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IEEE Standard for the Interface Between the Rail Subsystem and the Highway Subsystem at a Highway Rail Intersection

IEEE Vehicular Technology Society

Sponsored by the
Rail Transit Vehicle Interface Standards Committee

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IEEE Standard for the Interface Between the Rail Subsystem and the Highway Subsystem at a Highway Rail Intersection

Sponsor

Rail Transit Vehicle Interface Standards Committee
of the
IEEE Vehicular Technology Society

Approved 11 September 2002

IEEE-SA Standards Board

Abstract: The logical and physical interfaces and the performance attributes for the interface between the rail subsystem and the highway subsystem at a highway rail intersection are defined in this standard.
Keywords: highway rail grade crossing, highway rail intersection

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Introduction

(This introduction is not part of IEEE Std 1570-2002, IEEE Standard for the Interface Between the Rail Subsystem and the Highway Subsystem at a Highway Rail Intersection.)

A highway rail intersection (HRI) is the name given by the National Intelligent Transportation System (ITS) Architecture to a highway-rail grade crossing. The Federal Railroad Administration (FRA) defines a highway-rail grade crossing as "a location where a public highway, road, street, or private roadway, including associated sidewalks and pathways, crosses one or more railroad tracks at grade." This applies equally to whether the rail subsystem is part of the general system of freight railroads or part of the general passenger rail system including intercity passenger and commuter rail and rapid transit. The Federal Highway Administration (FHWA) defines a highway-rail grade crossing as "the general area where a highway and a railroad's right of way cross at the same level, within which are included the railroad tracks, highway, and traffic control devices for highway traffic traversing that area." The FHWA continues on to define a train as "one or more locomotives, with or without cars, that operate on rails or tracks and to which all other traffic must yield the right-of-way by law at highway-rail grade crossings." This definition also applies to either mainline railroads or rail rapid transit systems.

This standard defines the interface between the railroad side and the highway side of a highway-rail grade crossing. One of the prime purposes of this interface has been to preempt traffic signal operation when a train is approaching in order to allow traffic to clear from the vicinity of the crossing. Historically, this has been done with a voltage conveyed by a pair of wires where the absence of the voltage causes the highway traffic signal to begin its preemption operation. This interface is designed according to both fail-safe and closed-loop principles (and is required to be so designed by federal regulations). This standard prescribes a digital communications interface providing equivalent functions while maintaining the required safety attributes. Within the defined interface, flexibility has been provided for information to be provided that has not historically been available. As a minimum, this interface will support preemption operation as is presently done by an interconnection circuit. Future upgrades in functionality are supported by this interface but the user must be aware that this may increase the overall cost of the systems. This standard only allows for the possibility of additional functionality on either side of the interface; it does not mandate that functionality. This standard also follows the architecture defined in the National ITS Architecture.

Figure INT-1 shows a typical installation of equipment at a highway-rail grade crossing. There was substantial discussion on the allocation of components within either the roadway or the railroad subsystem. Since this standard focuses on the interface between the railroad wayside equipment terminator and the roadway subsystem, actual allocation of components is irrelevant as the interface is flexible enough to support alternative placements should they prove viable in the future. Figure INT-1 shows the predominant configuration for existing equipment (supported by existing or in-process standards). Clause 2 of this standard identifies existing standards for these interfaces.

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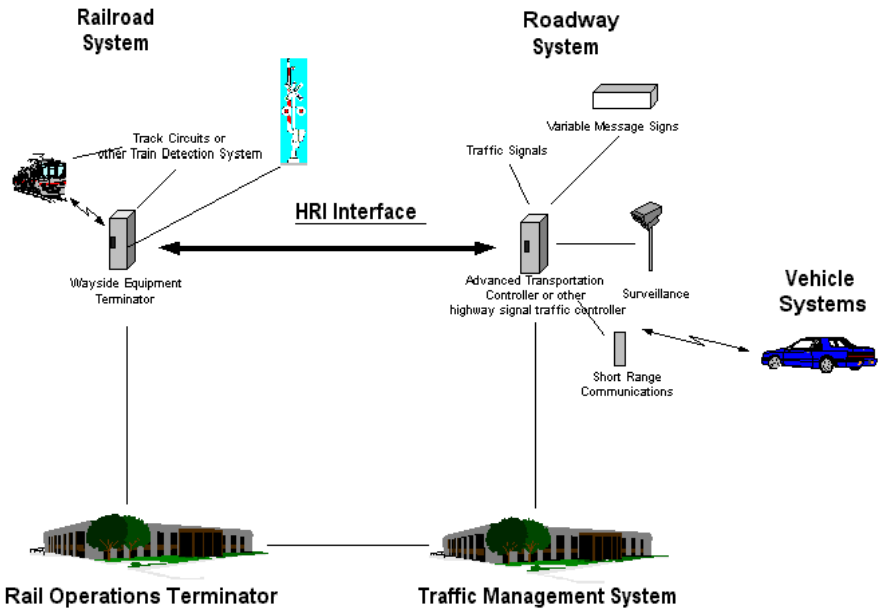

Figure INT-1—HRI interface overview

All direct digital communications between the railroad and roadway systems take place via wayside equipment terminators in the railway system and advanced transportation controllers (or highway traffic signal controllers) in the roadway system. This HRI interface standard specifies direct communications only between wayside equipment terminators and advanced transportation controllers and does not cover communications to/from/between rail operations terminators and traffic management systems, which will be the subject of a separate standard.

Wayside equipment terminators consist of numerous railway control functions such as crossing controllers, grade crossing predictors, event recorders, etc. These functions typically reside in physically separate devices and communicate with one another via an internal communications network. This standard makes no assumptions about technologies used to implement any of the functions.

Likewise, the advanced transportation controller may consist of numerous roadway control functions such as vehicle presence detectors, traffic controllers, etc. The advanced transportation controller is the National ITS Architecture definition for the device that controls a variety of roadway functions. For this standard, it is intended that this ATC definition also apply to highway traffic signal controllers. Like the railroad wayside functions, these roadway functions also communicate to one another via an internal communications network. The HRI interface provides the means for control functions in either the wayside equipment terminators or the advanced transportation controllers to communicate with one another.

The HRI interface can be thought of as consisting of both a virtual (logical) component and a physical component. The virtual component provides the communications channel between functions in the wayside equipment terminators and the advanced transportation controllers. This component consists of the message formats and information content that flow between the two systems. The physical component of the HRI interface facilitates the transfer of data between the internal data network within the wayside equipment terminators and the internal network within the advanced transportation controllers. This physical component acts as a bridge between these two independent networks. The virtual and physical HRI interfaces are illustrated in the point-to-point HRI interface configuration shown in Figure INT-2. The HRI physical interface may consist of either a simple point-to-point configuration as illustrated, or as a multipoint-to-multipoint interconnection (i.e. network) of wayside equipment gateways and ATC gateways.

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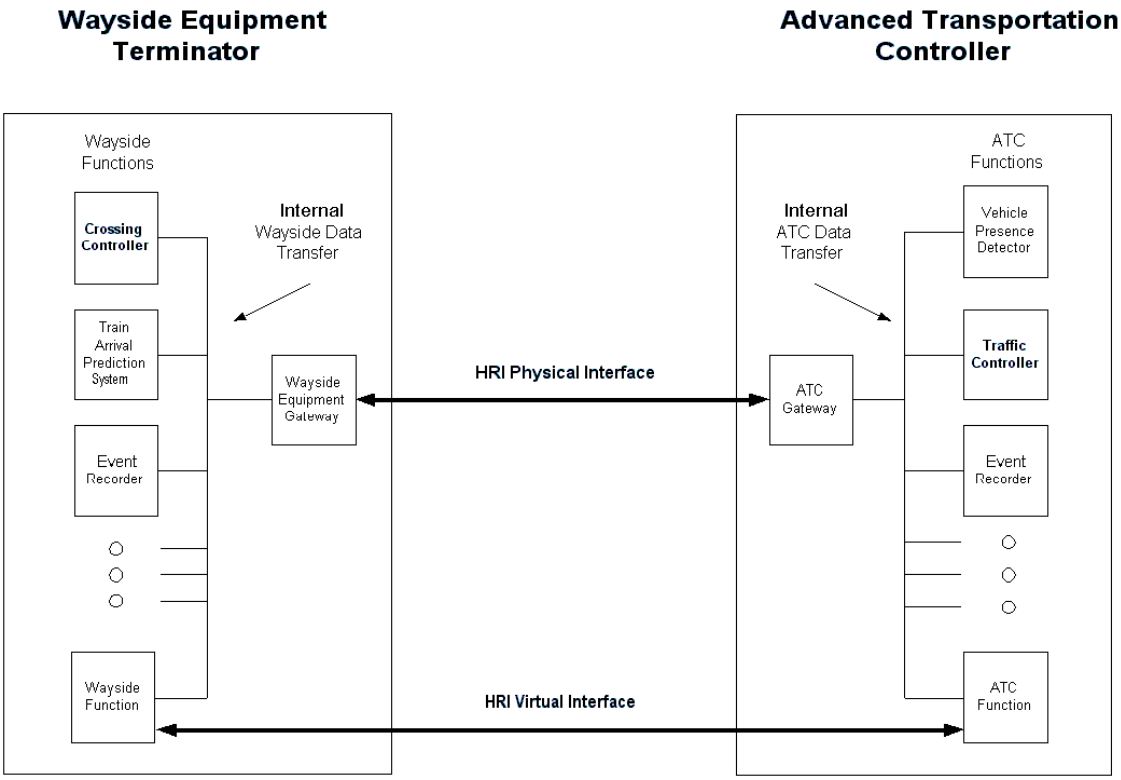

Figure INT-2—HRI interface

As shown in Figure INT-2, the HRI interface architecture consists of four functional entities:

— *Wayside functions:* These are the functions within the railroad wayside equipment terminator that obtain, calculate, or otherwise generate the railroad system information that is to be transmitted across the HRI interface to the roadway system. These functions may also process data received from the roadway system over the HRI interface. There are typically multiple wayside functions within a single wayside equipment terminator.

— *Wayside gateway:* The railroad wayside gateway function acts as both an internal router and an interface bridge controller. The wayside gateway is responsible for interfacing to the individual wayside functions within a wayside equipment terminator and routing outgoing HRI messages across the HRI interface to the appropriate ATC gateway. Likewise, the wayside gateway function routes incoming information received from an ATC gateway to the appropriate wayside function within the wayside equipment terminator.

— *ATC gateway:* The roadway ATC gateway function is the companion function to the wayside gateway on the roadway side of the HRI physical interface. It routes incoming messages received over the HRI interface to the appropriate ATC function over the internal ATC network. Likewise, the ATC gateway also routes outgoing messages from the source ATC function to the appropriate wayside gateway.

— *ATC functions:* These functions are the companion functions to the wayside functions in the railroad system. The ATC functions are the functions within the advanced traffic controller that obtain, calculate, or otherwise generate the roadway system information that is to be transmitted across the HRI interface to the railroad system. Likewise, these functions may also process data received from the railroad system over the HRI interface. There are typically multiple ATC functions within a single advanced traffic controller.

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The selection of the protocol standards for the HRI interface was driven by the following high-level considerations:

— *Railroad and roadway system independence:* Railroad and roadway data communication systems have evolved essentially independently of one another, driven by requirements unique to their respective applications. The HRI interface architecture is specified in such a manner as to not unduly impact existing communication protocols currently used in railway and roadway data communication systems.

— *Multiple interface options:* More than one set of protocols is specified for the HRI interface to provide equipment manufacturers the flexibility to implement the HRI interface in a manner that best fits the circumstances of a particular installation.

— *Cost effectiveness:* The HRI interface protocols have been selected in large part due to their common use throughout the communications industry. Large market acceptance of these protocols assures availability of cost-effective hardware and software components needed to implement these protocols.

— *Limited system administration:* The HRI interface protocols have been specified in such a manner as to limit the overall system administration required to implement data communications between wayside and ATC equipment. Given that different administrative authorities control railroad and roadway equipment, the HRI interface architecture is designed to minimize coordination and administration (e.g., device addressing) of existing equipment on both sides of the HRI interface.

Participants

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IEEE Standard for the Interface Between the Rail Subsystem and the Highway Subsystem at a Highway Rail Intersection

1. Overview

This standard establishes logical and physical interface requirements for the highway rail intersection (HRI) interface. This standard is divided into the following clauses:

- *Clause 1:* provides the scope and purpose of this standard.
- *Clause 2:* lists references to other standards that are required in applying this standard.
- *Clause 3:* provides abbreviations, acronyms, and definitions for terms used in this standard.
- *Clause 4:* lists the requirements for data communications over the HRI interface and specifies the communications protocols for each layer of the HRI interface.
- *Clause 5:* describes the data, message layouts, and performance attributes for information transmitted across the HRI interface.
- *Annexes:* provide additional relevant information and examples to help the reader understand the applications of this standard. These annexes are provided for informative purposes only and do not form part of the HRI standard.

1.1 Scope

This standard defines the logical and physical interfaces, and the performance attributes for the interface between the rail subsystem and the highway subsystem at a highway rail intersection.

1.2 Purpose

Coordination between the rail subsystem and the highway subsystem is part of creating a national intelligent transportation system (ITS) architecture covering multiple modes of transportation. Existing standards address analog interfaces between these subsystems at the highway rail intersection. This standard will extend that information to include digital data communication. Standardizing the interface will allow interoperability between a wide variety of equipment and enhance safety through a set of well-defined interface and performance attributes.

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1.3 Existing applications

Existing installations and projects in progress prior to the effective date of this standard need not comply with the new or revised requirements of this edition, except where specifically required by the authority having jurisdiction.

2. References

This standard shall be used in conjunction with the following publications. This standard is based on the version and date of the following publications as shown below. Revisions to these publications may not apply. Such revisions will be reviewed for continued applicability when this standard is next reviewed. In case of a conflict between this standard and the referenced document, this standard shall take precedence. Those provisions of the referenced documents, which are not in conflict with this standard, shall apply as referenced.

ATCS Specification 200, May 1995, Revision 4.0.[1]

DEC, "The Ethernet—A Local Area Network," Version 2.0, Digital Equipment Corporation, Intel Corporation, Xerox Corporation; November 1982.

IEEE Std 802.3™, 2000 Edition, IEEE Standard for Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications.[2, 3]

ISO/IEC 3309:1993(E), Information Technology—Telecommunications and information exchange between systems—High-level data link control (HDLC) procedures—Frame structure.[4, 5]

RFC 768:1980, User Datagram Protocol.[6]

RFC 791:1981, Internet Protocol—DARPA Internet Program Protocol Specification.

RFC 793:1981, Transmission Control Protocol—DARPA Internet Program Protocol Specification.

RFC 894:1984, A Standard for the Transmission of IP Datagrams over Ethernet Networks.

TIA/EIA-232-F-97, Interface Between Data Terminal Equipment and Data Circuit-Terminating Equipment Employing Serial Binary Data Interchange.[7]

TIA/EIA-422-B-94, Electrical Characteristics of Balanced-Voltage Digital-Interface Circuits.

TIA/EIA-485-A-98, Electrical Characteristics of Generators and Receivers for Use in Balanced Digital Multipoint Systems.

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[1]ATCS Specification 200 is now available in Section K-II of the AAR Manual of Recommended Practices and has been renamed AAR Specification S-5800. Copies are available from the Transportation Technology Center, Inc., Publications Department, P. O. Box 79780, Baltimore, MD 21279, USA (http://www.aar.com).

[2]IEEE publications are available from the Institute of Electrical and Electronics Engineers, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA (http://standards.ieee.org/).

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[4]ISO/IEC publications are available from the ISO Central Secretariat, Case Postale 56, 1 rue de Varembé, CH-1211, Genève 20, Switzerland/Suisse (http://www.iso.ch/). ISO/IEC publications are also available in the United States from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (http://global.ihs.com/). Electronic copies are available in the United States from the American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, NY 10036, USA (http://www.ansi.org/).

[5]ISO/IEC 3309:1993(E) has been withdrawn; however, copies can be obtained from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (http://global.ihs.com/).

[6]Information on RFC documents can be obtained at http://www.ietf.org/rfc.

[7]TIA/EIA publications are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado 80112, USA (http://global.ihs.com/).

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3. Definitions, abbreviations and acronyms

3.1 Definitions

For the purposes of this standard, the following terms and definitions apply. IEEE 100, *The Authoritative Dictionary of IEEE Standards Terms* [B4][8], should be referenced for terms not defined in this clause.

3.1.1 authority having jurisdiction: The entity that defines the contractual (including specification) requirements for the procurement of the HRI interface equipment.

NOTE—It is likely that there will be separate authorities having jurisdiction over the railway subsystem and the highway subsystem.

3.1.2 active grade crossing warning system: The flashing-light signals, with or without warning gates, together with the necessary control equipment used to inform road users of the approach or presence of trains at a highway-rail grade crossing.

3.1.3 advanced preemption: Notification of an approaching train is forwarded to the highway signal traffic signal controller unit or assembly by railroad equipment for a period of time prior to activating the railroad active warning devices.

3.1.4 advance preemption time: This period of time is the difference in the maximum preemption time required for highway traffic signal operation and the minimum warning time required for railroad operations.

3.1.5 advanced transportation controller: A complete electrical device mounted in a cabinet for controlling the operation of a variety of functions within the roadway subsystem as defined in the National ITS Architecture Version 3.0.

NOTE—For the purposes of this standard, a highway traffic signal controller shall also be considered as an advanced transportation controller.

3.1.6 controller assembly: A complete electrical device mounted in a cabinet for controlling the operation of a highway traffic signal installation.

3.1.7 crossing: *See:* **highway-rail grade crossing**.

3.1.8 entrance gate: A highway rail crossing warning gate used on the approach lanes of traffic toward a highway rail grade crossing.

3.1.9 exit gate: A highway rail crossing warning gate used on the exit lanes of traffic from a highway rail grade crossing.

3.1.10 fail-safe: A design philosophy applied to safety-critical systems such that the result of a hardware failure or the effect of software error shall either prohibit the system from assuming or maintaining an unsafe state, or shall cause the system to assume a state known to be safe.

3.1.11 fail-safely: The implementation of a function in a fail-safe manner.

3.1.12 gate down: A crossing gate is in the down position when it is some predetermined number of degrees from vertical (typically 85 to 92 degrees depending on specific gate mechanism adjustment).

[8]The numbers in brackets correspond to those of the bibliography in Annex D.

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3.1.13 gate up: A crossing gate is in the up position when it is some predetermined number of degrees from horizontal (typically 85 to 92 degrees depending on specific gate mechanism adjustment).

3.1.14 highway: A general term denoting a public way for purposes of travel, including the entire area within the right-of-way. *Syn:* **road; street**.

3.1.15 highway-rail grade crossing: (1) A location where a public highway, road, street, or private roadway, including associated sidewalks and pathways, crosses one or more railroad tracks at grade. **(2)** The general area where a highway and a railroad's right of way cross at the same level, within which are included the railroad tracks, highway, and traffic control devices for highway traffic traversing that area. **(3)** For purposes of this standard, a crossing is the intersection of a highway and up to 8 tracks controlled by a single independent warning system. *Syn:* **crossing; highway rail intersection; roadway-rail intersection**.

3.1.16 highway rail intersection: *See:* **highway-rail grade crossing**.

3.1.17 highway traffic signal: A power-operated traffic control device by which traffic is warned or directed to take some specific action. These devices do not include power-operated signs, illuminated pavement markers, barricade warning lights, or steady burning electric lamps.

3.1.18 highway traffic signal controller: A complete electrical device mounted in a cabinet for controlling the operation of a highway traffic signal installation.

