A Project Document of the Connected Intersections (CI) Committee

DRAFT

CI ConOps v01.02

Concept of Operations (ConOps) for the Connected Intersections (CI) Implementation Guide

Draft v01.02 – October 30, 2020

Foreword

This document was developed by engaging with stakeholders representing the industry at large including but not limited to Car manufacturers, State DOTs, local municipalities, and was supported by the USDOT ITS Joint Program Office (JPO). Several associations - such as the American Association of State Highway Transportation Officials (AASHTO), Institute of Transportation Engineers (ITE), the National Electrical Manufacturers Associations (NEMA), Institute of Electrical and Electronics Engineers (IEEE), and SAE International - were involved in ensuring balanced and effective stakeholder representation and adherence to standards development process as Standards Development Organizations (SDOs).

Recent Minor Version Revision History

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CI_ConOpsDraft1.01	09/08/20	Lahiri	Incorporate feedback from ConOps Walkthrough
CI_ConOpsDraft1.00g-pxc-D1.docx	08/31/20	Chan	Includes edits from comments and Day 1 of the ConOps walkthrough
CI_ConOpsDraft1.00g.docx	08/18/20	Chan	Distributed to CI Committee for comments.
CI_ConOpsDraft1.00f.docx	08/17/20	Chan	Additional text and input from all other TFs.
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CI_ConOpsDraft1.00d.docx	08/07/20	Chan, Insignares	Additional input through 8/7 from TF co-chairs on context diagram, SPaT/MAP TF
CI_ConOpsDraft1.00c.docx	07/27/20	Chan	Additional changes and updates. Includes comments from co-chairs and SMEs thru 7/24.
CI_ConOpsDraft1.00b.docx	07/20/20	Chan	Initial Draft. Submitted to CI Co-Chairs.
CI_ConOpsDraft1.00a.docx	06/26/20	Chan	Formatting
CI_ConOpsDraft1.00.docx	06/26/20	Lahiri	Initial layout of ConOps

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Section 1
General Information [Informative]

1.1 Scope

This document, the Connected Intersection (CI) Implementation Guide, defines the key capabilities and interfaces a connected signalized intersection must support to ensure interoperability with production vehicles for state and local infrastructure owner/operators (IOO). A connected intersection is defined as an infrastructure system that broadcasts signal, phase, and timing (SPaT), mapping information (MAP), and position correction data to vehicles.

This CI Implementation Guide addresses the ambiguities and gaps identified by early deployers and provides guidance to generate messages and develop applications for signalized intersections that are interoperable across the United States, especially for automated transportation systems. This document focuses on harmonizing the existing SPaT messages deployed, using the United States Department of Transportation (USDOT) sponsored *Cooperative Automated Transportation Clarifications for Consistent Implementations (CCIs) To Ensure National Interoperability Connected Signalized Intersections* as a starting point.

This document was developed with the combined effort of stakeholders representing the industry at large including IOOs, Automotive Original Equipment Manufacturers (OEMs), Fleet and Truck operators, safety advocacy groups, multimodal partners and end users of data and services. Several associations - SAE International (SAE), American Association of State Highway Transportation Officials (AASHTO), National Electrical Manufacturers Associations (NEMA), Institute of Electrical and Electronics Engineers (IEEE) and Institute of Transportation Engineers (ITE) - are involved in ensuring balanced and effective stakeholder representation and adherence to consensus-based Development Process

The Implementation Guide follows a Systems Engineering Process (SEP), so the contents of this document include Concept of Operations (ConOps), a System Requirements (Functional Requirements), and System Design Details sections.

The CI Implementation Guide defines procurement and implementation guidance and the expectations leading to minimum performance requirements for a connected intersection. It is intended to be used by IOOs to provide guidance on how to implement an interoperable connected intersection. For OEMs and other application developers, this document provides an explanation on what data and connected vehicle messages are being provided from an interoperable connected intersection so safety applications can be developed for production vehicles, with an initial focus on the Red-Light Violation Warning application. The NRTM in Section 3.x provides the guidance to IOOs for the procurement of a connected intersection.

1.2 References

1.2.1 Normative References

Normative references contain provisions that, through reference in this text, constitute provisions of this CI Implementation Guide. Other references in this document might provide a complete understanding or provide additional information. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this CI Implementation Guide are encouraged to investigate the possibility of applying the most recent editions of the standards listed.

Identifier	Title
SAE J2735_202007	V2X Communications Message Set Dictionary, SAE International, published 2020.

1.2.2 Other References

The following documents and standards may provide the reader with a more complete understanding of connected intersections; however, these documents do not contain direct provisions that are required by the CI Implementation Guide. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on the CI Implementation Guide are encouraged to investigate the possibility of applying the most recent editions of the standard listed.

Identifier	Title
U.S. Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT)	Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT), USDOT, http://local.iteris.com/arc-it/
CCI	Cooperative Automated Transportation Clarifications for Consistent Implementations (CCIs) To Ensure National Interoperability Connected Signalized Intersections, Version 1.9.5, June 2020
IEEE 610-1990	IEEE Standard Glossary of Software Engineering Terminology, IEEE, 1990
IEEE 829-2008	IEEE Std 829 IEEE Standard for Software and System Test Documentation, IEEE, 2008
IEEE 1012-2016	IEEE Standard for System, Software, and Hardware Verification and Validation, IEEE, 2016.
IEEE 1362-1998	IEEE Guide for Information Technology System Definition - Concept of Operations (ConOps) Document, IEEE, 1998
	Enabling Connected Intersections Concept Paper – Working Draft to Support Discussions of the IOO/OEM Forum SPaT/RLVW Group
MUTCD	Manual on Uniform Traffic Control Devices for Streets and Highways, 2009 Edition including Revision 1 and 2 dated May 2012, Federal Highway Administration, United States Department of Transportation
The NTCIP Guide (NTCIP 9001, v04)	The NTCIP 9001, The NTCIP Guide, v04, AASHTO / ITE / NEMA, published July 2009
RSU Standardization	Concept of Operations (ConOps) for the Roadside Unit (RSU) Standard, v01.06, July 12, 2020

1.2.3 Contact Information

1.2.3.1 Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT)

The Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) may be viewed online at:

http://local.iteris.com/arc-it/

ARC-IT is the US ITS reference architecture and includes all content from the (now deprecated) National ITS Architecture v7.1 and the Connected Vehicle Reference Implementation Architecture (CVRIA) v2.2.

1.2.3.2 FHWA Documents

U.S. Department of Transportation Federal Highway Administration (FHWA) documents (with designations FHWA-JPO-…) are available at the U.S. Department of Transportation National Transportation Library, Repository & Open Science Access Portal (ROSA P):

https://rosap.ntl.bts.gov/

1.2.3.3 IEEE Standards

IEEE standards can be purchased on-line in electronic format or printed copy from:

Techstreet
6300 Interfirst Dr.
Ann Arbor, MI 48108
(800) 699-9277
www.techstreet.com/ieee

1.2.3.4 NTCIP Standards

Copies of NTCIP standards may be obtained from:

NTCIP Coordinator
National Electrical Manufacturers Association
1300 N.17th Street, Suite 900
Rosslyn, Virginia 22209-3801
www.ntcip.org
e-mail: ntcip@nema.org

Draft amendments, which are under discussion by the relevant NTCIP Working Group, and amendments recommended by the NTCIP Joint Committee are available.

1.2.3.5 SAE International Documents

Copies of SAE International documents may be obtained from:

SAE International
400 Commonwealth Drive
Warrendale, PA 15096
www.sae.org

1.3 Terms

The following terms, definitions, acronyms, and abbreviations are used in this document.

Term	Definition
Connected Intersections (CI)	An infrastructure system that broadcasts signal, phase and timing (SPaT), mapping information and position correction data to On-Board Units and Mobile Units.
Interchangeability	The capability to exchange devices of the same type on the same communications channel and have those devices interact with others devices of the same type using standards-based functions. Source: The NTCIP Guide
Interface	A shared boundary across which information is passed. Source: IEEE Std 610, IEEE Standard Glossary of Software Engineering Terminology, 1990.

Term	Definition
Interoperability	The ability of two or more systems or components to exchange information and to use the information that has been exchanged. Source: IEEE Std 610, IEEE Standard Glossary of Software Engineering Terminology, 1990.
Mobile Unit (MU)	A device used to wirelessly communicate with other devices for safety and mobility purposes carried by a pedestrian, bicyclist, work zone worker, or other traveler. Source: Concept of Operations (ConOps) for the Roadside Unit (RSU) Standard, v01.06, July 12, 2020.
On-Board Units (OBU)	A device used to wirelessly communicate with other devices for safety and mobility purposes installed in a vehicle as original equipment or as aftermarket equipment (sometimes referred to as an "aftermarket safety device (ASD)". Source: Concept of Operations (ConOps) for the Roadside Unit (RSU) Standard, v01.06, July 12, 2020.
Roadside Unit (RSU)	A transportation infrastructure communications device located on the roadside that provides V2X connectivity between OBUs/MUs and other parts of the transportation infrastructure including traffic control devices, traffic management systems, and back-office systems. Note: Devices that are not part of the transportation infrastructure, such as cellular base stations or satellites, are not RSUs. Source: Concept of Operations (ConOps) for the Roadside Unit (RSU) Standard, v01.06, July 12, 2020.
Robustness	Degree to which a system or component can function correctly in the presence of invalid inputs or stressful environmental conditions. Source: ISO/IEC/IEEE 24765:2017 Systems and software engineering-Vocabulary
Transportation Field Devices	Devices and electronic systems that monitor and control traffic operations on a roadway. Examples include a traffic signal controller and a roadside unit.
Vulnerable Road User (VRU)	A term applied to those most at risk in traffic, i.e. those unprotected by an outside shield. VRUs are pedestrians (especially children, seniors and people with disabilities), bicyclists, and motor cyclists. Source: Concept of Operations (ConOps) for the Roadside Unit (RSU) Standard, v01.06, July 12, 2020.

1.4 Abbreviations

The abbreviations and acronyms used in this document are defined below.

AASHTO	American Association of State Highway Transportation Officials

ARC-IT	Architecture Reference for Cooperative and Intelligent Transportation
CAT	Cooperative Automated Transportation Coalition
CCI	Clarifications for Consistent Implementations (CCIs) To Ensure National Interoperability - Connected Signalized Intersections (document)
CI	Connected Intersection
ConOps	Concept of Operations
CV	Connected Vehicle
DSRC	Dedicated Short Range Communication
FHWA	Federal HighWay Administration
FO	Functional Object
GNSS	Global Navigation Satellite System
IEEE	Institute of Electrical and Electronics Engineers
IMU	Inertial Measurement Unit
IOO	Infrastructure Owner/Operator
ITE	Institute of Transportation Engineers
MPH	miles per hour
MU	Mobile Units
MUTCD	Manual of Uniform Traffic Control Devices
NEMA	National Electrical Manufacturers Associations
NRTM	Needs to Requirements Traceability Matrix
OBU	On-Board Units
OEM	Automotive Original Equipment Manufacturers
RLVW	Red-Light Violation Warning
RTK	Real-Time Kinematic
RTM	Requirements Traceability Matrix
SAE	SAE International
SCMS	Security Credentials Management System
SDO	Standards Development Organizations
SEP	Systems Engineering Process
SPaT	Signal Phase and Timing
USDOT	United States Department of Transportation
V2I	Vehicle-to-Infrastructure
VRU	Vulnerable Road User

Section 2
Concept of Operations [Normative]

Section 2 defines the user needs that subsequent sections this CI Implementation Guide addresses. Accepted system engineering processes detail that requirements should only be developed to fulfill well-defined user needs. The first stage in this process is to identify the ways in which the system is intended to be used. In the case of the CI Implementation Guide, this first stage entails identifying the various ways in which the IOOs may provide and Automotive OEMs may use SPaT, MAP and positioning data at a connected intersection in a consistent, interoperable manner.

This concept of operations provides the reader with:

a) a detailed description of the scope of the CI Implementation Guide document;
b) identifies the key capabilities and interfaces for a connected intersection;
c) an understanding of the perspective of the developers of this document; and
d) a testing framework to verify conformance to the CI Implementation Guide.

Section 2 is intended for all readers and users of the CI Implementation Guide, including:

a) **Transportation Managers.** IOO personnel responsible for making decisions about operational strategies to implement and configuring transportation field devices.
b) **Transportation Operators.** IOO personnel responsible for monitoring the transportation infrastructure and implementing transportation strategies.
c) **Transportation Engineers.** IOO personnel responsible for planning or designing the transportation infrastructure.
d) **Maintenance Personnel.** IOO personnel responsible for ensuring that transportation field devices operate as intended.
e) **Third-party data providers.** Non-IOO entities that provide SPaT and maintain SPaT and MAP data.
f) **System Integrators.** Entities that brings together different components or subsystems into a whole system that functions together.
g) **Application Developers.** Developers providing applications that run on on-board units (OBUs), Mobile Units (MUs), Roadside Units (RSUs) and transportation field devices; and custom applications that run from a central server, cloud service, or back-office location.
h) **Testers.** Entities that develop test procedures to verify the SPaT MAP, and positioning data is consistently and reliably provided by IOOs, and properly used by applications.

For the first five categories of readers, Section 2 is useful to understand what SPaT MAP, and positioning data should be provided.

For the last three categories of readers, Section 2 provides a more thorough understanding as to why the more detailed requirements exist later in the CI Implementation Guide, and how SPaT and MAP data is derived.

