



Module I261: Vehicle- to-Infrastructure (V2I) ITS Standards for Project Managers

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Module Description

This module is an introduction to the connected vehicle environment, with a focus on a standards-based vehicle-to-infrastructure communications. I101, *Using ITS Standards – An Overview*, is a recommended prerequisite for participants. A companion module is I262, *Vehicle-to-Vehicle (V2V) ITS Standards for Project Managers*, which focuses on standards-based vehicle-to-vehicle communications.

1. Introduction/Purpose

The connected vehicle environment has the potential to significantly reduce vehicular crashes, provide operators of surface transportation systems with more timely and accurate system performance data to better manage their systems, and provide travelers with access to specific traveler information. In such an environment, each vehicle on the roadway can also potentially serve as a data collector, providing transportation planners with a wealth of real-time travel data.

This module provides an introduction to the connected vehicle environment and a description of the potential benefits and capabilities of a Vehicle-to-Infrastructure (V2I) environment. The module presents several V2I safety, mobility, and environmental applications and discusses the types of information that may be exchanged between the different devices that make up the V2I environment.

The module then presents the ITS Standards that help support the deployment of a V2I application and a V2I infrastructure. The module also introduces some of the challenges to designing and implementing a V2I infrastructure, and provides some strategies and approaches to deploying the V2I infrastructure.

It is essential that agencies use standards in deploying connected vehicle technologies to maximize the benefits from the connected vehicle environment. By taking this module, participants will learn what connected vehicle standards exist, where to find the standards, and how to use the connected vehicle standards to procure, implement and operate standards-based devices and equipment. Deploying these connected vehicle standards will support interoperability, minimize future integration costs, make procurements easier, and facilitate regional and national integration.

2. Reference to Other Standards

USDOT

- USDOT ITS Standards Program, <http://www.standards.its.dot.gov/>



ASTM

- ASTM E2213 – 03 (2010) – Standard Specification for Telecommunications and Information Exchange Between Roadside and Vehicle Systems – 5 GHz Band Dedicated Short Range Communications (DSRC) Medium Access Control (MAC) and Physical Layer (PHY) Specifications, ASTM, <http://www.astm.org/Standards/E2213.htm>

IEEE

- Working Group Activities: IEEE 1609 Family of Standards for Wireless Access in Vehicular Environments (WAVE), IEEE, http://standards.ieee.org/develop/wg/1609_WG.html
- IEEE 1609.0-2013 – IEEE Guide for Wireless Access in Vehicular Environments (WAVE) – Architecture, IEEE, <http://standards.ieee.org/findstds/standard/1609.0-2013.html>
- IEEE 1609.2-2013 - IEEE Standard for Wireless Access in Vehicular Environments — Security Services for Applications and Management Messages, IEEE, <http://standards.ieee.org/findstds/standard/1609.2-2013.html>
- IEEE 1609.3-2010 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services, IEEE, <http://standards.ieee.org/findstds/standard/1609.3-2010.html>
- IEEE 1609.3-2010/Cor 1-2012 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE)--Networking Services Corrigendum 1: Miscellaneous Corrections, IEEE, http://standards.ieee.org/findstds/standard/1609.3-2010-Cor_1-2012.html
- IEEE 1609.4-2010 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE)--Multi-channel Operation, IEEE, <http://standards.ieee.org/findstds/standard/1609.4-2010.html>
- IEEE 1609.11-2010 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE)--Over-the-Air Electronic Payment Data Exchange Protocol for Intelligent Transportation Systems (ITS), IEEE, <http://standards.ieee.org/findstds/standard/1609.11-2010.html>
- IEEE 1609.12-2012 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Identifier Allocations, IEEE, <http://standards.ieee.org/findstds/standard/1609.12-2012.html>
- IEEE 802.11-2012 – IEEE Standard for Information technology – Telecommunications and information exchange between systems. Local and metropolitan area networks – Specific requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications, IEEE, <http://standards.ieee.org/about/get/802/802.11.html>