3.1.19 interconnection: The electrical connection between the railroad active warning system and the traffic signal controller assembly for the purpose of preemption.

3.1.20 interconnection circuit: A control circuit using a closed-circuit principle. Referenced in the Federal Highway Administration Manual on Uniform Traffic Control Devices [B2] as a "supervised circuit" activated by a train approaching a highway-rail grade crossing which preempts the operation of a highway traffic signal controller.

3.1.21 interface: The points where two or more physical systems or subsystems meet to transfer energy or information.

3.1.22 island: That portion of the highway rail grade crossing where the highway directly crosses the railroad tracks.

3.1.23 island occupancy: For detection purposes, a train is said to be occupying the island when it is a minimum of 20 ft and a maximum of 100 ft from either edge of where the highway crosses the tracks.

3.1.24 minimum warning time—through train movements: The least amount of time active warning devices shall operate prior to the arrival of a train at a highway-rail grade crossings.

3.1.25 monitored interconnected operation: An interconnected operation that has the capability to be monitored by the railroad and/or highway authority at a location away from the highway-rail grade crossing.

3.1.26 preemption: The transfer of normal operation of traffic signals to a special mode.

3.1.27 preemption design time: Design time for highway traffic signal preemption. Equal to the sum of the minimum warning time and advance preemption time. *See also:* **advance preemption time; minimum warning time**.

NOTE—Advance preemption time may be zero. *See also:* **simultaneous preemption**.

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3.1.28 preemption warning active: Preemption warning active occurs when the train is within the preemptive design time. *See also:* **preemption design time**.

3.1.29 road: *See:* **highway**.

3.1.30 roadway-rail intersection: *See:* **highway-rail grade crossing**.

3.1.31 safe: Having acceptable risk of the occurrence of a hazard.

3.1.32 safety: Freedom from those conditions that can cause death, injury, occupational illness, or damage to or loss of equipment or property, or damage to the environment.

3.1.33 safety assurance: A characteristic of the implementation of a system which assures a level of safe operation.

3.1.34 safety-critical: A term applied to a system or function, the correct performance of which is critical to safety of personnel and/or equipment; also a term applied to a system or function, the incorrect performance of which may result in an unacceptable risk of a hazard. *See also:* **fail-safe**.

NOTES

1—Such a designation may require the incorporation of additional special safety design features.

2—Vital functions are a subset of safety-critical functions.

3.1.35 simultaneous preemption: Notification of an approaching train is forwarded to the highway traffic signal controller unit or assembly and railroad active warning devices at the same time.

3.1.36 street: *See:* **highway**.

3.1.37 traffic control devices: All signs, signals, markings, islands, and other devices used to regulate, warn, or guide traffic, placed on, over, or adjacent to a street, highway, road, pedestrian facility, or bicycle path by authority of a public body or official having jurisdiction.

3.1.38 traffic control signal (traffic signal): Any highway traffic signal by which traffic is alternately directed to stop and permitted to proceed. *See also:* **highway traffic signal**.

3.1.39 train: One or more locomotives, with or without cars, that operates on rails or tracks and to which all other traffic must yield the right-of-way by law at highway-rail grade crossings.

3.1.40 vital function: A function in a safety-critical system that is required to be implemented in a fail-safe manner.

NOTE—Vital functions are a subset of safety-critical functions.

3.1.41 warning system active: This is the period during which an active grade crossing warning system is in its operational state (e.g. lights are flashing, bells are ringing). For active grade crossing warning systems equipped with gates, this time starts when the lights start to flash even though the gates have not necessarily started any motion.

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3.2 Abbreviations and acronyms

AAR	Association of American Railroads
AASHTO	American Association of State Highway and Transportation Officials
ANSI	American National Standards Institute
APTA	American Public Transportation Association
AREMA	American Railway Engineering and Maintenance-of-Way Association
ASCE	American Society of Civil Engineers
ATC	advanced transportation controller
ATCS	advanced train control systems
DARPA	Defense Advanced Research Projects Agency
DOT	Department of Transportation
EIA	Electronics Industry Association
FHWA	Federal Highway Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HRI	highway rail intersection
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers, Inc.
ISO	International Organization for Standardization
ITE	Institute of Transportation Engineers
LRV	light rail vehicle
LSB	least significant bit
MUTCD	Manual on Uniform Traffic Control Devices
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NTCIP	National Transportation Communications for ITS Protocol
OSI	open systems interconnection
RFC	request for comments
SAE	Society of Automotive Engineers
TIA	Telecommunications Industry Association
TCP	transmission control protocol
UDP	user datagram protocol
UTC	coordinated universal time

4. HRI interface data communication protocols

4.1 HRI interface protocol requirements

4.1.1 Network support

This HRI interface standard identifies protocols that shall support both point-to-point and network configurations of Wayside Gateways and ATC Gateways.

4.1.2 Data throughput

The HRI interface protocols shall support gateway-to-gateway data transfer rates of at least 19.2 kbps.

NOTE—Generally speaking, the data transfer requirements for the HRI interface are relatively modest—individual message transfers are small (<128 bytes/packet) and the periodicity of the transfers is on the order of seconds.

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4.1.3 Packet size

The HRI interface protocols shall support the transfer of individual HRI message packets up to 128 bytes in length.

4.1.4 Data transfer

The HRI interface protocols shall be capable of transferring a 128-byte message packet across the interface in less than 250 msec (nominally).

4.1.5 Safety-critical message transmission

The HRI interface protocols shall incorporate a communication error detection scheme that meets the safety standards as defined in ATCS Specification 200[9].

4.2 HRI interface protocol architecture

The International Organization for Standardization's (ISO's) seven-layer Open Systems Interconnect (OSI) basic reference model of protocol design shall be used to structure the HRI interface protocol architecture. These layers are:

- *Layer 7: application layer*—Selects appropriate service for the application. An application is the actual hardware and/or software entity that performs a function in either the railway or roadway systems.
- *Layer 6: presentation layer*—Provides data formatting (reformatting) and identification.
- *Layer 5: session layer*—Coordinates the interaction between applications.
- *Layer 4: transport layer*—Provides for end-to-end data integrity and quality of service in communications.
- *Layer 3: network layer*—Switches and routes information.
- *Layer 2: data link layer*—Transfers units of information across a physical link. Provides media access control, synchronization, framing, and error detection and recovery.
- *Layer 1: physical layer*—Moves bits across a medium.

Figure 1 shows the relationship between the OSI model and the HRI interface components. Individual data communication protocols are specified between peer entities (same layer) in adjacent components.

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

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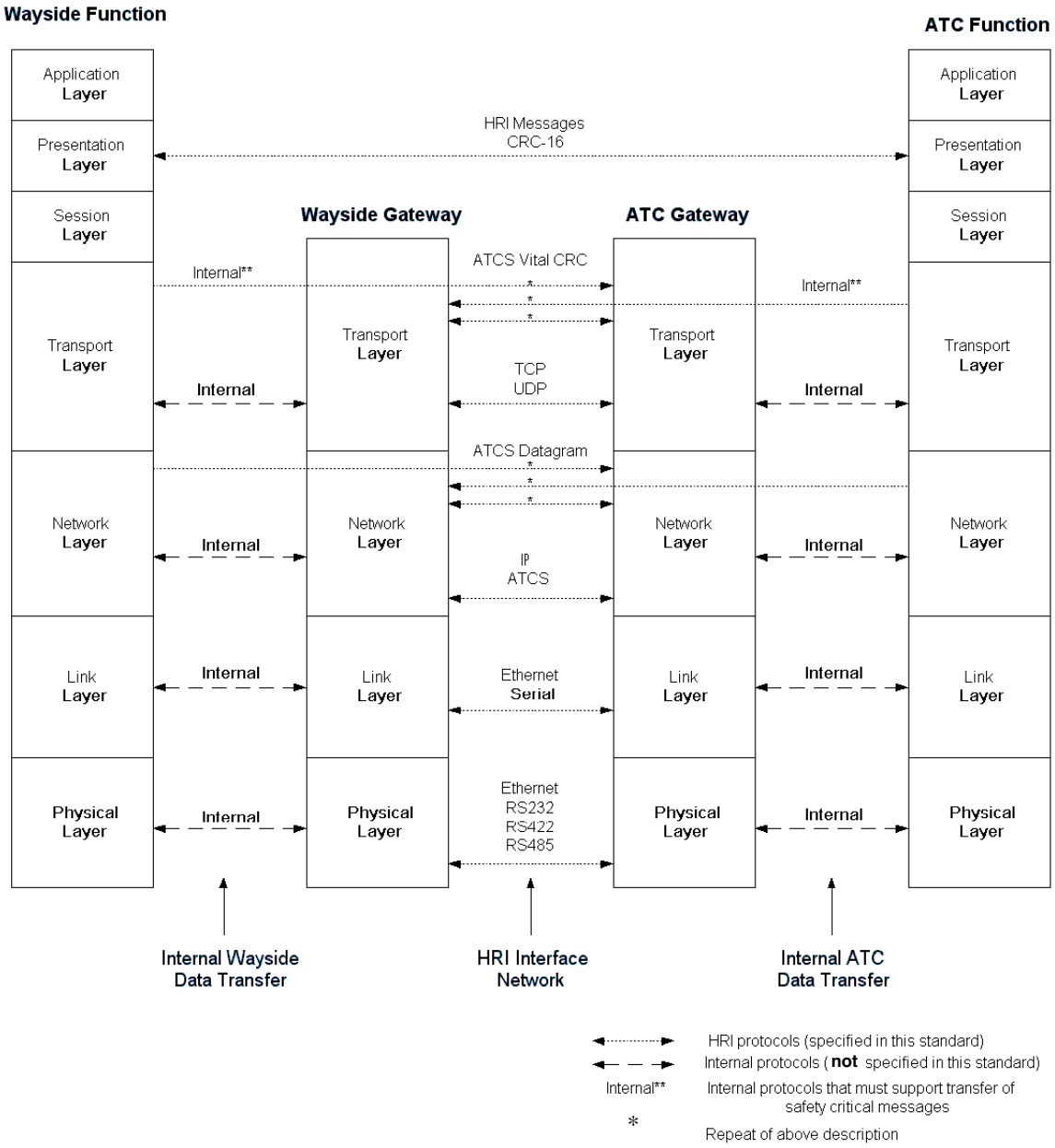

Figure 1—HRI interface architecture model

4.3 HRI interface protocol specifications

4.3.1 Layer 7: application layer

There are no specified layer 7 HRI interface protocol requirements.

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4.3.2 Layer 6: presentation layer

The presentation layer of the HRI interface involves the transfer of HRI messages between wayside and ATC processing functions. Specification of the content and format of the HRI messages exchanged over the HRI interface can be found in Clause 5.

4.3.2.1 Description

Each HRI message description contained in Clause 5 consists of three components; the HRI message header information (message length and a time stamp), the HRI message data, and a CRC-16 used to verify end-to-end data transfer of HRI messages between their source and destinations.

Normally, a CRC-16 check would be considered part of the transport layer in an ideal OSI architecture model. The non-vital CRC-16 specified in this standard has been moved to the presentation layer to clearly differentiate this non-vital CRC from the additional vital CRC that is applied to vital HRI messages at the transport layer (see 4.3.4.2.2.1). In most implementation situations, the processing that produces the HRI message will likely be separate (both functionally and physically) from the vital CRC processing.

4.3.2.2 Specified protocol

4.3.2.2.1 CRC-16

The data in every HRI message shall be protected via the 16-bit cyclic redundancy check (CRC). This 16-bit CRC is transmitted most significant bit (first) to least significant bit (last) and is calculated according to the following polynomial:

$$G(x) = x^{16} + x^{12} + x^5 + 1$$

The calculation is described in paragraph 3.6 of ISO 3309-1993(E). The CRC is calculated on all fields from the message length through the last byte of the message data (see Figure 5).

NOTE—This type of CRC is commonly used in data communications systems to detect transmission errors. When received by the destination function, the CRC is recalculated based on the received data and compared to the received CRC to verify the integrity of the received message. This level of CRC protection is considered to be “non-vital” in the sense that it is not used to vitally detect errors in the transfer of safety-critical data.

4.3.3 Layer 5: session layer

There are no specified layer 5 HRI interface protocol requirements.

4.3.4 Layer 4: transport layer

4.3.4.1 Description

The purpose of the HRI interface transport layer protocol is to insure the integrity of the HRI message after it has been transferred across the HRI interface. Of particular importance, the HRI interface transport layer is responsible for the verification of safety-critical HRI messages. This requirement to verify safety-critical message transfers coupled with the requirement to maintain the independence of the wayside and ATC systems forces a somewhat non-standard layer 4 protocol architecture, as was illustrated in Figure 1.

Message transfer across the HRI interface is based on the premise that the wayside and ATC sides of the HRI interface are independent systems with little or no knowledge of the internal architecture, networks, or addressing schemes used on the other side of the HRI interface. The realities associated with implementing a data interface between two such independent systems dictate that the interface protocols must have minimal

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impact upon existing architectures yet still meet the requirements for data transfer and verification across the HRI interface. As a consequence of this desire to minimize impact on existing wayside and ATC systems, the transport layer protocols shall consist of two distinct levels:

— *Upper level:* The upper-level transport layer is responsible for ensuring the data integrity of the transfer of vital HRI messages between their vital source and vital destination. This upper-level transport layer performs data verification checks for safety-critical HRI messages. Non-vital messages do not require this upper-level transport layer protection as non-vital CRC protection of the HRI message is performed at the presentation layer.
— *Lower (local) level:* The local level transport layer is responsible for ensuring the data integrity of an HRI message as it is transferred across a single physical interface. Safety-critical verification checks are not performed at this level.

4.3.4.2 Upper-level transport layer protocols

4.3.4.2.1 Description

HRI messages typically originate, and are consumed, in wayside or ATC functions. The ultimate destinations for all wayside-generated HRI messages are ATC functions and vice versa. However, addressing an HRI message directly to its ultimate destination would require system-wide addressing knowledge to be available in all wayside and ATC functions that generate or receive HRI messages. The realities of implementation suggest that this level of information sharing between systems will not be practical to obtain and/or coordinate. Consequently, HRI message transfer from vital source to vital destination will occur in two separate transport layer data transfers; external transfer between the vital source and the gateway on the other side of the HRI interface and then internal transfer from the receiving gateway to the ultimate destination function.

In this dual-step transfer scheme, message source functions need only know the address of the destination wayside or ATC gateways. In addition, wayside and ATC gateways require only routing information for their respective internal systems to transfer an inbound HRI message to its ultimate destination.

In addition to limiting the amount of system wide information required in the wayside and ATC systems, this dual-transfer process provides for a single processing point for safety-critical message verification. By utilizing the local gateways as the destination for all external upper-level layer 4 transfers, the safety-critical verification algorithms can be performed in one location rather than be dispersed amongst the various destination wayside and ATC functions. Based upon message labels, the initial gateways will have the capability to route the message to the appropriate function independently of the interface protocol. When using this capability, it is necessary for the system designer to maintain the required level of safety through message transfer in this independent network.

This standard does provide for a second option as to the upper-level transport layer source of HRI messages. Normally, the source of an HRI message generated in the ATC system is an ATC function. Being the HRI message source, the ATC function would need to be cognizant of the address of the destination wayside gateway per the previously described dual-step transfer process. If it is desired to completely insulate the source ATC function from having any information at all about the wayside systems, the ATC gateway can be used as a virtual source of the HRI message for external transfer of outbound HRI messages.

Virtual sourcing of an HRI message is accomplished by transferring the HRI message from the initial source ATC function to the ATC gateway via an internal upper-level transport layer protocol. This internal transport layer protocol is not specified in this standard and is left to the system designer to implement, but it must provide sufficient error detection capability to support the transfer of safety-critical information. Once the HRI message has been transferred to the ATC gateway, the gateway can then act as the virtual source for the outbound (external) HRI message transfer per the upper-level layer 4 protocols. In this manner, all wayside system information required in the ATC system can be contained within the ATC gateway.

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In a similar manner, the wayside gateway can act as the upper-level transport layer virtual source for wayside generated HRI messages.

It is left up to the system designer to select and implement the appropriate HRI message source options (function or gateway).

An overview of the layer 4 upper-level HRI message source and destination pairs is illustrated below in Figure 2. This illustration provides the same information provided in Figure 1, but with each of the potential source and destination pairs broken out separately.

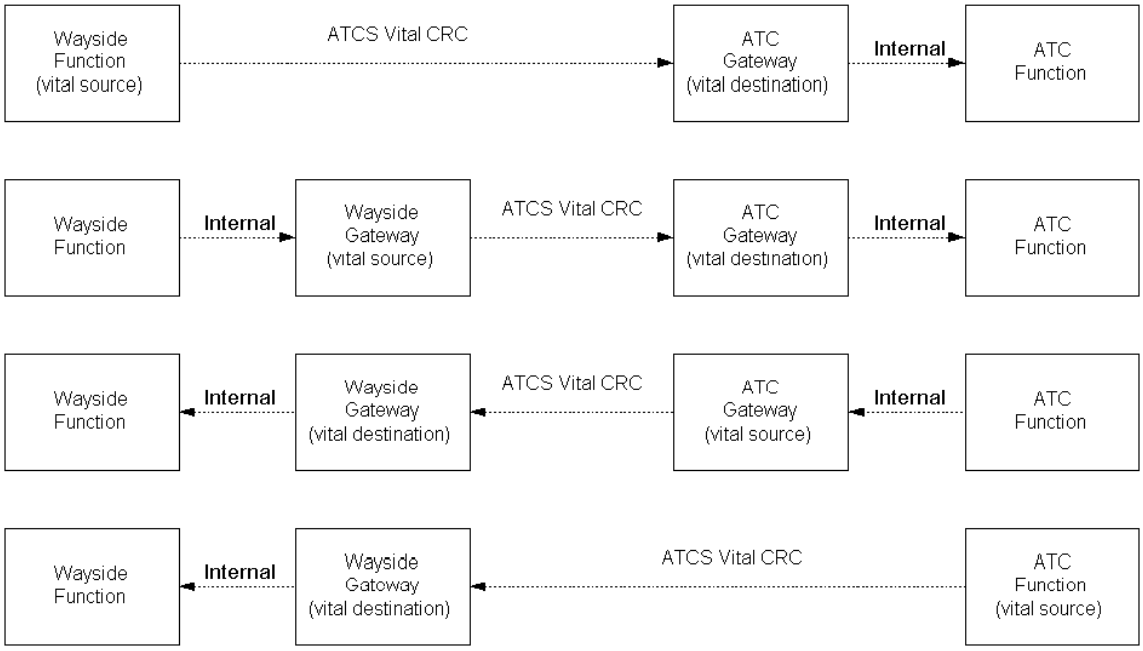

Figure 2—Layer 4 upper-level HRI message source and destination pairs

4.3.4.2.2 Specified protocol

The upper-level transport layer protocol verifies end-to-end data transfer of safety-critical (vital) HRI messages between the source and the gateway destination for external message transfers.

NOTE—Safety-critical messages will contain both the CRC-16 required of all HRI messages in addition to the ATCS vital CRC. While recognizing that this provides redundant levels of error detection protection for safety-critical messages, this approach should simplify implementation of these CRC functions. In most cases, the processing that produces the HRI message will be separate from the vital CRC processing. Consequently, forcing the generation of the CRC-16 for all messages produces a single CRC-16 processing thread for all HRI messages. The ATCS vital CRC can be added further down the processing string when appropriate.