2.1 Tutorial [Informative]

A concept of operations describes a proposed system from the users' perspective. Typically, a concept of operations is used to ensure that system developers understand the users' needs. Within the context of this CI Implementation Guide, the concept of operations documents the intent of each feature that a connected intersection provides.

The terms “Normative” and “Informative” are used to distinguish parts of this ConOps that must be conformed to (Normative) and those that are there for informational purposes (Informative). It is possible for a section to be identified as Normative but have subsections that are identified as Informative. If a section is Normative then all of its subsections are Normative unless identified otherwise. This entire ConOps section is Normative unless otherwise indicated.

The concept of operations starts with a discussion of the current situation and issues that have led to the need to deploy connected intersections, and then led to the development of this Implementation Guide. This discussion is presented in layman's terms such that both the potential users of the system and the system developers can understand and appreciate the situation.

The concept of operations then documents key aspects about the proposed system, including:

- **Reference Physical Architecture.** The reference physical architecture (view) defines the overall context of the connected intersection system and defines what components and interfaces are addressed by this CI Implementation Guide. The reference physical architecture is supplemented with one or more samples that describe how the reference physical architecture may be realized in an actual deployment.
- **Needs.** The needs identify and describe the various functions that users may want components of the CI to perform. These needs, also called features, are derived from the high-level user needs identified in the problem statement (Section 2.2) but are refined and organized into a more manageable structure that forms the basis of the traceability tables contained in Section 3.
- **Operational Scenarios.** The operational scenarios allow a reader to understand the different parts of the proposed functions of the CI and how they interact; and may highlight situations where an ambiguity or gap currently exists among deployed connected intersections and/or current standards.

The other sections of this ConOps are as follows:

- **Operational Policies and Constraints.** A narrative description of specific policies or constraints relative to the operational environment that have a direct impact on the implementation of this CI Implementation Guide.
- **Relationship to the ITS National Architecture [Informative].** This section describes how a CI implementation fits into the ITS National Architecture.
- **Testing and Conformity Verification Management.** This section describes the need for a testing framework to verify that an implementation conforms to the CI Implementation Guide.

Section 3 Requirements uses the needs, also called features, identified in the analysis of the system to define the various requirements for a CI. Each user need traces to one or more requirements, and each requirement is derived from at least one need. This traceability is documented in a needs to requirements traceability matrix (NRTM) where each user need will map to all the requirements that fulfill that need.

Like user needs, the requirements are identified by a collaboration of a broad base of stakeholders and some are drawn from existing documents. Each requirement is captured in Section 3 Requirements in a formal manner along with the rationale which justifies the inclusion of the need. Each requirement identified is then presented in the Requirements Traceability Matrix (RTM) in Annex A, which defines how the requirement is fulfilled.

2.2 Current Situation and Problem Statement [Informative]

CIs are defined as an infrastructure **system** equipped to broadcast SPaT data, mapping information and position correction data to support safety applications on OBUs/MUs.

CIs are being deployed as part of USDOT's Connected Vehicle Pilots program and as part of the United States' National Connected Vehicle SPaT Deployment Challenge. The SPaT Challenge was issued to state and local public sector transportation IOOs in 2017 to deploy infrastructure that broadcasts SPaT data. The SPaT Challenge provided IOOs with an entry point to deploying a connected vehicle infrastructure, allowing those IOOs to gain experience in procuring, installing and operating vehicle-to-infrastructure (V2I) deployments.

Early deployments of CIs demonstrated there are issues related to providing infrastructure data in a consistent manner that will be compatible with production vehicles and in-vehicle devices. The Cooperative Automated Transportation (CAT) Coalition identified the Red-Light Violation Warning (RLVW) application as one of 3 critical focus areas. The USDOT-sponsored CAT Coalition *Clarifications for Consistent Implementations (CCIs) To Ensure National Interoperability - Connected Signalized Intersections* (CCI) document states:

> "It is understood by deployers that the established standards alone will not ensure open compatibility with production vehicles. Existing standards often include optional elements or flexibility given the variety of objectives or ways a system may be deployed. In some cases, the optional elements or flexibility may be interpreted differently for different deployments, despite the common objectives and applications of each deployment. These differences could lead to a lack of interoperability that prevents vehicles from using data at Connected Signalized Intersections across different jurisdictions.
>
> Infrastructure Owner Operators (IOOs) and original equipment manufacturers (OEMs) need to reach common agreement on interpretations and clarifications regarding known ambiguities so that data from all Connected Signalized Intersections can support vehicle applications, regardless of the jurisdiction or vehicle type."

The CCI document then identifies and addresses known ambiguities for both mandatory and optional elements for a CI. However, the CCI represents only a subset (a single application - RLVW) of potential problems with implementing a connected vehicle environment.

Figure 1 is a depiction of how IOOs use standards today, and the process issues IOOs encounter that could prevent national interoperability for a CI.

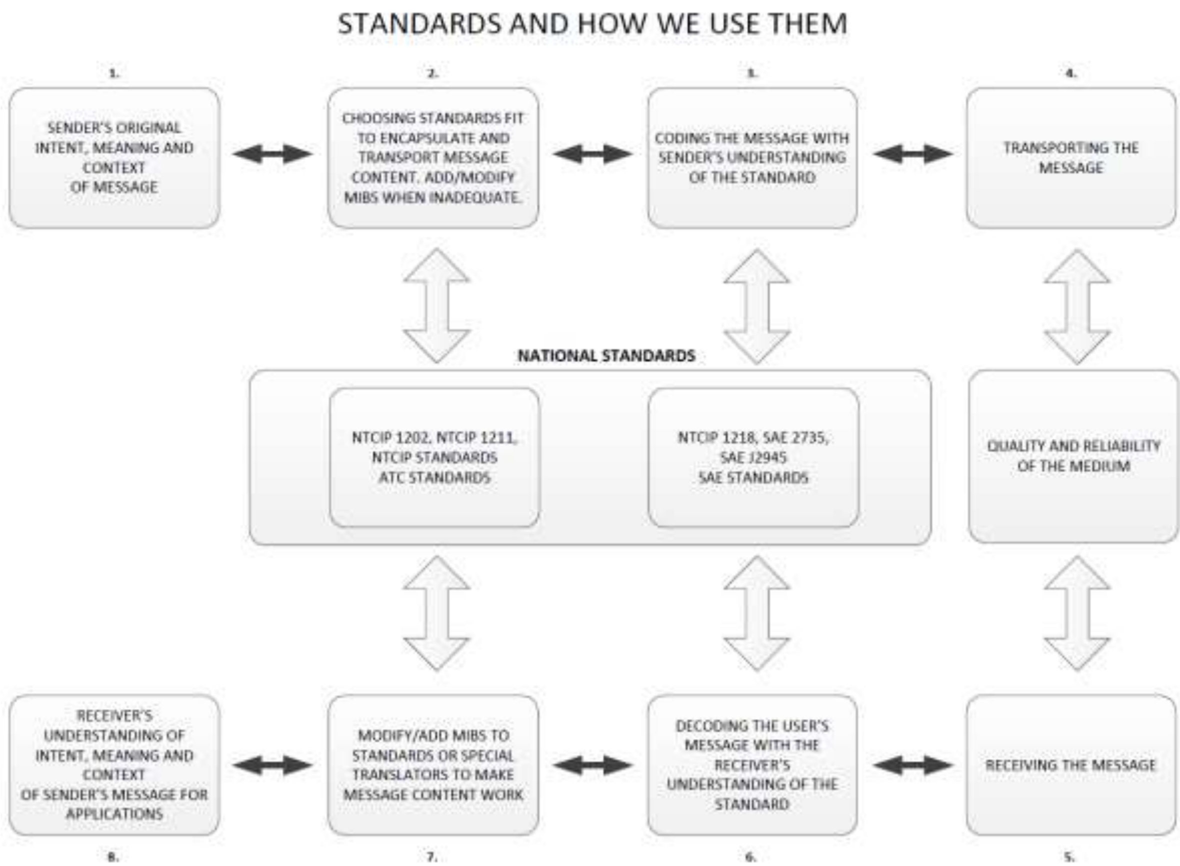


Figure 1. How Standards are used in a Connected Intersection

The sender collects data such as real time signal status from traffic signal controllers.

To share this data with other devices, the sender must choose a national transportation standard(s) that supports messages that can be used to send this as much of this data as possible in its original context, such as NTCIP 1202 v03A. The sender must encode the data into the messages as specified by the selected standard, packaging all the data to be sent into the message for transporting to the receiver. The sender may modify the message by adding some objects that are not specified in the standard. This may be necessary to communicate all the data in the original context the sender wishes to send the data with. For example, traffic signal controllers designed for NTCIP 1202 v02 require custom objects to support connected vehicle applications. In a similar way, the national transportation standard selected by the computing device may contain options. The computing device may select one option and create the message in that way, while the receiver may expect or understand the message in the context of the other option."

Upon receiving the message, the receiver must decode the message and extract the original data. The sender and receiver may interpret standards differently. Unless the sender and receiver have a mutual agreement, the receiver may interpret the message differently than the sender and may not understand the original context the sender sent the data with. Additionally, in the event that the message is sent though an unreliable, poor quality medium, the message may lose some data but the receiver may not be aware of the lost data and the original context of the message. Without understanding the original context of the message, the receiver's system may not respond to the message as it otherwise would. A receiver may also receive the same type of message from other sender, but each sender may send messages with different context and the receiver would have to interpret the messages differently.

This situation is exacerbated in a situation such as a CI, where the sender and receiver are from different industries - the IOOs responsible for operating and maintaining the transportation system; and the automotive OEMs that use the transportation system.

The difference between the sender's original context of the message and the receiver's interpretation of the message, and the choices of options results in ambiguities that this CI Implementation Guide is meant to address.

2.3 Reference Physical Architecture [Informative]

This section presents an overview of what a complete CI "system" may look like for users of the CI, including the IOO that operates and maintains the infrastructure, and travelers through the CI. The section describes the "actors" that participate in the CI, including the producers and consumers of information, and are addressed by this CI Implementation Guide. Figure 2 is a graphical depiction (context diagram) of the physical architecture for the CI.

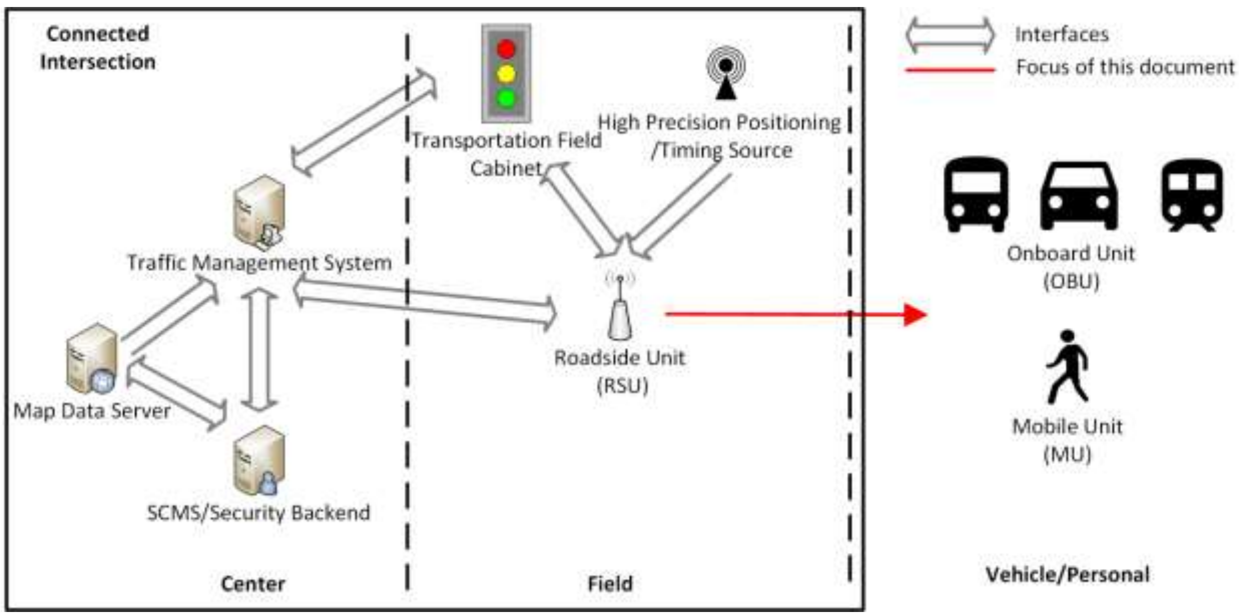


Figure 2. Connected Intersection

At the highest level of abstraction, the physical architecture consists of center components, field components, vehicle components and personal components. The Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT) defines these components as:

- **Center.** An entity that provides application, management, administrative, and support functions from a fixed location not in proximity to the road network. The terms "back office" and "center" are used interchangeably. Center is a traditionally a transportation-focused term, evoking management centers to support transportation needs, while back office generally refers to commercial applications.
- **Field.** These are intelligent infrastructure distributed near or along the transportation network which perform surveillance (e.g. traffic detectors, cameras), traffic control (e.g. traffic signal controllers), information provision (e.g. dynamic message signs) and local transaction (e.g., tolling, parking) functions. Typically, their operation is governed by transportation management functions running in back offices. Field also includes RSU and other non-DSRC (Dedicated Short Range Communication) wireless communications infrastructure that provides communications between Mobile elements and fixed infrastructure.

- **Personal.** Equipment used by travelers to access transportation services pre-trip and en route. This includes mobile/handheld as well as desktop equipment owned and operated by the traveler.
- **Vehicle.** Vehicles, including driver information and safety systems applicable to all vehicle types.

