Module 11: Transit and the Connected Vehicle Environment/Emerging Technologies, Applications, and Future Platforms

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Module Description

This module is an introduction to the connected vehicle environment for transit, with a focus on standards-based communications. Module 1, "Introduction to ITS Standards," Module 2, "Transit Management Standards, Part 1 of 2," Module 3, "Transit Communications Interface Protocols, Part 1 of 2," Module 4, "Transit Communications Interface Protocols, Part 2 of 2," and Module 5, "Transit Management Standards, Part 2 of 2," are recommended prerequisites for participants. This course is a recommended optional module for decision-makers, project managers, and project engineers.

1. Introduction/Purpose

The connected vehicle environment currently being researched by USDOT has the potential to transform surface transportation systems so that vehicular crashes are significantly reduced, travelers have access to specific traveler information, and operators of the surface transportation systems have access to more accurate system performance data, thereby optimizing surface transportation systems to minimize environmental impacts. For transit operators, this environment provides an opportunity to improve public transit service by increasing transit productivity, efficiency, and accessibility while providing its users with better transit services and information.

This module provides participants with an introduction to the transit connected vehicle environment and its potential benefits to transit operators and users. The module outlines some of the data that may be exchanged between connected devices and the standards that support those exchanges, and illustrates how that information may be used to create a safe, stable, interoperable, and reliable transit system.

2. References to Standards

USDOT

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

3GPP

- 3rd Generation Partnership Project, http://www.3gpp.org/

APTA

- Transit Communications Interface Protocols (TCIP) Standard Development Program, APTA, http://www.aptatcip.com/

ASTM

- ASTM E2213 – 02 (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/DATABASE.CART/HISTORICAL/E2213-02.htm
- 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

Google

- Google Developers, General Transit Feed Specification (GTFS), https://developers.google.com/transit/gtfs/
- Google Developers, GTFS-realtime, https://developers.google.com/transit/gtfs-realtime/

CEN

- Service Interface for Real Time Information CEN/TS 15531, http://user47094.vs.easily.co.uk/siri/

ITE

- Traffic Management Data Dictionary (TMDD), ITE, http://www.ite.org/standards/tmdd/

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
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- 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

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_2009– Dedicated Short Range Communications (DSRC) Message Set Dictionary, SAE, http://standards.sae.org/j2735_200911/
- 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

Term	Definition
Application	A piece of software that processes inputs for a specific use or purpose
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 broadcasts required by V2V safety applications but can be used with many other types of applications.

Term	Definition
Connected Device	Any device used to transmit to or receive messages from another device. A connected device can be subcategorized as On-Board Equipment (OBE), Aftermarket Safety Device (ASD), Vehicle Awareness Device (VAD), or RoadSide Equipment (RSE). In many cases the connected device will be a (Dedicated Short Range Communications (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 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 the functionalities and information exchanges needed to provide connected vehicle applications.
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.
Dynamic Ridesharing (D-RIDE)	Connected vehicle application for transit that enables travelers to use personal devices to facilitate carpooling.
Dynamic Transit Operations (T-DISP)	Connected vehicle application for transit that enables travelers to use personal devices to request transit trips.
Integrated Dynamic Transit Operations (IDTO)	Bundle of connected vehicle applications specifically related to mobility for transit. Includes Transit Connection Protection, Dynamic Transit Operations, and Dynamic Ridesharing.
Integrated Multi-Modal Electronic Payment	Connected vehicle application that can be used for transit fare payment.

Term	Definition
Intelligent Transportation Systems (ITS)	Systems that apply data processing and data communications to surface transportation to increase safety and efficiency. These systems often integrate components and users from many domains, both public and private.
Intermittent Bus Lanes (IBL)	Connected vehicle application which allows roadway lanes to be dynamically designated for transit use only.
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 must fulfill.
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.
Light Vehicle	Passenger cars and light trucks and vans (LTVs). LTVs consist of trucks of 10,000 pounds gross vehicle weight or less; pickups, vans, minivans, truck-based station wagons, and sport utility vehicles (SUVs).
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 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 Roadside Units [RSUs]). Among the message types and applications supported by this device are vehicle safety messages used to exchange information on each vehicle's dynamic movements for coordination and safety.
Railroad Crossing Warning (RCW)	A connected vehicle safety application that alerts motorists approaching a railroad crossing if they are on course to a train collision.
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, and interface to the backhaul communications network necessary to support the applications, and to 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).

Term	Definition
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 RSUs may have connectivity to other nodes or the Internet.
Route ID for the Visually Impaired (RVI)	A connected vehicle application that allows visually impaired transit travelers using a personal device to receive route and destination information for an approaching transit vehicle.
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.
Smart Park and Ride	A connected vehicle application that provides real-time park and ride information to travelers
Transit Connection Protection (T-CONNECT)	Connected vehicle application that allows travelers to request that a transit connection be guaranteed.
Transit Signal Priority	Application that allows a transit vehicle to request priority over other vehicles at an intersection.
Transit Stop Request	Connected vehicle application that allows travelers to request that a transit vehicle stop.
Transit Vehicle at Station/Stop Warning	Connected vehicle application for safety that warns drivers if a transit vehicle is pulling in or out of a transit stop.
V2X	A wireless interface to exchange information between a vehicle and another type of device.
Vehicle	A self-propelled transport device, along with any attachments (e.g., trailers) that is a legal user of the transportation network.
Vehicle-to-Infrastructure (V2I)	A wireless interface to exchange information between a vehicle and the infrastructure
Vehicle-to-Pedestrian (V2P)	A wireless interface to exchange information between a vehicle and pedestrians.
Vehicle-to-Vehicle (V2V)	A wireless interface to exchange information between a vehicle and another nearby vehicle.
Vehicle Turning Right in Front of a Transit Vehicle (VTRFTV)	A connected vehicle safety application that warns a transit vehicle at a near-side transit stop if a vehicle is on course to make a right turn in front of the transit vehicle.

