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WELCOME

U.S. Department of Transportation

Office of the Assistant Secretary for
Research and Technology

Welcome

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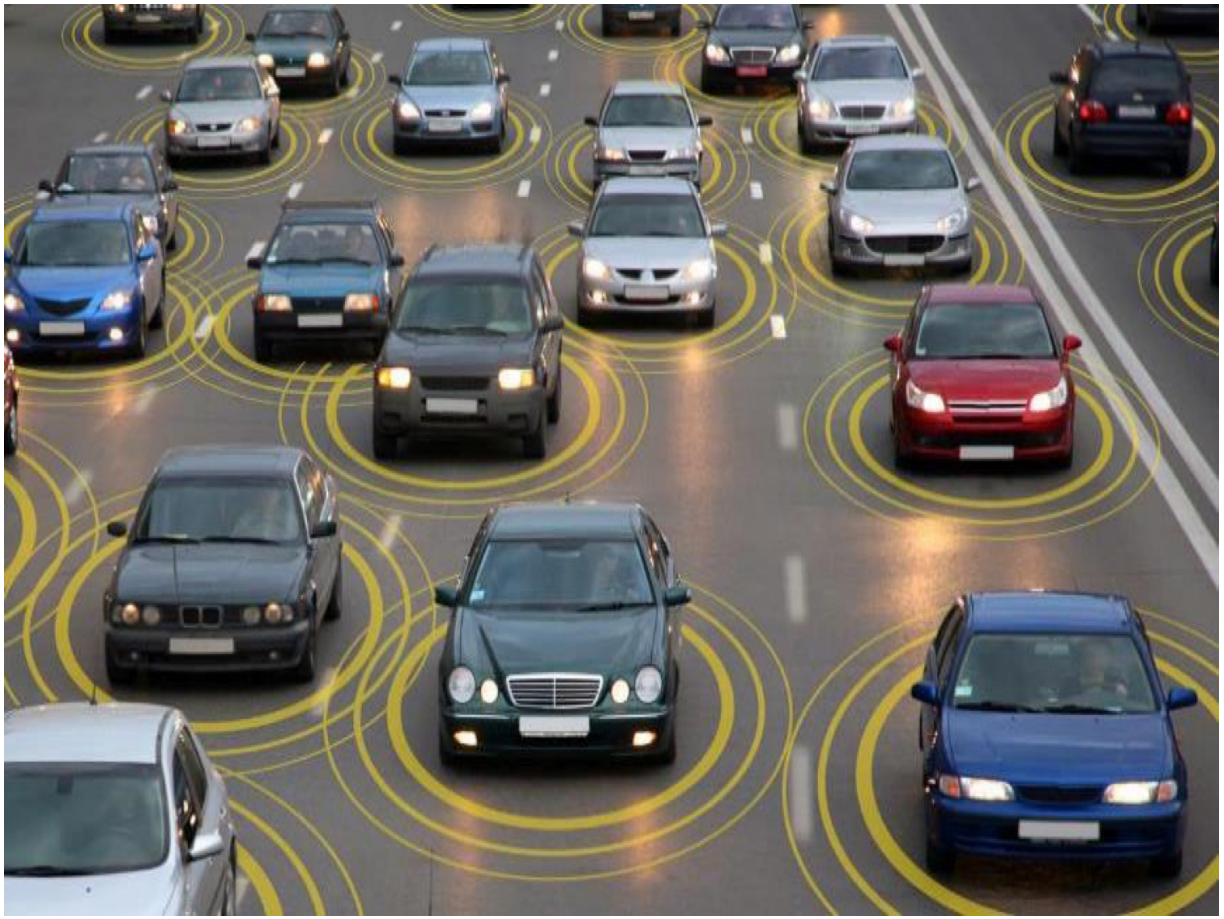
CV265

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



Instructor

Raman K Patel, Ph.D., P.E.

President

RK Patel Associates, Inc.

Learning Objectives

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

Discuss Role of IEEE 1609.3 Networking Services

Discuss Role of IEEE 1609.4 Multi-Channel Operations

Discuss Role of IEEE 1609.2 Security Services and Identify WAVE Implementation Issues and Challenges

Learning Objective 1

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

Connected Vehicle (CV) Environment

CV Environment Consists of:

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

CV Communications:

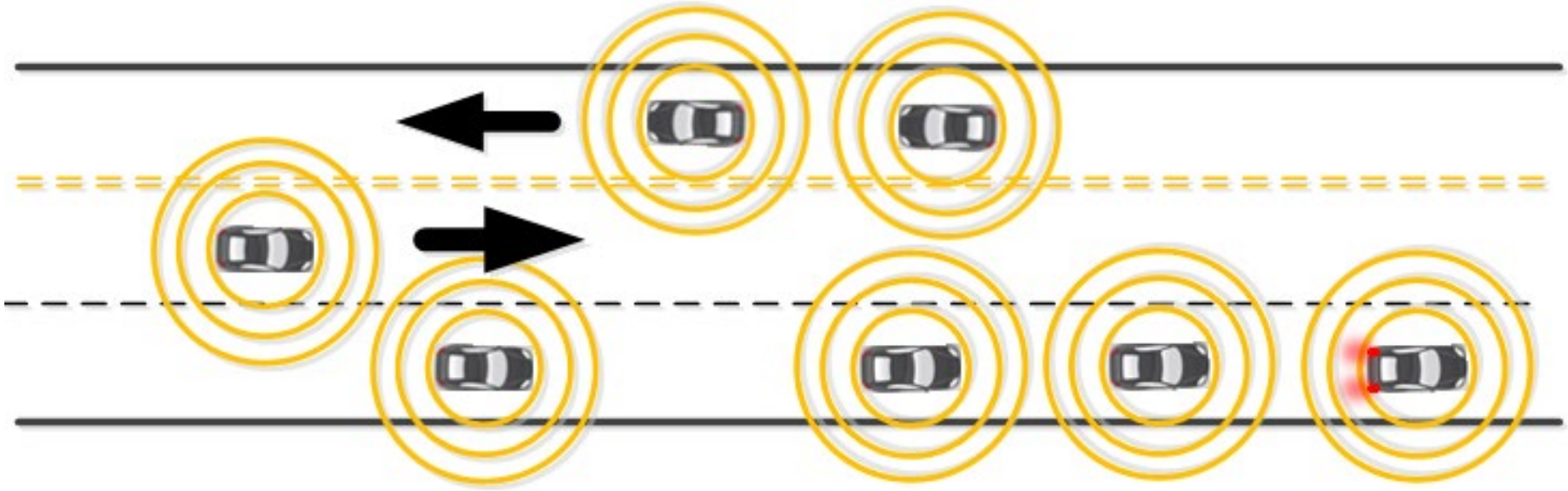
- Wireless
- Mixture of:
  - Local short-range communications
  - Remote communications, e.g. devices to Traffic Management Center (TMC)

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

CV Environment is Unique

Dynamic Operational Characteristics

- **Participants** constantly changing
- **Devices** need to communicate under changing speeds-doppler shifts
- Safety **applications** require frequent communications (messages)



WAVE (Wireless Access for Vehicular Environments)

WAVE is a Communication System

- Provides (ad-hoc) **wireless connectivity** for V2X to enable safety and mobility applications-higher layer entities
- Provides **privacy** (pseudonimity) and **security** (authentication and data integrity)

Greater situational awareness of events

Purpose and Mission of WAVE Standards

Mission

*"The WAVE standards enable the development of **interoperable low-latency**, **low overhead** WAVE devices that can provide communications in support of transportation safety, efficiency, and sustainability, and that can enhance user comfort and convenience."* IEEE 1609.0 std.

Example
Latency is a measure of time delay experienced in a system; e.g. Forward Collision Warning application limits 0.1 sec latency, measured between end points.

IEEE
Institute of Electrical and Electronics Engineers

Source: USDOT

Standardized Direct Communication Technologies that use WAVE

1. Dedicated Short Range Communication (DSRC) uses Published Standards:

- SAE J2945/1 V2V safety applications
- IEEE 1609 family (1609.3 Networking)

2. LTE-V2X Under Preparation

- LTE-V2X-Sidelink Mode 4 using the PC5 Interface (3GPP, Release 14,15)
- Uses SAEJ3161/1 and IEEE 1609.3 revision (pending)

LTE-Long Term Evolution
3GPP-Third Generation Partnership Project
SAE-Society of Automotive Engineers
IEEE-Institute of Electrical and Electronics Engineers

SAE Standards/Documents Published

Uses WAVE

- J2735: V2X Data Dictionary (technology-neutral revision nearly complete)
- J3061: Systems engineering enhancements to J2735 (information report)

SAE Standards/Documents Published (cont.)

Uses WAVE

- J2945: Systems engineering guidance and common design elements
- J2945/1: V2V safety applications (DSRC-based BSM application – revision published April 2020)
- J2945/2: V2V safety awareness *recommended practice* (builds on 2945/1)
- J2945/3: Road Weather applications
- J2945/5: Security guidelines for connected vehicle applications
- J2945/9: Vulnerable road user *recommended practice*

SAE Standards/Documents in Development

Uses WAVE

- J2945/1A: Vehicle-level test procedures for V2V safety communications (companion to J2945/1)
- J2945/4: Road safety applications (e.g. curve speed warning, work zone safety, reduced speed zones)
- J2945/6: Adaptive cruise control and platooning
- J2945/7: Positioning enhancements for V2X systems
- J2945/8: Cooperative perception system

- J2945/A: Next generation mapping (a more general, layered approach to maps for use by applications)
- J2945/B: Signalized intersection applications
- J2945/C: Probe data
- J2945/D: Road user to road user courteous communication

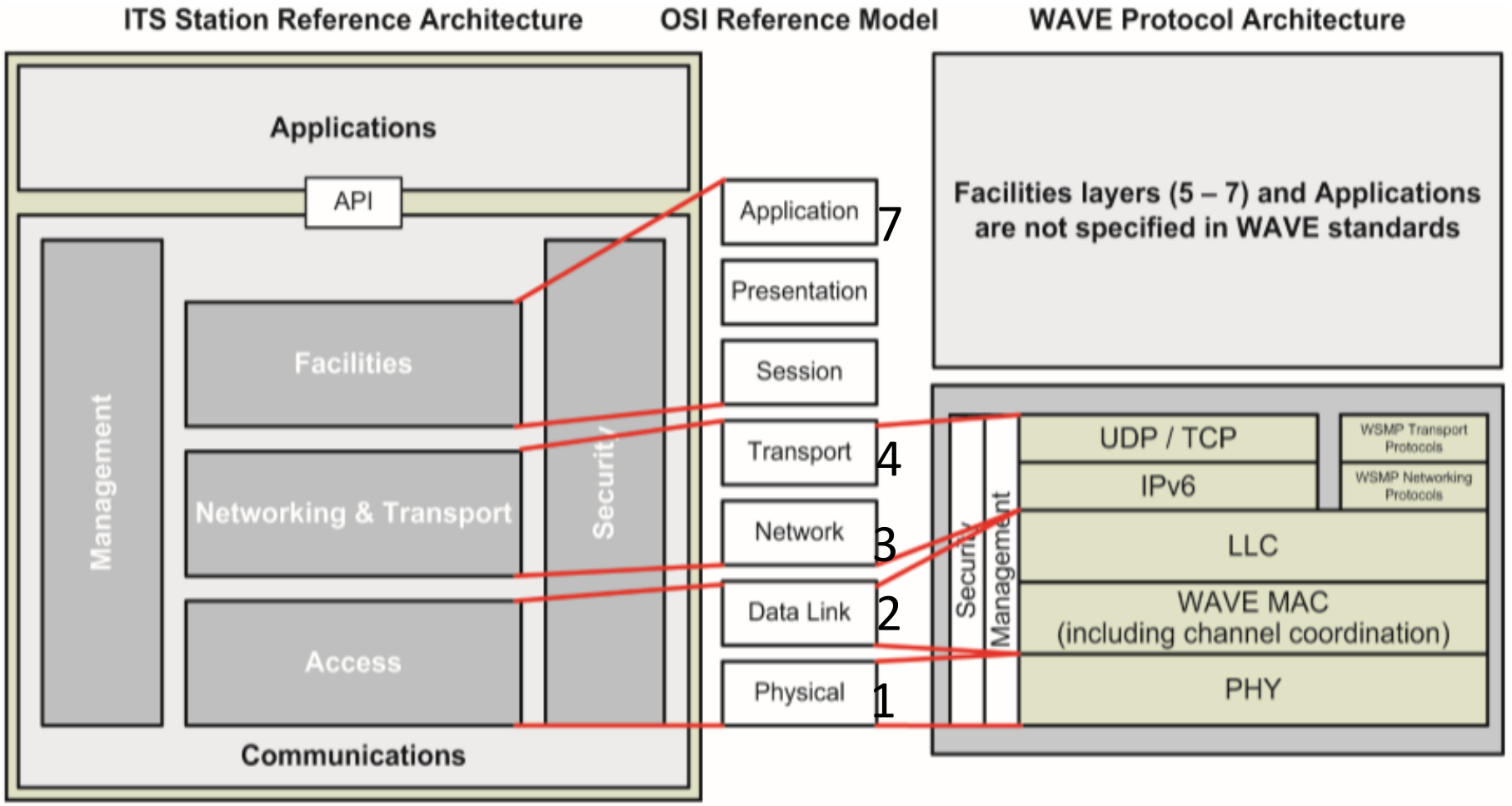
SAE Standards/Documents in Development (cont.)