The physical elements involved are described below.

- **Traffic Management System.** The systems used by traffic operations staff to configure, control, monitor, and collect data from transportation field devices to manage traffic.
- **SCMS/Security Backend.** A system that provides and manages security certificates to support trust within the CI system.
- **Map Data Server.** A server that contains the roadway geometry data that may be shared by the infrastructure to OBUs/MUs.
- **Roadside Unit (RSU).** A transportation field device that performs the data exchange between OBUs, MUs, and other infrastructure elements.
- **Transportation Field Cabinet.** A field cabinet containing devices and electronic systems that monitor and control traffic operations on a roadway. Includes the traffic signal controllers that allow different conflicting movements to travel across a roadway in a safe, orderly manner.
- **High Precision Positioning/Timing Source.** Source data service which could be a base station or a satellite allowing the system to calculate positioning and UTC for system processes, or provide position corrections. An example of a High Precision Positioning/Timing Source is a GNSS receiver.
- **On-Board Unit (OBU).** Performs the data exchange between the infrastructure and a vehicle and installed in a vehicle (includes an after-market device). An OBU may contain applications that process the data received from the infrastructure and other sources such as another OBU.
- **Mobile Unit (MU).** Performs the data exchange between the infrastructure and a road user. MUs may be integrated with cellular phones or otherwise be carried by pedestrians, cyclists, other travelers, or workers in the roadway.

The lines between the physical elements represents the interfaces that are addressed by the CI Implementation Guide, primarily for security reasons, although the focus is on the interface between the connected intersection, specifically the RSU and the applications on the OBUs/MUs. Interfaces within the CI are shown primarily for security reasons. Other interfaces may exist among the components outside a connected intersection, such as between the SCMS/Security Backend and the OBU/MU, but are not depicted in the diagram since those interfaces are not addressed in this CI Implementation Guide.

This initial CI Implementation Guide prioritizes support for the RLVW application so OEMs can begin to deploy and validate this application in production vehicles. The RLVW application is described in more detail in the RLVW Operational Scenario in Section 2.6.1. However, needs for other SPaT-based and MAP-based safety applications that were considered relatively easy to implement and can be completely defined within the project schedule are also included in this CI Implementation Guide.

2.4 Needs

The needs for a connected intersection follow.

2.4.1 Architectural Needs

A connected intersection needs to use a communications technology to exchange data with the applications on an OBU/MU in a timely manner. This feature allows an application on an OBU/MU to receive data, such as signal timing information, with enough low latency so the application can properly process the data from the CI and react to the dynamic situation at the intersection. The reaction may include providing warnings or alerts to the driver or Vulnerable Road Users (VRUs), or taking an appropriate action.

2.4.2 Messages

This section identifies needs related to a connected intersection providing information from the infrastructure.

2.4.2.1 Message Performance Needs

This section identifies performance needs for a connected intersection providing information from the infrastructure.

2.4.2.1.1 Uniform

A connected intersection needs to provide a consistent (or uniform) representation of the situation and operating conditions. Uniform data fields increase interoperability between the infrastructure components and the applications that use the data to aid drivers and VRUs.

For example, connected intersections should provide a uniform representation of roadway features. Inconsistencies in how roadway features are represented lead to inconsistent usage and interpretations by applications that use roadway features. A uniform representation of roadway features increases the effectiveness of the applications that aid drivers and vulnerable road users.

2.4.2.1.2 Message Accuracy

A connected intersection needs to provide assurances that the data provided by the infrastructure is accurate and represents what is happening at the intersection so an application can trust the data. Inaccurate data reduces the effectiveness of the applications that use the data.

For example, the duration of a signal interval may be influenced by external processes. There are configurations when an external process, such as cabinet relays or a separate system controlling the active timing intervals (e.g., hold/force off/stop time), is being used for either supervisory control over the traffic controller timing or post processing of controller outputs. In these cases, the traffic controller may have limited information thereby limiting the ability to predict the future state of the intersection and therefore cannot provide accurate signal interval duration information. For these cases, the source of the signal interval duration data should be the separate system.

2.4.2.1.3 Robustness

A connected intersection needs to be robust. When subject to anomalous data and commands, the connected intersection and its components function properly and are not corrupted. These components may have different failure modes operational states that are consistent and repeatable under different operational conditions. An example is what data should still be broadcasted if the connected intersection is unable to provide the current movement state.

The connected intersection and its components also function properly under the maximum simultaneous data traffic possible on all communications interfaces. Applications depend on continuous and proper operation under extreme demands on the system.

2.4.2.1.4 Concise Messages

A connected intersection needs to provide concise messages so that complete data describing the situation can fit within the maximum message size supported by the communications stack. Small message sizes also suffer much less from packet loss than larger messages.

2.4.2.1.5 Advanced Notification

A connected intersection needs to provide data far enough in advance of the intersection with respect to both time and distance so the application on an OBU/MU can process the data in time to react to a situation. This allows the proper interpretation of the data by the applications and may provide more options for drivers, VRUs or applications to react to the dynamic situation at the intersection. The reaction may involve providing warnings or alerts to the driver or VRU, or taking an appropriate action. For example, the coverage area needed will be different for a CI where average vehicle approach speeds are 20 miles per hour (MPH) when compared to a CI where the average vehicle speed for an approach is 50 mph.

2.4.2.1.6 Timeliness

A connected intersection needs to indicate changes in state and timing with low latency so that the applications on an OBU/MU can react to the most current information in a timely manner. Timely information to applications provides effective and reliable services that aid road users.

2.4.2.1.7 Quality Assurance

The CI needs to produce quality information. The information needs to produce the best set of messages (e.g., SPaT message) that represents the current situation and conditions at the intersection.

2.4.2.2 Generic Message Data Needs

This section identifies generic data needs for a connected intersection providing information from the infrastructure.

2.4.2.2.1 Time Source

A connected intersection needs to use the same time reference and with sufficient precision as OBUs/MUs so non-infrastructure applications can properly interpret time points. This allows the proper interpretation of time-sensitive data by applications and permits reactions to be based on the same understanding of time.

2.4.2.2.2 Message Revision

A connected intersection needs to indicate if the data provided on a specific topic (other than the timestamp) is new and must be processed by the receiving application or is the same as a previous message and can be ignored.

2.4.2.2.3 Timestamp

A connected intersection needs to identify the time that the data provided by the infrastructure was generated. This allows an application using the same time source to determine the timeliness of the data.

2.4.2.3 Signal Timing Data Needs

This section identifies needs related to signal timing data that a connected intersection provides.

2.4.2.3.1 Intersection Identification

A connected intersection needs to provide the unique identifier of an intersection so an application can associate the signal timing data received with the intersection map data.

2.4.2.3.2 Intersection Status

A connected intersection needs to provide information about the current operational status of a signalized intersection so that an OBU/MU application can better interpret signal timing data provided about that intersection.

For example, the operational status may indicate if the signalized intersection is operating in preempt, external logic or in flash.

2.4.2.3.3 Current Movement State

A connected intersection needs to provide information about the current state of each movement, including a pedestrian movement, at the intersection so an application can provide the proper warnings, information or guidance to the driver or VRU. The current state identifies if a maneuver through an intersection is currently permitted and any restrictions. For example, the current state may indicate whether: a protected or permissive movement is allowed; a protected or permissive clearance (phase change interval) is in effect; the movement is required to stop then proceed; or remain or a movement may proceed with caution with possible conflicting traffic.

2.4.2.3.4 Next Movement State

A connected intersection needs to provide information about the next state of each movement at the intersection so an application can provide the proper warnings, information or guidance to the driver or VRU. The next state identifies if the next signal interval for a maneuver through an intersection will be permitted and any restrictions after a change. For example, the current state may indicate a protected or permissive movement, but the next state indicates when the current state changes, if the maneuver will change to a protected or permissive movement, or a clearance (e.g., yellow indication) interval will be in effect.

2.4.2.3.5 Time Change Details

A connected intersection needs to provide information about when the current signal interval (state) for each movement, including a pedestrian interval (state), at the intersection will change so an application can provide the proper warnings, information or guidance to the driver or VRU. The information provided must be accurate under all conditions such as during TSP (transit signal priority) and EVP (emergency vehicle preemption).

The need includes the following operational scenarios: 2.6.2.1 - Rest in Green.

2.4.2.3.6 Confidence Factor

A connected intersection needs to provide a confidence indicator for the predicted time when the current signal interval (state) for each movement at the intersection will change so an application can provide the proper warnings, information or guidance to the driver or VRU. At any point in time, the future signal interval of an intersection is subject to factors that may be unknown to a traffic signal controller such as the future intersection demand, a preemption operation, or a change in timing plan from a management system. Some applications, such as safety applications, depend on timing information with high certainty. Other applications may function adequately with less certain timing information. A confidence factor helps applications interpret the data.

2.4.2.3.7 Next Green

A connected intersection needs to provide the estimated time when each movement at an intersection is next allowed to proceed (e.g., green), excluding unexpected events such as a preemption request. This feature allows an application to provide information or guidance to a driver or VRU. The next green information partially satisfies the needs of an eco-driving application.

The next green information also helps an OBU/MU determine whether a permitted turn movement will change directly to a protected movement, will change to a protected movement after a clearance interval or will change to a stop condition after a clearance interval.

Note: The time for the next green is a prediction and may change at any time based on demand or other external conditions. This need has to be associated with a confidence / prediction level.

2.4.2.3.8 Enabled Lanes

A connected intersection needs to provide information about which revocable lanes are currently enabled so an application can determine what movements are currently allowed at an intersection. An IOO may define the same physical lane for different uses or with different restrictions depending on the time of day or on specific days. For example, a lane may be defined as an HOV lane during the morning rush hours, a reversible lane for special events (such as at an arena), and as a normal vehicle lane during all other times. This feature allows the connected intersection to indicate what restrictions are in effect.

2.4.2.3.9 Signal Timing and Roadway Indications Synchronization

A connected intersection needs to provide signal timing data that is synchronized with signal indication changes on the roadway within a defined tolerance. For safety and effectiveness, applications require consistency between the perceived state of the intersection by road users and the signal timing data received by the applications on an OBU/MU. Synchronization enables applications to safely and effectively provide services to road users.

2.4.2.4 Roadway Geometry Data Needs

This section identifies needs about the roadway geometry information that a connected intersection provides.

2.4.2.4.1 Intersection Geometry

A connected intersection needs to provide information about the lanes in and around an intersection so that an application on an OBU/MU can determine its position in relation to the lanes, stop bars, crosswalks and landing geometry of the intersection.

2.4.2.4.2 Lane Attributes

A connected intersection needs to provide information about the allowed use of each lane at an intersection so an application on an OBU/MU can determine the current allowed usage of the lanes around its position and can provide appropriate warnings, information and guidance to the driver or VRU. Lane attributes provided include the direction of travel permitted in the lane and lane use restrictions.

2.4.2.4.3 Allowed Maneuvers

A connected intersection needs to provide information about the allowed maneuvers of each lane at an intersection so the application on an OBU/MU can provide appropriate warnings, information and guidance to the driver or VRU. Allowed maneuvers define permitted turns from a lane, typically a vehicle lane, under different conditions.

2.4.2.4.4 Connections Between Lanes

A connected intersection needs to provide information about the permitted connections between ingress lanes and egress lanes at an intersection so an application on an OBU/MU can determine what signal timing data from the infrastructure applies to it. The application uses this information to provide appropriate warnings, information and guidance to the driver or VRU.

For example, this need ties a maneuver to a signal group so the application on an OBU can interpret what signal timing data applies.

2.4.2.4.5 Approach Speed Limit Information

A connected intersection needs to provide the posted or statutory speed limit, whichever is applicable, for each lane so an application in an OBU can provide advisories or warnings to a driver based on the speed limit.

2.4.2.4.6 Revocable Lanes

A connected intersection needs to identify lanes that are revocable. An IOO may define the same physical lane for different uses or with different restrictions depending on the time of day or on specific days. For example, a lane may be defined as an HOV lane during the morning rush hours, a reversible lane for special events (such as at an arena), and as a normal vehicle lane during all other times.

Note: The SPaT message will then identify which revocable lane is currently is active.

2.4.2.4.7 Signal Timing and Roadway Geometry Synchronization

A connected intersection needs to ensure that roadway geometry information being broadcast reflects the current operating state used to generate the signal timing data. The signal timing data and roadway geometry data cannot be viewed as independent, but then BOTH need to reflect the actual usage. The signal timing data and the operating roadway geometry HAVE to be agreement. If an entity changes the design geometry environment, it may necessitate a change in the signal timing data.

2.4.2.5 Positioning Data Needs

This section identifies needs about positioning that a connected intersection provides.

2.4.2.5.1 Positioning Corrections

A connected intersection needs to provide data in a standardized format that helps vehicles to achieve the required positioning and timing accuracy at intersections where this is needed. For example, position corrections data may provide information that allows an application on an OBU/MU to calculate its current position with enough accuracy to determine which lane it is in.

2.4.2.5.2 Real-Time Kinematic

When implementing Real-time Kinematic (RTK) positioning, all GNSS devices in the broader IOO system implementation need to use and broadcast a common RTK source as an RTCM broadcast, or the devices need to use a common (network-based, not broadcast) RTK source for their position correction.

2.4.3 Security

This section identifies security needs for a connected intersection.

2.4.3.1 Correct Operations

This section identifies the security needs for correct operations at a connected intersection.

