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

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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.

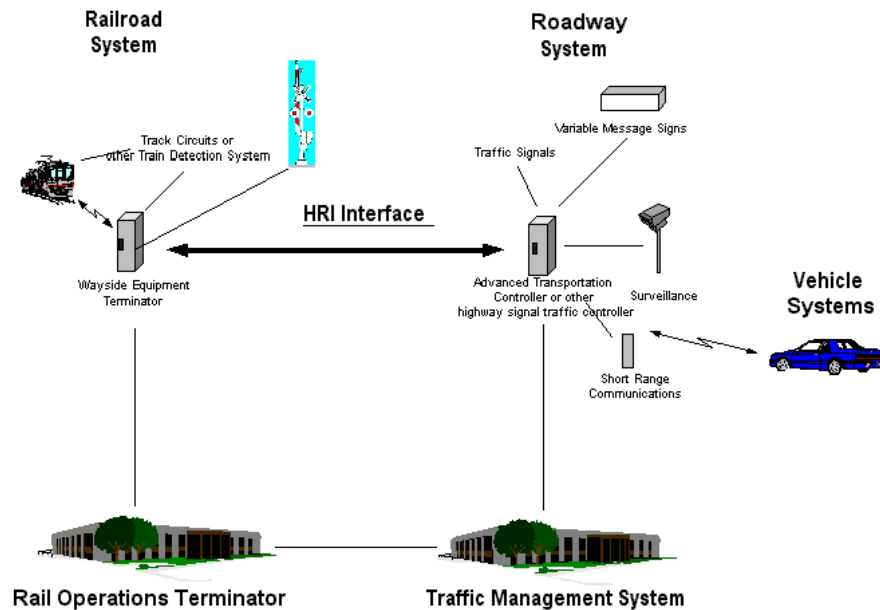


Figure INT-1 – HRI interface overview

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.

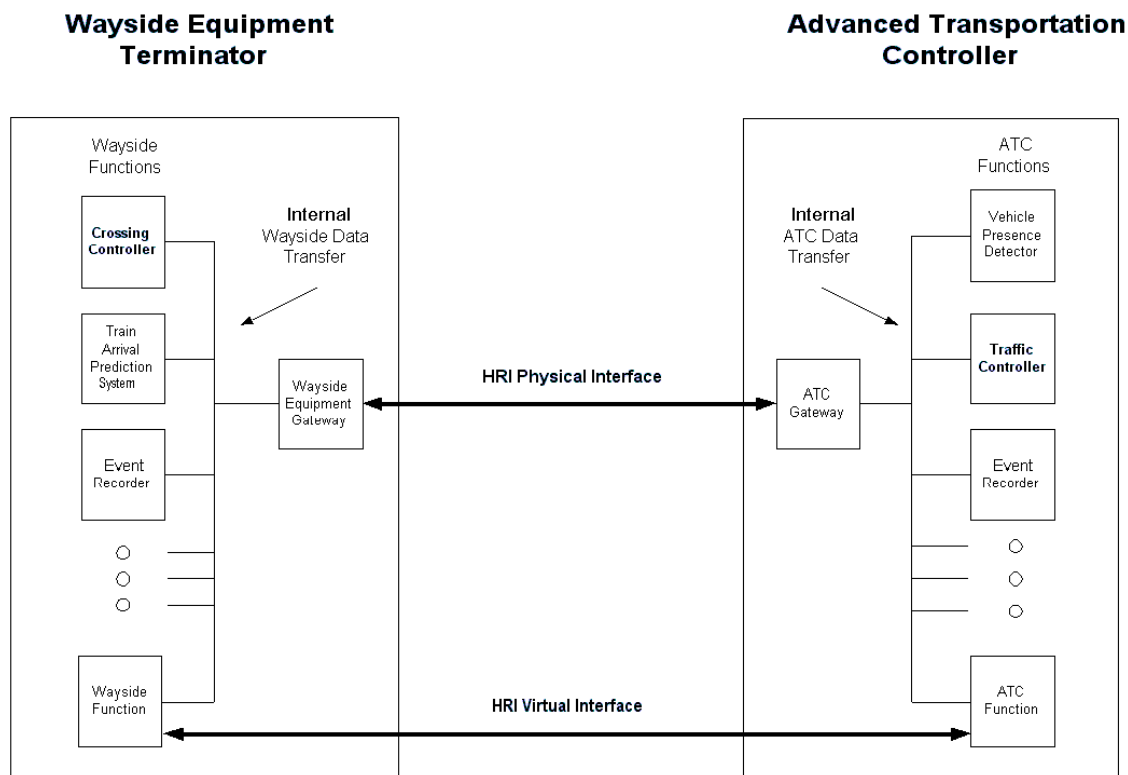


Figure INT-2—HRI interface

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.

