TN TDOT Department of Transportation

Dedicated Short Range Communication (DSRC) Statewide Guidance

Summary of Research and Design Considerations

Version 1.0

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Glossary

Several key technology components define the connected vehicle ecosystem in Tennessee, including:

- **Dedicated Short Range Communications (DSRC)** - A technology similar to Wi-Fi which is fast, secure and reliable that can be used continuously share important safety and mobility information between road users and the roadway infrastructure.
- **Roadside Unit (RSU)** — Device that sends messages to, and receives messages from, nearby vehicles. The RSU operates from a fixed position or a portable device, and includes a processor, data storage and communications capabilities on a secure channel with other equipped vehicles. RSUs use DSRC or other alternative wireless communications technologies.
- **Onboard Unit (OBU)** — Device located in the vehicle either as standard equipment or as an after-market device, capable of transmitting, processing, and storing messages necessary to support connected vehicle operations. Using DSRC or other alternative wireless technologies, OBU's interface with the standard equipment or aftermarket safety devices to communicate information to the driver.
- **Traffic Signal Controller** — Regulates the signal operation of a traffic signal. When paired with an RSU, allows for the communication of real-time traffic signal information between motorized and non-motorized users to maximize safety and traffic flow through the intersection.
- **Backhaul Communications** — A secure communications network between the highway agency and RSU to manage the device, collect data, transmit messages, or gain access to internet services.
- **Vehicle to Vehicle (V2V) Communications** — The wireless exchange of data among vehicles in close proximity.
- **Vehicle to Infrastructure (V2I) Communications** — Wireless exchange of critical safety and operational data between vehicles and the roads they use.
- **Back-office data processing** – the ability to collect and process data over V2I systems is critical to creating value of the system both to TDOT and to end-users.
- **Signal Phase and Timing (SPaT)** – Information housed in a traffic signal controller that describes the intersection approach being served by the controller at a given point in the traffic signal cycle.

1. Introduction

Purpose

The purpose of this document is to provide guidance for the deployment of Dedicated Short Range Communication (DSRC) technology on traffic signals within the state of Tennessee. This document does not cover the deployment of DSRC for freeway applications. Connected Vehicle (CV) technology is changing rapidly. This document captures the initial effort of the Tennessee Department of Transportation (TDOT) to deploy technology such as DSRC on signalized intersections. This is a living document that will be updated as technology changes and the programmatic deployment of DSRC matures within TDOT. The TDOT Specifications Committee will be engaged to develop standard specifications and drawings based on this guidance document. This process will take time and will result in updated versions of this guidance document. Updates to this document will be published via the Traffic Operations Memorandum (TOM).

Historically, TDOT's role in traffic signal operations and maintenance has been to fund and/or perform the design and construction of traffic signals that are warranted for intersections on the state highway system. At the completion of construction, the traffic signal is handed over to the local agency to operate and maintain. TDOT has identified the need to assist the local agencies to manage traffic on both the limited access roadway and signalized arterials in a holistic fashion to realize efficiencies in mobility and safety for Tennessee motorists.

CV infrastructure such as DSRC introduces an opportunity for TDOT and local signal agencies to work together to deploy, operate and maintain this new technology. Since this is uncharted territory for TDOT, discussions with the local signal agency that will be responsible for operations and maintenance of DSRC equipment should occur early in the process. A Memorandum of Understanding (MOU) may be needed in some cases to formalize these discussions.

Initial deployments of DSRC should be considered pilot projects and use a collaborative approach between TDOT, Designer, General Contractor, System Integrator, and Local Signal Agency. Before and after studies should be conducted, contract requirements for pilot deployments should be structured to allow for iterative testing and lessons learned to be collected. Early deployments of DSRC technology could be utilized for operational use cases such as SPaT, Traveler Information Message (TIM), and Red-Light Violation Warning (RLVW). Other use cases such as fleet, freight, and transit applications could be explored as the DSRC Program matures.

Intent

The DSRC statewide guidance document is intended to present a single resource for scoping, designing, and implementing a CV project as part of the Traffic Operations Program in Tennessee. The components of the CV system referenced herein is like many other devices used within TDOT's Traffic Engineering and ITS programs, however the process of design and integration are slightly different. For example, TDOT uses wireless communication technology and Advanced Transportation Controllers (ATC) in traffic signals. This document will provide both TDOT Project Managers, design consultants, system integrators, and general contractors with relevant standards that should be used in the design and implementation of a connected vehicle deployment using DSRC.

CV technologies enable all types of vehicles, roadways, other infrastructure, and mobile devices to communicate and share vital transportation information. While other types of connectivity, including via cellular networks, exists in vehicle systems and via mobile devices, the primary communications technology used to support CV safety applications is DSRC, which is similar to Wi-Fi. DSRC provides for fast, secure, and reliable communications, and is not vulnerable to interference throughout the spectrum, and is a core tenet of many safety-based V2X applications.

This guidance document will lay the groundwork for CV deployment using DSRC in the state of Tennessee.

This document is arranged as follows:

Part 1: Introduction, Summary of Research, and Introduction to the Signal Phase and Timing (SPaT) Challenge. Application of technology such as DSRC to traffic signal operations is uncharted territory. **A systematic approach to understand the context of the national discussion, state of the practice regarding communication and security standards, and lessons learned from various state and local agencies is critical to charting the course for Tennessee.**

Part 2: Implementation Guidance, Overview of the Design Process, Design Elements, Integration and Testing, and Operations and Maintenance. Although deployment of DSRC technology contains elements from the TDOT ITS project delivery process and TDOT traffic signal project delivery process, there are significant differences and interdependencies that must be explored and explained. Part 2 of this document will provide ITS and traffic signal designers with the guidance needed to deploy this technology.

Key reference documents include:

- DSRC Roadside Unit (RSU) Specifications Document (FWHW-JPO-17-589), Revision 4.1, Version 5, dated April 28, 2017
- Recommended Practices for DSRC Licensing and Spectrum Management (FHWA-JPO-16-267), dated December 2015
- SPaT Challenge Verification Document, Version 1.2, dated October 30, 2017

Key standards include:

- SAE J2735, J2945
- IEEE 802.11, 1609.x
- NTCIP 1202
- FCC Rule 47 CFR, Part 90, Subpart M6

2. Summary of Research

2.1 State of the Practice

The scope of this project included a survey of best practices, deployment methods, operational applications, and design considerations from state and local agencies who have utilized DSRC. Tasks include:

- Interview agencies who have deployed DSRC for ITS and/or traffic signal applications
- Research existing specifications, procurement documents and plans for DSRC deployments from other state DOT's and local agencies

- Review Federal Highway Administration (FHWA) requirements for SPaT Challenge and USDOT Security Credential Management System (SCMS) requirements for data security of broadcast message
- Research state of the practice for DSRC regarding data security, minimum specifications, Federal Communications Commission (FCC) license requirements, and traffic signal controller compatibility

Interviews were conducted with the following agencies/vendors:

- Florida DOT: Raj Ponnaluri
- City of Tallahassee, FL: Wayne Bryan; Josh Hollingsworth
- Utah DOT: Blaine Leonard
- City of Chattanooga: Kevin Comstock, Tommy Trotter
- City of Knoxville: Philip Reyes
- Cal Trans: Greg Larson

Information was gathered regarding DSRC deployments of various types, operational use cases, using various RSU and signal controller vendors. The primary lesson learned from the interviews is that agencies throughout the US have deployed DSRC with their internal staff, with agencies procuring equipment in a separate phase from the installation phase. The other lesson learned is that **technology, equipment standards, and uses for DSRC is evolving** and **equipment vendors have found interoperability to be very challenging**. Interview Summaries are found in Appendix A.

Equipment specifications and DSRC installation use cases were reviewed for the following RSU and Traffic Signal Controller Equipment Manufacturers:

- Miovision
- Intelite
- Econolite
- Siemens
- McCain
- Commsignia
- Cohda
- Arada/Lear
- Savari

The DSRC Statewide Guidance Document should be considered a living document and revisions should be developed as technology and best practices evolve. As future versions of the DSRC Statewide Guidance Document are developed, interviews should be conducted with the following agencies to expand the knowledge base of TDOT and local signal agencies:

State/Local Agencies/Academia

- Michigan DOT
- Texas DOT
- Minnesota DOT
- Wisconsin DOT
- North Carolina DOT
- Pennsylvania DOT
- City of Gainesville
- University of Tennessee, Knoxville
- University of Tennessee, Chattanooga
- University of Memphis

2.2 SPaT Challenge

The goal of the SPaT Challenge is to encourage state or local agencies throughout the United States to deploy DSRC broadcasts of SPaT at approximately 20 intersection locations, typically in a corridor or a network setting.

The American Association of State Highway and Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE), and ITS America (ITSA) working together through the Vehicle to Infrastructure Deployment Coalition (V2I DC) have challenged state and local public sector transportation infrastructure owners and operators (IOOs) to work together to achieve deployment of roadside Dedicated Short Range Communications (DSRC) 5.9 GHz broadcast radio infrastructure to broadcast signal phase and timing (SPaT) in real-time at signalized intersections on at least one road corridor or street network (approximately 20 signalized intersections) in each of the 50 states by January 2020.

The Crash Avoidance Metrics Partnership (CAMP) LLC V2I Consortium, a group of several automakers has developed a key resource titled the SPaT Challenge Verification document.
https://transportationops.org/sites/transops/files/SPaT_ChallengeVerification_Ver1.2_11_17_17.pdf
The intent of this document is to help to ensure that SPaT deployments are performed such that the data broadcast (SPaT and MAP messages, and position correction) are compatible and meet the minimum requirements to support the on-board applications that may be released by automobile manufacturers. The focus of the SPaT Challenge Verification Document is on ensuring compatibility with future Red Light Violation Warning (RLVW) applications.

Since the beginning of 2018, the National Operations Center of Excellence (NOCoE) has hosted a webinar series covering the SPaT Challenge, including design considerations and deployment. Full webinar recordings and slides can be found at the following link:
https://transportationops.org/spatchallenge/webinarseries. The information gathered from this series is summarized below:

- Initial SPaT Challenge Activities
- SPaT Challenge Design Considerations (Part 1)
- SPaT Challenge Design Considerations (Part 2)
- SPaT Challenge: J2735 MAP Creator Tool Demo
- SPaT Challenge Design Considerations (Part 3)
- SPaT Challenge Deployment and Validation
- SPaT Challenge Operational Deployments
- Beyond the SPaT Challenge

With the initial deployment of DSRC in Tennessee, TDOT should add the project to the SPaT Challenge Progress Map.

3. Implementation Guidance

3.1 Introduction

The intent of this section is to support agencies that have decided to deploy SPaT broadcasts by providing an overall summary of the implementation process.

- The intent of DSRC broadcast of SPaT at 5.9 GHz is to provide secure transmissions of the data with low latency during all weather conditions. V2I Applications such as Red Light Violation Warnings (RLVWs) are described by functional requirements of SPaT broadcasts at a frequency of 10 broadcasts per second, which has been proven using DSRC. Any delay in the DSRC broadcast would be both minimal and a reliable delay that does not fluctuate.
- Operating DSRC at signalized intersections also allows for two-way communications between the vehicle and the infrastructure. This may allow vehicles to communicate the lane they are traveling in to allow the signal controller to consider this as part of adaptive control. Similarly, transit or emergency vehicles may use the DSRC communications to send priority requests to the signal controllers.
- DSRC broadcasts of SPaT at the signalized intersections include lane specific details reporting the current signal phase and timing.
- DSRC broadcast of SPaT is a one-way broadcast to all vehicles approaching, and therefore there are no privacy concerns regarding a message being sent directly to specific vehicles.

3.2 Physical Architecture Drawing and Summary

The intent of this section is to describe the overall actions required for a SPaT broadcast deployment to help readers understand the concept of resources presented later in this document. The operation of a DSRC broadcast of SPaT messages can be described by a series of high level actions that must occur as discussed in the following subsections.

3.2.2 SPaT Messages Output from Traffic Signal Controller

The traffic signal controller located roadside at the intersection will generate the current signal phase and timing parameters used to control the signal heads and pedestrian crossing signals. National Transportation Communications for Intelligent Transportation Systems Protocol (NTCIP) 1202 compliant traffic signal controllers are typically capable of generating an output of the SPaT parameters as 1202 SPaT messages.

