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

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Target Audience

- Managers and operators of transit systems;
- Metropolitan Planning Organizations;
- Transit planners; and
- Private and public sector users, including manufacturers.
# Recommended Prerequisite(s)

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Curriculum Path (Decision-Maker)

- Introduction to ITS Transit Standards
  - Module 1

- Transit Management, Part 1 of 2
  - Module 2

- TCIP, Part 1 of 2
  - Module 3

- Traveler Information, Part 1 of 2
  - Module 6

- Electronic Fare Payment Systems
  - Module 10

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

Recommended Prerequisite Modules

Optional Modules
Curriculum Path (Project Manager)

- **Introduction to ITS Transit Standards**
  - Module 1
- **Transit Management, Part 1 of 2**
  - Module 2
- **Transit Management, Part 2 of 2**
  - Module 5
- **TCIP, Part 1 of 2**
  - Module 3
- **TCIP, Part 2 of 2**
  - Module 4
- **Traveler Information, Part 1 of 2**
  - Module 6
- **Traveler Information, Part 2 of 2**
  - Module 7
- **Arterial Management & Transit Signal Priority, Part 1 of 2**
  - Module 8
- **Arterial Management & Transit Signal Priority, Part 2 of 2**
  - Module 9
- **Electronic Fare Payment Systems**
  - Module 10
- **Transit and the Connected Vehicle Environment/Emerging Technologies, Applications, and Future Platforms**
  - Module 11

- **Recommended Prerequisite Modules**
- **Optional Modules**
Curriculum Path (Project Engineer)

- **Introduction to ITS Transit Standards**
  - Module 1
- **Transit Management, Part 1 of 2**
  - Module 2
- **Transit Management, Part 2 of 2**
  - Module 5
- **TCIP, Part 1 of 2**
  - Module 3
- **TCIP, Part 2 of 2**
  - Module 4
- **Traveler Information, Part 1 of 2**
  - Module 6
- **Traveler Information, Part 2 of 2**
  - Module 7
- **Arterial Management & Transit Signal Priority, Part 1 of 2**
  - Module 8
- **Arterial Management & Transit Signal Priority, Part 2 of 2**
  - Module 9
- **Electronic Fare Payment Systems**
  - Module 10
- **Transit and the Connected Vehicle**
  - Environment/Emerging Technologies, Applications, and Future Platforms
  - Module 11

**Legend**
- **Recommended Prerequisite Modules**
- **Optional Modules**

**Source**
- ITS Standards Training
- U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology
Learning Objectives

1. Describe the connected vehicle environment
2. Identify and evaluate the potential communications technologies that may be used in a transit connected vehicle environment
3. Identify the ITS standards that support the transit connected vehicle environment
4. Describe the applications being developed in a transit connected vehicle environment
5. Identify the challenges to the successful deployment of a transit connected vehicle environment
6. Describe strategies and approaches for deploying a transit connected vehicle environment
Learning Objective #1:
Describe the Connected Vehicle Environment

- Identify the features of a connected vehicle environment
- Identify the benefits of a transit connected vehicle environment
Identify the Features of a Connected Vehicle Environment

Transportation Challenges in the United States

- **Safety:** 4,000 transit crashes reported in 2009, resulting in more than 200 fatalities and more than 2,500 injuries
- **Mobility:** 4.8 billion hours in 2010 in congestion – near one full week for every traveler
- **Environment:** Transit systems collectively reduce CO2 emissions by 16.2 million metric tons by reducing private vehicle miles

Source: U.S. Department of Transportation, Texas Transportation Institute, American Public Transportation Association
Identify the Features of a Connected Vehicle Environment

Vehicles

- Have safety devices and sensors
- Have a navigation device
- Have a multimedia center

In addition, millions of people carry mobile devices today that have Global Positioning System (GPS) and can access data…

Source: U.S. Department of Transportation
Identify the Features of a Connected Vehicle Environment

What If?

- Vehicles shared their sensor information with other vehicles and the roadway
- Vehicles shared their current position with other vehicles and the roadway
- Vehicles received information from the roadway that could reduce the likelihood of incidents
- Vehicles received information from the roadway that could improve mobility (for example, reduce delays)

Source: U.S. Department of Transportation
Identify the Features of a Connected Vehicle Environment

What Is the Connected Vehicle Research Program?

- A research program to explore how transportation connectivity can enable applications that provide safety, mobility, and environmental benefits
- Transportation connectivity consists of:
  - Vehicles wirelessly sending information to other vehicles (vehicle-to-vehicle)
  - Vehicles wirelessly exchanging information with the infrastructure (vehicle-to-infrastructure)
  - Vehicles, infrastructure, and other mobile devices wirelessly maintaining real-time connectivity

- Connected Vehicle Reference Implementation Architecture (CVRIA)
  
  http://iteris.com/cvria/
Learning Objective #1

Identify the Features of a Connected Vehicle Environment

NHTSA ANPRM

- In August 2014, the National Highway Traffic Safety Administration (NHTSA) released an Advance Notice of Proposed Rulemaking (ANPRM) and a supporting research report
  - Proposed Federal Motor Vehicle Safety Standard (FMVSS) No. 150, to require vehicle-to-vehicle (V2V) communications capability for light vehicles, including minimum performance requirements for V2V devices and messages
  - V2V and vehicle-to-infrastructure (V2I) systems could potentially address 81% of all vehicle crash types
- Notice of Proposed Rulemaking (NPRM) by 2016
Identify the Benefits of a Connected Vehicle Environment

What Transit Challenges Can a Connected Vehicle Environment Address?

