CONNECTED VEHICLE DEPLOYMENT IN ADA COUNTY, IDAHO: LESSONS LEARNED

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2018 REGION 10 TRANSPORTATION CONFERENCE
OCTOBER 12TH, 2018 FAIRBANKS, AK
PROJECT OVERVIEW

FIELD EVALUATION OF V2I CONNECTED VEHICLE DEPLOYMENT IN ADA COUNTY, IDAHO - VALIDATING COMMUNICATION ARCHITECTURE AND CONTROL TECHNOLOGY READINESS

- Traffic signal system V2I and I2V data exchange
- Connected Vehicle–based priority for vehicles at signalized intersection approaches

Treasure Valley
SMART Arterial Management
Advanced Transportation & Congestion Management Technologies Deployment Initiative
USDOT Funding # 693J317NF0001
OVERVIEW: CONNECTED VEHICLE VS. AUTONOMOUS VEHICLES

WHAT IS THE DIFFERENCE?

SAE AUTOMATION LEVELS

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Automation. The full-time performance by the human driver of all aspects of the dynamic driving task, even when enhanced by warning or intervention systems.</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance. The driving-mode-specific execution by a driver assistance system of either steering or acceleration/ deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task.</td>
</tr>
<tr>
<td>2</td>
<td>Partial Automation. The driving-mode-specific execution by one or more driver assistance systems of both steering or acceleration/ deceleration using information about the driving environment and with the expectation that the human driver perform all remaining aspects of the dynamic driving task.</td>
</tr>
<tr>
<td>3</td>
<td>Conditional Automation. The driving-mode-specific performance by an automated driving system of all aspects of the dynamic driving task with the expectation that the human driver will respond appropriately to a request to intervene.</td>
</tr>
<tr>
<td>4</td>
<td>High Automation. The driving-mode-specific performance by an automated driving system of all aspects of the dynamic driving task, even if a human driver does not respond appropriately to a request to intervene.</td>
</tr>
<tr>
<td>5</td>
<td>Full Automation. The full-time performance by an automated driving system of all aspects of the dynamic driving task under all roadway and environmental conditions that can be managed by a human driver.</td>
</tr>
</tbody>
</table>

Fully Autonomous Intersections

V2V, V2I, I2V, I2X, X2V, V2X
CONNECTED VEHICLES – CURRENT IMPLEMENTATION STATUS

Planned and Operational Connected Vehicle Deployments
Where Infrastructure and In-Vehicle Units are Planned or In Use

- Planned Projects
- Operational Projects

*Projects shown include those sponsored by U.S. DOT and others.
**Device numbers for many of the planned projects are currently unavailable.

<table>
<thead>
<tr>
<th>Operational (52 Projects)*</th>
<th>Planned (23 projects)**</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrastructure Units</td>
<td>2,044</td>
<td>2,286</td>
</tr>
<tr>
<td>In-Vehicle Units</td>
<td>3,340</td>
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</tr>
</tbody>
</table>
CONNECTED VEHICLE TERMINOLOGIES

- V2I/V2V/V2X
  - Vehicle-to-Infrastructure, Vehicle-to-Vehicle, Vehicle-to-Everything

- DSRC – Dedicated Short Range Communications
  - Standards document: IEEE 802.11p (lower layer)
  - Defines the data link and physical layer of V2X communications
  - Operates on 75 MHz spectrum of 5.9GHz band (5.850-5.925GHz, 7 channels)

- WAVE – Wireless Access in Vehicle Environments
  - Standards document: IEEE 1609 (upper layer)
  - Defines the architecture, communications model, management structure, and security access
CONNECTED VEHICLE TERMINOLOGIES

• RSU/RSE – Road Side Unit / Road Side Equipment
  • RSU – Infrastructure DSRC radio module
  • RSE – RSU plus supporting equipment
  • Specified by WAVE and USDOT RSU Specifications 4.1
  • Messages defined by SAE J2735
  • Installed at intersection
  • Connected to traffic controller via Ethernet

• OBU/OBE – On Board Unit / On Board Equipment
  • OBU – Vehicle DSRC radio module
  • OBE – OBU plus supporting equipment
  • Specified by WAVE; Messages defined by SAE J2735
  • Installed in vehicle
  • Connected to vehicle ECU via CAN, mobile device via Wi-Fi, infotainment via Ethernet
CONNECTED VEHICLE J2735 MESSAGE TYPES

- **SPAT – Signal Phase and Timing**
  - Current phase status of intersection,
  - Includes intersection status, i.e. MCE, stop time, flash, PMT active, TSP active
  - Used in conjunction with MAP
  - RSU transmits ten SPAT messages per second to OBU

