
36	0.092	0.000	37	0.143	–0.013	38	–0.013	–0.079	39	–0.132	0.002
40	0.046	0.046	41	0.002	–0.132	42	–0.079	–0.013	43	–0.013	0.143
44	0.000	0.092	45	–0.013	0.143	46	–0.079	–0.013	47	0.002	–0.132
48	0.046	0.046	49	–0.132	0.002	50	–0.013	–0.079	51	0.143	–0.013
52	0.092	0.000	53	0.143	–0.013	54	–0.013	–0.079	55	–0.132	0.002
56	0.046	0.046	57	0.002	–0.132	58	–0.079	–0.013	59	–0.013	0.143
60	0.000	0.092	61	–0.013	0.143	62	–0.079	–0.013	63	0.002	–0.132

The single period of the short training sequence is extended periodically for 161 samples (about 8 μs), and then multiplied by the window function:

$$W(k) = \begin{bmatrix} 0.5 & k = 0 \\ 1 & 1 \le k \le 160 \\ 0.5 & k = 160 \end{bmatrix}$$

The last sample serves as an overlap with the following OFDM symbol. The 161 samples vector is shown in Table G.4. The time-windowing feature illustrated here is not part of the normative specifications.

Table G.4—Time domain representation of the short sequence

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
0	0.023	0.023	1	–0.132	0.002	2	–0.013	–0.079	3	0.143	–0.013
4	0.092	0.000	5	0.143	–0.013	6	–0.013	–0.079	7	–0.132	0.002
8	0.046	0.046	9	0.002	–0.132	10	–0.079	–0.013	11	–0.013	0.143
12	0.000	0.092	13	–0.013	0.143	14	–0.079	–0.013	15	0.002	–0.132
16	0.046	0.046	17	–0.132	0.002	18	–0.013	–0.079	19	0.143	–0.013
20	0.092	0.000	21	0.143	–0.013	22	–0.013	–0.079	23	–0.132	0.002
24	0.046	0.046	25	0.002	–0.132	26	–0.079	–0.013	27	–0.013	0.143
28	0.000	0.092	29	–0.013	0.143	30	–0.079	–0.013	31	0.002	–0.132
32	0.046	0.046	33	–0.132	0.002	34	–0.013	–0.079	35	0.143	–0.013
36	0.092	0.000	37	0.143	–0.013	38	–0.013	–0.079	39	–0.132	0.002
40	0.046	0.046	41	0.002	–0.132	42	–0.079	–0.013	43	–0.013	0.143

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Table G.4—Time domain representation of the short sequence *(continued)*

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
44	0.000	0.092	45	–0.013	0.143	46	–0.079	–0.013	47	0.002	–0.132
48	0.046	0.046	49	–0.132	0.002	50	–0.013	–0.079	51	0.143	–0.013
52	0.092	0.000	53	0.143	–0.013	54	–0.013	–0.079	55	–0.132	0.002
56	0.046	0.046	57	0.002	–0.132	58	–0.079	–0.013	59	–0.013	0.143
60	0.000	0.092	61	–0.013	0.143	62	–0.079	–0.013	63	0.002	–0.132
64	0.046	0.046	65	–0.132	0.002	66	–0.013	–0.079	67	0.143	–0.013
68	0.092	0.000	69	0.143	–0.013	70	–0.013	–0.079	71	–0.132	0.002
72	0.046	0.046	73	0.002	–0.132	74	–0.079	–0.013	75	–0.013	0.143
76	0.000	0.092	77	–0.013	0.143	78	–0.079	–0.013	79	0.002	–0.132
80	0.046	0.046	81	–0.132	0.002	82	–0.013	–0.079	83	0.143	–0.013
84	0.092	0.000	85	0.143	–0.013	86	–0.013	–0.079	87	–0.132	0.002
88	0.046	0.046	89	0.002	–0.132	90	–0.079	–0.013	91	–0.013	0.143
92	0.000	0.092	93	–0.013	0.143	94	–0.079	–0.013	95	0.002	–0.132
96	0.046	0.046	97	–0.132	0.002	98	–0.013	–0.079	99	0.143	–0.013
100	0.092	0.000	101	0.143	–0.013	102	–0.013	–0.079	103	–0.132	0.002
104	0.046	0.046	105	0.002	–0.132	106	–0.079	–0.013	107	–0.013	0.143
108	0.000	0.092	109	–0.013	0.143	110	–0.079	–0.013	111	0.002	–0.132
112	0.046	0.046	113	–0.132	0.002	114	–0.013	–0.079	115	0.143	–0.013
116	0.092	0.000	117	0.143	–0.013	118	–0.013	–0.079	119	–0.132	0.002
120	0.046	0.046	121	0.002	–0.132	122	–0.079	–0.013	123	–0.013	0.143
124	0.000	0.092	125	–0.013	0.143	126	–0.079	–0.013	127	0.002	–0.132
128	0.046	0.046	129	–0.132	0.002	130	–0.013	–0.079	131	0.143	–0.013
132	0.092	0.000	133	0.143	–0.013	134	–0.013	–0.079	135	–0.132	0.002
136	0.046	0.046	137	0.002	–0.132	138	–0.079	–0.013	139	–0.013	0.143
140	0.000	0.092	141	–0.013	0.143	142	–0.079	–0.013	143	0.002	–0.132
144	0.046	0.046	145	–0.132	0.002	146	–0.013	–0.079	147	0.143	–0.013
148	0.092	0.000	149	0.143	–0.013	150	–0.013	–0.079	151	–0.132	0.002
152	0.046	0.046	153	0.002	–0.132	154	–0.079	–0.013	155	–0.013	0.143
156	0.000	0.092	157	–0.013	0.143	158	–0.079	–0.013	159	0.002	–0.132
160	0.023	0.023									

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G.3.2 Generation of the long sequences

The frequency domain representation of the long training sequence part of the preamble is given in Table G.5.

Table G.5—Frequency domain representation of the long sequences

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
–32	0.000	0.000	-16	1.000	0.000	0	0.000	0.000	16	1.000	0.000
–31	0.000	0.000	-15	1.000	0.000	1	1.000	0.000	17	–1.000	0.000
–30	0.000	0.000	-14	1.000	0.000	2	–1.000	0.000	18	–1.000	0.000
–29	0.000	0.000	-13	1.000	0.000	3	–1.000	0.000	19	1.000	0.000
–28	0.000	0.000	-12	1.000	0.000	4	1.000	0.000	20	–1.000	0.000
–27	0.000	0.000	-11	–1.000	0.000	5	1.000	0.000	21	1.000	0.000
–26	1.000	0.000	-10	–1.000	0.000	6	–1.000	0.000	22	–1.000	0.000
–25	1.000	0.000	-9	1.000	0.000	7	1.000	0.000	23	1.000	0.000
–24	–1.000	0.000	-8	1.000	0.000	8	–1.000	0.000	24	1.000	0.000
–23	–1.000	0.000	-7	–1.000	0.000	9	1.000	0.000	25	1.000	0.000
–22	1.000	0.000	-6	1.000	0.000	10	–1.000	0.000	26	1.000	0.000
–21	1.000	0.000	-5	–1.000	0.000	11	–1.000	0.000	27	0.000	0.000
–20	–1.000	0.000	-4	1.000	0.000	12	–1.000	0.000	28	0.000	0.000
–19	1.000	0.000	-3	1.000	0.000	13	–1.000	0.000	29	0.000	0.000
–18	–1.000	0.000	-2	1.000	0.000	14	–1.000	0.000	30	0.000	0.000
–17	1.000	0.000	-1	1.000	0.000	15	1.000	0.000	31	0.000	0.000

The time domain representation is derived by performing IFFT on the contents of Table G.5, cyclically extending the result to get the cyclic prefix, and then multiplying with the window function given in G.3.1. The resulting 161 points vector is shown in Table G.6. The samples are appended to the short sequence section by overlapping and adding element 160 of Table G.4 to element 0 of Table G.6.

