Connected Vehicle Pilot Deployment Program Phase 4

System Design Document (SDD) – Wyoming CV Pilot

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16. Abstract

The Wyoming Department of Transportation's (WYDOT) Connected Vehicle (CV) Pilot Deployment Program is intended to develop a suite of applications that utilize vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) communication technology to reduce the impact of adverse weather on truck travel in the I-80 corridor. These applications support a flexible range of services from advisories, roadside alerts, parking notifications and dynamic travel guidance. Information from these applications is made available directly to the equipped fleets or through data connections to fleet management centers (who will then communicate it to their trucks using their own systems). The pilot will be conducted in three Phases. Phase I includes the planning for the CV pilot including the concept of operations development. Phase II is the design, development, and testing phase. Phase III includes a real-world demonstration of the applications developed as part of this pilot.

This Phase II document describes the detailed system design for the WYDOT CV Pilot. The report describes the overall system, followed by a detailed description of each of the system hardware and application components. The system described here was designed to meet user needs and functions described in the WYDOT CV Pilot Concept of Operations (ConOps) and the requirements enumerated in the WYDOT CV Pilot System Requirements (SyRS). The design is built upon the architecture described in the WYDOT CV Pilot System Architecture Document (SAD). This System Design Document (SDD) provides traceability of requirements from user needs through design. Finally, this 2018 revised version is an update to an earlier version of the report, reflecting more thoroughly fleshed out concepts and insights gained by the site during and at the end of Phase 2. Phase 4 updates to this document are for the migration from DSRC to C-V2X.

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1 Introduction

Wyoming is one of the first wave of CV Pilot sites selected to showcase the value of and spur the adoption of CV technology in the United States. CV technology is a broad term to describe the applications and the systems that leverage Cellular Vehicle-to-Everything (C-V2X) communications for vehicle-to-vehicle (V2V), vehicle-to-infrastructure (V2I) and infrastructure-to-vehicle (I2V) communication to improve safety, mobility and productivity of the users of the nation's transportation system.

As one of the three selected pilots, WYDOT is focusing on improving safety and mobility by creating new ways to communicate road and travel information to commercial truck drivers and fleet managers along the 402 miles of Interstate 80 (I-80 henceforth) in the State. For the pilot project, WYDOT concluded Phase 1 (planning) in September 2016 and then initiated Phase 2 (deployment) which is scheduled to conclude in April 2018. This will be followed by an demonstration period in the third phase. A fourth phase is now underway that will see the system convert from Dedicated Short Range Communications (DSRC) to C-V2X in 2023/2024.

Systems and applications developed in the pilot will enable drivers of connected vehicles to have improved awareness of potential hazards and of situations they cannot see. At a very high level, the pilot scope includes the following implementation elements:

- **Deploy about 75 roadside units (RSU)** that can receive and broadcast messages using DSRC along various sections on I-80. Migrated to C-V2X in Phase 4.
- **Equip around 400 vehicles, a combination of fleet vehicles and commercial trucks, with on-board units (OBU).** Of the 400 vehicles, at least 150 are planned to be heavy trucks. All vehicles are expected to be regular users of I-80. Several types of OBUs are being procured as part of the pilot and differ based on their communication capabilities, ability to integrate with the in-vehicle network, and connectivity to ancillary devices and sensors. All OBUs will have the functionality to broadcast Basic Safety Messages (BSM) Part I and will include a human-machine interface (HMI) to share alerts and advisories to drivers of these vehicles. The initial scope of the project includes the 400 vehicles for Phase 4, this will be pared down to an initial 10 vehicles outfitted with the C-V2X OBUs.
- **Develop several V2V, V2I, I2V applications** that will enable communication to drivers of alerts and advisories regarding various road conditions. These applications include support for in-vehicle dissemination of advisories for collision avoidance, speed management, detours, parking, and presence of work zones and maintenance and emergency vehicles downstream of their current location.
- **Enable overall improvements in WYDOT's traffic management and traveler information practices** by using data collected from connected vehicles. Targeted improvements include ingesting more location specific mobile road weather information system (RWIS) data and improving road condition dissemination via 511, Dynamic Message Signs (DMS) and other WYDOT sources.

1.1 Purpose of the System Design Document

This document describes the detailed system design for the Wyoming DOT Connected Vehicle Pilot (WYDOT CV Pilot). The report describes the overall system, followed by a detailed description of each of the system hardware and application components. The system described here was designed to meet user needs and functions described in the WYDOT CV Pilot Concept of Operations (ConOps) and the requirements enumerated in the WYDOT CV Pilot System Requirements (SyRS). The design is built upon the architecture described in the WYDOT CV Pilot System Architecture Document (SAD). This System Design Document (SDD) provides traceability of requirements from user needs through design.

This SDD is supported by the companion WYDOT CV Pilot Interface Control Document (ICD) which provides a detailed description of the internal and external interfaces for the WYDOT CV Pilot and the data, information, and messages that are communicated across those interfaces. For each interface, the ICD describes message structure and protocol, size and frequency of transmission of data, security, timing and sequencing.

In addition, the WYDOT CV Pilot ICD includes the WYDOT CV Pilot Standards Plan. The Plan lists the standards used by this CV Pilot Deployment, highlighting CV, Intelligent Transportation Systems (ITS) and any other standards that are used or are applicable to the components and interfaces in the WYDOT CV Pilot. A key component of the Standards Plan is the Standards Gaps. This section identifies interfaces that should be standardized, but have no standard yet, or have standards that require additional clarity or maturation.

The document is intended to describe the system design to stakeholders interested in design implementation details. The document may also be used as a resource by future CV Pilots and by state DOTs designing and deploying CV systems.

This document is loosely based upon IEEE Standard 1016-1998 (IEEE Recommended Practice for Software Design Descriptions). This document includes descriptions of both hardware and software.

1.2 Document Overview

This document is organized in six primary chapters as follows:

1 Introduction
2 System Level Design Description
3 Subsystems and Components Design
4 Acronyms
5 References
6 Requirements Traceability Matrix

Chapter 2 provides a design description of the overall WYDOT CV Pilot System, identifying the hardware, software, and application components and their primary features. By far, Chapter 3 is the largest providing detailed design descriptions of each of the components. For consistency, the same templates are used in describing each of the application and software components and the same templates are used in describing each of the hardware components. These templates are basic guidelines only, such that sections that are not applicable to the component under consideration may

be omitted. The template for application and software components in Chapter 3 uses the following headings:

- Function of the Software/Application
- Developer & version number
- Application Message and Alerts Descriptions
- Application Design Description
- Application Data Tables
- Application Configuration Data
- Application User Interface(s)
- Requirements Traceability
- ICD Traceability

The template for each of the system hardware and operations platform components in Chapter 3 uses the following headings:

- Function of the Component
    - Functions/Services
    - Input data/message flows
    - Output data/message flows
- Hardware Platform
    - Vendor/manufacturer & model number
    - Picture and physical description of hardware
    - Hardware physical interfaces
    - Hardware specifications relevant to CV function and performance
    - Hardware design description relevant to CV function and performance
    - Hardware configuration data
- Operating Platform/ Development Stack
    - Vendor & version number
    - Operating Platform specifications, particularly those related to CV function and performance (from Vendor)
    - Operating platform design description
    - Operating platform configuration data
- Communication interfaces
- Messages
- User Interface(s)
    - Description of Operations/Driver Interface (where applicable) with illustrations
    - Description of Maintenance User Interface with illustrations
- Requirements traceability
- ICD Traceability

Each component description in this SDD references the complementary ICD descriptions for each component interface. For each of these interfaces the ICD describes

- Interface Function
- Covered Information Flows (Maps to Triples)
- Dialogs (Message Flow Diagrams)
- Messages
- Data Elements

- Requirement Traceability

1.3 Assumptions

Some key assumptions and constraints are made in defining the features for the proposed system. As for the assumptions, these include the following:

- During the pilot design and demonstration, the number of connected vehicles is expected to be a fraction of the I-80 truck traffic. However, as the rate of connectivity grows, the system needs to be able to add new on-board units on vehicles and new roadside units to the CV environment along with the back-end systems to support data collection and use.
- Road weather forecasts by segment still will likely rely on a human meteorologist who is able to assimilate disparate datasets to generate a travel advisory. This does not apply for current observations or short-term alerts of impending conditions which may be based on reported conditions by connected vehicles directly.
- Cost-effective real-time monitoring of truck parking availability across the State of Wyoming can be accomplished to support CV Pilot objectives.
- ~~USDOT-developed~~ The ISS Security Credentialing Management Systems (SCMS) can support secure communications as part of a larger security management framework developed for the proposed system.

1.4 Constraints

The following constraints were also identified during the conceptualization of the system and are addressed as part of the proposed system:

- Policies regarding the responsibilities of various WYDOT divisions that play a role in supporting CV equipment.
- New agreements or modifications to existing SLAs to support CV technology and prioritize maintenance and support of the CV environment during the demonstration phase.
- Evaluation of WYDOT Executive Staff and Legislative priorities is necessary to continue budgetary support and buy-in from decision makers.
- WYDOT's manpower constraints require a careful analysis of job function changes due to the new system.
- WYDOT and fleet operators who are participants in the proposed system need to develop clear memorandums of understanding on roles and responsibilities of each party.
- Fleet management systems are expected to be proprietary with limited data availability due to competitiveness concerns. From a functional standpoint, this implies that performance requirements that rely on data collected from fleet management centers may be limited. However, the immediate evaluation needs may be greater than the requirements for day-to-day operations and these needs should be reflected in partnership agreements with fleets.

- Testing and demonstration of a majority of the pilot applications can occur only during winter seasons in 2017 and not through the year. For Phase 4 testing will be done from late summer 2023 through late summer 2024.
- Minimizing distraction to truck drivers is critical to any advisories and alerts issued by the system. Any in-vehicle advisory needs to be balanced with the demands of the driving tasks required of the truck driver during stressful conditions.
- Many important highway locations lack reliable, cost-effective commercial power and communications services.
- Commercial fleets' data proprietary concerns require a careful analysis (i.e., commercial vehicles may have limitations on the data they want to share versus data they are unwilling to share).
- The use of DSRC technology (C-V2X technology in Phase 4) in the pilot will be guided by the IEEE 1609.2, 1609.3, and 1609.4 standards for Security, Network Services and Multi-Channel Operation (IEEE, 2022, IEEE, 2020; IEEE, 2016c), the SAE J2735 Message Set Dictionary (SAE, 2020), and the recently released SAE J2945/1 Communication Minimum Performance Requirements standard (SAE, 2020). As standards change and evolve, system requirements will continue to evolve. SAE 3161 is a new standard to cover C-V2X.

1.5 Risks

The key risks for this Pilot are due to the fact that although connected vehicle technology has been in development for a number of years and a major Safety Pilot has been completed, the technology is continuing to evolve, particularly in the realm of V2I communications and applications. There have not been sufficient deployments of V2I technology to fully test and refine it, so that standards for interfaces and features are still in flux. Many of the hardware and software components described in this document have not been developed before and require time and budget to develop, integrate and test for the first time. CV engineers have sufficient history and experience with the fundamental elements of technology to be confident that they can achieve the objectives of the WYDOT DV Pilot. But key risks are schedule and budget risks resulting from the need for creating innovative solutions to overcome new challenges. These risks are being mitigated by staffing the program with highly creative and experienced engineers with a track record of rapid and efficient development, refinement, and deployment of new technology.

1.6 Rationale for Key Decisions

The design described in this document was developed by the project team to support WYDOT in achieving its objective to improve safety and reliability on the I-80 corridor especially during periods of adverse weather and when work zones are present. To achieve this primary objective, several new or modified capabilities, functions, processes, interfaces, and other changes were identified:

1. Capability changes – the system will:
    a) Add capability to collect highly localized event, weather and road condition information from equipped commercial, specialty and public fleet vehicles.

   b) Add capability to use collected information effectively to generate localized, timely notification both to fleet managers and to truckers on the road about adverse weather conditions.
   c) Add capability to support V2V communication of situational awareness that will take the management center out of the loop and improve timeliness and accuracy of alerts and advisories.
   d) Add limited capability to provide parking availability and status information to equipped trucks on the road during adverse weather conditions.
   e) Add capability to provide customized alerts and advisories to trucks based on their location along the I-80 corridor using roadside infrastructure.
2. System processing changes – the system will:
   a) Ingest, quality-check and process data gathered from connected vehicles and generate segment-level alerts and advisories.
   b) Provide capability for fleet management centers to request alerts and advisories, parking availability based on location.
   c) Store data generated from vehicles and controlling systems for performance measurement and evaluation.
3. Interface changes – new interfaces are developed to support activities and to manage, gather, compile and share data related to:
   a) Interfaces between vehicles, roadside, WYDOT centers and USDOT services for Core Services for the CV environment.
   b) Interfaces between host and remote vehicles for V2V Applications, specifically applications that relate to collision warning and communicating/receiving/relaying distress notifications (DNs). DN will not be included in Phase 4.
   c) Interfaces between vehicles and infrastructure for V2I Applications, specifically applications meant to raise awareness of hazardous conditions, such as work zones and road/weather condition.
   d) Interfaces for integration of CV applications with existing Wyoming Traveler Information System (WTIs).
   e) Interfaces with in-vehicle systems and third-party applications for road weather advisories for motorist, freight, maintenance and emergency response vehicles.
   f) An interface to support third-party dissemination of road condition.
4. Personnel changes – no new personnel are expected to be added as a result of the proposed system but the roles and responsibilities of existing WYDOT staff and pilot participants are expected to evolve during the course of system development and demonstration. Changes are expected in the following areas:
   a) TMC Operator roles and responsibilities – TMC operators have additional responsibilities in terms of monitoring alerts and advisories generated by the proposed system for accuracy and effectiveness.
   b) Weather providers/in-house meteorologist – In-house meteorologists will have new data sources to incorporate into advisory and forecast models.
   c) Specialty and public fleet drivers – Snowplow drivers and highway patrol troopers who are part of the proposed system will need training on how to interpret in-vehicle alerts and advisories.

d) Truck drivers – Truck drivers who are part of the proposed system will need training on how to interpret in-vehicle alerts and advisories.

e) Fleet management center personnel will need training on how to use the new services developed as part of the proposed system in their operations.

f) System developers and maintainers – WYDOT's Geographic Information System / Intelligent Transportation System (GIS/ITS) group along with external support consultants will be responsible for the maintenance of the proposed system adding to their current roles and responsibilities.

5. Environment changes – no significant changes are expected in the high-level operational environment of the I-80 corridor due to the proposed system.
6. Operational changes – some operational changes are expected to occur at WYDOT TMC because of the proposed system:
    a) WYDOT's policies on VSLs, road condition advisories, incident response are expected to change as result of the proposed system.
    b) Additionally, WYDOT TMC's role in parking management activities will increase beyond its current limited scope.
7. Support changes
    a) The inter-site backhaul communication capability offered by the Telecommunications Program will become more critical to support the changes in the newly proposed system. These changes may require an analysis of data transfer capabilities at various locations in the corridor prior to deployment to ensure that the communications channel can support the data exchanges required for the CV applications.

2 System Level Design Description

2.1 System Context

The main objectives of the WYDOT CV Pilot include:

- **Deploy and operate around 400 vehicles equipped with OBU with DSRC connectivity**. These vehicles will be a combination of snowplows, fleet vehicles, emergency vehicles and private trucks that will broadcast a BSM, collect vehicle, weather and road condition data, and provide it remotely to the WYDOT TMC. These vehicles will also receive in-vehicle alerts through the infrastructure and wirelessly from various applications developed as part of the pilot through a HMI.
- **Deploy and operate around 10 vehicles equipped with OBU with C-V2X connectivity**. These vehicles will be fleet vehicles that will broadcast BSM data and provide it remotely to the WYDOT TMC. These vehicles will also receive in-vehicle alerts through the infrastructure and wirelessly from various applications developed as part of the pilot through an HMI.
- **Deploy around 75 RSUs with C-V2X connectivity** that can transmit advisories and alerts through Traveler Information Messages (TIM) to equipped vehicles along I-80.
- **Leverage the data provided from the equipped vehicles to develop and demonstrate a suite of V2V and V2I applications**. As part of the pilot, several applications will be developed to support wide-area travel advisories, VSL postings, forecast road condition information, spot-specific warnings, work zones, and parking notifications.
- **Enable overall improvements in WYDOT's traffic management and traveler information practices** by using data collected from connected vehicles.

This project will develop systems that make relevant information directly available to, and shared among, equipped fleets. Information will be shared through linkages with fleet management centers (who will then communicate it to their trucks using their own communication systems) and other external third-party agencies and partners. Supporting the applications and the CV environment of roadside, vehicle and back-office infrastructure are core services that allow safe, secure, reliable operations of the system.

The CV Pilot is considered a System of Systems, with two Systems of Interest: The Vehicle System and the Wyoming CV System, illustrated in Figure 2-1. The Vehicle System includes four Sub-Systems that represent the various vehicle and equipment types to be used in the pilot. These Sub-Systems vary in their data collection and sharing capabilities. The Wyoming CV System includes the infrastructure used in the pilot and back-office systems in charge of the various processes that lead to the generation and distribution of advisories and alerts. Together, the Vehicle and Wyoming CV Systems support a variety of V2V and V2I applications. Both systems interface with external systems, including WYDOT, USDOT and the National Weather Service (NWS).

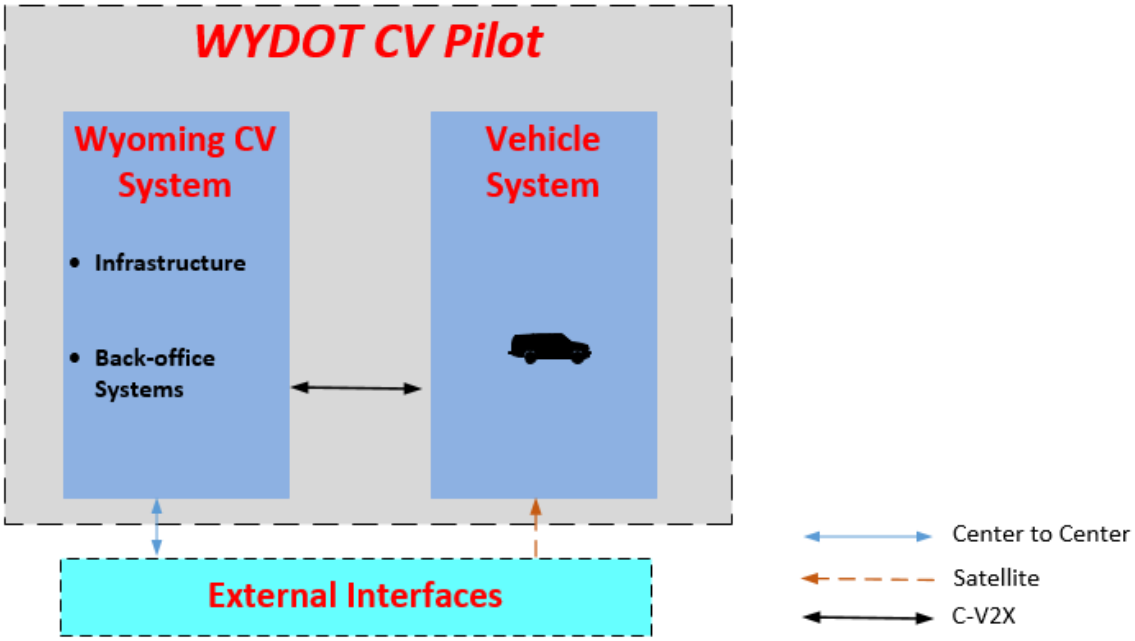


Figure 2-1 Wyoming CV Pilot System of Systems.
Source: WYDOT

The WYDOT CV Pilot Project will, at its core, provide key information to the drivers through five on-board applications: (1) Forward Collision Warning (FCW); (2) I2V Situational Awareness; (3) Distress Notification (DN); (4) Work Zone Warning (WZW); and (5) Spot Weather Impact Warning (SWIW). In addition, the CV Pilot project will support overall traffic management and traveler information services offered by WYDOT. A detailed explanation of the Wyoming CV Pilot project can be found in *Connected Vehicle Pilot Deployment Program Phase 2, System Architecture Document (SAD) (English et al., 2017*). Phase 4 of the system of systems has been pared down to no longer support the bulk of the vehicle systems that were supported in the earlier phases of the project. The updated Phase 4 System of Systems is seen in the figure below.

2.2 System Capabilities

This section describes functions to be performed by the *Vehicle System* and the *Wyoming CV System*. The *Vehicle System* will perform eight functions:

1. Collect CV Data – Connected vehicles wirelessly receive BSMs from other connected vehicles.
2. Collect TIMs – Wirelessly receives packets containing traveler information from the *Wyoming CV System* and distress information from other connected vehicles.
3. Manage and Process Information for Applications – Manages and processes information for the five on-board applications.
4. Provide In-Vehicle Application Alerts – Provides prioritized alerts and advisories for the Vehicle Operator.

5. Broadcast Vehicle Data – Broadcasts, at a predefined rate, vehicle information (BSMs) to other connected devices and to the *Wyoming CV System*.
6. Transmit Vehicle Data – Transmits vehicle log data to the *Wyoming CV System*. The transmission includes event logs (including those of other connected vehicles).
7. Store Data – Locally stores selected data collected and generated (both from the field and the applications) until they are transferred to the *Wyoming CV System*.
8. OBU Management – Logs availability and operational capability, including validating and obtaining certificates, time and location accuracy, logging system information, and routine wellness check.

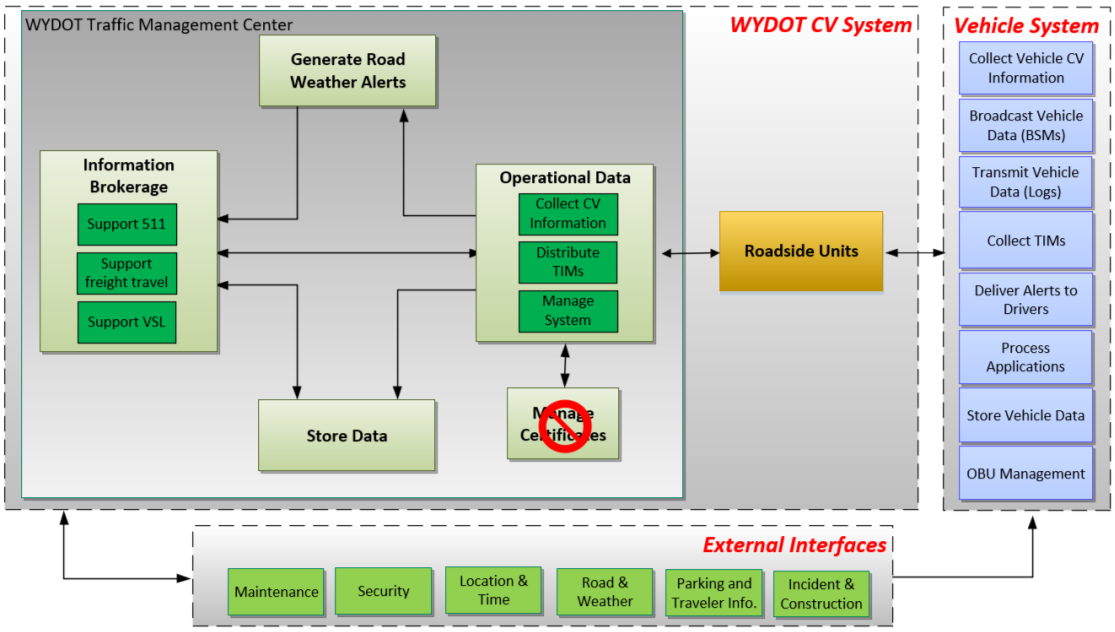
The Wyoming *CV System* performs six functions:

1. Collect CV Information – Collects data from the *Vehicle System*. Data collected includes BSMs Part I and Part II, event logs, and distress messages. Phase 4 will not include distress messages.
2. Generate Road Weather Alerts and Advisories – Generates segment-level advisories and alerts of both current and forecast road and weather conditions based on customizable thresholds.
3. Support Information Brokerage – Distributes Road Weather Alerts and Advisories to WYDOT's interfaces.
4. Distribute TIMs – Distributes the TIM to the *Vehicle System* and the SDX.
5. Store Data – Data generated is stored by the system.
6. Manage and Maintain System – The WYDOT Maintenance team monitors the system for availability and operational capabilities.

In addition to on-board vehicle applications, information generated by the Wyoming CV System is expected to be used to support WYDOT traffic management and traveler information. WYDOT expects to use the information from the pilot for the following purposes:

- **Setting and removing VSL along the I-80 corridor –** VSLs will be managed through the Wyoming Traveler Information (WTI) interface. When segment-level alerts and advisories are received from the *Wyoming CV System* in WTI, the TMC operator will have the option to reduce speed according to the normal operation protocols. Similarly, when speed limits are reduced due to information available from the TMC, this information will be communicated with the *Wyoming CV System* and shared as part of the TIM. The VSL zones utilize changeable yet enforceable speed limits in 143 miles along four (4) segments – 23 miles around Evanston, 25 miles around Green River, 57 miles along Elk Mountain and 47 miles between Cheyenne and Laramie.
- **Supporting 511 and other traveler information** – Road weather collected by the Wyoming CV System will be ingested into and processed by the Pikalert system for dissemination to the public, please note the Pikalert system will not be used in Phase 4 of the project. In addition, incident information collected by the CV system will be used to directly update the WTI. The WTI system, upon database saves, has the integrated logic to automatically update the 511 systems (web, phone, email/text messages, app) in near real time.
- **Supporting road weather advisories and freight-specific travel guidance through CVOP** – Information from the *Wyoming CV System* will update the CVOP system to provide freight-specific information to subscribed fleet partners. Currently, more than 800 firms subscribe to CVOP.

The functional architecture view describes the abstract functional elements or processes and their logical interactions via data flows that satisfy the system requirements. Figure 2-2 depicts the functional diagram of the Systems of Interest along with the external interfaces that interact with the CV Systems. Section 2.4 describes in more detail the internal and external interactions of each system.



NOTE ⃠ shows items not part of Phase 4.

Figure 2-2. Functions of the Wyoming CV System and the Vehicle System.
Source: WYDOT

2.3 Wyoming System Design and Decomposition

The *Wyoming CV System* includes the infrastructure used in the pilot and the back-office systems in charge of the various processes that lead to the generation and distribution of advisories and alerts for CV Pilot vehicles. The *Wyoming CV System* will be located at the WYDOT TMC. Additionally, this system provides external interfaces to share the advisories and alerts with the public and commercial vehicle operators.

The Wyoming CV System is composed of four Sub-Systems:

- Roadside Units (RSUs)
- Operational Data Environment (ODE)
- Data Broker (DB)
- Data Warehouse (DW)

2.3.1 Roadside Units

This Sub-System describes the physical units for deployment as part of the system along I-80. RSUs include C-V2X connectivity, application support, data storage, and other support services to enable

CV applications, such as necessary security certificates. WYDOT RSUs can be either fixed or portable equipment depending on the use. In general, RSUs serve as a two-way communication portal between connected vehicles and the ODE that provide information via C-V2X. About 75 RSUs are planned to be deployed in the pilot.

2.3.2 Operational Data Environment

The WYDOT ODE Sub-System receives information collected from connected devices, checks its quality, and then shares it with other Sub-Systems in charge of analyzing and distributing the information. The ODE also exports data to the Trihydro Situation Data Exchange (SDX) for USDOT-related activities. The ODE will be hosted at WYDOT TMC and uses the same codebase as the USDOT ODE. High-level requirements for the ODE are contained within the Task 4 ODE ConOps from the Southeast Michigan Test Bed Advanced Data Capture Field Testing. These include requirements for validation, integration, sanitization, and aggregation, which are combined in this document with the description of ODE processed data.

2.3.3 WYDOT Data Broker

WYDOT DB receives information from the ODE and some external systems, analyzes them, and shares them with the corresponding system or service including other sources. The DB supports the information brokerage of road weather alerts and advisories to WYDOT's Third-Party Interface (TPI), Transportation Reporting and Action Console (TRAC), WYDOT Traveler Information System (WTI), Road Condition Reporting System (RCRS), and Commercial Vehicle Operator Portal (CVOP). Additionally, this system takes in incident information from the Incident Console (IC), work zone data from the Construction Administrator (CA) and parking availability information from the WYDOT 511 Application. The DB also sends the information back to the ODE to support the dissemination of Traveler Information Messages (TIMs) to the RSUs and can also access historical data stored at the DW if needed.

2.3.4 WYDOT Data Warehouse

The WYDOT DW is a MongoDB database that stores various TMC- and CV-related data. The DW includes timestamped and geotagged logs of CV and non-CV data—information collected, generated and shared within the *Wyoming CV System*—that will be used for performance measurement.

2.4 Wyoming CV System External Interfaces

Figure 2-3 shows the physical architecture with interfaces numbered for reference and discussion here and in following sections. The Wyoming CV System includes the following external interfaces for exchanging data and information with external WYDOT and USDOT systems.[1]

- **I2V C-V2X Communications Interface** (Interface WE1 and VE1) Wireless DSRC interface provides communication between Wyoming CV System and Vehicle System through exchange of messages conforming to SAE J2735, SAE J3161 and SAE J2945/1. These will be C-V2X in Phase 4.

[1] In the figure, WE refers to Wyoming CV System external interfaces, WI refers to Wyoming CV System internal interfaces, VE refers to Vehicle System external interfaces and VI refers to Vehicle System internal interfaces.

- **Location and Time Service (LTS)** (Interfaces WE2 and WE 3) – Provides location and time information, which is later used to geotag and timestamp all information produced by the systems of interest.[2]
- **WYDOT 511 Application** (Interface WE5) – Provides information to the public regarding I-80's road weather and traffic conditions (e.g., road closure). The application is currently being updated to also share crowdsourced truck parking information with the CV Pilot.
- **WYDOT RCRS** (Interface WE6) – An Android tablet-based application that resides in WYDOT snow plows which enables field personnel (e.g., snowplow operators) to report weather and roadway pavement conditions following WYDOT's 8 Code (roadway condition), 9 Code (atmospheric) and 10 Code (other road condition) system.
- **WYDOT IC** (Interface WE7) – Provides timestamped and geotagged incident information on incidents along I-80 obtained from the WHP and other sources (e.g., maintenance).
- **WYDOT Construction Administration (CA)** (Interface WE8) – Provides timestamped and geotagged information of WYDOT's scheduled and unscheduled work-zone activities along I-80.
- **WTI** (Interface WE9) – Supports traveler information services to the public and to fleet management centers via various means (website, 511, 511 App, text, email, and alerts).
- **WYDOT TRAC** (Interface WE11) – An operator console used in the TMC to monitor and manage planned, ongoing, and forecast events and actions on facilities monitored by the TMC. The TRAC provides a tabular list of currently ongoing events that require operator attention. These events may be entered manually and can be reported based on other systems like RCRS, radio communications with field personnel and citizen reports.
- **WYDOT CVOP** (Interface WE12) – A subscription-based website created by WYDOT for providing advanced notification of forecasted conditions to commercial travelers and fleet managers. Currently there are over 800 companies subscribed to the CVOP. As part of the CV Pilot System, the CVOP will be enhanced to include current weather information for segments on I-80.
- **WYDOT ITS Maintenance** (Interface WE13) – Provides a mechanism to report service outages and resumption of services of WYDOT's ITS equipment.
- **Trihydro SDX** (Interface WE15) – A service operated by Trihydro that stores near real-time data and shares it with the remote users and developers for further distribution. As shown, this interface also supports communication of messages through **Satellite Service Provider (SSP)** satellites, allowing the system to transmit traveler-related information.
- **ISS/GHS Cloud SCMS** (Interfaces WE16 and WE17) – Generates security certificates to manage messages securely from connected devices. As shown, this interface also supports communication of messages through SSP satellites, allowing the system to use SCMS-related information.

