



Source: FHWA.

CAVe-in-a-Box

Workforce Development

Module 3: CAVe-in-a-box and System Design.

Disclaimer

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Previous Sessions Review

- Introduced Turner-Fairbank Highway Research Center (TFHRC) and equipment loan program.
- Introduced Vehicle-to-everything (V2X) Hub introduction.
- Provided V2X Hub practical overview.





Overview

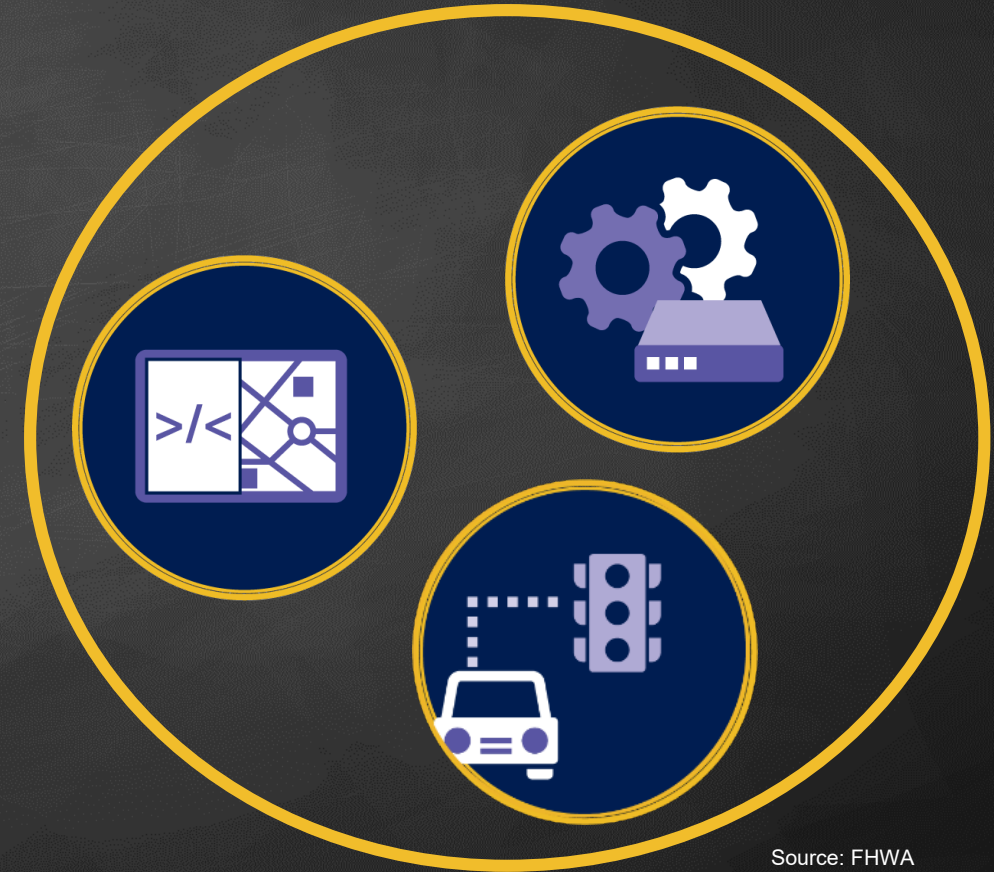
- Introduction to the educational tool CAVe-in-a-box.
- CAVe-in-a-box system design.
- A look into CAVe-in-a-box: Infrastructure kit.
- How data flows in CAVe-in-a-box?



Introduction

What is CAVe-in-a-box?

- Educational tool for laboratory purpose in technical workforce development.
- Enables hands-on teaching about connected and automated vehicles (CAVs).
- Portable intelligent transportation system (ITS) test kit.



Source: FHWA



Introduction

Why do we need the CAVe-in-a-box?

- Reduce the knowledge gap between workforce and technology.
- Provide hands-on experience.
- Build the kit as a test tool and support through the loan program.



Source: FHWA





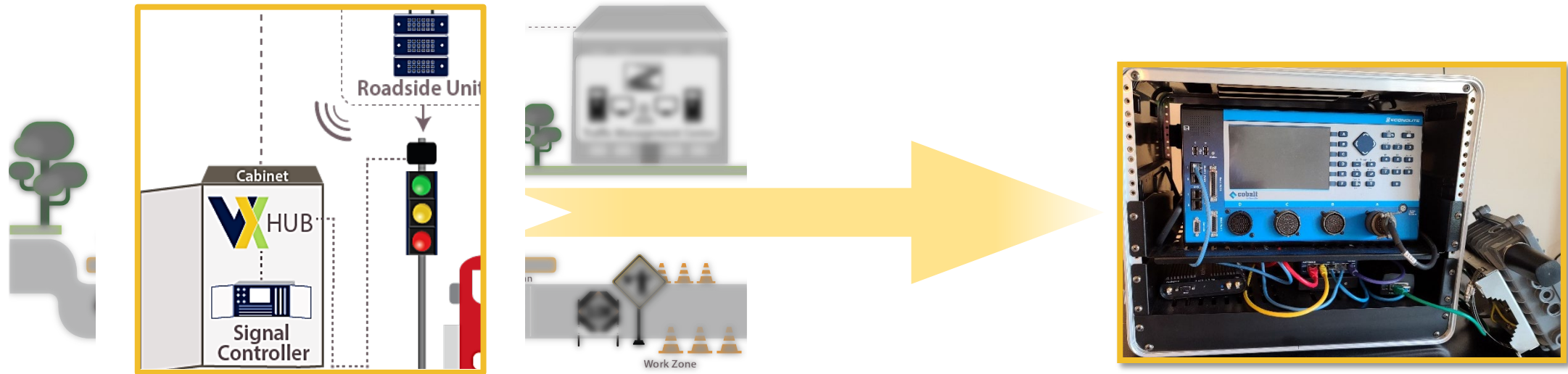
Introduction

Who is the test kit meant for?