Table G.6—Time domain representation of the long sequence

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
0	–0.078	0.000	1	0.012	–0.098	2	0.092	–0.106	3	–0.092	–0.115
4	–0.003	–0.054	5	0.075	0.074	6	–0.127	0.021	7	–0.122	0.017
8	–0.035	0.151	9	–0.056	0.022	10	–0.060	–0.081	11	0.070	–0.014
12	0.082	–0.092	13	–0.131	–0.065	14	–0.057	–0.039	15	0.037	–0.098
16	0.062	0.062	17	0.119	0.004	18	–0.022	–0.161	19	0.059	0.015

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Table G.6—Time domain representation of the long sequence *(continued)*

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
20	0.024	0.059	21	–0.137	0.047	22	0.001	0.115	23	0.053	–0.004
24	0.098	0.026	25	–0.038	0.106	26	–0.115	0.055	27	0.060	0.088
28	0.021	–0.028	29	0.097	–0.083	30	0.040	0.111	31	–0.005	0.120
32	0.156	0.000	33	–0.005	–0.120	34	0.040	–0.111	35	0.097	0.083
36	0.021	0.028	37	0.060	–0.088	38	–0.115	–0.055	39	–0.038	–0.106
40	0.098	–0.026	41	0.053	0.004	42	0.001	–0.115	43	–0.137	–0.047
44	0.024	–0.059	45	0.059	–0.015	46	–0.022	0.161	47	0.119	–0.004
48	0.062	–0.062	49	0.037	0.098	50	–0.057	0.039	51	–0.131	0.065
52	0.082	0.092	53	0.070	0.014	54	–0.060	0.081	55	–0.056	–0.022
56	–0.035	–0.151	57	–0.122	–0.017	58	–0.127	–0.021	59	0.075	–0.074
60	–0.003	0.054	61	–0.092	0.115	62	0.092	0.106	63	0.012	0.098
64	–0.156	0.000	65	0.012	–0.098	66	0.092	–0.106	67	–0.092	–0.115
68	–0.003	–0.054	69	0.075	0.074	70	–0.127	0.021	71	–0.122	0.017
72	–0.035	0.151	73	–0.056	0.022	74	–0.060	–0.081	75	0.070	–0.014
76	0.082	–0.092	77	–0.131	–0.065	78	–0.057	–0.039	79	0.037	–0.098
80	0.062	0.062	81	0.119	0.004	82	–0.022	–0.161	83	0.059	0.015
84	0.024	0.059	85	–0.137	0.047	86	0.001	0.115	87	0.053	–0.004
88	0.098	0.026	89	–0.038	0.106	90	–0.115	0.055	91	0.060	0.088
92	0.021	–0.028	93	0.097	–0.083	94	0.040	0.111	95	–0.005	0.120
96	0.156	0.000	97	–0.005	–0.120	98	0.040	–0.111	99	0.097	0.083
100	0.021	0.028	101	0.060	–0.088	102	–0.115	–0.055	103	–0.038	–0.106
104	0.098	–0.026	105	0.053	0.004	106	0.001	–0.115	107	–0.137	–0.047
108	0.024	–0.059	109	0.059	–0.015	110	–0.022	0.161	111	0.119	–0.004
112	0.062	–0.062	113	0.037	0.098	114	–0.057	0.039	115	–0.131	0.065
116	0.082	0.092	117	0.070	0.014	118	–0.060	0.081	119	–0.056	–0.022
120	–0.035	–0.151	121	–0.122	–0.017	122	–0.127	–0.021	123	0.075	–0.074
124	–0.003	0.054	125	–0.092	0.115	126	0.092	0.106	127	0.012	0.098
128	–0.156	0.000	129	0.012	–0.098	130	0.092	–0.106	131	–0.092	–0.115
132	–0.003	–0.054	133	0.075	0.074	134	–0.127	0.021	135	–0.122	0.017
136	–0.035	0.151	137	–0.056	0.022	138	–0.060	–0.081	139	0.070	–0.014
140	0.082	–0.092	141	–0.131	–0.065	142	–0.057	–0.039	143	0.037	–0.098
144	0.062	0.062	145	0.119	0.004	146	–0.022	–0.161	147	0.059	0.015
148	0.024	0.059	149	–0.137	0.047	150	0.001	0.115	151	0.053	–0.004

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Table G.6—Time domain representation of the long sequence *(continued)*

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
152	0.098	0.026	153	–0.038	0.106	154	–0.115	0.055	155	0.060	0.088
156	0.021	–0.028	157	0.097	–0.083	158	0.040	0.111	159	–0.005	0.120
160	0.078	0									

G.4 Generation of the SIGNAL field

G.4.1 SIGNAL field bit assignment

The SIGNAL field bit assignment follows 17.3.4 and Figure 115. The transmitted bits are shown in Table G.7, where bit 0 is transmitted first.

Table G.7—Bit assignment for SIGNAL field

##	Bit	Meaning		##	Bit	Meaning
0	1	RATE: R1		12	0	—
1	0	RATE: R2		13	0	—
2	1	RATE: R3		14	0	—
3	1	RATE: R4		15	0	—
4	0	Reserved		16	0	LENGTH (MSB)
5	0	LENGTH (LSB)		17	0	Parity
6	0	—		18	0	SIGNAL TAIL
7	1	—		19	0	SIGNAL TAIL
8	0	—		20	0	SIGNAL TAIL
9	0	—		21	0	SIGNAL TAIL
10	1	—		22	0	SIGNAL TAIL
11	1	—		23	0	SIGNAL TAIL

G.4.2 Coding the SIGNAL field bits

The bits are encoded by the rate 1/2 convolutional encoder to yield the 48 bits given in Table G.8.

G.4.3 Interleaving the SIGNAL field bits

The encoded bits are interleaved according to the interleaver of 17.3.5.6. A detailed breakdown of the interleaving operation is described in G.7. The interleaved SIGNAL field bits are shown in Table G.9.

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Table G.8—SIGNAL field bits after encoding

##	Bit	##	Bit	##	Bit	##	Bit	##	Bit	##	Bit
0	1	8	1	16	0	24	0	32	0	40	0
1	1	9	0	17	0	25	0	33	1	41	0
2	0	10	1	18	0	26	1	34	1	42	0
3	1	11	0	19	0	27	1	35	1	43	0
4	0	12	0	20	0	28	1	36	0	44	0
5	0	13	0	21	0	29	1	37	0	45	0
6	0	14	0	22	1	30	1	38	0	46	0
7	1	15	1	23	0	31	0	39	0	47	0

Table G.9—SIGNAL field bits after interleaving

##	Bit	##	Bit	##	Bit	##	Bit	##	Bit	##	Bit
0	1	8	1	16	0	24	1	32	0	40	1
1	0	9	1	17	0	25	0	33	0	41	0
2	0	10	0	18	0	26	0	34	1	42	0
3	1	11	1	19	1	27	0	35	0	43	1
4	0	12	0	20	0	28	0	36	0	44	0
5	1	13	0	21	1	29	0	37	1	45	1
6	0	14	0	22	0	30	1	38	0	46	0
7	0	15	0	23	0	31	1	39	0	47	0

G.4.4 SIGNAL field frequency domain

The encoded and interleaved bits are BPSK modulated to yield the frequency domain representation given in Table G.10. Locations –21, –7, 7, and 21 are skipped and will be used for pilot insertion.

Table G.10—Frequency domain representation of SIGNAL field

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
–32	0.000	0.000	–16	1.000	0.000	0	0.000	0.000	16	–1.000	0.000
–31	0.000	0.000	–15	–1.000	0.000	1	1.000	0.000	17	–1.000	0.000
–30	0.000	0.000	–14	1.000	0.000	2	–1.000	0.000	18	1.000	0.000
–29	0.000	0.000	–13	–1.000	0.000	3	–1.000	0.000	19	–1.000	0.000
–28	0.000	0.000	–12	–1.000	0.000	4	–1.000	0.000	20	–1.000	0.000
–27	0.000	0.000	–11	–1.000	0.000	5	–1.000	0.000	21	X	X

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Table G.10—Frequency domain representation of SIGNAL field *(continued)*

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
–26	1.000	0.000	–10	–1.000	0.000	6	–1.000	0.000	22	1.000	0.000
–25	–1.000	0.000	–9	–1.000	0.000	7	X	X	23	–1.000	0.000
–24	–1.000	0.000	–8	–1.000	0.000	8	1.000	0.000	24	1.000	0.000
–23	1.000	0.000	–7	X	X	9	1.000	0.000	25	–1.000	0.000
–22	–1.000	0.000	–6	–1.000	0.000	10	–1.000	0.000	26	–1.000	0.000
–21	X	X	–5	1.000	0.000	11	–1.000	0.000	27	0.000	0.000
–20	1.000	0.000	–4	–1.000	0.000	12	1.000	0.000	28	0.000	0.000
–19	–1.000	0.000	–3	1.000	0.000	13	–1.000	0.000	29	0.000	0.000
–18	–1.000	0.000	–2	–1.000	0.000	14	–1.000	0.000	30	0.000	0.000
–17	1.000	0.000	–1	–1.000	0.000	15	1.000	0.000	31	0.000	0.000

Four pilot subcarriers are added by taking the values {1.0,1.0,1.0,-1.0}, multiplying them by the first element of sequence $p_{0...126}$, given in Equation (27) (in 17.3.5.9), and inserting them into location {–21, –7,7,21}, respectively. The resulting frequency domain values are given in Table G.11.