3.2.3 Conversion of 1202 SPaT Messages to J2735 SPaT Messages

In order for the DSRC broadcasts of SPaT messages to be compliant with the Society of Automotive Engineers (SAE) J2735 standards for V2I message exchange, the 1202 SPaT messages must be converted into J2735 formats prior to broadcast. This will ensure that vehicles operating V2I communication capabilities can interpret the message communications. Currently, the J2735 Version 2016 is the latest version.

3.2.3 Generation of intersection MAP data

In order for vehicles approaching an intersection to interpret the SPaT messages being broadcast, the vehicle systems must have a reference to determine the approach (or signal phase) they are following, and therefore understand the current display on the signal head. This is accomplished by the DSRC broadcast including a MAP message broadcast. MAP data describes the physical geometry of the intersection, with topological models of lanes and the links between road segments. The MAP message is not created in real-time, but rather is a static description of the geometries of the intersection and vectors describing approaches. The vehicle systems will compare GPS location readings on the vehicle against the MAP message and determine the vehicle's approach.

3.2.4 Generation of GPS Correction data

In order for the vehicle to accurately identify the approach/phase using the MAP message, it is critical that the location of the vehicle (determined by the on-board GPS) is accurate. Inaccuracies can arise from atmospheric conditions or reduced satellite access. The Radio Technical Commission for Maritime Services (RTCM) broadcasts standardized GPS correction information that aids in minimizing the effects of these GPS errors. The general concept of RTCM is that a base station with a known location (the location may be known by either by surveying in the station location or operating a GPS receiver for a long continuous period of time) continuously receives satellite signals and determines a current latitude/longitude position given the current atmospheric conditions. The base station then compares the position determined with the current atmospheric conditions to the known location and computes a correction factor that corrects the current calculated position to the known position. This correction factor is the RTCM message that can be sent out to vehicles. Depending upon the vehicle and the GPS system on board, the vehicle may or may not be able to apply the correction factor. Creation of the RTCM message may either be done by operating a base station at the intersection, or by retrieving the RTCM from an on-line source, or by a central calculation at the TMC.

3.2.5 Combining SPaT, MAP, and RTCM for broadcast

The SPaT, MAP, and RTCM messages are combined and sent to the DSRC antenna for broadcast to the vehicles.

Figure 1 below illustrates a high level physical representation of the functions to be performed to accomplish real-time DSRC broadcast of SPaT messages. Actions drawn as white ovals represent those that are either performed now by traffic signal controllers (TSC) or that would be performed by TSC upgrades. Actions drawn as green ovals represent those functions that would require additional components beyond what is in typical signal control cabinets.

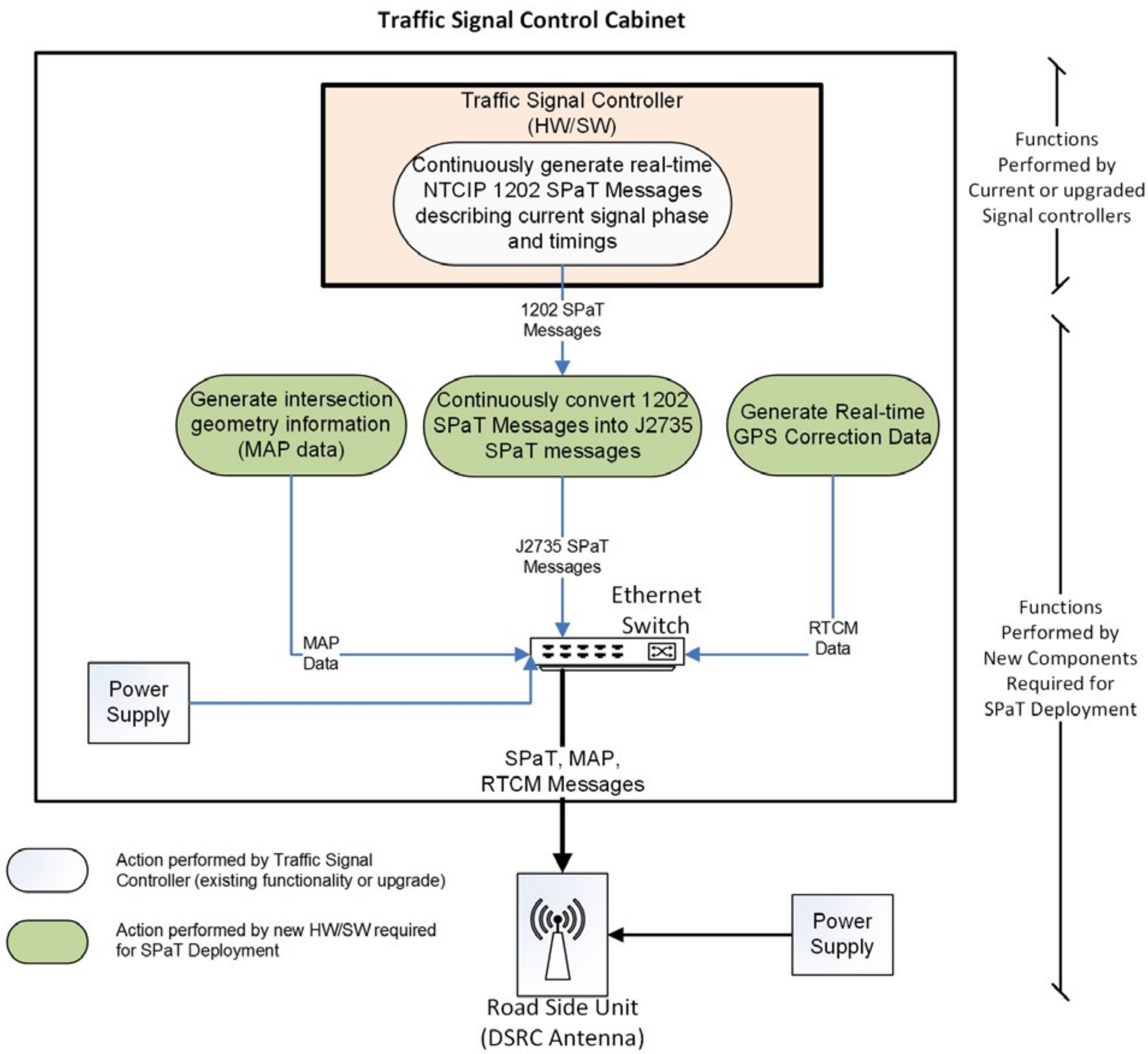


Figure 1 – Illustration of Functional Needs of SPaT Deployment

3.3 Overall SPaT Implementation Guidance

The intent of this section is to highlight and link to two documents that are available to support agencies and contractors as they deploy DSRC SPaT broadcasts: (1) DSRC Roadside Unit (RSU) Specifications Document and (2) DSRC Licensing and Spectrum Management Guide

In September 2016, FHWA completed a project that documented the process of deploying DSRC broadcasts of SPaT, MAP, and RTCM corrections. As part of this project, the project team created the V2I Hub Deployment Checklist and Guidance document, a checklist of common design, approval, and installation activities required to successfully complete deployment of DSRC systems. The V2I Hub recommends software and equipment that could be used to get started in the early stages of testing the waters for a DSRC deployment. The V2I Hub is mentioned here as an option for agencies, but at this point in the development of DSRC, it is not considered a long-term solution as it requires separate fail point hardware, another software to manage and secure, and an additional power feed needed in the cabinet.

3.3.1 DSRC Roadside Unit (RSU) Specifications Document (Resource #1)

The DSRC Roadside Unit (RSU) Specifications Document, FHWA -JPO -17 -589, dated April 28, 2017, provides details on hardware requirements that would be used to support SPaT, including:

- Chapter 2, System Overview defines an RSU that meets all requirements of the document specifications (page 5), which would support SPaT.
- Chapter 2, System Overview provides examples of various deployment configurations (pages 7-9).
- Chapter 2, Basic Functionality details RSU functionality with a context diagram including the inputs, outputs, enablers, and controls for supporting activities, including message broadcasts (page 10).
- Chapter 3 includes RSU system requirements that would apply to the hardware/software needed to support SPaT, organized into categories:
    - Power (pages 16-17);
    - Environmental (pages 17-21), including consideration of local weather-related conditions;
    - Physical (pages 21-22), including weight, enclosure, mounting;
    - Functional (pages 22-46), including broadcasting, positioning, system and interface log files, message processing, security, and USDOT Situation Data Clearinghouse and Warehouse;
    - Behavioral (pages 46-52), including operational states, modes, and configuration, and health and status monitoring;
    - Performance (pages 52-54), including radio performance; and
    - Interface (pages 54-66), including internal and external interfaces for DSRC, 802.11, IEEE 1609.2, IEEE 1609.3, IEEE 1609.4, and WAVE Service Advertisements.

3.3.2 DSRC Licensing and Spectrum Management Guide (Resource #2)

Introduction

The goal of the Recommended Practices for DSRC Licensing and Spectrum Management guide, FHWA-JPO-16-267, dated December 2015, is to make DSRC licensing requirements transparent and best practices accessible to any organization seeking to deploy Connected Vehicle Dedicated Short Range Communications (DSRC) Roadside Units (RSU) that support vehicle-to-infrastructure (V2I) communications. The document covers the following issues in-depth:

Understanding DSRC

For DSRC-based Connected Vehicle applications, the mobile service allocation is limited to Dedicated Short Range Communications Service (DSRCS) systems operating in the Intelligent Transportation System (ITS) radio service communications frequency band as defined by the Federal Communications Commission (FCC) in CFR 47 Part 2.1 In the United States. The DSRC service operates in the 5850 – 5925 MHz band (the 5.9 GHz band), and coexists as a primary use along with other Federal users authorized by the National Telecommunications and Information Administration (NTIA), as well as with a number of commercial satellite operators.

Use of the spectrum:
Other 5.9 GHz DSRC users have transmitters deployed in relatively distant and isolated areas with respect to the most trafficked roadway networks. In some cases, however, deployments may be near outer suburban and rural corridors. This document recommends a process for coordinating with these users to reduce interference.

Spectrum coordination:
Coordinating with other DSRC roadside users is an important ongoing management task for any agency using DSRC. In field deployments, adapting the design, siting, placement, location, power, antenna, and other elements that maximize performance and avoid interference of DSRC roadside units will be necessary.

Responsibilities:
Responsibilities for agencies planning to deploy RSUs include reviewing FCC service rules, regulations, and technical requirements; field deployment and planning; licensing administration and ongoing management activities. See the list below which outlines responsibilities for the deployment, commissioning and monitoring of DSRC system.

Deployment & Commissioning Tasks

- Site Selection, Deployment Design, and Service Planning
- Procurement and Equipment /Other Certifications
- FCC Licensing and Site Registration
- Coordination with Existing Federal and non- Federal Co-Primary Users (e.g. Fixed Satellite)
- Radio Frequency Analysis and Survey of "Unlicensed" Systems (e.g. Wi-Fi)
- Revisions to Design and Service Planning
- RSU Site Installation
- Security Credentialing and Service/Application Commissioning

Monitoring/Remediation & Optimization Tasks

- Service Channel/ Application Configuration Updates and Optimization
- Security Credential Updates
- Ongoing Coordination with *New* Primary Users
- Ongoing Coordination with *New* DSRC
- RSU Sites/Service Providers
- Updates to Radio Frequency Analysis Addressing New User

3.4 Installing New Hardware/Software to Support SPaT

3.4.1 Minimum Existing Field Equipment to Support SPaT

The following bullets describe the minimum hardware and software components that is required at the intersections where a SPaT broadcast is planned to be deployed:

- A traffic signal controller (TSC) with NTCIP 1202 SPaT message outputs via an open Ethernet port.

- An Ethernet switch in the traffic signal controller cabinet that has at least three ports available to all operate on the same subnet.
- Availability in the traffic signal controller cabinet's interior to locate or mount equipment.

3.4.2 Minimum New Hardware and Software Required to Support SPaT

Typical hardware and software components that need to be added to accomplish SPaT broadcasts include:

- Software to translate the NTCIP object oriented SPaT data into J2735 SPaT messages for broadcast;
- Creation of a MAP message to be broadcast that describes intersection geometry;
- Acquisition or creation of RTCM (GPS correction) messages for broadcast;
- The DSRC antenna providing broadcast of SPaT, MAP, RTCM;
- Network support for IPv6 for connecting to the SCMS; and
- Communications to link existing and new components.

3.4.3 Performance Requirements for SPaT, MAP, RTCM

Preliminary Performance Requirements for SPaT to support Red Light Violation Warning applications are:

1. SPaT broadcast at 10 Hz;
2. MAP broadcast at 1 Hz.
3. RTCM version 3.0 correction message type 1001 (GPS L1 Observations) at 5 Hz, and
4. The message type 1005 (Antenna Reference Point (ARP) coordinates) at 2 Hz.

