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Office of the Assistant Secretary for
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Welcome

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CV 261:

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

Updated October 2020

Instructor

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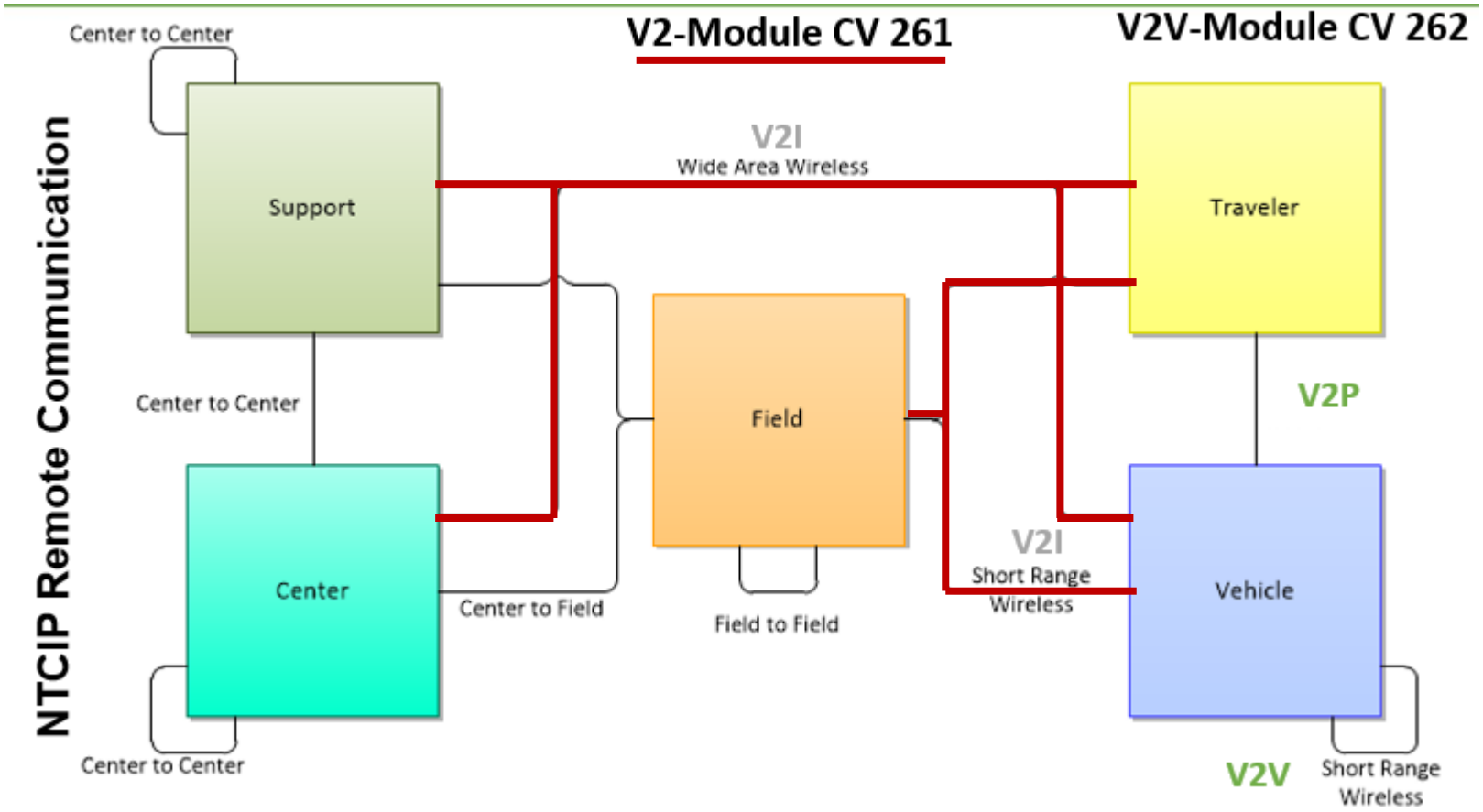
Learning Objectives

- Describe the Connected Vehicle (CV) Environment
- Discuss Vehicle to Infrastructure (V2I) Communications
- Describe the Role of Standards for Connected Vehicle Environment
- Address Challenges in Realizing a V2I Environment
- Review the Current Status of the Connected Vehicle Deployments

Learning Objective 1

Describe the Connected Vehicle (CV) Environment

Where V2I Discussion Fits Related to ARC-IT Framework



NTCIP: National Transportation Communications for ITS Protocol
ARC-IT: Architecture Reference for Cooperative and Intelligent Transportation

Components of the CV Environment

- **Vehicle to Everything (V2X)**
  - Vehicle to Infrastructure (V2I)
  - Vehicle to Vehicle (V2V)
  - Vehicle to Pedestrian (V2P)

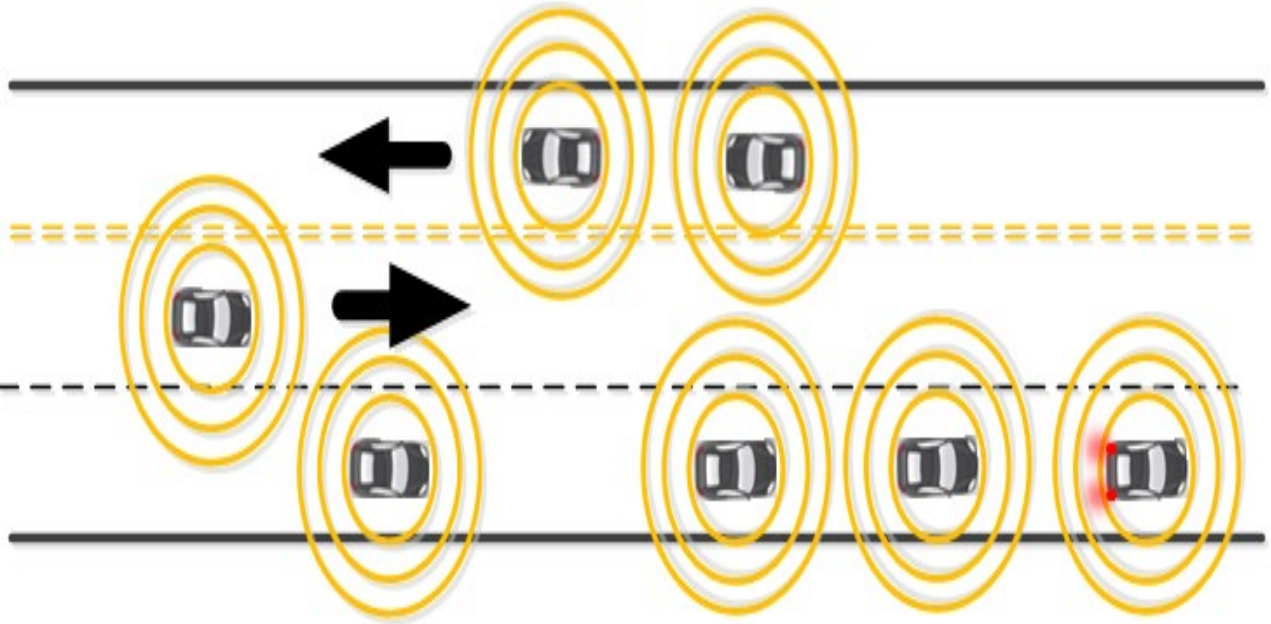
- **CV Communications, a Mixture of:**
  - Remote communications, e.g. devices to Traffic Management Center (TMC), using ITS standards
  - Local short-range wireless direct communications (broadcasts) using wireless/message standards

- **CV Safety/Mobility Applications**
  - Process messages/data and issue warnings/alerts to driver/users

Dynamic Ad-hoc V2X Wireless Connectivity

Participants constantly changing, communicate safety applications messages frequently under changing speeds-doppler shifts.

V2V



V2P

V2I

Identify V2I Services (Devices)

What is Roadside Unit (RSU)?

*A field device that supports secure communications with connected devices, and may include a computing platform running applications. The **RSU exchanges data among nearby connected devices** (vehicles or mobile devices), other ITS Roadside Devices, and management systems at centers (such as a Traffic Management Center (TMC) or a Connected Vehicle Back Office System).*

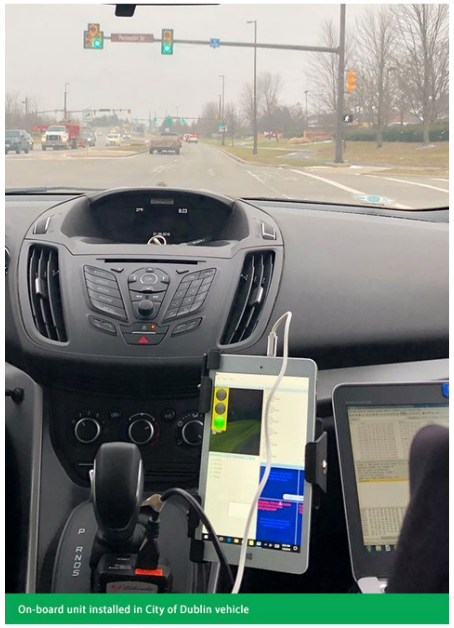
Ref: NTCIP 1218

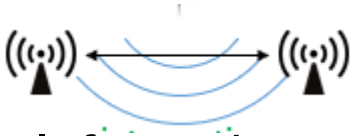
Identify V2I Services (Communication)

Primary Function of the RSU

Transmit/Receive Messages/Data from Devices Nearby

Onboard Unit (OBU)





