CV262: Vehicle-to-Vehicle (V2V) ITS Standards for Project Managers

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Updated November 5, 2019

Module Description

This module is an introduction to the connected vehicle environment, with a focus on a standards-based vehicle-to-vehicle communications. The I101 module, Using ITS Standards – An Overview, is a recommended prerequisite for participants. A companion module is CV261, Vehicle-to-Infrastructure (V2I) ITS Standards for Project Managers, which focuses on standards-based vehicle-to-infrastructure communications.

1. Introduction/Purpose

The connected vehicle environment has the potential to transform surface transportation systems such that vehicular crashes will be significantly reduced, operators of the surface transportation systems will have access to more accurate system performance data, travelers will have access to specific traveler information, and will the connected vehicle allow the surface transportation systems to be optimized to minimize environmental impacts.

This module provides an introduction to the connected vehicle environment, a description of the vehicle-to-vehicle (V2V) environment, and its potential benefits to the operators of surface transportation systems. The module presents several V2V safety, mobility, and environmental applications and discusses how these applications impact surface transportation operations. It also reviews the types of information that may be exchanged between the connected devices that make up the V2V environment.

The module then presents the ITS Standards that help support the deployment of the V2V environment and V2V applications. The module also introduces some of the challenges to implementing the V2V environment and how surface transportation systems can support the V2V environment.

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 interoperability.

2. Learning Objectives

a. **Describe the connected vehicle environment**
   Provides background on the components that are a part of the connected vehicle environment and the conditions under which these components are required to communicate with each other.

b. **Discuss the V2V communications**
   Identifies specific-use cases where V2V communications are important and the benefits that this technology provides to the public.

c. **Describe the roles of the standards for V2V communications**

Identifies key standards used for V2V communications and explains how these standards relate to one another in the communications stack.

d. **Address challenges in realizing a V2V environment**
Identifies key challenges that remain to the deployment of V2V technologies on a wide scale.

e. **Describe the current status of connected vehicles**
Summarizes the status of status of connected vehicles.

3. Reference to Other Standards

USDOT

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

IEEE

- IEEE 1609.0-2019 – IEEE Guide for Wireless Access in Vehicular Environments (WAVE) Architecture, IEEE, https://standards.ieee.org/standard/1609_0-2019.html
- IEEE 1609.2-2016 - IEEE Standard for Wireless Access in Vehicular Environments — Security Services for Applications and Management Messages, IEEE, https://standards.ieee.org/standard/1609_2-2016.html
- IEEE 1609.2a-2017 - IEEE Standard for Wireless Access in Vehicular Environments — Security Services for Applications and Management Messages – Amendment 1, IEEE, https://standards.ieee.org/standard/1609_2a-2017.html
- IEEE 1609.2b-2019 - IEEE Standard for Wireless Access in Vehicular Environments — Security Services for Applications and Management Messages – Amendment 2—PDU Functional Types and Encryption Key Management, IEEE, https://standards.ieee.org/standard/1609_2b-2019.html
- IEEE 1609.3-2016 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE) – Networking Services, IEEE, https://standards.ieee.org/standard/1609_3-2016.html
- IEEE 1609.4-2016 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE)—— Multi-channel Operation, IEEE, https://standards.ieee.org/standard/1609_4-2016.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 1609.12-2016 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE)— Identifier Allocations, IEEE, https://standards.ieee.org/standard/1609_12-2016.html
- IEEE 802.11-2016 – 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, https://standards.ieee.org/standard/802_11-2016.html