2.4.3.1.1 Data Trustworthiness

A connected intersection needs to ensure that data sources are trustworthy and provide correct data for use in creating CI messages so that message data reflects near-real time CI operating conditions, and applications and users respond appropriately.

2.4.3.1.2 Data Processing

A connected intersection needs to ensure that platforms that modify or perform any transformation on data that is subsequently used to create CI messages are trustworthy and operate correctly, including producing correct outputs so that transformed data reflects near-real time operating conditions, and applications and users respond appropriately.

2.4.3.1.3 Input Validation

A connected intersection needs to ensure that components reject incorrect inputs, or inputs that do not communicate appropriate levels of trustworthiness, so that components do not process data that mis-represents the CI operating environment.

2.4.3.1.4 Cyber Attacks

A connected intersection needs to ensure that all components involved in generating CI messages or inputs into CI messages are protected from cyber attacks so that malevolent actors may not gain access to or harm the CI system.

2.4.3.1.5 Cyber Attacks Recovery

A connected intersection needs to ensure that all components involved in generating CI messages or inputs into CI messages can recover from cyber attacks so that disruption due to cyber attacks is limited, allowing components to provide near-continuous CI operating environment data.

2.4.3.1.6 Resilience

A connected intersection needs to resilient and ensure that all components operate correctly and produce correct output in the case where the CI operating environment does not meet acceptable performance conditions so that applications and user actions remain safe and appropriate during these conditions.

For example, if the time of change for a traffic controller is not reliable, the RSU may still broadcast intersection status data but not time-of-change data for a SPaT message.

2.4.3.1.7 Secure Administration

A connected intersection needs to enable components to be updated or reconfigured by appropriately authorized actors if necessary, to improve resilience / security against cyber attacks so that selected components may be modified, as appropriate. For example, if some, but not all, components are vulnerable, it may be appropriate for an authorized actor to update/reconfigure selected components to allow those that are not affected by the cyber attack to continue operation, without interruption.

2.4.3.1.8 Authenticated Secure Update

A connected intersection needs to support remote, authenticated, verified updates so that components maintain a consistent level of current cyber-hygiene. For example, as new cyber threats are identified, protection software is updated for all system components.

2.4.3.2 Data Flow: Communications and Interface Security

This section identifies the security needs related to data flow (communications and interfaces).

2.4.3.2.1 Data Trustworthiness

A connected intersection needs to provide components receiving CI data with sufficient information to evaluate trustworthiness of received data so those components receive some assurance that the CI data reflect near-real time CI operating conditions, and applications and users respond appropriately.

2.4.3.2.2 Data Integrity

A connected intersection needs to ensure that CI data is not corrupted or changed as it passes across interfaces so that transformed data reflects near-real time operating conditions, and applications and users respond appropriately.

2.4.3.3 Network Monitoring

This section identifies the security needs for network monitoring to allow implementing mechanisms to detect faulty CI messages.

2.4.3.3.1 Misbehavior Reporting by Network Administrators

A connected intersection needs to provide a mechanism to allow IOO network administrators to detect incorrect data so that faulty CI messages do not compromise applications or user actions.

2.4.3.4 Credential Management

This section identifies the security needs for credential management.

2.4.3.4.1 Credential Provisioning

A connected intersection needs to ensure that components that send trusted information communicate using up-to-date credentials so that components establish trust with each other, as well as OBUs and MUs.

2.4.3.4.2 Management of Untrustworthy Devices

A connected intersection needs to provide a mechanism to modify the ability to participate in the system of any previously trusted device that is subsequently determined to be untrustworthy. This way untrustworthy devices do not have a negative impact on CI operations. For example, misbehaving devices credentials/certificates may be (temporarily or permanently) revoked.

This applies to devices within the connected intersections (e.g., TMS, transportation field cabinet, etc..) but not OBUs/MUs.

2.4.3.4.3 Credentialing System Access

The RSUs in a connected intersection need access to the SCMS or a credentialing system. This allows the RSU to verify the trustworthiness of the data.

Note: the OBU/MU also need access to the SCMS or a credentialing system so it can verify the messages from the connected intersection.

2.5 Operational Policies and Constraints

The following operational policies and constraints apply to the use of this CI Implementation Guide document.

a) The operation and maintenance of the connected signalized intersection are governed by the regulatory guidelines or policies for the operating agency that may include USDOT's and the relevant states' Manual of Uniform Traffic Control Devices (MUTCD), and state and local ordinances, policies and procedures.
b) The operation and maintenance of the connected signalized intersection uses the traffic signal timing principles and practices that have guided signal timing operations for many decades. Many of these principles and practices have been studied, researched and time tested. Significant changes to these principles and practices may require additional studies and research before they can be adopted and deployed.
c) Gaining complete nationwide uniformity in signal timing and operations may not be possible without changes in the current national governance framework. Currently no single entity governs the operation of every traffic signal. Every state, county and city is often responsible for their own traffic signals and may have their own approaches to signal timing and operations, within the constraints of laws and ordinances.
d) Vehicles and vehicle systems are subject to Federal Motor Vehicles Safety Standards, ISO 26262 – Road vehicles – Functional safety, ISO/PAS 21448:2019 – Road vehicles - Safety of the Intended Functionality, a number of voluntary guidelines and/or non-regulated standards as well as OEM internally specified requirements and/or design principles.
e) While developers are conscience of the need for guidance that is feasible and implementable, certain technologies may not be available given resource constraints.

2.6 Operational Scenarios

According to IEEE 1362-1998,

> “A scenario is a step-by-step description of how the proposed [system] should operate and interact with its users and its external interfaces under a given set of circumstances. Operational Scenarios help readers understand how all pieces of the system interact to provide operational capabilities. [IEEE 1362-1998]"

For the purposes of this project, the proposed system is a connected intersection or series of connected intersections as might be found along an arterial. The operational scenarios are optional for the CI Implementation Guide, but could be included if the operational scenario:

- Allows a reader to understand the different parts of the proposed functions of the CI and how they interact
- Highlights a situation where an ambiguity or gap currently exists but will be addressed by the CI

2.6.1 Red-Light Violation Warning (RLVW) Application

Title	Red-Light Violation Warning (RLVW) Application
Summary of Operations	The RLVW application on the OBU receives the MAP message from the CI. The application then determines the location of the intersection, what lane the vehicle is currently in, and where the vehicle is currently located relative to the stop bar of the lane. The application will also determine which lanes the vehicle will enter and exit the intersection, and the identifier for the connection between the ingress/egress lanes. The RLVW application on the OBU receives the SPaT message from the CI. The application then determines the intersection status, the current movement state for the vehicle's intended movement through the intersection (based on the expected ingress and egress lanes), and when the current movement state is expected to change. Based on the position of the vehicle, the current kinematics (speed, heading,

	acceleration) of the vehicle, the current movement state for the intended movement, and when the time the movement state is expected to change, the RLVW application provides advisories, warnings, or alerts to the driver.
Need	This operational scenario leads to most of the needs described in Section 2.4.

2.6.2 Signal Timing Scenarios

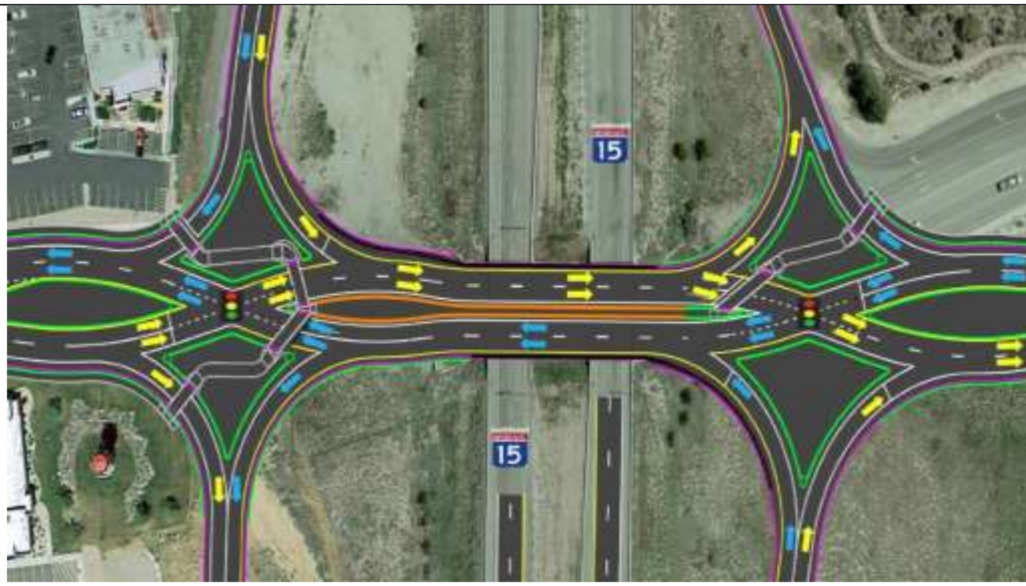
This section identifies common signal timing operations at a signalized intersection.

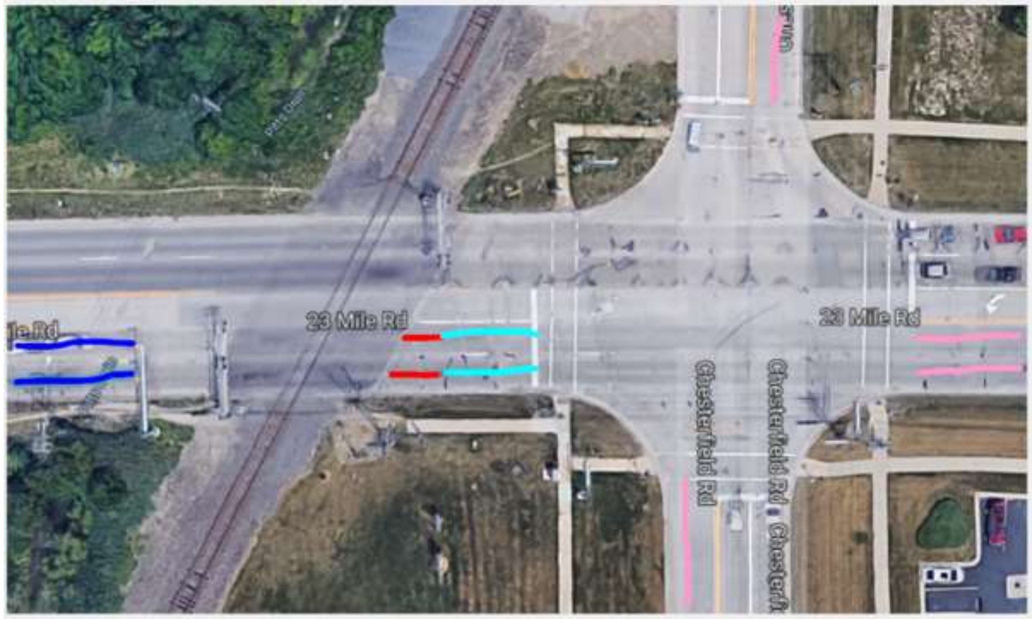
2.6.2.1 Rest in Green

Title	Rest in Green
Summary of Operations	The major street has a pre-defined green phase time. When this time is reached, the intersection transits to green “Rest Mode” where the major street continues in green operation until either a pedestrian actuation, a cross-street vehicle actuation, or an eventual timing out occurs. The connected intersection would either provide: • Time change details that indicates when the current green phase will change for certain; or • Time change details that indicates the minimum amount of time before the current green phase will change, if the time of change cannot be determined.
Need	There is a need to clarify exactly how the SPaT information is to be developed in conjunction with the confidence level (algorithm to be determined by task force) – for actuated operation including CIC/DSA and phase skipping.