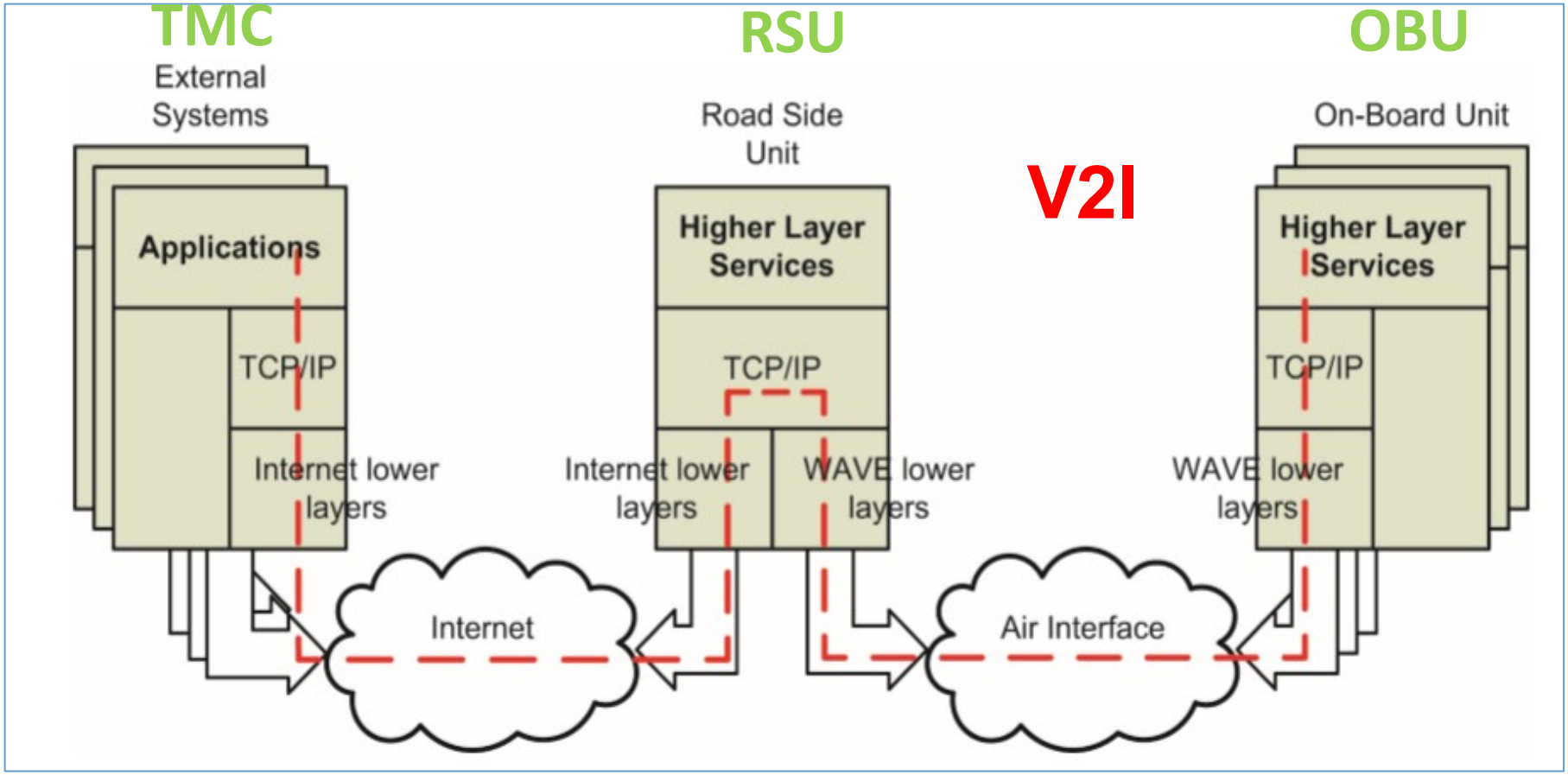
Information transfer Over-the-Air

Roadside Unit (RSU)

Source: City of Dublin, OH

Identify V2I Services (Internet Connectivity)

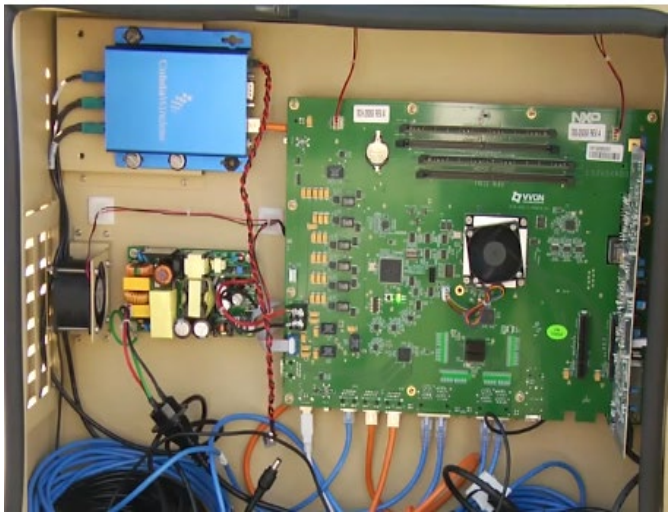
RSU Provides IPv6 Access to Remote Network



WAVE-Wireless Access in Vehicular Environments

Identify V2I Services (Application)

Device configures a list of applications, each with a PSID



Sources: NXP

Device is certified to conform to application specification (messages)

Source: ITS PCB Module T160

PSID: Provider Service Identifier (in US)

CV Applications Processing Representation

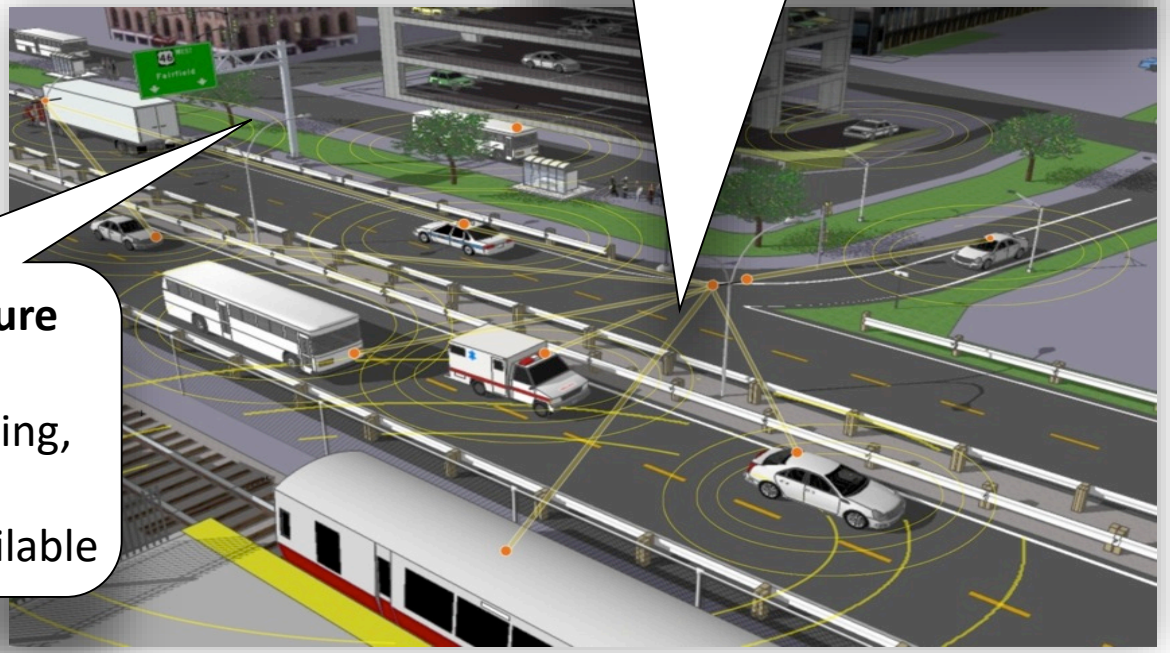
Application → Issues a Warning

Vehicle Data

Example Vehicle Data:
Latitude, Longitude, Speed, Brake Status, Turn Signal Status, Vehicle Length, Vehicle Width, Bumper Height

Infrastructure Data

Example Infrastructure Data:
Signal Phase and Timing,
Drive 35 mph,
50 Parking Spaces Available



Source: USDOT

Targeted CV Applications Address Challenges

Challenges

- 6.45 million+ crashes
- 36,550 fatalities
  - 6283 pedestrians (17%)
- 6 billion+ wasted hours
- Total Emissions-6.5 million metric tons of CO_2 equivalent

Benefits

- Reduce crashes by 20-80%

- Reduce congestion by 15-42%
- Improve mobility of those with disabilities
- Support Vehicle Connectivity

- Reduce pollution by ~10%

Sources: Data from USDOT, 2018

Technological Benefits of Vehicle Connectivity

CONNECTED AUTOMATION - GREATEST BENEFITS

Autonomous Vehicle **AV**

Operates in isolation from other vehicles using internal sensors

Connected Automated Vehicle

Leverages autonomous and connected vehicle capabilities

Additional Benefits Accrue with CAV

Connected Vehicle **CV**

Communicates with nearby vehicles and infrastructure

V2I, V2V Communication

U.S. Department of Transportation

Summary: V2I Communication

Understanding CV Environment

- ✓ Dynamic
- ✓ Includes V2X
- ✓ Short Range Communication
- ✓ Radio Broadcasts: Single Hop-Short Messages

Summary: V2I Communication (cont.)

"Build" Your Ad-hoc Wireless Infrastructure

1. Use ARC-IT framework to develop CV Architecture
2. Identify CV Applications using SEP
3. Procure compliant devices using standards
4. Conduct Testing and Certification Process

		V2I	V2V
	# Projects	Infrastructure	OBU/ASD
Planned	76	3,106	3,635
Operational	67	9,230	20,037
Total	143	12,336	23,672

OBU-Onboard Unit
ASD-Aftermarket Safety Device
SEP-Systems Engineering Process

36,008 CV Devices

Source: USDOT VOLPE, Aug 2020

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Question

Which of the following is NOT always a part of V2X communication services and not always used?

Answer Choices

a) Onboard Unit (OBU).

b) Roadside Unit (RSU).

c) Roadside Equipment (RSE).

d) Center to Field (C2F) Communication.

Review of Answers

a) Onboard Unit (OBU) is required for V2V communication.
Incorrect answer. OBU is part of V2V communication.

b) Roadside Unit (RSU) is required for V2I communication.
Incorrect answer. RSU is needed for V2I communication.

c) Roadside Equipment (RSE).
Incorrect answer because RSE is part of V2I communication.

d) Center to Field (C2F) Communication.
Correct answer, Typically, NTCIP covers C2F with remote communication.