Table G.11—Frequency domain representation of SIGNAL field with pilots inserted

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
–32	0.000	0.000	–16	1.000	0.000	0	0.000	0.000	16	–1.000	0.000
–31	0.000	0.000	–15	–1.000	0.000	1	1.000	0.000	17	–1.000	0.000
–30	0.000	0.000	–14	1.000	0.000	2	–1.000	0.000	18	1.000	0.000
–29	0.000	0.000	–13	–1.000	0.000	3	–1.000	0.000	19	–1.000	0.000
–28	0.000	0.000	–12	–1.000	0.000	4	–1.000	0.000	20	–1.000	0.000
–27	0.000	0.000	–11	–1.000	0.000	5	–1.000	0.000	21	–1.000	0.000
–26	1.000	0.000	–10	–1.000	0.000	6	–1.000	0.000	22	1.000	0.000
–25	–1.000	0.000	–9	–1.000	0.000	7	1.000	0.000	23	–1.000	0.000
–24	–1.000	0.000	–8	–1.000	0.000	8	1.000	0.000	24	1.000	0.000
–23	1.000	0.000	–7	1.000	0.000	9	1.000	0.000	25	–1.000	0.000
–22	–1.000	0.000	–6	–1.000	0.000	10	–1.000	0.000	26	–1.000	0.000
–21	1.000	0.000	–5	1.000	0.000	11	–1.000	0.000	27	0.000	0.000
–20	1.000	0.000	–4	–1.000	0.000	12	1.000	0.000	28	0.000	0.000
–19	–1.000	0.000	–3	1.000	0.000	13	–1.000	0.000	29	0.000	0.000
–18	–1.000	0.000	–2	–1.000	0.000	14	–1.000	0.000	30	0.000	0.000
–17	1.000	0.000	–1	–1.000	0.000	15	1.000	0.000	31	0.000	0.000

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G.4.5 SIGNAL field time domain

The time domain representation is derived by performing IFFT on the contents of Table G.11, extending cyclically, and multiplying by the window function

$$W(k) = \begin{bmatrix} 0.5 & k = 0 \\ 1 & 1 \le k \le 80 \\ 0.5 & k = 80 \end{bmatrix}$$

The resulting 81 samples vector is shown in Table G.12. Note that the time-windowing feature illustrated here is not a part of the normative specifications.

Table G.12—Time domain representation of SIGNAL field

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
0	0.031	0.000	1	0.033	–0.044	2	–0.002	–0.038	3	–0.081	0.084
4	0.007	–0.100	5	–0.001	–0.113	6	–0.021	–0.005	7	0.136	–0.105
8	0.098	–0.044	9	0.011	–0.002	10	–0.033	0.044	11	–0.060	0.124
12	0.010	0.097	13	0.000	–0.008	14	0.018	–0.083	15	–0.069	0.027
16	–0.219	0.000	17	–0.069	–0.027	18	0.018	0.083	19	0.000	0.008
20	0.010	–0.097	21	–0.060	–0.124	22	–0.033	–0.044	23	0.011	0.002
24	0.098	0.044	25	0.136	0.105	26	–0.021	0.005	27	–0.001	0.113
28	0.007	0.100	29	–0.081	–0.084	30	–0.002	0.038	31	0.033	0.044
32	0.062	0.000	33	0.057	0.052	34	0.016	0.174	35	0.035	0.116
36	–0.051	–0.202	37	0.011	0.036	38	0.089	0.209	39	–0.049	–0.008
40	–0.035	0.044	41	0.017	–0.059	42	0.053	–0.017	43	0.099	0.100
44	0.034	–0.148	45	–0.003	–0.094	46	–0.120	0.042	47	–0.136	–0.070
48	–0.031	0.000	49	–0.136	0.070	50	–0.120	–0.042	51	–0.003	0.094
52	0.034	0.148	53	0.099	–0.100	54	0.053	0.017	55	0.017	0.059
56	–0.035	–0.044	57	–0.049	0.008	58	0.089	–0.209	59	0.011	–0.036
60	–0.051	0.202	61	0.035	–0.116	62	0.016	–0.174	63	0.057	–0.052
64	0.062	0.000	65	0.033	–0.044	66	–0.002	–0.038	67	–0.081	0.084
68	0.007	–0.100	69	–0.001	–0.113	70	–0.021	–0.005	71	0.136	–0.105
72	0.098	–0.044	73	0.011	–0.002	74	–0.033	0.044	75	–0.060	0.124
76	0.010	0.097	77	0.000	–0.008	78	0.018	–0.083	79	–0.069	0.027
80	–0.109	0.000									

The SIGNAL field samples are appended with one sample overlap to the preamble, given in Table G.6.

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G.5 Generating the DATA bits

G.5.1 Delineating, SERVICE field prepending, and zero padding

The transmitted message shown in Table G.1 contains 100 octets or, equivalently, 800 bits. The bits are prepended by the 16 SERVICE field bits and are appended by 6 tail bits. The resulting 822 bits are appended by zero bits to yield an integer number of OFDM symbols. For the 36 Mbit/s mode, there are 144 data bits per OFDM symbol; the overall number of bits is ceiling (822/144) × 144 = 864. Hence, 864 – 822 = 42 zero bits are appended.

The data bits are shown in Table G.13 and Table G.14. For clarity, only the first and last 144 bits are shown.

Table G.13—First 144 DATA bits

##	Bit	##	Bit	##	Bit	##	Bit	##	Bit	##	Bit
0	0	24	0	48	0	72	1	96	0	120	1
1	0	25	1	49	0	73	0	97	0	121	0
2	0	26	0	50	0	74	1	98	0	122	0
3	0	27	0	51	0	75	1	99	0	123	0
4	0	28	0	52	0	76	0	100	0	124	0
5	0	29	0	53	0	77	0	101	0	125	0
6	0	30	0	54	0	78	1	102	0	126	0
7	0	31	0	55	0	79	1	103	0	127	0
8	0	32	0	56	0	80	1	104	0	128	0
9	0	33	0	57	0	81	1	105	0	129	0
10	0	34	0	58	0	82	1	106	0	130	1
11	0	35	0	59	0	83	0	107	0	131	1
12	0	36	0	60	0	84	1	108	0	132	1
13	0	37	0	61	1	85	1	109	1	133	1
14	0	38	0	62	1	86	0	110	0	134	0
15	0	39	0	63	0	87	0	111	0	135	0
16	0	40	0	64	0	88	0	112	0	136	1
17	0	41	1	65	0	89	1	113	1	137	0
18	1	42	1	66	0	90	1	114	1	138	0
19	0	43	1	67	1	91	0	115	0	139	0
20	0	44	0	68	0	92	0	116	1	140	1
21	0	45	1	69	0	93	1	117	0	141	1
22	0	46	0	70	0	94	0	118	1	142	1
23	0	47	0	71	0	95	1	119	1	143	1

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Table G.14—Last 144 DATA bits

##	Bit	##	Bit	##	Bit	##	Bit	##	Bit	##	Bit
720	0	744	0	768	1	792	1	816	0	840	0
721	0	745	0	769	0	793	1	817	0	841	0
722	0	746	0	770	1	794	1	818	0	842	0
723	0	747	0	771	0	795	0	819	0	843	0
724	0	748	0	772	0	796	1	820	0	844	0
725	1	749	1	773	1	797	0	821	0	845	0
726	0	750	0	774	1	798	1	822	0	846	0
727	0	751	0	775	0	799	0	823	0	847	0
728	1	752	0	776	1	800	1	824	0	848	0
729	1	753	0	777	0	801	0	825	0	849	0
730	1	754	1	778	0	802	0	826	0	850	0
731	0	755	0	779	0	803	1	827	0	851	0
732	1	756	1	780	0	804	1	828	0	852	0
733	1	757	1	781	1	805	0	829	0	853	0
734	1	758	1	782	1	806	0	830	0	854	0
735	0	759	0	783	0	807	1	831	0	855	0
736	1	760	0	784	0	808	1	832	0	856	0
737	0	761	1	785	1	809	0	833	0	857	0
738	1	762	0	786	0	810	1	834	0	858	0
739	0	763	0	787	1	811	1	835	0	859	0
740	0	764	1	788	1	812	0	836	0	860	0
741	1	765	1	789	0	813	1	837	0	861	0
742	1	766	1	790	1	814	1	838	0	862	0
743	0	767	0	791	1	815	1	839	0	863	0

G.5.2 Scrambling

The 864 bits are scrambled by the scrambler of Figure 117 (in 17.3.5.4). The initial state of the scrambler is the state 1011101. The generated scrambling sequence is given in Table G.15.

After scrambling, the 6 bits in location 816 (i.e., the 817th bit) to 821 (the 822nd bit) are zeroed. The first and last 144 scrambled bits are shown in Table G.16 and Table G.17, respectively.