ISO

- ISO/AWI TS 19091 – Intelligent transport systems – Cooperative ITS – Using V2I and I2V communications for applications related to signalized intersections. http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=63941

SAE

- Working Group Activities: SAE J2735_2014 – Dedicated Short Range Communications (DSRC) Message Set Dictionary, SAE, <http://standards.sae.org/wip/j2735/>
- Dedicated Short Range Communications (DSRC) Support Page, SAE, <http://www.sae.org/standardsdev/dsrc/>



- SAE J2735_2015– Dedicated Short Range Communications (DSRC) Message Set Dictionary, SAE, http://standards.sae.org/j2735_201504/
- SAE J2945 – Dedicated Short Range Communications (DSRC) Minimum Performance Requirements (Work in Progress), SAE, <http://standards.sae.org/wip/j2945/>
- SAE J3067 – Candidate Improvements to Dedicated Short Range Communications (DSRC) Message Set Dictionary [SAE J2735] Using Systems Engineering Methods, SAE, http://standards.sae.org/j3067_201408/

3. Glossary

To include additional descriptions/acronyms used primarily in the module.

Term	Definition
Aftermarket Safety Device (ASD)	A connected device in a vehicle that operates while the vehicle is mobile, but which is not connected to the data bus of the vehicle.
Application	A piece of software that processes inputs for a specific use or purpose.
Backhaul	The closed network communications links between a Traffic Management Center (or other back offices), links between TMCs, and field installations (such as traffic signal controllers, traffic cameras, and other sensors). This could also include the link between the Security Credential Management System (SCMS) and roadside distribution device.
Basic Safety Message (BSM)	The core data set transmitted by the connected vehicle (vehicle size, position, speed, heading acceleration, brake system status) and transmitted approximately 10x per second. A secondary set is available depending upon events (e.g., ABS activated) and contains a variable set of data elements drawn from many optional data elements (availability by vehicle model varies). This would be transmitted less frequently. The BSM is tailored for low latency; localized broadcast required by V2V safety applications but can be used with many other types of applications.
Connected Device	Any device used to transmit to or receive messages from another device. A connected device can be sub-categorized as an OBE, ASD, VAD, or RSE. In many cases, the connected device will be a DSRC device, but other types of communications can and are expected to be supported.
Connected Vehicle (CV)	A vehicle containing an OBU or ASD. Note that vehicles may alternatively include a Vehicle Awareness Device (VAD), which transmits the BSM but does not received broadcasts from other devices and cannot directly support vehicle-based applications.
Connected Vehicle Reference Implementation Architecture (CVRIA)	A set of system architecture views that describe the functions, physical and logical interfaces, enterprise/institutional relationships, and communications protocol dependencies within the connected vehicle environment. The CVRIA defines functionality and information exchanges needed to provide connected vehicle applications.



Term	Definition
Dedicated Short Range Communications (DSRC)	<p>The use of non-voice radio techniques to transfer data over short distances between roadside and mobile radio units, between mobile units, and between portable and mobile units to perform operations related to the improvement of traffic flow, traffic safety and other intelligent transportation service applications in a variety of public and commercial environments. [FCC, Dedicated Short Range Communications of Intelligent Transportation Services – Final Rule, FR Doc No: 99-30591]</p> <p>A technology for the transmission of information between multiple vehicles (V2V) and between vehicles and the transportation infrastructure (V2I) using wireless technologies.</p>
Intelligent Transportation Systems (ITS)	Systems that apply data processing and data communications to surface transportation, to increase safety and efficiency. ITS systems will often integrate components and users from many domains, both public and private.
Interoperability	The ability of two or more systems or components to exchange information and to use the information that has been exchanged. The dependence of the CV Environment on successful exchange of data between independent components results in a requirement that all V2I deployments.
Latency	A measure of time delay experienced in a system, the precise definition of which depends on the system and the time being measured. For a data element in this context, latency is the time difference between the time that data value is acquired by the source and the time the message is transmitted.
MAP	A message containing roadway geometric information.
NTCIP	The National Transportation Communications for Intelligent Transportation System Protocol (NTCIP) is a family of standards designed to achieve interoperability and interchangeability between computers and electronic traffic control equipment from different manufacturers.
On-Board Equipment (OBE)	This term refers to the complement of equipment located in the vehicle for the purpose of supporting the vehicle side of the applications. It is likely to include the DSRC radios, other radio equipment, message processing, driver interface, and other applications to support the use cases described herein. It is also referred to as the Vehicle ITS Station. When referring to the DSRC radio alone, the correct term is OBU (see below).
On-Board Unit (OBU)	A vehicle mounted device used to transmit and receive a variety of message traffic to and from other connected devices (other OBUs and RSUs). Among the message types and applications supported by this device are vehicle safety messages, a primary subject of this standard, used to exchange information on each vehicle's dynamic movements for coordination and safety.