- For transit, the connected vehicle environment can address:
  - **Safety challenges:** Including those unique to transit vehicles operating in environments with non-transit vehicles and pedestrians
  - **Mobility challenges:** Provides real-time and accurate transportation information so agencies and travelers can make more informed choices
  - **Environmental challenges:** Increased fuel efficiency and reduced recurring congestion
Identify the Benefits of a Connected Vehicle Environment

What Is the Transit Connected Vehicle Environment?

- Can lead to a new class of vehicles – connected and possibly autonomous
- V2V will open the gates for V2X: V2I, V2P
  - V2V: Vehicle-to-vehicle communications
  - V2I: Vehicle-to-infrastructure communications
  - V2P: Vehicle-to-pedestrian communications
  - V2X: Includes V2V, V2I, V2P, etc.
- Transit Managers:
  - How can the standards help me design or set up the design for a forward-looking capability to improve my transit service?
ACTIVITY
Which of the following can be improved by connected vehicles in public transportation?

**Answer Choices**

a) Roadway congestion  
b) Crash rates  
c) Fuel efficiency  
d) All of the above
Review of Answers

a) Roadway congestion

More efficient transit can lead to an increased mode shift to transit and reduce the number of vehicles on roadways.

b) Crash rates

Connected vehicle technologies can reduce the number of crashes.

c) Fuel efficiency

Connected vehicles can operate more efficiently and use less fuel.

d) All of the above

Correct! All of the above are true.
Summary of Learning Objective #1

Describe the Connected Vehicle Environment

- The concept of connected vehicles involves communicating with each other (V2V), with the surrounding infrastructure (V2I), and with other road users (V2P)

- Connected vehicles can address three major challenges in transportation:
  - Safety
  - Mobility
  - Environment
Learning Objective #2: Identify and Evaluate the Potential Communications Technologies That May Be Used in a Transit Connected Vehicle Environment

- Define Dedicated Short Range Communications (DSRC)
  - Describe the benefits of the 5.9 GHz frequencies
  - List the IEEE 1609 and IEEE 802.11p standards
  - Identify potential Issues with 5.9 GHz frequencies

- Identify other communications technologies being considered
  - Describe the benefits of using other communications technologies
  - Describe the potential issues with other communications technologies
Define Dedicated Short Range Communications (DSRC)

FCC Definition

- 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. DSRC systems may also transmit status and instructional messages related to the units involved.

- The term DSRC originated in the ASTM 2213-02 standard and is incorporated into the Federal Communications Commissions (FCC) Rule.

Source: Federal Communications Commission, Dedicated Short Range Communications of Intelligent Transportation Services – Final Rule, FR Doc No: 99-30591
Define Dedicated Short Range Communications (DSRC)

Frequencies

- Frequencies vary in the United States, Japan, and Europe
- In the United States, 75MHz of spectrum in the 5.9 GHz band allocated in 1999
- Seven 10MHz channels (provides the necessary bandwidth)
  - Channel 178 is the control channel
  - Channel 172 is the service channel for safety data
  - Channel 184 is the service channel for high-power public safety communications
Define Dedicated Short Range Communications (DSRC)

Describe the Benefits of DSRC

- Low latency (allows for high rate of transmission)
  - Information can be transmitted at a high rate (10 times per second)
  - Critical for V2V safety applications
- Short to medium range (< 300 meters reliably)
  - Advantage: Only interested in messages from nearby vehicles
  - Benefit: No interference from other distant incidents
  - Higher power permitted for emergency response vehicles (range can be 1 km)
- No subscription necessary
Define Dedicated Short Range Communications (DSRC)

Potential Issues and Limitations with DSRC

- Limited range may not be suitable for transit operations
  - On the V2I side, RoadSide Equipment (RSE) may be needed every 600 meters.
- Current vehicles need to be retrofitted with 5.9 GHz On-Board Equipment (OBE) to be able to communicate using DSRC
- Privacy and security of data
Define Dedicated Short Range Communications (DSRC)

On-Board Unit (OBU):

- Broadcasts a set of “basic” data such as vehicle location, speed, and direction of travel; AND/OR
- Receives data from other vehicles or the infrastructure

RoadSide Unit (RSU):

- Receives a set of “basic” data from an OBE on vehicles; AND/OR
- Broadcasts information to vehicles or other mobile devices
Define Dedicated Short Range Communications (DSRC)

Onboard Equipment

Source: FTA, Office of Research, Demonstration, and Innovation
Define Dedicated Short Range Communications (DSRC)

RoadSide Equipment (RSE)

- **RoadSide Unit (RSU)** - Represents the DSRC radio alone

**Learning Objective #2**

**Wireless Communications Device**
- Receives and transmits data through an antennae

**GPS Receiver**
- Provides position and time
- Provides timekeeping signal for applications

**Memory**
- Stores security certificates, application data, and other information

**Application Processing Unit**
- Processing unit that runs the applications

**Backhaul Modem Device**
- Receives and transmits data with a center
Define Dedicated Short Range Communications (DSRC)

General Communications Requirements

Required for Deployment:
Different manufacturers

How do we communicate?
Wireless on the same frequency.

