INTERNATIONAL STANDARD

**ISO/IEC 24771**

First edition
2009-04-01

# Information technology — Telecommunications and information exchange between systems — MAC/PHY standard for ad hoc wireless network to support QoS in an industrial work environment

*Technologies de l'information — Télécommunications et échange d'information entre systèmes — Norme MAC/PHY pour un réseau ad hoc sans fil qui supporte QoS dans un environnement de travail industriel*

Reference number
ISO/IEC 24771:2009(E)

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# Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

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ISO/IEC 24771 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 6, *Telecommunications and information exchange between systems.*

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# Information technology — Telecommunications and information exchange between systems — MAC/PHY standard for ad hoc wireless network to support QoS in an industrial work environment

## 1 Scope

This International Standard defines a protocol for the physical layer (PHY) and the data link layer in order to construct a reliable and high-speed data transmission network between devices on industrial sites such as factories and plants. This network specification provides a standardized protocol to provide a framework for various industrial devices to establish a simple, low-cost, energy-efficient, and high-speed network between them. In order to fulfil the service requirements of the factories and large plants, this network specification is designed to enable devices to establish a network by themselves without the help of any infrastructure and to reliably exchange various kinds of data, including real-time audio and video data, between them. In addition to high transmission rates, Quality of Service (QoS) for multimedia data - such as video - is also provided.

The devices mentioned in this International Standard refer to equipment that can be used on industrial sites such as factories and automated assembly lines. Devices include PLC (Programmable Logic Controller), and CNC (Computerized Numerical Controller) and manufacturing robots. However, beyond such conventional devices, devices mentioned in this document include personal IT devices that workers may carry and use while working, including cellular phones, personal industrial digital assistants (PDA), and laptop PCs.

## 2 Terms and definitions, and abbreviated terms

For the purposes of this document, the following terms and definitions, and abbreviated terms apply.

### 2.1 Terms and definitions

**2.1.1**
**access control**
control process to prevent unauthorized use of resources or bandwidth

**2.1.2**
**ad hoc network**
network that is spontaneously formed usually without system installation

NOTE Such networks are mainly characterized by time and space limitations.

**2.1.3**
**association**
service used to connect authorized devices in the network

**2.1.4**
**authentication**
device verification process allowing devices within the network to connect to one another

**2.1.5**
**coverage area**
territory over which two devices can achieve acceptable quality and performance while exchanging data

**2.1.6**
**dissociation**
service used in an established network

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**2.1.7**
**frame**
format of bits in a data exchange

**2.1.8**
**K**
prefix indicating multiplication by 1024

**2.1.9**
**Kμs**
unit of 1024 μs

**2.1.10**
**k**
prefix indicating multiplication by 1000

**2.1.11**
**logical channel**
data link channel sitting distinctly above the physical layer

**2.1.12**
**master**
station that manages the network by periodically transmitting a beacon packet

**2.1.13**
**MAC management protocol data unit**
**MMPDU**
data unit exchanged between two media access control apparatuses in order to implement the media access control management protocol

**2.1.14**
**MAC protocol data unit**
**MPDU**
data unit exchanged between two media access control apparatuses by means of utilizing the physical layer services

**2.1.15**
**MAC service data unit**
**MSDU**
data unit transmitted between media access control service access points

**2.1.16**
**mobile device**
device that utilizes communication networks while in motion

**2.1.17**
**packet**
structure of bits sent in one data transmission

**2.1.18**
**portable device**
station that is normally portable but must be in a fixed location in order to link to the communication network

**2.1.19**
**slave**
station in the network other than the master

**2.1.20**
**station**
device that can operate according to this International Standard

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## 2.2 Abbreviated terms

| | |
|---|---|
| ARQ | automatic repeat request |
| ARQN | automatic repeat request N |
| ASN.1 | abstract syntax notation 1 |
| BER | bit error rate |
| CAP | contention access period |
| CCA | clear channel assessment |
| CDMA | code division multiple access |
| CODEC | coder/decoder |
| CRC | cyclic redundancy check |
| CTS | clear to send |
| DA | destination address |
| DBPSK | differential binary phase shift keying |
| DCE | data communication equipment |
| DLL | data link layer |
| DOQPSK | differential offset quadrature phase shift keying |
| DQPSK | differential quadrature phase shift keying |
| FCS | frame check sequence |
| FEC | forward error correction |
| FER | frame error rate |
| HCS | header check sequence |
| IETF | internet engineering task force |
| IDU | interface data unit |
| IP | internet protocol |
| ISM | industrial scientific medicine |
| IWN | industrial wireless network |
| LAN | local area network |
| LFSR | linear feedback shift register |
| LLC | logical link control |
| LM | link manager |

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| | |
|---|---|
| LME | layer management entity |
| LMP | link manager protocol |
| LSB | least significant bit |
| MAC | medium access control |
| Master | network coordinator |
| MC-CDMA | multi-code CDMA |
| MCDU | MAC command data unit |
| MCPDU | MAC command protocol data unit |
| MDF | management-defined field |
| MIB | management information base |
| MLME | MAC layer management entity |
| MPDU | MAC protocol data unit |
| MSB | most significant bit |
| MSC | message sequence chart |
| MSDU | MAC service data unit |
| MTU | maximum transmission unit |
| NID | network ID |
| PAN | personal area network |
| PAR | project authorization request |
| PDU | protocol data unit |
| PER | packet error ratio |
| PHY | physical layer |
| PIB | PAN information base |
| PLME | physical layer management entity |
| PN | pseudo noise |
| PPDU | PHY protocol data unit |
| PPM | parts per million |
| PRNG | pseudo random number generator |
| PSDU | PHY service data unit |
| QAM | quadrature amplitude modulation |


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| | |
|---|---|
| QoS | quality of service |
| QPSK | quadrature phase shift keying |
| OQPSK | offset quadrature phase shift keying |
| RF | radio frequency |
| RFC | request for comments |
| RSSI | received signal strength indication |
| RTS | request to send |
| RTX | response timeout expired |
| RX | receive or receiver |
| SAP | service access point |
| SDP | service discovery protocol |
| SDU | service data unit |
| SEQN | sequential numbering scheme |
| SME | station management entity |
| SQ | signal quality |
| SRC | short retry count |
| SRES | signed response |
| SS | station service |
| TA | transmitter address |
| TCM | trellis coded modulation |
| TDD | time division duplex |
| TDMA | time division multiple access |
| TX | transmit or transmitter |
| TXE | transmit enable |
| WAN | wide area network |
| WLAN | wireless local area network |
| WM | wireless medium |

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# 3 Overview

This section defines the general attributes of the industrial wireless network and describes the attributes of the physical layer and data link layer. The physical layer is built upon a binary CDMA, and the data link layer is composed of the media access control (MAC) layer.

## 3.1 Characteristics

This International Standard is designed for the construction and management of an optimal network for industrial use applications.

### 3.1.1 Ad hoc network

This International Standard is based upon an ad hoc network that can be established even without a network infrastructure. A network is made up of two kinds of devices - a master and a slave, which is differentiated according to their functions. All stations can function as a master or a slave and one of them is selected as a master based on the device layout and its capabilities. An independent network structure is feasible without requiring infrastructure.

### 3.1.2 Quality of service

The number of devices participating in an industrial wireless network changes vastly over time due to the channel conditions and industrial mobile device operation characteristics of a wireless environment. The bandwidth allocated to each device and the transmission delay time also have a significant effect, making it difficult to support real-time multimedia traffic services that require a certain quality of service.

This document requires one station in the network to be the master, which allocates and controls resources and thereby manages the connection quality of each network traffic.

### 3.1.3 Binary CDMA technology

This International Standard uses Binary-CDMA technology so that it has strong noise resistance, inherent advantage of CDMA, and has another good capability of changing bandwidth finely,

and thereby has the advantages of noise resistance and finely tuned and flexible resource allocation.

First, Binary-CDMA possesses superior noise resistance that is characteristic of CDMA technology, and this is an outstanding attribute in a wireless network environment which, unlike a wireline network, has a high noise factor. In addition, the nature of Binary CDMA makes it possible to adjust the bandwidth by changing the number of codes used, thereby allowing flexible and finely-tuned resource allocation.

## 3.2 Components of network

The components of a network can be roughly depicted as shown in Figure 1. The primary component is the station. The first station trying to connect or establish a network becomes the master of the network and helps other stations to associate with it by periodically transmitting beacons. It also takes responsibilities such as quality of service and power management. The network is made up of two or more stations operating on the same wireless frequency channel in an industrial activity area.

### 3.2.1 Station

The station is the primary component of the network and is classified as either master or slave depending on its role. The master assumes full management, and no more than one can exist in a particular network. The master controls slaves by broadcasting beacons. Slaves send or receive data as directed by the master. To acquire time slots for data transfer, slaves make resource allocation requests to the master during the contention period.

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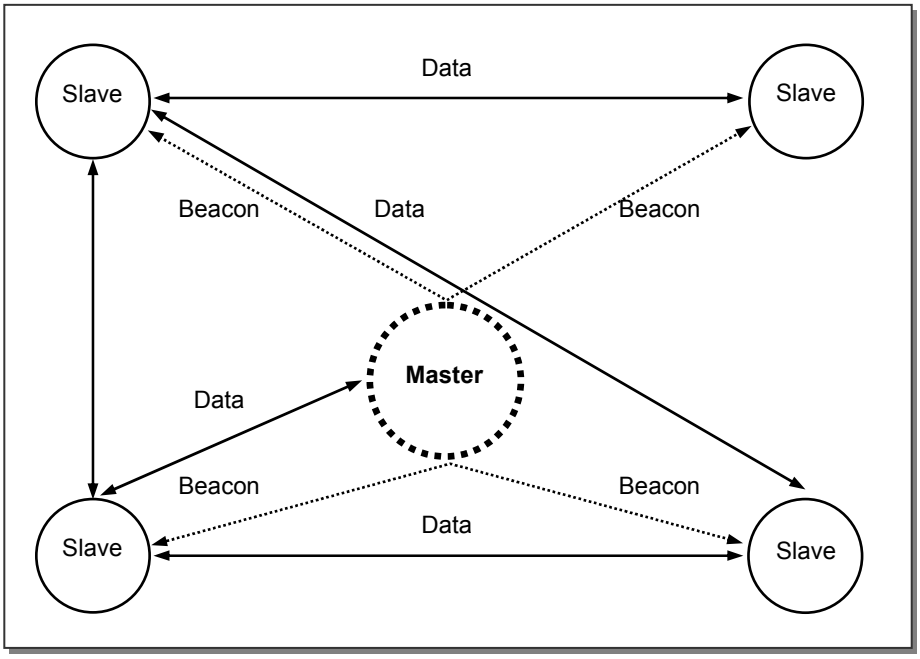


**Figure 1 - Network**

### 3.2.2 Resources

Stations in the network should acquire time slots from master to perform their aimed job – exchanging data. After a station acquired rights to use some time slots from master, it can transmit packets exclusively during assigned time slots. In this sense, this International Standard depicts time slots as resources, which stations in the network share and compete for. Time slots are supervised by the master and are distributed according to requests from slaves at the discretion of the master.

## 3.3 Functional overview

The media access control layer provides the following services:

- Network synchronization

- Data transmission

- Power management

- Change of the master

Data transmission and reception between stations are possible under different standards of quality of service.

### 3.3.1 Network synchronization

The network is established once the master transmits the beacon packet. The beacon packet contains the status information of the network, and all slaves in the network use this information to sync with the network. The superframe is roughly composed of three parts as shown in Figure 2, and each period has a variable length. (The allocation period must be a multiple of the timeslot length.)

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<table>
<tr><td rowspan="2">Beacon period</td><td rowspan="2">Contention period</td><td colspan="4">Allocation period</td></tr>
<tr><td>Time slot 1</td><td>Time slot 2</td><td>…</td><td>Time slot n</td></tr>
</table>

**Figure 2 - Superframe**

a) beacon period: the master transmits the beacon packet containing the network status information to the slaves.

b) contention period: the slaves and master send command packets such as associate/disassociate/grant packets, resource request/grant packets, and connect request/grant packets in a random access fashion.

c) allocation period: this is divided into multiple time slots, each allotted for one station. The station receiving the time slot can send synchronous/asynchronous data or command packets during that interval.

### 3.3.2 Data transmission

For data transmission, two types of connections – synchronous and asynchronous - are supported. Asynchronous connections, which have minimal overhead when establishing connections but do not have a guaranteed bandwidth, are primarily used when transmitting general data that is relatively insensitive to delays. Synchronous connections, which carry a large overhead when establishing connections but have a guaranteed bandwidth, are used to transmit data for real-time services such as audio and video.

This International Standard manages communication quality in three characteristics – delay, data rate, BER. Each device defines the communication quality of data stream to send in these three parameters and sends the defined quality parameters to master to get channel time allocation. Master collects communication request from slaves and allocate time slots to streams in order that each stream can be transmitted satisfying each one's needed communication quality. Afterward a master monitors quality of communication of stream to check whether it meets initial QoS request. If the communication quality deteriorates below initial request quality, master changes time slot allocation to meet initial QoS request.

This International Standard covers MAC-to-MAC QoS within 1-hop network that MAC layer can control.

#### 3.3.2.1 QoS parameter

Data transfers in this International Standard are differentiated as streams which are largely divided into synchronous stream and asynchronous stream, depending on whether a stream has QoS characteristic or not. Synchronous stream has 3 QoS parameter – Period, Data size to transmit per each period, BER, while asynchronous stream have only data size as a parameter.

Synchronous stream in this International Standard manages QoS with the following three parameters.

- Period: the period with which master allocates time slot. Each device is assigned at least a time slot within this period so that this value is equal to maximum delay.

- Data size to transmit per each period: the size of data that a slave will send during each period. Combined with period, this value decides data rate.

- BER: This value defines quality of communication in Bit Error Rate

Using above QoS parameters, devices can define their communication request with detail characteristics.

#### 3.3.2.2 Maintenance of QoS

A master of a network manages communication resource (time slots) centrally. Master collects network information (usage status of allocated time slots, channel quality of each channel) and communication request by itself or from slaves and allocates time slots to slaves in order that each communication can meet its QoS request. After allocating time slots, a master checks whether each communication meets its initial QoS request. If communication does not meet its QoS requirements, a master makes communication to meet its initial requirements by using the following actions.

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#### 3.3.2.2.1 Check and estimation of wireless channel environment

Master continuously monitors BER and SNR value of current wireless channel environment. When it detects the serious change of channel environment, a master takes an action to counterpart the change such as data rate change or frequency channel change.

#### 3.3.2.2.2 Dynamic link quality control

A master continuously monitors actual communication status of data streams in a network. When a communication quality of a stream goes worse than its pre-determined level, a master changes resource allocations in order that the communication quality should meet its pre-determined level. To increase communication quality of a stream, a master decreases data rate of the stream and allocates more time slots to compensate reduced data rate through resource allocation and change mechanism.

#### 3.3.2.2.3 Dynamic channel selection and change

When a master estimates that the network-wide communication quality of the current frequency channel goes worse than the acceptable level, it decides to change a frequency channel. Master notifies the new channel where network will be re-established to slaves, slaves leave current frequency channel and rejoin at the notified new channel. This function provides not only the ability to maintain the certain network-wide communication quality, but also interoperability to avoid collision with other kinds of wireless network.

### 3.3.3 Power management

In order to support mobile devices, efficient power management is critical. Each station is notified of the presence and timing of the incoming data during the corresponding superframe by means of the beacon packet, and can reduce power consumption by disabling the physical layer when not transmitting data. During a particular superframe, stations that are not transmitting data can be disabled until the next superframe period starts. Stations receiving data are enabled only during beacon periods and intervals during which they receive frames. Stations sending data or making requests are enabled during intervals when there is data to transmit.

### 3.3.4 Handover of the master

The master can decide whether to appoint another slave as the master based on the information it possesses about each slave's capabilities. If a newly connected station is determined to be better for the master, the master role may be handed over. Also, due to the nature of an ad hoc network, the master may unexpectedly cease operating or depart from the established service area. In such an event, one of the remaining slaves which is most suitable for the master is selected to manage the network.

## 3.4 Summary of operations

The superframe is divided into the beacon period, contention period, and allocation period, and the stations operate in different modes depending on the period.

### 3.4.1 Broadcasting during the beacon period

During the beacon period the master broadcasts a beacon packet to all slaves. The beacon packet includes information about the status and resource availability of the network, and the slaves receiving the beacon packet use this information to verify the correctness of the corresponding superframe as well as the allocated resources.

The master places network status information into the beacon packet and sends it out to all slaves.

### 3.4.2 Random access during the contention period

During the contention period the slave and master communicate via the CSMA/CA scheme. Slave sends command packets such as resource allocation requests to the master during this period, and the master sends back an acknowledgement or response packet.

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### 3.4.3 Exclusive access during the allocation period

During the allocation period, only the stations permitted by the master can communicate using the time slot and code assigned to them in the beacon packet. The master evaluates the currently available resources and decides whether or not to grant the slave's service request and allocate the resources. Data services that use asynchronous connections receive acknowledgements for the dispatched frames by default, and synchronous connections receive acknowledgements selectively.

## 3.5 Summary of states

A station has the following operational states.

- establishing the network

- associating with the network

- sending data

- changing the master

- disassociating from the network

- terminating the network

### 3.5.1 Establishing the network

The master establishes the network by filling a beacon packet with synchronization information such as the length of the superframe, contention period, and allocation period, and sending it out. The beacon packet includes the network ID as well as synchronization information, enabling the stations to identify the network they will connect with.

### 3.5.2 Associating with the network

Stations attempting to associate with the network periodically scan each frequency channel to listen for the beacon packet from the master. If the received packet is the beacon packet for the desired network, the process of associating with the relevant network's master is started, and if this succeeds, the link to the network is established.

When the station associates with the network, it sends its own capability information to the master. This capability information contains such information as the physical layer data transfer rate that can be supported, power management status, ability to function as the master, and size of memory, and based on this information the master may decide to initiate the process of changing the master.

### 3.5.3 Sending data

A slave to send data first requests resources for the transmission from the master during the contention period, and once it is allocated to the resources it uses them to send the data. Data transfer is possible between any stations – not only between master and slave, but also between slaves themselves. The master is involved only during the initial resource allocation process, thus enabling the stations to exchange data freely afterwards.


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### 3.5.4 Changing the master

The nature of an ad hoc network entails frequent changes of the master. The following cases are the two most likely scenarios.

- The current master is no longer able to service requests. (For example, it cannot meet the decided quality of service.)

- The master abruptly vanishes from the network. (It loses power or moves out of the network.)

### 3.5.5 Disassociating from the network

Stations currently associated with the network can disassociate from the network either spontaneously or at the will of the master.

In the case of spontaneous disassociation, the station sends a disassociate request to the master. If the master wants to disassociate from the network, it first hands over the master role to the most capable slave among the stations before disassociating.

If a certain slave is having trouble in receiving service due to network conditions, the master can forcibly disassociate it by sending a disassociate command.

### 3.5.6 Terminating the network

Terminating of the network can be categorized in two ways: normal termination by station request and abnormal termination due to unexpected events.

Normal termination refers to the case where the master receives the request from a slave, decides whether or not to terminate, then broadcasts this decision to all slaves, thereby dissolving the network. The master can also initiate this request.

Abnormal termination of the network refers to cases where the network is dissolved due to situations such as a network-wide power outage or exodus out of the industrial coverage area. However, such occurrences are highly unlikely.

# 4 Inter-layer interfaces

## 4.1 Summary

Both the MAC layer and the physical layer conceptually have management entities, called the MAC Layer Management Entity (MLME) and the Physical Layer Management Entity (PLME) respectively. These entities provide a service interface for layer management functions.

The physical layer provides an interface between the MAC sublayer and the wireless channel by means of the PHY firmware and the PHY hardware. The physical layer includes a conceptual management entity called a PLME. This entity provides a service interface by means of layer management functions. The PLME maintains a database for managed objects in the physical layer, also called the Management information base (MIB). The Device Management Entity (DME) is a layer independent from the other management entities and its functionality is beyond the scope of this International Standard. Simply stated, however, it is responsible for the inter-layer interfaces providing device management functions. The physical layer provides services through two Service Access Points (SAP). Data services are provided through the PD-SAP and management services are provided through the PLME-SAP. In addition, the physical layer provides DME-PLME-SAP interface, which is equivalent to the PLME-SAP interface except that it operates through DME rather than MLME.

In order for the MAC to operate correctly, each station must possess a Device Management Entity (DME). DME exists in each layer and is layer-independent. The functions of DME are beyond the scope of this International Standard and vary depending on implementation, but in general they carry out tasks such as receiving data from a layer or initializing another layer. Generally DME acts under the direction of a higher-level management application. Figure 3 shows the relationships between the various management entities.

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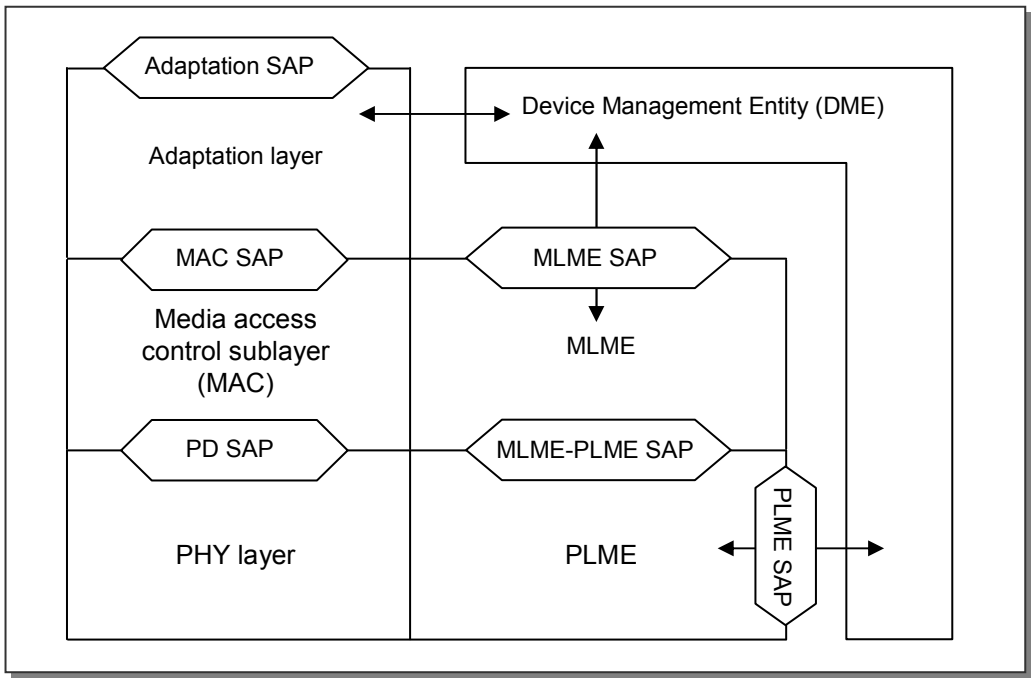


**Figure 3 - Protocol stack configuration**

## 4.2 General format of management primitives

Each sublayer's specific management information is organized into the relevant Management information base (MIB). Corresponding to the MIB of the PAN, the LAN/MAN contains the Management Information Base (MIB) that operates according to the Simple Network Management Protocol (SNMP). However, since management within Network is restricted to an individual network (i.e. one network does not interfere in the management of another) the MIB is used to define the specifications of each sublayer.

MLME and PLME are assumed to have a MIB for each sublayer, and the management primitives of the MIB are exchanged by means of management SAPs. The manager can "GET" or "SET" the value of the MIB attribute via the primitives. The "SET" request primitive can also trigger certain actions within the relevant layer.

A "GET" or "SET" primitive may be expressed in the form of a request accompanying a confirm primitive. Such primitives have the prefix MLME or PLME depending on whether the point of exchange is the MAC SAP or the PD SAP. DME utilizes the services provided by MLME through the MLME SAP.

In Table 1, "XX" stands for "MLME" or "PLME", and the parameters of the primitives are defined in Table 2.

**Table 1 - General management primitive overview**

| Name | Request | Confirm |
|---|---|---|
| XX-GET | Refer to 4.2.1 | Refer to 4.2.2 |
| XX-SET | Refer to 4.2.3 | Refer to 4.2.4 |


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**Table 2 - MLME/PLME general management primitive parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| MIBattribute | Octet string | Any MIB attribute | MIB attribute name |
| MIBValue | Variable | | MIB value |
| ResultCode | Enumeration | SUCCESS,<br>INVALID_MIB_ATTRIBUTE,<br>READ_ONLY_MIB_ATTRIBUTE,<br>WRITE_ONLY_MIB_ATTRIBUTE | Result of MLME or PLME request |

#### 4.2.1 MLME-GET.request and PLME-GET.request

These primitives request information about the relevant MAC MIB or PHY MIB. The semantics of these primitives are as follows.

XX-GET.request (

MIBattribute

)

The primitive parameters are defined in Table 2.

##### 4.2.1.1 Time of creation

DME and MLME (in the case of a PLME-GET.request) create these primitives to retrieve information from the MAC or PHY MIB.

##### 4.2.1.2 Effect

The relevant management entity fetches the requested MIB attribute from the database and returns the value as the result of XX-GET.confirm.

#### 4.2.2 MLME-GET.confirm and PLME-GET.confirm

These primitives return the result of an information request to the relevant MAC MIB or PHY MIB. The semantics of these primitives are as follows.

XX-GET.confirm (

Status,

MIBattribute,

MIBattributevalue

)

The primitive parameters are defined in Table 2.

##### 4.2.2.1 Time of creation

DME or MLME (in the case of a PLME-GET.confirm) create these primitives in response to an XX-GET.request.

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#### 4.2.2.2 Effect

If the status is SUCCESS, these primitives return the value of the relevant MIB attribute, otherwise they return the error code in the status field. Valid error status values include INVALID_MIB_ATTRIBUTE and WRITE_ONLY_MIB_ATTRIBUTE.

### 4.2.3 MLME-SET.request and PLME-SET.request

These primitives attempt to set the value of the relevant MAC MIB or PHY MIB attribute to the specified parameter. The semantics of these primitives is as follows.

XX-SET.request (

MIBattribute,

MIBattributevalue

)

The primitive parameters are defined in Table 2.

#### 4.2.3.1 Time of creation

These primitives are created when DME or MLME (in the case of PLME-SET.request) tries to set the relevant MAC/PHY MIB attribute.

#### 4.2.3.2 Effect

The relevant management entity tries to alter the value of the MIB attribute in the database. If the MIB is a reference to certain actions, this is interpreted as a request to execute the action. The management entity that receives this command responds by returning the result through a call to XX-SET.confirm.

### 4.2.4 MLME-SET.confirm and PLME-SET.confirm

These primitives return the result of the attempt to set the MAC MIB or PHY MIB attribute. The semantics of this primitive are as follows.

XX-SET.confirm (

Status,

MIBattribute

)

The primitive parameters are defined in Table 2.

#### 4.2.4.1 Time of creation

DME or MLME (in the case of PLME-SET.confirm) create these primitives in order to respond to the XX-SET.request.

#### 4.2.4.2 Effect

If the Status is SUCCESS, this means that the MIB attribute was set to the requested value. Otherwise, the Status field shows the error description. If the specified MIB attribute refers to a certain action, the primitive represents the success or failure of the execution of that action. Possible error status values include INVALID_MIB_ATTRIBUTE and READ_ONLY_MIB_ATTRIBUTE.


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## 4.3 MLME SAP

In this subclause, the services that MLME provides to DME are defined. These definitions are conceptual and do not specify a certain implementation or external interface.

The MLME SAP primitive generally follows the format of an ACTION.confirm in response to an ACTION.request. The ACTION.indication is used to inform DME of events from other stations, and the station selectively sends an ACTION.response to the indication. DME uses the services provided by MLME through MLME SAP, and those primitives are outlined in Table 3.

**Table 3 - MLME primitive summary**

| Name | Request | Indication | Response | Confirm |
|---|---|---|---|---|
| MLME-RESET | 4.3.1.1 | | | |
| MLME-SCAN | 4.3.2.1 | | | 4.3.2.2 |
| MLME-START | 4.3.3.1 | | | 4.3.3.2 |
| MLME-SYNCH | 4.3.4.1 | | | 4.3.4.2 |
| MLME-ATP-EXPIRED | | 4.3.4.3 | | |
| MLME-ASSOCIATE | 4.3.5.1 | 4.3.5.2 | 4.3.5.3 | 4.3.5.4 |
| MLME-STN-ASSOCIATION-INFO | | 4.3.5.5 | | |
| MLME-DISASSOCIATE | 4.3.6.1 | 4.3.6.2 | | 4.3.6.3 |
| MLME-MASER-HANDOVER | 4.3.7.1 | 4.3.7.2 | 4.3.7.3 | 4.3.7.4 |
| MLME-MASTER-INFO | 4.3.8.1 | 4.3.8.2 | 4.3.8.3 | 4.3.8.4 |
| MLME-PROBE | 4.3.9.1 | 4.3.9.2 | 4.3.9.3 | 4.3.9.4 |
| MLME-CREATE-STREAM | 4.3.10.1 | | | 4.3.10.2 |
| MLME-MODIFY-STREAM | 4.3.10.3 | | | 4.3.10.4 |
| MLME-TERMINATE-STREAM | 4.3.10.5 | 4.3.10.6 | | 4.3.10.7 |
| MLME-CHANNEL-STATUS | 4.3.11.1 | 4.3.11.2 | 4.3.11.3 | 4.3.11.4 |
| MLME-REMOTE-SCAN | 4.3.12.1 | 4.3.12.2 | 4.3.12.3 | 4.3.12.4 |
| MLME-NETWORK-PARM-CHANGE | 4.3.13.1 | | | 4.3.13.2 |
| MLME-TX-POWER-CHANGE | 4.3.14.1 | 4.3.14.2 | | 4.3.14.3 |
| MLME-SLEEP | 4.3.15.1 | 4.3.15.2 | 4.3.15.3 | 4.3.15.4 |

### 4.3.1 Reset

This mechanism describes the process of resetting the MAC. The parameters of this primitive are defined in Table 4.