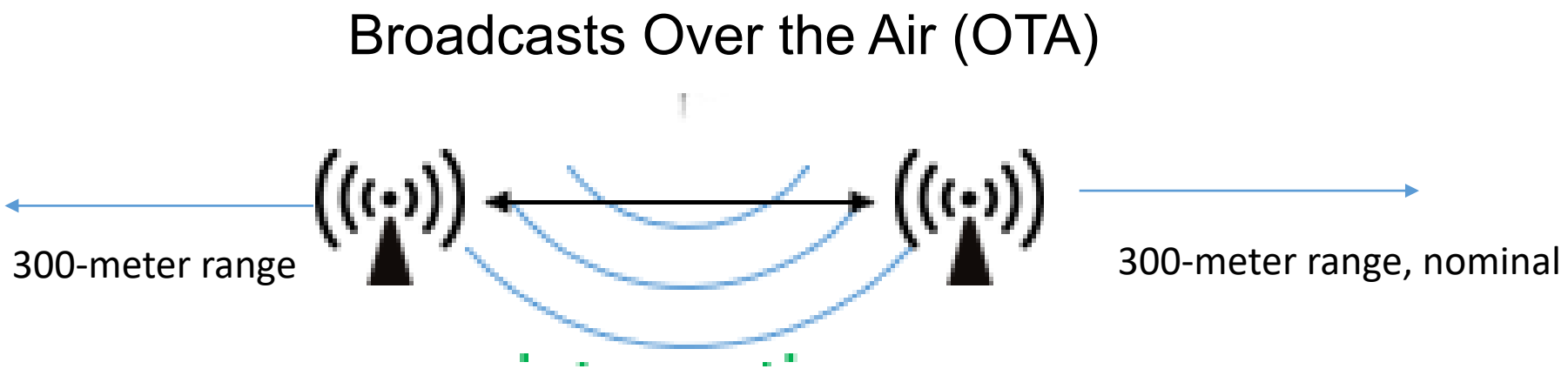
Learning Objective 2

Discuss Vehicle to Infrastructure (V2I) Communications

List the Components of V2I Network

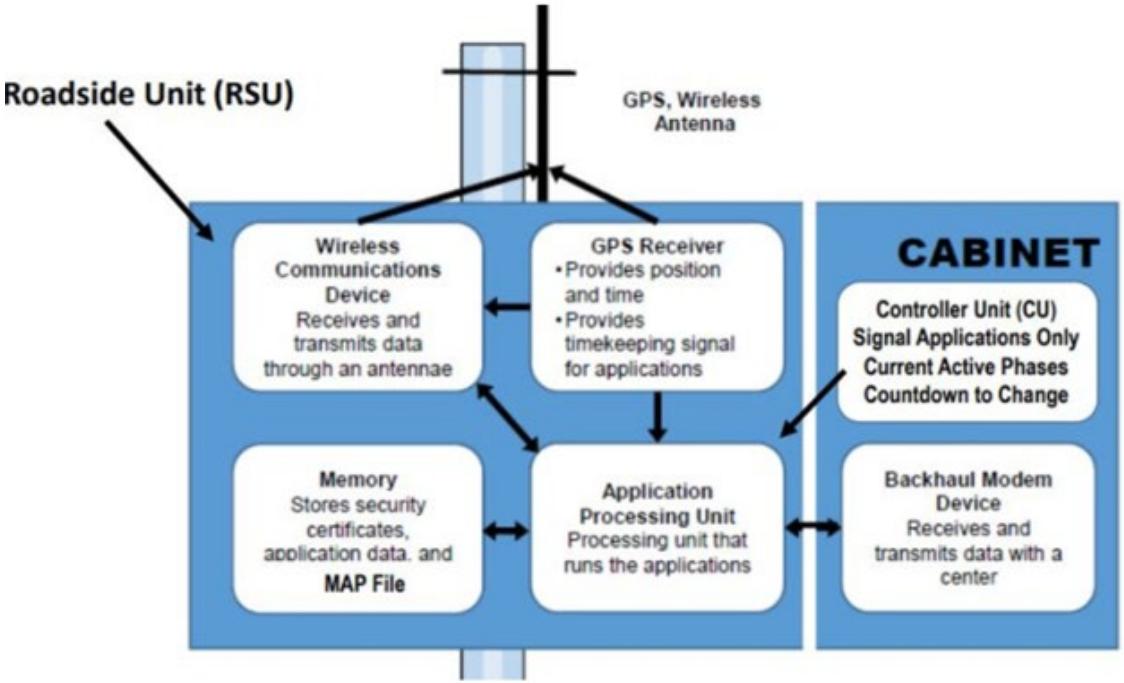
Communication Network

- ✓ Roadside Equipment (RSE)
- ✓ Roadside Unit (RSU)
- ✓ Backhaul Communication to TMC



Components of V2I Network: RSE

RSE Functions



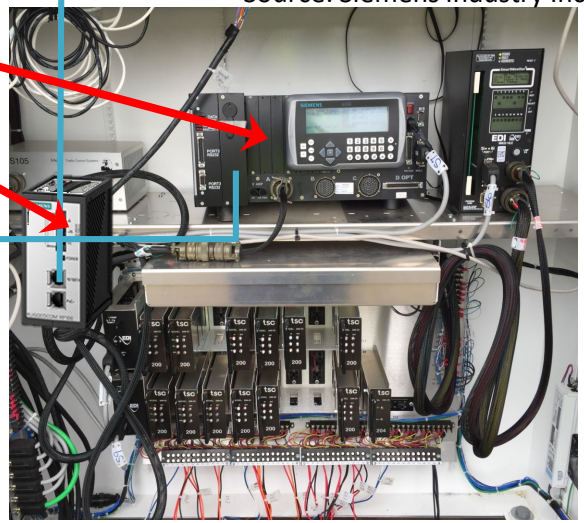
Global Positioning System (GPS) provides “UTC-Coordinated Universal Time” to synchronize devices.

Components of V2I Network: RSE

Typical RSE

- Antennas, lightning suppression
- Roadside Unit (RSU)
- Backhaul communication
- Traffic Controller:
  - Signalized intersection CV apps
  - Not used midblock, exits, speed
- Power over Ethernet (PoE) injector

Source: Siemens Industry Inc.



Source: PCM Module T160

Components of V2I Network: RSU

RSU Performs Radio Broadcasting Operation

- Key Factors Affecting RSU Installation
  - Available mounting infrastructure-Pole/Mast Arm/Gantry
  - Requires Line of Sight (LOS)
  - Coverage-Omnidirectional antenna
  - Power of Ethernet (POE)-cable, +48 VDC

Mast Arm Mounted

Pole Mounted

V2I Communication Requirements

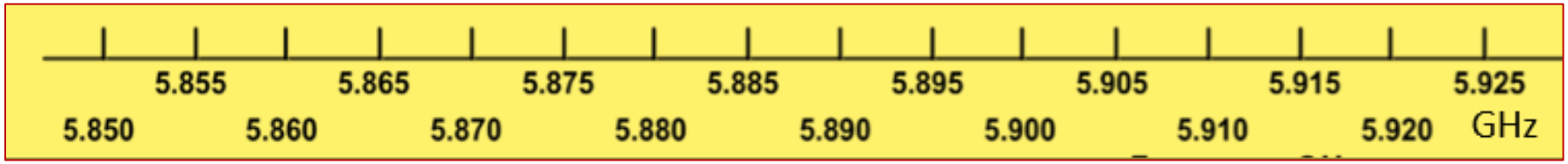
▪ Medium	DSRC (alternatively LTE-V2X)
▪ Standards	IEEE 1609.x (WAVE) IEEE 802.11 for DSRC
▪ Devices	RSU and OBU; Compliant to Standards
▪ Messages	Applications (V2I Safety/Mobility)
▪ Security	Security Credential Management System (SCMS)

WAVE-Wireless Access in Vehicular Environment
WSMP- (WSM-Wave Short Message Protocol (**WSMP**) and IPv6) are supported.
RSU-Roadside Unit
OBU-Onboard Unit
LTE-Long Term Evolution
DSRC-Dedicated Short Range Communication

Communication for CV Applications

Dedicated Short Range Communication (DSRC)

- Dedicated Radio Operation in 5.9 GHz spectrum
- Defined by IEEE 1609.x and 802.11 standards



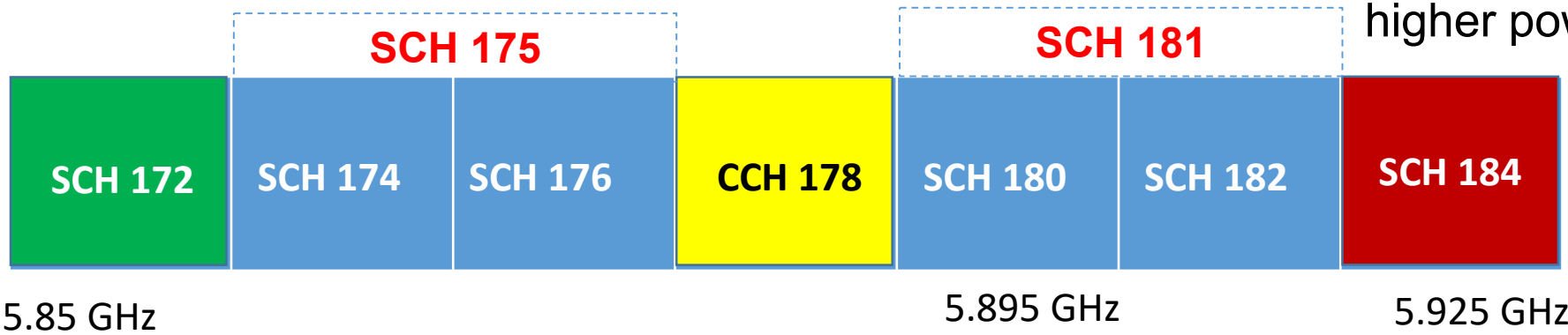
Current DSRC Channel Design

Channel Assignment

Service Channel (SCH)172 dedicated to public safety applications e.g. collision warning

Control Channel (CCH) 178 advertises services available on other channels

SCH 184 reserved for emergency vehicles uses higher power



Example of Assignment
SCH 174-176 for Downloading application software and operational parameters

Example of Assignment
SCH 180-182 for uploading mobility-operations and performance logs

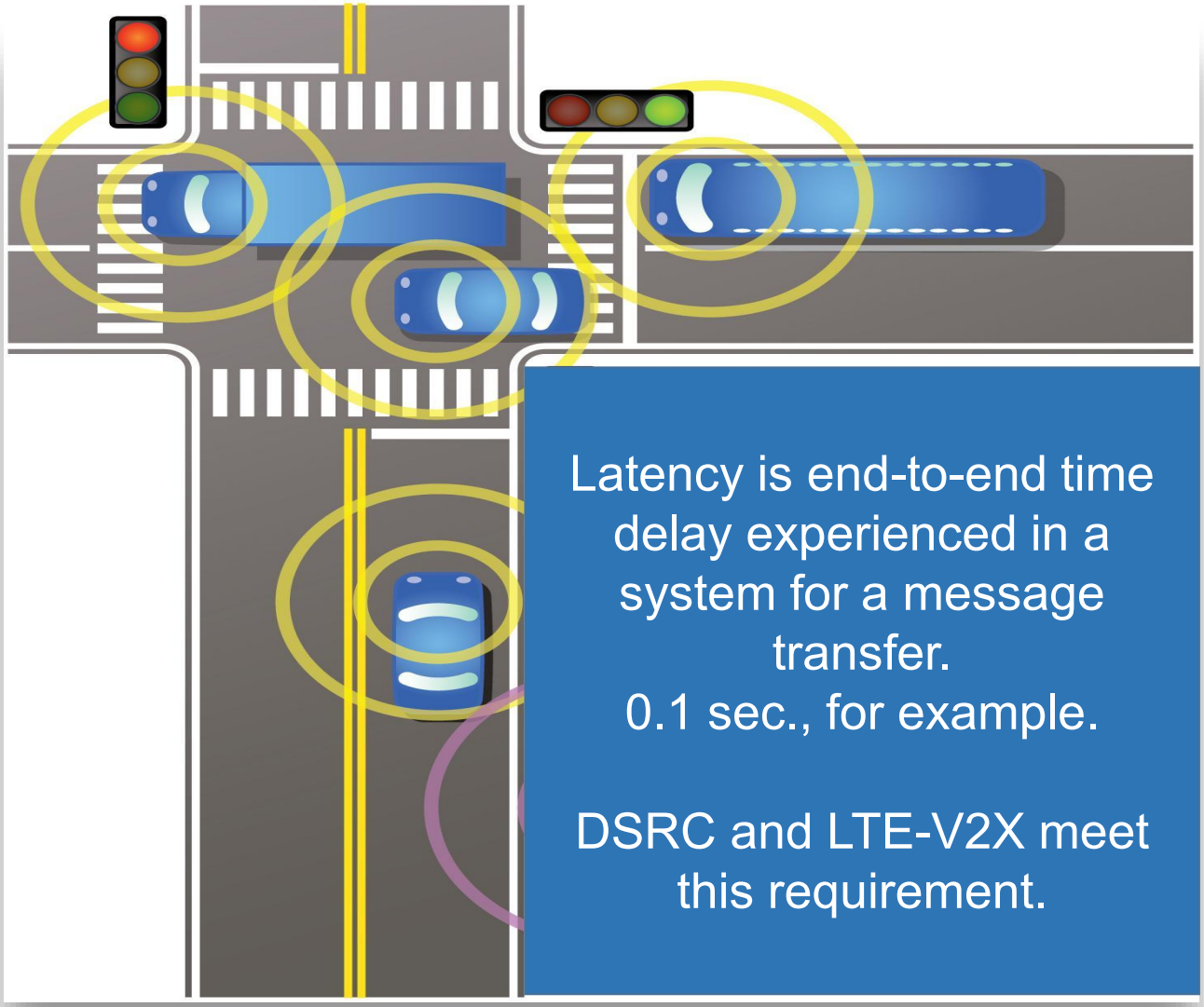
Communication for CV Applications

Emerging Technology: LTE-V2X

- Defined by 3GPP, Release 14
- Dedicated Radio in 5.9 GHz spectrum
- Enables network independent communication (PC5 Interface)
- Enables network services in licensed spectrum for complementary services (V2N-UU interface)
- IEEE 1609 WAVE standards adjustments for LTE-V2X applications are under preparation

3GPP-Third Generation Partnership Project
LTE-Long Term Evolution

Low Latency Communication Requirements



Latency is end-to-end time delay experienced in a system for a message transfer.
0.1 sec., for example.