2.6.2.2 Two or More Signals or Intersections with One Controller

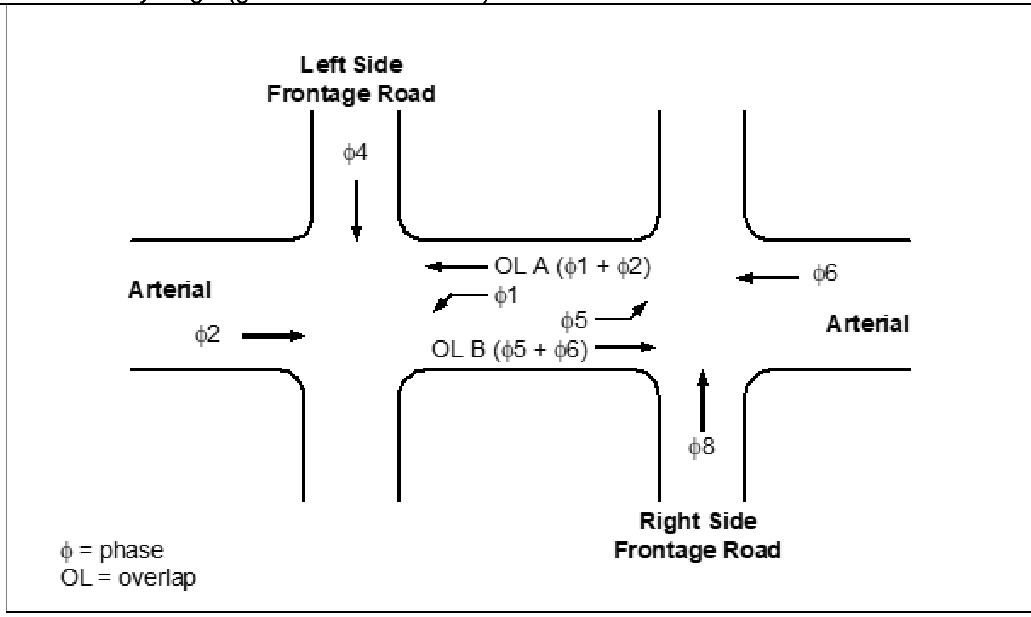
Title	Two or More Signals or Intersections with One Controller
Summary of Operations	This operational scenario addresses a single traffic signal controller used to control two or more intersections (usually closely spaced) or signalization of an advanced approach, driveway, or maneuver related to the main intersection. The geometry of these intersections creates some additional challenges in creating MAPs and signal groups because of distances, interior maneuvers, and additional stop bar locations. In each of these cases, SPaT and MAP must be communicated consistently and accurately to prevent a vehicle from stopping on a green signal indication or running a red signal indication. Examples of uses cases in this scenario are: 1) Two closely spaced intersection a) Texas Diamond b) Diverging Diamond 2) Box intersection (2 divided highways crossing or frontage road intersections at a 3-level diamond interchange) 3) Signalized driveway upstream of a signalized intersection driven by one controller to handle spillback 4) Railroad crossing upstream of a signalized intersection with stop bar and signal head in advance of crossing driven by one controller to handle spillback 5) Signalized crosswalk close to the intersection 6) Michigan Left-Turn where the U-turn is signalized 7) Signalized roundabout

Graphics	 

2.6.2.3 Texas Diamond Intersections

Title	Texas Diamond Intersections
Summary of Operations	Texas Diamond Intersections also commonly known as diamond interchanges function as an interface between a freeway and a surface street. Most Texas freeways are characterized by frontage roads. The Texas Diamond is the intersection of the frontage roads with a surface street. The two frontage roads on either side of the freeway form two intersections with the surface street. Figure 1 illustrates a simplified version of the phasing configuration of the Texas diamond interchange. The phasing is similar to the NEMA configuration of a typical intersection and is characterized by: • Phase 2 and Phase 6 are phases for arterial through movements similar to a typical intersection. • Phase 4 and Phase 8 are phases for frontage road movements similar to through movements on a cross street. • Phase 1 is a phase for an internal left turn movement that opposes Phase 2 and Phase 5 is a phase for an internal left turn movement that opposes Phase 6. • Overlap A (OL A) is an internal overlap that is ON when Phase 1 OR Phase 2 are ON. • Overlap B (OL B) is an internal overlap that is ON when Phase 5 OR Phase 6 are ON. While diamond interchange operations are primarily impacted by the spacing between the two intersections, traffic patterns also can influence the operational strategies. The operational philosophy is to optimize external demands while ensuring that the interior does not get backed up. A diamond interchange can be operated in three sequences when operating according to TxDOT Specifications. • Three phase - Three phase sequence is typically used when spacing between the two intersections is large (usually greater than 400 feet). The large spacing allows for storage of interior left turning vehicles that enter the interchange • Four phase - Four phase sequence is typically used when spacing between the two intersections is small (usually less than 400 feet). The small spacing requires a phasing sequence that ensures that no vehicles stop in the interior of the

	interchange. • Separate intersection mode - Separate intersection mode is usually applied when the spacing between the two intersections of a diamond interchange is very large (greater than 800 feet).
Graphics	
Needs	**SPaT Message Needs** Most diamond interchanges in Texas are operated using a single controller. Most of the phasing sequences uses typical phases which can potentially be translated to phase groups. These phases and phase groups are very similar to the phases and phase groups for a typical intersection. Hence it is possible for a diamond interchange to have a single SPaT message in spite of having two intersections. The SPaT data necessary to compile a SPaT message can be generated by the traffic signal controller. **MAP Message Needs** Texas Diamonds can vary in width. Due to constraints of DSRC range, larger number of approaches (six instead of four approaches at a typical intersection and size of the MAP message, it might be necessary to generate a separate MAP message for each side of the diamond interchange. These two MAP messages can then be broadcast using two separate RSUs located at each intersection. Each intersection will have a unique IntersectionID which can support in identifying which intersection the vehicle is approaching when a vehicle receives two MAP messages from two different RSUs.

2.6.2.4 Florida T Intersection

Title	Florida T Intersection
Summary of Operations	A Florida-T intersection's configuration is a step above a traditional T intersection. The Florida-T encourages safer operations by providing both deceleration and acceleration lanes for left turning vehicles. Florida-T intersections can also be signalized when needed to create adequate gaps in traffic for turn movements into and out of the T-leg of the intersection. Even with signalization, one direction of through traffic can continue through the intersection without stopping. Two examples are shown below; one with peds, one without. Each presents questions

<table>
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for the traffic controller issues TF on whether or not the current timing parameters account for these uncertainties/complications:
Summary of considerations for this scenario:

How does a phase resting indefinitely report min time, maxtime, and likely time? Is that what a driver expects?
Does an overlap that’s constantly bridging accurately report that it will bridge when it’s included phases are transitioning from one to the next?
How does a phase that’s resting indefinitely but can/will suddenly get terminated by a ped impact the timing and confidence reports?
In cases where a controller allows a “phase next” decision to be changed past the point of yellow clearance… If an overlap is bridging (say to go from 4 to 5 in the example above), but a late ped call arrives on ped 8 – the overlap will stop bridging and terminate. This brings up two considerations for SPaT timings;

The controller (if in coordination) will now transition, making confidence go down
The phase will take longer to get to than expected because the overlap trail yellow and red needs to be served beyond its included phase clearance since it started clearing late.

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<td>Graphics</td>
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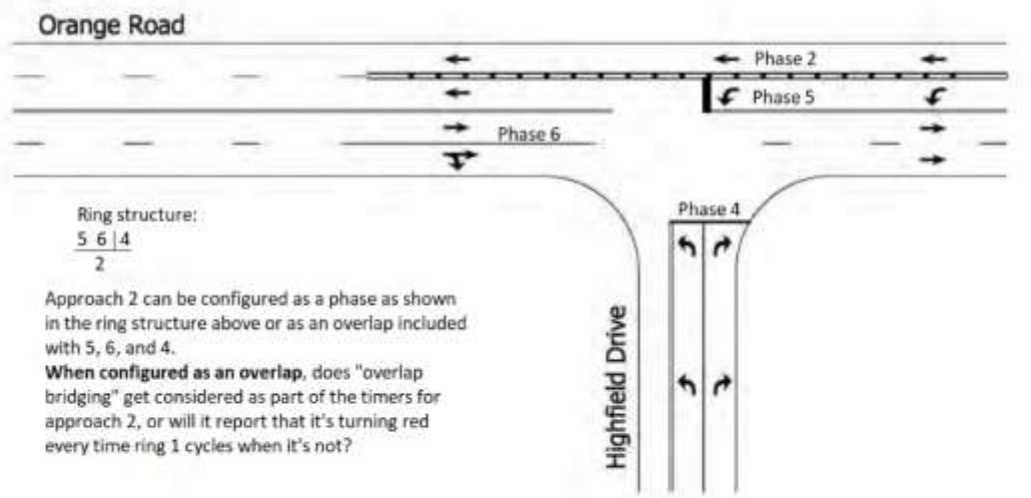

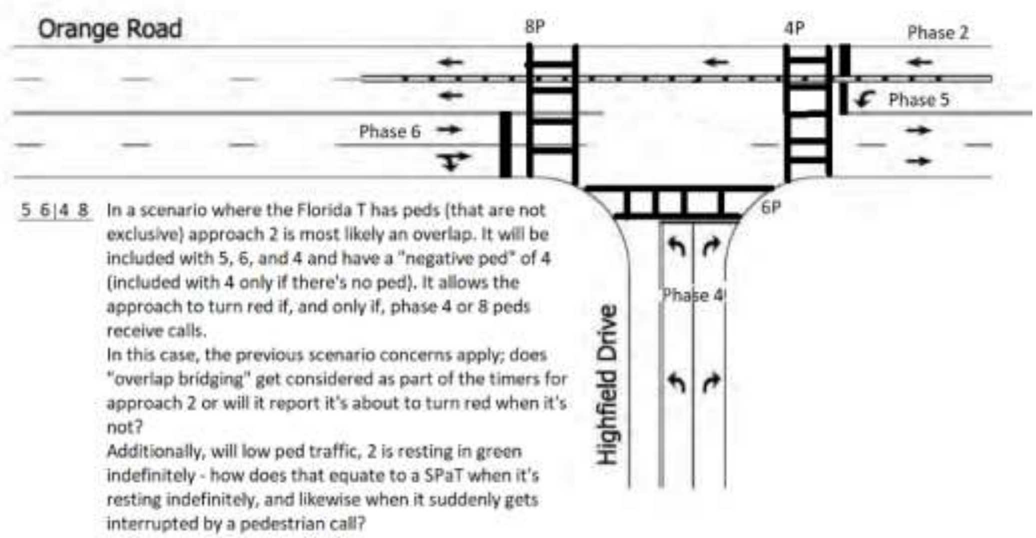

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2.6.2.5 User Logic - Outside the "knowledge" of the Controller

<table>
<tr><td>Title</td><td>User Logic - Outside the "knowledge" of the controller</td></tr>
<tr><td>Summary of Operations</td><td>Definition: outside the knowledge of the controller. This implies external manipulation of the actual phase timing and/or interval timing – which is not related to the internal timing algorithms of the traffic controller. These inputs may determine the specific phase timing or the termination of a phase rather than the internal traffic control logic/timers.

Examples of such external control “operations” might include:
• NEMA Control Commands
o Older ATMS supervisory control used the NEMA inputs such as HOLD, FORCE-OFF, (PHASE/PEDESTRIAN) OMIT. Central systems transmit these “commands” to the traffic controller which changes state based on receipt of the command – i.e. it terminates a phase (FORCE-OFF) or skips a phase (OMIT). The excerpt below is from NTCIP 1202:

5.2.5 Phase Control Table
. . .
5.2.5.4 Phase Hold Control
phaseControlGroupHold OBJECT-TYPE
SYNTAX INTEGER (0..255)
ACCESS read-write
STATUS mandatory
DESCRIPTION "<Definition> This object is used to allow a remote entity to hold phases in the device. When a bit = 1, the device shall activate the System Phase Hold control for that phase. When a bit = 0, the device shall not activate the System Phase Hold control for that phase.
Bit 7: Phase # = (phaseControlGroupNumber * 8)
Bit 6: Phase # = (phaseControlGroupNumber * 8) - 1
Bit 5: Phase # = (phaseControlGroupNumber * 8) - 2
Bit 4: Phase # = (phaseControlGroupNumber * 8) - 3
Bit 3: Phase # = (phaseControlGroupNumber * 8) - 4
Bit 2: Phase # = (phaseControlGroupNumber * 8) - 5
Bit 1: Phase # = (phaseControlGroupNumber * 8) - 6
Bit 0: Phase # = (phaseControlGroupNumber * 8) - 7
The device shall reset this object to ZERO when in BACKUP Mode. A write to this object shall reset the Backup timer to ZERO (see unitBackupTime).
<Object Identifier> 1.3.6.1.4.1.1.1206.4.2.1.1.5.1.4"
REFERENCE "NEMA TS 2 Clause 3.5.3.11.1"
::= { phaseControlGroupEntry 4 }

The controller should know that it is being remotely managed, and could convey this information, but it affects the time remaining in a green – a FORCE-OFF will terminate the current green and start the clearance process (amber and all-red) and then start the next phase with calls for service. It should be noted that a FORCE-OFF is not required to terminate the phase; the phase could time-out before the FORCE-OFF is received depending on demand. This is supervisory control.

Examples of the commands supported are listed in NTCIP 1202:</td></tr>
</table>

```
PhaseControlGroupEntry ::= SEQUENCE {
      phaseControlGroupNumber          INTEGER,
      phaseControlGroupPhaseOmitINTEGER,
      phaseControlGroupPedOmitINTEGER,
      phaseControlGroupHold            INTEGER,
      phaseControlGroupForceOff        INTEGER,
      phaseControlGroupVehCall         INTEGER,
      phaseControlGroupPedCall         INTEGER }
```

Those highlighted are actual controls – where the "calls" are simply placing a request on the phase.

- These same functions (e.g. HOLD, FORCE-OFF, PHASE/PEDESTRIAN OMIT) can also be activated using the cabinet wiring – and can be applied by such devices as local preemptors, local TSP management devices. Historically, many "customized" operations were handled using these external signals.
- "Local" pushbutton operation (police control), and time of day, or local operator implementation of cabinet flash. (Signals on-off and flashing.)

For the controls indicated above, the traffic controller is unlikely to have any indication of what is about to occur until the command is received or the input is activated.

COMMENT: It may be necessary to require some changes to the traffic control cabinet wiring or hardware to provide SPaT and MAP information. As others have noted, it is likely that anything less than an ATC (or equivalent) with modified software and/or hardware upgrades will be required to join the CV ECO system.

Comment: Either the controller or the RSU need to be made aware such conditions so that it can manage the "confidence" of the data being provided to the RSU.