SAE

- SAE J2735_201603 – Dedicated Short Range Communications (DSRC) Message Set Dictionary, SAE, https://www.sae.org/standards/content/j2735_201603/
- SAE J2945_201712 – Dedicated Short Range Communications (DSRC) Systems Engineering Process Guidance for SAE J2945/X Documents and Common Design Concepts, SAE, https://www.sae.org/standards/content/j2945_201712/
- SAE J2945/1_201603 – On-Board System Requirements for V2V Safety Communications, SAE, https://www.sae.org/standards/content/j2945/1_201603/
- SAE J2945/2_201810 – Dedicated Short Range Communications (DSRC) Performance Requirements for V2V Safety Awareness, SAE, https://www.sae.org/standards/content/j2945/2_201810/
- SAE J2945/6 (WIP) – Performance Requirements for Cooperative Adaptive Cruise Control and Platooning, SAE, https://www.sae.org/standards/content/j2945/6/
- SAE J2945/8 (WIP) – Cooperative Perception System, SAE, https://www.sae.org/standards/content/j2945/8/
- SAE J2945/9_201703 – Vulnerable Road User Safety Message Minimum Performance Requirements, SAE, https://www.sae.org/standards/content/j2945/9_201703/
- SAE J3067_201708 – Candidate Improvements to Dedicated Short Range Communications (DSRC) Message Set Dictionary [SAE J2735] Using Systems Engineering Methods, SAE, https://www.sae.org/standards/content/j3067_201408/
- SAE J3161 (WIP) – On-Board System Requirements for LTE V2X V2V Safety Communications, SAE, https://www.sae.org/standards/content/j3161/

4. Glossary

Term	Definition
Access Layer	See SubNet Layer
Application	An application process providing application entity functionality as defined by the ITS reference architecture.
Application Entity	The portion of the ITS station reference architecture that provides domain-related functionality (i.e., not merely support functionality such as management or security processes).
Application Process	The concept of a piece of software that processes inputs for a specific use or purpose. Application processes can exist within the management, application, or security entities of the ITS Station Architecture. For example, a word processor is an application process within the application entity whereas MS Word is an “implementation” of the word processor application. Logic that can select between the use of a Wi-Fi and Ethernet connection would be an example of an application process within the management entity.

Term	Definition
Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT)	A USDOT-developed common framework for planning, defining, and integrating intelligent transportation systems. It is a mature product that reflects the contributions of a broad cross-section of the ITS community (transportation practitioners, systems engineers, system developers, technology specialists, consultants, etc.).
Basic Safety Message (BSM)	The message containing the core data set transmitted by the connected vehicle for safety-related purposes (vehicle size, position, speed, heading acceleration, brake system status). The message includes an optional extension that can report additional data depending upon events (e.g., anti-lock brakes activated) but the availability of types of extension data varies by vehicle model. The BSM is tailored for low latency; localized broadcast required by V2V safety applications but can be used with many other types of applications.
Cellular Vehicle-to-Anything	A form of DSRC based on 3GPP LTE technology.
Connected Device	Any device used to transmit or receive messages from another device. Within the scope of V2X, we specifically mean those connected devices that are a part of an ITS trust domain, thereby allowing them to transmit and receive messages with other ITS-trusted connected devices. Within the scope of this course (V2V and V2P), we specifically mean those connected devices that are a part of *the* ITS trust domain established by the SCMS, thereby allowing them to transmit and receive messages with SCMS-trusted connected devices A connected device can be sub-categorized as an OBU or RSU.
Connected Vehicle (CV)	A vehicle containing an OBU
Dedicated Short Range Communications (DSRC)	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] A technology for the transmission of information between multiple vehicles (V2V) and between vehicles and the transportation infrastructure (V2I) using wireless technologies.
Facilities Layer	The portion of an ITS station communications stack that structures data, manages sessions, and encodes data for application processes
Intelligent Transportation Systems (ITS)	Systems that apply data processing and data communications to surface transportation, to increase safety, efficiency, and sustainability. ITS systems will often integrate components and users from many domains, both public and private.