DSRC and LTE-V2X meet this requirement.

Identified CV Applications

Detailed Descriptions Available at:
https://www.its.dot.gov/pilots/cv_pilot_apps.htm

Each category is linked to individual application.

Please click title for description.

V2I Safety
- Red Light Violation Warning
- Curve Speed Warning
- Stop Sign Gap Assist
- Spot Weather Impact Warning
- Reduced Speed/Work Zone Warning
- Pedestrian in Signalized Crosswalk Warning (Transit)

V2V Safety
- Emergency Electronic Brake Lights (EEBL)
- Forward Collision Warning (FCW)
- Intersection Movement Assist (IMA)
- Left Turn Assist (LTA)
- Blind Spot/Lane Change Warning (BSW/LCW)
- Do Not Pass Warning (DNPW)
- Vehicle Turning Right in Front of Bus Warning (Transit)

Agency Data
- 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

Environment
- Eco-Approach and Departure at Signalized Intersections
- Eco-Traffic Signal Timing
- Eco-Traffic Signal Priority
- Connected Eco-Driving
- Wireless Inductive/Resonance Charging
- Eco-Lanes Management
- Eco-Speed Harmonization
- Eco-Cooperative Adaptive Cruise Control
- Eco-Traveler Information
- Eco-Ramp Metering
- Low Emissions Zone Management
- AFV Charging / Fueling Information
- Eco-Smart Parking
- Dynamic Eco-Routing (light vehicle, transit, freight)
- Eco-ICM Decision Support System

Road Weather
- Motorist Advisories and Warnings (MAW)
- Enhanced MDSS
- Vehicle Data Translator (VDT)
- Weather Response Traffic Information (WxTINFO)

Mobility
- Advanced Traveler Information System
- Intelligent Traffic Signal System (I-SIG)
- Signal Priority (transit, freight)
- Mobile Accessible Pedestrian Signal System (PED-SIG)
- Emergency Vehicle Preemption (PREEMPT)
- Dynamic Speed Harmonization (SPD-HARM)
- Queue Warning (Q-WARN)
- Cooperative Adaptive Cruise Control (CACC)
- Incident Scene Pre-Arrival Staging Guidance for Emergency Responders (RESP-STG)
- Incident Scene Work Zone Alerts for Drivers and Workers (INC-ZONE)
- Emergency Communications and Evacuation (EVAC)
- Connection Protection (T-CONNECT)
- Dynamic Transit Operations (T-DISP)
- Dynamic Ridesharing (D-RIDE)
- Freight-Specific Dynamic Travel Planning and Performance
- Drayage Optimization

Smart Roadside
- Wireless Inspection
- Smart Truck Parking

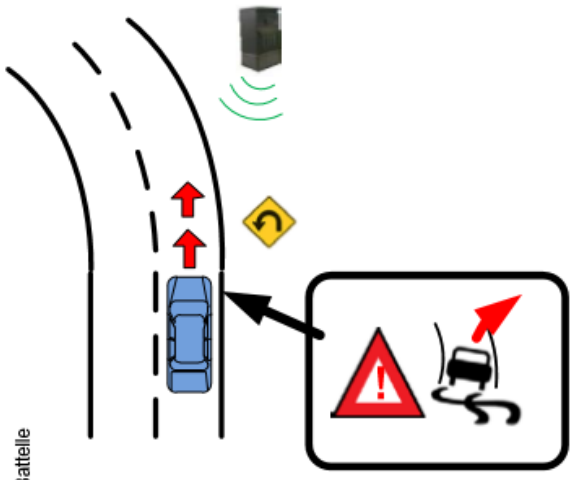
Targeted V2I Applications Examples

SPaT Data Enables Many High-Value Applications for Safety/Mobility and Environment

- RED Light Violation Warning (RLVW)
- Pedestrian in Signalized Crosswalk Warning (PSCW)
- Intersection Movement Assist (IMA)
- Traveler Information
- Transit Signal Priority (TSP)
- Eco-Traffic Signal Timing

Illustration: Curve Speed Warning (CSW) Application

Approaching traffic unaware of the sharp curve and of black ice condition



Source: Battelle

Driver Vehicle Interface (DVI) Example

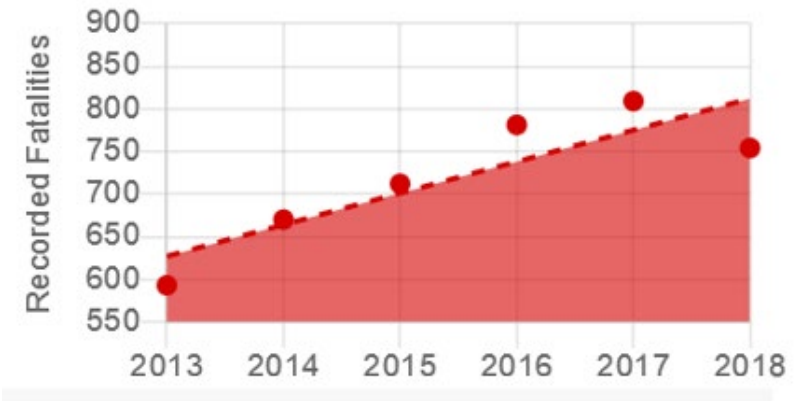
If the speed exceeds the limit, driver receives a warning

Source: Oregon Department of Transportation.

Driver negotiates the curve safely-observes recommended speed

Illustration: Reduced Speed Work Zone Warning (RSZW) Application

Fatalities resulting from Work Zone crashes



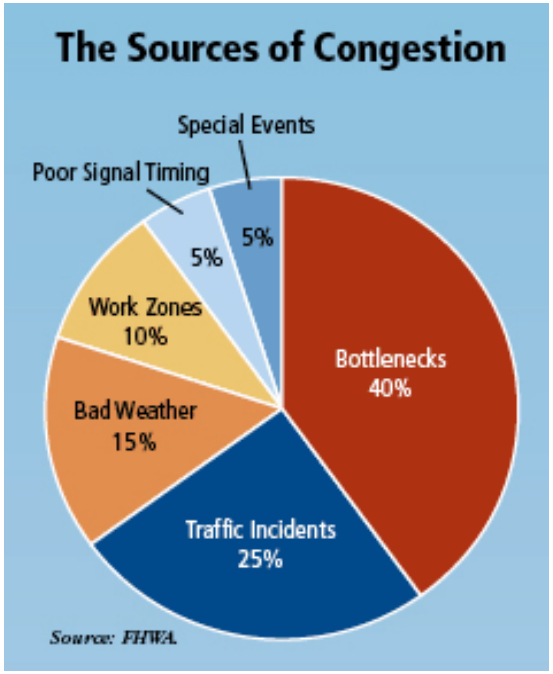
Driver is alerted in in real-time

Source: Maricopa County, AZ DOT

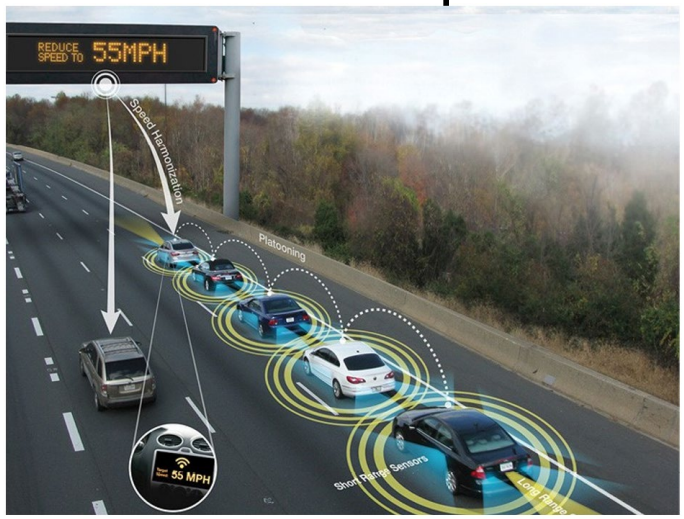
Mobility Applications (V2I/V2V)

Speed harmonization to improve safety and mobility

- Reduced rear-end crashes
- Provide Smoother lane merging and bottlenecks



- Provide real-time conditions at congested locations to TMC
- Drivers receive optimal recommended speeds

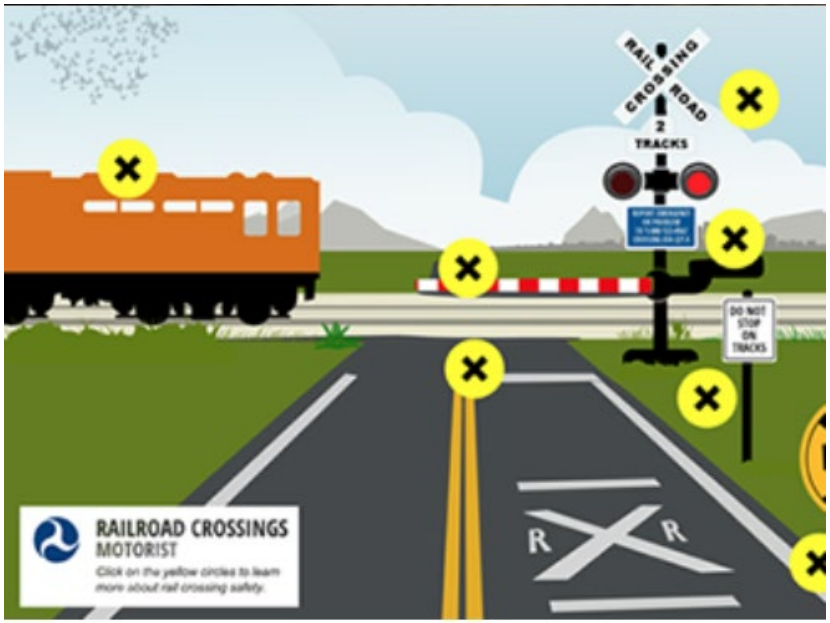


U.S. DOT

Safety Applications (V2I/V2V)

Railroad Crossing Violation Warning (RCVW)

- 685 crashes in 2018
- 281 fatalities



- Train Approaching Warning

Source: USDOT

Assessment of Impacts of Alerts Enhanced-Pedestrian in Crossing Warning (E-PCW)

6590 pedestrians fatalities in 2019-GHSA

GCRTA

- 81% Correct alerts
- 10% Incorrect alerts
- 9% False alerts

16% Increase in driver braking response; resulting in reduction in conflicts with pedestrians.

Preparation for V2I Communication

Key Steps

1. Prepare Communication Infrastructure
2. Ensure Communication Requirements are met:
   - ✓ DSRC 5.9 GHz Channel Design (or alternative medium such as LTE-V2X PC5 interface)
   - ✓ Standards
   - ✓ RSUs
   - ✓ Applications
   - ✓ Security
   - ✓ Testing/Certification

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Question

Which of the following is NOT a V2I application?