Uses WAVE

- J3161/1: On-Board System Requirements for LTE-V2X V2V Safety Communications
  - Uses 3GPP PC5, Mode 4 for the physical interface
- J3161: C-V2X Deployment Profiles
- J3180: Cooperative perception system
- J3186: Maneuver sharing and coordinating

- J3216: Cooperative driving automation taxonomy and definitions (companion to SAE J3016)
- J3217: Electronic fee collection (V2X-based tolling)
- J3224: Sensor sharing for cooperative and automated driving

WAVE's Relationships to Other Protocol Models



WSMP-Wave Short Message Protocol
OSI-Open System Interconnect
ETSI- European Telecommunications Standards Institute
API-Application Programming Interface
LLC-Logical Link Control

Source: IEEE 1609.0 Std.

IEEE 1609 Family of Standards (2016)

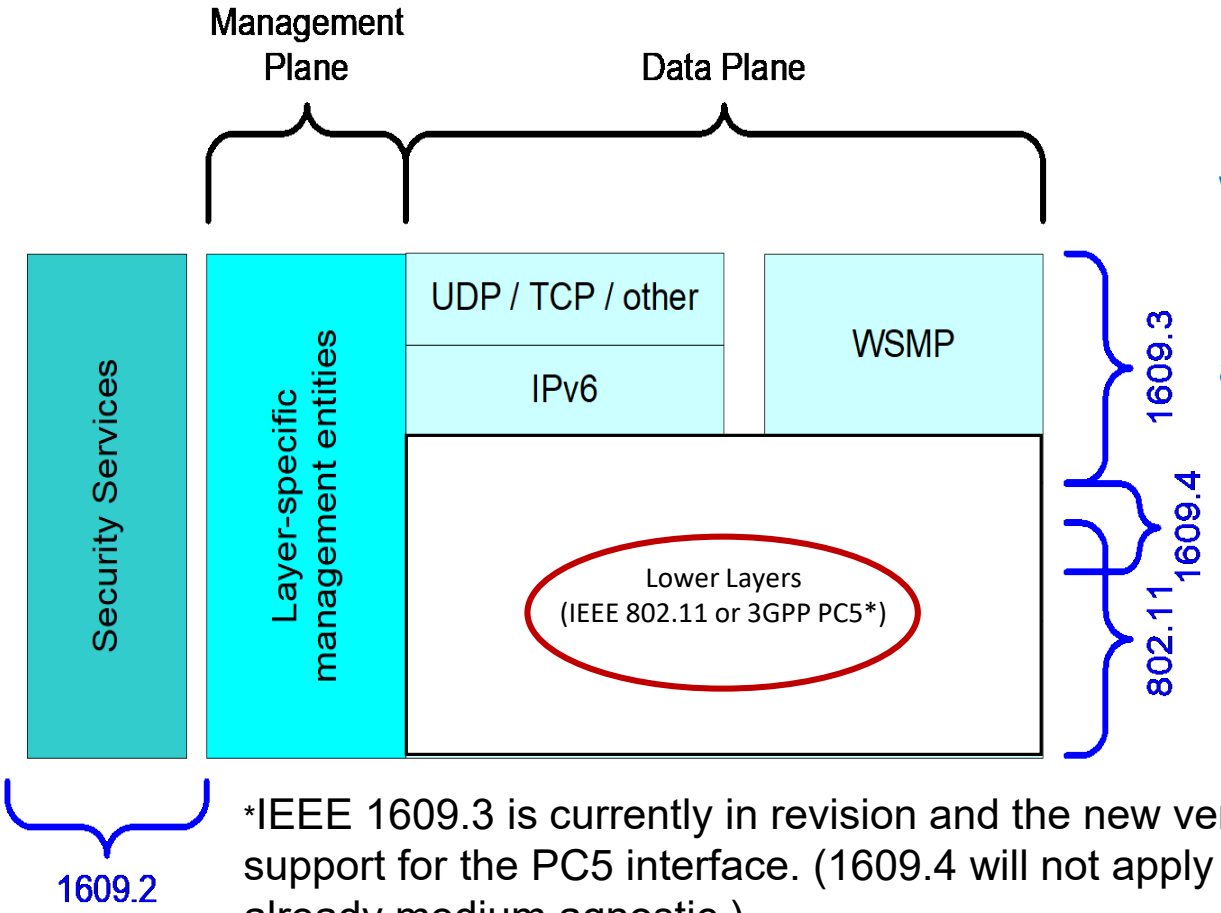
Standards Deployed in WAVE Protocol Stack-Devices

- 1609.0 Guide (Architecture)
- 1609.2 Security Services
- 1609.3 Networking Services
- 1609.4 Multi-channel Operation
- 1609.12 Identifier Allocations
- IEEE 802.11:MAC sublayer and PHY Layer

MAC-Media Access Control
PHY-Physical Layer
WSMP-WAVE Short Message Protocol

SUPPLEMENT

WAVE is Customized Protocol Architecture



Higher layer entity is NOT shown here.

WSMP is customized for low latency communication, in general. IPv6 features are also optimized for low latency.

Multi-Channel Operation

MAC/PHY (other standards)

*IEEE 1609.3 is currently in revision and the new version will provide explicit support for the PC5 interface. (1609.4 will not apply to LTE-V2X; 1609.2 is already medium agnostic.)

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

Courtesy-Justin McNew

SUPPLEMENT

Uses of Protocols

WSMP

- Customized for **low latency** needs of CV applications
- Compact, but ONLY supports **broadcast** of “single hop” short messages
- Common protocol for both Network and Transport layers

Well-suited to message-based applications.

IPv6

- Adjusted for **low latency** needs
- Higher overheads, supports **Unicast,** larger messages (information transfer-private conversations or network communications)
- Deployed as UDP/IP or TCP/IP

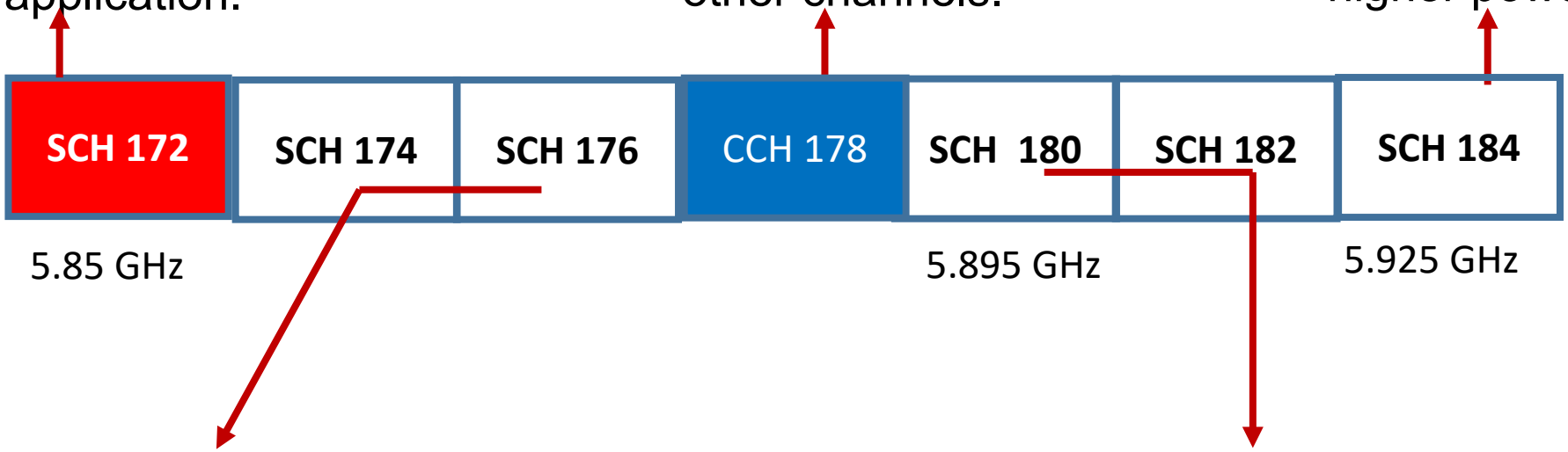
DSRC 5.9 GHz Spectrum Assigned by FCC

Radio Channels Current Design

Service Channel (SCH) dedicated to safety of life and property applications, e.g. safety and awareness application.

Control Channel (CCH) broadcasts WAVE Service Advertisement (WSA) to indicate what is available on other channels.

Reserved for emergency vehicles, allows for higher power.



DOWNLOAD- application software and operational parameters, e.g. Over-the-Air fleet OBUs updates, w/o touching them.

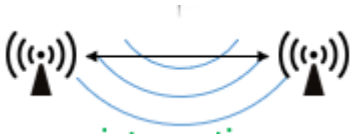
UPLOADING- mobility-operations and performance logs.

WAVE Devices

Devices Transmit/Receive Messages (data) from other Devices in the Vicinity

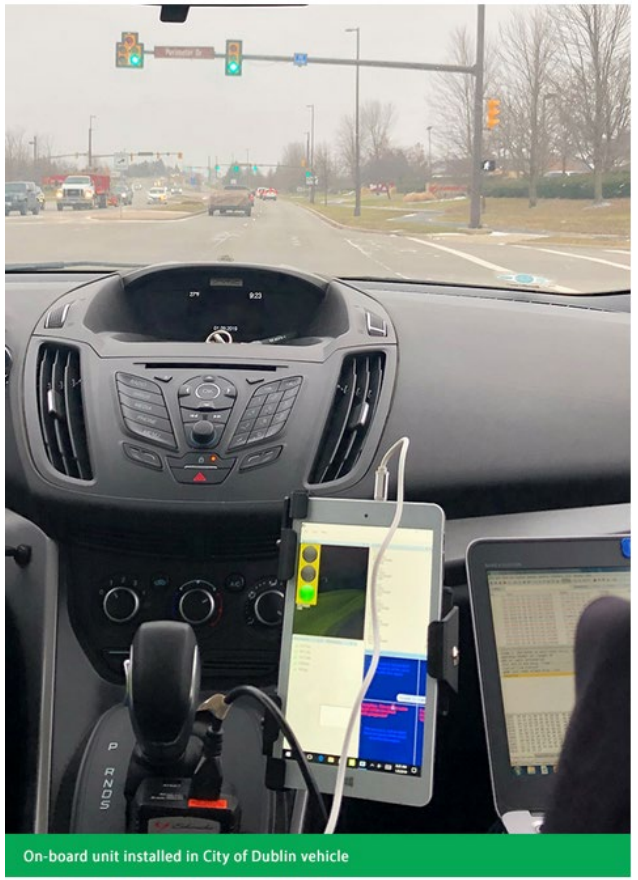
Roadside Unit (RSU)

Source: City of Dublin, OH



Information transfer Over-the-Air

Onboard Unit (OBU)



WAVE Device Performs Two Roles

Provider issues a WSA (nominally on the CCH 178) to indicate available opportunity on SCHs.

User monitors CCH 178 for a WSA, makes determination to participate or not to participate.

WSA-WAVE Service Advertisement

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Question

Which of the following is an incorrect statement related to WAVE System?

Answer Choices

a) WAVE devices deploy IEEE 1609.3 standard.

b) WSMP/IPv6, both protocols can be used at network layer.

c) WAVE Service Advertising (WSA) indicates BSMs on SCH 172.

d) V2X includes all forms of CV communication services.

Review of Answers

a) WAVE devices deploy IEEE 1609.3 standard.

Statement is correct. IEEE 1609.3 standard provides networking capability.

b) WSMP/IPv6, both protocols can be used at network layer.

Statement is correct. Both protocols are deployable at network layer.

c) WAVE Service Advertising (WSA) indicates BSMs on SCH 172.

Incorrect. WSA is NOT used for safety channel SCH 172.

d) V2X includes all forms of CV communication services.

Statement is correct. V2X includes everything: V2V, V2I, V2P…

Learning Objective 2

Discuss Role of IEEE 1609.3 Networking Services

IEEE 1609.3 Networking Services

Collection of Management and Data Services

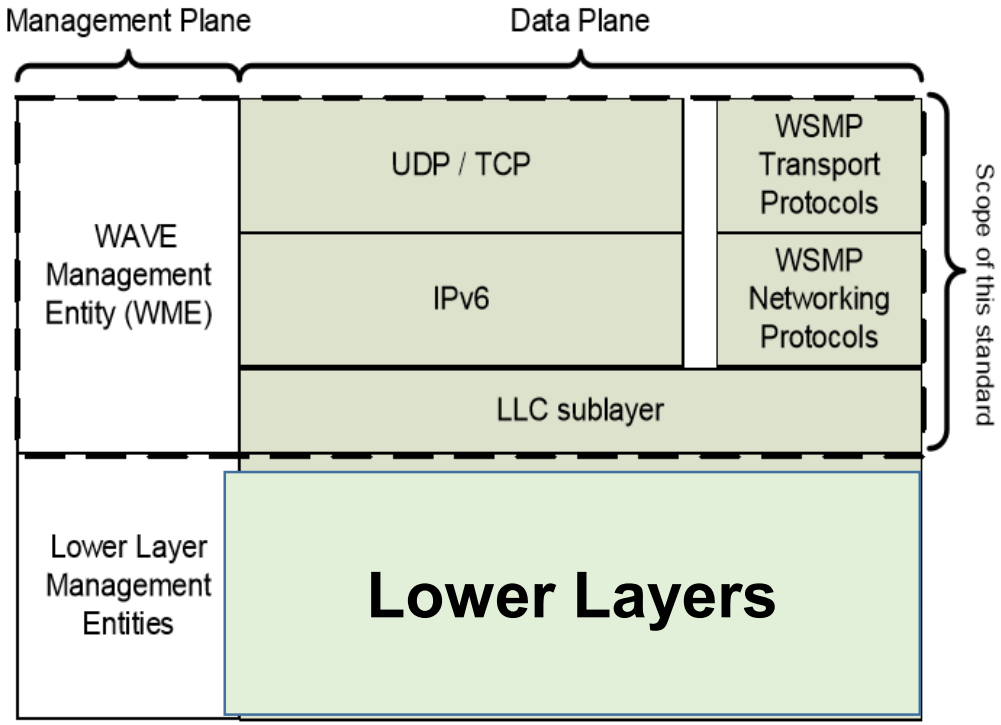
Management Plane contains the functions that **indirectly** manage the entities in the data plane