**Table 4 - MLME-RESET primitive parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| SetDefaultMIB | Boolean | TRUE, FALSE | If TRUE, all MIB attributes are reset to their default values. If FALSE, the MAC is reset but all MIB values remain what they were prior to the execution of the MLME-RESET.request primitive |
| ResetTimeout | Duration | 0 ~ 65535 | The time in which the reset process must be completed, in msec |

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#### 4.3.1.1 MLME-RESET.request

This primitive requests a reset of the MAC entity. The semantics are as follows.

MLME-RESET.request (

SetDefaultMIB,

ResetTimeout

)

The primitive parameters are defined in Table 4.

##### 4.3.1.1.1 Time of creation

DME sends this message to MLME to restore the MAC to its initial state.

##### 4.3.1.1.2 Effect

When the primitive is received, if the station is associated with the current network, MLME sends a disassociate request command to the master (see 5.5.1.3). In all cases, the slave MLME sets the MAC to its initial state, and resets all variables but is still consistent with the SetDefaultMIB (see Table 4).

When the master MLME receives this primitive, it behaves the same way as a slave MLME, except for cases when it has been disassociated from the network after transferring the master role or is performing a shutdown of network.

If the ResetTimeout occurs while MLME is still executing network disassociations, master handover, or network shutdown, MLME resets the MAC and cancels the interrupted process.

### 4.3.2 Scan

This mechanism determines the existence of the network in the communication channel. The parameters of this primitive are defined in Table 5.

PiconetDescriptionSet is the set of PiconetDescriptions, and a PiconetDescription is composed of the elements in Table 6.


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**Table 5 - MLME-SCAN primitive parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| OpenScan | Boolean | TRUE, FALSE | Whether or not the scan is open (an open scan refers to search for any beacon frame) |
| NID | integer | 0-65535 | ID of the specific network to scan |
| ChannelList | Array of integers | 0 – maximum channels supported by the physical layer | List of channels to search during a scan |
| Channel scanDuration | time | 0-65535 | The time it takes for the station to scan one channel |
| NumberOfNetworks | integer | 0-255 | Number of discovered networks (number of PiconetDescriptions in the PiconetDescriptionSet) |
| PiconetDescriptionSet | Network Description set | As defined in Table 6 | The set of all attributes of the discovered networks, returned as the result of a scan request |
| NumberOfChannels | integer | 0 - maximum channels supported by the physical layer | Number of channels to scan |
| ChannelRatingList | Array of integers | 0- maximum channels supported by the physical layer | List of channels sorted by quality (best to worst) |
| ResultCode | enumeration | SUCCESS, INVALID_PARAMETERS | Result of MLME request |

**Table 6 - PiconetDescription elements**

| Name | Type | Valid range | Description |
|---|---|---|---|
| MasterSTNAddress | MACaddress | all MACaddress | MACaddress of the master of the discovered network |
| NID | As defined in Table 5 | As defined in Table 5 | NID of the discovered network |
| ScannedFrameType | enumeration | BEACON, NON-BEACON | Type of the discovered frame |
| ChannelIndex | integer | 0-255 | Index of frequency channel on which the network was discovered |
| SuperframeDuration | time | 0-65536 | Length (msec) of the superframe of the discovered network |
| CPEndTime | integer | 0-65525 | The end time of the contention period of the discovered network |

#### 4.3.2.1 MLME-SCAN.request

This primitive requests a scan of the MAC entity. The semantics are as follows.

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MLME-SCAN.request (

OpenScan,

NID,

ChannelList

Channel scanDuration

)

The primitive parameters are defined in Table 5.

#### 4.3.2.1.1 Time of creation

When a manual SCAN is initiated for a search of a specified NID or an arbitrary NID of a network, DME sends this message to MLME.

#### 4.3.2.1.2 Effect

When MLME receives this primitive from DME, it executes a manual SCAN of the channels in the Channel List. When this SCAN is completed, MLME responds to DME with the result of the SCAN through a call to MLME-SCAN.confirm.

### 4.3.2.2 MLME-SCAN.confirm

This primitive and its parameters are collected during the SCAN and sent back upon the completion of the SCAN. The semantics are as follows.

MLME-SCAN.confirm (

NumberOfNetworks,

PiconetDescriptionSet,

NumberOfChannels,

ChannelRatingList,

ResultCode

)

The primitive parameters are defined in Table 5.

#### 4.3.2.2.1 Time of creation

This message is sent to DME when MLME completes the requested SCAN or when the parameters of MLME-request are incorrect.

#### 4.3.2.2.2 Effect

DME sends a notification of the result of the SCAN process.

### 4.3.3 Startup of network

This mechanism supports the process of creating a new network. The parameters used in this primitive are outlined in Table 7.


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**Table 7 - MLME-START primitive parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| NID | As defined in Table 5 | As defined in Table 5 | new network NID |
| ChannelIndex | As defined in Table 6 | As defined in Table 6 | Index of frequency channel on which to create network |
| SuperframeDuration | As defined in Table 6 | As defined in Table 6 | As defined in Table 6 |
| PiconetMaxTxPower | As defined in 5.4.7 | As defined in 5.4.7 | As defined in 5.4.7 |
| ResultCode | enumeration | SUCCESS, ALREADY_STARTED, NETWORK_DETECTED, INVALID_PARAMETER, CHANNEL_INTERFE-RENCE | Result of MLME request |

#### 4.3.3.1 MLME-START.request

This primitive requests the creation of a new network to the MAC entity. The semantics are as follows.

```
MLME-START.request      (
                        NID,
                        ChannelIndex,
                        SuperframeDuration,
                        PiconetMaxTXPower
                        )
```

The primitive parameters are defined in Table 7.

##### 4.3.3.1.1 Time of creation

This is created when DME requests that a station become the master and startup a new network.

##### 4.3.3.1.2 Effect

MLME begins the creation process described in 6.1, and invokes MLME-START.confirm to report the result.

#### 4.3.3.2 MLME-START.confirm

This primitive reports the result of the network creation.

```
MLME-START.confirm              (
                        ResultCode
                        )
```

The primitive parameters are defined in Table 7.

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#### 4.3.3.2.1 Time of creation

This is created as a result of an MLME-START.request from DLME.

#### 4.3.3.2.2 Effect

DME reports the result of the creation process of network. A ResultCode of SUCCESS indicates that the station is now the master. If all channels have already been taken by another Network, the ResultCode is set to NETWORK_DETECTED. If network is already started, ResultCode is set to ALREADY_STARTED. If network cannot be started because the noise on the frequency channel indicated for the startup is too severe, the ResultCode is set to CHANNEL_INTERFERENCE. If there is an error in a parameter, the ResultCode is set to INVALID_PARAMETERS.

MLME begins the creation process described in 6.1, then calls MLME-START.confirm to report the result.

### 4.3.4 Synchronization

This mechanism is a preparatory step for a station to network. This primitive also notifies DME when a station has gone out-of-sync. The primitive parameters are defined in Table 8.

**Table 8 - MLME-SYNCH primitive parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| NID | As defined in Table 5 | As defined in Table 5 | ID of network to sync |
| ChannelIndex | As defined in Table 6 | As defined in Table 6 | The frequency channel on which to search network |
| Channel scan-Duration | As defined in Table 5 | As defined in Table 5 | Time to scan network |
| ResultCode | Enumeration | SUCCESS, TIMEOUT, INVALID_PARAMETER | Result of MLME-SYNCH.request |

#### 4.3.4.1 MLME-SYNCH.request

This primitive initiates the process of synchronizing with a network. The semantics are as follows.

```
MLME-SYNCH.request    (
                      NID,
                      ChannelIndex,
                      ChannelScanDuration
                      )
```

The primitive parameters are defined in Table 8.

#### 4.3.4.1.1 Time of creation

DME creates this when initiating the process of synchronizing with a specific beacon.


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#### 4.3.4.1.2 Effect

When MLME receives this primitive from DME, MLME scans until it finds the beacon corresponding to the specific channel or the channel scan duration time is exceeded. If the desired beacon is found, an MLME-SYNCH.confirm is sent to DME with the ResultCode set to SUCCESS. If the channel scan duration time limit is exceeded the ResultCode is set to TIMEOUT.

### 4.3.4.2 MLME-SYNCH.confirm

This primitive notifies DME of the success or failure of the requested network synchronization. The semantics are as follows.

MLME-SYNCH.confirm (

ResultCode

)

The primitive parameters are defined in Table 8.

#### 4.3.4.2.1 Time of creation

MLME creates this when the requested network synchronization task is completed.

#### 4.3.4.2.2 Effect

DME is notified of the result of the synchronization task.

### 4.3.4.3 MLME-ATP-EXPIRED.indication

This primitive indicates that the station is no longer able to hear the beacon. The semantics are as follows.

MLME-ATP-EXPIRED.indication ()

#### 4.3.4.3.1 Time of creation

An MLME other than the master creates this when it has been unable to receive a beacon for longer than the Association Timeout Period (ATP).

#### 4.3.4.3.2 Effect

DME receives notice that the ATP has timed out.

## 4.3.5 Association

The following primitives support the association of stations to network. The primitive parameters are defined in Table 9.

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**Table 9 - MLME-ASSOCIATE.primitive parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| OrigID | Integer | Valid addresses as defined in 5.2.1.3 | The address to associate or the address assigned by the master |
| STNAddress | MACaddress | valid MACaddress | The MACaddress of the station sending the associate request |
| CapabilityField | As defined in 5.4.5 | As defined in 5.4.5 | The capability of the station sending the associate request to the master |
| Association-TimeoutPeriod | Duration | as defined in 5.5.1.1 | Maximum association time as defined in 5.5.1.1 |
| Max-Associations | Integer | 0-255 | Maximum number of stations that the master can manage |
| MaxRRBs | Integer | 0-255 | The maximum number of resource request blocks that the master can manage |
| TxPowerLevel | As defined in 5.4.7 | As defined in 5.4.7 | As defined in 5.4.7 |
| STNID | integer | Valid address as defined in 5.2.1.3 | If the association is successful, the assigned address of the station, otherwise the assigned association address |
| Association-Status | enumeration | DISASSOCIATED, ASSOCIATED | Indication of whether the station is newly associating or disassociating |
| AssocTimeout | time | 0-65535 | The time in which MLME must receive a reply to the associate request |
| ReasonCode | integer | As defined in 5.5.1.2 | The explanation for the reply to the associate request |
| ResultCode | enumeration | SUCCESS, DENIED, NEIGHBOR_ UNSUPPORTED, TIMEOUT | Indication of whether or not the request was granted or denied, or whether the timeout was exceeded |

#### 4.3.5.1 MLME-ASSOCIATE.request

This primitive initiates the association process with a network. The semantics are as follows.

```
MLME-ASSOCIATE.request      (
                            PiconetType,
                            CapabilityField,
                            AssociationTimeoutPerid,
                            MAXRRBs,
                            TxPowerLevel,
                            NetworkserviceInquiry,
                            AssocTimeout
                            )
```

The primitive parameters are defined in Table 9.


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#### 4.3.5.1.1 Time of creation

This is created when DME attempts to associate with network.

#### 4.3.5.1.2 Effect

When DME receives this primitive through the MLME-SAP, it creates an associate request command packet and sends it to the master MLME.

### 4.3.5.2 MLME-ASSOCIATE.indication

This primitive reports that an associate request packet has been received.

MLME-ASSOCIATE.indication (

OrigID,

STNAddress,

CapabilityField,

AssociationTimeoutPeriod,

MaxAssociations

)

The primitive parameters are defined in Table 9.

#### 4.3.5.2.1 Time of creation

This is created to notify DME that the master MLME has received an associate request packet from a currently unassociated station.

#### 4.3.5.2.2 Effect

When DME receives this primitive, if the OrigID is the UnassocID, DME determines whether to grant the associate request of the station, and sends back the result via MLME-ASSOCIATE.response through MLME-SAP.

When DME receives this primitive, if OrigID is the STNID that has just been assigned to the station desiring association, the master is being notified that the station has successfully received the assigned STNID, and does not reply with MLME-ASSOCIATE.response.

### 4.3.5.3 MLME-ASSOCIATE.response

This primitive is created as a response to an MLME-ASSOCIATE.indication. The semantics are as follows.

MLME-ASSOCIATE.response (

OrigID,

STNAddress,

AssociationTimeoutPeriod,

ReasonCode

)

The primitive parameters are defined in Table 9.

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#### 4.3.5.3.1 Time of creation

This is created when the master MLME receives an MLME-ASSOCIATE.indication.

#### 4.3.5.3.2 Effect

When the master MLME receives this primitive from DME, it creates an association response packet and sends it back.

### 4.3.5.4 MLME-ASSOCIATE.confirm

This primitive informs DME that initiated the association whether the associate request was successfully carried out. The semantics are as follows.

```
MLME-ASSOCIATE.confirm        (
                                    STNID,
                                    AssociationTimeoutPeriod,
                                    ReasonCode,
                                    ResultCode
                                    )
```

The primitive parameters are defined in Table 9.

#### 4.3.5.4.1 Time of creation

MLME sends this to DME when the association is completed or the timeout is exceeded.

#### 4.3.5.4.2 Effect

The DME that initiated the association receives this primitive and determines whether the associate request was successfully carried out. If successful, it receives a unique STNID, otherwise it remains in an unassociated state with no unique STNID.

### 4.3.5.5 MLME-STN-ASSOCIATION-INFO.indication

This primitive informs all associated stations in network of the station association information in the beacon. The semantics are as follows.

```
MLME-STN-ASSOCIATION-INFO.indication (
                                    STNAddress,
                                    STNID,
                                    AssociationStatus
                                    )
```

The primitive parameters are defined in Table 9.

#### 4.3.5.5.1 Time of creation

MLME sends this to DME when it receives the beacon containing the association information of other stations.


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#### 4.3.5.5.2 Effect

DME collects information about the station that has just been associated or disassociated from network through this primitive.

### 4.3.6 Disassociation

The following primitives are used when a station is disassociated from network or when the master is trying to disassociate a station. The primitive parameters are defined in Table 10.

**Table 10 - MLME-DISASSOCIATE primitive parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| TrgtID | integer | Valid addresses as defined in 5.2.1.3 | Address of destination station of MLME request |
| OrigID | integer | Valid addresses as defined in 5.2.1.3 | Address of station initiating the MLME request |
| DisassocTimeout | time | 0-65535 | Time in which the task must be completed once the MLME disassociate request is made |
| ReasonCode | integer | As defined in 5.5.1.2 | Reason for disassociate request |
| ResultCode | enumeration | SUCCESS, ACK_TIMEOUT | Result of MLME request |

#### 4.3.6.1 MLME-DISASSOCIATE.request

This primitive initiates the disassociate request. The semantics are as follows.

```
MLME-DISASSOCIATE.request     (
                              TrgtID,
                              ReasonCode,
                              DisassocTimeout
                              )
```

The primitive parameters are defined in Table 10.

#### 4.3.6.1.1 Time of creation

DME sends this to MLME when attempting to start the disassociation process.

#### 4.3.6.1.2 Effect

When the slave MLME receives this primitive, the slave MLME sends a disassociate request command to the master DME.

When the master MLME receives this primitive, it sends a disassociate request command to the DME of the station to disassociate.

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#### 4.3.6.2 MLME-DISASSOCIATE.indication

This primitive reports that a disassociate request packet has been received. The semantics are as follows.

MLME-DISASSOCIATE.indication (

OrigID,

ReasonCode

)

The primitive parameters are defined in Table 10.

##### 4.3.6.2.1 Time of creation

MLME sends this to DME when the master or a station receives a disassociate request packet.

##### 4.3.6.2.2 Effect

The target DME is notified of the reason for the disassociate request.

#### 4.3.6.3 MLME-DISASSOCIATE.confirm

This primitive reports the result of the disassociate request. The master MLME receives notification of the station to disassociate by means of this primitive. The semantics are as follows.

MLME-DISASSOCIATE.request (

TrgtID,

ResultCode,

)

The primitive parameters are defined in Table 10.

##### 4.3.6.3.1 Time of creation

After the disassociate request command is sent, once the acknowledgement packet is received or the acknowledgement timeout is exceeded, MLME sends this to DME. If the MLME initiating the disassociate process receives the acknowledgement packet, it considers the disassociate process to have been successfully carried out, and if the acknowledgement time limit has been exceeded, it considers the process to have failed.

##### 4.3.6.3.2 Effect

The result of the disassociation is reported through this primitive which initiated the disassociation.

### 4.3.7 Handover of master role

The following primitives are used when the current master transfers its authority to the most capable station within network. The primitive parameters are defined in Table 11.


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**Table 11 - MLME-Master-HANDOVER primitive parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| MasterCapable-STNID | integer | Valid STNID as defined in 5.2.1.3 | STNID of station to which the master wants to handover its authority |
| NumberOfSTNs | integer | 0-255 | Number of stations in network |
| NmbrHndOvrBcns | integer | (1+maximum beacon loss)-255 | Number of times that a beacon containing the relevant information blocks must be broadcasted prior to the actual handover of master authority |
| HandoverTimeout | time | 0-65535 | Time limit in which the MLME request must be actually executed |
| HandoverStatus | enumeration | STARTED, CANCELLED | Indicates whether the handover of the master role to another station has been started or cancelled |
| ResultCode | enumeration | SUCCESS, TIMEOUT | Result of MLME request |

#### 4.3.7.1 MLME-MASTER-HANDOVER.request

This primitive requests the start of the handover of the master authority to another station. The semantics are as follows.

MLME-MASTER-HANDOVER.request (
MasterCapableSTNID
NmbrHdnOvrBcns,
HandoverStatus,
HandoverTimeout
)

The primitive parameters are defined in Table 11.

##### 4.3.7.1.1 Time of creation

This primitive is sent to MLME when the master DME tries to handover its authority to another station or cancels the handover operation.

##### 4.3.7.1.2 Effect

When MLME receives this primitive, it sends a master handover command packet to the destination station.

#### 4.3.7.2 MLME-MASTER-HANDOVER.indication

This primitive reports that a master handover command packet has been received. The semantics are as follows.

MLME-MASTER-HANDOVER.indication (
NumberOfSTNs,
HandoverStatus,
)

The primitive parameters are defined in Table 11.

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#### 4.3.7.2.1 Time of creation

When MLME receives the master handover command packet from the master, it sends this primitive to DME. It also sends this primitive to DME the first time it broadcasts the beacon as the new master.

#### 4.3.7.2.2 Effect

If HandoverStatus is STARTED, DME receives notice that MLME has begun the process of master handover, and if HandoverStatus is CANCELED, DME learns that the master handover process has been cancelled.

### 4.3.7.3 MLME-MASTER-HANDOVER.response

This primitive initiates the response to an MLME-MASTER-HANDOVER.indication. The semantics are as follows.

MLME-MASTER-HANDOVER.response ()

#### 4.3.7.3.1 Time of creation

Once the master DME receives an MLME-MASTER-HANDOVER.indication with a HandoverStatus of SUCCESS and an MLME-MASTER-INFO.confirm, the master DME sends this primitive to MLME.

#### 4.3.7.3.2 Effect

When the new master MLME receives this primitive from DME, it is notified that DME is ready to take on the role of master.

### 4.3.7.4 MLME-MASTER-HANDOVER.confirm

This primitive notifies the requesting DME that the job is completed. The semantics are as follows.

MLME-MASTER-HANDOVER.confirm (

ResultCode

)

The primitive parameters are defined in Table 11.

#### 4.3.7.4.1 Time of creation

After the master MLME hands over its master function and sends its last beacon, it sets ResultCode to SUCCESS and sends this primitive to DME. If the master was unable to send the desired data to the destination station, it sends a primitive to DME with ResultCode set to TIMEOUT.

#### 4.3.7.4.2 Effect

The master DME is notified of the success or failure of the MLME-MASTER-HANDOVER.request. If the master sends the last beacon before the master handover timeout, ResultCode is set to SUCCESS, otherwise it is set to TIMEOUT.

### 4.3.8 Data request

This mechanism is used when a station requests information from the master about a specific station or all stations in network. The primitive parameters are defined in Table 12.


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**Table 12 - MLME-MASTER-INFO primitive parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| QueriedSTNID | integer | Valid addresses as defined in 5.2.1.3 | ID of the station about which information is being requested from the master (if set to the broadcasting address, this indicates a request for information about all stations) |
| OrigID | integer | Valid addresses as defined in 5.2.1.3 | ID of station initiating the MLME request |
| STNInfoSet | As defined in 5.5.4.2 | As defined in 5.5.4.2 | Set of information about the station being queried |
| MasterInfo-Timeout | time | 0-65535 | Time in which the task must be completed once the MLME receives the request |
| ResultCode | enumeration | SUCCESS, TIMEOUT | Result of MLME request |

#### 4.3.8.1 MLME-MASTER-INFO.request

This initiates the process of requesting information concerning a specific station or all stations. The semantics are as follows.

MLME-MASTER-INFO.request (

QueriedSTNID,

MasterInfoTimeout

)

The primitive parameters are defined in Table 12.

##### 4.3.8.1.1 Time of creation

This primitive is sent to MLME when DME requests information from the master about a specific station or all stations.

##### 4.3.8.1.2 Effect

When MLME receives this primitive, it sends the station information request packet to the master.

#### 4.3.8.2 MLME-MASTER-INFO.indication

This primitive indicates that the station information request command packet has been received. The semantics are as follows.

MLME-MASTER-INFO.indication (

QueriedSTNID,

OrigID

)

The primitive parameters are defined in Table 12.

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#### 4.3.8.2.1 Time of creation

MLME sends this to DME upon receiving the station information request packet.

#### 4.3.8.2.2 Effect

When DME receives this primitive, it responds to MLME with MLME-MASTER-INFO.response.

### 4.3.8.3 MLME-MASTER-INFO.response

This primitive initiates a response to MLME-MASTER-INFO.indication. The semantics are as follows.

MLME-MASTER-INFO.response (

OrigID,

STNInfoSet

)

The primitive parameters are defined in Table 12.

#### 4.3.8.3.1 Time of creation

DME sends this primitive to MLME as a response to MLME-MASTER-INFO.indication.

#### 4.3.8.3.2 Effect

When the master MLME receives this primitive, it sends the station information response packet to the requesting station.

### 4.3.8.4 MLME-MASTER-INFO.confirm

This primitive informs the DME which initiated the station information probe that the process has been completed. The semantics are as follows.

MLME-MASTER-INFO.confirm (

TrgtID,

InfoElementList,

ResultCode

)

The primitive parameters are defined in Table 12.

#### 4.3.8.4.1 Time of creation

MLME sends this primitive to DME when the station information response command packet is received or the time limit has been exceeded.

#### 4.3.8.4.2 Effect

When the DME requesting the station information receives this primitive, it learns the success or failure of the station information request it sent to the master. If failure, it retransmits another MLME-MASTER-INFO.request for the same information. If success, DME receives the information it requested.


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### 4.3.9 Network node data probe

The following primitives are used when a station requests information about another station in network. The primitive parameters are defined in Table 13.

**Table 13 - MLME-PROBE primitive parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| TrgtID | integer | Valid addresses as defined in 5.2.1.3 | Address of destination station of the MLME request |
| OrigID | integer | Valid addresses as defined in 5.2.1.3 | Address of station initiating the MLME request |
| InfoElementMap | 2 byte | 0x0000 – 0xFFFF | Information request as defined in 5.5.4.1 |
| InfoElementList | Variable length of byte | - | Response to information request as defined in 5.5.4.2 |
| ProbeTimeout | time | 0-65535 | Time limit in which the task must be completed once the MLME has made the request |
| ResultCode | enumeration | SUCCESS, TIMEOUT | Result of MLME request |

#### 4.3.9.1 MLME-PROBE.request

This primitive initiates the process of requesting specific information from a destination station. The semantics are as follows.

```
MLME-PROBE.request    (
                      TrgtID,
                      InfoElementMap,
                      InfoElementList,
                      ProbeTimeout
                      )
```

The primitive parameters are defined in Table 13.

##### 4.3.9.1.1 Time of creation

This primitive is sent to MLME when DME requests information about another station in network.

##### 4.3.9.1.2 Effect

When MLME receives this primitive, it sends an information request command packet to the destination station.

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#### 4.3.9.2 MLME-PROBE.indication

This primitive reports that there has been a request made for specific information through an information probe packet. The semantics are as follows.

```
MLME-PROBE.indication   (
                        OrigID,
                        InfoElementMap
                        )
```

The primitive parameters are defined in Table 13.

##### 4.3.9.2.1 Time of creation

MLME sends this to DME when it receives the information probe packet.

##### 4.3.9.2.2 Effect

When DME receives the MLME-PROBE.indication, it responds to MLME through MLME-PROBE.response.

#### 4.3.9.3 MLME-PROBE.response

This primitive initiates a response to MLME-PROBE.indication. The semantics are as follows.

```
MLME-PROBE.response   (
                        OrigID,
                        InfoElementMap,
                        InfoElementList,
                        ProbeTimeout
                        )
```

The primitive parameters are defined in Table 13.

##### 4.3.9.3.1 Time of creation

DME sends this primitive to MLME as a response to MLME-PROBE.indication.

##### 4.3.9.3.2 Effect

When MLME receives this primitive, it sends the information probe command packet to the station that initiated the information probe.

#### 4.3.9.4 MLME-PROBE.confirm

This primitive notifies the DME that initiated the information probe that the process has completed. The semantics are as follows.

```
MLME-PROBE.confirm    (
                        TrgtID,
                        InfoElementList,
                        ResultCode
                        )
```

The primitive parameters are defined in Table 13.


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#### 4.3.9.4.1 Time of creation

MLME sends this primitive to DME when it receives the information probe command packet or the time limit has been exceeded.

#### 4.3.9.4.2 Effect

When the DME that requested the information probe receives this primitive, it is notified of the success or failure of the information probe. If failure, another MLME-PROBE.request for the same information is resent. If success, DME is notified of the requested information.

### 4.3.10 Strean creation, modification, termination

This mechanism supports the creation, modification, and shutdown processes of the resources allocated for streams. The primitive parameters are defined in Table 14.

**Table 14 - MLME-CREATE-STREAM, MLME-MODIFY-STREAM, MLME-TERMINATE-STREAM primitive parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| TrgtID | integer | Valid addresses as defined in 5.2.1.3 | Address of destination station of MLME request |
| RequestTimeout | time | 0-65535 | Time limit in which the task must be completed once MLME has made the request |
| StreamIndex | integer | 1-255 | Index of stream to create, modify, or terminate |
| ACKPolicy | enumeration | IMM_ACK, NO_ACK, DLY_ACK | acknowledgement policy to be used by stream |
| RR-DesiredData | integer | As defined in 5.5.2 | As defined in 5.5.2 |
| RR-Period | time | As defined in 5.5.2 | As defined in 5.5.2 |
| RR-BER | 2 byte | As defined in 5.5.2 | As defined in 5.5.2 |
| AllocatedTime | integer | 0-65535 | Length of periodically allocated time slot, in msec |
| StreamReqID | integer | 0-255 | As defined in 5.5.2 |
| ReasonCode | integer | As defined in 5.5.1.2 | As defined in 5.5.2 |
| ResultCode | enumeration | SUCCESS, FAILURE, ILLEGAL_ DENIED, TIMEOUT | Result of MLME request |

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#### 4.3.10.1 MLME-CREATE-STREAM.request

This primitive is used to request the allocation of resources. The semantics are as follows.

MLME-CREATE-STREAM.request (

TrgtID,

StreamReqID,

ACKPolicy,

Priority,

RR-Period,

RR-DesiredData,

RR-BER

)

The primitive parameters are defined in Table 14.

##### 4.3.10.1.1 Time of creation

This is created when DME tries to initiate the process of negotiating resource allocation between the slave and master. The purpose of this process is to create a synchronized data stream between stations in network. If streams that are multicast or broadcast try to use an acknowledgment other than No-ACK, it does not send a resource allocation request command packet to the master MLME and instead sets ResultCode to ILLEGAL_ACK_POLICY and returns this in a MLME-CREATE-STREAM.confirm.

##### 4.3.10.1.2 Effect

When MLME receives this primitive through the MLME-SAP, it creates a resource allocation request command and sends it to the master MLME.

#### 4.3.10.2 MLME-CREATE-STREAM.confirm

This primitive is used to grant or deny a resource allocation request. The semantics are as follows.

MLME-CREATE-STREAM.confirm (

StreamReqID,

StreamIndex,

AllocatedTime,

ResultCode

)

The primitive parameters are defined in Table 14.


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#### 4.3.10.2.1 Time of creation

The MLME sends this primitive to DME when one of the following events occurs.

- Timeout exceeded

- Resource allocation response command packet indicating that the request has been denied

- Resource allocation response command packet indicating that the request has been granted, and a beacon containing the resource allocation information

#### 4.3.10.2.2 Effect

When DME receives this primitive, it learns the success or failure of the stream request.

### 4.3.10.3 MLME-MODIFY-STREAM.request

This primitive is used to modify a stream that currently has allocated resources. The semantics are as follows.

MLME-MODIFY-STREAM.request (

StreamID,

RR-Period,

RR-DesiredData,

RR-BER

)

The primitive parameters are defined in Table 14.

#### 4.3.10.3.1 Time of creation

This primitive is created when DME wants to modify current resource allocation for a stream.

#### 4.3.10.3.2 Effect

When MLME receives this primitive through the MLME-SAP, it creates a resource allocation request command and sends to the master MLME.

### 4.3.10.4 MLME-MODIFY-STREAM.confirm

This primitive is used to report the granting or denial of a resource allocation modification request. The semantics are as follows.

MLME-MODIFY-STREAM.confirm (

StreamIndex,

AllocatedTime,

ResultCode

)

The primitive parameters are defined in Table 14.

