Vehicle-to-Infrastructure (V2I)

Message Lexicon

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16. Abstract

To help with Vehicle-to-Infrastructure (V2I) deployments, a V2I Message Lexicon was developed that explains the relationships and concepts for V2I messages and identifies the ITS standards where they may be found. This lexicon document provides a brief history and background for connected vehicle (CV) and infrastructure-focused standards that relate to CV V2I applications, and explain the construction of V2I messages using current communications standards. Additional information is provided to help understand concepts and activities that are related to V2I messages and briefly review recent and forthcoming standards that support CV applications.

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Vehicle-to-Infrastructure (V2I) Message Lexicon

Introduction

To help with deployments a lexicon was developed that explains the relationships and concepts for V2I messages and identifies the ITS standards where they may be found. A lexicon defines the vocabulary of a subject[1]. In short, it defines the concepts and definitions used by that subject so all involved will understand how to interpret said subject. A V2I Message Lexicon is therefore a collection of concepts and definitions for V2I messages.

This section identifies the contents of a V2I message, how the message is constructed, how the message relates to applications, how the message is packaged for the DSRC protocol, and how the message relates to deployments.

What the V2I Message Lexicon Consists of

There are a series of ITS Standards that define the connected vehicle (CV) interface to other vehicles, personal devices and the infrastructure. Figure 1 shows the relationships between the connected vehicle standards, the infrastructure standards, and the version history of connected vehicle standards that led up to where we are today. The "Current & Future" dotted line box represents standards available for connected vehicle implementations. The complete set of CV standards and the latest available versions of these standards can be found at www.standards.its.dot.gov/LearnAboutStandards/ResearchInitiatives. Prior standards' versions are out of date and not backward compatible. Figure 1 is divided into two main standards areas. The top area is CV standards. The bottom area shows infrastructure-focused standards that are related to the CV V2I applications. The CV standards show up on the right-hand side of the figure. The historical documents that contributed to these standards are shown on the left. "Current & Future" standards are either published or being developed now, and will continue to be developed as applications are defined. The application centric standards, known as the SAE J2945/x family and ISO TS 19091, focus on how the interfaces will support one or more applications. These standards define the operational concepts, functional and performance requirements, dialogs (also known as message exchanges), and identify the necessary message elements required by the application(s) to function correctly. Since multiple applications may use one or more messages, the SAE J2735 standard (Dedicated Short Range Communications (DSRC) Message Set Dictionary) is a data dictionary and

[1] Merriam-Webster's Collegiate Dictionary, Tenth Edition, 1993, page 669

only defines message contents. This allows selected messages (BSM[2], SPaT[3], MAP[4], SSM[5], SRM[6], etc.) to be sent and used by more than one application. Currently, the SAE J2945/x family consists of a Dedicated Short Range Communication (DSRC) Systems Engineering Process Guidance for J2945/x Documents and Common Design Concepts standard (SAE J2945/0), On-board System Requirements for V2V Safety Communications standard (SAE J2945/1) and Dedicated Short Range Communications (DSRC) Performance Requirements for V2V Safety Awareness (SAE J2945/2), V2I related standards and profiles (SAE J2945/TBD), and Vulnerable Road User Safety Message Minimum Performance Requirements (SAE J2945/9). The global use standard (SAE J2945/0) contains concepts and standardized solutions that are used by more than one SAE J2945/x standard and is generic in nature. Specifics required to support specific V2I applications are defined in associated V2I J2945/x or the ISO TS 19091 standards. The Intelligent Transport Systems — Cooperative ITS — Using V2I and I2V Communications for Applications Related to Signalized Intersections (ISO TS 19091) standard supports V2I applications dealing with signalized and non-signalized intersections and should be strongly considered for use since it contains standardized solutions specific to US operations.

Figure 1 also identifies that there are multiple protocols that can be used by the SAE J2945/x standards to accomplish their purposes. The cellular protocols are currently defined by the 3G Partnership Project (3GPP) telecom industry standards. The Dedicated Short Range Communications (DSRC) are defined in the IEEE 1609[7] series and IEEE 802.11[8] standards.

The IEEE 1609 family of standards is a series of standards that define how the DSRC protocol works and how security is to be used. A set of clarification notes have been recently published for IEEE 1609.2 and these notes will be incorporated into IEEE 1609.2 at a later date. The SAE J2945/x standards identify the protocols and media to be used to implement a specific application. In short, the SAE J2945/x and ISO TS 19091 standards define how interfaces are used to meet national interoperability requirements. As described above, the SAE J2945/x, and ISO TS 19091 standards define how an interface works for one or more application while the SAE J2735 standard defines the messages used by the SAE J2945/x and ISO TS 19091 standards.

The current development status for ITS standards is provided at https://www.standards.its.dot.gov/StdsSummary.

