Standards Requirements Package 8: Signal Priority for Transit and Emergency Vehicles

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1. Introduction to Standards Requirements Documentation

The Standards Requirements Packages are intended to be used in conjunction with the other architecture documents. In particular, the introductory chapters of the Standards Requirements Document provide contextual material and explanations/justifications of some of the methods used to evaluate and rate architecture flows. However, it is recognized that many people may initially only receive a given Standards Requirements Package, without the associated supporting material. To aid these individuals, we offer some generic introductory material to promote understanding of the context and approach used to create a Standards Requirements Package. Ultimately, any standards development organization pursuing an ITS-related standard should ensure that they have access to a complete set of the architecture documents as a reference source.

1.1 Standards Requirements Document Executive Summary

The executive summary of the Standards Requirements Document is reproduced here, to provide a sense of the overall goals and content of the document.

The Standards Requirements Document ("SRD") collects information from the other National ITS Architecture program documents and reorganizes it in a manner intended to support the development of critical ITS standards. The key results in the SRD are a reference model for the National ITS Architecture, a rating scheme for evaluating the standardization issues associated with individual data flows that make up the architecture interfaces, and then a set of priority groupings of interfaces into standards requirements "packages". These results and the major conclusions are summarized below.

The introductory section explains the structure of the SRD and its intended usage. The strategy is that the reference model provides the overall context for a standards development organization ("SDO"). A given SDO can pull a particular package of standards requirements out of the document and then use the reference model as a quick reference to the overall architecture. More detailed needs will require going to the original source documents, such as the Logical or Physical Architectures.

The next section provides the rationale for several different ratings schemes applied to the architecture interconnects and flows. These include interoperability requirements, technology maturity assessments, stakeholder interest. All architecture interconnects were examined with respect to these measures. The stakeholder interest and interoperability requirements in particular were then used as the basis for selecting the standards requirements packages. In general, interfaces associated with mobile systems had both the greatest stakeholder interest and the most stringent interoperability requirements. Following close behind were interfaces associated with Traffic Management and Information Service Provider subsystems.

The Architecture Reference Model is provided next as a high level definition of the components that form the National ITS Architecture. It depicts the interconnectivity of the subsystems and terminators, their definitions, and suitable types of communications strategies. This reference model is an important tool for communicating the full breadth of the architecture at an abstracted level. In the SRD it is intended as a contextual reference, but, as a separate document, the reference model has received international circulation through the International Standards Organization (ISO) as a basis for documenting and comparing ITS architectures.

The "meat" of the SRD is the set of standards requirements packages. Each package is a special grouping of standards requirements and contextual information intended to be used in a nearly standalone fashion by an SDO. Thus, packages have been selected that cover the key ITS priorities, maintain the integrity and vision of the National ITS Architecture, and also are perceived as having an interested stakeholder constituency that will help drive standardization. This is a difficult balancing act, but the following 13 packages were identified as covering the high priority standardization needs for the architecture program:

1. Dedicated Short Range Communications (DSRC, formerly “VRC”)
2. Digital Map Data Exchange and Location Referencing Formats
3. Information Service Provider Wireless Interfaces
4. Inter-Center Data Exchange for Commercial Vehicle Operations
5. Personal, Transit, and HAZMAT Maydays
6. Traffic Management Subsystem to Other Centers (except EMS)
7. Traffic Management Subsystem to Roadside Devices and Emissions Monitoring
8. Signal Priority for Transit and Emergency Vehicles
9. Emergency Management Subsystem to Other Centers
10. Information Service Provider Subsystem to Other Centers (except EMS and TMS)
11. Transit Management Subsystem Interfaces
12. Highway Rail Intersections (HRI)
13. Archive Data Management Subsystem Interfaces

These 13 areas cover much of the National ITS Architecture and represent the distillation of stakeholder interests and architecture interoperability requirements. If standardization can be achieved in the near term for all or most of these packages, then ITS will be a long ways towards achieving the original vision captured in the user service requirements.

1.2 Constructing a Standards Requirements Package

The intent of creating a Standards Requirements Package is to facilitate efforts to standardize some subset of the National ITS Architecture. The “packaging” process involves abstracting and reorganizing information from other documents, primarily the Logical and Physical Architectures. We have gone through a number of iterations to try and achieve a format that is understandable and useful for SDO's; in the end, while there is not a universal consensus, we have tried to address the substance of most of the comments received.

This Standards Requirements Package has the following main components:

- General introduction to the scope and intent of this package
- Message transaction sets
- Decomposition of the interfaces
- Communications Considerations
- Constraints
- Leveled Data Item definitions

The general introduction is self-explanatory, but the other items require some explanation. We will address them one at a time:

Message Transaction Sets: In order to accomplish a given activity, a series of messages usually have to be exchanged between two or more subsystems. These messages, as a group, constitute a message transaction set. The sequencing of the messages is shown via an ISO-style message sequence chart. Typically the physical architecture flow or highest level logical architecture data flows represent individual messages.

Interface Decomposition: This is the hierarchy of items that constitute an interface. It starts with the interface between two subsystems itself, which is then decomposed into physical architecture flows. Each of the physical architecture flows is then decomposed into a set of Leveled Architecture Flows. These sets of flows have been created in order to capture the essential information described by the National ITS Architecture on each Subsystem interface of interest. The Leveled Architecture Flows can be thought of as a simplified view of the logical architecture information, removing aggregation of data which does not add value to describing the essential information on the interface, and removing some of the lower level details in the existing data flows. These leveled architecture flows are traceable to flows in the logical architecture. The physical architecture data flows are labeled with the type of communications technology appropriate for that flow. Figure 1 shows an example of an interface decomposition. The leveled data items represent a simplification of the logical architecture information to focus on the essential data on each subsystem interface. They have been developed in order to provide traceability between the ITS standards being developed and the National ITS Architecture. Once a draft standard has been developed, the question that must be addressed is whether the standard addresses completely all elements of the National ITS Architecture interface. Due to the complex hierarchical nature of the Logical Architecture data flows, comparison with standards outputs is very difficult. By creating a simplified view of each interface, it is possible to more effectively trace the standards outputs to the National ITS Architecture.