- Community college educators.
- Educational laboratory and hands-on learning.
- Researchers interested in CAVs.



CAVe-in-a-Box in a Perspective



- An ITS.
- Portable ITS.
- CAVe-in-a-box.



System Design

Infrastructure Kit

- **Roadside Unit Kit**
 - Roadside unit (RSU).
 - Signal controller.
 - Wired network switch with Power over Ethernet (PoE).
 - Power.
 - Touchscreen.

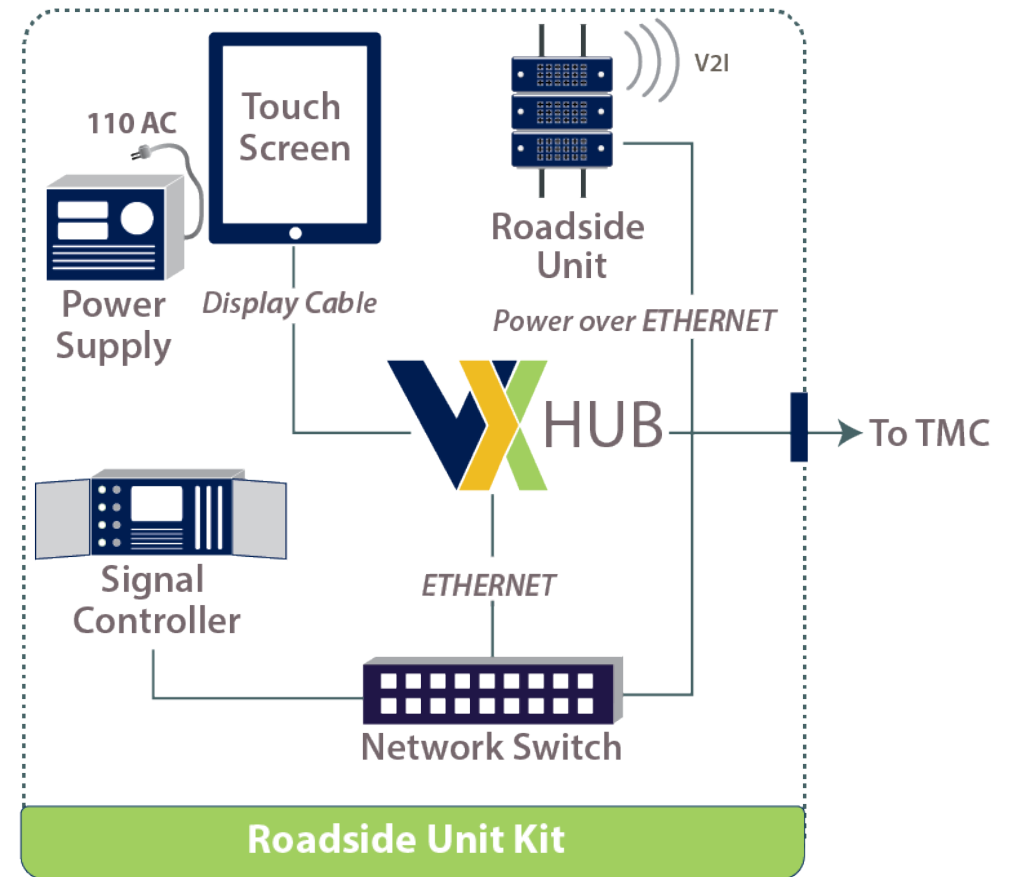
Mobile Kit

- **Onboard Unit Kit**
 - Onboard unit (OBU).
 - Controller area network (CAN) connector).
 - Car power.
 - Wired network switch.
 - Antenna mount.
- **Onboard Unit Kit w/ Touchscreen**
 - OBU.
 - CAN connector.
 - Car power.
 - Wired network switch.
 - Antenna mount.
 - Touchscreen.



System Diagram: RSU Kit

- Emulates infrastructure component of an ITS.
- Employs V2X Hub for messaging and coordination with different plugins.
- Can be installed on any test location or laboratory.
- Used for testing or teaching different ITS applications, such as basic safety message (BSM), signal phase and timing (SPaT), map data (MAP), and traveler information message (TIM).