The infrastructure standards that relate to the CV environment are the NTCIP 1202 Actuated Signal Controllers, NTCIP 1204 Environmental Sensor Systems, NTCIP 1211 Signal Prioritization, and the NTCIP 1213 Electrical and Lighting Management standards[9]. Other NTCIP standards (e.g. NTCIP 1209 Transportation Sensor Systems, NTCIP 1210 Signal System Masters, etc.) may also be appropriate depending on the types of information needed by a specific V2I application. The

[2] Basic Safety Message, SAE J2735-201603
[3] Signal Phase and Timing, SAE J2735-201603
[4] SAE J2735-201603
[5] Signal Status Message, SAE J2735-201603
[6] Signal Request Message, SAE J2735-201603
[7] http://standards.ieee.org/findstds/standard/1609.0-2013.html
[8] http://standards.ieee.org/about/get/802/802.11.html
[9] http://www.ntcip.org/library/documents/

infrastructure already uses these standards to control signalized intersections, grant prioritization for transit vehicles, determine when to dim or brighten street lighting, and to determine road and weather conditions that affect driving. In order to reduce the possibility for misinterpretation, the same definitions defined in the NTCIP standards are used in the SAE J2735 data dictionary.

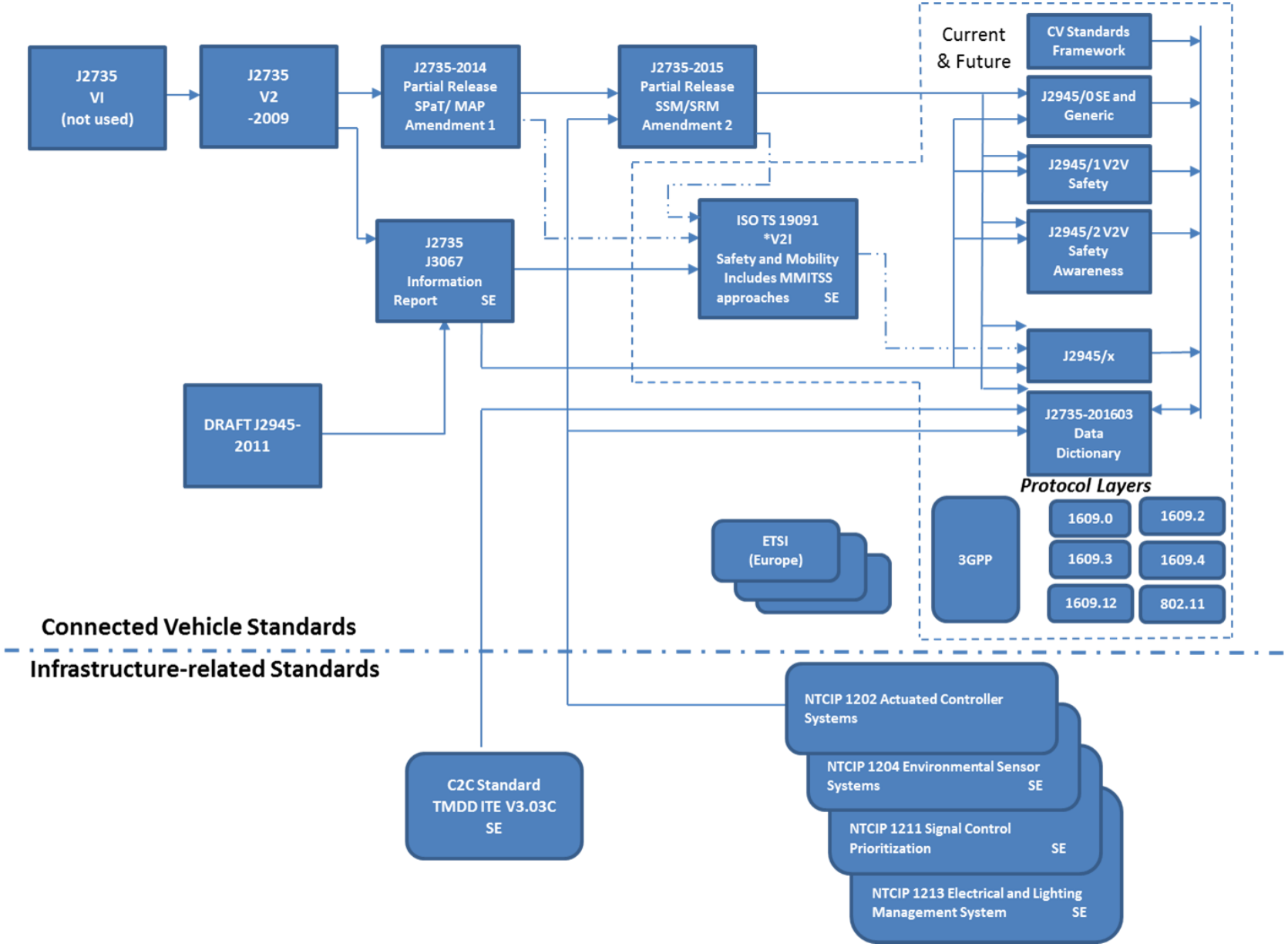


Figure 1: Framework of Connected Vehicle Standards

Source: USDOT

How V2I Messages Are Constructed

V2I message packets follow the pattern shown in Figure 2. The frame is constructed in four steps and each step provides a new frame that contains the frame from the previous step. The diagram shows where the V2I message content, related to a specific application, occurs within the transmitted DSRC frame. The first frame (WSMP Frame) contains the BSM, SPaT, MAP, or other application related messages and provides the necessary control information to process the application related message (how long the message is, what type of message it is, etc.). The application related message is contained in the "WSM Data" part of the WSMP Frame.