Term	Definition
ITS Station (ITS-S) reference architecture	A reference model to describe how application processes within a device are able to communicate to other devices. The model is defined in ISO 21217 and is based on the ISO Open Systems Interconnect (OSI) Reference Model (ISO 7498-1), but simplifies the OSI model by grouping some layers together and extends the OSI model to explicitly defining the management, application, and security entities that drive communications and provide support functionality to the basic OSI stack.
Interoperability	Degree to which two or more systems, products or components can exchange information and use the information that has been exchanged. [ISO 24765:2017]
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.
Management Entity	The portion of an ITS station that manages the configuration of the device
Network and Transport Layer	The portion of an ITS station communications stack that is responsible for communicating between a source and destination device
On-Board Equipment (OBE)	This term refers to the complement of equipment located in the vehicle for 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.
Original Equipment Manufacturer (OEM)	An original equipment manufacturer refers to the entity that originally manufactures an item that may be branded and sold by others. In the Connected Vehicle Environment, it is commonly used to refer to those who provide components to the automobile manufacturers.
Security Certificate Management System (SCMS)	A public key infrastructure (PKI) approach to security involving the management of digital certificates that are used to sign and authenticate messages that are exchanged among connected devices that might have no direct relationship with each other.
Vehicle	A self-propelled transport device, along with any attachments (e.g., trailers), that is a legal user of the transportation network.
Security Entity	The portion of an ITS station that provides security services to the other parts of the ITS station
SubNet Layer	The portion of an ITS station communications stack that is responsible for communications over one communications link
Vehicle-to-Infrastructure (V2I)	The exchange of information between a vehicle and a roadside device or centralized equipment to enhance safety, mobility, and sustainability

Term	Definition
Vehicle-to-Pedestrian (V2P)	The exchange of information between a vehicle and a connected device representing a pedestrian or other vulnerable road user to enhance safety, mobility, and sustainability.
Vehicle-to-Vehicle (V2V)	The exchange of information between vehicles to enhance safety, mobility, and sustainability.
Vehicle-to-Anything (V2X)	The exchange of information between a vehicle one or more connected devices to enhance safety, mobility, and sustainability. The other connected device might be another vehicle, a pedestrian or other vulnerable road user device, a roadside station, or a central system.
Wireless Access in Vehicular Environments (WAVE)	A radio communications system intended to provide seamless, interoperable services to transportation users
WAVE Short Message Protocol (WSMP)	A low-overhead TransNet Layer protocol designed for use over DSRC

5. Acronyms

3GPP	3rd Generation Partnership Project
5G	5th Generation (cellular technology)
ATTRI	Accessible Transportation Technologies Research Initiative
BSM	Basic Safety Message
C-ITS	Cooperative ITS
C-V2X	Cellular Vehicle-to-Anything
CAMP	Collision Avoidance Metrics Partnership
CO2	Carbon Dioxide
CV	Connected Vehicle
DSRC	Dedicated Short Range Communications
FCC	Federal Communications Commission
GHz	Gigahertz
GPS	Global Positioning System
IEEE	Institute of Electrical and Electronic Engineers
ISO	International Standards Organization
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
JPO	Joint Program Office
LTE	Long-Term Evolution (cellular technology)
OBE	On-Board Equipment
OBU	On-Board Units
POC	Proof-of-Concept
SAE	Society of Automotive Engineers
SCMS	Security Credential Management System
SDO	Standards Development Organization

USDOT	United States Department of Transportation
V2I	Vehicle-to-Infrastructure
V2P	Vehicle-to-Pedestrian
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Anything
WAVE	Wireless Access in Vehicular Environments
WIP	Work in Progress
WSMP	WAVE Short Message Protocol

6. Supplemental Figures

Figure 1 shows how the various components of the vehicle's on-board equipment interact to provide connected vehicle services.

