CV273: Introduction to SPaT / MAP Messages

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Module Description

This module is an introduction to the *Signal Phase and Timing (SPaT)* and *MAP Data* messages that may be broadcasted at signalized intersections to assist the deployment of applications related to signalized intersections in a connected vehicle environment. These two messages are defined by *SAE J2735_201603, Dedicated Short Range Communications (DSRC) Message Set Dictionary*. *I101: Using ITS Standards – An Overview*, and *CV261: Vehicle-to-Infrastructure (V2I) ITS Standards for Project Managers*, are recommended prerequisites for participants.

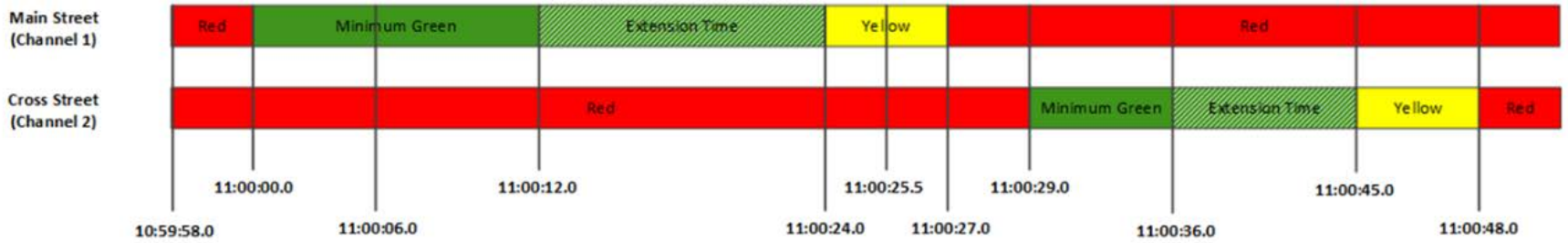
1. Introduction/Purpose

Connected vehicles (CV), a component of the Cooperative Intelligent Transportation System (C-ITS) environment, have the potential to significantly reduce vehicular crashes, provide operators of surface transportation systems with more timely and accurate system performance data to better manage their systems, and provide travelers with access to specific traveler information. To maximize these benefits, agencies should deploy systems that conform to established standards. Proper deployment of standards-conformant equipment and systems will support interoperability, minimize future integration costs, make procurements easier, and facilitate regional and national integration.

The purpose of this module is to introduce transportation managers and specification writers on the purpose and contents of the SPaT and MAP messages, which are key messages exchanged between CV applications related to signalized intersections. The module will focus on two aspects for using the messages - what information can be provided by each standardized message, and implementation considerations related to each message. The implementation considerations will discuss what information needs to be provided to satisfy an operational need of the agency, security considerations, and existing tools to support implementation and efforts to standardize implementation of these two messages to facilitate interoperability, as well as regional and national integration.

2. Samples/Examples

Figure 1 is an example of the timing values for a basic signalized intersection. The timestamp and other times are in tenths of a second in the current hour, while eventState is an enumerated value of the current state of the movement, defined in SAE J2735_201603 (DE_MovementPhaseState).



timeStamp	35980	0	60	120	240	255	270	290	360	450	480
SignalGroupID 2											
startTime	35790	0	0	0	240	240	270	270	270	270	270
minEndTime	0	120	120	120	270	270	410	410	410	410	410
maxEndTime	0	240	240	240	270	270	500	500	500	500	500
likelyEndTime	0	150	150	240	270	270	500	500	500	500	500
nextTime	0	410	410	500	500	500	500	500	500	500	500
eventState	3	5	5	5	7	7	3	3	3	3	3
SignalGroup 4											
startTime	35980	35980	35980	35980	35980	35980	35980	290	290	450	480
minEndTime	170	170	170	170	170	170	170	360	360	480	500
maxEndTime	290	290	290	290	290	290	290	450	450	480	500
likelyEndTime	200	200	200	290	290	290	290	450	450	480	500
nextTime	200	200	200	290	290	290	290	700	700	700	700
eventState	3	3	3	3	3	3	3	5	5	7	3

Assumes the following: a) fixed 3.0 second yellow and 2.0 second red for both approaches.
b) likely green time of 15.0 seconds for main street and 16.0 seconds for cross street
c) For illustrative purposes only, upon reaching the end of minimum green, actuations extend green times to the full extension time (maximum green)

Figure 1. Example Timing Chart (Source: NTCIP 1202 v03, Figure 13)

Figure 2 and Figure 3 presents parts of an example of a use case provided in ISO TS 19091.

