Infrastructure Connectivity Certification Test Procedures for Infrastructure-Based Connected Automated Vehicle Components

Signal Phase and Timing – NTCIP 1202 v03

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16. Abstract

The successful deployment and operation of connected vehicle systems will require that devices and applications developed by different providers are compatible, interoperable, non-interfering, and in some instances, perhaps, interchangeable. Some devices, systems, and applications, such as active safety applications, may be required to meet minimum operational performance standards. A list of questions was distributed to potential stakeholders to gather information on which aspects of the industry should be considered for certification. The results were compiled and consolidated into a list of recommendations that yielded three applications to be addressed under this project. This document contains test case procedures for one of the three applications.

The testing will address the certification needs of the signal phase and timing (SPaT) application within the confines of the NTCIP 1202 v03 standard, which handles the interface for communication of SPaT information between a signal controller and a management center. The scope for testing includes data objects contained in NTCIP 1202 v03 that are critical and required for constructing a SPaT message.

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List of Acronyms

ASC	actuated signal control
CAV	connected automated vehicle
CTL	certification test lab
CV2X	cellular vehicle-to-everything
DSRC	dedicated short-range communication
DUT	device under test
FHWA	Federal Highway Administration
GPS	global positioning system
HRDO	Office of Operations Research and Development
IP	internet protocol
ITS	intelligent transportations system
MIB	management information base
NTCIP	National Transportation Communications for Intelligent Transportation Systems Protocol
OID	object identifier
PC	personal computer
RSE	roadside equipment
RSU	roadside unit
SAE	Society of Automotive Engineers
SNMP	simple network management protocol
SPaT	signal phase and timing
UDP	user datagram protocol
USDOT	United States Department of Transportation
V2X	vehicle-to-everything

Test Case Procedures Approvals

Coordination and Approvals

Contributors

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Approver(s)

The signatures below constitute the approval of this plan.

Deb Curtis ***Project Manager***	***(Date)***	*(Name)* ***(Title)***	***(Date)***

Chapter 1. Introduction

Background

The United States Department of Transportation's (USDOT) connected vehicle program aims to improve safety, enhance mobility, and reduce the environmental footprint of our transportation systems through connected vehicle technology. In support of that goal, the Federal Highway Administration (FHWA) Office of Operations Research and Development (HRDO) performs transportation operations and research and development (R&D) at the Saxton Transportation Operations Laboratory (STOL), established at the Turner-Fairbank Highway Research Center (TFHRC).

Connected transportation systems use connected vehicle technology to link vehicles and mobile devices to each other, to transportation infrastructure, and to the larger communication infrastructure requiring trusted communications and interoperability. USDOT is assessing services and applications that realize the full potential of connected vehicles, travelers, and infrastructure to enhance current operational practices and transform future surface transportation systems. To realize this potential, connected vehicle equipment and applications must meet minimum performance requirements, conform to common technical standards, guidelines, and specifications, and interoperate with one another. Certification testing provides a formal means of verifying that a device, application, or service conforms to these requirements.

The successful deployment and operation of connected vehicle systems requires that devices, systems, and applications developed by different providers are compatible, interoperable, non-interfering, and in some instances, perhaps, interchangeable. Some devices, systems, and applications, such as active safety applications, may be required to meet minimum operational performance standards. A list of questions was distributed to potential stakeholders to gather information on which aspects of the industry should be considered for certification. The results were compiled and consolidated into a list of recommendations that yielded three applications to be addressed under this project. This document contains test case procedures for one of the three applications.

Test Scope

Testing will address the certification needs of the signal phase and timing (SPaT) application in the confines of the National Transportation Communications for Intelligent Transportation Systems Protocol (NTCIP) 1202 v03 standard, which handles the interface for communication of SPaT information between a signal controller and a management center. The testing scope includes data objects contained in NTCIP 1202 v03 that are critical and required for constructing a SPaT message, as defined in Society of Automotive Engineers (SAE) J2735.

Items and Features to Be Tested

Major NTCIP 1202 v03 functional areas that will be evaluated in this test plan are described below:

- Enable/disable SPaT data.

SPaT data should be enabled or disabled according to users' needs.

- SPaT timing.
    - System time.

A traffic signal controller's internal time is expected to be synchronized with a reliable time source (i.e., "disciplined time" in the NTCIP 1202 v03 text). It is very important to ensure the internal time of all components in a connected system is synchronized.

- SPaT data timestamp.

The generation time of SPaT data should be obtained.

- SPaT data critical elements.
  - Intersection identifier.

The intersection identifier is used to identify the intersection for which SPaT data are generated.

- Intersection status.

This item provides the status of the target intersection.

- Movement status.

This item contains the movement status for vehicles or pedestrians (if applicable).

- Movement minimum end times.

This item contains the minimum end time for each current vehicle or pedestrian (if applicable) movement.

- Movement maximum end times.

This item contains the maximum end time for each current vehicle or pedestrian (if applicable) movement.

- SPaT data performance.
  - SPaT maximum transmission start time.
  - Movement time point minimum transmission rate.
  - SPaT data request transmission rate.
  - SPaT event reporting latency.

A few performance measures of SPaT data are expected to be tested. The objective of testing performance measures is to verify that a traffic signal controller provides SPaT data in a timely manner, which is critical for every SPaT-based connected automated vehicle (CAV) application.