4.3.4.2.2.1 ATCS vital CRC

All safety-critical HRI messages shall be protected via the safety-critical CRC-32 as specified in ATCS specification 200. The CRC-32 polynomial is specified in Annex D of ATCS Specification 200 under “Definition of the Transport Layer Vital Redundancy Check Code.” A commentary on calculation methods for this check are located in Annex Y of ATCS Specification 200.

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The calculation of the ATCS CRC covers byte 4 (source and destination address length) through byte {28 + N}, the last byte of application data (see Figure A.1).

NOTE—Verification of safety-critical data following transmission is a fundamental requirement of the HRI interface. The ATCS vital CRC algorithms have been successfully utilized in the railroad industry for many years to detect errors in safety-critical data transmitted over the data networks used in railroad control systems. These algorithms provide the quantitative verification required to insure vital detection of data transmission errors in safety-critical control functions. The specifications for these algorithms are contained in ATCS Specification 200.

4.3.4.3 Lower-level transport layer protocols

4.3.4.3.1 Description

The lower-level transport layer protocols provide end-to-end data transfer verification across the HRI physical interface. These lower-level protocols do not provide verification for safety-critical HRI messages.

Lower-level transport layer protocols are specified only for the wayside gateway–ATC gateway physical interface. The other two lower-level layer 4 interfaces shown in Figure 1—the wayside function–wayside gateway interface and the ATC gateway–ATC function interface—are considered to be internal to the wayside and ATC systems, respectively. Consequently, no HRI interface protocol requirements are specified for these internal interfaces other than they shall support the successful transfer of data between the devices. The selection and implementation of the data transfer protocols for these internal lower-level layer 4 interfaces are left up to the system designer/equipment manufacturer.

4.3.4.3.2 Specified protocols

There is no requirement to utilize a lower-level transport layer protocol across the wayside gateway–ATC gateway physical interface. If the system designer chooses, no transport layer protocol need be implemented.

If a lower-level transport layer protocol is to be implemented across the wayside gateway–ATC gateway physical interface, two lower-level transport layer protocols are specified for use; transmission control protocol (TCP) and user datagram protocol (UDP).

4.3.4.3.2.1 Null protocol

The system designer shall have the option to choose to not implement a lower-level transport layer protocol across the wayside gateway–ATC gateway physical interface.

4.3.4.3.2.2 TCP

The system designer shall have the option to choose to implement the TCP protocol as the lower-level transport layer protocol across the wayside gateway–ATC gateway physical interface.

NOTE—TCP is generally used in conjunction with the IP protocol (at the network layer) to provide transport layer data transfer functions. The specifications for this protocol are readily available to the public (see RFC 793:1981) and conform to the NTCIP Standards Framework developed as part of the National ITS Architecture.

TCP port number 3439 shall be used for all TCP-based HRI data communications.

4.3.4.3.2.3 UDP

The system designer shall have the option to choose to implement the UDP protocol as the lower-level transport layer protocol across the wayside gateway–ATC gateway physical interface.

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NOTE—The UDP protocol is another standard transport layer protocol that is typically used in conjunction with the IP protocol. The specifications for this protocol are readily available to the public (see RFC 768:1980) and conform to the NTCIP Standards Framework developed as part of the National ITS Architecture.

UDP port number 3439 shall be used for all UDP-based HRI data communications.

4.3.5 Layer 3: network layer

4.3.5.1 Description

The network layer is responsible for providing the addressing scheme necessary for routing HRI messages from their source to their destination. Specification of a single network layer protocol across all entities in the HRI interface architecture is not feasible due to the independent nature of the wayside and ATC systems. Consequently, a dual-level network layer architecture (like that specified for the transport layer), with the upper level governing external HRI message transfers and the lower-level governing transfers across the HRI physical interface, is specified.

The upper level in this dual-network level architecture provides a standard addressing scheme that is compatible with the upper-level transport layer protocols described in 4.3.4. In an ideal OSI-based layered protocol architecture, the individual protocol layers are independent of one another. However, the use of the ATCS vital CRC protocol in the upper-level transport layer protocol requires the use of the ATCS source and destination networking addressing scheme at the upper-level network layer. This interdependence drives the selection of the ATCS network datagram for use as the upper-level network layer protocol.

Like the upper-level transport layer protocol, the upper-level network layer protocol is used only for external transfer of HRI messages. Internal transfer of HRI messages within the wayside and ATC systems or transfer across the HRI physical interface require a lower (local) level of addressing to enable the transport of the HRI message. From an implementation standpoint, the upper-level addressing is "wrapped" inside local network datagrams, which utilize a second level of local addresses, for transport across these internal interfaces and across the HRI physical interface.

4.3.5.2 Upper-level network layer protocol

4.3.5.2.1 Description

The upper-level network layer protocol provides the addressing scheme necessary to route an HRI message from its source to its destination. The HRI message source and destination definitions are the same as those used in the upper-level transport layer protocol discussion (see 4.3.4.2.1).

In addition, the upper-level network layer protocol supports the ATCS vital CRC protocol used in the upper-level transport level protocol.

4.3.5.2.2 Specified protocol

4.3.5.2.2.1 ATCS network datagram

The ATCS network layer datagram (ATCS Specification 200) packet shall be utilized as the upper-level network layer protocol in the HRI interface architecture.

Each individual ATCS datagram shall be "framed" by a 6-byte framing header, as shown in Figure 3.

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NOTES

1—The addition of this 6-byte framing header provides the means to parse individual ATCS datagrams from a received data stream that may contain more than one ATCS datagram in a single “read” operation. This situation can be encountered when streaming protocols such as TCP or serial are employed.

2—The message length field includes the 2 message length bytes.

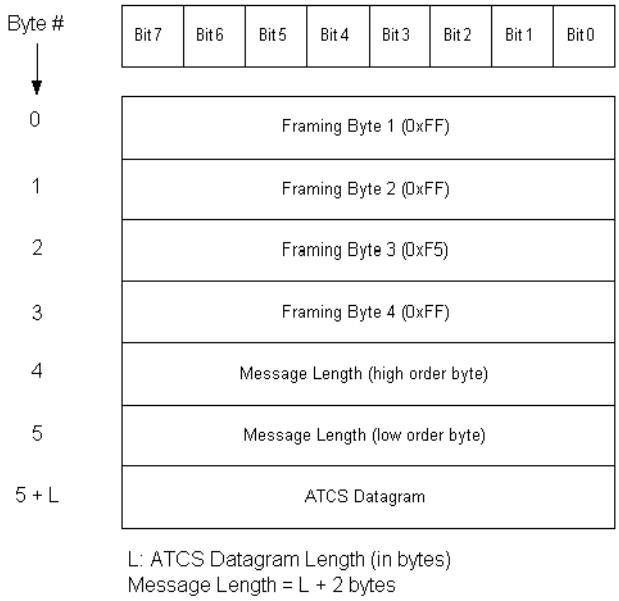

Figure 3—ATCS datagram framing header

4.3.5.2.3 Addressing scheme

The ATCS datagram addressing scheme and packet format was chosen because of its widely accepted use as a recognized standard in the railroad industry and contains all the information fields necessary to facilitate routing across the defined HRI interface architecture. The ATCS datagram also supports the use of the ATCS vital CRC data verification algorithms. The choice of the ATCS network addressing scheme has little impact on existing wayside equipment as this protocol is already in general use within railroad systems. The impact on roadway systems, which do not currently utilize the ATCS protocol, is limited by utilizing the ATCS addressing protocol only in support of external message transfers. The lower (local) level network protocols that may be in use within ATC equipment will not be impacted by the use of the ATCS network protocol at the upper level.

The ATCS network datagram format is specified in ATCS Specification 200. For informational purposes, an overview of the ATCS network datagram and its data fields are provided in Annex A. If any discrepancies exist in the information contained in Annex A and ATCS Specification 200, then ATCS Specification 200 will govern.

The ATCS network addressing scheme is based on the use of the 14-digit binary coded decimal (BCD) addressing scheme illustrated in Figure 4.

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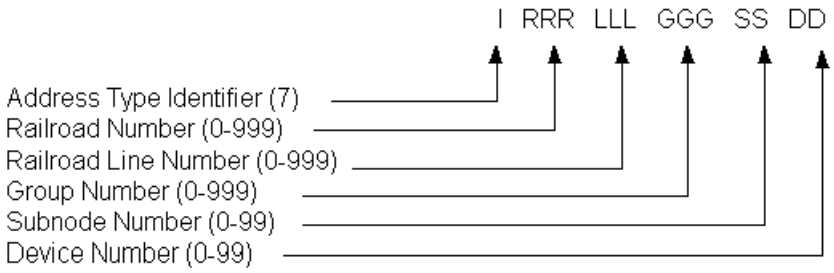

Figure 4—ATCS network addressing scheme

The address type identifier used in all HRI messages shall be "7." The remaining fields in the 7RRRLLLGGGSSDD address are:

— *RRR:* a 3-digit code representing the railroad.
— *LLL:* a 3-digit code representing the railroad line.
— *GGG:* a 3-digit code representing a physical group of equipment (typically at one location).
— *SS:* a 2-digit code for each subnode within a physical group of equipment.
— *DD:* a 2-digit code for each device within a subnode.

A unique railroad number (RRR) is assigned and maintained by the Association of American Railroads (AAR) for each railroad company. This railroad number is used in the address of each wayside control devices operated along the railroad operated by the railroad company. In addition to the existing set of assigned railroad numbers, the AAR has assigned the following railroad numbers specifically for HRI use:

— *Railroad number 051:* Used to identify all ATC devices communicating across an HRI interface.
— *Railroad number 052:* Used by wayside devices communicating across an HRI interface to identify non-ATCS-assigned railroads such as light rail or transit systems.

The LLL/GGG IDs are used to uniquely identify a group of wayside equipment components such as a wayside equipment terminator. The SS/DD IDs uniquely identify devices within the wayside equipment group.

The LLL, GGG, SS, and DD IDs for wayside equipment are assigned and controlled by the railroad company. The LLL/GGG ID used by the ATC devices will be the same address as assigned by the railroad or transit authority. If the ATC devices use the SS and DD IDs for their internal use, they are assigned and controlled by the local highway controlling authority.

NOTES

1—The local highway controlling authorities must insure that all ATC devices operating within an HRI interface network have unique addresses.

2—On non-ATCS controlled railroad properties (railroad number 052), identical addressing of wayside equipment is a possibility. The local railroad or transit authority must insure that all wayside devices operating within an HRI interface network have unique addresses.

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4.3.5.3 Lower-level network layer protocols

4.3.5.3.1 Description

The lower-level network layer protocol provides the means to route an HRI message across the HRI physical interface. Implementation of a lower-level network layer protocol is necessary only when there exists more than one wayside gateway and one ATC gateway within the HRI interface configuration (i.e. a network configuration).

Lower-level network layer protocols are specified only for the wayside gateway–ATC gateway physical interface. The other two lower-level network layer interfaces shown in Figure 1, the wayside function–wayside gateway interface and the ATC gateway–ATC function interface, are considered to be internal to the wayside and ATC systems, respectively. Consequently, no HRI interface protocol requirements are specified for these internal interfaces other than they shall support the successful transfer of data between the devices. The selection and implementation of the data transfer protocols for these internal lower-level network layer interfaces are left up to the system designer/equipment manufacturer.

NOTE—The use of a lower-level addressing scheme must be coordinated with the higher-level ATCS addresses (coordinated IP and ATCS addresses, for example). This will require a minimal amount of overall system administration of both the wayside and ATC systems.

4.3.5.3.2 Specified protocols

There is no requirement to utilize a lower-level network layer protocol across the wayside gateway–ATC gateway physical interface. If the system designer chooses, no network layer protocol need be implemented.

If a lower-level network layer protocol is to be implemented across the wayside gateway–ATC gateway physical interface, three lower-level network layer protocols are specified for use: internet protocol (IP) and ATCS.

4.3.5.3.2.1 Null protocol

The system designer shall have the option to choose to not implement a lower-level network layer protocol across the wayside gateway–ATC gateway physical interface.

NOTE—A null network protocol is suitable for use in serial communications.

4.3.5.3.2.2 IP

The system designer shall have the option to choose to implement the IP protocol as the lower-level network layer protocol across the wayside gateway–ATC gateway physical interface.

NOTE—The IP protocol is a common and widely used network layer protocol found in many data communications systems. The specifications for this protocol are readily available to the public (see RFC 791:1981) and conform to the NTCIP Standards Framework developed as part of the National ITS Architecture.

4.3.5.3.2.3 ATCS

The system designer shall have the option to choose to implement the ATCS protocol as the lower-level network layer protocol across the wayside gateway–ATC gateway physical interface.

NOTE—The upper-level network layer protocol can also be used as the lower-level network layer protocol across the wayside gateway–ATC gateway interface. The use of the ATCS network protocol (ATCS Specification 200) as the lower-level network layer protocol eliminates the need to utilize two protocol levels in the network layer–the upper-level ATCS datagram packet can be used as is without being “wrapped” in an additional lower-level network layer protocol.

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4.3.6 Layer 2 (data link layer) and layer 1 (physical layer)

4.3.6.1 Description

The link and physical layer protocols provide the physical infrastructure and bit transfer control across the HRI physical interface.

Link and physical layer protocols are specified only for the wayside gateway–ATC gateway interface. The other two link and physical layer interfaces shown in Figure 1, the wayside function–wayside gateway interface and the ATC gateway–ATC function interface, are considered to be internal to the wayside equipment terminator and advanced traffic controller, respectively. Consequently, no HRI interface protocol requirements are specified for these internal interfaces other than they support the successful transfer of data between the devices. The selection and implementation of the data transfer protocols for these internal link and physical interfaces are left up to the system designer/equipment manufacturer.

It is the responsibility of the system designer to select the appropriate link and physical layer protocols that are compatible with the one another and with the selected higher-level network protocols.

NOTE—The use of RF wireless modems is not precluded provided that the modems appear "transparent" to the HRI protocol stack. For example, many RF modems interface to devices via an RS-232 interface. From the perspective of the HRI protocol stack, communications are taking place across an RS-232 interface, not an RF link. The fact that RF transmission is indeed taking place is unknown to the communicating devices on either side of the HRI interface.

4.3.6.2 Specified protocols

4.3.6.2.1 Ethernet

The system designer shall have the option to choose to implement the ethernet protocol, per DEC, Version 2.0, as the link layer protocol across the wayside gateway–ATC gateway physical interface.

If IP is utilized at the network layer above an ethernet layer across the HRI interface, encapsulation of IP datagrams within the ethernet frame shall be in accordance with RFC 894:1984.

The system designer shall have the option to choose to implement the ethernet protocol on any recognized ethernet physical layer protocol across the wayside gateway–ATC gateway physical interface.

NOTES

1—The ethernet protocol is a very commonly used link layer protocol that is typically run on top of a 10/100BaseT physical layer transmission media. Ethernet conforms to the NTCIP Standards Framework developed as part of the National ITS Architecture. The standards for both the link layer (Ethernet II) and physical layer (IEEE 802.3) for Ethernet II are readily available to the public (see Clause 2).

2—The Ethernet II link layer protocol mentioned above is now specified in IEEE Std 802.3. Refer to 3.2.6.b.

4.3.6.2.2 Serial–RS232

The system designer shall have the option to choose to implement an RS232-compatible serial protocol as the link and physical layer protocols across the wayside gateway–ATC gateway physical interface.

NOTE—The RS232 serial interface protocol is a commonly used point-to-point protocol. The standards for RS232 are readily available to the public (see TIA/EIA-232-F-97). This interface protocol will only support point-to-point serial links. Consequently, this protocol is not applicable for network configurations.

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4.3.6.2.3 Serial–RS422

The system designer shall have the option to choose to implement an RS422-compatible serial protocol as the link and physical layer protocols across the wayside gateway–ATC gateway physical interface.

NOTE—The RS422 serial interface protocol is a commonly used point-to-point protocol. The standards for RS422 are readily available to the public (see TIA/EIA-422-B-94). This interface protocol will only support point-to-point serial links. Consequently, this protocol is not applicable for network configurations.

4.3.6.2.4 Serial–RS485

The system designer shall have the option to choose to implement an RS485-compatible serial protocol as the link and physical layer protocols across the wayside gateway–ATC gateway physical interface.

NOTE—The link and physical protocol layers that support the RS485 network layer protocol are similar to the RS422 protocols, but have been designed to support the multi-point interconnection capability afforded by an RS485 compatible network layer protocol. The standards for RS485 are readily available to the public (see TIA/EIA-485-A-98).

5. HRI messages

Table 1 lists the HRI messages defined for exchange over the HRI interface.

NOTE—HRI messages designated as safety-critical imply that all information contained in them and transferred across the HRI interface must be processed in a safety-critical manner.

Table 1—HRI messages

Message ID	Message name	Source	Destination	Safety-critical?
9.4.40	HRI Rail Crossing Operational State	Railroad System	Roadway System	Yes
9.4.41	HRI Approaching Train Information	Railroad System	Roadway System	No
9.1.41	HRI Approaching Train Information Request	Roadway System	Railroad System	No
9.4.42	HRI Wayside Equipment Status	Railroad System	Roadway System	No
9.1.42	HRI Wayside Equipment Status Request	Roadway System	Railroad System	No
9.4.43	HRI Roadway Obstacle Detection State	Roadway System	Railroad System	Yes
9.4.44	HRI ATC Equipment Status	Roadway System	Railroad System	No
9.1.44	HRI ATC Equipment Status Request	Railroad System	Roadway System	No
9.4.45	HRI User-Specific Wayside Message	Railroad System	Roadway System	No
9.1.45	HRI User-Specific Wayside Message Request	Roadway System	Railroad System	No
9.4.46	HRI User-Specific ATC Message	Roadway System	Railroad System	No
9.1.46	HRI User-Specific ATC Message Request	Railroad System	Roadway System	No

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The standard data format used by each HRI message is shown in Figure 5. A description of each data field in the HRI message standard data format is provided in Table 2.