What language are we using?
Agree on the grammar and dictionary.

How many people are talking in the room?
Talk louder or softer, or change rooms or channels.

How do we trust each other?
Authentication.
Define Dedicated Short Range Communications (DSRC)

Standards Are Essential

- Supports interoperability to maximize potential benefits
  - Interoperability: The ability of two or more systems or components to exchange information and use the information that has been exchanged
    - For example, AM/FM radio broadcasts
  - Makes testing easier
  - Helps with the design and procurement of a system
Define Dedicated Short Range Communications (DSRC)

Communications Standards

- Transmission Standards
  - ASTM 2213-03
  - IEEE 802.11-2012
  - IEEE 1609 Family

- Interface Standard
  - SAE J2945 Family

- Data Standards
  - APTA TCIP
  - SIRI
  - GTFS
  - SAE J2735
Identify the ITS Standards to Support Communications between the Components

**ASTM 2213-03**

*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*

- Describes a MAC and PHY specification for wireless connectivity using DSRC services
  - PHY: the radio chips and the intervening environment in between
  - MAC: the message protocols that allows applications to ‘connect’ to the PHY
- Basis for IEEE 802.11p amendment
Define Dedicated Short Range Communications (DSRC)

IEEE 802.11-2012

IEEE Standard for Information Technology – Telecommunications and Information Exchange Between Systems Local and Metropolitan Area Network-Specific Requirements Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications

- Provides wireless connectivity among fixed, portable, and moving stations (STAs) within a local area
  - Supports wireless connectivity in vehicular environments
  - Specifies channel bandwidths, operating classes, transmit power classification, transmission masks, and alternate channel requirements in the 5.9 GHz spectrum
- IEEE 802.11p amendment is included in IEEE 802.11-2012
Define Dedicated Short Range Communications (DSRC)

IEEE 1609.x Family

- **IEEE 1609.0™-2013: Architecture (Guide)**
  - Describes the architecture and operation of a Wireless Access in Vehicular Environments (WAVE) system based on IEEE 1609 standards and IEEE Std. 802.11-2012
  - Enables the development of interoperable low-latency, low-overhead WAVE devices that can provide communications in support of transportation safety, efficiency, and sustainability, and can enhance user comfort and convenience
Define Dedicated Short Range Communications (DSRC)

IEEE 1609.x Family

- *IEEE Std 1609.2™-2013: Security Services for Applications and Management Messages*
  - Specifies security processing requirements and message sets for secure WAVE radio system operation
  - Specifies communications security for WAVE Service Advertisements and WAVE Short Messages and additional security services that may be provided to higher layers
Learning Objective #2

Define Dedicated Short Range Communications (DSRC)

IEEE 1609.x Family

- **IEEE Std 1609.3™-2010, Networking Services**
  - Specifies networking services required for operation of a WAVE system that employs standard IPv6 protocol, introduces a WAVE Short Message Protocol (WSMP), and provides a collection of management functions supporting WAVE services.

- **IEEE Std 1609.4™-2010, Multi-Channel Operation Applications and Management Messages**
  - Specifies extensions to IEEE Std 802.11-2012 MAC layer for multichannel operations, i.e., operating alternately on the control channel and one of several service channels.
  - Includes the following features:
    - Channel timing and switching
    - MAC-layer readdressing in support of pseudonymity
Define Dedicated Short Range Communications (DSRC)

IEEE 1609.x Family

- **IEEE Std 1609.11™-2010, Over-the-air Electronic Payment Data Exchange Protocol for ITS**
  - Application-level IEEE 1609 standard, communication technology independent, specifies a payment over-the-air protocol referencing ISO standards

- **IEEE P1609.12™, WAVE - Provider Service Identifier Allocation (PSID)**
  - Specifies allocations of WAVE identifiers defined in the IEEE 1609TM series of standards
  - Records the Provider Service Identifier (PSID) allocation decisions made by the IEEE 1609 working group and other identifiers used by the WAVE standards
Identify Other Communications Technologies Being Considered

Wireless Local Area Network (WLAN)

- Short to medium range broadcast communications (under 300 m)
- Examples:
  - Dedicated Short Range Communications
  - Wi-Fi
  - Bluetooth, including follow-ons such as AllSeen
  - LTE-D
  - 3GPP (3rd Generation Partnership Project) investigating using LTE mobile networks for V2X
Identify Other Communications Technologies Being Considered

Wireless Wide Area Network (WWAN)

- High-Speed Cellular Data (LTE, LTE-Advanced, 5G)
  - Advantages:
    - Provide high bandwidth data communications
    - Widely deployed
    - Increasingly available in vehicles
  - Disadvantages:
    - Not suitable for low latency applications
    - Requires subscriptions
Which of the following is NOT a current attribute of DSRC?