Term	Definition
WAVE	Wireless Access in Vehicular Environments. A WAVE system is a radio communications system intended to provide seamless, interoperable services to transportation.

4. Acronyms

3GPP	3rd Generation Partnership Project
AASHTO	American Association of State Highway Transportation Officials
ANPRM	Advance Notice of Proposed Rulemaking
APTA	American Public Transportation Association
ASTM	American Society for Testing and Materials
AVL	Automatic Vehicle Location
BSM	Basic Safety Message
CAD	Computer Aided Dispatch
CEN	European Committee for Standardization
CFR	Code of Federal Regulations
CSR	Common Safety Request
CVRIA	Connected Vehicles Reference Implementation Architecture
D-RIDE	Dynamic Ridesharing
DXFS	Data Exchange Feed Specification
DSRC	Dedicated Short Range Communications
ETA	Estimated Time of Arrival
EVA	Emergency Vehicle Alert
FCC	Federal Communications Commission
FTA	Federal Transit Administration
FMVSS	Federal Motor Vehicle Safety Standard
GAO	General Accounting Office
GPS	Global Positioning System
GTFS	General Transit Feed Specification
IBL	Intermittent Bus Lanes
IDTO	Integrated Dynamic Transit Operations
IEEE	Institute of Electrical and Electronics Engineers
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
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

P2P	Peer-to-Peer
PHY	PHYsical layer
PSID	Provider Service Identifier
RCW	Railroad Crossing Warning
RFA	Request for Applications
RSA	Roadside Alert
RSE	RoadSide Equipment
RSU	RoadSide Unit
RTCM	Radio Technical Commission for Maritime Services
RTSMIP	Real Time Safety Management Information Program
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users
SCMS	Security Credential Management System
SDO	Standards Development Organization
SIRI	Service Interface for Real Time Information
SPaT	Signal Phase and Timing
SRM	Signal Request Message
SSM	Signal Status Message
STA	Station
TCIP	Transit Communications Interface Protocols
T-Connect	Transit Connection Protection
T-DISP	Dynamic Transit Operations
TIM	Traveler Information Message
TSP	Transit Signal Priority
USDOT	United States Department of Transportation
V2I	Vehicle-to-Infrastructure
V2P	Vehicle-to-Pedestrian
V2V	Vehicle-to-Vehicle
V2X	Vehicle-to-Other Connected Device
VTRW	Vehicle Turning Right in Front of a Transit Vehicle Warning
WAVE	Wireless Access in Vehicular Environments
WLAN	Wireless Local Area Network
WSMP	WAVE Short Message Protocol
WWAN	Wireless Wide Area Network

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). http://www.gpo.gov/fdsys/pkg/FR-1999-11-26/html/99-30591.htm
- 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. http://www.nhtsa.gov/staticfiles/rulemaking/pdf/V2V/Readiness-of-V2V-Technology-for-Application-812014.pdf
- 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

Deployment (General)

- Research and Innovative Technology Administration, Connected Vehicle Research. http://www.its.dot.gov/connected_vehicle/connected_vehicle_research.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

Transit Connected Vehicles

- RITA- Intelligent Transportation Systems - Transit Connected Vehicle Research Program FACT Sheet. http://www.its.dot.gov/factsheets/transit_connectedvehicle.htm

6. Study Questions

1. Which of the following can be improved by connected vehicles in public transportation?
   a) Roadway congestion
   b) Crash rates
   c) Fuel efficiency
   d) All of the above

2. Which of the following is NOT a current attribute of DSRC?
   a) Low latency
   b) No subscription required
   c) Widely deployed in vehicles
   d) Short to medium range

3. Which of the following is NOT a formal standard?
   a) GTFS
   b) APTA TCIP
   c) CEN SIRI
   d) SAE J2735

4. Which of the following is NOT an Integrated Dynamic Transit Operations (IDTO) application area?
   a) Transit Connection Protection (T-CONNECT)
   b) Dynamic Transit Operations (T-DISP)
   c) Dynamic Ridesharing (D-RIDE)
   d) Forward Collision Warning (FCW)

5. Which of the following are potential barriers to implementation of transit connected vehicles?
   a) Security concerns
   b) Privacy concerns
   c) Evolving standards
   d) All of the above

6. What portion of the connected vehicle environment is NHTSA proposing a rulemaking?
   a) V2V safety applications for all vehicles
   b) V2V safety applications for light vehicles
   c) V2I communications capability for light vehicles
   d) V2V and V2I communications capability for all vehicles