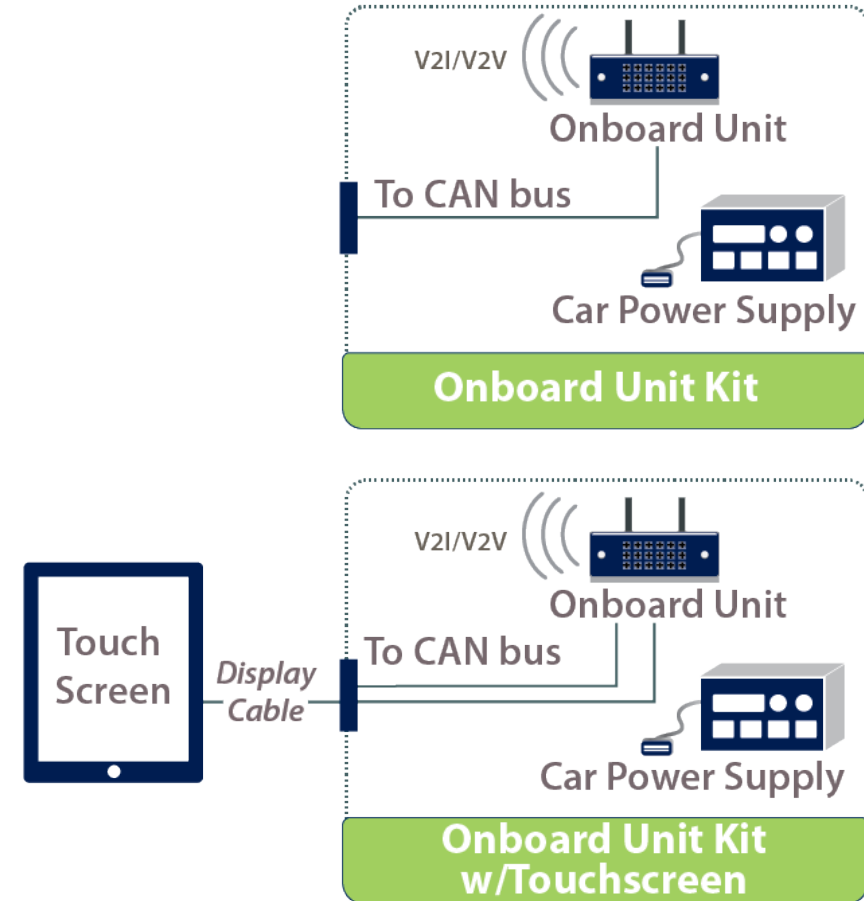


TMC = Transportation Management Center.



System Diagram: OBU Kit

- Emulates mobile component of an ITS.
- Uses OBU for messaging and connectivity with RSU Kit.
- Can be easily installed on any test vehicles.
- Used for testing or teaching different ITS applications, such as BSM, SPaT, MAP, and TIM.





Source: FHWA

Inside CAVe-in-a-box: Infrastructure Kit



Building CAVe-in-a-Box: Infrastructure Kit

This picture displays the equipment installed within the box.

Items include:

1. Traffic controller.
2. Network router.
3. Network switch.
4. V2X Hub.
5. The box.
6. Power strip.
7. Shelves.
8. RSU.



Controller Assembly



Device is mechanically fastened to the rack-mount shelf.



Hardware Shelf Assembly



Network Switch.



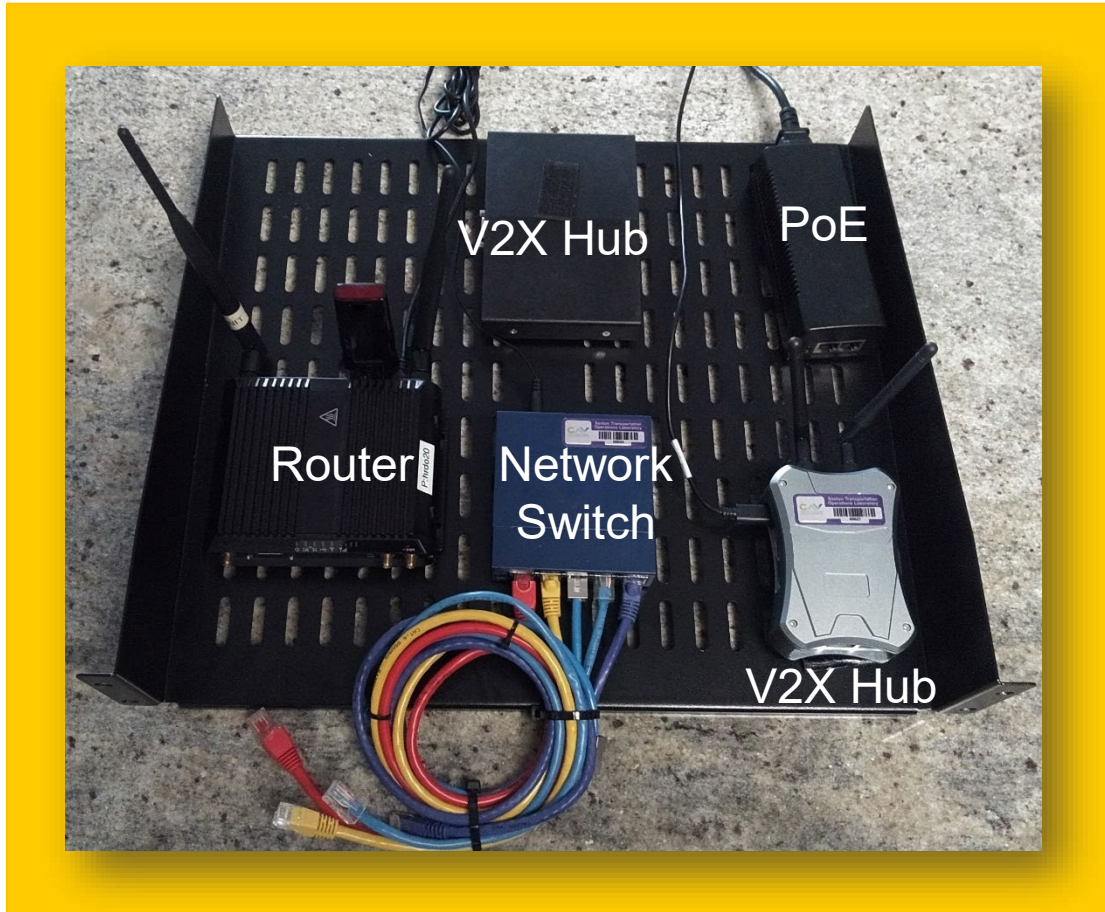
Router.



V2X Hub.



Hardware Shelf Assembly



Devices have been mounted using hook-and-loop strips and wired accordingly.



Final Assembly (Front)



The hardware shelf is installed first, followed by the controller shelf. The shelves are mechanically fastened to the sides of the box.



Final Assembly (Rear)



The power strip and RSU are fastened to the rear of the box.





Let's take a look inside the infrastructure kit!