**Answer Choices**

a) Low latency  
b) No subscription required  
c) Widely deployed in vehicles  
d) Short to medium range
Review of Answers

a) Low latency

Incorrect. Low latency is a benefit of DSRC.

b) No subscription required

Incorrect. No subscription makes technology more accessible.

c) Widely deployed in vehicles

Correct! At this time, there are relatively few vehicles equipped with DSRC.

d) Short to medium range

Incorrect. Short to medium range is a core characteristic of DSRC.
Summary of Learning Objective #2

Identify and Evaluate the Potential Communications Technologies That May Be Used in a Transit Connected Vehicle Environment

- DSRC is only one wireless communications technology that can be used for exchanging information in connected vehicles
- DSRC has the benefits of low latency, a short to medium range, and no required subscription
- IEEE 802.11 and IEEE 1609 family of standards are communications standards that are used for DSRC
Learning Objective #3: Identify the ITS Standards That Support the Transit Connected Vehicle Environment

- Identify the messages being broadcasted
ITS Standards for Transit

TCIP: Transit Communications Interface Protocol

- Published by the American Public Transportation Association (APTA)
- Specified in Data Exchange Feed Specification (DXFS) for Real-Time System Management Information Program (RTSMIP) to satisfy SAFETEA-LU §1201 / 23 CFR 511
- Defines standardized interfaces for the exchange of information (data) among transit business systems, subsystems, components, and devices
- Does not account for dynamic service
ITS Standards for Transit

SIRI: Service Interface for Real-Time Information

- Developed by European Committee for Standardization (CEN)
- Specified in Data Exchange Feed Specification (DXFS) for Real-Time System Management Information Program (RTSMIP) to satisfy SAFTEA-LU §1201 / 23 CFR 511
- Covers delivery of static and real-time transit schedule information
ITS Standards for Transit

GTFS: General Transit Feed Specification

- Developed by Google
- Covers static schedule information (GTFS) and real-time transit service information (GTFS-realtime)
- GTFS is the most commonly used for static transit schedule data
- GTFS-realtime is not in common use, but is becoming more common
- Specification – not a standard
- Not subjected to a formal standardization process
ITS Standards for Transit

TMDD: Traffic Management Data Dictionary

- Developed and published by the American Association of State Highway and Transportation Officials (AASHTO) and Institute of Transportation Engineers (ITE)
- Center-to-center standard for exchanging transportation information between a traffic management center and other centers
- Provides real-time information about road network conditions and incidents
ITS Standards for Transit

SAE J2735: Dedicated Short Range Communications (DSRC) Message Set Dictionary

- Developed and published by the Society of Automotive Engineers
- Defines messages and data elements for connected devices

Basic Safety Message (BSM)

- Message set to be broadcast by vehicles
- Part I contains “basic” data elements that are necessary for safety applications and are expected to be broadcast frequently
- Part II data elements are broadcast less frequently as needed or as requested
ITS Standards for Transit

SAE J2735: Dedicated Short Range Communications (DSRC) Message Set Dictionary

BSM Part I includes (partial list):

- **Location** (longitude, latitude, elevation) – where it is
- **Positional Accuracy** – how accurate the position is
- **Speed** – the rate at which the vehicle is moving
- **Transmission** – the status of the transmission gears
- **Heading** – the direction the vehicle is facing
- **Steering Wheel Angle** – the rate for change of direction
- **Acceleration** – the rate the vehicle speed is changing
- **Brake System Status** – if brakes are being applied
ITS Standards for Transit

SAE J2735: Dedicated Short Range Communications (DSRC) Message Set Dictionary

BSM Part II:

- Part II data elements are broadcast as needed or as requested

- **Event Flags** – indicates an unusual event has occurred. Includes hazard lights, anti-lock brake system activated, traction control system activated, stability control activated, hard braking, stop line violation, external lights changed, wipers changed, flat tire, vehicle disabled, air bag deployment
  - Also indicates if the vehicle is an emergency vehicle on a service call, or a vehicle placarded for and carrying hazardous materials

- **Obstacles** – based on vehicle sensors or sudden vehicle movements to avoid a potential obstacle
ITS Standards for Transit

SAE J2735: Dedicated Short Range Communications (DSRC) Message Set Dictionary

BSM Part II:

- **Vehicle Weight and Height**
- **Exterior Lights** – status of lights for environmental purposes or to determine the driver’s intent
- **Vehicle Bus (J1939)** – information from a vehicle bus
- **Vehicle Identification** – includes a VIN number and vehicle type
- **Vehicle Type** – bus is an enumeration
ITS Standards for Transit

SAE J2735: Dedicated Short Range Communications (DSRC) Message Set Dictionary

- **MAP Data Message:** Message to provide roadway geometric information – currently only intersection geometry
  - Lane widths, path, location
  - Lane types – driving lanes, crosswalks, special lanes, barriers
  - Lane attributes – allowable movements
  - Priority zones