Communications Considerations provides a discussion of the basic nature of the communications modalities that are suitable for supporting the interfaces in the particular standards requirements package. This section identifies some high level requirements, but the primary focus is to provide information that is viewed as useful to the initiation of the standardization process.

Constraints lists the architecture flows and any constraints placed upon them.

Leveled Data Items: This section provides a set of definitions for each of the leveled data elements included in the Interface Decomposition section. These definitions are simplified versions of the definitions contained in the Logical Architecture Data Dictionary, providing just the essential information to define the key elements of a subsystem interface.

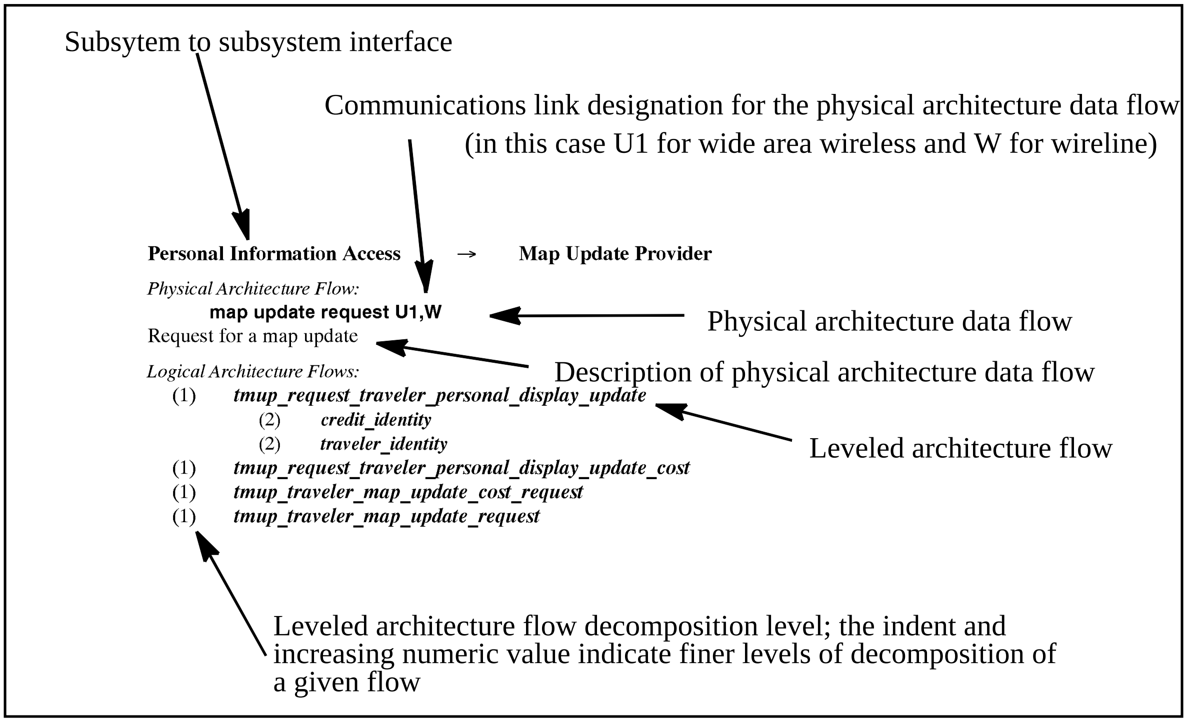

Figure 1 - Example of the parts of an interface decomposition

As a final clarification, it is useful to remind readers of the distinction between the layers in the ISO OSI communications reference model and the layers in the National ITS Architecture. For purposes of analysis and discussion, the National ITS Architecture has been portrayed as having three layers: *the transportation, the communications, and the institutional layer*. The first two are of concern here. The transportation layer contains all the functionality of the National ITS Architecture. As a consequence, any discussion of interfaces, messages, data dictionary entries, etc., is drawn from the information in the transportation layer. The communications layer describes the technology required to support the information exchange needs of the transportation layer. These National ITS Architecture layers can be roughly mapped to the ISO OSI reference model; the transportation layer is typically at or above the application layer and the communications layer is most often concerned with the lowest four layers of the ISO OSI reference model. The interested reader is directed to the Communications Analysis Document for a more substantial explanation of this relationship.

This explanation of the layers is offered here because the terminology can be confusing. Every effort has been made to clarify when the “layered model” is the National ITS Architecture and when it is the OSI reference model. In general, when the term “communications layer” is used in the Standards Requirements Document, it refers to the National ITS Architecture ”layer”.

2 Introduction to this Standards Package

This standards requirements package captures the requirements for providing traffic signal priority or signal preemption for transit and emergency vehicles. There are two distinct ways (which are both covered in this package) to handle this function. The more complex incorporates real time communications between the Transit Management Subsystem (TRMS) and the Traffic Management Subsystem (TMS) which would then handle the signal control. The simpler method involves using local Dedicated Short Range Communications (DSRC) based cycle modification. The advantage to the TMS controlled approach is that better strategies can be pursued that limit risks to other drivers and minimize disruption to overall traffic flow.

This package includes the data flows in the Emergency Vehicle (EVS)-Roadside (RS) and Transit Vehicle (TRVS)-RS interfaces to address the local DSRC based approach. To complete this part of the definition of the package, the RS-TMC interface is included to show the reporting of the receipt of the priority/preemption requests to the TMS.

Part of the definition of this package includes some of the data flows in the TMS-Emergency Management Subsystem (EM) and TMS-Transit Management Subsystem (TRMS) interfaces, specifically those associated with requesting and granting signal priority. Since Standards Requirements Package 9: Emergency Management Subsystem to Other Centers addresses the general TMC-EM interface (among others), standardization of this package should be coordinated with the standardization of that package.

The subsystems and the physical architecture data flows that are applicable to this standards package are shown in Figure 2.