The WAVE Short Messaging Protocol (WSMP) Frame is then placed in the "LLC Data" part of the Logical Link Control (LLC) Frame. The purpose of the LLC Frame is to ensure data integrity and the V2I message is the payload in this frame (information field).

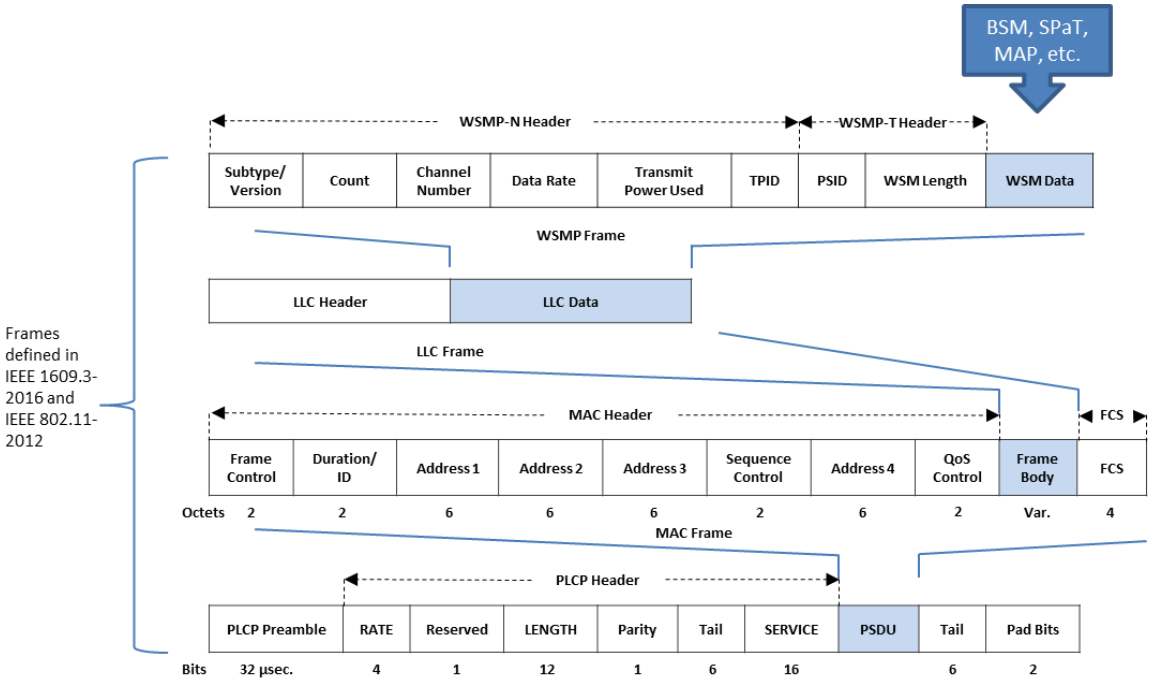
The LLC Frame is placed in the "Frame Body" part of the MAC Frame. The media access control (MAC) Frame provides the addressing information for the message (similar to an address on an envelope) and any special delivery controls.

The MAC Frame is placed in the "PSDU" part of the Physical Layer (PHY) Frame. The purpose of the PHY Frame is to ensure the whole message is delivered correctly over the medium being used (e.g., 5.9 GHz as defined in IEEE 802.11). Once the PHY Frame is completed, the frame is ready for transmission over the air. Please note that if a message is quite large, it can be broken up across multiple frames.

Think of the above frames as control steps needed to get a message to a destination. Similar to the delivery steps for a registered letter, each step is necessary to ensure the letter (or message) arrives at the correct destination on time and with all of its contents. In addition, the above steps control the notification of others that an error occurred in sending the letter (or message) so the sender can decide what to do about it (for those messages that are transaction based). For broadcast messages the message is sent out without any way to acknowledge that someone received it. Both transaction and broadcast message dialogs will be used in different V2I applications.