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#### 4.3.10.4.1 Time of creation

The MLME sends this primitive to DME when one of the following events occurs.

- Timeout exceeded

- Resource allocation response command packet indicating that the request has been denied

- Resource allocation response command packet indicating that the request has been granted, and a beacon containing the modified resource allocation information

#### 4.3.10.4.2 Effect

When DME receives this primitive, it learns the success or failure of the stream request.

### 4.3.10.5 MLME-TERMINATE-STREAM.request

This primitive is used to request the termination of a stream. The semantics are as follows.

```
MLME-TERMINATE-STREAM.request   (
                                    StreamIndex,
                                    RequestTimeout
                                    )
```

The primitive parameters are defined in Table 14.

#### 4.3.10.5.1 Time of creation

This is created when MLME requests the termination of an existing stream.

#### 4.3.10.5.2 Effect

When the station MLME receives this primitive, it sets the parameters pertaining to the stream termination and sends a resource allocation request command.

### 4.3.10.6 MLME-TERMINATE-STREAM.confirm

This primitive is used to report the success or failure of the stream termination request. The semantics are as follows.

```
MLME-TERMINATE-STREAM.confirm   (
                                    StreamIndex,
                                    ResultCode
                                    )
```

The primitive parameters are defined in Table 14.

#### 4.3.10.6.1 Time of creation

This primitive is sent to DME when the station MLME has received an acknowledgement packet for the stream termination resource allocation request packet, or the request time limit has been exceeded.


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#### 4.3.10.6.2 Effect

When DME receives this primitive, it learns the success or failure of the stream termination request.

#### 4.3.10.7 MLME-TERMINATE-STREAM.indication

This primitive reports to the station that the stream has been terminated. The semantics are as follows.

MLME-TERMINATE-STREAM.indication (

StreamIndex

)

The primitive parameters are defined in Table 14.

#### 4.3.10.7.1 Time of creation

The station MLME sends this to DME when it receives a beacon containing resource allocation information about a stream with no currently allocated resources. It also sends the primitive to the station when it is unable to allocate resources for a period exceeding the specified time limit.

#### 4.3.10.7.2 Effect

DME is notified of the termination of the resource allocation corresponding to the StreamIndex by means of this primitive.

### 4.3.11 Channel state

This primitive provides the ability to verify a frequency channel state. The primitive parameters are defined in Table 15.

**Table 15 - MLME-CHANNEL-STATUS primitive parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| TrgtID | integer | As defined in 5.2.1.3 | STNID targeted by the MLME request |
| OrigID | integer | As defined in 5.2.1.3 | STNID initiating the MLME request |
| MeasurementWindow-Size | integer | 0-65535 | As defined in 5.5.4.4 |
| TXFrameCount | integer | 0-65535 | As defined in 5.5.4.4 |
| RXFrameCount | integer | 0-65535 | As defined in 5.5.4.4 |
| RXFrameErrorCount | integer | 0-65535 | As defined in 5.5.4.4 |
| RXFrameLostCount | integer | 0-65535 | As defined in 5.5.4.4 |
| ChannelStatus-Timeout | time | 0-65535 | Time limit for the completion of the response to the MLME request, in msec |
| ResultCode | enumeration | SUCCESS, TIMEOUT | Result of MLME request |

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#### 4.3.11.1 MLME-CHANNEL-STATUS.request

This primitive initiates the process of verifying the channel between two stations in a network. The semantics are as follows.

```
MLME-CHANNEL-STATUS.request   (
                              TrgtID,
                              ChannelStatusTimeout
                              )
```

The primitive parameters are defined in Table 15.

##### 4.3.11.1.1 Time of creation

DME sends this to MLME when it wants to know the state of the channel between itself and the TrgtID station.

##### 4.3.11.1.2 Effect

When MLME receives this primitive from DME, it sends a channel state request command packet to the TrgtID station.

#### 4.3.11.2 MLME-CHANNEL-STATUS.indication

This primitive reports that a channel state request command packet has been received. The semantics are as follows.

```
MLME-CHANNEL-STATUS.indication   (
                                 OrigID,
                                 )
```

The primitive parameters are defined in Table 15.

##### 4.3.11.2.1 Time of creation

MLME sends this primitive to DME when it receives a channel state request command packet.

##### 4.3.11.2.2 Effect

When DME receives this primitive, it sends a MLME-CHANNEL-STATUS.response to MLME.

#### 4.3.11.3 MLME-CHANNEL-STATUS.response

This primitive indicates DME's response to a MLME-CHANNEL-STATUS.indication. The semantics are as follows.

```
MLME-CHANNEL-STATUS.response   (
                               OrigID,
                               MeasurementWindowSize,
                               TxFrameCount,
                               RxFrameCount,
                               RxFrameErrorCount,
                               RxFrameLostCount
                               )
```

The primitive parameters are defined in Table 15.


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#### 4.3.11.3.1 Time of creation

DME responds to MLME with this primitive when it receives a MLME-CHANNEL-STATUS.indication.

#### 4.3.11.3.2 Effect

MLME creates a channel state response command packet and sends it to the requesting station.

### 4.3.11.4 MLME-CHANNEL-STATUS.confirm

This primitive reports to the DME initiating the channel state request that the request has been completed. The semantics are as follows.

```
MLME-CHANNEL-STATUS.confirm     (
                                    TrgtID,
                                    MeasurementWindowSize,
                                    TxFrameCount,
                                    RxFrameCount,
                                    RxFrameErrorCount,
                                    RxFrameLostCount,
                                    ResultCode
                                    )
```

The primitive parameters are defined in Table 15.

#### 4.3.11.4.1 Time of creation

MLME sends this primitive to DME when it receives the channel state response command packet or the time limit has been exceeded.

#### 4.3.11.4.2 Effect

The DME that initiated the request learns of the success or failure of the channel state request.

### 4.3.12 Remote scan

These primitives are used by a master to make a slave to perform channel scan on behalf of it. The primitive parameters are defined in Table 16.

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**Table 16 - MLME-REMOTE-SCAN primitive parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| TrgtID | integer | As defined in 5.2.1.3 | STNID of target STNID |
| ChannelList | As defined in Table 5 | As defined in Table 5 | List of channels to be scanned |
| Remote scan-Timeout | time | 0-65535 | Time limit for responding to the master, in msec |
| NumberOfNetworks | integer | 0-255 | As defined in 5.5.4.7 |
| RemotePiconet-DescriptionSet | RemotePiconetDescription Set | As defined in Table 17 | Other network information in the response for the scan result |
| NumberOfChannels | As defined in Table 5 | As defined in Table 5 | As defined in Table 5 |
| ChannelRatingList | As defined in Table 5 | As defined in Table 5 | As defined in 5.5.4.7 |
| ReasonCode | integer | As defined in 5.5.4.7 | As defined in 5.5.4.7 |
| ResultCode | enumeration | SUCCESS, TIMEOUT | Result of MLME request |

**Table 17 - RemotePiconetDescription elements**

| Name | Type | Valid range | Description |
|---|---|---|---|
| MasterSTNAddress | MACaddress | valid MACaddress | Master MACaddress of discovered network |
| NID | integer | As defined in Table 5 | NID of discovered network |
| ScannedFrameType | enumeration | BEACON, NON-BEACON | Discovered frame type |
| ChannelIndex | integer | 0-255 | Frequency channel of discovered network |

#### 4.3.12.1 MLME-REMOTE-SCAN.request

This primitive is used by the master to request the channel scan of a station. The semantics are as follows.

```
MLME-REMOTE-SCAN.request    (
                            TrgtID,
                            ChannelList,
                            Remote scanTimeout
                            )
```

The primitive parameters are defined in Table 16.

##### 4.3.12.1.1 Time of creation

This primitive is sent to MLME when the master requests the remote channel scan of the TrgtID station.


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#### 4.3.12.1.2 Effect

When MLME receives this primitive, it sends a remote channel scan request command packet to the specified station.

### 4.3.12.2 MLME- REMOTE-SCAN.indication

This primitive reports that a remote channel scan request command packet has been received from the master. The semantics are as follows.

MLME-REMOTE-SCAN.indication (

ChannelList

)

The primitive parameters are defined in Table 16.

#### 4.3.12.2.1 Time of creation

MLME sends this primitive to DME when it receives a remote scan request command packet.

#### 4.3.12.2.2 Effect

DME sends MLME either a MLME-SCAN.request to execute the requested channel scan, or a MLME-REMOTE-SCAN.response with a ResultCode indicating that the remote scan could not be executed.

### 4.3.12.3 MLME- REMOTE-SCAN.response

This primitive is DME's response to a MLME-REMOTE-SCAN.indication. The semantics are as follows.

MLME-REMOTE-SCAN.response (

NumberOfNetworks,

RemotePiconetDescriptionSet,

NumberOfChannels,

ChannelRatingList,

ReasonCode

)

The primitive parameters are defined in Table 16.

#### 4.3.12.3.1 Time of creation

This primitive is sent to MLME after either DME denies the MLME-REMOTE-SCAN.request or grants the request, performs the MLME-SCAN.request, and receives a MLME-SCAN.confirm.

#### 4.3.12.3.2 Effect

When MLME receives this primitive, it sends a remote channel scan response command packet to the specified station.

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#### 4.3.12.4 MLME- REMOTE-SCAN.confirm

This primitive reports the completion of the request to the master to perform a channel scan of a destination station and obtain the results. The semantics are as follows.

MLME-REMOTE-SCAN.confirm (

TrgtID,

NumberOfNetworks,

RemotePiconetDescriptionSet,

NumberOfChannels,

ChannelRatingList,

ReasonCode,

ResultCode

)

The primitive parameters are defined in Table 16.

##### 4.3.12.4.1 Time of creation

MLME sends this primitive to DME when the remote channel scan response command packet has been received or the time limit has been exceeded.

##### 4.3.12.4.2 Effect

The DME initiating the request is notified of the success of failure of its request. If unsuccessful and the ResultCode is TIMEOUT, the scan request is resent to the same station, and if the ResultCode is REQUEST_DENIED, it is resent to a different station. If successful, DME is notified of the result of the channel scan performed by the destination station.

### 4.3.13 Network parameter modification

These primitives enable the master to modify network attributes. The primitive parameters are defined in Table 18.

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**Table 18 - MLME-NETWORK-PARM-CHANGE primitive parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| NewChannelIndex | integer | Dependent on the physical layer | New channel frequency of network |
| NmbrOfChange-Beacons | integer | 0-255 | Number of superframes to repeat the information about the network parameter modification |
| SuperframeLength | time | 0-65535 | Superframe length, in msec |
| ChangeType | enumeration | CHANNEL, SIZE, NID,POWER | Indicates what to modify |
| NID | integer | 0-65535 | network ID |
| PiconetMaxTX-Power | As defined in 5.4.7 | As defined in 5.4.7 | Maximum transmit power allowed within network |
| ResultCode | enumeration | SUCCESS, TIMEOUT, INVALID_PARAMETERS | Result of MLME request |

#### 4.3.13.1 MLME-NETWORK-PARM-CHANGE.request

This primitive is used to initiate the process of changing the frequency channel, superframe length, maximum network transmit power, or NID. The semantics are as follows.

MLME-NETWORK-PARM-CHANGE.request (

ChangeType,

NmbrOfChangeBeacons,

NewChannelIndex,

SuperframeLength,

NID,

PiconetMaxTxPower

)

The primitive parameters are defined in Table 18.

##### 4.3.13.1.1 Time of creation

This primitive is sent to MLME when the master DME decides to modify a network parameter.

##### 4.3.13.1.2 Effect

If ChangeType is Power, the master MLME sets the maximum transmit power field included in the synchronization information of the beacon to PiconetMaxTXPower. In all other cases the appropriate action is executed depending on the ChangeType parameter.

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#### 4.3.13.2 MLME-NETWORK-PARM-CHANGE.confirm

This primitive verifies that the MLME-NETWORK-PARM-CHANGE.request has been executed. The semantics are as follows.

MLME-NETWORK-PARM-CHANGE.confirm (

ResultCode

)

The primitive parameters are defined in Table 18.

##### 4.3.13.2.1 Time of creation

The master MLME sends out a beacon with the modified parameters, and sends this primitive to DME.

##### 4.3.13.2.2 Effect

The master DME is notified through this primitive that the network parameter modification has been completed.

### 4.3.14 Adjustment of power

This mechanism supports the ability to increase or decrease the transmission power of the station. The primitive parameters are defined in Table 19.

**Table 19 - MLME-TX-POWER-CHANGE primitive parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| TgrtID | integer | As defined in 5.2.1.3 | STNID of destination station |
| TxPowerChange-Value | integer | -127-127 | Requested amount of change to transmit power, in dB |
| TxPowerChange-Timeout | time | 0-65535 | Time limit for the response to the MLME request to be completed |
| ResultCode | enumeration | SUCCESS, TIMEOUT | Result of MLME request |

#### 4.3.14.1 MLME-TX-POWER-CHANGE.request

This primitive requests the increase or decrease in the transmit power of the destination station. The semantics are as follows.

MLME-TX-POWER-CHANGE.request (

TrgtID,

TxPowerChangeValue,

TxPowerChangeTimeout

)

The primitive parameters are defined in Table 19.


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#### 4.3.14.1.1 Time of creation

This primitive is sent to MLME when DME wishes to modify the transmit power of the destination station.

#### 4.3.14.1.2 Effect

MLME sends a transmit power change request command packet to the destination station.

### 4.3.14.2 MLME-TX-POWER-CHANGE.indication

This primitive indicates that the transmit power change request command packet has been received. The semantics are as follows.

MLME-TX-POWER-CHANGE.indication (

TxPowerChangeValue

)

The primitive parameters are defined in Table 19.

#### 4.3.14.2.1 Time of creation

When MLME receives the transmit power change request command packet, it sends this primitive to the station.

#### 4.3.14.2.2 Effect

DME receives this primitive and depending on the request, either modifies the power or ignores the request.

### 4.3.14.3 MLME-TX-POWER-CHANGE.confirm

This primitive indicates that the transmit power change request has been completed. The semantics are as follows.

MLME-TX-POWER-CHANGE.confirm (

ResultCode

)

The primitive parameters are defined in Table 19.

#### 4.3.14.3.1 Time of creation

MLME sends this primitive to DME when it receives an acknowledgement or the acknowledgement time limit has been exceeded.

#### 4.3.14.3.2 Effect

The requesting DME is notified of the success or failure of the power adjustment request. In case the power adjustment fails, such as in the event that the acknowledgement is not received within the time limit, DME may retransmit the MLME-TX-POWER-CHANGE.request. If successful, DME receives notification that the power adjustment request task was successfully carried out by receiving a primitive with a ResultCode of SUCCESS.

### 4.3.15 Power saving

This mechanism supports a means of saving power by putting a station into sleep state. The primitive parameters are defined in Table 20.

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**Table 20 - MLME-SLEEP primitive parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| OrigID | integer | As defined in 5.2.1.3 | STNID making the MLME request |
| SleepPeriod | time | 0-65535 | Period of sleep state |
| SleepReason-Code | integer | As defined in 5.5.3.2 | As defined in 5.5.3.2 |
| SleepTimeout | time | 0-65535 | Time limit for the completion of the task once MLME makes the request |
| ResultCode | enumeration | SUCCESS, TIMEOUT | Result of MLME request |

#### 4.3.15.1 MLME-SLEEP.request

This primitive requests the master to allow a station to go to sleep. The semantics are as follows.

MLME-SLEEP.request (

SleepPeriod,

SleepTimeout

)

The primitive parameters are defined in Table 20.

##### 4.3.15.1.1 Time of creation

This is created when a station sends a request to the master to go to sleep.

##### 4.3.15.1.2 Effect

When this primitive is received from DME, MLME sends a sleep state request command packet to the master.

#### 4.3.15.2 MLME-SLEEP.indication

This primitive indicates that the master DME has received a sleep state request command packet. The semantics are as follows.

MLME-SLEEP.indication (

OrigID,

SleepPeriod,

)

The primitive parameters are defined in Table 20.

##### 4.3.15.2.1 Time of creation

This is created when the master MLME receives a sleep state request command packet.


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#### 4.3.15.2.2 Effect

When MLME receives this primitive, the master DME uses MLME-SLEEP.response to respond. The SleepPeriod is then readjusted to be a multiple of the current superframe length.

### 4.3.15.3 MLME-SLEEP.response

This primitive is executed by the master as a response to a sleep state request. The semantics are as follows.

MLME-SLEEP.response (

OrigID,

SleepPeriod,

SleepReasonCode

)

The primitive parameters are defined in Table 20.

#### 4.3.15.3.1 Time of creation

This is created when the master DME receives a MLME-SLEEP.indication from MLME.

#### 4.3.15.3.2 Effect

When MLME receives this primitive, it sends a sleep state request packet to the requesting station.

### 4.3.15.4 MLME-SLEEP.confirm

This primitive reports the completion of the sleep state request to the requesting DME. The semantics are as follows.

MLME-SLEEP.confirm (

SleepPeriod,

SleepReasonCode,

ResultCode

)

The primitive parameters are defined in Table 13.

#### 4.3.15.4.1 Time of creation

MLME sends this primitive to DME when the sleep state request command packet is received or the time limit has been exceeded.

#### 4.3.15.4.2 Effect

When the DME sending the sleep state request receives this primitive, it learns the success or failure of the sleep state request. If TIMEOUT, it retransmits another MLME-SLEEP.request with a request for the same set of information.

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## 4.4 MAC management

In order to manage the MAC sublayers of a station, the MAC MIB is composed of managed object, attributes, actions, and notifications. The MAC MIB is divided into six groups: master, attributes, association, network security, and media access list. In the following table, 'static' indicates that the parameter generally does not change, and 'dynamic' indicates that when the station is active the parameter may change.

### 4.4.1 MAC MIB master group

The MAC MIB master group in Table 21 incorporates the station's master capability and current network attributes.

**Table 21 - MAC MIB master group parameters**

| Managed object | Octets | Definition | Type |
|---|---|---|---|
| MACMIB_CFPDuration | 2 | CFP length | dynamic |
| MACMIB_SuperframeDuration | 2 | Superframe length | dynamic |
| MACMIB_MasterCapable | 1 bit | 1 if the station is capable of being master, otherwise 0 | static |
| MACMIB_MasterDesMode | 1 bit | 1 if the station desires to be master | dynamic |
| MACMIB_MaxAssociations | 2 | Maximum number of slaves that can be managed if the station becomes master | static |
| MACMIB_MaxCTBs | 2 | Maximum number of resource blocks that can be managed if the station becomes master | static |

### 4.4.2 MAC MIB attributes group

The MAC MIB attribute group in Table 22 incorporates the station's capabilities and attributes.

**Table 22 - MAC MIB attribute group parameters**

| Managed object | Octets | Definition | Type |
|---|---|---|---|
| MACMIB_STNAddress | 6 | MACaddress of station | static |
| MACMIB_STNID | 1 | station ID | dynamic |
| MACMIB_SleepSupported | 1 | 0x00: does not support sleep mode<br>0x01: supports sleep mode | static |
| MACMIB_MaxStreams | 1 | Maximum number of streams that the station can manage | static |
| MACMIB_PowerSource | 2 | 0x00: wireline power supply<br>0x01: battery power supply | dynamic |


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### 4.4.3 MAC MIB assocation group

The MAC MIB association group in Table 23 incorporates the association and disassociation information of the station in the current network.

**Table 23 - MAC MIB association group parameters**

| Managed object | Octets | Definition | Type |
|---|---|---|---|
| MACMIB_STNServicesBroadcast | 1 | 0x00: station is sending information about its own services<br>0x01: station is not sending information about its own services | dynamic |
| MACMIB_MasterServicesBroadcast | 1 | 0x00: master is sending information about its own services<br>0x01: master is not sending information about its own services | dynamic |

## 4.5 MAC SAP

The MAC provides stream and non-stream services to the higher adaptation layer. This service maps the resource allocation request needed for the service of each traffic link to a particular stream. Streams provide the means by which resource allocation can be managed for uplink (slave to master), downlink (master to slave), and peer-to-peer (slave to slave) data traffic. Resource allocation requests for uplink streams (slave to master), downlink streams (master to slave) and peer-to-peer streams (slave to slave) can be managed.

A stream can be dynamically created, modified, or terminated. An existing stream may need to be changed depending on its service type. Asynchronous traffic can also dynamically reserve resources or terminate. For example, bursty IP services may need to change the resource allocation request.

The MAC SAP is the logical interface between the MAC and the higher adaptation layer. This logical interface incorporates a set of primitives and their definitions. These primitives and definitions are described conceptually here, but through this the process of the parameters exchanged between the MAC and adaptation layer can be understood.

The MAC SAP primitives are defined in Table 24.

**Table 24 - MAC SAP primitive summary**

| Name | Request | Indication | Response | Confirm |
|---|---|---|---|---|
| MAC-ASYNC-DATA | 4.5.1 | 4.5.3 | | 4.5.2 |
| MAC-ISOCH-DATA | 4.5.4 | 4.5.6 | | 4.5.5 |

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The primitive parameters are defined in Table 25.

**Table 25 - MAC-ASYNC-DATA and MAC-ISOCH-DATA primitive parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| TrgtID | integer | Values defined in 5.2.1.3 | Target STNID of MAC request |
| OrigID | integer | Values defined in 5.2.1.3 | STNID initiating the MAC request |
| Priority | integer | 0-7 | Data priority |
| ACKPolicy | enumeration | immediate acknowledgement, no acknowledgement, delayed acknowledgement | acknowledgement policy of relevant MSDU |
| StreamIndex | octet | 0-255 | Stream to which the data is being sent |
| Transmission-Timeout | time | 0-65535 | Time limit for data transfer (msec) |
| Length | integer | 0-2035 | MSDU length |
| Data | variable length octet | | Data portion of MSDU |
| ResultCode | enumeration | SUCCESS, TX_TIMEOUT, DLY_ACK_FAILED, INVALID_ACK_POLICY, INVALID_STREAM | Result of MAC request |

### 4.5.1 MAC-ASYNC-DATA.request

This primitive initiates the asynchronous data transfer from one MAC entity to another MAC entity or entities. The semantics are as follows.

MAC-ASYNC-DATA.request (

TrgtID,

OrigID,

Priority,

ACKPolicy,

TransmissionTimeout,

Length,

Data

)

The primitive parameters are defined in Table 25.

#### 4.5.1.1 Time of creation

Once the adaptation layer receives the data transfer request from the higher layer, it sends it to the MAC SAP.

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#### 4.5.1.2 Effect

When this primitive is received, the MAC formats the MSDU according to the input parameters and sends it to the PD-SAP; then the MSDU passes through the wireless media and is sent to the peer MAC entity. If the acknowledgement policy is set to delayed acknowledgement, the MAC does nothing and returns an error indication with MAC-ASYNC-DATA.confirm.

### 4.5.2 MAC-ASYNC-DATA.confirm

This primitive reports whether the packet has successfully been sent to the adaptation layer or failed due to a timeout. The semantics are as follows.

MAC-ASYNC-DATA.confirm (

TrgtID,

OrigID,

Priority,

ResultCode

)

The primitive parameters are defined in Table 25.

#### 4.5.2.1 Time of creation

This primitive is created when the MAC successfully completes the packet transfer or fails due to a TX_TIMEOUT event or (in the case of an immediate acknowledgement policy) an acknowledgement has not been received by the time the maximum retry limit is reached. If ACKPolicy is set to delayed acknowledgement, ResultCode is set to INVALID_ACK_POLICY.

#### 4.5.2.2 Effect

When the adaptation layer receives this primitive it notifies the appropriate higher layer of the transfer result.

### 4.5.3 MAC-ASYNC-DATA.indication

This primitive reports to the adaptation layer that it has received an asynchronous MSDU. The semantics are as follows.

MAC-ASYNC-DATA.indication (

TrgtID,

OrigID,

Length,

Data

)

The primitive parameters are defined in Table 25.

#### 4.5.3.1 Time of creation

This is created when the asynchronous MSDU received by the MAC has been successfully processed.

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#### 4.5.3.2 Effect

When the adaptation layer receives this primitive, it notifies the appropriate higher layer of the received packet.

### 4.5.4 MAC-ISOCH-DATA.request

This primitive initiates the synchronous data transfer from one MAC entity to another MAC entity or entities. The semantics are as follows.

```
MAC-ISOCH-DATA.request    (
                          StreamIndex,
                          TransmissionTimeout,
                          Length,
                          Data
                          )
```

The primitive parameters are defined in Table 25.

#### 4.5.4.1 Time of creation

After the adaptation layer receives the data transfer request from the higher layer and sets the appropriate StreamIndex, it sends it to the MAC SAP.

#### 4.5.4.2 Effect

When this primitive is received, the MAC formats the MSDU according to the input parameters and sends it to the PD-SAP; then the MSDU passes through the wireless media and is sent to the peer MAC entity. If it is not the station creating the requested stream, MLME does not send the packet, and instead responds through a MAC-ISOCH-DATA.confirm with a ResultCode of INVALID_STREAM.

### 4.5.5 MAC-ISOCH-DATA.confirm

This primitive indicates the success or failure of the packet transmission to the adaptation layer. The semantics are as follows.

```
MAC-ISOCH-DATA.confirm    (
                          StreamIndex,
                          ResultCode
                          )
```

The primitive parameters are defined in Table 25.

#### 4.5.5.1 Time of creation

This primitive is created when the MAC successfully completes the packet transfer or fails due to a TX_TIMEOUT event or (in the case of an immediate acknowledgement policy) an acknowledgement has not been received by the time the maximum retry limit is reached. A delayed acknowledgement may be used, but if the receiving end does not support this acknowledgement type the ResultCode is set to DLY_ACK_FAILED.


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#### 4.5.5.2 Effect

When the adaptation layer receives this primitive it sends the transmission result to the appropriate higher layer.

### 4.5.6 MAC-ISOCH-DATA.indication

This primitive reports to the adaptation layer that a synchronous MSDU has been received. The semantics are as follows.

MAC-ISOCH-DATA.indication (

TrgtID,

OrigID,

Length,

Data

)

The primitive parameters are defined in Table 25.

#### 4.5.6.1 Time of creation

This is created when the synchronous MSDU received by the MAC has been successfully processed.

#### 4.5.6.2 Effect

When the adaptation layer receives this primitive, it notifies the appropriate higher layer of the received packet.

## 4.6 PHY specification

### 4.6.1 PD-SAP

The PD-SAP transports the MAC protocol data units (MPDUs) between device MAC sublayer entities. Table 26 describes the primitives supported by the PD-SAP. Each primitive is described in the referenced clause.

**Table 26 - PD-SAP primitives**

| PD-SAP Primitive | Request | Confirm | Indication |
|---|---|---|---|
| PD-DATA | 4.6.1.1 | 4.6.1.2 | 4.6.1.3 |
| PD-CCA-START | 4.6.1.4 | 4.6.1.5 | |
| PD-CCA-END | 4.6.1.6 | 4.6.1.7 | |
| PD-CCA | | | 4.6.1.8 |
| PD-TX-START | 4.6.1.9 | 4.6.1.10 | |
| PD-TX-END | 4.6.1.11 | 4.6.1.12 | |
| PD-RX-START | 4.6.1.13 | 4.6.1.14 | 4.6.1.16 |
| PD-RX-END | 4.6.1.15 | 4.6.1.17 | 4.6.1.19 |
| PD-PS | 4.6.1.20 | 4.6.1.21 | |

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**Table 27 - PD-SAP parameters**

| Name | Type | Valid range | Description |
|---|---|---|---|
| psduLength | Unsigned Integer | ≤aMaxPHYPacketSize | Number of bytes in the PSDU to be transmitted by the physical layer entity |
| status | Enumeration | SUCCESS, RX_ON, TRX_OFF | Result of packet transmit request |
| LQI | Octet | PHY dependent | Link quality index;<br>Varies according to implementation |
| ChannelStatus | Enumeration | BUSY or IDLE | Execution result of CCA request |
| TXDataRate, RXDataRate | integer | 0,1,2,3 | See constant amplitude coding method in Table44<br>00 = RATE1, 01 = RATE2,<br>02 = RATE3, 03 = RATE4 |
| TXLength, RXLength | 2 Octets | *minimum payload length – maximum payload length* | MAC frame length |
| TXPowerLevel | Octet | Varies according to PHY | Transfer power |
| TXMACHead, RXMACHead | 2 Octets | valid MAC header | MAC header excluding the sequence check |
| TXAntSelect | Octet | 0-255 | Antenna used for transmission<br>0 is always valid but other values may be used depending on implementation |
| RSSI | Octet | PHY dependent | Receive signal strength<br>Varies according to implementation |
| RXERROR | Enumeration | NO_ERROR, FORMAT_VIOLATION, CARRIER_LOST, UNSUPPORTED_RATE | Receive error type |
| PSLevel | integer | 0-PHYMIB_NumPSLevels | Specifies the powersave mode |
| PSResultCode | Enumeration | SUCCESS, FAILED, UNSUPPORTED_MODE | Result of powersave mode request |

#### 4.6.1.1 PD-DATA.request

This primitive is sent from the MAC sublayer to the physical layer entity and is used to request transmission of a MPDU (PSDU).

##### 4.6.1.1.1 Definition of service primitives

The following interface is provided.

PD-DATA.request (

psduLength,

)

Table 27 defines the PD-DATA.request primitive parameters.


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#### 4.6.1.1.2 Time of generation

This occurs when the MAC sublayer entity requests transmission of a MPDU to the physical layer entity.

#### 4.6.1.1.3 Effect

When it is received by the physical layer entity, it triggers the transmission of the given PSDU. If the transceiver is activated (TX_ON), the physical layer creates a PPDU including the PSDU and sends it. Once the physical layer entity has completed the transmission it sends a PD-DATA.confirm primitive with a SUCCESS indication to the MAC sublayer entity. If the primitive is received when the receiver is activated (RX_ON) or the transceiver is deactivated (TRX_OFF) the physical layer entity sends a PD-DATA.confirm primitive with an RX_ON or TRX_OFF status to the MAC sublayer entity.