Analysis and Report Findings

The test conductors will analyze the test results and prepare a test report for each vendor and submit the report to the vendor. These reports provide guidance to vendors regarding implementations that either meet or partially meet the requirements evaluated as part of this test. These reports should not, in any way, serve as official approval, confirmation, or certification by the USDOT.

Upon request, the test conductors may also support briefings with the vendor to explain the results. The test conductors may also support information exchange and collaboration on the recommended next steps.

Test Objective

The objective of this document is to describe the process for certifying and evaluating implementations of NTCIP 1202 v03 SPaT objects. Only the features of NTCIP 1202 v03 that feed into creating the SAE J2735 SPaT message are considered. Certification will be used as a procurement tool for CAV device deployers.

Chapter 2. Test Environment

Tests will be conducted at a certification test laboratory (CTL), such as OmniAir and its affiliates.

Test Environment Requirements

To conduct tests outlined in this test plan, each test environment must have the following configuration and equipment:

- A power source appropriate to the device under test (DUT).
- Physical or virtual traffic signal controller(s) that are National Transportation Communications for Intelligent Transportation Systems Protocol (NTCIP) 1202 v03 compatible.
- A simple network management protocol (SNMP) browser.
- A software package that can monitor and collect data on the target communication layer (e.g., Wireshark). (Note: this document uses Wireshark as an example to illustrate test procedures. This does not indicate the authors endorse Wireshark.)
- A computer with vehicle-to-everything (V2X) decoder.
- An optional global positioning system (GPS) to provide location and system time. GPS can be provided by:
    - Access to the open sky.
    - A GPS repeater (license may be required).
    - A GPS simulator.

Qualification Criteria

A CTL is expected to have sufficient resources (e.g., equipment; personnel with related expertise) to complete all tests identified in this test plan.

Chapter 3. Test Schedule, Personnel, and Documentation

This section contains a high-level test schedule, required personnel to execute tests, and a description of several documents that should be used to record test activities and results.

Test Schedule

Table 1 lists the anticipated activities of the evaluation process after a device is admitted to the certification testing process. These activities are required for each vendor under the test.

Table 1. Test activities.

ID	Activity	Estimated Duration
1	Initial hardware inspection	1 day
2	Initial configuration to operate in the applicable test environment	1 day
3	Full evaluation	2 weeks
4	Document results and submit a final report	1 week

Personnel

The required number and qualifications of staff to complete testing activities will depend on the organization. Table 2 lists the staff anticipated to complete the activities in the estimated duration shown in table 1.

Table 2. Test personnel.

Title	Minimum Number
Test director/manager	1
Test conductor	1
Test operator	1–2
Roadside equipment technology expert	1
Vendor representative	1 per vendor
Test observers	As desired

Test Director (Quality Assurance Manager)

The test director supervises and controls all tests; reviews and approves test procedures; has authority to direct test activities; and is responsible for communicating test status to all stakeholders. The test director notifies key stakeholders of the test schedule in advance of the scheduled start.

Test Conductor

The test conductor is responsible for running daily test activities and remains in contact with vendors, as needed, to communicate which tests are being run and receive support input during testing. The test conductor distributes test scripts, forms, and other pertinent information, and answers questions.

Throughout the test day, the test conductor verifies that entrance criteria have been met for each test run, verifies readiness of test participants and equipment, and announces the start and end of each testing period. The test conductor also ensures other participants execute tests according to procedures. At all times, the test conductor is responsible for judging how to proceed if incidents or exceptions occur and canceling and rescheduling tests in the event a failure prevents a test from being executed.

At the end of the test period, the test conductor writes up the results of various completed test runs and incidents or exceptions that occurred. The status report is emailed to relevant stakeholders.

Test Operator

The test operator defines and executes test procedures to evaluate each device and records the outputs and overall results of each test.

Roadside Equipment Technology Expert

The technology expert has extensive knowledge of the technology under test. This includes use cases, underlying and enabling technologies, communication protocols; data transfer mechanism(s), and security. The technology expert advises the test conductor, as needed.

Vendor Representative

The vendor representative supports the test conductors and test operators during all testing phases, as required. Support is provided in person or remotely. A representative of the vendor of each device being certified should be involved in the testing.

Test Observers

Test observers witness test runs at the certification test lab's (CTL) discretion.

Note: Some roles can be combined such that a single person assumes up to two roles (i.e., the test conductor can also be the test operator).

Documentation

Test Records

Specific test information, including test environment, test execution, and attendees/participants/observers, are captured for each test. Each requirement evaluated will be marked with a P or an F, indicating success (pass) or failure (fail). All failures, work-arounds, and deviations from procedure are recorded in a comments section of the form. These entries are entered electronically during testing.

Risks and Mitigation

Risks include product risks and project risks. Product risks include flaws in the content or structure of a message due to misunderstandings or errors in implementation; these may be expected since the standard is newly released. These risks may be mitigated by accepting from reputable manufacturers devices whose primary functionalities have gone through other qualification testing or have been used in the field. Project risks include a lack of trained staff due to new and evolving test tools, rigid deadlines, and changing industry standards and requirements. Again, since the standard is newly released, traffic signal control vendors need time to fully implement this standard, which may affect the availability of devices to test. This may be mitigated by the fact that vendors have been aware of the upcoming standard for several years, which may speed implementation.