The V2I Safety Applications Performance Requirements, Volume 1 for Common Requirements (FHWA-JPO-17-589) and Volume 3 for RLVW (FHWA-JPO-250) contain performance requirements for the storage, transmission, and processing of SPaT, MAP, and RTCM messages for the issuance of RLVW notifications, alerts, and warnings.

4. Design Process

4.1 Designer Responsibilities

The designer responsibilities shall be comparable to the responsibilities for other ITS and traffic signal design activities for TDOT. The deliverable by the designer may be different, project to project, based on the type of contract that the designer is working on.

The designer shall be required to perform the following tasks:

- Perform System Engineering Analysis and prepare Project System Engineering Management Plan in accordance with TDOT Regional ITS Architecture and FHWA Rule 940. If the particular DSRC

deployment is determined to be a Low Risk ITS deployment, the Low Risk ITS Architecture form may be used as found in TDOT ITS Project Development Guidelines, dated July 20, 2016.
- Confirm the intended operational use (application) of the connected vehicle equipment (Signal Phase and Timing (SPaT), Fleet Management, Weather, Work Zone, Curve Warning, etc.)
- Identify candidate locations for the deployment of connected vehicle equipment which meets the project requirements
- Identify the components to be used for the deployment
- Optimize component placement to meet the project requirements
- Development of plans, specifications and estimates including a DSRC Channel Plan for each RSU

4.2 General Contractor Responsibilities

The general contractor responsibilities shall be comparable to the responsibilities for other ITS and traffic signal deployments except for integration. **The general contractor shall be responsible for full integration of the connected vehicle system. This may require subcontract with specialty wireless or ITS communication contractor.**

The contractor shall be required to perform the following tasks:

- Procurement of all equipment called for in the plans, specifications, and estimates
- Configuration of all equipment to default setting prior to deployment
- Development of MAP Files
- Loading of the DSRC applications, including SPaT, MAP, and RTCM on the RSU
- Local/Stand Alone testing of all equipment
- Responsible for installation/integration/testing of backhaul communications
- Submit required FCC information for licensing
- Perform frequency analysis for radio interference at the desired mounting height
- Field installation of all equipment
- Device configuration and testing of all DSRC elements
- Network configuration and testing of all DSRC elements in cooperation with TDOT or local signal agency IT Network staff
- Coordination with TDOT, TDOT's representative and/or local signal agency
- Coordinate with TDOT and/or local signal agency to implement security requirements
- Acceptance testing – subsystem and final system tests

4.3 TDOT Responsibilities

- Update of standard specifications, approved product list, and special provisions to reflect current standards
- Guidance for the configuration of traffic signal controller for SPaT network parameters
- RSU/FCC Licensing Request and Management
- Program Management
- Establishing Security Management and Commercial Agreements
- Establishing network and center to field communications

- Establishing IP4/IP6 network connectivity

4.4 Signal Maintaining Agency Responsibilities

- Maintaining Security Management and Commercial Agreements
- Maintaining network and center to field communications
- Maintaining IP4/IP6 network connectivity
- Operate and maintain field equipment
- Maintain the ability to share DSRC data with TDOT in a format agreed to by both agencies

5. Design Elements

5.1 Introduction

The design of CV equipment will include a variety of components to support the deployment of infrastructure. Sections of Special Provision 725 and Standard Specification for Road and Bridge Construction, Section 730 will be needed.

Provisions that are required for deployment, but are not readily available on the TDOT website can be requested by the ITS Program Office. See link above for contact information.
https://www.tn.gov/tdot/intelligent-transportation-systems.html

Connected vehicle deployment sites will include a combination of the following components:

5.2 Road Side Unit (RSU)

The RSU transmits data from the traffic signal to nearby vehicles or infrastructure elements that can receive 5.9Ghz DSRC communications. All current commercially-available RSUs use power-over-Ethernet to power the device. Power over Ethernet (PoE) injectors reside in the cabinet and connect to the 110v power supply.

Designers shall include an update to Special Provision 725 with all projects that include an RSU.
The Section 4.3.14 (Project Testing) of the provision includes local device assembly tests for the RSU during the brick and mortar deployment by the General Contractor.

When designing the location and specific placement of an RSU site, the following criteria should be considered.

- **Collocation:** Wherever feasible, an RSU shall be collocated at CCTV, DMS or traffic signal locations sites to take advantage of the existing roadside infrastructure, power and communications equipment.
- **Mounting Height** - Per the FCC regulations the DSRC radio shall be mounted at a maximum height of 26 feet above the roadway surface before a maximum Equivalent Isotopically Radiated Power (EIRP) limitation occurs. Mounting height on the structure may need to be lowered/raised to meet the maximum height allowance.

- **Mounting Offset** - Designers must evaluate the RSU mounting offset from the desired structure to maximize range of the device. For example: pole locations set further back from the roadway, should consider using a bracket arm (ex: 6-18 feet) for mounting the RSU. Pole locations that are behind guardrail near to the roadway, may use a standard L bracket arm for securing the RSU to the pole.
- **Clear Line of Sight** - RSU mounting location shall be optimized to achieve clear line of sight to the roadway, free of radio frequency (RF) signal path interference from trees, bridges, overpasses and other structures. Should line of site not be able to be achieved to all traffic approaches to a site from a single mounting location, multiple RSUs may be required to serve the overall site needs.
- **Spectrum Analysis**: DSRC spectrum coordination must be completed to assure all FCC regulatory requirements are met and to ensure no interference with other existing radio frequency (RF) signals is present. Section 12 (Wireless Radio Communications) of SP 725 provides specific guidance.
- **Detection Range:** A maximum detection range of 1,000 meter radius shall be used in the design planning of the RSU for coverage.
- **Mounting Distance:** The distance an RSU can be mounted from a cabinet location is subject to the limited range of Ethernet cabling. Typically, this maximum allowable distance is approximately 328 feet, unless an Ethernet signal booster is used.

Designers shall develop anticipated coverage maps for the RSU at the desired location to ensure optimal DSRC Coverage.

5.3 Managed Field Ethernet Switch

The Managed Field Ethernet Switch (MFES) is used for transmitting data for all Ethernet based devices at the local device cabinet will vary based on the given procurement. The configuration/use of the device will also vary depending on the network architecture in which the switch is deployed.

All CV deployments shall include a Layer 2 or Layer 3 MFES to allow for data transmission within the network architecture. The type of MFES will vary based on the network architecture. See Section 15.2.2 (Network Switch) of SP 725 for further guidance.

For projects that are designed to utilize the local agency ITS communication network, designers shall include the applicable sections of SP 725 for testing the switch for project acceptance. This is needed as it is expected that the contractor will be required to integrate the switch at the RSU location to the overall communications network, like other devices in the project.

5.4 Backhaul Communication Media

The backhaul communication media used to send CV data over the network will vary from site to site. Sites designed outside of the local agency ITS communication network will typically make use of cellular or cable modems to make an internet connection, but may in the future include connection to state-owned infrastructure as TDOT and local signal agencies modernize their systems. Sites designed within the local agency ITS network or a partner agency backhaul network will make use of the communication media that is available within the project corridor (wireless, fiber).

Based on current standards, the minimum amount of throughput/bandwidth required for each DSRC radio is 1 Mbps. However, the throughput requirements vary based on project requirements. The designers shall plan for a minimum throughput of 1 Mbps to ensure all data is transmitted minimizing packet loss.

System Integrators must perform throughput testing for cellular deployment sites to verify an upload speed of 1Mbps can be achieved. For cable deployment sites, the designer shall verify with the service provider that a dedicated 1Mbps link can be established.

For sites designed on state-owned infrastructure with wireless radios, the designer shall perform a wireless site evaluation to verify sufficient throughput. For sites designed on fiber the designer shall complete a fiber link budget.

DSRC sites that make use of cellular leased services shall design the complete system to include the modem, antenna and cabling to make the modem fully functional. All DSRC deployments on the cellular communication platform shall utilize 4G services to ensure the site can transmit data through the internet at the highest available throughput.

DSRC sites that make use of cable leased services shall include all equipment and cabling to bring the cable service provider service lines to the proposed ITS cabinet. The modem is typically provided by the service provider and included in the monthly fee. The deployment shall also include the hardware needed to establish an internet connection and ensure that the data transmitting from the DSRC site can be done in a secure fashion. The designer shall be required to ensure the service provider can provide a static IPv6 address. Dynamic addresses provided by the service provider is not an acceptable solution. Requirements for the IPv6 circuit can be found under the integration section below.

For projects that are designed on to a leased communication network (cellular, cable), designers shall provide guidance for testing the modem prior to project acceptance.

For projects that are designed on state-owned wireless/fiber infrastructure, the designer shall utilize the specification for the type of media.

5.5 Equipment Cabinet

All ancillary components such as power supplies, network switches, and communication media must be located inside an ITS and/or Traffic Signal cabinet. For traffic signals intending to support SPaT broadcast, a traffic signal controller capable of SPaT output will be required.

Requirements for the signal cabinet, controller, and ancillary appurtenances are governed by Section 6 (Equipment Cabinets) of SP 725 and Section 730.25 through 730.27 of TDOT Standard Specifications.

For RSU deployments that are co-located with an existing ITS Site, the following elements should be considered as part of the design:

- Verify space availability for the power supplies, network switches, communication media
- Verify power availability and tie in for the RSU and the ancillary components
- Verify communications ports are available on the network switch/modem

- Verify available conduit entries in to the cabinet are present for communication cabling from the RSU.

5.6 Specifications

Designers will be required to utilize a combination of specifications depending on the type of project. The following table will help guide designers to select the appropriate standard specifications and frequently used special provisions for the type of deployment. Federal references such as FHWA DSRC RSU Specification v4.1a (FHWA-JPO-17-589) is the primary requirements document for DSRC. This document will be used in future revisions of TDOT Standard Specifications as use of DSRC matures. TDOT may also develop an amendment to FHWA DSRC RSU v.4.1a to provide clarifications on requirements specifically for TDOT projects.

Table 2: Specification Comparison – SP725 and Section 730 of Standard Specifications

Specification	Standard Specification/Special Provision Section(s)
Project Overview	730.01, 725.1.1.1
Basic Methods and Materials for ITS Work	730.08-730.21, 725.1.1.7, 725.4.2, 725.5.2, 725.6.2, 725.7.2, 725.8.2, 725.9.2, 725.11.2, 725.12.2.3, 725.14.2
Protect ITS Infrastructure	725.11.2.6
Grounding, Bond, Lightning Protection, Surge Protection	730.19, 730.21, 725.5.3.4, 725.5.3.5, 725.6.3.1, 725.7.3.1, 725.8.2.11, 725.12.2.5, 725.11.2.10
5.9 GHz DSRC Radio	725.12
Managed Ethernet Switch	725.15.2.2, 725.15.2.3
Cellular Modem	725.12.2.1
Cable Modem (est. cost to contractor)	730.38
Cable Modem, Integrate	725.12.2
System Integration and Testing	725.1.5.1-725.1.5.10, 730.22
Local Testing	725.1.5.1-725.1.5.10, 730.23
Fiber Optics	725.4
Unlicensed Wireless Communication Link	725.12.2.1
Field Security Appliance	730.16, 730.22
Digital NEMA Type Controller and Cabinet	725.6.2
Cabinet, Intelligent Transportation Systems	725.6

5.7 Communication System

A communication system is required to enable end-end data transfer between center-to-field and between components locally at the site. This section will review the various network architectures for RSU deployments around the state including deployments using leased lines (cellular/cable) and deployments that are on the state-owned network (wireless/fiber via TMC head-end). Designers shall be required to adhere to the network architecture for each given deployment.

The goal of each RSU deployment is to ensure the following communication is established:

- Communication between RSU and traffic signal controllers (if applicable)
- End to end communication between RSU and TDOT's network
- End to end communication between RSU and SCMS digital certificate server for certificate request and renewal

While designers are not required to design the end to end communication, they should be aware of the architecture and equipment required to be in place for the System Integrator to establish communications.

