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Transportation Challenges Facing the U.S.

Safety
- 35,092 highway deaths in 2015
- 6.1 million crashes in 2014
- Leading cause of death for ages 11, 16-24

Mobility
- 6.9 billion hours of travel delay
- $160 billion cost of urban congestion

Environment
- 3.1 billion gallons of wasted fuel
- 56 billion lbs of additional CO₂

Data Sources: NHTSA, CDC, TTI
Photo Source: U.S. DOT
Why Connected Vehicle Technology?

- Safety, safety, safety ... Real-time pre-crash warning
- There is new/emerging technology that offers an opportunity to enhance safety through Dedicated Short-Range Communication (DSRC).
- Also, the technology is different than traditional ITS deployments but the technology will leverage existing ITS networks for national interoperability along with an embedded privacy/security mechanism.
Basics of DSRC

- **What it is**
  - Low latency medium adapted for a highly mobile vehicle environment

- **How the technology works**
  - Data can be distributed in a broadcast mode (300m range – line of sight)
  - Peer-to-peer data exchanges
  - Engineered to work well in a moving vehicle environment

- **75 MHz of spectrum in the 5.9 GHz DSRC band allocated in 1999; amended in 2004 and 2006; sharing challenges in the last two years**

- **USDOT is NOT opposed to spectrum sharing:**
  - With the condition that unlicensed devices provide interference-free operations of crash avoidance safety systems in real-word conditions

- **NHTSA has submitted an NPRM on V2V communications to OMB**
Fully Connected Vehicles

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

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

Source: U.S. DOT
# Connected Vehicle Applications

## V2I Safety
- Right 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)

## 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 vehicles, transit, freight)
- Eco-ICM Decision Support System

## 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

## 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**

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

## Smart Roadside
- Wireless Inspection
- Smart Truck Parking
Major CV Pilot Sites

- Wyoming DOT CV Pilot
- New York City CV Pilot
- Columbus Smart City
- Tampa CV Pilot
CV Safety Applications

**Work Zone Warning**
Alerts the driver to use caution when traveling through a work zone.

**Curve Speed Warning**
Alerts the driver if current speed is too fast for an approaching curve.

Source: U.S. DOT
CV Road Weather Applications

Road Weather Connected Vehicle Applications
Issues alerts and advisories of unsafe road weather conditions

Weather-Responsive Traffic Management
Connected vehicles provide road weather information to assist in adjusting signal timing intervals at signalized intersections and posted speed limits, including near work zones, when severe weather affects road conditions.

Source: U.S. DOT
CV Mobility Applications

Queue Warning and Speed Harmonization
Warns drivers of congestion ahead, as well as provides target speed advice.

Oncoming Vehicles
Warns drivers of lane closings and reduced speeds when approaching incident zones.

Responder Vehicles
Warns on-scene responders of vehicles approaching the incident zone at speeds or in lanes that pose a high risk to their safety.

Source: U.S. DOT
CV Environment Applications

Eco-Traffic Signal Priority
Gives signal priority to transit vehicles approaching a signalized intersection, taking into consideration the vehicle’s location, speed, type, schedule, and number of passengers. Priority decisions are based on real-time traffic and emissions data to produce the least amount of emissions at signalized intersections.

Source: U.S. DOT

Eco-Approach and Departure at Signalized Intersections
Traffic signals broadcast data about their current signal phase and timing (SPaT). Vehicle applications use these data to determine speed advice that can be presented to drivers allowing them to adapt their vehicle's speed to pass the next traffic signal on green or to decrease to a stop in the most eco-friendly manner. More advanced applications leverage cooperative adaptive cruise control (CACC) capabilities. Start-stop technology may be used to turn the vehicle’s engine off while the vehicle is stopped at a red light.
CV Data Capture and Management Applications

Data Capture and Management
Collects data from connected vehicles, mobile devices, and the infrastructure to create multimodal applications that provide travelers with real-time information such as the status of traffic levels, parking availability, transit schedules, traffic signals, and road weather conditions.

Source: U.S. DOT
Texas CV Activities

- I-35 Connected Work Zone (CWZ)
- TxDOT CV Research
- TxDOT CV Demonstration
  - Over-height vehicle detection & warning
  - In-vehicle signing
  - Enhancing work zone safety with connected automation
  - Wrong-way driving detection & alert
  - Road condition monitoring
- TxDOT’s Involvement in National CV Initiatives
  - CVPFS, AASHTO CAV TWG, and V2IDC

The 2016 ITS Texas Annual Meeting

November 11, 2016
I-35 Connected Work Zone

- Expand existing I-35 traveler information during construction
  - In-vehicle messaging for commercial vehicles
  - Communications
    - 1st Phase: Cellular
    - 2nd Phase: DSRC
- Enhancement to the Texas component of the U.S. DOT’s Freight Advanced Traveler Information System (FRATIS) project
  - Corridor optimization for freight
TxDOT CV Research