### 4.6.1.2 PD-DATA.confirm

This is used to confirm that the MAC sublayer entity has sent a MPDU (PSDU) to another MAC sublayer entity.

#### 4.6.1.2.1 Definition of service primitives

The following interface is provided.

```
PD-DATA.confirm     (
                    status
                    )
```

Table 27 defines the PD-DATA.confirm primitive parameters.

#### 4.6.1.2.2 Time of generation

The physical layer entity sends this to the MAC sublayer entity as a response to the PD-DATA.request primitive when the requested PSDU is transmitted.

#### 4.6.1.2.3 Effect

The MAC sublayer completes the data transmission.

### 4.6.1.3 PD-DATA.indication

The physical layer reports the MPDU (PSDU) transmission to the MAC sublayer entity.

#### 4.6.1.3.1 Definition of service primitives

The following interface is provided.

```
PD-DATA.indication  (
                    psduLength,
                    LQI
                    )
```

Table 27 defines the PD-DATA.indication primitive parameters.

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#### 4.6.1.3.2 Time of generation

This takes place when the physical layer sends the received PSDU to the MAC sublayer entity. If the received psduLength is lower than *minimum payload length* or greater than *maximum payload length* nothing happens.

#### 4.6.1.3.3 Effect

The MAC sublayer entity should process received data as a MPDU according to the MAC specification.

### 4.6.1.4 PD-CCA-START.request

The physical layer requests a clear channel assessment (CCA, 7.7.5).

#### 4.6.1.4.1 Definition of service primitives

The following interface is provided.

PD-CCA.request ()

This primitive has no parameters.

#### 4.6.1.4.2 Time of generation

Whenever the CSMA-CA algorithm needs to adjust the channel, DME generates this and sends it to the physical layer.

#### 4.6.1.4.3 Effect

The receive channel assessment is executed.

### 4.6.1.5 PD-CCA-START.confirm

The physical layer informs the MAC layer that the receive channel assessment (CCA, 7.7.5) has been started.

#### 4.6.1.5.1 Definition of service primitives

The following interface is provided.

PD-CCA.confirm ()

This primitive has no parameters.

#### 4.6.1.5.2 Time of generation

Whenever a PD-CCA-START.request is received the physical layer generates and sends this to the MAC layer.

#### 4.6.1.5.3 Effect

The MAC may proceed to obtain and update the CCA result

### 4.6.1.6 PD-CCA-END.request

The MAC layer requests termination of the clear channel assessment (CCA, 7.7.5).

#### 4.6.1.6.1 Definition of service primitives

The following interface is provided.

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PD-CCA.request ()

This primitive has no parameters.

#### 4.6.1.6.2 Time of generation

This is generated when the MAC layer wants the physical layer to terminate the receive channel assessment.

#### 4.6.1.6.3 Effect

The receive channel assessment is terminated.

### 4.6.1.7 PD-CCA-END.confirm

The physical layer informs the MAC layer that the receive channel assessment (CCA, 7.7.5) has been terminated.

#### 4.6.1.7.1 Definition of service primitives

The following interface is provided.

PD-CCA.confirm ()

This primitive has no parameters.

#### 4.6.1.7.2 Time of generation

This is generated by the physical layer as a response to PD-CCA-END.request and sent to the MAC layer once the receive channel assessment is terminated.

#### 4.6.1.7.3 Effect

The MAC stops obtaining the CCA result.

### 4.6.1.8 PD-CCA.indication

The physical layer reports the current channel state to the MAC layer.

#### 4.6.1.8.1 Definition of service primitives

The following interface is provided.

PD-CCA.indication (

Channel Status

)

Table 27 defines the PD-CCA.indication primitive parameters.

#### 4.6.1.8.2 Time of generation

Whenever the channel state changes from BUSY (IDLE) to IDLE (BUSY) the physical layer reports this to the MAC layer. The physical layer keeps the channel in a BUSY state until the aCCADetectTime period ends.

#### 4.6.1.8.3 Effect

The MAC may use the channel status to perform the CSMA/CA algorithm.

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#### 4.6.1.9 PD-TX-START.request

The MAC layer requests the start of a MPDU transmission to the physical layer.

##### 4.6.1.9.1 Definition of service primitives

The following interface is provided.

PD-TX-START.request (

TXDataRate,

TXLength,

TXPowerLevel,

TXAntSelect,

TXMACHead

)

Table 27 defines the PD-TX-START.request primitive parameters.

##### 4.6.1.9.2 Time of generation

The MAC layer sends this to the physical layer whenever a MPDU needs to be sent. TXMACHead is sent so that the physical layer can calculate the sequence check.

##### 4.6.1.9.3 Effect

The physical layer starts the frame transmission.

#### 4.6.1.10 PD-TX-START.confirm

The physical layer reports the frame transmission initiation to the MAC layer.

##### 4.6.1.10.1 Definition of service primitives

The following interface is provided.

PD-TX-START.confirm ()

This primitive has no parameters.

##### 4.6.1.10.2 Time of generation

This is triggered by the physical layer when it receives a PD-TX-START.request and is ready to receive data from the MAC layer.

##### 4.6.1.10.3 Effect

The MAC layer sends data to the physical layer.

#### 4.6.1.11 PD-TX-END.request

The MAC layer requests the termination of a MPDU transmission to the physical layer.


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#### 4.6.1.11.1 Definition of service primitives

The following interface is provided.

PD-TX-END.request ()

This primitive has no parameters.

#### 4.6.1.11.2 Time of generation

This is generated whenever a PD-DATA.confirm is received from the physical layer.

#### 4.6.1.11.3 Effect

The current transmission is terminated.

### 4.6.1.12 PD-TX-END.confirm

The physical layer informs the MAC layer of the termination of the frame transmission.

#### 4.6.1.12.1 Definition of service primitives

The following interface is provided.

PD-TX-END.confirm ()

This primitive has no parameters.

#### 4.6.1.12.2 Time of generation

The physical layer generates this after a PD-TX-END.request is received and all data has been transmitted.

#### 4.6.1.12.3 Effect

The MAC can initiate the next transmit, receiver, or power management operation.

### 4.6.1.13 PD-RX-START.request

MAC layer requests that the physical layer activate the receiver and select the specified antenna.

#### 4.6.1.13.1 Definition of service primitives

The following interface is provided.

```
PD-RX-START.request     (
                        RXAntSelect,
                        )
```

Table 27 defines the PD-RX-START.request parameters.

#### 4.6.1.13.2 Time of generation

The MAC layer sends this to the physical layer whenever it anticipates a transmission of a MPDU to the current device.

#### 4.6.1.13.3 Effect

The PHY begins PHY preamble acquisition. It subsequently issues a PD-RX-START.confirm to the MAC.

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#### 4.6.1.14 PD-RX-START.confirm

The physical layer reports to the MAC layer that the receiver has been activated.

##### 4.6.1.14.1 Definition of service primitives

The following interface is provided.

PD-RX-START.confirm ()

This primitive has no parameters.

##### 4.6.1.14.2 Time of generation

This is generated when PD-RX-START.request is received and the physical layer's receiver has been activated.

##### 4.6.1.14.3 Effect

The MAC can receive a PD-RX-START.indication primitive.

#### 4.6.1.15 PD-RX-END.request

MAC layer requests termination of a MPDU transmission to the physical layer.

##### 4.6.1.15.1 Definition of service primitives

The following interface is provided.

PD-RX-END.request ()

This primitive has no parameters.

##### 4.6.1.15.2 Time of generation

This is generated whenever a PD-DATA.confirm is received from the physical layer.

##### 4.6.1.15.3 Effect

The current transmission is terminated.

#### 4.6.1.16 PD-RX-START.indication

The physical layer generates this when the physical layer header and MAC layer header has been successfully transmitted.

##### 4.6.1.16.1 Definition of service primitives

The following interface is provided.

```
PD-RX-START.indication      (
                            RXDataRate,
                            RXLength,
                            RXMACHead,
                            RSSI
                            )
```

Table 27 defines the PD-RX-START.indication parameters.


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#### 4.6.1.16.2 Time of generation

The physical layer sends this to the MAC layer whenever the physical layer successfully completes a sequence check at the start of a new PPDU.

#### 4.6.1.16.3 Effect

The MAC can receive a PD-DATA.indication primitive

### 4.6.1.17 PD-RX-END.request

The MAC layer requests the deactivation of the receiver to the physical layer.

#### 4.6.1.17.1 Definition of service primitives

The following interface is provided.

PD-RX-END.request ()

This primitive has no parameters.

#### 4.6.1.17.2 Time of generation

This is generated when the MAC layer requests the deactivation of the receiver to the physical layer.

#### 4.6.1.17.3 Effect

The PHY stops the reception and issues a PD-RX-END.confirm to the MAC

### 4.6.1.18 PD-RX-END.confirm

The MAC layer is informed that the physical layer receiver has been deactivated.

#### 4.6.1.18.1 Definition of service primitives

The following interface is provided.

PD-RX-END.confirm ()

This primitive has no parameters.

#### 4.6.1.18.2 Time of generation

The physical layer generates this after receiving a PD-RX-END.request.

#### 4.6.1.18.3 Effect

The MAC can initiate the next transmit, receiver or power management operation.

### 4.6.1.19 PD-RX-END.indication

The physical layer informs the MAC layer that the MPDU currently being received has been terminated.

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#### 4.6.1.19.1 Definition of service primitives

The following interface is provided.

PD-RX-END.indication (

LQI,

RXERROR

)

The primitive parameters are defined in Table 27.

#### 4.6.1.19.2 Time of generation

The receive state machine indicates that the reception was completed, regardless of error. At this time, RXERROR has one of the following values.

NO_ERROR : no error occurred in the processing of received data.

FORMAT_VIOLATION : incorrect format of the received PPDU.

CARRIER_LOST : MPDU processing impossible due to failure of carrier restoration.

UNSUPPORTED_RATE : unsupported data rate detected when receiving the PPDU.

This is generated when the MAC layer requests to the physical layer that the receiver be deactivated.

#### 4.6.1.19.3 Effect

The MAC is provided with a reference time for determining the end of the received frame on the local air interface.

### 4.6.1.20 PD-PS.request

The MAC layer requests to the physical layer that the specified powersave mode be instituted.

#### 4.6.1.20.1 Definition of service primitives

The following interface is provided.

PD-PS.request (

PSLevel

)

The primitive parameters are defined in Table 27.

#### 4.6.1.20.2 Time of generation

This is generated by the MAC layer when a change is needed to the powersave mode in the physical layer.

#### 4.6.1.20.3 Effect

A change to the powersave mode is made if possible, and the result is sent through a PD-PS.confirm primitive.


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#### 4.6.1.21 PD-PS.confirm

The physical layer reports the result of the requested powersave mode change to the MAC layer.

##### 4.6.1.21.1 Definition of service primitives

The following interface is provided.

PD-PS.confirm (

PSResultCode

)

The primitive parameters are defined in Table 27.

##### 4.6.1.21.2 Time of generation

The physical layer receives the PD-PS.request primitive from the MAC layer and sends the result of the specific powersave mode change to the MAC layer.

##### 4.6.1.21.3 Effect

The MAC use PSResultCode to the PD-PS.request primitive.

### 4.6.2 PLME-SAP

The physical layer management object service access points (PLME-SAP) enable the operational language between MLME and PLME. Additional physical layer management object service access points (DME-PLME-SAP) enable the operational language between DME and PLME, and this interface is equivalent to the PLME-SAP interface. Table 28 defines the primitives supported by PLME-SAP. Table 29 lays out the individual parameters.

**Table 28 - PLME-SAP primitives**

| PLME-SAP Primitive | Request | Confirm | Indication |
|---|---|---|---|
| PLME-ED | 4.6.2.1 | 4.6.2.2 | |
| PLME-GET | 4.6.2.3 | 4.6.2.4 | |
| PLME-SET | 4.6.2.5 | 4.6.2.6 | |
| PLME-RESET | 4.6.2.7 | 4.6.2.8 | |
| PLME-TESTMODE | 4.6.2.9 | 4.6.2.10 | |

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**Table 29 - PLME-CCA.confirm parameters**

| Name | Type | Valid range | Comments |
|---|---|---|---|
| Edstatus | Enumeration | SUCCESS,<br>TRX_OFF, or TX_ON | Result of energy detection request |
| EnergyLevel | Integer | 0x00-0xff | Energy detection level of current channel |
| MIBAttribute | Enumeration | As defined Table 49 | Desired physical layer MIB attribute |
| MIBStatus | Enumeration | SUCCESS,<br>INVALID_ATTRIBUTE,<br>INVALID_VALUE | Result of request for MIB attribute information |
| MIBAttributeValue | Various | Attribute specific | Desired physical layer MIB attribute value |
| ResetResultCode | Enumeration | SUCCESS, FAILED | Response to reset request |
| TEST_ENABLE | Boolean | True, false | if true the physical layer test mode is activated according to the following parameters. |
| TEST_MODE | integer | 1, 2, 3 | TEST_MODE is one of the following.<br>01 = receive mode<br>02 = continuous transmit mode<br>03 = 50% efficiency periode mode |
| DataRate, | integer | 0,1,2,3 | Refer to constant amplitude coding method in Table 44<br>00 = RATE1, 01 = RATE2,<br>02 = RATE3, 03 = RATE4 |
| SCRAMBLE_STATE | Boolean | True, false | if true the scrambler operational state is activated |
| TestResultCode | Enumeration | SUCCESS, FAILED,<br>UNSUPPORTED_MODE | Test mode result |

#### 4.6.2.1 PLME-ED.request

PLME requests an energy detection measurement

##### 4.6.2.1.1 Definition of service primitives

The following interface is provided.

PLME-ED.request ()

This primitive has no parameters.

##### 4.6.2.1.2 Time of generation

DME generates this and requests an energy detection measurement to PLME.

##### 4.6.2.1.3 Effect

If the receiver is activated (RX_ON) PLME tells the physical layer to perform an energy detection measurement. When PLME completes the energy detection is generates a PLME-ED.confirm primitive.


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#### 4.6.2.2 PLME-ED.confirm

The result of the energy detection measurement is reported.

##### 4.6.2.2.1 Definition of service primitives

The following interface is provided.

PLME-ED.confirm (

EDstatus,

EnergyLevel

)

Table 29 defines the primitive parameters.

##### 4.6.2.2.2 Time of generation

PLME generates this as a response to a PLME-ED.request and sends it to DME after the energy detection is measured. The status value of a successful energy detection measurement is SUCCESS and a failed measurement due to a faulty transceiver is reported as the current state of the transceiver (TRX_OFF or TX_ON).

##### 4.6.2.2.3 Effect

The result of the energy detection measurement is reported to DME.

#### 4.6.2.3 PLME-GET.request

Information about a physical layer MIB attribute is requested.

##### 4.6.2.3.1 Definition of service primitives

The following interface is provided.

PLME-GET.request (

MIBAttribute

)

Table 29 defines the primitive parameters.

##### 4.6.2.3.2 Time of generation

DME generates this to obtain information from the physical layer MIB of PLME.

##### 4.6.2.3.3 Effect

PLME extracts the requested MIB attribute from the database and sends the results through a PLME-GET.confirm primitive.

#### 4.6.2.4 PLME-GET.confirm

The result of the requested information from the physical layer MIB is reported.

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#### 4.6.2.4.1 Definition of service primitives

The following interface is provided.

PLME-GET.confirm (

MIBstatus,

MIBAttribute,

MIBAttributeValue

)

Table 29 defines the primitive parameters.

#### 4.6.2.4.2 Time of generation

PLME generates this as a response to a PLME-GET.request primitive and sends it to DME.

#### 4.6.2.4.3 Effect

If the state parameter is SUCCESS the requested physical layer MIB value is sent, otherwise an error is indicated.

### 4.6.2.5 PLME-SET.request

A request is made to set the physical layer MIB attribute to the specified value.

#### 4.6.2.5.1 Definition of service primitives

The following interface is provided.

PLME-SET.request (

MIBAttribute,

MIBAttributeValue

)

Table 29 defines the primitive parameters.

#### 4.6.2.5.2 Time of generation

DME generates this to set the physical layer MIB attribute to the specified value and sends it to PLME.

#### 4.6.2.5.3 Effect

PLME attempts to store the specified physical layer MIB attribute in the database and reports the result through a PLME-SET.confirm primitive.

### 4.6.2.6 PLME-SET.confirm

This reports the result of the attempt to set the physical layer MIB attribute to the specified value.


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#### 4.6.2.6.1 Definition of service primitives

The following interface is provided.

PLME-SET.confirm (

MIBstatus,

MIBAttribute

)

Table 29 defines the primitive parameters.

#### 4.6.2.6.2 Time of generation

PLME sends this to DME as the response to the PLME-SET.request primitive.

#### 4.6.2.6.3 Effect

If the state value is SUCCESS it means the MIB attribute was set as requested, otherwise an error is indicated if the MIB attribute was unable to be set for some reason.

### 4.6.2.7 PLME-RESET.request

This requests a reset of the physical layer. To prevent accidental data transmission while receiving, the state must be changed to receive mode.

#### 4.6.2.7.1 Definition of service primitives

The following interface is provided.

PLME-RESET.request ()

This primitive has no parameters.

#### 4.6.2.7.2 Time of generation

This is generated whenever a physical layer reset is requested.

#### 4.6.2.7.3 Effect

The physical layer resets all transceiver state machines to their initial states and converts to receive mode.

### 4.6.2.8 PLME-RESET.confirm

This requests reset of the physical layer. To prevent accidental data transmission during receiving data, the state must be changed to receive mode.

#### 4.6.2.8.1 Definition of service primitives

The following interface is provided.

PLME-RESET.confirm (

ResetResultCode

)

Table 29 defines the primitive parameters.

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#### 4.6.2.8.2 Time of generation

PLME generates this as the result of a PLME-RESET.request.

#### 4.6.2.8.3 Effect

DME or MLME is notified of the result of the reset.

### 4.6.2.9 PLME-TESTMODE.request

A conversion of the physical layer to test operational mode is requested. The parameters mentioned here are handled as options when implemented.

#### 4.6.2.9.1 Definition of service primitives

The following interface is provided.

```
PLME-TESTMODE.request    (
                         TEST_ENABLE,
                         TEST_MODE,
                         SCRAMBLE_STATE,
                         DataRate
                         )
```

Table 29 defines the primitive parameters.

#### 4.6.2.9.2 Time of generation

This is generated whenever a request is made to convert the physical layer to test mode.

#### 4.6.2.9.3 Effect

The physical layer is converted to test mode.

### 4.6.2.10 PLME-TESTMODE.confirm

This requests the physical layer to change to test operational. The parameters mentioned here are handled as options when implemented.

#### 4.6.2.10.1 Definition of service primitives

The following interface is provided.

```
PLME-TESTMODE.confirm    (
                         TestResultCode
                         )
```

Table 29 defines the primitive parameters.

#### 4.6.2.10.2 Time of generation

PLME generates this as the result of a PLME-TESTMODE.request.


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#### 4.6.2.10.3 Effect

DME or MLME is notified of the result of test mode initiation.

### 4.6.3 Physical layer enumerated description

Table 30 lists the valid physical layer protocol enumerated values

**Table 30 - Physical layer enumerated values**

| Enumerated | value | Comments |
|---|---|---|
| BUSY | 0x01 | busy channel is detected through CCA |
| IDLE | 0x02 | idle channel is detected through CCA |
| INVALID_ATTRIBUTE | 0x03 | Recognition of an unsupported attribute is requested |
| INVALID_VALUE | 0x04 | Invalid value for the setting of the parameter is requested |
| RX_ON | 0x05 | Activation of receiver is requested |
| SUCCESS | 0x06 | When a SET/GET, energy detection, modification of transceiver, or a synchronous packet transfer succeeds |
| TRX_OFF | 0x07 | Transceiver is currently inactive or deactivation is requested |
| TX_ON | 0x08 | Transceiver is currently active or activation is requested |
| NO_ERROR | 0x09 | No error has occurred |
| FORMAT_VIOLATION | 0x0A | Error in format |
| CARRIER_LOST | 0x0B | Carrier not found |
| UNSUPPORTED_RATE | 0x0C | unsupported data rate |

# 5 Mac frame format

This chapter describes the format of the MAC frames.

5.1 is an overview of the frames.

5.2 describes the general format of all frames.

5.3 details the format of each frame.

5.4 describes the format of information blocks used in the network to convey information.

5.5 describes the command blocks carried by command frames.

## 5.1 Overview

All MAC frames are composed of the following elements.

a) frame header: frame control information needed to exchange data between stations such as source/destination station ID, frame sequence number, etc. Information located in this portion is used to distinguish frame types and stations exchanging frames. Frame reliability can also be enhanced by error-checking of exchanged frames.

b) frame body: composed of actual payload carrying the data exchanged between stations and FCS to check for payload errors.

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## 5.2 General format of MAC frames

This International Standard uses the common frame formats shown in Figure 4, and each field is defined in detail in the following clauses.

| 2 | 2 | 1 | 1 | 1 | 1 | variable | 4 |
|---|---|---|---|---|---|---|---|
| network ID | Frame control | Source station ID | Destination Station ID | streamID | Sequence number | payload | FCS |
| Frame header | | | | | | frame body | |

**Figure 4 - Format of MAC frame**

### 5.2.1 Frame header

Frame header contains information for the transmission or reception of the frame, flow control, and error checking.

#### 5.2.1.1 NID

The network ID is the ID that distinguishes a network. This is a unique value that does not overlap with other network IDs and remains as long as the network continues to exist.

#### 5.2.1.2 Frame control

Frame control elements are composed of fields such as frame type, first fragment, last fragment, acknowledgement policy, delayed acknowledgement request, protocol version, etc. Their format is shown in Figure 5.

| bit 0-3 | 4-5 | 6 | 7 | 8 | 9-10 | 11-15 |
|---|---|---|---|---|---|---|
| frame type | acknowledgement policy | First fragment | Last fragment | delayed acknowledgement request | Protocol version | reserved |

**Figure 5 - Format of frame control fields**

##### 5.2.1.2.1 Frame type

The frame type field is 4 bits in length. Table 31 shows the defined frame types and values. Examples of the usage of these types are shown in 5.3.

**Table 31 - Frame types**

| Value | Frame type description |
|---|---|
| 0000 | beacon |
| 0001 | acknowledgement |
| 0010 | command |
| 0011 | data (stream or non-stream) |
| 0100 | RTS |
| 0101 | CTS |
| 0110~1111 | reserved |


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#### 5.2.1.2.2 Acknowledgement policy

Acknowledgement policy field is 2 bits in length. In the case where the received frame is an acknowledgement frame it indicates the type of the acknowledgement frame, otherwise it indicates the acknowledgement policy of the destination station of the frame.

Delayed acknowledgement policy can only be used for data frames, and multicast or broadcast frames do not use acknowledgements. (When multicast or broadcast frames are received, the acknowledgement policy field is ignored and the destination station does not send an acknowledgement.) The following are the possible values of the acknowledgement method field.

0: no acknowledgement: destination station does not acknowledge the transmitted frame, and the source station considers the transmission successful regardless of the actual result. This method can be used for frames that are transmitted 1:1 or 1:N, which do not require acknowledgement.

1: immediate acknowledgement: The station that received the frame sends an acknowledgement frame as a response to the source station after a short frame interval. This acknowledgement policy can only be used for 1:1 frame transmissions.

2: delayed acknowledgement: the station receiving the frame sends a delayed acknowledgement frame per 5.3.2.2. This acknowledgement policy can only be used for 1:1 frame transmissions.

3: implicit acknowledgement: This method is used when the receiving station sends an immediate acknowledgement or other data frames as an acknowledgement. This acknowledgement policy can only be used for 1:1 frame transmissions, and can only be used during the allocation period, not the contention period.

#### 5.2.1.2.3 First fragment

The first fragment field is 1 bit in length. ‘1’ indicates that frame is the start of a data or command (MSDU/MCDU) from a higher layer, while ‘0’ means that it is not the start.

#### 5.2.1.2.4 Last fragment

The last fragment field is 1 bit in length. ‘1’ indicates that frame is the end of a data or command (MSDU/MCDU) from a higher layer, while ‘0’ means that it is not the end.

#### 5.2.1.2.5 Delayed acknowledgement request

The delayed acknowledgement request field is 1 bit in length. This is only valid for data frames of streams using the current delayed acknowledgement policy. This field is set to ‘1’ and sent when the source station of the stream is requesting that a delayed acknowledgement frame be sent to the destination station.

#### 5.2.1.2.6 Protocol version

Protocol version information is 2 bits in length. The size and location is fixed and independent of the protocol version of the system. The current value is 0, and is incremented by 1 each time a new version is released. When a station receives a packet with a version higher than its own, it discards it without notifying the source station.

### 5.2.1.3 Station ID

In the MAC frame there are two types of station IDs – the destination station ID and source station ID – and each are 8 bits in length. The source station ID is the ID of the station sending the frame, and the destination station ID is the ID of the station receiving the frame. Each station ID is assigned by the master when the station is associated with network, and the possible values are as follows.

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- 0x00: used by master of network

- 0xFF: used by broadcast frames

- 0xFE: used by stations in the process of association which have not yet been assigned an ID by the master

- 0xFD: used by multicast frames

#### 5.2.1.4 Stream ID

This is composed of 8 bits and is used to identify data streams. It is only valid for data frames, and in other frame types this is set to 0 and ignored.

| bit:7 | 6:4 | 3:0 |
|---|---|---|
| Stream type | priority | stream index |

**Figure 6 - Format of stream ID field**

The field is composed of 3 parts.

The stream index field is 4 bits in length. Each station may freely use any value other than '0' (which indicates non-stream data), but each value must be uniquely assigned by the master.

The priority field is 3 bits in length, and it indicates the stream priority.

The stream type field is 1 bit in length, and '1' means isochronous service, while '0' means asynchronous service.

Frames that do not belong to an existing stream or which do not need a stream connection are non-stream type data, and these are sent with a stream ID of 0. The relevant station determines whether to use an isochronous stream or an asynchronous stream.

#### 5.2.1.5 Sequence number

The sequence number field is 8 bits in length and shows the frame sequence number.

In data frames, a sequence number between 0 and 255 is assigned by means of an incremental counter by each stream, and once it reaches 255 it wraps back to 0.

For frames that are not data type frames, a sequence number between 0 to 255 is assigned by a counter.

### 5.2.2 Frame body

The frame body portion is variable length and is composed of the payload and FCS. The payload format may vary depending on the frame type of the frame control field, and the FCS is used to check for errors in the frame.

#### 5.2.2.1 Payload

The data that is actually exchanged between stations is carried in a variety of formats.

#### 5.2.2.2 Frame check sequence

The Frame Check Sequence (FCS) is 32 bits in length, and is used to verify that the MPDU was received without error. It is generated using the following standard generator polynomial of degree 32:

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


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The FCS is the 1's complement of the modulo 2 sum of the remainders in (a) and (b) below:

a) The remainder resulting from $[x^k * (x^{31} + x^{30} + \cdots)]$ divided (modulo 2) by g(x). The value k is the number of bits in the calculation field.

b) The remainder resulting from the calculation field contents, treated as a polynomial, multiplied by $x^{32}$ and then divided by g(x).

At the transmitter, the initial remainder of the division shall be preset to all ones and is then modified via division of the calculation fields by the generator polynomial g(x). The 1's complement of this remainder is the FCS field.

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

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

## 5.3 Frame formats

A total of six types of frames are defined, and each frame is coded with different usage codes as shown in Table 32, depending on type.

**Table 32 - Usage codes by frame type**

| Frame type | Usage code |
|---|---|
| beacon | network command code |
| Acknowledgement | network command code |
| Command | network command code |
| data (stream or non-stream) | Variable depending on conditions |
| RTS | network command code |
| CTS | network command code |

### 5.3.1 Beacon

This is used during the beacon period to broadcast information to stations associated with network. The beacon packet structure is shown in Figure 7.

<table>
<tr><td>8</td><td>2</td><td>2</td><td>2</td><td>1</td><td>1</td><td>Variable</td><td>4</td></tr>
<tr><td rowspan="2">Frame header</td><td>beacon sequence number</td><td>superframe length</td><td>allocation period start time</td><td>network standard code</td><td>reserved</td><td rowspan="2">beacon payload</td><td rowspan="2">FCS</td></tr>
<tr><td colspan="5">network synchronization information</td></tr>
</table>

**Figure 7 - Beacon frame format**

The beacon sequence number is used to tag each beacon and synchronize slave operations (such as modifying frequency or sleep state). It is incremented by 1 on each transmission.

The superframe length field shows the superframe length in units of usec.

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The allocation period start time field shows the start time of the allocation period in the superframe in units of usec.

The network standard code field is used to show the code rates when a slave sends a command code.

The beacon frame payload holds the information blocks described in Table 33, and each is described in detail in 5.4.

**Table 33 - Beacon frame body**

| Information block | Content | When loaded |
|---|---|---|
| Station UID | 48 bit master IEEE 802 address | as necessary |
| network synchronization parameter | Synchronization information needed by the network stations to synchronize with network | as necessary |
| Transmit power | Maximum transmit power within network | as necessary |
| channel modification | Information needed when changing channels | as necessary |
| Resource allocation | Present state of current superframe resource distribution | as necessary |

The beacon frame's frame control field is set to values as shown in Table 34.

**Table 34 - Setting the control field of the beacon frame**

| Subfield | Value when sent | Action when received |
|---|---|---|
| frame type | Value of beacon frame in 5.2.1.2.1 | decoded |
| Acknowledgement policy | 0 | ignored |
| First fragment | 0 | Ignored |
| Last fragment | 0 | Ignored |
| delayed acknowledgement request | 0 | Ignored |
| Protocol version | Protocol version | decoded |

The destination station ID of the beacon frame header is set to the broadcast ID and the source station ID is set to the master ID. The stream ID and sequence number are set to 0 and ignored when received.