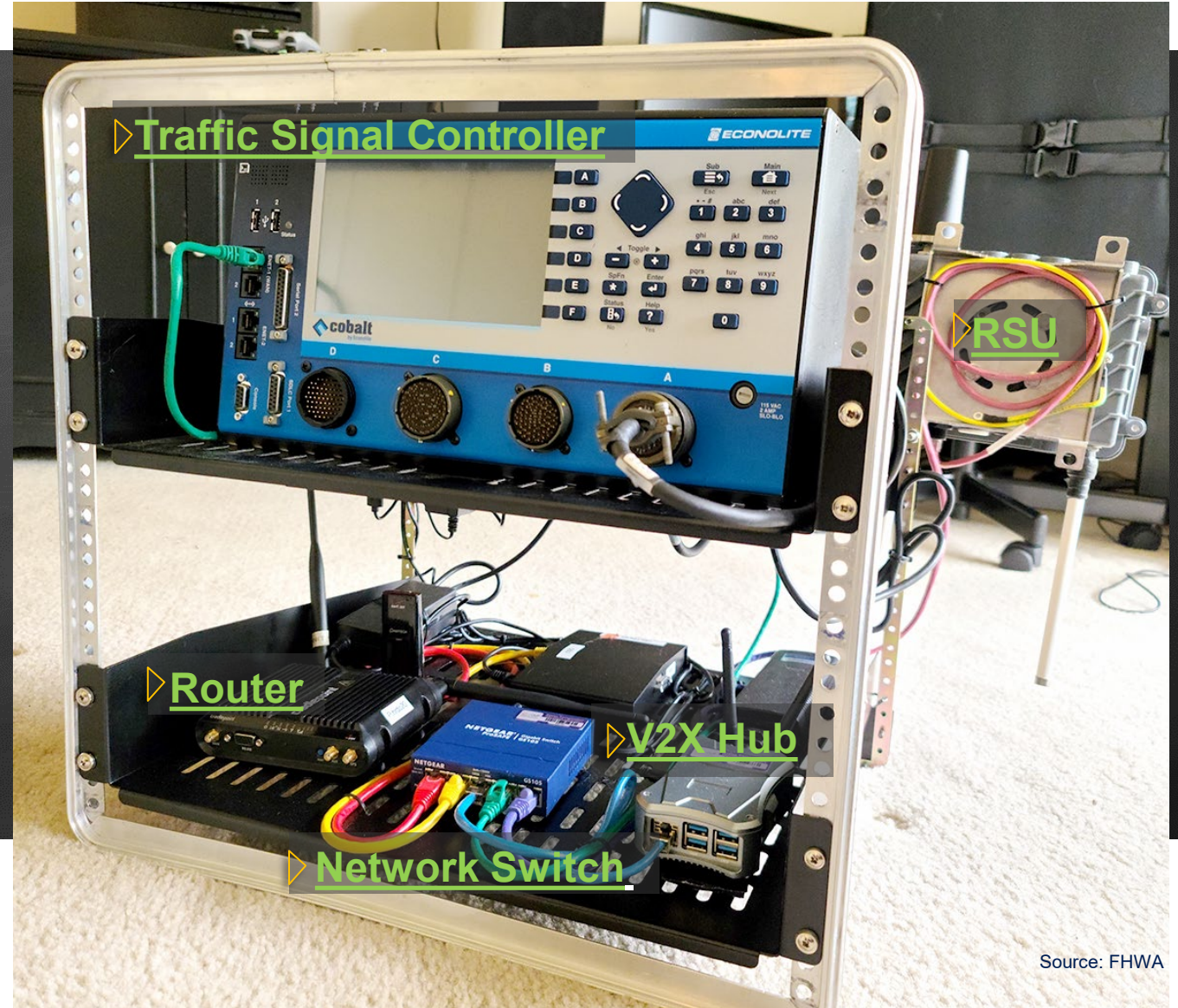


N Router

The wireless router mounted in the box enables wireless connectivity for the entire system. Understanding how the router, along with the other mounted networking components, enable the box to work with the TMC requires a basic grasp of network engineering, as well the IEEE 802.11 standards for wireless networks.

on the requirements.

CLICK TEXT for more information.





Introduction to Data Flows

- Data Flow Methods:

- Ethernet.
- Fiber.
- Wireless:
 - DSRC.
 - C-V2X.
 - Cellular.

- Data Flow Message Standards (Types):
 - SAE International J2735* (SPaT, MAP, TIM, personal safety message (PSM), signal request message (SRM), signal status message (SSM), BSM, etc.).
 - NTCIP 1202 (v2, v3)** SPaT objects.
 - Hypertext transfer protocol (HTTP) (Extensible Markup Language (XML) streams).