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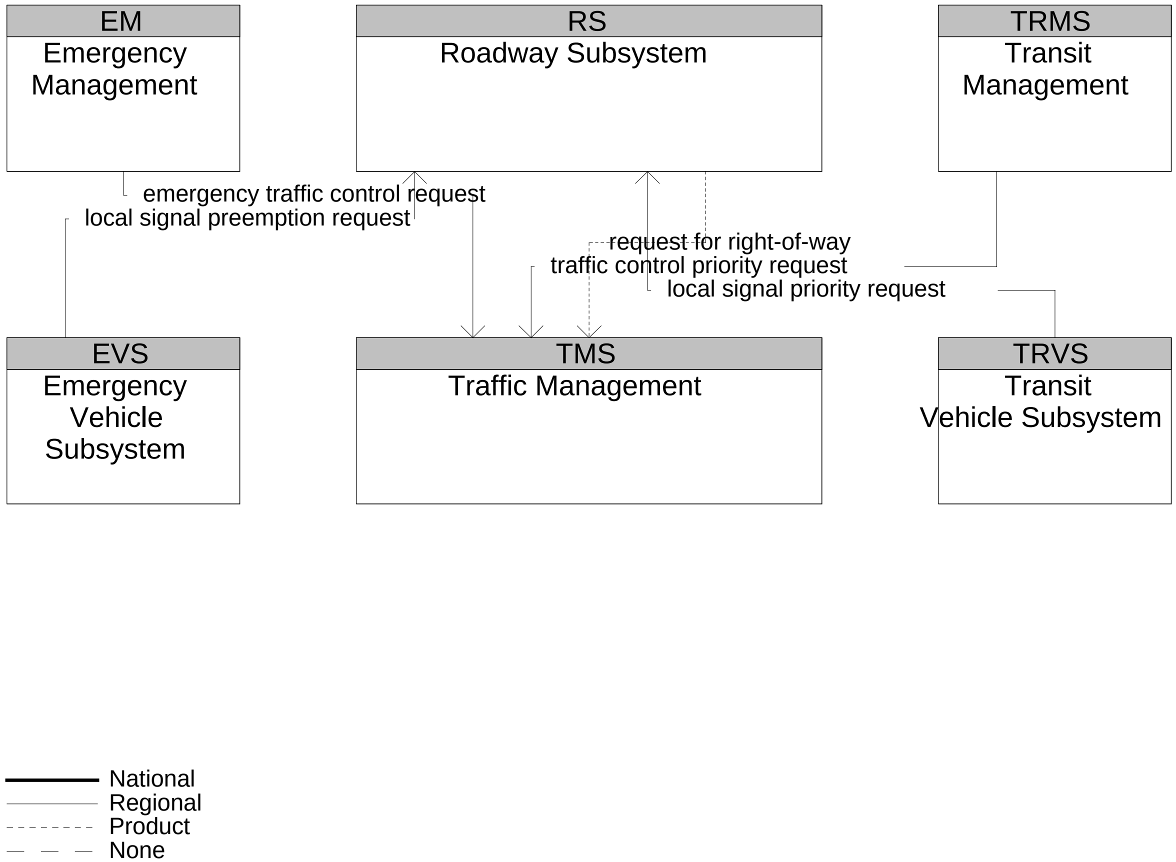

Figure 2 - Interfaces for Signal Priority for Transit and Emergency Vehicles

3 Transaction Sets for Signal Priority and Preemption for Transit and Emergency Vehicles

Based on the top level physical architecture data flows presented in the previous section, we can define the transaction sets needed to accomplish different ITS tasks. A message sequence chart format along the lines of those defined under ISO standardization is used for clarity of presentation. The emergency vehicle will typically request signal preemption: turning the phase green when the vehicle approaches the intersection (no matter what the phase should have been based on its cycle). The transit vehicle will typically request signal priority: extension of a green phase to allow the vehicle to pass through the intersection (the phase is not arbitrarily changed to allow passage of the vehicle).

3.1 Dedicated Short Range Communications (DSRC) Based Transactions

This first class of transactions addresses the case where the vehicle sends a request to roadside controllers to give the vehicle preemption or priority at a signal.

3.1.1 Emergency Vehicle Subsystem to Roadway Subsystem Interface

In this first signal preemption scenario the vehicle sends a request to the controller at the intersection it is approaching. The data is sent via a DSRC link, so communications with the intersection does not occur until the vehicle is within a few hundred feet of the intersection. Using this approach it is not possible for the vehicle to communicate with the intersection outside of the range of the DSRC link. The action that the intersection controller takes is not subject to any centralized coordination -- the intersection controller provides the preemption based upon a prearranged strategy. A status is sent from the roadside controller to the TMS to indicate that it is processing a preemption request (see Section 3.1.3.).

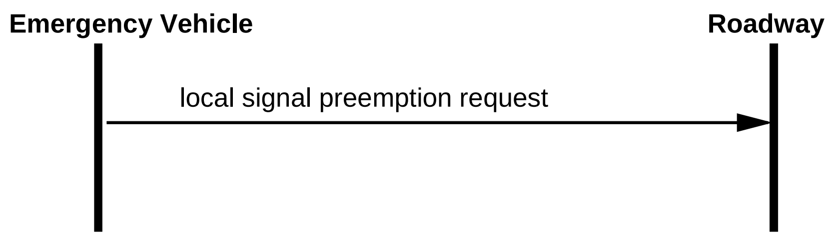

Figure 3 - Emergency Vehicle and Roadway Subsystem Transaction Set

3.1.2 Transit Vehicle Subsystem to Roadway Subsystem Interface

Similar to emergency vehicles, transit vehicles in the first signal priority scenario send a request to the controller at the intersection they are approaching. The data is sent via a DSRC link, so communication with the intersection does not occur until the vehicle is within a few hundred feet of the intersection. Using this approach it is not possible for the vehicle to communicate with the intersection outside of the range of the DSRC link. The action that the intersection controller takes is not subject to any centralized coordination -- the intersection controller provides the preemption based upon a prearranged strategy. A status is sent from the roadside controller to the TMS to indicate that it is processing a preemption request (see Section 3.1.3.).