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Table G.15—Scrambling sequence for seed 1011101

##	Bit	##	Bit	##	Bit	##	Bit	##	Bit	##	Bit	##	Bit	##	Bit
0	0	16	1	32	0	48	1	64	0	80	0	96	0	112	1
1	1	17	0	33	1	49	1	65	1	81	0	97	0	113	0
2	1	18	1	34	1	50	1	66	1	82	1	98	1	114	0
3	0	19	0	35	0	51	1	67	1	83	1	99	0	115	1
4	1	20	1	36	1	52	0	68	0	84	1	100	0	116	1
5	1	21	0	37	0	53	1	69	0	85	0	101	1	117	0
6	0	22	0	38	0	54	0	70	0	86	1	102	0	118	0
7	0	23	1	39	0	55	0	71	1	87	1	103	0	119	0
8	0	24	1	40	0	56	1	72	1	88	1	104	0	120	1
9	0	25	1	41	1	57	0	73	1	89	1	105	0	121	0
10	0	26	0	42	0	58	1	74	1	90	0	106	0	122	1
11	1	27	0	43	1	59	0	75	1	91	0	107	0	123	1
12	1	28	1	44	0	60	0	76	1	92	1	108	1	124	1
13	0	29	1	45	1	61	0	77	1	93	0	109	0	125	0
14	0	30	1	46	0	62	1	78	0	94	1	110	0	126	1
15	1	31	1	47	1	63	1	79	0	95	1	111	0		

Table G.16—First 144 bits after scrambling

##	Bit	##	Bit	##	Bit	##	Bit	##	Bit	##	Bit
0	0	24	1	48	1	72	0	96	0	120	0
1	1	25	0	49	1	73	1	97	0	121	0
2	1	26	0	50	1	74	0	98	1	122	1
3	0	27	0	51	1	75	0	99	0	123	1
4	1	28	1	52	0	76	1	100	0	124	1
5	1	29	1	53	1	77	1	101	1	125	0
6	0	30	1	54	0	78	1	102	0	126	1
7	0	31	1	55	0	79	1	103	0	127	0
8	0	32	0	56	1	80	1	104	0	128	1
9	0	33	1	57	0	81	1	105	0	129	1
10	0	34	1	58	1	82	0	106	0	130	1
11	1	35	0	59	0	83	1	107	0	131	0
12	1	36	1	60	0	84	0	108	1	132	0

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Table G.16—First 144 bits after scrambling *(continued)*

##	Bit	##	Bit	##	Bit	##	Bit	##	Bit	##	Bit
13	0	37	0	61	1	85	1	109	1	133	1
14	0	38	0	62	0	86	1	110	0	134	0
15	1	39	0	63	1	87	1	111	0	135	0
16	1	40	0	64	0	88	1	112	1	136	1
17	0	41	0	65	1	89	0	113	1	137	0
18	0	42	1	66	1	90	1	114	1	138	1
19	0	43	0	67	0	91	0	115	1	139	1
20	1	44	0	68	0	92	1	116	0	140	1
21	0	45	0	69	0	93	1	117	0	141	1
22	0	46	0	70	0	94	1	118	1	142	0
23	1	47	1	71	1	95	0	119	1	143	0

Table G.17—Last 144 bits after scrambling

##	Bit	##	Bit	##	Bit	##	Bit	##	Bit	##	Bit
720	0	744	0	768	1	792	0	816	0	840	0
721	1	745	0	769	0	793	0	817	0	841	0
722	1	746	0	770	1	794	1	818	0	842	0
723	1	747	1	771	0	795	1	819	0	843	0
724	1	748	0	772	0	796	0	820	0	844	1
725	1	749	1	773	0	797	0	821	0	845	1
726	0	750	1	774	0	798	0	822	0	846	1
727	1	751	1	775	0	799	0	823	0	847	0
728	1	752	0	776	1	800	1	824	1	848	1
729	0	753	0	777	1	801	0	825	1	849	1
730	0	754	1	778	1	802	0	826	0	850	1
731	0	755	1	779	0	803	0	827	1	851	1
732	1	756	1	780	1	804	1	828	1	852	0
733	0	757	0	781	1	805	1	829	1	853	0
734	1	758	0	782	0	806	0	830	0	854	1
735	0	759	1	783	0	807	0	831	0	855	0
736	0	760	0	784	0	808	1	832	0	856	1
737	0	761	0	785	0	809	1	833	1	857	1

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Table G.17—Last 144 bits after scrambling *(continued)*

##	Bit	##	Bit	##	Bit	##	Bit	##	Bit	##	Bit
738	1	762	0	786	1	810	0	834	1	858	0
739	0	763	1	787	0	811	0	835	1	859	0
740	0	764	0	788	1	812	1	836	1	860	1
741	1	765	1	789	0	813	0	837	1	861	0
742	1	766	0	790	0	814	1	838	1	862	0
743	1	767	1	791	0	815	0	839	1	863	1

G.6 Generating the first DATA symbol

G.6.1 Coding the DATA bits

The scrambled bits are coded with a rate Ω convolutional code. The first 144 scrambled bits of Table G.16 are mapped into the 192 bits of Table G.18.

Table G.18—Coded bits of first DATA symbol

##	Bit	##	Bit	##	Bit	##	Bit	##	Bit	##	Bit
0	0	32	1	64	0	96	1	128	1	160	1
1	0	33	0	65	1	97	0	129	1	161	1
2	1	34	0	66	0	98	0	130	0	162	1
3	0	35	1	67	0	99	0	131	0	163	0
4	1	36	1	68	1	100	1	132	0	164	0
5	0	37	1	69	0	101	1	133	0	165	0
6	1	38	0	70	1	102	1	134	0	166	0
7	1	39	1	71	0	103	1	135	0	167	0
8	0	40	1	72	1	104	1	136	0	168	1
9	0	41	0	73	1	105	1	137	1	169	1
10	0	42	1	74	1	106	0	138	0	170	0
11	0	43	1	75	1	107	0	139	0	171	1
12	1	44	0	76	1	108	0	140	0	172	0
13	0	45	1	77	0	109	0	141	0	173	0
14	0	46	0	78	1	110	0	142	1	174	1
15	0	47	1	79	1	111	0	143	1	175	1
16	1	48	1	80	1	112	1	144	1	176	1
17	0	49	0	81	1	113	1	145	1	177	1

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Table G.18—Coded bits of first DATA symbol *(continued)*

##	Bit	##	Bit	##	Bit	##	Bit	##	Bit	##	Bit
18	1	50	0	82	1	114	0	146	1	178	1
19	0	51	1	83	0	115	0	147	0	179	0
20	0	52	1	84	1	116	1	148	0	180	1
21	0	53	0	85	0	117	0	149	0	181	0
22	0	54	1	86	0	118	0	150	0	182	1
23	1	55	0	87	0	119	0	151	0	183	1
24	1	56	0	88	1	120	0	152	0	184	1
25	1	57	0	89	1	121	1	153	0	185	0
26	1	58	0	90	0	122	1	154	0	186	1
27	1	59	1	91	0	123	1	155	1	187	1
28	0	60	1	92	0	124	0	156	1	188	0
29	0	61	1	93	0	125	0	157	0	189	0
30	0	62	0	94	1	126	1	158	0	190	1
31	0	63	1	95	0	127	1	159	1	191	0

G.6.2 Interleaving the DATA bits

The interleaver is defined as a two-permutation process. The index of the coded bit before the first permutation shall be denoted by *k*; *i* shall be the index after the first and before the second permutation; and *j* shall be the index after the second permutation, just prior to modulation mapping. The mapping from *k* to *i* is shown in Table G.19, and the mapping from *i* to *j* is shown in Table G.20.