Data Plane contains **ONLY** data exchange functions

WSA Monitoring

MIB Maintenance

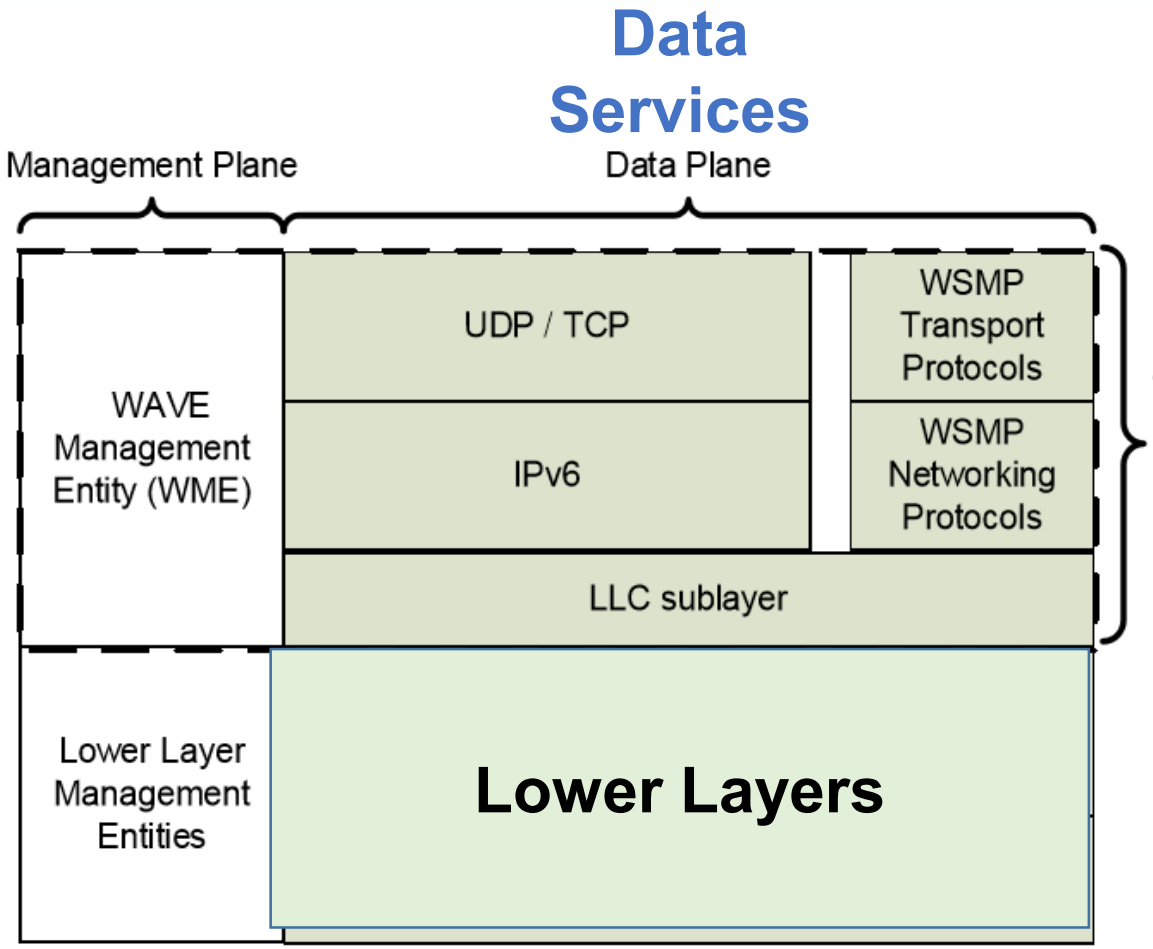
IPv6 Configuration



MIB-Management Information Base

Source: IEEE 1609.0

IEEE 1609.3 Networking Services



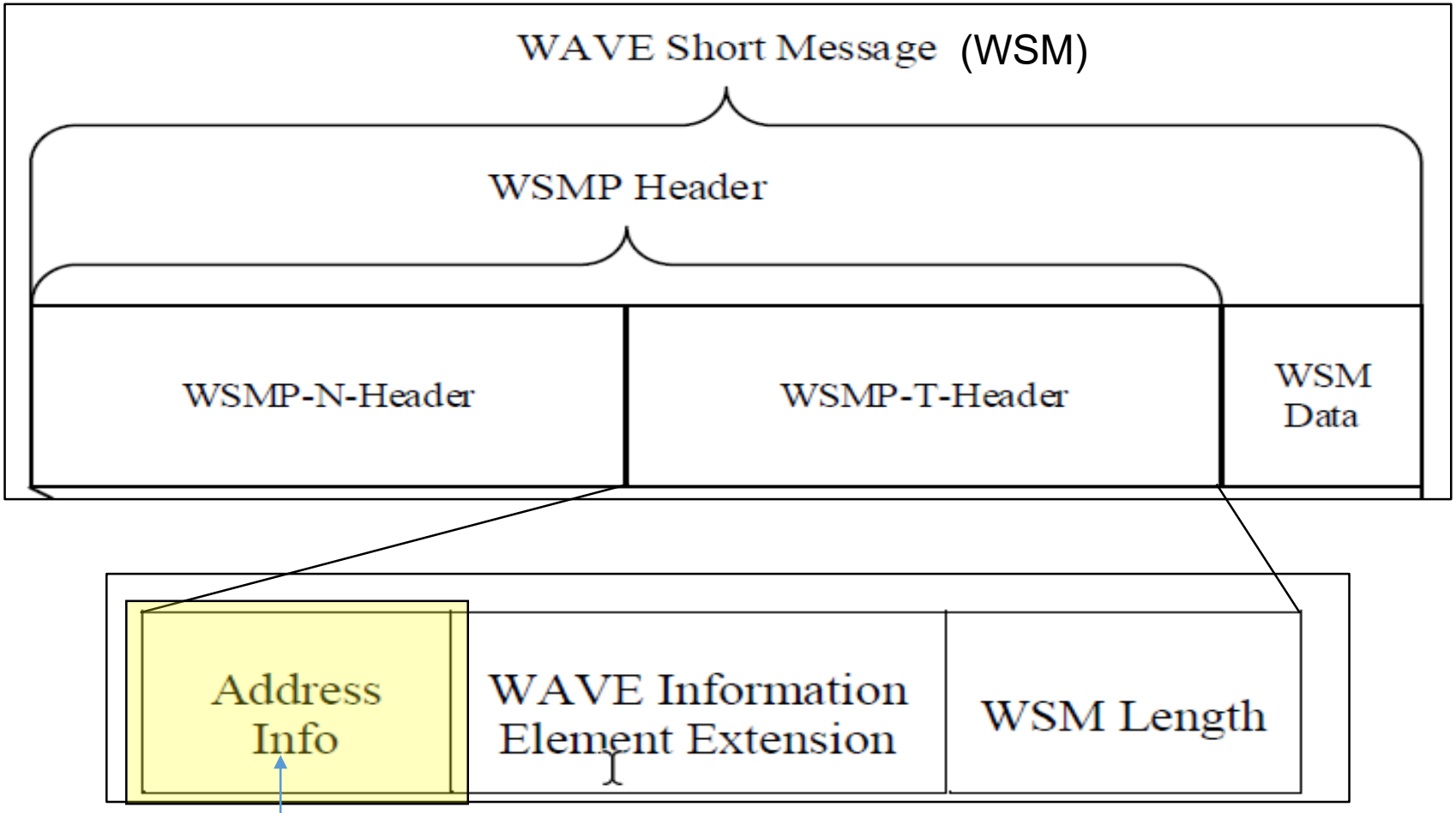
WSMP is for one-hop broadcast messages e.g. BSMs.

IPv6 is used for larger data exchanges (e.g. probe data uploads), unicast messages (e.g. private conversations) and network communications (e.g. using RSU as a router).

Both are separate and distinct networking protocols, and one does not depend on the other (e.g., IPv6 frames are not transported over WSMP, or vice versa).

IEEE 1609.3 Networking Services

Data Services



PSID-Provider Service Identifier

Source: Ken Vaughn

Provider Service Identifier (PSID)

Nearly 100 applications are registered with unique integer as PSID

WAVE device creates a list of PSIDs that have active receive processes at higher layers, e.g. BSMs 0x20.

When a WSM arrives, if the PSID matches one of those on the list, the WSM payload is forwarded to that process.

https://standards.ieee.org/products-services/regauth/psid/public.html

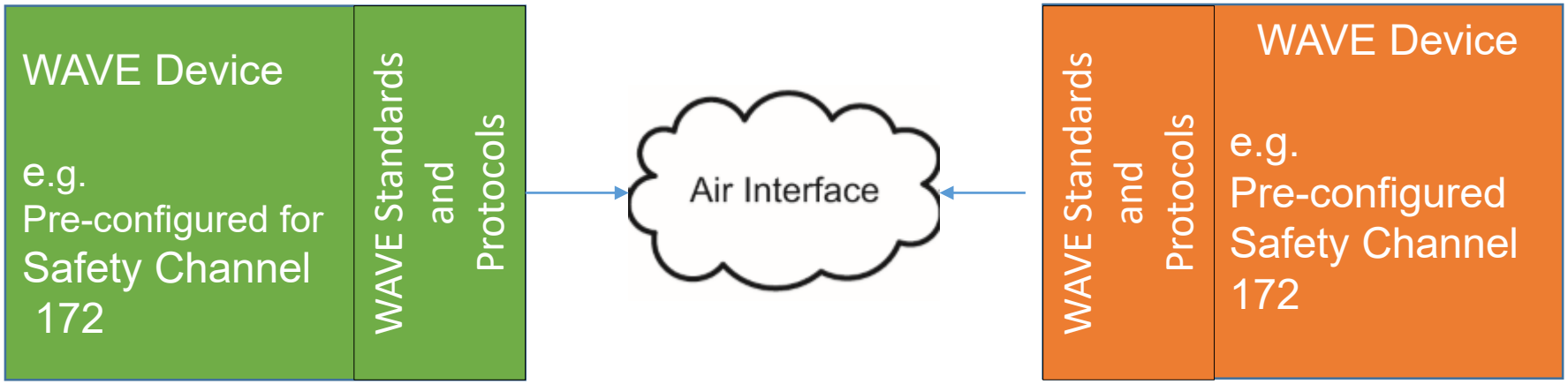
SUPPLEMENT

WAVE Communications Scenarios

Scenario 1: SCH 172 Communications

- Preconfigured WAVE devices-SCH operation; WSA is Not required

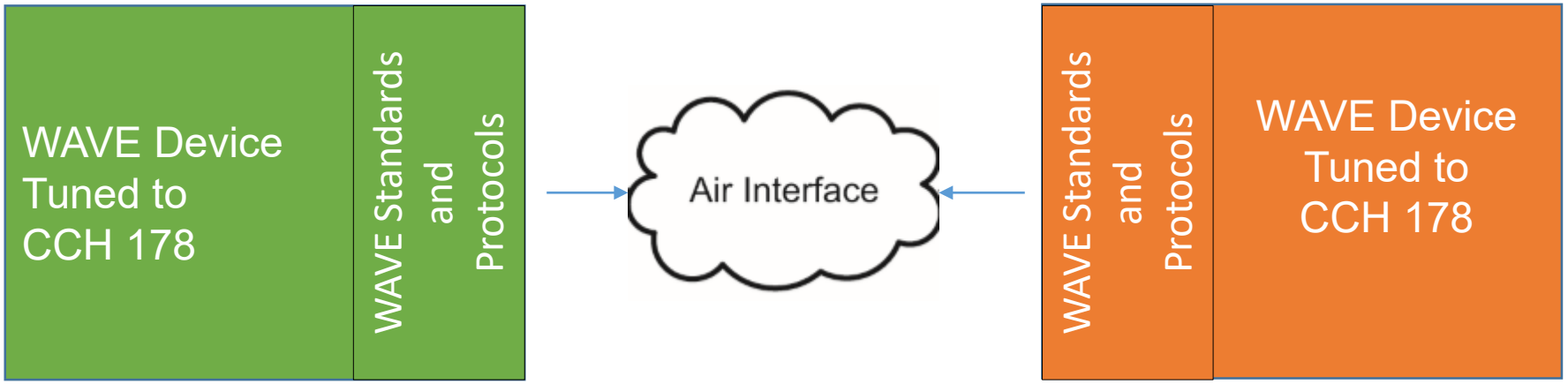
Example 1: V2V, BSMs are broadcasted 10X per sec.
Example 2: V2I, SPaT/MAP data can also be transmitted on 172