Term	Definition
RoadSide Equipment (RSE)	Term used to describe the complement of equipment to be located at the roadside; the RSE will prepare and transmit messages to the vehicles and receive messages from the vehicles for the purpose of supporting the V2I applications. This is intended to include the DSRC radio, traffic signal controller where appropriate, interface to the backhaul communications network necessary to support the applications, and support such functions as data security, encryption, buffering, and message processing. It may also be referred to as the roadside ITS station. When speaking of the DSRC radio alone, the correct term is RSU (see below).
RoadSide Unit (RSU)	A connected device that is only allowed to operate from a fixed position (which may in fact be a permanent installation or from temporary equipment brought on-site for a period of time associated with an incident, road construction, or other event). Some RSEs may have connectivity to other nodes or the Internet.
Security Certificate Management System (SCMS)	A public key infrastructure approach to security involving the management of digital certificates that are used to sign and authenticate messages among legitimate but unknown vehicles and/or equipment and/or other points of connection.
Signal Phase and Timing (SPaT)	A message type that describes the current state of a signal system and its phases and relates this to the specific lanes (and therefore to maneuvers and approaches) in the intersection.
Vehicle	A self-propelled transport device, along with any attachments (e.g., trailers), that is a legal user of the transportation network.
V2I	Vehicle-to-Infrastructure communications: a system designed to wirelessly exchange information between a vehicle and the infrastructure.
V2V	Vehicle-to-Vehicle communications: a system designed to transmit basic safety information between vehicles to facilitate warnings to drivers concerning impending crashes.
WAVE	Wireless Access in Vehicular Environments. A WAVE system is a radio communications system intended to provide seamless, interoperable services to transportation.

4. Acronyms

AACNR	Advanced Automatic Crash Notification Relay
AASHTO	American Association of State Highway and Transportation Officials
AFV	Alternative Fuel Vehicle
ANPRM	Advance Notice of Proposed Rulemaking
ASD	Aftermarket Safety Devices
ASTM	American Society for Testing and Materials
BSM	Basic Safety Message
CAMP	Collision Avoidance Metrics Partnership
CME	Certificate Management Entities
CSR	Common Safety Request



CVRIA	Connected Vehicles Reference Implementation Architecture
DNPW	Do Not Pass Warning
DSRC	Dedicated Short Range Communications
EMDSS	Enhanced Maintenance Decision Support System
EVA	Emergency Vehicle Alert
FCC	Federal Communications Commission
FCW	Forward Collision Warning
GAO	General Accounting Office
GPS	Global Positioning System
ICA	Intersection Collision Avoidance
IEEE	Institute of Electrical and Electronic Engineers
INC-ZONE	Incident Scene Work Zone Alerts for Drivers and Workers
ISD	Integrated Safety Devices
ISO	International Standards Organization
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
LTE	Long-Term Evolution
LTE-D	Long-Term Evolution Direct
MAC	Medium Access Control
MDSS	Maintenance Decision Support System
NEMA	National Electrical Manufacturers Association
NHTSA	National Highway Traffic Safety Administration
NMEA	National Marine Electronics Association
NPRM	Notice of Proposed Rulemaking
NTCIP	National Transportation Communications for ITS Protocol
OBE	On-Board Equipment
OBU	On-Board Units
OVW	Oversize Vehicle Warning
P2P	Peer-to-Peer
PHY	Physical layer
PSID	Provider Service Identifier
RCW	Railroad Crossing Warning
RFA	Request For Applications
RLVW	Red Light Violation Warning
RSA	Roadside Alert
RSD	Retrofit Safety Devices
RSE	RoadSide Equipment
RSU	RoadSide Unit
RSZW	Reduced Speed Zone Warning
RTCM	Radio Technical Commission for Maritime Services
SAE	Society of Automotive Engineers
SCMS	Security Credential Management System
SDO	Standards Development Organization
SPaT	Signal Phase and Timing
SRM	Signal Request Message
SSM	Signal Status Message
STA	Station