- **Traveler Information Message (TIM):** Provides focused traveler information to the public
  - Can assign start times, duration, and priority
  - Applicable regions or direction of travel
  - Content based on SAE J2540, ITIS Phrase Lists (International Traveler Information Systems)
ITS Standards for Transit

SAE J2735: Dedicated Short Range Communications (DSRC) Message Set Dictionary

- **Signal Phase and Timing (SPaT):** Provides signal phase and timing information from one or more traffic signal controllers
  - General controller status
  - What movements (by lane) are currently allowed and when the movement state will end
    - Includes signal indication
    - Includes vehicle and pedestrian counts
    - Tied to the MAP data message
ITS Standards for Transit

SAE J2735: Dedicated Short Range Communications (DSRC) Message Set Dictionary

- **Signal Request / Signal Status Message (SRM/SSM):**
  Provides signal priority request and status messages for fleet vehicles
  - Uses approach and desired egress lane, and estimated times
  - **Vehicle VIN** – An identifier for the vehicle making the request. Does not have to be the vehicle VIN
  - **Transit Status** – ADA access in progress, loading of bicycle in progress, vehicle door open, relative occupancy (empty, full)
  - Uses NTCIP 1211 concepts such as vehicle class type and vehicle class level
ITS Standards for Transit

SAE J2735: Dedicated Short Range Communications (DSRC) Message Set Dictionary

- **Probe Messages**: Used to collect, store, and forward sensor data from along a segment of roadway from the vehicle
- **Emergency Vehicle Alert (EVA)**: Broadcasts warning messages to other vehicles that an emergency vehicle is operating in the vicinity and additional caution is required
- **Roadside Alert (RSA)**: Intended for alerting or roadway hazards
- **Intersection Collision Avoidance (ICA)**: Uses information from vehicles to build intersection collision avoidance systems
- **National Marine Electronics Association (NMEA) Corrections, Radio Technical Commission for Maritime Services (RTCM) Corrections**: Used to calibrate GPS locations for vehicles and mobile devices to increase the absolute and relative accuracy
ITS Standards for Transit

SAE J2945 Family

- Currently titled Dedicated Short Range Communications (DSRC) Minimum Performance Requirements
- Each standard (J2945/n) may contain a concept of operations, requirements, information level dialog definitions, and the design content in the form of messages and data elements (defined in SAE J2735) for a specific interface (or set of applications)
  - Defines the operational and performance requirements
    - How often a message is sent (minimum, typical, maximum)
    - Minimum quality requirements
ITS Standards for Transit

SAE J2945 Family

- **J2945/0** will define common requirements for DSRC
  - Includes systems engineering content (concept of operations, requirements, message exchanges, and message content)

- **J2945/1** will define the minimum performance requirements for V2V safety applications
  - Standards compliance (IEEE, SAE, FCC)
  - BSM transmission
  - Security and privacy

- **J2945/2** will define other requirements for V2V safety
  - Includes systems engineering content (concept of operations, requirements, message exchanges, and message content)
ITS Standards for Transit

SAE J2945 Family

- **J2945/3**: Placeholder for V2I infrastructure centric applications
- **J2945/4**: Placeholder for MAP/SPaT intersection safety applications
- **J2945/5**: Placeholder for traveler information messages (TIM)
- **J2945/6**: Performance Requirements for Cooperative Adaptive Cruise Control and Platooning
- **J2945/9**: Performance Requirements for Safety Communications to Vulnerable Road Users
ITS Standards for Transit
General Communications Requirements (Using DSRC)

How do we communicate?
IEEE 802.11, IEEE 1609.3.

What language are we using?
SAE J2735, SAE J2945, APTA TCIP, GTFS, SIRI, TMDD

How many people are talking in the room?
IEEE 1609.4

How do we trust each other?
IEEE 1609.2 certificates
ITS Standards for Transit

- Conceptually, all of the transit standards contain messages that cover the same basic data concepts:
  - Vehicle Location
    - Latitude
    - Longitude
  - Estimated Time of Arrival
    - Trip identifier
    - Stop identifier
    - Estimated arrival time

- Additionally, the following message types are needed for some connected vehicle applications, but are not yet included:
  - Dynamic trip requests
  - Connection protection requests (partially covered by TCIP and SIRI)
  - Rideshare messages
Which of the following is NOT a formal standard?

