ITS ePrimer
Module 13: Connected Vehicles

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Learning Objectives

1. Provide an overview of the connected vehicle program
2. Understand history, evolution, and future direction of connected vehicle program
3. Understand the tools that are available from the USDOT
4. Understand basic technologies and core systems
5. Understand key policy, legal, and funding issues
Definition of a Connected Vehicle Environment

Wireless connectivity among vehicles, the infrastructure, and mobile devices, resulting in transformative change to:

- Highway safety
- Mobility
- Environmental impacts

Source: USDOT
Wireless Communications for Connected Vehicles

Core technology for Connected Vehicle applications

- Safety-related systems to be based on Dedicated Short Range Communications
- Non-safety applications may be based on other technologies

- DSRC characteristics:
  - 75 MHz of dedicated bandwidth at 5.9 GHz
  - Low latency
  - Limited interference
  - Performance under adverse conditions

Source: USDOT
Connected Vehicle Benefits

Connected Vehicles will benefit the public good by:

- Reducing highway crashes
  - Potential to address up to 81% of unimpaired crashes
- Improving mobility
- Reducing environmental impact

Additional benefits to public agency transportation system management and operations
Historical Context

Current program results from more than a decade of research:

- 2003 – Vehicle Infrastructure Integration (VII) program formed by USDOT, AASHTO, and carmakers
- 2006 – VII Concept of Operations published by USDOT
- 2011 – VII renamed to Connected Vehicle program
- 2011-2013 – Testing to determine future of NHTSA Rulemaking
- 2014-2016 – Focus of program shifts towards deployment
Connected Vehicle Program Today

Current research addresses key strategic challenges:

- Remaining technical challenges
- Testing to determine actual benefits
- Determining if benefits are sufficient to warrant implementation of infrastructure components
- Issues of public acceptance
- Address deployment related issues
Key Milestones

- There are many key milestones associated with the program
  - 2014 NHTSA Advanced Notice of Proposed Rulemaking focused on the implementation of DSRC in light vehicles
  - 2016 NHTSA Final Rulemaking on DSRC implementation is expected
  - FHWA Infrastructure Deployment Guidance
Dedicated Short-Range Communications

- Technologies developed for vehicular communications
  - FCC allocated 75 MHz of spectrum in 5.9 GHz band
  - To be used to protect the safety of the traveling public
- A communications protocol similar to WiFi
  - Derived from the IEEE 802.11 standard
  - DSRC includes WAVE Short Message protocol defined in IEEE 1609 standard
- Design range of a DSRC access point is 200 m
  - Actual range varies
  - Typical installations at intersections and other roadside locations
Key DSRC Functional Capabilities

- DSRC is the only short-range wireless technology that provides:
  - Fast network acquisition, low-latency, high-reliability communications link
  - An ability to work with vehicles operating at high speeds
  - An ability to prioritize safety messages
  - Tolerance to multipath transmissions typical of roadway environments
  - Performance that is immune to extreme weather conditions (e.g., rain, fog, snow)
  - Protection of security and privacy of messages
Cellular Communications

- USDOT committed to DSRC for active safety, but will explore other wireless technologies
- Cellular communications is a candidate for some safety, mobility, and environmental applications
  - LTE technologies can provide high-speed data rates to a large number of users simultaneously
  - Technologies are intended to serve mobile users
  - Good coverage – all urban areas and most major highways
- Next generation cellular technologies have potential to expand the role cellular plays
**Connected Vehicle Safety Pilot**

- Approximately 2,800 vehicles (cars, buses, and trucks) equipped with V2V devices
- Provided data for determining the technologies’ effectiveness at reducing crashes
- Includes vehicles with embedded equipment and others that use aftermarket devices or a simple communications beacon

Image source: USDOT
Safety Pilot V2V Applications

- Applications to be tested include:
  - Forward Collision Warning
  - Electronic Emergency Brake Lights
  - Blind Spot Warning/Lane Change Warning
  - Intersection Movement Assist
  - Do Not Pass Warning
  - Left Turn Assist

Source: USDOT
V2I Safety Applications

- Use data exchanged between vehicles and roadway infrastructure to identify high-risk situations and issue driver alerts and warnings
  - Traffic signals will communicate signal phase and timing (SPaT) data to vehicles to deliver active safety messages to drivers

Source: USDOT
Connected Vehicle Applications

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

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

**Agency Data**
- Probe-based Pavement Maintenance
- Probe-enabled Traffic Monitoring
- Vehicle Classification-based Traffic Studies
- CV-enabled Turning Movement & Intersection Analysis
- CV-enabled Origin-Destination Studies
- Work Zone Traveler Information

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

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

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

**Smart Roadside**
- Wireless Inspection
- Smart Truck Parking
Building Blocks

Source: USDOT

Source: USDOT
Connected Vehicle Technology

- Onboard or mobile equipment
- Roadside equipment
- Communications systems
- Core systems
- Support systems