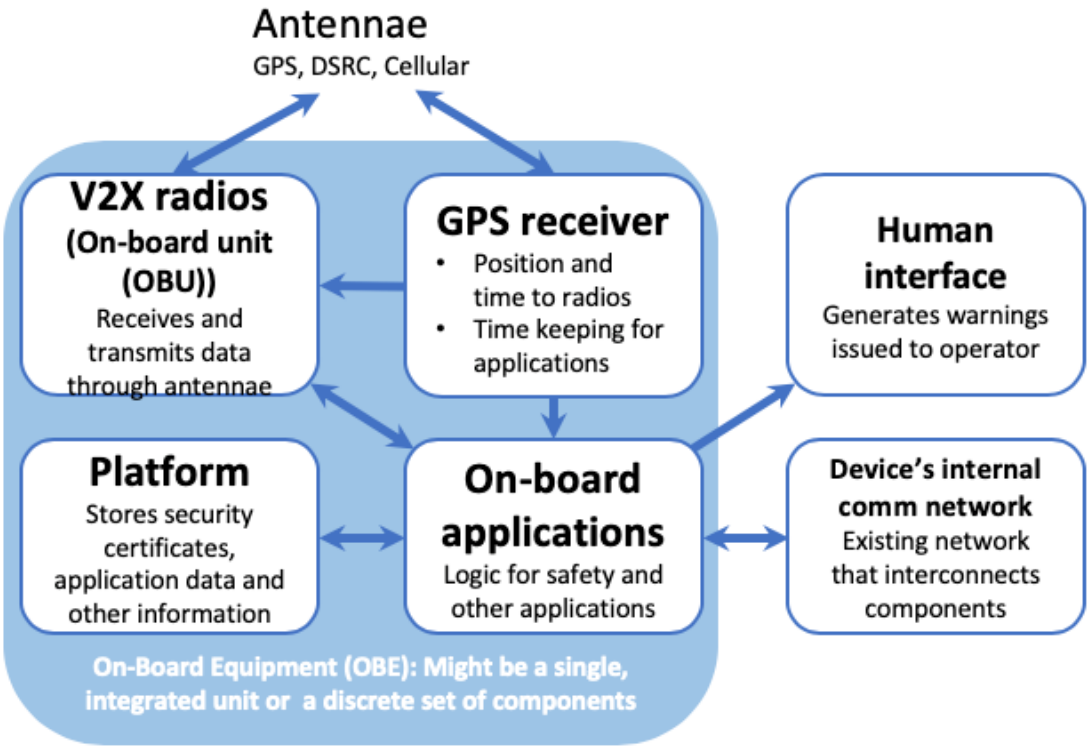

Figure 1: Components of the V2X network

The on-board applications provide the logic for all connected vehicle applications, such as safety, mobility, and sustainability related applications. These applications rely upon the Platform to store security certificates, application data, and other information. The on-board applications use one or more V2X radios to receive and transmit data via the vehicle's antennae. Multiple radios are typically required due to the need to manage communications on multiple channels simultaneously. The on-board applications also use the GPS receiver to identify its position and to keep its time synchronized with other devices (e.g., vehicles, pedestrians, roadside devices). All of these components make up the connected vehicle on-board equipment (OBE).

The on-board connected vehicle applications might also need to interact with other equipment contained in the vehicle that is not considered a part of the OBE. For example, the on-board applications might need to access the CAN-bus to determine the vehicle speed, braking status, anti-lock brake status, etc. Finally, the on-board applications might also need to convey information to the driver or vehicle occupants via the provided human interface components.

7. References

Resources

- Connected Vehicle Basics, https://www.its.dot.gov/cv_basics/index.htm
- Connected Vehicle Pilot Deployments, https://www.its.dot.gov/pilots/
- Connected Vehicle Deployment Resources, https://www.its.dot.gov/deployment_resources.htm
- Security Credential Management System (SCMS), https://www.its.dot.gov/resources/scms.htm
- Connected Vehicle Research, https://www.its.dot.gov/research_areas/connected_vehicle.htm
- Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT), http://arc-it.org

Webinars

- Effect on ITS Planning and Development in a Connected Vehicle Environment, July 26, 2018. https://www.pcb.its.dot.gov/t3/s180726_Effects_on_ITS_Planning_Development_CV_Environment.aspx
- Transportation Cyber-Physical Security: Things We Should Know, May 10, 2018. https://www.pcb.its.dot.gov/t3/s180510_Transportation_Cyber-Physical_Security.aspx
- The Role of Connected & Automated Vehicles: How Can Urban Areas Use the Data They Create? October 11, 2019. https://www.pcb.its.dot.gov/t3/s171011_Role_of_Connected_and_Automated_Vehicles.aspx
- Connected Vehicle (CV) Technology for Improving Transit Operations, April 26, 2017. https://www.pcb.its.dot.gov/t3/s170426_CV_Technology_Improving_Transit_Operations.aspx
- Data and Connected Vehicle Support of Active Traffic Management Strategies, October 31, 2016. https://www.pcb.its.dot.gov/t3/s161031_Data_and_Connected_Vehicle_Support_of_Active_Traffic_Management_Strategies.aspx
- Connected Vehicles and Rural Road Weather Management, July 28, 2016. https://www.pcb.its.dot.gov/t3/s160728_Connected_Vehicles_and_Rural_Road_Weather_Management.aspx