Chapter 4. Test Case Procedures

This section contains information about individual test case procedures, which are used to certify and evaluate if a traffic signal controller can provide necessary National Transportation Communications for Intelligent Transportation Systems Protocol (NTCIP) 1202 v03 SPaT objects for target signal phase and timing (SPaT) applications.

General Test Environment Setup

Chapter 2 presented the minimum device requirements for executing the below test cases. Figure 1 shows a general test environment setup. Device under test (DUT) can be any physical or virtual device that provides SPaT data according to the NTCIP 1202 v03 standard. A personal computer (PC) is needed to conduct all test cases. A user-preferred simple network management protocol (SNMP) browser is expected to be installed on this PC.

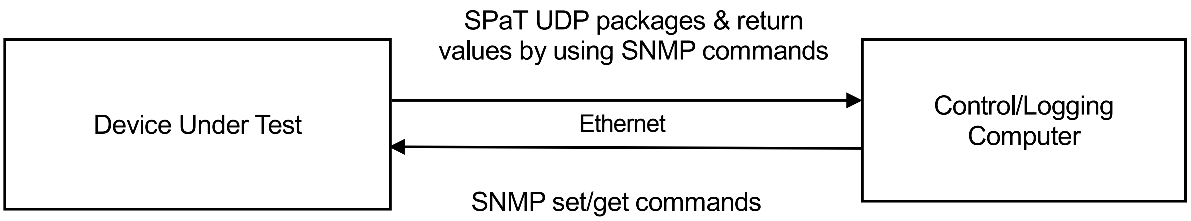

Figure 1. Test environment setup.

Source: *Federal Highway Administration*

The following steps are necessary to configure the DUT and logging computer before conducting test cases described in this document. The steps should be altered, as necessary, by the device manufacturer:

- Configure DUT.
    - Power on DUT.
    - Configure desirable traffic signal timing plans.
    - Configure the preferred internet protocol (IP) address for DUT. (Note: IP addresses of DUT and logging computer need to be within the same subnet.)
    - Configure the destination IP address of the SPaT user datagram protocol (UDP) package as the IP address of the logging computer.
- Configure control/logging computer.
    - Power on the computer.
    - Configure the desired SNMP browser and load the NTCIP 1202 v03 management information bases (MIB).
    - Configure a software package that can monitor and collect data on the target communication layer (e.g., Wireshark).

- Configure time source.
  - Ensure the DUT and the control/logging device are synchronized using a common time source. This may be done by synchronizing one with the other, or by synchronizing to a third source, such as a global positioning system (GPS).

After configuring the DUT and computer, these two devices must be connected within a subnet by using an Ethernet cable or a network switch. The test operator needs to ensure the communication between the two devices is set up.

Enable/Disable Signal Phase and Timing Data

Test cases in this section evaluate if a traffic signal controller can start and stop generating SPaT data.

Table 3. Enable/disable signal phase and timing data.

Test Case #	**STATUS-01**
Test Case	**Enable/Disable SPaT Data**
Reference	*NTCIP 1202 v03 (December 2018): Section 5.17.4*
Objective	Verify that users can enable and disable the generation of SPaT data from a traffic signal controller
Entrance Criteria	The traffic signal controller under test complies with NTCIP 1202 v03
Data Inputs	SNMP commands generated by a user
Data Outputs	The traffic signal controller under test generates or stops generating SPaT data, according to the user's configuration
Exit Criteria	Users can successfully enable and disable the generation of SPaT data from a traffic signal controller
Test Procedures	It is assumed the SPaT message is disabled by default. If the assumption is not true, the test operator should conduct test 2 first. Test 1 (enable SPaT): • The test conductor uses Wireshark to monitor communication between traffic signal controller and PC to verify the SPaT function is disabled (i.e., no SPaT UDP package exists). If not, conduct test 2 first. • The test conductor uses the SNMP set function to enable SPaT messages (OID: 1.3.6.1.4.1.1.1206.4.2.1.16.4; value: 1). Then, using Wireshark, the test conductor should be able to find SPaT UDP packages are sent from controller to PC. Test 2 (disable SPaT): • The test conductor uses Wireshark to monitor communication between traffic signal controller and PC to verify the SPaT function is enabled (i.e., find SPaT UDP packages are sent from controller to PC). • The test conductor uses the SNMP set function to disable SPaT messages (OID: 1.3.6.1.4.1.1.1206.4.2.1.16.4; value: 0). Then, using Wireshark, the test conductor should be able to find the controller stopped sending SPaT UDP packages to PC.

Test Case #	**STATUS-01**
Test Case	**Enable/Disable SPaT Data**
	This test is passed when both test 1 and test 2 are passed.

Signal Phase and Timing Message Timing

System Time

The test cases in this section evaluate timing source requirements of a traffic signal controller.

Table 4. Maximum number of time sources.