TIM	Traveler Information Message
USDOT	United States Department of Transportation
VAD	Vehicle Awareness Device
VDTO	Vehicle Data for Traffic Operations
VTRFTV	Vehicle Turning Right in Front of a Transit Vehicle
WAVE	Wireless Access in Vehicular Environments
WHWZ	Warnings about Hazard in a Work Zone
WLAN	Wireless Local Area Network
WSMP	WAVE Short Message Protocol
WUWZ	Warnings about Upcoming Work Zone
WWAN	Wireless Wide Area Network
V2I	Vehicle-to-Infrastructure
V2P	Vehicle-to-Pedestrian
V2V	Vehicle-to-Vehicle

5. References

Connected Vehicle Basics

- ITS ePrimer – Module 13: Connected Vehicles.
<http://www.pcb.its.dot.gov/eprimer/module13.aspx>
- Research and Innovative Technology Administration, “T3 Webinar: Connected Vehicle Basics.” http://www.pcb.its.dot.gov/t3/s140424_cv_basics.asp
- Federal Highway Administration, “Connected Vehicles Environment Fundamentals 101”, http://stsmo.transportation.org/Documents/ConnectedVehiclesToInfrastructure101_PresentationRev7.pdf
- Research and Innovative Technology Administration, “Vehicle-to-Vehicle Communication: A New Generation of Driver Assistance and Safety (Video)”, July 9, 2013.
http://www.its.dot.gov/library/media/v2v_video.htm

Federal Register and Requests

- Federal Communications Commission, 47 CFR Parts 2 and 90, “Dedicated Short Range Communications of Intelligent Transportation Services – Final Rule, FR Doc No: 99-30591” Federal Register Volume 64, Issue 227 (November 26, 1999).
- National Highway Traffic Safety Administration, 49 CFR 571, “Federal Motor Vehicle Safety Standards: Vehicle-to-Vehicle (V2V) Communications, Docket No. NHTSA-2014-0022”, Federal Register, August 20, 2014.
<http://www.nhtsa.gov/About+NHTSA/Press+Releases/NHTSA-issues-advanced-notice-of-proposed-rulemaking-on-V2V-communications>
- National Highway Traffic Safety Administration, “Vehicle-to-Vehicle Communications: Readiness of V2V Technology for Application, Report No. DOT HS 812 014”, August, 2014.
- National Highway Traffic Safety Administration, “Vehicle-to-Vehicle Security Credential Management System; Request For Information”, October 10, 2014.
<http://www.safercar.gov/v2v/pdf/V2V-SCMS-RFI-Oct-2014.pdf>



- Federal Highway Administration, “Request for Application - Connected Vehicle - Next Stage Certification Environment”, DTFH6114RA00014, June 18, 2014.
<http://www.grants.gov/web/grants/view-opportunity.html?oppld=258008>

Deployment (General)