Table G.19—First permutation

k	*i*	*k*	*i*	*k*	*i*	*k*	*i*	*k*	*i*	*k*	*i*	*k*	*i*	*k*	*i*
0	0	24	97	48	3	72	100	96	6	120	103	144	9	168	106
1	12	25	109	49	15	73	112	97	18	121	115	145	21	169	118
2	24	26	121	50	27	74	124	98	30	122	127	146	33	170	130
3	36	27	133	51	39	75	136	99	42	123	139	147	45	171	142
4	48	28	145	52	51	76	148	100	54	124	151	148	57	172	154
5	60	29	157	53	63	77	160	101	66	125	163	149	69	173	166
6	72	30	169	54	75	78	172	102	78	126	175	150	81	174	178
7	84	31	181	55	87	79	184	103	90	127	187	151	93	175	190
8	96	32	2	56	99	80	5	104	102	128	8	152	105	176	11
9	108	33	14	57	111	81	17	105	114	129	20	153	117	177	23

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Table G.19—First permutation *(continued)*

k	*i*	*k*	*i*	*k*	*i*	*k*	*i*	*k*	*i*	*k*	*i*	*k*	*i*	*k*	*i*
10	120	34	26	58	123	82	29	106	126	130	32	154	129	178	35
11	132	35	38	59	135	83	41	107	138	131	44	155	141	179	47
12	144	36	50	60	147	84	53	108	150	132	56	156	153	180	59
13	156	37	62	61	159	85	65	109	162	133	68	157	165	181	71
14	168	38	74	62	171	86	77	110	174	134	80	158	177	182	83
15	180	39	86	63	183	87	89	111	186	135	92	159	189	183	95
16	1	40	98	64	4	88	101	112	7	136	104	160	10	184	107
17	13	41	110	65	16	89	113	113	19	137	116	161	22	185	119
18	25	42	122	66	28	90	125	114	31	138	128	162	34	186	131
19	37	43	134	67	40	91	137	115	43	139	140	163	46	187	143
20	49	44	146	68	52	92	149	116	55	140	152	164	58	188	155
21	61	45	158	69	64	93	161	117	67	141	164	165	70	189	167
22	73	46	170	70	76	94	173	118	79	142	176	166	82	190	179
23	85	47	182	71	88	95	185	119	91	143	188	167	94	191	191

Table G.20—Second permutation

i	*j*	*i*	*j*	*i*	*j*	*i*	*j*	*i*	*j*	*i*	*j*	*i*	*j*	*i*	*j*	*i*	*j*
0	0	24	24	48	48	72	72	96	96	120	120	144	144	168	168
1	1	25	25	49	49	73	73	97	97	121	121	145	145	169	169
2	2	26	26	50	50	74	74	98	98	122	122	146	146	170	170
3	3	27	27	51	51	75	75	99	99	123	123	147	147	171	171
4	4	28	28	52	52	76	76	100	100	124	124	148	148	172	172
5	5	29	29	53	53	77	77	101	101	125	125	149	149	173	173
6	6	30	30	54	54	78	78	102	102	126	126	150	150	174	174
7	7	31	31	55	55	79	79	103	103	127	127	151	151	175	175
8	8	32	32	56	56	80	80	104	104	128	128	152	152	176	176
9	9	33	33	57	57	81	81	105	105	129	129	153	153	177	177
10	10	34	34	58	58	82	82	106	106	130	130	154	154	178	178
11	11	35	35	59	59	83	83	107	107	131	131	155	155	179	179
12	13	36	37	60	61	84	85	108	109	132	133	156	157	180	181
13	12	37	36	61	60	85	84	109	108	133	132	157	156	181	180
14	15	38	39	62	63	86	87	110	111	134	135	158	159	182	183

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Table G.20—Second permutation *(continued)*

i	*j*	*i*	*j*	*i*	*j*	*i*	*j*	*i*	*j*	*i*	*j*	*i*	*j*	*i*	*j*
15	14	39	38	63	62	87	86	111	110	135	134	159	158	183	182
16	17	40	41	64	65	88	89	112	113	136	137	160	161	184	185
17	16	41	40	65	64	89	88	113	112	137	136	161	160	185	184
18	19	42	43	66	67	90	91	114	115	138	139	162	163	186	187
19	18	43	42	67	66	91	90	115	114	139	138	163	162	187	186
20	21	44	45	68	69	92	93	116	117	140	141	164	165	188	189
21	20	45	44	69	68	93	92	117	116	141	140	165	164	189	188
22	23	46	47	70	71	94	95	118	119	142	143	166	167	190	191
23	22	47	46	71	70	95	94	119	118	143	142	167	166	191	190

As a specific example, consider the case of $k = 17$ (the 18th bit after encoding and puncturing). It is mapped by the first permutation to $i = 13$ and by the second permutation to $j = 12$ (the 13th bit before mapping).

The interleaved bits are shown in Table G.21.

Table G.21—Interleaved bits of first DATA symbol

##	Bit	##	Bit	##	Bit	##	Bit	##	Bit	##	Bit
0	0	32	0	64	0	96	0	128	0	160	0
1	1	33	1	65	0	97	1	129	0	161	0
2	1	34	1	66	0	98	1	130	0	162	0
3	1	35	1	67	1	99	0	131	1	163	0
4	0	36	0	68	0	100	1	132	1	164	0
5	1	37	0	69	0	101	1	133	0	165	0
6	1	38	1	70	0	102	1	134	1	166	0
7	1	39	1	71	0	103	0	135	1	167	0
8	1	40	0	72	1	104	0	136	0	168	0
9	1	41	0	73	0	105	0	137	1	169	0
10	1	42	0	74	0	106	1	138	1	170	0
11	1	43	0	75	1	107	1	139	0	171	0
12	0	44	0	76	1	108	1	140	1	172	1
13	0	45	0	77	0	109	0	141	0	173	1
14	0	46	0	78	1	110	0	142	1	174	0
15	0	47	0	79	0	111	0	143	1	175	1

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Table G.21—Interleaved bits of first DATA symbol *(continued)*

##	Bit		##	Bit		##	Bit		##	Bit		##	Bit		##	Bit
16	1		48	1		80	0		112	1		144	1		176	1
17	1		49	0		81	0		113	1		145	0		177	0
18	1		50	1		82	0		114	1		146	0		178	1
19	0		51	1		83	1		115	1		147	1		179	1
20	1		52	1		84	1		116	0		148	1		180	0
21	1		53	1		85	1		117	1		149	0		181	0
22	1		54	1		86	0		118	0		150	0		182	1
23	1		55	1		87	1		119	1		151	0		183	1
24	1		56	0		88	0		120	0		152	0		184	0
25	1		57	0		89	0		121	1		153	1		185	1
26	0		58	0		90	0		122	1		154	0		186	1
27	0		59	1		91	1		123	0		155	0		187	0
28	0		60	0		92	0		124	1		156	0		188	1
29	1		61	0		93	0		125	0		157	0		189	1
30	0		62	0		94	1		126	0		158	1		190	0
31	0		63	1		95	0		127	1		159	1		191	1

G.6.3 Mapping into symbols

The frequency domain symbols are generated by grouping 4 coded bits and mapping into complex 16-QAM symbols according to Table 90 (in 17.3.5.7). For instance, the first 4 bits (0 1 1 1) are mapped to the complex value, –0.316 + 0.316j, inserted at subcarrier #26.

Four pilot subcarriers are added by taking the values {1.0,1.0,1.0,–1.0}, multiplying them by the second element of sequence p, given in Equation (27) (in 17.3.5.9), and inserting them into location {–21,–7,7,21}, respectively.

The frequency domain is shown in Table G.22.

Table G.22—Frequency domain of first DATA symbol

##	Re	Im		##	Re	Im		##	Re	Im		##	Re	Im
–32	0.000	0.000		–16	–0.949	0.316		0	0.000	0.000		16	–0.316	–0.949
–31	0.000	0.000		–15	–0.949	–0.949		1	–0.316	0.949		17	–0.949	0.316
–30	0.000	0.000		–14	–0.949	–0.949		2	0.316	0.949		18	–0.949	–0.949
–29	0.000	0.000		–13	0.949	0.316		3	–0.949	0.316		19	–0.949	–0.949
–28	0.000	0.000		–12	0.316	0.316		4	0.949	–0.949		20	–0.949	–0.949

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Table G.22—Frequency domain of first DATA symbol *(continued)*

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
–27	0.000	0.000	–11	–0.949	–0.316	5	0.316	0.316	21	–1.000	0.000
–26	–0.316	0.316	–10	–0.949	–0.316	6	–0.316	–0.316	22	0.316	–0.316
–25	–0.316	0.316	–9	–0.949	–0.316	7	1.000	0.000	23	0.949	0.316
–24	0.316	0.316	–8	–0.949	–0.949	8	–0.316	0.949	24	–0.949	0.316
–23	–0.949	–0.949	–7	1.000	0.000	9	0.949	–0.316	25	–0.316	0.949
–22	0.316	0.949	–6	0.949	–0.316	10	–0.949	–0.316	26	0.316	–0.316
–21	1.000	0.000	–5	0.949	0.949	11	0.949	0.316	27	0.000	0.000
–20	0.316	0.316	–4	–0.949	–0.316	12	–0.316	0.949	28	0.000	0.000
–19	0.316	–0.949	–3	0.316	–0.316	13	0.949	0.316	29	0.000	0.000
–18	–0.316	–0.949	–2	–0.949	–0.316	14	0.949	–0.316	30	0.000	0.000
–17	–0.316	0.316	–1	–0.949	0.949	15	0.949	–0.949	31	0.000	0.000

The time domain samples are produced by performing IFFT, cyclically extending, and multiplying with the window function in the same manner as described in G.4.5. The time domain samples are appended with one sample overlap to the SIGNAL field symbol.