### 5.3.2 Acknowledgement

Acknowledgement frames are of two types - immediate acknowledgement frames and delayed acknowledgement frames – and are encoded with the network standard code rates. While the immediate acknowledgement frame is composed only of a frame header with a frame body, the delayed acknowledgement frame contains a payload and is thus composed of both frame header and frame body. Frame control fields in an acknowledgement frame are set as in Table 35.


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**Table 35 - Setting the control field of the beacon frame**

| Subfield | Value when sent | Action when received |
|---|---|---|
| frame type | Value of acknowledgement frame as shown in 5.2.1.2.1 | decoded |
| acknowledgement policy | Value of frame type of acknowledgement frame | decoded |
| First fragment | 0 | Ignored |
| Last fragment | 0 | Ignored |
| delayed acknowledgement request | 0 | Ignored |
| Protocol version | Protocol version | decoded |

The acknowledgement frame's source station ID field is set to the Destination station ID of the received frame, and the Destination station ID field is set to the source station ID of the received frame.

The stream ID and stream sequence number are set to 0 and ignored when received.

#### 5.3.2.1 Immediate acknowledgement

The immediate acknowledgement frame is composed of only a frame header without a frame body as in Figure 8, and can be used during any period. It is encoded using the network standard code rates.

| 2 | 2 | 1 | 1 | 1 | 1 | 4 |
|---|---|---|---|---|---|---|
| network ID | Frame control | source station ID | Destination station ID | streamID | Sequence number | FCS |
| Frame header | | | | | | |

**Figure 8 - Immediate acknowledgement frame format**

#### 5.3.2.2 Delayed acknowledgement

When the destination station receives a delayed acknowledgement request in a stream using delayed acknowledgement, it uses delayed acknowledgement only during the allocation period. The frame format is as shown in Figure 9, and is encoded using the standard codes.

| 8 | 2 | 7 | 7 | … | 7 | 4 |
|---|---|---|---|---|---|---|
| Frame header | length (=7*m) | Record of stream-1 | Record of stream-2 | …. | Record of stream-m | FCS |
| | payload | | | | | |
| | frame body | | | | | |

**Figure 9 - Delayed acknowledgement frame payload format**

The stream record field is as shown in Figure 10.

| byte:1 | 1 | 1 | 4 |
|---|---|---|---|
| stream ID | Starting sequence number | Ending sequence number | Bitmap of receive status |

**Figure 10 - Format of record for stream-m**

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The stream ID field is 2 bytes and is used by the data to identify the stream using delayed acknowledgement. When 32 or more frames are being acknowledged in the stream, one or more information blocks can be used.

The starting sequence number is 2 bytes and indicates the sequence number of the first frame corresponding to the receive status bitmap. Likewise, the ending sequence number is 2 bytes and indicates the sequence number of the last frame corresponding to the receive status bitmap.

The receive status bitmap is 4 bytes, and each bit represents the success or failure of each frame received in the stream. The first bit of the receive status bitmap corresponds to the frame containing the starting sequence number and the rest of the bits correspond in order to the frames with the following numbers. A bit value of '1' in the receive status bitmap indicates a successful reception, and '0' indicates that the receive was unsuccessful.

### 5.3.3 Command

The command frame is used during the contention period for exchanges between master and slave, and during the allocation period for exchanges between slaves. It is sent during the relevant station's assigned timeslot or the contention period, and one frame can hold one or more command blocks as shown in Figure 11. 5.5 describes the command types in detail.

<table>
<tr><td>byte:8</td><td>(1+2+L1)</td><td>(1+2+L2)</td><td>…..</td><td>(1+2+Ln)</td><td>4</td></tr>
<tr><td rowspan="3">Frame header</td><td>Command block-1</td><td>Command block-2</td><td>….</td><td>Command block-n</td><td rowspan="3">FCS</td></tr>
<tr><td colspan="4">payload</td></tr>
<tr><td colspan="4">frame body</td></tr>
</table>

**Figure 11 - Format of record for stream-m**

The frame header stream ID is set to 0 and ignored when received.

While the command payload is of variable length, the command block is laid out in 2-byte increments in the frame body. If the command block length is not in 2-byte units when the command payload is created, it is padded with 0's to fill the length and the length field indicates only the significant portion.

### 5.3.4 Data (stream or non-stream)

This is used primarily using the allocation period to send data, and it may be used during the contention period to exchange data of short length as well. The format of a data frame is shown in Figure 12, and is encoded using a variety of codes.

| byte:8 | variable | 4 |
|---|---|---|
| Frame header | Variable length data | FCS |

**Figure 12 - Data frame format**

### 5.3.5 RTS (Request To Send)

The RTS frame format is shown in Figure 13.

| byte:2 | 2 | 1 | 1 | 2 | 4 |
|---|---|---|---|---|---|
| NID | Frame control | source station ID | Destination station ID | RTS time | FCS |

**Figure 13 - RTS frame format**


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### 5.3.6 CTS (Clear To Send)

The CTS frame format is shown in Figure 14.

| byte:2 | 2 | 1 | 2 | 4 |
|---|---|---|---|---|
| NID | Frame control | source station ID | CTS time | FCS |

**Figure 14 - CTS frame format**

## 5.4 Information block

The information block is detailed in Table 36, and each individual part is described in detail in the following clauses.

**Table 36 - Information blocks**

| Information block ID | information |
|---|---|
| 0 | station UID |
| 1 | station name |
| 2 | station type |
| 3 | network synchronization |
| 4 | capability |
| 5 | maximum supported time slot |
| 6 | channel modification |
| 7 | power management parameter |
| 8 | maximum transmit power |
| 9 | resource allocation |
| 10 | new master notification |
| 11 | sleep state notification |
| 12-255 | reserved |

The format of the information block is shown in Figure 15. The first byte is the information block ID, and the second byte is the data length ($L_n$) in byte units. The next $L_n$ bytes are the data. More than one information block may be included in a frame and there are no restrictions on the order.

The information block in a frame body is arranged in 2 byte units. When the frame body is made, if the information block is not in units of 2 bytes, 0's are appended to the end of the data to fill the 2-byte length. However, the length field of the information block indicates only the significant data length (excluding the zeroes used for padding). When the frame body is opened and the payload read out, only the actual data is read based on the field length, and the padded zeroes are ignored.

| byte:1 | 1 | Ln |
|---|---|---|
| Information block ID | Length (=Ln) | data |

**Figure 15 - Information block format.**

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### 5.4.1 Station UID

The station UID information block is shown in Figure 16.

| byte:1 | 1 | 6 |
|---|---|---|
| Information block ID (=0) | length (=6) | Station ID |

**Figure 16 - Station UID information block format**

The station UID is the 48 bit IEEE 802 address of the source station.

### 5.4.2 Station name

The station name information block is shown in Figure 17.

| byte:1 | 1 | variable |
|---|---|---|
| information block ID (=1) | length (<256) | station name |

**Figure 17 - Station name information block format**

The station name is the name of the source station recognized by the user, and the maximum length is 256 bytes.

### 5.4.3 Station type

The station type information block is shown in Figure 18.

| byte:1 | 1 | 3 |
|---|---|---|
| information block ID (=2) | length (=3) | station type |

**Figure 18 - Station type information block format**

The station type field represents the station type. The 3-byte representation of the station type has not yet been defined.

### 5.4.4 Network synchronization

The network synchronization information block is shown in Figure 19.

| byte:1 | 1 | 1 | 1 | 2 |
|---|---|---|---|---|
| information block ID (=3) | length (=4) | Modification information | Counter | Value to change |

**Figure 19 - Network synchronization information block format**

The modification information field indicates the network synchronization information to be changed in the future. The value to change will be altered according to this field.

If this field is 1, it means the superframe length will change, and if 2 it means that the channel in use will change.


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The counter field represents the point at which the modified network synchronization information applies. For example, if the current beacon sequence number is 3 and the counter field is 2, the modified synchronization information will take effect after a beacon sequence number of 5 is received.

The value to change field represents the value of the network synchronization information to be modified, and its meaning varies according to the value of the modification information. If the modification information field is 1, it indicates the new superframe length in usec, and if 2 it indicates the new channel ID.

### 5.4.5 Capabilities

The capability information block is shown in Figure 20, and its fields are laid out in Figure 21 The values of the capability information block do not change once a station is associated with network until the station disassociates itself. The master's capability field value does not change while it remains master of network.

| byte:1 | 1 | 2 |
|---|---|---|
| information block ID (=4) | length (=2) | capability |

**Figure 20 - Capability information block format**

| 2 byte | | | | | | |
|---|---|---|---|---|---|---|
| bit:b0 | b1 | b2 | b3 | b4~b7 | b8~b11 | b12~b15 |
| task | master capable | real-time stream support | Sleep state support | Amount of available power | Amount of memory | undefined |

**Figure 21 - Capability fields format**

The task bit represents the current station's role, and if the station is master it is set to '1', otherwise '0'.

The master capable bit is set to '1' if the station is capable of becoming master of network, otherwise '0'.

The realtime stream support bit is set to '1' if the station supports real-time streams, otherwise '0'.

The sleep state support bit is set to '1' if the device uses sleep state for power saving, and in the case of the master this bit is always 0.

The available power field indicates the amount of power left in the station. '1111' means that the station is being supplied from a stable source of power.

The memory field indicates the MAC memory size of the station in units of 258KB.

### 5.4.6 Maximum supported time slot

The maximum supported time slot information block is shown in Figure 22.

| byte:1 | 1 | 1 |
|---|---|---|
| Information block ID (=5) | Length (=1) | Maximum number of supported time slots |

**Figure 22 - Maximum support timeslot information block format**

The maximum supported time slot field indicates the maximum number of supported time slots that can be allocated to a source station.

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### 5.4.7 Maximum transmit power

The maximum transmit power information block is shown in Figure 23.

| byte:1 | 1 | 1 |
|---|---|---|
| information block ID (=8) | length (=1) | Maximum transmit power |

**Figure 23 - Maximum transmit power information block format**

The maximum transmit power field shows the maximum transmit power allowed by network in 2's complement form, in dBm units. For example, +2dBm is encoded as 0x02, and -2dBm is encoded as 0xFE. Also, 0x7F means that the master does not restrict the transmit power.

### 5.4.8 Resource allocation

The resource allocation information block is shown in Figure 24. Due to restrictions on the length field a information block can be a maximum of 256 bytes, therefore if needed the master can divide the resource allocation information and load it into multiple information blocks in the beacon. The destination station puts together all resource allocation information in the received beacon frame. To facilitate the combination of the resource allocation information blocks, the master sequences them by the channel time.

| byte:1 | 1 | 6 | 6 | …. | 6 |
|---|---|---|---|---|---|
| information block ID (=9) | length (=n*6) | resource allocation block-1 | resource allocation block-2 | …. | resource allocation block-n |

**Figure 24 - Resource allocation information block format**

Resource allocation information blocks are made up of many resource allocation blocks, and each block is arranged in the order of the start time of the time slot. The resource allocation block is shown in Figure 25.

| byte:1 | 1 | 1 | 1 | 1 | 1 |
|---|---|---|---|---|---|
| source station ID | Destination station ID | streamID | Start of allocated slot | Length of allocated slot | Allocated code |

**Figure 25 - Resource allocation block format**

The source station ID indicates the station to which resources have been allocated.

The destination station ID indicates the station to which the source station is sending the frame, and if this ID is the broadcast ID, the source station sends broadcast frames during the time slot.

The start time field is composed of two parts, and the first four bits represent the start time slot index while the last four bits represent the number of allocated time slots.

The stream ID field indicates the stream that is being used for transmission by means of the the resources.

The allocated time slot field represents the starting slot for the allocated time slot. '1' is for the first slot of the allocation period, and '0' is for the contention period. If this field is set to '0', it means that the station with destination station ID is waking up during its contention period.

The number of allocated time slots field represents the number of allocated time slots, and this number of time slots is allocated to the source station from the time slots represented in the start time slot index field.


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The allocated code field represents the usage mode of the physical layer as shown in 7.4.3

### 5.4.9 New master notification

The new master notification information block is shown in Figure 26.

| byte:1 | 1 | 6 | 1 | 2 |
|---|---|---|---|---|
| information block ID (=10) | length (=9) | new master station UID | new master ID | Time limit for handover |

**Figure 26 - New master notification information block format**

The new master station UID field represents the unique number of the station to become master.

The new master ID field represents the currently assigned ID of the station to become master.

The handover time limit field represents the time limit in which the station must become the master.

### 5.4.10 Sleep state notification

The sleep state notification information block, which reports the entry of a station into sleep state and the wakeup time, is shown in Figure 27.

| byte:1 | 1 | 1 | 1 | … | 1 | 1 |
|---|---|---|---|---|---|---|
| information block ID (=11) | length (=2*N) | beacon counter #1 | sleeping station ID #1 | … | beacon counter #N | sleeping station ID #N |

**Figure 27 - Sleep state notification information block format**

The beacon counter field represents the number of superframes remaining until the sleeping station can wake and hear the beacon. For example, if this value is 2, it means that the station wakes up and hears the beacon after 2 superframes (including the superframe of this beacon), and if 1 it means that it will receive the next superframe in the contention period.

The sleeping station ID field represents the ID of the station in a sleep state.

## 5.5 Command block

Each command block is composed of a 2-byte command type field, a 2-byte length field, and a variable-length command payload, as shown in Figure 28.

<table>
<tr><td colspan="2">byte:1</td><td>2</td><td>$L_x$</td></tr>
<tr><td colspan="2">command type</td><td rowspan="2">length (=$L_x$)</td><td rowspan="2">Command payload</td></tr>
<tr><td>type(4 bit)</td><td>command(4bit)</td></tr>
</table>

**Figure 28 - Command block format**

Commands are roughly divided into four types as shown in Table 37, and each command is described in detail in the following clauses. The command type field is divided into two subfields – the type subfield and the command subfield.

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**Table 37 - Command types**

| Type<br>(type subfield: 4 bits) | Command<br>(command value subfield: 4 bits) |
|---|---|
| network management<br>(0x1) | associate request (0x1) |
| | associate response (0x2) |
| | disassociate request (0x3) |
| | master handover (0x4) |
| stream management<br>(0x2) | resource allocation request(0x1) |
| | resource allocation response(0x2) |
| | resource allocation modify (0x3) |
| | resource allocation termination (0x4) |
| | delayed transmission verification resynchronization (0x5) |
| power management<br>(0x3) | sleep state request (0x1) |
| | sleep state response (0x2) |
| | activation notification (0x3) |
| | transmit power adjustment (0x4) |
| other<br>(0x4) | station information request (0x1) |
| | station information response (0x2) |
| | data query (0x3) |
| | channel status request (0x4) |
| | channel status response (0x5) |
| | remote channel scan request (0x6) |
| | remote channel scan response (0x7) |
| | application specific (0x08) |

### 5.5.1 Network management

#### 5.5.1.1 Associate request

This is the command block used to associate a new station to the network built by the master.

The acknowledgement policy is set to immediate acknowledgement, and the first fragment, last fragment, retransmit, and delayed acknowledgement request fields are set to 0 and ignored when received.

The network ID field of an associate request sent by a disassociated station is set to 0, and for an associate request from a station already registered it is set to the current network ID value.

The source station ID is set to ‘0xFE’ to indicate a station with no assigned ID, and the destination station ID is set to ‘0’ to indicate the master.

The command block to be carried as the payload is shown in Figure 29.


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| byte:1 | 2 | 6 | 2 | 2 |
|---|---|---|---|---|
| command type (=0x11) | Length (variable) | station UID | capability | Time limit for association (usec) |

**Figure 29 - Associate request command block format**

The station UID field represents the 48 bit IEEE 802 address of the station requesting association.

The capability field indicates the capability of the station requesting association as shown in Figure 21.

The allocation ID field is set to '0xFE' and ignored when received.

If a response to the associate request is not received within the time specified by the association time limit field, the station is disassociated and an attempt is made to associate again. Also if the master does not receive a frame from the station during this time, it disassociates the station and waits for an associate request.

#### 5.5.1.2 Associate response

This is the command block that the master sends as a response to the station requesting the association.

The acknowledgement policy is set to immediate acknowledgement, and the first fragment, last fragment, retransmit, and delayed acknowledgement request fields are set to 0 and ignored when received.

The network ID field is set to the current network ID.

The source station ID is set to '0' to indicate the master, and the destination station ID is set to '0xFE'.

The command block to be carried in the payload is shown in Figure 30.

| byte:1 | 2 | 6 | 1 | 1 |
|---|---|---|---|---|
| command type (=0x12) | length (variable) | station UID | Allocated ID | reason |

**Figure 30 - Associate response command block format**

The station UID field represents the 48 bit unique number of the station requesting association. The master uses the value in the previously received associate request frame to fill this field. When two or more stations are awaiting an associate response from the master, they use the station UID field of the associate response frame to determine whether the frame is intended for themselves.

The allocated ID field is filled with the ID to be assigned to the station requesting association. The station begins communicating using the assigned ID, and it is retained until the station is disassociated. If the master denies the associate request, this field is set to '0xFE' and the reason code field is set to the reason for denial.

Valid reason codes are the following.

- 0: the maximum number of stations handled by network are already associated

- 1: no bandwidth exists for a new station

- 2: poor channel state

- 3: the master is terminating and no alternate master exists in network

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- 4: station is attempting to disassociate

- 5: channel is being changed

- 6: master handover is taking place

- 7: station authentication is failed

- 8-255: reserved

#### 5.5.1.3 Disassociate request

The master or slave can make a disassociate request, and the command block format in shown in Figure 31.

| byte:1 | 2 | 6 | 1 |
|---|---|---|---|
| command type (=0x13) | length (=7) | station UID | Reason code |

**Figure 31 - Disassociate request payload format**

The station UID field represents the 48 bit IEEE 802 address of the station requesting disassociation.

Valid reason codes are the following.

- 0: station status is expired (must associate again)

- 1: poor channel state

- 2: station has exceeded its allotted channel time

- 3: master is terminating and there is no alternate master

- 4: station is attempting to disassociate

- 5-255: reserved

#### 5.5.1.4 Master handover

This command is used when the master hands over its authority to another master-capable station in the network. The master compares the capabilities of the stations in the network and hands over its authority to the most eligible station. he capabilities evaluated when selecting the master are laid out in order of preference in Table 38.

**Table 38 - Order of preference when comparing capability**

| sequence | Information | comments |
|---|---|---|
| 1 | Station status | master state is preferred |
| 2 | RTC bit | RTC = 1 is preferred |
| 3 | SEC bit | SEC = 1 is preferred |
| 4 | PS bit | PS = 0 is preferred |
| 5 | Power availability field | Higher value is preferred |
| 6 | Memory field | Higher value is preferred |
| 7 | Storage type bit | Higher value is preferred |
| 8 | Station UID | Higher valued is preferred |


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The master handover command block format is shown in Figure 32.

| byte:1 | 2 | 2 | 6 | 6. | 2 |
|---|---|---|---|---|---|
| command type (=0x14) | length (=16) | Number of stations | master station UID | alternate master station UID | Handover time limit |

**Figure 32 - Master handover command block format**

The number of stations field is the total number of stations currently connected to the network.

The master station UID represents the unique ID of the master station.

The alternate master station UID represents the unique ID of the alternate master station to take on the role of master.

The handover time limit field represents the interval in which the new master must inherit the relevant information from the current master and generate a beacon frame, starting from the most recent beacon frame sent by the current master. The unit of time is 8μs and the maximum is 524280μs.

Once the current master sends the station information, it no longer transmits beacon frames.

### 5.5.2 Stream management

#### 5.5.2.1 Resource allocation request

The resource allocation request command block format is shown in Figure 33. The resource allocation request record format is shown in Figure 34.

| byte:1 | 2 | 6 | 6 | | 6 |
|---|---|---|---|---|---|
| command type (=0x21) | length(=n*6) | resource allocation request record for stream-1 | resource allocation request record for stream-2 | …. | resource allocation request record for stream-n |

**Figure 33 - Resource allocation request command block format**

| byte:1 | 1 | 1 | 1 | 2 |
|---|---|---|---|---|
| Destination station ID | Stream request ID | Resource allocation period (Kμs) | Amount of data to transmit each period (byte) | Required BER level |

**Figure 34 - Resource allocation request record format**

The stream request ID field is 1 byte and is generated to prevent duplication of stream connection request identifiers. This identifier is used with the ID of the requesting station, and is maintained while the stream is transmitting or receiving frames later on.

The resource allocation period field represents the allocation period of the resources allocated to the stream.

The minimum necessary data per period field represents the minimum amount of data that must be sent each period for stream transmission, and if the resources to be allocated are smaller than this size, the master terminates the stream services.

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The minimum transmitted data per period field indicates the appropriate amount of data to be sent per period for stream transmission.

The required BER level field indicates the BER level required by the stream. This field is divided into a mantissa (first byte) and an exponent (second byte), and the required BER is calculated by mantissa*10^(-1*exponent).

#### 5.5.2.2 Resource allocation response

This frame is sent as a response to a resource allocation request or modification request.

| byte:1 | 2 | 1 | 1 | 1 | 1 | 1 |
|---|---|---|---|---|---|---|
| command type (=0x22) | length (=5) | stream request ID | streamID | Number of periodically allocated time slots | Number of allocated codes | Reason code |

**Figure 35 - Resource allocation response command block format**

The stream request ID field is defined in 5.5.2.1.

The stream ID field enables the identification of many streams between source/destination stations. The highest 4 bits show the media type, and the lowest 4 bits show the sequence number. The combination of source station ID, destination station ID, and stream ID together identify a stream in network.

The periodic allocation time slot field shows the number of time slots requested by the slave to be allocated in each period.

The number of allocated codes field indicates the number of codes to be assigned to the slave.

The reason code field shows whether the resource allocation request was successfully executed, and the values are as follows.

- 0: success

- 1: request from a station not associated with network

- 2: the requested priority is not supported

- 3: stream is terminated by the master

- 4: stream is terminated by the destination station

- 5: insufficient resources

- 6: destination station is in powersave mode

- 7: request denied

- 8-255: reserved

#### 5.5.2.3 Resource allocation modification request

The resource allocation modification command block format is shown in Figure 36. The resource allocation modification request record format is shown in Figure 37.


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| byte:1 | 2 | 6 | 6 | | 6 |
|---|---|---|---|---|---|
| command type (=0x23) | Length (n*6) | resource allocation modification record for stream-1 | resource allocation modification record for stream-2 | …. | resource allocation modification record for stream-n |

**Figure 36 - Resource allocation modification command block format**

| byte:1 | 1 | 1 | 1 | 2 |
|---|---|---|---|---|
| Destination station ID | streamID | Resource allocation period (Kμs) | Amount of data to transmit per period (Byte) | Required BER level |

**Figure 37 - Resource allocation modification request record format**

The stream ID field indicates the ID of the stream requesting the resource allocation modification.

The resource allocation period field represents the allocation period of the resources allocated to the stream.

The minimum necessary data per period field represents the minimum amount of data that must be sent each period for stream transmission, and if the resources to be allocated are smaller than this size, the master terminates the stream services.

The minimum transmitted data per period field indicates the appropriate amount of data to be sent per period for stream transmission.

The required BER level field indicates the BER level required by the stream. This field is divided into a mantissa (first byte) and an exponent (second byte), and the required BER is calculated by mantissa*10^(-1*exponent).

#### 5.5.2.4 Resource allocation termination

This frame is sent as a response to a resource allocation request or modification request.

| byte:1 | 2 | 1 | 1 | 1 | 1 |
|---|---|---|---|---|---|
| command type (=0x24) | length (=4) | Source station ID | Destination station ID | stream ID | Reason code |

**Figure 38 - Resource allocation termination command block format**

The source station ID field is the ID of the station transmitting on the stream whose resource allocation is being terminated.

The destination station ID field is the ID of the station receiving on the stream whose resource allocation is being terminated.

The stream ID field is the ID of the stream whose resource allocation is about to be terminated.

The reason code field indicates whether the resource allocation termination request was successful, and the values are as follows.

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- 0: stream transmit terminated

- 1: stream receive terminated

- 2: stream transmit abnormally halted

- 3: stream received abnormally halted

- 4: stream terminated by master

- 5: source station terminated

- 6: destination station terminated

- 7: destination station is in powersave mode

- 8-255: reserved

#### 5.5.2.5 Delayed acknowledgement resynchronization

Only stations that are sending streams 1:1 to other stations using a delayed acknowledgement policy may send a delayed acknowledgement resynchronization. The command block format is shown in Figure 39.

| byte:1 | 2 | 3 | 3 | … | 3 |
|---|---|---|---|---|---|
| command type (=0x25) | length (=3*m) | stream-1 record | stream-2 record | …. | stream-m record |

**Figure 39 - Delayed acknowledgement resynchronization command block format**

The record format is shown in Figure 40.

| byte:1 | 2 |
|---|---|
| stream ID | Resynchronization sequence number |

**Figure 40 - Delayed acknowledgement resynchronization command record format**

The stream ID field is 2 bytes and represents the stream to be resynchronized between the source station and destination station.

The resynchronization sequence number field is 2 bytes and represents the sequence number of the first frame after the command.

### 5.5.3 Power management

#### 5.5.3.1 Sleep state request

Stations that wish to go into a sleep state while associated with the network must receive permission from the master to do so. This command is used to request permission to go to sleep and the format is shown in Figure 41.

| byte:1 | 2 | 2 |
|---|---|---|
| command type (=0x31) | length (=2) | Sleep period |

**Figure 41 - Sleep state request command block format**


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The sleep period field represents the time from the entry into sleep state until the station wakes up and receives a beacon.

#### 5.5.3.2 Sleep state response

The master can grant or deny a sleep state request, and the station can only go to sleep if the master grants the request.

| byte:1 | 2 | 2 | 2 | 1 |
|---|---|---|---|---|
| command type (=0x32) | length (=4) | sleep period | beacon sequence number at start of sleep | reason code |

**Figure 42 - Sleep state response command block format**

The sleep period field is the period of time until the sleeping station will wake and hear a beacon. If the master denies the sleep request this field is set to '0' and the reason code is set to the reason for the denial; if this field is not '0' the reason code is ignored.

The beacon sequence number at start of sleep is the sequence number of the beacon that starts the sleep state of the station. The station receives a beacon with this sequence number and begins to sleep from the next superframe.

The reason code values as are follows.

- 0: no resources

- 1: channel change in progress

- 2: master handover in progress

- 3: unknown reason

- 4-255: reserved

#### 5.5.3.3 Activation indication

This command is used by a station in a sleep state or with a granted sleep state request, in order to request reactivation from the master. After acknowledgement of this command, the master halts buffering for the station and sends frames to the station.

| byte:1 | 2 |
|---|---|
| command type (=0x33) | length (=0) |

**Figure 43 - Activation indication command block format**

#### 5.5.3.4 Transmit power adjustment

This command is used to adjust transmit power for a station, and the format is shown in Figure 44.

| byte:1 | 2 | 1 |
|---|---|---|
| command type (=0x34) | length (=1) | Transmit power |

**Figure 44 - Transmit power adjustment command block format**

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The transmit power field shows the transmit power adjustment amount requested by the station in 2's complement format, in dBm. For example +2dBm is encoded as 0x02, and -2dBm is encoded as 0xFE. Also, 0x7F means that a transmit power adjustment has not been requested.

### 5.5.4 Other

#### 5.5.4.1 Station information request

This is used when a slave requests information about a specific station or stations from the master, and the format is shown in Figure 45.

| byte:1 | 2 | 1 |
|---|---|---|
| command type (=0x41) | length (=1) | ID of target of information request |

**Figure 45 - Station information request command block format**

The information request ID field represents the assigned ID of the station about whom the slave is requesting information from the master. If this field is set to the broadcast ID, it means that the request concerns all stations.

#### 5.5.4.2 Station information response

The station information response command block format used by the master to respond to station information requests is shown in Figure 46.

| byte:1 | 2 | 12 | 12 | … | 12 |
|---|---|---|---|---|---|
| command type (=0x42) | length (=12*N) | station1 station information block | station2 station information block | … | station1 station information block |

**Figure 46 - Station information response command block format**

The requested information about each station currently associated with the network is included in data records, and the format is shown in Figure 47.

| byte:6 | 1 | 1 | 2 | 2 |
|---|---|---|---|---|
| station UID | station ID | state | capability | sleep period |

**Figure 47 - Station information block format**

The station UID field represents the 48 bit IEEE address of the station.

The station ID field represents the ID assigned by the master.

If the state field is 0 it means that the station has been associated but not yet verified, and if 1, it means that the station has been associated.

The capability field shows the station capability as in Figure 21.

The sleep period represents the sleep period if the station is sleeping.


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#### 5.5.4.3 Data query

The data query command is used to request information from a station or respond to it. This command can be exchanged between two stations in network. The components of this frame are shown in Figure 48. The stream ID in the Frame header of the data query command is set to 0 and ignored when received.

| byte:1 | 2 | 2 | variable |
|---|---|---|---|
| command type (=0x43) | length | data request | information block |

**Figure 48 - Data query command block format**

The upper 15 bits of the data request field are a bitmap of the requested information. The requesting station sets each bit corresponding to the requested information to 1. The location of bits in the data request field is equivalent to that of the information block ID in the information block. In other words, the n-th bit of the data request field corresponds to the information block with an ID of 'n'. If all data request fields are set to 0, the station is requesting no information but reporting its own information to the source station.

The data request field's MSB determines whether the rest of the bits are a bitmap or a representation of the request information block ID.

The information block field is a list of information blocks as explained in 5.4. Each information block can be flexibly arranged, and not all information blocks need to be contained therein.