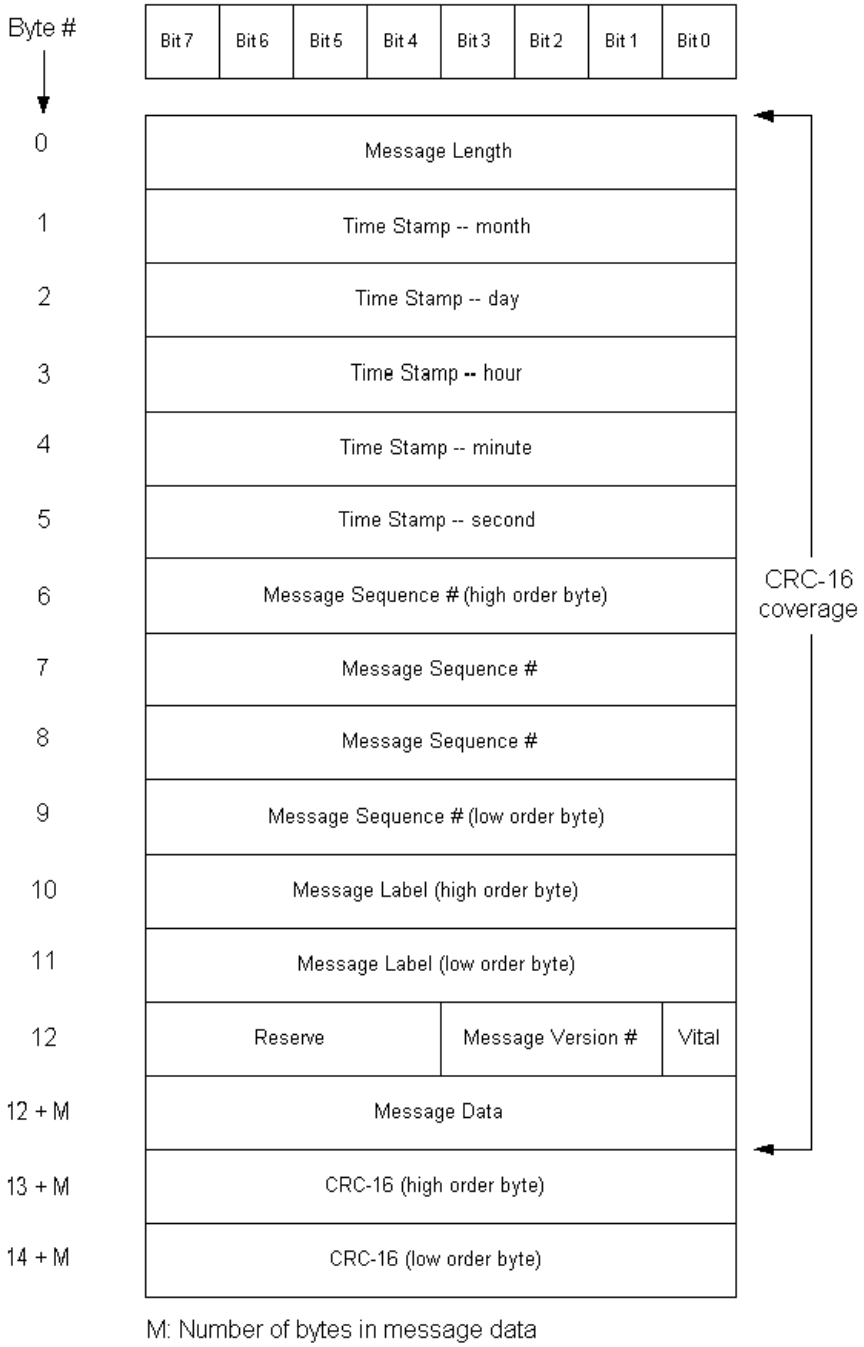

Figure 5—HRI message data format

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Table 2—HRI message data field descriptions

Byte location	Field name	Field description	Note
0	*Message Length*	*Total length of the HRI message packet, including the message length byte (15 + M bytes)*	*Max length=127 bytes*
1	*Time Stamp–month*	*Month (1–12)*	*UTC*
2	*Time Stamp–day*	*Day (1–31)*	*UTC*
3	*Time Stamp–hour*	*Hour (0–24)*	*UTC*
4	*Time Stamp–minute*	*Minute (0–59)*	*UTC*
5	*Time Stamp–second*	*Second (0–59)*	*UTC*
6–9	*Message Sequence Number*	*Incremental sequence number for each message. Four bytes are used to conform to standard practice within the railroad industry of using a 4-byte sequence number for safety-critical applications. Using a 4-byte sequence number reduces the probability of receiving a "stale" (e.g., unflushed buffers at startup) message being accepted as legitimate to 1 in 2^{32}.* *NOTE—Additional steps must be taken to insure rejection of stale messages at processor startup (e.g., sequence number being reset to 0 at processor startup) such as flushing the first received vital messages from a vital source.*	*Unique sequence numbers for each different HRI message.*
10–11	*Message Label*	*ATCS Message Label*	
12	*Vital*	*Vital (i.e., Safety-Critical) Message* *0=Non-vital* *1=Vital*	*Set to 0 (non-vital Message)*
12	*Message Version Number*	*HRI Message Version Number (1–8)*	*Used for message version control. See message attributes for current value.*
12	*Reserve*	*Not used*	*Not used, set to 0*
13–(13 + M)	*Message Data*	*HRI Message Data (M bytes in length)*	*Max length=112 bytes*
(14 + M)	CRC-16	16-bit CRC. Covers all bytes in the message packet prior to the CRC field. $G(x) = x^{16} + x^{12} + x^5 + 1$	Calculated for all messages, vital, and non-vital

NOTES
1—The rows which contain *italic text* in this table identify the area covered by the CRC-16.
2—Byte locations 0 through 9 constitute the HRI header information identified in the examples in Annex B.

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5.1 HRI rail crossing operational state (9.4.40)

The description and attributes of this message are provided in Table 3. The data format for this message is shown in Figure 6. The descriptions for each data field in this message are provided in Table 4.

Table 3—HRI rail crossing operational state message attributes

Name:	HRI rail crossing operational state
Message number:	9.4.40
Message label:	4904
Message version:	1
Message type:	Safety-critical (vital)
Source:	Wayside device
Destination:	ATC device
Priority:	1
Transmission rate:	Once per second
Max message length:	1 packet
Packet length:	Variable, minimum of 5 bytes (1 crossing, 0 trains), maximum of 112 bytes
Purpose:	Provide safety-critical railway crossing status information to the roadway system
NOTES:	

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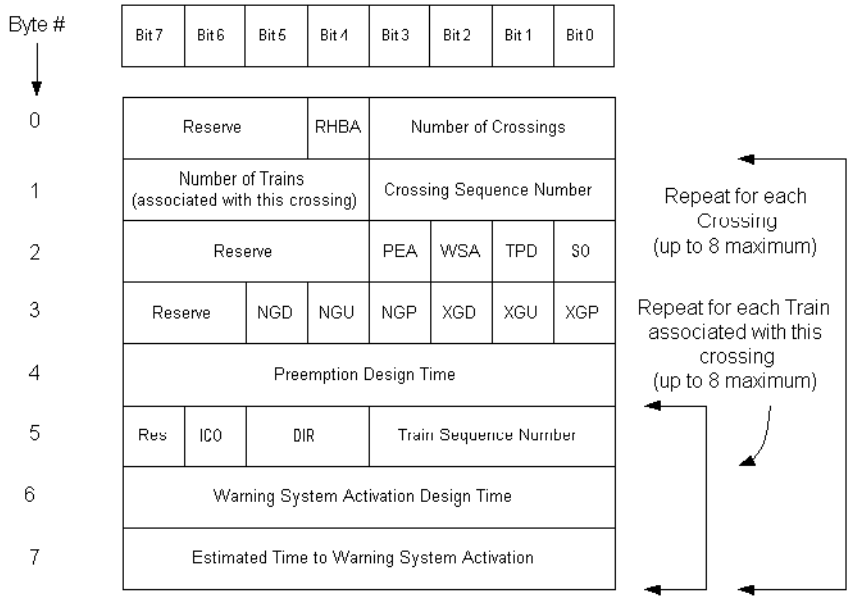

NOTE 1—The overall message length is dependent upon the number of crossings and the number of trains associated with each crossing. Although a maximum of up to 8 crossings and 8 trains per crossing can be specified, the maximum number of trains cannot be specified for the maximum number of crossings as the total message length would exceed 112 bytes, the maximum message length allowed for the data in an HRI message. The user must insure that the overall data message length does not exceed 112 bytes.

NOTE 2—This information is the “Application Data” as seen in the examples in Annex B.

Figure 6—HRI rail crossing operational state message data format

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Table 4—HRI rail crossing operational state message field descriptions

Byte location	Field name	Field description	NOTE
0	Number of Crossings	Total number of crossings (1–8). NOTE—A crossing is defined as the intersection of a roadway and from1 to 8 tracks that is controlled by an independent warning system.	Minimum of 1 crossing, maximum of 8 crossings.
0	RHBA	Receiving vital heartbeat message (Message 9.4.43) from the ATC system. 0=Not Receiving Message 9.4.43 1=Receiving Message 9.4.43	The definition of receiving or not receiving the message is determined locally (e.g., receive OK if received a 9.4.43 message within the last 3 seconds).
0	Reserved	Not used.	Not used, set to 0.
1	Crossing Sequence Number	HRI interface specific internal ID number assigned for each crossing.	1–8
1	Number of Trains associated with this crossing.	Total number of trains associated with this crossing (0–8).	Minimum of 0 trains, maximum of 8 trains.
2	SO	System operational 0=System not operational 1=System operational	Overall health check showing RR system operational.
2	TPD	Train presence detection 0=No train present 1=Train present The “OR” of train detection for all trains on all tracks that will intersect the crossing.	A train has been detected either on approach or island (not necessary for motion to be detected yet).
2	WSA	Warning system active 0=Not activated 1=activated	See Clause 3 (Definitions).
2	PEA	Preemption warning active 0=Not active 1=Active	See Clause 3 (Definitions).
2	Reserved	Not used.	Not used, set to 0.
3	XGP	Exit gate(s) present 0=Exit gate(s) not present 1=Exit gate(s) present The “AND” of all gates at the crossing.	See Clause 3 (Definitions).
3	XGU	Exit gate(s) up 0=Exit gate(s) not up 1=Exit gate(s) up The “AND” of all gates at the crossing.	See Clause 3 (Definitions).
3	XGD	Exit gate(s) down 0=Exit gate(s) not down 1=Exit gate(s) down The “AND” of all gates at the crossing.	See Clause 3 (Definitions).

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Table 4—HRI rail crossing operational state message field descriptions (continued)

Byte location	Field name	Field description	NOTE
3	NGP	Entrance gate(s) present 0=Entrance gate(s) not present 1=Entrance gate(s) present The "AND" of all gates at the crossing.	See Clause 3 (Definitions).
3	NGU	Entrance gate(s) up 0=Entrance gate(s) not up 1=Entrance gate(s) up The "AND" of all gates at the crossing.	See Clause 3 (Definitions).
3	NGD	Entrance gate(s) down 0=Entrance gate(s) not down 1=Entrance gate(s) down The "AND" of all gates at the crossing.	See Clause 3 (Definitions).
3	Reserved	Not used.	Not used, set to 0.
4	Preemption Design Time	Design time for the preemption system.	LSB = 1 second (0–255 seconds).
5	Train Sequence Number	HRI interface specific internal ID number assigned for each train associated with this crossing.	0–8, 0 is no train approaching, 1–8 are assigned sequentially.
5	DIR	Direction 0=Heading East/North* 1=Heading West/South* 2=Unknown	Needed for second train warning. Direction (E or W) will be defined on RR track plans.
5	ICO	Island occupied 0=Island circuit unoccupied 1=Island circuit occupied	See Clause 3 (Definitions).
5	Reserved	Not used.	Not used, set to 0.
6	Warning System Activation Design Time	Design time for the warning activation system.	LSB=1 second (0–254 seconds). This is the design time for the number of seconds that the warning system will be active prior to the train arriving at the crossing.
7	Estimated Time to Warning System Activation	Seconds to warning system activation. This parameter is an estimate based on data processed by safety-critical equipment designed for this function (see AREMA Signal and Communications Manual [B1]). Its value can increase, decrease, or remain constant as a function of time. NOTE—Estimated Time to Arrival=Design Time for Warning System Activation + Time to Warning System Activation. Only valid prior to warning system activation.	LSB=1 second (0–255 seconds) A value of 255 means an unknown warning time, which may be used when the train has been detected but the Estimate Time to Warning System Activation has not yet been determined with sufficient accuracy. A value of 254 means 254 seconds or longer.

* East/North and West/South designations do not imply geographical orientation, but refer to the directional designation for the track.

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5.2 HRI approaching train information (9.4.41)

The description and attributes of this message are provided in Table 5. The data format for this message is shown in Figure 7. The descriptions for each data field in this message are provided in Table 6.

Table 5—HRI approaching train information message attributes

Name:	HRI approaching train information
Message number:	9.4.41
Message label:	4905
Message version:	1
Message type:	Informational (non-vital)
Source:	Wayside device
Destination:	ATC device
Priority:	1
Transmission rate:	First transmission when train is 5 minutes from the crossing, once per 15 seconds thereafter until train enters the crossing, or per request.
Max message length:	1 packet
Packet length:	10 bytes
Purpose:	Provide train time of arrival estimates to the roadway system.
NOTES:	An individual message is generated for each train currently present. The intent of this message is to provide advance informative information for use in highway traffic planning. This information is considered non-safety-critical as it is subject to substantial variation as the train approaches the crossing. This message is intended for use in potential future systems, as much of the information is not available from systems existing at the time of publication of this standard. Message transfers between the control centers can also provide similar information. Train IDs will be generated locally and do not necessarily relate to train IDs contained on the actual train. If this message is generated per receipt of a request message and no train is present, the train ID will be set to 0.

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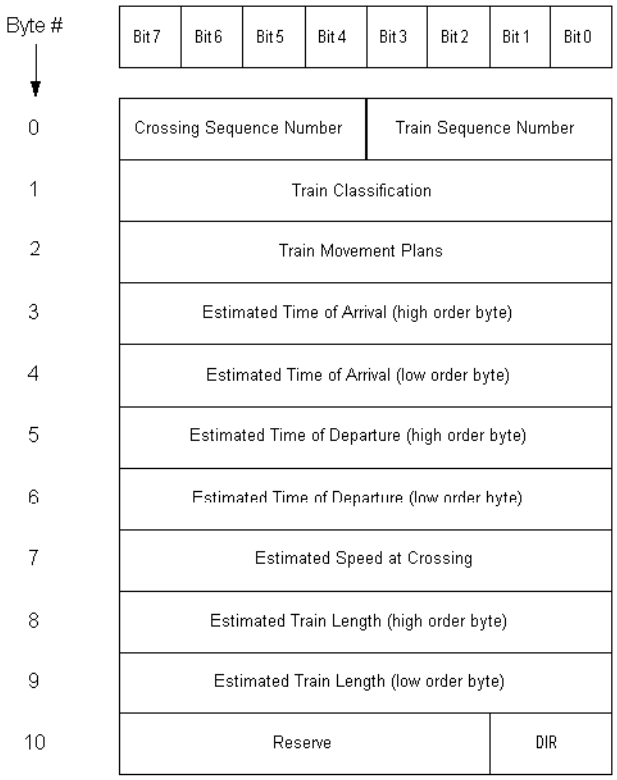

Figure 7—HRI approaching train information message data format

Table 6—HRI approaching train information message field descriptions

Byte location	Field name	Field description	NOTE
0	Train Sequence Number	HRI interface specific internal ID number assigned for each train.	1–8 Set to 0 if message is generated per request and there is no train present.
0	Crossing Sequence Number	HRI interface specific internal ID number assigned for each crossing.	1–8
1	Train Classification	0: Unknown 1: Freight 2: Passenger 3: Light rail transit 4: Heavy rail transit 5: High-speed rail A (79 to 125 mph) 6: High-speed rail B (>125 mph) 7–255: Reserve	0–255

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Table 6—HRI approaching train information message field descriptions (continued)

Byte location	Field name	Field description	NOTE
2	Train Movement Plans	0: Unknown 1: Near-side station stop 2: Through move 3: Switching activity 4–255: Reserve	0–255
3–4	Estimated Time of Arrival	Estimated time until the approaching train reaches the HRI crossing.	LSB=1 second
5–6	Estimated Time of Departure	Estimated time until train clears the crossing.	LSB=1 second
7	Estimated Speed at Crossing	Estimated speed of the train at the HRI crossing in kph. Projected speed prior to crossing, actual speed at crossing.	LSB=1 kph
8–9	Estimated Train Length	Estimate of the train length in meters.	LSB=1 m
10	DIR	Train direction 0=Heading East/North* 1=Heading West/South* 2=unknown	Direction will be as defined on RR crossing location plans.
10	Reserve	Not used.	Not used, set to 0.

* East/North and West/South designations do not imply geographical orientation, but refer to the directional designation for the track

5.3 HRI approaching train information request (9.1.41)

The description and attributes of this message are provided in Table 7. The data format for this message is shown in Figure 8. The descriptions for each data field in this message are provided in Table 8.

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Table 7—HRI approaching train information request message attributes

Name:	HRI approaching train information request
Message number:	9.1.41
Message label:	4713
Message version:	1
Message type:	Query (non-vital)
Source:	ATC device
Destination:	Wayside device
Priority:	1
Transmission rate:	Determined by ATC device
Max message length:	1 packet
Packet length:	1 byte
Purpose:	Request the wayside device to send an HRI approaching train information message.
NOTES:	A single request message will result in an individual HRI approaching train information message (9.4.41) being returned for each Train ID currently present. This message is used by the highway subsystem to request an update on the train arrival information more often than the normal 15 second update rate defined for message 9.4.41.

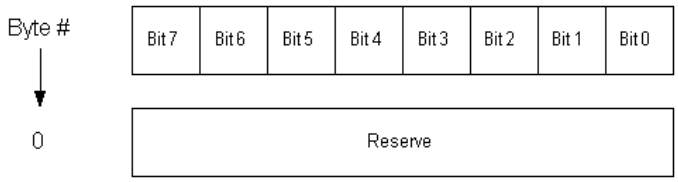

Figure 8—HRI approaching train information request message data format

Table 8—HRI approaching train information request message field descriptions

Byte location	Field name	Field description	NOTE
0	Reserve		

5.4 HRI wayside equipment status (9.4.42)

The description and attributes of this message are provided in Table 9. The data format for this message is shown in Figure 9. The descriptions for each data field in this message are provided in Table 10.

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Table 9—HRI RR wayside equipment status message attributes

Name:	HRI wayside equipment status
Message number:	9.4.42
Message label:	4906
Message version:	1
Message type:	Informational (non-vital)
Source:	Wayside device
Destination:	ATC device
Priority:	1
Transmission rate:	On request or when there has been a change in status.
Max message length:	1 packet
Packet length:	1 byte
Purpose:	Provide general status of the RR wayside equipment at the HRI to the roadway system.
NOTES:	Message information content and format is reserved for future use. Potential uses include information on broken gate arms, etc., operating on standby power, etc.

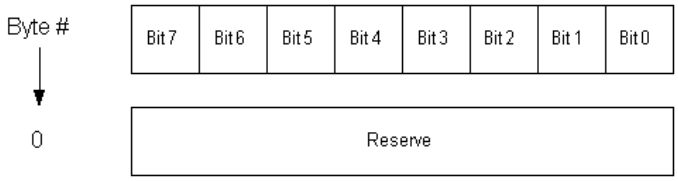

Figure 9—HRI wayside equipment status message data format

Table 10—HRI wayside equipment status message field descriptions

Byte location	Field name	Field description	NOTE
0	Reserve		

5.5 HRI wayside equipment status request (9.1.42)

The description and attributes of this message are provided in Table 11. The data format for this message is shown in Figure 10. The descriptions for each data field in this message are provided in Table 12.

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Table 11—HRI wayside equipment status request message attributes

Name:	HRI wayside equipment status request
Message number:	9.1.42
Message label:	4714
Message version:	1
Message type:	Query (non-vital)
Source:	ATC device
Destination:	Wayside device
Priority:	1
Transmission rate:	Determined by ATC device.
Max message length:	1 packet
Packet length:	1 byte
Purpose:	Request the wayside device to send an HRI wayside equipment status message.
NOTES:	

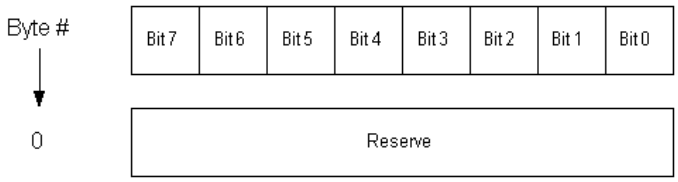

Figure 10—HRI wayside equipment status request message data format

Table 12—HRI wayside equipment status request message field descriptions

Byte location	Field name	Field description	NOTE
0	Reserve		

5.6 HRI roadway obstacle detection state (9.4.43)

The description and attributes of this message are provided in Table 13. The data format for this message is shown in Figure 11. The descriptions for each data field in this message are provided in Table 14.