Answer Choices

a) Curve Speed Warning (CSW)

b) Transit Signal Priority (TSP)

c) Forward Collision Warning (FCW)

d) Railroad Crossing Violation Warning (RCVW)

Review of Answers

a) Curve Speed Warning (CSW)

Incorrect. CSW is a V2I application.

b) Transit Signal Priority (TSP)

Incorrect. TSP is a V2I mobility application.

c) Forward Collision Warning (FCW)

Correct! FCW is a V2V application, not V2I.

d) Railroad Crossing Violation Warning (RCVW)

Incorrect. It is a V2I application.

Learning Objective 3

Describe the Role of the Standards in a Connected Vehicle Environment

Why are standards consider essential?

Support interoperability to maximize benefits

- Interoperability-the ability of two or more systems or components to exchange information and use the information that has been exchanged

Agencies can specify compliant V2X devices for applications from multiple vendors

- Helps with the planning, system design and procurement of a CV system

Consistent messages can be constructed for multiple applications

- Short messages delivered with low latency communication

Types of Standards Required for V2I Communication

Transmission Standards for Wireless Connectivity	✓ IEEE 802.11(2016) DSRC Radio Operation ✓ IEEE 1609 Family of Standards for Wireless Access in Vehicular Environments (WAVE) (2016, v3.0) for messages exchange
Interface and Dictionary Standards	✓ SAE J2945/x Interface Standards ✓ SAE J2735 V2X Communications Message Set Dictionary
ITS Field Devices and Center to Center Communication Standards	✓ NTCIP Standards ✓ RSU Specification v4.1 (2016)

Transmission Standards for Wireless Connectivity

IEEE 802.11 (2016)

- Describes specification for wireless connectivity using DSRC services for:
  - Media Access Control (MAC): the message protocols that allow applications to ‘connect’ to the PHY layer
  - PHY: the radio chips and the intervening environment in between
- IEEE 802.11 enables Ad-hoc wireless communication with IEEE 1609.x standards

Transmission Standards for Wireless Connectivity

IEEE 1609™ Family of Standards for Wireless Access in Vehicular Environments (WAVE)

IEEE 1609.0: Guide for Wireless Access in Vehicular Environments (WAVE) Architecture (2019)

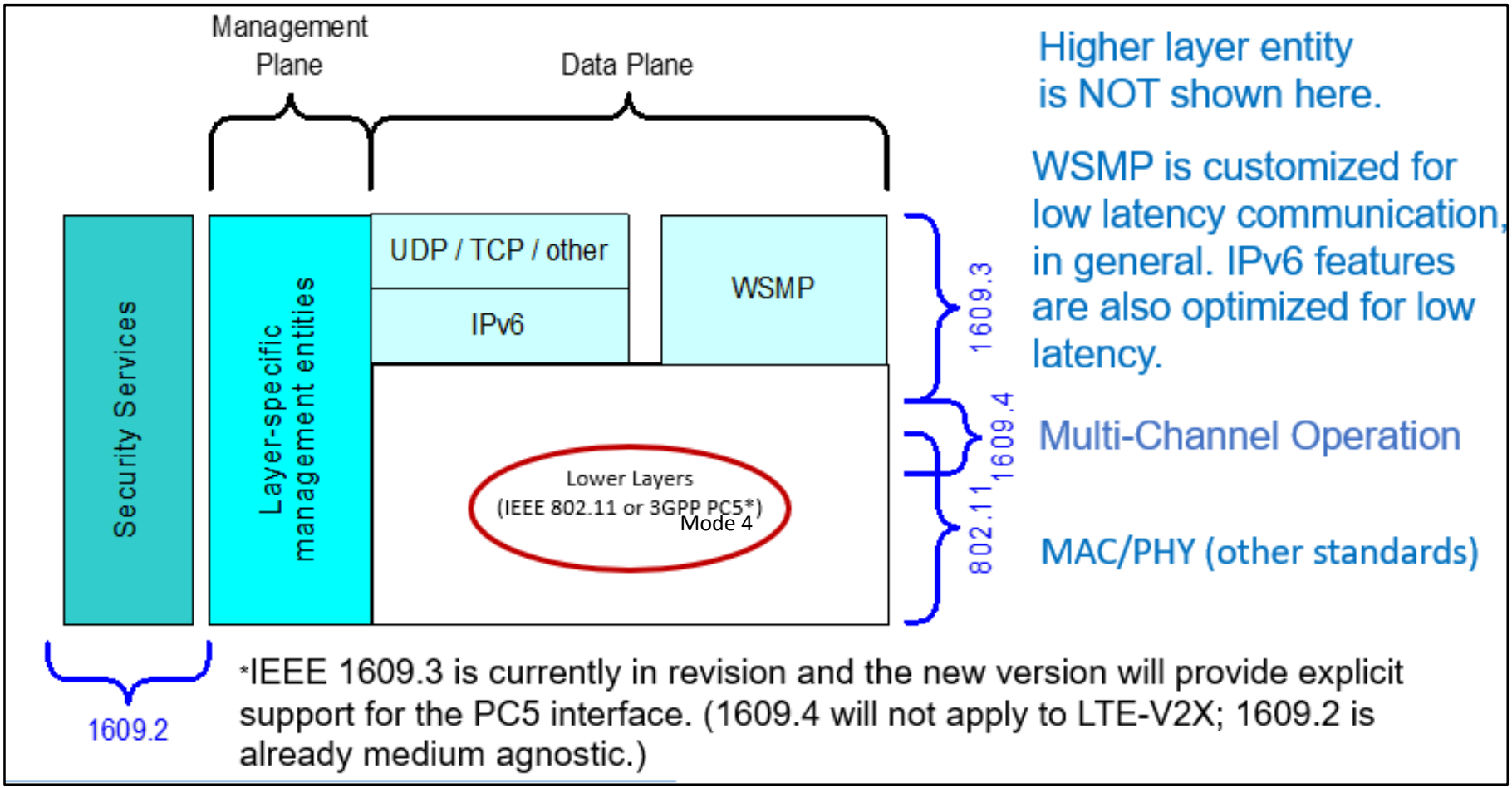
IEEE 1609.2: Security Services for Applications and Management Messages
1609.2.1 adds Security Credential Management System (SCMS) (pending)

IEEE 1609.3: Network and Transport Services

IEEE 1609.4: Multi-Channel Operation Standards

IEEE 1609.12: Identifier Allocations

WAVE Architecture Supports DSRC and LTE-V2X Communications



WSMP-WAVE Short Message Protocol
TCP-Transmission Control Protocol
IP-Internet Protocol
UDP-User Datagram Protocol
MAC-Media Access Control

(SAE stds. at Application Layer, not shown here)

Source: Justin McNew, IEEE 1609 WG, October 2020

Interface and Data Dictionary Standards

Standards

- SAE J2945 Systems Engineering Guidance
- SAE J2945/3 Requirements for Road Weather Applications

Practices

- SAE J2945/2 V2V Awareness Application
- SAE J2945/9 Vulnerable Road User Application

https://www.sae.org/standards/content/j2945_201712/

Interface and Data Dictionary Standards

SAE J2945/x Sets Performance Requirements

- How to use management, facilities, and security to implement a specific application, as defined by use cases
- Performance/functional requirements:
  - What, when and **how often** a message is sent (minimum, typical, maximum)
  - Minimum quality requirements
  - Security requirements
  - Dialogs and data
  - Requirements Traceability Matrix (RTM)

Example:
BSM, 10X/sec.

https://www.sae.org/standards/content/j2945_201712/

Interface and Data Dictionary Standards

SAE J2735 V2X Communications Message Set Dictionary Specifies (2020):

Data Elements (DE)
Primitive Objects e.g. Speed

Data Frames (DF)
Collection of Data Elements

Messages (MSG)
Collection of Data Elements and Data Frame(s)

For BSMs, Part I covers core data elements for safety applications, broadcasted **frequently**, e.g. speed.

For BSMs, Part II covers Data elements to be added to Part I data, but broadcasted **less frequently**, e.g. windshield wiper status.

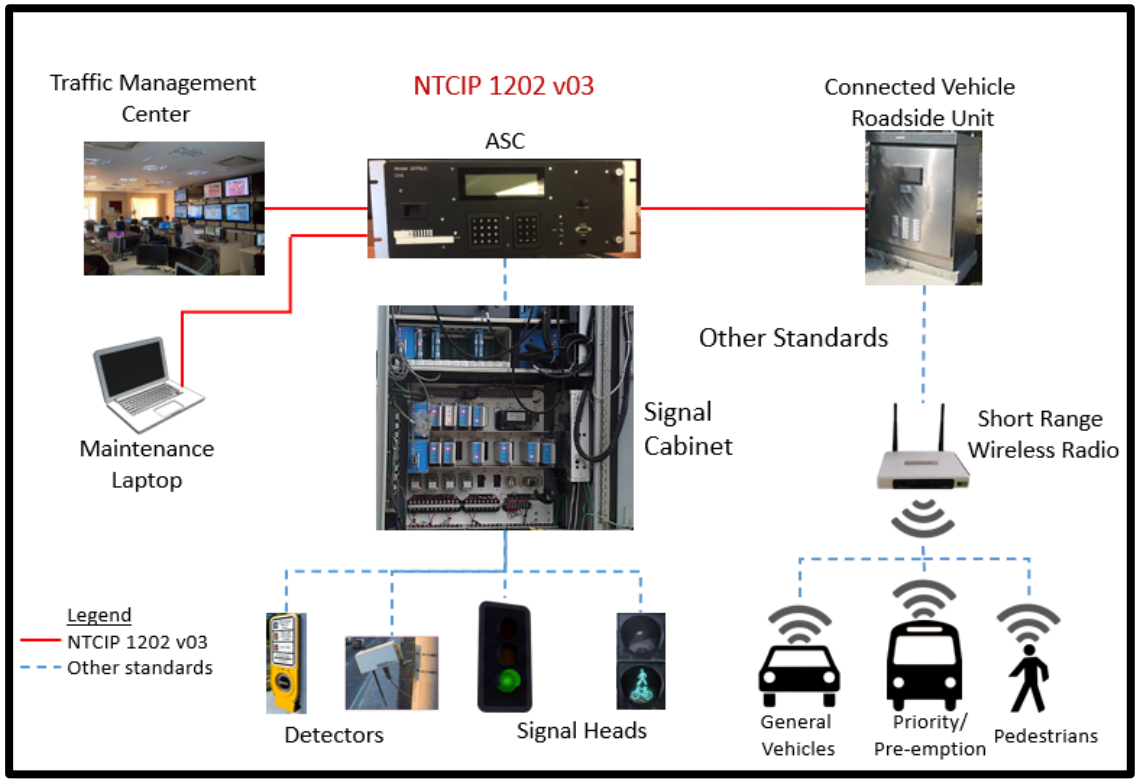
Interface and Data Dictionary Standards

SAE J2735 Messages for CV Applications

MessageFrame (FRAME) BasicSafetyMessage (BSM) CommonSafetyRequest (CSR) EmergencyVehicleAlert (EVA) IntersectionCollisionAvoidance (ICA) MapData (MAP) NMEAcorrections (NMEA) PersonalSafetyMessage (PSM) ProbeDataManagement (PDM	ProbeVehicleData (PVD) RoadSideAlert (RSA) RTCMcorrections (RTCM) SignalPhaseAndTiming Message (SPaT) SignalRequestMessage (SRM) SignalStatusMessage (SSM) TravelerInformation Message (TIM) TestMessages