#### 5.5.4.4 Channel state request

This is sent to a station to find out its current channel state, and the format is shown in Figure 49.

| byte:1 | 2 |
|---|---|
| command type (=0x44) | length (=0) |

**Figure 49 - Channel state request command block format**

#### 5.5.4.5 Channel state response

This command is sent as a response to the station requesting the channel state, and the format is shown in Figure 50.

| byte:1 | 2 | 2 | 2 | 2 | 2 | 2 |
|---|---|---|---|---|---|---|
| command type (=0x45) | length(=10) | assessment period (kμs) | number of transmitted frames | number of received frames | number of erroneous frames received | number of lost frames |

**Figure 50 - Channel state response command block format**

The assessment period field represents the time for the channel assessment in kμs.

The number of transmitted frames represents the total number of frames sent by the station.

The number of received frames represents the total number of frames received by the station, and this number includes only those frames with the source station ID set to this station.

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The number of erroneous frames received represents the total number of erroneous frames received by the station. Here an erroneous frame means a frame that passed the PHY header error-check but did not pass the frame error-check.

The number of lost frames represents the total number of frames whose existence is expected but have not been received. If a received frame's sequence number is not one higher than the previously received frame in the stream, this indicates that a frame has been lost in the interim, and the difference between the consecutive frames' sequence numbers minus 1 is the number of lost frames. These differences are summed up across all streams and placed into the number of lost frames field. Resent frames are excluded from this calculation.

#### 5.5.4.6 Remote channel scan request

This is used by the master to request a remote channel scan to a slave to find out the channel state of a different frequency. Only the master can send this command frame, and the format is shown in Figure 51.

| byte:1 | 2 | 2 |
|---|---|---|
| command type (=0x46) | length (=N) | channel bitmap |

**Figure 51 - Remote channel scan request command block format**

The channel bitmap field shows the channels to be scanned in a bitmap format. The Nth bit corresponds to the Nth channel, and if the bit is 1 the channel is scanned, otherwise it is not scanned.

#### 5.5.4.7 Remote channel scan response

This is sent by a station to the master as a response to a remote channel scan request, and the format is shown in Figure 52.

| byte:1 | 2 | 1 | 1 | 5 | 5 | … | 5 |
|---|---|---|---|---|---|---|---|
| Command type (=0x47) | Length (=1 or 3+5*N) | Reason code | Number of channels (=N) | Channel information record #1 | Channel information record #2 | … | Channel information record #N |

**Figure 52 - Remote channel scan response command block format**

The reason code field has the following values.

- 0: success

- 1: requested denied

- 2: invalid channel index was requested

- 3-255: reserved

If this field is 0, no fields follow afterwards, and the length of the command is 1.

The number of channels field represents the number of channels that are scanned and reported.

| byte:1 | 1 | 2 | 1 |
|---|---|---|---|
| channel ID | channel quality | network ID | scanned frame type |

**Figure 53 - Channel information block format**


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The channel ID field represents the ID of the scanned channel.

The channel quality field represents the quality of the scanned channel.

The network ID field represents the network ID discovered during the scan. If this field is 0, it means that no network was discovered.

The scanned frame type field represents the type of the frame discovered during the scan. This field only has relevance when the network ID field is not 0.

#### 5.5.4.8 Application specific

This purpose of this command is to allow vendors to perform the enhanced operation that is out of this standard. For example, by using this command, devices in the network exchange more detailed information such as queue size or number of collision to provide QoS. The frame format is illustrated below.

| byte:1 | 3 | 1 | variable |
|---|---|---|---|
| command type (=0x48) | Vendor Unique ID | length (=3+N) | Vendor defined command |

**Figure 54 - Application specific command format**

## 6 MAC feature description

This chapter describes the role of the MAC layer.

6.1 describes how each station establishes or associates itself with the network.

6.2 describes how the stations individually access the media by period.

6.3 describes how the master and slave synchronize with the superframe by means of the beacon packet.

6.4 describes the means by which the quality of service of the streams between the stations is ensured. Each stream is allocated to the resources to satisfy their individual quality of service, and the resources are adjusted to support quality of service even if channel conditions change.

6.5 describes the process of fragmentation and defragmentation.

6.6 describes the acknowledgement of a transmitted packet and the retransmission process when transmissions have failed.

6.7 describes the efficient power saving method.

6.8 describes the dynamic channel changing method when data communication becomes difficult due to excessive channel noise or too many stations are occupying one frequency channel.

6.9 lists the values of the parameters used in the MAC layer.

### 6.1 Network formation and association

For one station to communicate with another, they must first be associated with network. Basically, once the station scans each frequency channel to find a existing network, if one exists it associates itself with it, otherwise it appoints itself master and forms a new network on a specific frequency channel. (Forming a new network means periodically transmitting beacon packets on a certain frequency channel.) However, depending on the station's capabilities it may simply continue scanning without forming a network, or may form a new network regardless of whether or not one already exists. In the latter case, if a network already exists on every frequency channel, the formation of a new network may be abandoned.

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### 6.1.1 Channel scanning

Each station listens passively for a beacon frame from the master in order to discover an existing network.

The station selects a certain frequency channel and waits for a beacon frame for *channel scan time*, and if it hears a beacon from the master during this interval it determines that there exists a network on this frequency channel, otherwise it determines that no network exists on the frequency channel and moves on to the next frequency channel to scan.

When DME specifies a NID in its scan request, it ignores all beacons other than the beacon from the specified network, and in the case of an open scan where no such designation is made, all beacons are received.

Most stations continuously scan each frequency channel to find an existing network, but stations whose DME has determined not to become the master wake up one per *channel scan period* and perform one channel scan in *channel scan time* in order to reduce power consumption.

### 6.1.2 Network ID

The master ensures that its newly formed network ID does not overlap with another network. The method of this generation is beyond the scope of this International Standard.

### 6.1.3 Association

Stations disassociated with a network may request network association during the contention period, and when the master receives the request it responds with an associate request acknowledgement. The master determines whether to grant the station's network associate request and reports the result in an associate response frame. If association has been granted, the associate response frame contains the assigned ID, and when denied the reason for denial is reported. If the station wanting association does not receive an associate response within the associate response time limit, it retries the associate request. The slave sets the associate response time limit.


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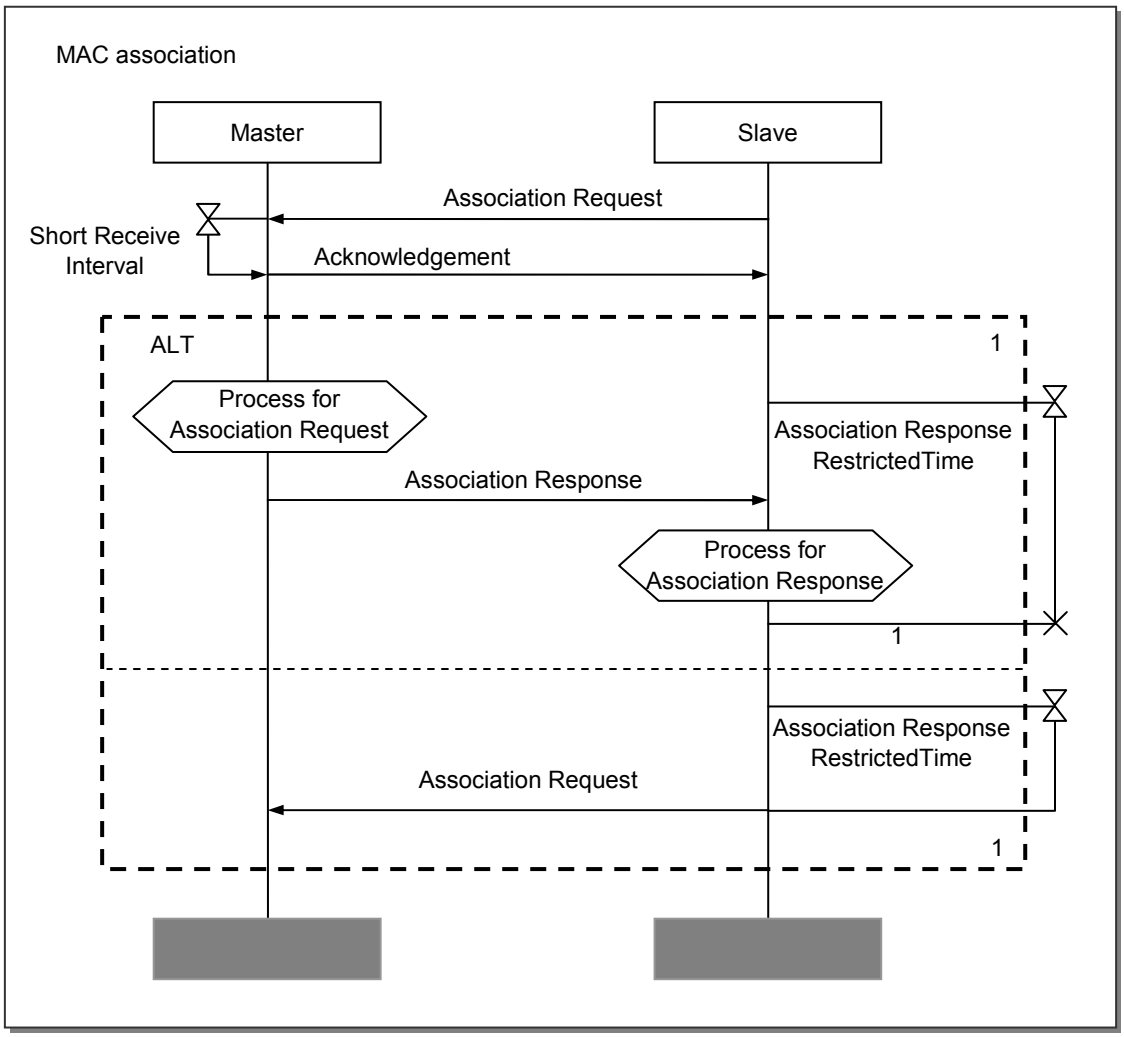


**Figure 55 - Association Process**

### 6.1.4 Disassociation

Stations desiring to disassociate from network send a disassociate request and reason code to the master, and the master acknowledges this disassociate request with acknowledgement packet.

### 6.1.5 Master handover

Since the master must receive resource allocation requests from associated stations and notify other stations of the resource allocation result through beacon frames, its power consumption is large compared to slaves. Also, since the capabilities of the whole network depend on the processing capabilities of the master station, more hardware capabilities is required. Therefore, the station with the highest power capacity or hardware performance needs to be selected as master of network.

If a station superior to the master exists among the associated stations, the current master may handover its master role to that station.

## 6.2 Media access

The superframe is divided into three periods – the beacon period, contention period, and allocation period – and each period uses different media access methods. During the beacon period the master uses broadcasting to send beacon packets, and during the contention period and allocation period the stations use CSMA/CA and TDMA/CDMA respectively to access the media.

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In the allocation period, media access is achieved by the pair of two resources – time and codes. This means that in order to transmit a packet a station must be allocated a unique time slot and set of codes.

Stations use only the network standard code rates set by the master in the beacon period and contention period of the superframe, and during the allocation period they use the code rates assigned by the master.

### 6.2.1 Code assignment

The master can specify the codes to be used in network. All packets other than data packet are encoded with the network standard codes set by the master, and data packet are encoded with codes that the master has assigned to streams.

Therefore, packets other than data packets which are exchanged during the beacon period and contention period use the network standard code rates, and in the allocation period several codes allocated by the master may be freely exchanged. For data packets to be transmitted during the contention period, network standard code rates must be used.

There is a trade-off between bandwidth and interference resistance, so when interference is low and channel conditions are good the master maximizes data transfer rate by using as many codes as possible, while if interference is high and channel conditions are poor it improves interference resistance by reducing the codes for data transfer. When the master assigns codes for a data stream it takes into consideration the quality of service requested by the stream.

### 6.2.2 Inter-frame space

Three types of frame spaces exist - short inter-frame space (SIFS), backoff inter-frame space (BIFS), and retransmission inter-frame space (RIFS). Short inter-frame space is shorter than backoff inter-frame space, and the actual values of these two are determined by physical layer attributes such as Rx/Tx turn around time of RF module, frame processing time, etc.

Acknowledgement packets for all packets sent during the allocation period or contention period are sent after a period of short inter-frame space. Even if an acknowledgement packet is not needed a short inter-frame space may apply between two consecutive data packets.

BIFS is used during the backoff interval of the contention period. In the contention period, once all slaves have determined that the media is idle, after BIFS they may decrement the backoff counter or send data.

RIFS is used to retransmit packets during the allocation period. (Retransmission of packets during the contention period is also described in 6.2.3.)

### 6.2.3 Access during the contention period

During the contention period, exclusive access to the media is not ensured through unique allocation of codes and time from the master, therefore each station uses the competitive CSMA/CA method to access the media.

If the station has a packet to send and the media is idle during the backoff period as calculated in 6.2.3.1, the packet is sent.


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#### 6.2.3.1 Backoff process

When frames other than the immediate acknowledgement frame are sent during the contention period the following rules apply.

The backoff algorithm uses the following information.

- retry_count: 0, 1, 2, 3

- backoff_window(retry_count): [7, 15, 31, 63]

- pBackoffSlot: as defined in 7.2.2

- bw_random(retry_count): random integer selected from the normal distribution [0. backoff_window(retry_count)]. There is no statistical correlation between one station's random number and another. If a station does not have a random number generator, the station's unique MACaddress or other information can be used with the pseudo-random number generator (PRNG) to generate the random number. The PRGN must be retained to maintain the pseudo-random format of numbers to be generated in the future. It is important to ensure the non-inter-dependency of the random numbers between the stations.

The backoff time in the contention period is measured in the medium and indicates the time for the station to send the data. Once the station determines that the media is idle, before beginning the backoff algorithm it waits for the BIFS time. At the start of the contention period after the station sends the beacon frame it waits during the SIFS time and then starts the backoff algorithm. If the beacon is divided such that two or more beacons occur in sequence, after the final beacon it waits for the SIFS time and then begins.

The station calculates the backoff_count using the formula *backoff_count = bw_random(retry_count)* and maintains this using a counter. The counter is decremented by 1 only when the media is idle during pBackoffSlot. When the packet is first sent, the retry_count is set to 0. When a channel is in use, the backoff counter is suspended. When the backoff counter reaches 0, it starts frame transmission.

The backoff counter must be suspended during periods other than the contention period. It must also be suspended during the contention period when there is not enough time left to send the desired frame. The backoff counter is maintained independent of the superframe period, which means that it is not reset for each beacon. If the time elapsed after the packet is queued for transmission exceeds the transmit time limit, the backoff counter is reset and the packet transmission is aborted.

After a packet needing acknowledgement packet is sent, if no acknowledgement packet is received, the retry_count is incremented. However, the retry_count cannot exceed a maximum of 3, so an attempt to retransmit the failed packet is made up to twice. The backoff_count is recalculated using a new retry_count.

### 6.2.4 Access during the allocation period

During this period each station has exclusive access to the media during the time slot assigned to itself. The master distributes time slots in the allocation period to each station. In the assigned time slot each station can have exclusive access to the media, and during this assigned slot the station can exchange data in a peer-to-peer with other stations without intervention from the master. The master specifies the start time and length of each time slot, source/destination station, and codes to be used in the beacon, thereby ensuring exclusive access to the media for each station to send packets.

In this period the station uses allocated codes to exchange data with other stations. Since the time slot and code allocation is broadcasted to all stations by means of the beacon frame, each station can know its own time for sending or receiving data.

The inter-frame interval in the allocation period uses SIFS as shown in Figure 56, and the frame transmission must be completed within SIFS + Guard time from the end of the period. The Guard time is calculated as follows.

Guard time = *maximum superframe length* * *clock drift* / 1,000,000 * 2

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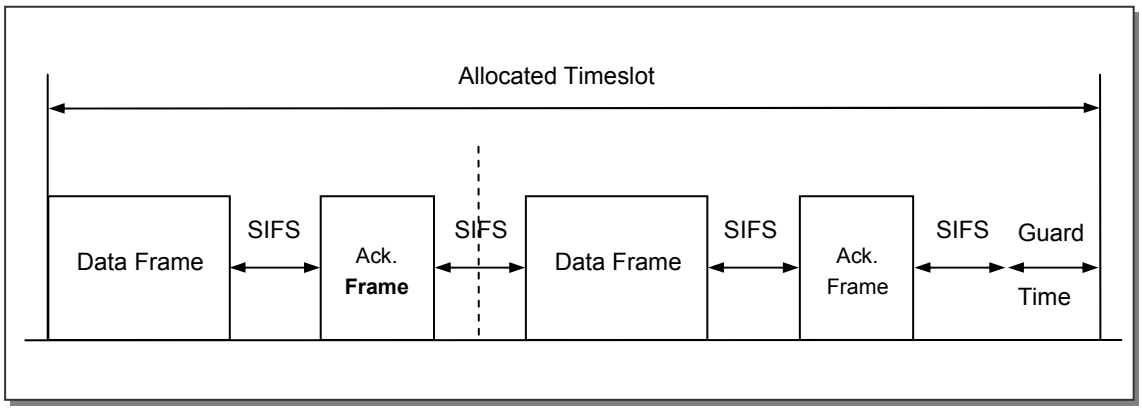


**Figure 56 - Inter-frame space in the allocated time slots**

## 6.3 Synchronization

All stations participating in a particular network are synchronized by the beacon packet. In the beacon packet transmitted during the beacon period of each superframe, the synchronization information for the associated station is included.

### 6.3.1 Superframe synchronization

The superframe is divided into three periods as shown in Figure 57, and slaves synchronize to the master's superframe by using the information in the beacon frame received from the master. The superframe length is set to *superframe length* and the beacon is repeated by that time period, and the length of the allocation period is variable or an multiple of *slot length*. The time between a beacon frame and the allocation period is used for the contention period.

The length of the contention period must be greater than *minimum* contention *period length.*

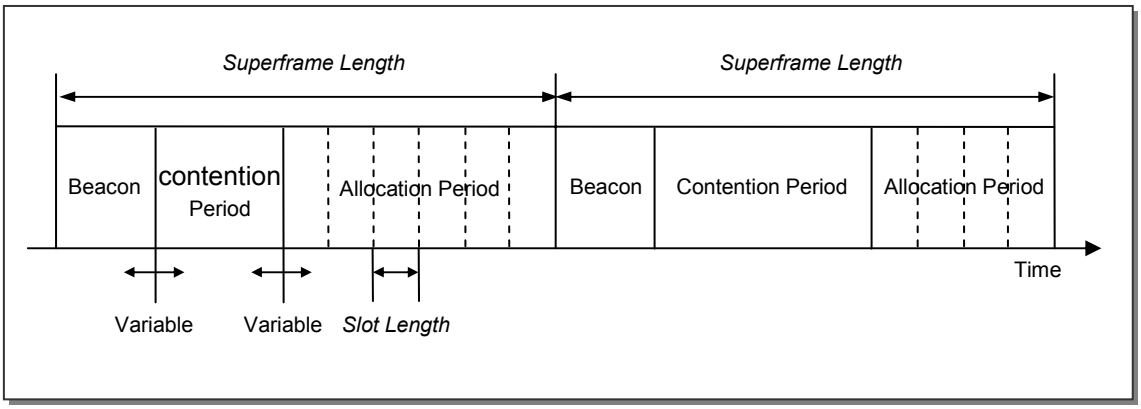


**Figure 57 - Superframe synchronization**

The beacon packet contains the start time of allocation period, and using this start time and the time the beacon is received, slaves in network can determine start and end time of each superframe.

### 6.3.2 Beacon generation

The master fills the beacon frame with the allocation period start time and time slot allocation information and sends it.


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#### 6.3.3 Beacon reception

Slave can determine the boundaries of the contention period and allocation period from the allocation period's starting offset in the beacon, and determine the start and end time of the time slot allocated to them from the time slot allocation information.

#### 6.3.4 Synchronization

All stations in network synchronize by means of receiving beacon packets from the master. Disassociated stations use manual scanning to hear beacon packets and synchronize. Therefore, stations wanting to associate with network must hear a beacon frame at least once before being able to associate. If an associated station cannot hear a beacon frame, it waits till it hears the next beacon frame in order to synchronize. If a beacon frame is not heard within *connection time limit,* slave determines that the network is terminated and finishes all relevant exchange of network stream.

### 6.4 Resource allocation

Data transmitted is categorized as synchronous data and asynchronous data. Synchronous data, which has QoS requirements, builds stream for transmission, and the master continuously monitors the transmission status from connection till termination. On the other hand, for asynchronous data which does not have QoS requirements there is no need of a stream connection, and resources are requested and allocated as needed for data transmission. An example algorithm that allocates time slots to meet its QoS requirements is described in "0.. Example scheduler and admission control". However scheduling and admission control implementations are vendor-specific and beyond the scope of this International Standard.

#### 6.4.1 Transmission of synchronous data

The following clauses describe stream management, connection, termination, and prioritization. Each station must support the connection of at least one stream, and the maximum number of supported streams is dependent on the nature of the user application.

##### 6.4.1.1 Stream connection

A stream is built when the station sending the stream requests the setup and resource allocation for the stream, and the master allocates a streamID and resources for that purpose. At the start of the stream creation the streamID is assigned by the master, but afterwards the sending and receiving stations manage the stream through a 1:1 communication method. A station receiving or sending a new stream sends a resource allocation request command to the master, and the connection process is shown in Figure 58. The master decides the time slot and codes for the stream based on the allocation period, size of data, and required BER, and periodically allocates resources for the stream until data transfer for that stream terminates.

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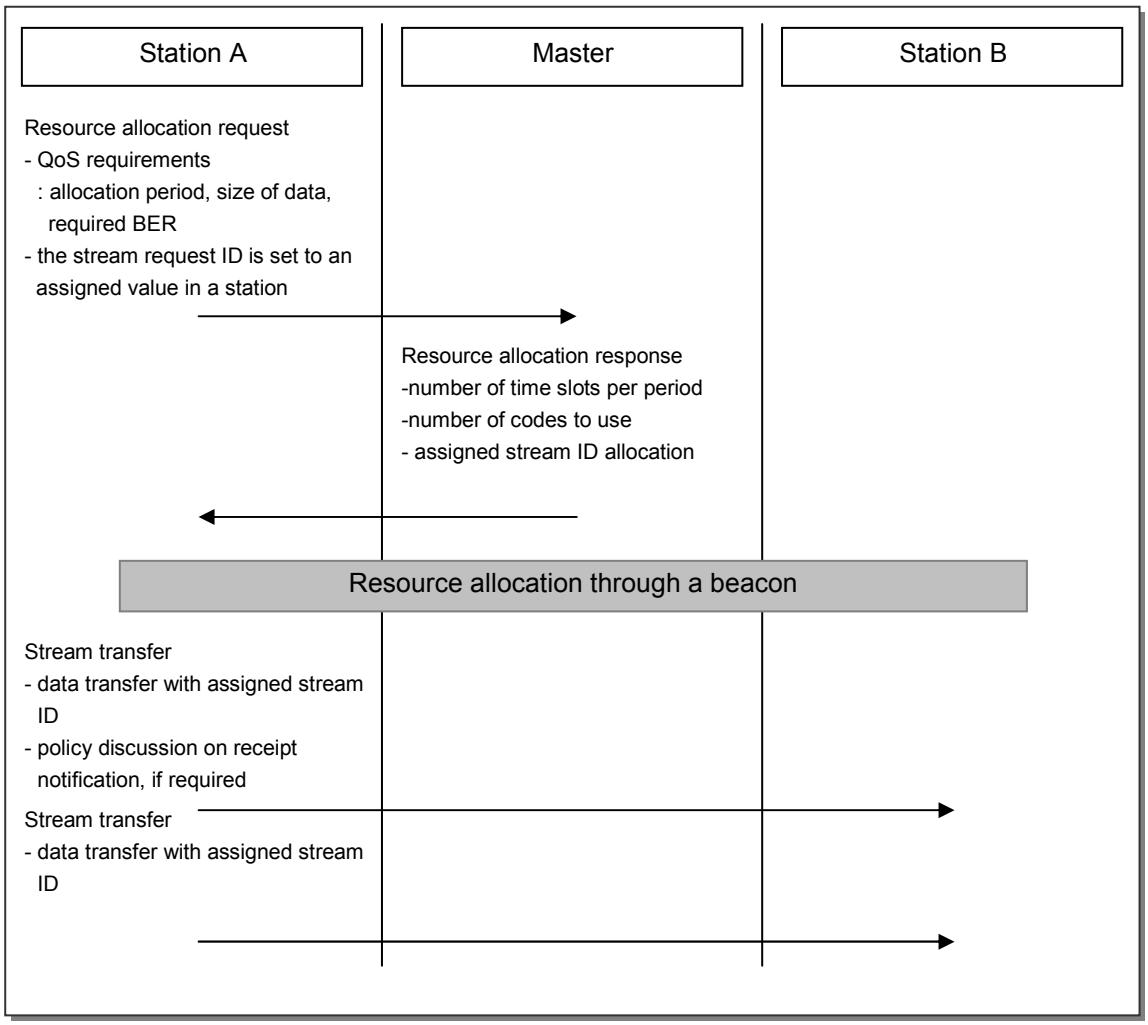


**Figure 58 - Stream connection process for synchronized data transmission**

#### 6.4.1.2 Stream QoS modification

When changing the stream's QoS requirements, the station sending the stream can achieve this by sending a resource allocation request command to the master. In such a case, the stream request ID is set to 0, and the stream ID is set to the formerly assigned stream ID. When the master receives a stream modification request, it sends the response in a resource allocation response command to the slave.

When the master receives a request to change the QoS requirements, if the stream's allocated resources can be modified, the resource allocation changes are put into a resource allocation response command and sent, and the changes apply from the next superframe. If the master wants to deny this request, it simply sets the field of the resource to be allocated (number of time slots or codes) to 0, populates the reason code with the reason for denial, and sends the response.

#### 6.4.1.3 Stream terminating

If the station sending the stream or the station receiving the stream wants to terminate it, it sends the master a resource allocation response command with the reason code set to 'request denied'. When the master receives this stream response request, it stops allocating resources for the stream. When the sending and receiving stream are not allocated resources for more than *allocation period*maximum beacon loss*, they interpret this as a sign that the stream has been terminated and abandon service for that stream.


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#### 6.4.1.4 Prioritization

The scheduler in the master determines the actual prioritization, and that is beyond the scope of this International Standard, but here the guidelines for prioritization are presented.

The master gives preference to the connected stream in network with the highest priority when allocating resources. The master remembers the priorities of all currently connected streams, and uses this to allocate channel time and codes to streams.

Each station can decide upon its own transfer method within the allocated channel time, but with the exception of synchronous streams with higher priority must be transmitted before lower priority streams. Asynchronous streams or streams sent to sleeping stations must be transmitted according to a predetermined schedule, and are therefore excluded from the prioritization rules.

### 6.4.2 Asynchronous data transmission

When a slave transmits asynchronous data with no QoS requirements, it makes resource allocation requests during the contention period, and the master allocates resources enabling asynchronous data transmission. The slave's resource allocation request does not contain the period or BER requirement information, and only holds the size of the data to be sent. The master first allocates resources for synchronous data requiring a stream connection, and allocates any remaining resources for asynchronous data.

A slave sends resource allocation request command to the master during the contention period, and waits for a resource allocation response command during the RequestTimeout time shown in 4.3.10. While waiting for a response command the slave also stays awake during the contention period and waits for a response from the master. If the resource allocation response command is received or resources are allocated for the stream through a beacon even before a response is received, it interprets this as a response to its request and sends the packet using the allocated resources.

## 6.5 Fragmentation and defragmentation

When the length of data to be sent exceeds the fragmentation limit, the data goes through a process of being divided into many smaller fragments before being sent. The receiving station reassembles the data fragments by means of a defragmentation process and restores the data to its original length.

The source station can freely designate the fragmentation limit depending on the type of transmission stream and channel state, but all fragments of this stream except the last must be of the same length, and once set it must be applied to the fragmentation limit of all fragments.

The first bit of the frame control field of the first fragment to be sent is set to 1, and the last fragment's final bit is set to 1. (If the fragment is both the first and last, both values are set to 1.) All other fragments besides the first and last set their first/final bits to 0/0.

The reassembly takes place in the MAC layer and is transparent to the higher layer. After the fragmented data is completely reassembled in the MAC layer it is sent to the higher layer. The destination station must discard the entire data, even if one fragment is lost. If delayed acknowledgement is used, the receiving station can request a retransmission of the fragment from the most recent fragment's sequence number within the retransmission window.

There is no theoretical limit on the fragmentation limit. However, the fragmentation limit is restricted by implemental considerations to *maximum fragment limit*.

## 6.6 Acknowledgement and retransmission

To receive acknowledgements for data transmitted, there are four methods: no acknowledgement, immediate acknowledgment, delayed acknowledgement, and implicit acknowledgement. The acknowledgement method to be used is recorded in the Frame header.

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### 6.6.1 No acknowledgement

If the acknowledgement policy is no acknowledgement, the source station that sends the frame does not wait for acknowledgement, and automatically assumes that the data transmission was successful.

### 6.6.2 Immediate acknowledgement

If immediate acknowledgement is used, the source station expects an acknowledgement packet immediately after sending the data, and the destination station sends an acknowledgement packet after a SIFS once data is received. This acknowledgement method can be used in both the contention period and allocation period.

### 6.6.3 Delayed acknowledgement

When a delayed acknowledgement policy is adopted, once the source station sends data, the acknowledgement for the data is sent to the source station during the destination station's time slot. If such a method is used the source station can continuously send data packets and receive a one-time acknowledgement afterwards. The source station must store packets up to the pre-decided size of the delay acknowledgement window in order to enable retransmission until an acknowledgement is not received. Destination station should send the delayed acknowledgement before the delayed acknowledgement window of source station is exhausted.

The destination station can send an acknowledgement packet at any time up till the retransmission window is exhausted, and the source station can request the transmission of an acknowledgement packet by setting the delayed acknowledgement request field in the frame header to '1'.