Test Case #	**TIMING-01**
Test Case	**Maximum Number of Time Sources**
Reference	*NTCIP 1202 v03 (December 2018): Section 5.4.22.1*
Objective	Verify that a traffic signal controller supports at least a one-time source
Entrance Criteria	The traffic signal controller under test complies with NTCIP 1202 v03
Data Inputs	SNMP commands generated by a user
Data Outputs	Notes from the test conductor indicating the maximum number of time sources the traffic signal controller under test could support
Exit Criteria	At least one suitable time source is identified that the traffic signal controller under test could support
Test Procedures	• The test operator uses the get function of an SNMP browser with OID 1.3.6.1.4.1.1.1206.4.2.1.3.22.1 to obtain the maximum number of time sources the traffic signal controller under test could support. • The test operator verifies the returned value is not less than 1. Otherwise, this test is failed.

Table 5. Select traffic signal controller time source.

Test Case #	**TIMING-02**
Test Case	**Select Traffic Signal Controller Time Source**
Reference	*NTCIP 1202 v03 (December 2018):Section 5.4.22.3*
Objective	Verify that users can select suitable time source(s) for a traffic signal controller
Entrance Criteria	The traffic signal controller under test complies with NTCIP 1202 v03
Data Inputs	SNMP commands generated by the user to select suitable time sources (i.e., lineSync, rtcSqwr, crystal, gnss, ntp)

Test Case #	TIMING-02
Test Case	**Select Traffic Signal Controller Time Source**
Data Outputs	SNMP reply indicating the traffic signal controller under test's time source(s) is selected according to the user's choice
Exit Criteria	Users could configure a traffic signal controller's time sources
Test Procedures	• The test operator uses the set function of an SNMP browser with OID 1.3.6.1.4.1.1.1206.4.2.1.3.22.3 to set the desired time source for the traffic signal controller under test. The value for different time sources are: o 1: other o 2: lineSync o 3: rtcSqwr o 4: crystal o 5: gnss o 6: ntp • The test operator uses the get function of an SNMP browser with OID 1.3.6.1.4.1.1.1206.4.2.1.3.22.3 to verify the desired time source for the traffic signal controller under test is selected. The two steps above are repeated six times to verify all possible time sources could be selected. This test is failed if any of them could not be set. • In addition, the test operator also uses the set function of an SNMP browser with OID 1.3.6.1.4.1.1.1206.4.2.1.3.22.3 to set the invalid value to see if the traffic signal controller under test accepts these values. For example: o -1 o 0 o 7 This test is also failed if the traffic signal controller under test accepts these values.

Table 6. Traffic signal controller time source status.

Test Case #	TIMING-03
Test Case	**Traffic Signal Controller Time Source Status**
Reference	*NTCIP 1202 v03 (December 2018):Section 5.4.22.3*
Objective	Verify the preferred time source(s) of a traffic signal controller is active and correct
Entrance Criteria	The traffic signal controller under test complies with NTCIP 1202 v03
Data Inputs	SNMP commands generated by the user
Data Outputs	SNMP reply indicating the preferred time source(s) of a traffic signal controller under test is active; the traffic signal controller's clock is correct
Exit Criteria	The preferred time source(s) of a traffic signal controller under test is active; the traffic signal controller's clock is correct

Test Case #	TIMING-03
Test Case	**Traffic Signal Controller Time Source Status**
Test Procedures	After test case TIMING-02, the suitable time source for a traffic signal controller under test was selected. Then, using the following steps, the test operator verifies the selected time source is active: • The test operator uses the get function of an SNMP browser with OID 1.3.6.1.4.1.1.1206.4.2.1.3.22.3 to obtain the selected time source for the traffic signal controller under test. The expected return value is one of the following values: ○ 1: other ○ 2: lineSync ○ 3: rtcSqwr ○ 4: crystal ○ 5: gnss ○ 6: ntp • The test operator uses the get function of an SNMP browser with OID 1.3.6.1.4.1.1.1206.4.2.1.3.22.4 to get the active time source of the traffic signal controller under test. The return value is expected to be the same as the step above. Otherwise, this test is failed.

Signal Phase and Timing Data Timestamp

Table 7. Signal phase and timing data timestamp.

Test Case #	TIMING-04
Test Case	**SPaT Data Timestamp**
Reference	*NTCIP 1202 v03 (December 2018):Section 5.17.1*
Objective	Obtain the time of day that SPaT data were generated by a traffic signal controller
Entrance Criteria	The traffic signal controller under test complies with NTCIP 1202 v03
Data Inputs	SNMP commands generated by the user
Data Outputs	SNMP reply indicating the time when SPaT data were created
Exit Criteria	Users could get the time when SPaT data were created
Test Procedures	• The test operator uses the get function of an SNMP browser with OID 1.3.6.1.4.1.1.1206.4.2.1.16.1 to obtain the time of day that SPaT data were generated by a traffic signal controller. The valid return values are: ○ “ ” <blank> ○ Or the expected format and range of each byte are: ▪ Byte 1 indicates hours. The correct range is 0 to 23. ▪ Byte 2 indicates minutes. The correct range is 0 to 59. ▪ Byte 3 indicates seconds. The correct range is 0 to 60.

Test Case #	TIMING-04
Test Case	SPaT Data Timestamp
	▪ Byte 4 & 5 indicate milliseconds. The correct range is 0 to 999. This test is failed if the return value is not the same as above.

Signal Phase and Timing Data Critical Elements

The test case specifications in this section evaluate critical SPaT data elements for encoding SPaT messages.

Intersection Identifier

Table 8. configure intersection identifier.