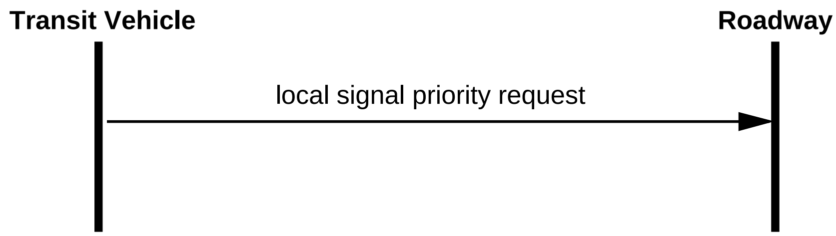

Figure 4 - Transit Vehicle and Roadway Subsystem Transaction Set

3.1.3 Roadway to TMS

As shown in Figure 5, the roadway controller units send a message to the TMS to inform the center that it is processing a priority or right-of-way request. This information will allow the TMS to (reactively) adjust its signal coordination strategy.

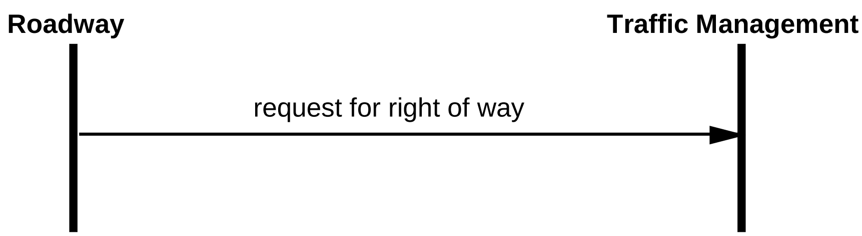

Figure 5 - Roadway and Traffic Management Subsystem Transaction Set

3.2 Center to TMS

This class of transactions addresses a more complex case where the Emergency Management Subsystem (EM) or Transit Management Subsystem (TRMS) have real time knowledge of the location of their vehicles and pass this information on to the TMS allowing signal preemption or priority to originate from the TMS.

3.2.1 Emergency Management Subsystem to TMS

Based on information about a particular emergency vehicle that is en route to an incident, the EM can send a request directly to the TMS for signal preemption and priority routing along the route. The emergency vehicle request message for emergency traffic control identifies each segment of a route that an emergency vehicle is expected to follow. The start time of the emergency vehicle route is identified, as well as the estimated arrival time at each segment. If the vehicle is en route then the timestamped location will also be sent. The TMS can then prepare a proactive strategy to give the emergency vehicle preemption signal service.

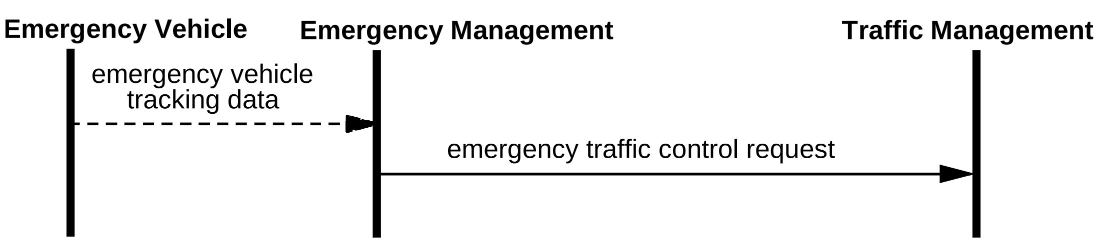

Figure 6 - Emergency Management and Traffic Management Subsystem Transaction Set

3.2.2 Transit Management Subsystem to TMS

Similar to emergency management, the TRMS can use information collected about the transit vehicles (location and timestamp) and send a request to the TMS for signal priority to be given to its vehicles. The TRMS would process the vehicle data to determine general transit vehicle priority as well as an individual transit vehicle priority (e.g., to assist an individual vehicle that is behind schedule to return to schedule). Transit Management sends the location, time, and route data to the TMS. The TMS analyzes the real-time routes chosen by emergency, transit, and other participating vehicles, determines an appropriate signal coordination strategy, and sends this to the Roadway Subsystem. The TMS also sends a signal priority status back to the TRMS to indicate the action it has taken.

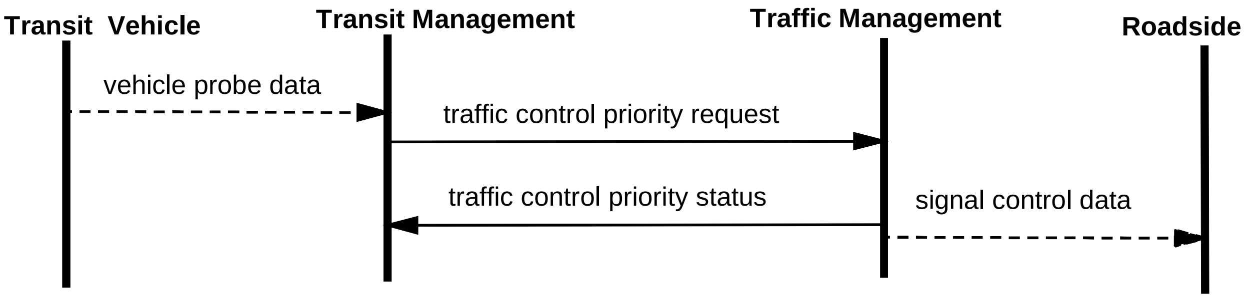

Figure 7 - Transit Management and Traffic Management Subsystem Transaction Set

4 Interface Decomposition

This section shows the interface decomposition for the interfaces covered in this package. The format shows the interface followed by the first physical architecture data flow in the interface and its description. Each of the physical architecture flows is then decomposed into its constituent leveled data items, which in turn are decomposed hierarchically into more basic leveled architecture flows. The leveled data items are numbered and indented to indicate which are top level flows (1) and which are constituent data flows (numbered 2 and lower). The description of the top level leveled data item is given. The full leveled data item definition for the top level flows and for all the constituent flows is given in Section 7. That section contains the leveled data item entries, listed in alphabetical order, for all of the leveled data items contained in this package. The leveled data items represent a simplification of the logical architecture information to focus on the essential data on each subsystem interface. They are traceable to the original logical architecture data elements, and have been developed in order to provide traceability between the ITS standards being developed and the National ITS Architecture. Once a draft standard has been developed the question that must be addressed is whether the standard completely addresses all elements of the National ITS Architecture interface. Due to the complex hierarchical nature of the Logical Architecture data flows, comparison with standards outputs is very difficult. By creating a simplified view of each interface, it is possible to more effectively trace the standards outputs to the National ITS Architecture.