### 6.6.4 Implicit acknowledgement

The implicit acknowledgement policy is only allowed during the allocation period. It is similar to immediate acknowledgement in that the station sending the data waits immediately for an acknowledgement, but differs in that the destination station acknowledges by sending a data packet that is not a simple acknowledgement packet. Stations sending implicit acknowledgements can request acknowledgement for their transmitted data using methods other than implicit acknowledgement.

### 6.6.5 Retransmission

During the contention period the acknowledgement method described in 6.2.3 is used.

When immediate acknowledgements or implicit acknowledgements are used during the allocation period, the source station waits for acknowledgement packets after a short inter-frame space after sending the data. When receiving an acknowledgement packet, it transmits other data after waiting for a SIFS after the acknowledgement packet it received, and if it does not receive an acknowledgement packet it retransmits the data after RIFS.

When delayed acknowledgement is used, the source station denies any retransmit request from a destination station for data that is outside the retransmission window. In such cases, by sending a delayed acknowledgement resynchronization command the relayed acknowledgement window between source and destination station is resynchronized.

#### 1.1.1.1 Duplicate frame detection

If the source station does not receive acknowledgement, it may send a duplicate frame to the destination station even if the data has already been received. Such duplicate frames can be weeded out by using the stream ID and sequence number in the frame.

## 6.7 Power saving

Slaves can know when they transmit or receive packets decoding beacon packets, and can reduce unnecessary power consumption by only activating their physical layer when needed. To reduce power consumption even further, sleep mode can be used.


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### 6.7.1 Saving power in a connected state

When there is no packet to transmit, a slave associated with network activates its physical layer and listens for beacons only during the beacon period. When hearing a beacon packet, if the command or data packet is intended for itself, it activates its physical layer in its allocated time slot during the contention period or allocation period and receives the packet.

Stations to send a command packet activate the physical layer during the contention period to send the packet, and if they need a response to the command packet they activate the physical layer and wait for a response packet during the contention period until the *command response time limit* runs out. Stations to send a data packet activate the physical layer in their allocation period and send the data packet.

When the master has no packet to transmit/receive, it activates the physical layer and transmits or receives packets during the beacon period and contention period. When the master has data to send to the slaves, it notifies them of the time they will receive it (the contention period or allocation period), and communicates with the slaves during the slaves' waking time.

### 6.7.2 Sleep state

When a slave has no data to send or receive, it can go to sleep by requesting to do so and receiving permission from the master. After master and slave exchange sleep state request and response, the period parameters relating to sleep state are set.

When a slave is granted permission to go into sleep state, it goes to sleep and cannot send or receive packets during that time. Also, it wakes up and receives beacons once per period as arranged with the master, in order to determine whether there is a data packet to receive. If there is data to receive, it receives it during the allocation period, otherwise it goes back to sleep.

Stations that are not sleeping can determine the IDs of the stations that are asleep and their wakeup periods by listening to beacons. If they need to send data to stations that are asleep, they request resource allocation from the master, and if successful, the master allocates resources to the sleeping station via the beacon heard during its wakeup period. Thus the sleeping station remains awake during its allocation period, and the station wishing to transmit will send the data during that period. When data is received, this automatically indicates that the sleeping station has been awakened from its sleep.

## 6.8 Dynamic channel management

### 6.8.1 Channel state probe

Stations in network may also use channel state request commands to find out the channel state between stations. Channel state request commands and channel state response commands both use an immediate acknowledgement policy. Stations wanting to access channel quality send a channel state request command to the destination station, and the receiving station reports the channel state information via a channel state response command.

### 6.8.2 Remote Channel state probe

A remote channel state probe occurs when the master requests another slave in network to scan another frequency channels on behalf of the master and the slave performs the requested channel scan and reports the result. The master may adjust the maximum transmit power or change channels depending on the result of this remote Channel state probe.

The master is unable to scan other frequency channels because of having to periodically generate beacons and allocate resources; therefore it makes use of capable slaves in network to assess the quality of other frequency channels. The master may also use this feature to determine the existence of other networks that are too remotely located to directly communicate with.

The master begins this process by sending a remote channel scan request command to a slave with the frequency channel list. The slave must obey the master's request if possible, but if it cannot perform the

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remote channel state scan it denies the request by sending a remote channel scan response command with the response code set to “request denied”. If the request is denied, the master can send the remote channel scan request to another slave.

If the slave complies with the master’s request, it scans the requested channel one by one and puts the result into a remote channel response command and sends it to the master. If the slave unexpectedly receives a beacon from another master, it informs the master that there is an overlap between two networks by sending information about this received beacon in a remote channel response command.

### 6.8.3 Frequency channel change

If the master checks the current channel state through other slaves and determines that there is excessive interference, it notifies the stations of the new frequency channel and the channel change time limit via a beacon so that they can migrate to the new frequency channel and start a new network. If the beacon is changing the channel, the channel change information must be repeated at least *maximum beacon loss* times. As soon as the slave receives the channel change beacon, it tries to change channels, and when it receive a new beacon on the newly changed channel it means the channel change was completed. If no beacon is received on the new channel by the specified time limit, stations form a new network on that frequency channel.

## 6.9 MAC parameters

**Table 39 - MAC layer parameters**

| name | value | comments |
|---|---|---|
| Minimum contention period length | 1 msec | |
| Command response time limit | 100 msec | |
| Slot usage verification time | 250 usec | |
| Slot length | 1 msec | |
| Connection termination time | 400 msec | |
| resource allocation response time | 100msec | |
| Maximum fragmentation | 2047octets | |
| Maximum beacon loss | 4 | |
| channel scan time | =superframe length | |
| channel scan period | = 100 * channel scan time | |
| minimum superframe length | 5120 usec | |
| maximum superframe length | 65535 usec. | |
| Minimum payload length | 12 octets | |
| Minimum allocation period start time | 2048 usec | |
| Maximum payload length | 2047 octets | |
| maximum allocation period start time | 5000 usec | |
| Clock drift | 25ppm | |

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# 7 PHY specifications

## 7.1 General specifications

The physical layer performs the following operations

- Activation and deactivation of the RF transmitter/receiver

- Energy detection of the current channel.

- Link quality index of the received frame

- Clear channel assessment for CSMA/CA

- Frequency channel selection

- Data transmission/reception

## 7.2 General requirements

### 7.2.1 Operating frequency range

The PHY layer operates in the ISM band starting at 2.4GHz and ending at 2.4835GHz, which does not require government authorization in the United States, Japan, Europe and Canada. In the 2.4 GHz ISM band, a maximum of ten frequency channels can coexist and its center frequency is as follows.

$$f_k = 2406 + 8 \times kMHz, \quad for\ k = 0,1,\cdots,9$$

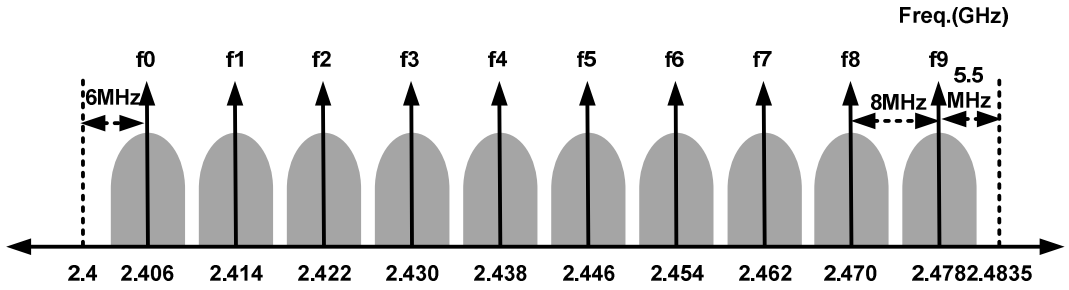


**Figure 59 - Operating frequency channels**

The center frequency of each of the 10 channels in the 2.4GHz ISM band is depicted in Table 40.

**Table 40 - Center frequency of 10 channels**

| Channel ID | Center frequency |
|---|---|
| 0 | 2.406 GHz |
| 1 | 2.414GHz |
| 2 | 2.422 GHz |
| 3 | 2.430 GHz |
| 4 | 2.438 GHz |
| 5 | 2.446 GHz |
| 6 | 2.454 GHz |
| 7 | 2.462 GHz |
| 8 | 2.470 GHz |
| 9 | 2.478 GHz |

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### 7.2.2 PHY layer timing

PHY layer timing parameters for the 2.4Ghz PHY are given in Table 41. A conformant implementation shall support the interframe spacing parameters, given in Table 42.

**Table 41 - PHY layer timing parameters**

| Name | Value | comments |
|---|---|---|
| aSIFSTime | ≤ 10us | Rx-to-Tx turnaround time |
| aCCADetectTime | ≤ 15us | CCA detection time |
| aCHSwitchTime | ≤ 500us | Channel switching time |

**Table 42 - Interframe space parameter**

| MAC Parameter | Corresponding PHY Parameter | Description |
|---|---|---|
| SIFS | aSIFSTime | As defined in 6.2.2 |
| BIFS | aSIFSTime+ aCCADetectTime | As defined in 6.2.2 |
| RIFS | 2×aSIFSTime+ aCCADetectTime | As defined in 6.2.2 |
| pBackoffSlot | aCCADetectTime | As defined in 6.2.3.1 |

### 7.2.3 Receive-to-transmit turnaround time

The Rx-to-Tx turnaround time shall be aSIFSTime, including power-up ramp. Rx-to-Tx turnaround time shall be measured at the air interface from the trailing edge of the last symbol received until the first symbol of the PHY preamble.

### 7.2.4 Transmit-to-receive turnaround time

Tx-to-Rx turnaround time shall be less than aSIFSTime, including power-down ramp specified in 7.6.8. Tx-to-Rx turnaround time shall be measured at the air interface from the trailing edge of the last transmitted symbol until the receiver is ready to begin the reception of the next PHY frame.

### 7.2.5 Channel switch time

The channel switch time is defined as the time starting with reception of the last valid bit at the antenna on one channel until a station is ready to transmit/receive on a new channel. The channel switch time shall be less than 500 μs, is defiend as aCHSwitchTime parameter.

### 7.2.6 Maximum frame size

The maximum frame length allowed shall be 2047 octets. This total includes the frame payload and FCS but not the PHY preamble, PHY header, or HCS.

## 7.3 PHY Protocol Data Unit (PDU) format

### 7.3.1 General format

This clause defines the format of the PPDU. The PPDU (depicted in Figure 60) is transmitted in little-endian (LSB first) format. This transmission format applies for both PHY and MAC layers, and each PPDU conforms to the basic sequence below.

a) PHY Preamble for bit and frame synchronization at receiver.

b) PHY Header including type of FEC, rate, length of payload, and header check sequence.

c) Variable-length payload containing the PSDU.


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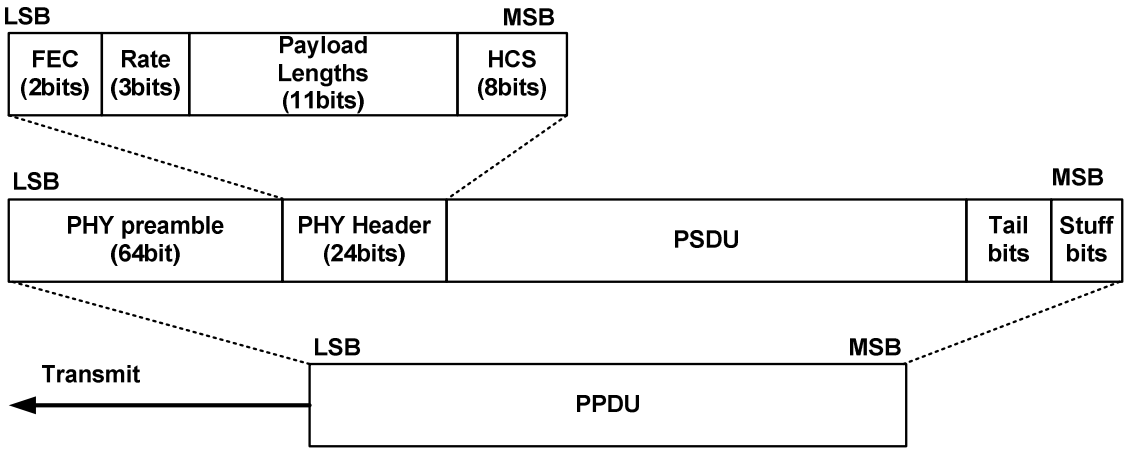


**Figure 60 - PHY Protocol Data Unit (PDU) format**

### 7.3.2 Preamble

A PHY preamble shall be prepended to the PHY header to aid receiver algorithms related to synchronization, carrier-offset recovery, and signal equalization. Preamble sequence is defined as follows.

Preamble sequence $[b_0\, b_1\, b_2 \ldots b_{63}]$ = [ 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0101 0100 ]

In the above sequence, the left side is the LSB and the starting point for transmission.

The preamble shall consist of multiple periods of a special sequence of 16 QPSK symbols called a CAZAC (constant amplitude zero auto-correlation) sequence, which demonstrates the property of constant amplitude zero auto-correlation. The CAZAC sequence shall be denoted as $\{C_0\ C_1\ C_2 \ldots\ldots C_{15}\}$. Each element Ci of the CAZAC sequence shall have a complex value representing the in-phase and quadrature components of a QPSK-type sequence, as shown in Table 43.

**Table 43 - CAZAC sequence**

| CAZAC sequence element | I value | Q value |
|---|---|---|
| $C_0$ | 0 | 0 |
| $C_1$ | 0 | 0 |
| $C_2$ | 0 | 0 |
| $C_3$ | 0 | 0 |
| $C_4$ | 1 | 0 |
| $C_5$ | 1 | 1 |
| $C_6$ | 0 | 1 |
| $C_7$ | 0 | 0 |
| $C_8$ | 1 | 1 |
| $C_9$ | 0 | 0 |
| $C_{10}$ | 1 | 1 |
| $C_{11}$ | 0 | 0 |
| $C_{12}$ | 0 | 1 |
| $C_{13}$ | 1 | 1 |
| $C_{14}$ | 1 | 0 |
| $C_{15}$ | 0 | 0 |

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The 1024 PHY preamble sequence shall be constructed by modulo-2 addition (exclusive OR) of CAZAC with the 64 preamble sequence, [$b_0$ $b_1$ $b_2$ …. $b_{63}$]. The complete physical layer preamble is shown in Figure 61.

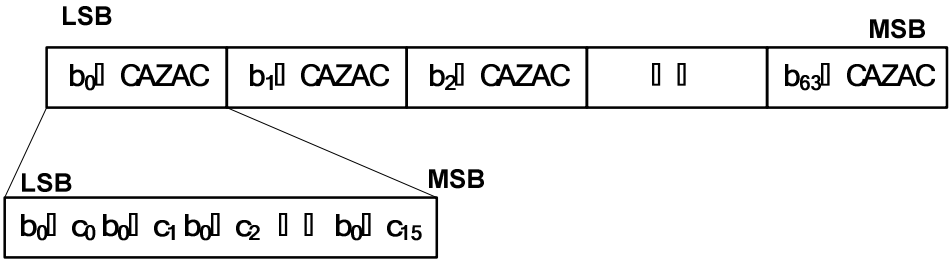


**Figure 61 - Preamble format**

### 7.3.3 PHY Header

The PHY header is composed of the FEC type, rate, payload length and header check sequence as depicted in Figure 62.

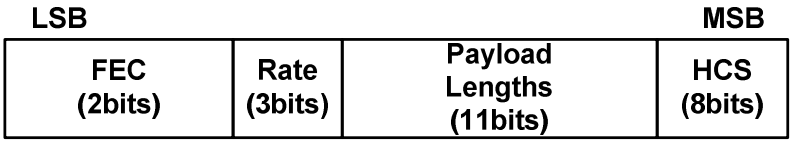


**Figure 62 - PHY Header**

The PHY header consists of two octets that identify the number of octets in the payload(PPDU), the error correction coding of the MAC frame body, and constant envelope coding. The payload length does not include the tail symbols or the stuff bits. The LSB of the PHY header is sent first, followed by the remaining bits in sequential order.

#### 7.3.3.1 Forward Error Correction

The field is described in more detail below:

**Table 44 - Forward Error Correction**

| bit (b1 b0) | FEC |
|---|---|
| 00 | Non encoding |
| 01 | 1/3 rate encoding |
| 10 | 2/3 rate encoding |
| 11 | reserved |

1/3 rate encoding is implemented by repeating the bit three times. 2/3 rate encoding is a (15,10) shortened Hamming code. The generator polynomial is $g(D) = (D+1)(D^4 + D + 1)$. This corresponds to 65 in octal notation. The LFSR generating this code is depicted in Figure 63. Initially all register elements are set to zero. The 10 information bits are sequentially fed into the LFSR with the switches S1 and S2 set in position 1. Then, after the final input bit, the switches S1 and S2 are set in position 2, and the five parity bits are shifted out. The parity bits are appended to the information bits. Thus each block of 10 information bits is encoded into a 15-bit codeword. This code can correct all single errors and detect all double errors in each codeword. Since the encoder operates with information segments of length 10, tail bits of value 0 may have to be appended after the CRC bits. The total number of bits to encode - i.e. the scrambled PSDU bytes and tail bits - shall be a multiple of 8. Thus, the number of tail bits to append must be the lowest possible number that achieves this (i.e. in the interval 0...9). These tail bits are not included in the payload length indicator.


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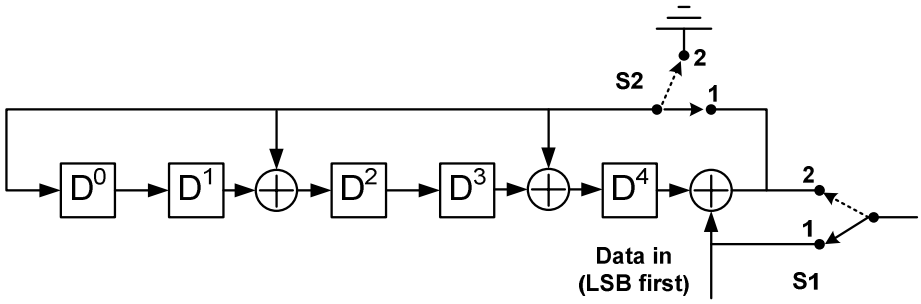


**Figure 63 - LFSR generating the (15,10) shortened Hamming code**

#### 7.3.3.2 Constant Envelope Coding

The field is described in more detail below:

**Table 45 - Constant Envelope Coding**

| bit (b4 b3 b2) | Constant Envelope Coding |
|---|---|
| 000 | RATE1 (7.4.3.1) |
| 001 | RATE2 (7.4.3.2 |
| 010 | RATE3 (7.4.3.3) |
| 011 | RATE4 (7.4.3.4) |
| 100~111 | reserved |

#### 7.3.3.3 Payload length

The length indicator indicates the number of bytes (i.e. 8-bit words) in the payload, including the MAC header, the MSDU, and the CRC code.

#### 7.3.3.4 Header check sequence (HCS)

The HCS generating LFSR is depicted in Figure 64. The generator polynomial is given by

$$g(D) = (D+1)(D^7 + D^4 + D^3 + D^2 + 1) = D^8 + D^7 + D^5 + D^2 + D + 1 .$$

Initially this circuit is preloaded with [0000 0000]. Then the data is shifted in with the switch S set in position 1. When the last data bit has been clocked into the LFSR, the switch S is set in position 2, and the HEC can be read out from the register. The LFSR bits are read out from right to left (i.e., the bit in position 7 is the first to be transmitted, followed by the bit in position 6, etc.).

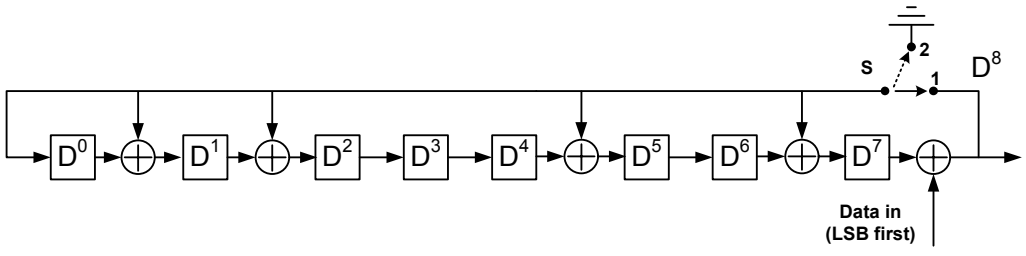


**Figure 64 - LFSR circuit generating the HEC**

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### 7.3.4 PHY payload

The PHY payload is composed of the MAC Header, the MSDU, and the frame check sequence to check the integrity of the MAC Header and MSDU. All parts of PSDU are scrambled.

#### 7.3.4.1 Scrambling

A side-stream scrambler shall be used for the PHY payload(PSDU).The PHY preamble, PHY header and header check sum shall not be scrambled. The polynomial *g(D)* for the pseudo random binary sequence (PRBS) generator shall be

$$g(D) = 1 + D^{14} + D^{15}$$

where *D* is a single bit delay element. The polynomial forms not only a maximal length sequence but also is a primitive polynomial. By the given generator polynomial, the corresponding PRBS $d_k$ is generated as

$$d_k = d_{k-14} \oplus d_{k-15}$$

where $\oplus$ denotes modulo-2 addition. The side-stream scrambler at the transmitter shall be initialized with a [1111 1111 1111 1111] vector.

The scrambled data bits, $s_n$, are obtained as follows

$$b_k = s_k \oplus d_k$$

where $b_n$ represents the unscrambled data bits.

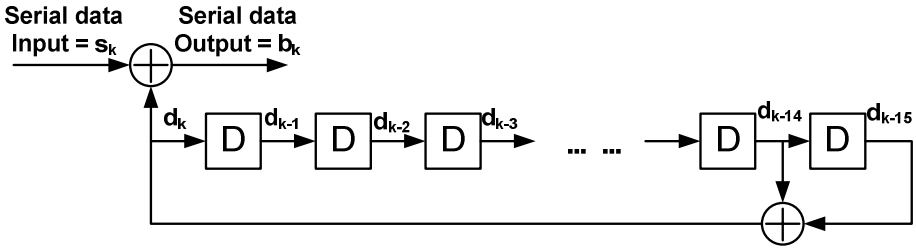


**Figure 65 - Scrambler Block Diagram**

#### 7.3.4.2 Stuff bits

If the total length of the scrambled PSDU is not an integral multiple of the number of bits/symbols that will be used to modulate the scrambled PSDU, then stuff bits shall be appended to the scrambled PSDU prior to modulation. The stuff bits may be set to either 0 or 1 and shall be ignored when the frame is received. Note that the stuff bits are not a part of FCS calculation. A compliant PHY shall add enough stuff bits so that the length of the scrambled PSDU including the stuff bits is an integral multiple of the number of bits/symbols that are used to modulate the scrambled PSDU.

## 7.4 Modulation and coding

### 7.4.1 Spreading code

The Wash Hadamard code with a length of 16 is used for spreading, and a $2^k \times 2^k$ Walsh code can be generated via the following matrix:


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$$H_k = \begin{bmatrix} H_{k-1} & H_{k-1} \\ H_{k-1} & \overline{H}_{k-1} \end{bmatrix} = \begin{bmatrix} h_1 \\ h_2 \\ \vdots \\ h_{2^k} \end{bmatrix}$$

where $H_1$ is given as follows.

$$H_1 = \begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}$$

Where $H_4$ is given as follows.

$$H_4 = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 \\ 0 & 1 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 \\ 0 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 1 & 1 & 0 & 1 & 0 & 1 & 0 & 1 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 1 & 1 & 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 0 & 0 & 1 & 1 \\ 0 & 1 & 1 & 0 & 1 & 0 & 0 & 1 & 1 & 0 & 0 & 1 & 0 & 1 & 1 & 0 \end{bmatrix}$$

### 7.4.2 QPSK modulation

The PHY shall employ quadrature phase-shift keying (QPSK) for data symbol modulation.

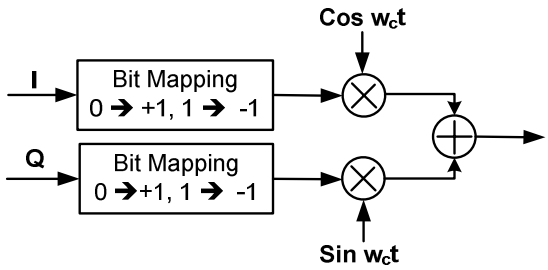


**Figure 66 - QPSK modulation**

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### 7.4.3 Constant envelope coding

There are four different schemes, RATEi, i∈{1, 2, 3, 4}, for constant envelope coding, and these methods can support different data rates. A DEV can select the RATEi according to the required QoS, data rate, and channel quality.

#### 7.4.3.1 RATE1

This is equivalent to the conventional spread spectrum scheme. Binary input information is multiplied by the spreading signal, with a spreading gain of 16. To avoid interchannel interference, a different walsh code $h_i$ is selected for a different channel according to the following rule:

$$i = (\mathrm{CHNL_ID} + 1)$$

CHNL_ID is given in Table 40. The data rate is 0.34 Mb/s, and one bit can be transmitted by 16 symbols.

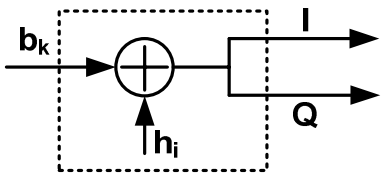


**Figure 67 - RATE1 block diagram**

#### 7.4.3.2 RATE2

This is equivalent to bi-orthogonal modulation. Among 3-bit input data, 2-bit selects one of four orthogonal codes, as follows:

$$sel = \begin{cases} i, & b_{k+1}b_{k+2} = 00, \\ i+1, & b_{k+1}b_{k+2} = 01, \\ i+2, & b_{k+1}b_{k+2} = 10, \\ i+3, & b_{k+1}b_{k+2} = 11, \end{cases}$$

where *sel* is the selected index of the orthogonal code.

The selected orthogonal code is multiplied by another 1-bit data.

The data rate is 1.0 Mb/s, and 3 bits can be transmitted by 16 symbols.

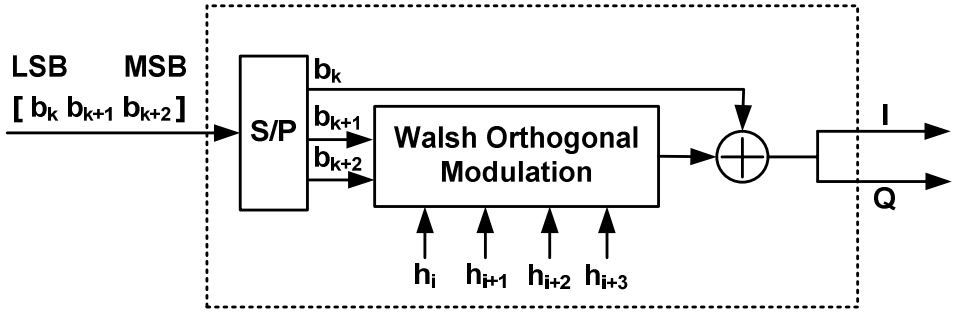


**Figure 68 - RATE2 block diagram**


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To avoid interchannel interference, a different walsh code $i$ is selected for a different channel according to the following rule:

$$i = (4 \times \text{CHNL_ID}) \mod 16$$

where mod is the modulus after division.

#### 7.4.3.3 RATE3

This is an extension of RATE2. It consists of four bi-orthogonal modulators, three basic modules, one constant envelope encoding module, and a parallel summer for producing a constant envelope signal. Among the four modulators, one is a constant envelope encoder, in which three parity bits are generated from three groups of parallel 9-bit input data, as follows:

$$\begin{aligned} r_k &= \overline{b_k \oplus b_{k+3} \oplus b_{k+6}} \\ r_{k+1} &= b_{k+1} \oplus b_{k+4} \oplus b_{k+7} \\ r_{k+2} &= b_{k+2} \oplus b_{k+5} \oplus b_{k+8} \end{aligned}$$

Parity bits are not only used for constant envelope encoding but also for parity check or error control coding in the receiver.

Each 2-bit selects one of four orthogonal codes, as follows:

$$sel_i = \begin{cases} 4i, & b_{k+3i+1}b_{k+3i+2} = 00, \\ 4i+1, & b_{k+3i+1}b_{k+3i+2} = 01, \\ 4i+2, & b_{k+3i+1}b_{k+3i+2} = 10, \\ 4i+3, & b_{k+3i+1}b_{k+3i+2} = 11, \end{cases}$$

$$sel_{const} = \begin{cases} 12, & r_{k+1}r_{k+2} = 00, \\ 13, & r_{k+1}r_{k+2} = 01, \\ 14, & r_{k+1}r_{k+2} = 10, \\ 15, & r_{k+1}r_{k+2} = 11, \end{cases}$$

where $i = 0,1,2$, and $sel_i$ and $sel_{const}$ are the selected indices among four orthogonal codes.

The data rate is 3.1 Mb/s, and 9 bits can be transmitted by 16 symbols.