Test Case #	DATA_ELEM-01
Test Case	Configure Intersection Identifier
Reference	*NTCIP 1202 v03 (December 2018):Section 5.18.1.2.2*
Objective	Configure intersection identifier for a traffic signal controller
Entrance Criteria	The traffic signal controller under test complies with NTCIP 1202 v03
Data Inputs	SNMP commands generated by the user
Data Outputs	The intersection identifier for a traffic signal controller
Exit Criteria	Users can configure intersection identifier for a traffic signal controller
Test Procedures	• The test operator uses the set function of an SNMP browser with OID 1.3.6.1.4.1.1.1206.4.2.1.17.1.2.1.2 to an ID for the intersection at which the traffic signal controller under test is located. A value within the correct range (from 0 to 65535) is selected. The following three values are recommended to test: o 0 o 32768 o 65535 • The test operator uses the get function of an SNMP browser with OID 1.3.6.1.4.1.1.1206.4.2.1.17.1.2.1.2 to verify the intersection ID is the same as the set value. • The test operator uses the set function of an SNMP browser with OID 1.3.6.1.4.1.1.1206.4.2.1.17.1.2.1.2 to an ID for the intersection at which the traffic signal controller under test is located. A value less than the correct range (i.e., from 0 to 65535) is selected (e.g., -1). An error message is expected to be obtained from the SNMP browser. • The test operator uses the get function of an SNMP browser with OID 1.3.6.1.4.1.1.1206.4.2.1.17.1.2.1.2 to verify the intersection ID is not changed.

Test Case #	DATA_ELEM-01
Test Case	Configure Intersection Identifier
	• The test operator uses the set function of an SNMP browser with OID 1.3.6.1.4.1.1.1206.4.2.1.17.1.2.1.2 to an ID for the intersection at which the traffic signal controller under test is located. A value larger than the correct range (i.e., from 0 to 65535) is selected (e.g., 65536). An error message is expected to be obtained from the SNMP browser. • The test operator uses the get function of an SNMP browser with OID 1.3.6.1.4.1.1.1206.4.2.1.17.1.2.1.2 to verify the intersection ID is not changed.

Intersection Status

Table 9. intersection status.

Test Case #	DATA_ELEM-02
Test Case	Intersection Status
Reference	*NTCIP 1202 v03 (December 2018):Section 7.2.1*
Objective	Check the status of a signalized intersection
Entrance Criteria	The traffic signal controller under test complies with NTCIP 1202 v03
Data Inputs	SNMP commands generated by the user
Data Outputs	Status of a signalized intersection
Exit Criteria	The correct status of a signalized intersection is reported

Test Procedures	• The test operator uses the get function of an SNMP browser with OID 1.3.6.1.4.1.1.1206.4.2.17.1.1 to get the status of the intersection at which the traffic signal controller under test is located. When the traffic signal controller has a valid status, the corresponding byte's value is not 0. According to NTCIP 1202, the traffic signal controller's status should be one of the following modes:
	  o Bit 0 =1: remote manual control.
	  o Bit 1 =1: when Bit 4 =1 (i.e., Stop Time in unitAlarmStatus2).
	  o Bit 2: when unitFlashStatus is other (Bit 2 =1), faultMonitor (Bit 2 =5), or mmu (Bit 2 =6).
	  o Bit 3 =1: the preemptState for any preempt is any value other than other (Bit 3 =1), notActive (Bit 3 =2), or notActiveWithCall (Bit 3 =3).
	  o Bit 4 =1: a signal priority request is servicing.
	  o Bit 5 =1: fixedTime mode. Bits 5 and 6 are mutually exclusive.
	  o Bit 6 =1: actuated mode. Bits 5 and 6 are mutually exclusive.
	  o Bit 7: the unitFlashStatus is automatic (Bit 7 =1), localManual (Bit 7 =4), or in startup (Bit 7 =7).
	  o Bit 8 =1: controller failure or failure in operation.

Test Case #	**DATA_ELEM-02**
Test Case	**Intersection Status**
	○ Bit 9: reserved. ○ Bit 10 =1: a spatMapActivationCode value has changed within the previous two coordination cycles. ○ Bit 11 =1: the current cycle is the first cycle that a new set of enabledLanesBits is used. ○ Bit 12 =1: the mapActivatePlanError is any value other than none. ○ Bit 13 =1: any spatPortStatus object is any value other than normal.

Movement status

Table 10. Maximum signal phase and timing movement maneuvers.

Test Case #	**DATA_ELEM-03**
Test Case	**Maximum SPaT Movement Maneuvers**
Reference	*NTCIP 1202 v03 (December 2018):Section 7.2.4*
Objective	Get the maximum SPaT movement maneuvers
Entrance Criteria	The traffic signal controller under test complies with NTCIP 1202 v03
Data Inputs	SNMP commands generated by the user
Data Outputs	Test conductor notes indicating the maximum SPaT movement maneuvers under current traffic signal and timing plan
Exit Criteria	Users could get the maximum SPaT movement maneuvers within the correct range (from 1 to 16) under current traffic signal and timing plan
Test Procedures	• The test operator uses the get function of an SNMP browser with OID 1.3.6.1.4.1.1206.4.2.17.1.4 to obtain the maximum SPaT movement maneuvers of the traffic signal controller under test. The valid value is from 1 to 16. • The test operator verifies the obtained values match the maximum SPaT movement maneuvers under the current traffic signal and timing plan. The test is failed if the return value is not within the range from 1 to 16 or it does not match the value of the current traffic signal time plan.