Table A.12 — SA2: Red light violation warning

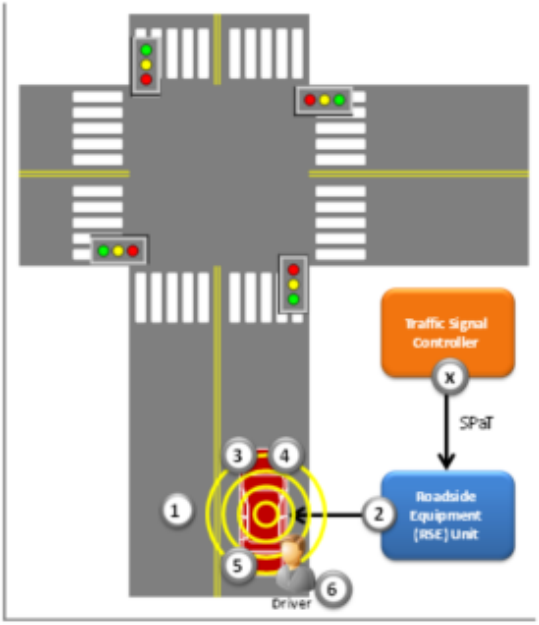
Use Case Name	Red Light Violation Warning
Category	Safety
Infrastructure Role	Data provider
Short Description	This use case describes provision of signal timing information to approaching vehicles to help prevent red light violations
Goal	Roadside equipment sends MAP and SPaT in real-time to approaching vehicles, which utilize the information to notify driver of need to stop to avoid potential red light violation
Constraints	RSE transmit performance adequate for approaching vehicles' timely DSRC reception Security Management System in place to allow OBE to check RSE messages RSE messages meet minimum performance requirements Intersection approach roadway segments mapped to sufficient accuracy and differentiates lanes governed by each signal phase Positioning performance adequate to match vehicle with lane-specific signal phases, if applicable OBE driver interface/algorithm with appropriate timing/inputs established
Geographic Scope	Local signalized intersection & approaching roadway segments
Actors	OBE-equipped vehicles with red light violation warning application RSE connected to local traffic signal controller
Illustration(example)	
Preconditions	MAP message reflects current intersection geometry

Figure 2 ISO TS 19091 Example Use Case (Part 1)

Main flow(example)	1. OBE-equipped vehicle enters DSRC range (i.e. for OBE receive/RSE transmit) of RSE (note that if another medium is used, the same assumption applies). 2. RSE transmits MAP and SPaT information 3. OBE verifies that RSE messages are acceptable (authentic, valid, meet MPR) 4. OBE matches vehicle location to intersection geometry/lane and associated signal phase 5. OBE determines if vehicle is expected to violate red indication based on vehicle trajectory and other information 6. If violation is expected, OBE provides information to driver to stop at appropriate time (in time to stop)
Alternate flow(s)	4a. OBE also utilizes turn signal information and/or other vehicle parameters to match with signal phase 5a. OBE also considers vehicle stopping parameters (e.g. size/weight) 6a. OBE utilizes other information (e.g. image processing of traffic light, etc.) as a backup to determine whether information to stop should be provided to driver 6b. OBE initiates action directly with vehicle if violation is expected
Post-conditions	Vehicle crosses stop bar before red onset or stops on red before entering intersection
Information Requirements	SPaT: Current Maneuver permitted, remaining time for maneuver, yellow clearance time, red clearance time, next maneuver to be serviced MAP: Intersection Geometry, Permitted maneuvers
Issues	Determining turn lane prior to approach Violation based on current signal phase vs. future MPR/acceptability of current RSE messages
Source docs/references	CEN#1 p. 3; USDOT J2735™SE Candidate Use Case #1, p. 4