DSRC has security services for application and management messages as defined in IEEE 1609.2-2016. The primary purpose of the security services is to provide authentication and mitigate threats. Encryption is also available to provide for confidentiality and data integrity.

Trusted certificates are used to authorize a device to work in the system. At the application level, additional security can be added to ensure that only those authorized can use the actual application data. Applications can specify the security method used within the application. Although the operational concepts are defined in IEEE 1609.0 and 1609.2 the actual system is still under definition.



Source: Modified from IEEE 1609.3 and IEEE 802.11

Figure 2: V2I Message Construction

The process to construct and deconstruct a packet, sent between two devices or entities, is shown in Figure 3. The construction (see left-hand side of Figure 3) and deconstruction (see right-hand side of Figure 3) process follows the frame structure of the packet. The transmitted packet consists of all four frames. The applications mostly deal with the first frame (WSMP) at both ends. The contents of the message type (BSM, SPaT, MAP, etc.) are used by the application to enact or control a given operation. For example: a BSM sent by a vehicle can be used by the Basic Local Traffic Signal Actuation application to sense the demand on specific lanes at an intersection. Note that messages are defined in the SAE J2735 standard and what parts of the message are necessary to support a given application are being defined in the SAE J2945/x series of standards. Please note that the SAE J2735 standard specifies that Unaligned Packed Encoding Rules (UPER) encoding is to be used.

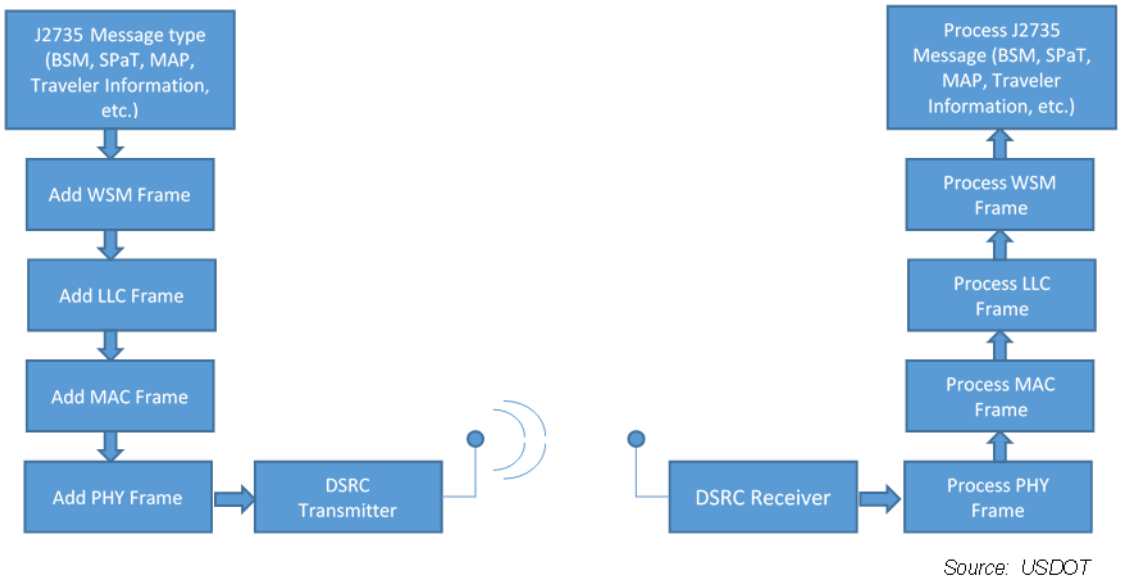


Figure 3: DSRC Message Construction/Deconstruction Process

How V2I Messages Relate to Deployments

Ultimately, V2I messages are used to convey information between vehicles and the infrastructure. To accomplish this, the following deployment activities and concepts (see Table 1) relate to the use of V2I messages:

Table 1: V2I Message-Related Deployment Activities and Concepts

Activity/Concept	Relationship to V2I Messages	Additional Information
Relationship to the Connected Vehicle Reference Implementation Architecture (CVRIA)[10]	The CVRIA reflects communications needed to support V2I applications deployed between the vehicle and the infrastructure. The CVRIA identifies the type of interfaces required to implement information flows between vehicles and infrastructure, between the infrastructure and back office, and between any other combination of communicating entities necessary to implement an application.	Information flows are related to the type of V2I messages to be used. Deployers will use interfaces, defined in the CVRIA, needed to support the V2I operational needs defined in the Concept Life-Cycle Stage.