In general, the system integrator is responsible for the following:

- Design for the required throughput at the site.
    - Cellular leased services – the designer shall perform a speedtest
    - Cable leased sercies - verify required upload speeds with the cable provider when coordinating for cable service
    - Agency-owned ITS Network – Wireless – perform wireless site surveys
    - Agency-owned ITS Network – Fiber – perform fiber link budget analysis
- Including all of the required communication media/hardware on the design drawings as applicable – network switches, modems, fiber hardware assemblies, etc.
- Identify potential cabinet modifications to support communication equipment/hardware
- Providing a cabinet wiring diagram for the connection of the components
- Include the appropriate equipment specifications

5.7.1 Communication Architecture for Agency-Owned ITS Network

In an agency-owned architecture environment (compared to Leased Communication Services), the site shall be designed following TDOT's traditional design practice for both wireless and fiber optic deployments in to the ITS environment. The communication resource will be required to be integrated to the ITS network by the general contractor and thus, the appropriate testing provisions must be added to construction contracts.

TDOT has already established a security policy to allow for data transfer between the state IT network and the internet. The designer will not be required to include any integration/testing to 3rd parties. Figure 2 below shows an example of communication architecture for an agency owned ITS network.

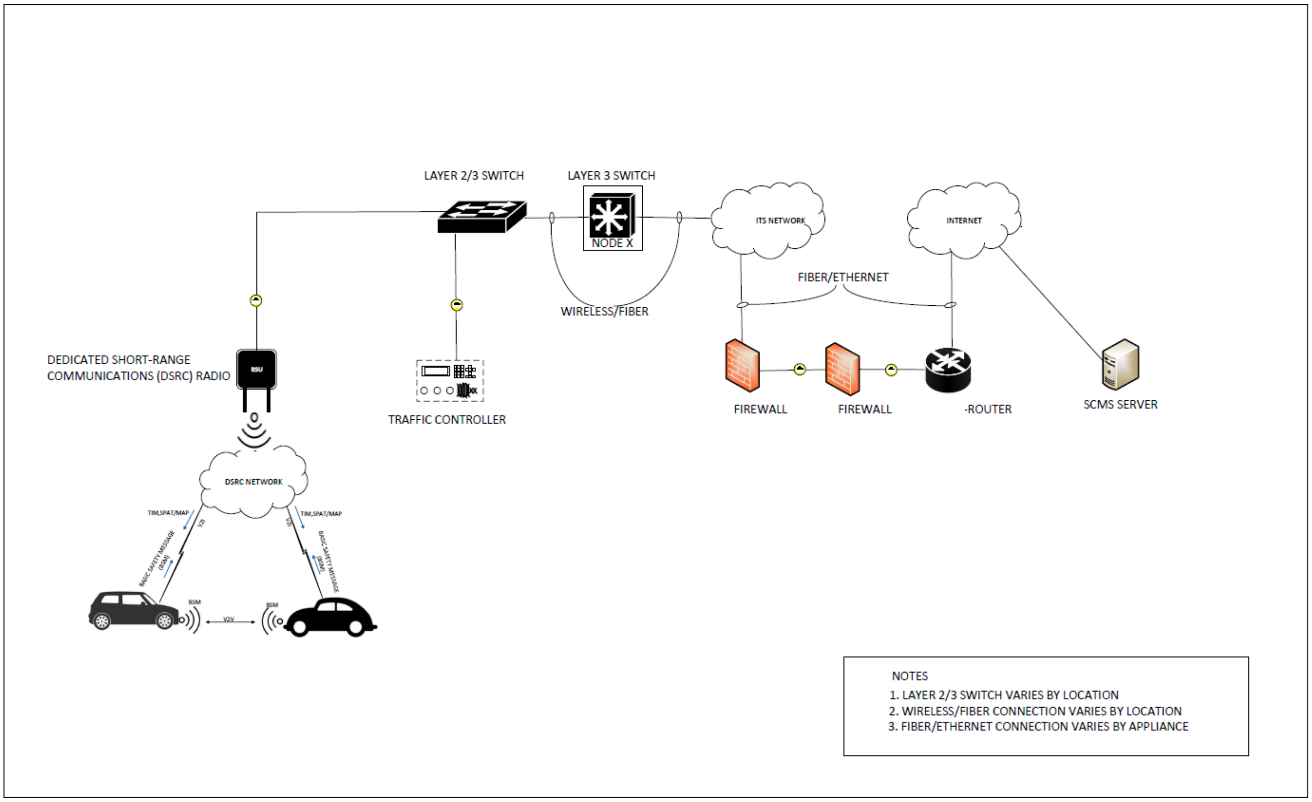


Figure 2: SAMPLE COMMUNICATION ARCHITECTURE FOR AGENCY OWNED ITS NETWORK

6. Integration and Testing Services

6.1 Overview

System integration and testing of the CV devices will be completed by the General Contractor/System Integrator. System integration and testing requirements includes the following:

- Complete the network integration and configurations of CV devices into the Local Agency ITS communication network
- Coordinate with TDOT and the Local Agency to file the required DSRC licensing forms with the FCC
- Configure the backhaul communication
- Upgrade the firmware of the RSU's to the latest standards/certifications as needed.
- Upgrade the firmware of the Traffic Signal Controllers as needed, to support SPaT broadcast
- Conduct testing required to prove functionality and operation for local, subsystem and final system.
- Assist TDOT as needed during the testing of the applications with their partners.

6.2 Networking and Configuration

High-level system architecture diagrams typically depict the interconnectivity of proposed devices, including delineation of IPv6 and IPv4 required connectivity. The primary device responsible for providing WSMP and IPv6 functionality over DSRC in a V2I implementation is a RSU. This device typically has two interfaces, a DSRC radio and an Ethernet interface. RSUs are considered layer 3 network devices, and route IPv6 traffic between their Ethernet and DSRC interfaces. The Ethernet interface is connected to the local network, which must support IPv6 connectivity to the Internet to enable DSRC-equipped vehicles to access the SCMS offered by commercial providers. RSUs also support IPv4, but only on the Ethernet interface. This allows administrators to manage the device and for local IPv4 data sources to provide data to the RSU without a global IPv6 requirement.

In summary, a fully functional V2I implementation supports global IPv6 connectivity from a vehicle, through an intersection RSU, to back office services and local IPv4 connectivity between the RSU and other local data sources.

6.2.1 IP and Networking Requirements

All RSU units shall include dual-stacked IPv4/IPv6 capability. IPv4 address shall allow for support the following;

1. Secure Shell protocol (SSH) device management, which provides secure access to remote computers within the ITS network
2. BSM forwarding if ITS network infrastructure isn't IPv6 ready to support BSM forwarding in IPv6
3. IP communication with Traffic Signal Controller to receive SPaT data.

IPv6 address shall allow for the following:

1. End to end communication with the state or local agency network data repository server to deliver raw data
2. End to end communication with SCMS digital certificate server for certificate request and renewal
3. SSH remote device management from only allowed IPv6 addresses
4. Simple Network Management Protocol (SNMP) remote device management and state of health monitoring

6.3 Security Requirements:

Secure the Ingress/Egress devices using combinations of the following:

- Implement network segmentation (Virtual Local Area Network, VLANS)
- Install Firewall and implement Protocol Filters, Access Control Lists, and Network Policies
- Apply Router/Firewall Filters, Access Control Lists, and Network Policies to Internet router
- Restrict communications to only approved Public IPv4 and IPv6 addresses/URLs
- Restrict communications to only approved Public IPv4 and IPv6 ports

- Deny communications from internal IPv4 addresses
- Deny communications from internal IPv4 ports
- Implement an IPSec tunnel between the Internet Firewall Appliance and the Checkpoint Firewall
- Implement an IPSec tunnel between the Internet Endpoint and the Checkpoint Firewall
- Enable access logging to System Log (SYSLOG) or monitoring server

Securing the field CV device:

- Secure the field CV devices using combinations of the following:
- Switch Layer 2 VLANs
- Apply Switch Filters, Access Control Lists, and Network Policies
- Restrict communications to only approved IPv4 and IPv6 addresses/URLs
- Restrict communications to only approved IPv4 and IPv6 ports
- Restrict System User Access to only approved users
- Enable access logging to SYSLOG or monitoring server
- Disable unused switch ports
- Enable MAC based port security or 802.1x

General security best practices:

- Change default passwords before attaching to live network, including Simple Network Management Protocol (SNMP) configuration by device
- Use only strong passwords based on the local security policy
- Implement SSH communication / HTTPS
- Disable Telnet / HTTP services
- Change default SNMP community strings
- Ensure native VLANs are tagged on all 802.1Q trunks
- Implement or integrate an access logging and monitoring solution to identify attacks
- Regularly check for Operating System (Firewall, Router, Switch, Linux, Windows, etc.…) vulnerabilities and install the proper security patches and updates
- Explicitly disable IPv6 if it is not required.

6.4 RSU Licensing

DSRC RSUs shall be licensed in accordance with 47 CFR Part 90 Subpart M6 of the FCC's rules. FCC Public Notice DA 04-31658 provides the details of the DSRC RSU licensing process.

TDOT IPO is responsible for filing the required forms with the FCC and maintaining accurate records of all licensing paperwork. TDOT has obtained a non-exclusive DSRC geographic area license for the State of Tennessee which authorizes them to operate in all channels of the 5.9GHZ band in the entire state.

The IPO is responsible for filing the FCC 601 Schedule M form online to register each individual RSU location under the geographic area license or call sign provided by the FCC. Schedule M requires the following information:

Table 3: RSU Licensing Responsibilities

Required Information	**FCC**	**TDOT**	**General Contractor/System Integrator**
Call sign	X		
Licensee name		X	
RSU identification number	X		
RSU site coordinates			X
Channel number(s): should refer to IEEE 1609 Standard for identification of service channels			X
Equipment class: Based on relevant zone “of RSU transmissions at proposed site.			X
Transmit Power			X
Antenna height			X
Antenna manufacturer and model			X
Antenna gain			X
Antenna azimuth			X
Antenna elevation angle			X
Registration data		X	

General Contractor/System Integrator must coordinate to record all the RSU data required for registration and provide to the IPO for filing.

It is recommended a spreadsheet be created by the System Integrator for each RSU deployment project and the IPO maintain an overall database for all the RSU’s in the state.

6.5 Backhaul Integration

Backhaul integration includes local integration to the ITS cabinet site and integration to the TDOT ITS or local agency network. Based on the location of the RSU the backhaul communication media includes wireless links and fiber optic communication.

6.6 Creating MAP Files

The RSU devices that will be deployed throughout the Tennessee roadway network and in locations that are enabled and integrated with traffic signal controllers are capable of broadcasting current SPaT information in combination with intersection lane and intersection layout configurations as a MAP broadcast message component.

The spatial accuracy (both horizontal and vertical) are important factors in broadcasting a properly formed safety-oriented broadcast message from the RSU to a vehicle. In addition, the intersection layout specific direction, lane position and lane type are also important elements to broadcast accurate. These affect or impact downstream application logic for the OBU vehicle device, and should be coupled with vehicle heading, path prediction, location (Latitude, Longitude, Elevation), speed within the Basic Safety Message (BSM). As a result of these end to end broadcast components needing accurate spatial information, it is important that the Department implement collection methods that are consistent and allow for update/management of message data by location over time (which message is broadcasting from which RSU, including how long a specific message is being sent and when a message should no longer be broadcasted from a specific RSU), as part of a systematic management and controlled/tested and verified message assembly application, workflow and process.

6.7 Acceptance Testing

The acceptance testing requirement for DSRC equipment will generally follow the same steps and procedures followed for the acceptance testing of the standard ITS and traffic signal devices with the addition of specific testing required for the RSU operation and functionality as well as final testing of applications with TDOT partners and Local Signal Agency. Section 1 of SP 725 includes Factory Acceptance Test (FAT), Bench Test Component (BTC), Bench Test System (BTS), Pre-Installation Test (PIT), Stand Alone Test (SAT), Conditional System Acceptance Tests and Burn-In Period procedures and party responsible for each.

The procedures listed here apply only to RSU operation and functionality testing and will not include testing of backhaul communication or ITS network components. The testing shall be conducted by the general contractor that will be procuring and installing the devices. TDOT consultants or TDOT reps should be present during the testing.