[2] The location is obtained from a GPS using WGS-84 coordinates system, and time is provided using UTC from GPS time.

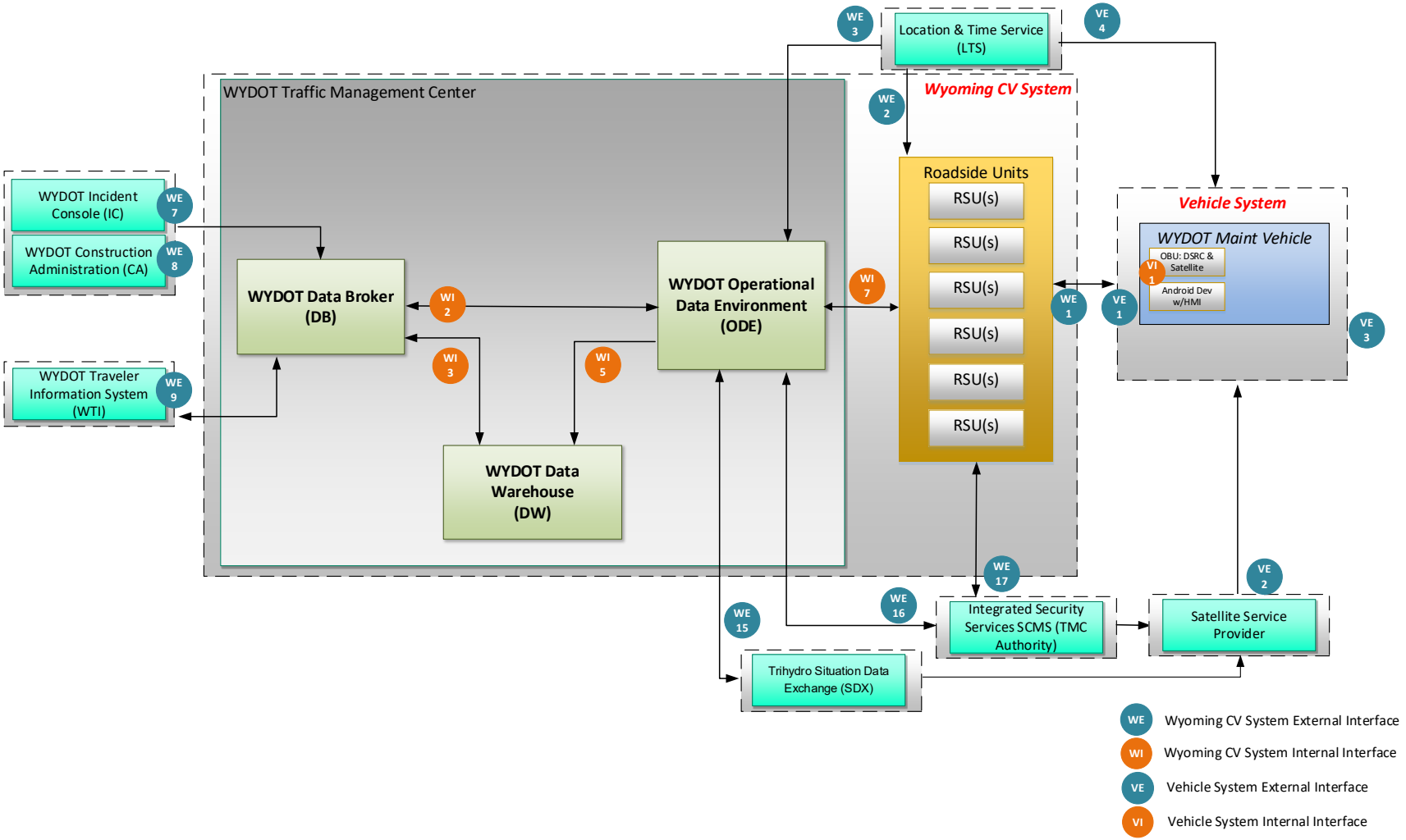


Figure 2-3. Physical View of WYDOT CV Pilot System Architecture with Numbered Interfaces.
Source: WYDOT

2.5 Vehicle System Design and Decomposition

The *Vehicle System* represents the deployment of on-board equipment, sensors, and an HMI that will support CV applications. All vehicles that are part of the *Vehicle System* will have the following core capabilities:

- Ability to share and receive information via C-V2X communication from other connected devices (vehicles and RSUs).
- Ability to broadcast BSM Parts I and II.
- Receive TIMs via DSRC and Satellite.
- An HMI that allows alerts and advisories to be communicated with the driver.

2.6 Pilot On-Board Applications Functionality

The WYDOT CV Pilot will develop four on-board applications that will provide key information to the drivers of equipped vehicles. In addition to on-board applications, information generated by the *Wyoming CV System* is planned to support ongoing WYDOT traffic management and traveler information services. WYDOT expects to use the information from the pilot for:

- Setting and removing VSLs along the I-80 corridor.
- Supporting 511 and other traveler information.
- Supporting road weather advisories and freight-specific travel guidance through WYDOT's CVOP.

The following subsections provide a view of the applications to be developed for this Pilot.

2.6.1 Forward Collision Warning (FCW)

FCW is a V2V communication-based safety feature that issues a warning to the driver of the connected host vehicle in case of an impending front-end collision with a connected vehicle ahead in traffic in the same lane and direction of travel on both straight and curved geometry roadways as illustrated in Figure 2-4. FCW will help drivers avoid or mitigate front-to-rear vehicle collisions in the forward path of travel. This application is critically important for safety along I-80 in conditions when snowplows are moving slower than following traffic and/or when visibility may be limited due to adverse weather. The application does not attempt to control the host vehicle to avoid an impending collision. This application will follow the description from standard SAE J2945/1 March 2016 Section 4.2.4.

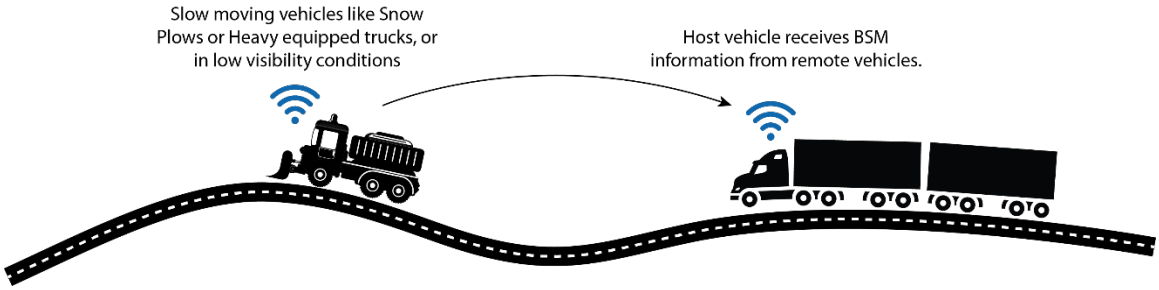


Figure 2-4. Forward Collision Warning Concept Diagram.
Source: WYDOT

2.6.2 Infrastructure-to-Vehicle (I2V) Situational Awareness

One of the important promises of Connected Vehicle technology is the delivery of up-to-date travel information to drivers that impacts their safety and mobility. The WYDOT CV Pilot will implement an I2V Situational Awareness application that assembles important travel information from back-office systems and communicates that directly to drivers through both C-V2X and satellite communications. This application enables delivery of relevant downstream road condition information to drivers along I-80 in Wyoming, including: Weather alerts, Speed restrictions, Vehicle restrictions, Road conditions, Incidents ahead, Truck parking[3], and Road closures.

This information is expected to enhance both safety and traveler mobility along the corridor. The generic application is illustrated in Figure 2-5. It should be noted that the 402 miles of Wyoming I-80 is too long to provide cost effective C-V2X communications coverage. Accordingly, the WYDOT CV Pilot will implement satellite-based communications to send situational awareness road condition information directly to satellite enabled connected vehicles along the entire length of Wyoming I-80, when out of range of C-V2X communications. This application will follow the description from SAE J3067 August 2014 Section 2.9.3.6.

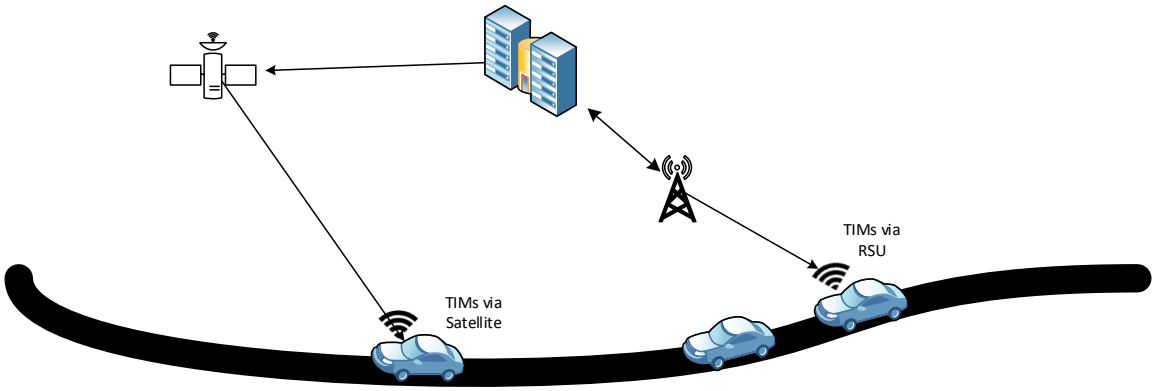


Figure 2-5. I2V Situational Awareness Concept Diagram.

[3] As part of this project, the WYDOT CV Pilot team will update the WYDOT 511 Application for personal information devices (e.g. smartphones) to capture crowdsourced truck parking information and to share that with commercial vehicle drivers, particularly during inclement road weather conditions

Source: WYDOT

2.6.3 Work Zone Warning (WZW)

The WZW Application provides information about the conditions that exist in a work zone which the host vehicle is approaching (illustrated in Figure 2-6). This capability provides approaching vehicles with information about work zone activities that could present unsafe conditions for the workers or the host vehicle, such as obstructions in the vehicle's travel lane, lane closures, lane shifts, speed reductions or vehicles entering/exiting the work zone. This application will follow the TIM WZW described in SAE J2735 March 2016 Part 3 in Section 6.142.

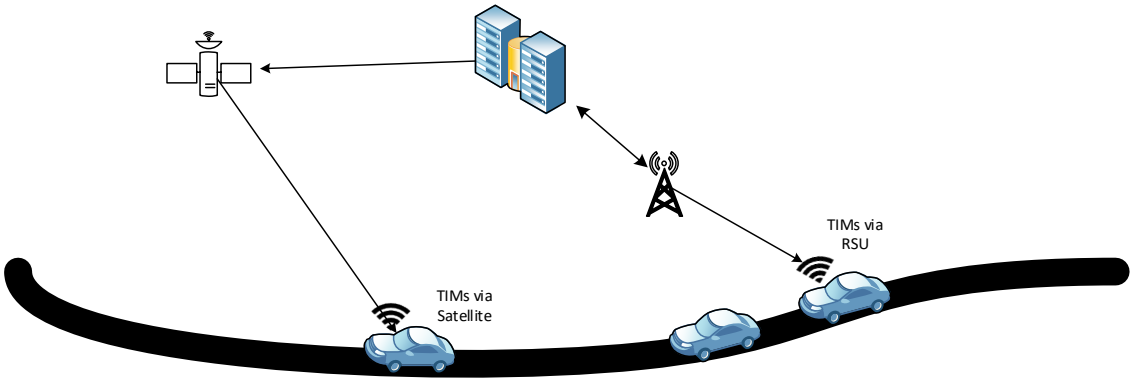


Figure 2-6. Work Zone Warning Concept Diagram.
Source: WYDOT

2.6.4 Spot Weather Impact Warning (SWIW)

SWIW is a special case of I2V Situational Awareness that enables hazardous road condition information due to weather, such as fog or icy roads, to be broadcast from a RSU and received by the connected host vehicles (see Figure 2-7). This application, however, is distinct from other I2V Situational Awareness applications in that it provides more localized information (i.e., at the segment level instead of area wide or region wide). This application will follow the TIM advisory content from part 3 defined in SAE J2735 Section 6.142 for ITIS data elements 6.54 for weather conditions and 6.55 for winds defined in SAE J2540_2.

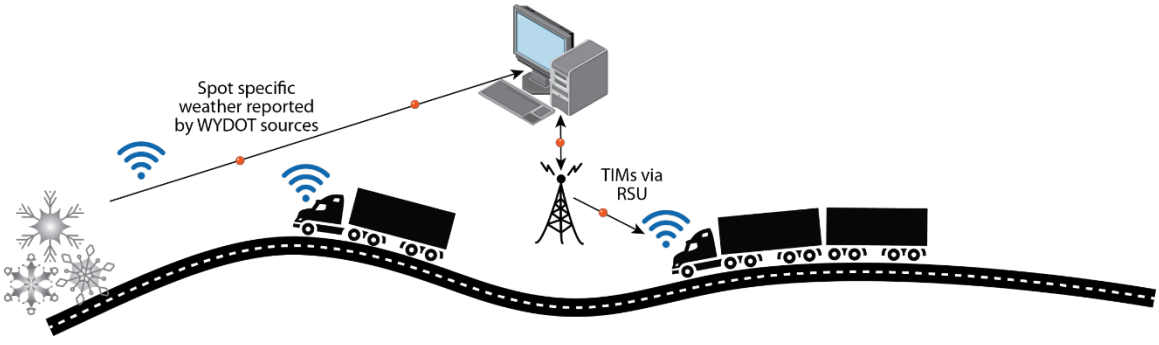


Figure 2-7 Spot Weather Impact Warning concept diagram.
Source: WYDOT

2.7 System Modes and States

This section describes the three modes of operation for the proposed system.

2.7.1.1 Normal Operations

During normal operations, the full suite of CV applications, described in Section 2.6 and 2.7, are available. Objects in the CV environment are being monitored by the WYDOT TMC and are functioning normally.

2.7.1.2 Degraded Mode

In a degraded mode, some of the vehicle or infrastructure objects in the CV environment are not functioning as intended. Depending on the nature of the degradation, different functions and processes are available. For example, *Vehicle System* malfunctions would limit the availability of on-board applications. Operations are limited to wide area advisories via 511 and the use of traditional ITS (DMS and HAR) for roadside communications through existing WYDOT interfaces. On the other hand, failure of specific RSUs in the proposed system can be managed with redundancy in RSU deployment and wide area communications (such as satellite).

2.7.1.3 Back-up Mode

In a back-up mode, some of the *Wyoming CV System* Sub-Systems like the ODE, and DB are not functioning as intended. Due to the risk associated with malfunctioning center system, all CV-related use-cases would be suspended and the proposed system would revert back to pre-CV state of operations.

2.8 Major System Constraints

The following constraints were identified during the conceptualization of the system and are considered as part of the system design:

- Vehicle to vehicle interactions is limited by the presence of connected vehicles in vicinity of each other during conditions of interest.
- Minimizing distraction to truck drivers is critical to any advisories and alerts issued by the system. Any in-vehicle advisory needs to be balanced with the demands of the driving tasks required of the truck driver during stressful conditions.
- Many important highway locations lack reliable, cost-effective commercial power and communications services.
- The use of C-V2X technology in the pilot will be guided by the IEEE 1609.2, 1609.3, and 1609.4 standards for Security, Network Services and Multi-Channel Operation (IEEE, 2016a, IEEE, 2016b; IEEE, 2016c), the SAE J2735 Message Set Dictionary (SAE, 2016b), and the recently released SAE J2945/1 Communication Minimum Performance Requirements standard (SAE, 2016a). As standards change and evolve, system requirements will continue to evolve.

2.9 Application System Level Design and Decomposition

This section of the SDD provides a system level design description of the core applications and a decomposition, describing the functions performed by system components (in Figure 2-3) relevant to the application and message flow between components.

2.9.1 Forward Collision Warning

This section describes the information flow and the responsibilities for each of the components involved with the Forward Collision Warning Application.

2.9.1.1 System Level Design

Figure 2-8 shows the communication flows amongst the different components for the Forward Collision Warning application.

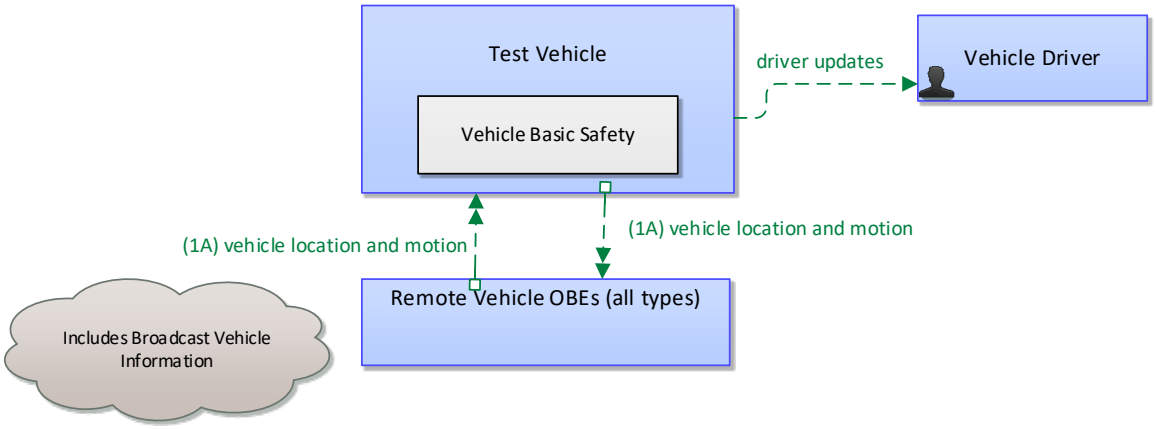


Figure 2-8. Forward Collision Warning Data Flows.
Source: WYDOT

2.9.1.2 OBU Functions

Functions responsible by the OBU for the forward collision warning application include monitoring BSMs from other connected vehicles traveling. If a speed difference is detected that would indicate a possible or imminent collision then an alert would be issued to the driver of the vehicle.

2.9.2 Work Zone Warning

This section describes the information flow and the responsibilities for each of the components involved with the Work Zone Warning application.

2.9.2.1 System Level Design

Figure 2-9 shows the communication flows between objects for the Work Zone Warning application functionality. Individual object responsibilities for the overall functionality of the system are described below.

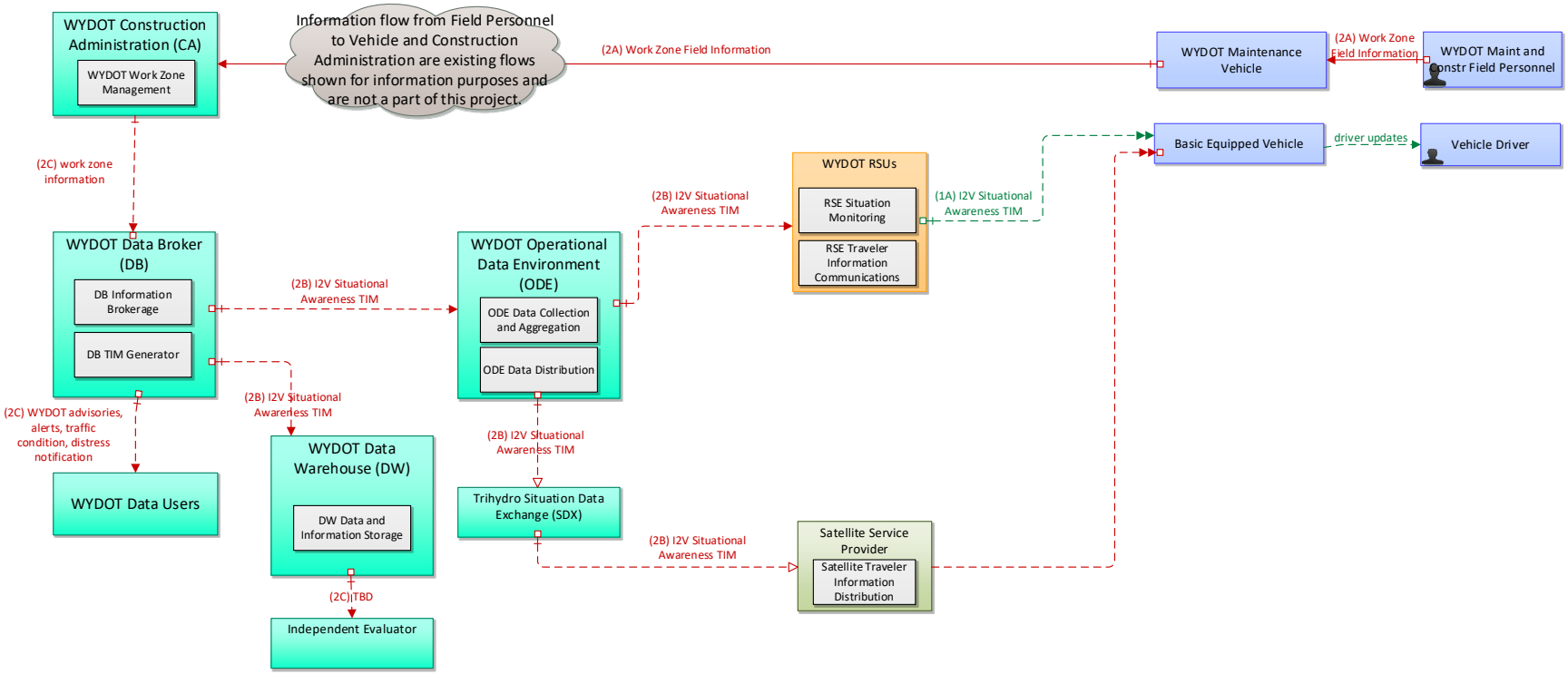


Figure 2-9. Work Zone Warning flow diagram.
Source: WYDOT

2.9.2.2 Construction Administrator (CA) Functions

The CA Application is responsible for notifying the WYDOT Data Broker Representational state transfer (REST) Service application of all Construction events that will be occurring within the I-80 corridor. Updates that shall be communicated include new construction planned, updates to existing construction areas, and delays or cancelations for planned construction projects. Construction information provided to the Data Broker application shall include work zone road surface conditions, expected delays, speed reduction, lane restrictions, work zone geographic area, as well as other work zone information. Additionally, the CA application will be responsible for handling any error codes that are returned from the Data Broker application and displaying those to the user.

2.9.2.3 Data Broker Functions

The WYDOT Data Broker application will be responsible for using the information provided by the CA application to build the appropriate TIM request to the ODE service. The Data Broker will be responsible for housing the business logic involved in determining which RSU's should broadcast the work zone warnings as well as the start date/time and duration of the TIM broadcast. This information will then be sent to the ODE for dispersal to the specified RSU's. Once a response is received from the ODE for the TIM request the TIM message contents, ODE response code, and current time will be pushed to the Data Warehouse for storage. The Data Broker will then send a response to the Construction Administration application of success/fail along with an error message when appropriate.

2.9.2.4 DW Functions

The Data Warehouse will be responsible for storing information on when the TIM was sent out, which RSU's the TIM was sent to, the ODE response from the TIM request, and the TIM contents sent to the RSU. This information will be later used for performance measurement data.

2.9.2.5 ODE Functions

The ODE application shall be responsible for disbursing the Work Zone Warning TIM messages to all of the RSU's specified through the SNMP protocol. The ODE shall also post the TIM to the USDOT Situational Data Warehouse when requested in the REST call. The ODE shall then return a response to the requesting application indicating a success/fail response code and error message when appropriate.

2.9.2.6 RSU Functions

The RSU shall broadcast all Work Zone Warning messages received by the ODE during the time period specified.

2.9.2.7 SDX/Satellite functions

The SDX/Satellite functions shall transmit Work Zone Warnings through Sirius XM Radio to areas indicated as being affected by the Work Zone Warnings.

2.9.2.8 OBU Functions

The OBU shall alert the driver of work zone warning received by the RSU. All relevant information for the work zone warning shall be communicated to the user.

2.9.3 I2V Situational Awareness and Spot Weather Impact Warning Application

This section describes the information flow and the responsibilities for each of the components involved with the I2V Situational Awareness and Spot Weather Impact Warning Application.

2.9.3.1 System Level Design

Figure 2-10 show the data flows for TIM's being pushed from the WYDOT Data Broker application to the ODE/RSUs and finally delivered to OBUs in a given area.

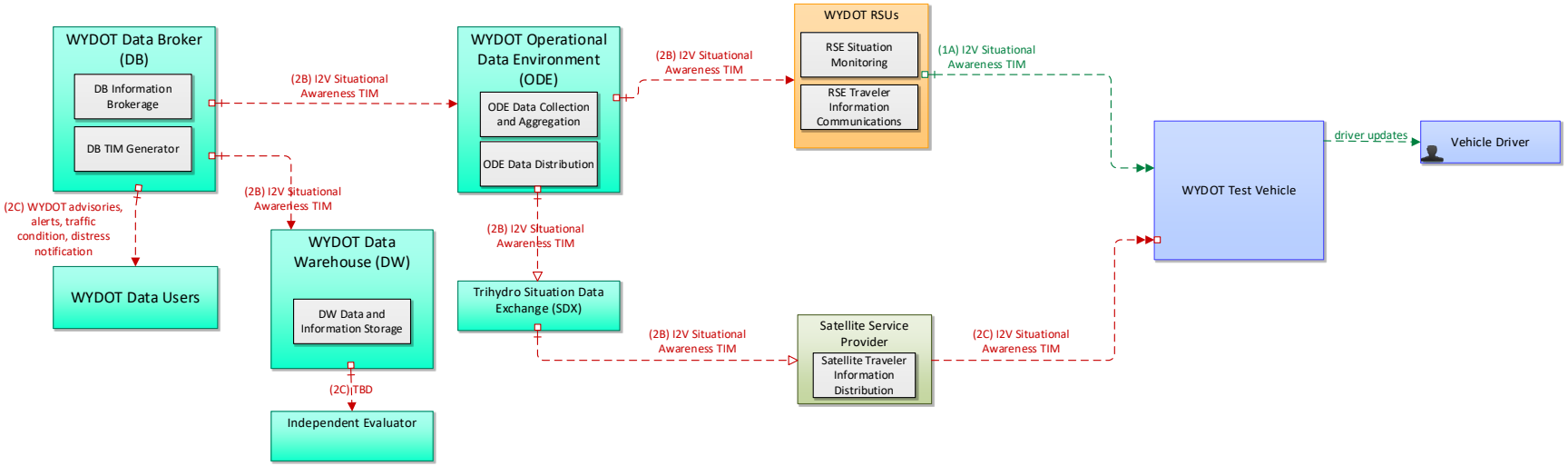


Figure 2-10. I2V outflow diagram.
Source: WYDOT

Figure 2-11 shows the communication flows for different applications within the TMC for the I2V situational awareness application.

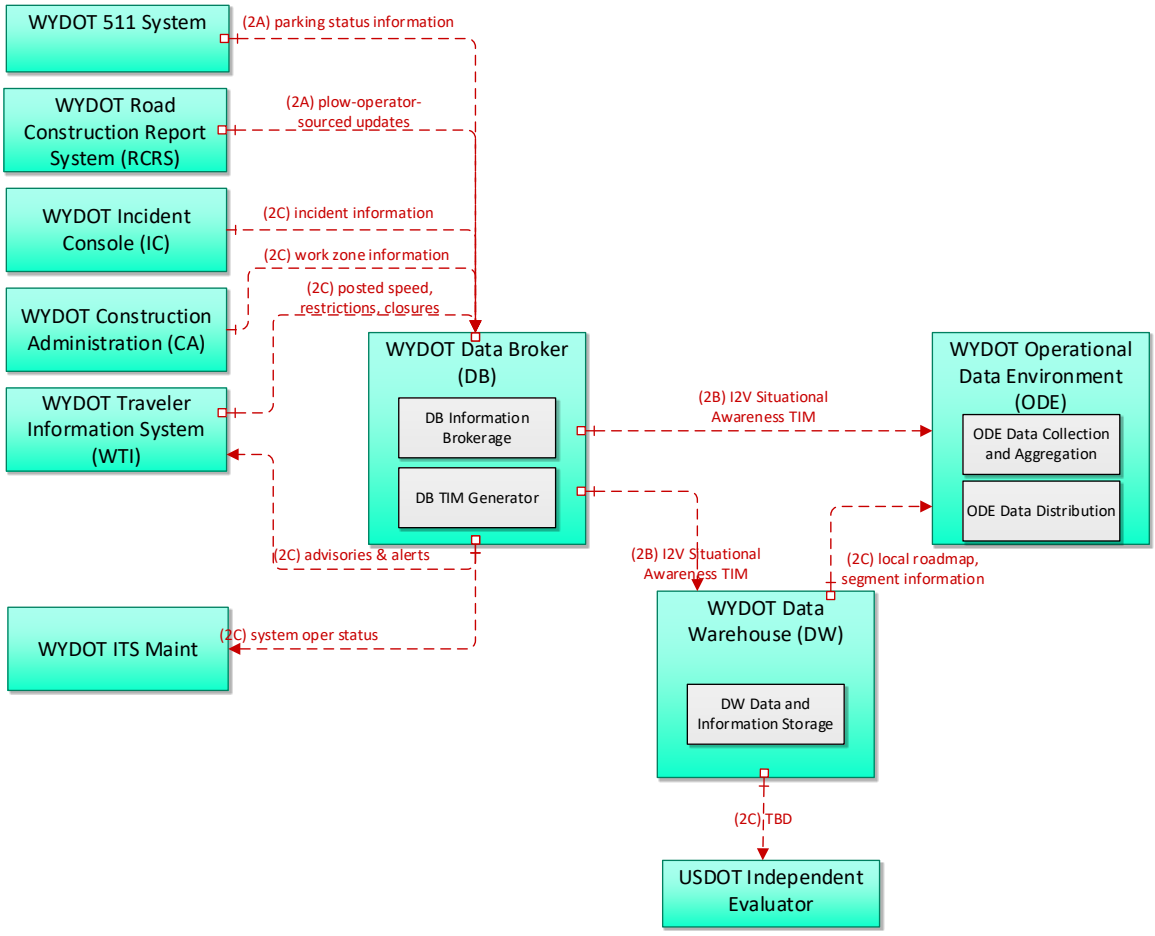


Figure 2-11. I2V TMC flow diagram.
Source: WYDOT

2.9.3.2 OBU Functions

Functions responsible by the OBU for the I2V situational awareness application include sending data from the OBU to the RSU and receiving and displaying TIM messages from the RSU to the driver. Data sent to the RSU may include log data as well as BSM part 1 and part 2 data. For vehicles outfitted with weather sensors the OBU will be responsible for uploading environmental data logs to the ODE. Additionally, all vehicles will also transmit BSM part 1 and part 2 data to the RSU. For Phase 4 no vehicles will be outfitted with weather sensors.

2.9.3.3 RSU Functions

Functions responsible by the RSU include broadcasting TIM messages and forwarding BSM messages on to the ODE.

2.9.3.4 ODE Functions

ODE functions for the I2V Situational Awareness application include processing and making all data from BSM's and environmental data available for consumption by other applications via a Kafka data stream. The ODE will be responsible for validating and unencrypting environmental data logs deposited to the ODE. Additionally, the ODE is also responsible for posting and Situational Data TIM messages to the RSUs for broadcasting purposes as well as posting TIM messages to the Trihydro SDX when indicated.

2.9.3.5 DB Functions

The Data Broker functions for the I2V Situational Awareness application include processing incoming warnings and alerts from the WYDOT TMC applications and determining the affected area and posting TIM messages to the ODE for appropriate RSUs and SDX deployment.