Introduction to Data Flows

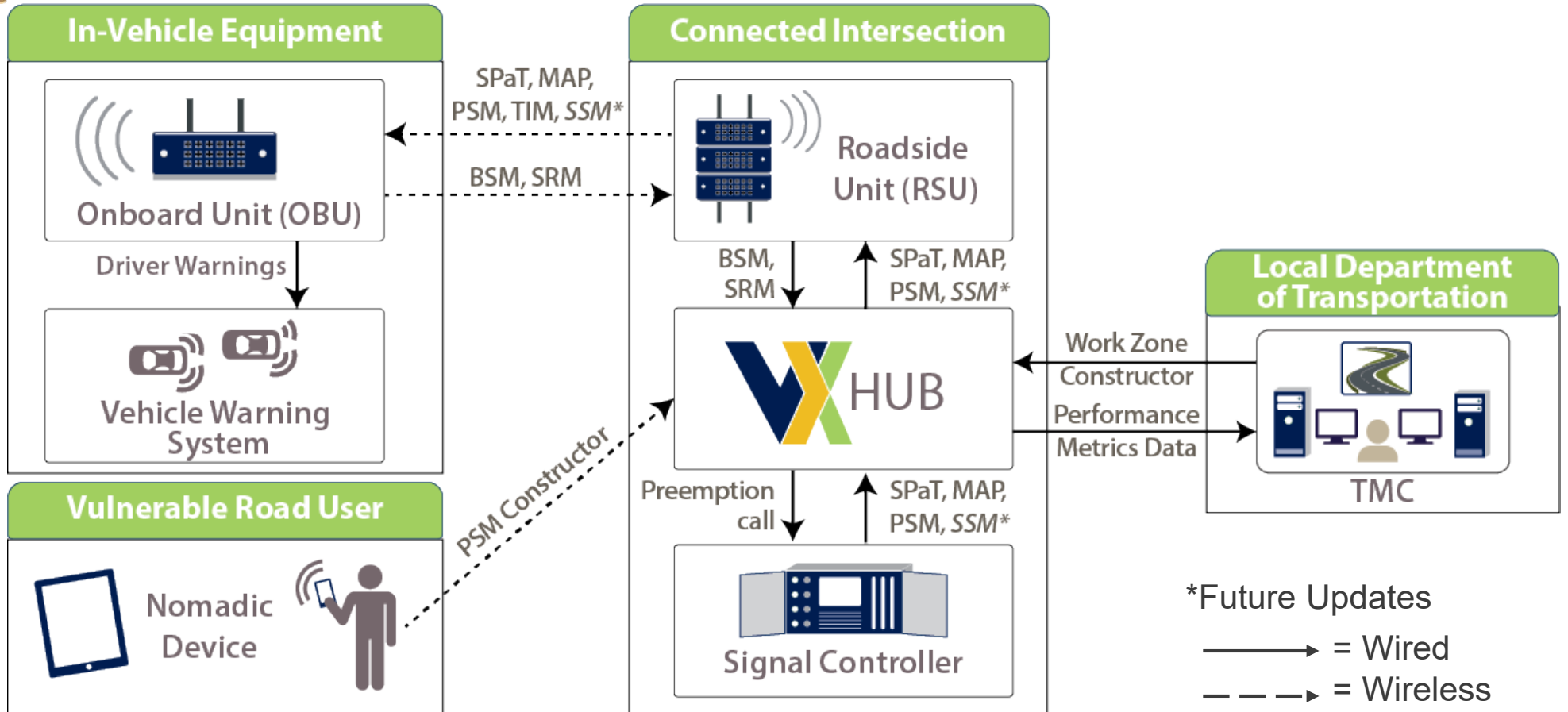
Connected Vehicle Applications

- Red Light Violation Warning.
- Stop Sign Violation Warning.
- Work Zone Safety Warning.
- Curve Speed Warning.
- Pedestrian Ahead Warning.
- Emergency Vehicle Preemption.
- Transit Signal Priority.
- Forward Collision Warning.
- Intersection Movement Assist.





CAVe-in-a-Box Data Flow Diagram





UDP, WAVE, POST (HTTP)

- UDP:
 - Unidirectional.
 - Send to IP address and port number.
 - No handshake.
- IEEE 802.11p for ITS*.
 - 5.9 Gigahertz (Ghz) frequency.
- HTTP Post: Request method to send data to a web server.

*2020, IEEE Standards Association, 802.11p-2010 - IEEE Standard for Information technology-- Local and metropolitan area networks-- Specific requirements-- Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications Amendment 6: Wireless Access in Vehicular Environments





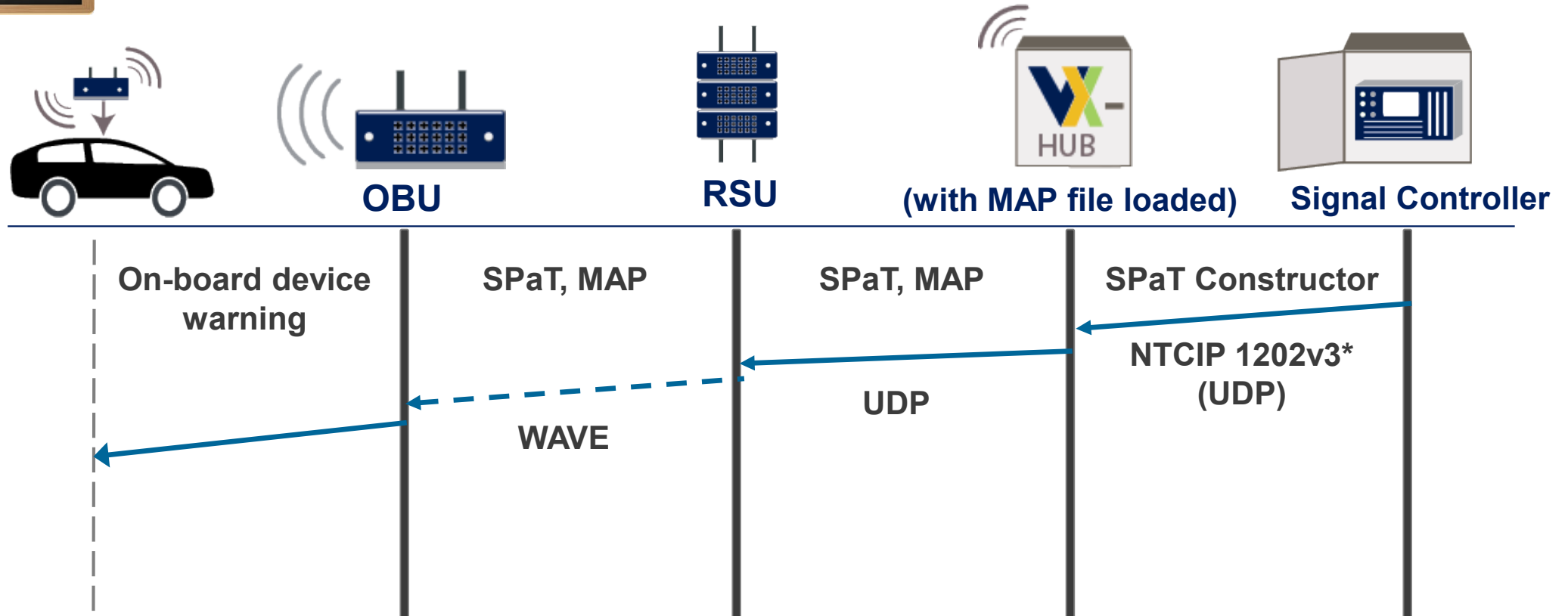
SPaT, MAP, and NTCIP 1202

- NTCIP– 1202 v3**:
 - Standard for traffic control equipment.
 - Output SPaT information through Simple Network Management Protocol (SNMP) data objects.
- SPaT (SAE J2735)**:
 - Status of all configured phases of the light.
 - Interval change time.
 - Signal group-to-phase mapping.
- MAP (SAE J2735)**:
 - Intersection geometry.
 - Lane-to-signal group mapping.
 - Lanes, approaches, road signs, etc.