**Answer Choices**

a) Google GTFS  
b) APTA TCIP  
c) CEN SIRI  
d) SAE J2735
Review of Answers

a) Google GTFS

Correct! While GTFS is often considered the de facto standard for transit, it has not undergone a formal standardization process.

b) APTA TCIP

Incorrect. APTA TCIP undergoes a formal standardization process.

c) CEN SIRI

Incorrect. CEN SIRI undergoes a formal standardization process.

d) SAE J2735

Incorrect. SAE J2735 undergoes a formal standardization process.
Summary of Learning Objective #3

Identify the ITS Standards That Support the Transit Connected Vehicle Environment

- Several data standards are available for transit agencies in a connected vehicle environment
- SAE J2735 is a data standard and SAE J2945 is an interface standard specifically for the connected vehicle environment
Learning Objective #4: Describe the Applications Being Developed in a Transit Connected Vehicle Environment

- Identify transit-specific safety applications
- Identify transit-specific mobility applications
Applications

- Pieces of software that process inputs for a specific use or purpose
  - Could be burned on a chip
  - It is through applications that we obtain the benefits of a connected vehicle environment

- The next several slides identify the most frequently cited applications identified by USDOT for transit connected vehicles
  - Not all transit connected vehicle applications are identified
  - Most applications will use their own (device) sensor readings in addition to inputs from other connected devices
Applications

V2V Safety Applications

Source: Connected Vehicle Reference Implementation Architecture (CVRIA)
Applications

V2V Safety Applications

Source: Connected Vehicle Reference Implementation Architecture (CVRIA)
Applications

V2V Safety Applications

Vehicle Turning Right in Front of a Transit Vehicle

Vehicle Turning Right in Front of Bus
Warns a bus driver when a vehicle attempts to turn right in front of the bus as the bus pulls away from a bus stop.

Source: FTA Office of Research, Development, and Innovation (left)/ U.S. Department of Transportation (right)
Applications

V2V Safety Applications

Connected Vehicle Safety for Rail
Warns drivers if there is a train approaching and if there is a potential risk of collision, as well as provides drivers with information on the estimated amount of time until the train clears the intersection.

Source: U.S. Department of Transportation
Applications

Transit Specific Mobility Applications

Integrated Dynamic Transit Operations (IDTO) consist of three application areas that strive to improve mobility for transit passengers. These rely on a connected network of transit management centers.

- **Transit Connection Protection (T-CONNECT):** Allows passengers who must make a connection to complete their trip to request that the outgoing transit vehicle wait for the incoming vehicle to arrive.

- **Dynamic Transit Operations (T-DISP):** Permits passengers to use mobile devices to request demand-responsive trips.

- **Dynamic Ridesharing (D-RIDE):** Allows passengers to utilize mobile devices to facilitate ridesharing arrangements.

*Source: Connected Vehicle Reference Implementation Architecture (CVRIA)*
Applications

Other Transit Specific Applications

- **Integrated Multi-Modal Electronic Payment**: Uses connected vehicle roadside and vehicle systems to provide the electronic payment capability.

- **Intermittent Bus Lanes (IBL)**: Provides the ability to dynamically dedicate bus lanes during peak demand times to enhance transit operations mobility.

- **Transit Vehicle at Station/Stop Warning**: Inform nearby vehicles and travelers of the presence of a transit vehicle at a station or stop, and its intention of pulling in or out.

- **Smart Park and Ride System**: Provides real-time information on Park and Ride capacity and supports travelers' decision-making on where best to park and make use of transit alternatives.

- **Eco-Transit Signal Priority**: Allows a transit vehicle to request signal priority with emissions as a factor.

*Source: Connected Vehicle Reference Implementation Architecture (CVRIA)*
ACTIVITY
Which of the following is NOT an Integrated Dynamic Transit Operations (IDTO) application area?

**Answer Choices**

a) Transit Connection Protection (T-CONNECT)
b) Dynamic Transit Operations (T-DISP)
c) Dynamic Ridesharing (D-RIDE)
d) Forward Collision Warning (FCW)
Review of Answers

a) Transit Connection Protection (T-CONNECT)
   Incorrect. T-CONNECT is part of IDTO.

b) Dynamic Transit Operations (T-DISP)
   Incorrect. T-DISP is part of IDTO.

c) Dynamic Ridesharing (D-RIDE)
   Incorrect. D-RIDE is part of IDTO.

d) Forward Collision Warning (FCW)
   Correct! Forward Collision Warning is not an IDTO application but a V2V safety application.
Summary of Learning Objective #4

Describe the Applications Being Developed in a Transit Connected Vehicle Environment

- The Integrated Dynamic Transit Operations (IDTO) bundle has three applications:
  - Transit Connection Protection (T-CONNECT)
  - Dynamic Transit Operations (T-DISP)
  - Dynamic Ridesharing (D-RIDE)

- There are three transit-specific connected vehicle safety applications:
  - Railroad Crossing Warning (RCW)
  - Transit Vehicle at Station/Stop Warnings
  - Vehicle Turning Right in Front of a Transit Vehicle Warning (VTRW)
Learning Objective #5: Identify the Challenges to the Successful Deployment of a Transit Connected Vehicle Environment

- Describe technical issues related to deployment
- Describe institutional issues such as privacy, data ownership, and security
- Identify lessons learned from pilot programs
- List resources for further reading and information
Describe Technical Issues Related to Deployment

Standards Are Still Evolving

- Align with NHTSA regulatory decision on V2V deployment and research needs
  - Guidance provided to Standards Development Organizations to have stable, approved, and published standards by September 2015
- Updates to standards based on prototypes and field tests
  - For example, there is a “wish list” for Part II data elements from stakeholders
- Harmonization of protocols and standards with each other and with international efforts
- Standards for transit connected vehicle applications are not fully developed
Describe Technical Issues Related to Deployment

