SPaT in Anaheim – a First Look

PRESENTATION FOR ITS CALIFORNIA, SEPTEMBER 18, 2017

BY JOHN THAI, P.E.

CITY OF ANAHEIM
DRIVER DISTRACTIONS ON THE RISE
20 YEARS AGO...

A demonstration of the automated highway system in San Diego (1997)
A researcher demonstrates the driverless car by showing his hands aren't on the wheel (1997)
WHAT ARE CONNECTED VEHICLES?

“Connected vehicle research is a multimodal initiative that aims to enable safe, interoperable networked wireless communications among vehicles, the infrastructure, and passengers’ personal communications devices.”

Source: USDOT, ITS JPO
<table>
<thead>
<tr>
<th>SAE level</th>
<th>Name</th>
<th>Narrative Definition</th>
<th>Execution of Steering and Acceleration/Deceleration</th>
<th>Monitoring of Driving Environment</th>
<th>Fallback Performance of Dynamic Driving Task</th>
<th>System Capability (Driving Modes)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Human driver monitors the driving environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>No Automation</td>
<td>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>
<td>Human driver</td>
<td>Human driver</td>
<td>Human driver</td>
<td>n/a</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>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>
<td>Human driver and system</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>2</td>
<td>Partial Automation</td>
<td>the driving mode-specific execution by one or more driver assistance systems of both steering and 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>
<td>System</td>
<td>Human driver</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td></td>
<td>Automated driving system (&quot;system&quot;) monitors the driving environment</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Conditional Automation</td>
<td>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>
<td>System</td>
<td>System</td>
<td>Human driver</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>4</td>
<td>High Automation</td>
<td>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>
<td>System</td>
<td>System</td>
<td>System</td>
<td>Some driving modes</td>
</tr>
<tr>
<td>5</td>
<td>Full Automation</td>
<td>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>
<td>System</td>
<td>System</td>
<td>System</td>
<td>All driving modes</td>
</tr>
</tbody>
</table>

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A CONNECTED VEHICLE APPLICATION

Intersection Collision Avoidance

DaimlerChrysler Research & Technology North America, Inc.
THE FREEWAY ENVIRONMENT

Vehicle Automation on Freeways

Cooperative Adaptive Cruise Control (CACC)
- Drivers have the convenience of setting their desired speed and having the vehicle safely maintain the speed.
- The CACC systems recognize the presence of a slower vehicle ahead and road grade and then automatically adjusts the speed to follow the other vehicle safely.

CACC and Eco-Speed Harmonization
- CACC systems may accept target speeds established by the traffic management centers (TMCs) that can optimize traffic performance for the environment.
- By having all CACC vehicles maintain the same speed that allows the best traffic/environmental performance, “speed harmonization” is achieved as the traffic stream moves smoothly and efficiently.

CACC/Vehicle Platooning and Eco-Lanes
- Eco-Lanes are specially managed and targeted at optimizing performance for the environment.
- TMCs can set target speeds and recommend closer following (shorter gaps) between CACC vehicles for which drivers can agree to accept ("opt-in").
- Eco-Lanes can support Vehicle Platooning.
- Shorter gaps, combined with speed harmonization can help minimize congestion and reduce emissions.

Source: Noblis, September 2013

U.S. Department of Transportation
THE URBAN ENVIRONMENT

Eco-Signal Operations

1. SPaT Data
2. I2V Communications: SPaT and GID Messages
3. V2V Communications: Basic Safety Messages
4. Vehicle Equipped with the Eco-Approach and Departure at Signalized Intersections Application (CACC capabilities optional)

Source: USDOT, November 2013
WHY SPAT IS NECESSARY

• Improved accuracy!
  • Every cycle is different!
  • “The controller is just as surprised as you are when the phases end, ” Dr. Larry Head (sometime in 2004).
  • V2V, as defined in the standard, doesn’t account for SPaT.
Figure 2.2-2 illustrates the content of the so-called Here I Am (HIA) message. The HIA message is essentially a BSM, although it is intended to be transmitted by vehicles without any ability to make use of received BSMs. This message is 330 octets and represents a 27.12 kbps data load per vehicle on the wireless link.