2.9.3.6 DW Functions

The Data Warehouse function for the I2V Situational Awareness application includes storing environmental and BSM data.

2.9.3.7 SDX/Satellite functions

The SDX/Satellite functions for the I2V Situational Awareness application include storing TIM messages and sending TIM messages via Sirius XM radio to vehicles in the affected area specified in the TIM geographic area indicated.

2.9.4 Truck Parking

This section describes the information flow and the responsibilities for each of the components involved with the Truck Parking Application.

2.9.4.1 System Level Design

Figure 2-12 shows the communication flows amongst the different components for the Truck Parking application.

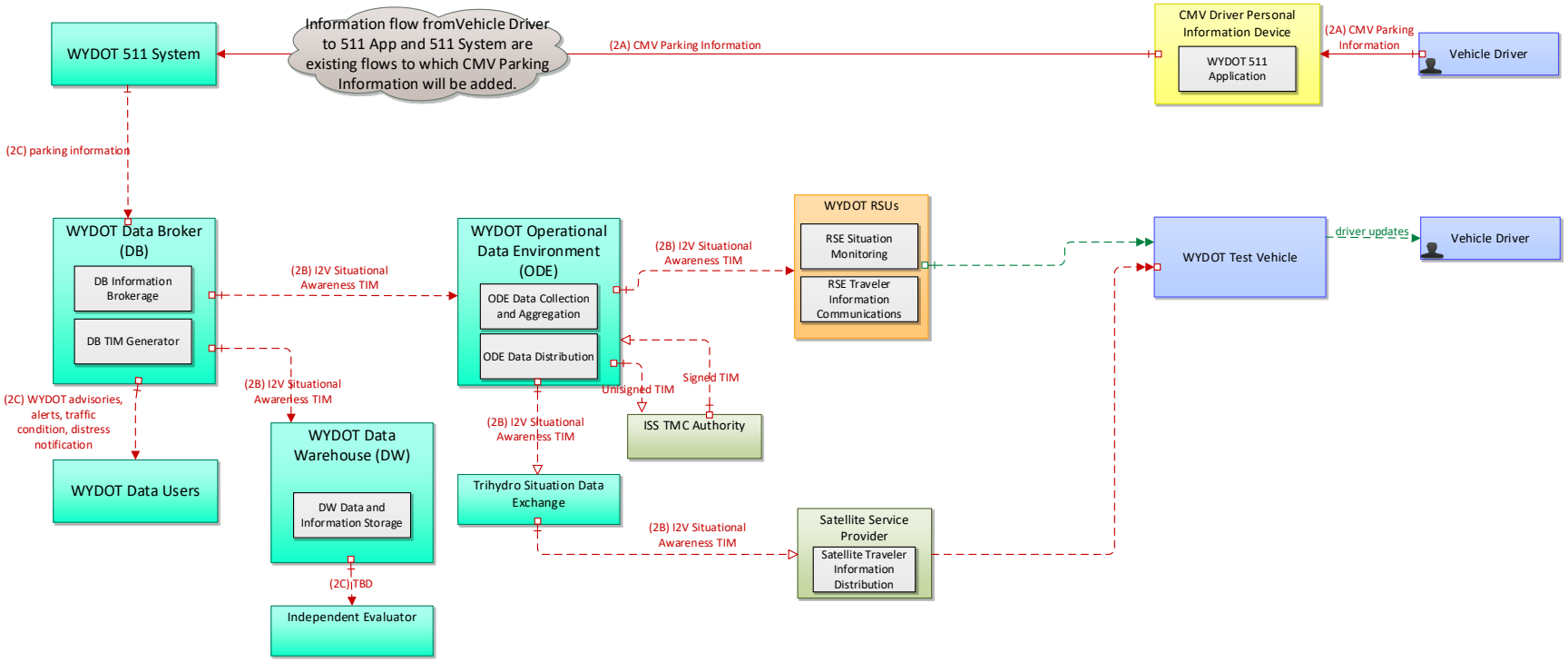


Figure 2-12. Truck Parking Data Flows.
Source: WYDOT

2.9.4.2 511 Application Functions

Functions of the 511 app for the truck parking application include displaying truck parking information on a layer in the 511 app map and allowing users to submit new availability reports for truck parking locations. Information included in the map includes truck parking locations and the ability for a user to view the status of parking availability. Additionally, the 511 app functionality will include the ability for a user to submit a truck parking status report for a given truck parking area.

2.9.4.3 DB Functions

The Data Broker application is responsible for functions to receive truck parking user updates for parking from the 511 app. The Data Broker application will then post all truck parking reports to the Data Warehouse and post parking updates to appropriate RSU's via the ODE.

2.9.4.4 DW Functions

The Data Warehouse functions will allow all truck parking data to be stored and retrieved by appropriate applications.

2.9.4.5 ODE Functions

The ODE functions for the Truck Parking application will allow the Data Broker to post TIM messages to appropriate RSUs on the current availability of truck parking locations.

2.9.4.6 RSU Functions

The RSU functions for the Truck Parking application will broadcast TIM messages with the current status of nearby truck parking facilities.

2.9.4.7 SDX/Satellite functions

The SDX/Satellite functions for the Truck Parking application include broadcasting TIM messages to vehicles in appropriate geographic regions with current information for the status of truck parking locations.

2.9.4.8 OBU Functions

The OBU functions for the Truck Parking application include displaying truck parking information broadcast from RSUs to users.

2.10 Summary List of Message/Data Flows and Interfaces

The ICD companion document contains a full list of all external interface message flows for the Wyoming CV Pilot. The table in the ICD document has the following headings.

- Interop Cat Num - Indicates if the interface is used by different pilot sites.
- Shared / Custom - Indicates of the interface is shared across pilots or is unique to WYDOT.
- Instance ID - A unique identifier for the flow from the CV Pilot Technical Roundtable.
- Flow Name - Name for the data flow operation or interaction between source and destination.

- Source Element - The component/device which provides data for the flow.
- Destination Element - The device which consumes the data for the flow.
- WYDOT Interface Number- The interface number from the Physical View in Figure 2-3.
- Vendor Interface Number - Identifier used by component developers for cross reference.

2.11 Networking and Communications

2.11.1 RSU Backhaul Description

The WYDOT Network backhaul originates from the Headquarters building at 5300 Bishop Blvd. in Cheyenne, WY from an IT Router. A network cable is run to a Communication Media Module (CMM) switch which feeds a Point to Point (PTP) Radio. Another PTP Radio is then located along the I-80 corridor at the site of an RSU. From here the PTP radio feeds into another CMM switch which feeds a wireless access point (Wi-Fi). A subscriber module/station then connects to the access point and directly feeds into a switch and on to the RSU. This process is then repeated for points further along the I-80 corridor. A simplified diagram of this can be seen in Figure 2-13.

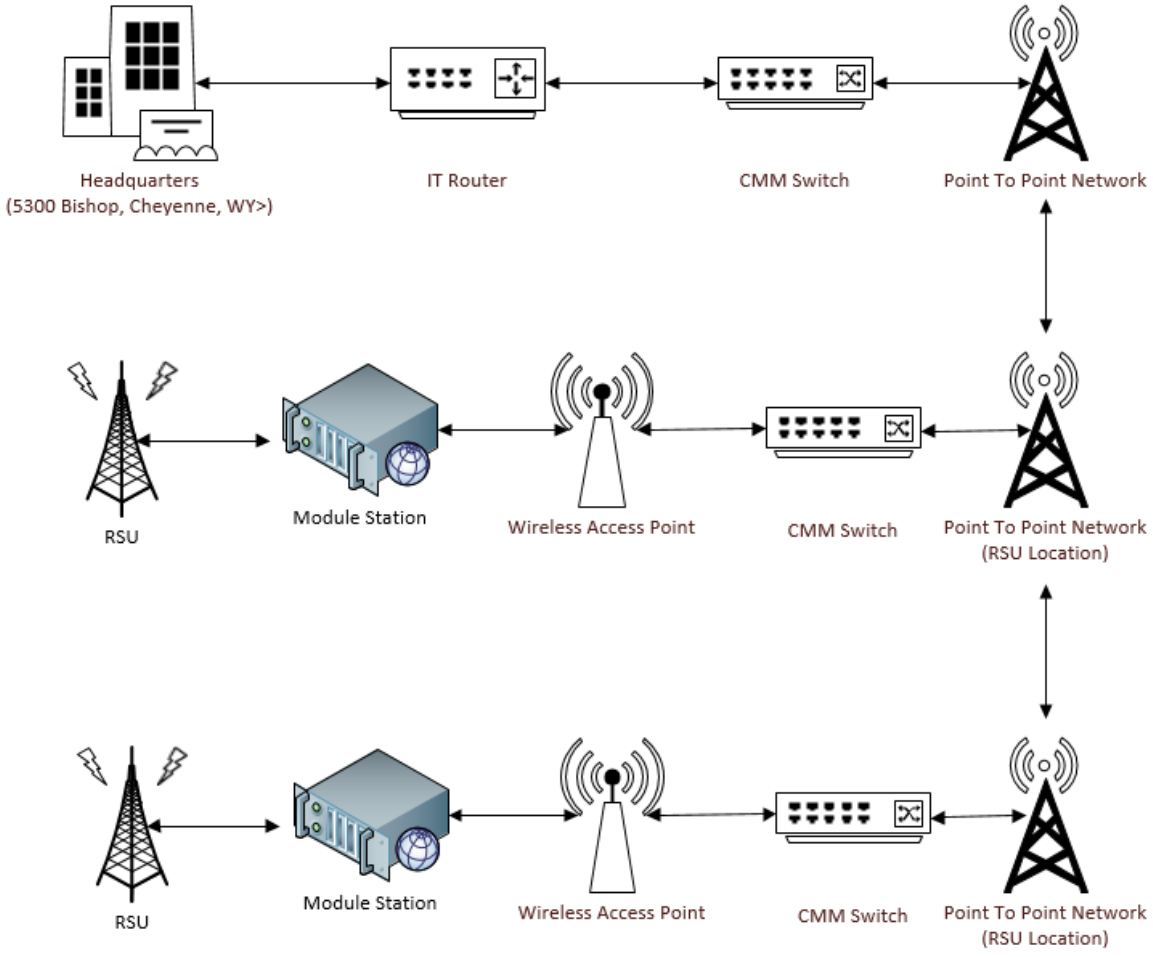


Figure 2-13. Simplified WYDOT Backhaul.
Source: WYDOT

The overall network for WYDOT can be viewed in Figure 2-14

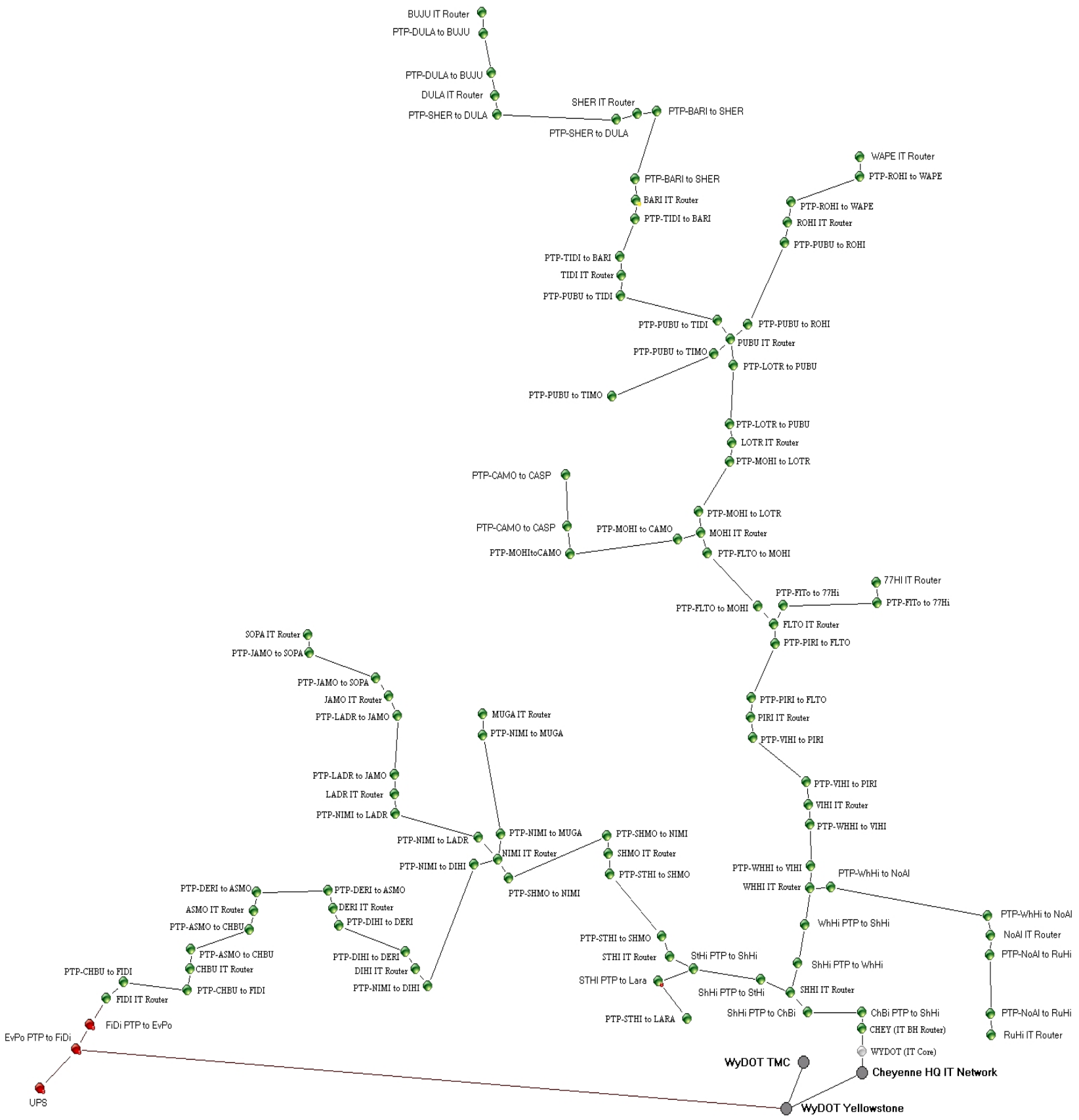


Figure 2-14. WYDOT Backhaul.
Source: WYDOT

2.11.2 Internal Systems Communication

Communications within the system will follow the protocols outlined below.

- TMC Application communications: Most communications between TMC applications and services will be done through http requests. Communication between REST services and the Mongo database will rely on a TCP connection.
- RSU Communications: Communications to the RSUs will go through either SNMP (for posting TIMs and accessing data from RSUs) or SSH (for firmware upgrades and logging into the RSU operating system).

2.11.3 Communications Security Overview

Figure 2-15 provides an overview of the communication security between physical objects. There are two primary methods for securing data in motion the CV system, through SCMS signing and through encryption using a public and private key along with Secure Copy (SCP).

Log files that include environmental, event, and distress notification data are protected by encrypting the log files using a public and private key along with a common encryption algorithm. Once encrypted the data is transferred via SCP directly from the RSU or OBU to the ODE. For the OBU the RSU will act as a router to allow direct copy of the log files to the RSU. In Phase 4 distress notification will not be included.

The BSMs and TIM messages are protected by SCMS signing for all DSRC communications and encryption for non-broadcast communications. The data that connects third parties to the WYDOT data center will be done over encrypted Secured Socket Layer (SSL) tunnels. This will be for access to the Commercial Vehicle Operator Portal (CVOP), REST service end points and other web sites that need protection (not for general public access). For back haul connections from RSU's and traditional ITS equipment, data will be protected with Internet Protocol Security (IPSEC) Virtual Private Networks (VPN) or private networks. Figure 2-15 provides an overview of the communication security between physical objects. The data in motion is protected by SCMS signing for all C-V2X communications and encryption for non-broadcast communications. The data that connects third parties to the WYDOT data center will be done over encrypted Secured Socket Layer (SSL) tunnels. This will be for access to the Commercial Vehicle Operator Portal (CVOP), REST service end points and other web sites that need protection (not for general public access). For back haul connections from RSU's and traditional ITS equipment, data will be protected with Internet Protocol Security (IPSEC) Virtual Private Networks (VPN) or private networks. Figure 2-15 provides an overview of the communication security between physical objects. The data in motion is protected by SCMS signing for all C-V2X communications and encryption for non-broadcast communications. The data that connects third parties to the WYDOT data center will be done over encrypted Secured Socket Layer (SSL) tunnels. This will be for access to the Commercial Vehicle Operator Portal (CVOP), REST service end points and other web sites that need protection (not for general public access). For back haul connections from RSU's and traditional ITS equipment, data will be protected with Internet Protocol Security (IPSEC) Virtual Private Networks (VPN) or private networks. Figure 2-15 provides an overview of the communication security between physical objects. The data in motion is protected by SCMS signing for all DSRC communications and encryption for non-broadcast communications. The data that connects third parties to the WYDOT data center will be done over encrypted Secured Socket Layer (SSL) tunnels. This will be for access to the Commercial Vehicle Operator Portal (CVOP), REST service end points and other web sites that need protection (not for general public access). For back haul connections from RSU's and traditional

ITS equipment, data will be protected with Internet Protocol Security (IPSEC) Virtual Private Networks (VPN) or private networks.

The ISS SCMS system is an external system provided by Green Hills. This pilot will interface with the SCMS and use it as part of the security solution. The SCMS design calls for the use of a PKI where a central authority issues credentials in the form of short-lived pseudonym certificates to certified devices (e.g., OBU on vehicles) that possess a valid enrollment certificate. These short-lived certificates are used to sign BSMs prior to transmission. The device changes these pseudonym certificates on a regular basis over the course of each trip to protect the end user privacy. The purpose of attaching certificates and signing each BSM is to allow the receiver to determine if the transmitter is authorized and to ensure the integrity of the signed message. This is accomplished by verifying the digital signature on the message and verifying the transmitter's short-lived certificate by following the chain of trust, verifying the transmitter has adequate credentials to send the message contents, as well as verifying that the credentials have not expired. The receiving device must also verify that the credentials of the transmitter have not been placed on a global revocation list that is managed and distributed by the SCMS.

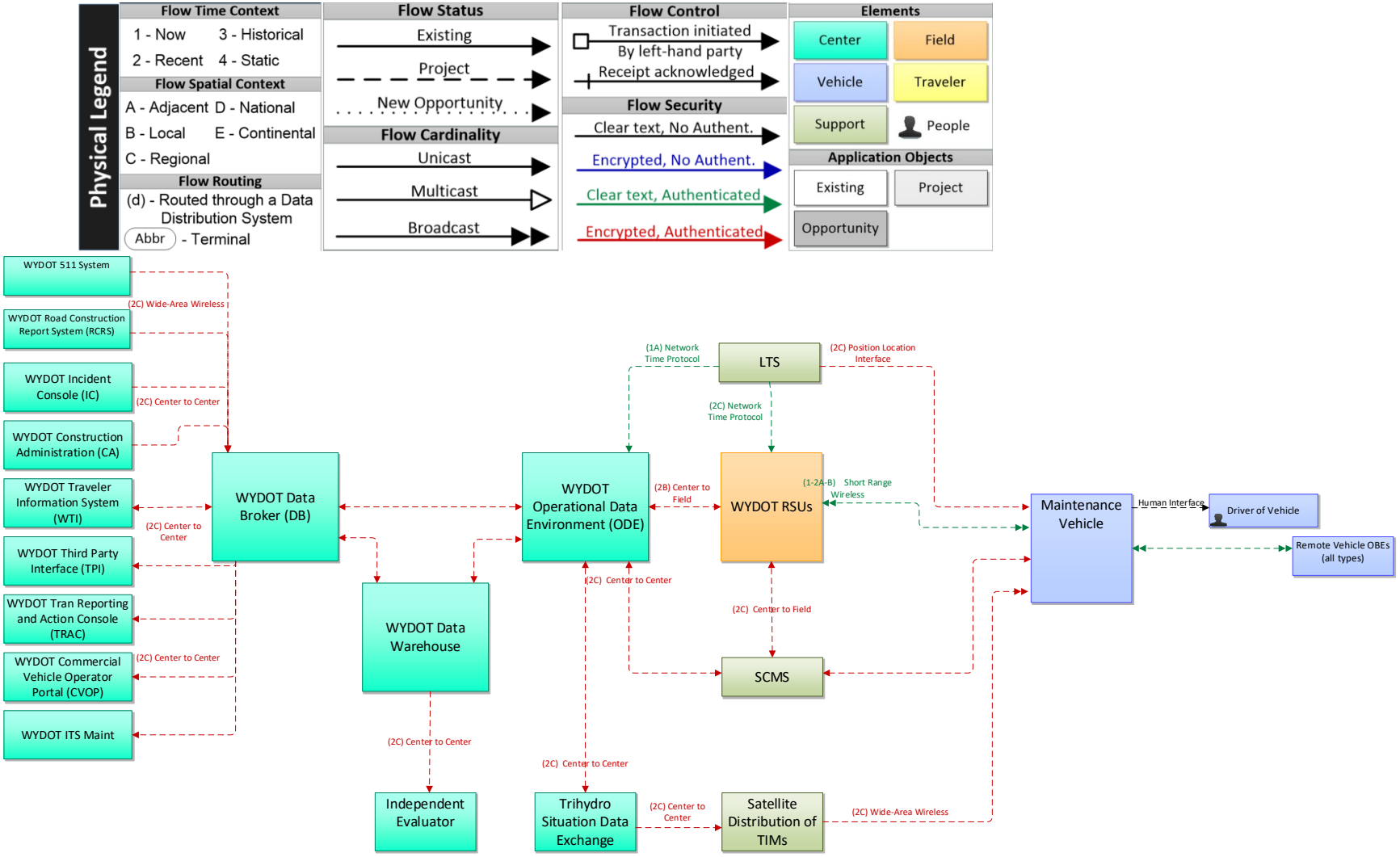


Figure 2-15. Communication Security Diagram for the CV Pilot.
Source: WYDOT

2.12 Protection of Personally Identifiable Information

Users' privacy will be managed through the collection of only required data, aggregated where possible to further protect individual privacy. An example of this is to provide a count of CVs that pass an RSU to the Center rather than provide individual vehicle data to the Center to calculate the count. Once data is collected it will be encrypted both over the air for unicast data and on the wire to the Center (using IPSEC VPN technology) to protect privacy. To protect user data over C-V2X radio communications the pilot will use the ISS SCMS system to sign communication and provide certificates for encryption.

PII, defined as any data emitted, collected, or stored that can be used alone, or in combination with other data, to distinguish or trace an individual's identity, will be only collected where necessary to demonstrate the effectiveness of CV during the pilot phase. This will be needed for some of the performance measurements required to demonstrate the safety improvements of the system. For this pilot, WYDOT's fleet vehicles will be used for performance measures and data will be collected to track individual vehicles' BSM data as well as weather data. There are other occasions where PII can be developed by the aggregation of data from multiple sources. For example, if an incident were to occur in view of a camera and RSU these two data feeds could be aggregated to produce PII. This is true with general travel outside of the CV pilot and the pilot does not add privacy protections to remove these currently available systems. The data collected containing PII for performance measurement will be encrypted in transmission as well as in storage to protect privacy.

2.13 Component Selection

Specifics of software, hardware and maintenance selected for implementation in this CV Pilot are described in the Comprehensive Acquisition Plan. In all cases the team applied a systematic process to select components for implementation which meet the objectives and requirements for the WYDOT CV Pilot system.

3 Subsystems and Components Design

This section of the SDD covers each subsystem/component that is part of the overall system. Legacy systems that are not being updated as part of the CV Pilot deployment are not defined in extensive detail in this section and rely on references to existing design documentation. Context is provided for references to external design documentation.

3.1 Wyoming CV System Subsystems and Components

This section documents the system design for the Wyoming CV Subsystems and Components that make up the Wyoming CV pilot system.

3.1.1 Roadside Units Design

This section documents the function and design of the Roadside Units that will be deployed for the WYDOT CV pilot system. Please note that the information in these sections will be limited as the RSUs for the most part will be treated as a black box with just the expected functionality described. The chosen RSU vendor for the C-V2X equipment is Commsignia and they will be expected to adequately implement the applications described below.

3.1.1.1 Function of the Component

The RSUs are intended to be the primary communication link between WYDOT infrastructure and vehicles. Functions provided by RSUs as well as data flows are provided in the sections below.

3.1.1.1.1 Functions/Services Brief description

The RSU is the primary communication piece for information dissemination, monitoring, and collection with OBU outfitted vehicles. The RSU is responsible for the following services/functions:

- RSU's collect BSMs which are broadcast by OBUs in passing vehicles.
- RSU's broadcast TIM messages to OBUs in passing vehicles.
- RSU's send security credentials to OBUs in passing vehicles.
- RSU's serve as routers so OBUs can securely copy their stored logs through to the ODE server.
- RSU's interact with Field Location and Time Source service to retrieve current GPS location and time.
- RSUs interact with Network Time Service to synchronize time on RSU.
- RSUs interact with SCMS for device enrollment information.
- RSUs interact with SCMS in order to monitor and report misbehavior.
- RSU's upload logs of BSMs received from OBUs in passing vehicles.
- ODE sends TIM messages along with delivery instructions to RSUs. The RSUs are to broadcast these TIMs to passing OBUs.

3.1.1.1.2 Input Data/Message Flows

Input data to RSUs consist of BSMs, TIMs, SCMS certificates, and location/time information. BSMs are collected from vehicles as they pass within range of a RSU. The RSU also receives location and time information from a field location and time service as well as a network time service. RSUs collect SCMS certificate information for the RSU as well as for requesting OBUs.

3.1.1.1.3 Output Data/Message Flows

Output data from RSUs consist of BSMs, TIMs, SCMS certificates, and traffic situation data. BSMs are bundled and forwarded periodically without modification to the ODE. SCMS certificates are pushed out to requesting OBUs.

3.1.1.2 RSU Hardware Platform

3.1.1.2.1 Vendor/manufacturer & model

Commsignia is the RSU manufacturer. The model is the Commsignia V2X RSU Unit.

3.1.1.2.2 Picture and physical description of hardware

The Commsignia RSU is encased in a weatherproof case and contains antennas for Wi-Fi and V2X connections. Additionally, the RSU unit comes with an integrated GPS. Figure 3-1 shows a Commsignia RSU.

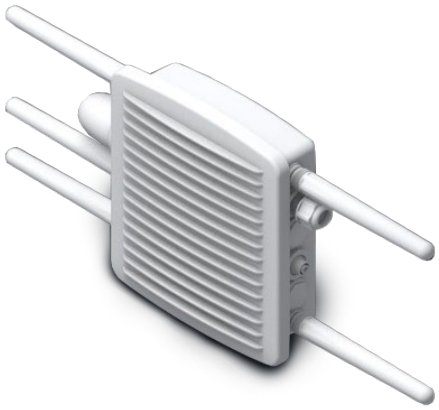


Figure 3-1. Commsignia V2X RSU Unit.
Source: Commsignia

3.1.1.2.3 Hardware physical interfaces (RS232, Ethernet, etc.)

The RSU Unit has the following physical interfaces.

- *Antenna 2 x C-V2X, 2x DSRC 1 x Wi-Fi, 1x Bluetooth, 1 x LTE/3G, 1 x GNSS*
- *Data 1 x ETH, ~~2 x USB, 1 x CAN, 1 x OBD-II~~*
- *Other Power connector*
- ~~*Reset button*~~
- *2 x Bicolor LEDs*
- ~~*Extension 2 x Mini PCIe slots (these are used by Wifi and 4G cards)*~~
- *Video HDMI 1.4a*
- *Line out 3.5mm jack*

3.1.1.2.4 Hardware specifications, particularly those related to CV function and performance (from Vendor)

Table 3-1 details the RSU's core features. These devices will be installed along I-80 as well as rest stops and WYDOT fueling areas. Locations have been selected based on availability for power, high speed back haul, and a mount at least 8 meters high. If an RSU is mounted higher than 8 meters, the EIRP must be adjusted to maintain compliance with FCC regulations.

Table 3-1. RSU Hardware Specifications.

Hardware	Specification
CPU	800MHz Freescale/NXP i.MX 6
OS	Linux / RTOS (V2X)
RAM	2 GB DDR3 SDRAM
Flash	4 GB eMMc
Storage	Dual micro SD Card slot
Ethernet	10/100/1000 Mbps Ethernet
External I/O	GPIO (optional)
Supervisor	Yes
Power supply	802.3at passive PoE (surge and reverse polarity protected)
Backup power	Yes (10s Store & Shutdown) (optional)
Positioning	Advanced GNSS
Wifi	Dual band a/b/g/n
Bluetooth	BLE 5.0
Cellular	3G / LTE (MiMo)

3.1.1.2.5 Hardware design description relevant to CV function and performance

RSUs include C-V2X connectivity, application support, data storage, and other support services to enable CV applications, such as necessary certificates. WYDOT RSUs can be either fixed or portable equipment depending on the use. In general, RSUs serve as a two-way communication portal between connected vehicles that provide information through C-V2X/Wi-Fi and the ODE. About 75 RSUs are planned to be deployed.

3.1.1.3 RSU Operating Platform/ Development Stack

The section below contains details of the RSU hardware/Operating System design.

3.1.1.3.1.1 Schematic of major modules/functions

The operating system platform incorporates all of the hardware seen in Figure 3-2. The Operating System is a Linux based kernel that provides functionality for integrating all of the hardware components in the RSU.

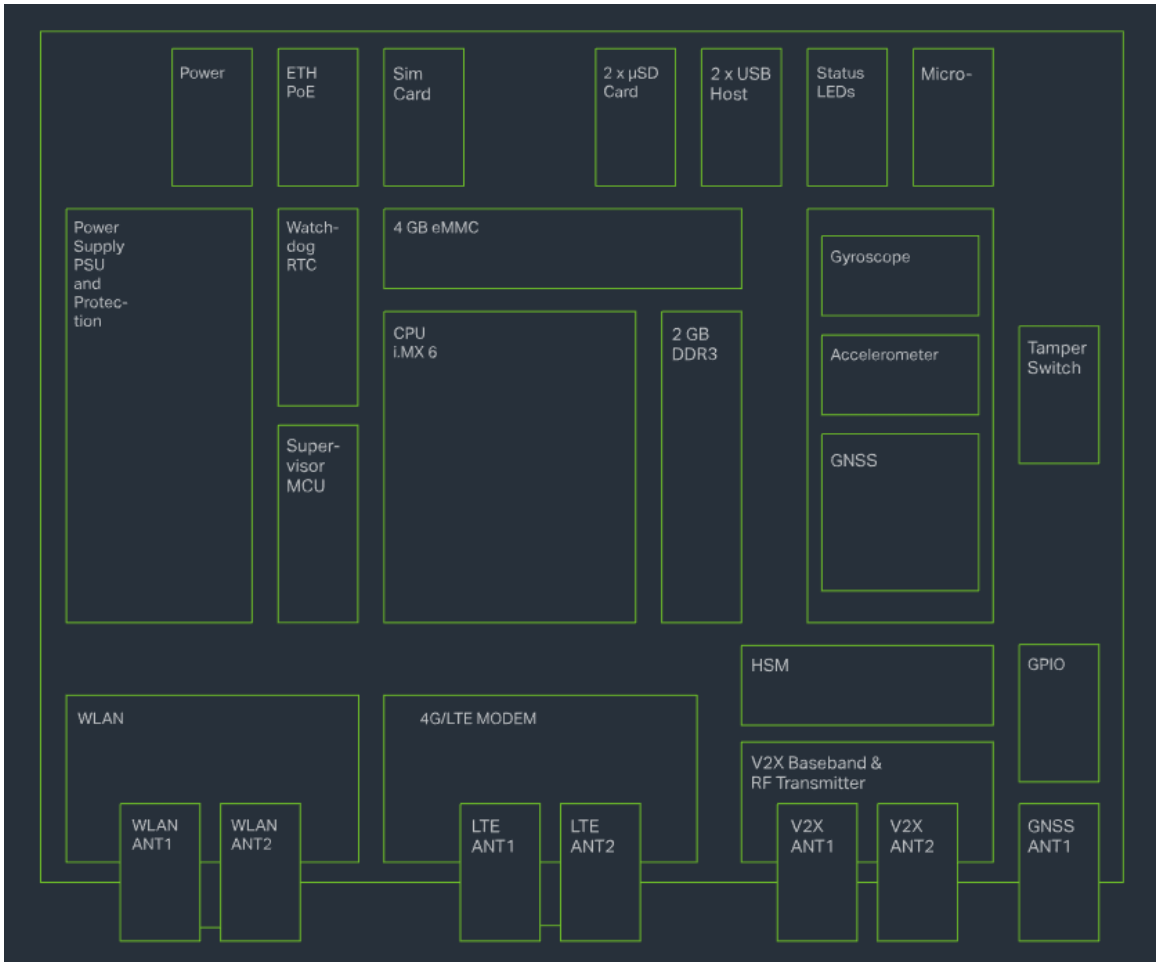


Figure 3-2. Block Diagram of RSU.
Source: Commsignia

3.1.1.4 RSU Communication Interfaces

Communication Interfaces are defined in the corresponding ICD (sections 5.9, 5.10 5.11, 5.14, and 5.18).