Standards Implementation

- Basic Safety Message Part II is optional
  - Event flags, path history, and path prediction are proposed to be mandatory for V2V safety
- Channel congestion on radio systems
- Currently very few guidance documents on deploying these standards
Describe Technical Issues Related to Deployment

Implementation Issues

- Two devices need to be equipped to gain benefits of V2X
  - One device must broadcast and another device must receive at the same time
- Managing the environment and the challenges during the “roll out”
  - Few vehicles will be “fully” equipped
  - Managing the entire range of capabilities – different vehicles have different devices and different capabilities
- Near-field tracking is possible
Describe Technical Issues Related to Deployment

Testing / Certification

- Define testing program and certification
  - Conformance testing (to standards)
  - Compliance testing (with regulations or legal requirements)
  - USDOT intends to enter a cooperative agreement
- Proposed device and application certification that includes:
  - Environmental Capabilities (e.g., temperature, vibration)
  - Communication Protocol Capabilities (e.g., DSRC interoperability)
  - Interface Abilities (e.g., message syntax and content)
  - Overall Application Abilities (i.e., verifies the system-level function)
  - Security Credential Management System (SCMS)
Describe Institutional Issues

Privacy

- Privacy between users and third parties
- Can’t track a vehicle to its source and destination without appropriate authorization (for example, electronic payments)
- IEEE 1609.3 describes the use of changing MAC address at random intervals
- SAE J2945 standards address this by assigning and changing an identifier on a frequent basis
Describe Institutional Issues

Security

- Exchange of trusted and authenticated data between users and applications
- Message validity
- In October 2014, NHTSA released a Request For Information seeking information related to the security system to support V2X operations
  - Noted that the security system will not be established by NHTSA regulation
  - Envisions an SCMS to support trusted, safe/secure V2X communications and to protect driver privacy appropriately
- Based on IEEE 1609.2, which defines how to use, revoke, and refresh certificates
Identify Lessons Learned from Pilot Programs

Integrated Dynamic Transit Operations (IDTO)

- Demonstrate the technical feasibility of these applications, including examining the impacts and benefits of the integrated solution:
  - Transit Connection Protection (T-CONNECT)
  - Dynamic Transit Operations (T-DISP)
  - Dynamic Ridesharing (D-RIDE)

- Test Sites:
  - Columbus, Ohio, USA
  - Central Florida, USA

- Standards
  - GTFS-realtime
Identify Lessons Learned from Pilot Programs

Integrated Dynamic Transit Operations (IDTO)

Findings limited due to data constraints

- T-CONNECT: High value added by knowing when connecting vehicles will arrive, and whether a connection is feasible. Value of information on connections led to repeat usage of new travel patterns and a limited number of protected connections

- T-DISP: Although demand-response service was not in the demonstration, there was demand for the trip planning features

- D-RIDE: No rideshare service in the demonstration
Identify Lessons Learned from Pilot Programs

Integrated Dynamic Transit Operations (IDTO)

- Institutional Observations
  - Data access can be more difficult than expected
  - Elements of data may diverge from plans due to institutional concerns

- Other Observations
  - T-CONNECT can offer value; the challenge is finding circumstances where a benefit can be provided beyond what the system is already producing
  - Information can matter to users
  - Agencies see a benefit and are willing to work with other groups and share information to realize the benefit
  - Agencies desire increased collaboration to increase efficiency
Identify Lessons Learned from Pilot Programs

Integrated Dynamic Transit Operations (IDTO)

- Utilizes information that most agencies/providers already publish; some “standard,” most not
- Requires flexibility/changes in policy to support T-CONNECT
- Need to consider user privacy concerns
- Full integration with CAD/AVL systems a necessary next step
- Creating standards for the data exchange a necessary next step
List Resources for Further Reading and Information

Connected Vehicle Reference Implementation Architecture (CVRIA)

- A reference framework that spans all ITS standards activities and provides a means of detecting gaps, overlaps, and inconsistencies between the standards
- Can be used as a resource for planning or deployment
- Includes an application list, with emerging application requirements and standards to be considered for deployment for each application
- Will be migrated to the next major revision of the U.S. National ITS Architecture

- [http://iteris.com/cvria/](http://iteris.com/cvria/)
List Resources for Further Reading and Information

**ITS Standards**


List Resources for Further Reading and Information

ITS Standards


List Resources for Further Reading and Information

More Resources

- USDOT website (General):
  [http://www.its.dot.gov/connected_vehicle/connected_vehicle_research.htm](http://www.its.dot.gov/connected_vehicle/connected_vehicle_research.htm)

- USDOT website (Transit):

- T3 Webinar: Transit Safety and Mobility Applications in a Connected Vehicle World:

- DMA Webinar, IDTO:

- See Student Supplement for additional resources
Which of the following are potential barriers to implementation of transit connected vehicles?