ITS Field Device Standards

Overview of the Scope of NTCIP 1202 ASC Standard



ASC-Actuated Signal Controller

Source: ITS PCB Module A315B

ITS Field Device Standards

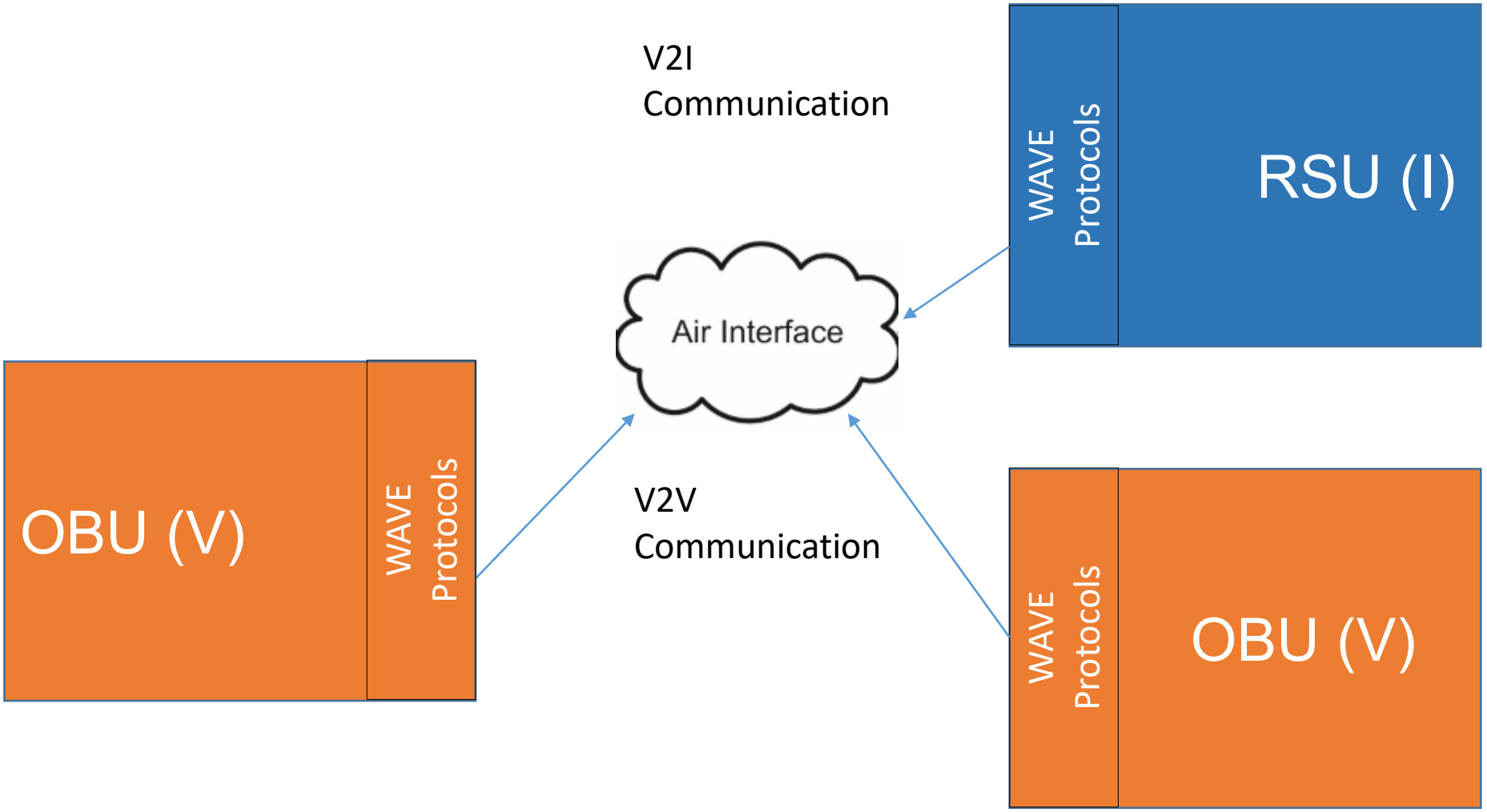
RSU Specification v4.1

- Sets the minimum requirements for RSU capable of acting as a network edge device
- Includes system requirements for:
  - Power
  - Environmental
  - Physical
  - Functional
  - Behavioral
  - Performance
  - Interface

https://rosap.ntl.bts.gov/view/dot/3600

Air Interface for V2X Communication

Supported by WAVE and IPv6 protocol stacks



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Question

Which of the following standards is NOT directly related to DSRC V2I communication, but can be used?

Answer Choices

a) IEEE 1609 family (WAVE)

b) SAE J2735 V2X communications message dictionary

c) NTCIP 1202 v3.0 (ASC)

d) IEEE 802.11

Review of Answers

a) IEEE 1609 Family (WAVE)

Incorrect. IEEE 1609 family standards enables wireless connectivity.

b) SAE J2735 V2X communications message dictionary

Incorrect. It supports the BSM.

c) NTCIP 1202 v3.0

Correct! It is part of the NTCIP application standards, not V2I wireless connectivity.

d) IEEE 802.11

Incorrect. It supports the PHY layer medium in WAVE implementation for DSRC.

Learning Objective 4

Address Challenges in Realizing V2I Environment

CASE STUDY

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Image Source: Thinkstock USDOT

CV Project Development Challenges

Where to Start?

Project Level

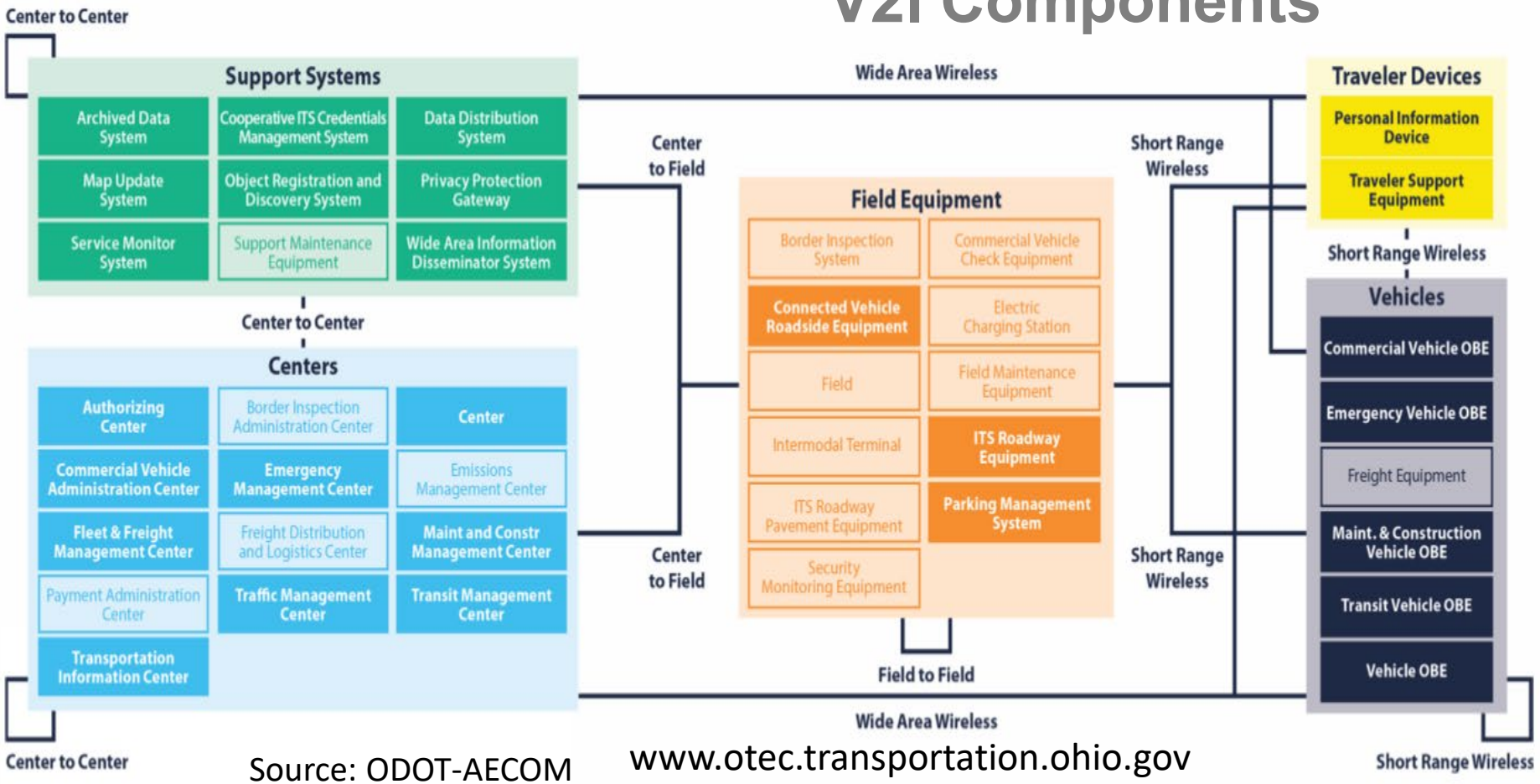
- Goals/objectives identified in the Concept of Operations (ConOps)
- Scope of Project: Regional CV? Scalability?
- Coverage Area: RSU locations for V2I (highways, intersections, transit routes)
- User Need-based V2I Applications, and CV Architecture (follow SEP)
- Other project-specific or MPO regional planning issues

MPO-Metropolitan Planning Organization
SEP-Systems Engineering Process

Step 1: Follow ARC-IT Framework Guidance

Example: Ohio Statewide Architecture Framework

V2I Components



Source: ODOT-AECOM

www.otec.transportation.ohio.gov

Step 2: Identify CV/AV Applications: Prioritize

ODOT Identified 109 Applications

Application	Need-Based	Project-Based	Future Projects
Curve Speed Warning	●		
End of Ramp Deceleration Warning (ERDW)	●		
Reduced Speed Zone Warning/Lane Closure		●	
Pedestrian in Signalized Crosswalk Warning	●		
Red Light Violation Warning	●		
SPaT MAP Display Signal Timing, Time to Green	●	●	
Wrong Way Entry (WWE)	●		
Speed Limit Warning			●
Spot Weather Impact Warning	●	●	
Restricted Lane Warnings			●
Oversize Vehicle Warning			●
Stop Sign Violation Warning	●	●	
Stop Sign Gap Assist	●	●	

Source: ODOT-AECOM, www.otec.transportation.ohio.gov

Institutional Challenges

Data Ownership and Privacy

- Need to limit distribution of sensitive data
  - Prevent sharing of sensitive data that can be combined to reveal personally identifiable information
  - Establish rules on what information can be shared and used for what purposes
- Need for anonymity of vehicles and vulnerable road users
  - Prevent tracking of individuals
  - Allow personal information when needed (e.g., tolling)

Institutional Challenges (cont.)

Data Management Requires Partnerships

- TMC Backhaul Processing
- Coordinated Infrastructure Deployment
  - ✓ Collect data, Share data and Interact

Example: Transit OBU must receive "SPaT" data and be able to issue a Signal Request Message (SRM) for TSP in a multi-jurisdictional operation.