[10] http://www.iteris.com/cvria/

Activity/Concept	Relationship to V2I Messages	Additional Information
Regional Architecture	The National ITS Architecture depicts the infrastructure communications needed to support V2I applications. The National ITS Architecture will also specify the type of interfaces used by the infrastructure to collect and disseminate data in support of the V2I applications to be deployed.	Deployers will develop a regional architecture that reflects both the CV operations and infrastructure operations the applications require. Often this regional architecture is existent and need only be modified to reflect the deployment. Development of a regional architecture can use the Turbo Architecture tool.
Project Architecture	The project architecture reflects the goals of operations specific to a particular project/deployment applications. The project architecture will be focused on the applications to be deployed, and provide the level of specificity necessary to document a concept of operations inclusive of all project applications.	Deployers will develop a local architecture that reflects both the CV operations and infrastructure operations the applications require. Development of a project architecture can use the SET-IT tool.
Applications to be Implemented	The type of applications determine the V2I messages used in the system.	Deployers use the J2945/x or ISO TS 19091 standards to specify which parts of the required V2I messages will be used to support an application. All the rules for their use are to be provided in the J2945/x or ISO TS 19091 standards.

Activity/Concept	Relationship to V2I Messages	Additional Information
Certification Testing	Before a device can be used in the CV system, it must be authorized to receive security certificates from the Security Credential Management System (SCMS). Authorization only comes after the device has passed a series of certification tests designed to verify the capabilities said device claims to support (standards conformance testing).	The USDOT certification testing program will be applicable for testing of mobile devices (portable and fixed), vehicles, and road-side equipment used for V2I applications. USDOT certification testing will eventually lead to independent certification testing and will be managed by industry organizations.
Obtaining Security Certificates and the SCMS	The security certificates are needed to verify V2I and I2V messages. A device/system, for a given make and model, will not have access to security certificates from the SCMS until after said device/system has been certified by the appropriate industry organizations authorized to certify. The SCMS will also provide the certificate revocation lists for those devices/systems that are no longer allowed to work on the network.	USDOT is working with industry to develop the SCMS to issue security certificates.
USDOT Professional Capacity Building (PCB) Program	Courses are being developed by USDOT's PCB program to help deployers of V2I applications understand how to deploy in a consistent way. In addition, courses are being developed by the Certification Testing Program to be used by certification organizations to help local agencies, device manufacturers, and vehicle manufacturers understand how their equipment and will be certified.	Introductory courses are being developed now.

Which V2I messages are related to which applications are still being developed as are some of the messages. Table 2 shows a list of V2I applications as currently defined in the CVRIA. Please note that CVRIA is not the only source identifying applications (e.g. SAE Framework Paper, TC204 documents, etc.). Consequently, there are differences in the application names and definitions. It is anticipated that the merged CVRIA/National ITS Architecture will eventually contain the master set of applications and their descriptions.

Table 2: V2I Applications

Agency Data Applications	Environmental	Mobility
• Probe-based Pavement Maintenance • Probe-enabled Traffic Monitoring • Vehicle Classification-based Traffic Studies • CV-enabled Turning Movement & Intersection Analysis • CV-enabled Origin-Destination Studies • Work Zone Traveler Information	• Eco-Approach and Departure at Signalized Intersections • Eco-Traffic Signal Timing • Eco-Traffic Signal Priority • Connected Eco-Driving • Eco-Lanes Management • Eco-Speed Harmonization • Eco-Cooperative Adaptive Cruise Control • Eco-Multimodal Real-Time Traveler Information • Eco-Ramp Metering • Low Emissions Zone Management • Eco-Smart Parking • Dynamic Eco-Routing (light vehicle, transit, freight) • Eco-ICM Decision Support System • Roadside Lighting • Electronic Charging Station Management	• Advanced Traveler Information System • Intelligent Traffic Signal System • Transit Signal Priority • Freight Signal Priority • Mobile Pedestrian • Emergency Vehicle Preemption • Speed Harmonization • Queue Warning • Cooperative Adaptive Cruise Control • Incident Scene Pre-Arrival Staging Guidance for Emergency Responders • Incident Scene Work Zone Alerts for Drivers and Workers • Emergency Communications and Evacuation • Transit Connection Protection • Dynamic Ridesharing • Dynamic Transit Operations • Integrated Multimodal Electronic Payment • Intermittent Bus Lanes • Route ID for the Visually Impaired • Smart Park and Ride System • Transit Stop Request • Receive Parking Availability and Service Information • Traveler Information – Smart Parking

Road Weather	Transit Safety	V2I Safety
• Road-Weather Advisories and Warnings for Motorist • Enhanced MDSS • Weather Response Traffic Information • Road-Weather Information for Freight Carriers • Road-Weather Management for Maintenance Systems • Variable Speed Limits for Weather Responsive Traffic Management	• Transit Pedestrian Indication • Transit Vehicle at Station/Stop Warnings • Vehicle Turn Right in Front of a Transit vehicle	• Curve Speed Warning • Oversize Vehicle Warning • Pedestrian in Signalized Crosswalk Warning • Railroad Crossing Warning • Red Light Violation Warning • Reduced Speed Zone Warning • Stop Sign Gap Assistance • Stop Sign Violation Warning • Warning about Hazards in a Work Zone • Warning about Upcoming Work Zone

The list of applications above may also relate to specific service packages in the National ITS Architecture and the CVRIA.