SPaT and MAP Messages



Source: FHWA

 = Wireless
 = Wired

* 2018, NTCIP Joint Committee, National Transportation Communications for ITS Protocol RS: Object Definitions for Actuated Signal Controllers (ASC) Interface version v03.26 and v02.





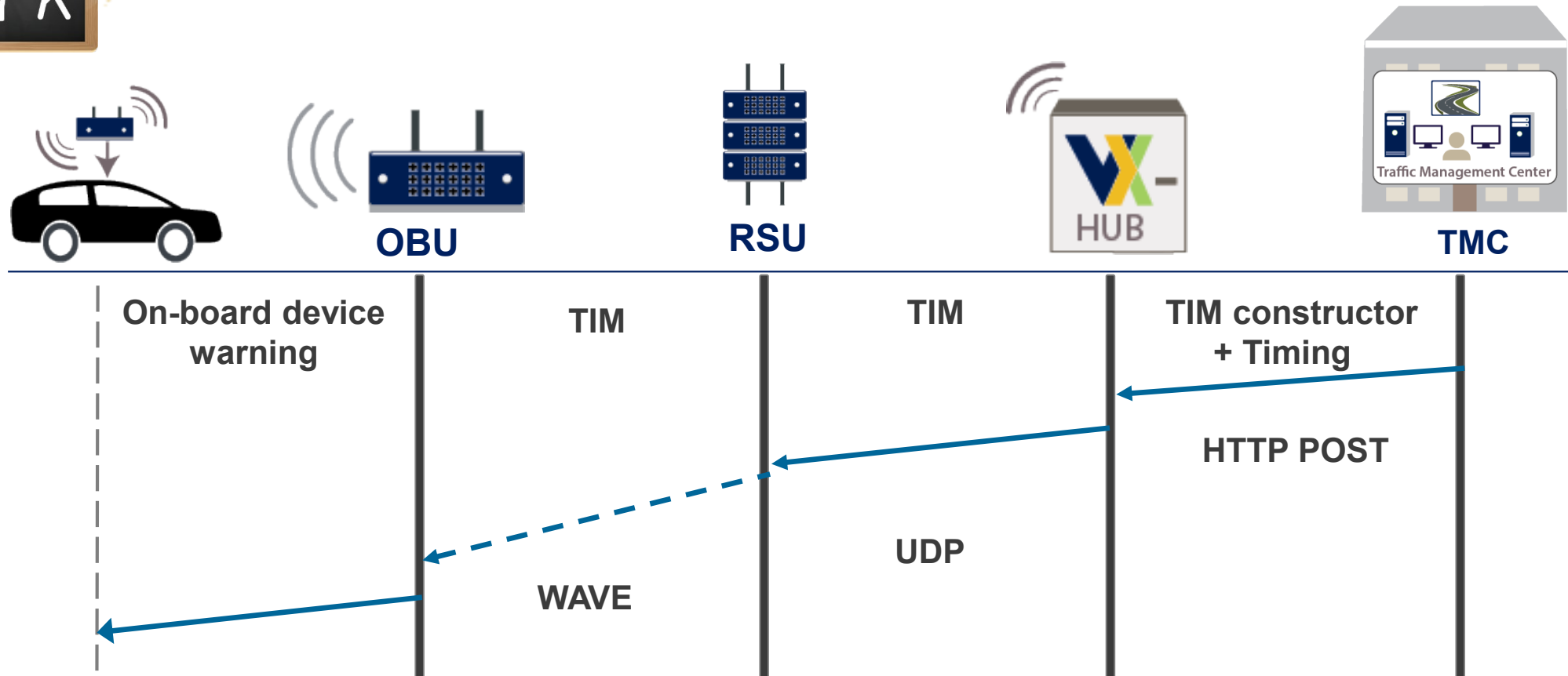
TIM Messages

- TIM constructor:
 - XML-encoded stream.
 - Work zone status and timing.
 - Work zone geometry, road signs, International Traveler Information System (ITIS) codes, etc.
- TIM (SAE J2735*):
 - Work zone geometry, road signs, and ITIS codes.
 - Unaligned Packed Encoding Rules (UPER)-encoded.
 - Curve speed warning, work zones, etc.