WAVE Communications Scenarios

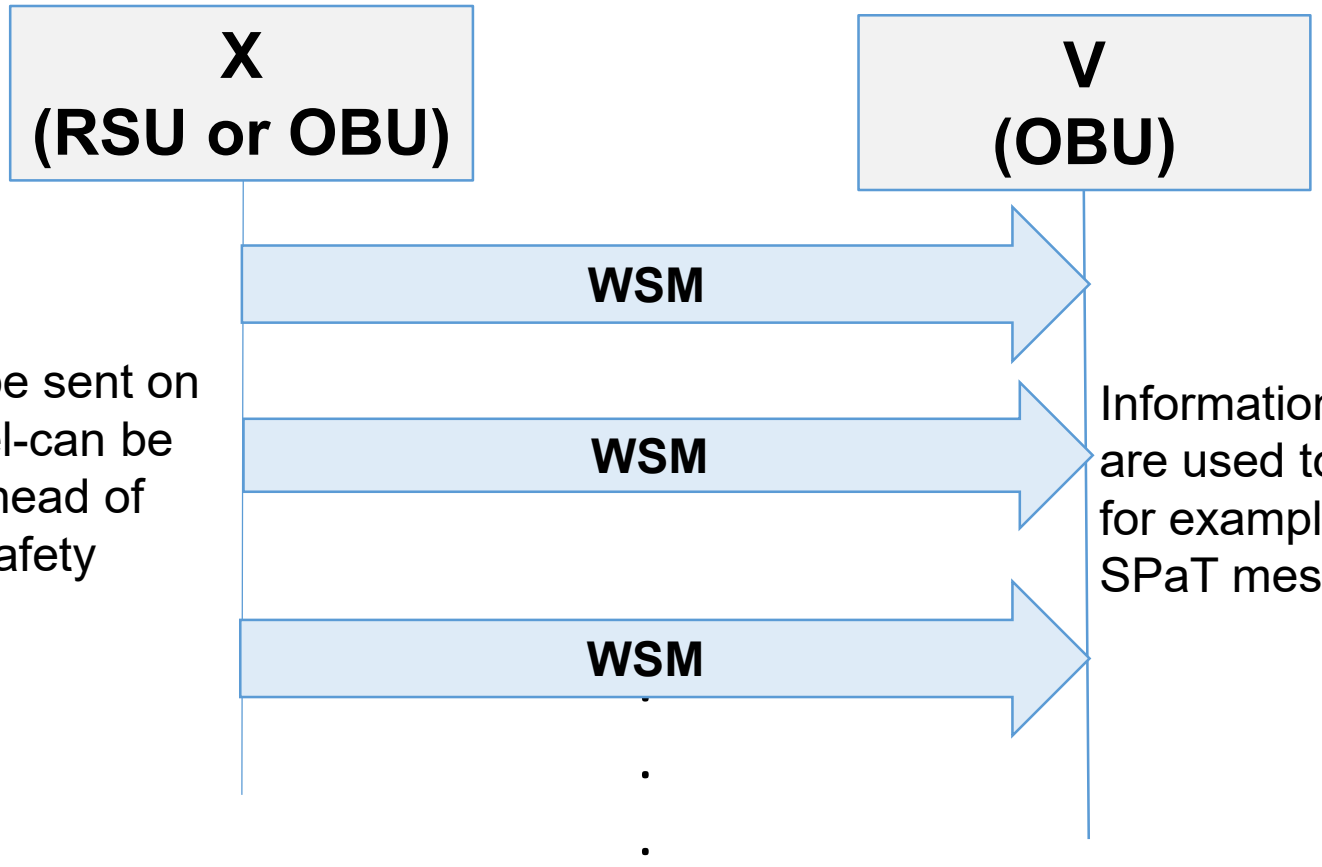
Scenario 2: CCH 178 Communications

- Nearby devices tuned to CCH 178 receive WSA at a time of transmission
- **Provider** device sends WSAs indicating where opportunity is available
- **User** device, listening for opportunity, may decide to participate or not to participate



Example of WSM Transmission (V2X)

How it Works (V2X)-Information Broadcasts



WSM can be sent on any channel-can be specified ahead of time (e.g. safety channel).

Information Broadcasts are used to transmit, for example BSMs, SPaT messages.

Source: Courtesy Justin McNew

Illustration of V2V Safety

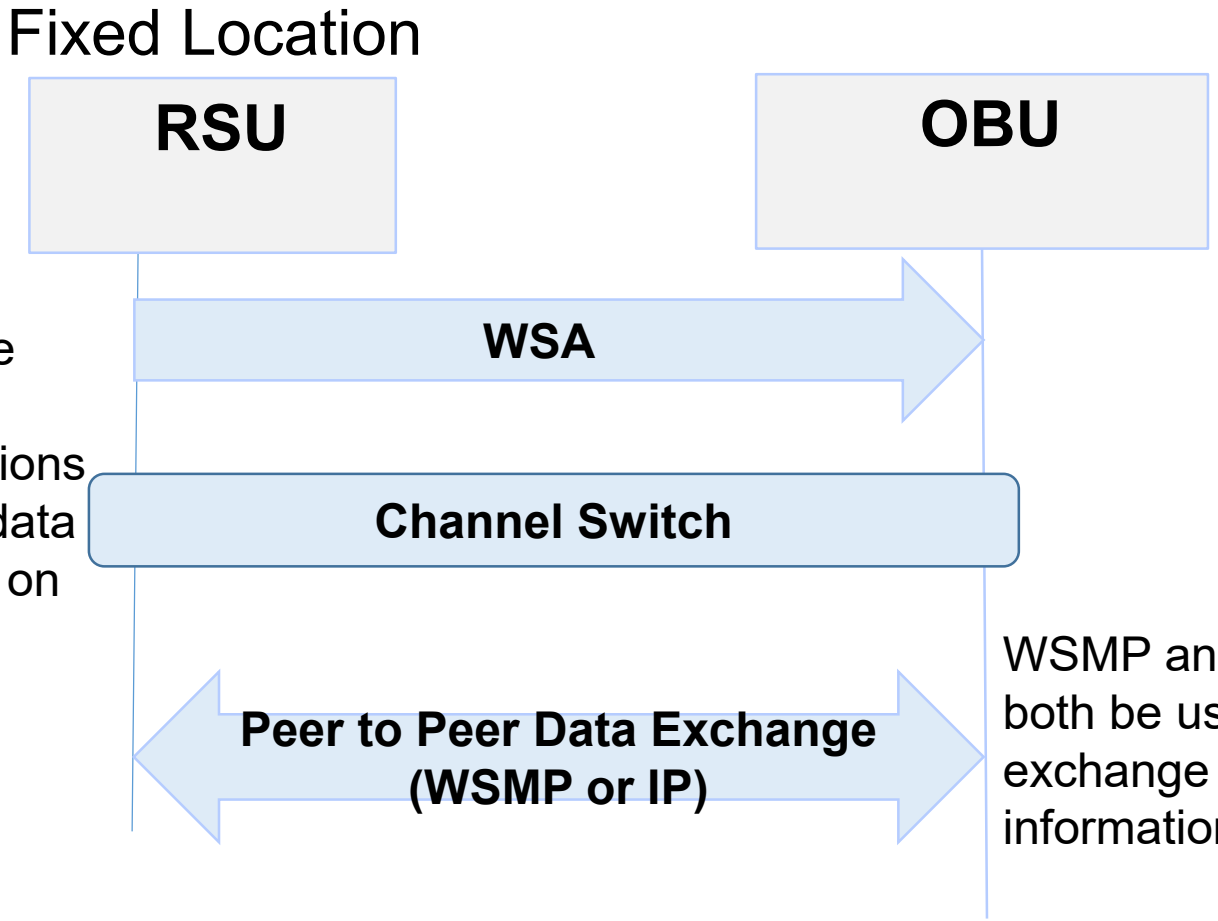
1. **Sending-Provider** device broadcasts BSM messages (10x per sec.) over WSMP on SCH 172 (WSA not required).

PSID (0x20 hex) in the WSMP header identifies the V2V safety and awareness application such as FCW.

2. **Receiving-User device** recognizes the PSID 0x20 as the V2V safety and awareness, and passes it to registered applications, such as FCW shown here and many others.

Example of Localization with RF Coverage

How it Works (V2I)-Localized Data Exchange

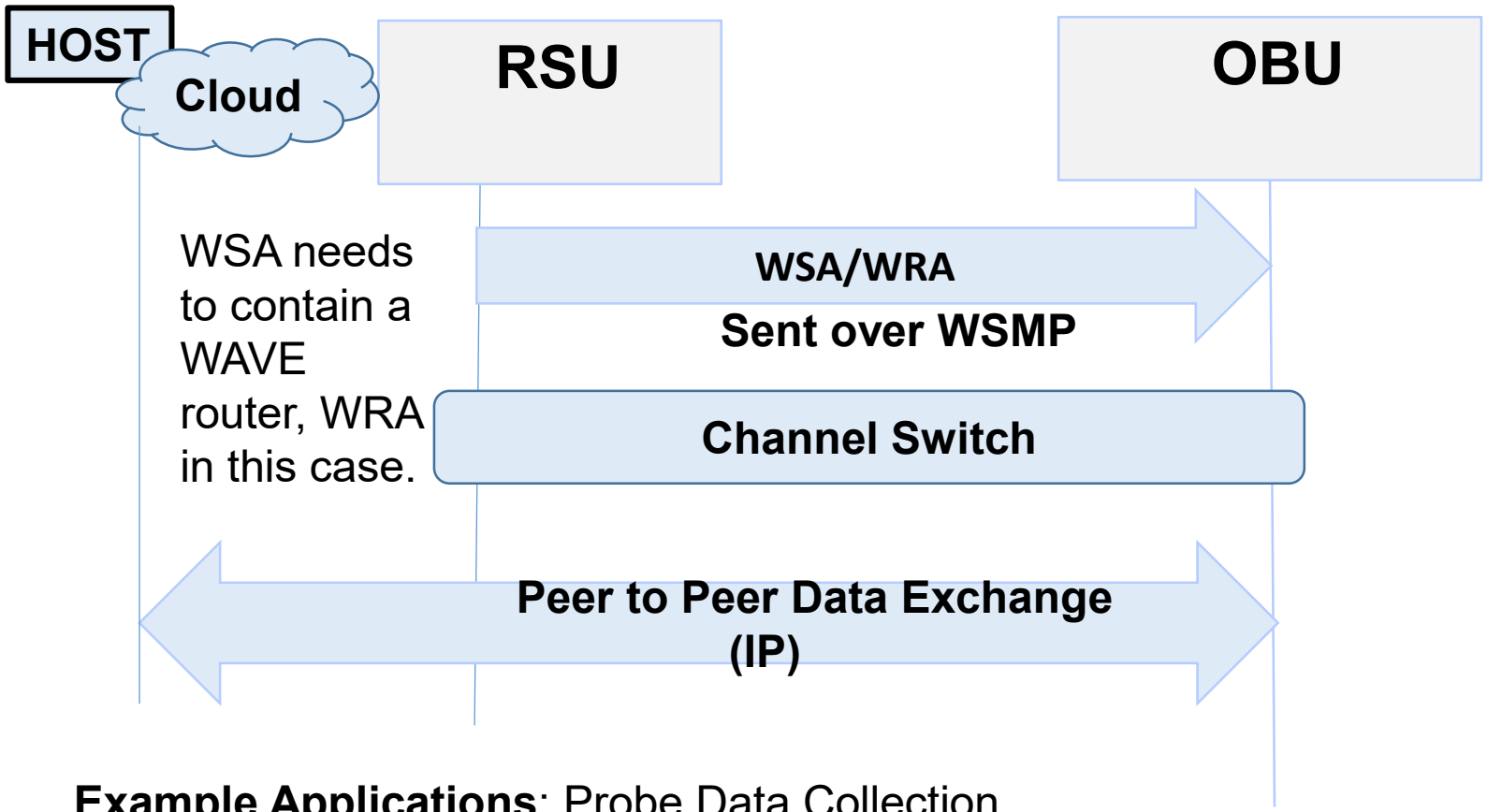


This approach can be used, for example, to support electronic fee collection.

Source: Courtesy Justin McNew

Example of WSM Transmission (V2X)

How it Works (V2I)-Cloud Based



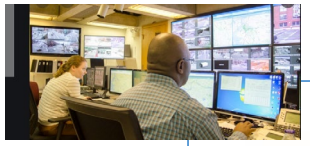
Example Applications: Probe Data Collection, Road Weather Data Collection/Distribution, SCMS

Source: Courtesy Justin McNew

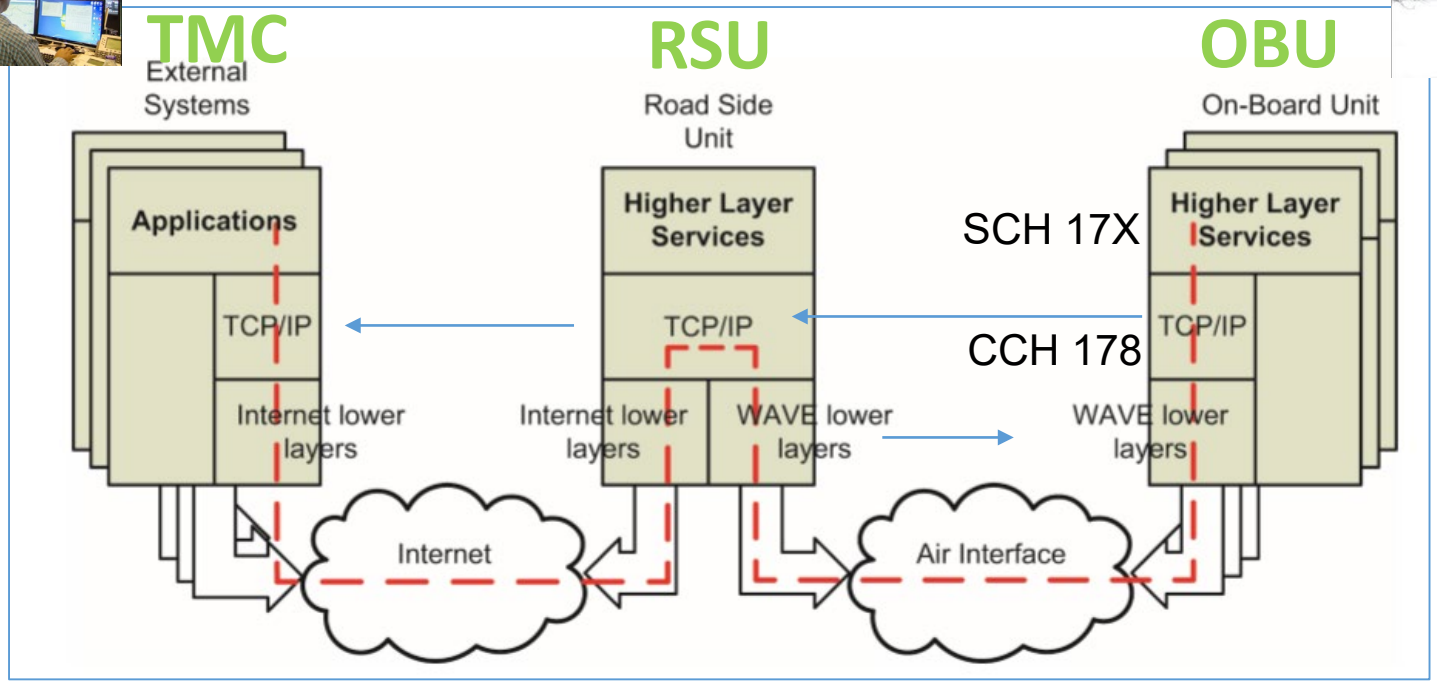
Internet Connectivity with IPv6 Communication

Illustration of RSU Role as Gateway (V2I)

- Most Typically CCH 178 transmits WSA (with WRA)
- SCHs (except 172) provide IPv6 communication



City of Boston



Source: IEEE 1609.0 Std.