A list is provided of the CV Applications that are currently supported by existing ITS Standards and documentation (see Annex A or https://www.standards.its.dot.gov/LearnAboutStandards/CV_apps). The following issues should be considered as an agency considers implementing V2I applications. USDOT is supporting the development of ITS standards and early deployments.

- Is the application and its interfaces clearly defined in respective standards so it can be implemented consistently by the agency, system integrators, vehicle manufacturers and device manufacturers?
- How will the certification testing support the deployment of an application?
- How can I get security certificates for a device/system model and version that has successfully passed all certification testing required by the application?
- Is a life-cycle defined for the implementation and maintenance of the CV system that includes a clear systems engineering process that:
    - Defines the operations the agency plans to deploy;
    - Provides a clear architecture to guide the deployment;
    - Utilizes traceability and verification methods to validate that user needs are being satisfied by system requirements, design contents are fulfilling the requirements, and testing is robust enough to ensure the system being deployed will satisfy the agencies user needs; and
    - Develop a test plan that defines how the infrastructure system will be verified and certified for use with other CV equipment.

Summary

The above described process has been designed to accommodate the wide variety of uses for V2I communications. This wide scope of prospective uses makes the process of deploying V2I communications more complex. It should also be noted that V2I communications are media independent as presented. However, the media used is dependent upon the performance and scalability requirements for the applications. In order to support national interoperability, each region and jurisdiction must deploy interfaces that operate the same way for a given application to ensure interoperability. Use of systems engineering methods will greatly help to achieve national interoperability one region or jurisdiction at a time.

Annex A – Connected Vehicle Applications Supported by ITS Standards (as of 6/30/2016)

The following applications (Table 3) are currently supported by the indicated standards (either in ballot or soon to be in ballot). Note that the communications protocol stack standards (e.g. IEEE 802.11 and 1609.x or 3GPP were purposely not included in this list). Also note that some of the applications are not DSRC dependent and could be implemented with other media (e.g. 3GPP protocols).

Table 3: Supporting Standards for V2I Applications

Title	Short Description & Goal	Standard
PR1: Localized Public Transport Signal Priority (TSP)	This use case describes the basic priority control for connected Public Transport vehicles. The goal is to improved Public Transport efficiency and reliability.	ISO TS 19091
PR1-a: Localized Transit Signal Priority – Near Side Stop	This use case describes the basic priority control for connected Public Transport vehicles for near side stops. The goal is to improved Public Transport efficiency and reliability.	ISO TS 19091
PR2: Public Transport Signal Priority along an arterial (group of intersections)	This use case describes the basic priority control for a connected Public Transport vehicle travelling through a section of signalized intersections. The goal is to improved Public Transport efficiency and reliability.	ISO TS 19091
PR3: Localized Freight Signal Priority	This use case describes the basic priority control for connected heavy vehicles. The goal is to improve freight movement efficiency and reliability.	ISO TS 19091
PR3-a: Localized Freight Signal Priority with a Platoon	This use case describes the basic priority control for a connected heavy vehicle platoon. The goal is to improve freight movement efficiency and reliability.	ISO TS 19091

Title	Short Description & Goal	Standard
PR3-b: Arterial Freight Signal Priority for a Platoon	This use case describes the basic priority control for a connected freight platoon travelling through a section of signalized intersections. The goal is to improve freight movement efficiency and reliability.	ISO TS 19091
PR4: Emergency Vehicle Single or Multiple Vehicles (normal power public service on board equipment (PSOBE))	This use case describes the basic emergency vehicle preemption control for connected emergency response vehicles (Police, fire, ambulance, etc.). The nature of those vehicles permitted to make such requests will depend on the region and local laws. Note that this use case does not deal with the vehicle based applications that warn the driver to take appropriate action to avoid the approaching (rear, front, side) emergency vehicle. The goal is to improve emergency response efficiency and reliability.	ISO TS 19091
PR5: Emergency Vehicle Single or Multiple Vehicles (high power PSOBE)	This use case differs from the previous use case because it is based on the concept of a one-way broadcast to the intersection – such that the intersection is likely to "hear" the SRM before the vehicle (OBE) can hear the intersection SPaT message. It is anticipated that if the high power PSOBE is supported for such vehicles (Police, fire, ambulance, etc.) the intersection can receive advance warning of the approaching vehicle and take the appropriate steps to facilitate movement through the intersection based on a specific scenario(s). The nature of those vehicles permitted to make such requests will depend on the region and local laws. Note that this use case does not deal with the vehicle based applications that warn the driver to take appropriate action to avoid the approaching (rear, front, side) emergency vehicle. The goal is to improve emergency response efficiency and reliability.	ISO TS 19091
PR6: Mixed Emergency Vehicle and Other Priority Eligible Vehicles	This use case describes multiple priority requesting vehicles including an emergency vehicle and a platoon of public transport vehicles. The nature of those vehicles permitted to make such requests will depend on the region and local laws. The goal is Improved priority granting efficiency and reliability.	ISO TS 19091