The final testing for the RSU shall be conducted from the TDOT Region TMC or Traffic Operations Center at the local agency by the TDOT or local agency System Integrator. TDOT or local agency representatives should be present during the testing. The goal of the Conditional Acceptance Test is to verify end to end communication between TDOT ITS or Local Signal Network and RSU devices. To prepare for the field testing the System Integrator must confirm the TDOT or Local Signal Agency Firewall, RSU and IPv4/6 routing are operational. The final End-to-End Acceptance should include driving a vehicle with an OBU through the intersection/system and verifying all DSRC messages are formatted correctly and contain the correct data. For SPaT/Map specifically, a SPaT Visualizer should be utilized to verify the RSU is broadcasting SPaT, the correct Map, and that the Map accurately represents the intersection

7. Maintenance/Operations Requirements

Maintenance of the RSU infrastructure for the CV deployments will be critical to ensure optimal performance of the equipment. A preventative maintenance plan should be developed by the local signal agency along with their maintenance contractor to include at least the following items:

- Firmware Updates – ITS Maintenance will be required to update firmware on both the RSU and signal controller as new standards are implemented and as new SPaT firmware updates are available
- Verification of condition of the RSU and ancillary components such as mounting, cabling, antenna every 6 months
- Verification waterproofing of the device every 6 months
- Maintenance shall also include all traditional ITS elements at the site including cabinets and power.

Operations of the RSU should be continuously monitored through an available SNMP tool to ensure the device is operational (on/off). The monitoring through SNMP shall follow TDOT ITS or local signal agency standard procedures by maintenance for monitoring device availability.

A verification that the application is operational is another key element. Depending on the running applications and expected message sets, TDOT and the local signal agency should verify the correct messages (BSM, Traveler Information Messages ([TIM], SPaT) are being delivered for the intended application.

APPENDIX A: Interview Summaries

Interview Notes

DSRC Statewide Guidance Project

Blaine Leonard, Utah DOT – 5/31/18

- Topics to cover:
  - What are various types of SPaT deployments?
  - Have any states deployed “maintenance agnostic system”?
  - Miovision or other intermediate black box between RSU and controller
  - Recommend states that are similar to TN
- States: not much interaction with signals
- SPaT challenge agency isn’t the state but local agencies, with state assistance
- I-24: pick signals at interchange
- SPaT challenge: Con Ops doc will be a good one
- Upgrade Signal cabinets
  - ATC
  - Communication: fiber, wireless (interconnect)
- Econolite Cobalt: sells a co-processer card that does “CV stuff”
  - Get data out of controller, convert J2735 message set
- Savari: major RSU vendor (Utah has used, not using it anymore)
  - Used Econolite CV processer board and Intellite CV
- DSRC: handful of suppliers (6 or 8) but hardware is still maturing
  - Were installing 3 or 4 at a time, they don’t have manufacturing capability
- Lear bought Arroda
- Cohda – Australian based, USDOT likes, good service,
- Siemens – supplier to Tampa
- “Enso”
- Wave Mobile
- Commsignia
- Safari
- SPaT Models:
  - Pick a corridor, hang some DSRC, connect to ATC and broadcast SPaT and MAP
  - WashDOT – 2 or 3 signals scattered around the state
  - VDOT – DSRC along the freeway
- Agencies understand DSRC and how to deploy it
- Send a message to automakers who want to get this done (Toyota)
- UDOT: DSRC in buses, TSP corridor
- Michigan: TSP
- MN: snowplow application, Fleet vehicles
- DSRC: 5.9 GHz
  - FCC license to operate in this band (statewide geographic area)
- Dedicated for traffic signal safety applications (other potential users = Military)
- Must register each DSRC unit (lat/long)
  - Ask for elevation/mounting heights
  - Antenna characteristics
- Build date: update the FCC registration
- FCC website: Can search for specific “IQ”

- Michigan DOT: every new signal, rebuild will be DSRC capable
- Automakers in TN: Select installations close to auto locations
- SPaT, MAP, red light violation warning, SRM (signal request message), SSM (signal status message), BSM (basic safety message from car mandatory elements)
- How to monitor if DSRC is working:
  - Portable OBU or other monitoring device
  - SCMS: in order to secure the message
- Tampa / NY / Wyoming: major pilots have to do SCMS as part of FHWA funding
- “Green Hills” route supplier create and supply security certifications
- UDOT and others are broadcasting on unsecured SPaT and MAP
  - Realize that when BSM is broadcast, data / message security will be needed
  - UDOT doesn’t see major risk (worse case is car doesn’t receive green light information)

What about hacker with “back door” into controller – yellow, green, red, ITS network? Ask Brian Reed or Scott

Interview Notes

DSRC Statewide Guidance Project

Greg Larson, Cal Trans – 7/19/2018

- Red light violation warning (doesn't need backhaul)
  - SPaT
  - MAP
- TSP
  - Early green
  - Extended green
- Security is a concern → mechanism for SCMS
- Cal trans test bed month: uses cell communications
  - Radio "stupid" no intelligence
  - Roadside processor linux board
  - Controller 2070/ATC, 2 processor cards
  - $2K-$4K
- AZDOT: partner with automakers in TN
- Options for "DSRC Capable" vs. actual implementation of SPaT and MAP messages
  - Can you do it without backhaul?
  - What are the limitations if no backhaul?
    - No way to monitor broadcast
    - No way to do PM/ troubleshoot without site road
    - No way to gather data on performance of the system
- No backhaul case
  - What are the risks?
  - How to do it – simple steps
  - Is it viable to install DSRC hardware and do a second phase to set up message sets, SCMS, etc.?

Interview Notes

DSRC Statewide Guidance Project

Josh Hollingsworth, City of Tallahassee - 12/13/2017

- Status: about ½ of intersections already have DSRC employed and in need of software upgrade
- Specs/ plans: Genesis CEI will be used to call out line of sight
- Installation: city forces did install PoE radio on mast arm
- DSRC frequency 5.9 GHz
    - FCC license
- FCC 4.0 version upward compatible, 4.1 version security compatible
- Which vendor:
    - Intellite (brand of radio) CV application: message from radio is standardized; proprietary link
    - Controller upgrade: Intellite firmware upgrade for CAV can push upgrade from TME for CV
    - Portable onboard units: TERL, City, FSU
    - ATSPM – UDOT 30 intersections, high res data
    - KITS: recording signal timing, event logging data
    - UDOT software: still have to sift through
- DSRC line of sight/positioning of transmitter maint.
- Controller is collecting phase/time info
    - Confidence interval for actuated signals
    - Pre timed is easy
- Max time CV software: software in Intellite (Linux platform)
- MAP messages reside in the controller
    - Upload/download lanes; associated with phases
- AASHTO Web tool to create MAP message
- TERL Demo
- DSRC Radio: 2-way – TX-RX
    - Sends info to on board unit
- 3 Parts (testing + demo at all three)
    - Controller
    - Radio
    - On Board Unit
- Dr. Moses FSU: study on DSRC/ SPaT/ ATSPM
- GDOT "Maxtime" module Intellite firmware

Josh Hollingsworth, Wayne Bryan, Steve Bryan – 12/18/2017

- City install equipment
- Project without a set of plans
- FDOT procurement
    - Siemens
    - “Wave mobile” (distributed by Control Tech.)
    - Intellite – 2070 communications
    - Power = CAT 5
    - Radio mounted roadside unit
    - Interoperable is key
    - Might be rebranding to sell to Control Tech.
    - Public safety band FCC license
- 2 Apps on Controller (NTCIP to radio):
    - Max connect (MAP data resident here)
    - Max time
- Any ATC controller: TDOT installs, locals maintain
- TERL deployed proof of concept: 2 vendors, 3 radios each
    - Radio and antennae
- Radio:
    - Translator box – controller
    - “Max connect” – CV software
    - “Maxtime” – linuxx module
    - Max “U” – central software
- Seattle, WA:
    - Latency thresholds
    - USDOT MAP tool
    - Maybe an app for smartphones?
    - No OBU → calibrated GPS
- Special Notes:
    - No recurring fees contractor
    - Site survey: prove it works
    - Summary of the report, plans DSRC capable

Interview Notes

DSRC Statewide Guidance Project

Kevin Speakman, TDOT – 7/3/2018

- Signal Maintenance agreement with local jurisdiction – need to review
- Geographic license? Do locals have one? Knoxville County Regional Level?
  - For Ethernet TDOT installs, whose network locals come in after?
- Start with statewide license
  - Transfer to local
  - Whoever purchases the equipment
  - Prequalified vendor list?
- AASHTO working group discussed DSRC
- 2 Classes of DSRC RSU
  - Chip set in the unit
  - WiFi (controlled latency)
- Co-primary
  - NTIA Feds users of FCC
  - High Power Radar Sites
  - Ft. Campbell (70 km radius)
  - Arnold Engineering Airforce Base
  - RF Engineering: emphasize how important to DSRC employment
- TDOT designs/ constructs signal (purchases the equipment)
  - FCC license in TDOT name, then transferred to local
  - Ethernet communication: When does it get put in? If it is put in when signal is constructed, how is it integrated to local ATMS network?
- FCC needs a firm to advertise the use of the frequency/ channel
  - Allow 30-90 days

Interview Notes

DSRC Statewide Guidance Project

Philip Reyes, City of Knoxville – 6/7/2018

- Proof of concept
- University Research
  - ETSU / UT
  - Arroda RSU / OBU
  - Trafficware firmware 980 ATC
- SPaT to OBU and handheld smartphone app
- Pedestrian warning for cross walks
- Vehicle warning for pedestrians
- Initial Timing
- SPaT limit:
  - Max 1
  - Max 2
  - Est. time left (max + current time)

Coordination: SPaT gets goofed up

Interview Notes

DSRC Statewide Guidance Project

Raj Ponnaluri, FDOT – 12/15/2017

- Raj will send along RFP
- Status: by end of January aim to have all RSO installed
- "Control Technologies": by the end of February begin field testing
- RSUs have been delivered, on board units are on the way
- FSU research project
- Data security:
    - I-95 CV Coalition
    - I-75 FRAME
    - DSRC 75 miles, 1 per mile US 331/US 401
    - D2/D5 – RFP December 2018
        - RFP for design-build August 2018
- ATC MTD grant – D5 call Jeremy
    - Bike / Pedestrian Safety
- Central Pl. AV proving ground / test bed
- Gainesville SPaT: 27 units deployed between University Blvd. and Archer 23rd
    - Bike / Pedestrian Safety
- UF "AID Project": $1 million in grants to FHWA
    - 13 signals + crosswalks
    - Passive pedestrian detection
- CV/Arterial Management Specialist (Raj promotion!)
- Gainesville Autonomous Shuttle – Regional Transit System, April 2018
- Control Technologies, Temple, Siemens, FLIR
    - $360K on 24 intersections
    - 35 RSU: $3K-$5K
    - 5 OBU: $5K-$8K
- Lessons learned:
    - Procurement process
    - IPV4 to IPV6 (internet of things)
- Don't get too worried about DSRC vs. 5G

Webinar Notes

DSRC Statewide Guidance Project

SPaT Challenge Webinar #3 – 4/17/2018

- Blaine Leonard – Utah DOT
- David Kelly – Subcarrier Systems Corp.
- DSRC message set
- MAP (static): orthogonal, converted from lat/long
- SPaT (dynamic): more than just signal times
- DSRC transmit compressed MAP message point data then the offset to the next point
- Eco-driving: adjust power based on “time to red”

SPaT Challenge Webinar #3 – 4/17/2018

- Blaine Leonard – Utah DOT
- David Kelly – Subcarrier Systems Corp.
- DSRC message set
- MAP (static): orthogonal, converted from lat/long
- SPaT (dynamic): more than just signal times
- DSRC transmit compressed MAP message point data then the offset to the next point
- Eco-driving: adjust power based on “time to red”

SPaT Challenge Webinar #4 – 4/24/2018

- Blaine Leonard – Utah DOT
- Kyle Rush – Leidos
- Matthew Marchese
- ISD: intersection Situation Data (hybrid of MAP and SPaT)
- Encoding menu
- MAP creator tool

SPaT Challenge Webinar #5 – 5/15/2018

- Blaine Leonard – Utah DOT
- WSA: wave service advertisement; RSU broadcast
- RSU specs 3.0 to 4.1
- SCMS: security credential management system (industry standard)
- SNMP: simple network management protocol
    - Traditional, direct loading of message files (SCP, FTP, etc.)
- Message forward: should RSU forward (1609) headers? Configurable through NTCIP 1218
    - WSA handles immediate forward message
- RSU set: allows multiple RSU’s to operate as a single unit
- RSU 4.1 spec and test plan
- Raj P.: FDOT project status
    - RSU might need to be 2 or more per intersection due to line of sight
    - MCTT multi-channel test tool