Technical Challenges

Key Areas

- WAVE and SAE standards are evolving
- Communication technologies (e.g. DSRC, LTE-V2X)
- System integration issues (interoperability)
- Security: SCMS implementation, IEEE 1609.2.1 pending*
- Intersection management (V2I, NTCIP 1202 v3.0)
- DSRC radio operation-software updates
- Testing and Certification
- V2I Security challenge: RSU Spec 4.1 requires SNMP v3 for Security, but ASC 1202 is SNMP v1-based. (work in progress*)

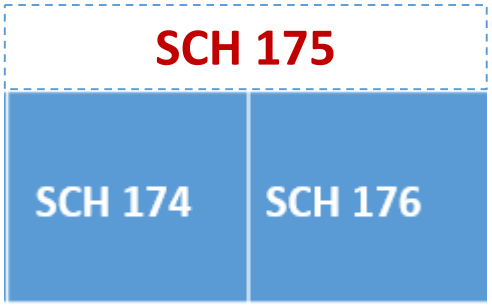
SCMS: Security Credential Management System

* As of October 2020

Technical Challenges (cont.)

Can new/updated applications (software) be installed into RSU/OBU (vehicles)?

- Conceptually, they could be installed like with a smart phone, Over the Air (OTA) using a DSRC channel (e.g. SCH 174)



- Applications and interactions between applications are likely to require extensive testing

Technical Challenges (cont.)

Testing Requirements: What will be tested, how and by who?

10 vendors participated in the equipment testing

Source: http://www.cflsmartroads.com/projects/CVAV_D5_Testing.html

Technical Challenges (cont.)

Certification Requirements

- Conformance to standards
  - Each standard should have a conformance clause (statement); understand what it means
  - Understand how to test for conformance to the standard; be aware of versions of standard
- Compliance to FCC regulations/legal requirements
- Performance testing of applications. Did it work?
- Security certificate will be authorized only after the device certification

Technical Challenges (cont.)

Training Modules on CV Testing Available at: https://www.pcb.its.dot.gov/stds_modules.aspx

- CV-T160 Connected Vehicles Certification Testing Introduction
- T101 – Introduction to ITS Standards Testing
- T201 – How to Write a Test Plan
- T202 – Overview of Test Design Specifications, Test Cases and Test Procedures

Summary of Implementation Issues and Support

Stakeholders

Public Agencies
Vehicle Designers
OEM Manufacturers
ASD Vendors
Developers of Applications/Standards
Testing Engineers
Certification Groups
Academic Researchers
Vehicle/Fleet Owners

Implementation Issues

- **Data Exchange Support**:
  - ITS Information
  - SPaT-MAP-BSM messages
- **Standards/Interoperability Support**
  - IEEE 802.11 (2016)
  - IEEE 1609.X (2016)
  - SAE J2735
  - USDOT v4.1-RSU specs.
  - NTCIP 1202 v3, V2IHUB for controller interfaces
- **Support for**:
  - WAVE: WSMP-v3
  - IPv06
- **Security**: SCMS-v2.0

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Question

Which of the following is not a technical challenge?

Answer Choices

a) Testing for conformance to standards.

b) Certification and interoperability testing of devices.

c) Over the air Firmware (software) upgrades for devices.

d) Data ownership.

Review of Answers

a) Testing for conformance to standards.
Incorrect. Testing is a critical step to ensure conformance to published standards, it is a technical challenge.

b) Certification and interoperability testing of devices.
Incorrect: CV devices such RSU have been addressed as a technical challenge.

c) Over the air Firmware (software) upgrades for devices.
Incorrect. Software updates over the air is a technical challenge that is easily addressed.

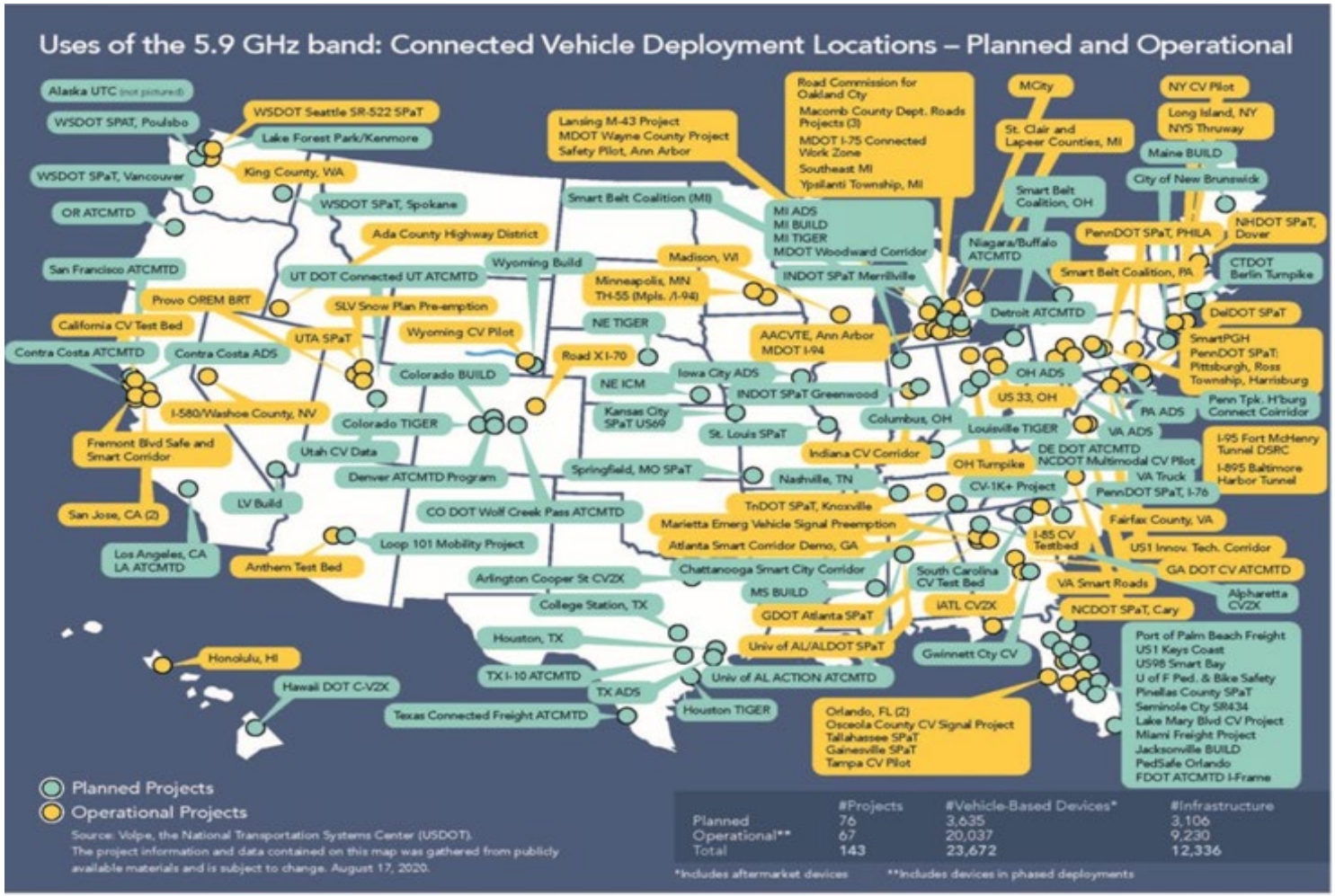
d) Data ownership.
Correct! Generally, an Institutional Challenge addressed by the project management.

Learning Objective 5

Review the Current Status of the Connected Vehicle Deployments

US CV Deployments

36,000 CV Devices Deployed as of August 17, 2020

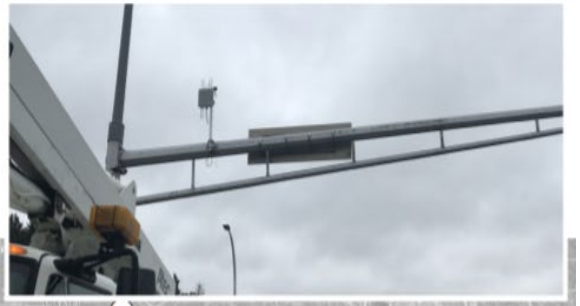


Source: USDOT- VOLPE

Example: Snow plow Signal Priority (SPSP)-MnDOT

Provides plows the ability to request extended green or early green phases at traffic signals (SPaT)

vehicle-to-infrastructure (V2I) technology, which helps vehicles "talk" to infrastructure to improve safety and efficiency of roadway users.



Challenge Addressed

A Snow plow Operator needs **reduced disruption** of snow plow operations at signalized intersections, which results in incomplete snow removal and uneven application of surface treatments.

CV Devices Implementation: Wyoming DOT

Wyoming Pilot (WYDOT)	Complete	Target
WYDOT Maintenance Fleet Subsystem On-Board Unit (OBU)	35	90
Integrated Commercial Truck Subsystem OBU	0	25
Retrofit Vehicle Subsystem OBU	16	255
WYDOT Highway Patrol	0	35
Total Equipped Vehicles	**51**	**~405**
Roadside Units (RSU) along I-80	**75**	**75**

Source: USDOT 7/1/2920

Noteworthy Observation: use of WYDOT's Systems Engineering documents helped CDOT to leverage lessons learned and avoid many potential mistakes, particularly on RSU operational data. (July 2020)

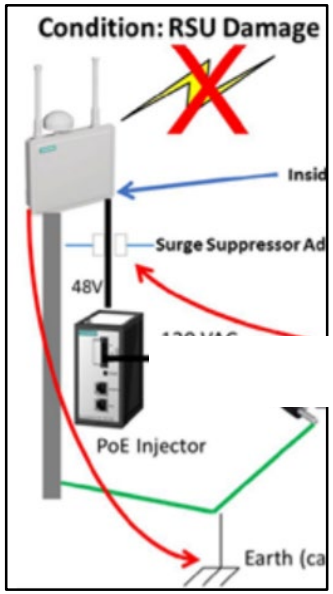
https://www.its.dot.gov/pilots/wydot_deployments.htm

https://ntl.bts.gov/about_ntl.html.

CV Devices Implementation: Tampa CV Pilot

Tampa Pilot (THEA)	Complete	Target
Private Light-Duty Vehicles Equipped with On-Board Unit (OBU)	701	1,080
HART Transit Bus Equipped with OBU	7	10
TECO Line Street Car Equipped with OBU	8	8
Total Equipped Vehicles	**716**	**~1,000**
Roadside Units (RSU) at Downtown Intersections	**47**	**47**

79

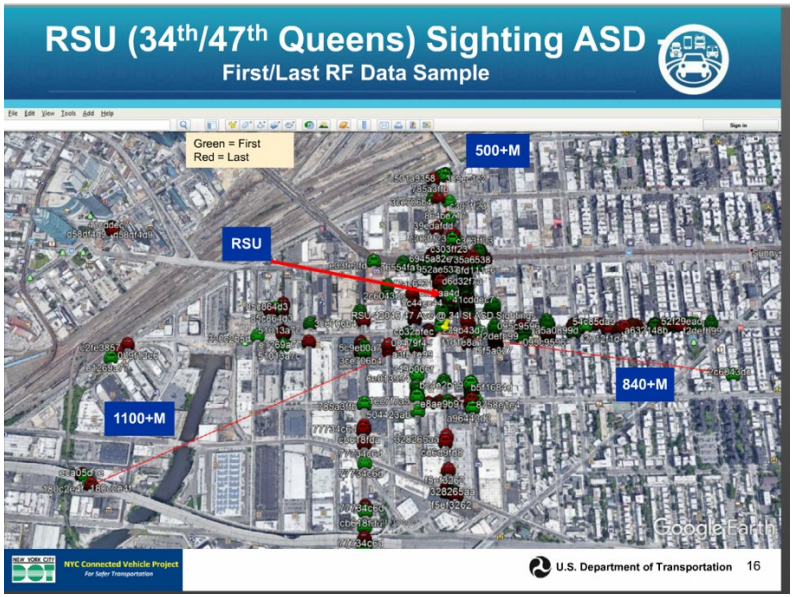


Noteworthy Observation: Pilot found that four of the forty-four RSUs were not communicating with the Master server. After a series of investigations, THEA concluded that some RSUs were not grounded properly and that lightning strikes were causing damage to the RSUs.