Title	Short Description & Goal	Standard
SA1: Dilemma Zone Protection	This use case describes detection of equipped vehicles approaching a traffic signal that, upon onset of yellow, may find it challenging to either stop before the stop bar or continue through the intersection before the signal turns red. Vehicles in this situation are termed dilemma zone vehicles though their actual location may vary. The goal is to detect potential dilemma zone vehicles and pass information to the signal controller to minimize occurrences.	ISO TS 19091
SA2: Red Light Violation Warning	This use case describes provision of signal timing information to approaching vehicles to help prevent red light violations. Roadside equipment sends MAP and SPaT messages in real-time to approaching vehicles, which utilize the information to notify driver of the need to stop to avoid potential red light violation.	ISO TS 19091
SA3: Stop Sign Violation Warning	This use case describes provision of stop sign location information to approaching vehicles to help prevent stop sign violations (running). Roadside equipment sends MAP and SPaT messages to vehicles, which utilize the information to notify a driver of the need to stop to avoid running stop sign.	ISO TS 19091
SA4: Turning Assistant – Oncoming Traffic	This use case describes the provision of information on approaching oncoming traffic to vehicle(s) waiting to turn at a signalized intersection. Roadside equipment sends MAP, SPaT, and Sensor information to a vehicle waiting to turn across oncoming traffic to warn its driver of potential conflicts.	ISO TS 19091
SA5: Turning Assistant – Vulnerable Road User Avoidance	This use case describes provision of information on vulnerable road users (e.g., cyclists, pedestrians) to turning traffic at a signalized intersection. Roadside equipment sends MAP, SPaT, and Sensor information to a vehicle about to turn to warn its driver of potential conflicts with vulnerable road users.	ISO TS 19091

Title	Short Description & Goal	Standard
SA6: Non-signalized Crossing Traffic Warning	This use case describes provision of information on cross traffic at a non-signalized intersection. Roadside equipment sends MAP and sensor information (position, movement from OBE-equipped vehicles or roadside sensors) to vehicle. The information provided includes trajectory of crossing traffic to prevent potential crossing path crashes.	ISO TS 19091
SA7: Crossing Vulnerable Road User Advisory (Non-signalized)	This use case describes provision of information on vulnerable road users (e.g. cyclists, pedestrians) to traffic at a non-signalized intersection. Roadside equipment sends MAP, SPaT, and Sensor information to a vehicle that is approaching a pedestrian/vulnerable road user crossing, at a non-signalized intersection, in order to warn the driver of potential conflicts with pedestrian/vulnerable road users.	ISO TS 19091
MS1: Basic Local Traffic Signal Actuation	This use case describes basic real-time traffic signal actuation by connected vehicles in the vicinity of a single intersection. Roadside equipment utilizes real-time information on the motion and specific characteristics of approaching vehicles to provide more precise demand information to the local traffic signal controller, thereby increasing efficiency and reducing emissions for the intersection.	ISO TS 19091
MS2: Platoon Detection for Coordinated Signals	This use case describes provision of vehicle platoon characteristics to facilitate real-time arterial-level traffic signal timing adjustments. This case only targets timing optimization (i.e. does not send directions to drivers). Roadside equipment relays vehicle platoon information to BOPC [Back Office Processing Centre (a.k.a. Traffic Management Centre)] which uses information to dynamically adjust signal timing offsets.	ISO TS 19091
MS3: Congested Intersection Adjustment	This use case describes detection of persistent traffic signal phase failures on one or more maneuvers and executing mitigating adjustments to traffic signal plans at the intersection(s). Multi-intersection adjustments involve a BOPC. The objective is to reduce impacts of phase failures at a congested intersection by utilizing adjustments to traffic signal timing based on mitigation strategies.	ISO TS 19091