<table>
<thead>
<tr>
<th>Message Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Millisecond stamp</td>
</tr>
<tr>
<td>Temp ID (MAC addr)</td>
</tr>
<tr>
<td>Latitude</td>
</tr>
<tr>
<td>Longitude</td>
</tr>
<tr>
<td>Elevation</td>
</tr>
<tr>
<td>Speed</td>
</tr>
<tr>
<td>Heading</td>
</tr>
<tr>
<td>Accel. Frame (4way)</td>
</tr>
<tr>
<td>Brake Status</td>
</tr>
<tr>
<td>Steering Angle</td>
</tr>
<tr>
<td>Throttle Position</td>
</tr>
<tr>
<td>Exterior Lights</td>
</tr>
<tr>
<td>Vehicle Size</td>
</tr>
</tbody>
</table>
The SPaT message includes the current movement state of each active phase and values from which the OBE can project the duration of the permissive phase (unless it is changed by an event such as preemption).

The structure of the SPaT Message is shown in Figure 2.2-3 below.

<table>
<thead>
<tr>
<th>Data Elements</th>
<th>Type/Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Object ID</td>
<td>Unsigned 8 Bit Integer</td>
</tr>
<tr>
<td>Object Size</td>
<td>Unsigned 8 Bit Integer</td>
</tr>
<tr>
<td>Approach ID</td>
<td>Unsigned 8 Bit Integer</td>
</tr>
<tr>
<td>Signal Phase Indications</td>
<td>32 Bit Bitmask</td>
</tr>
<tr>
<td>Countdown Timer Confidence</td>
<td>2x Unsigned 4 Bit Integers</td>
</tr>
<tr>
<td>Time to Signal Phase Change (Countdown Time)</td>
<td>32 Bit Bitmask</td>
</tr>
<tr>
<td>Yellow Duration</td>
<td>Unsigned 8 Bit Integer</td>
</tr>
</tbody>
</table>

Figure 2.2-3. SPaT Message Structure
(Ref: SAE J2735 [18])
SPAT IMPLEMENTATION GUIDANCE (12/2016)

Figure 1 – Illustration of Functional Needs of SPaT Deployment
A MODEL FOR SPAT DEPLOYMENT
TYPICAL SPAT TESTBED DEPLOYMENT IN ANAHEIM

Diagram:
- HARDENED ETHERNET SWITCH
- POE SWITCH MODE B
- 2070 CONTROLLER NTCIP 1202
- RSU
- Outdoor, underground burial rated Ethernet cable
- IEEE 1609
  SPaT, MAP, TIM etc.
- ANAHEIM TMC
- OBU

Legend:
- Ethernet Switch
- Controller
- RSU
- Ethernet Cable
- Time-Sensitive Networking
- OBU

Description:
The typical SPAT testbed deployment in Anaheim involves connecting various components as follows:

1. **HARDENED ETHERNET SWITCH** serves as the central nodes, providing connectivity and protection for the network.
2. **POE SWITCH MODE B** is connected to the switch, ensuring power over Ethernet functionality.
3. **2070 CONTROLLER NTCIP 1202** provides system control and interfaces with traffic management systems.
4. **RSU** (Roadside Units) facilitate communication with vehicles and other roadside equipment.
5. The Ethernet cable is designed to withstand outdoor and underground conditions.
6. **ANAHEIM TMC** integrates with the network for traffic management operations.
7. **OBU** (On-Board Units) in vehicles communicate with RSUs over the network, enabling real-time traffic management and intelligent transportation systems.

The diagram outlines the logical flow and interconnection of these elements, emphasizing the critical components and their roles in maintaining a robust and secure network for traffic management.
ANAHEIM BOULEVARD AS SPAT TESTBED
WHAT DOES IT LOOK LIKE INSIDE THE CABINET?