SPaT Challenge Webinar #6 – 6/12/2018

- Steve Norvosad – HNTB
- Jay Parikh – CAMP
- Joe Gorman – Michigan DOT
- SCMS: What are risks of SPaT without SCMS?
  - Message verification from Auto Industry
  - PII: personally identifiable information
- Safety risks exist with the simple SPaT message if it isn't accurate
- RTCM: is it needed for every intersection?
  - Configuration, complexity, open sky, good visibility
- System level: RSU to controller
  - Business process for signal group and ITS group within DOT
- Message level: over the air (OTA) broadcast
- Application level
- Output from controller: V2I Hub, NCTIP 1202 coordinate system architecture signals vs. ITS
- New firmware may make old hardware SPaT compatible
- SAE J2735 2016_03
- Optional data elements: verify that they are all included for desired applications
- FCC Ch. 172: Safety of life applications:
  - May do SPaT on one channel and MAP on another
  - Alternate along a corridor if signals are close together
- Chris Stanley – Leidos (wrote 4.1 specification); CAV support services
- Equipment Loan Program: connect Steve Bryan with this service
- MAP creator tool

SPaT Challenge Webinar #7– 7/17/2018

- Joanna Wadsworth
  - Las Vegas Driverless Shuttle
  - 4 separate deployment / use cases
  - Lessons learned: Pilot projects are a good way to go
- Elizabeth White (VDOT / VA Tech)
  - Northern VA 30 arterial RSU SPaT + MAP, 19 Freeway RSU
  - Smarterroads.org
  - McCain 2070
  - Adv. Traffic Solutions D4 Firmware (custom firmware update)
  - VDOT – MIST central software
  - 50 POV w/ OBU to rec. SPaT
- UDOT ("Neelo")
  - 30 intersections using intellite central software
  - 26 intellite
  - 4 econolite
  - MAP message:
    - Used high res google mapping
    - Had survey crew to validate
  - Look at cabinet layout sketch using separate roadside application processor (RSP) on a linnux board in the cabinet
  - Interoperability affected by firmware upgrades

SPaT Challenge Webinar #8; Q&A– 8/4/2018

- USDOT pilot sites: checked interoperability
  - 6 or 7 different vendors, were able to get them working

- Time to change coding for trafficware for NTCIP 1202 v 3
- Fail safe for driverless shuttle? Has operator on board, can take control if needed
    - DSRC has failed in one instance; looking for redundancy
- What happens to SPaT / MAP broadcast if road / intersection is under construction and you have lane closures or sh
    - Looking at management software
- Length of time for FCC licensing process
    - Worked with vendor
    - Specific info about radios; GPS lat/long
    - 4 to 6 weeks for processing by FCC
- GPS accuracy: RTK base station may be needed
- Lear, Savari, Cohda tested by Utah
- PoE install inside the pole or in separate conduit strapped to pole
- Is there an issue with PoE in same conduit with power and fiber and CAT5?
- VTT1 has used Cohda MKS to develop applications and run software
- 3 Cases:
    - Software on Linnux
    - Signal controller runs software
    - DSRC / RSU vendor runs software
- SCMS value is to certify that the message sent ot the vehicle is a valid message
    - Network firewall is not a substitute
- Maintenance? Internal resources UDOT, Las Vegas

APPENDIX B: Sample Specification Language

Appendix B

Sample Specification Language:

The following specification language has been assembled from various sources as minimum standards that should be used as a sample to develop standard specifications for TDOT. This should be done in cooperation with TDOT Traffic Operations and Construction Office in a future phase of the DSRC Statewide Guidance Project. **This sample specification language should not be used in construction contract documents without coordination with the appropriate TDOT Offices.**

1.0 Device Requirements

1.1 General Requirements

This section identifies the DSRC RSU and OBU general requirements:

- The devices described in this document are deployment grade electronic instruments that must be capable of both transmitting and receiving 5.9 GHz DSRC for facilitating connected vehicle applications. Each unit shall include all components necessary for complete functionality of the unit. Types of proposed devices include Road Side Unit (RSU), On Board Units (OBUs), Traffic Controller, and handheld units or referred to as Multi Channel Test Tool (MCTT).
- If Vendors have multiple generations of hardware available, they shall offer only the latest version of their equipment for this bid.

1.2 Minimum Technical Requirements

This section identifies the minimum equipment requirements for the project.

1. All devices offered shall be new and available for purchase from the awarded Vendor.
2. DSRC Road Side Units (RSUs) shall be carrier grade.
3. RSU must comply with USDOT RSU Device Design Specification v4.0, and be capable of a firmware upgrade to v4.1 (including the Hardware Security Module) at no additional cost.
4. DSRC two-way communication protocol shall employ and integrate the Institute of Electrical and Electronics Engineers (IEEE) 802.11p, 1609.0-1609.12 standards and the Society of Automotive Engineers (SAE) J2735_201603 message set dictionary.
5. RSUs shall support the remote antenna hook up of at least 60 ft.
6. RSUs shall support an Internet Protocol (IP) IPv4 connection to the USDOT Proof of Concept Security Credential Management System (SCMS).
7. RSUs shall transmit the Signal Phasing and Timing (SPaT), Traveler Information Messages (TIMs), and intersection geometry (or MAP) messages as defined in SAE J2735_201603.
8. RSUs shall forward Basic Safety Messages (BSMs) received from passing vehicles to a configurable remote network host

9. OBUs shall transmit the BSM as defined by SAE J2945/1
10. OBUs shall process BSM, SPaT, MAP and TIMs and provide applicable information to driver
11. The RSU and OBU shall support both 10 and 20 MHz channels in the 5.9 GHz DSRC band.
12. The RSU shall support Global Positioning System (GPS) as specified in USDOT RSU Specification 4.0/4.1.
13. The OBU shall support Global Positioning System (GPS) as specified in SAE J2945/1.
14. The RSU devices shall integrate with the supplied traffic signal controllers and shall connect to an existing IP network via Ethernet.
15. The RSU devices shall have software applications installed which will accept information from signal controllers and broadcast SPaT messages.
16. OBU devices shall be of the "carry-in" type; a portable device intended for use in the vehicle but not integrated into the vehicle system.
17. The OBU shall be capable of being powered by in-vehicle systems.
18. The RSU hardware shall be able to use Power over Ethernet (PoE) of at least PoE 802.3af. (Note one or more intersection may require PoE over 300 ft.)
19. Any additional enclosures required to accommodate supporting equipment shall be National Electrical Manufacturers Association (NEMA) rated with surge protection.

1.3 Contractor Prequalification

1. Experience providing equipment for, and working on similar vehicle to infrastructure (V2I) tests or projects.
2. Experience working with USDOT’s Affiliated Connected Vehicle Test Beds and Pilots.
3. Staff availability and resumes showing experience in similar V2I installation projects.
4. Experience working with Basic Safety Message standard SAE J2735_201603 and SAE J2945/1 latest version.
5. Equipment is an approved Federal DSRC broadcasting equipment and are tested and approved USDOT projects per RSU specifications described in this document.
6. Ability to provide RSU system and other materials as shown in the contract plans within thirty (30) days of the Notice to Proceed (NTP).
7. Ability to perform training and oversight for the installers and other staff.

1.4 Qualitative Standards and Criteria

The Vendor shall ensure the following standards and criteria are followed:

1. DSRC RSU specifications document – preferable version 4.1, or 4.0 that is forward compatible with 4.1.
   Version 4.0:
   http://docplayer.net/11087167-Dsrc-roadside-unit-rsu-specifications-document.html Version 4.1:
   http://www.fdot.gov/traffic/Doc_Library/PDF/USDOT%20RSU%20Specification%204%201

_Final_R1.pdf
2. 5.9 GHz DSRC Technical Specifications
3. DSRC Message Set Directory – the SAE J2735_201603 Library for BSM, SPaT, MAP, and TIM: https://www.sae.org/standardsdev/dsrc/
4. Best Practices for Surveying and Mapping Roadway and Intersections for Connected Vehicles; Connected Vehicle Pooled Fund Study; May 15, 2016; http://escholarship.org/uc/item/4f88m75k#page-1
5. USDOT SPaT Documentation Obtain from www.itsforge.net
6. USDOT SCMS http://www.its.dot.gov/pilots/pdf/SCMS_POC_EE_Requirements.pdf or later
7. USDOT Intersection MAP and SPaT Tool https://webapp2.connectedvcs.com/

APPENDIX C: Sample Typical Detail Drawings

STRAIN POLE GENERAL NOTES

Ⓐ LOCATIONS OF SIGNAL POLES SHOWN ON PLANS ARE APPROXIMATE AND CAN BE ADJUSTED UP TO 2' TO AVOID UTILITIES. ADJUSTMENTS GREATER THAN 2' MUST BE REVIEWED AND APPROVED BY ENGINEER.

Ⓑ ALL STRAIN POLES AT AN INTERSECTION SHALL BE SAME DIAMETER AND BOLT CIRCLE.

Ⓒ TYPICAL AERIAL POWER SERVICE ENTRANCE IS THROUGH WEATHER HEAD AND DOWN POLE INTERNALLY.IF CABINET IS POLE MOUNTED, AS AN ALTERNATE POWER SERVICE CABLE MAY BE RUN DOWN OUTSIDE OF STEEL STRAIN POLE IN 1" RGS RISER. UNDERGROUND POWER SERVICE SHALL BE RUN THROUGH SEPARATE 1" RGS CONDUIT THROUGH POLE FOUNDATION (SEE STD. DWG. T-SG-5).

Ⓓ POWER SERVICE CABLE SHALL BE RUN ON SEPARATE MESSENGER CABLE (2' ABOVE SPAN WIRE WITH SIGNAL OR DETECTOR CABLES).

Ⓔ ADDITIONAL WEATHER HEADS MAY BE INSTALLED FOR EASE OF CABLE ENTRANCE IF NECESSARY (TO BE FIELD DRILLED AND TAPPED).

Ⓕ ENTRANCES FOR POLE MOUNTED SIGNAL HEADS SHALL BE FIELD DRILLED TO ENSURE PROPER PLACEMENT.

Ⓖ RED INDICATIONS TO BE APPROXIMATELY SAME HEIGHT. HANGER CONNECTOR EXTENDER OR TETHER EXTENDER MAY BE REQUIRED.

Ⓗ PEDESTRIAN SIGNAL HEADS TO BE CLAMSHELL MOUNTED UNLESS OTHERWISE SHOWN ON PLANS.

Ⓘ SEE STD. DWG. T-SG-4 FOR ADDITIONAL DETAILS.

DSRC INSTALLATION GENERAL NOTES

Ⓐ DSRC RADIO AND COMPONETS SHALL BE INSTALLED PER LATEST FCC STANDARDS AND REGULATIONS.

Ⓑ ALL COUNDUITS AND DUCTS SHALL BE SEALED WITH A RUBBER FITTING OR A WEATHER HEAD.

Ⓒ ALL MOUNTING HARDWARE SHALL BE STAINLESS STEEL.

Ⓓ BRACKET ARM PAID FOR AS A PART OF ROAD SIDE UNIT PAY ITEM.

Ⓔ THE MAXIMUM HEIGHT FOR MOUNTING OF THE DSRC RADIO SHALL BE 26 FEET ABOVE THE ROADWAY SURFACE.