- Research and Innovative Technology Administration, Connected Vehicle Research, http://www.its.dot.gov/connected_vehicle/connected_vehicle.htm
- Intelligent Transportation Systems Joint Program Office - Research. <http://www.its.dot.gov/index.htm>
- Connected Vehicle Reference Implementation Architecture (CVRIA). <http://iteris.com/cvria/>
- Research and Innovative Technology Administration, DSRC Fact Sheet, http://www.its.dot.gov/factsheets/dsrc_factsheet.htm
- ITE Connected Vehicle Support Project, <http://www.ite.org/connectedvehicle/>
- AASHTO Connected Vehicle Infrastructure Deployment Analysis. http://ntl.bts.gov/lib/43000/43500/43514/FHWA-JPO-11-090_AASHTO_CV_Deploy_Analysis_final_report.pdf
- 2015 FHWA Vehicle to Infrastructure Deployment Guidance and Products - Draft v9a, September 29, 2014. http://stsmo.transportation.org/Documents/V2I_DeploymentGuidanceDraftv9.pdf
- National Connected Vehicle Field Infrastructure Footprint Analysis - Final Report, June 27, 2014. http://stsmo.transportation.org/Documents/AASHTO%20Final%20Report%20_v1.1.pdf
- National Connected Vehicle Field Infrastructure Footprint Analysis - Final Report - Executive Summary. <http://stsmo.transportation.org/Documents/Exec%20Summary%20Final.pdf>
- National Connected Vehicle Field Infrastructure Footprint Analysis - Executive Briefing. <http://stsmo.transportation.org/Documents/Executive%20Briefing.pdf>
- National Connected Vehicle Field Infrastructure Footprint Analysis - Applications Analysis - July 31, 2013. http://stsmo.transportation.org/Documents/Applications_Analysis%20v3%20july%202013.pdf
- National Connected Vehicle Field Infrastructure Footprint Analysis - Deployment Concepts. http://stsmo.transportation.org/Documents/Deployment_Concepts.pdf
- National Connected Vehicle Field Infrastructure Footprint Analysis - Deployment Scenarios. http://stsmo.transportation.org/Documents/Task%206a%20AASHTO_CV_Footprint_Deployment_Scenarios_v2.pdf

Research Qualified Products List

- 5.9 GHz DSRC Vehicle Awareness Device Specification v3.8. http://www.its.dot.gov/testbed/PDF/Vehicle_Awareness_Device_Specification-r3-8%2020140322.pdf



- 5.9 GHz DSRC Aftermarket Safety Device Specification v3.1.
http://www.its.dot.gov/testbed/PDF/ASD_Device_Design_Specification_3_1%2020140322.pdf
- 5.9 GHz DSRC Roadside Equipment Device Specification v3.0.
http://www.its.dot.gov/safety_pilot/pdf/T-10001-T2-05_RSE_Device_Design_Specification_v30.pdf
- DSRC Roadside Unit (RSU) Specifications Document v4.0.
http://www.its.dot.gov/testbed/PDF/USDOT_RSUSpecification4%200_Flnal.pdf

6. Study Questions

1. Which of the following is NOT a method to reduce crashes in a V2I environment?
 - a) Through a website
 - b) Through driver warnings
 - c) Through infrastructure controls
 - d) Through vehicle controls

2. Which of the following is not a V2I safety application?
 - a) Red Light Violation Warning
 - b) Forward Collision Warning
 - c) Curve Speed Warning
 - d) Stop Sign Gap Assist

3. Which of the following is a data standard?
 - a) IEEE 802.11-2012
 - b) IEEE 1609.x Family of Standards
 - c) SAE J2735
 - d) USDOT FHWA Vehicle Awareness Device Specification

4. What is a challenge to deploying connected vehicles during the initial “rollout”?
 - a) Each automobile vendor uses its own protocol
 - b) There have been no field tests of connected equipment
 - c) No expected rule requiring vehicles be equipped
 - d) Very few vehicles are equipped



5. What is the current status of connected vehicle standards?
 - a) The standards are stable so no revisions are needed
 - b) The standards are being revised based only on lessons learned from pilot deployments and field tests
 - c) The standards are being revised based only on existing USDOT regulations
 - d) The standards are being revised based on lessons learned and harmonization with each other