4.1 Emergency Vehicle Subsystem -> Roadway Subsystem

Physical Architecture Flow: local signal preemption request U2
Direct control signal or message to a signalized intersection that results in preemption of the current control plan and grants right-of-way to the requesting vehicle.

Logical Architecture Flows:
(1) ***emergency_vehicle_junction_preemption***
This data item contains data necessary for an emergency services vehicle to be given preemption (priority) at an indicator that is particular set of junction control signals.

(1) ***emergency_vehicle_pedestrian_preemption***
This data item contains data necessary for an emergency services vehicle to be given preemption (priority) at an indicator that is particular set of pedestrian signals.

(1) ***emergency_vehicle_ramp_preemption***
This data item contains the data necessary for an emergency services vehicle to be given preemption (priority) at an indicator that is particular set of highway entry ramp control signals.

(1) ***emergency_vehicle_sign_preemption***
This data item contains data necessary for an emergency services vehicle to have a message output giving it preemption (priority) at an indicator that is a particular dynamic message sign (dms) or fixed message sign that has a transit priority message that can be displayed.

4.2 Transit Vehicle Subsystem -> Roadway Subsystem

Physical Architecture Flow: local signal priority request U2
Request from a vehicle to a signalized intersection for priority at that intersection.

Logical Architecture Flows:
(1) ***transit_vehicle_junction_preemption***

This data item contains data necessary for a transit vehicle to be given preemption (priority) at an indicator that is a particular set of junction control signals. The data item is sent directly from the transit vehicle to the junction controller, which is assumed to be capable of giving priority to the correct phase(s) for any received preemption request.

(1) ***transit_vehicle_pedestrian_preemption***
This data item contains data necessary for a transit vehicle to be given preemption (priority) at an indicator that is a particular set of pedestrian signals. The data item is sent directly from the transit vehicle to the pedestrian controller, which is assumed to be capable of giving priority to the correct phase.

(1) ***transit_vehicle_ramp_preemption***
This data item contains the data necessary for a transit vehicle to be given preemption (priority) at an indicator that is a particular set of highway entry ramp control signals. The data item is sent directly from the transit vehicle to the ramp controller, which is assumed to be capable of giving priority to the correct ramp or lane if multiple ramps or lanes are involved.

(1) ***transit_vehicle_sign_preemption***
This data item contains data necessary for a transit vehicle to have a message output giving it preemption (priority) at an indicator that is a particular dynamic message sign (dms) or fixed message sign that has a transit priority message that can be displayed. The data item is sent directly from the transit vehicle to the sign controller.

4.3 Emergency Management -> Traffic Management

Physical Architecture Flow: emergency traffic control request W
Special request to preempt the current traffic control strategy in effect at one or more signalized intersections or highway segments. For example, this flow can request all signals to red-flash, request a progression of traffic control preemptions along an emergency vehicle route, or request another special traffic control plan.

Logical Architecture Flows:
(1) ***emergency_traffic_control_request_list***
This data item contains a list of the route segments that have been provided for use by an emergency vehicle, together with the arrival time at each segment. The data will be used to generate changes to the current traffic management strategy to give the emergency vehicle priority.

(2) ***date***

(2) ***route_segment_estimated_arrival_time***

(2) ***route_segment_identity***

(2) ***time***

4.4 Roadway Subsystem -> Traffic Management

Physical Architecture Flow: request for right-of-way W
Forwarded request from signal prioritization, signal preemption, pedestrian call, multi-modal crossing activation, or other source for right-of-way.

Logical Architecture Flows:
(1) ***indicator_input_data_from_roads***
This data item contains the actual state of operation of the roadside and grade crossing indicators used to

pass instructions to drivers and travelers on roads (surface streets) within the geographic and/or jurisdictional area(s) served by the function. It is used for centralized monitoring the operation of the indicators.

(2) ***indicator_response_state***

(1) ***multimodal_crossing_sensor_data***
This data item contains the multimodal crossing data obtained from processing the other inputs from sensors around the road network.

(2) ***crossing_close_duration***

(2) ***crossing_close_time***

(2) ***crossing_identity_list***

(1) ***pedestrian_sensor_data***
This data item contains the pedestrian data obtained from processing the other inputs from sensors around the road network.

(2) ***node_identity_list***

(2) ***pedestrian_demand***

4.5 Transit Management -> Traffic Management

Physical Architecture Flow: traffic control priority request W
Request for signal priority at one or more intersections along a particular route.

Logical Architecture Flows:
(1) ***transit_highway_overall_priority***
This data item contains requests and information about the overall priority which should be given to one or more transit vehicles at all points in the freeway network served by the function, as opposed to priority requests from individual vehicles at specific locations. This priority will apply at an individual junction, or along a selected transit route if that is specified.

(1) ***transit_ramp_overall_priority***
This data item contains requests and information on the overall priority which should be given to one or more transit vehicles over a wide area as opposed to priority requests from individual vehicles at a particular set of ramp signals.

(1) ***transit_road_overall_priority***
This data item contains requests and information about the overall priority which should be given to one or more transit vehicles at all junctions and/or pedestrian crossings in the road network served by the function, as opposed to priority requests for individual vehicles at specific locations. As this is a 'blanket' application of priority, no list of indicators is needed.

4.6 Traffic Management -> Transit Management

Physical Architecture Flow: traffic control priority status W
Status of signal priority request functions at the roadside (e.g. enabled or disabled).

Logical Architecture Flows:

(1) ***transit_highway_priority_given***
This data item contains confirmation that the requested priority has been given to transit vehicles throughout the freeway network served by the function.