- ITS Applications for Bicycles and Pedestrians, December 2, 2015. https://www.pcb.its.dot.gov/t3/s151202_ITS_Apps_for_Bikes_Peds.asp
- Connected Vehicle Workforce, September 10, 2015. https://www.pcb.its.dot.gov/t3/s150910_connected_vehicles_workforce.asp
- ITS ePrimer – Module 13: Connected Vehicles, March 2016. http://www.pcb.its.dot.gov/eprimer/module13.aspx
- Connected Vehicle Basics, April 24, 2014. http://www.pcb.its.dot.gov/t3/s140424_cv_basics.asp
- Vehicle-to-Vehicle Communication: A New Generation of Driver Assistance and Safety, July 9, 2013. https://www.its.dot.gov/communications/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. https://www.federalregister.gov/documents/2017/01/12/2016-31059/federal-motor-vehicle-safety-standards-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?oppId=258008
- National Highway Traffic Safety Administration, 49 CFR 571, "Federal Motor Vehicle Safety Standards: V2V Communications," Docket No. NHTSA-2016-0126, *Federal Register*, January 12, 2017.

Case Studies

- USDOT, "Connected Vehicle Pilot Deployment Program: Success Stories and Lessons Learned," https://www.its.dot.gov/pilots/success_lessonslearned.htm
- Shah, K. and Parentela E., "A Case Study on Potential Benefits of V2V Communication Technology on Freeway Safety," https://www.westernite.org/annualmeetings/15_Las_Vegas/Papers/7C-Shah.pdf
- New York City DOT, "NYC Connected Vehicle Project: For Safer Transportation," https://www.cvp.nyc

8. Study Questions

1. **Which of the following does the USDOT NOT include in its list of benefits of connected vehicles?**

a) Improved Safety
b) Improved Environment
c) Enhanced Entertainment
d) Improved Mobility

2. **Which of the following is NOT an identified component of the V2V network?**
   a) Vehicle powertrain
   b) Safety application logic
   c) GNSS (GPS) receiver
   d) Memory for security certificates or application data

3. **What data is NOT included as a Basic Safety requirement?**
   a) Location of Vehicle
   b) Weight of Vehicle
   c) Length of Vehicle
   d) Steering Wheel Angle

4. **Which is NOT a benefit of using ITS Standards?**
   a) Supports interoperability
   b) Eliminates institutional issues
   c) Makes testing easier
   d) Makes procurements easier

5. **Which of the following is NOT a part of the ITS Station Architecture?**
   a) Application Entity
   b) Facilities Layer
   c) Security Entity
   d) Presentation Layer

6. **Which of the following is an application data standard?**
   a) IEEE 802.11
   b) IEEE 1609.x Family of Standards
   c) SAE J2735

d) SAE J2945/1

7. **Which of the following has NOT been identified in this presentation as a V2V service that agencies might need to consider implementing?**
   a) Work zone warnings
   b) Fleet management
   c) Emergency vehicle warnings
   d) Slow vehicle warnings

8. **What is a current challenge to deploying connected vehicles?**
   a) Security
   b) Privacy
   c) Evolving standards
   d) All of the above

9. **Which of the following is NOT a current connected vehicle activity?**
   a) Revising ITS standards based on lessons learned
   b) Establishing a USDOT certification laboratories for connected devices
   c) Establishing a long-term Security and Credentialing Management System (SCMS)
   d) Revising ARC-IT for emerging and revised application requirements

10. **Which of the following is the USDOT currently testing in relation to communication technology alternatives offered by C-V2X and DSRC?**
    a) Access Layer
    b) TransNet Layer
    c) Facilities Layer
    d) Management Entity