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Table 13—HRI roadway obstacle detection state message attributes

Name:	HRI roadway obstacle detection state
Message number:	9.4.43
Message label:	4907
Message version:	1
Message type:	Safety-critical (vital)
Source:	ATC device
Destination:	Wayside device
Priority:	1
Transmission rate:	Once per second
Max message length:	1 packet
Packet length:	3 bytes
Purpose:	Provide safety-critical railway crossing obstacle information to the railroad system.
NOTES:	It is not the intention of this standard to precisely define functionality of obstacle detection, but to provide a framework for transferring information. Specific functionality will be agreed to between the highway authority and the rail authority.

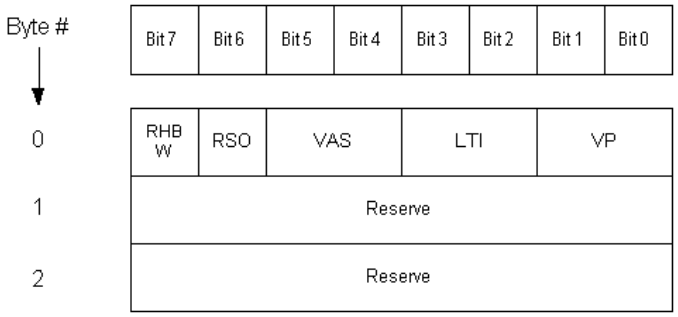

Figure 11—HRI roadway obstacle detection state message data format

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Table 14—HRI roadway obstacle detection state message field descriptions

Byte location	Field name	Field description	NOTE
0	VP	Vehicle present with gate down 0=No vehicle present 1=Vehicle present 2=Not implemented 3=Reserved	Specific functionality is not defined but the intent is to indicate when a highway vehicle is present on the island after the entrance gates have been lowered.
0	LTI	Long term obstacle indicator 0=No obstacle 1=Long term obstacle present 2=Not implemented 3=Reserved	Specific functionality is not defined, but the intent is to indicate when a highway vehicle has been occupying the island, as locally defined.
0	VAS	Vehicle arrestor barrier status 0=Vehicle arrestor barrier not ok 1=Vehicle arrestor barrier ok 2=Not implemented 3=Reserved	Specific functionality is not defined but the intent is to indicate if an external vehicle arrestor barrier is operational.
0	RSO	Roadway system operational 0=System not operational 1=System operational	The highway traffic subsystem is operational (e.g., traffic lights working correctly).
0	RHBW	Receiving vital heartbeat message (message 9.4.40) from the wayside system 0=Not receiving message 9.4.40 1=Receiving message 9.4.40	The definition of receiving or not receiving the message is determine locally (e.g., receive ok if received a 9.4.40 message within the last 3 seconds).
1	Reserve	Not used.	Not used, set to 0.
2	Reserve	Not used.	Not used, set to 0.

5.7 HRI ATC equipment status (9.4.44)

The description and attributes of this message are provided in Table 15. The data format for this message is shown in Figure 12. The descriptions for each data field in this message are provided in Table 16.

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Table 15—HRI ATC equipment status message attributes

Name:	HRI ATC equipment status
Message number:	9.4.44
Message label:	4908
Message version:	1
Message type:	Informational (non-vital)
Source:	ATC device
Destination:	Wayside device
Priority:	1
Transmission rate:	On request or when there has been a change in status.
Max message length:	1 packet
Packet length:	1 byte
Purpose:	Provide general status of the ATC equipment at the HRI to the railroad system.
NOTES:	Message information content and format is reserved for future use.

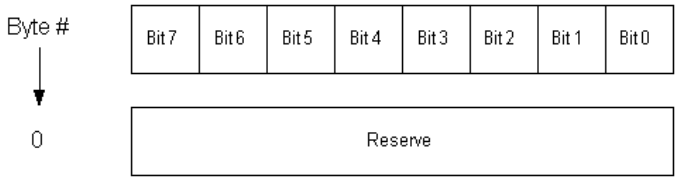

Figure 12—HRI ATC equipment status message data format

Table 16—HRI ATC equipment status message field descriptions

Byte location	Field name	Field description	NOTE
0	Reserve		

5.8 HRI ATC equipment status request (9.1.44)

The description and attributes of this message are provided in Table 17. The data format for this message is shown in Figure 13. The descriptions for each data field in this message are provided in Table 18.

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Table 17—HRI ATC equipment status request message attributes

Name:	HRI ATC equipment status request
Message number:	9.1.44
Message label:	4716
Message version:	1
Message type:	Query (non-vital)
Source:	Wayside device
Destination:	ATC device
Priority:	1
Transmission rate:	Determined by wayside device.
Max message length:	1 packet
Packet length:	1 byte
Purpose:	Request the ATC device to send an HRI ATC equipment status message.
NOTES:	

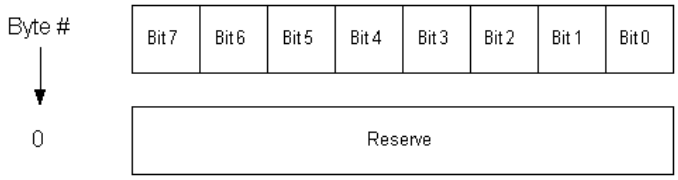

Figure 13—HRI ATC equipment status request message data format

Table 18—HRI ATC equipment status request message field descriptions

Byte location	Field name	Field description	NOTE
0	Reserve		

5.9 HRI user-specific wayside message (9.4.45)

The description and attributes of this message are provided in Table 19. The data format for this message is shown in Figure 14. The descriptions for each data field in this message are provided in Table 20.

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Table 19—HRI user-specific wayside message attributes

Name:	HRI user-specific wayside message
Message number:	9.4.45
Message label:	4909
Message version:	1
Message type:	Informational or safety-critical (implementation option)
Source:	Wayside device
Destination:	ATC device
Priority:	1
Transmission rate:	On request or on a periodic basis.
Max message length:	1 packet
Packet length:	Up to 112 bytes.
Purpose:	Provide a general purpose informational message to facilitate transmission of user-defined information from a wayside device to an ATC device.
NOTES:	Message information content and format is locally defined by the system administrator of the local HRI interface. A 2-byte user ID is provided to enable different manufacturers or system administrators to define unique sets of user-specific messages using this single message type. In these cases, internal message types, identifiers and other typical "header" information would be included within the user-defined data payload. This message type can be defined as either informational or safety-critical (vital) by the manufacturer or system administrator.

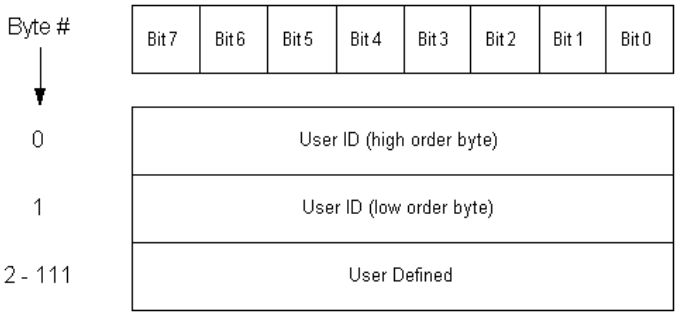

Figure 14—HRI user-specific wayside message data format

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Table 20—HRI user-specific wayside message field descriptions

Byte location	Field name	Field description	NOTE
0–1	User ID	User ID that uniquely defines user-defined message sets.	Assigned and controlled by the local HRI interface system administrator.
2–111	User-defined	Data content and format is defined by the local HRI interface system administrator.	Max message length of 110 bytes.

5.10 HRI user-specific wayside message request (9.1.45)

The description and attributes of this message are provided in Table 21. The data format for this message is shown in Figure 15. The descriptions for each data field in this message are provided in Table 22.

Table 21—HRI user-specific wayside message request attributes

Name:	HRI user-specific wayside message request
Message number:	9.1.45
Message label:	4717
Message version:	1
Message type:	Query
Source:	ATC device
Destination:	Wayside device
Priority:	1
Transmission rate:	Determined by ATC device (if request message required).
Max message length:	1 packet
Packet length:	1 byte
Purpose:	Request the wayside device to send an HRI user-specific wayside message.
NOTES:	

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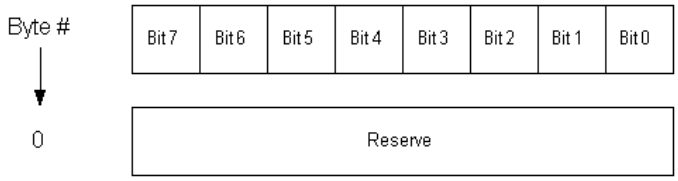

Figure 15—HRI user-specific wayside message request data format

Table 22—HRI user-specific wayside message request field descriptions

Byte location	Field name	Field description	NOTE
0	Reserve		

5.11 HRI user-specific ATC message (9.4.46)

The description and attributes of this message are provided in Table 23. The data format for this message is shown in Figure 16. The descriptions for each data field in this message are provided in Table 24.

Table 23—HRI user-specific ATC message attributes

Name:	HRI user-specific ATC message
Message number:	9.4.46
Message label:	4910
Message version:	1
Message type:	Informational or safety-critical (implementation option)
Source:	ATC device
Destination:	Wayside device
Priority:	1
Transmission rate:	On request or on a periodic basis.
Max message length:	1 packet
Packet length:	Up to 112 bytes.
Purpose:	Provide a general purpose informational message to facilitate transmission of user-defined information from an ATC device to a wayside device.
NOTES:	Message information content and format is locally defined by the system administrator of the local HRI interface. A 2-byte user ID is provided to enable different manufacturers or system administrators to define unique sets of user-specific messages using this single message type. In these cases, internal message types, identifiers and other typical "header" information would be included within the user-defined data payload. This message type can be defined as either informational or safety-critical (vital) by the manufacturer or system administrator.

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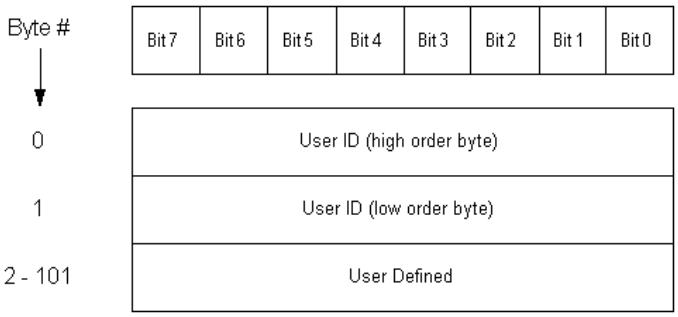

Figure 16—HRI user-specific ATC message data format

Table 24—HRI user-specific ATC message field descriptions

Byte location	Field name	Field description	NOTE
0–1	User ID	User ID that uniquely defines user-defined message sets.	Assigned and controlled by the local HRI interface system administrator.
2–111	User-defined	Data content and format is defined by the local HRI interface system administrator.	Max message length of 110 bytes.

5.12 HRI user-specific ATC message request (9.1.46)

The description and attributes of this message are provided in Table 25. The data format for this message is shown in Figure 17. The descriptions for each data field in this message are provided in Table 26.

Table 25—HRI user-specific ATC message request attributes

Name:	HRI user-specific ATC message request
Message number:	9.1.46
Message label:	4718
Message version:	1
Message type:	Query (non-vital)
Source:	Wayside device
Destination:	ATC device
Priority:	1
Transmission rate:	Determined by wayside device (if request message required).
Max message length:	1 packet
Packet length:	1 byte
Purpose:	Request the ATC device to send an HRI user-specific ATC message.
NOTES:	

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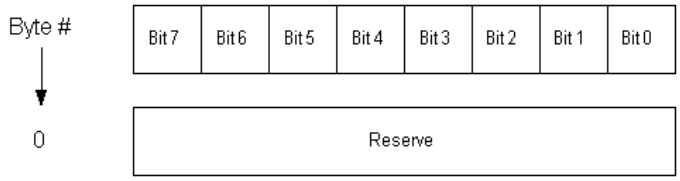

Figure 17—HRI user-specific ATC message request data format

Table 26—HRI user-specific ATC message request field descriptions

Byte location	Field name	Field description	NOTE
0	Reserve		

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Annex A

(informative)

ATCS datagram format

The ATCS network layer datagram format is provided in this annex for informational purposes only. If any discrepancies exist in the information contained in Annex A and ATCS Specification 200, ATCS Specification 200 will govern.

The data format for the ATCS network layer datagram is provided in Figure A.1. Many of the fields in the ATCS network layer datagram are not utilized in the HRI message network layer and are consequently set to a fixed value. The default ATCS network layer datagram used by the HRI message network layer (with non-used fields set to their fixed values) is provided in Figure A.2 and its associated data field descriptions are provided in Table A.1

NOTE—This example is illustrative and forms neither any part of this standard nor recommend specific implementations.

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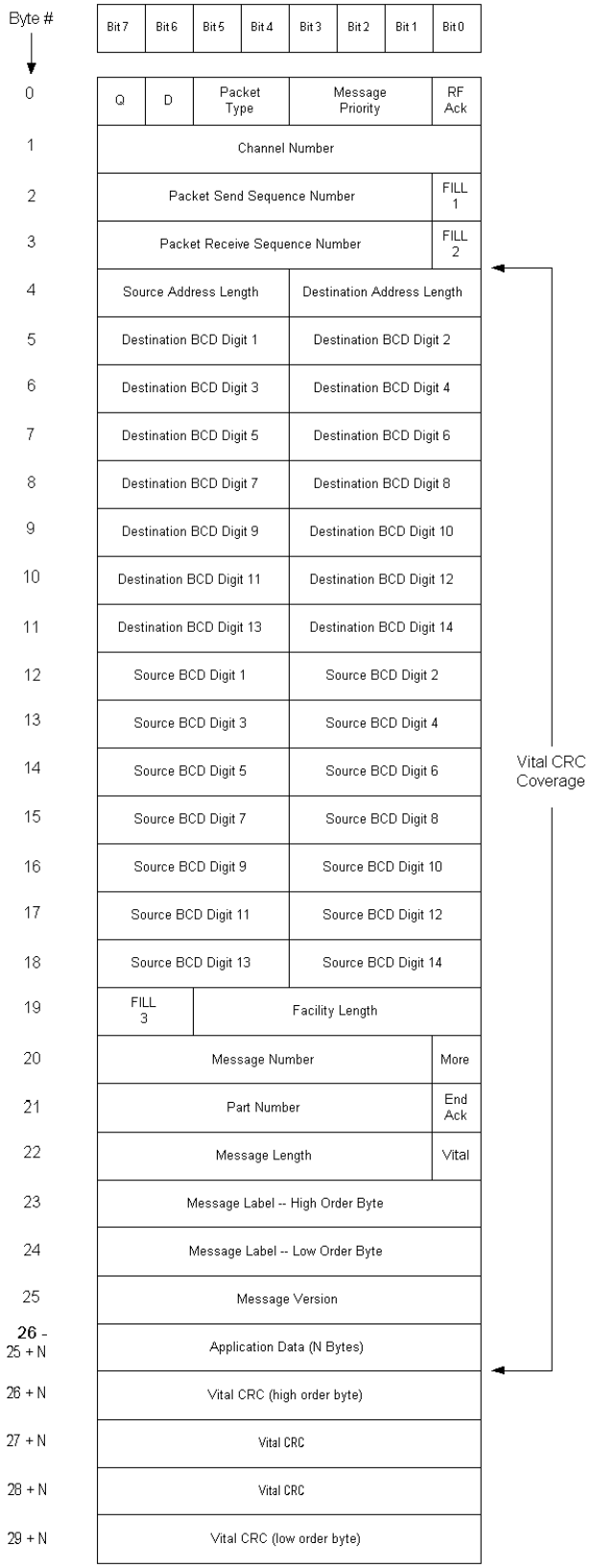

Figure A.1—ATCS network layer datagram data format

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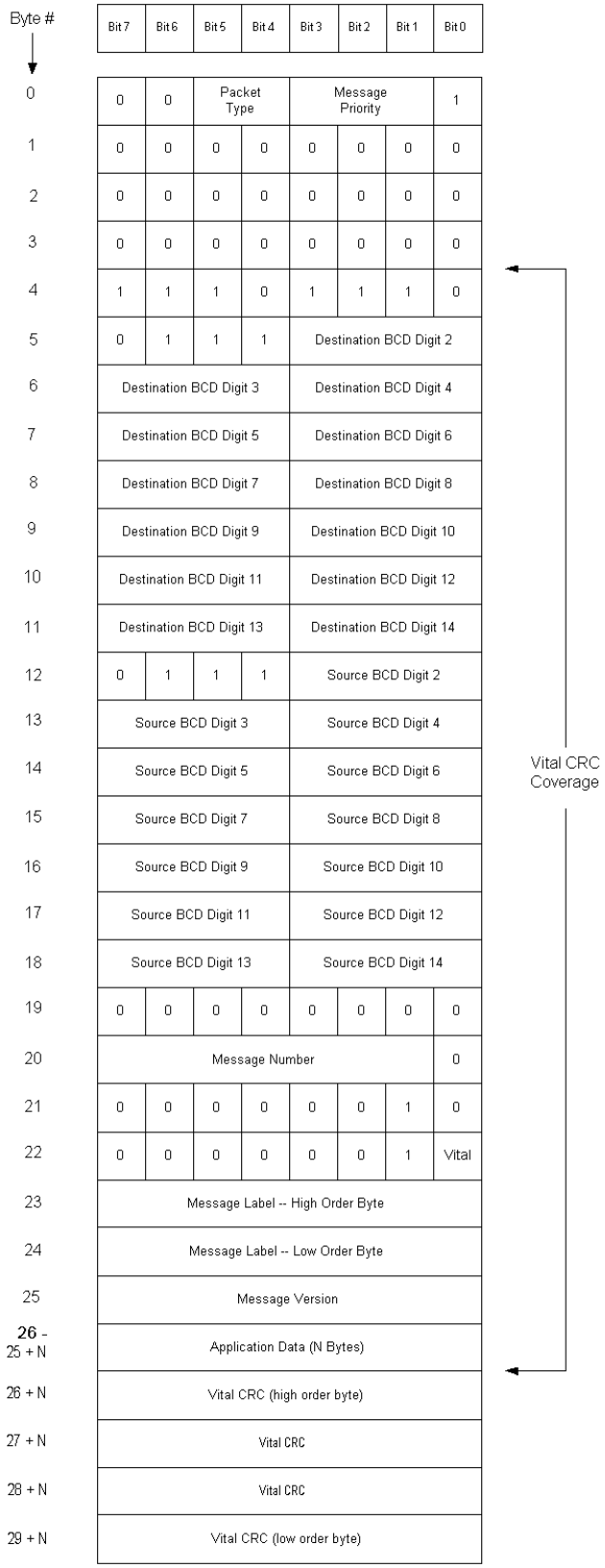

Figure A.2—ATCS network layer datagram data format—HRI message defaults

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Table A.1—ATCS network layer datagram field descriptions—HRI message defaults

Byte location	Field name	Field description	NOTE
0	Q	Qualifier bit	Not used, set to 0.
0	D	Delivery confirm bit	Not used, set to 0.
0	Packet Type	00=Nack 10=Info 11=Ack	All currently defined message types are “Info.”
0	Message Priority	0 is the highest priority level.	Set to 0 for all messages.
0	RF Ack	RF acknowledgement bit, set to 1 if disabled.	Not used, set to 1.
1	Channel Number	Always set to 0.	Not used, set to 0.
2	Packet Send Sequence Number	Not used.	Not used, set to 0.
2	Fill 1	Fill bit, not used.	Not used, set to 0.
3	Packet Receive Sequence Number	Not used.	Not used, set to 0.
3	Fill 2	Fill bit, not used.	Not used, set to 0.
4	Source Address Length	Source length=14 for all messages.	Set to 14 (1110_2).
4	Destination Address Length	Destination length=14 for all messages.	Set to 14 (1110_2).
5	Destination BCD Digit 1	Address type identifier, all messages are Type 7.	Set to 7 (0111_2).
5	Destination BCD Digit 2	First digit of the 3-digit railroad number.	
6	Destination BCD Digit 3	Second digit of the 3-digit railroad number.	
6	Destination BCD Digit 4	Third digit of the 3-digit railroad number.	
7	Destination BCD Digit 5	First digit of the 3-digit railroad line number.	
7	Destination BCD Digit 6	Second digit of the 3-digit railroad line number.	
8	Destination BCD Digit 7	Third digit of the 3-digit railroad line number.	
8	Destination BCD Digit 8	First digit of the 3-digit physical group number.	