WRA-WAVE Routing Advertisement
TMC-Traffic Management Center

EXAMPLE

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Question

Which of the following is NOT included in the IEEE 1609.3 standard?

Answer Choices

a) WSA (WAVE Service Advertisement).

b) PSID (Provider Service Identifier).

c) WSMP (WAVE Short Message Protocol)/IPv6.

d) BSM (Basic Safety Message).

Review of Answers

a) WSA (Wave Service Advertisement).

Incorrect. WSA is included in 1609.3.

b) PSID (Provider Service Identifier).

Incorrect. PSID is included in 1609.3.

c) WSMP/IPv6.

Incorrect. Both protocols are included in 1609.3 standard.

d) BSM (Basic Safety Message).

Correct! BSM is <u>NOT</u> included in 1609.3; it is part of J2735/J2945.1 standards.

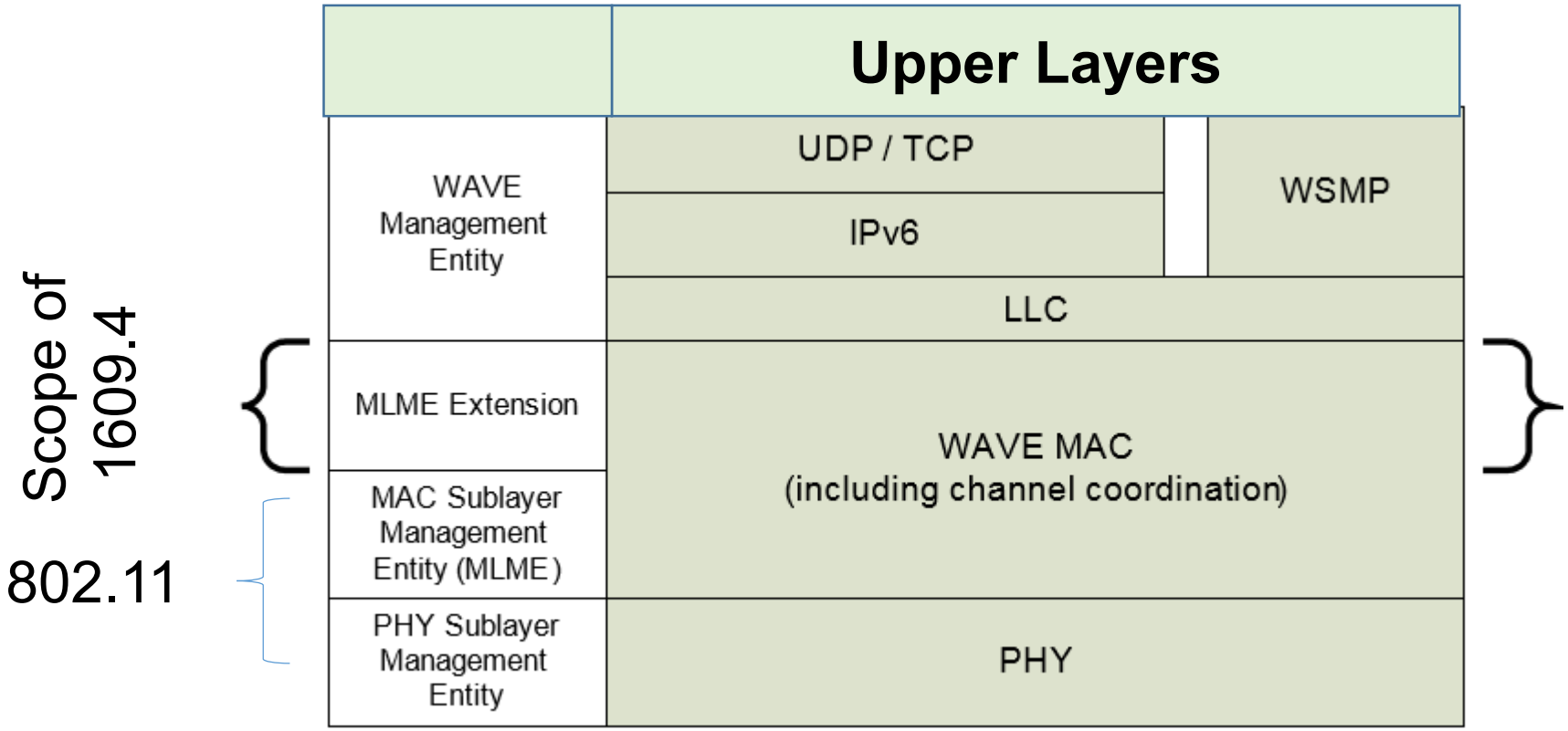
Learning Objective 3

Discuss Role of IEEE 1609.4 Multi-Channel Operations

Role of IEEE 1609.4 Multi-Channel Operation

Management Plane Provides:

- ✓ Multi-channel Synchronization
- ✓ Channel Access
- ✓ MIB Maintenance
- ✓ Readdressing (MAC address)

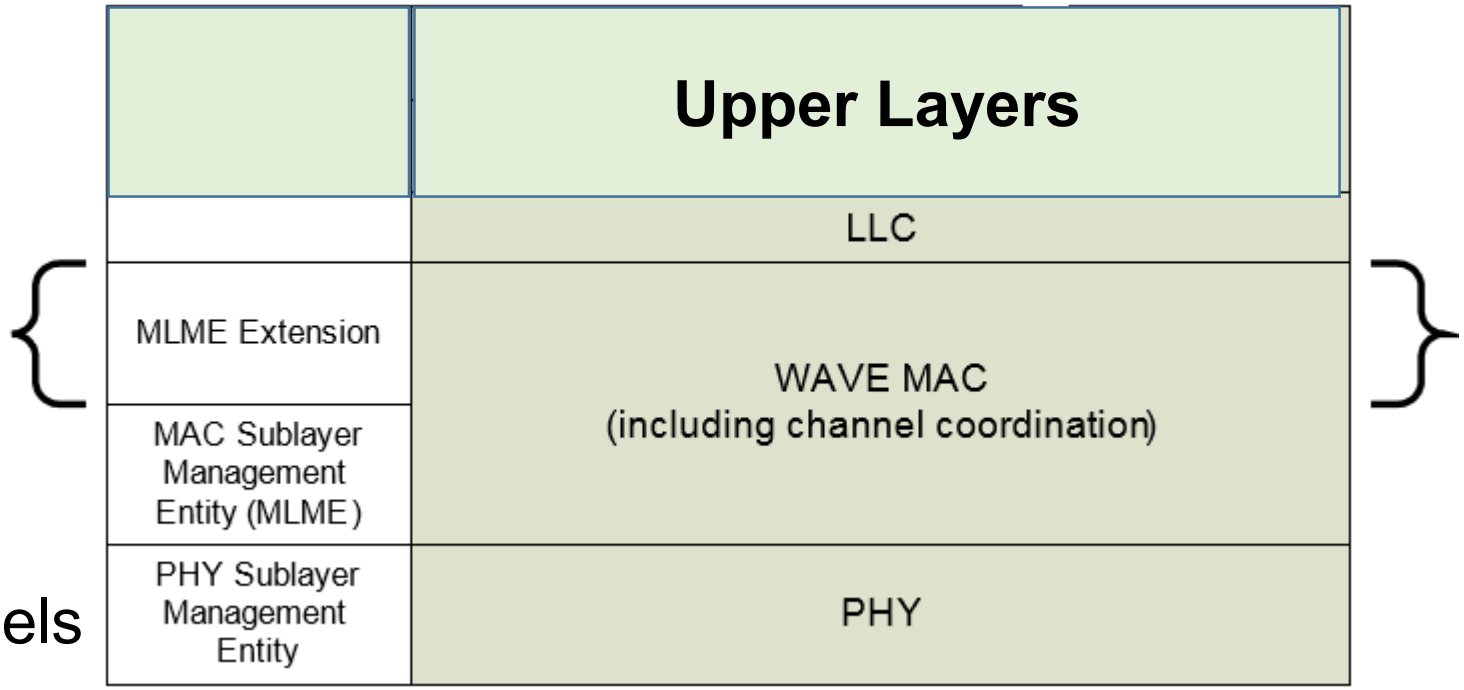


Role of IEEE 1609.4 Multi-Channel Operation

Data Services

Data Plane

Scope of 1609.4

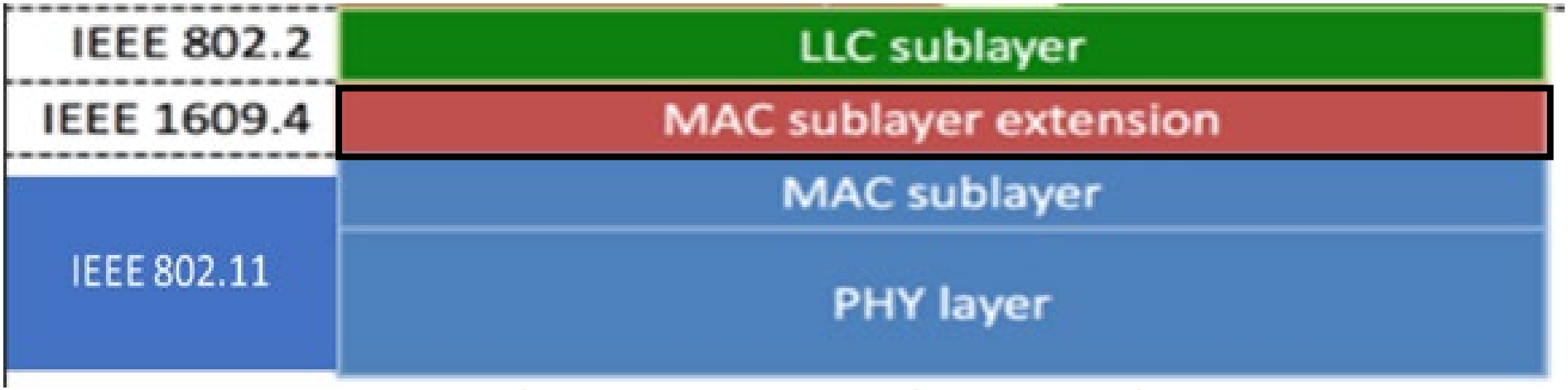


Multi-Channels

LLC: Logical Link Control

Role of IEEE 1609.4 Multi-Channel Operation

Provides extension to 802.11 MAC sublayer to utilize more than one channel and coordination

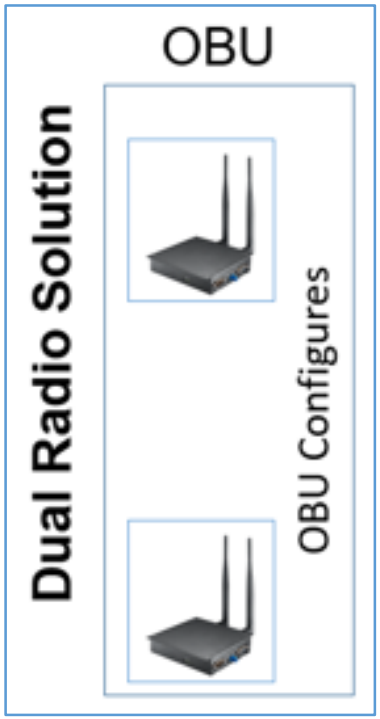


Supports Multi-Channel Operation in Current Design

Role of IEEE 1609.4 Multi-Channel Operation

Supports Dual Radio Operation

- Dual radios can operate on multiple channels to ensure full benefits of safety and other information of interest



Radio 1 typically tuned to SCH 172 for safety messages such as collision warning alerts.

Radio 2 can be configured for switching to (other) SCHs for ITS information.