Table 11. Signal phase and timing movement status.

Test Case #	**DATA_ELEM-04**
Test Case	**SPaT Movement Status**
Reference	*NTCIP 1202 v03 (December 2018):Section 7.2.5.3*
Objective	Get the status of each SPaT movement

Test Case #	DATA_ELEM-04
Test Case	SPaT Movement Status
Entrance Criteria	The traffic signal controller under test complies with NTCIP 1202 v03
Data Inputs	SNMP commands generated by the user
Data Outputs	SNMP reply indicating the status of each SPaT movement
Exit Criteria	Users could get the status of each SPaT movement

Test Procedures

- The test operator uses the get function of an SNMP browser with OID 1.3.6.1.4.1.1.1206.4.2.17.1.5.1.3 to obtain the status of SPaT movement maneuvers of the traffic signal controller under test. The valid values are shown in the following figure:

```
+----------------+----------------+-----+----------------+--------+
| movementManeuver|               |     |                |        |
|      State     |        A       |  B  |        C       | Notes  |
+----------------+----------------+-----+----------------+--------+
| unavailable (0) |      Any      | Any |   Unavailable  |        |
| 1 - See Note E |       Any      | Any |   See Note A   |        |
| 2 - See Note E |   flashRed (5) |  0  |  Green or Red  |        |
| 3 - See Note E |       Any      | Any |       Red      |        |
| 4 - See Note E |       N/A      | N/A |       N/A      |        |
| 5 - See Note E | permissive (3) |  0  |      Green     |        |
| 6 - See Note E | protected (2)  | > 0 |      Green     | Note B |
| 6 - See Note E | protected (2)  |  0  |      Green     |        |
| 7 - See Note E |       Any      | Any |     Yellow     | Note D |
| 8 - See Note E | protected (2)  | Any |     Yellow     | Note E |
| 9 - See Note E | flashYellow (4) |  0 | Green or Yellow |       |
+----------------+----------------+-----+----------------+--------+

Note A: The channel output is neither Green, Yellow or Red.
Note B: If one or more of the octets in movementManeuverGreenIncluded
       is NOT 'Red' or is Dark.
Note C: Unless the preceding movementManeuverState was protected-
       movement-allowed.
Note D: Only if the preceding movementManeuverState was protected-
       movement-allowed.
Note E: The definition of the value can be found in SAE J2735_201603
       DE_MovementPhaseState.
```

Source: *Draft NTCIP 1202 v03.27, p 470*

The test is failed if the status of any movement is different from statuses in figure 2.

Table 12. Signal phase and timing movement type.

Test Case #	DATA_ELEM-05
Test Case	SPaT Movement Type
Reference	*NTCIP 1202 v03 (December 2018):Section 7.2.5.10*
Objective	Get SPaT movement type

Test Case #	DATA_ELEM-05
Test Case	SPaT Movement Type
Entrance Criteria	The traffic signal controller under test complies with NTCIP 1202 v03
Data Inputs	SNMP commands generated by the user
Data Outputs	SNMP reply indicating the type of each SPaT movement (i.e., protected, permissive, flashYellow, flashRed, and other)
Exit Criteria	Users can get the type of each SPaT movement
Test Procedures	• The test operator uses the get function of an SNMP browser with OID 1.3.6.1.4.1.1.1206.4.2.17.1.5.1.10 to obtain the status of SPaT movement maneuvers of the traffic signal controller under test. The valid values are: o 1: other. o 2: protected. o 3: permissive. o 4: flashYellow. o 5: flashRed. The test is failed if the returned value is not within the valid range (from 1 to 5).

Signal Phase and Timing Signal State Minimum End Times

Table 13. Signal phase and timing signal state minimum end times.

Test Case #	DATA_ELEM-06
Test Case	SPaT Signal State Minimum End Times
Reference	*NTCIP 1202 v03 (December 2018):Section 7.2.7.2*
Objective	Get minimum end times of each SPaT signal state
Entrance Criteria	The traffic signal controller under test complies with NTCIP 1202 v03
Data Inputs	SNMP commands generated by the user
Data Outputs	SNMP reply indicating the minimum end times of each SPaT signal state
Exit Criteria	Users could get minimum end times of each SPaT signal state
Test Procedures	• The test operator uses the get function of an SNMP browser with OID 1.3.6.1.4.1.1.1206.4.2.17.1.7.1.2 to obtain minimum end times of each SPaT signal state. The expected values are: o Valid values: from 0 to 35999. o 36000: infinite or beyond the range. o 36001: undefined or unknown. The test is failed if the returned value is not within the range (from 0 to 36001).

Signal Phase and Timing Signal State Maximum End Times

Table 14. Signal phase and timing signal state maximum end times.