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Table A.1—ATCS network layer datagram field descriptions—HRI message defaults (continued)

Byte location	Field name	Field description	NOTE
9	Destination BCD Digit 9	Second digit of the 3-digit physical group number.	
9	Destination BCD Digit 10	Third digit of the 3-digit physical group number.	
10	Destination BCD Digit 11	First digit of the 2-digit subnode number.	
10	Destination BCD Digit 12	Second digit of the 2-digit subnode number.	
11	Destination BCD Digit 13	First digit of the 2-digit device number.	
11	Destination BCD Digit 14	Second digit of the 2-digit device number.	
12	Source BCD Digit 1	Address type identifier, all messages are Type 7.	Set to 7 (0111).
12	Source BCD Digit 2	First digit of the 3-digit railroad number.	
13	Source BCD Digit 3	Second digit of the 3-digit railroad number.	
13	Source BCD Digit 4	Third digit of the 3-digit railroad number.	
14	Source BCD Digit 5	First digit of the 3-digit railroad line number.	
14	Source BCD Digit 6	Second digit of the 3-digit railroad line number.	
15	Source BCD Digit 7	Third digit of the 3-digit railroad line number.	
15	Source BCD Digit 8	First digit of the 3-digit physical group number.	
16	Source BCD Digit 9	Second digit of the 3-digit physical group number.	
16	Source BCD Digit 10	Third digit of the 3-digit physical group number.	
17	Source BCD Digit 11	First digit of the 2-digit subnode number.	
17	Source BCD Digit 12	Second digit of the 2-digit subnode number.	
18	Source BCD Digit 13	First digit of the 2-digit device number.	

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Table A.1—ATCS network layer datagram field descriptions—HRI message defaults (continued)

Byte location	Field name	Field description	NOTE
18	Source BCD Digit 14	Second digit of the 2-digit device number.	
19	Fill 3	Fill bits, not used.	Not used, set to 0.
19	Facility Length	Not used.	Not used, set to 0.
20	Message Number	ATCS message sequence number, used for duplicate message detection.	
20	More	More multi-packet messages, not used.	Not used, set to 0.
21	Part Number	Used in multi-packet messages, not used.	Not used, set to 1.
21	End Ack	End-to-end message acknowledgement, not used.	Not used, set to 0.
22	Message Length	Number of packets in multi-packet message, not used.	Not used, set to 1.
22	Vital	Vital (i.e., "safety-critical") message (1=vital, 0=non-vital).	
23–24	Message Label	Label=((512) * P1) + (64*P2) + P3 P1=9 (Wayside device monitoring and control) P2= 0 – Control 1 – Query 2 – Status 3 – Commands 4 – General P3=Message number (0–63) within P1 and P2 groups.	
25	Message Version	ATCS message version.	Individual message version.
26–(25+N)	Application Data	HRI message packet, N bytes in length (max length of 128 bytes).	
(26 + N)–(29 + N)	Vital CRC (4 bytes)	32-bit vital CRC, see ATCS specifications.	Used only on vital messages.

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Annex B

(informative)

HRI message transfer examples

Two message transfer examples are provided in this informative annex to illustrate the transfer of an HRI message from its source to its destination across the HRI interface. Both examples describe the transfer of the HRI rail crossing operational state message (9.4.40) as it traverses the protocol layers from its source in the wayside to its destination in the ATC. This message is a safety-critical (vital) message.

NOTE—These are illustrative examples and form neither any part of this standard nor recommend specific implementations.

The message source in both examples is a crossing controller function in a wayside equipment terminator. The message destination in both examples is a traffic controller function in an ATC. The HRI interface in both examples consists of the following protocol stack:

Transport Layer–Upper Level:	ATCS Vital CRC, ATCS CRC-16
Transport Layer–Lower Level:	TCP
Network Layer–Upper Level:	ATCS Datagram
Network Layer–Lower Level:	IP
Link Layer:	Ethernet
Physical Layer:	10BaseT

In both examples, the HRI message source is the crossing controller function in the wayside equipment terminator. The difference between the two examples lies in the location of the vital source address for the network and transport layer addressing used in the ATCS datagram. In the first example, the ATCS datagram is generated in the wayside equipment gateway. In the second example, the ATCS datagram is generated at the HRI message source—the wayside crossing controller function.

The HRI message used in both examples, 9.4.40, provides the operational state of the rail crossing. For illustration purposes, the rail crossing in these examples consist of a single crossing with two tracks, with a train having recently activated the warning system on track 2 (the crossing gates are on their way down). Track 1 is unoccupied. No exit gates are present at the crossing. The information field descriptions for this example HRI message are shown in Table B.1 and the bit layout for the example message is provided in Figure B.1.

In example 1, the HRI message is transferred across the internal wayside network to the wayside gateway, which then acts as the ATCS vital source for the HRI message, as shown in Figure B.2. Consequently, the ATCS datagram is generated in the wayside gateway.

In example 2, the crossing controller acts not only as the HRI message source, but also as the ATCS vital source, as shown in Figure B.3. Thus, the ATCS datagram is generated in the crossing controller function in this second example. In this example, an ATCS address must be assigned to the crossing controller function since it is the ATCS datagram source. An ATCS address for the crossing controller was not required in example 1 since the ATCS datagram was generated in the wayside gateway function.

In both examples, the ATCS vital destination is the ATC gateway. It is in the ATC gateway that the ATCS datagram's vital CRC is checked to insure that the message has arrived uncorrupted over the HRI interface. In both examples, the message is then transferred across the internal ATC network to its ultimate destination, the traffic controller function in the ATC.

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The message transfer path through the protocol stack in example 1 is shown in Figure B.4. The packing and unpacking scheme as the message is transferred through the protocol stack for example 1 is shown in Figure B.5.

Likewise, the message transfer path through the protocol for example 2 is shown in Figure B.6. The packing and unpacking scheme as the message is transferred through the protocol stack for example 2 is shown in Figure B.7.

Table B.1—Example HRI message 9.4.40 field descriptions

Byte location	Field name	Field description	Value used in example
0	Number of Crossings	Total number of crossings (1–8).	1
0	RHBA	Receiving vital heartbeat message (message 9.4.43) from the ATC system. 0=Not receiving message 9.4.43 1=Receiving message 9.4.43	1
0	Reserved	Not used.	0
1	Crossing Sequence Number	HRI interface specific internal ID number assigned for each crossing.	1
1	Number of Trains	Number of trains associated with this crossing.	1
2	SO	System operational. 0=System not operational 1=System operational	1
2	TPD	Train presence detection. 0=No train present 1=Train present The “OR” of train detection for all trains on all tracks that will intersect the crossing.	1
2	WSA	Warning system active. 0=Not activated 1=Activated	1
2	PEA	Preemption warning active 0=Not active 1=Active	1
2	Reserved	Not used.	0
3	XGP	Exit gate(s) present. 0=Exit gate(s) not present 1=Exit gate(s) present The “AND” of all gates at the crossing.	0
3	XGU	Exit gate(s) up. 0=Exit gate(s) not up 1=Exit gate(s) up The “AND” of all gates at the crossing.	0 (don’t care, no exit gates present).

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Table B.1—Example HRI message 9.4.40 field descriptions (continued)

Byte location	Field name	Field description	Value used in example
3	XGD	Exit gate(s) down. 0=Exit gate(s) not down 1=Exit gate(s) down The "AND" of all gates at the crossing.	0 (don't care, no exit gates present).
3	NGP	Entrance gate(s) present. 0=Entrance gate(s) not present 1=Entrance gate(s) present The "AND" of all gates at the crossing.	1
3	NGU	Entrance gate(s) up. 0=Entrance gate(s) not up 1=Entrance gate(s) up The "AND" of all gates at the crossing.	0 (gates have started to come down).
3	NGD	Entrance gate(s) down. 0=Entrance gate(s) not down 1=Entrance gate(s) down The "AND" of all gates at the crossing.	0 (gates are not completely down yet).
3	Reserved	Not used.	0
4	Preemption Design Time	Design time for the preemption system.	30 seconds.
5	Train Sequence Number	HRI interface specific internal ID number assigned for each train.	6 (internal ID number is sequentially assigned).
5	DIR	Direction. 0=Heading East 1=Heading West 2=Unknown	1
5	ICO	Island occupied. 0=Island circuit unoccupied 1=Island circuit occupied	0 (has not reached crossing yet).
5	Reserved	Not used.	0
6	Warning System Activation Design Time	Design time for the warning activation system.	20 seconds.
7	Estimated Time to Warning System Activation	Seconds to warning system activation. This parameter is an estimate based on data processed by safety-critical equipment designed for this function (see AREMA Signal and Communications Manual (2001) [B1]). Its value can increase, decrease, or remain constant as a function of time. NOTE—Estimated Time to Arrival=Design Time for Warning System Activation + Time to Warning System Activation. Only valid prior to warning system activation.	0 seconds (don't care, warning system has been activated).

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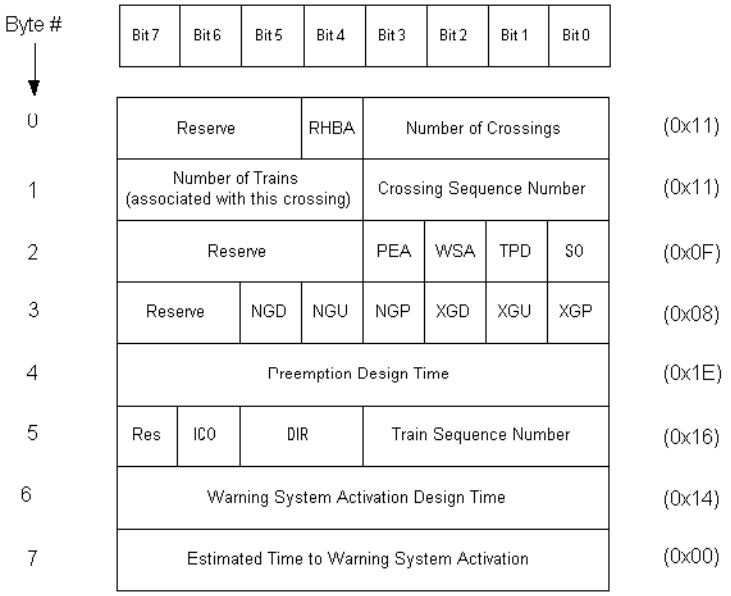

Figure B.1—Example HRI message 9.4.40 bit layout

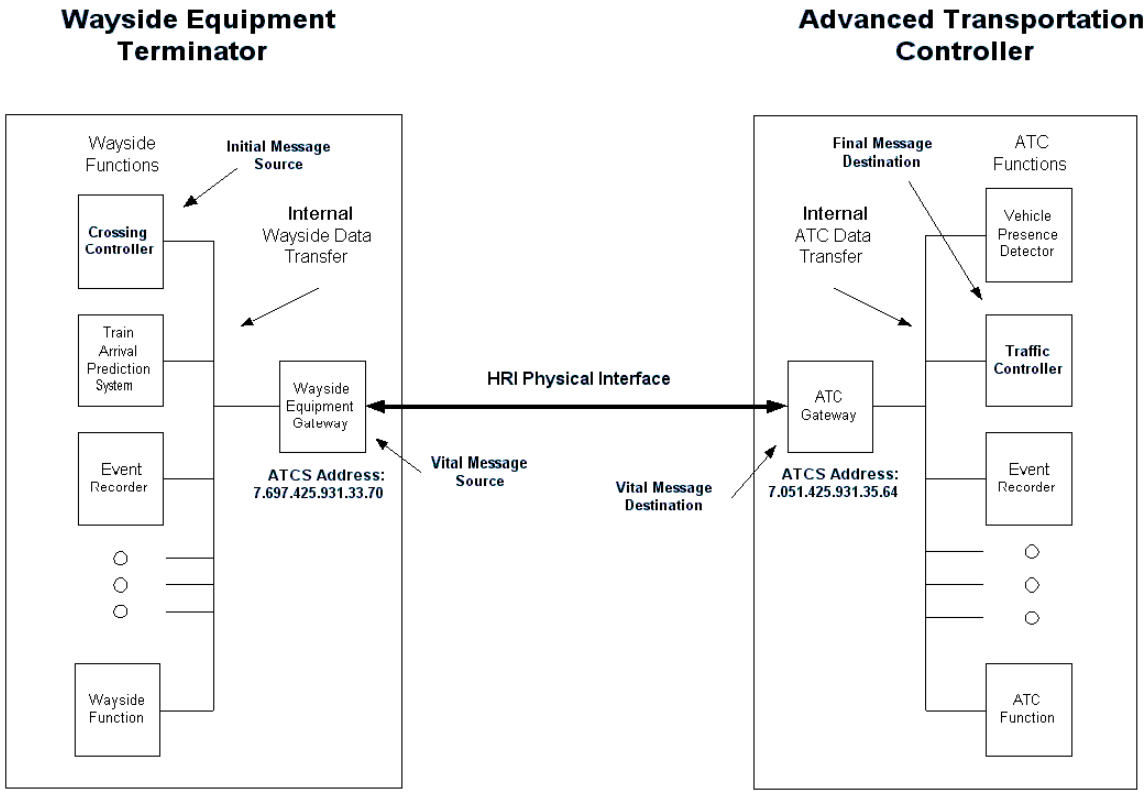

Figure B.2—Example 1: wayside gateway vital source–ATC gateway vital destination

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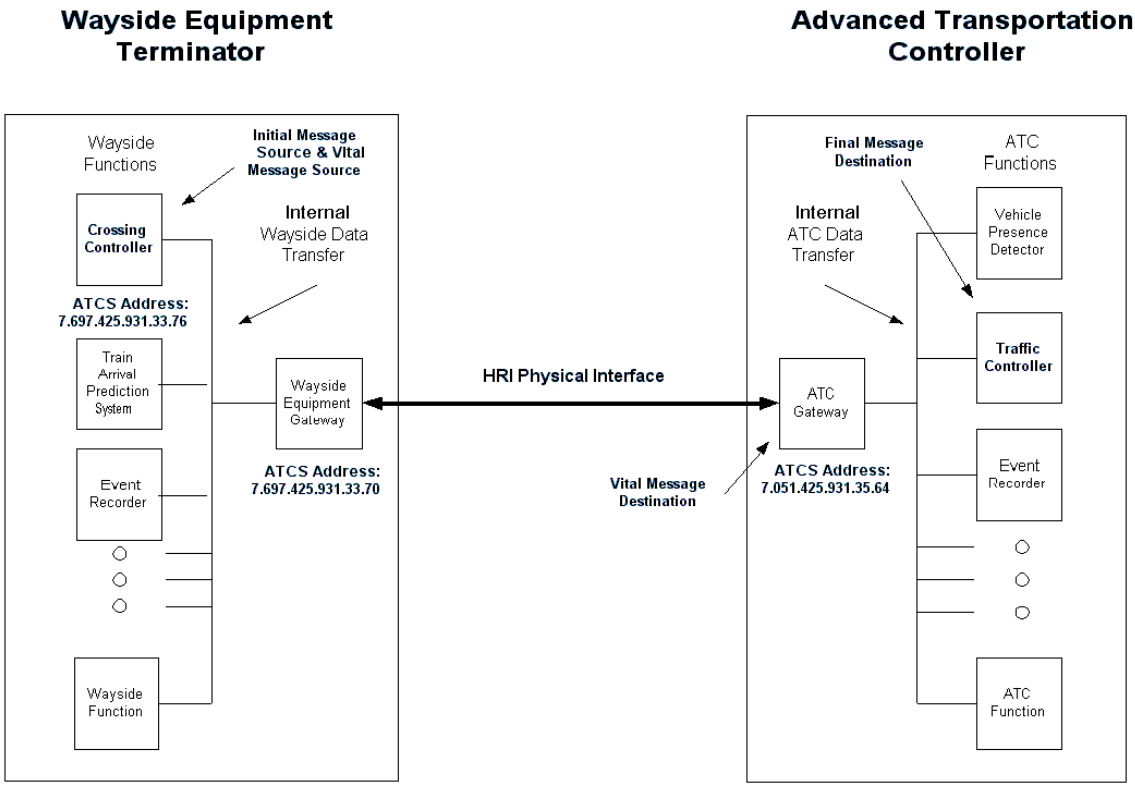

Figure B.3—Example 2: crossing controller vital source–ATC gateway vital destination

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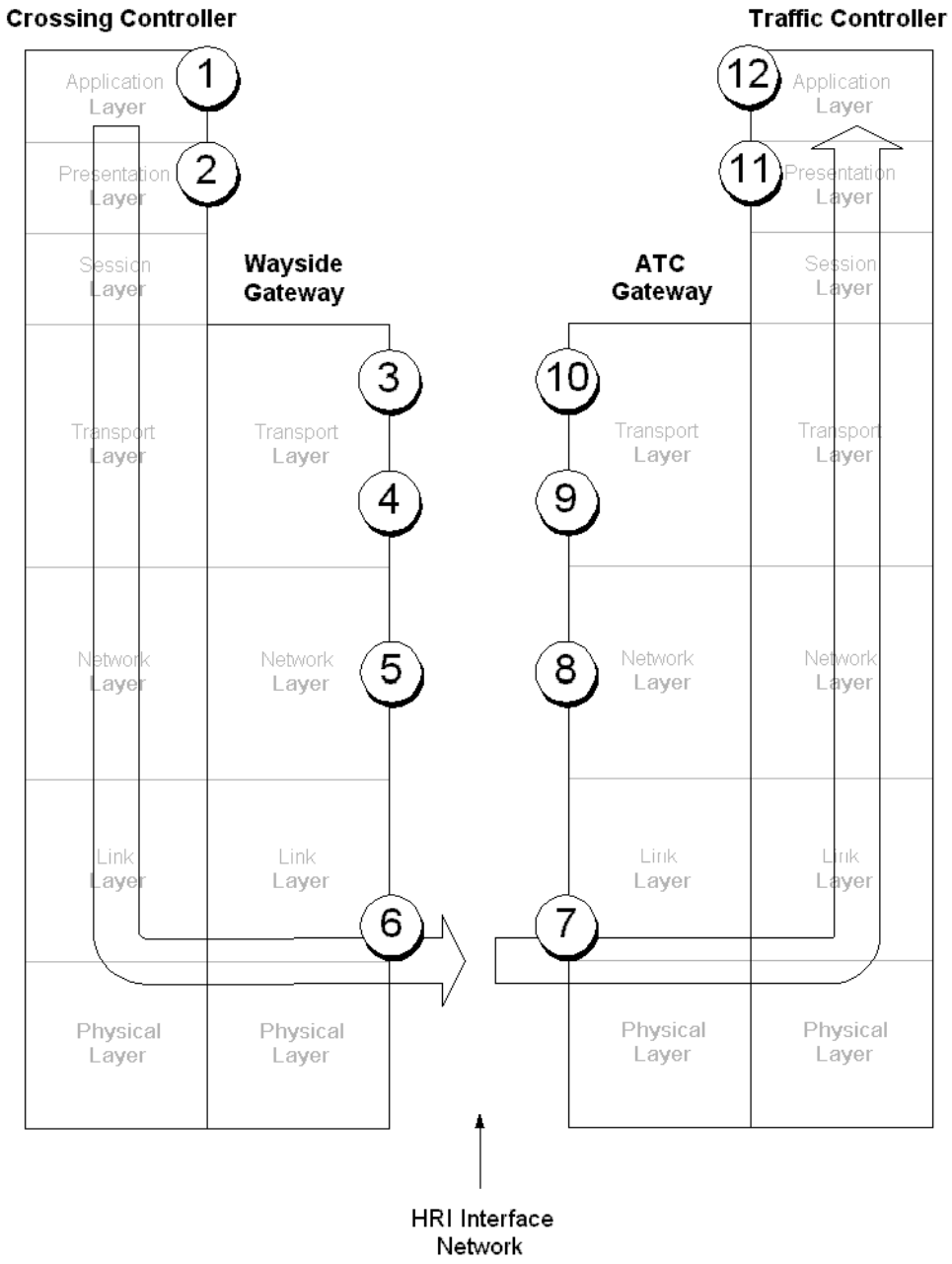