THE EXISTING ETHERNET SWITCH

THE POE
WHAT DOES IT LOOK LIKE OUTSIDE?
MAP DATA REQUIREMENTS

• MAP data file needed for each RSU
• MAP data based on CV application (What is your vision?)
• MAP data must include phase to lane assignments, distance to intersection, lane attributes, speed limits can be useful, etc.
• MAP data created with Extensible Markup Language (XML)
MAP DATA FOR ANAHEIM & LINCOLN
REVISED MAP DATA STANDARD FOR V2I

Which is MAP set is better suited for collision avoidance application?
UPDATED MAP DATA AT ANAHEIM & LINCOLN
WHAT DOES/MIGHT SPAT LOOK LIKE AT 10 HZ?
ANAHEIM BOULEVARD AS SPAT TESTBED IN ACTUALITY
A BETTER TESTBED – FOR A PRICE…
PLANNING FOR SPAT (ON **YOUR** PART)

- WHAT IS YOUR GOAL FOR CV?
  - PICK APPLICATION (SAFETY, MOBILITY, ECO, …)
    - V2I? V2V?
  - WHERE TO DEPLOY?

- WHAT DOES THIS APPLICATION REQUIRE OF YOU & YOUR AGENCY?
  - INFRASTRUCTURE (CONTROLLER, COMM., CABINET REAL ESTATE…)
  - CAPITAL FUNDING
  - STAFF EXPERTISE & TRAINING
  - FUNDING FOR OPERATIONS, MAINTENANCE & INVENTORY
  - PERFORMANCE MEASURES
  - CONTINUING HW/SW UPDATES/REVISIONS
NON V2I WAYS OF TRANSMITTING SPAT DATA

- Traffic Technology Services receives signal data
- Provides MAP message (detailed map of intersection)
- Provides SpAT Message (current signal status, predicted signal switch time, confidence of prediction)

OEM backend system and vehicle receives authentication token
Once validated, OEM system sends MAP and SpAT messages to vehicle

Information displayed only if high confidence in timeliness and accuracy of prediction
CONNECTED VEHICLES LEGISLATION DOESN’T YET ADDRESS V2I

<table>
<thead>
<tr>
<th>State</th>
<th>Intent of Legislation</th>
<th>Enacted</th>
<th>Operator</th>
<th>Liability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nevada</td>
<td>Testing, Individual Ownership</td>
<td>June 2011, revised July 1, 2013.</td>
<td>The regulation stipulates an endorsement on driver’s license to operate</td>
<td>Manufacturer not liable for damages if vehicle is converted by third party.</td>
</tr>
<tr>
<td>Florida</td>
<td>Testing, Development, Operation</td>
<td>April 2012</td>
<td>Vehicles may be operated by persons with a valid driver’s license</td>
<td>Manufacturer not liable for damages if vehicle is converted by a third party.</td>
</tr>
<tr>
<td>California</td>
<td>Testing, Operation</td>
<td>September 2012</td>
<td>Employees, contractors, or other persons designated by the manufacturer of the autonomous technology</td>
<td>No mention of Liability.</td>
</tr>
<tr>
<td>District of Columbia</td>
<td>Testing, Operation</td>
<td>January 2013</td>
<td>--</td>
<td>Manufacturer not liable for damages if vehicle is converted by a third party.</td>
</tr>
<tr>
<td>Michigan</td>
<td>Testing, Operation</td>
<td>March 2014</td>
<td>Carmakers, auto suppliers and developers</td>
<td>Manufacturer not liable for damages if vehicle is converted by a third party.</td>
</tr>
</tbody>
</table>
CONCLUSION & RESOURCES

- Are V2I and SPaT technologies for you?
  - Systems Engineering review process may be useful
- Philosophical debate: which device (and therefore, who) is responsible/liable for SPaT accuracy: the controller, the RSU or the OBU?
- Connected Vehicle Planning
- USDOT link to V2I
  - https://www.its.dot.gov/research_archives/safety/v2i_comm_safety.htm