Connected Vehicles & Vehicle-to-Infrastructure Communications

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Today’s Transportation Challenges

Safety
- 33,561 highway deaths in 2012
- 5.615 million crashes in 2012
- Leading cause of death for ages 4, 11-27

Mobility
- 5.5 billion hours of travel delay
- $121 billion cost of urban congestion

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

Data Sources:
2011 Annual Urban Mobility Report, Texas Transportation Institute (Feb 2013)
Connected Vehicle Program

ITS Research = Multimodal and Connected

Drivers/Operators

Vehicles and Fleets

Connectivity

Wireless Devices

Infrastructure
ITS Research Program Components

**Applications**
- **Safety**
  - V2V
  - V2I
  - Safety Pilot
- **Mobility**
  - Real Time Data Capture & Management
  - Dynamic Mobility Applications
- **Environment**
  - AERIS
  - Road Weather Applications

**Technology**
- Harmonization of International Standards & Architecture
- Human Factors
- Systems Engineering
- Certification
- Test Environments

**Policy**
- Deployment Scenarios
- Financing & Investment Models
- Operations & Governance
- Institutional Issues
Connected Vehicle Environment

Infrastructure Messages
- Signal Phase and Timing
- Fog Ahead
- Train Coming
- Drive 35 mph
- 50 Parking Spaces Available

Vehicle Data
- latitude, longitude, time, heading angle, speed, lateral acceleration, longitudinal acceleration, yaw rate, throttle position, brake status, steering angle, headlight status, wiper status, external temperature, turn signal status, vehicle length, vehicle width, vehicle mass, bumper height

Image Source: Thinkstock/USDOT
The Path To Deployment

Defined V2V Apps

Defined Safety (V2I), Mobility (V2V & V2I), AERIS & Weather Apps

Application Development

NHTSA Decision Light Vehicles

NHTSA Decision Heavy Vehicles

Pilots/Early Deployments

FHWA Deployment Guidelines

2011

2012

2013

2014

2015

2016
Research Towards Implementation

• Multi-modal, transformational applications
• Requires a robust, underlying technological platform:
  o Well-defined technologies
  o Standard interfaces
  o Certified processes
• Goal to deploy stable, interoperable, reliable systems

Vision: Transform surface transportation safety, mobility, and environmental performance through a connected vehicle environment.
Communications Technology

• **What it is**
  o Wi-Fi radio adapted for vehicle environment
  o Inexpensive to produce in quantity
  o Original FCC spectrum allocation in 1999
  o FCC revised allocation in 2004 and 2006

• **How the technology works**
  o Messages transmitted 10 times/sec (300m range – line of sight)
    - Basic Safety Message: vehicle position, speed, heading, acceleration, size, brake system status, etc.
    - Privacy is protected (vehicle location is NOT tracked)

• **Challenges of the technology**
  o Vehicles and infrastructure need to be equipped to gain benefit

• **Other Communications Modes**
  o Cellular 4G
  o Satellite
  o Fiber optic.
Safety Pilot

- ~2,800 vehicles (cars, buses, and trucks) equipped with V2V devices
- 29 RSE devices
- Includes vehicles with integrated safety applications and others that use aftermarket devices (i.e., not built into the vehicle)
- Applications 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

Provide data for determining the technologies’ effectiveness at reducing crashes

Source: U.S. DOT/UMTRI
Connected Vehicle Pooled Fund Study

- Established in 2009
- Currently involves:
  - 12 States (Virginia is lead state)
  - Maricopa County, AZ
- Aid transportation agencies in justifying and promoting the deployment of cooperative transportation systems through modeling, development, engineering, and planning activities
  - Major Programs – CTSPFS

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State and local agency involvement in application development
V2I Reference Implementation

• A system of specifications and requirements that allow the various components of V2I hardware, software and firmware to work together.
• An agency will be able to select the capabilities and applications desired at a given installation.
• Closely coordinated with CVRIA http://standards.its.dot.gov/ (under Development Activities)
V2I Safety Applications

Curve Speed Warning

Driver Vehicle Interface (DVI) Example

Smart Roadside

Traffic Signal Controller

RSE

SPaT Message and MapData Message

NOTE:
Option 1 – This option includes sending an alert when the crosswalk signal has been activated.
Option 2 – This option includes the use of a pedestrian detection system to detect the presence of a pedestrian in the crosswalk.