Figure B.4—Message transfer path–example 1

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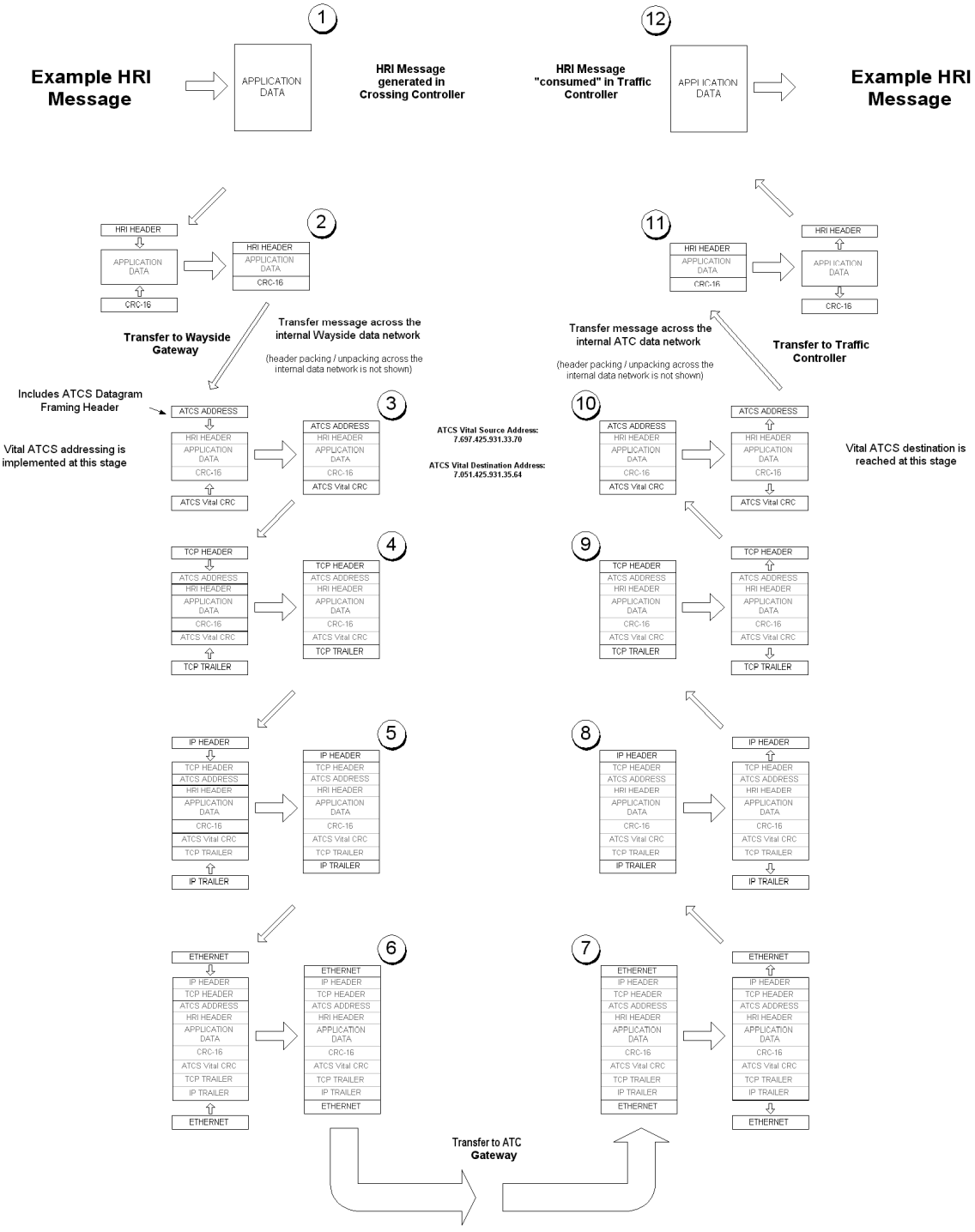

NOTE—Application data shown here equates to message data shown in Figure 7 of this standard.

Figure B.5—Message packing scheme–example 1

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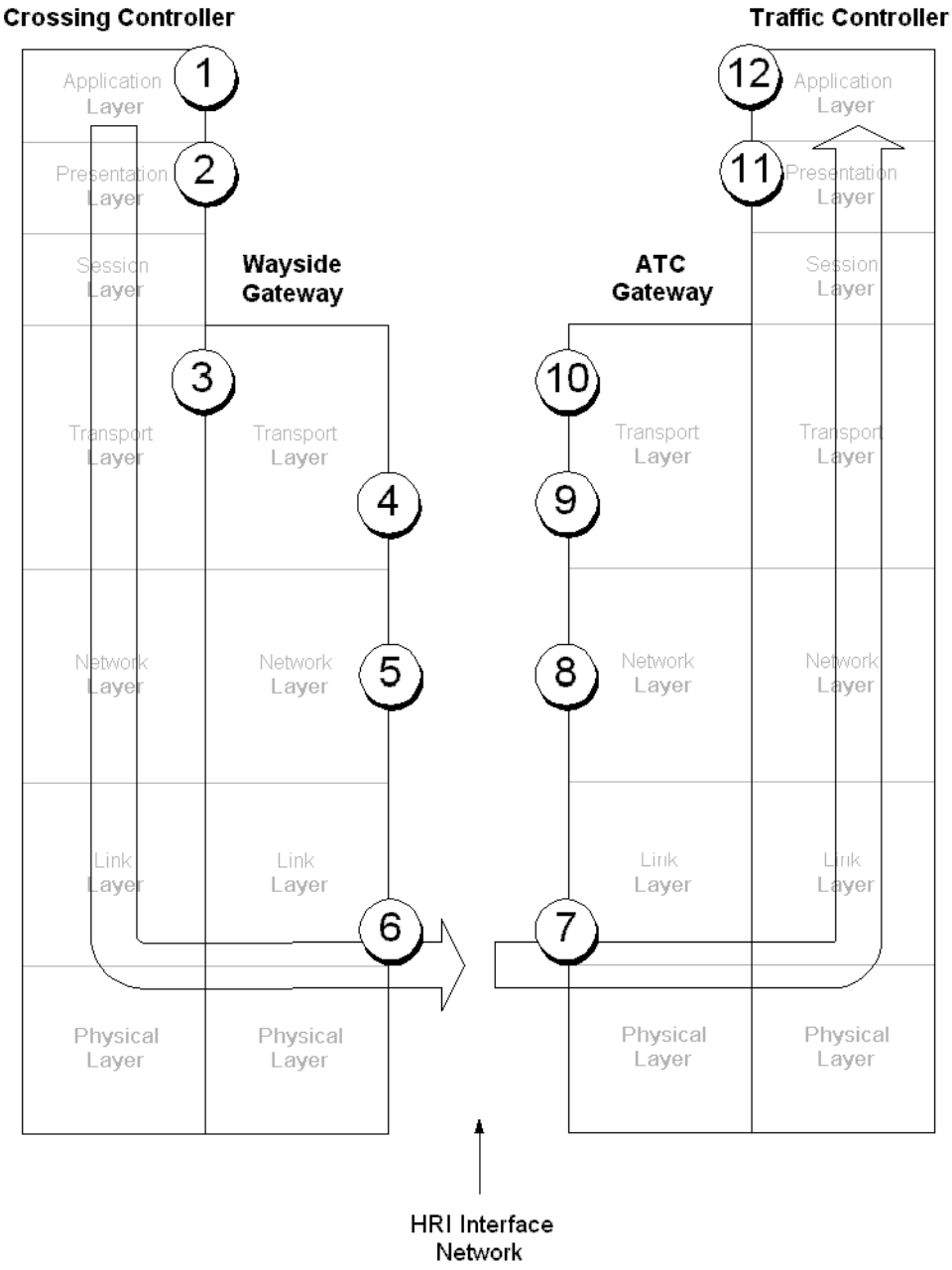

Figure B.6—Message transfer path–example 2

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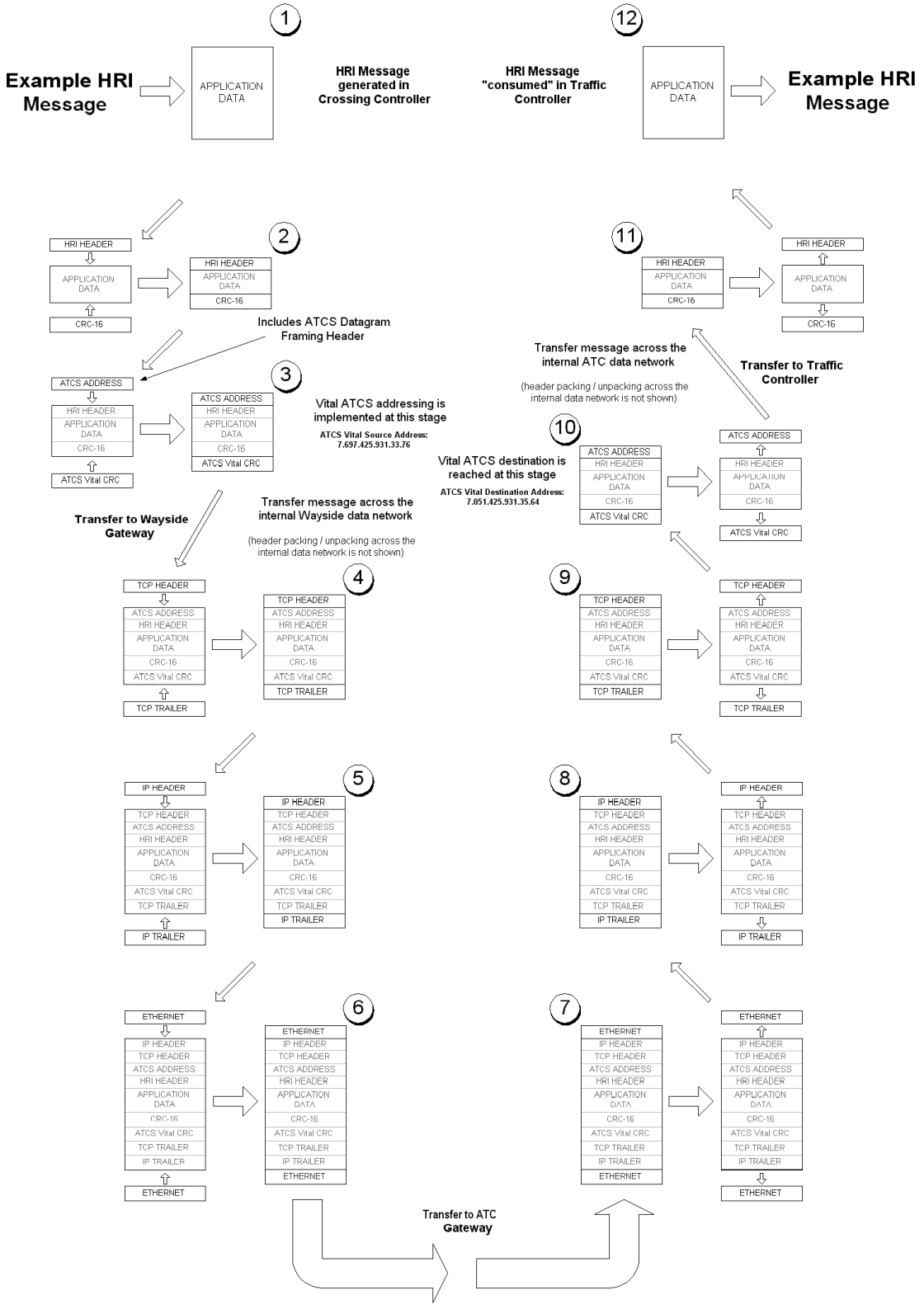

NOTE—Application data shown here equates to message data shown in Figure 7 of this standard.

Figure B.7—Message packing scheme–example 2

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Annex C

(informative)

HRI message flow examples

This informative annex shows some typical interconnection techniques at various types of crossings and concludes with a typical message flow example for one application.

The following example in Figure C.1 shows a typical application with a single connection between a single railway subsystem and a single highway subsystem. This will cover the majority of applications. In this example, the heavier line labeled “1570 interface” identifies a point-to-point connection following the conventions of this standard.

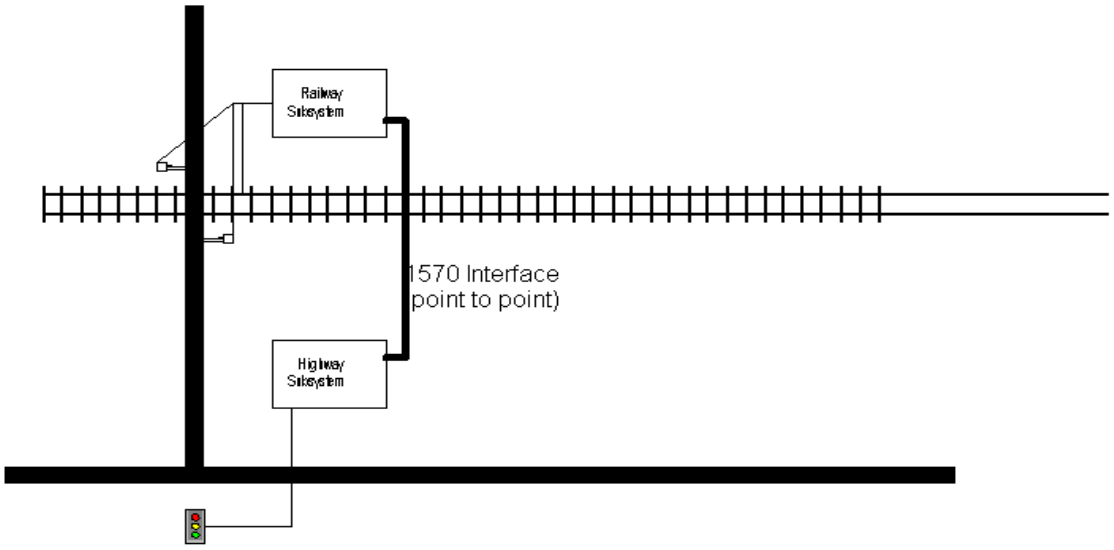

Figure C.1—Example application number 1

The following examples show alternative ways of connecting a single railway subsystem to multiple highway subsystems. The first diagram shows two independent highway subsystems and a single railway subsystem interconnected over a single networked interconnection as defined in this standard. The second diagram shows the application with a single point-to-point application between a railway subsystem and one of the highway subsystems (as defined in this standard). The interconnection between the two highway subsystems can then be done internally within the highway subsystem.

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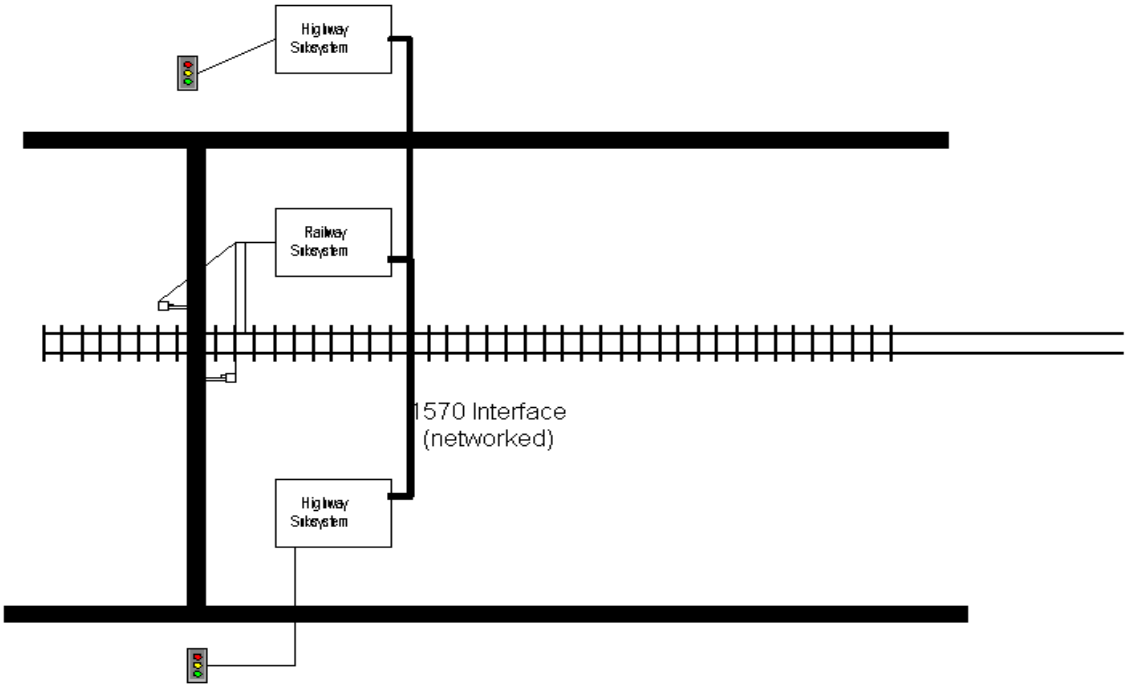

Figure C.2—Example application number 2

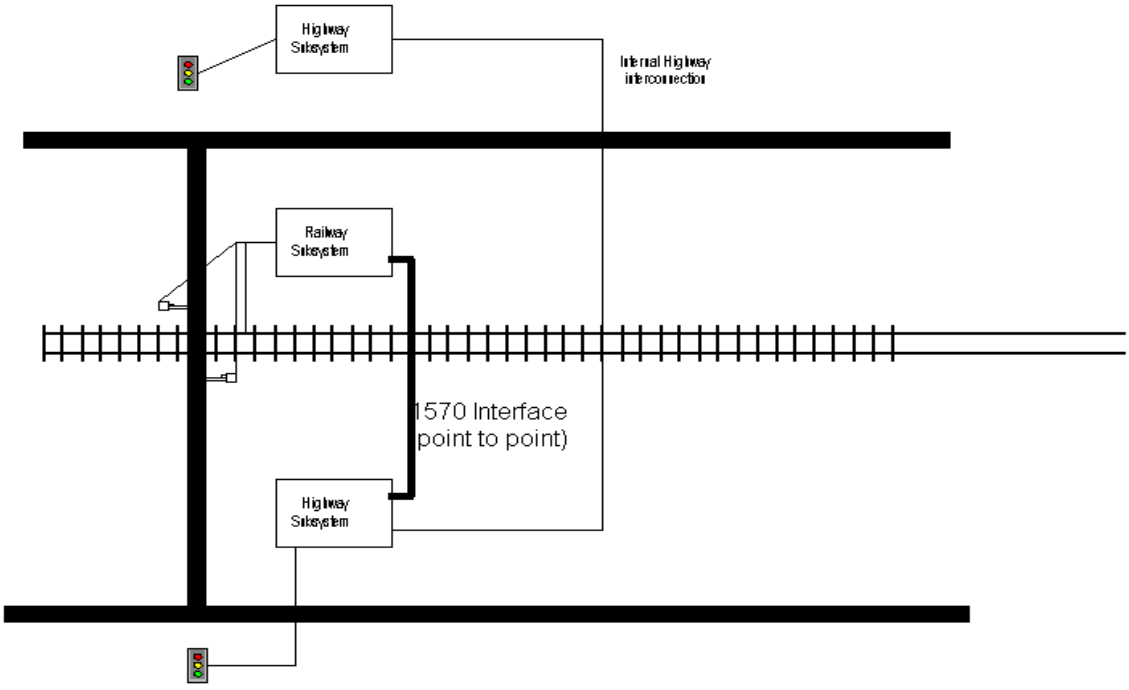

Figure C.3—Example application number 3

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The examples in Figure C.4 and Figure C.5 show alternative ways of connecting multiple railroad subsystems to a single highway subsystem. The example in Figure C.4 shows an internal railroad connection between the two railroad subsystems with a point-to-point interface (as defined in this standard) from one of the railroad subsystems to the highway subsystem. The example in Figure C.5 shows a networked interconnection between all three subsystems.