Figure 3 ISO TS 19091 Example Use Case (Part 2)

3. Reference to Other Standards

USDOT

- USDOT ITS Standards Program, http://www.standards.its.dot.gov/

IEEE

- IEEE 1609.3-2016 – IEEE Standard for Wireless Access in Vehicular Environments (WAVE) -- Networking Services, IEEE, 2016. https://standards.ieee.org/standard/1609_3-2016.html

ISO

- ISO/AWI TS 19091 – Intelligent transport systems – Cooperative ITS – Using V2I and I2V communications for applications related to signalized intersections. https://www.iso.org/standard/73781.html

NTCIP

- NTCIP 1202 v03, Object Definitions for Actuated Signal Controllers (ASC) Interface, NEMA, May 2019. http://www.ntcip.org/wp-content/uploads/2019/07/NTCIP-1202v0328A.pdf

SAE

- SAE J2735_201603 – Dedicated Short Range Communications (DSRC) Message Set Dictionary, SAE, http://standards.sae.org/j2735_201603/
- SAE J2945_201712 - Dedicated Short Range Communication (DSRC) Systems Engineering Process Guidance for SAE J2945/X Documents and Common Design Concepts, SAE, https://www.sae.org/standards/content/j2945_201712/
- SAE J2945/1_201603 – On-Board System Requirements for V2V Safety Communications, SAE, https://www.sae.org/standards/content/j2945/1_201603/

4. Case Studies

- "SPaT Interoperability Experience in Anaheim, CA", John Thai, P.E. City of Anaheim, Presentation, Annual Conference and Exhibition, 2018. https://itscalifornia.org/Content/AnnualMeetings/2018/Presentations/S4P1.pdf

5. Glossary

To include additional descriptions/acronyms used primarily in the module.
List out in alphabetical order.

Term	Definition
Data Elements	Smallest named item of data that conveys meaningful information and has a defined set of attributes
Data Frames	Collections of data elements

Term	Definition
Intelligent Transportation Systems (ITS)	Systems that apply data processing and data communications to surface transportation, to increase safety and efficiency. ITS systems will often integrate components and users from many domains, both public and private.
Interoperability	The ability of two or more systems or components to exchange information and to use the information that has been exchanged. The dependence of the CV Environment on successful exchange of data between independent components results in a requirement that all V2I deployments.
MAP	A message containing roadway geometric information. See SAE J2735.
Message	A structured string of data elements used to convey information.
On-Board Unit (OBU)	This term refers to the complement of equipment located in the vehicle for the purpose of supporting the vehicle side of the applications. It is likely to include the DSRC radios, other radio equipment, message processing, driver interface, and other applications to support the use cases described herein.
Revocable lane	A lane definition that can be enabled or disabled. Each revocable lane represents a possible regulatory state for a given physical lane. Whether the lane is enabled or disabled is broadcasted in the SPaT message.
Roadside Unit (RSU)	Devices that serve as the demarcation component between vehicles and other mobile devices and existing traffic equipment. Note: From DSRC Roadside Unit (RSU) Specification Document v4.1.
Signal Phase and Timing (SPaT)	A message type that describes the current state of a signal system and its phases and relates this to the specific lanes (and therefore to maneuvers and approaches) in the intersection. See SAE J2735.