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 way-side 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.

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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.

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 802.3TM, 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.

¹ATCS 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>).

²IEEE 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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⁴ISO/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/>).

⁵ISO/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/>).

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

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

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).

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

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.**

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.

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.

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 200⁹.

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.

⁹Information on references can be found in Clause 2.

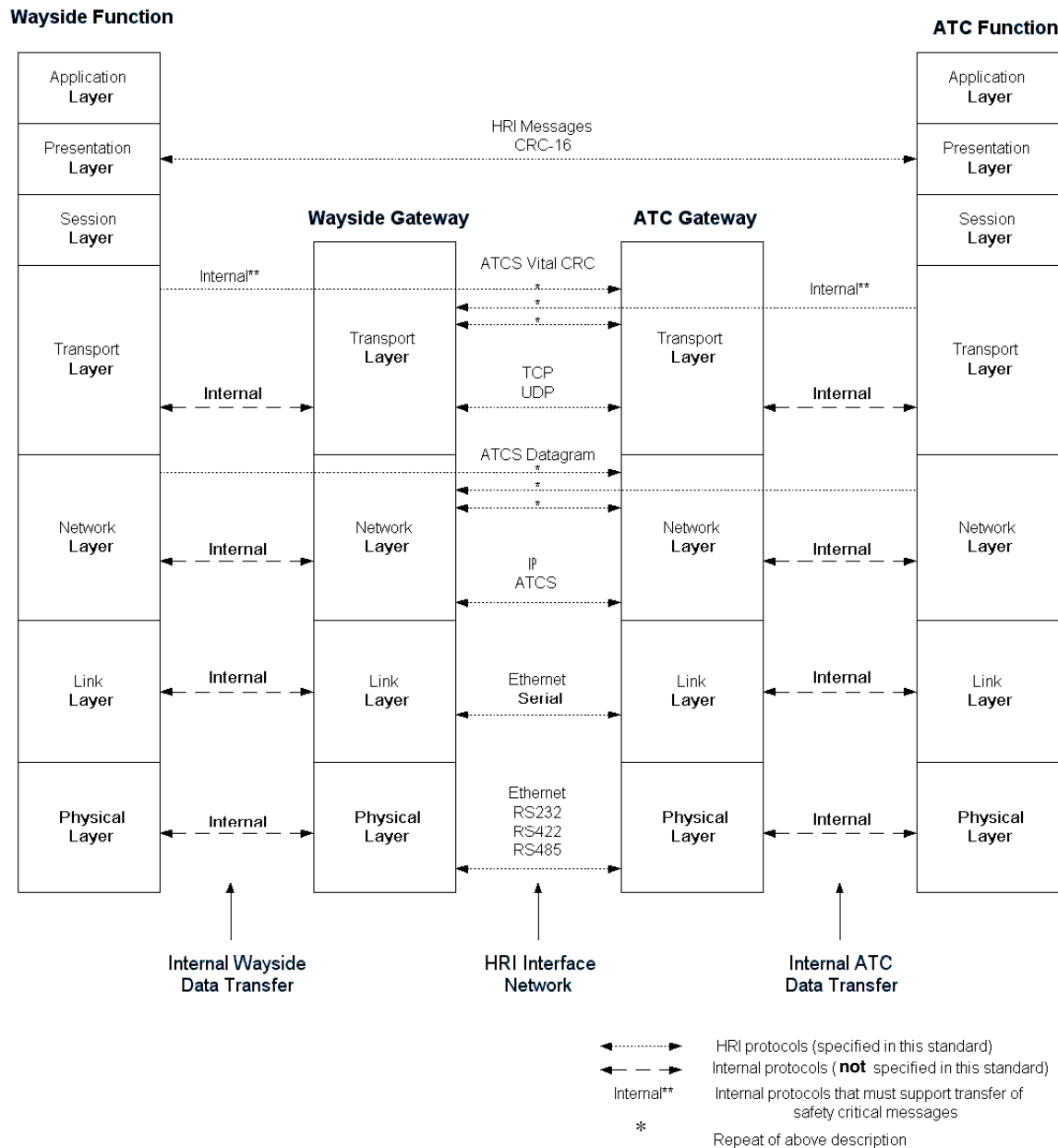


Figure 1 — HRI interface architecture model

4.3 HRI interface protocol specifications

4.3.1 Layer 7: application layer

There are no specified layer 7 HRI interface protocol requirements.