Source: USDOT
Standards

- Base Building Block
  - A vehicle must communicate with all enabled vehicles
  - A vehicle’s ability to communicate with roadside infrastructure must not be limited
  - Vehicles must work into the future
- SAE J2735
- SAE J2945
- IEEE 1602
- CVRIA helps designers make decisions regarding proper standards use

Source: USDOT
CVRIA

- Connected Vehicle Reference Implementation Architecture
- Uniform process, tools and graphical language to support CV deployment and operations
- Creates three distinct but related views:
  - Physical View (Things)
  - Enterprise View (People / Organizations)
  - Communications Views (Information)
- SET-IT – Visio-based tool to create architecture views

Source: USDOT
Security Credential Management

- Connected Vehicle Environment relies on the ability to trust the validity of the message source
  - Accidental or malicious issue of false messages could have severe consequences
  - Users have and expectation of appropriate privacy in the system
- A prototype system was deployed and used as part of the Safety Pilot Model Deployment
- The second generation or Proof of Concept system is being developed by CAMP and NHTSA and will be used to support the CV Pilot program
Certification

- Certification of devices is critical to long-term success and operations
- USDOT is working with industry to develop a certification process and service to support the CV Pilots and other early deployers
- Certification activities are focused on Road Side Units
  - Conformance to the message protocols
  - Conformance to performance requirements
WELCOME TO THE RESEARCH DATA EXCHANGE

The Research Data Exchange (RDE) is developed as a transportation data sharing system that promotes sharing of both archived and real-time data from multiple sources (including vehicle probes) and multiple modes. This new data sharing capability will better support the needs of ITS researchers and developers while reducing costs and encouraging innovation.

The primary purpose of the DCM (Data Capture and Management) Research Data Exchange is to provide a variety of data-related services that support the development, testing, and demonstration of multi-modal transportation mobility applications being pursued under the USDOT ITS Dynamic Mobility Applications (DMA) Program and other connected vehicle research activities. Data accessible through the Research Data Exchange will be well-documented and freely available to the public. The vision of the DCM Program is to enhance current operational practices and transform future transportation systems management through the active acquisition and systematic provision of integrated data from infrastructure, vehicles, and travelers. This data is available to researchers, application developers, and others.

Source: USDOT
Data Environments in the RDE

- 14 Current Data Environments:
  - CV data from Leesburg, Ann Arbor, Orlando, and Detroit
  - Road Weather warnings from Detroit demo
  - Multi-modal traffic and signal data from Pasadena, Seattle, Portland, and San Diego
  - Probe data from Southeast Michigan testbed

- 8 Data Environments Coming Soon - Dynamic Mobility Applications
  - Multi-Modal Intelligent Signal Systems (MMITSS)
  - Intelligent Network Flow Optimization (INFLO)
  - Integrated Dynamic Transit Operation (IDTO)

- 25+ New Data Sets to Be Added to RDE in 2016
Open Source Application Development Portal (OSADP)

Welcome to Open Source Application Development Portal!
A channel for distributing and collaborating on transportation related open source applications

Join us!

Statistics
Application Releases: 36
Application Downloads: 10,000

LATEST APPLICATION RELEASES
- SPaT 1.2
  Signal Phase and Timing
- VEDM-CAY 1.0
  VISSIM External Driver Model for Connected and Automated Vehicles
- BSM-Data-Emulator 1.0
  Basic Safety Message Data Emulator
- P-ODE 1.0
  Prototype Operational Data Environment
- CACC:VISSIM 1.0
  Cooperative Adaptive Cruise Control VISSIM

www.itsforge.net

40+ applications available to download

Source: USDOT
OSADP

- **Purpose:** web-based access & collaboration on source code & documentation for open source transportation applications

- **Objectives:**
  - Reuse of software wherever possible
  - Transparent and collaborative application development
  - Provide complete application package

- **Features:** Over 40 applications available
  - Resources to use & download applications
  - Forums for discussions on applications
  - Platform to test (GitHub) applications before posting
  - Developer uploader guide & submittal (e.g., upload, collaboration)
Connected Vehicle Core Systems Support

- Current implementations of CVRIA, including:
  - Situation Data Warehouse and Clearinghouse
  - SCMS and ORDS
- All applications are free to use and include support from USDOT CVCS Contractor.
- All support requests will come through new online Service Desk
- Sign up for support at [https://cvcs.samanage.com](https://cvcs.samanage.com)
- Service Desk phone number will be established in near future
USDOT Connected Vehicle Pilot Program

- USDOT initiative to spur deployment and begin to address ongoing deployment and operational issues.
- Proposed projects identified local needs, set performance goals and selected CV applications to meet those goals