3.1.1.5 Requirements Traceability

The following requirements are applicable to this component and met by this design:

- SCMS-REQ-1 Wyoming CV System (WCVS) SCMS Use **Phase 4 will use the ISS SCMS.**
- SCMS-REQ-1.1 SCMS Wyoming CV System Certificates **Phase 4 will use the ISS SCMS**

- SCMS-REQ-1.2 SCMS Wyoming CV System Misbehavior Reporting **This is outside the scope of Phase 4.**
- SCMS-REQ-1.3 SCMS Wyoming CV System Certificates Revocation List (CRL) **This is outside the scope of Phase 4.**
- SCMS-REQ-1.4 SCMS Wyoming CV System Rejection **This is outside the scope of Phase 4.**
- RSU-REQ-3 SCMS **Phase 4 will use the ISS SCMS**
- RSU-REQ-4 LTS
- RSU-REQ-6 Safety Communication
- RSU-REQ-7 Broadcast
- RSU-REQ-10 Management and Performance **Phase 4 will not include management and performance data collection.**
- RSU-REQ-11 Distribute to ODE
- RSU-REQ-12 Receive Update
- RSU-REQ-13 RSU Equipment

3.1.1.6 ICD Traceability

The following interfaces are applicable to this component and its design. A reference to the location of the interface within the ICD is also provided.

General Interface	Action within Interface	Section No.
OBU <-> RSU	OBU Broadcasts BSM (Part I & II) which is received by RSU	5.9.1
	RSU Broadcasts TIMs which are received by OBUs	5.9.2
	OBU Utilizes RSU Broadcast SCMS Services	5.9.3
RSU <-> Field Location and Time Source (FLTS)	RSU retrieves location and time from LTS	5.10.1
Network Time Service (NTP) <-> RSU	RSU Synchronizes Time using NTP	5.11.1
USDOT Prototype SCMS <-> RSU	RSU Device Enrollment (Bootstrapping)	5.14.1
	RSU Application Certificate Provisioning	5.14.2
	RSU Security Policy and Networking Information	5.14.3
	RSU Misbehavior Reporting	5.14.4
	RSU Security Credential Revocations	5.14.5
ODE <-> RSU	RSU Sends Traffic Situation Data to the ODE	5.18.1
	ODE Sends TIMs to RSUs	5.18.2

3.1.2 RSU Applications Design

3.1.2.1 RSU Roadway Traffic Information Dissemination

This section describes the information flow and the responsibilities for each of the components involved with the RSU Roadway Traffic Information Dissemination application.

3.1.2.1.1 Function of the Application

The sections below describe the function of the Roadway Traffic Information Dissemination application.

3.1.2.1.1.1 Functions/Services Brief description

This application includes dissemination of information to vehicles and drivers, including traffic and road conditions, incident information, work zone information, parking information, weather information and broadcast alerts within a defined radius. Traffic Information Messages (TIM) dispersal notifications are received from the ODE.

Traveler Information Messages consist of standard ITIS codes (shown in Table 3-2) and are broadcast on channel 183. These messages are transmitted by the RSU with periodicity of 1 second (or configured interval). ITIS codes relevant to a specific region are configured by the traffic controller and encoded as a TIM message, which is then broadcasted by the RSU.

3.1.2.1.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

Figure 3-3 shows the high-level communications for the RSU Roadway Traffic Information Dissemination along the highway.

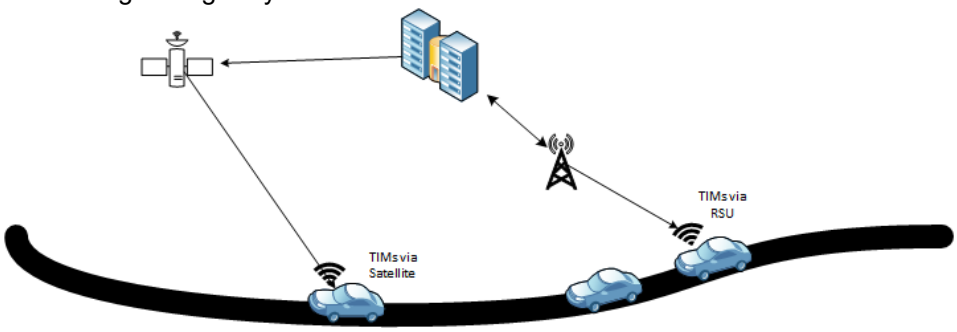


Figure 3-3. RSU Roadway Traffic Information Dissemination highway communications.
Source: WYDOT

3.1.2.1.1.3 Input Data/Message Flows

The RSU vendor is expected to support a Store and Repeat module that will broadcast a TIM message for the life of the TIM.

3.1.2.1.1.4 Output Data/Message Flows

Output from the Roadway Traffic Information Dissemination application includes packets from the TIM application that are registered with an Ethernet (dot3) logical link control layer and transmitted.

3.1.2.1.2 Developer & version number

Commsignia is the primary application development group responsible for this application.

3.1.2.1.3 Application Message and Alerts Descriptions

The following sections described the messages and alerts that may be transmitted by the traffic information dissemination application.

3.1.2.1.3.1 Descriptions and illustrations of messages and alerts issued by this application.

Table 3-2 shows the alerts and messages that are issued by the Traffic Information Dissemination application for broadcast to OBU's. For detailed descriptions of how each of these messages are formatted please see Appendix A.

Table 3-2. Traffic Information Dissemination Alerts and Messages.

ITIS Code	Description	Category
268	Speed Limit	speedLimit
513	Accident	advisory
531	Incident	advisory
550	Hazardous material spill	advisory
770	Closed	advisory
774	Closed for the season	advisory
777	Reduced to one lane	workZone
1042	Avalanche control activities	advisory
1025	Road Construction	workZone
1292	Herd of animals on roadway	advisory
1310	Landslide	advisory
2050	Wide load	advisory
2568	No trailers	advisory
2573	Width Limit	advisory
2574	Height Limit	advisory
3084	Wildfire	advisory
3841	Major event	advisory
4103	No parking spaces available	exitService
4104	Only a few parking spaces available	exitService
4105	Spaces Available	exitService
4223	No parking information available	exitService
4865	Severe weather	advisory
4868	Snow	advisory
4871	Winter Storm	advisory
4885	Rain	advisory
5127	Strong winds	advisory
5378	Fog	advisory
5383	Visibility reduced	advisory
5385	Blowing snow	advisory
5908	Black ice	advisory
5895	Wet pavement	advisory
5906	Ice	advisory
5907	Icy patches	advisory
5927	Snow drifts	advisory
6011	Dry pavement	advisory
6156	Snow tires or chains required	advisory
7425	Keep to right	workZone
7426	Keep to left	workZone

ITIS Code	Description	Category
7443	Reduce your speed	speedLimit
7169	Drive carefully	advisory
7170	Drive with extreme caution	advisory
7173	Increase normal following distance	advisory
7186	Prepare to stop	workZone
7188	Stop at next safe place	advisory
7189	Only travel is absolutely necessary	advisory
12037	Falling rocks	advisory
Below are advisory strings up to 500 characters, used due to not equivalent in J2540		
"Extreme blow over risk"	Extreme blow over risk	advisory
"Closed to light, high-profile vehicles"	Closed to light, high-profile vehicles	advisory
"Advise no light trailers"	Advise no light trailers	advisory
"Closed due to border state request from Colorado"	closed due to border state request from Colorado	advisory
"Closed due to border state request from Idaho"	closed due to border state request from Idaho	advisory
"Closed due to border state request from Montana"	closed due to border state request from Montana	advisory
"Closed due to border state request from Nebraska"	closed due to border state request from Nebraska	advisory
"Closed due to border state request from South Dakota"	closed due to border state request from South Dakota	advisory
"Closed due to border state request from Utah"	closed due to border state request from Utah	advisory
"Closed due to border state request from Multiple States"	closed due to border state request from Multiple States	advisory
"Closed due to law enforcement request"	closed due to law enforcement request	advisory
"Closed due to local authority request"	closed due to local authority request	advisory

3.1.2.1.3.2 Describe algorithm to determine when messages and alerts are issued.
All the messages that are issued by the Traffic Information Dissemination application in Table 3-2 follow the same algorithm used in the traffic information dissemination application. Once the TIM application receives a request an alert or advisory is broadcast from the TIM application.

3.1.2.1.4 Requirements Traceability
The following requirements are applicable to this component and met by this design:

- WCVS-REQ-8 Internal Brokerage **PA-REQ-2 and PA-REQ-4 are not supported with Phase 4.**
- WCVS-REQ-10 Distribute TIM
- WCVS-REQ-10.1 Distribute TIM to VS
- RSU-REQ-2 Distribute TIM to VS

3.1.2.1.5 ICD Traceability
The following interfaces are applicable to this component and its design. A reference to the location of the interface within the ICD is also provided.

General Interface	Action within Interface	Section No.
OBU <-> RSU	OBU Broadcasts BSM (Part I & II) which is received by RSU	5.9.1
	RSU Broadcasts TIMs which are received by OBUs	5.9.2
ODE <-> RSU	RSU Sends Traffic Situation Data to the ODE	5.18.1
	ODE Sends TIMs to RSUs	5.18.2

3.1.3 TMC Design

This is a *general description of existing hardware and operations environment* and *components that were added to support new CV system, such as storage arrays*. This outline will need to be adapted to fit the specifics of the TMC environment. This information is to help guide other TMCs on what they may need to do to support CV applications.

In order to support the addition of the CV system to the WYDOT TMC infrastructure was added and updated. The sections below describe what equipment has been added and what systems the new equipment supports.

3.1.3.1 Function of the Component

The updated TMC hardware is designed to improve the performance and the capabilities of the TMC infrastructure.

3.1.3.1.1 Functions/Services Brief description
Two servers, a storage array and 24-port 10GBase-T Ethernet switch have been purchased to support the CV Pilot. This infrastructure provides a fault-tolerant computing environment to host the ODE as well as the Mongo database for data storage. This new equipment is located at the WYDOT Transportation Management Center (TMC) data center in Cheyenne.

3.1.3.1.2 Storage Area Network

The following figure shows the storage area network connections with the computer servers. The storage area network is built with redundant 10 Gbps VLANs. Each VLAN contains dedicated Ethernet ports for the DELL storage controller (at the bottom) and each of the two servers (at the top).

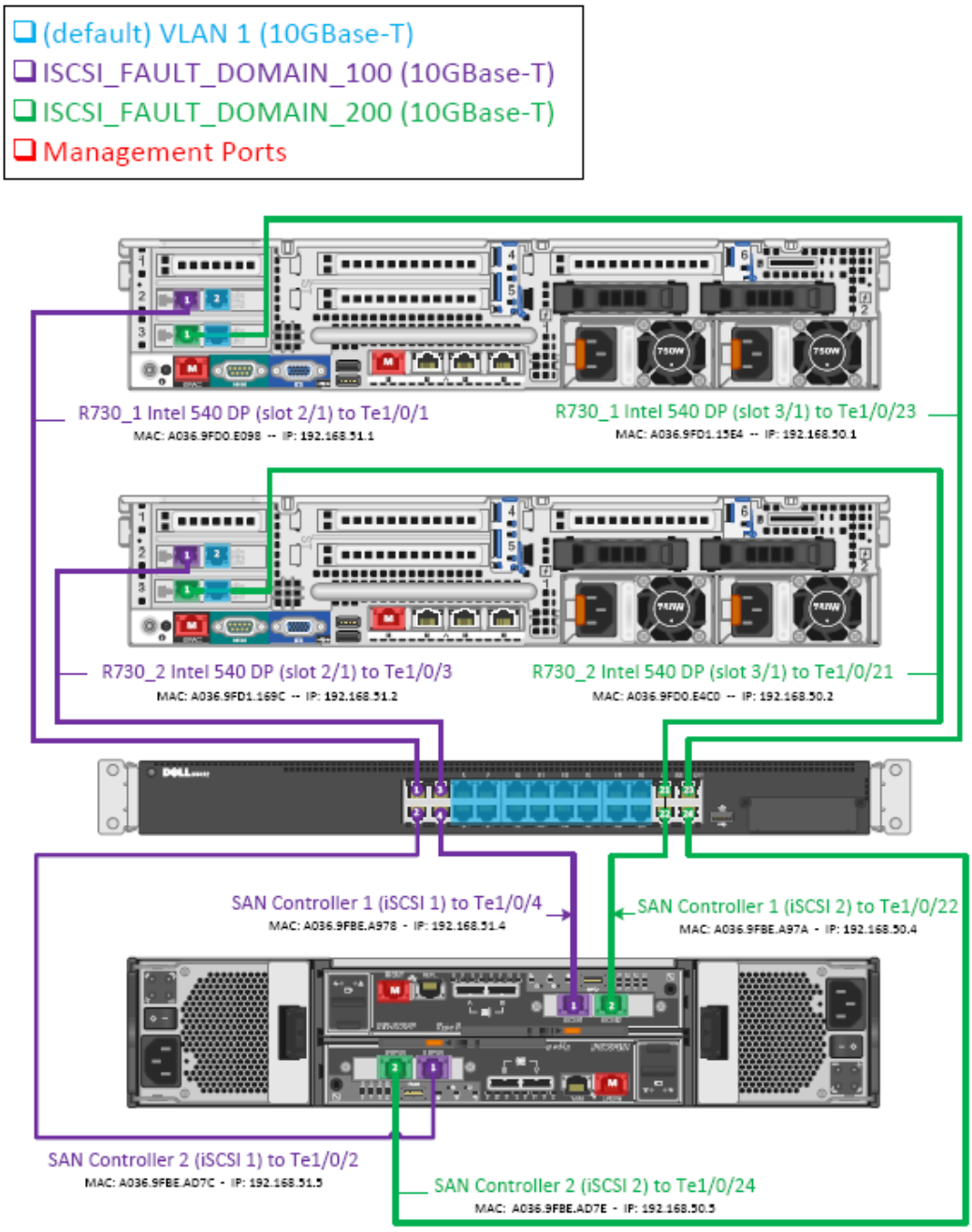


Figure 3-4. Storage Area Network.
Source WYDOT

3.1.3.1.3 Server Cluster Network

The following figure shows the server network connections to the WYDOT TMC. Each server has dual 10 Gbps Ethernet connections to a central 10GBase-T switch.

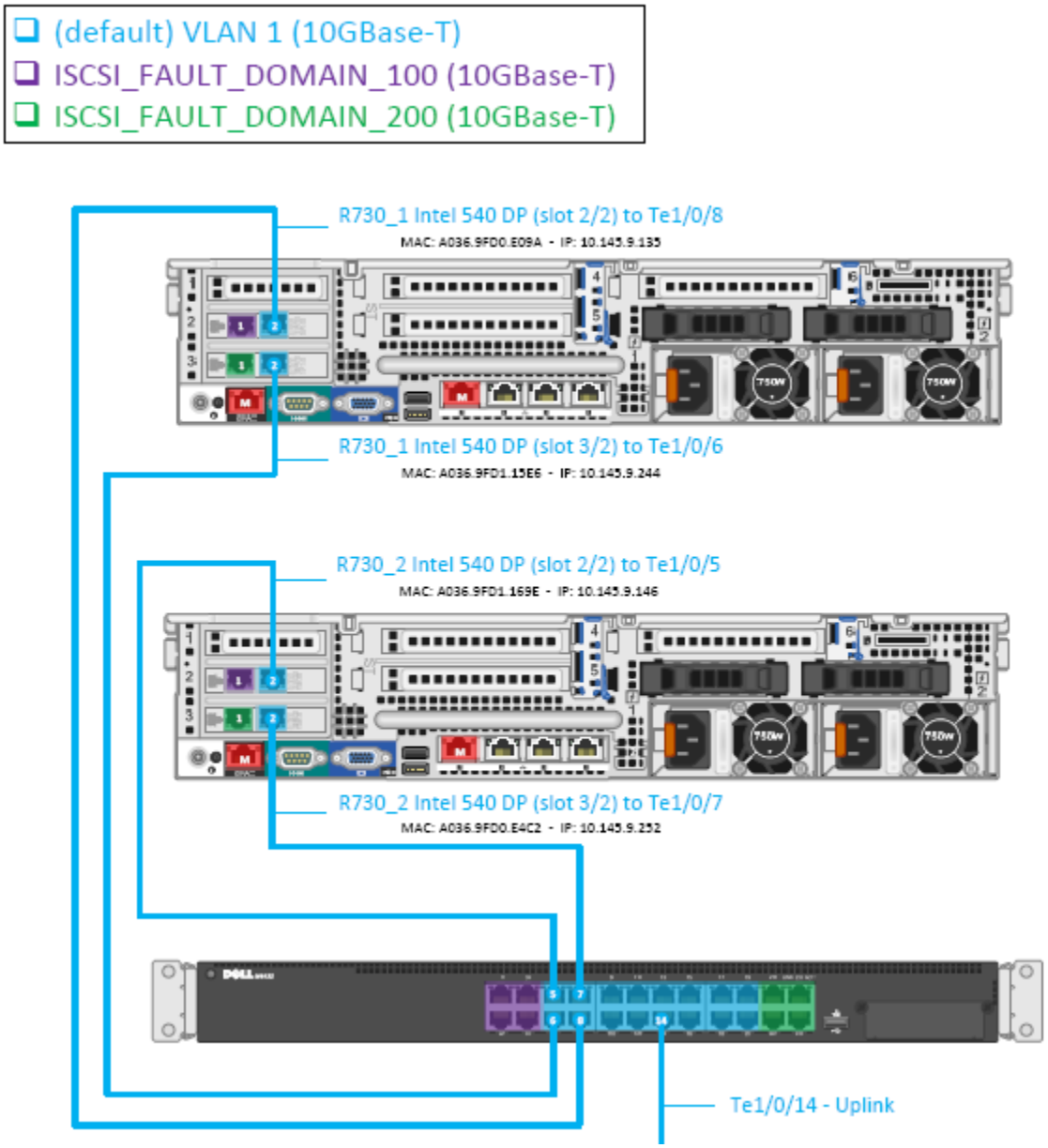


Figure 3-5. Server Cluster Network.
Source WYDOT

3.1.3.2 TMC Hardware Platform

The TMC will procure servers, storage array, and a networking switch to host the TMDD third-party interface, ODE, Data Warehouse as well as management software for the RSU's. The Third-party interface which publishes TMDD data, and the Operational Data Environment software are integral components of the WYDOT Pilot.

3.1.3.2.1 Vendor/manufacturer & model number,

Table 3-3 describes the supporting hardware purchased for the CV pilot project.

Table 3-3. Table of supporting CV hardware.

Category	Manufacturer/Description	Model Number	Quantity
Server	Dell PowerEdge R730 Server	210-ACXU	2
Server	Intel Xeon 18 core CPU	E5-2697 v4 2.3GHz	4
Server	120 GB Solid State Drives, 6Gbps SATA	400-AEIB	4
Server	32GB RDIMM, 2400MT/s, DDR	370-ACNS	16
Server	PERC H730P Integrated RAID Controller	405-AAEH	2
Server	Intel Ethernet X540 2-port Adapter	540-BBHZ	4
Server	Broadcom 5720 4-port 1Gb Network	540-BBBW	2
Server	iDRAC8 Enterprise Controller	385-BBHO	2
Storage Array	Dell SCv2020 ISCSI	210-ADRU	1
Storage Array	Dell 1.2TB, SAS 12Gb, 10K, 2.5", HDD	400-AHEB	24
Switch	Dell Networking N4032, 24x 10GBaset-T switch	210-ABVS	1
Switch	C2G 2t Cat6 Unshielded Ethernet cables	A7523371	21
Hardware Security Module	ISS Traffic Management Center (TMC) Authority Appliance Pair	ISS-TMC-WYDOT-YR3	2

3.1.3.2.2 Picture and physical description of hardware

Figure 3-6 shows the WYDOT server chosen to run the CV ODE and other supporting applications.

Figure 3-6. Dell PowerEdge R730 Server.
Source: Dell

Figure 3-7 shows the WYDOT storage array chosen to store CV data.

Figure 3-7. Dell SCv2020 ISCSI Storage Array.
Source: Dell

Figure 3-8 shows the WYDOT network switch chosen to support the CV project.

Figure 3-8. Dell Networking N4032, 24x 10GBaset-T switch.
Source: Dell

Figure 3-9 shows the WYDOT Hardware Security Module chosen to support the CV project. Not in use for Phase 4, the TMCA is cloud hosted for Phase 4.

Figure 3-9. Integrated Security Solutions Hardware Security Module.
Source: Integrated Security Solutions

3.1.3.2.3 Hardware physical interfaces (RS232, Ethernet, etc.)

The Servers have the following physical interfaces:

- Ethernet adapters
- Hot-plug hard drive bays

The Storage Array has the following physical interfaces:

- FC ports
- iSCSI (base-T) ports
- SAS ports

The Network Switch has the following physical interfaces:

- 10GBaseT ethernet ports
- Hot swap expansion module bay

3.1.3.2.4 Hardware specifications, particularly those related to CV function and performance (from Vendor)

Both servers have redundant (RAID-1) boot devices, multi-path IO connections (iSCSI over 10GBase-T) to the Storage Array, redundant Ethernet connections for management and redundant 10GBase-T primary data links to both the public internet and to the existing WYDOT intranet.

Both servers will run Microsoft's Hyper-V 2016 Server edition and applications running on the servers will be hosted in Virtual Machines. All storage for Virtual Machines will be located on the Storage Array. Microsoft Failover Cluster Manager and Microsoft Cluster Shared Volumes will be used to enable live Virtual Machine migration between the servers and together with a regular backup plan will insure quick recovery for either a failed server or virtual machine.

Each server contains two Intel Xeon, 18 Core CPUs and 256 GB of DDR3 memory. The CPUs were selected based on price/performance per core up to the level where incremental price/performance began to diminish. The CPU and memory configurations were selected to maximize performance for virtual machine environments.

The storage array contains (24) 1.2TB SAS HDDs and has a formatted capacity of 19TB. The storage array uses RAID configuration, hot spare disks and dual redundant controllers to insure data integrity and fault tolerance. The storage array is connected to both servers using multi-path iSCSI over 10GB Ethernet.

The storage array will host Virtual Machine images for servers hosting the ODE as well as management software for the RSU's according to the system requirements.

The storage array is configured with:

- (24) Dell 1.2TB, SAS 12Gb, 10K, 2.5", HDD
- Four years' hardware and software support

The switch has (24) 10GBase-T copper Ethernet ports, redundant power supplies and supports layer-2 and layer-3 capabilities.

The switch serves as the interconnect fabric for the servers and storage array. The switch also connects to the existing WYDOT intranet.

The following additional items were purchased for the switch:

- Cat6 Ethernet cables
- Four years' hardware and software support

The Hardware Security Module (HSM) chosen for this project can check and digitally sign Traveler Information Messages at the TMC level and allows for delivery of TIMs to specified RSUs. The HSM will be housed within the TMC alongside the other software with a direct connection to the ODE server for a secure wired connection for signing TIMs before delivery. Figure 3-10 shows a typical HSM setup within the TMC environment. As part of the purchase of the HSM software from ISS the HSM is responsible for all interactions to/from the SCMS system including retrieving new security certificates and signing/returning signed certificates.

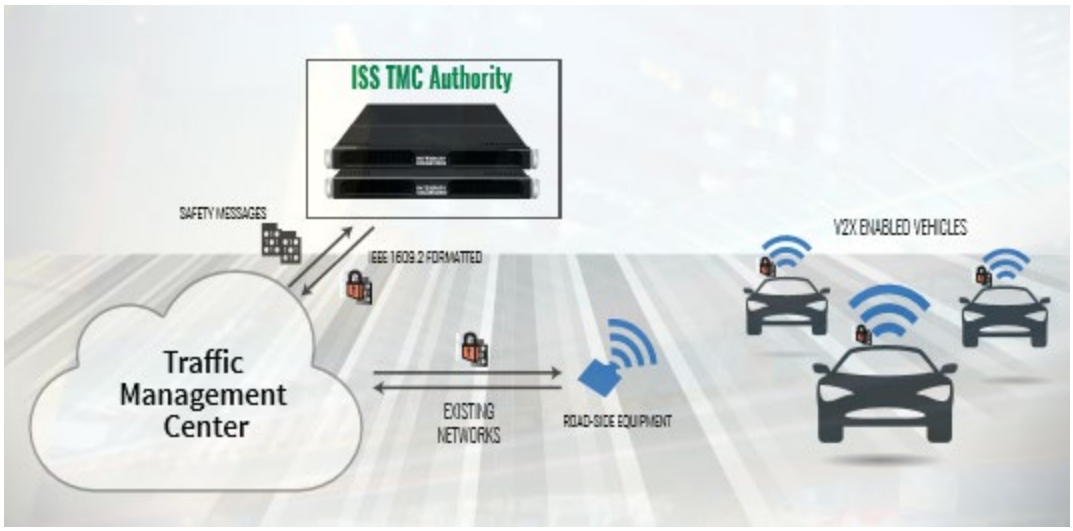


Figure 3-10. HSM working diagram.
Source: Integrated Security Solutions

3.1.3.2.5 Hardware Configuration Data

Table 3-4 shows the Hardware configuration data for the added hardware components of the CV system.

Table 3-4. Hardware Configuration Data

Hardware	Configuration
Servers	• (2) Intel Xeon CPUs • 256 GB of DDR memory • (2) 120 GB Solid State Boot Drives • Integrated RAID Controller, 2GB Cache • (2) Intel 10GBASE-T, dual port Ethernet Adapters • Broadcom 1GB, quad port, Ethernet Card • iDRAC8 Enterprise, integrated Dell Remote Access Controller • Four years' hardware and software support
Storage Array	• (24) Dell 1.2TB, SAS 12Gb, 10K, 2.5", HDD • Four years' hardware and software support

3.1.3.3 TMC Operating Platform

The TMC Operating platform includes multiple software solutions that will handle different aspects of the CV pilot program. These

3.1.3.3.1 Operating Platform specifications, particularly those related to CV function and performance (from Vendor)

Both physical servers will run Microsoft Hyper-V Server 2016, which is a stand-alone product that contains only the Windows hypervisor, a Windows Server driver model, and virtualization components. This edition of Microsoft Server 2016 is available free of charge. Open-source Linux (Ubuntu & Debian) and existing licenses for Microsoft Windows Server will run on the virtual machines hosted by the servers.

3.1.3.4 Requirements Traceability

Please note that the requirements traceability for this section includes applications that are not discussed in the design portion of the application. This is due to the fact that the hardware is where the applications will be housed or the hardware will provide vital support. The following requirements are applicable to this component and met by this design:

- WCVS-REQ-11 Store VS Data
- WCVS-REQ-11.1 Store BSM
- WCVS-REQ-11.2 Store Environment Sensor Data **Environmental Sensor Data is not part of Phase 4.**
- WCVS-REQ-11.3 Store Distress Messages **Distress Messages will not be part of Phase 4.**
- WCVS-REQ-12 Store Generated Alerts/Advisories **Not part of Phase 4.**
- WCVS-REQ-14 Store System Monitoring Data
- WCVS-REQ-16 Monitored Functions
- WCVS-REQ-16.1 Sub-System Availability
- WCVS-REQ-16.3 Availability for Interfaces
- WCVS-REQ-16.4 Availability for Data Storage
- WCVS-REQ-17 Archive Data
- WCVS-REQ-18 Management and Performance Policy **Performance measures and performance data will not be part of Phase 4.**
- WCVS-REQ-20 Manage Safe Communications
- WCVS-REQ-21 Manage CV Equipment
- WCVS-REQ-22 Test CV Equipment
- WCVS-REQ-23 Track CV Equipment
- WCVS-REQ-24 Update WCVS Equipment
- WCVS-REQ-25 Update VS Equipment
- DW-REQ-1 Store Data
- DW-REQ-1.1 Store Alerts/Advisories
- DW-REQ-1.1.1 Store Alerts/Advisories-Precipitation Hazard **Not in Phase 4**
- DW-REQ-1.1.2 Store Alerts/Advisories-Road Condition Hazard **Not in Phase 4**
- DW-REQ-1.1.3 Store Alerts/Advisories-Visibility Hazard **Not in Phase 4**
- DW-REQ-1.1.4 Store Alerts/Advisories-Work Zone Hazard
- DW-REQ-1.1.5 Store Alerts/Advisories-Incident Hazard
- DW-REQ-1.1.6 Store Alerts/Advisories-Parking
- DW-REQ-1.2 Store Vehicle System Data
- DW-REQ-1.3 Store TIM
- DW-REQ-1.4 Store System Monitoring Data
- DW-REQ-2 Share Data
- DW-REQ-2.1 Share Data with TPI **Not in Phase 4**
- DW-REQ-2.2 Share Data with SDC **The SDC will not be part of Phase 4.**
- DW-REQ-2.3 Share Data with RDE **The RDE will not be part of Phase 4.**
- DW-REQ-3 Data Storage Administration
- DW-REQ-3.1 Maintain System Data Tables
- DW-REQ-3.1.1 CVE Data
- DW-REQ-3.2 Manage Data Storage Security
- DW-REQ-3.2.1 User Access

- DW-REQ-3.2.2 Unauthorized Access
- DW-REQ-3.3 Manage Data System
- DW-REQ-3.3.1 System Back-ups
- DW-REQ-3.3.2 Import/Export
- DW-REQ-3.3.3 Version Control
- DW-REQ-3.4 Manage Data Archive
- DW-REQ-4 Receive Data
- HSM-REQ-1 Receive from ODE **Not in Phase 4**
- HSM-REQ-2 Share with ODE **Not in Phase 4**
- HSM-REQ-3 Receive from SCMS **Not in Phase 4**
- HSM-REQ-4 Share with SCMS **Not in Phase 4**

3.1.3.5 ICD Traceability

The following interfaces are applicable to this component and its design. A reference to the location of the interface within the ICD is also provided.