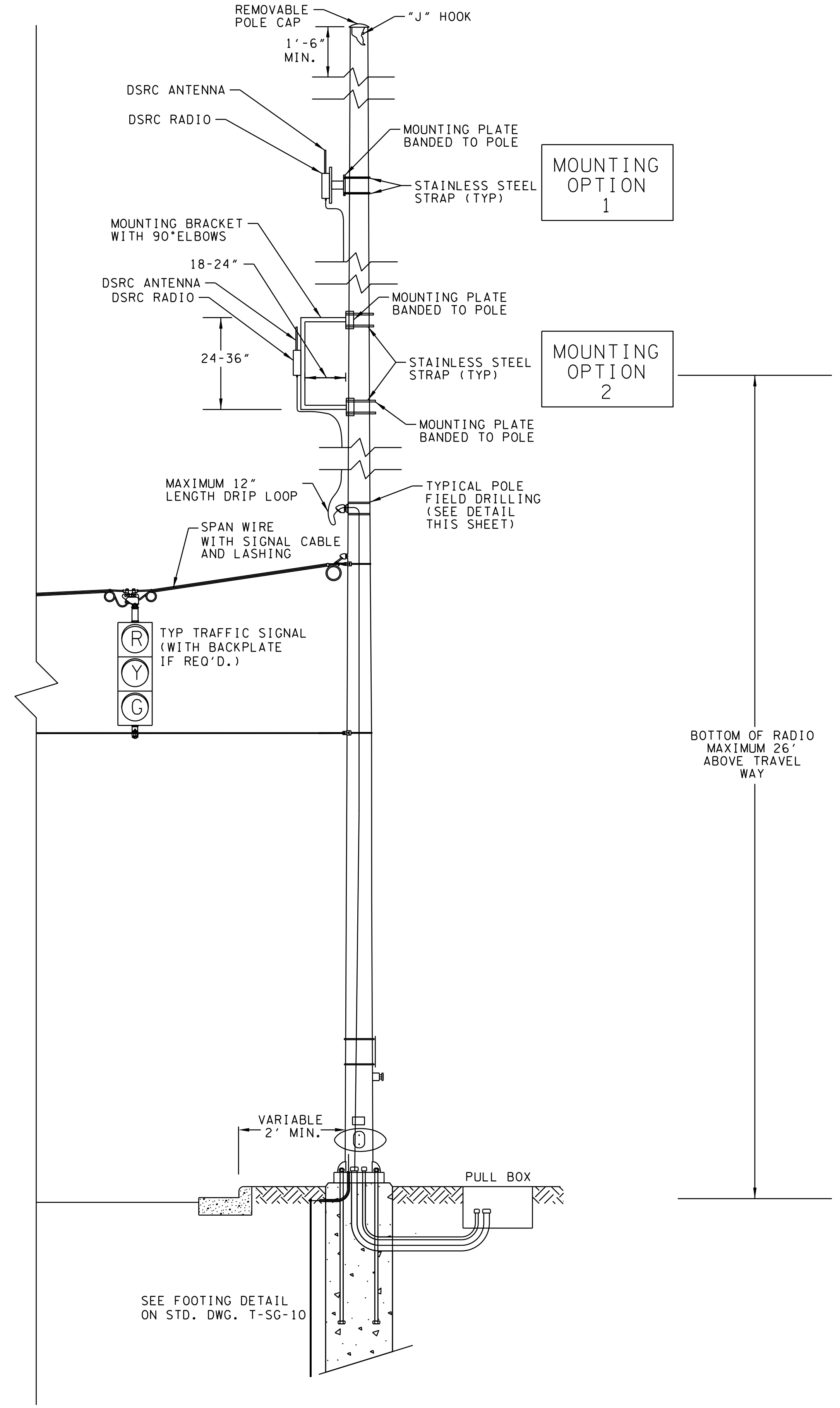
Ⓕ RSU SHALL BE MOUNTED IN SUCH A MANNER TO ACHIEVE CLEAR LINE OF SIGHT TO THE ROADWAY FOR ALL INTERSECTION APPROACHES.

Ⓖ THE CONTRACTOR SHALL FIELD IDENTIFY THE MOUNTING LOCATION THAT PROVIDES THE MAXIMUM AMOUNT OF COVERAGE FOR ALL INTERSECTION APPROACHES. THE FINAL LOCATION SHALL BE APPROVED BY THE ENGINEER PRIOR TO INSTALLATION.

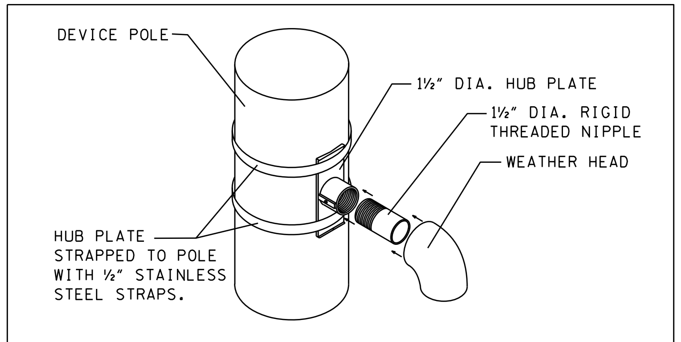
Ⓗ THE METHOD AND MATERIALS USED TO MOUNT THE DSRC SHALL BE DETERMINED BY THE CONTRACTOR AND APPROVED BY THE ENGINEER PRIOR TO INSTALLATION.

Ⓘ CONNECT DSRC RADIO/ANTENNA TO PROCESSOR AND TRAFFIC SIGNAL CONTROLLER IN SIGNAL CABINET USING POWER OVER ETHERNET CABLING AS APPROVED BY THE ENGINEER.

Ⓙ DSRC MANUFACTURER REPRESENTATIVE SHALL BE PRESENT DURING DSRC EQUIPMENT INSTALLATION AND SET UP.



TYPICAL SPAN WIRE DSRC MOUNTING DETAIL



NOTE: 1½" HOLE TO BE DRILLED BEHIND HUB PLATE. ALL FIELD DRILLED HOLES SHALL BE LOCATED AFTER EQUIPMENT POSITION HAS BEEN DETERMINED SO THAT A MAXIMUM 12" DRIP LOOP IS MAINTAINED. COST OF FIELD DRILLED HOLES TO BE INCLUDED IN THE COST OF THE DEVICE OR POLE.

TYPICAL POLE FIELD DRILLING

N.T.S.

STATE OF TENNESSEE
DEPARTMENT OF
TRANSPORTATION

DSRC
STRAIN POLE
MOUNTING
DETAILS

8-3-18 | T-SG-8A

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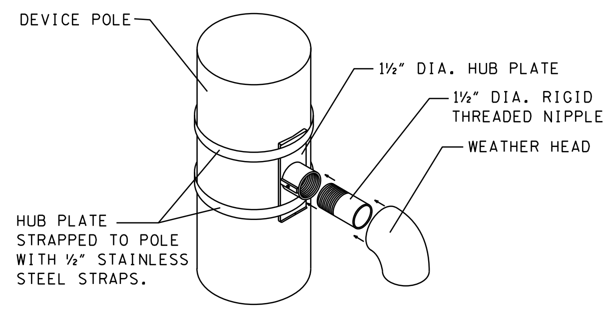
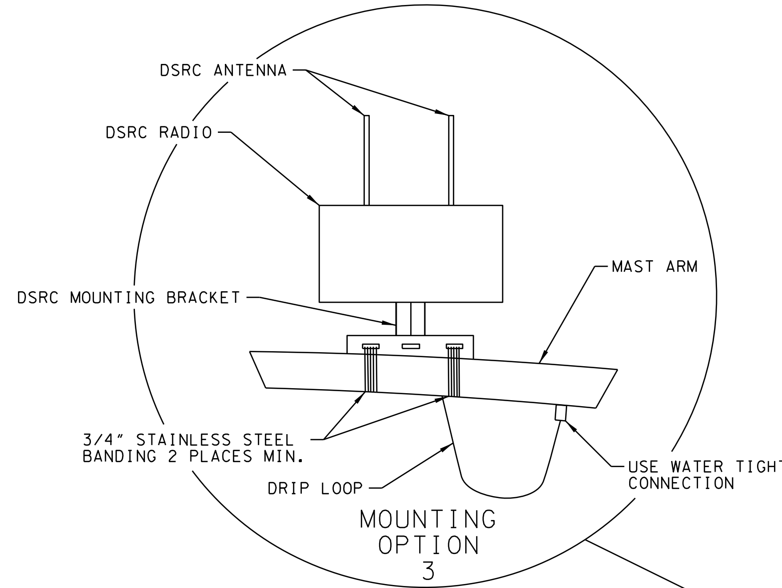


NOTE: 1½" HOLE TO BE DRILLED BEHIND HUB PLATE. ALL FIELD DRILLED HOLES SHALL BE LOCATED AFTER EQUIPMENT POSITION HAS BEEN DETERMINED SO THAT A MAXIMUM 12" DRIP LOOP IS MAINTAINED. COST OF FIELD DRILLED HOLES TO BE INCLUDED IN THE COST OF THE DEVICE OR POLE.

TYPICAL POLE FIELD DRILLING
N.T.S.



MAST ARM GENERAL NOTES

Ⓐ MAST ARM POLE FOUNDATIONS MAY BE ADJUSTED UP TO 2'. ADJUSTMENTS GREATER THAN 2' MUST BE REVIEWED AND APPROVED BY ENGINEER. THE CONTRACTOR SHALL BE RESPONSIBLE FOR VERIFYING ARM LENGTH IS ADEQUATE FOR PROPER SIGNAL HEAD PLACEMENT PER T-SG-7A THROUGH T-SG-7S.

Ⓑ IF CABINET IS POLE MOUNTED, POWER SERVICE CABLE MAY BE RUN DOWN OUTSIDE OF STEEL STRAIN POLE IN 1" RGS RISER AS ALTERNATE TO INTERNAL RUN. UNDERGROUND POWER SERVICE SHALL BE RUN THROUGH SEPARATE 1" RGS CONDUIT THROUGH POLE FOUNDATION (SEE STD. DWG. T-SG-5).

Ⓒ ENTRANCES FOR MAST ARM AND POLE MOUNTED SIGNAL HEADS SHALL BE FIELD DRILLED TO ENSURE PROPER PLACEMENT.

Ⓓ THE BOTTOM OF ALL SIGNAL HEADS ON EACH APPROACH TO BE APPROX. SAME HEIGHT.

Ⓔ PEDESTRIAN SIGNAL HEADS TO BE CLAMSHELL MOUNTED UNLESS OTHERWISE SHOWN ON PLANS.

Ⓕ VIBRATION DAMPER PLATE SHOULD BE INSTALLED ON ALL MAST ARMS 50' OR LONGER AND ALWAYS BE INSTALLED AT OUTSIDE TIP.

DSRC INSTALLATION GENERAL NOTES

Ⓐ DSRC RADIO AND COMPONETS SHALL BE INSTALLED PER LATEST FCC STANDARDS AND REGULATIONS.

Ⓑ ALL COUNDUITS AND DUCTS SHALL BE SEALED WITH A RUBBER FITTING OR A WEATHER HEAD.

Ⓒ ALL MOUNTING HARDWARE SHALL BE STAINLESS STEEL.

Ⓓ BRACKET ARM PAID FOR AS A PART OF ROAD SIDE UNIT PAY ITEM.

Ⓔ THE MAXIMUM HEIGHT FOR MOUNTING OF THE DSRC RADIO SHALL BE 26 FEET ABOVE THE ROADWAY SURFACE.

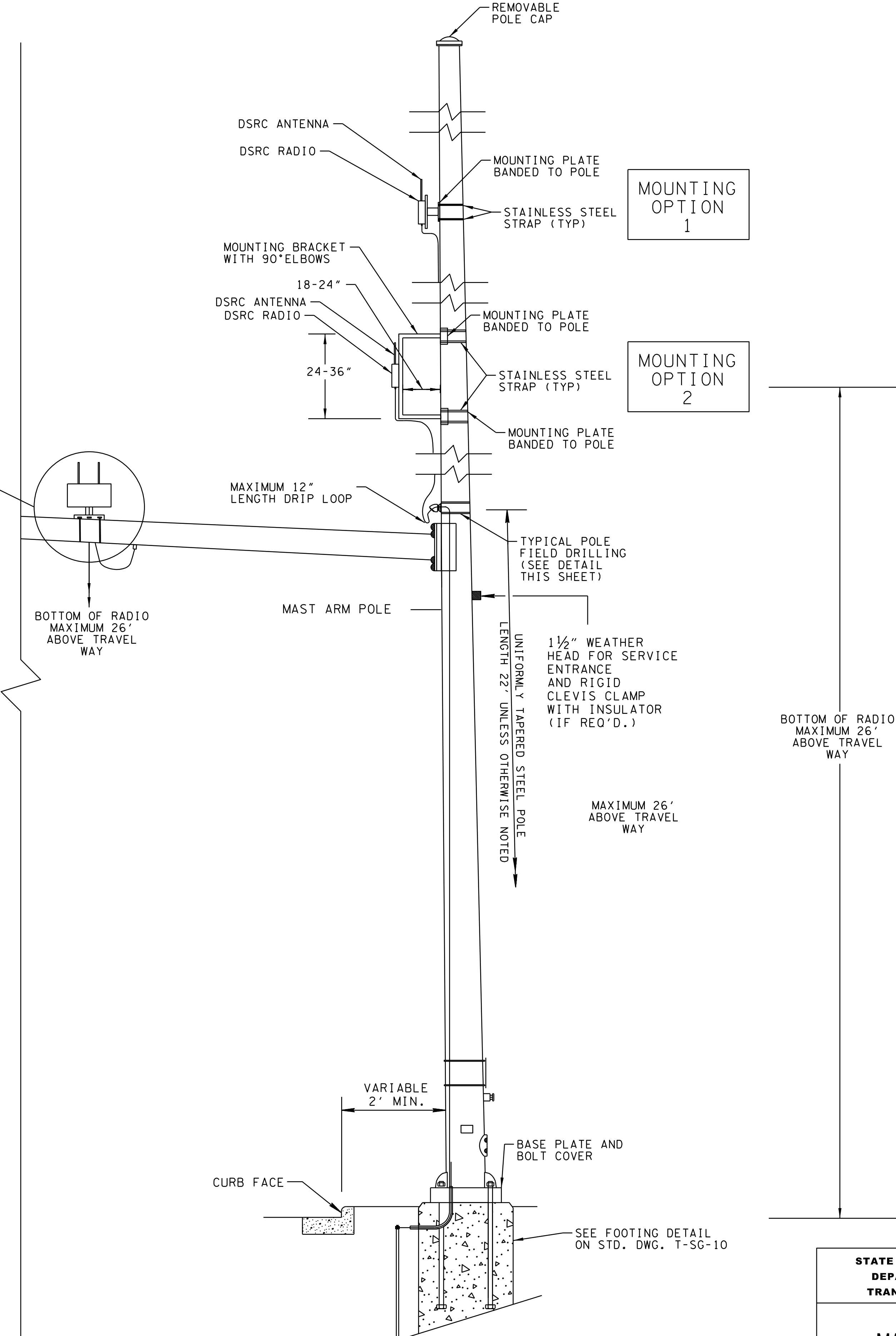
Ⓕ RSU SHALL BE MOUNTED IN SUCH A MANNER TO ACHIEVE CLEAR LINE OF SIGHT TO THE ROADWAY FOR ALL INTERSECTION APPROACHES.