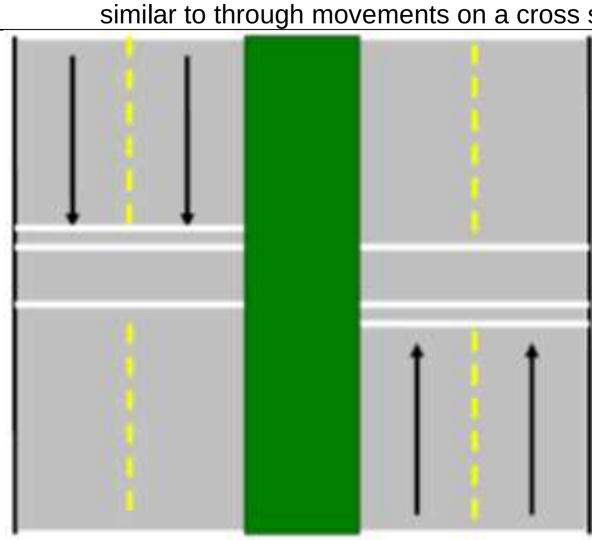
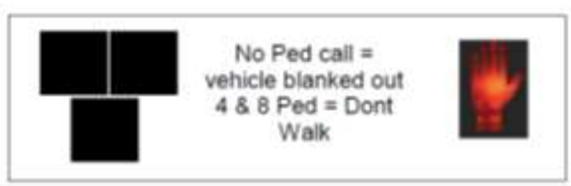
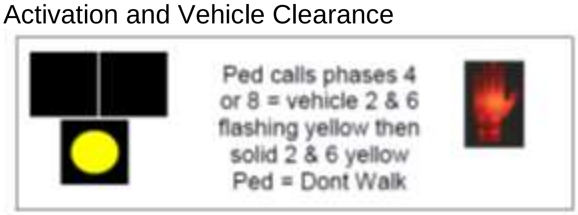
Notes:

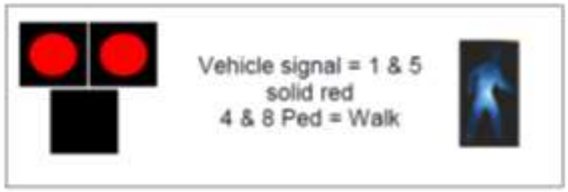
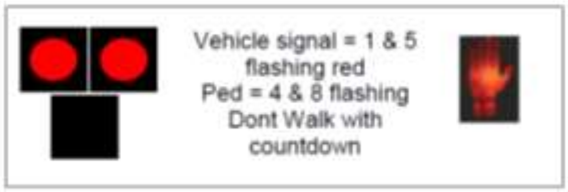
- If the central computer system issues supervisory control over the local controller through the NTCIP input signals (e.g. HOLD, FORCE-OFF, OMIT) there are other input/settings which may affect the operation of the controller.
- HOLD essentially "freezes" the traffic controller in its current state - phase hold – and the controller will stay in that display until the HOLD line is released – then if there are calls on successive phases, it will service those calls. However, without other calls, the fully actuated controller may simply remain in the phase until there is another call – or until the HOLD is reapplied.

I previously provided comments on the adaptive control using Dynamic Spit Assessment (DSA) and Critical Intersection Control (CIC). In these cases, the ATMS can dynamically change the split, cycle length, and even the offset causing transition. DSA simply adjusts the split time on a cycle by cycle basis – similar to critical intersection control based on demand in real time. When this change is "determined" or implemented determines the timing for the Next cycle. Some controllers may do this before the top of cycle, during the clearance, or during the initial portion of the phase. There probably needs to be some uniformity for this.

2.6.2.6 High-Intensity Activated Crosswalk Beacon (HAWK)

Title	High-Intensity Activated Crosswalk Beacon (HAWK)
Summary of Operations	A HAWK signal uses traditional traffic signal and pedestrian signal indications at crosswalks not located at the intersection of two roadways to assist pedestrian crossing a roadway. When not activate, the vehicle signal indications are blanked out (dark) and the crossing pedestrian signal indications display a solid "DON'T WALK." The HAWK becomes active when a pedestrian call is placed to the controller (either through a pedestrian pushbutton or a direct input from a pedestrian sensor). Upon receiving a call,

	the • The vehicle signals start flashing yellow for a user programmed interval. • After timing the activation interval, the vehicle signals transition to a solid yellow for specified interval, advising motorists to prepare to stop • After completing the transition interval, the vehicle traffic signals display a solid red. An optional “all-red” clearance interval is permitted. • After the optional clearance interval has expired, the pedestrian signal indication will display a solid “WALK” indication for a specified interval. • After the WALK signal expires, the overhead vehicle signal displays an alternating flashing red signal to indicate that motorists may proceed when safe (after coming to a full stop). Simultaneously, the pedestrian is shown a flashing DON’T WALK” with a countdown indicating the time left to cross. • Once the pedestrian clearance interval has expired, the vehicle signal will transition to dark and the pedestrian indication will display a solid DON’T WALK indication. The intersection will rest in this state until activated by another pedestrian. Phase 4 and Phase 8 are phases for frontage road movements similar to through movements on a cross street.
Graphics	 Typical Hawk Intersection diagram Initial State  Activation and Vehicle Clearance  Pedestrian Interval

	 Pedestrian Clearance 

2.6.2.7 Dynamic Lane Use

Title	Dynamic Lane Use
Summary of Operations	Issue: Infrastructure owners goals include maximizing available capacity and reducing delay for all users of the built environment. As such, infrastructure owners are continuously exploring opportunities to respond to user demand for finite capacity. For signalized intersections, infrastructure owners may consider options to dynamically adjust allowable lane movements by time of day to meet an operational objective. Example 1: One common practice includes reversible lanes, or flex lanes, where a center lane is used for one-way operation entering an urban area during morning peak periods, and a reverse one-way operation is allowed to exit the urban area in an evening peak period. At signalized intersections, allowable left turn movements will change to avoid conflicts, and often use blank out signs (lane control signals) to indicate to drivers the allowable movement. Signal heads may go dark for off peak direction where use is prohibited. Example 2: A more recent variation is the dynamic left turn intersection introduced in 2020 in North Carolina. In this configuration, the number of allowable left-turn lane movements vary by time of day operation. During peak periods when left turn demand is highest, dual left turn lanes are allowable as protected movements with signal heads displayed as green arrows as usual. In off peak periods when left turn demand is lower, only the inner (leftmost) left turn lane is an allowable movement that can be served as a permissive movement (e.g., flashing yellow arrow) or a protected one lane left turn movement to clear queued vehicles in the left turn lane. This allows mainline movement to be served more efficiently and reduce delay. Blank out signs may be used to inform drivers of allowable lane use.
Graphics	Reversible (flex lane) lane signal head transition at Route 173 (5400 S) and 2700 W in Taylorsville, Utah: Video: https://www.youtube.com/watch?v=xs1iix82hc4 Dynamic Left Turn Intersection at Tyron Road and Cary Parkway in Cary, North Carolina, US70 Business at Town Center Boulevard in Clayton, North Carolina: Graphic: https://www.ncdot.gov/news/press-releases/Documents/Dynamic%20left%20turn%20graphic%20higher%20res.pdf Video: https://www.youtube.com/watch?v=Km-cz8rkLK4&feature=youtu.be

2.7 Relationship to the ITS National Architecture [Informative]

This section describes which portions of the Architecture Reference for Cooperative and Intelligent Transportation, known as ARC-IT, are addressed by this CI Implementation Guide. Three service packages in the ITS National Architecture fall into scope: TM04 Connected Vehicle Traffic Signal System, VS12 Pedestrian and Cyclist Safety, and SU05 Location and Time. Figure 3 shows the key interfaces from these three service packages and the flows of information that is exchanged among the Physical Objects that are within the scope of this CI Implementation Guide. Refer to Figure 2 to identify which of these interfaces are addressed by the CI Implementation Guide. A Physical Object is a system or device that provides ITS functionality as part of ITS.

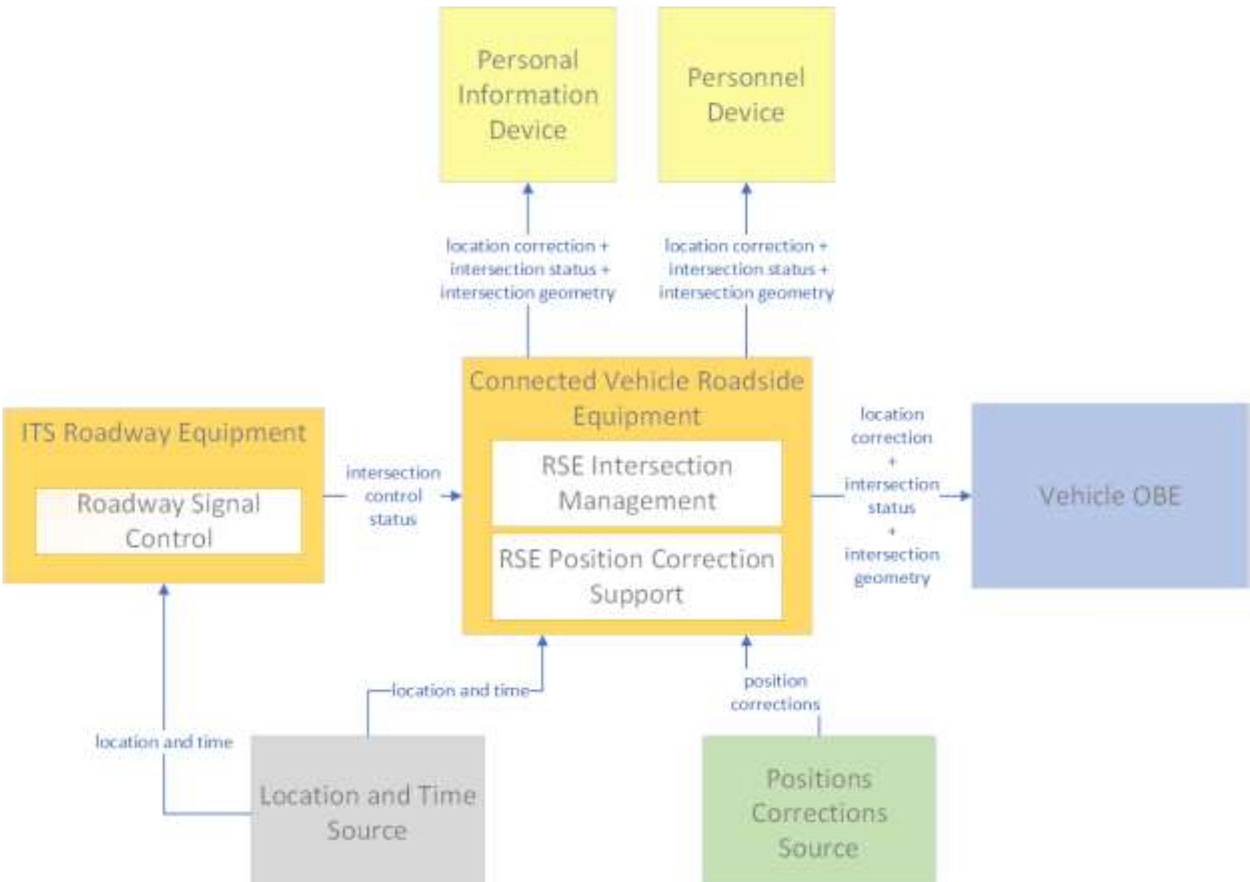


Figure 3. ARC-IT Physical View

The Physical View of ARC-IT also defines the functions in each Physical Object, which are called Functional Objects (FO). The FOs that provide the functionality from the three service packages are described below.

- **Roadway Signal Control.** This FO includes the field elements that monitor and control signalized intersections. It includes the traffic signal controllers, detectors, conflict monitors, signal heads, and other ancillary equipment that supports traffic signal control. It also includes field masters, and equipment that supports communications with a central monitoring and/or control system, as applicable. The communications link supports upload and download of signal timings and other parameters and reporting of current intersection status. It represents the field equipment used in all levels of traffic signal control from basic actuated systems that operate on fixed timing plans through adaptive systems. It also supports all signalized intersection configurations, including those that accommodate pedestrians.

- **RSE Intersection Management.** This FO manages uses short range communications to support connected vehicle applications that manage signalized intersections. It communicates with approaching vehicles and ITS infrastructure (e.g., the traffic signal controller) to enhance traffic signal operations.
- **RSE Position Correction Support.** This FO broadcasts differential positioning data to enable precise locations to be determined by passing vehicles, supporting Connected Vehicle applications that require highly accurate positioning.

2.8 Testing and Conformity Verification Management

This section contains a framework for the testing that must be provided to verify that an implementation conforms to the CI Implementation Guide. This framework can be used to create a Verification Plan for the CI Implementation Guide, which will be described in more detail in later sections. Test Framework elements are described in the sections below.

2.8.1 Testing and Conformance

This section identifies needs to support testing that an implementation conforms to the CI Implementation Guide.

2.8.1.1 Conformance Statement

The CI test methodology needs to verify that a CI conforms with the CI Implementation Guide.

To claim conformance with this CI Implementation Guide, an implementation shall satisfy the mandatory and selected optional requirements as identified in the Needs to Requirements Traceability Matrix (NRTM).

Note: The following is added to clarify the conformance statement in lieu of a NRTM. The details below capture thoughts related to future requirements and design being developed in other groups.

a) Conformance with J2735 data dictionary message structure
b) Conformance with J2735 data dictionary message data element value specified limits (e.g., value ranges, string lengths, enumerated list values)
c) Conformance as defined in the CI Implementation Guide for optional usage of message construction (e.g. map node point offset represented as a 32 bit XY offset)
d) Conformance with the required (mandatory) data elements as per the CI Implementation Guide
e) Conformance with data and reference integrity with SPaT and MAP messages. For example:
    a. Intersection ID in SPaT and MAP represent the same intersection
    b. minEndTime in SPaT correlates with signal intervals

2.8.1.2 Conformance Definitions

This section identifies terms relevant to conformance needs for a connected intersection.