Interface	Action within Interface	Section No.
WYDOT 511 System <-> WYDOT Data Broker	WYDOT 511 System sends Parking data WYDOT DB	5.8.1
Network Time Service (NTP) <-> ODE	ODE Synchronizes Time using NTP	5.12.1
ODE <-> HSM	ODE Uses HSM to sign TIMs	5.15.1
USDOT Prototype SCMS <-> HSM	ODE Device Enrollment (Bootstrapping)	5.43.1
	ODE Application Certificate Provisioning	5.43.2
	ODE Security Policy and Networking Information	5.43.3
	ODE Misbehavior Reporting	5.43.4
	ODE Security Credential Revocations	5.43.5
ODE <-> OBU	OBU Copies Log File to ODE	5.16.1
	ODE Updates OBU Firmware OTA	5.16.2
ODE <-> WY Maintenance Vehicle (OBU)	OBU Copies Weather Environmental Data to ODE	5.17.1
ODE <-> RSU	RSU Sends Traffic Situation Data to the ODE	5.18.1
	ODE Sends TIMs to RSUs	5.18.2
ODE <-> Pikalert	ODE Sends Vehicle Environmental Data to Pikalert System	5.19.1
	ODE Sends Environmental Situation Data to Pikalert System	5.19.2
ODE <-> WYDOT Data Warehouse	ODE Sends Traffic Situation Data to WYDOT DW	5.20.1
ODE <-> WYDOT Data Broker	ODE Sends DNM to WYDOT DB	5.21.1
	WYDOT Data Broker sends TIMs to ODE	5.21.2

ODE <-> Situational Data Warehouse (SDX)	ODE Transmits TIM to SDX	5.22.1
Pikalert <-> Weather Sources	Weather Information Sources provide data to Pikalert	5.25.1
Pikalert <-> WYDOT DB	WYDOT DB Retrieves Road Weather Alerts from Pikalert	5.27.1
	WYDOT DB Retrieves Road Weather Forecasts from Pikalert	5.27.2
WYDOT DB <-> WYDOT TRAC	DB Sends Emergency Notification to TRAC	5.28.1
	DB Sends Road Weather Alert from Pikalert to TRAC	5.28.2
WYDOT DB <-> WYDOT CVOP	DB sends segment advisories and alerts to CVOP	5.29.1
	CVOP Manages Road Weather Forecast Data Using DB	5.29.2
WYDOT DB <-> WYDOT ITS Maintenance	DB reports malfunctioning RSU to WYDOT ITS	5.30.1
WYDOT DB <-> WYDOT Incident Console IC	WYDOT Incident to the WYDOT DB	5.31.1
WYDOT DB <-> WYDOT Construction Administration	WYDOT CA sends new construction project to the DB	5.32.1
WYDOT DB <-> WYDOT RCRS	Plow-Operator Sourced Road Condition and VSL Recommendation Updates to WYDOT Data Broker	5.33.1
WYDOT DB <-> WYDOT WTI	WYDOT DB Sends Road Weather Advisories and Alerts to WYDOT Traveler Information System	5.34.1
	WTI sends posted speeds, restrictions and closures to WYDOT DB	5.34.2
WYDOT Data Broker <-> WYDOT Data Warehouse	WYDOT DB Archives TIMs to the WYDOT DW	5.35.1
WYDOT DW <-> Third Party Interface (TPI)	Third Party retrieves WYDOT traffic and road conditions	5.36.1
ODE <-> SDC	ODE publishes CV data containing PII to SDC	5.37.1
WYDOT DW <-> SDC	WYDOT DW publishes CV data containing PII to SDC	5.38.1
WYDOT DB <-> SDC	WYDOT DB Manually Uploads data to SDC	5.39.1
ODE <-> RESEARCH DATA EXCHANGE (RDE)	ODE Publishes CV data without PII to RDE	5.40.1
WYDOT DW <-> RESEARCH DATA EXCHANGE (RDE)	WYDOT DW publishes CV data without PII to RDE	5.41.1

WYDOT DB <-> RDE	WYDOT DB Manually Publishes data to RDE	5.42.1

3.1.4 TMC Services Applications Design

3.1.4.1 Operational Data Environment (ODE)

Please note that the design for the ODE references the JPO-ODE as this is the documentation from the ODE development team that is currently developing the ODE. The ODE that will be installed on the WYDOT servers will be the WYDOT ODE but the functionality will remain the same as what is described in the sections below.

3.1.4.1.1 Function of the Application

An Operational Data Environment is a real-time data acquisition and distribution software system that processes and routes data from Connected-X devices—including connected vehicles (CV), personal mobile devices, infrastructure components, and sensors—to subscribing applications to support the operation, maintenance, and use of the transportation system, as well as related research and development efforts.

The ODE is intended to complement a connected vehicle infrastructure by brokering, processing and routing data from various data sources, including connected vehicles, field devices, Transportation Management Center (TMC) applications and a variety of other data users. Data users include but not limited to transportation software applications, Research Data Exchange (RDE), Trihydro Situation Data Exchange. Phase 4 will not continue the use of the RDE.

Due to security concerns the ODE cannot directly interface with the SCMS in order to sign outgoing TIMs. In order to get around this and still maintain the feature of being able to push out TIMs the ODE interfaces with a Hardware Security Module (HSM) that allows signing of certificates. Further information on the process of interacting with the HSM and the signing and sending of signed TIMs can be found in the ODE user manual (https://github.com/usdot-jpo-ode/jpo-ode/blob/develop/docs/JPO_ODE_UserGuide.docx).

3.1.4.1.1.1 Functions/Services Brief description

As a data provisioning service, the ODE can provision data from disparate data sources to software applications that have placed data subscription requests to the ODE. On the other direction, the ODE can accept data from CV applications and broadcast them to field devices through Road Side Units (RSU) and the Trihydro Situation Data Exchange which in turn will transmit the data to Sirius XM satellites for delivery to the connected vehicles in the field.

While provisioning data from data sources to data users, the ODE also will perform necessary security/credential checks and as needed, data validation and sanitization.

- Data validation is the process of making a judgment about the quality of the data and handling invalid data as prescribed by the system owners.
- Data sanitization is the modification of data as originally received to reduce or eliminate the possibility that the data can be used to compromise the privacy of the individual(s) that might be linked to the data.

3.1.4.1.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

This application is not directly involved with vehicle communications on the highway.

3.1.4.1.1.3 Input Data/Message Flows

The JPO-ODE will be designed to support the following mechanisms for inputting ASN.1 encoded BSMs, TIM messages in a human readable encoded format (e.g. JSON), environmental and various other system logs. Log data definitions can be found in the ICD under the ODE <-> OBU interface definition.

- **Streaming Data Producers (Direct):** Applications can directly interact with the messaging service through the use of the service's native API and publish messages to be processed by the ODE. *This interface will be available only to applications residing inside a private network domain.*
- **Streaming Data Producers (WebSocket):** Applications can interact with the messaging service and publish messages to be processed by the ODE. *This interface will be available to all applications whether residing in the private network domain or in the cloud. For cloud applications Secure WebSocket (wss) protocol will be required.*
- **RESTful API Data Producers:** Applications can connect with the ODE though a RESTful API and submit messages to the messaging service through HTTP POST commands. *This interface will be available to all applications whether residing in the private network domain or in the cloud. For cloud applications Secure HTTP (https) protocol will be required.*
- **File System Data Producers**: Encoded message files and log files messages can be dropped into a shared file system location and systematically pulled in to the data broker. *This interface will be available to applications residing in the private network domain or in the cloud. This interface will only available through Secure Copy (scp).*

Database Data Producer: A shared database where encoded messages are stored can also be connected directly into the ODE to monitor and process new records. *This interface will be available only to applications residing in the private network domain.*

Figure 3-11 shows the data flow diagram for all available input and output for the ODE application.

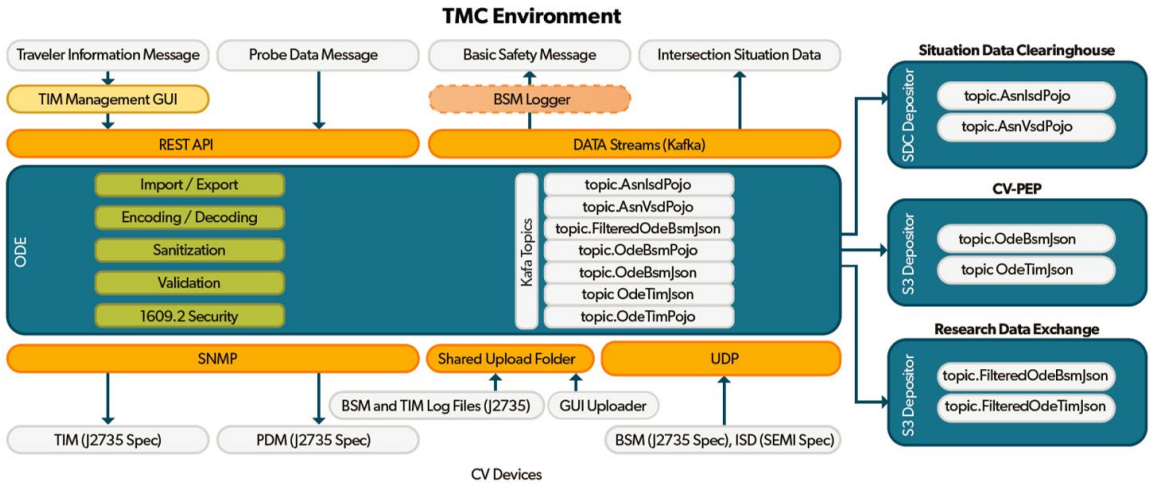


Figure 3-11. ODE Data Flow Diagram.
Source: USDOT

3.1.4.1.1.4 Output Data/Message Flows

The JPO-ODE will be designed to support the following mechanisms for outputting decoded BSM, Map and Spat data.[4]

- **Streaming Data Consumers (Direct):** Applications can subscribe directly to the messaging service through the use of the messaging service's native API. *This interface will be available only to applications residing in the private network domain.*
- **Streaming Data Consumers (WebSocket):** Applications can subscribe to the messaging service through the use of a standard WebSocket API. *This interface will be available to all applications whether residing in the private network domain or in the cloud. For cloud applications Secure WebSocket (wss) protocol will be required.*
- **RESTful API Data Consumers:** Applications can connect directly with a RESTful API and submit messages to the messaging service through HTTP commands. *This interface will be available to all applications whether residing in the private network domain or in the cloud. For cloud applications Secure HTTP (https) protocol will be required.*
- **File System Data Consumers:** Using a shared file repository, applications can monitor collection of data messages. *This interface will be available to applications residing in the private network domain or in the cloud. This interface will only be available through Secure Copy (scp).*
- **Database Data Consumers**: Data messages can be directly inserted into a shared application database and made available for queries.

Figure 3-11 shows the data flow diagram for all output data of the ODE application. Data feeds for the Research Data Exchange will be able to be configured to automatically output data to Amazon S3 buckets.

3.1.4.1.2 Developer & version number

Development of this application is currently being performed by the Booz Allen Hamilton development team.

Version Number 2.0

3.1.4.1.3 Application Message and Alerts Descriptions

The following sections describe the messages and alerts issued by the ODE application.

3.1.4.1.3.1 Descriptions and illustrations of messages and alerts issued by application.

Table 3-5 lists the messages and alerts are issued by the ODE application:

Please note: The ODE interface uses the file system to copy a file from source to destination. As a result, the messages and alerts generated by the copy command are platform dependent. The following table describes a sample set of exit codes returned by SCP command, but they may differ from the system on which ODE is deployed and running.

[4] Initial release of the ODE will only support BSM. Map and SPaT will be supported in follow on releases as other CV pilots will adopt the JPO-ODE for their deployment.

Table 3-5. Messages and alerts issued by the ODE application.

#	Message/Alert
0	Operation was successful
1	General error in file copy
2	Destination is not directory, but it should be
3	Maximum symlink level exceeded
4	Connecting to host failed.
5	Connection broken
6	File does not exist
7	No permission to access file.
8	General error in sftp protocol
9	File transfer protocol mismatch
10	No file matches a given criteria
65	Host not allowed to connect
66	General error in ssh protocol
67	Key exchange failed
68	Reserved
69	MAC error
70	Compression error
71	Service not available
72	Protocol version not supported
73	Host key not verifiable
74	Connection failed
75	Disconnected by application
76	Too many connections
77	Authentication cancelled by user
78	No more authentication methods available
79	Invalid user name

Table 3-6. File Copy Data Deposit Messages and Alerts.

Message or Alert	Communication Method	Description
See Table 3-5 for "copy" function Messages and Alerts	Command exit code	See Table 3-5 for "copy" function Messages and Alerts
Post-copy: "IMPORTER - Unable to open or process file: {}" FileNotFoundException	Application log file	When a data file is copied into one of the ODE upload folders, ODE will try to open the file and process its content. This error message is logged when ODE fails to open the file due to file not being present.
"IMPORTER - Unable to open or process file: {}" SecurityException	Application log file	When a data file is copied into one of the ODE upload folders, ODE will try to open the file and process its content. This

Message or Alert	Communication Method	Description
		error message is logged when ODE fails to read the file due to lack of Java security privileges.
“IMPORTER - Unable to open or process file: {}” "Error decoding data."	Application log file	When a data file is copied into one of the ODE upload folders, ODE will try to open the file and process its content. This error message is logged when ODE fails to decode the data from ASN.1 format.

3.1.4.1.3.2 Describe algorithm to determine when messages and alerts are issued

Table 3-7 describes the algorithm used to determine the error message issued.

Table 3-7. Algorithms for determining alerts

Message or Alert	Algorithm
See Table 3-5 for “copy” function Messages and Alerts	Platform dependent
Post-copy: “IMPORTER - Unable to open or process file: {}” FileNotFoundException	If the file does not exist when ODE starts to process it or for some other reason cannot be opened for reading, this message is logged in the application log file.
“IMPORTER - Unable to open or process file: {}” SecurityException	If a security manager exists and its checkRead method denies read access to the file, a message will be logged to the application log file.”
“IMPORTER - Unable to open or process file: {}” "Error decoding data."	If the message is not encoded to the expected ASN.1 encoding, ODE will raise this error to indicate failure to decode the data.

3.1.4.1.3.3 Summary tables of criteria for issuing messages and alerts

Table 3-8 shows the criteria used for issuing messages and alerts from the ODE.

Table 3-8. ODE Summary table for alerts

Message or Alert	Criteria
See Table 3-5 for “copy” function Messages and Alerts	Platform dependent
Post-copy: “IMPORTER - Unable to open or process file: {}” FileNotFoundException	File does not exist when ODE starts to process the file.
“IMPORTER - Unable to open or process file: {}” SecurityException	ODE does not have permission to process the file.
“IMPORTER - Unable to open or process file: {}” "Error decoding data."	Message is encoded incorrectly.

3.1.4.1.4 Application Design Description

JPO ODE will be developed according to the micro-services architecture pattern. The micro-services architecture pattern is a highly scalable design pattern and a viable alternative to monolithic applications[5] and service-oriented architectures.

The micro-services pattern consists of three major concepts:

1. *Separately deployed units*: As illustrated in Figure 3-12, each component of the micro-services architecture is deployed as a separate unit, allowing for easy deployment, increased scalability, and a high degree of component decoupling.
2. *Service component*: In micro-services architecture, we deal with service components, which can vary in granularity from a single module to a large portion of the application. Service components contain one or more modules (Java classes) that represent either a single-purpose function (e.g., decode BSMs from ASN.1) or an independent portion of a large business application (e.g., sanitize BSM data according to the client request).
3. *Distributed architecture*: All the components within the architecture are fully decoupled from one other and accessed through a messaging service. This concept is what allows microservices architecture pattern achieve some of its superior scalability and deployment characteristics.

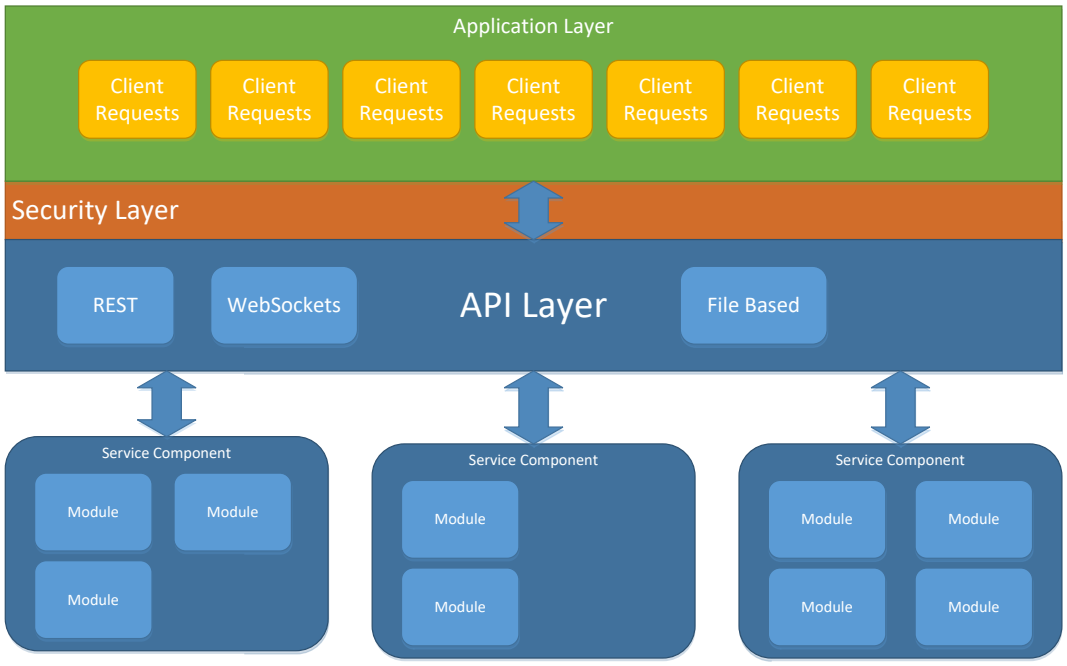


Figure 3-12. Basic Micro-services architecture pattern.
Source: USDOT

[5] In software engineering, a **monolithic application** describes a single-tiered software **application** in which the user interface and data access code are combined into a single program from a single platform. A **monolithic application** is self-contained, and independent from other computing **applications**.

3.1.4.1.4.1 Description of modules/functions

JPO ODE provides the following features and functions to TMC applications:

1. Managing SNMP Devices — over SNMP Protocol, the ODE can ping and assess the health of an existing Roadside Unit to ensure the system is up and running. To trigger a specific heartbeat call, the ODE provides two separate interfaces to deploy a message to an RSU.
2. Logging Events — ODE uses Logback logging framework to log application and data events.
3. IEEE 1609.2 Compliance — TBD
4. SCMS Certificate Management — The ODE will interface with the SCMS through the method defined in the SCMS Wiki (https://wiki.campllc.org/display/SCP/SCMS+CV+Pilots+Documentation).
5. Inbound BSM Distribution — ODE accepts Inbound BSMs via File Copy Data Deposit mechanism. The ODE propagates BSM data to applications via a subscription service provided by Kafka messaging hub. The ODE offers two Kafka BSM subscription formats, JSON and serialized Java objects (also referred to as POJO). ODE uses Kryo serializer for serializing POJOs before publishing.
6. Inbound Sensor Log Data Distribution — ODE accepts weather sensor logs and makes them available via a Kafka stream. The ODE offers two Kafka BSM subscription formats, JSON and serialized Java objects (also referred to as POJO). ODE uses Kryo serializer for serializing POJOs before publishing.
7. Inbound Event Log Distribution – ODE accepts event logs and makes them available via a Kafka stream. The ODE offers two Kafka BSM subscription formats, JSON and serialized Java objects (also referred to as POJO). ODE uses Kryo serializer for serializing POJOs before publishing. The ODE will parse and retain data from the log file name and additional fields within log (like time from BSM)
8. Outbound TIM Broadcast — ODE accepts TIM messages and other metadata parameters for broadcasting TIM messages via the REST API interface. The ODE accepts data elements in JSON which are then sent via SNMP to an array of Roadside Units (RSUs) which are also specified in that same JSON string. Outbound TIM broadcasts may also be posted to the SDX for distribution through Satellite to OBUs. Deposited TIMs shall be compliant with J3067 section 3.5.8 standards for TIM definition and the TIM format is defined in J2735 section 5.16, TIM contents are defined in table 7-2 of the ICD document.
9. Inbound TIM/DN Distribution — Inbound TIMs (including distress notifications) will be verified through the SCMS, parsed, and provided as JSON and POJO objects in a Kafka stream as soon as they are received by the ODE (time not to exceed 5 minutes).
10. Data Validation — Basic data validation will be added to the ODE REST functionality for creating TIM messages. Basic validation will initially include data type validation and bounds detection.
11. Data Sanitization — Sanitization is performed based on geographic region, speed, and is configurable to remove given fields from received BSM and TIM data. All sanitized data is provided in a Kafka stream and can be setup to directly deposit to an Amazon S3 bucket for the RDE input.
12. Location and Time Services – The ODE will use standard location and time services with outgoing TIM messages and for any instances where LTS services are required.

3.1.4.1.4.2 Diagram of process flow/algorithms between major modules/functions

See Figure 3-13 for a diagram of the process flow between application layers within the ODE.

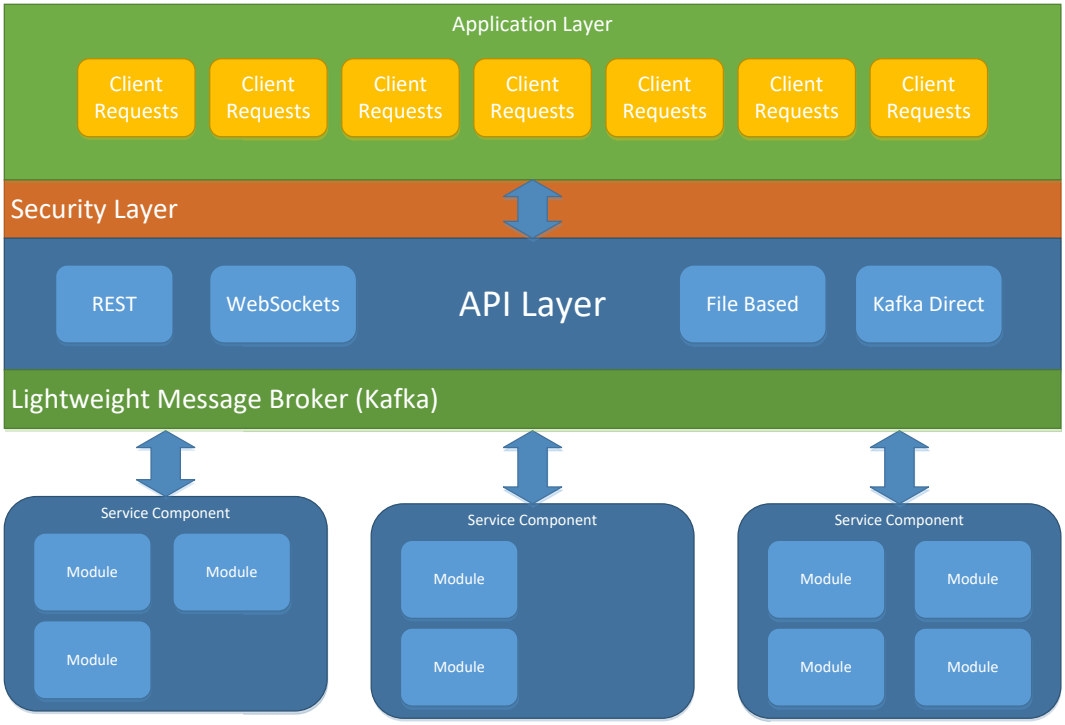


Figure 3-13. Centralized messaging topology.
Source: USDOT

3.1.4.1.4.3 Descriptions of process flow/algorithms between major modules/functions

For JPO ODE, a *centralized messaging* topology is being envisioned. This topology uses a lightweight centralized message broker (e.g., Kafka). The lightweight message broker found in this topology does not perform any orchestration, transformation, or complex routing; rather, it is just a lightweight transport to access remote service components. The single point of failure and architectural bottleneck issues usually associated with a centralized broker are addressed through broker clustering. The lightweight message broker found in this topology does not perform any orchestration, transformation, or complex routing; rather, it is just a lightweight transport to access remote service components. The single point of failure and architectural bottleneck issues usually associated with a centralized broker are addressed through broker clustering.

Broker clustering refers to the ability of the message broker to scale horizontally and proportionally with the demands of the connected applications and services, ensuring the reliability of the messages rerouted through the broker. If needed, the message brokers can be distributed across multiple nodes to continue to provide services despite outages of one or more nodes and be able to scale in and out automatically as the data volume scales down and up.

If broker clustering is utilized, however, messages will not be guaranteed to be delivered in the same order as they arrived. In that case another caching service or data store will be responsible for re-ordering the messages based on a sequence key.

Apache Kafka (Kafka) is the messaging framework that will be incorporated in the JPO ODE implementation. Figure 3-14 below highlights the concepts used in the Kafka implementation. Kafka has three key capabilities:

1. Publish/Subscribe: It lets you publish and subscribe to streams of records. In this respect it is similar to a message queue or enterprise messaging system.

2. Persistent and Reliable: It lets you store streams of records in a fault-tolerant way.
3. Stream Processing: It lets you process streams of records as they occur.

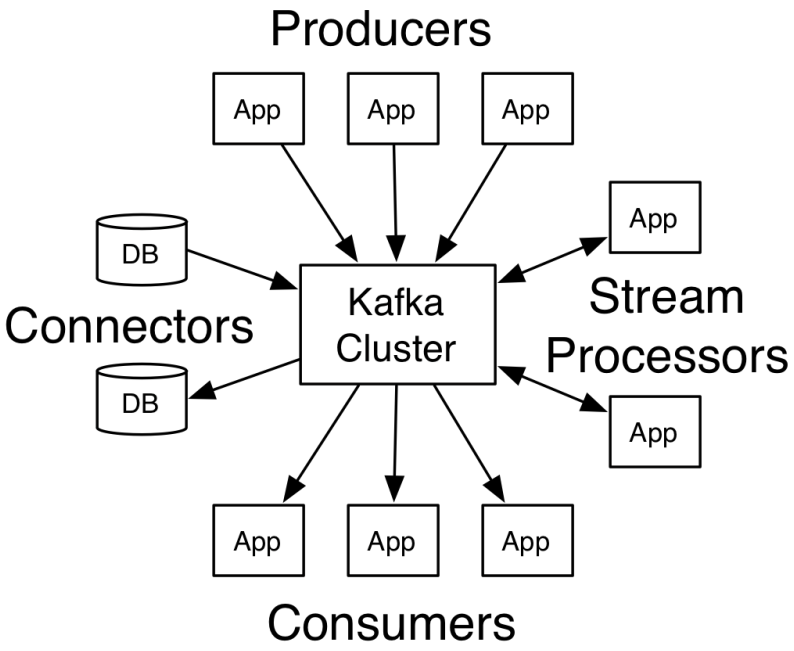


Figure 3-14. Kafka Concepts.
Source: USDOT

In order to connect to Kafka, there are 4 core API's that systems can use to communicate with the broker.

- The Producer API allows an application to publish a stream of records to one or more Kafka topics.
- The Consumer API allows an application to subscribe to one or more topics and receive a stream of records. Multiple applications can subscribe to a single topic and process messages in parallel via Kafka's consumer group handling.
- The Streams API allows an application to act as a *stream processor*, consuming an input stream from one or more topics and producing an output stream to one or more output topics, effectively transforming the input streams to output streams.
- The Connector API allows building and running reusable producers or consumers that connect Kafka topics to existing applications or data systems. For example, a connector to a relational database might capture every change to a table.

The ODE utilizes these Kafka concepts and the framework has been designed as depicted in Figure 3-15.

- The input services represent the publisher in the system.
- The BSM decoder service consumes an encoded topic and publishes a decoded topic.
- Applications such as the management console and gateways consume the output decoded messages.

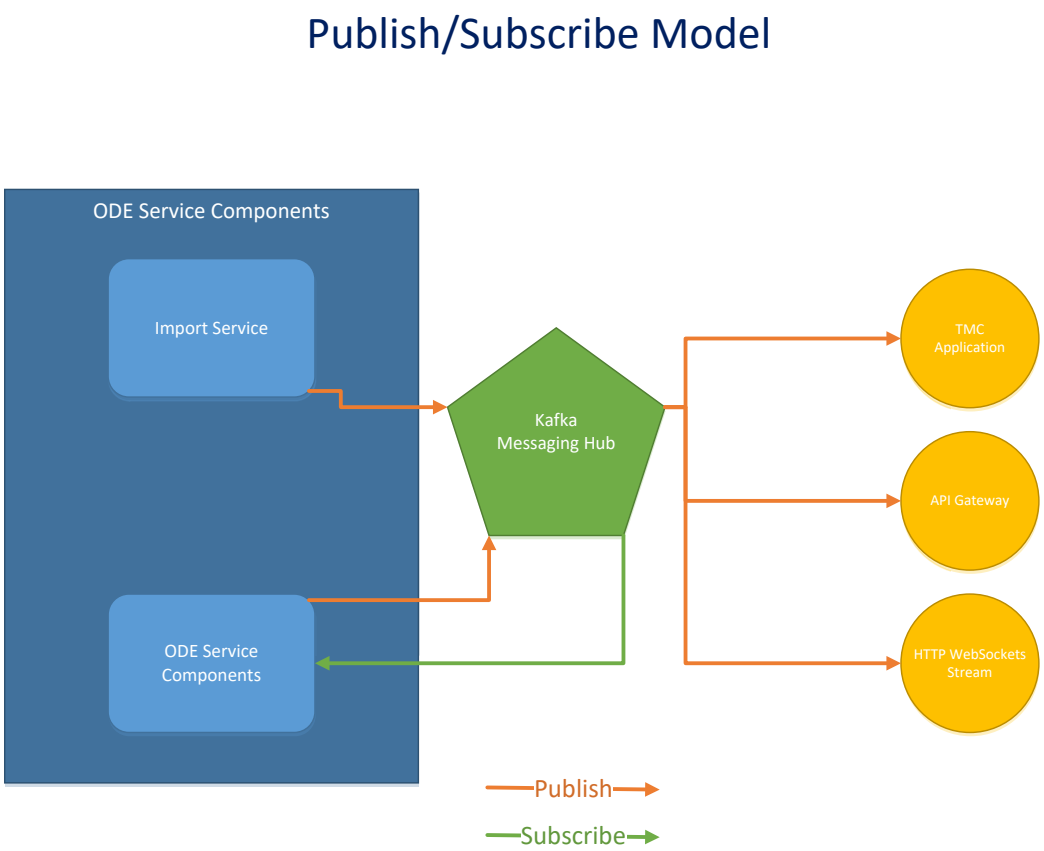


Figure 3-15. Kafka Publish/Subscribe Model.
Source: USDOT

3.1.4.1.5 Application Data Tables

The ODE does not directly access any database, it is meant as a data broker and facilitator of data within the CV environment.

3.1.4.1.5.1 Input data description tables

A full list of all parameters used for data input to the ODE system can be found in the ODE User Guide at: https://github.com/usdot-jpo-ode/jpo-ode/blob/develop/docs/JPO_ODE_UserGuide.docx.

3.1.4.1.5.2 Output data description tables

A full list of all parameters used for data output of the ODE system can be found in the ODE User Guide at: https://github.com/usdot-jpo-ode/jpo-ode/blob/develop/docs/JPO_ODE_UserGuide.docx.

The Privacy Protection Module defines all parameters used for sanitization of data and can be found in Section 7.8 of the ODE User Guide referenced above.

3.1.4.1.5.3 Data/database storage description diagrams and tables

The ODE does not have any data storage features.

3.1.4.1.6 Application User Interface(s)

This application has no user interface. The interface is strictly meant as an application program interface (API) for the CV system.

3.1.4.1.6.1 Description of Operations/Driver Interface with illustrations

This application has no driver interface.

3.1.4.1.6.2 Description of Maintenance User Interface with illustrations

This application has no maintenance user interface.