(1) ***transit_ramp_priority_given***
This data item contains confirmation that the overall priority request for one or more transit vehicles over the ramp signals in a wide area as opposed to priority requests from individual vehicles at a particular set of ramp signals has been given.

(1) ***transit_road_priority_given***
This data item contains confirmation that the requested priority has been given to transit vehicles throughout the road network served by the function.

5 Communications Layer Requirements

This chapter describes relevant requirements regarding the Communications Layer for the portion of the ITS National Architecture covered by this package. In general the Communications Layer supports the four lower layers of the OSI model (transport, network, data link, and physical layer). A complete description of the Communications Layer is contained in the ITS National Architecture Communications Analysis Document. In addition to actual requirements the section contains some informational notes which are included in brackets.

For this standards requirements package there are two relevant communication types: Wireless Dedicated Short Range Communications (DSRC) (u2) and Wireline communications (w). Wide Area Wireless (u1) communications is required for the emergency vehicle to EM (and transit vehicle to TRMS) in order to provide real time vehicle location, but these interfaces are not directly detailed in this package. The transit vehicle to TRMS interface is fully covered in Standards Package 11.

5.1 Communications Services: Wireline and Wireless

The communication services define the exchange of information between two points and are independent of media and application (i.e., ITS user service). In essence, they are a specified set of user-information transfer capabilities provided by the communication layer to a user in the transportation layer.

Communication services consist of two broad categories, *interactive* and *distribution*. Interactive services allow the user to exchange data with other users or providers in real or near real time, asking for service or information and receiving it in the time it takes to communicate or look up the information. Distribution services allow the user to send the same message to multiple other users.

Interactive services may be either ***conversational*** or ***messaging***. Conversational implies the use of a two-way connection established before information exchange begins and terminated when the exchange is completed. Messaging, on the other hand, works more like electronic mail being exchanged between users. The messages are exchanged without establishing a dedicated path between the two sites. Each message is addressed and placed on the network for transmission, intermixed with messages from other users. The communications community labels this mode of communication a “datagram” service.

Distribution services may be either ***broadcast*** or ***multicast*** and may be used over wireline and/or wireless communication links. Broadcast messages are those sent to all users while multicast messages are sent only to a subset of users. Multicast differs from broadcast in its use of a designated address for all users and user groups. Examples of broadcast information might include current weather or road conditions, whereas multicast information might be information sent to all drivers working for a specific company. A changing group membership could be the set of users traveling between two locations or with a certain destination, for which unique information must be transmitted. The services that can be supported using circuit or packet connection mode include voice, video, image, and data. (See Appendix A-1 of the communication document for a complete description.)

An additional class of communications services is location services. These fall into two categories: (1) the services that do not use the communication network (i.e., GPS, and stand alone terrestrial systems); (2) location services that use the network for providing the service (e.g., cellular based systems). In the latter case, the location services fall under the interactive services. The service will be rendered by a service provider in response to a request for information or help.

The class of communications service for each Architecture Flow in this standards package is defined in a table in the following section.

5.2 Wireline Communication Elements (w)

The wireline links represent wide area network communications elements, which can take a number of forms. Typically, it will be a data network of some kind. Physically the network can be fiber, coaxial, twisted pair, or even microwave. It can be an ITS dedicated network, such as a communications system installed by a public agency to pass messages between a Traffic Management subsystem and associated Roadway subsystems distributed across a region. Alternatively it can be a privately deployed network owned and operated by a communication service provider, where operators of ITS subsystems pay a service fee for connection to and use of the network or lease the lines. More than one network used for ITS may coexist in a region, and these networks will be connected (or internetworked) to support ITS message communication between subsystems that are attached to different networks.

It is expected that the current trend toward ubiquitous internetworking of public and private data networks, as currently embodied in the "Internet", for example, will continue. This will enable inter-subsystem messaging across local, regional, and national distances. What the Internet is rapidly evolving to (as security and reliability issues of today's Internet are addressed) has been referred to as the "National Information Infrastructure"or "NII".

In the near term, we expect that many communication elements will be dedicated, as they primarily are today. As commercial data networks are deployed, interconnected, and mature, and the cost of access and use of these private data networks drops, we expect more and more wireline networks for ITS to be supplied from Communication Service Providers (CSPs). The time when the transition from private data networks to commercial data networks becomes practical and economical will vary by region. We expect this transition to be analogous to the transition that was made early in this century from private phone networks to the Public Switched Telephone Network (PSTN). Our expectation is that in the 20-year time frame, most ITS communications will be provided by CSPs.

Table 1 shows the wireline architecture flows in this standards package.

Table 1. Wireline Data Flows (w) for Signal Priority

Source	Destination	Architecture Flow	Communication Service	Rationale and Critical Attributes
Emergency Management	Traffic Management	emergency traffic control request	Conversational data, conversational speech	Low delay bursty data or conversational speech
Roadway Subsystem	Traffic Management	request for right-of-way	Conversational data, Messaging data	Minimum delay in data communication for forward and reverse link may be required
Traffic Management	Transit Management	traffic control priority status	Conversational data, Messaging data	Minimum delay in data communication for forward and reverse link may be required
Transit Management	Traffic Management	traffic control priority request	Messaging data	

The primary requirements for the wireline communications layers include the utilization of open standards for the communications protocols. For the links to the TMS, the evolving ITS standard protocol is the National Transportation Communications for ITS Protocol (NTCIP). This standard is being developed for the transmission of data and messages between ITS elements. The initial version of the NTCIP is being developed to support the interface from the TMS to traffic controllers and DMS signs. Work is underway to extend this to other roadside equipment. Plans are also in place to extend the protocol for center to center communications. In the area of center to center communications there are several existing and developing communications standards to choose from. These include ATM, Frame Relay, MAN (IEEE 802.6), and FDDI. At the network layers, TCP/IP is a widespread standardized protocol. The key is that by using standard communication protocol suites the regional integration of the wireline data shown above will most readily be accomplished.