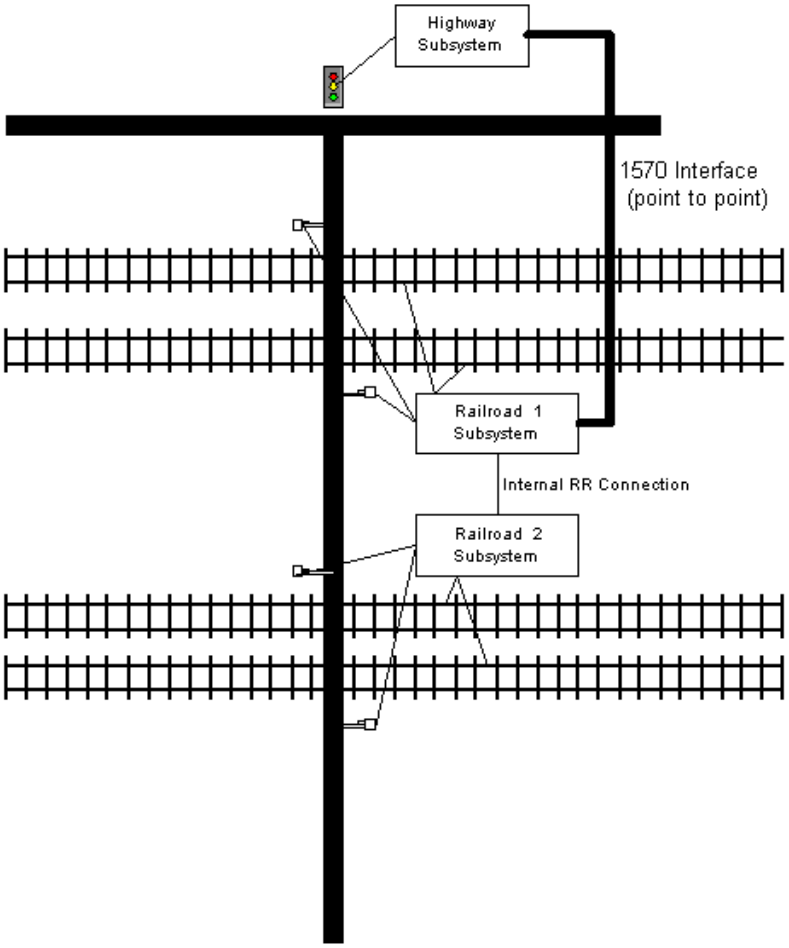

Figure C.4—Example application number 4

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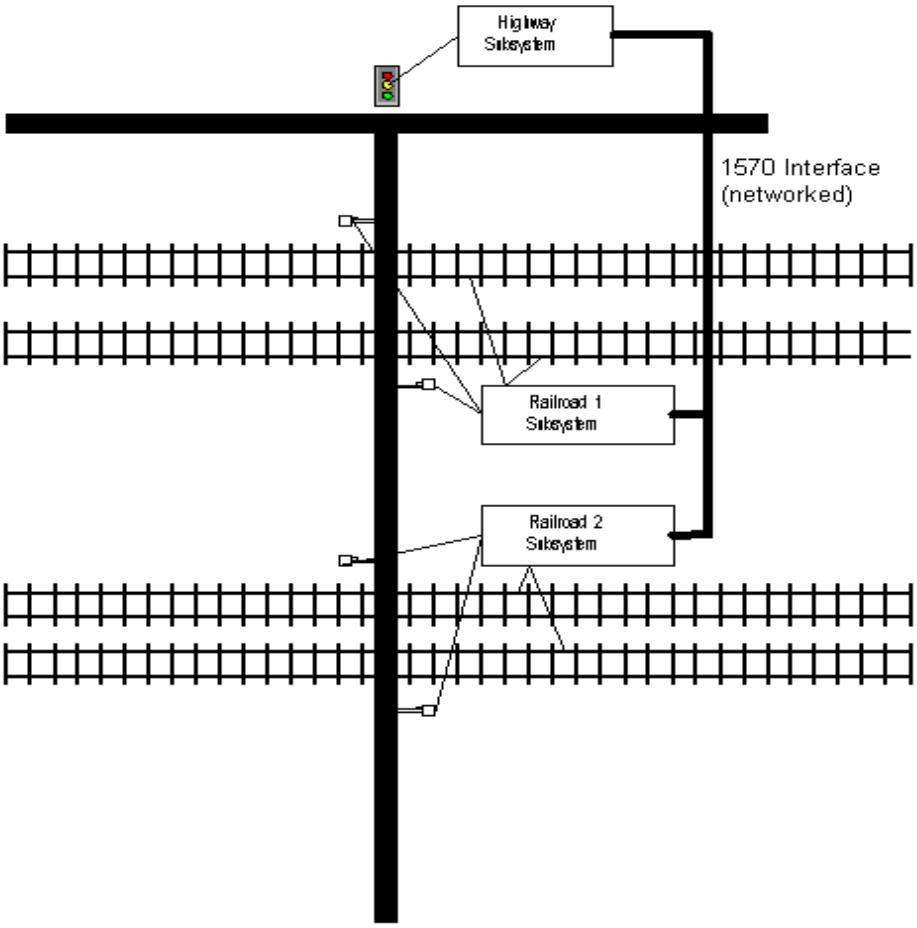

Figure C.5—Example application number 5

This portion of the annex illustrates a typical application message flow sequence. The example message flow contained in Figure C.6 through C.16 considers a one-track crossing location with a design time of 25 seconds for the warning systems to begin activation before an approaching train. A design time of 32 seconds for preemption is also assumed. The example message flow contained in Figure C.6 through C.16 assumes approach of an Eastbound train on track 1 whose presence is detected 40 seconds prior to entering the crossing, with motion prediction beginning 32 seconds prior to entering the crossing. Messages will actually be sent every second, but the example only shows messages when an important status change occurs. There are entrance gates, but no exit gates.

Single bits set to a “ONE” are highlighted and underlined. Information changing from the previous condition is shown in highlighted sections.

It is assumed that the highway side of the subsystem is sending its heartbeat message (9.4.43) on the one second basis so that RHBA is always set.

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Reserve		RHBA	Number of Crossings = **0001**			
Number of Trains = **0000**			Crossing Sequence Number = **0001**			
Reserve			PEA	WSA	TPD	SO
Reserve	NGD	NGU	NGP	XGD	XGU	XGP
Preemption Design Time = 0010 0000 (32 seconds)						

Figure C.6—Action: normal state, no train approaching

Reserve		RHBA	Number of Crossings = **0001**			
Number of Trains = **0001**			Crossing Sequence Number = **0001**			
Reserve			PEA	WSA	TPD	SO
Reserve	NGD	NGU	NGP	XGD	XGU	XGP
Preemption Design Time = 0010 0000 (32 seconds)						
Res	ICO	DIR = 10 (unknown)	Train Sequence Number = **0001 (first train)**			
Warning System Activation Design Time = 0001 1001 (25 seconds)						
Estimated Time to Warning System Activation = 1111 1111 (unknown)						

Figure C.7—Time X+0: action: train initially detected approaching (40 seconds prior to entering crossing)

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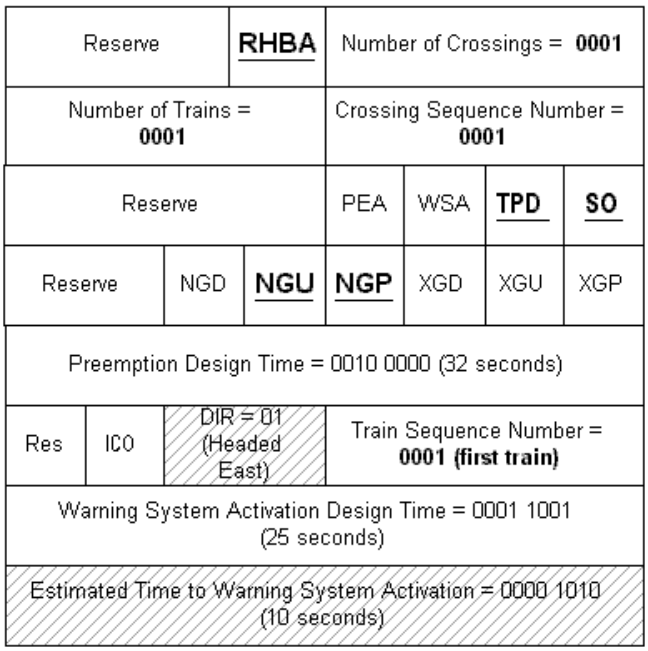

Figure C.8—Time X+5: action: motion detected, 35 seconds until crossing occupied

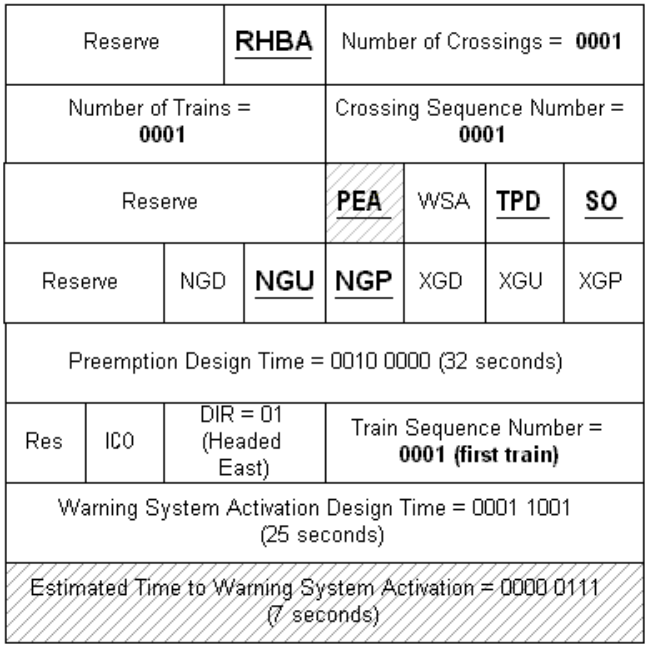

Figure C.9—Time X+8: action: motion detected, 32 seconds until crossing occupied, preemption activation

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Reserve		RHBA	Number of Crossings = **0001**			
Number of Trains = **0001**			Crossing Sequence Number = **0001**			
Reserve			PEA	WSA	TPD	SO
Reserve	NGD	NGU	NGP	XGD	XGU	XGP
Pre-Emption Design Time = 0000 1000 (32 seconds)						
Res	IC0	DIR = 01 (Headed East)	Train Sequence Number = **0001 (first train)**			
Warning System Activation Design Time = 0000 0111 (25 seconds)						
Estimated Time to Warning System Activation = 0000 0000 (0 seconds)						

Figure C.10—Time X+15: action: motion detected, 25 seconds until crossing occupied, warning system active (bells and lights active)

Reserve		RHBA	Number of Crossings = **0001**			
Number of Trains = **0001**			Crossing Sequence Number = **0001**			
Reserve			PEA	WSA	TPD	SO
Reserve	NGD	NGU	NGP	XGD	XGU	XGP
Preemption Design Time = 0010 0000 (32 seconds)						
Res	IC0	DIR = 01 (Headed East)	Train Sequence Number = **0001 (first train)**			
Warning System Activation Design Time = 0001 1001 (25 seconds)						
Estimated Time to Warning System Activation = 0000 0000 (0 seconds)						

Figure C.11—Time X+18: action: motion detected, 22 seconds until crossing occupied, warning system active (bells and lights active, gates started downward motion)

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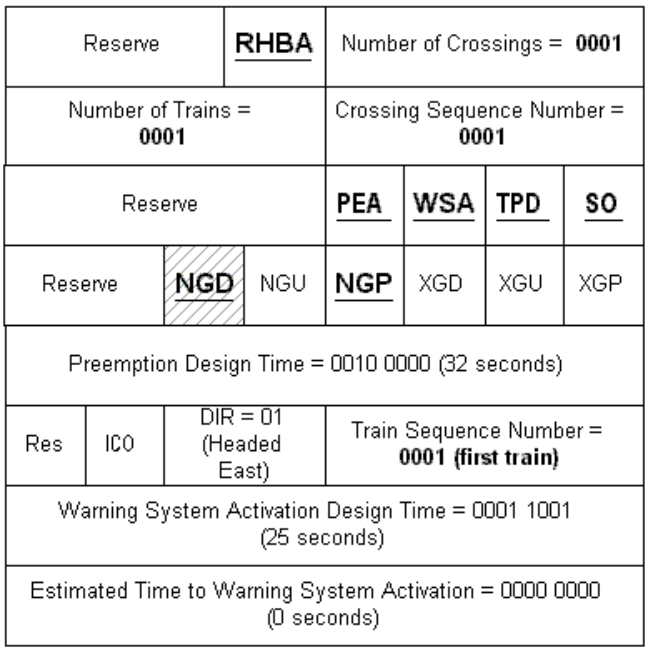

Figure C.12—Time X+24: action: motion detected, 16 seconds until crossing occupied, warning system active (bells and lights active, gates horizontal)

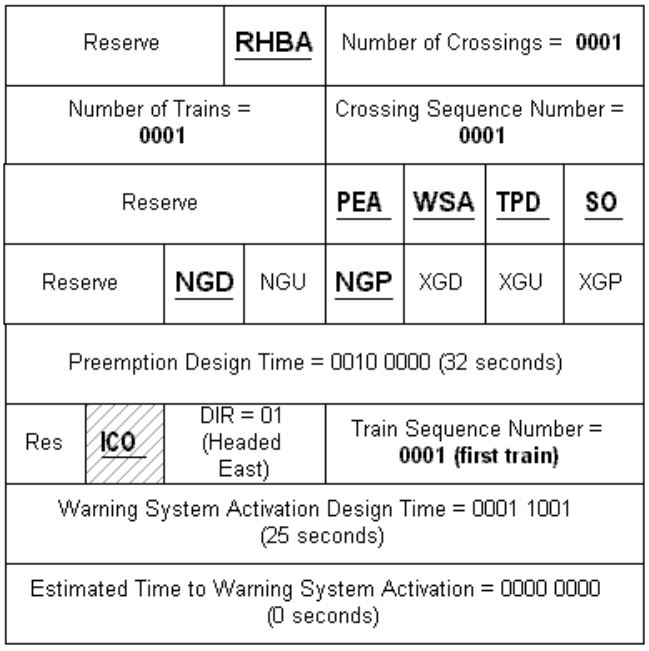

Figure C.13—Time X+40: action: motion detected, warning system active (bells and lights active, gates horizontal), island occupied

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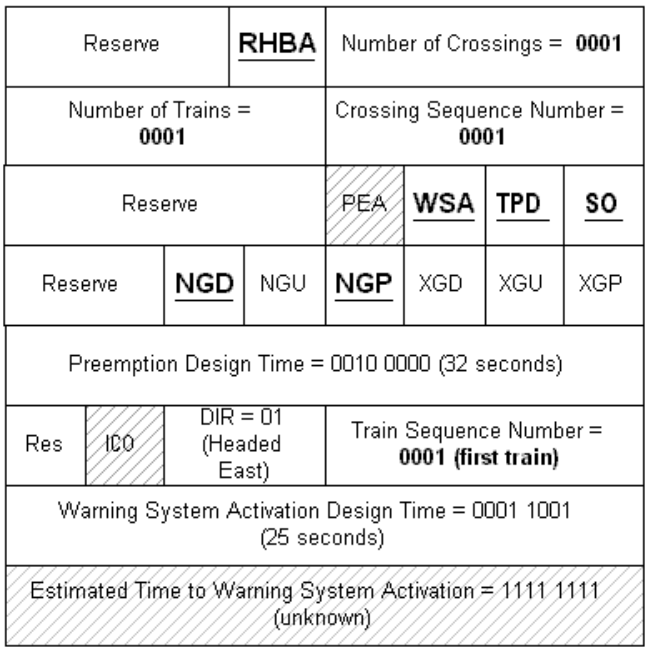

Figure C.14—Time X+80: action: assume train occupies crossing for 40 seconds. Warning system active (bells and lights active, gates horizontal), island unoccupied

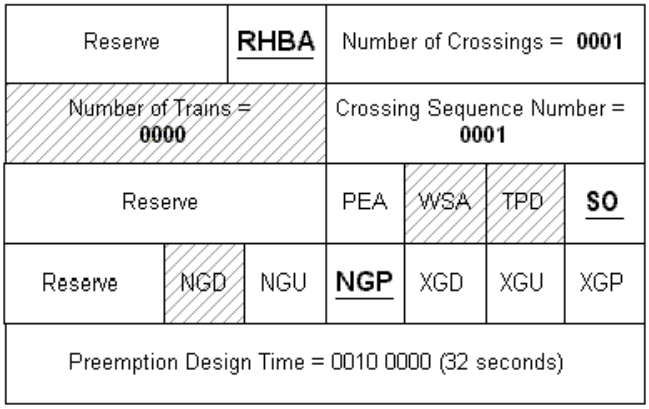

Figure C.15—Time X+82: action: warning system no longer active, gates are starting to move to vertical position

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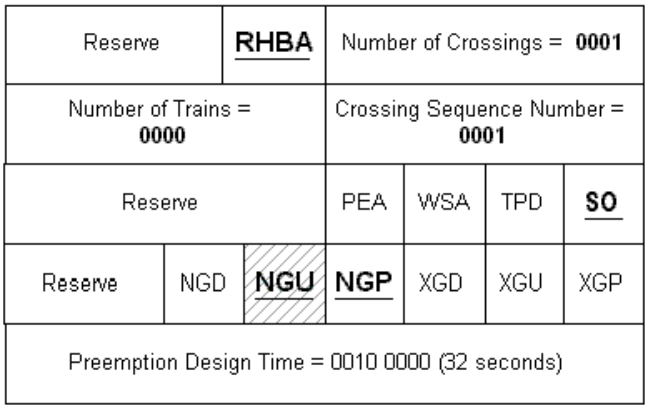

Figure C.16—Time X+88: action: crossing clear for traffic movement (normal condition)

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Annex D

(informative)

Bibliography

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