Red Light Violation Warning

Driver Infrastructure Interface (DII) Example
(dynamic signal)

Driver Vehicle Interface (DVI) Example
(static alert message)

Stop Sign Gap Assist

Driver Infrastructure Interface (DII) Example

Local Safety System / Processor

Pedestrian Warning Application for Transit Vehicles

NOTE:
Option 1 – This option includes sending an alert when the crosswalk signal has been activated.
Option 2 – This option includes the use of a pedestrian detection system to detect the presence of a pedestrian in the crosswalk.
<table>
<thead>
<tr>
<th>Program</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>MMITSS:</strong></td>
<td>Multimodal Intelligent Traffic Signal System</td>
</tr>
<tr>
<td><strong>INFLO:</strong></td>
<td>Intelligent Network Flow Optimization</td>
</tr>
<tr>
<td><strong>R.E.S.C.U.M.E.:</strong></td>
<td>Response, Emergency Staging and Communications, Uniform Management, and Evacuation</td>
</tr>
<tr>
<td><strong>Enable ATIS:</strong></td>
<td>Enable Advanced Traveler Information Systems</td>
</tr>
<tr>
<td><strong>IDTO:</strong></td>
<td>Integrated Dynamic Transit Operations</td>
</tr>
<tr>
<td><strong>FRATIS:</strong></td>
<td>Freight Advanced Traveler Information Systems</td>
</tr>
</tbody>
</table>

**Other Programs:**
- ICM
- ATDM
- Weather
Environmental Applications

- Eco-Signal Operations
  - Eco-Approach and Departure at Signalized Intersections*, DSRC
  - Eco-Traffic Signal Timing*
  - Eco-Traffic Signal Priority*, DSRC

- Dynamic Eco-Lanes
  - Dynamic Eco-Lanes Management*
  - Eco-Speed Harmonization*
  - Eco-Cooperative Adaptive Cruise Control*, DSRC
  - Eco-Ramp Metering*

- Dynamic Low Emissions Zones
  - Dynamic Emissions Pricing*

- Support for Alternative Fuel Vehicle Operations
  - Engine Performance Optimization
  - Alternative Fuel Vehicle (AFV) Charging / Fueling*

- Eco-Traveler Information
  - Dynamic Eco-Routing*
  - Eco-Smart Parking*
  - Connected Eco-Driving DSRC
  - Multi-Modal Traveler Information*

- Eco-Integrated Corridor Management (Eco-ICM)
  - Eco-ICM Decision Support System
  - Applications from the Other Transformative Concepts

Notes
* Denotes Application requiring V2I Communication
DSRC Denotes Applications Requiring Dedicated Short Range Communications (DSRC) or Other Low Latency Communications

Image Source: Thinkstock/USDOT

U.S. Department of Transportation
Research and Innovative Technology Administration
ITS Joint Program Office
Connected Vehicle Pilot Program

**Proposed Program Schedule**
- Summer-Fall 2014 - Regional Pre-Deployment Workshops/Webinars
- Early 2015 - Solicitation for Wave 1 Pilot Deployment Concepts
- Early 2017 - Solicitation for Wave 2 Pilot Deployment Concepts
- September 2020 - Pilot Deployments Complete

**Resources**
- ITS JPO Website: [http://www.its.dot.gov/](http://www.its.dot.gov/)
- CV Pilots Program Website: [http://www.its.dot.gov/pilots](http://www.its.dot.gov/pilots)
Infrastructure Deployment Planning

- National Cooperative Highway Research Program (NCHRP 03-101)
  - Costs and Benefits of Public-Sector Deployment of Vehicle to Infrastructure Technologies
- AASHTO National Connected Vehicle Field Infrastructure Footprint Analysis
- Standardized interfaces (CVRIA)
- Certification processes
- Nationwide Security Credential Management System (SCMS)
- State and local agency test beds

2015 FHWA Deployment Guidance
Exploratory Research

- Vehicle to Motorcycle
- Vehicle to Pedestrian
- Vehicle Automation
  - Can proceed independently of connectivity to a point
  - Greatly enhanced with connectivity to other vehicles and infrastructure
- Benefits of Connectivity
  - Increases availability, speed, and reliability of information
  - Enables coordination of automated traffic streams

The full potential benefits of road vehicle automation can only be achieved through a connected environment.

Source: Continental Automotive Group
Safe and Connected Automation

- **Safe**
  - Meets requirements for functional safety, cybersecurity, and system performance
- **Connectivity**
  - Includes all types of communication with vehicles and infrastructure (Wi-Fi, DSRC, Cellular, etc.)

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**Autonomous Vehicle**
Operates in isolation from other vehicles using internal sensors

**Connected Vehicle**
Communicates with nearby vehicles and infrastructure
Not automated (level 0)

**Connected Automated Vehicle**
Leverages autonomous automated and connected vehicles
Key Questions

• How do we maintain the driver’s privacy?
• What specific data elements do you need?
• How often do you need them?
• What are the benefits of the applications?
• How do you get the data?
  o Installation of equipment?
  o Purchase from a vendor?
• What new opportunities are there with cellular and a world of apps?
Challenges Ahead

**Policy Opportunities & Challenges**

- Privacy/
  Cyber security
- Governance
- Funding/
  Sustainability
- Data ownership
- Interoperability
- Risk/
  Liability
- Implementation

**Stakeholders**

- Public/consumers
- Automakers
- Equip. Suppliers
- Public agencies
- Business/Industry
- Interest groups
- Innovators
- Academia
- ..and many more!

Image: istock.com
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