G.7 Generating the additional DATA symbols

The generation of the additional five data symbols follows the same procedure as described in Clause 5. Special attention should be paid to the scrambling of the pilot subcarriers. Table G.23 lists the polarity of the pilot subcarriers and the elements of the sequence $p_{0\ldots126}$ for the DATA symbols. For completeness, the pilots in the SIGNAL are included as well. The symbols are appended one after the other with a one-sample overlap.

Table G.23—Polarity of the pilot subcarriers

i	OFDM symbol	Element of p_i	Pilot at #-21	Pilot at #-7	Pilot at #7	Pilot at #21
0	SIGNAL	1	1.0 +0 j	1.0 +0 j	1.0 +0 j	–1.0 +0 j
1	DATA 1	1	1.0 +0 j	1.0 +0 j	1.0 +0 j	–1.0 +0 j
2	DATA 2	1	1.0 +0 j	1.0 +0 j	1.0 +0 j	–1.0 +0 j
3	DATA 3	1	1.0 +0 j	1.0 +0 j	1.0 +0 j	–1.0 +0 j
4	DATA 4	–1	–1.0 +0 j	–1.0 +0 j	–1.0 +0 j	1.0 +0 j
5	DATA 5	–1	–1.0 +0 j	–1.0 +0 j	–1.0 +0 j	1.0 +0 j
6	DATA 6	–1	–1.0 +0 j	–1.0 +0 j	–1.0 +0 j	1.0 +0 j

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G.8 The entire packet

The packet in its entirety is shown in Table G.24. The short sequences section, the long sequences section, the SIGNAL field, and the DATA symbols are separated by double lines.

Table G.24—The entire packet

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
0	0.023	0.023	1	–0.132	0.002	2	–0.013	–0.079	3	0.143	–0.013
4	0.092	0.000	5	0.143	–0.013	6	–0.013	–0.079	7	–0.132	0.002
8	0.046	0.046	9	0.002	–0.132	10	–0.079	–0.013	11	–0.013	0.143
12	0.000	0.092	13	–0.013	0.143	14	–0.079	–0.013	15	0.002	–0.132
16	0.046	0.046	17	–0.132	0.002	18	–0.013	–0.079	19	0.143	–0.013
20	0.092	0.000	21	0.143	–0.013	22	–0.013	–0.079	23	–0.132	0.002
24	0.046	0.046	25	0.002	–0.132	26	–0.079	–0.013	27	–0.013	0.143
28	0.000	0.092	29	–0.013	0.143	30	–0.079	–0.013	31	0.002	–0.132
32	0.046	0.046	33	–0.132	0.002	34	–0.013	–0.079	35	0.143	–0.013
36	0.092	0.000	37	0.143	–0.013	38	–0.013	–0.079	39	–0.132	0.002
40	0.046	0.046	41	0.002	–0.132	42	–0.079	–0.013	43	–0.013	0.143
44	0.000	0.092	45	–0.013	0.143	46	–0.079	–0.013	47	0.002	–0.132
48	0.046	0.046	49	–0.132	0.002	50	–0.013	–0.079	51	0.143	–0.013
52	0.092	0.000	53	0.143	–0.013	54	–0.013	–0.079	55	–0.132	0.002
56	0.046	0.046	57	0.002	–0.132	58	–0.079	–0.013	59	–0.013	0.143
60	0.000	0.092	61	–0.013	0.143	62	–0.079	–0.013	63	0.002	–0.132
64	0.046	0.046	65	–0.132	0.002	66	–0.013	–0.079	67	0.143	–0.013
68	0.092	0.000	69	0.143	–0.013	70	–0.013	–0.079	71	–0.132	0.002
72	0.046	0.046	73	0.002	–0.132	74	–0.079	–0.013	75	–0.013	0.143
76	0.000	0.092	77	–0.013	0.143	78	–0.079	–0.013	79	0.002	–0.132
80	0.046	0.046	81	–0.132	0.002	82	–0.013	–0.079	83	0.143	–0.013
84	0.092	0.000	85	0.143	–0.013	86	–0.013	–0.079	87	–0.132	0.002
88	0.046	0.046	89	0.002	–0.132	90	–0.079	–0.013	91	–0.013	0.143
92	0.000	0.092	93	–0.013	0.143	94	–0.079	–0.013	95	0.002	–0.132
96	0.046	0.046	97	–0.132	0.002	98	–0.013	–0.079	99	0.143	–0.013
100	0.092	0.000	101	0.143	–0.013	102	–0.013	–0.079	103	–0.132	0.002
104	0.046	0.046	105	0.002	–0.132	106	–0.079	–0.013	107	–0.013	0.143
108	0.000	0.092	109	–0.013	0.143	110	–0.079	–0.013	111	0.002	–0.132
112	0.046	0.046	113	–0.132	0.002	114	–0.013	–0.079	115	0.143	–0.013

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Table G.24—The entire packet *(continued)*

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
116	0.092	0.000	117	0.143	–0.013	118	–0.013	–0.079	119	–0.132	0.002
120	0.046	0.046	121	0.002	–0.132	122	–0.079	–0.013	123	–0.013	0.143
124	0.000	0.092	125	–0.013	0.143	126	–0.079	–0.013	127	0.002	–0.132
128	0.046	0.046	129	–0.132	0.002	130	–0.013	–0.079	131	0.143	–0.013
132	0.092	0.000	133	0.143	–0.013	134	–0.013	–0.079	135	–0.132	0.002
136	0.046	0.046	137	0.002	–0.132	138	–0.079	–0.013	139	–0.013	0.143
140	0.000	0.092	141	–0.013	0.143	142	–0.079	–0.013	143	0.002	–0.132
144	0.046	0.046	145	–0.132	0.002	146	–0.013	–0.079	147	0.143	–0.013
148	0.092	0.000	149	0.143	–0.013	150	–0.013	–0.079	151	–0.132	0.002
152	0.046	0.046	153	0.002	–0.132	154	–0.079	–0.013	155	–0.013	0.143
156	0.000	0.092	157	–0.013	0.143	158	–0.079	–0.013	159	0.002	–0.132
160	–0.055	0.023	161	0.012	–0.098	162	0.092	–0.106	163	–0.092	–0.115
164	–0.003	–0.054	165	0.075	0.074	166	–0.127	0.021	167	–0.122	0.017
168	–0.035	0.151	169	–0.056	0.022	170	–0.060	–0.081	171	0.070	–0.014
172	0.082	–0.092	173	–0.131	–0.065	174	–0.057	–0.039	175	0.037	–0.098
176	0.062	0.062	177	0.119	0.004	178	–0.022	–0.161	179	0.059	0.015
180	0.024	0.059	181	–0.137	0.047	182	0.001	0.115	183	0.053	–0.004
184	0.098	0.026	185	–0.038	0.106	186	–0.115	0.055	187	0.060	0.088
188	0.021	–0.028	189	0.097	–0.083	190	0.040	0.111	191	–0.005	0.120
192	0.156	0.000	193	–0.005	–0.120	194	0.040	–0.111	195	0.097	0.083
196	0.021	0.028	197	0.060	–0.088	198	–0.115	–0.055	199	–0.038	–0.106
200	0.098	–0.026	201	0.053	0.004	202	0.001	–0.115	203	–0.137	–0.047
204	0.024	–0.059	205	0.059	–0.015	206	–0.022	0.161	207	0.119	–0.004
208	0.062	–0.062	209	0.037	0.098	210	–0.057	0.039	211	–0.131	0.065
212	0.082	0.092	213	0.070	0.014	214	–0.060	0.081	215	–0.056	–0.022
216	–0.035	–0.151	217	–0.122	–0.017	218	–0.127	–0.021	219	0.075	–0.074
220	–0.003	0.054	221	–0.092	0.115	222	0.092	0.106	223	0.012	0.098
224	–0.156	0.000	225	0.012	–0.098	226	0.092	–0.106	227	–0.092	–0.115
228	–0.003	–0.054	229	0.075	0.074	230	–0.127	0.021	231	–0.122	0.017
232	–0.035	0.151	233	–0.056	0.022	234	–0.060	–0.081	235	0.070	–0.014
236	0.082	–0.092	237	–0.131	–0.065	238	–0.057	–0.039	239	0.037	–0.098
240	0.062	0.062	241	0.119	0.004	242	–0.022	–0.161	243	0.059	0.015
244	0.024	0.059	245	–0.137	0.047	246	0.001	0.115	247	0.053	–0.004

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Table G.24—The entire packet *(continued)*