Role of IEEE 802.11

Role of 802.11 is to Move Data between MAC/PHY Peers

- Describes specification for wireless connectivity using DSRC services

https://ieeexplore.ieee.org/document/6361248

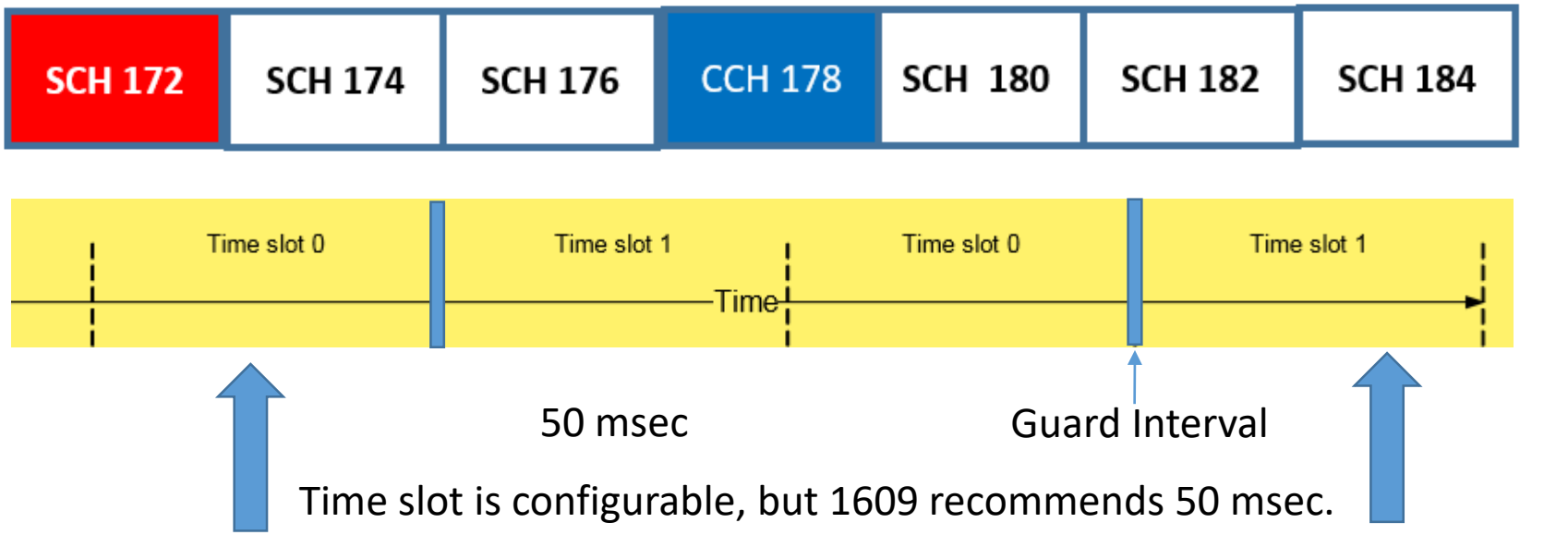
MAC/PHY Layers

- **MAC Address**
  - IEEE assigned globally unique identifier-48 bits size, used in transferring data packets across data link
- **IP Address**
  - Layer 3 address (128 bits in IPv6; 32 bits in IPv4), used in local network
- Both are subjected to change often in WAVE communication to provide anonymity

What is Channel Coordination?

Channel Coordination Supports Data Exchange

Involving one or more switching devices with concurrent alternating operation on **multiple channels**



Channel Coordination

Multi-Channel Operation at Lower Layers

- Includes when and how a device is allowed to access the PHY layer to transmit data (multi-channel operation)
- Access to specific radio channel(s) is provided by **MLME** as directed by WME

MLME-MAC sublayer Layer Management Entity
WME-WAVE Management Entity

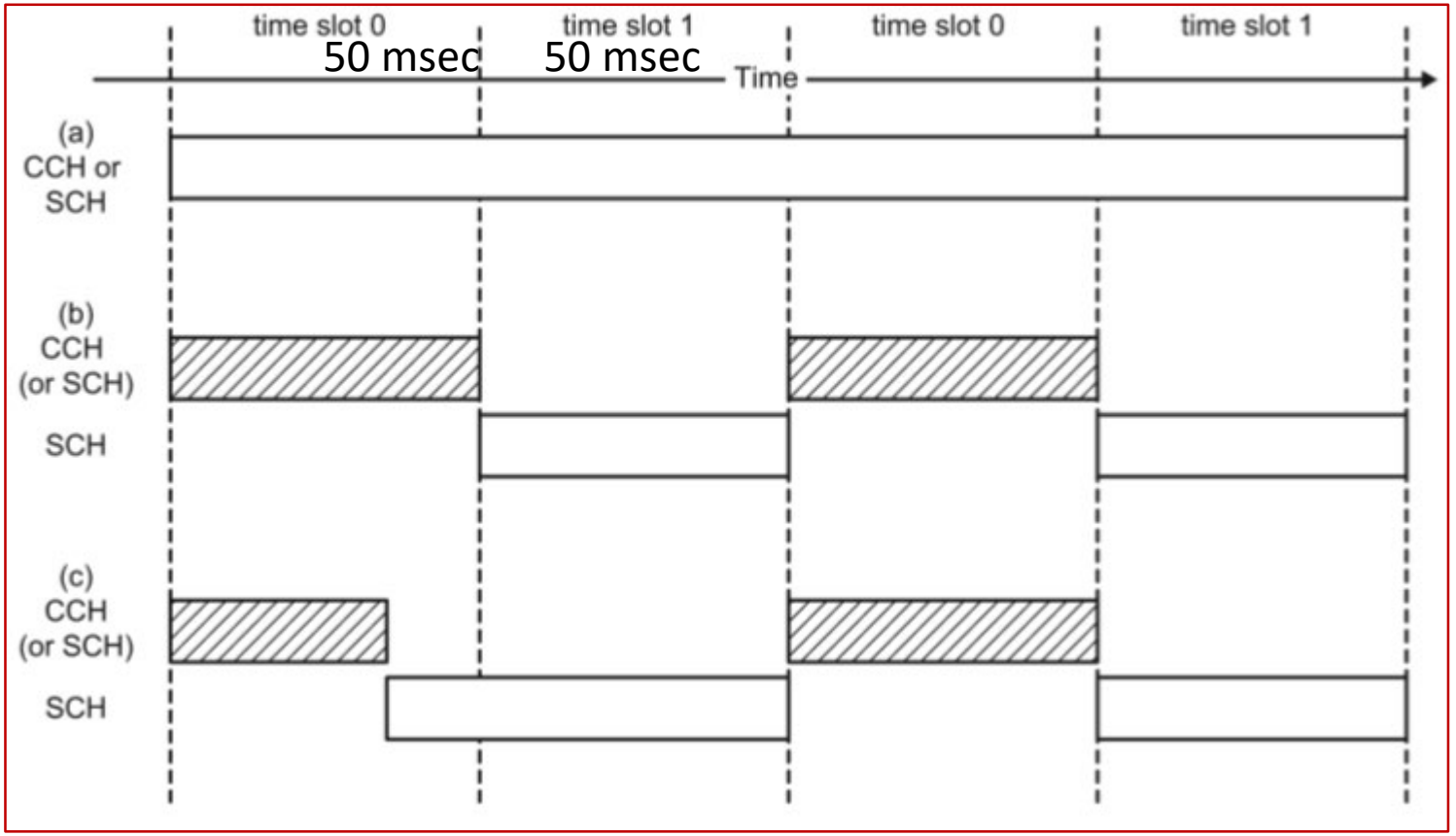
Channel Coordination

Access Options

Continuous Access

Alternating Access

Immediate Access



Immediate access can be combined with continuous access to allow an extended time on channel (i.e. until the transection is done).

Multi-Channel Synchronization with UTC

Coordinated Universal Time (UTC) Derived from GPS (GNSS) on the Device

RSU-OBU Communication, V2X Communication

GPS-Global Positioning System, also called
GNSS-Global Navigation Satellite System

https://time.is/UTC

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Question

Which of the following is an incorrect statement?

Answer Choices

a) IEEE 1609.4 supports channel switching capability.

b) BSM messages are typically received on SCH 172.

c) Channel switching operation occurs at Network layer.

d) Dual radio ensures continuous listening of safety messages.

Review of Answers

a) IEEE 1609.4 supports channel switching capability.

Correct Statement. 1609 provides channel switching capability.

b) BSM messages are typically received on SCH 172.

Correct statement. SCH 172 is typically reserved for BSMs.

c) Channel switching operation occurs at Network layer.

Incorrect statement, Channel switching occurs at PHY layer.

d) Dual radio ensures continuous listening of safety messages.

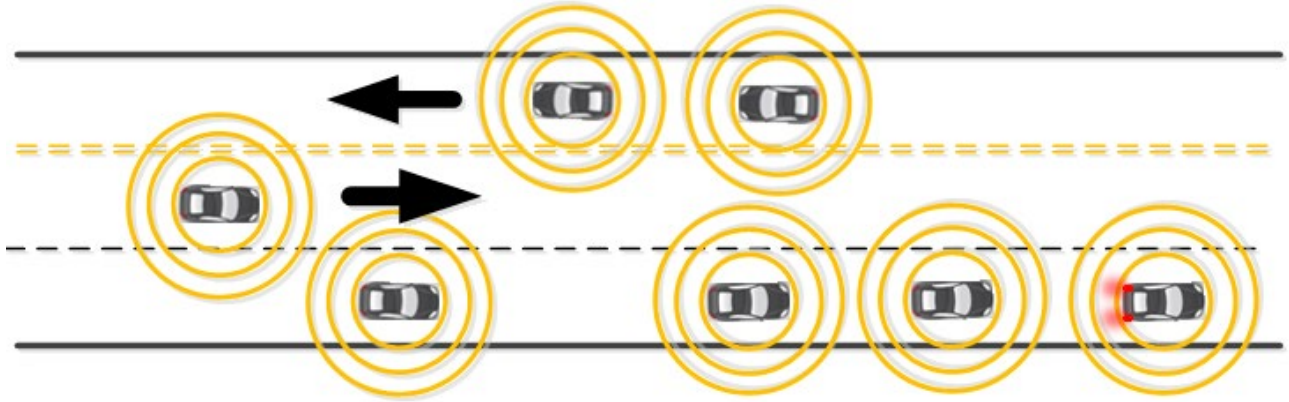
Correct statement. Radio 1 tuned to SCH 172 for safety messages, Radio 2 can switch to other SCHs.

Learning Objective 4

Discuss Role of IEEE 1609.2 Security Services and Identify WAVE Implementation Issues and Challenges

WAVE Communication Security Challenges

Consider 2 vehicles, part of dynamic ad-hoc network

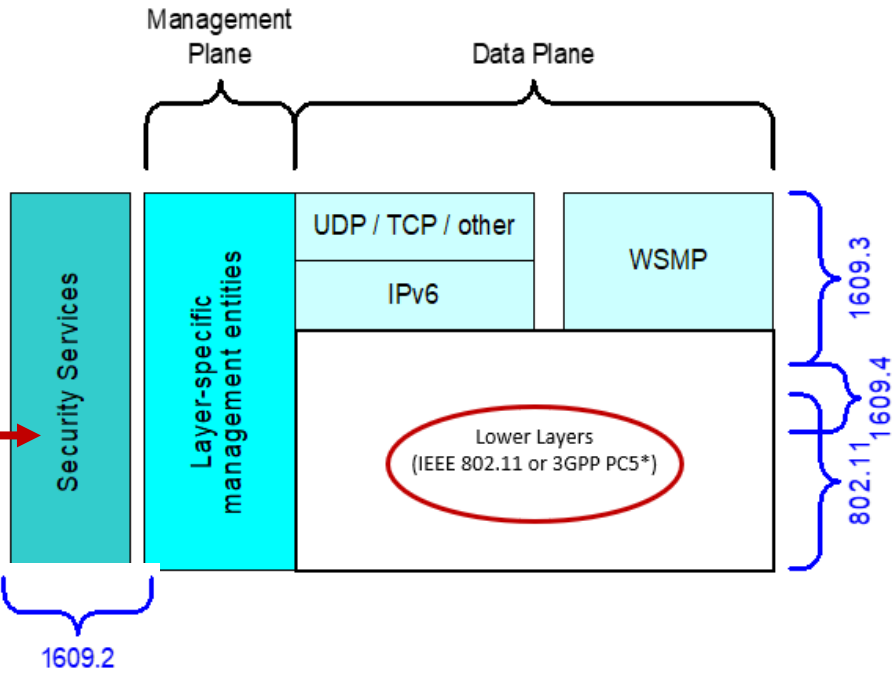


- Never encountered each other
- Must establish trust with each other
- Might only have seconds before a collision
- Need to maintain anonymity
- System needs capability to revoke credentials when needed, very large number of devices

Role of 1609.2: Security Services

Features

- Signing/verification services (e.g. used for V2V broadcast messages)
- WSMP payloads (both broadcast and unicast) can be signed or signed and encrypted
- ISO 21177 is one option for encryption-it uses TLS with 1609.2 certificates
- Security is NOT a layer, but a **plane** that spans the entire stack, uses 1609.2 services to establish trust



TLS-Transport Layer Security

ISO/TS 21177:https://www.iso.org/standard/70056.html

Role of 1609.2: Security Services

Additional Features

- Ongoing amendments/revisions under 1609.2.1 will support SCMS implementation
- Support the Certificate Authority (CA)

SCMS-Security Credential Management System

WAVE Security Services

- Certificate is distributed over **WSMP**
- CRL is distributed by the SCMS over **IP** interface
- Certificates are issued with limited lifespans/regularly renewed through an automated process; this allows the size of the CRL to be managed
- CRL is the outcome of Misbehavior Detection (MBD); revokes trust from these users

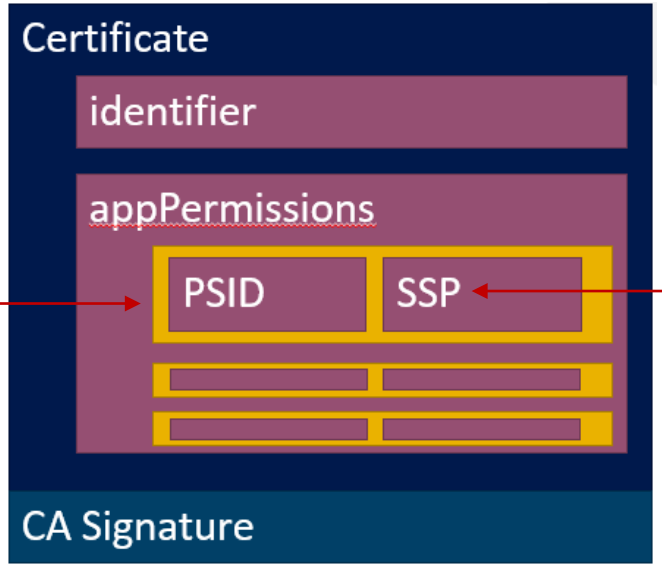
CRL-Certificate Revocation List

Role of 1609.2: Security Services

Digital Certificate Defines Credentials Granted

- Transmit authorizations
- Receiver checks if the sender has the permissions to carry out the actions