3.1.4.1.7 Requirements Traceability

The following requirements are applicable to this component and met by this design:

- SDC-REQ-1 Data Provided to the SDC **The SDC will not be supported in Phase 4.**
- RDE-REQ-1 Data Provided to the RDE **The RDE will not be supported in Phase 4.**
- ODE-REQ-1 Collect CV Data
- ODE-REQ-2 Data Processing
- ODE-REQ-3 Distribute Data
- ODE-REQ-3.1 Distribute TIM to RSU
- ODE-REQ-3.2 Distribute TIM to SDW
- ODE-REQ-3.3 Distribute to Pikalert **Pikalert will not be part of Phase 4.**
- ODE-REQ-3.4 Distribute to Data Warehouse
- ODE-REQ-3.4.1 Distribute to Data Warehouse-BSM
- ODE-REQ-3.4.2 Distribute to Data Warehouse-DNM **Phase 4 will not include distress notification messages.**
- ODE-REQ-3.4.3 Distribute to Data Warehouse-ES **Environmental sensor data will not be collected in Phase 4**.
- ODE-REQ-3.5 Distribute to Data Broker **Distress information will not be part of Phase 4.**
- ODE-REQ-3.6 Distribute to SDC **The SDC will not be part of Phase 4.**
- ODE-REQ-3.7 Distribute to RDE **The RDE will not be part of Phase 4.**
- ODE-REQ-4 SCMS **Phase 4 will use the ISS SCMS**
- ODE-REQ-5 LTS
- ODE-REQ-6 OBU Update. **The ODE will not be part of OTA firmware updates in Phase 4.**
- ODE-REQ-7 Receive from Data Broker
- VS-REQ-31 IVAA WZW
- SDX-REQ-1 Data Provided to the SD X
- WCVS-REQ-1.3 Collect Distress Messages **Distress Messages will not be part of Phase 4.**
- WCVS-REQ-2 Validate Data
- WCVS-REQ-8 Internal Brokerage **PA-REQ-2 and PA-REQ-4 are not supported with Phase 4.**
- WCVS-REQ-9 Create TIM
- WCVS-REQ-10 Distribute TIM
- WCVS-REQ-10.1 Distribute TIM to VS
- WCVS-REQ-10.2 Distribute TIM to SDW
- HSM-REQ-1 Receive from ODE **Not in Phase 4**
- HSM-REQ-2 Share with ODE **Not in Phase 4**

3.1.4.1.8 ICD Traceability

The following interfaces are applicable to this component and its design. A reference to the location of the interface within the ICD is also provided.

Interface	Action within Interface	Section No.
Network Time Service (NTP) <-> ODE	ODE Synchronizes Time using NTP	5.12.1
HSM <-> ODE	ODE Uses HSM to sign TIMs	5.15.1
USDOT Prototype SCMS <-> HSM	ODE Device Enrollment (Bootstrapping)	5.43.1
	ODE Application Certificate Provisioning	5.43.2
	ODE Security Policy and Networking Information	5.43.3
	ODE Misbehavior Reporting	5.43.4
	ODE Security Credential Revocations	5.43.5
ODE <-> OBU	OBU Copies Log File to ODE	5.16.1
	ODE Updates OBU Firmware OTA	5.16.2
ODE <-> WY Maintenance Vehicle (OBU)	OBU Copies Weather Environmental Data to ODE	5.17.1
ODE <-> RSU	RSU Sends Traffic Situation Data to the ODE	5.18.1
	ODE Sends TIMs to RSUs	5.18.2
ODE <-> Pikalert	ODE Sends Vehicle Environmental Data to Pikalert System	5.19.1
	ODE Sends Environmental Situation Data to Pikalert System	5.19.2
ODE <-> WYDOT Data Warehouse	ODE Sends Traffic Situation Data to WYDOT DW	5.20.1
ODE <-> WYDOT Data Broker	ODE Sends DNM to WYDOT DB	5.21.1
	WYDOT Data Broker sends TIMs to ODE	5.21.2
ODE <-> Situational Data Warehouse (SDW)	ODE Transmits TIM to SDW	5.22.1

3.1.4.2 TMC Data Brokerage (WTIDB)

The following sections describe the design of the TMC Data Broker service application.

3.1.4.2.1 Function of the Application

As the WYDOT existing system data broker, this system already receives, transmits and archives many data feeds. With the addition of the connected vehicle pilot, the WTIDB will support new data exports to keep the CVOP and supply updated information to the ODE for TIMs. The details for these data processing systems are defined below.

3.1.4.2.1.1 Functions/Services Brief description

Functions/Services provided by the WTIDB Service shall include handling 511 app updates for parking areas, interfacing with the ODE, and allowing various TMC applications to push/pull data from the CV environment including the RCRS, IC, TRAC, WTI, CVOP, and CA applications.

3.1.4.2.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway
This application is not directly involved with vehicle communications on the highway.

3.1.4.2.1.3 Input Data/Message Flows
Input Data/Message flows to the WTIDB application for CV integration shall consist of the following:

- Construction Information from the ConAdmin application
- Distress Notifications from the ODE application
- Posted speeds, restrictions, and closures from the Wyoming Traveler Information application
- Incident information from the Incident Console application
- Snow plow operator weather, road condition and VSL recommendations from the RCRS
- Other road condition reports to include Wyoming's 10 codes (see Sys Requirements for definition)
- Truck Parking availability information from the WYDOT 511 app
- Current TIM information from the DW

All input flows except the ODE input shall consist of applications calling the Data Broker via a REST service hosted within the WYDOT server environment. The ODE input flows will consist of the Data Broker monitoring a Kafka feed provided by the ODE. Please note that the messages to the DB from the RCRS application are an existing system that will not change. Data from the RCRS is only used by operators as part of the decision process to push CV information messages out. All RCRS data received will contain a timestamp and location information associated with the data.

3.1.4.2.1.4 Output Data/Message Flows
Output Data/Messages flows from the WTIDB application for CV integration shall consist of the following:

- TIM messages to the ODE application
- Emergency Notifications and Road Weather alerts to TRAC system
- Road Weather Advisories and Alerts to WTI
- TIM Messages to the DW
- Report malfunctioning RSU to WYDOT ITS

3.1.4.2.2 Developer & version number
The Developers working with the Data Broker application include Ivan Yourshaw and the Trihydro software development team.

3.1.4.2.3 Application Message and Alerts Descriptions
The following sections describe the application messages and alerts this application may generate. Please note that this application is a service so has no direct contact with any participant while traveling on the road.

3.1.4.2.3.1 Descriptions and illustrations of messages and alerts issued by application
Table 3-9 describes all messages and alerts that may be issued by the WTIDB application related to the CV features.

Table 3-9 Descriptions of messages and alerts issued by WTIDB.

Message or Alert	Communication Method	Description
ODE Inaccessible	Http Response	Error: "Failed accessing ODE endpoint"
TIM Generation Error	Http Response	Error: "Failed to generate TIM message"
Database Access Error	Http Response	Error: "Database error encountered"
Road Weather Alert	Http Request	This alert will be raised to the TRAC system with details from Pikalert
Truck Parking Availability Update	Http Request	Message notifying TRAC system of a new crowd sourced parking availability submission

3.1.4.2.3.2 Describe algorithm to determine when messages and alerts are issued

The algorithms used to determine messages and alerts are shown below.

ODE Inaccessible: A request is sent to the ODE REST service and a timeout response is received from the request.

TIM Generation Error: A request is sent to the ODE REST service to create a new TIM message. In a case where the ODE responds but sends an error message instead of a success the error is raised and returned as the response. The ODE error is also provided in the response.

Database Access Error: Access to the data warehouse is either unsuccessful or an operation on the database was unsuccessful. The database error is returned along with the generic error message.

Truck Parking Availability Update: This message is generated when a 511 app user submits a truck parking availability update. The message is received via the Data Broker REST service and a new message is then created and pushed to the TMC TRAC system for an Operator to handle. Please note that the default parking availability is "Spaces available". The default parking availability will be reverted to after 2 hours of no submitted information for the truck parking area. Upon parking submission this service shall call the GenerateTruckParkingTIM endpoint of the TIM_Generator service. This call shall specify the TIM to be broadcast from nearby RSUs and through satellite delivery for a period of 2 hours. The call to generate the TIM shall lake less than 5 seconds to complete.

3.1.4.2.3.3 Summary tables of criteria for issuing messages and alerts

Table 3-10 displays a list of messages and alerts that may be raised by the Data Broker application given the criteria is met. The table describes the message as well as corresponding criteria.

Table 3-10. List of criteria for issuing messages and alerts

Message or Alert	Issue Criteria
ODE Inaccessible	• Communication failure when calling the ODE service
TIM Generation Error	• ODE returns an error when attempting to generate a TIM message
Database Access Error	• Data Warehouse returns an error • Data Warehouse connection fails
Truck Parking Availability Update	• 511 app user submits a new parking availability update for a given (specified) parking area.

Message or Alert	Issue Criteria
	• Availability options will include the following: Spaces available, only a few spaces available, Full parking lot • User submissions will be timestamped with a UTC time of submission and stored in an Oracle database

3.1.4.2.4 Application Design Description

The Data Broker application shall be updated in order to integrate with the new CV data and features. The Data Broker will be the primary communication point between the TMC web/desktop applications, data warehouse, and the ODE. The Data Broker will extend its current REST interface to include functions allowing users to push/pull data meant for the road condition alerts, ODE TIM message distribution, and crowd sourced truck parking information.

The Data Broker is also responsible for storing information related to all Active TIMs for each RSU in the WYDOT system. This allows the Data Broker to update existing TIMs as well as remove TIMs that are no longer needed or relevant. These processes are broken up into adding new TIMs, updating existing TIMs, and removing existing TIMs, the logic for each is as follows:

Adding a new TIM:

1. Data Broker receives a request to create a new TIM for a given set of RSUs.
2. Data Broker adds TIM through the RSU and retrieves the index of the added TIM.
3. Data Broker records the TIM in the local Data Warehouse.

Updating an Existing TIM:

1. Data Broker receives a request to update an existing TIM for a given set of RSUs.
2. Data Broker retrieves the TIM information from the local Data Warehouse and sends a request to the ODE to update the TIM on the given set of RSUs.
3. Data Broker records the updated TIM information in the local Data Warehouse.

Removing an Existing TIM:

1. Data Broker receives a request to remove an existing TIM for a given set of RSUs.
2. Data Broker retrieves the TIM information from the local Data Warehouse and sends a request to the ODE to delete the TIM on the given set of RSUs.
3. Data Broker removes the TIM information from the active TIMs in the local Data Warehouse.

Figure 3-16 below shows interactions with the different applications that the Data Broker shall perform.

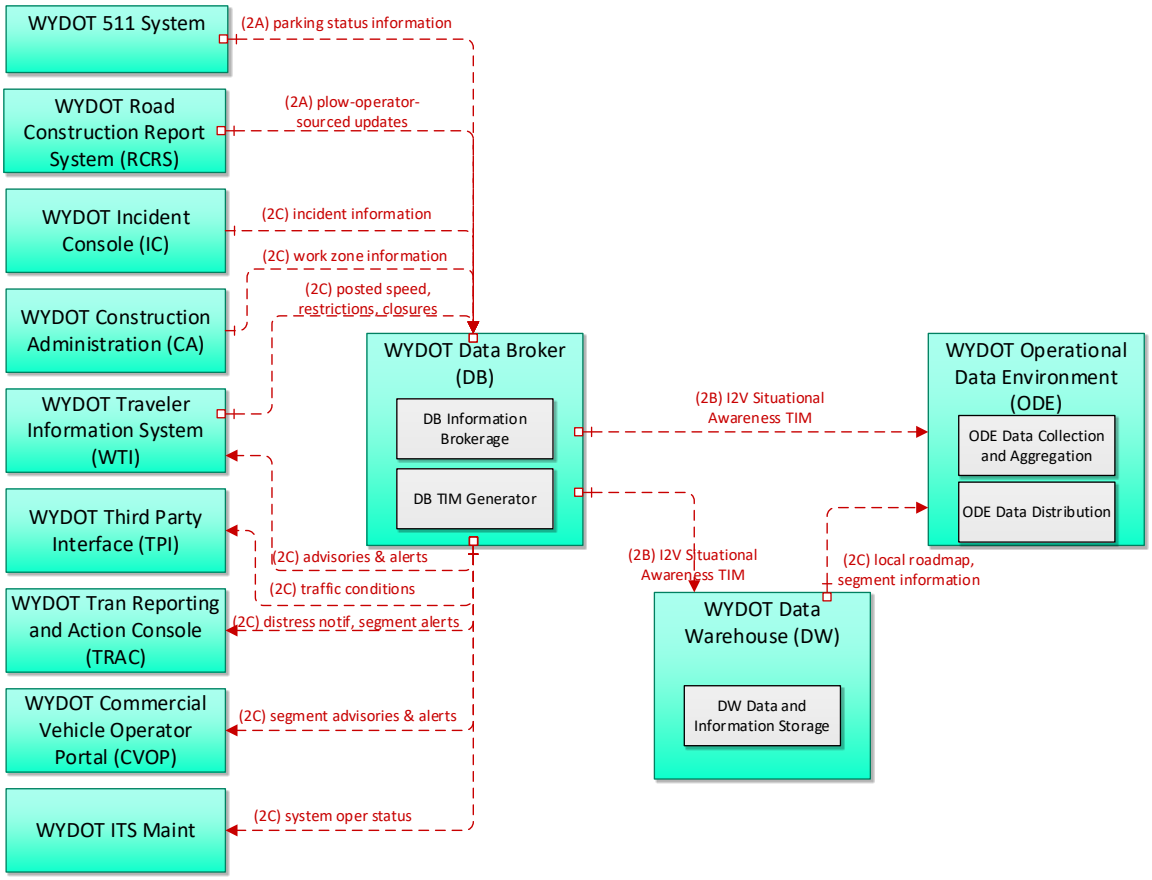


Figure 3-16 Data Broker CV Integration.
Source: WYDOT

All interactions shall be performed over a RESTful service interface except for the Emergency notification communication between the ODE and the Data Broker application. In the case of the emergency notification communication that feed will be performed as the Data Broker application monitors a Kafka communication channel.

3.1.4.2.4.1 Schematic of major modules/functions

See Figure 3-16 for the major modules of the Data Broker application which include a TIM_Generator and an Information Brokerage module.

3.1.4.2.4.2 Description of modules/functions

Descriptions for the major modules/functions are listed below.

Information Brokerage Module: This module will be responsible for distributing information amongst the different applications including distributing situational awareness information, alerts and advisories, construction information, Pikalert weather alerts and forecasts, and road closure information. A list of functions and descriptions can be found in Table 3-11 below.

Table 3-11. Information Brokerage Functions

Function	Description
GetRoadWeatherAdvisories	Retrieves road weather advisory information. Optional filter criteria allow the caller to retrieve information only for a specific road segment(s).
GetTrafficConditions	Retrieves traffic condition information. Optional filter criteria allow the caller to retrieve information only for a specific road segment(s).
GetDistressNotifications	Retrieves Distress Notifications currently active within the system. Optional filter criteria allow the caller to retrieve information only for a specific road segment(s).
GetSystemOperationStatus	Retrieves the current CV system operating status for all RSUs
GetTruckParkingInformation	Retrieves current crowd sourced truck parking information.
GetWorkZoneInformation	Retrieves current work zone information. Optional filter criteria allow the caller to retrieve information only for a specific road segment(s).

TIM_Generator Module: This module is provided to allow TMC applications to call the Data Broker and send out TIM information messages for broadcast at specified RSU locations. A list of functions can be found in Table 3-12 below. RSUs included in the TIM will be calculated through the starting and end mile markers of the area affected by the TIM message. Based on a configurable buffer for the area of where RSUs will distribute given TIMs a geographic query is run to determine the RSUs that will be sent the TIM message for distribution. Outgoing TIM messages will be sent to the RSU immediately and will be available for broadcast purposes on the RSUs within 5 minutes of being sent by the Data Broker application. All outgoing TIM messages are also recorded in the Data Warehouse. Additionally, all TIM messages will also be sent to the SDX for distribution via satellite.

Table 3-12. TIM_Generator Functions

Function	Description
GenerateWorkZoneWarningTIM	This function takes construction information provided by the caller and formats a valid Work Zone Warning object then calls the ODE to distribute the TIM to the specified RSUs.
GenerateVSLTIM	This function accepts VSL information provided by the caller and formats a valid VSL TIM call to the ODE for TIM distribution to specified RSUs.
GenerateSpotWeatherTIM	This function accepts Spot Weather warning information provided by the caller and formats a valid Spot Weather Impact Warning object then calls the ODE to distribute the TIM to the specified RSUs.
GenerateRoadClosureTIM	This function accepts Road Closure information provided by the caller and formats a valid Road Closure object then calls the ODE to distribute the TIM to the specified RSUs. Closure information provided includes closure beginning point, closure end point, closure start time, and potential return to normal time.
GenerateTruckParkingTIM	This function accepts Truck Parking information provided by the caller and formats a valid Truck Parking object then calls the ODE to distribute the TIM to the specified RSUs.

Function	Description
GenerateRoadWeatherAdvisoryTIM	This function accepts Road Weather Advisory information provided by the caller and formats a valid Road Weather Advisory object then calls the ODE to distribute the TIM to the specified RSUs.
GenerateVehicleRestrictionsTIM	This function accepts Vehicle Restriction information including height and weight restrictions, restriction starting point, restriction ending point, restriction start time, and potential return to normal time.
GenerateDMSAdvisoryTIM	This function accepts generic Dynamic Message Sign (DMS) information provided by the caller and formats a valid DMS object then calls the ODE to distribute the TIM to specified RSUs.
GenerateTIM	This function accepts generic TIM information and passes it along to the ODE to generate TIM messages that are outside of the common TIM messages listed above.
GenerateIncidentTIM	This function accepts Incident information and generates a valid TIM based on the location of the incident, the direction of travel that is affected, and the type of incident (hazardous spill, accident, etc)

Event Logging Module: This module continuously monitors the ODE for all incoming event logs and pushes all event log information to the Data Warehouse. For details on the event logs and what they contain please see the corresponding OBU and RSU Support Services applications. All weather event logs are pushed to the Data Warehouse. Event logs are written to the database as soon as they are received from the ODE (maximum of 5-minute processing time).

3.1.4.2.4.3 Diagram of process flow/algorithms between major modules/functions

Figure 3-17 shows the process flow between the different applications for the Data Broker Information Brokerage module.

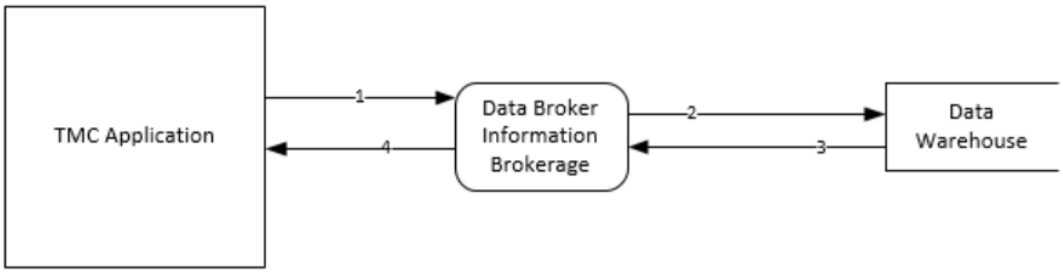


Figure 3-17 Information Brokerage module process flow.
Source: WYDOT

Figure 3-18 shows the process flow between the different applications for the Data Broker TIM_Generator module.

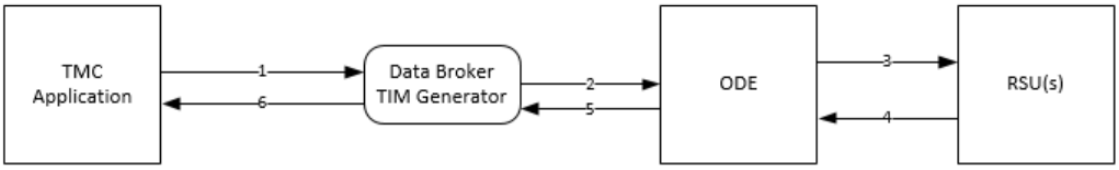


Figure 3-18 Data Broker TIM_Generator process flow.
Source: WYDOT

3.1.4.2.4.4 Descriptions of process flow/algorithms between major modules/functions
Process flows for calls to the Data Broker Information Brokerage module all follow the same pattern as shown in Figure 3-17: 1) Information from the data warehouse is requested from the Information Brokerage module. 2) From here the Information Brokerage module will retrieve requested information from the Data Warehouse. 3) The Data Warehouse retrieves and returns the requested information. 4) The Information Brokerage will then format the data and finally return the requested data to the requesting TMC application. This same pattern is followed for all information requests from the Data Warehouse.

Process flows for calls to the Data Broker TIM_Generator module also follow a similar pattern, show in Figure 3-18: 1) A TMC application requests a TIM be generated and sent to a specified set of RSUs. 2) The TIM_Generator module formats the request and sends it on to the ODE for process and RSU notification. 3) The ODE adds a TIM broadcast to specified RSUs. 4) Success/Fail message is returned from the RSUs to the ODE. 5) The ODE passes along the success/fail message from the RSUs. 6) The TMC application is notified of the success/failure of the TIM message broadcast. Please note that as soon as a TIM is generated it will be available for drivers to view. This process should be sub second processing. Information from the TMC operator determines what information is sent to the ODE for the TIM.

3.1.4.2.5 Application Data Tables
The following sections describe the application data tables related to the Data Broker application.

3.1.4.2.5.1 Input data description tables
Input data for the Data Brokerage application consists of TIM messages from the ODE as well as 511 parking availability information. Parking availability is stored within the existing data schema so no updates will be made for this information. The TIM message receipt as well as outgoing TIM messages will be recorded in a new tablespace within the Oracle database (Figure 3-19).

3.1.4.2.5.2 Output data description tables
Output data from the Data Brokerage application consists of road condition, alerts, advisories, parking availability, and distress notifications data. All of this data is already handled in the current database schema that WYDOT has in place.

3.1.4.2.5.3 Data/database storage description diagrams and tables
Figure 3-19 below shows the new ERD to hold TIM message data (both outbound and inbound Distress Notification data).

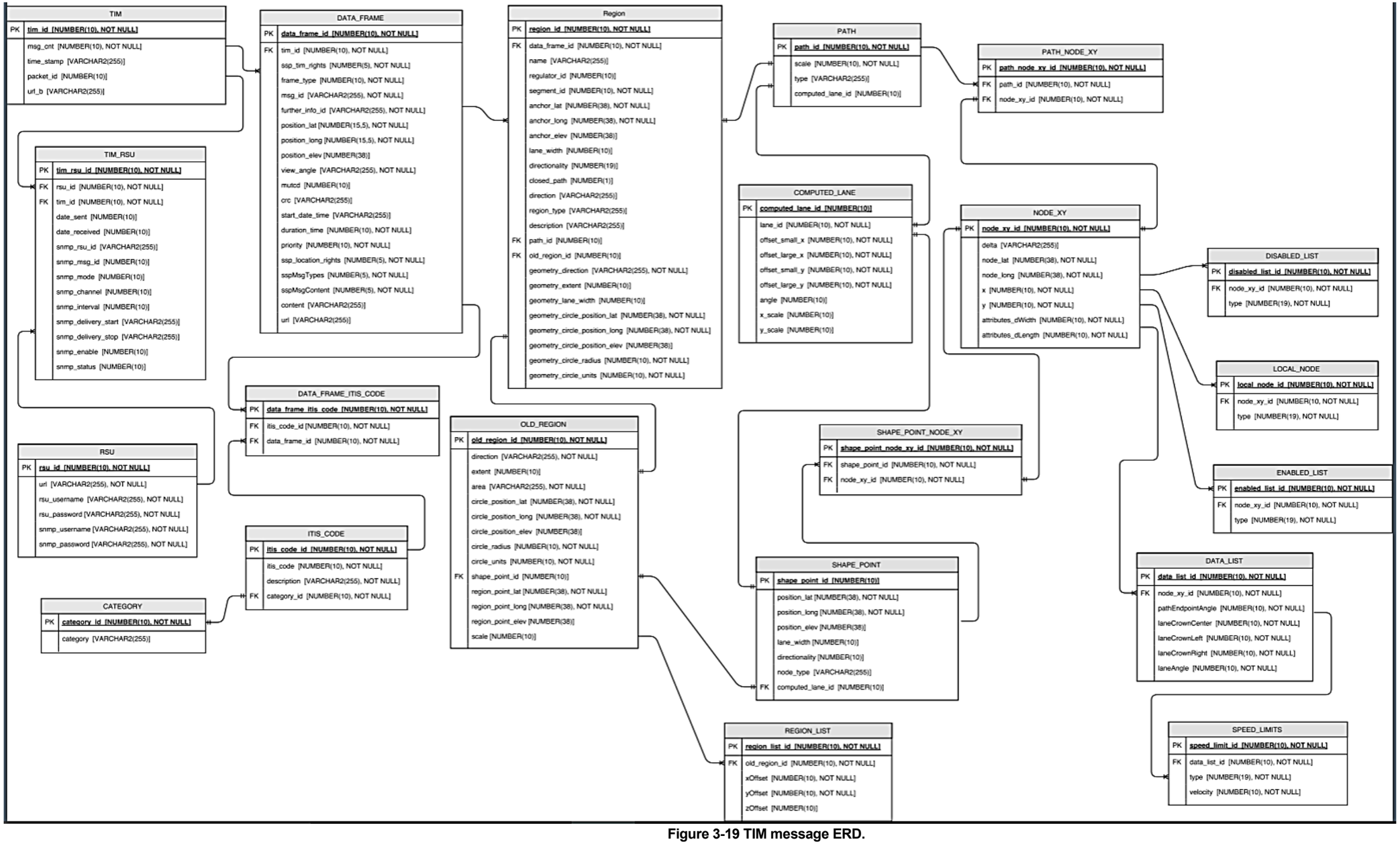


Figure 3-19 TIM message ERD.
Source: WYDOT

3.1.4.2.6 Application User Interface(s)

This application is a REST service and does not contain a User Interface.

3.1.4.2.6.1 Description of Operations/Driver Interface with illustrations

This application contains no driver interface operations.

3.1.4.2.6.2 Description of Maintenance User Interface with illustrations

This application contains no maintenance interface operations.

3.1.4.2.7 Requirements Traceability

The following requirements are applicable to this component and met by this design:

- DB-REQ-1 Receive from External Interfaces
- DB-REQ-2 Distribute to External Interfaces **TPI-REQ-1 is not part of Phase 4.**
- DB-REQ-4 Receive from Pikalert **Pikalert will not be part of Phase 4.**
- DB-REQ-4.1 Receive Alerts and Advisories **Not in Phase 4.**
- DB-REQ-4.2 Receive Forecast **Not in Phase 4.**
- DB-REQ-5 Distribute to ODE
- DB-REQ-6 Receive from ODE **Distress information will not be part of Phase 4.**
- DB-REQ-7 Distribute to Data Warehouse **Distress Notification and Forecast not in Phase 4**
- DB-REQ-8 Receive Data from DW
- DB-REQ-9 Distribute to SDC
- 511-REQ-1 511App Parking Data Collection
- 511-REQ-1.1 Availability
- 511-REQ-1.2 Default
- 511-REQ-1.3 Time
- 511-REQ-1.4 Location
- 511-REQ-1.5 Protocol
- 511-REQ-1.6 Schema
- 511-REQ-2 Timeframe
- TRAC-REQ-1 TRAC Updates **Not part of Phase 4.**
- TRAC-REQ-1.1 Distress Notification **Not part of Phase 4.**
- TRAC-REQ-1.1.1 Transmission Time **Not part of Phase 4.**
- TRAC-REQ-1.2 Segment Alerts **Not part of Phase 4.**
- TRAC-REQ-1.2.1 Transmission Time **Not part of Phase 4.**
- TRAC-REQ-1.2.2 Segment Alerts-Pikalert **Not part of Phase 4.**
- RCRS-REQ-1 RCRS Data Sharing
- RCRS-REQ-1.1 Road Condition
- RCRS-REQ-1.2 Weather
- RCRS-REQ-1.3 Other Road Condition
- RCRS-REQ-1.4 Report Time
- RCRS-REQ-1.5 Location
- RCRS-REQ-1.6 Transmit Time
- WTI-REQ-1 WTI Inputs **Not part of Phase 4.**
- WTI-REQ-1.1 Current Segment Alerts **Not part of Phase 4.**
- WTI-REQ-1.1.1 Transmission Time **Not part of Phase 4.**
- WTI-REQ-1.2 Forecast Segment Alerts **Not part of Phase 4.**

- WTI-REQ-1.2.1 Forecast Time **Not part of Phase 4.**
- WTI-REQ-1.2.2 Forecast Update **Not part of Phase 4.**
- WTI-REQ-2 WTI Outputs
- WTI-REQ-2.1 Posted Speed
- WTI-REQ-2.2 Vehicle Restrictions
- WTI-REQ-2.2.1 Restriction Information
- WTI-REQ-2.2.2 Restriction Start Time
- WTI-REQ-2.3 Posted Messages
- WTI-REQ-2.3.1 Message Information
- WTI-REQ-2.4 Posted Closures
- WTI-REQ-2.4.1 Closure Beginning
- WTI-REQ-2.4.2 Closure End
- WTI-REQ-2.4.3 Closure Start Time
- CVOP-REQ-1 CVOP Inputs
- CVOP-REQ-1.1 Current Segment Alerts
- CVOP-REQ-1.1.1 Transmission Time
- CVOP-REQ-1.2 Forecast Segment Alerts **Not part of Phase 4.**
- CVOP-REQ-1.2.1 Forecast Time **Not part of Phase 4.**
- CVOP-REQ-1.2.2 Forecast Update **Not part of Phase 4.**
- IC-REQ-1 IC Data Sharing
- IC-REQ-2 Protocol
- IC-REQ-3 Schema
- IC-REQ-4 Transmission
- CA-REQ-1 CA Data Sharing
- CA-REQ-2 Protocol
- CA-REQ-3 Schema
- CA-REQ-4 Transmission
- ITSM-REQ-1 WYDOT ITS Alerts
- WCVS-REQ-4.5 Incident Hazard
- WCVS-REQ-4.6 Parking
- WCVS-REQ-7 External Brokerage with WYDOT Interfaces
- WCVS-REQ-7.1 Receive from WYDOT External Interfaces
- WCVS-REQ-7.2 Distribute to WYDOT External Interfaces **TPI-REQ-1 is not supported with Phase 4.**
- WCVS-REQ-8 Internal Brokerage **PA-REQ-2 and PA-REQ-4 are not supported with Phase 4.**
- DW-REQ-2.4 Share Data with DB

3.1.4.2.8 ICD Traceability

The following interfaces are applicable to this component and its design. A reference to the location of the interface within the ICD is also provided.

Interface	Action within Interface	Section No.
ODE <-> WYDOT Data Broker	ODE Sends DNM to WYDOT DB	5.21.1
	WYDOT Data Broker sends TIMs to ODE	5.21.2
Pikalert <-> WYDOT DB	WYDOT DB Retrieves Road Weather Alerts from Pikalert	5.27.1

	WYDOT DB Retrieves Road Weather Forecasts from Pikalert	5.27.2
WYDOT DB <-> WYDOT TRAC	DB Sends Emergency Notification to TRAC	5.28.1
	DB Sends Road Weather Alert from Pikalert to TRAC	5.28.2
WYDOT DB <-> WYDOT CVOP	DB sends segment advisories and alerts to CVOP	5.29.1
	CVOP Manages Road Weather Forecast Data Using DB	5.29.2
WYDOT DB <-> WYDOT ITS Maintenance	DB reports malfunctioning RSU to WYDOT ITS	5.30.1
WYDOT DB <-> WYDOT Incident Console IC	WYDOT Incident to the WYDOT DB	5.31.1
WYDOT DB <-> WYDOT Construction Administration	WYDOT CA sends new construction project to the DB	5.32.1
WYDOT DB <-> WYDOT RCRS	Plow-Operator Sourced Road Condition and VSL Recommendation Updates to WYDOT Data Broker	5.33.1
WYDOT DB <-> WYDOT WTI	WYDOT DB Sends Road Weather Advisories and Alerts to WYDOT Traveler Information System	5.34.1
	WTI sends posted speeds, restrictions and closures to WYDOT DB	5.34.2
WYDOT Data Broker <-> WYDOT Data Warehouse	WYDOT DB Archives TIMs to the WYDOT DW	5.35.1

3.1.4.3 Service Monitor Device Management

The sections below describe the application design for the Service Monitor Device Management application.