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

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.

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.

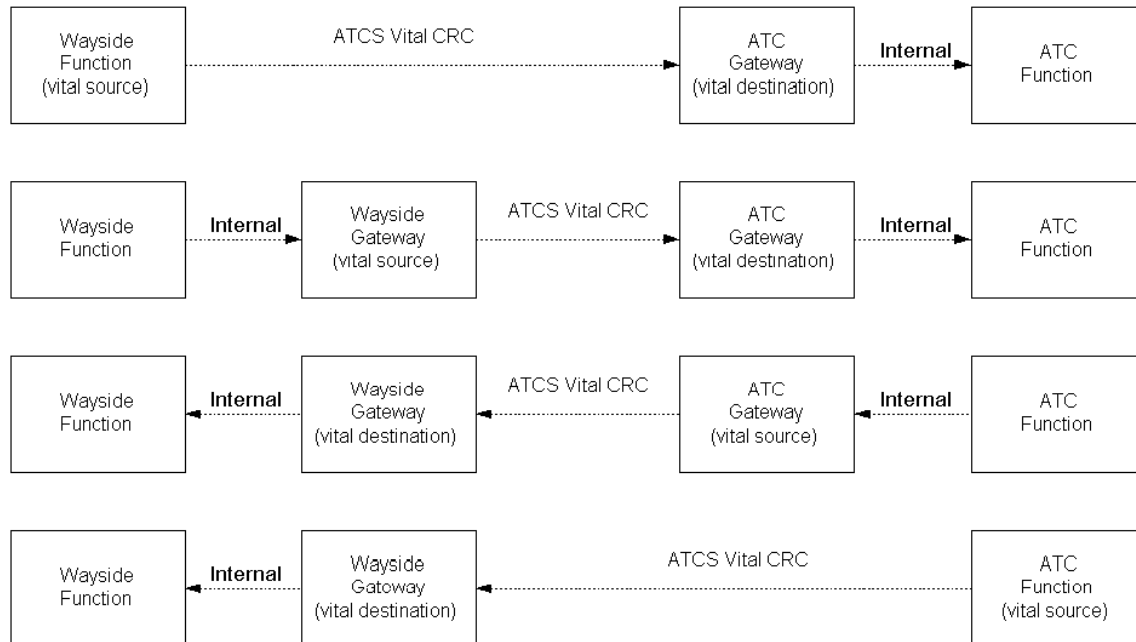


Figure 2—Layer 4 upper-level HRI message source and destination pairs

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.

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.

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.

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.

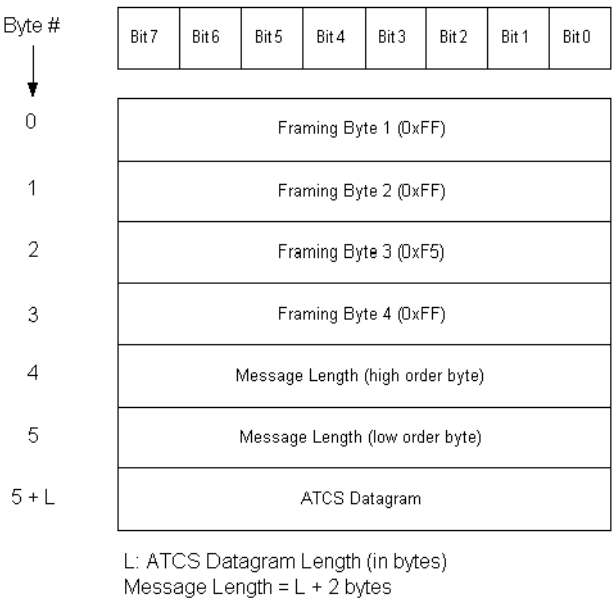


Figure 3—ATCS datagram framing header

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.