Ⓖ THE CONTRACTOR SHALL FIELD IDENTIFY THE MOUNTING LOCATION THAT PROVIDES THE MAXIMUM AMOUNT OF COVERAGE FOR ALL INTERSECTION APPROACHES. THE FINAL LOCATION SHALL BE APPROVED BY THE ENGINEER PRIOR TO INSTALLATION.

Ⓗ THE METHOD AND MATERIALS USED TO MOUNT THE DSRC SHALL BE DETERMINED BY THE CONTRACTOR AND APPROVED BY THE ENGINEER PRIOR TO INSTALLATION.

Ⓘ CONNECT DSRC RADIO/ANTENNA TO PROCESSOR AND TRAFFIC SIGNAL CONTROLLER IN SIGNAL CABINET USING POWER OVER ETHERNET CABLING AS APPROVED BY THE ENGINEER.

Ⓙ DSRC MANUFACTURER REPRESENTATIVE SHALL BE PRESENT DURING DSRC EQUIPMENT INSTALLATION AND SET UP.



TYPICAL MAST ARM DSRC MOUNTING DETAIL

STATE OF TENNESSEE DEPARTMENT OF TRANSPORTATION

DSRC MAST ARM MOUNTING DETAILS

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APPENDIX D: Sample Pay Items and Plan Notes

Appendix D

Sample Plan Notes:

The following sample language for plan notes has been assembled from various sources as minimum standards that should be used as a sample to develop typical plan notes for TDOT. This should be done in cooperation with TDOT Traffic Operations Office and Construction Office and in a future phase of the DSRC Statewide Guidance Project. **This sample language for plan notes should not be used in construction contract documents without coordination with the appropriate TDOT Offices.**

Road Side Unit (RSU):

- RSUs shall comply with FHWA JPO-17-589 and USDOT RSU Specification 4.1, or 4.0 and be firmware upgradable to 4.1 within 2 months of purchase.
- RSUs shall comply with the USDOT Proof-of-Concept Security Credential Management System (SCMS) with a firmware update when the SCMS is available.
- RSU shall broadcast WAVE Service Announcement (WSA) to advertise the SCMS services including IP address.
- The Vendor shall supply an RSU Software Development Kit (SDK).

On Board Unit (OBU) Needed for testing, validation purposes

- OBUs shall broadcast Basic Safety Messages as defined in SAE J2945/1.
- OBUs shall support DSRC applications based on SAE J2735_201603 defined messages including at a minimum, Signal Phase and Timing (SPaT), MAP, and Traveler Information Messages (TIMs).
- OBUs shall be compliant with the following IEEE standards:
    - 1609.0-2016 or later
    - 1609.2-2016 or later
    - 1609.3-2016 or later
    - 1609.4-2016 or later
    - 1609.12-2016 or later
- OBUs shall comply with the USDOT Proof-of-Concept SCMS with a firmware update when the SCMS is available.
- OBUs shall receive and process WAVE Service Announcements (WSAs)
- The Vendor shall supply an OBU SDK

Sample Pay Items:

The following sample language for Pay Items has been assembled from various sources as minimum standards that should be used as a sample to develop Pay Items for TDOT. This should be done in cooperation with TDOT Traffic Operations Office and Construction Office in a future phase of the DSRC Statewide Guidance Project. **This sample language for pay items should not be used in construction contract documents without coordination with the appropriate TDOT Offices.**

SP 725 should include the following pay items. Standard Specification 730 should include reference back to SP 725 so that both specifications will not need to be updated. The required content for each pay item should be developed; the titles provided are to be used as a guide to how the elements of DSRC installation could be structured.

725-28.01	Each	Road Side Unit (RSU) must include mounting hardware and cabling.
725-28.02	Each	Connected Vehicle (CV) Module for Controller (ATC)
725-28.03	Each	Connected Vehicle (CV) Module for Central Software
725-28.04	Each	Modify Cabinet (Description)
725-28.05	Each	Network Configuration
725-28.06	Each	Wireless Router
725-28.07	Each	Ethernet Switch (Field Layer 2)
725-28.08	Each	Ethernet Switch (Description)
725-28.20	LS	System Integration (OBU and MCTT will be needed for validation of system communications)
725-28.21	LS	Burn-In Period
725-28.22	LS	Spare Parts
725-28.23	LS	Training

The following footnotes should be considered for inclusion in pay item descriptions:

- Contractor shall be responsible for providing a fully functional and operational DSRC deployment, including all equipment and components
- Contractor shall be responsible for providing an approved testing plan for DSRC deployment

APPENDIX E: Sample Test Plan Language

Appendix E

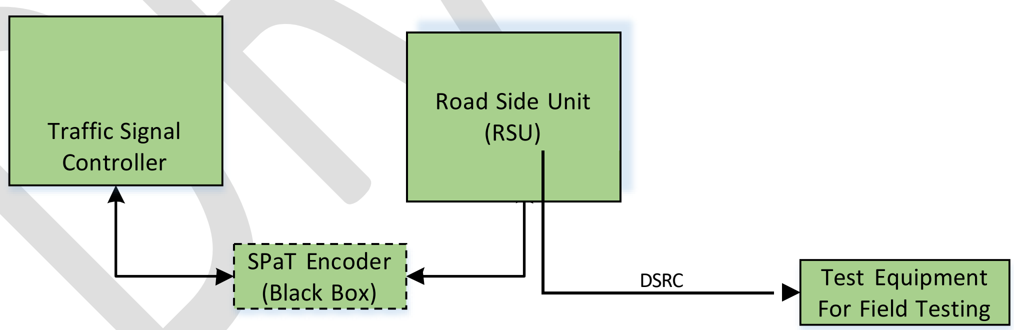
Sample Test Plan Language:

The following sample test plan language has been assembled from various sources as minimum standards that should be used as a sample to develop typical test plans for TDOT. This should be done in cooperation with TDOT Traffic Operations Office and Construction Office and in a future phase of the DSRC Statewide Guidance Project. **This sample test plan language should not be used in construction contract documents without coordination with the appropriate TDOT Offices.**

1. At a minimum, equipment required for validation testing shall include:
   One RSU, one (1) OBU, and one (1) multi-channel test tool (MCTT).
2. Vendor will utilize the traffic signal controller as installed according to project plans and specifications.
3. At least one signal with each RSU mounting scenario shall be tested.
4. Vendor will be provided with the MAP data created using the USDOT Intersection MAP and SPaT Message Creator Tool to use during testing. Alternatively, the Vendor may use the MAP data created for the project.
5. The Vendor shall connect and test their system using OBU and MCTT in the presence of testing staff and document their findings.
6. The Vendor shall make their qualified and experienced staff available during testing and provide hands on demonstration to the staff on configuring, installing, and testing the system.
7. The goal of the testing is to ensure:

- SPaT, and MAP, and TIM data comply with SAE J2735_201603
- SPaT message status matches the Signal Head status
- BSMs comply with SAE J2735_201603 using OBUs and MCTT.

SPaT and MAP Data Broadcasting Scheme



If the RSU does not encode SPaT data directly from the signal controller, the Vendor may need to install a SPaT encoder/processing unit between the RSU and traffic signal controller to broadcast SPaT and MAP data as part of testing.

APPENDIX F: Sample Project Plan Markup

Project Plan for Markup to be determined

APPENDIX G: Cost Information

Description	unit	quantity	FDOT/Tallahassee		Utah DOT		Michigan DOT		AZ DOT		VA DOT	
			price	extension	price	extension	price	extension	price	extension	price	extension
RSU w/ SPaT encoder/processing unit	assembly	1	$ 7,600.00	$ 7,600.00	$ 10.00	$ 10.00	$ 15.00	$ 15.00	$ 20.00	$ 20.00		$ -
Attachment Cable for RSU Antennas	LF	1	$ 2.00	$ 2.00		$ -		$ -				
RSU power and communication cables	LF	1	$ 2.00	$ 2.00		$ -		$ -				
OBU including all necessary hardware (cabling, mounting brackets, GPS antenna, DSRC antenna, Driver Display Unit, power and communication cables, etc.	Each	1	$ 8,300.00	$ 8,300.00		$ -		$ -				
RSU Cable Connectors, including: Data Cable, Antenna, Power	Each	1	$ 65.00	$ 65.00		$ -		$ -				
DSRC Multi-Channel Test Tool (MCTT) with Diagnostic Software	Each	1	$ 6,000.00	$ 6,000.00		$ -		$ -				
Training Support	Hrs per site	2	$ 50.00	$ 100.00		$ -		$ -				
On-Site Configuration Support	Hrs per site	8	$ 500.00	$ 4,000.00		$ -		$ -				
RF Engineering	Hrs per site	8	$ 125.00	$ 1,000.00		$ -		$ -				
Civil Engineering	Hrs per site	8	$ 125.00	$ 1,000.00		$ -		$ -				
ITS JPO Estimates								$ -				
RSU	assembly	1					$ 3,750.00	$ 3,750.00	$ 1,000.00	$ 1,000.00	$ 3,500.00	$ 3,500.00
RSU incidentals	LS per site	1					$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00
Communication Connection Equipment	LS per site	1					$ 1,300.00	$ 1,300.00	$ 1,300.00	$ 1,300.00	$ 1,300.00	$ 1,300.00
Power Connection Equipment	LS per site	1					$ 300.00	$ 300.00	$ 300.00	$ 300.00	$ 300.00	$ 300.00
Additional Installation Equipment	LS per site	1					$ 3,500.00	$ 3,500.00	$ 600.00	$ 600.00	$ 3,300.00	$ 3,300.00
		Total (hardware)						**$ 9,850.00**		**$ 4,200.00**		**$ 9,400.00**
installation labor	LS per site	1					$ 2,500.00	$ 2,500.00	$ 2,400.00	$ 2,400.00	$ 2,500.00	$ 2,500.00
construction inspection (18% of hardware cost)	LS per site	1					$ 1,500.00	$ 1,500.00	$ 600.00	$ 600.00	$ 1,200.00	$ 1,200.00
		Total (installation)						**$ 4,000.00**		**$ 3,000.00**		**$ 3,700.00**
Radio Survey	LS per site	1					$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00
Map/GID Generation	LS per site	1					$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00
Planning	LS per site	1					$ 700.00	$ 700.00	$ 400.00	$ 400.00	$ 600.00	$ 600.00
Design	LS per site	1					$ 2,100.00	$ 2,100.00	$ 1,100.00	$ 1,100.00	$ 1,800.00	$ 1,800.00
System Integration & License	LS per site	1					$ 1,500.00	$ 1,500.00	$ 1,500.00	$ 1,500.00	$ 1,500.00	$ 1,500.00
Traffic Control	LS per site	1					$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00	$ 1,000.00
		Total (design)						**$ 7,300.00**		**$ 6,000.00**		**$ 6,900.00**
		Total (ITS JPO Est)						**$ 21,150.00**		**$ 13,200.00**		**$ 20,000.00**
		Total		**$ 28,069.00**		$ 10.00						
		Total - without OBU		**$ 19,769.00**								
		Total - without OBU and MTT		**$ 12,769.00**								