- TxDOT 0-6836: Commercial Truck Platooning
- TxDOT 0-6837: Assessment of Innovative and Automated Freight Systems and Development of Evaluation Tools
- TxDOT 0-6838: Bringing Smart Transport to Texans: Ensuring the Benefits of a Connected and Autonomous Transport System in Texas
- TxDOT 0-6845: Connected Vehicle Problems, Challenges and Major Technologies
- TxDOT 0-6847: An Assessment of Autonomous Vehicles: Traffic Impacts and Infrastructure Needs
**TxDOT CV Research (cont’d)**

- TxDOT 0-6848: Transportation Planning Implications of Automated/Connected Vehicles on Texas Highways
- TxDOT 0-6849: Implications of Automated Vehicles on Safety, Design and Operation of the Texas Highway System
- TxDOT 0-6851: Strategies for Managing Freight Traffic Through Urban Areas
- TxDOT 0-6867: Wrong-Way Driving Connected Vehicle Demonstration
- TxDOT 0-6875: Autonomous and Connected Vehicle Test Bed to Improve Transit, Bicycle, and Pedestrian Safety
- TxDOT 0-6877: Communications and Radar-Supported Transportation Operations and Planning (CAR-STOP)
Over-Height Detection and Warning

Bridge Hit Warning

1: Infrastructure OH sensor detects OH vehicle
2: RSE identifies specific vehicle and warning is displayed to the driver
3: Vehicle exits and uses bypass – Warning is removed from driver display
4A: Vehicle does not exit – Additional warnings presented. Vehicle automatically slows if available.
4B: Vehicle is disabled or speed limited prior to hitting the bridge, if available. Emergency responders automatically notified.
In-Vehicle Signing

WARNING!
OVERHEIGHT!
In-Vehicle Signing (cont’d)

- Speed limit: 65 mph
- Jackson - Keller Rd
- West Ave
- Honeysuckle Lane
- 1/4 mile
- Exit 18

- Interstate 410
- Exit 16

- Exit 35 mph
- Bridge may ice in cold weather

- West
- North
- East
- South
- El Paso
- San Antonio

- Exit only
Enhancing Work Zone Safety with Connected Automation

**LEGEND**

1. Maintenance crew can control automated crash cushion vehicle using tablets or gesture recognition
2. Automated crash cushion vehicle monitors other vehicles to predict impending collisions and can then notify other vehicles and road maintenance crew
3. Upstream vehicle receives advisory message regarding the stationary work zone
4. Traffic Management Center uses vehicle to infrastructure communication to monitor stationary work zone

To Infrastructure Devices
(Cameras, Electronic Signs, etc.)

CAUTION ROADWORK AHEAD!
Wrong-Way Driving Detection and Alert

Connected Vehicle Demonstrations
Wrong Way Driver Detection and Alert

1. Region monitored for wrong way driver detection
2. Roadside equipment monitors BSMs and detects wrong way driver
3. Wrong way driver alerts generated via infrastructure to vehicle and approaching vehicles are alerted
4. TMC operator and responders are notified of wrong way driver

Autonomous safe stop
Road Condition Monitoring

- **RCM Hardware**
  - Accelerometer $10
  - Arduino $20

- **RCM Algorithm**
  - Process vertical acceleration data
  - Combine with GPS for speed and location
  - Calculate Roughness
  - Compare to threshold
  - Send message over DSRC
  - Plot on heat map
RCM Components and Sub-functions

Vehicle

Training: Vehicle is driven on smooth roadway to determine system characteristics. (Executed Once)

Detection: Vehicle classifies defects by comparing to training data. (Executed Continuously after Training)

Defect Location and Severity

Storage: Rating and location are stored for recall.

Clustering: Stored data from multiple vehicles is used to identify defects and problem locations.

Display: Data is made available to human operators for decision making.
RCM Heat Map and Detail View
TxDOT’s Involvement in National CV Initiatives

- Connected Vehicle Pooled Fund Study
  - Program to support the development and deployment of connected vehicle applications

- AASHTO Connected and Automated Vehicle Work Group
  - Promote the convergence of AV and CV to create “connected automated vehicles (CAV)”

- V2I Deployment Coalition
  - Support implementation of FHWA’s V2I Guidance
  - Provide leadership on CV Deployment Guidance
  - Establish CV Deployment Strategies
  - Provide Support on Continued Research to Support CV Deployment
  - Support Standards Development
Chapter 1. Introduction
- Intent of the document
- Significance of V2I
- Available Connected Vehicle Standards

Chapter 2. Federal-aid eligibility for V2I deployments
- General eligibility for V2I activities
- Brief summary of Federal-aid Programs for V2I

Chapter 3. Guidance
- Hardware and Software device certification
- Use of Right-of-Way
- Use of public sector fleets (including incident responder vehicles)
- Using Public-Private Partnerships (P3s)
- Communication technologies
- Security and privacy in a Cooperative ITS Environment
Funding for Infrastructure Deployment

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

- Continue to develop and deploy CV applications for mobility and safety
- Identify viable options for financial and investment strategies
- Analyses required to support infrastructure deployment decisions
- 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
Questions and Comments

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