3.1.4.3.1 Function of the Application

This application provides the functions necessary to manage devices, including network management, operational status monitoring, and application performance monitoring. Devices managed will include RSU's and OBU's.

3.1.4.3.1.1 Functions/Services Brief description

This application shall provide the following functions/services:

- Ability to retrieve the current status of all RSUs.
- Ability to update an RSU.
- Ability to update a given OBU.
- Ability to monitor RSUs and send notifications when an issue is found with one.
- Ability to monitor the ODE for performance measures (WCVS-REQ-16.2).
- Ability to update OBUs over the air.
- Ability to monitor availability of Data Storage.

3.1.4.3.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway.

Figure 3-20 shows how over the air updates would be handled from RSUs to OBUs.

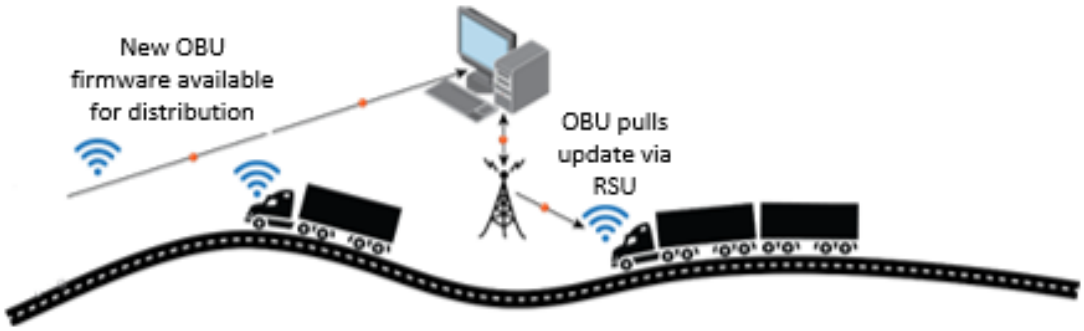


Figure 3-20. Over the air updates from RSUs to OBUs.
Source: WYDOT

3.1.4.3.2 Input Data/Message Flows

Input data for the Service Monitor Device Management service include various management requests listed below.

- Retrieve RSUs status
- Retrieve ODE performance status
- Retrieve ODE Status
- Update RSU
- Update OBU

3.1.4.3.3 Output Data/Message Flows

Output data for the Service Monitor Device Management service includes the following message flows:

- Current RSUs status
- Current ODE performance
- Success/Fail of RSU update
- Success/Fail of OBU update
- Notification of RSU network issue

The data flows can be seen in Figure 3-21.

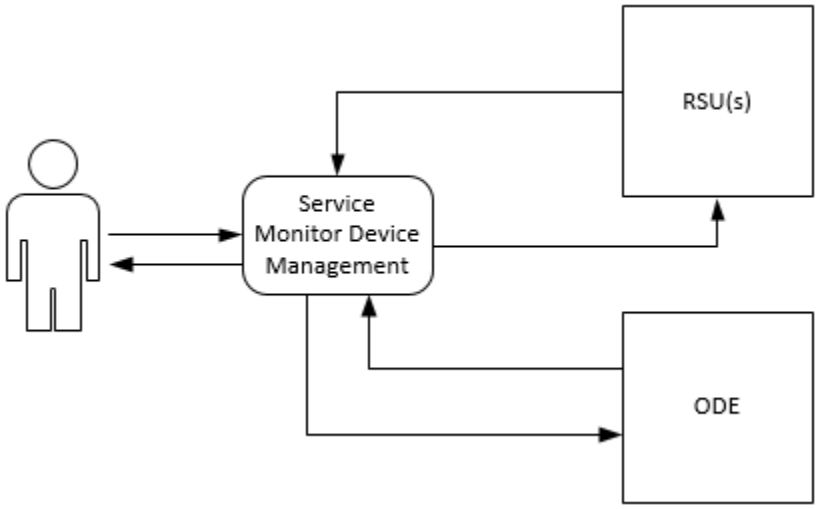


Figure 3-21. Service Monitor Device Management data flows.
Source: WYDOT

3.1.4.3.4 Developer & version number
Developers responsible for the Service Monitor Device Management service include the Trihydro team.

3.1.4.3.5 Application Message and Alerts Descriptions
The following sections describe the application messages and alerts this application may generate. Please note that this application is a service so has no direct contact with any participant while traveling on the road.

3.1.4.3.5.1 Descriptions and illustrations of messages and alerts issued by application
Table 3-13 describes the messages and alerts returned from the Service Monitor Device Management service.

Table 3-13. Service Monitor Device Management message and alerts

Message or Alert	Communication Method	Description
ODE Inaccessible	Http Response	Error: "Failed accessing ODE endpoint"
RSU Update Error	Http Response	Error: "Failed updating RSU" – additional details will be provided of the exact error received from the RSU
Authorization Exception	Http Response	Status Code 403 Authorization failure
Disk Usage Error	Http Response	Error: "Disk space under 10% availability"

3.1.4.3.5.2 Describe algorithm to determine when messages and alerts are issued
The algorithms used to determine messages and alerts are shown below.

ODE Inaccessible: A request is sent to the ODE REST service and a timeout response is received from the request.

RSU Update Error: A request is sent to update an RSU. A python script is run as a background process to update the RSU given the latest version of the firmware available. An error response from the python script generates an update error and the python response as well as the output from the script is returned to the caller.

Authorization Exception: The Service Monitor Device Management service requires a valid access token for each request to the service. An authenticated user is given an access token that is valid for a time period. That token must be included in every request made by that user. If a request is made to the web service without an access token or with an expired access token, then an authorization exception is generated. This error is communicated to the user with a specific error status and error text in the http response header returned from a user information request.

Disk Usage Error: An IPMonitor function setup to monitor the disk usage for the ODE and database servers and send notifications when disk availability falls below 10%. Monitored data is stored in the database.

3.1.4.3.6 Summary tables of criteria for issuing messages and alerts

Table 3-14 displays a list of messages and alerts that may be raised by the Service Monitor Device Management application given the criteria is met. The table describes the message as well as corresponding criteria.

Table 3-14. List of criteria for issuing messages and alerts

Message or Alert	Issue Criteria
ODE Inaccessible	Communication failure when calling the ODE service
RSU Update Error	Python update script generates error when attempting to update the RSU
AuthorizationException	Invalid or missing id token in an http request

3.1.4.3.7 Application Design Description

The following sections describe the design for the Service Monitor Device Management REST service.

3.1.4.3.8 Description of modules/functions

Service Monitor Device Management REST Service: This service shall be built using the Spring REST service framework. The Service functions are described in Table 3-15. In addition to the functions listed below the service will also continuously monitor the status of RSU's and notify users when an RSU network issue arises.

Table 3-15. Service Monitor Device Management REST functions

Function Name	Description
GetRSUStatus	Retrieves the status of all RSUs currently in the Wyoming system and returns the status results as an array of RSU status objects.
GetODEPerformanceStatus	Retrieves the current status and performance metrics of the ODE system by running a series of tests on the ODE to measure current throughput and response time. Also returns the current

Function Name	Description
	ODE status (up or down). Additionally, this method also checks the message input queue for the ODE and returns the status of the input queue as part of the result. If the ODE contains messages over 5 minutes old then a failed result is returned as part of the result.
UpdateRSU	Attempts to Update an RSU to a given version of firmware. This function kicks off a python script that will update the RSU. Any errors encountered are returned in the response to the user.
GetSDXStatus	Retrieves the current status and space available within the Trihydro SDX.

3.1.4.3.8.1 Diagram of process flow/algorithms between major modules/functions
Figure 3-21 shows the process flow for the major modules/functions within the Service Monitor Device Management REST service.

3.1.4.3.8.2 Descriptions of process flow/algorithms between major modules/functions
The process flows between major modules/functions are defined below.

Service Monitor Device Management REST Service and RSU Update Script: The Service Monitor Device Management service will call the python script with RSU configuration parameters as well as an update version. The python script will be responsible for updating the RSU and returning a result of the update back to the Java REST service.

Please note that now it is envisioned that the RSU and OBU updates/configuration are different enough to warrant separate Python scripts. If it is possible to combine them into 1 script in order to maximize code reuse and minimize maintenance of multiple scripts, then the two scripts will be consolidated into one and a parameter will be added to determine the type of update to be done. The overall process flow will remain the same.

3.1.4.3.9 Application Data Tables
The following sections describe the data input and output for the different functions within the service.

3.1.4.3.9.1 Input data description tables
Table 3-16 describes the input parameters for the function calls to the rest service.

Table 3-16. Function input parameters

Function Name	Parameter	Type	Description
GetRSUStatus	RSU_IPs (optional)	String [ ]	The list of RSU IP addresses to retrieve the status of. If this parameter is null then the status of all RSUs are retrieved.
GetODEPerformanceStatus	ODE_IP	String	The IP address to the ODE to retrieve metrics for.
UpdateRSU	RSU_IPs	String [ ]	The list of RSU IP addresses to update.
UpdateRSU	Version	String	The version number of the firmware to upgrade the RSUs to

3.1.4.3.9.2 Output data description tables

Table 3-17 describes the output parameters for the function calls from the REST service.

Table 3-17. Function output parameters

Function Name	Parameter	Type	Description
GetRSUStatus	Success	Boolean	Returns true if the function succeeded otherwise false.
GetRSUStatus	Error	String	The Error Message is populated with the error encountered if the success is false. The string is empty if no error was encountered.
GetRSUStatus	Status	RSU_Status [ ]	The list of RSU_Status Objects. The RSU_Status object is defined as follows: • **RSU_ID** – integer (unique ID for the RSU) • **RSU_IP** – string (IP address for the RSU) • **Status** – Enumeration *Available* – can ping/SSH *Ping* – can ping but SSH fails *Unavailable* – unable to ping • **Longitude** – Java.Math.BigDecimal • **Latitude** - Java.Math.BigDecimal • **Elevation** - Java.Math.BigDecimal
GetODEPerformanceStatus	Success	Boolean	Returns true if the function succeeded otherwise false.
GetODEPerformanceStatus	Error	String	The Error Message is populated with the error encountered if the success is false. The string is empty if no error was encountered.
GetODEPerformanceStatus	Status	ODE_Status	The ODE_Status object is defined as follows: • **PingTime** – double (Current Ping time for the ODE (in milliseconds)) • **BSMProcessTime** – double (Current time for the ODE to process a BSM and make it available to the Kafka feed (in milliseconds)) • **TIMProcessTime** - double (Current time for the ODE to process a TIM and distribute it to a given RSU (in milliseconds))
UpdateRSU	Success	Boolean	Returns true if the function succeeded otherwise false.
UpdateRSU	Error	String	The Error Message is populated with the error encountered if the success is false. The string is empty if no error was encountered.

3.1.4.3.9.3 Data/database storage description diagrams and tables

Figure 3-22 shows the ERD for the Service Monitor Device Management REST service.

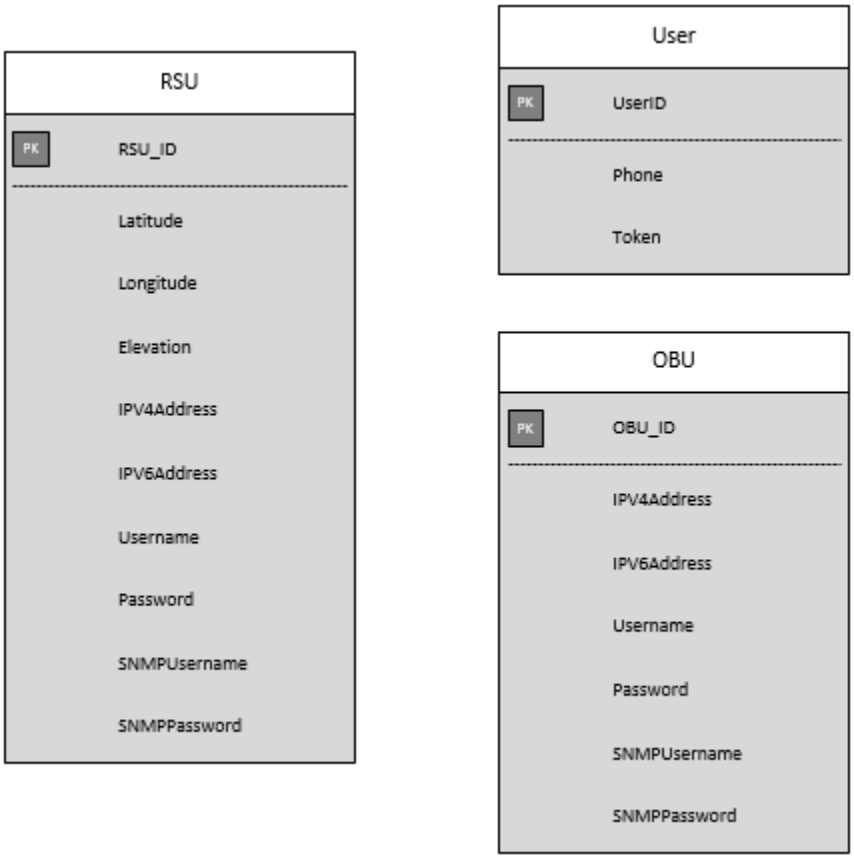


Figure 3-22. Service Monitor Device Management ERD.
Source: WYDOT

3.1.4.3.10 Application User Interface(s)
This application is a service and does not contain any user interfaces.

3.1.4.3.10.1 Description of Operations/Driver Interface with illustrations
This application contains no driver interface operations.

3.1.4.3.10.2 Description of Maintenance User Interface with illustrations
This application contains no maintenance user interface operations.

3.1.4.3.11 Requirements Traceability
The following requirements are applicable to this component and met by this design:

- WCVS-REQ-15 Notifications
- WCVS-REQ-16 Monitored Functions
- WCVS-REQ-16.1 Sub-System Availability
- WCVS-REQ-16.2 Sub-System Performance
- WCVS-REQ-16.3 Availability for Interfaces
- WCVS-REQ-16.4 Availability for Data Storage
- WCVS-REQ-17 Archive Data
- WCVS-REQ-18 Management and Performance Policy **Performance measures and performance data will not be part of Phase 4.**

- WCVS-REQ-20 Manage Safe Communications
- WCVS-REQ-21 Manage CV Equipment
- WCVS-REQ-22 Test CV Equipment
- WCVS-REQ-23 Track CV Equipment
- WCVS-REQ-24 Update WCVS Equipment
- WCVS-REQ-25 Update VS Equipment
- ITSM-REQ-1 WYDOT ITS Alerts

3.1.4.3.12 ICD Traceability

The following interfaces are applicable to this component and its design. A reference to the location of the interface within the ICD is also provided.

Interface	Action within Interface	Section No.
WYDOT DB <-> WYDOT ITS Maintenance	DB reports malfunctioning RSU to WYDOT ITS	5.30.1

3.1.5 TMC Website/Desktop Applications Design

3.1.5.1 WYDOT Transportation Reports and Action Console (TRAC)

The following sections describe the design for the TRAC application.

3.1.5.1.1 Function of the Application

The TRAC is an operator console used in the TMC to monitor and manage planned, ongoing, and forecast events and actions on facilities monitored by the TMC. The TRAC provides a tabular list of actions that require operator attention. As events progress, operators mark actions as complete. The TRAC receives information from various sources available to the TMC (e.g., citizen reports, 511 App, RCRS, field reports) but can also include operator inputs. The TRAC interface is the primary interface for communicating information to the operators in the TMC. Additionally, the CV Pilot will use the TRAC system for events to directly influence the traveler information that is being provided.

3.1.5.1.1.1 Functions/Services Brief description

This application will be updated to include CV messages/alerts/updates for TMC operators to review and to take appropriate actions on. The TRAC user interface will stay consistent with what it's been in the past. TRAC messages to TMC operators will be consolidated where appropriate to reduce the amount of "noise" that an operator will be exposed to.

3.1.5.1.1.2 Graphical illustration of the Application from the Users Perspective

Figure 3-23 shows the TRAC user interface for TMC operators. This interface allows TMC operators to view and handle issues coming into the TMC based on priority.

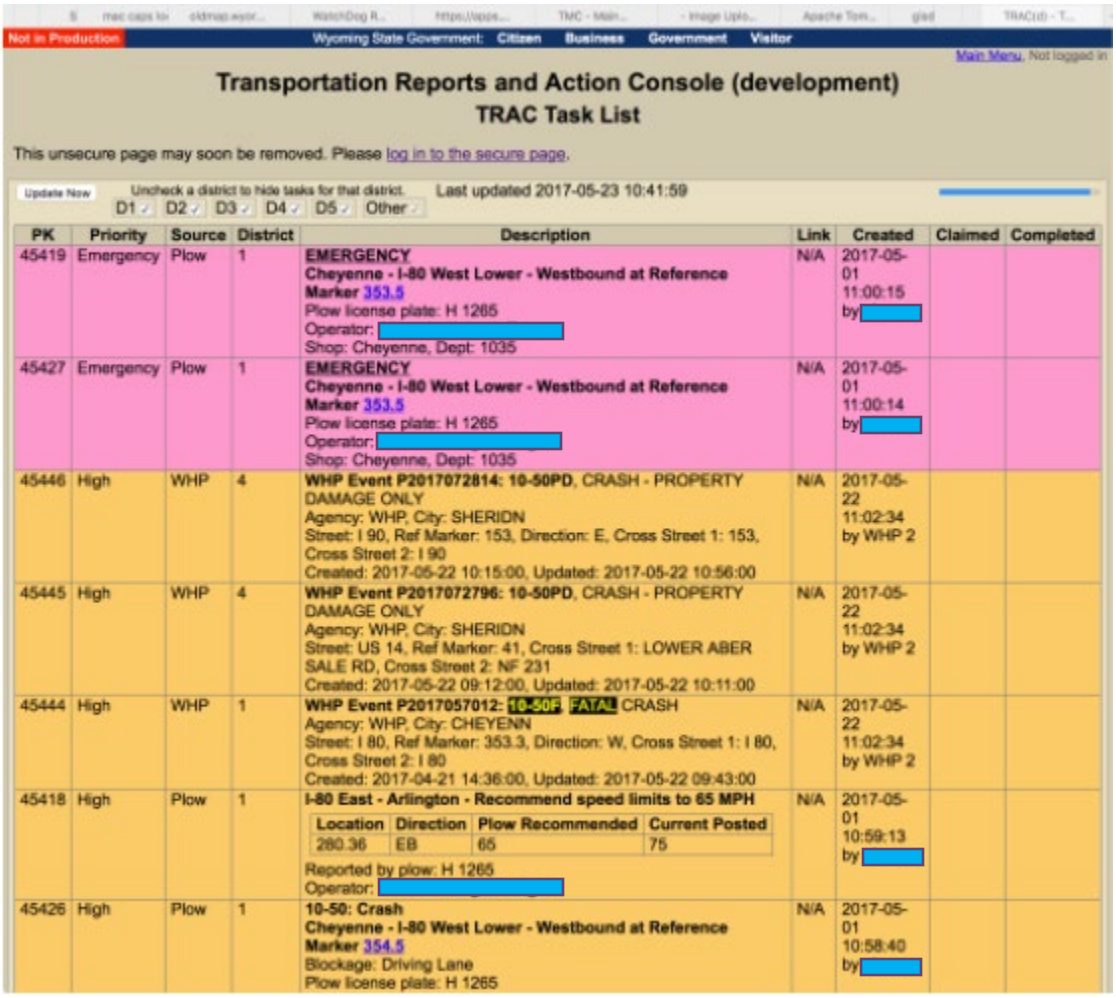


Figure 3-23. TRAC User Interface.
Source: WYDOT

3.1.5.1.1.3 Input Data/Message Flows

Figure 3-24 shows the input data flows for the TRAC application. The main input will be from the Data Broker application. This service will notify the TRAC service for items that require TMC attention. The TRAC service will also periodically query the Data Warehouse for Truck Parking availability updates coming in from the 511 app. These updates will be aggregated for TMC operators to review and handle as needed.

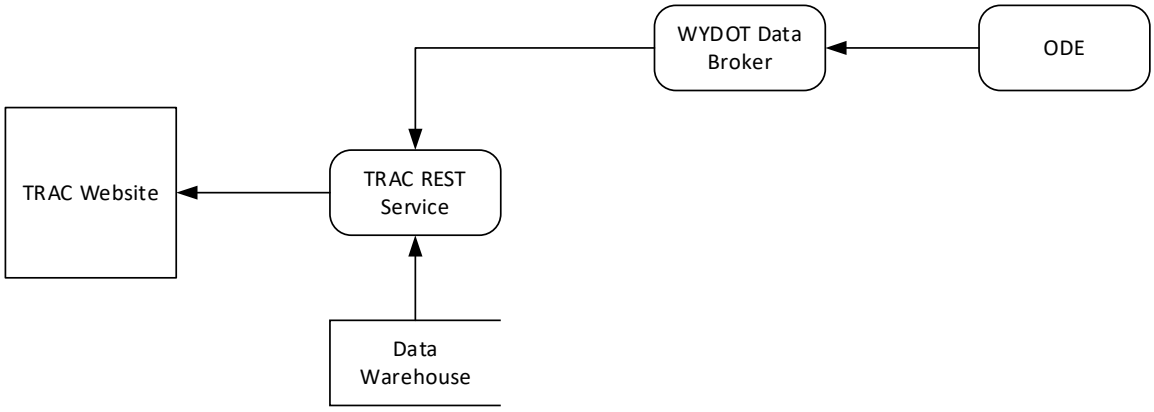


Figure 3-24. TRAC Input Data Flows.
Source: WYDOT

3.1.5.1.1.4 Output Data/Message Flows
Figure 3-25 shows Output data/flows from the TRAC application. Please note that only updated flows are shown in the figure. The TRAC REST service will contain the bulk of the updates for outbound data. Specifically, TMC approvals for the TRAC system will trigger a call to the Data Broker to generate appropriate TIM messages.

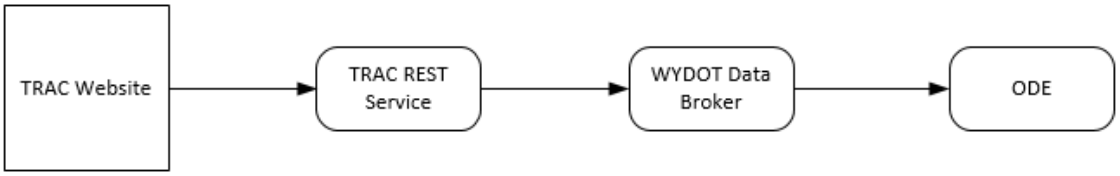


Figure 3-25. TRAC Output flows.
Source: WYDOT

3.1.5.1.2 Developer & version number
The primary developer for the TRAC enhancements will be David Rush

3.1.5.1.3 Application Message and Alerts Descriptions
The sections below describe the Messages and alerts issued by this application with the updated CV interface.

3.1.5.1.3.1 Descriptions and illustrations of messages and alerts issued by application
Table 3-18 describes the messages and alerts issued by CVOP.

Table 3-18 TRAC Messages and Alerts

Message or Alert	Communication Method	Description
Truck Parking Availability	Http Response	This is a Low priority message displayed on the TRAC website that displays the new parking availability updates.

3.1.5.1.3.2 Describe algorithm to determine when messages and alerts are issued
Table 3-19 describes the algorithms used to determine when a message or alert is issued to the TRAC user.

Table 3-19. TRAC Messages and Alerts algorithms

Message or Alert	Issue Criteria
Truck Parking Availability	New submissions have been made from the 511 app for truck parking availability within a configurable timeframe.

3.1.5.1.3.3 Summary tables of criteria for issuing messages and alerts
Table 3-19 summarizes the messages and alerts as well as the criteria used to issue them.

3.1.5.1.4 Application design description
There are no large design updates needed to integrate the CV data into the TRAC system. The current application is well designed and will be extended to be able to receive data related to Truck Parking availability as well as updates to the TRAC REST service to submit TIM messages to the Data Broker from the TRAC REST Service. The current TRAC functionality will support TRAC-REQ-1 and all sub requirements for the system through existing functionality. The WTIDB application will be responsible for submitting alerts and notifications defined in Requirement TRAC-REQ-1 and all sub requirements to the TRAC system within the specified timeframe.

3.1.5.1.4.1 Schematic of major modules/functions
Figure 3-26 shows the only major updates to the TRAC modules. This includes a new REST service function to retrieve and alert the TRAC application to any new parking availability that has been submitted in a configurable amount of time (see section 3.1.5.2.6 for the configuration parameter).

Figure 3-26. Parking availability.
Source: WYDOT

3.1.5.1.4.2 Description of modules/functions
Parking Availability: This function periodically calls the Data Warehouse to retrieve any newly submitted parking availability updates. Any new updates are consolidated and displayed to the TMC from within the TRAC console.

3.1.5.1.4.3 Diagram of process flow/algorithms between major modules/functions
See Figure 3-26 for a process flow between the major modules for the truck parking availability.

3.1.5.1.4.4 Descriptions of process flow/algorithms between major modules/functions
Parking Availability: The process kicks off from the REST service request to the Data Warehouse for any parking availability submissions in the last number of minutes (configurable). If there have been any submissions the results are aggregated and then sent back to the TRAC application for display and appropriate action by the TMC Operator.

3.1.5.1.5 Application Data Tables

This application has no proposed changes to the existing data tables.

3.1.5.1.5.1 Input data description tables

This application has no proposed changes to the input data description tables.

3.1.5.1.5.2 Output data description tables

This application has no proposed changes to the output data description tables.

3.1.5.1.5.3 Data/database storage description diagrams and tables

This application has no proposed changes to the existing database schema.

3.1.5.1.6 Application Configuration Data

Table 3-20 shows the new configuration parameters that will be added to the TRAC application.

Table 3-20. TRAC Configuration Parameters

Property	Default Value	Description
TruckParkingFrequency	60	The time (in minutes) used to check the data warehouse for truck parking updates.

3.1.5.1.7 Application User Interface(s)

Figure 3-23 shows the TRAC application interface.

3.1.5.1.7.1 Description of Operations/Driver Interface with illustrations

This application contains no driver interface operations.

3.1.5.1.7.2 Description of Maintenance User Interface with illustrations

This application contains no maintenance interface operations.

3.1.5.1.8 Requirements Traceability

The following requirements are applicable to this component and met by this design:

- TRAC-REQ-1 TRAC Updates **Not part of Phase 4.**
- TRAC-REQ-1.1 Distress Notification **Not part of Phase 4.**
- TRAC-REQ-1.1.1 Transmission Time **Not part of Phase 4.**
- TRAC-REQ-1.2 Segment Alerts **Not part of Phase 4.**
- TRAC-REQ-1.2.1 Transmission Time **Not part of Phase 4.**
- TRAC-REQ-1.2.2 Segment Alerts-Pikalert **Not part of Phase 4.**

3.1.5.1.9 ICD Traceability

The following interfaces are applicable to this component and its design. A reference to the location of the interface within the ICD is also provided.

Interface	Action within Interface	Section No.
WYDOT DB <-> WYDOT TRAC	DB Sends Emergency Notification to TRAC	5.28.1
	DB Sends Road Weather Alert from Pikalert to TRAC	5.28.2

3.1.5.2 WYDOT Wyoming Traveler Information (WTI)

The sections below describe the design of the WTI enhancements for integration with the new CV data. Please note that this application's functionality does not change much for CV integration. Most of the requirements that this application is tied to are actually implemented in the TMC Data Brokerage application.

3.1.5.2.1 Function of the Application

This application provides center monitoring and control of variable speed limits systems. It monitors data on traffic and environmental conditions collected from sensors along the roadway. Based on the measured data, it calculates and sets suitable speed limits. It controls equipment that posts the current speed limits and displays additional information such as basic safety rules and current traffic information to drivers. This will be an extension of the WTI system.

3.1.5.2.1.1 Functions/Services Brief description

The following functions shall allow the WTI application to integrate with CV data.

Truck Parking Availability Updates: New functionality shall allow TMC operators to set availability based on user submitted parking reports sent to the Operators via the TRAC system.

3.1.5.2.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

This application is not directly involved with vehicle communications on the highway.

3.1.5.2.1.3 Input Data/Message Flows

Input data flows to the WTI application consist of crowd sourced truck-parking information originating from the WYDOT Data Warehouse. All communications to the WTI application pass through the WYDOT Data Broker application. The Input Data/Message Flows are shown in Figure 3-27.

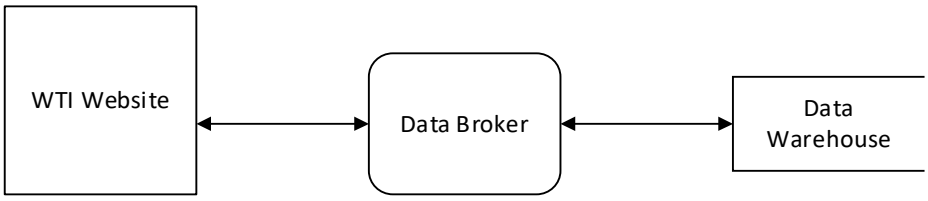


Figure 3-27. Input Data Flows for WTI.
Source: WYDOT

3.1.5.2.1.4 Output Data/Message Flows

Output data/message flows from the WTI application for the CV integration updates include data flows for road weather condition updates, VSL updates, and truck parking updates. Updates shall be pushed to both the Data Warehouse and to the ODE for TIM message broadcasting on the RSUs. Figure 3-28 shows the output data/message flow for the WTI application.

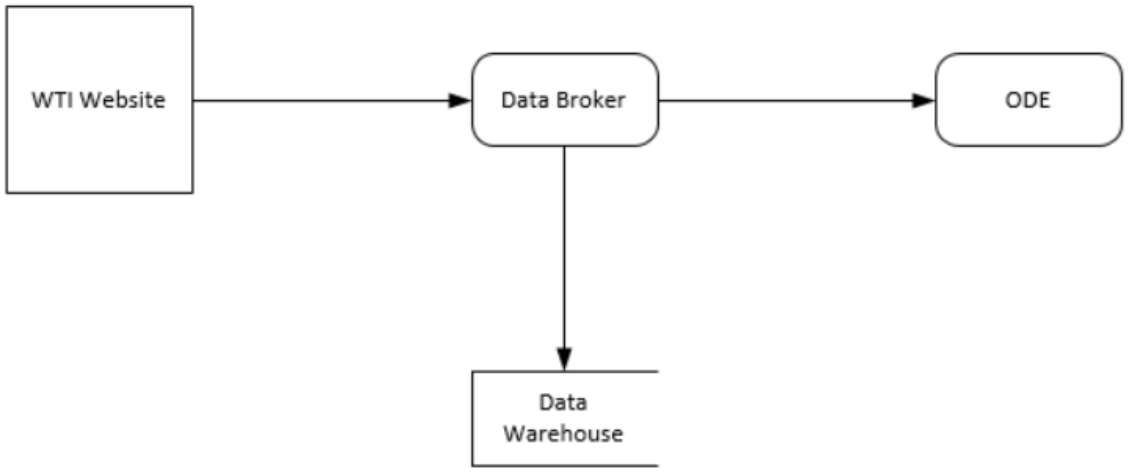


Figure 3-28. WTI Output Data/Message Flows.
Source: WYDOT

3.1.5.2.2 Developer & version number
WYDOT will be responsible for the development of this application.

3.1.5.2.3 Application Message and Alerts Descriptions
The following sections describe the messages/alerts specific to the CV integration for the WTI application.