TIM Messages



Source: FHWA

--- = Wireless
— = Wired





PSM Messages

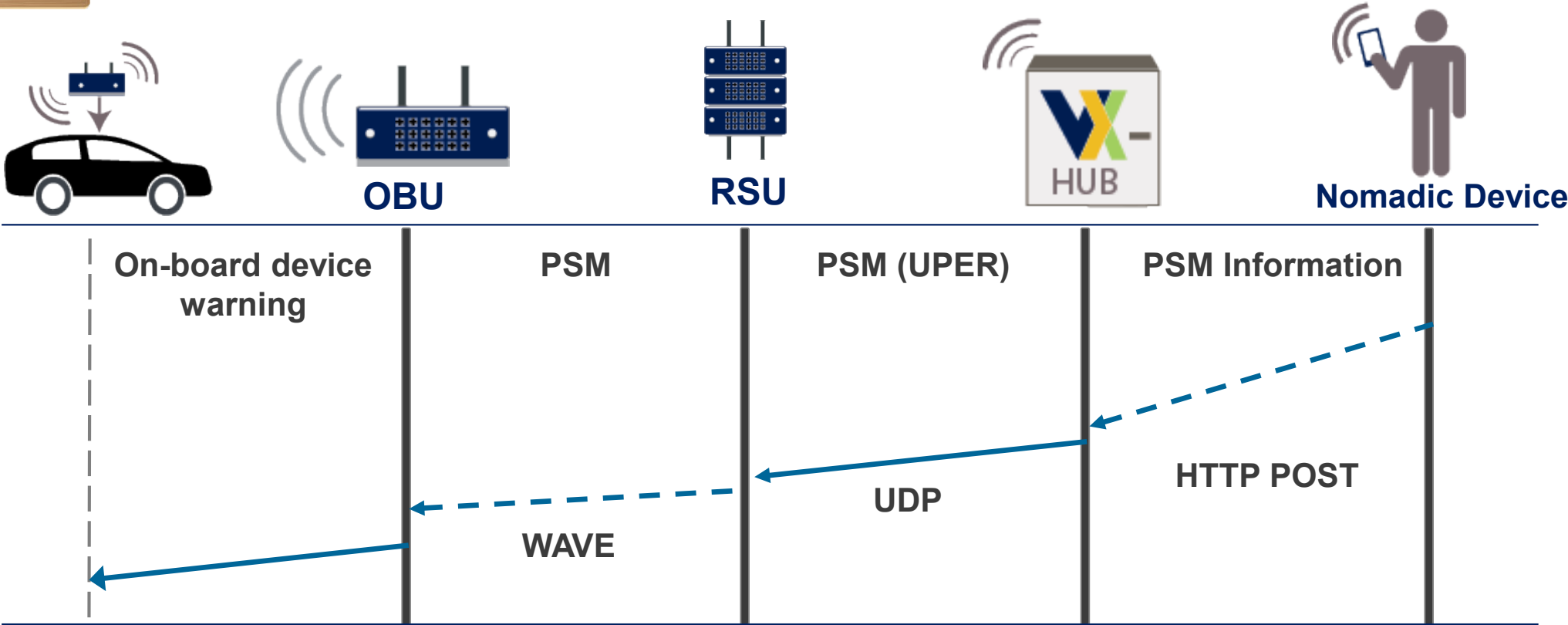
- PSM Constructor:
 - XML-encoded stream.
 - Speed, heading, and position for Vulnerable Road User (VRU).
 - Nomadic device.
- PSM (SAE J2735*):
 - Speed, heading, and position for VRU.
 - UPER-encoded.
 - Pedestrian present alerts, etc.

* 2009, SAE International, J2735_200911 - Dedicated Short Range Communications (DSRC) Message Set Dictionary.





PSM Messages



Source: FHWA

--- = Wireless
— = Wired





BSM Messages

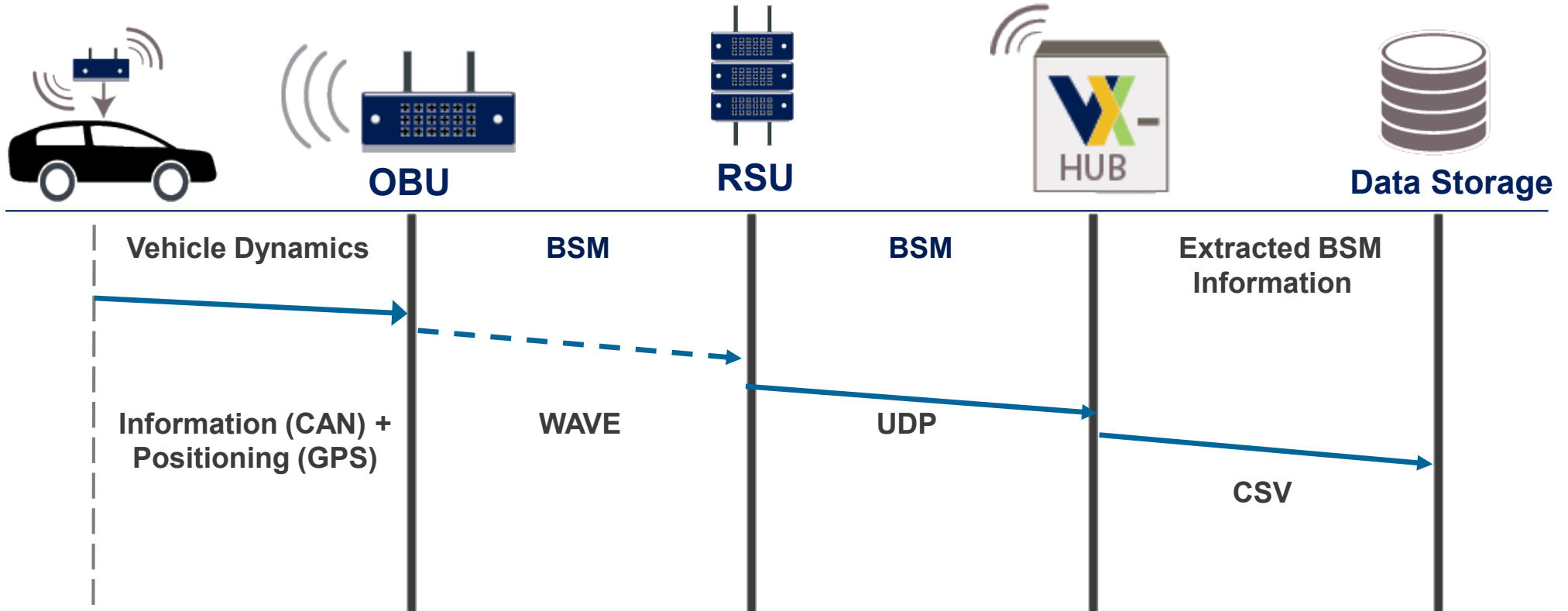
- BSM (SAE J2735*):
 - Part I:
 - Vehicle position, speed, and heading.
 - BSM temporary identifier.
 - Part II:
 - Vehicle type, size, and trailer information.
 - Lights and sirens status for emergency vehicles.