Title	Short Description & Goal	Standard
MS4: Traffic Signal Optimal Speed Advisory	This use case describes provision of traffic signal information to approaching vehicles to enable speed adjustment, and lane switching, to optimize vehicle trajectory for smooth operation of the vehicle. Roadside equipment sends MAP and SPaT in real-time to approaching vehicles, which utilize the information to notify driver of optimal speed to smoothly stop or traverse the intersection.	ISO TS 19091
MS5: Signalized Corridor Eco-Driving Speed Guidance	This use case describes the provision of traffic signal information to approaching vehicles to enable speed and lane adjustments to optimize vehicle trajectory for improved fuel efficiency in a corridor. Roadside equipment sends MAP and SPaT messages in real-time to approaching vehicles, which utilize the information to notify vehicles of optimal speed and lane use to smoothly stop or traverse the intersection using less fuel	ISO TS 19091
MS6: Idling Stop Support	This use case describes provision of traffic signal timing information to vehicles stopped at a signal to enable engine shutoff. Roadside equipment sends MAP and SPaT messages in real-time to vehicles stopped at the intersection to enable drivers/vehicles to turn off engines while idling (stopped).	ISO TS 19091
MS7: Start Delay Prevention	This use case describes provision of traffic signal timing information to vehicles stopped at a signal to enable efficient resumption of flow. Roadside equipment sends MAP and SPaT messages in real-time to vehicles stopped at the intersection to enable drivers/vehicles to prepare for startup efficiently.	ISO TS 19091
MS9: Inductive Charging at Signals	This use case describes provision of inductive charging information to vehicles stopped at a signal. Actual charging transaction and technology is outside the scope. Roadside equipment sends MAP and SPaT messages in real-time to vehicles stopped at the intersection to enables vehicles to establish temporary charging.	ISO TS 19091

Title	Short Description & Goal	Standard
MS10: Don't Block the Box	This use case describes OBE equipped vehicles determining whether they can enter and clear an intersection or stopping until they can enter and clear. Roadside equipment sends MAP and SPaT messages in real-time to vehicles approaching the intersection to enable vehicles to determine whether to enter the intersection or to wait.	ISO TS 19091
Emergency Electronic Brake Lights (EEBL)	The EEBL safety application warns the driver of the host vehicle (HV) in the case of a hard-braking event by a remote vehicle (RV) that is ahead and in the same lane or an adjacent lane. Upon receiving such event information, the HV determines the relevance of the event and provides a warning to the driver, if appropriate.	J2945/1
Forward Crash Warning (FCW)	The FCW safety application warns the driver of the HV in the case of an impending rear-end crash with an RV directly ahead in the same lane and direction of travel. The FCW is intended to help drivers avoid or mitigate rear-end vehicle crashes in the forward path of travel.	J2945/1
Blind Spot Warning/Lane Change Warning (BSW/LCW)	The BSW/LCW safety application warns the driver of the HV during a lane change attempt if the blind-spot zone into which the HV intends to move into is, or will soon be, occupied by another vehicle traveling in the same direction. Moreover, the application may also provide advisory information that is intended to inform the driver of the HV that a vehicle in an adjacent lane is positioned in a blind-spot zone of the HV when a lane change is not being attempted.	J2945/1
Intersection Movement Assist (IMA)	The IMA safety application warns the driver of an HV when it is not safe to enter an intersection due to a crash possibility with RVs.	J2945/1
Left Turn Assist (LTA)	The LTA safety application warns the driver of an HV that, due to oncoming traffic, it may not be safe to proceed when attempting a left turn.	J2945/1

Title	Short Description & Goal	Standard
Control Loss Warning (CLW)	The CLW safety application warns the driver of the HV in the case of an emergency control loss event (defined as activation of the Antilock Brake System, Traction Control System, or Stability Control System) by an RV traveling in the same or opposite direction. The RV broadcasts control loss event information within the BSM. Upon receiving such event information, the HV determines the relevance of the event and provides a warning to the driver of the HV.	J2945/1
Emergency Vehicle Alert (EVA)	The EVA application alerts the driver about the location of and the movement of public safety vehicles responding to an incident so the driver does not interfere with the emergency response. Note that other related use cases outside of the current scope make use of the infrastructure to allow authorized Public Safety Vehicles to traverse a signalized intersection. This application helps drivers to avoid collisions with nearby emergency vehicles and to clear the roadway so that emergency vehicles can proceed more effectively.	J2945/2
Roadside Alert (RSA)	This use case is used by non-standard vehicles to communicate stopped or slow-moving behaviors which may obstruct or complicate mainstream traffic to other drivers and vehicles. This may require drivers to be alert or take action to provide additional clearance to roadside activities. This application helps drivers to avoid collisions with nearby non-standard vehicles such as school buses and others that may disturb the free flow of traffic as part of their routine operations; and to provide additional clearance for roadside activities.	J2945/2
Situational Awareness – Weather Conditions	This use case describes a vehicle broadcasting potential inclement weather, as determined by the vehicle's sensors. It provides warnings to alert road users about inclement weather conditions that might call for a reduction of speed or other action.	J2945/2
Situational Awareness – Obstacle (SAW – O)	This use case describes a vehicle broadcasting the presence of a potential obstacle in the roadway. It provides warnings to alert road users to a potential obstacle in the roadway.	J2945/2

Title	Short Description & Goal	Standard
Situational Awareness – Suboptimal Road Segment Conditions	This use case describes a vehicle broadcasting potentially suboptimal road conditions. It provides warnings to alert road users to a potential suboptimal road condition.	J2945/2

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