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
248	0.098	0.026	249	–0.038	0.106	250	–0.115	0.055	251	0.060	0.088
252	0.021	–0.028	253	0.097	–0.083	254	0.040	0.111	255	–0.005	0.120
256	0.156	0.000	257	–0.005	–0.120	258	0.040	–0.111	259	0.097	0.083
260	0.021	0.028	261	0.060	–0.088	262	–0.115	–0.055	263	–0.038	–0.106
264	0.098	–0.026	265	0.053	0.004	266	0.001	–0.115	267	–0.137	–0.047
268	0.024	–0.059	269	0.059	–0.015	270	–0.022	0.161	271	0.119	–0.004
272	0.062	–0.062	273	0.037	0.098	274	–0.057	0.039	275	–0.131	0.065
276	0.082	0.092	277	0.070	0.014	278	–0.060	0.081	279	–0.056	–0.022
280	–0.035	–0.151	281	–0.122	–0.017	282	–0.127	–0.021	283	0.075	–0.074
284	–0.003	0.054	285	–0.092	0.115	286	0.092	0.106	287	0.012	0.098
288	–0.156	0.000	289	0.012	–0.098	290	0.092	–0.106	291	–0.092	–0.115
292	–0.003	–0.054	293	0.075	0.074	294	–0.127	0.021	295	–0.122	0.017
296	–0.035	0.151	297	–0.056	0.022	298	–0.060	–0.081	299	0.070	–0.014
300	0.082	–0.092	301	–0.131	–0.065	302	–0.057	–0.039	303	0.037	–0.098
304	0.062	0.062	305	0.119	0.004	306	–0.022	–0.161	307	0.059	0.015
308	0.024	0.059	309	–0.137	0.047	310	0.001	0.115	311	0.053	–0.004
312	0.098	0.026	313	–0.038	0.106	314	–0.115	0.055	315	0.060	0.088
316	0.021	–0.028	317	0.097	–0.083	318	0.040	0.111	319	–0.005	0.120
320	0.109	0.000	321	0.033	–0.044	322	–0.002	–0.038	323	–0.081	0.084
324	0.007	–0.100	325	–0.001	–0.113	326	–0.021	–0.005	327	0.136	–0.105
328	0.098	–0.044	329	0.011	–0.002	330	–0.033	0.044	331	–0.060	0.124
332	0.010	0.097	333	0.000	–0.008	334	0.018	–0.083	335	–0.069	0.027
336	–0.219	0.000	337	–0.069	–0.027	338	0.018	0.083	339	0.000	0.008
340	0.010	–0.097	341	–0.060	–0.124	342	–0.033	–0.044	343	0.011	0.002
344	0.098	0.044	345	0.136	0.105	346	–0.021	0.005	347	–0.001	0.113
348	0.007	0.100	349	–0.081	–0.084	350	–0.002	0.038	351	0.033	0.044
352	0.062	0.000	353	0.057	0.052	354	0.016	0.174	355	0.035	0.116
356	–0.051	–0.202	357	0.011	0.036	358	0.089	0.209	359	–0.049	–0.008
360	–0.035	0.044	361	0.017	–0.059	362	0.053	–0.017	363	0.099	0.100
364	0.034	–0.148	365	–0.003	–0.094	366	–0.120	0.042	367	–0.136	–0.070
368	–0.031	0.000	369	–0.136	0.070	370	–0.120	–0.042	371	–0.003	0.094
372	0.034	0.148	373	0.099	–0.100	374	0.053	0.017	375	0.017	0.059
376	–0.035	–0.044	377	–0.049	0.008	378	0.089	–0.209	379	0.011	–0.036

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Table G.24—The entire packet *(continued)*

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
380	–0.051	0.202	381	0.035	–0.116	382	0.016	–0.174	383	0.057	–0.052
384	0.062	0.000	385	0.033	–0.044	386	–0.002	–0.038	387	–0.081	0.084
388	0.007	–0.100	389	–0.001	–0.113	390	–0.021	–0.005	391	0.136	–0.105
392	0.098	–0.044	393	0.011	–0.002	394	–0.033	0.044	395	–0.060	0.124
396	0.010	0.097	397	0.000	–0.008	398	0.018	–0.083	399	–0.069	0.027
400	–0.139	0.050	401	0.004	0.014	402	0.011	–0.100	403	–0.097	–0.020
404	0.062	0.081	405	0.124	0.139	406	0.104	–0.015	407	0.173	–0.140
408	–0.040	0.006	409	–0.133	0.009	410	–0.002	–0.043	411	–0.047	0.092
412	–0.109	0.082	413	–0.024	0.010	414	0.096	0.019	415	0.019	–0.023
416	–0.087	–0.049	417	0.002	0.058	418	–0.021	0.228	419	–0.103	0.023
420	–0.019	–0.175	421	0.018	0.132	422	–0.071	0.160	423	–0.153	–0.062
424	–0.107	0.028	425	0.055	0.140	426	0.070	0.103	427	–0.056	0.025
428	–0.043	0.002	429	0.016	–0.118	430	0.026	–0.071	431	0.033	0.177
432	0.020	–0.021	433	0.035	–0.088	434	–0.008	0.101	435	–0.035	–0.010
436	0.065	0.030	437	0.092	–0.034	438	0.032	–0.123	439	–0.018	0.092
440	0.000	–0.006	441	–0.006	–0.056	442	–0.019	0.040	443	0.053	–0.131
444	0.022	–0.133	445	0.104	–0.032	446	0.163	–0.045	447	–0.105	–0.030
448	–0.110	–0.069	449	–0.008	–0.092	450	–0.049	–0.043	451	0.085	–0.017
452	0.090	0.063	453	0.015	0.153	454	0.049	0.094	455	0.011	0.034
456	–0.012	0.012	457	–0.015	–0.017	458	–0.061	0.031	459	–0.070	–0.040
460	0.011	–0.109	461	0.037	–0.060	462	–0.003	–0.178	463	–0.007	–0.128
464	–0.059	0.100	465	0.004	0.014	466	0.011	–0.100	467	–0.097	–0.020
468	0.062	0.081	469	0.124	0.139	470	0.104	–0.015	471	0.173	–0.140
472	–0.040	0.006	473	–0.133	0.009	474	–0.002	–0.043	475	–0.047	0.092
476	–0.109	0.082	477	–0.024	0.010	478	0.096	0.019	479	0.019	–0.023
480	–0.058	0.016	481	–0.096	–0.045	482	–0.110	0.003	483	–0.070	0.216
484	–0.040	0.059	485	0.010	–0.056	486	0.034	0.065	487	0.117	0.033
488	0.078	–0.133	489	–0.043	–0.146	490	0.158	–0.071	491	0.254	–0.021
492	0.068	0.117	493	–0.044	0.114	494	–0.035	0.041	495	0.085	0.070
496	0.120	0.010	497	0.057	0.055	498	0.063	0.188	499	0.091	0.149
500	–0.017	–0.039	501	–0.078	–0.075	502	0.049	0.079	503	–0.014	–0.007
504	0.030	–0.027	505	0.080	0.054	506	–0.186	–0.067	507	–0.039	–0.027
508	0.043	–0.072	509	–0.092	–0.089	510	0.029	0.105	511	–0.144	0.003

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Table G.24—The entire packet *(continued)*