* 2009, SAE International, J2735_200911 - Dedicated Short Range Communications (DSRC) Message Set Dictionary.





BSM Messages



Source: FHWA

— = Wireless
— = Wired

CSV: Comma Separated Values
GPS: Global Positioning System





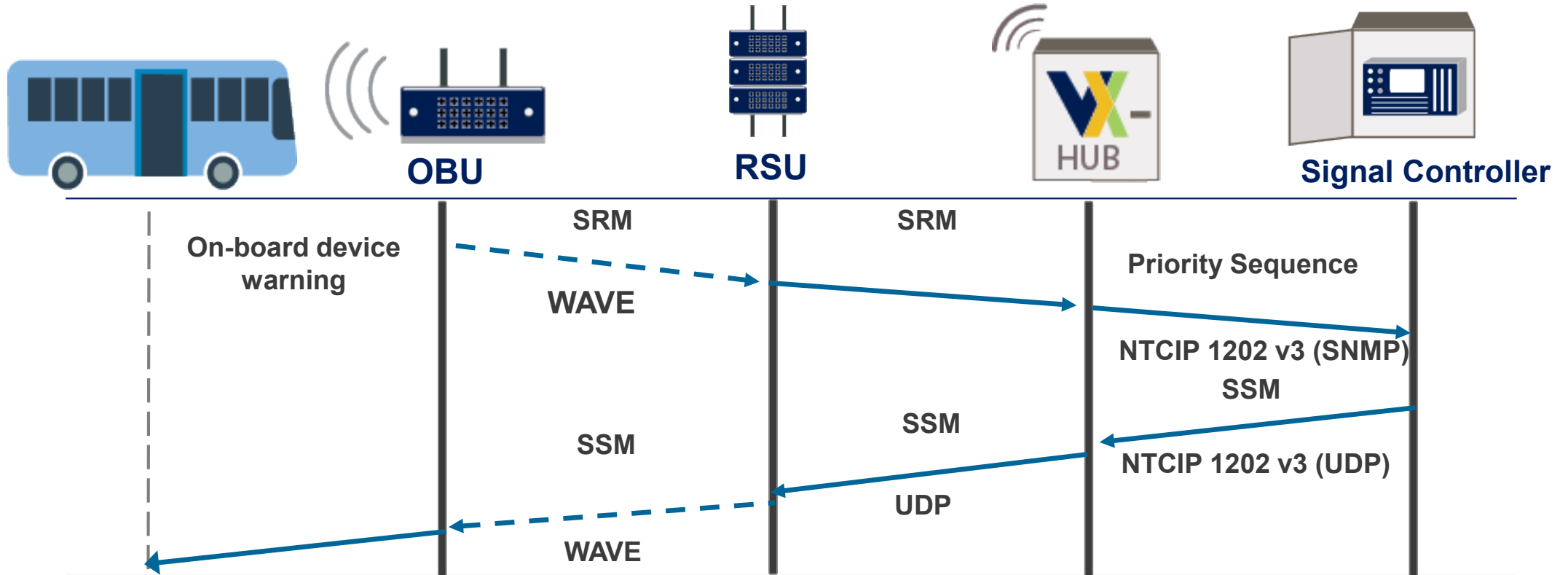
SRM and SSM

- SRM (SAE J2735*):
 - Request priority at the approach lane.
 - BSM vehicle identifier.
 - Vehicle position, speed, and heading.
- NTCIP —1202 v3** : Call priority table based on approach lane.
- SSM (SAE J2735*):
 - Status of request (approved/denied).
 - Status of traffic light.





Transit Signal Priority and Preemption



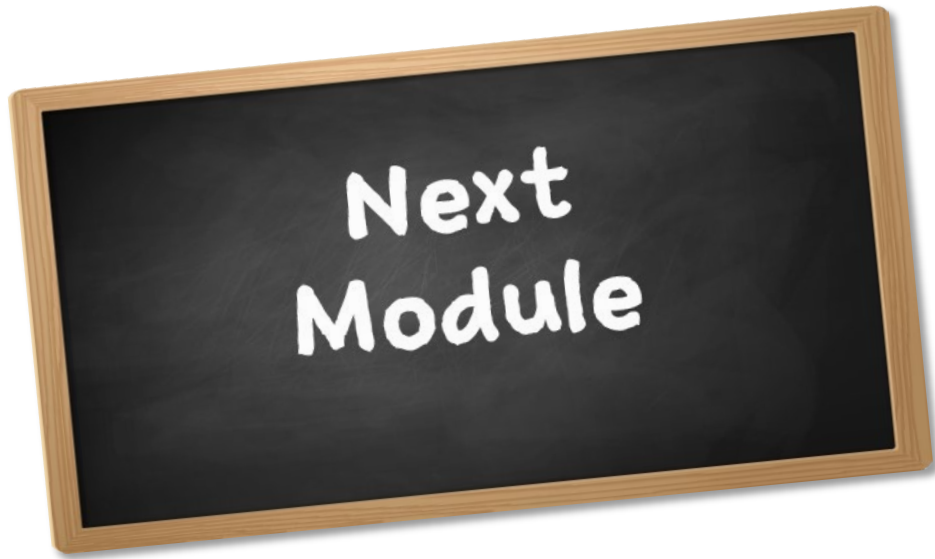
Source: FHWA



Contact Us! 

CAVSupportServices@dot.gov





Next, we will learn more about the V2X Hub software





Thanks!

Questions?