- **MAP – Map Data**
  - Geographic road information based on GPS coordinates
  - Includes lane geometry and descriptions/attributes (including phase assignments)
  - RSU transmits one MAP message per second to OBU

- **BSM – Basic Safety Message**
  - Positional info, speed, heading, transmission state, steering wheel angle, acceleration, brake status, and size of vehicle
  - OBU transmits ten BSMs every second
CONNECTED VEHICLE J2735 MESSAGE TYPES

- TIM – Traveler Information Message
  - Sends traveler advisories (incl. traffic information, traffic incidents, major events, evacuations, etc.) and (static) road signs to OBU from RSU

- RTCM – Radio Technical Commission For Maritime Services
  - Provides differential corrections for GPS to increase absolute and relative accuracy

- SRM – Signal Request Message
  - Sent by OBU to RSU to view current status of signals
  - Can be used for preemption or priority signal requests

- SSM – Signal Status Message
  - Sent by RSU in response to SRM
  - Current status of signals and pending/active/denied preemption or priority requests
  - Both SRM and SSM function similar to SPAT with the addition of acknowledgement
CONNECTED VEHICLE TRAFFIC SIGNAL SYSTEM ARCHITECTURE

SPaT: Signal Phase and Timing
MAP: Intersection Geometry Map
BSM: Basic Safety Message
DSRC: Dedicated Short Range Communications
RSU: Road Side Unit
OBU: On Board Unit
ADA COUNTY CONNECTED VEHICLE TEST
FOUR INTERSECTIONS – FOUR RSU VENDORS

Major Issues -- Lessons
• Traffic Controllers/RSUs Compatibility
• Initial Installation/Setup process
• GPS accuracy and availability
• Connected vehicle control logic (what to do with all these data) -- RSU role?
• RSU/OBS Data Exchange “stability”
• Cyber Security (jamming)
## RSU/OBU Data Exchange - Example

<table>
<thead>
<tr>
<th>Time</th>
<th>Total Elapsed</th>
<th>Δelapsed (Interval)</th>
<th>ΔTx RSU</th>
<th>ΔRx OBU</th>
<th>ΔTx OBU</th>
<th>ΔRx RSU</th>
<th>ΔRx OBU Dropped</th>
<th>ΔRx RSU Dropped</th>
</tr>
</thead>
<tbody>
<tr>
<td>10:06 AM</td>
<td>4 mins</td>
<td>4 mins</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10:10 AM</td>
<td>7 mins</td>
<td>3 mins</td>
<td>51</td>
<td>51</td>
<td>2556</td>
<td>2556</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10:13 AM</td>
<td>10 mins</td>
<td>3 mins</td>
<td>22</td>
<td>22</td>
<td>1104</td>
<td>1104</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>10:16 AM</td>
<td>12 mins</td>
<td>2 mins</td>
<td>41</td>
<td>41</td>
<td>2081</td>
<td>2081</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11:05 AM</td>
<td>59 mins</td>
<td>47 mins</td>
<td>17</td>
<td>17</td>
<td>839</td>
<td>839</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>11:08 AM</td>
<td>1 hr 2 mins</td>
<td>3 mins</td>
<td>585</td>
<td>398</td>
<td>29550</td>
<td>28974</td>
<td>187 (32%)</td>
<td>576 (2%)</td>
</tr>
<tr>
<td>11:11 AM</td>
<td>1 hr 5 mins</td>
<td>3 mins</td>
<td>30</td>
<td>0</td>
<td>1520</td>
<td>441</td>
<td>30 (100%)</td>
<td>1079 (71%)</td>
</tr>
<tr>
<td>11:14 AM</td>
<td>1 hr 8 mins</td>
<td>3 mins</td>
<td>37</td>
<td>0</td>
<td>1901</td>
<td>160</td>
<td>37 (100%)</td>
<td>1741 (92%)</td>
</tr>
<tr>
<td>12:37 PM</td>
<td>2 hr 31 mins</td>
<td>1 hr 23 mins</td>
<td>28</td>
<td>0</td>
<td>1423</td>
<td>114</td>
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- **10:10 AM**
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- **10:16 AM**
- **10:18 AM**
- **11:05 AM**
- **11:08 AM**
- **11:11 AM**
- **11:14 AM**
- **12:37 PM**

### Packets TX/RX in-between intervals
- ΔTx RSU
- ΔRx OBU
- ΔTx OBU
- ΔRx RSU

### Packets dropped in-between intervals
- ΔRx OBU Dropped
- ΔRx RSU Dropped
SECURITY OF BSM DATA EXCHANGE
THANK YOU

Questions