2.8.1.2.1 Conformance

Conformance is how well something, such as a product, service or a system, meets the CI Implementation Guide.

2.8.1.2.2 Conformance Testing

Conformance testing is testing to determine whether a product or system meets the CI Implementation Guide.

2.8.1.2.3 Interface

The IEEE Std 610™, IEEE Standard Glossary of Software Engineering Terminology, defines an interface as a shared boundary across which information is passed [IEEE Std 610, p. 41].

The specification of this boundary, the system interface, is the focus of testing in this CI Implementation Guide. Testing of a system only through stimulus and response via interfaces is generally referred to as "Black box testing".

2.8.1.2.4 Interoperability

Interoperability is defined as the ability of two or more systems or components to exchange information and to use the information that has been exchanged [IEEE Std 610, p. 42].

The purpose of interface testing as described in this CI Implementation Guide is to achieve interoperability between a CI and an OBU, and between a CI and a MU.

2.8.1.2.5 Interchangeability

Interchangeability reflects the capability to exchange devices of the same type on the same communications channel and have those devices interact with others devices of the same type using standards-based functions [NTCIP Guide, p. 2].

This definition is provided for discussion purposes as hardware interchangeability is out-of-scope, as described in Section 2.8.1.3.3, Clarifying Assumptions.

2.8.1.3 Testing and Conformance Scope Overview [Informative]

2.8.1.3.1 Testing and Conformance Scope Diagram

Figure 4, based on Figure 2. Connected Intersection, identifies the scoping elements for testing and conformance covered in this Implementation Guide.

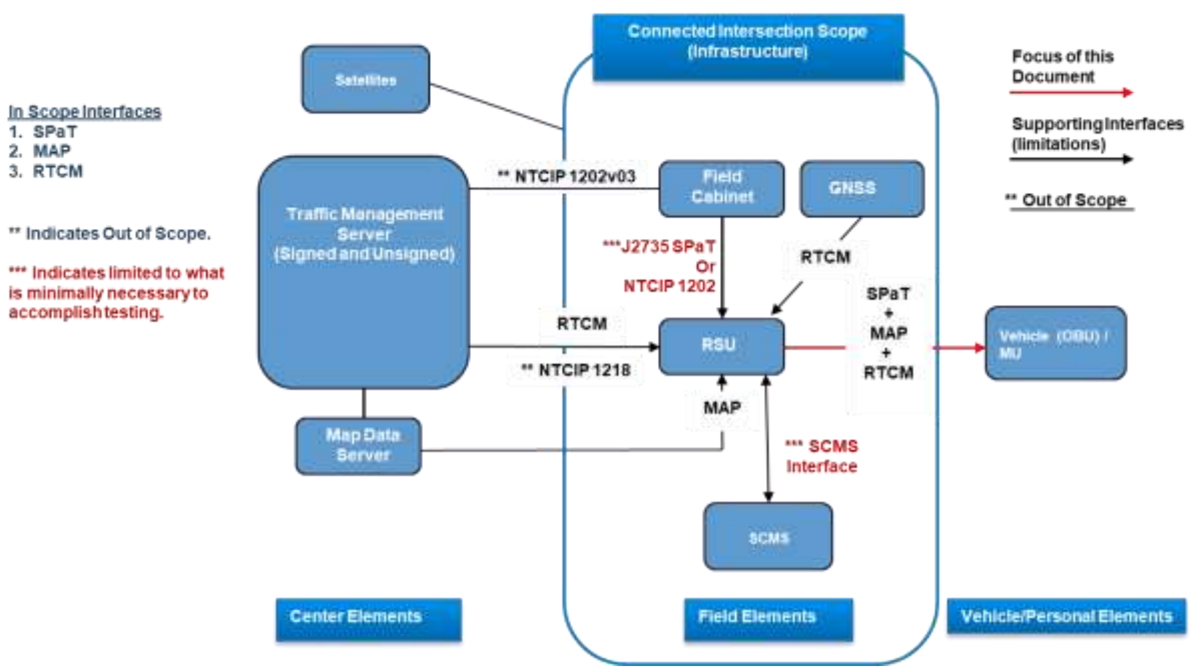


Figure 4. Testing and Conformity Scope Context Diagram

2.8.1.3.2 Testing and Conformance Scope Matrix

Table 1 below provides additional supporting detail related to testing and conformance scope.

Table 1. Testing and Conformance Scope Matrix

Scope Item	In-Scope (Yes/No/Limitations)
Internal Device Interfaces (OBU, RSU & Field Cabinet)	
Conformance	Yes (Limited to Messages / Data and Performance established by Standards)
Minimum Performance	RSU (Limitations/Broadcast)
Interoperability	Yes (Messages/Data Elements)
Hardware Interchangeability	Connections per RSU Standard
GNSS/GPS Accuracy	No
GNSS/GPS Elements	Yes (Messages/Data Elements)
RF & GNSS Interference	No
External Interfaces & Applications	
MAP Generation & its Realtime Accuracy	No
MAP Elements & its Usage Conformance	Yes (Messages/Data Elements)
MAP Security Profile	Yes (Messages/Data Elements)
SPAT Generation & its Realtime Accuracy	Yes (Limited to Comparison of Packet Data Captured)
SPAT Elements & its Usage Conformance	Yes (Messages/Data Elements)
SPAT Security Profile	Yes (Messages/Data Elements)
RTCM Generation & its Realtime Accuracy	No
RTCM Elements & its Usage Conformance	Yes (Messages/Data Elements)
RLVW Application Conformance	Yes (Messages/Data Elements)
RLVW Application Security	Yes (Messages/Data Elements)
RLVW Application Interoperability	Yes (Limited / Outbound Only)
RLVW Application Performance	No
SCMS Enrollment Process	No
SCMS Certificate Access	Yes
SCMS Device Loading	No
SCMS Transition (between expired and new certificates)	Yes (Limited)
Traffic Management Server	No
Transportation Field Cabinet / equipment	No
Other Interfaces	
NTCIP 1202 v03A	Limited (V2X subset)
NTCIP 1218 v01	No

2.8.1.3.3 Clarifying Assumptions

- Testing the security system is out of scope for this CI Implementation Guide. However, testing will be done with SCMS security in place.
- The SPaT data will be an output via an interface from a device in the Transportation Field Cabinet to the RSU and that is a test point. The second test point is the SPaT message output from the RSU.
- The source of the MAP data is from a Map Data Server and may be exchanged with a device in the Transportation Field Cabinet or the Traffic Management System. The MAP data (possibly in the form of a MAP message) is then sent to the RSU and broadcast.
- The High Precision Positioning/Timing Source (HPP/TS) is typically contained within an RSU. However, the GNSS signal comes from the external environment (e.g., satellite).

- The RSU is capable of using Immediate Forwarding and Store and Repeat functions
- The TMS interacts directly with the RSU and/or through the Transportation Field Cabinet.
- Pedestrians activate crosswalks manually at intersections.

2.8.1.3.4 Testing and Conformance Objectives: Operational Verification and Conformance

- **SPaT/MAP.** Verify SPaT / MAP broadcast through over-the-air capture of data. While verification at the OBU/MU is outside the scope of this CI Implementation Guide, a data sniffer may be used an alternative.
- **High Precision Positioning/Timing Source.** Verify Time and Location data provided from Satellites (Live) or from a Network at the RSU.
- **RSU.** Verify that the RSU transmits SPAT / MAP / RTCM messages. Receiver locations are unknown. Verification is achieved by over-the-air captures (i.e., verification of the captured data).
- **Vehicle (OBU).** Verify an OBU receives SPAT / MAP / RTCM Messages. While verification from the OBU is outside the scope of this CI Implementation Guide, a data sniffer may be used an alternative.
- **Pedestrians (MU).** While verification from the MU is outside the scope of this CI Implementation Guide, a data sniffer may be used as an alternative.

2.8.1.4 Infrastructure Testing

The CI test methodology needs test procedures to ensure that the infrastructure provides data to the OBUs/MUs that conforms to the CI Implementation Guide.

2.8.1.4.1 Validate Message Data Needs

The CI test methodology needs to test/verify that a CI provides message data to the OBU/MU that conforms to the CI Implementation Guide. The message data needs are documented in Section 2.4.2, Messages.

2.8.1.4.2 Reference Integrity Message Data Needs

The CI test methodology needs to test/verify referential integrity of CI message data that conforms to the CI Implementation Guide. For example, the intersection identifier for an intersection contained as part of the Signal Timing (SPaT) data must match the intersection identifier contained in a Road Geometry (MAP) for the intersection. Note: This may be a gap in the data content.

2.8.2 Test Methodology

The CI test methodology needs to describe the methods and approach to testing.

2.8.2.1 Test Methodology Concepts

Figure 5 illustrates a high-level concept for test execution and is an illustration of the contents presented in Table 1.

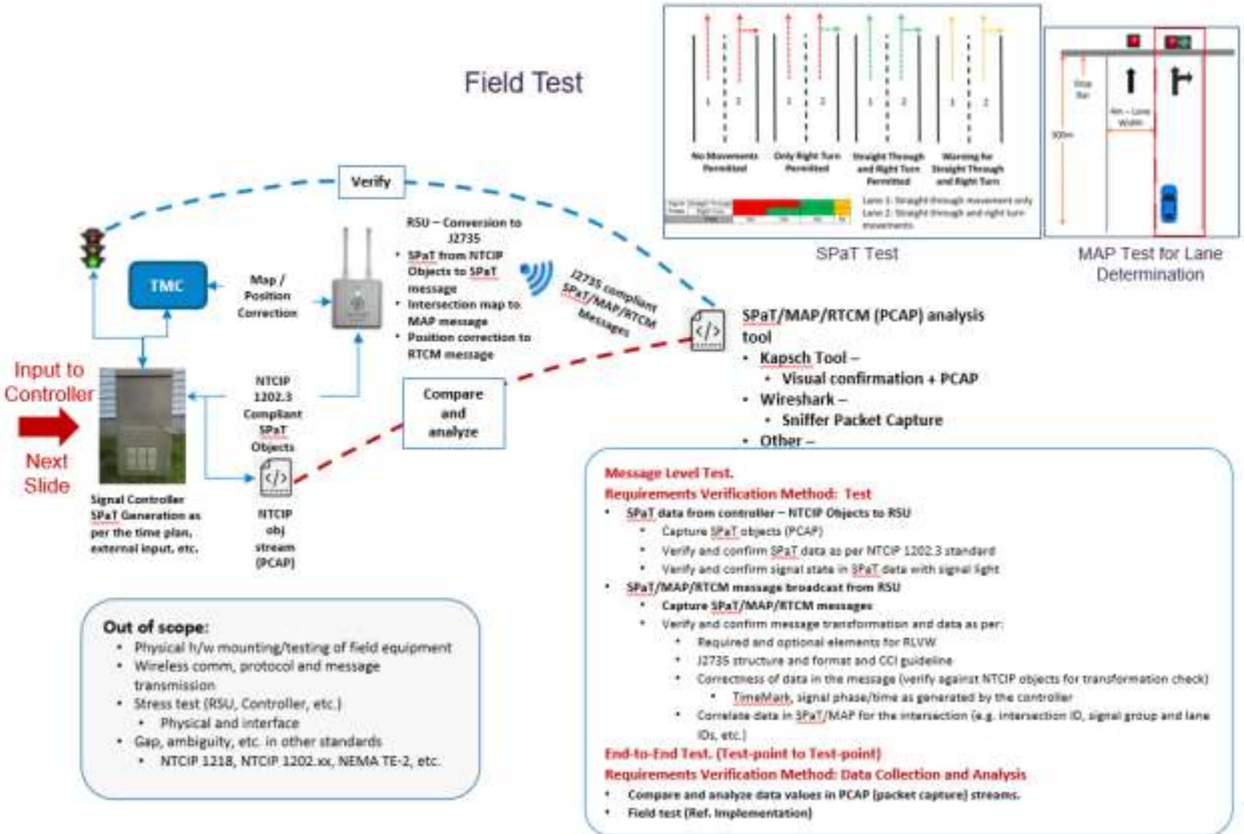


Figure 5. Test Methodology Concepts

2.8.2.2 Test Environment

The CI test methodology needs to describe the test environment to provide a basis for comprehensive and consistent testing.

Figure 6 below provides additional detail regarding test environment elements related to SPaT testing.