PSID identifies **application** for which a sender is authorized to generate signed secured messages



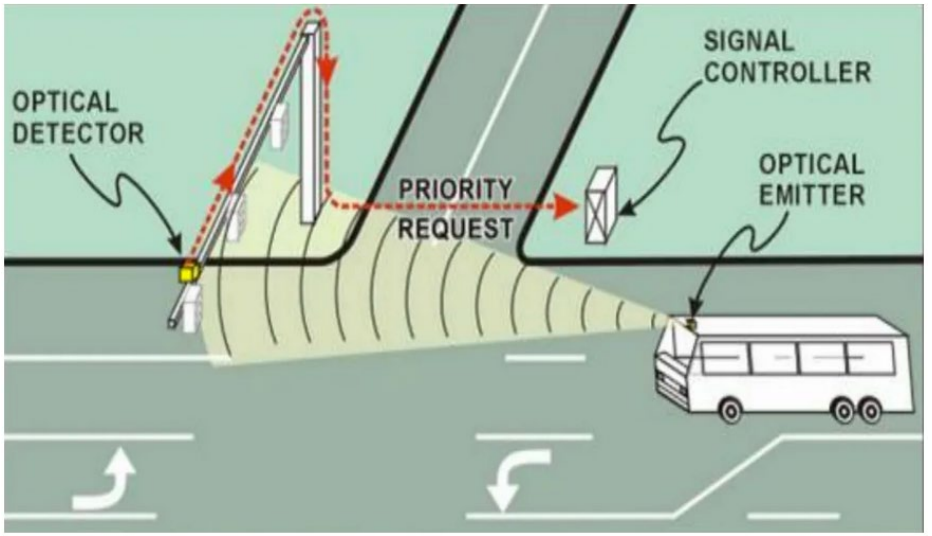
SSP (Service Specific Permissions) indicates **authorizations** defined by the application

Source: William Whyte

Certificate Authority (**CA**)

Example: Certificate SSP in TSP V2I Application

SSP authorizes Transit/Emergency vehicles to make priority request; others may have various levels of permission (if any)



Role of 1609.2: Security Services

Role of Application in Signing a Message

- Application (**higher layer entity**) requests security services to sign a message
- Cryptographically binds a certificate to each message
  - Demonstrates it originated a given message and the message has not been altered
  - Cryptographic binding is called “signing”
  - Credential is issued by a Certificate Authority or CA
- Some messages are signed and unencrypted (for authentication purposes)
  - Others are signed and encrypted (for authentication and data protection purposes)

Signing focuses on integrity, encryption is for confidentiality.

Role of 1609.2: Security Services

Security Considerations for WSA

- All WSAs must be signed (PSID 0x87)
- Misbehavior reporting service can be advertised in a WSA
- WSA security header indicates weather or not the message is secured (a signed-SPDU) or it is encrypted.

WSA-WAVE Service Advertisement
SPDU- Secured Protocol Data Unit

WAVE Implementation Challenges

Key Areas

- Evolving WAVE standards (2016)…..
- Multiple communication support (e.g. DSRC, LTE-V2X)
- Dual Radio operation needs
- System integration issues (interoperability)
- Procurement issues, multiple vendor relationships
- SCMS implementation
- Intersection management (V2I, Traffic Controller)
- Other project-specific or MPO regional planning issues

MPO-Metropolitan Planning Organization

Stakeholders-Specific Issues

Stakeholders

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

Issues

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

Protocol Implementation Conformance Statement (PICS)

Illustration

PICS Sample Portion (Full Table on page 118, IEEE 1609.3)

Item	Feature	Value	Reference	Status	Support
N1.	**DATA PLANE**		—	—	
N1.1.	**LLC**		5.2	M	YES
N1.1.1.	LLC extensions for WSMP		7.5	N1.3:M	YES
N1.2.	**IPv6**		5.3, 6.4	O1	YES
N1.2.1.	Use stateless configuration		6.4	O	
N1.2.2.	IP readdressing		6.4.2	M	
N1.2.3.	Send IP datagrams		5.3	O2	
N1.2.4.	Receive IP datagrams		5.3	O2	
N1.2.4.1.	Receive by link-local address		6.4	M	
N1.2.4.2.	Receive by global address		6.4	M	YES
N1.2.4.3.	Receive by host multicast addresses		6.4	O3	
N1.2.4.4.	Receive by router multicast addresses		6.4	O3	
N1.2.5.	UDP		5.4	O	
N1.2.6.	TCP		5.4	O	YES
N1.2.7.	Other IETF protocols	()[a]	5.4	O	
N1.3.	**WSMP**		5.5	O1	
N1.3.1.	***WSM reception***		5.5.3	O4	
N1.3.1.1.	Check WSMP Version number	()[b]	5.5.3, 8.3.2	M	
N1.3.1.2.	Check Subtype field	()[r]	5.5.3, 8.3.2	M	YES
N1.3.1.3.	Check TPID field	()[s]	5.5.3, 8.3.2	M	
N1.3.1.4.	WAVE Info Elem Extension field		8.1.1	M	
N1.3.1.5.	Deliver message based on Address Info (PSID)		5.5.3	M	

My agency anticipates large data transfers, so I need both IPv6 and WSMP

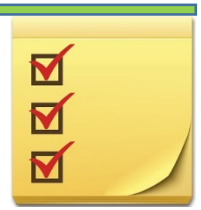
M-Mandatory, O-Optional

Who Benefits from use of PICS

In General, CV Project Deployment Stakeholders Benefit from the Project Level PICS

Specifically,

1. An **implementer** of WAVE devices may use the PICS to indicate which features are supported by an implementation.
2. A **vendor** "unambiguously knows", upfront, what project needs are and no finger pointing….avoid disputes later.
3. A **tester** may use the PICS as a checklist against which to verify conformance.
4. A **system integrator's** "peace of mind" …at end of project interoperable devices will function as intended for safety/mobility applications in CV environment.

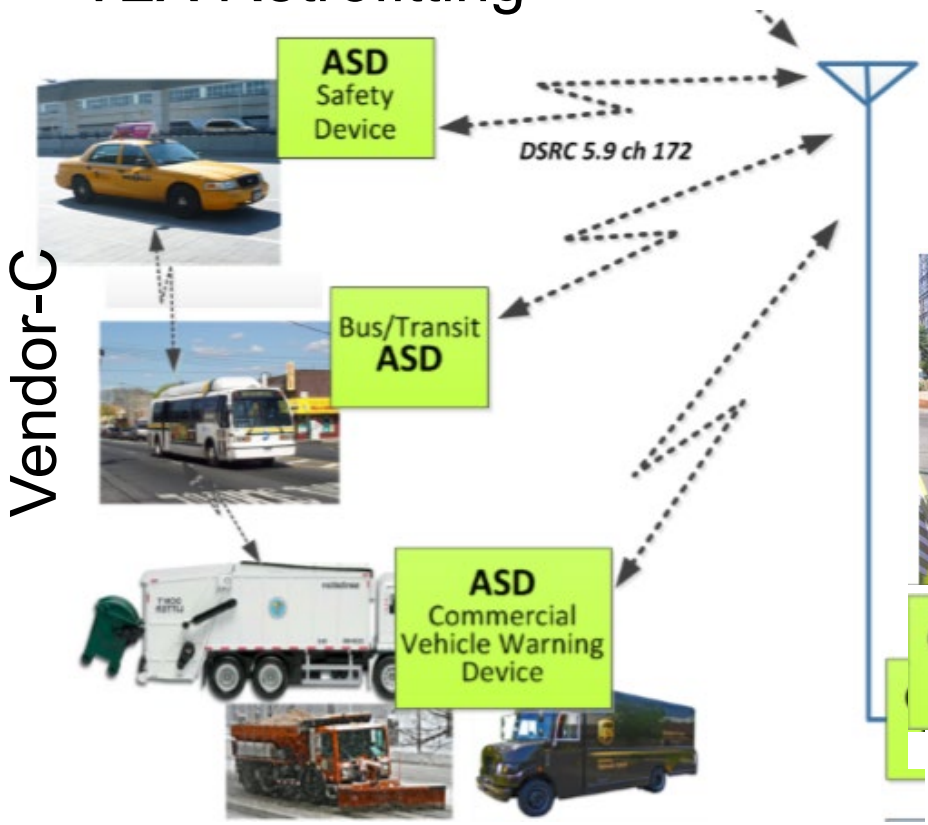


Multivendor Relationships

System Integration Across Devices: "What are we procuring?"

Vendor resistance to providing necessary information

V2X Retrofitting

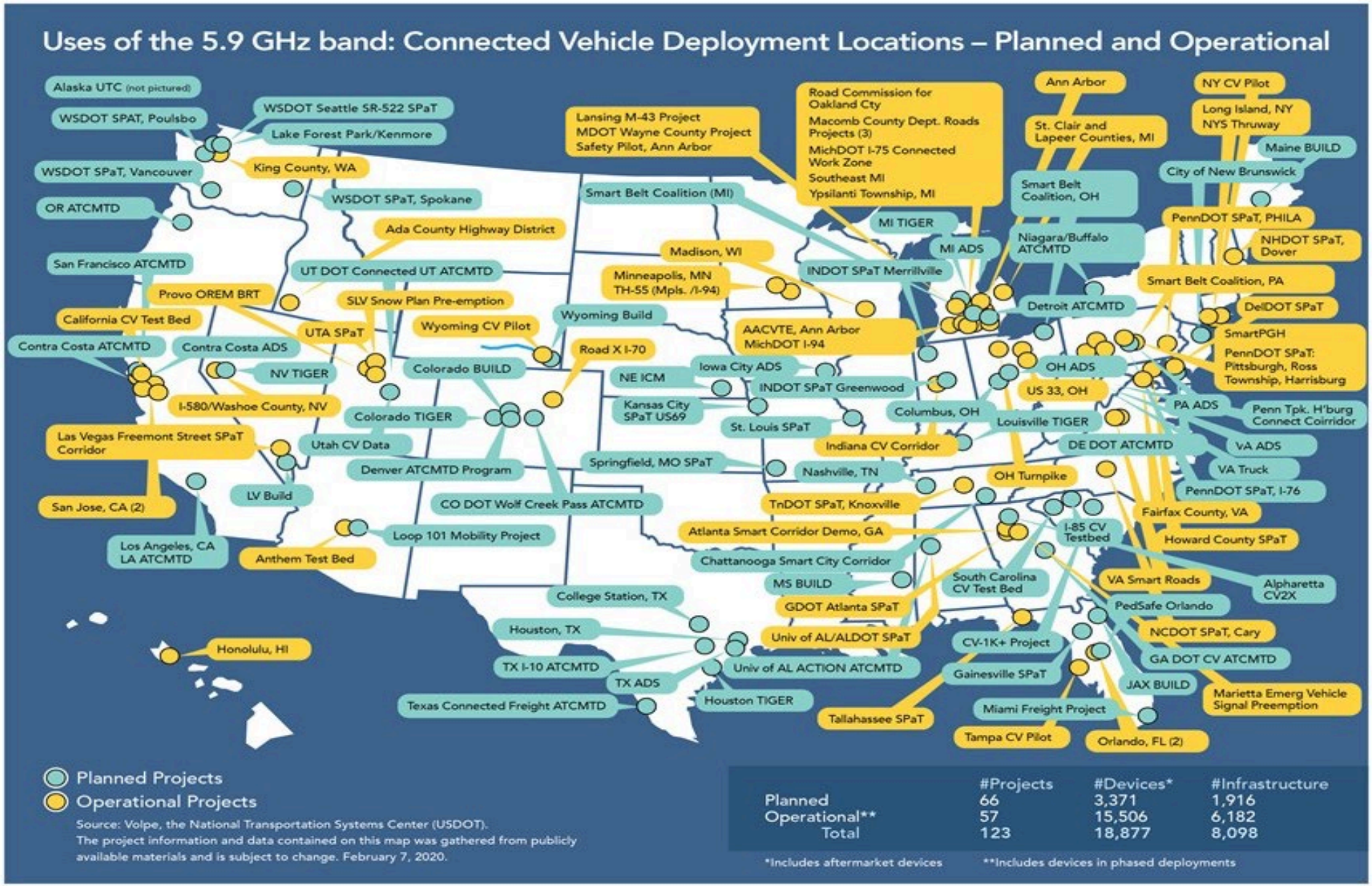


Interfacing RSU Vendor-A

Advanced Solid-State Traffic Controller (ASTC)

Note: Ethernet ports available for connection to CV units

US CV Deployments (67 planned, 57 operational)



WAVE Devices Implementation (CV Pilots)

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	17	255
WYDOT Highway Patrol	0	35
Total Equipped Vehicles	**52**	**~405**
Roadside Units (RSU) along I-80	**75**	**75**