Test Case #	**DATA_ELEM-07**
Test Case	**SPaT Signal State Maximum End Times**
Reference	*NTCIP 1202 v03 (December 2018):Section 7.2.7.3*
Objective	Get maximum end times of each SPaT signal state
Entrance Criteria	The traffic signal controller under test complies with NTCIP 1202 v03
Data Inputs	SNMP commands generated by the user
Data Outputs	SNMP reply indicating the maximum end times of each SPaT signal state
Exit Criteria	Users could get maximum end times of each SPaT signal state
Test Procedures	• The test operator uses the get function of an SNMP browser with OID 1.3.6.1.4.1.1.1206.4.2.17.1.7.1.3 to obtain the maximum end times of each SPaT signal state. The expected values are: o Valid values: from 0 to 35999. o 36000: infinite or beyond the range. o 36001: undefined or unknown. The test is failed if the returned value is not within the range (from 0 to 36001).

Signal Phase and Timing Data Performance

The test case listed in this section evaluates critical data elements for evaluating SPaT data performance.

Signal Phase and Timing Maximum Transmission Start Time

Table 15. Signal phase and timing maximum transmission start time.

Test Case #	**DATA_PERF-01**
Test Case	**SPaT Maximum Transmission Start Time**
Reference	*NTCIP 1202 v03 (section 3.6.3 Signal Phase and Timing Data Performance Requirements)*
Objective	Ensure a traffic signal controller begins initial transmission of SPaT data objects, after a value change of SPaT data
Entrance Criteria	The traffic signal controller under test complies with NTCIP 1202 v03
Data Inputs	Timestamped SNMP commands generated by a traffic signal controller
Data Outputs	Timestamped SNMP replies indicating SPaT maximum transmission start time

Test Case #	DATA_PERF-01
Test Case	SPaT Maximum Transmission Start Time
Exit Criteria	The SPaT maximum transmission start time is 10 milliseconds or a value predefined by an agency
Test Procedures	• The test operator configures the traffic signal controller under test to generate SPaT UDP packets, according to procedures described in test case XXX-01. • The test operator uses Wireshark to collect SPaT UDP packets sent from the traffic signal controller to the PC for at least 5 seconds. • The test operator identifies the time that a value has changed and determines the time difference between the change and the received packet. The identified time difference should be no larger than 10 milliseconds or a value predefined by an agency. Otherwise, this test is failed.

Movement Time Point Minimum Transmission Rate

Table 16. Movement time point minimum transmission rate.

Test Case #	DATA_PERF-02
Test Case	Movement Time Point Minimum Transmission Rate
Reference	*NTCIP 1202 v03 (section 3.6.3 Signal Phase and Timing Data Performance Requirements)*
Objective	Ensure a traffic signal controller sends the time point refers to an RSE no less than movement time point minimum transmission rate
Entrance Criteria	The traffic signal controller under test complies with NTCIP 1202 v03
Data Inputs	Timestamped SNMP commands generated by a traffic signal controller
Data Outputs	Timestamped SNMP reply indicating the movement time point minimum transmission rate of a traffic signal controller
Exit Criteria	Movement time points minimum transmission rate of a traffic signal controller is once/100 milliseconds or a value predefined by an agency
Test Procedures	• The test operator configures the traffic signal controller under test to generate SPaT UDP packets, according to the procedures described in test case XXX-01. • The test operator uses Wireshark to collect events that a traffic signal controller tries to set the time point refers to the PC for at least 1 second. • The test operator identifies the time difference between received times of two consecutive events. The identified time difference should be no larger than 100 milliseconds or a value predefined by an agency. Otherwise, this test is failed.

Signal Phase and Timing Data Request Transmission Rate

Table 17. Signal phase and timing data request transmission rate.

Test Case #	**DATA_PERF-03**
Test Case	**SPaT Data Request Transmission Rate**
Reference	*NTCIP 1202 v03 (section 3.6.3 Signal Phase and Timing Data Performance Requirements)*
Objective	Ensure an RSE can successfully get SPaT data objects from a traffic signal at a nominal request transmission rate
Entrance Criteria	The traffic signal controller under test complies with NTCIP 1202 v03
Data Inputs	SPaT data request generated by an RSE
Data Outputs	Timestamped packets containing SPaT data and the SPaT data request transmission rate
Exit Criteria	SPaT data request transmission rate is once/100 milliseconds or a value predefined by an agency
Test Procedures	• The test operator uses the get function to obtain values from the signalStatusTable from the traffic signal controller under test at an interval of 100 milliseconds. • The test operator uses Wireshark to collect events that a traffic signal controller replies to the get function on demand. • The test operator identifies the time difference between received times of two consecutive events. The identified time difference should be no larger than 100 milliseconds or a value predefined by an agency. Otherwise, this test is failed.

Signal Phase and Timing Data Latency

Table 18. Signal phase and timing latency.

Test Case #	**DATA_PERF-04**
Test Case	**SPaT Latency**
Reference	*NTCIP 1202 v03 (section 3.6.3 Signal Phase and Timing Data Performance Requirements)*
Objective	Ensure the SPaT latency is acceptable
Entrance Criteria	The traffic signal controller under test complies with NTCIP 1202 v03
Data Inputs	None

Test Case #	DATA_PERF-04
Test Case	SPaT Latency
Data Outputs	Timestamped SPaT data and signal head status (Note: NTCIP 1202 defines the SPaT latency as “the time difference between SPAT data available to the RSU and the assertion of corresponding ASC outputs controlling the signal heads.”[1])
Exit Criteria	SPaT latency is not over ± 50 milliseconds
Test Procedures	• The test operator connects a traffic signal head with the traffic signal controller under test and ensures traffic signal head and controller are synchronized with no latency (i.e., change to green, yellow, or red at the same time). • The test operator configures the traffic signal controller under test to generate SPaT UDP packets, according to procedures described in test case XXX-01. • The test operator uses Wireshark to collect SPaT UDP packets sent from the traffic signal controller to the PC for at least a cycle. At the same time, the test operator uses a suitable software to collect events of green, yellow, and red changes of the traffic signal head. • The test operator identifies the start times of green, yellow, and red from SPaT UDP packets and the logs of traffic signal head. The test operator compares these time events between SPaT UDP package and traffic signal head for the same color (i.e., green, yellow, and red). The differences are expected to not be over ± 50 milliseconds. Otherwise, this test is failed.