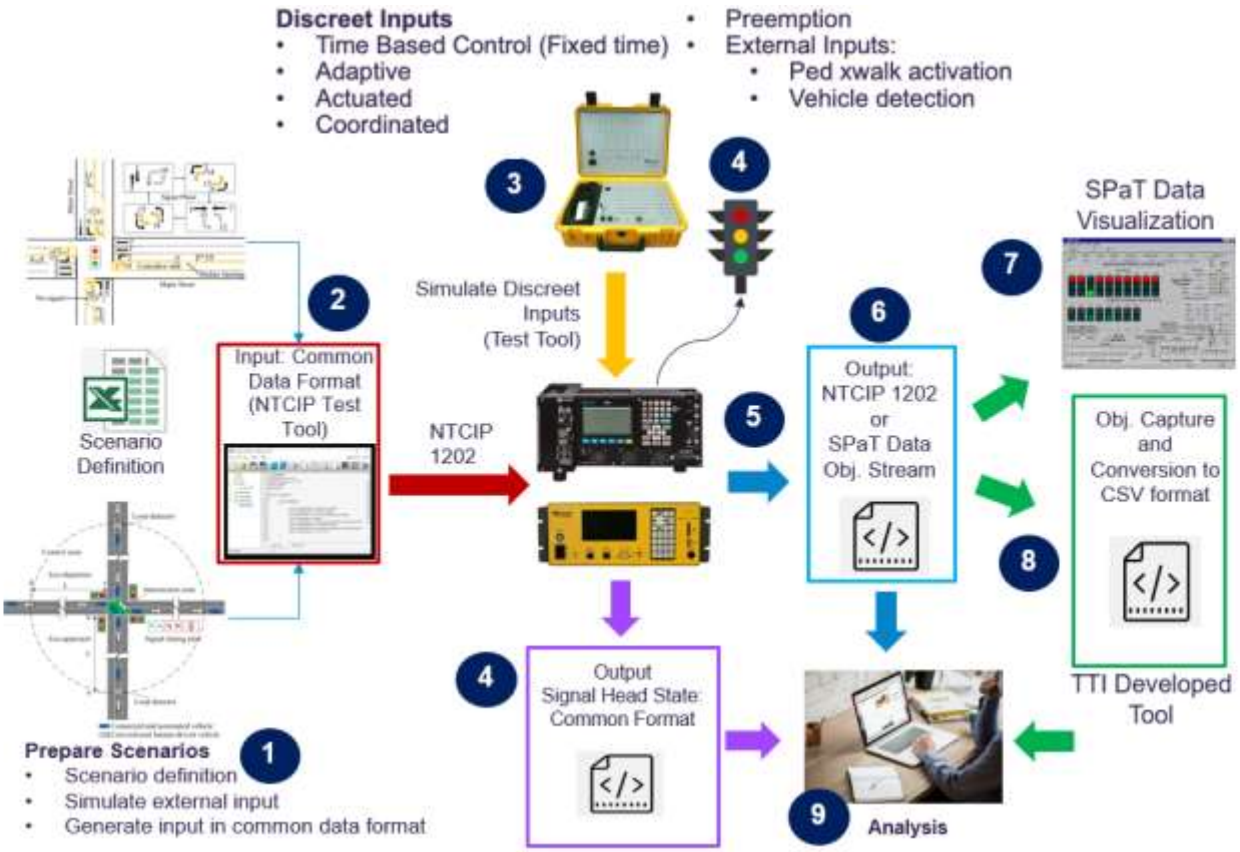


Figure 6. Example Test Environment for SPaT Testing

The numbers reflect potential steps to be described in a test procedure. A high-level example is shown below.

1. Prepare operational test scenarios.
2. NTCIP Test tool test input (operational scenario) to Controller (e.g. From Laptop).
3. Test tool (e.g., suitcase tester) generates discreet inputs to Controller. E.g. Pedestrian crosswalk activation, vehicle detection
4. Controller output to Signal Head and to a file (CSV format).
5. Simultaneous with Step 4, Controller outputs NTCIP 1202 v03 (SPaT Data) for RSU.
6. Controller outputs from Step 5 are captured in a PCAP File.
7. Simultaneous with Step 6, a Visualization Tool shows Signal State and Controller Output destined for RSU.
8. Test tool (e.g., TTI Test Tool) converts byte-oriented SPaT data or NTCIP 1202 v03 packets to a CSV file.
9. The output data captures from Controller are time synchronized to verify controller outputs are correct for a given set of initial inputs defined in steps 1, 2, and 3.

2.8.3 Message Level Testing

The CI test methodology needs to describe methods to test/verify the data format, data structure, and values of data content in messages.

2.8.3.1 Positive Testing

The CI test methodology needs to describe methods to test/verify positive outcomes/results when correct inputs are provided to the CI.

2.8.3.2 Negative Testing

The CI test methodology needs to describe methods to test/verify correct error handling when negative (incorrect) inputs are provided to the CI.

2.8.3.3 Boundary Testing

The CI test methodology needs to describe methods to test/verify correct error handling for boundary conditions (values) inputs are provided to the CI.

2.8.3.4 Packet Capture Analysis-based Testing

The CI test methodology needs to describe methods of data collection for analysis-based testing.

2.8.3.5 Field Environment Analysis

The CI test methodology needs to describe methods of data collection for analysis in field environments. For example, the SPaT matches the signal indication, and that the MAP represents the proper lane geometrics for lane determination.

2.8.3.6 Load and Stress Testing

The CI test methodology needs to describe methods of data collection for load and stress testing for both laboratory and field conditions.

2.8.4 Test Documentation

The CI test methodology needs to develop test documentation to guide comprehensive testing.

Test documentation, as described in IEEE Std 829 IEEE Standard for Software and System Test Documentation, include the following:

- **Test Planning.**
    - **Test Plan.** Provides the requirements to be tested, test environment, staffing needs, agency resources, schedule, and test tools.
- **Requirements Verification.**
    - **Test Cases.** Provides the inputs to and outputs from the software or software-based system being tested to verify a requirement.
    - **Test Procedures.** Provide test steps required to execute each test case.
- **Test Execution.**
    - **Test Logs.** Provide a chronological record of relevant details about the execution of tests.
    - **Test Anomaly Reports.** Provide documentation of any event that occurs during the testing process that requires investigation.
- **Conformance Summary.**
    - **Test Summary Report.** Provides a summary of major testing activities, events, and results of testing, identifies anomalies and resolution status (resolved/unresolved), and relevant metrics collected.

Figure 7 below illustrates the relationships of the various test documentation described above.

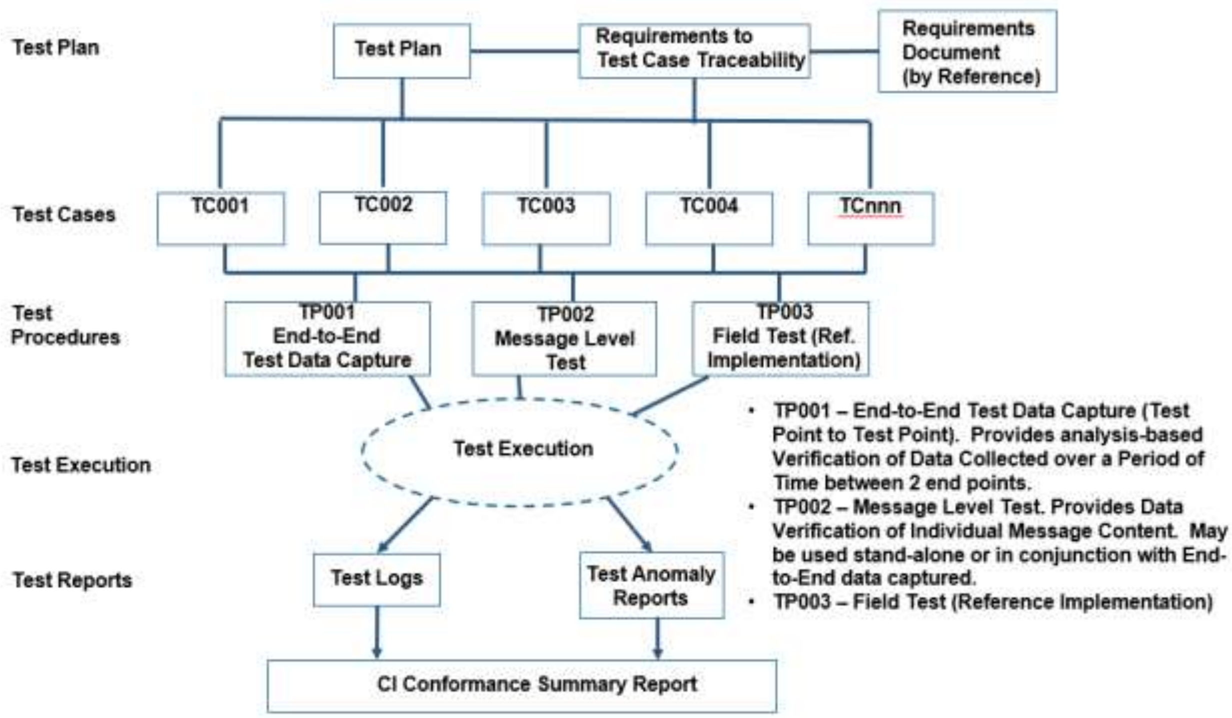


Figure 7. Test Documentation Relationships

2.8.5 Requirements Verification Methods

The CI test methodology needs to describe the methods of requirements verification. It is generally accepted that there are 4 methods of requirements verification:

- **Inspection.** Examination of the system using one of your five senses. This test method is used for verification through a visual comparison that the requirement has been satisfied. For example, the Vendor shall provide training on the troubleshooting of the system, including local intersection and central portions.
- **Demonstration.** Manipulation of the system to verify that the results are as planned or expected. This test method is used for a requirement that the system can demonstrate without external test equipment.
- **Analysis.** Verification of system using models, calculations and testing equipment. This test method is used for a requirement that is fulfilled indirectly through a logical conclusion or mathematical analysis of a result. For example, algorithms for congestion: the designer may need to show that the requirement is met through the analysis of count and occupancy calculations in software or firmware.
- **Test.** Verification of system using a controlled and predefined series of inputs to ensure specific and predefined outputs are produced. This test method is used for a requirement that requires some external piece of test equipment (such as logic analyzer or voltmeter).

2.8.6 Test Cases

The CI test methodology needs to describe test cases that define the test inputs and expected outcomes to verify one or more requirements.

2.8.7 Test Coverage

The CI test methodology needs to verify that testing provides coverage of all stated requirements.

Note: This may be done by verifying that test cases are developed for each requirement, at least once. Typically, a test case to requirements traceability matrix is used to assist with test coverage assessment.

2.8.8 Test Procedures

The CI test methodology needs a consistent set of procedures for executing test cases.

2.8.9 Identify Existing Test Documentation

The CI test methodology needs to gather information regarding available test documentation applicable to testing of connected intersections.

2.8.10 Identify Existing Test Tools

The CI test methodology needs to gather information regarding available test tools and which CI interfaces are covered by the test tools.

2.8.11 Configuration and Change Management Needs

The CI test methodology needs to perform testing when changes are made to the CI. These changes may include:

- CI Configuration Changes: software, firmware, hardware changes
- Changes in Standards: SAE J2735 version (2009, 2016, 2020)
- Message element table: Mandatory Elements, Optionals made Mandatory
- Controller Parameters: E.g., Timing plans

Annex A - User Requests

This annex identifies needs and requirements that were identified and considered by the CI Committee or its task forces for this CI Implementation Guide, but were not included. The rationale on why these needs and requirements were not included is also provided. This section is included for consideration for future editions of the CI Implementation Guide.

A.1 Needs

This sub-section identifies user needs that were identified and considered by the CI Committee or its task forces.

A.1.1 Mobility Applications

The CI Committee did not consider user needs for mobility applications for this version of the CI Implementation Guide. As stated in Section 2.3, only user needs to support the RLVW application were considered due to time and resource constraints. Other needs to support SPaT-based and MAP-based safety applications were considered if that were considered relatively easy to implement and can be completely defined within the project schedule are also included in this CI Implementation Guide.

A.1.2 Queue Information at an Intersection

The CI Committee considered a need to provide vehicle queue data at an intersection. This information is used by mobility applications such as an eco-driving application. However, additional infrastructure equipment, such as detectors, are needed by IOOs to provide more reliable data. The SPaT/MAP task force decided there was insufficient time to address this need at this time.

A.1.3 Indication of Pedestrians or Bicyclists in a Crosswalk

The CI Committee considered a need to provide the presence of pedestrians or bicyclists in a crosswalk at an intersection. While this information can be used by OBU applications for safety, additional infrastructure equipment, such as detectors, are needed by IOOs to provide data with a high level of confidence. The SPaT/MAP task force decided there was insufficient time to address this need at this time.

A.1.4 Signal Priority and Preemption

The CI Committee considered a need to provide the status of signal priority or preemption requests at an intersection. A need statement could read: "A connected intersection needs to provide information about current priority or preemption requests so an application can provide the proper warnings, information or guidance to the vehicle. The RLVW implementation should neither preclude SRM and SSM nor SPaT messages and signal timing changes based on these messages." The Committee decided that there was insufficient time to address this need at this time.

A.1.5 Advisory Speeds

The CI Committee considered a need to provide advisory speeds for a movement at an intersection so an application can provide appropriate information or guidance to a driver. This need would also partially satisfy the needs of eco-driving applications. However, the IOOs did not currently have enough experience from with field testing to define requirements and testing approaches.

A.1.6 Misbehavior Reporting by OBUs

The CI Committee considered a need, "A connected intersection needs to provide a mechanism to allow OBUs to report incorrect data from the infrastructure so that faulty CI messages do not compromise applications or user actions." However, the CI Committee agreed this need is out of scope at this time and could require a large amount of effort. The CI Committee also noted that an OBU can report that it sees a conflict between the message and what it sees (e.g., via an on-board camera), but this conflict is not addressed by any group/standard right now.

A.1.7 Misbehavior Reporting by IOO Field Devices

The CI Committee considered a need, "A connected intersection needs to provide a mechanism to allow IOO field devices to report incorrect data from the infrastructure so that faulty CI messages do not compromise applications or user actions." However, the CI Committee agreed this need is out of scope at this time and could require a large amount of effort. The CI Committee also noted this need is not addressed by any group/standard right now.

A.1.8 Levels of Testing

The CI Committee considered a need, "The CI test methodology needs to define Levels of Testing." However, the CI Committee agreed there was insufficient time to address this need at this time.

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