Source: USDOT
7/1/2020

CV Devices Implementation: NYC Pilot Project

Installed over 1900 vehicles of a scheduled 3000 and Installed 447 RSUs of a scheduled 450, as of 9/29/20



Typical RSU Installation

Noteworthy Observation: Verified Over-the-Air Firmware updates and applications parameters; multi-vendors environment.

Lesson Learned from Deployments

Multiple-vendors ASD Interoperability Testing

Lesson Learned from Deployments

What have we tested?

- ✓ V2V/V2I Communications
- ✓ Interoperability, tested the reception of OTA (broadcasts) messages; BSMs, SPaT/MAP

Applications **performance** testing was done separately by CV Pilots within their own test programs.

OTA-Over The Air

https://www.its.dot.gov/pilots/index.htm

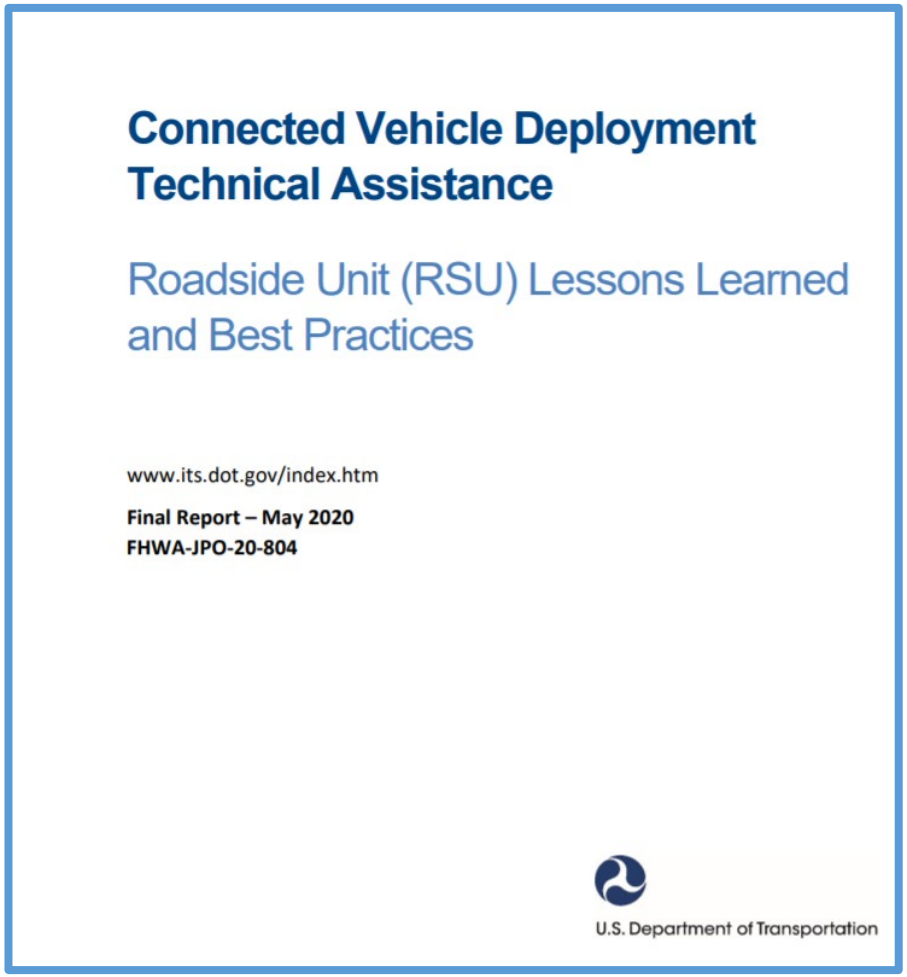
RSU Related Lessons Learned from CV Pilots Deployments

Best Practices

- Procurement
- Installations
- Testing
- Standards

Procurement 12: Reduce risk by selecting multiple suppliers.

Design 18: Design RSUs to continue broadcasting through jamming activities.

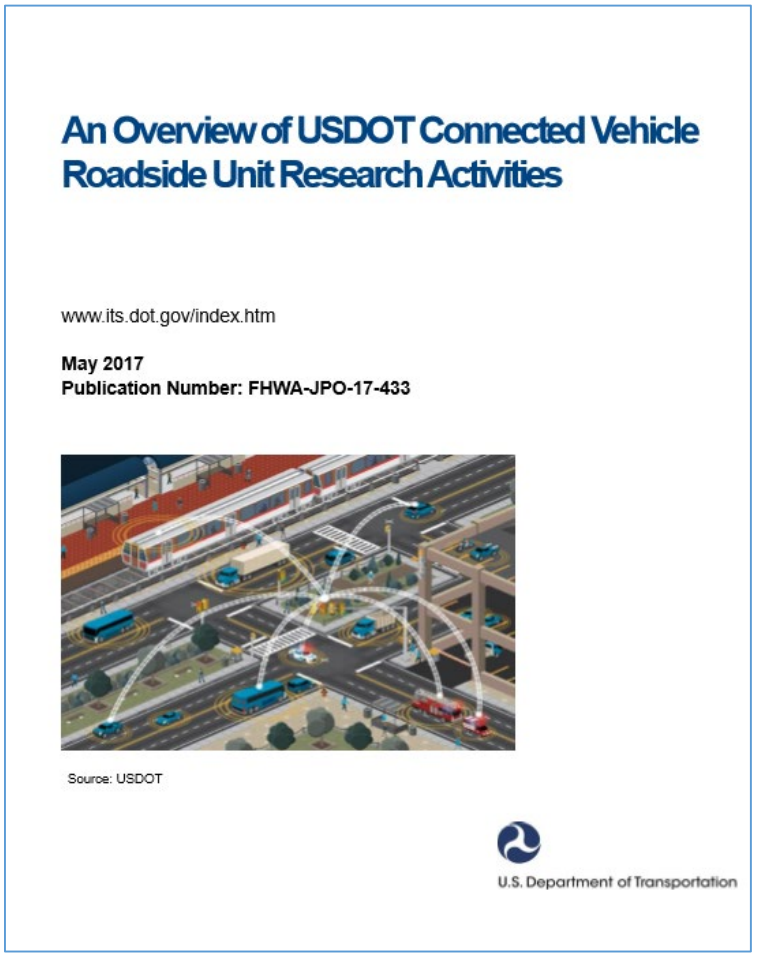


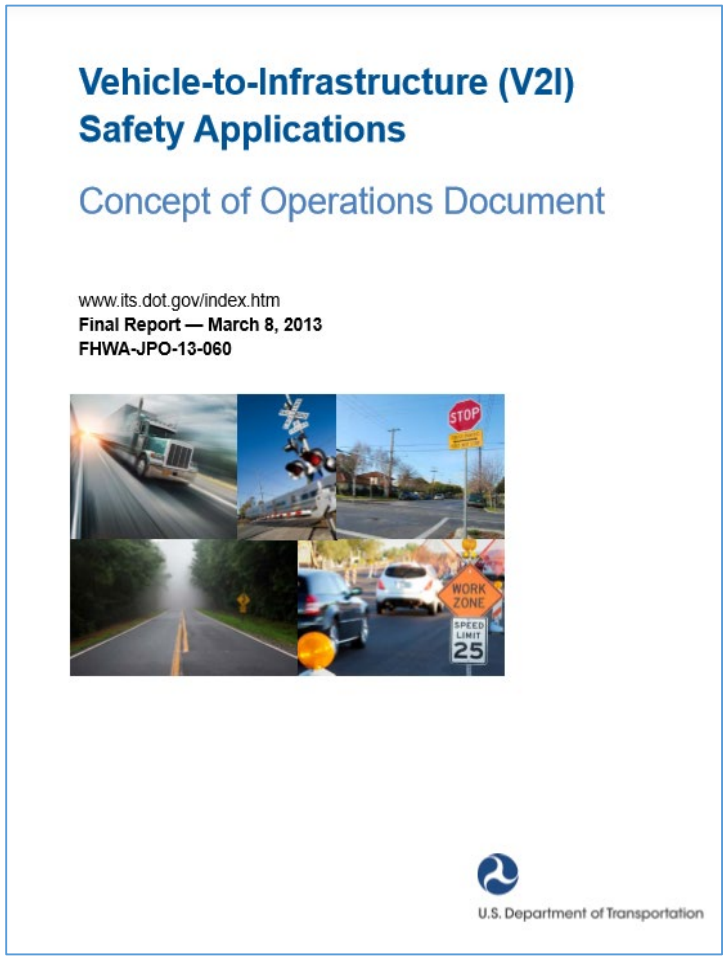
https://www.pcb.its.dot.gov/CV_deployer_resources.aspx

Resources for CV Training Available at: https://www.pcb.its.dot.gov/stds_modules.aspx

- CV 261: (V2I) ITS Standards for Project Managers
- CV 262: (V2V) ITS Standards for Project Managers
- CV 263: Roadside Unit (RSU) Requirements
- CV 265: Introduction to IEEE 1609 Family of Standards
- CV 273: Introduction to SPaT/MAP Messages
- CV 271: Using the ISO TS 19091 Standard to Implement V2I Intersection Applications Introduction
- CSE 201: Security Credential Management (SCMS)
- CSE 202: Introduction to Cybersecurity
- Transit 11: Transit and the Connected Vehicle Environment/Emerging Technologies, Applications, and Future Platforms
- Transit 24: Transit Signal Priority (TSP) in a Connected Environment

Additional Information on V2I Applications





https://www.its.dot.gov/v2i/index.htm

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Question

Which of the following is NOT a true statement?

Answer Choices

a) Testing has shown that Interoperability is achievable.

b) V2I applications such TSP are successfully deployed.

c) DSRC is a reliable communication medium.

d) Performance testing is completed during CV pilots.

Review of Answers

a) Testing has shown that Interoperability is achievable.
Incorrect, Devices/systems are tested and found to be interoperable.

b) V2I applications such as TSP are successfully deployed.
Incorrect, TSP application is widely implemented.

c) DSRC is a reliable communication medium.
Incorrect, DSRC has been successfully used in US for both V2V and V2I communications.

d) Performance testing is completed during CV Pilots.
Correct! Performance testing was left to agencies, not performed by the CV pilots.

Module Summary

Describe the Connected Vehicle (CV) Environment.

Discuss Vehicle to Infrastructure (V2I) Communications.

Describe the of Roles of the Standards in a Connected Vehicle Environment.

Address Challenges in Realizing V2I Environment.

Review the Current Status of the Connected Vehicle Deployments.

We have Now Completed the V2X Curriculum

- **CV 261:** Vehicle-to-Infrastructure (V2I) ITS Standards for Project Managers
- **CV 262:** Vehicle-to-Vehicle (V2V) ITS Standards for Project Managers
- **CV 263:** Roadside Unit (RSU) Requirements
- **CV 265**: Introduction to IEEE 1609 Family of Standards
- **CV T160**: Connected Vehicle Certification Testing Introduction

Thank you for completing this module

Feedback

Please use the Feedback link below to provide us with your thoughts and comments about the value of the training.

Thank you!