[1] American Association of State Highway and Transportation Officials (AASHTO), Institute of Transportation Engineers (ITE), and National Electrical Manufacturers Association (NEMA), *NTCIP 1202 v03 National Transportation Communications for ITS Protocol Object Definitions for Actuated Signal Controllers (ASC) Interface* (2019), 210.

Appendix A. Battelle Signal Phase and Timing Management Information Base

Currently, no National Transportation Communications for Intelligent Transportation Systems Protocol (NTCIP) 1202 v03 compatible firmware is available on the market. To get users familiar with this test plan, this plan could also be used to investigate signal phase and timing (SPaT) functionalities of a traffic signal controller that is operating a pre-NTCIP 1202 v03 compatible firmware. All the test procedures in the test plan can also be used without major changes. The only thing users need to change is the object identifier(s) (OID) of each test case.

Battelle research group developed a SpaT management information base (MIB) support document.[2] This document lists a group of SPaT OIDs for ASC/3 controllers as shown below. Users can use these OIDs to execute test cases in this plan to get an understanding of this test plan.

Objects

1.3.6.1.4.1.1206.3.47.1	spatTimeToChangeTable	NODE	(0)
1.3.6.1.4.1.1206.3.47.1.1	spatTimeToChangeEntry	NODE	(1)
1.3.6.1.4.1.1206.3.47.1.1.1	spatTimeToChangePhaseNumber	LEAF	INTEGER
1.3.6.1.4.1.1206.3.47.1.1.2	spatVehMinTimeToChange	LEAF	INTEGER
1.3.6.1.4.1.1206.3.47.1.1.3	spatVehMaxTimeToChange	LEAF	INTEGER
1.3.6.1.4.1.1206.3.47.1.1.4	spatPedMinTimeToChange	LEAF	INTEGER
1.3.6.1.4.1.1206.3.47.1.1.5	spatPedMaxTimeToChange	LEAF	INTEGER
1.3.6.1.4.1.1206.3.47.2	spatOvlpTimeToChangeTable	NODE	(0)
1.3.6.1.4.1.1206.3.47.2.1	spatOvlpTimeToChangeEntry	NODE	(1)
1.3.6.1.4.1.1206.3.47.2.1.1	spatTimeToChangeOvlpNumber	LEAF	INTEGER
1.3.6.1.4.1.1206.3.47.2.1.2	spatOvlpMinTimeToChange	LEAF	INTEGER
1.3.6.1.4.1.1206.3.47.2.1.3	spatOvlpMaxTimeToChange	LEAF	INTEGER
1.3.6.1.4.1.1206.3.47.3	spatDiscontinuousChangeFlag	LEAF	INTEGER
1.3.6.1.4.1.1206.3.47.4	spatFlashingOutputPhaseStatus	LEAF	INTEGER
1.3.6.1.4.1.1206.3.47.5	spatFlashingOutputOverlapStatus	LEAF	INTEGER
1.3.6.1.4.1.1206.3.47.6	spatIntersectionStatus	LEAF	INTEGER

[2] Dustin DeVoe, *SPAT MIB Support Document*, Battelle, July 23, 2012.

Appendix B. Basic Simple Network Management Protocol Functions

In this test plan, a simple network management protocol (SNMP) is used to obtain and set values for different parameters in a traffic signal controller. To help novice SNMP users, two frequently used SNMP functions are provided below. The authors of this test plan do not endorse any SNMP browser or software. Users can select any SNMP browser or software that meets their needs. Net-SNMP is free software that supports SNMP v1, v2c, and v3.[3] Net-SNMP is selected to illustrate how to use SNMP get and set functions.

- Get function:[4]

  Syntax: snmpget –c public [OID]

For example, get the value of the maximum number of time sources that a device under test supports:

snmpget –c public 1.3.6.1.4.1.1.1206.4.2.1.3.22.1

- Set function:[5]

  Syntax: snmpset –c public [OID] [value type] [value]

  Value type:

  - i: integer
  - u: unsigned
  - s: string
  - x: hex string
  - d: decimal string
  - n: Null obj
  - o: objID
  - t: time ticks
  - a: IP address
  - b: bits

For example, enable SPaT data:

snmpset –c public 1.3.6.1.4.1.1.1206.4.2.1.16.4 –i 1

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[3] Net-SNMP (website), last modified Tuesday, February 26, 2013, http://www.net-snmp.org/.
[4] "SNMPGET" web page, Net-SNMP, last updated February 8, 2002, http://www.net-snmp.org/docs/man/snmpget.html.
[5] "SNMPGET" web page.

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