5.3 Wireless Communication Elements (u1 and u2)

All of the wireless communication links in this standards package consist of short range communications mobile to fixed, defined as u2 in the Communications Architecture. The u2 link is required to provide service between tetherless (or mobile) and close-proximity base stations, as occurs when a tetherless user communicates with a toll station for toll collection, a parking lot booth for fee collection, or the reception of information from roadside transmitters (roadside sign information). The primary use for this link is for rapid query-response interchanges and for local broadcast of information to nearby mobile users. The interchange must take place quickly as the vehicle will need the response for subsequent action. When used for two-way communications interference between users is reduced either by physical separation of users or by use of different frequencies within the same band. When the data flow is one directional, it is typically a broadcast function from the fixed station to the mobile user. The u2 link provides wireless communication between the mobile user and the stationary user, or in the reverse direction.

The Communication Layers for Dedicated Short Range Communications are strong candidates for standardization in order to achieve national interoperability. The DSRC links described above have the following requirements:

- High reliability: P (bit error) $<10^{-6}$ when vehicle is moving at speeds up to 200 km/h by a fixed roadside reader and with vehicle transponder separation of a minimum of 0.5 meters.
- High data rates [typically 300 - 600 Kbps].
- Two-way communication is a general requirement for DSRC, and the DSRC link should be able to support duplex communications. [Although there are some applications, e.g., in-vehicle signing, requiring only one way communications.]
- Utilize one frequency band for transmission and receipt of signals. (It is advantageous for national interoperability for all DSRC systems to be using the same basic frequency band, otherwise national interoperability can only be achieved by having readers that work at multiple frequency bands.) [Currently the band being utilized is 902-928 MHz. There is increasing interference from other non-ITS sources in this band, so a move to the 5.8 GHz band is being considered. A band very near this has already been specified in Europe for DSRC applications.]
- No network layer requirements -- only physical layer and data link layers are required. [There are some implementations of DSRC that utilize a network layer to achieve separation between adjacent beacons. The roadside beacons will be part of a network, but the beacon to vehicle link typically will not be.]
- Utilize an open communications protocol. [At the Data link layer this could be a High Level Data Link Control (HDLC) or a non-proprietary Time Division Multiple Access (TDMA) protocol.]

The architecture flows utilizing the u2 interface are given in Table 2.

Table 2. Short range Wireless Data Flows (u2) for Signal Priority

Source	Destination	Architecture Flow	Communication Service	Rationale and Critical Attributes
Emergency Vehicle Subsystem	Roadway Subsystem	Local signal preemption request	Conversational data	Short range bursty data communication while in motion, when passing by specific locations at speeds up to 200 km/h.
Transit Vehicle Subsystem	Roadway Subsystem	Local signal priority request	Conversational data	Data transfer while in motion, when passing by specific locations at speeds up to 200 km/h.

The communication layers for Dedicated Short Range Communications are strong candidates for standardization in order to achieve national interoperability. The DSRC links described above have the following requirements:

- High reliability: P (error) $<10^{-6}$ when vehicle is moving at up to 160 km/h by a fixed roadside reader.
- High data rates (typically greater than 300 Kbps).
- Two way communication is a general requirement for DSRC (although there are some applications requiring only one way communications).
- Utilize one frequency band for transmission and receipt of signals. (It is advantageous for national interoperability for all DSRC systems to be using the same basic frequency band, otherwise national interoperability can only be achieved by having readers that work at multiple frequency bands.) Currently the band being utilized is 902-928 MHz. There is increasing interference from other non-ITS sources in this band, so a move to the 5.8 GHz band is being considered. A band very near this has already been specified in Europe for DSRC applications.
- No network layer requirements -- only physical layer and data link layers are required. (There are some implementations of DSRC that utilize a network layer to achieve separation between adjacent beacons. The roadside beacons will be part of a network, but the beacon to vehicle link typically will not be.)
- Utilize an open communications protocol. At the Data link layer this could be a High Level Data Link Control (HDLC) or a non-proprietary Time Division Multiple Access (TDMA) protocol.

6 Constraints

This chapter identifies Physical Architecture intersubsystem message performance requirements below the application layer.

6.1 Assessment Categories

The following categories have been used in rating the constraints that exist on the physical data flows.

1. Performance

   a. Emergency Priority (E)

      Essentially ”real-time” requirements. Emergency data that is time critical must be received by a certain absolute time, or it is useless. For these flows, the communication channel may require priority in emergencies. The data channels required must be operational even when there is an emergency that might place other loads on the interface. A private communication channel or frequency may be required to satisfy the requirement.

   b. Reliability(R)

      This category encompasses both the concepts of reliability and availability. Data must be delivered reliably. Loss can not be tolerated. The communication link must also have high availability. Failure of the communication medium may result in severe accident. This communication channel may require redundant paths or extra attention paid to potential failure modes. For wireline cases, this may indicate alternate phone or other connections are required. For wireless cases (e.g., for AHS applications), special attention will be paid to the transmitters, receivers, and potential interference for these connections.

   c. Timing (T)

      The timing constraints are critical. If communication does not occur within set limits system failures can occur. Timing for most ITS communication services is based on the response to a request for data. Because of this, common communication media designed to handle voice data will likely support these requirements. The beacon interface has special requirements of identifying the vehicle as well as exchanging information before the vehicle gets out of range. This is more of a problem with vehicles traveling at speed. The architecture constrains such time critical access to data such that the data is available at the beacon site. This obviates the need for explicit specification of other timing information to support data transfer over a short range beacon.

      This timing constraint is related to (but not the same as) another attribute often discussed in specifying systems: latency. Latency is used to quantify end-to-end processing and transmission time (round trip delays). Data with a latency requirement must be handled within a certain time interval. This differs from ”time criticality” in that it is a relative rather than absolute time requirement (i.e., latency: interface screen must update every 2 seconds; time criticality: route instructions must be received 30 seconds prior to first turning action). Because latency requirements are greatly affected by the implementation of the subsystem elements, it cannot be specified directly when discussing only the interface between two subsystems.

2. Data Sensitivity

   a. Security (S)

Access to the data must be restricted. Data itself must be secure during transmission. This is typically used for financial information.

b. Privacy(P)

Anonymity of the data source or recipient must be protected. This is typically used for personal information.