BSM	Basic Safety Message
C-ITS	Cooperative Intelligent Transportation System
CV	Connected Vehicle
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
IEEE	Formerly Institute of Electrical and Electronics Engineers
ISO	International Standards Organization
ITS	Intelligent Transportation Systems
NMEA	National Marine Electronics Association Message
OBU	On-Board Unit
PRL	Protocol Requirements List
RSU	Roadside Unit
RTCM	Radio Technical Commission for Maritime Services Message
SAE	Formerly Society of Automotive Engineers International
SPaT	Signal Phase and Timing

SRM	Signal Request Message
SSM	Signal Status Message
TS	Technical Specification
USDOT	United States Department of Transportation
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle

6. References

Connected Vehicle Basics

- ITS ePrimer – Module 13: Connected Vehicles. http://www.pcb.its.dot.gov/eprimer/module13.aspx
- Research and Innovative Technology Administration, "T3 Webinar: Connected Vehicle Basics." http://www.pcb.its.dot.gov/t3/s140424_cv_basics.asp
- Federal Highway Administration, "Connected Vehicles Environment Fundamentals 101", http://sp.stsmo.transportation.org/Documents/ConnectedVehiclesToInfrastructure101_PresentationRev7.pdf
- CITE - Consortium for ITS Training and Education, "Regional Operations Forums: Connected Vehicles and the Future of Transportation", https://youtu.be/HNS17Iq9QCw
- ITE Connected Vehicle Support Project, https://www.ite.org/technical-resources/connected-vehicle/

Deployment (General)

- Research and Innovative Technology Administration, Connected Vehicle Research, http://www.its.dot.gov/research_areas/connected_vehicle.htm
- Research and Innovative Technology Administration, DSRC Fact Sheet, http://www.its.dot.gov/factsheets/dsrc_factsheet.htm
- U.S. Government Accountability Office Intelligent Transportation Systems: Vehicle-to-Infrastructure Technologies Expected to Offer Benefits, but Deployment Challenges Exist, GAO-15-775, Published Sept 15, 2015, http://gao.gov/products/GAO-15-775
- 2019 Urban Mobility Report, Texas A&M University, https://mobility.tamu.edu/umr/
- National Operations Center of Excellence, Implementation Guide, SPAT Challenge, https://transportationops.org/spatchallenge/resources/Implementation-Guide
- USDOT, Connected Vehicle Pilot Deployment Program, https://www.its.dot.gov/pilots/

SAE International

- SAE J3067 – Candidate Improvements to Dedicated Short Range Communications (DSRC) Message Set Dictionary [SAE J2735] Using Systems Engineering Methods, SAE, http://standards.sae.org/j3067_201408/
- SAE J2945/A - Recommended Practices for MAP/SPaT Message Development - SAE International, Proposed
- SAE J2945/B - Recommended Practices for Signal Preemption Message Development - SAE International, Proposed

7. Study Questions

1. Which of the following user needs for a signalized intersection is not addressed with SPaT data?
    a. Receive currently allowed vehicle movements
    b. Receive lane location descriptions
    c. Receive suggested vehicle speeds
    d. Receive estimated times when signal indications will change
2. Signal timing information for how many intersections can be included in a single SPaT message?
    a. Only one signalized intersection
    b. Only one signalized and one non-signalized intersection
    c. Up to two signalized intersections along an arterial
    d. Up to 32 signalized intersections
3. Which of the following attributes for a lane is included in a MAP message?
    a. The centerline locations of a lane
    b. The permitted direction of travel of the lane
    c. The permitted vehicle types that may use the lane
    d. All of the above
4. When broadcasting SPaT and MAP messages, which of the following issues must be considered?
    a. Only one intersection is described in each SPaT and MAP message
    b. All MAP messages must be accompanied by a SPaT message
    c. Other standards may limit the number of bytes in a message
    d. SPaT and MAP messages must use the same broadcast rate

Icons to be used in ITS PCB Standards Training PowerPoints

A key of these icons that may be found in the PowerPoint presentations.

1) **Background information:** General knowledge that is available elsewhere and is outside the module being presented. This will be used primarily in the beginning of slide set when reviewing information readers are expected to already know.

2) **Tools/Applications:** An industry-specific item a person would use to accomplish a specific task, and applying that tool to fit your need.

3) **Remember:** Used when referencing something already discussed in the module that is necessary to recount.

4) **Refer to Student Supplement:** Items or information that are further explained/detailed in the Student Supplement.

5) **Example:** Can be real-world (case study), hypothetical, a sample of a table, etc.

Checklist: Use to indicate a process that is being laid out sequentially.