**Answer Choices**

a) Security concerns  
b) Privacy concerns  
c) Evolving standards  
d) All of the above
Review of Answers

a) Security concerns

*Security concerns are a potential barrier because transit agencies must trust and authenticate the information.*

b) Privacy concerns

*Privacy concerns are a potential barrier to protect a transit passenger’s data from other than their intended use.*

c) Evolving standards

*Evolving standards are a potential barrier because interoperability is affected.*

d) All of the above

*Correct! All of the above are issues.*
Summary of Learning Objective #5

Identify the Challenges to the Successful Deployment of a Transit Connected Vehicle Environment

- Standards related to transit connected vehicles are still evolving
- Few vehicles are currently equipped with DSRC technology, which makes implementation difficult
- Privacy, security, technical, and institutional issues are all barriers to the successful deployment of a transit connected vehicle environment
- Findings from IDTO pilot programs have been limited
Learning Objective #6: Describe Strategies and Approaches for Deploying a Transit Connected Vehicle Environment

- NHTSA ANPRM
- Deployment considerations
- Procurement considerations
- Conformance considerations
Describe Strategies and Approaches for Deploying

NHTSA ANPRM

- Only applies to V2V communications
  - V2I is not mandated
    - Rulemaking is expected to require light vehicles to support broadcasting and receiving BSMs, but not other messages
- What investments can be made by transit to leverage national deployment of connected vehicles to improve safety, mobility, and the environment?
  - Another technology for collecting information and improving safety, mobility, and the environment
    - Take advantage of:
      - National interoperability and functionality not found in today’s ITS deployments
      - Real-time data without significant investments
Describe Strategies and Approaches for Deploying

Start considering connected vehicle communications equipment and standards when new ITS equipment is purchased and installed

- **Transit vehicle**
  - Interfaces with the CAD/AVL system on transit vehicles
  - Provisions for On-Board Equipment (OBE) for V2V safety applications

- **Infrastructure (for example, at transit stops or stations)**
  - Cabinet space to house external devices
  - Reliable power supply
  - Secure backhaul communications link
Describe Strategies and Approaches for Deploying

Deployment

- Support for the collection, integration, monitoring, and dissemination of connected vehicle data

- Agency/Partner Cooperation (for example, traffic agency)
  - Coordinate deployment of a connected vehicle infrastructure
  - Share data and interact

- For example, specify an OBE to:
  - Receive Signal Phasing and Timing (SPaT) messages
  - Transmit Signal Request Messages (SRM) for transit signal priority
Describe Strategies and Approaches for Deploying Procurements

- Develop standards-based specifications
  - Conformance to the transmission standards, interface standards, and data standards required for the implementation
  - Select communications media(s) to be supported
  - Support security infrastructure

- Develop test plans
  - Identify the scope of and purpose for testing
    - Identify how to verify conformance to the referenced standards
    - Identify the system requirements (for example, application functions)
  - Identify how testing will be performed
Describe Strategies and Approaches for Deploying Conformance

- Each standard should have a conformance clause (statement)
  - Understand what the conformance clause means
  - Understand when the conformance clause applies
  - Understand how to test for conformance to the standard
- There are other PCB modules on ITS standards and testing ITS standards:
  - T101 – Introduction to ITS Standards Testing
  - T201 – How to Write a Test Plan
  - T202 – Overview of Test Design Specifications, Test Cases and Test Procedures
What portion of the connected vehicle environment is NHTSA proposing a rulemaking?

Answer Choices

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
Review of Answers

a) V2V safety applications for all vehicles
   Incorrect. NHTSA has not yet proposed rulemaking for heavy vehicles.

b) V2V safety applications for light vehicles
   Correct! NHTSA has proposed rulemaking for V2V communications on light vehicles.

c) V2I communications capability for light vehicles
   Incorrect. NHTSA has not proposed rulemaking for V2I communications capability for any vehicles.

d) V2V and V2I communications capability for all vehicles
   Incorrect. NHTSA has not proposed V2I communications capability for any vehicles and V2V for only light vehicles.
Summary of Learning Objective #6

Describe Strategies and Approaches for Deploying a Transit Connected Vehicle Environment

- NHTSA ANPRM proposed rulemaking could require all light vehicles to support vehicle-to-vehicle communications, and the Basic Safety Message (BSM)
- Connected vehicles should be considered when deploying new ITS
- Agency cooperation, standards-based procurements, strong test plans, and conformance statements to the standards are keys to success
What We Have Learned

1) Connected vehicles can address three major challenges in transportation: __safety__, __mobility__, and __environment__. 

2) **Dedicated Short Range Communications (DSRC)** technology has the benefit of being low latency, short to medium range, and not requiring a subscription.

3) The use of __standards__ will create an interoperable connected vehicle environment.

4) **Applications** are pieces of software that process inputs for a specific use or purpose.

5) The **Connected Vehicle Reference Implementation Architecture (CVRIA)** provides a framework that defines the interfaces for connected vehicle applications.
Thank you for completing this module.

Click here to open the feedback form

OR

Please provide us your feedback:

http://www.pcb.its.dot.gov/standards_training.aspx

(insert exact location for feedback for each module as well as link to Transit ITS Standards - page to be developed as part of standards training site)