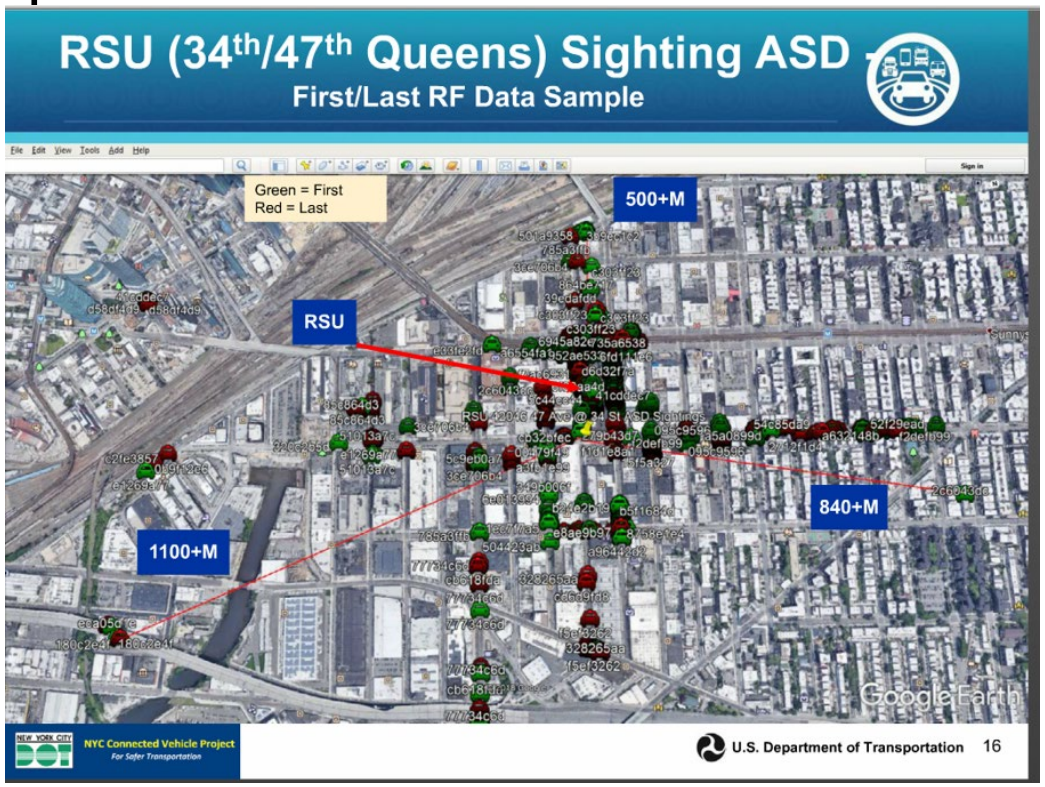
Tampa Pilot (THEA)	Complete	Target
Private Light-Duty Vehicles Equipped with On-Board Unit (OBU)	727	1,080
HART Transit Bus Equipped with OBU	7	10
TECO Line Street Car Equipped with OBU	8	8
Total Equipped Vehicles	**742**	**~1,100**
Roadside Units (RSU) at Downtown Intersections	**47**	**47**

Devices use WAVE Standards (2016) v3

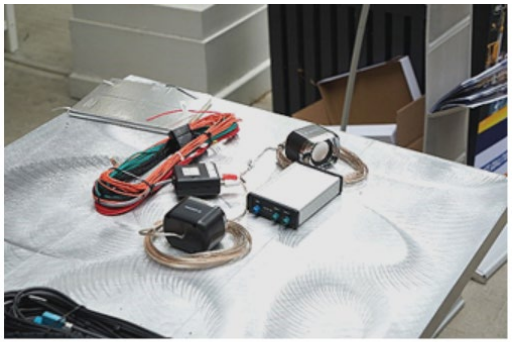
Source: USDOT
3/1/2020

WAVE Devices Implementation: NYC Pilot Project

- Installed 1606 vehicles of a scheduled 3000, June 2020
- Installed 400 RSUs of a scheduled 450
- Verified Over-the-Air Firmware updates and applications parameters

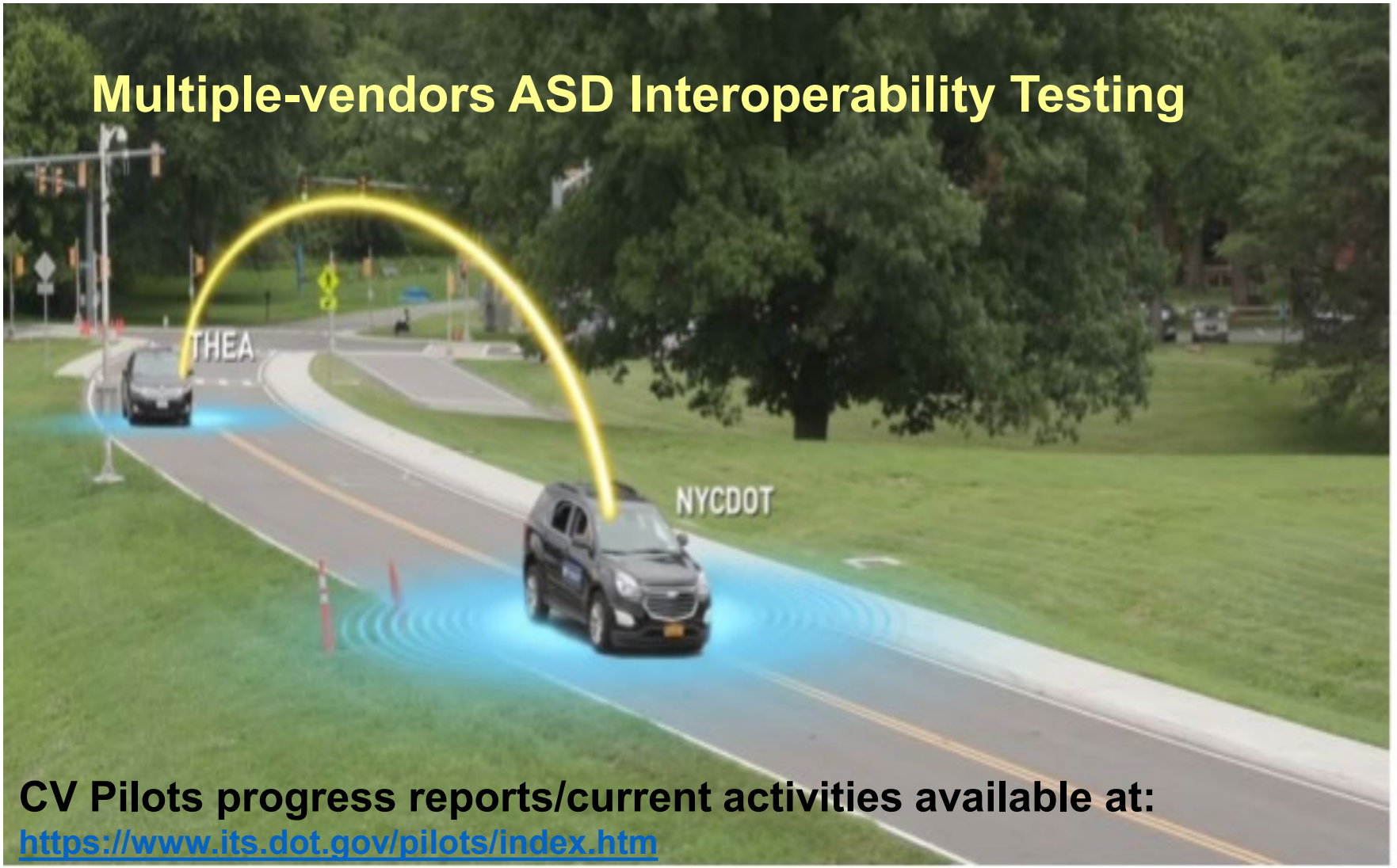


Typical RSU Installation



CV equipment, including the ASD and pair of speakers, prior to installation in the NYCDOT vehicle.
Source: NYCDOT

Lessons Learned from Deployments



CV Pilots progress reports/current activities available at:
https://www.its.dot.gov/pilots/index.htm

Lessons Learned from Deployments (cont.)

What have we tested?

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

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

Source: USDOT, 2018

OTA-Over The Air

CASE STUDY

STANDARDS ITS TRAINING

U.S. Department of Transportation
ITS Joint Program Office
Image Source: Thinkstock USDOT

WAVE Devices Testing for Interoperability

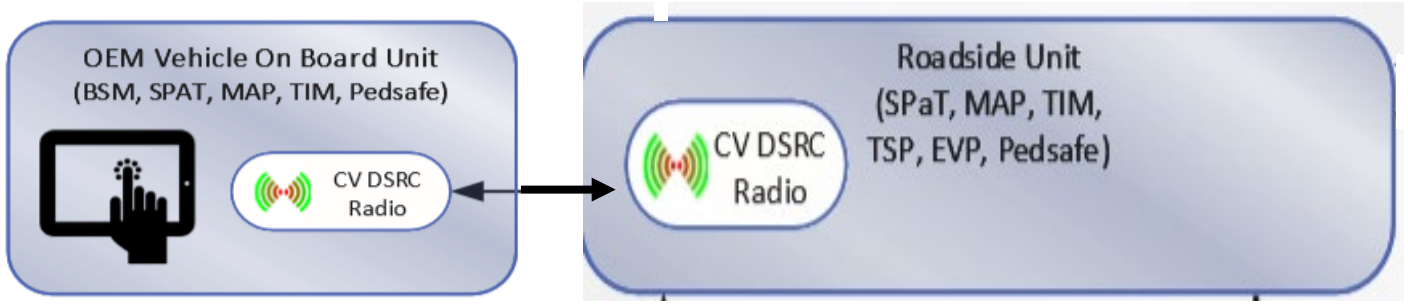
Source: http://www.cflsmartroads.com/projects/CVAV_D5_Testing.html

Testing Strategy: Test Equipment + Messages

Lab Setup included a total of 21 manufacturers and 3 types of devices

- 5 controller manufacturers
- 9 RSU manufacturers
- 7 OBU manufacturers

Field test validation at two locations, to test end-to-end communication (transmit/receive)



SPaT-Signal Phasing and Timing
TIM-Traveler Information Messages
EVP-Emergency vehicle Pre-emption

WAVE Device and "Standards Conformance"

Conformance is defined as the adherence of an implementation to the requirements of one or more specific standard or technical specifications

-ISO/IEC 10641:1993

WAVE device is defined as a device that is conformant to the following standards:

- IEEE Std 1609.3
- IEEE Std 1609.4
- IEEE Std 1609.12
- IEEE Std 1609.2 (when sending secured WSAs or using 1609.2 certificates)
- IEEE Std 802.11, operating outside the context of a basic service set

Source: IEEE 1609.0 (2019) page 25

WAVE Device and "Standards Conformance"

For IEEE Std 1609.3 conformance, a device implements at least the following features:
— LLC sublayer
— IPv6 or WSMP, or both
— Transmit or receive, or both

For IEEE Std 1609.4 conformance, a device implements at least the following features:
— OCBActivated communication (as specified in IEEE Std 802.11)
— Transmit or receive, or both — EDCA and user priority when transmitting

EDCA-Enhanced Channel Distributed Access
OCBA-Outside the Context of a Basic Service

Source: IEEE 1609.0 (2019) page 25

Example for Compliance Language for Dual Radios

4.8.2 DSRC

4.8.2.1 FCC Regulation 47 CFR Compliance: The RSU shall comply with Federal Communications Commission (FCC) Code of Federal Regulations Title 47 Parts 0, 1, 2, 15, 90, and 95.

4.8.2.2 Each RSU shall include 2 radios capable of operating on all 7 channels of the DSRC spectrum and capable of having their output level modified for each channel and each message.

4.8.2.3 Nominally one channel will be 172 and shall monitor the BSM messages, and transmit the SPaT, MAP, and RTCM messages.

4.8.2.4 The second channel will be 178 and shall alternate or change between channels and modes for the support of IP communications and messages necessary for the CVPD support of software and parameter updates and log downloads to the TMC.

Source: City of New York, RSU Specification, 2017, page 81
https://www.cvp.nyc/project-status

Radio Transmission Commission for Maritime Services (**RTCM**)

ACTIVITY

STANDARDS ITS TRAINING

U.S. Department of Transportation
Office of the Assistant Secretary for
Research and Technology

Question

Which of the following is an Incorrect statement?

Answer Choices

a) WAVE supports both WSMP and IPv6 protocols.

b) Compliant WAVE devices are typically interoperable.

c) PICS should be included in a CV project specification.

d) WSA broadcasts opportunity on any channel.

Review of Answers

a) WAVE supports both WSMP and IPv6 protocols.

Incorrect. WAVE supports both protocols.

b) Compliant WAVE devices are typically interoperable.

Incorrect. They are tested for messages exchange for interoperability.

c) PICS should be included in the CV project specification.

Incorrect. PICS can be used as a checklist for conformance to WAVE standards.

d) WSA broadcasts opportunity on any channel.

Correct Answer! WSA is typically issued on CCH 178.

CV Technical Resources

- Supplement provides references for the following:
  - Current WAVE standards documents
  - SAE Messages standards documents
  - CV Pilots lessons learned
  - Annex C, IEEE1609.0: Prof of Testing/Certification of WAVE devices
- RSU standard development effort (ITE)

  https://www.ite.org/technical-resources/standards/rsu-standardization/
- DSRC Roadside Unit (RSU) Specifications Document v4.1

  www.cflsmartroads.com

SUPPLEMENT

CV Training Modules Available

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

- CV-T160 Connected Vehicles Certification Testing Introduction
- CV-261 (V2I) ITS standards for Project Managers
- CV-262 (V2V) ITS Standards for Project Managers
- CV-271: Using the ISO TS 19091 Standard to Implement V2I Intersection Applications Introduction
- CV-273: Introduction to SPaT/MAP Messages
- Transit 11: Transit and the Connected Vehicle Environment/Emerging Technologies, Applications, and Future Platforms
- Transit 24: Transit Signal Priority (TSP)
- CSE-201: Security Credential Management (SCMS)
- CSE-202: Introduction to Cybersecurity

Learning Objectives

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

Discuss Role of IEEE 1609.3 Networking Services

Discuss Role of IEEE 1609.4 Multi-Channel Operations

Discuss Role of IEEE 1609.2 Security Services and Identify WAVE Implementation Issues and Challenges

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!