6.2 Architecture Flow Constraints

Table 3. Architecture Flow Constraints

Source	Destination	Architecture Flow	Interconnects	Communication Service	Special Constraints
Emergency Management	Traffic Management	emergency traffic control request	W	Conversational data, conversational speech	E
Emergency Vehicle Subsystem	Roadway Subsystem	local signal preemption request	U2	Conversational data	T,E
Roadway Subsystem	Traffic Management	request for right-of-way	W	Conversational data, Messaging data	R
Transit Vehicle Subsystem	Roadway Subsystem	local signal priority request	U2	Conversational data	T

7 Data Dictionary Elements

This section contains the leveled data item (LDI) definitions for all the leveled data item elements listed in this standards requirements package.

The LDI's are given in alphabetical order.

crossing_close_duration

This data item contains the time duration for which a crossing must close to vehicular (roads and highway) traffic to permit the passage of the alternate item, e.g. railroad, river traffic, aircraft, etc. and is used to influence the control of signalized traffic intersections provided by the Provide Device Control facility.

crossing_close_time

This data item contains the time period before a crossing must close to vehicular (road and highway) traffic to permit the passage of the alternate item, e.g. railroad, river traffic, aircraft, etc. and is used to influence the control of signalized traffic intersections provided by the Provide Device Control facility.

crossing_identity_list

This data item contains a list of multimodal crossings to which the accompanying data applies.

date

This data item specifies a calendar date that is normally used to indicate currency or effectivity of other data.

emergency_traffic_control_request_list

This data item contains a list of the route segments that have been provided for use by an emergency vehicle, together with the arrival time at each segment. The data will be used to generate changes to the current traffic management strategy to give the emergency vehicle priority.

emergency_vehicle_junction_preemption

This data item contains data necessary for an emergency services vehicle to be given preemption (priority) at an indicator that is particular set of junction control signals.

emergency_vehicle_pedestrian_preemption

This data item contains data necessary for an emergency services vehicle to be given preemption (priority) at an indicator that is particular set of pedestrian signals.

emergency_vehicle_ramp_preemption

This data item contains the data necessary for an emergency services vehicle to be given preemption (priority) at an indicator that is particular set of highway entry ramp control signals.

emergency_vehicle_sign_preemption

This data item contains data necessary for an emergency services vehicle to have a message output giving it preemption (priority) at an indicator that is a particular dynamic message sign (dms) or fixed message sign that has a transit priority message that can be displayed.

indicator_input_data_from_roads

This data item contains the actual state of operation of the roadside and grade crossing indicators used to pass instructions to drivers and travelers on roads (surface streets) within the geographic and/orjurisdictional area(s) served by the function. It is used for centralized monitoring the operation of the indicators.

indicator_response_state

This data item contains the current state of an indicator that is being used to control traffic on the roads (surface streets) and highways. It is used to check that the indicator is performing as requested and may form the basis for a fault report if it is not.

multimodal_crossing_sensor_data

This data item contains the multimodal crossing data obtained from processing the other inputs from sensors around the road network.

node_identity_list

This data item contains a list of nodes for which data is being provided. These nodes will comprise all of those on both the road (surface street) and highway network served by the function.

pedestrian_demand

This data item contains processed pedestrian surveillance data obtained from sensors within the road (surface street) and highway network served by the TMC. The data is used to determine the traffic control strategy for signalized traffic intersections.

pedestrian_sensor_data

This data item contains the pedestrian data obtained from processing the other inputs from sensors around the road network.

route_segment_estimated_arrival_time

This data item contains the estimated time at which the route segment end point will be reached.

route_segment_identity

This data item identifies a route segment by name, location, or other standard location reference.

time

This data item contains the current time of day and will be associated with other data items and (possibly) a date.

transit_highway_overall_priority

This data item contains requests and information about the overall priority which should be given to one or more transit vehicles at all points in the freeway network served by the function, as opposed to priority requests from individual vehicles at specific locations. This priority will apply at an individual junction, or along a selected transit route if that is specified.

transit_highway_priority_given

This data item contains confirmation that the requested priority has been given to transit vehicles throughout the freeway network served by the function.

transit_ramp_overall_priority

This data item contains requests and information on the overall priority which should be given to one or more transit vehicles over a wide area as opposed to priority requests from individual vehicles at a particular set of ramp signals.

transit_ramp_priority_given

This data item contains confirmation that the overall priority request for one or more transit vehicles over the ramp signals in a wide area as opposed to priority requests from individual vehicles at a particular set of ramp signals has been given.

transit_road_overall_priority

This data item contains requests and information about the overall priority which should be given to one or more transit vehicles at all junctions and/or pedestrian crossings in the road network served by the function, as opposed to priority requests for individual vehicles at specific locations. As this is a 'blanket' application of priority, no list of indicators is needed.

transit_road_priority_given

This data item contains confirmation that the requested priority has been given to transit vehicles throughout the road network served by the function.

transit_vehicle_junction_preemption

This data item contains data necessary for a transit vehicle to be given preemption (priority) at an indicator that is a particular set of junction control signals. The data item is sent directly from the transit vehicle to the junction controller, which is assumed to be capable of giving priority to the correct phase(s) for any received preemption request.

transit_vehicle_pedestrian_preemption

This data item contains data necessary for a transit vehicle to be given preemption (priority) at an indicator that is a particular set of pedestrian signals. The data item is sent directly from the transit vehicle to the pedestrian controller, which is assumed to be capable of giving priority to the correct phase.

transit_vehicle_ramp_preemption

This data item contains the data necessary for a transit vehicle to be given preemption (priority) at an indicator that is a particular set of highway entry ramp control signals. The data item is sent directly from the transit vehicle to the ramp controller, which is assumed to be capable of giving priority to the correct ramp or lane if multiple ramps or lanes are involved.

transit_vehicle_sign_preemption

This data item contains data necessary for a transit vehicle to have a message output giving it preemption (priority) at an indicator that is a particular dynamic message sign (dms) or fixed message sign that has a transit priority message that can be displayed. The data item is sent directly from the transit vehicle to the sign controller.