Source: USDOT
CV Pilot Wave 1 Sites

New York City Pilot Deployment Site Map
(Source: http://www.its.dot.gov/pilots/pdf02_CVPilots_NYC.pdf)

Wyoming I-80 Corridor Connected Vehicle Map
(Source: http://www.its.dot.gov/pilots/pdf04_CVPilots_Wyoming.pdf)

Connected Vehicle Pilot Deployment-Downtown Tampa
(Source: http://www.its.dot.gov/pilots/pdf03_CVPilots_Tampa.pdf)

All figures - Source: USDOT
Smart Cities Challenge

- $40m to support technology deployments to help mid-sized cities prepare for the future.
- Integrate emerging transportation data, technologies, and applications with existing systems across a city.
- Help cities, citizens, and businesses achieve goals for safety, mobility, sustainability, and economic vitality in an increasingly complex, interdependent and multimodal world.
- 78 Applicants
- 7 Finalists announced March 12
- Winner to be announced in June/July

Source: USDOT
Policy and Institutional Issues

- May limit successful deployment
- Collaborative effort among USDOT, industry stakeholders, vehicle manufacturers, state and local governments, associations, and citizens
- Policy issues and associated research fall into four categories:
  - Implementation Policy Options
  - Technical Policy Options
  - Legal Policy Options
  - Implementation Strategies
Implementation Policy Options

Topics to be addressed:
- Viable options for financial and investment strategies
- Model structures for governance with identified roles and responsibilities
- Analyses required to support infrastructure deployment decisions

SCMS Implementation and Operations
- Availability of the 5.9GHz band
Technical Policy Options

- Analysis of technical choices for V2V and V2I technologies and applications
  - Identify if options require new institutional models or can leverage existing assets and personnel
- Technical analyses related to Core System, deployment and operations, system interfaces, and device certification and standards
Legal Policy Options

- Analysis of liability and limitations to risk
- Policy and practices regarding privacy
- Policies on intellectual property and data ownership
Implementation Strategies

- AASHTO conducted a Connected Vehicle Field Infrastructure Deployment Analysis and a Footprint Analysis of a national deployment
  - Infrastructure deployment decisions by state and local transportation agencies depend on nature and timing of benefits
  - Benefits depend on availability of Connected Vehicle equipment installed in vehicles
    - Original equipment
    - After-market devices
Funding for Infrastructure Deployment

- Key task facing state and local DOTs is the need to identify a funding mechanism.
  - Capital and ongoing operations and maintenance costs
- Agencies can consider various funding categories to support deployment.
  - ITS budget or federal/state funds with ITS eligibility
  - Safety improvement program
  - Funds set aside for congestion mitigation or air quality improvement projects
  - Public–private partnerships
- FAST-Act mainstreams CV infrastructure funding
Summary

- The Connected Vehicle Environment:
  - Wireless connectivity among vehicles, infrastructure, and mobile devices
  - Transformative changes in highway safety, mobility, and environmental impact
  - Broad stakeholder base – government, industry, researchers

- Potential benefits
  - Use of V2V and V2I may address 81% of unimpaired crashes in all vehicle types
  - Reduce congestion and vehicle emissions
USDOT has provided a number of tools to support deployment, including the CVRIA, RDE and OSADP.

NHTSA rule on V2V is expected in 2016.

Applications allow systems and technologies to deliver services and benefits to users in three broad categories:

- Safety applications (including those based on V2V or V2I communications)
- Dynamic mobility applications
- Environmental applications
Summary (cont’d)

- DSRC technologies developed specifically for vehicular communications
  - 5.9 GHz reserved for transportation safety by the FCC
  - Bandwidth is under attack
- DSRC will be used for V2V and V2I active safety
  - Cellular communications can be explored for other safety, mobility, and environmental applications
- The Security Credential Management System is being developed to establish trust and privacy amongst users
  - Long-term issues associated with the operations of the SCMS are still unresolved.
Policy and institutional issues are topics that may limit or challenge successful deployment.

The USDOT continues to invest in the deployment of these technologies to support ongoing development activities.

- Connected Vehicle Pilot Program
- Smart Cities Challenge
- USDOT Test Bed and Connected Vehicle Core Services

AASHTO has developed a significant body of work to support deployment decisions by the public sector.
References

- AASHTO Subcommittee on Transportation Systems Web site: stsmo.transportation.org/
- Vehicle to Infrastructure Deployment Coalition Web site: www.transportationops.org/V2I/V2I-overview
- Connected Vehicle Reference Implementation Architecture Web Site: www.iteris.com/cvria
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Questions?

1. What types of benefits may accrue from the implementation of the Connected Vehicle Environment?

2. Over the next few years, where will the USDOT be testing and demonstrating CV Technologies through their Connected Vehicle Pilot Program?