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
512	–0.069	–0.041	513	0.132	0.057	514	–0.126	0.070	515	–0.031	0.109
516	0.161	–0.009	517	0.056	–0.046	518	–0.004	0.028	519	–0.049	0.000
520	–0.078	–0.005	521	0.015	–0.087	522	0.149	–0.104	523	–0.021	–0.051
524	–0.154	–0.106	525	0.024	0.030	526	0.046	0.123	527	–0.004	–0.098
528	–0.061	–0.128	529	–0.024	–0.038	530	0.066	–0.048	531	–0.067	0.027
532	0.054	–0.050	533	0.171	–0.049	534	–0.108	0.132	535	–0.161	–0.019
536	–0.070	–0.072	537	–0.177	0.049	538	–0.172	–0.050	539	0.051	–0.075
540	0.122	–0.057	541	0.009	–0.044	542	–0.012	–0.021	543	0.004	0.009
544	–0.030	0.081	545	–0.096	–0.045	546	–0.110	0.003	547	–0.070	0.216
548	–0.040	0.059	549	0.010	–0.056	550	0.034	0.065	551	0.117	0.033
552	0.078	–0.133	553	–0.043	–0.146	554	0.158	–0.071	555	0.254	–0.021
556	0.068	0.117	557	–0.044	0.114	558	–0.035	0.041	559	0.085	0.070
560	0.001	0.011	561	–0.099	–0.048	562	0.054	–0.196	563	0.124	0.035
564	0.092	0.045	565	–0.037	–0.066	566	–0.021	–0.004	567	0.042	–0.065
568	0.061	0.048	569	0.046	0.004	570	–0.063	–0.045	571	–0.102	0.152
572	–0.039	–0.019	573	–0.005	–0.106	574	0.083	0.031	575	0.226	0.028
576	0.140	–0.010	577	–0.132	–0.033	578	–0.116	0.088	579	0.023	0.052
580	–0.171	–0.080	581	–0.246	–0.025	582	–0.062	–0.038	583	–0.055	–0.062
584	–0.004	–0.060	585	0.034	0.000	586	–0.030	0.021	587	0.075	–0.122
588	0.043	–0.080	589	–0.022	0.041	590	0.026	0.013	591	–0.031	–0.018
592	0.059	0.008	593	0.109	0.078	594	0.002	0.101	595	–0.016	0.054
596	–0.059	0.070	597	0.017	0.114	598	0.104	–0.034	599	–0.024	–0.059
600	–0.081	0.051	601	–0.040	–0.069	602	–0.069	0.058	603	–0.067	0.117
604	0.007	–0.131	605	0.009	0.028	606	0.075	0.117	607	0.118	0.030
608	–0.041	0.148	609	0.005	0.098	610	0.026	0.002	611	–0.116	0.045
612	–0.020	0.084	613	0.101	0.006	614	0.205	–0.064	615	0.073	–0.063
616	–0.174	–0.118	617	–0.024	0.026	618	–0.041	0.129	619	–0.042	–0.053
620	0.148	–0.126	621	–0.030	–0.049	622	–0.015	–0.021	623	0.089	–0.069
624	–0.119	0.011	625	–0.099	–0.048	626	0.054	–0.196	627	0.124	0.035
628	0.092	0.045	629	–0.037	–0.066	630	–0.021	–0.004	631	0.042	–0.065
632	0.061	0.048	633	0.046	0.004	634	–0.063	–0.045	635	–0.102	0.152
636	–0.039	–0.019	637	–0.005	–0.106	638	0.083	0.031	639	0.226	0.028
640	0.085	–0.065	641	0.034	–0.142	642	0.004	–0.012	643	0.126	–0.043

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Table G.24—The entire packet *(continued)*

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
644	0.055	0.068	645	–0.020	0.077	646	0.008	–0.056	647	–0.034	0.046
648	–0.040	–0.134	649	–0.056	–0.131	650	0.014	0.097	651	0.045	–0.009
652	–0.113	–0.170	653	–0.065	–0.230	654	0.065	–0.011	655	0.011	0.048
656	–0.091	–0.059	657	–0.110	0.024	658	0.074	–0.034	659	0.124	0.022
660	–0.037	0.071	661	0.015	0.002	662	0.028	0.099	663	–0.062	0.068
664	0.064	0.016	665	0.078	0.156	666	0.009	0.219	667	0.147	0.024
668	0.106	0.030	669	–0.080	0.143	670	–0.049	–0.100	671	–0.036	–0.082
672	–0.089	0.021	673	–0.070	–0.029	674	–0.086	0.048	675	–0.066	–0.015
676	–0.024	0.002	677	–0.030	–0.023	678	–0.032	0.020	679	–0.002	0.212
680	0.158	–0.024	681	0.141	–0.119	682	–0.146	0.058	683	–0.155	0.083
684	–0.002	–0.030	685	0.018	–0.129	686	0.012	–0.018	687	–0.008	–0.037
688	0.031	0.040	689	0.023	0.097	690	0.014	–0.039	691	0.050	0.019
692	–0.072	–0.141	693	–0.023	–0.051	694	0.024	0.099	695	–0.127	–0.116
696	0.094	0.102	697	0.183	0.098	698	–0.040	–0.020	699	0.065	0.077
700	0.088	–0.147	701	–0.039	–0.059	702	–0.057	0.124	703	–0.077	0.020
704	0.030	–0.120	705	0.034	–0.142	706	0.004	–0.012	707	0.126	–0.043
708	0.055	0.068	709	–0.020	0.077	710	0.008	–0.056	711	–0.034	0.046
712	–0.040	–0.134	713	–0.056	–0.131	714	0.014	0.097	715	0.045	–0.009
716	–0.113	–0.170	717	–0.065	–0.230	718	0.065	–0.011	719	0.011	0.048
720	–0.026	–0.021	721	–0.002	0.041	722	0.001	0.071	723	–0.037	–0.117
724	–0.106	–0.062	725	0.002	0.057	726	–0.008	–0.011	727	0.019	0.072
728	0.016	0.059	729	–0.065	–0.077	730	0.142	–0.062	731	0.087	0.025
732	–0.003	–0.103	733	0.107	–0.152	734	–0.054	0.036	735	–0.030	–0.003
736	0.058	–0.020	737	–0.028	0.007	738	–0.027	–0.099	739	0.049	–0.075
740	0.174	0.031	741	0.134	0.156	742	0.060	0.077	743	–0.010	–0.022
744	–0.084	0.040	745	–0.074	0.011	746	–0.163	0.054	747	–0.052	–0.008
748	0.076	–0.042	749	0.043	0.101	750	0.058	–0.018	751	0.003	–0.090
752	0.059	–0.018	753	0.023	–0.031	754	0.007	–0.017	755	0.066	–0.017
756	–0.135	–0.098	757	–0.056	–0.081	758	0.089	0.154	759	0.120	0.122
760	0.102	0.001	761	–0.141	0.102	762	0.006	–0.011	763	0.057	–0.039
764	–0.059	0.066	765	0.132	0.111	766	0.012	0.114	767	0.047	–0.106
768	0.160	–0.099	769	–0.076	0.084	770	–0.049	0.073	771	0.005	–0.086
772	–0.052	–0.108	773	–0.073	0.129	774	–0.129	–0.034	775	–0.153	–0.111

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Table G.24—The entire packet *(continued)*

##	Re	Im	##	Re	Im	##	Re	Im	##	Re	Im
776	–0.193	0.098	777	–0.107	–0.068	778	0.004	–0.009	779	–0.039	0.024
780	–0.054	–0.079	781	0.024	0.084	782	0.052	–0.002	783	0.028	–0.044
784	0.040	0.018	785	–0.002	0.041	786	0.001	0.071	787	–0.037	–0.117
788	–0.106	–0.062	789	0.002	0.057	790	–0.008	–0.011	791	0.019	0.072
792	0.016	0.059	793	–0.065	–0.077	794	0.142	–0.062	795	0.087	0.025
796	–0.003	–0.103	797	0.107	–0.152	798	–0.054	0.036	799	–0.030	–0.003
800	0.039	–0.090	801	0.029	0.025	802	0.086	–0.029	803	0.087	–0.082
804	0.003	–0.036	805	–0.096	–0.089	806	–0.073	–0.046	807	0.105	–0.020
808	0.193	0.018	809	–0.053	–0.073	810	–0.118	–0.149	811	0.019	–0.019
812	–0.042	0.026	813	0.041	0.009	814	0.028	–0.076	815	–0.038	–0.068
816	–0.011	0.010	817	–0.134	–0.064	818	0.069	–0.067	819	0.057	0.006
820	–0.134	0.098	821	0.152	0.036	822	0.041	–0.085	823	–0.099	–0.049
824	0.089	–0.099	825	–0.046	0.018	826	–0.112	0.135	827	–0.064	0.018
828	–0.022	0.053	829	0.041	0.077	830	–0.021	0.145	831	0.007	0.179
832	0.059	0.041	833	0.023	0.064	834	0.062	0.022	835	0.110	–0.081
836	–0.016	–0.054	837	–0.014	–0.017	838	0.171	0.008	839	0.070	–0.027
840	–0.015	0.002	841	–0.012	0.053	842	–0.125	0.009	843	–0.040	0.012
844	0.036	0.114	845	0.007	0.090	846	–0.016	–0.082	847	–0.008	–0.013
848	0.091	0.030	849	0.072	–0.068	850	0.051	0.063	851	–0.004	0.049
852	–0.130	–0.048	853	–0.121	0.061	854	–0.095	0.078	855	0.011	0.005
856	0.049	0.001	857	–0.014	–0.011	858	0.009	–0.063	859	–0.031	0.040
860	–0.011	0.004	861	–0.033	–0.111	862	–0.115	0.137	863	–0.025	0.049
864	0.020	–0.160	865	0.029	0.025	866	0.086	–0.029	867	0.087	–0.082
868	0.003	–0.036	869	–0.096	–0.089	870	–0.073	–0.046	871	0.105	–0.020
872	0.193	0.018	873	–0.053	–0.073	874	–0.118	–0.149	875	0.019	–0.019
876	–0.042	0.026	877	0.041	0.009	878	0.028	–0.076	879	–0.038	–0.068
880	–0.006	0.005									

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