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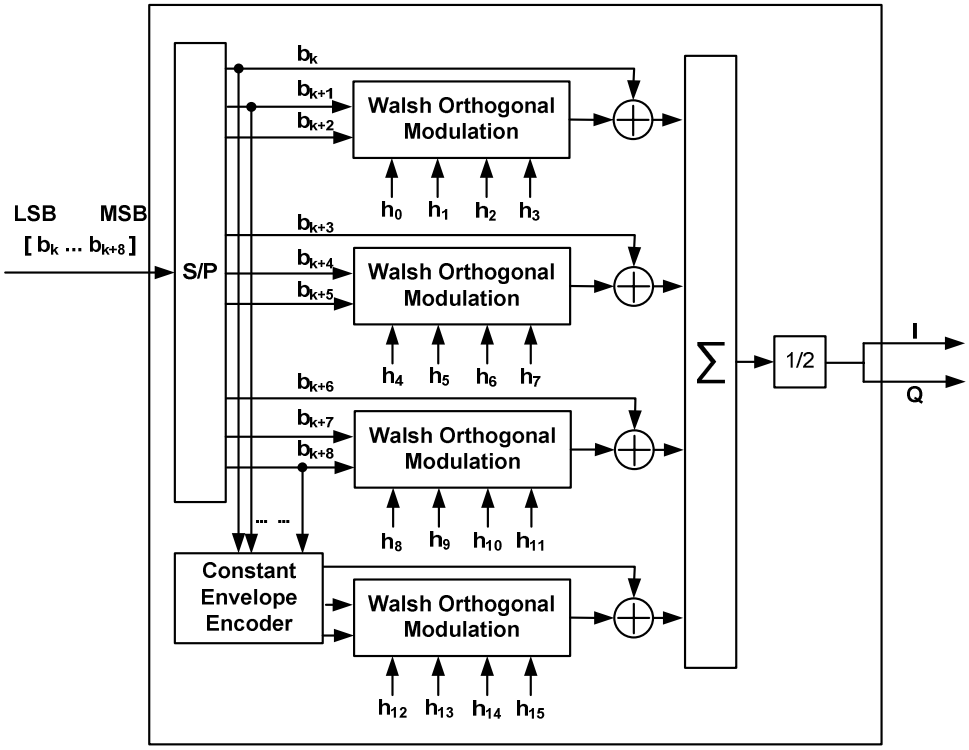


**Figure 69 - RATE3 block diagram**

#### 7.4.3.4 RATE4

This is similar to RATE3, though I/Q is fed with different data. 18-bit is divided into two parts, and then each group is converted by a RATE3 modulator.

The data rate is 6.2 Mb/s, and 18 bits can be transmitted by 16 symbols.

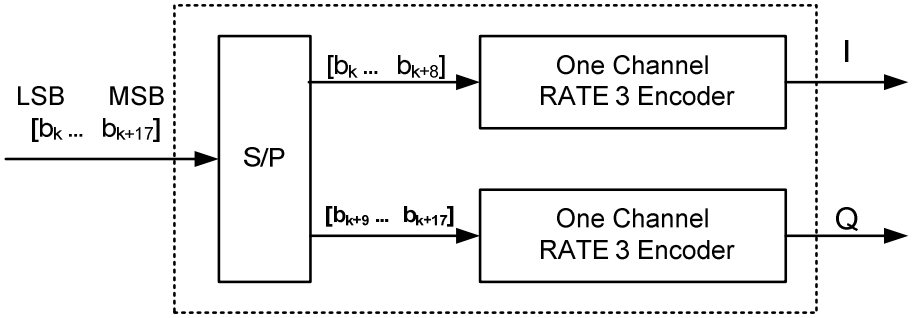


**Figure 70 - RATE4 block diagram**

### 7.4.4 Modulation methods for PHY PDU

The PHY preamble, header, and payload are modulated through different methods. Each modulation scheme is explained in the subclauses.

#### 7.4.4.1 Modulation method for preamble

The 1024 PHY preamble sequence is constructed by modulo-2 addition (exclusive OR) of CAZAC with the 64-preamble sequence [$b_0$, $b_1$, $b_2$ ..$b_{63}$].


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The preamble sequence is used for frame synchronization, timing recovery, carrier recovery, and channel estimation.

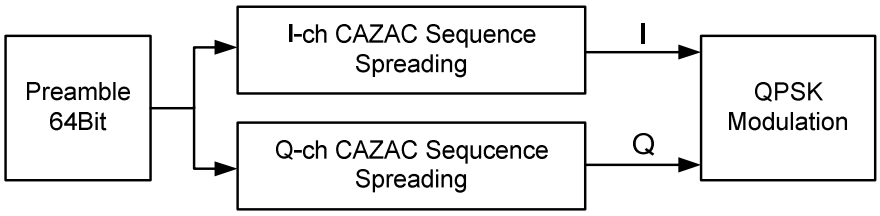


**Figure 71 - Preamble modulation**

#### 7.4.4.2 Modulation method for header

The header shall be modulated by RATE1, which is the most robust in dealing with channel noise.

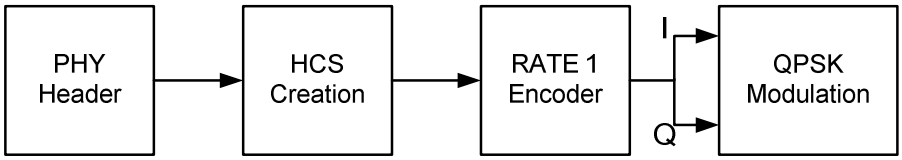


**Figure 72 - Header modulation**

#### 7.4.4.3 Modulation method for payload

Payload may be modulated by RATEi, i=1,2,3,4, according to the required QoS, data rate, and interference.

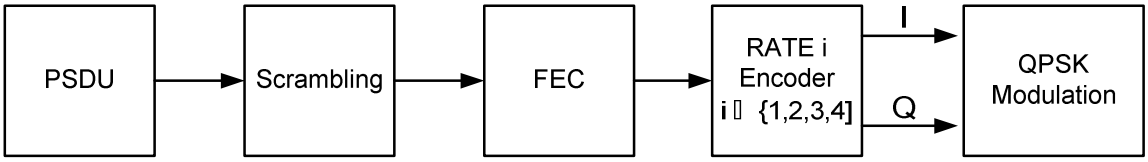


**Figure 73 - Payload modulation**

### 7.4.5 Data rate

The modulation method is QPSK, and the data rate is determined by to the following equation:

$$\text{Data rate} = 343.8\,kbps \times n$$

where n is the number of bit transmitted once through 16 symbols, and can have the values 1, 3, 9, and 18. The available data rate is given in

**Table 46 - Data rate according to modulation type**

| Type of constant amplitude modulation | N (number of bit transmitted through 16 symbols) | Data rate (Mbps) | Number of orthogonal modulation block | Constant amplitude block | I/Q channel data |
|---|---|---|---|---|---|
| RATE1 | 1 | 0.34 | 0 | × | same |
| RATE2 | 3 | 1.0 | 1 | × | same |
| RATE3 | 9 | 3.1 | 4 | O | same |
| RATE4 | 18 | 6.2 | 8 | O | different |

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### 7.4.6 QPSK Modulation and constellation

Figure 74 shows a signal constellation of QPSK modulation used in this International Standard. As shown in Figure 74, the signal has constant amplitudes.

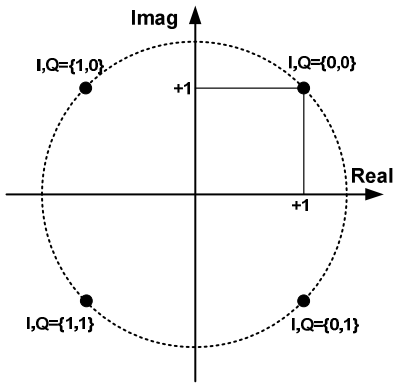


**Figure 74 - Signal constellation- of QPSK**

## 7.5 PHY layer constants and PHY MIB attribute

PHY layer parameters are given in Table 47, and PHY MIB attributes are given in Table 48.

**Table 47 - PHY layer constants**

| name | value | comments |
|---|---|---|
| Frame time | 10~50 msec | Frame length |
| Slot time | 1ms | Slot length |
| Preamble time | 186 us | 64bits X 16 chips / 5.5MHz |
| Header time | 69.8 us | 24bits X 16 chips / 5.5MHz |
| MaxPHYpacketSize | 2047 Bytes | Payload length |

**Table 48 - PHY MIB characteristics group parameters**

| Managed object | Octets | Definition | Type |
|---|---|---|---|
| PHYMIB_CurrentChannel | 1 | Indicates the channel that is currently being used | |
| PHYMIB _SymbolPerOctet | 1 | Number of symbol per octets | |
| PHYMIB _MAXTxPower | 1 | The maximum TX power that the DEV is capable of using 5.4.7, implementation dependant. | |
| PHYMIB _CCAThreshold | 1 | The CCA threshold in dBm, encoded in 2's complement format. The value is implementationdependent | |
| PHYMIB _PacketLengthMax | 2 | Maximum frame length | |
| PHYMIB _RATE | 1 | 0x00 = RATE1, 0x01 = RATE2, 0x02 = RATE3, 0x 03 = RATE4 | |
| PHYMIB _TYPE | 1 | 0x00 = 2.4GHz | |
| PHYMIB_RegDomainsSupported | Variable | One octet for each regulatory domain supported, as defined for PHYPIB_CurrentRegDomain | |
| PHYMIB_CurrentRegDomain | 1 | 0x00 = Korea, 0x01 = European Telecommunications Standards Institute (ETSI) , 0x02 = Federal Communications Commission(FCC), 0x03 = Industry Canada (IC),0x04 = Association of Radio Industries and Businesses (ARIB) | |
| PHYMIB_LQIVector | 1 | Link Quality indicator from 0 to 31 | |

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## 7.6 Transmitter specification

### 7.6.1 Error vector magnitude (EVM) definition

The modulation accuracy of a compliant transmitter is determined with an error-vector magnitude (EVM) measurement. In order to calculate this measurement, a time record of N received signal coordinate pairs $(\tilde{I}_k, \tilde{Q}_k)$ is captured. For each received symbol, a decision is made as to which symbol was transmitted. The ideal position of the chosen symbol (the center of the decision box) is represented by the vector $(I_k, Q_k)$. The error vector $(\Delta I_k, \Delta Q_k)$ is defined as the distance from this ideal position to the actual position of the received symbol.

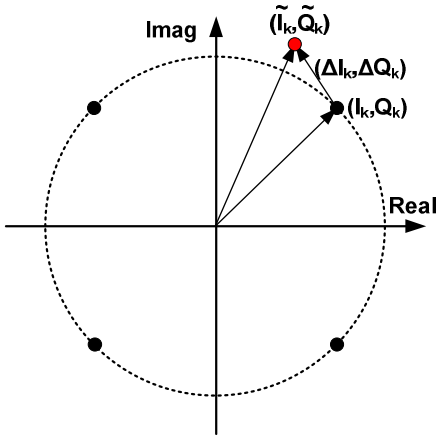


**Figure 75 - Error vector calculation**

Thus, the received vector is the sum of the ideal vector and the error vector.

$$(\tilde{I}_k, \tilde{Q}_k) = (I_k, Q_k) + (\Delta I_k, \Delta Q_k)$$

The EVM for this International Standard is defined as

$$EVM \equiv \sqrt{\frac{\frac{1}{N}\sum_{k=1}^{N}(\Delta I_k^2 + \Delta Q_k^2)}{C_{\max}^2}} \times 100\ \%$$

where $C_{\max}$ is the magnitude of the vector to the outermost constellation point and $(\Delta I_k, \Delta Q_k)$ is the error vector.

### 7.6.2 EVM calculated values

A compliant transmitter shall have EVM values of less than 7% for all of the modulation levels supported by the PHY when measured for 1000 symbols. The error vector measurement shall be made on baseband I and Q data after recovery through an ideal reference receiver system. The ideal reference receiver shall perform carrier lock, symbol timing recovery and amplitude adjustment while making the measurements. The ideal reference receiver shall have a data filter impulse response that approximates that of an ideal root raised cosine filter with 30% excess bandwidth.

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### 7.6.3 Transmitter power spectrum mask

The transmitted spectral products shall be within the limits specified in Table 49. The power shall be measured relative to the highest average power in a 100 kHz bandwidth measured within ± 3.575 MHz of the center frequency.

**Table 49 - Transmit PSD limits**

| Frequency | Relative limit |
|---|---|
| 4MHz < \|f – fc\| < 8MHz | -30 dBr |
| 8 MHz < \|f – fc\| < 11MHz | -10/3(\|f – fc\| + 4) dBr |
| 11MHz < \|f – fc\| | -50 dBr |

A graphical (informative) representation of the transmit PSD is shown in Figure 76.

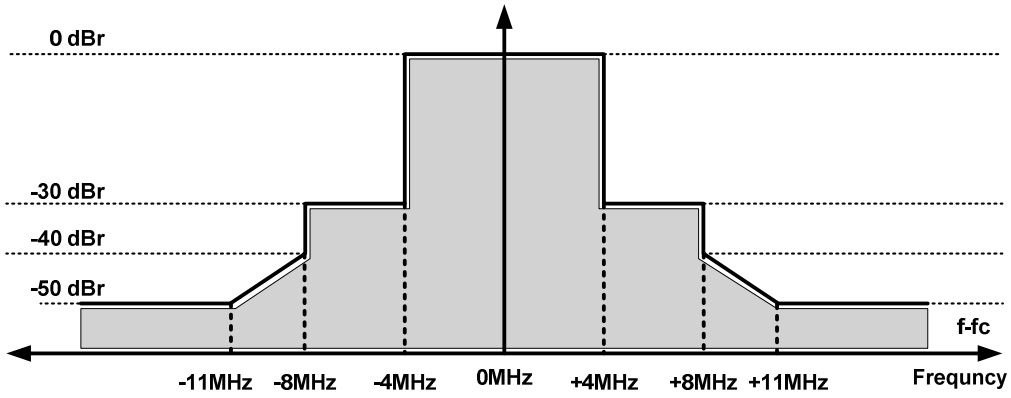


**Figure 76 - Transmit power spectrum mask**

### 7.6.4 Signal waveform filter

Each symbol generates a waveform according to the following squared-root raised cosine filter.

$$p(t) = \begin{cases} \dfrac{2\alpha}{\pi\sqrt{T_c}} \times \dfrac{\cos((1+\alpha)\pi t / T_c) + \sin((1+\alpha)\pi t / T_c)}{1 - 16\alpha^2 t^2 / T_c^2}, & 0 \le t \le T_c, \\ 0, & \text{otherwise} \end{cases}$$

where $\alpha = 0.3$.

### 7.6.5 Error tolerance for carrier frequency

Maximum error tolerance for center frequency of a received signal is ±25 ppm.

### 7.6.6 Transmitter data rate

The PHY layer provides a data rate of 6Mchips/s ±25ppm.

### 7.6.7 Synchronization

The transmit center frequency and the symbol rate shall be derived from the same reference oscillator.

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### 7.6.8 Transmitter response time

The transmit power-on ramp is defined as the time it takes for the RF power emitted by the compliant DEV to rise from less than 10% to greater than 90% of the maximum power to be transmitted in the frame. The transmit power-on ramp shall be less than 2 µs. The transmit power-down ramp is defined as the time it takes for the RF power emitted by the compliant DEV to fall from greater than 90% to less than 10% of the maximum power to be transmitted in the frame.

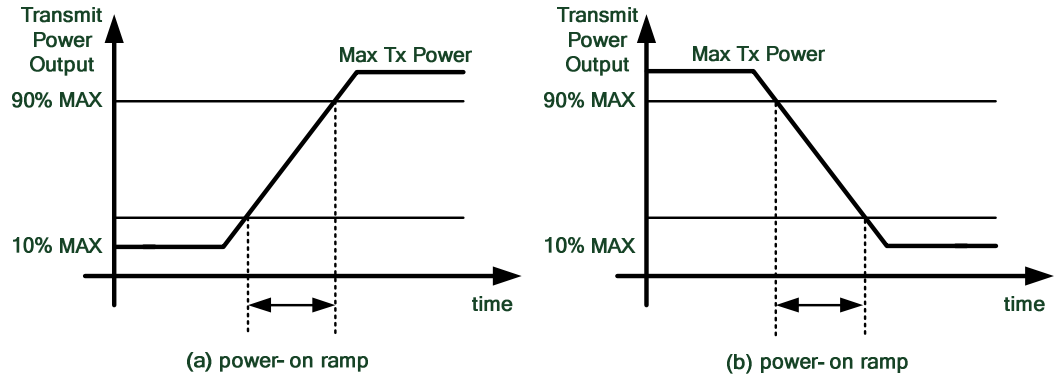


**Figure 77 - Transmitter RF response time**

### 7.6.9 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 QPSK modulation. A 100 kHz resolution bandwidth shall be used to perform this measurement.

### 7.6.10 Transmit power

The strength of RF power allowed in the 2.4GHz ISM band differs from country to country, and measurement methods also differ. The requirements stated in this clause are given as power levels at the antenna connector of the equipment. If the equipment does not have a connector, a reference antenna with 0 dBi gain is assumed.

**Table 50 - Transmit power**

| Maximum Output Power | Minimum Output Power |
|---|---|
| 100mW(20dBm) | 1mW(0dBm) |

## 7.7 Receiver specifications

### 7.7.1 Error rate criteria

The error rate criteria specifies a frame error rate (FER) of less than 8% with a frame payload length of 1024 octets of pseudo-random data generated with a PN23 sequence as defined by

$$x_{n+1} = x_n^{23} + x_n^5 + 1.$$

Note that the frames used for measuring the error rate criteria include not only the frame payload of 1024 octets, but also the PHY preamble, PHY header, MAC header, HCS and the FCS.

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### 7.7.2 Receiver sensitivity

The receiver sensitivity is the minimum power level of the incoming signal, in dBm, present at the input of the receiver for which the error rate criterion in 7.7.1 is met. The error ratio shall be determined after any error correction has been applied. Compliant systems may have a lower actual sensitivity than the reference sensitivity. A compliant DEV shall achieve at least the reference sensitivity, –80 dBm for the QPSK modulation format that the DEV supports.

### 7.7.3 Maximum input power

The receiver maximum input level is the maximum power level of the incoming signal, in dBm, present at the input of the receiver for which the error rate criteria in 7.7.1 is met. A compliant receiver shall have a receiver maximum input level of at least -10 dBm for each of the modulation formats that the DEV supports.

### 7.7.4 Receiver Energy detection (ED)

The receiver ED measurement is intended for use by a network layer as part of a channel selection algorithm. It is an estimate of the received signal power within the bandwidth of an channel. No attempt is made to identify or decode signals on the channel. The ED time shall be equal to eight symbol periods.

### 7.7.5 Clear channel assessment (CCA)

The 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 2: Carrier sense only. CCA shall report a busy medium only upon the detection of a signal with the modulation and spreading characteristics of the specification. This signal may be above or below the ED threshold.

- CCA Mode 3: Carrier sense with energy above threshold. CCA shall report a busy medium only upon the detection of a signal with the modulation and spreading characteristics of the specification, and with energy above the ED threshold.

### 7.7.6 Received CCA performance

A compliant receiver provides CCA capability by performing energy detection in the received signal bandwidth. The start of a valid preamble sequence at a receive level equal to or greater than the minimum sensitivity for the QPSK base rate, as described in 7.7.2, shall cause CCA to indicate medium busy with a probability of >90 % within four CAZAC periods, as described in 7.3.2. The receiver CCA function shall in all circumstances report medium busy with any signal 20 dB above the minimum sensitivity for the QPSK base rate. The CCA detection time shall be equal to aCCADetectTime. The CCA shall be maintained as busy until the end of the frame for which the inverted CAZAC sequence was detected.

### 7.7.7 Received Signal Strength Index

RSSI is defined as the power relative to the maximum receiver input power level, as described 7.7.3, in 8 steps of 8 dB with +/- 4 dB step size accuracy. The range covered shall be a minimum of 40 dB. The steps shall be monotonic. The RSSI power shall be the average power measured in the last CAZAC sequence of the PHY preamble, as described 7.3.2. This number is reported via the PHY-RX-START.indication, as described 4.6.1.16, if that particular PHY interface is has been implemented.

### 7.7.8 Link Quality Index (LQI)

The LQI measurement is a characterization of the strength and/or quality of a received packet. The measurement may be implemented using receiver ED, a signal-to-noise ratio estimation, or a combination of these methods. The use of the LQI result by the network or application layers is not specified in this standard. The LQI measurement shall be performed for each received packet, and the result shall be reported to the MAC sublayer. The receiver shall report the SNR as a 5 bit number that covers a range from 6 dB to 21.5 dB of SNR. The value 0x00000 shall correspond to less than or equal to 6 dB SNR and 0x11111 shall correspond to more than or equal to 21.5 dB SNR with equal steps in between.


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# Annex A
(informative)

# Example scheduler and admission control

The slot allocation procedure is described in “6.4 Resource allocation”, and stream creation, termination and modification procedures are also explained there. Following scheduling algorithm and admission control algorithm are example algorithms to meet its QoS requirements and connection priority. However these scheduling and admission control implementations are vendor-specific and can be chosen according to their needs.

## A.1 Scheduling algorithm

This scheduling algorithm is a example algorithm to allocate time slots to meet its QoS requirements regardless of the length of the superframe. Master manages time slot allocation to each stream by keeping ATS interval and duration information, which is calculated at setup. Allocated time slot (ATS) interval is defined by the unit of millisecond. Hence a master manages the following table in Figure A.1 to schedule ATS to streams.

| Destination station ID | Source station ID | Stream ID | ATS interval | ATS duration | ATS position |
|---|---|---|---|---|---|
| | | | | | |

**Figure A.1 - Stream info table in master**

ATS position defines the position where the next time slots will be allocated to and is updated to the value of the current ATS position plus ATS interval after the current ATS is successfully allocated. In the case of first ATS allocation, ATS position is set first as the infinity and then updated as a last position of the superframe, if there are available time slots. Master always maintains this list by the ascending order of ATS position. If the first stream in this list is allocatable in this superframe, it is allocated to time slots, defined by ATS position. If other stream already occupied the time slots, the stream is allocated to the next time slots and its ATS position is updated with the following equation.

$$T_{ATS_postion,i} = T_{ATS_postion,i} + T_{ATS_\mathrm{int}erval,i}$$

where, $T_{ATS_position,i}$ and $T_{ATS_interval,\ i}$ mean ATS position and interval of each stream.

A master repeats this scheduling process until ATS position + ATS duration of the top steam in the list exceeds the current superframe. After the scheduling ends, for the all stream in the list, ATS position value is reduced by the length of allocation period and the start time of next allocation period in order to express next ATS position as a relative time.

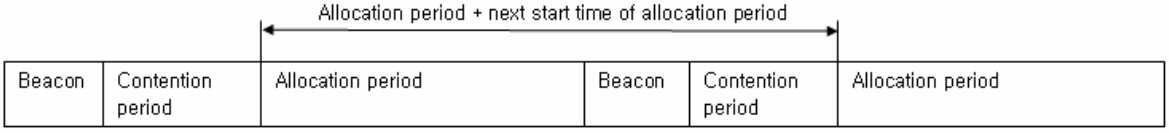


**Figure A.2 - Calculation of ATS Position**

By allocating time slots this way, slaves can get time slots allocated by a certain period. However, this method prevents the waste of time slots, but may result in fragmentation of ATS like depicted in Figure A.3 (a) To avoid fragmentation, a master allocates a stream to positions starting from the otherwise unused time slots, when the ATS interval of prior stream is less than the ATS interval of current ATS * α (0≦α≦1) like depicted

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in Figure A.3 (b) , where the value of $\alpha$ can be chosen accordingly based on stream characteristics and channel environment. For the stream sensitive to delay, small $\alpha$ is chosen to limit the range of slot position change. When channel usage is low, which means low loss due to fragmentation, small $\alpha$ is chosen, while large $\alpha$ is chosen when channel usage is high.

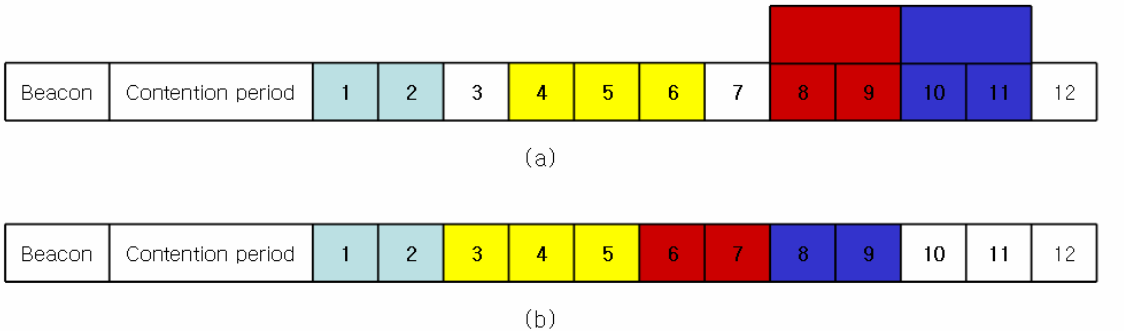


**Figure A.3 - Fragmentation of ATS(a) and enhance for it(b)**

ATS duration and ATS interval are decided based on characteristics of traffics. On average, the wait time until packet is transmitted should be about 1/2 of ATS interval so that ATS interval should be less than two times of maximum delay defined in QoS request. The value of ATS duration is recommended to be the multiple of transmit time of average packet to increase the efficiency. The relation of ATS duration, ATS interval, maximum delay and data rate is depicted in the following equation.

$$T_{ATS_duration,i} = n \times T_{avg.packet_TX_time,i} = \frac{R_{Desired,i}}{R_{channel}} \times T_{ATS_interval,i}$$

$$T_{ATS_interval,i} \leq 2 \times T_{Delay_boumd,i}$$

where $T_{ATS_duration,i}$, $T_{ATS+interval,i}$ and $T_{DelayBound,i}$ are ATS duration, ATS interval and maximum delay of each stream.

$T_{avg.packet_TX_time,i}$ is the transfer time of an average packet.
$R_{Desired,i}$ is the required data rate for a stream
*n* is a natural number

Large *n* means small ATS interval and delay, but can results in the unused time slots, since the ATS interval is smaller than packet generation interval. The above equation can be changed to the below equation, based on which n should be chosen.

$$n \leq \frac{R_{Desired,i} \times 2 \times T_{Delay_bound,i}}{R_{channel} \times T_{avg.packet_TX_time,i}}$$

## A.2 Admission control Algorithm

To support QoS, the Connection Admission Control (CAC) to control the accept/reject of devices and stream communication should be used. A example of CAC is illustrated.

Channel usage ($U_{channel}$) of each stream is calculated using following expression.


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$$U_{channel} = \frac{T_{cp}}{T_{\sup erframe_\inter val}} + \sum_{i=0}^{N} \left( \frac{T_{ATS_Duration,i}}{T_{ATS_Interval,i}} \right)$$

where, $T_{cp}$ is the length of contention period

$T_{Superfram_Interval}$ is the interval of the superframe.

$N$ is the total number of streams listed in stream information table.

In the ideal case, when the sum of $U_{channel}$ reaches 1, it means all time slots are used. However, because of fragmentation and duplication problem, allocating time slots until the sum reaches 1 does not support QoS. Hence, to support QoS, master should allocation time slots while it satisfying the below condition.

$$\beta > U_{channel} \left(0 < \beta < 1\right)$$

where, $\beta$ should be chosen according to fragmentation and characteristic of time slot allocation

Flowchart of time slot allocation algorithm is depicted in Figure A.4

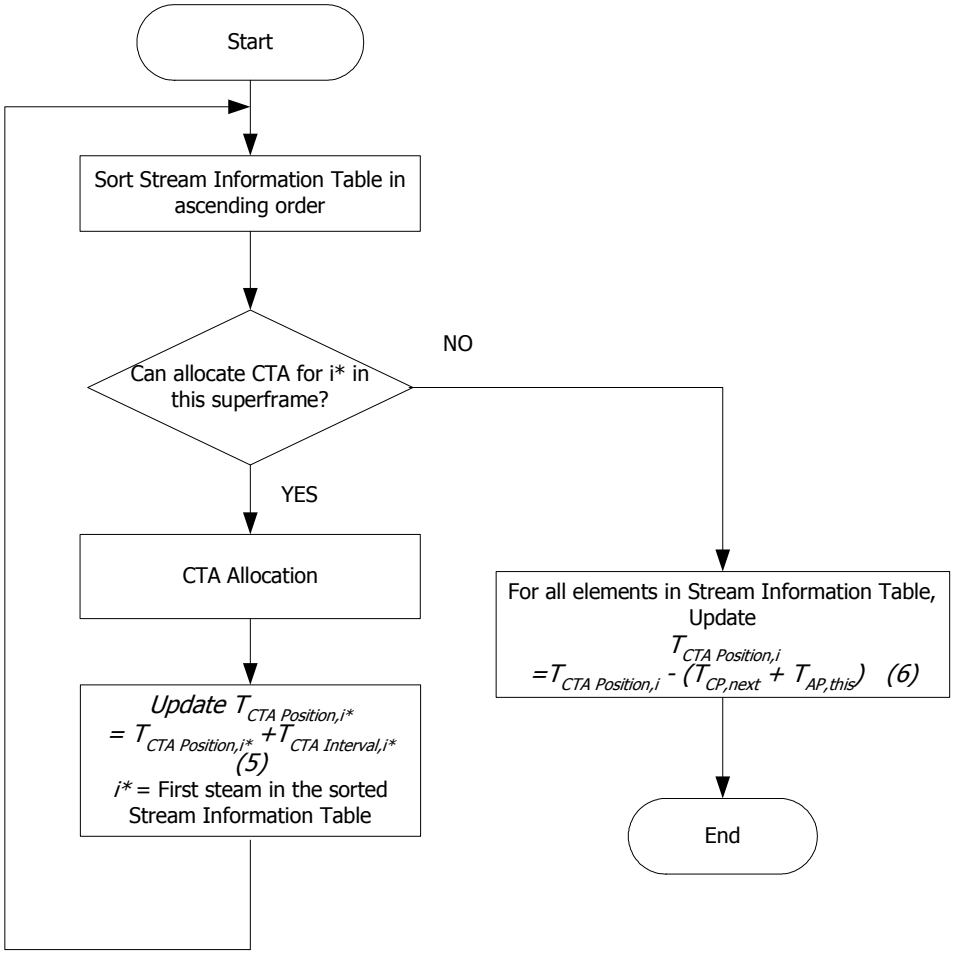


**Figure A.4 - Slot allocation algorithm**

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