3.1.5.2.3.1 Descriptions and illustrations of messages and alerts issued by application
Table 3-21 describes messages and alerts that may be issued by the WTI application related to the CV project enhancements.

Table 3-21. WTI CV Messages and Alerts

Message or Alert	Communication	Description
TIM Update Error	Http Response	Error: "Failed attempting to submit a TIM to the Data Broker" – additional details will be provided of the exact error received from the Data Broker

3.1.5.2.3.2 Describe algorithm to determine when messages and alerts are issued
TIM Update Error: This alert is issued when the Data Broker returns a failure to submit the TIM message to the ODE or if the ODE is inaccessible. Details received from the Data Broker application shall be passed back to the ConAdmin user interface and displayed to the end user.

3.1.5.2.3.3 Summary tables of criteria for issuing messages and alerts
Table 3-22 shows a summary of messages and alerts issued by the WTI application along with the criteria required in order to issue the message or alert.

Table 3-22. Summary table of Messages and Alerts for WTI

Message or Alert	Issue Criteria
TIM Update Error	• Data Broker returns a failed response when requesting a TIM be added to an RSU • The Data Broker response times out

3.1.5.2.4 Application Design Description

The following sections describe the design for the CV updates that shall be applied to the WTI application.

3.1.5.2.4.1 Schematic of major modules/functions

Figure 3-29 shows the Major Modules/Functions associated the CV integration in the WTI application.

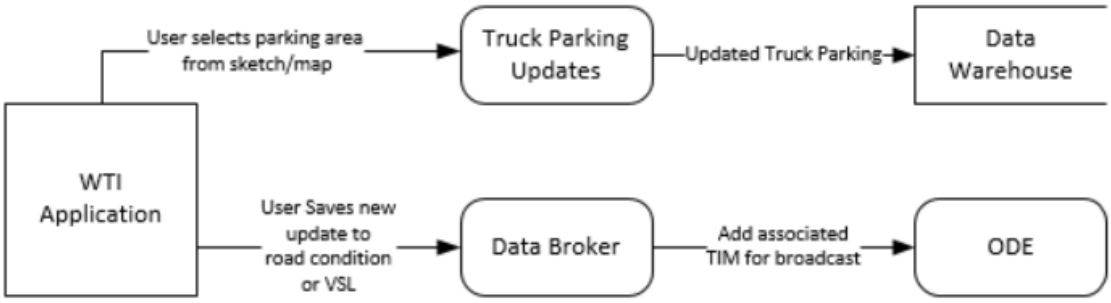


Figure 3-29. WTI Major Modules/Functions.
Source: WYDOT

3.1.5.2.4.2 Description of modules/functions

The following modules/functions shall be added to the WTI application in order to integrate with the new CV data.

Truck Parking Availability Module: This module will be a new window within the WTI application that will allow TMC Operators to view crowd sourced parking information and make updates to the parking availability based on crowd-sourced information. This module will be developed using C# on the Windows Presentation Foundation (WPF) platform. The module will allow users to select a parking area on a map and then submit updated parking availability based on the crowd-sourced information available in the TRAC messaging system.

TIM Message Integration: The bulk of the development needed to integrate road condition and VSL TIMs into the WYDOT environment will be performed within the Data Broker application. However, the WTI application will be updated to handle error messages related to the Data Brokers integration of the ODE calls.

3.1.5.2.4.3 Diagram of process flow/algorithms between major modules/functions

Figure 3-29 shows the process flow/algorithms between the major modules/function for the CV integration in WTI.

3.1.5.2.4.4 Descriptions of process flow/algorithms between major modules/functions

Truck Parking Availability Module: This module process flow will begin with a TMC operator opening up a new window where a map or sketch of I-80 along with available parking areas will be displayed. From here, the TMC operator can click on any of the parking areas and select from a dropdown list what the current parking availability should be set to. The user clicks save and a call to the Data Broker service is then made in order to update the database with the new parking availability information. Once the database is updated the information will then be available to the 511 app, WYOROAD.INFO, and CVOP websites.

TIM Message Integration: Integrating the TIM messages should be seamless for the WTI Operator. The only proposed changes include notifying the operator when a TIM message fails to get created.

3.1.5.2.5 Application Data Tables

No data table updates are proposed for the WTI CV integration.

3.1.5.2.5.1 Input data description tables

No data table updates are proposed for the WTI CV integration.

3.1.5.2.5.2 Output data description tables

No data table updates are proposed for the WTI CV integration.

3.1.5.2.5.3 Data/database storage description diagrams and tables

No data table updates are proposed for the WTI CV integration.

3.1.5.2.6 Application Configuration Data

No new configuration parameters are proposed for the WTI CV integration.

3.1.5.2.7 Application User Interface(s)

Figure 3-30 shows a mockup of the WTI interface for truck parking.

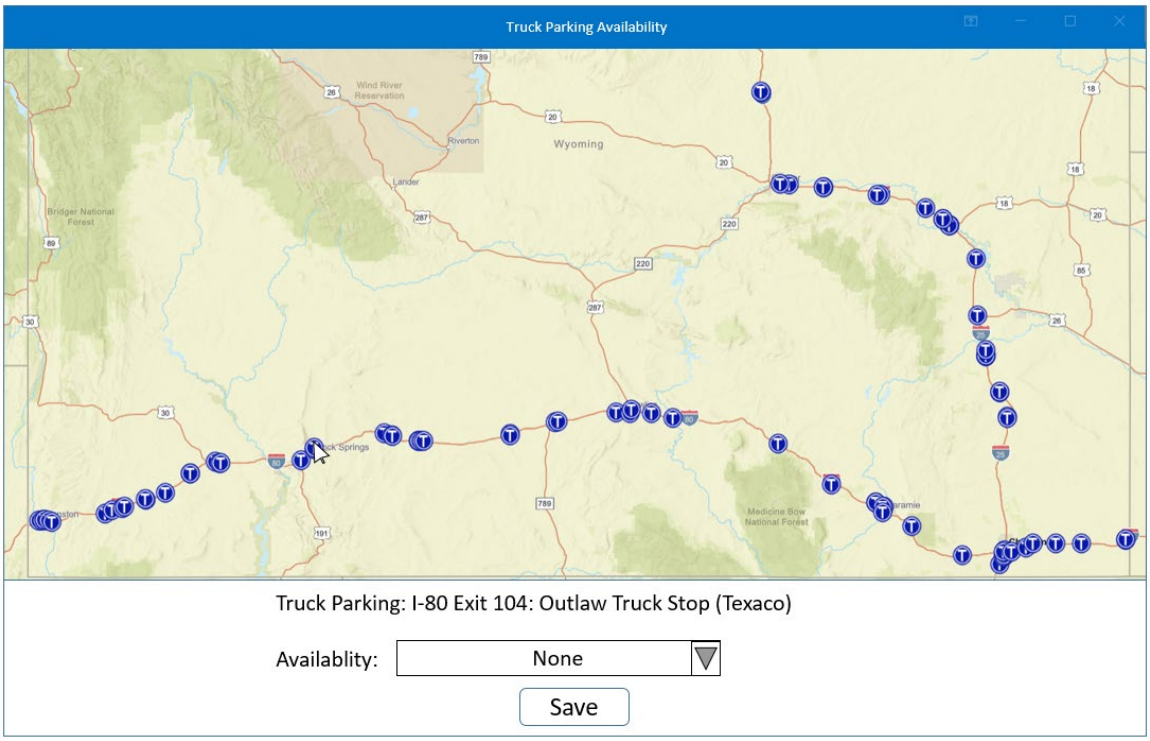


Figure 3-30. WTI Truck Parking window mockup.
Source: WYDOT

3.1.5.2.7.1 Description of Operations/Driver Interface with illustrations
This application contains no driver interface operations.

3.1.5.2.7.2 Description of Maintenance User Interface with illustrations
This application contains no maintenance interface operations.

3.1.5.2.8 Requirements Traceability
The following requirements are applicable to this component and met by this design:

- WTI-REQ-1 WTI Inputs **Not part of Phase 4.**
- WTI-REQ-1.1 Current Segment Alerts **Not part of Phase 4.**
- WTI-REQ-1.1.1 Transmission Time **Not part of Phase 4.**
- WTI-REQ-1.2 Forecast Segment Alerts **Not part of Phase 4.**
- WTI-REQ-1.2.1 Forecast Time **Not part of Phase 4.**
- WTI-REQ-1.2.2 Forecast Update **Not part of Phase 4.**
- WTI-REQ-2 WTI Outputs
- WTI-REQ-2.1 Posted Speed
- WTI-REQ-2.2 Vehicle Restrictions
- WTI-REQ-2.2.1 Restriction Information
- WTI-REQ-2.2.2 Restriction Start Time
- WTI-REQ-2.3 Posted Messages
- WTI-REQ-2.3.1 Message Information
- WTI-REQ-2.4 Posted Closures
- WTI-REQ-2.4.1 Closure Beginning
- WTI-REQ-2.4.2 Closure End

- WTI-REQ-2.4.3 Closure Start Time

3.1.5.2.9 ICD Traceability

The following interfaces are applicable to this component and its design. A reference to the location of the interface within the ICD is also provided.

Interface	Action within Interface	Section No.
WYDOT DB <-> WYDOT WTI	WYDOT DB Sends Road Weather Advisories and Alerts to WYDOT Traveler Information System	5.34.1
	WTI sends posted speeds, restrictions and closures to WYDOT DB	5.34.2

3.1.5.3 WYDOT Construction Administration (CA)

3.1.5.3.1 Function of the Application

This application coordinates work plans with maintenance systems (ConAdmin) so that work zones are established that have minimum traffic impact. Traffic control strategies are implemented to further mitigate traffic impacts associated with work zones that are established, providing work zone information to driver information systems such as dynamic message signs.

3.1.5.3.1.1 Functions/Services Brief description

The ConAdmin application shall be updated/extended to include functions that notify the ODE of planned construction areas. The ConAdmin will add a feature that will allow users to specify a geographic region that will be affected by the planned construction as well as a feature that allows users to specify a buffer area in order to determine which RSUs need to broadcast the work zone warning TIM.

3.1.5.3.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

This application is not directly involved with vehicle communications on the highway.

3.1.5.3.1.3 Input Data/Message Flows

Input data flows related to the CV updates include geographic regions for the construction area as well as the geographic region for all RSUs that will encompass the work zone warning broadcasts.

3.1.5.3.1.4 Output Data/Message Flows

Messages flowing from the ConAdmin application for CV enhancements include sending requests to the Data Broker application to submit Work Zone Warning TIMs. The TIMs will be sent to specific RSUs in the geographic area specified and only broadcast during the time specified. Work Zones and related condition information will be sent to the Data Broker application and on to RSUs as TIM messages within 5 minutes of a user clicking on the button to generate a new Work zone or update an existing Work Zone.

3.1.5.3.2 Developer & version number

WYDOT will be responsible for the development of this application.

3.1.5.3.3 Application Message and Alerts Descriptions

The following sections describe the messages and alerts issued by this application.

3.1.5.3.3.1 Descriptions and illustrations of messages and alerts issued by application

Table 3-23 describes the messages and alerts that are issued by the ConAdmin application.

Table 3-23. ConAdmin Messages and Alerts.

Message or Alert	Communication Method	Description
TIM Update Error	Http Response	Error: "Failed attempting to submit a work zone warning TIM to the RSU" – additional details will be provided of the exact error received from the ODE

3.1.5.3.3.2 Describe algorithm to determine when messages and alerts are issued

TIM Update Error: This alert is issued if the Data Broker returns a failure to submit the TIM message to the ODE or if the ODE is inaccessible. Details received from the Data Broker application shall be passed back to the ConAdmin user interface and displayed to the end user.

3.1.5.3.3.3 Summary tables of criteria for issuing messages and alerts

Table 3-24 is a summary table of message and alerts along with the criteria for issuance for the ConAdmin application.

Table 3-24. ConAdmin Message and Alert Issue criteria.

Message or Alert	Issue Criteria
TIM Update Error	• Data Broker returns a failed response when requesting a TIM be added to an RSU • The Data Broker response times out

3.1.5.3.4 Application Design Description

The ConAdmin enhancements will include adding a call from the ConAdmin application to the WYDOT Data Broker as well as user interface enhancement to define the geofence for the area that the Construction area will encompass. Currently the application only allows the user to specify the centroid for the construction site.

3.1.5.3.4.1 Schematic of major modules/functions

Figure 3-31 shows the major functions that will be built to integrate the existing ConAdmin application into the new CV environment.

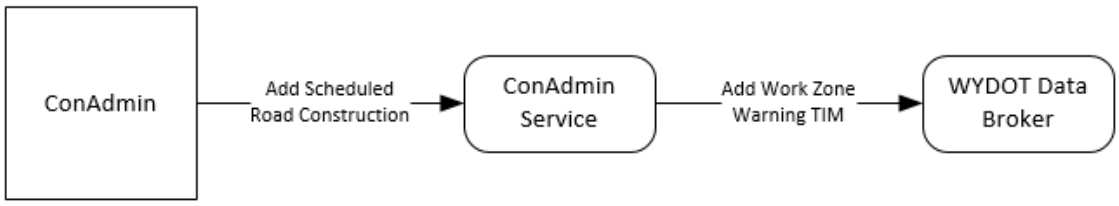


Figure 3-31. Schematic of Major ConAdmin CV Functions.
Source: WYDOT

3.1.5.3.4.2 Description of modules/functions

The major functions that need to be built for CV integration will be the user interface function for choosing the geofence area for a construction zone and the function to call the WYDOT Data Broker application to generate the TIM message for a given set of RSUs.

Select Work Zone Area: A new tool will be added to the ConAdmin application allowing users to specify the work zone area on a map and submitting this along with other work zone information to the system.

Add Work Zone Warning TIM: This function will allow the website to submit a TIM message for a given Work Zone to the Data Broker application.

3.1.5.3.4.3 Diagram of process flow/algorithms between major modules/functions

Figure 3-31 shows the process flow amongst the different modules/functions for the ConAdmin application.

3.1.5.3.4.4 Descriptions of process flow/algorithms between major modules/functions

The process flow amongst the modules/functions will be as follows: a user will begin work on a new planned work zone. Users will be required to enter a geo fence for work zones along the I-80 corridor. Once a user saves the work zone then the information will be forwarded to Add Work Zone Warning TIM function. This function will determine the RSUs that reside within a buffer of the work zone area and submit a new Work Zone Warning TIM message to the affected RSUs.

3.1.5.3.5 Application Data Tables

The following sections describe affected input/output data tables for the ConAdmin application.

3.1.5.3.5.1 Input data description tables

Table 3-25 describes the functional input parameters for the new ConAdmin CV integration.

Table 3-25. ConAdmin Function Input Parameters

Function Name	Parameter	Type	Description
AddWorkZoneWarningTIM	RSU_IPs	String [ ]	The list of RSU IP addresses to push the Work Zone Warning TIM message to.
AddWorkZoneWarningTIM	Begin milemarker	int	The starting milemarker for the Construction Zone.
AddWorkZoneWarningTIM	End Milemarker	Int	The ending mile marker for the Construction Zone
AddWorkZoneWarningTIM	Buffer	int	The number of miles that the notification buffer should extend to incorporate affected RSUs
AddWorkZoneWarningTIM	Work times	string	The scheduled time of work
AddWorkZoneWarningTIM	LaneClosures	String	The lanes (including shoulders) schedule for closure.
AddWorkZoneWarningTIM	Construction begin date	Date	The Date that the construction is scheduled to begin on
AddWorkZoneWarningTIM	Construction duration	int	The number of days the construction is scheduled to last.

3.1.5.3.5.2 Output data description tables

Table 3-26 shows all of the ConAdmin output parameters for the new CV functions.

Table 3-26. ConAdmin Function Output Parameters

Function Name	Parameter	Type	Description
AddWorkZoneWarningTIM	Result	String	This is the result of the call. This will either contain text of the success or failure.

3.1.5.3.5.3 Data/database storage description diagrams and tables

Only one new field will need to be added to the existing database to handle the Work Zone Warning. This field will be the Shapefile that specifies the area of the Work Zone.

3.1.5.3.6 Application Configuration Data

There is no new application configuration data needed for the CV integration enhancements to ConAdmin.

3.1.5.3.7 Application User Interface(s)

The following figure shows a mockup of the new user interface for specifying a Work Zone

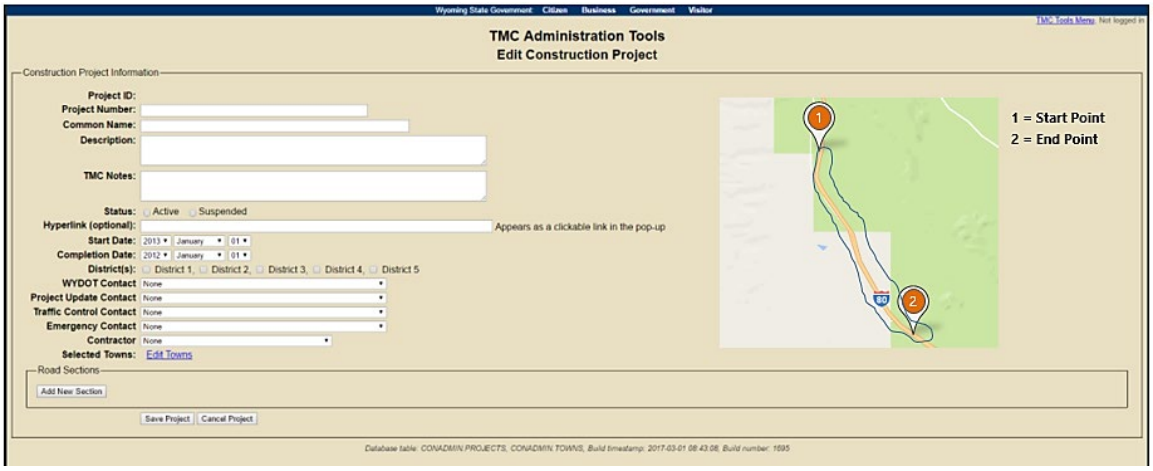


Figure 3-32. Work Zone Area mockup.
Source: WYDOT

3.1.5.3.7.1 Description of Operations/Driver Interface with illustrations

This application contains no driver interface operations.

3.1.5.3.7.2 Description of Maintenance User Interface with illustrations

This application contains no maintenance interface operations.

3.1.5.3.8 Requirements Traceability

The following requirements are applicable to this component and met by this design:

- CA-REQ-1 CA Data Sharing
- CA-REQ-2 Protocol
- CA-REQ-3 Schema
- CA-REQ-4 Transmission

- WCVS-REQ-4.4 Work Zone Hazard

3.1.5.3.9 ICD Traceability

The following interfaces are applicable to this component and its design. A reference to the location of the interface within the ICD is also provided.

Interface	Action within Interface	Section No.
WYDOT DB <-> WYDOT Construction Administration	WYDOT CA sends new construction project to the DB	5.32.1

3.1.5.4 WYOROAD.INFO Website (Extension & Interface)

3.1.5.4.1 Function of the Application

This application will extend the current WYOROAD.INFO website to include improved data from the CV pilot including data from work zone warnings, Spot weather information, situational data, and incident information. It will get information for updates from the WTIDB services engine and from WTI.

3.1.5.4.1.1 Functions/Services Brief description

This applications functions/services related to the CV integration include displaying CV related weather alerts/warnings, VSL updates, and truck parking availability on the public WYOROAD.INFO website. Please note that no software development will be required in order to integrate this data as the application will pull from the existing data warehouse that will contain all of the CV related data updates.

3.1.5.4.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

This application is not directly involved with vehicle communications on the highway.

3.1.5.4.1.3 Input Data/Message Flows

Figure 3-33 shows a flow diagram consisting of two sources feeding information into the Data Broker: ODE and 511 App. The Data Broker sends the information further to the Data Warehouse, and then ultimately to WYOROAD.INFO.

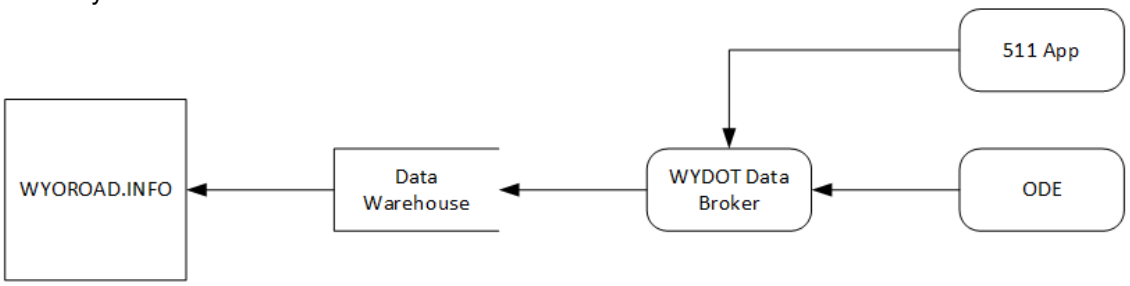


Figure 3-33. WYOROAD.INFO Input flows.
Source: WYDOT

3.1.5.4.1.4 Output Data/Message Flows

The WYOROAD.INFO website is a read only public website that just displays road condition and supplemental travel related information for the public.

3.1.5.4.2 Developer & version number

This application was developed and is maintained by WYDOT.

3.1.5.4.3 Application Message and Alerts Descriptions
No additional messages or alerts will be developed for this application related to the CV project.

3.1.5.4.3.1 Descriptions and illustrations of messages and alerts issued by application
No additional messages or alerts will be developed for this application related to the CV project.

3.1.5.4.3.2 Describe algorithm to determine when messages and alerts are issued
No additional messages or alerts will be developed for this application related to the CV project.

3.1.5.4.3.3 Summary tables of criteria for issuing messages and alerts
No additional messages or alerts will be developed for this application related to the CV project.

3.1.5.4.4 Application Design Description
No changes will be made to the WYOROAD.INFO website based on the integration of CV data.

3.1.5.4.4.1 Schematic of major modules/functions
No changes will be made to the WYOROAD.INFO website based on the integration of CV data.

3.1.5.4.4.2 Description of modules/functions
No changes will be made to the WYOROAD.INFO website based on the integration of CV data.

3.1.5.4.4.3 Diagram of process flow/algorithms between major modules/functions
No changes will be made to the WYOROAD.INFO website based on the integration of CV data.

3.1.5.4.4.4 Descriptions of process flow/algorithms between major modules/functions
No changes will be made to the WYOROAD.INFO website based on the integration of CV data.

3.1.5.4.5 Application Data Tables
No changes will be made to the WYOROAD.INFO database for the CV integration.

3.1.5.4.5.1 Input data description tables
No changes will be made to the WYOROAD.INFO database for the CV integration.

3.1.5.4.5.2 Output data description tables
No changes will be made to the WYOROAD.INFO database for the CV integration.

3.1.5.4.5.3 Data/database storage description diagrams and tables
No changes will be made to the WYOROAD.INFO database for the CV integration.

3.1.5.4.6 Application Configuration Data
No additional configuration data will be needed for the integration of CV data into the WYORROAD.INFO Application User Interface(s)

3.1.5.4.6.1 Description of Operations/Driver Interface with illustrations
This application contains no driver interface operations.

3.1.5.4.6.2 Description of Maintenance User Interface with illustrations
This application contains no maintenance interface operations.

3.1.5.4.7 Requirements Traceability
There are no requirements applicable to this component since this design is outside the scope of this project.

3.1.5.4.8 ICD Traceability
There are no interfaces applicable to this component since this design is outside the scope of this project.

3.2 Vehicle Subsystems and Components

3.2.1 DSRC/C-V2X & Satellite OBU Design (Commsignia)

This OBU type is a Commsignia dual-mode DSRC/C-V2X. This OBU hardware is planned to be installed on WYDOT Maintenance Vehicles.

3.2.1.1 Function of the Component

These OBUs are intended to be the primary communication link between WYDOT RSUs and vehicles. Functions provided by OBUs as well as data flows are provided in the sections below. The design for this OBU shall meet the sensitivity requirements specified in J2945-1 section 6.4.2.

3.2.1.1.1 Functions/Services Brief description
This OBU sub-system has the ability to:

- Receive TIMs via DSRC and Satellite
- Receive BSM Parts I and II
- Broadcast BSM Parts I and II

3.2.1.1.2 Input Data/Message Flows
Input flows for the OBU include TIM and BSM messages. BSM messages are used for applications such as Forward Collision Warning. TIM messages are input from RSUs as well as from satellite reception from Sirius and will be used to display I2V Situational awareness, Work Zone Warning, and Spot Weather Impact Warning applications.

3.2.1.1.3 Output Data/Message Flows
Output flows for the OBU include BSM messages. BSM messages are transmitted continuously and are used for the Forward Collision Warning application.

3.2.1.2 OBU Hardware Platform

This OBU will be treated as a black box with the OBU hardware platform and software system setup as proprietary.

3.2.1.2.1 Vendor/manufacturer
The manufacturer of the OBU is Commsignia.

3.2.1.2.2 Picture and physical description of hardware
The Commsignia OBU is comprised of an antenna and the main OBU housed in a separate waterproof box that mounts in a vehicle and can be wired into the vehicle power. The OBU can be seen in Figure 3-34.

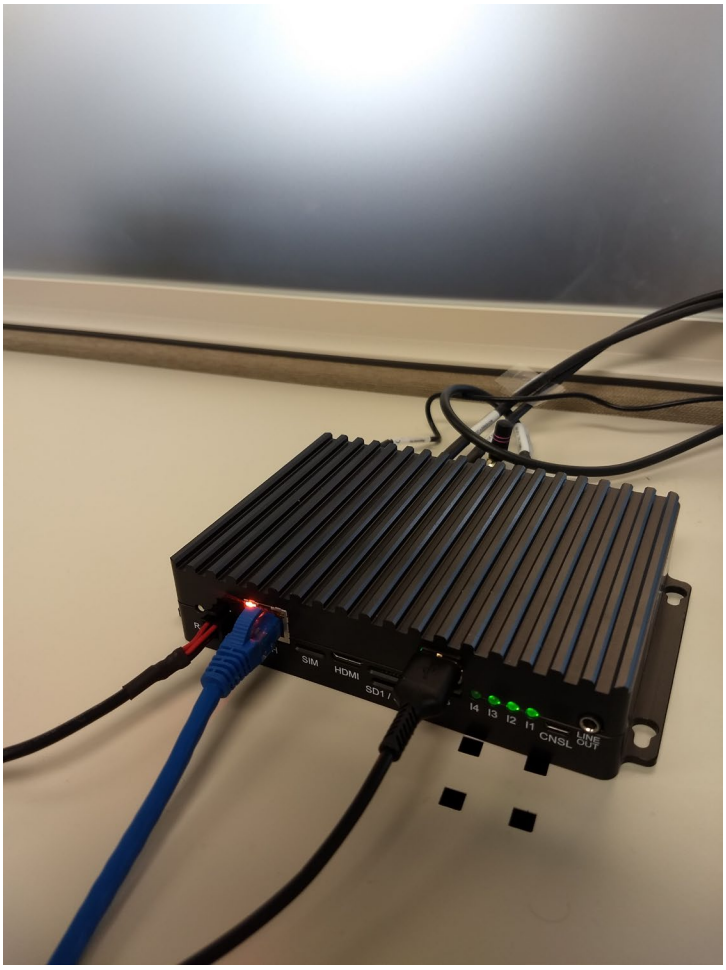


Figure 3-34. Commsignia OBU.
Source: WYDOT

3.2.1.2.3 Hardware physical interfaces (RS232, Ethernet, etc.)

The Commsignia OBU contains the following interfaces. The OBU will also include an Android based Human Machine Interface (HMI).

- 2 VX2 ports
- 2 Wi-Fi ports
- 2 LTE/3G ports
- 1 GNSS port
- 1 Ethernet port
- 1 CAN port
- 2 USB ports
- 1 OBD-II port
- 1 HDMI video port
- 2 Mini PCIe slots
- 3.5mm jack

3.2.1.2.4 OBU Requirements

Commsignia will supply an OBU that shall provide the following features.

- Access to the OBU shall be restricted with login credentials.
- All communication ports shall have access control (e.g. configurable firewalls and access control lists).
- OBU must be fully compatible with the ISS SCMS and SCMS Manager.
- OBU shall be compatible with the ISS SCMS as described in the SyRS.
- OBU SCMS functionality shall include local certificate chain file processing, and spectrum related updates.
- OBU SCMS functionality should include certificate revocation list (CRL) processing and misbehavior detection.
- OBU host processor and operating software shall perform an integrity check on boot.
- OBU shall provide evidence to detect tampering (e.g. opening of the case) through tamper-evident seals. Unused ports shall include plastic caps. The RSU shall be FIPS 140-2 level 3 compatible.
- OBU shall support CAMP v1.2.2 protocols.
- JTAG shall be irreversibly disabled on the main CPU and the HSM.
- OBU must be remotely updatable.
- Firmware updates must be digitally signed using a cryptosystem no weaker than AES-128/ECCp256.
- OBU shall be able to store multiple certificates for the SCMS components in the event a new certificate is issued before an old certificate expires (ICA, ECA, PCA). The OBU must store two (2) enrollment certificates.
- Secure boot shall use a cryptosystem no weaker than AES-128/ECCp256.
- CRL processing must support CRL Series 1, 2, 3, and 256.
- OBU shall support SMCS requirements outlined at https://www.scmsmanager.org/publications, including end-entity certificate re-enrollment specification, ASN.1 for Misbehavior Reporting, Misbehavior Report and Application Specification, Elector Technical Specification, and Elector Policy.
- OBU shall utilize an HSM for SCMS cryptographic information.
- FIPS 140-2 level 2 compatibility is required, but WYDOT prefers level 3 compatibility.

3.2.1.3 OBU Communication Interfaces

This hardware component contains the following communication interfaces:

- OBU <-> OBU
- OBU <-> Vehicle Driver
- OBU <-> Vehicle Location and Time Service
- OBU <-> Vehicle CAN Bus
- OBU <-> RSU
- USDOT Prototype SCMS <-> OBU
- ODE <-> OBU
- ODE WY Maintenance Vehicle (OBU)
- Satellite <-> OBU

For details on all communication interfaces listed please see the corresponding section in the Interface Control Document.

3.2.1.4 OBU Messages

Messages sent to/from the OBU are detailed in the corresponding Interface Control Document.

3.2.1.5 Requirements Traceability

The following requirements are applicable to this component and met by this design:

- LTS-REQ-4 VS LTS Time
- LTS-REQ-5 VS LTS Time Standard
- LTS-REQ-6 VS LTS Location
- VS-REQ-1 Receive BSM **In Phase 4 this will be done with C-V2X rather than DSRC**.
- VS-REQ-2 Receive TIM
- VS-REQ-2.1 Receive TIM through DSRC **In Phase 4 this will be done with C-V2X rather than DSRC.**
- VS-REQ-2.2 Receive TIM through Satellite
- VS-REQ-3 Receive Distress Information **Distress information will not be part of Phase 4.**
- VS-REQ-4 Collect Vehicle Data **Not part of Phase 4**
- VS-REQ-4.1 Collect Vehicle Status Data **Not part of Phase 4**
- VS-REQ-4.2 Collect Dimension Data **Not part of Phase 4**
- VS-REQ-4.2.1 Vehicle Dimension Data **Not part of Phase 4**
- VS-REQ-4.2.2 Vehicle Trailer Data **Not part of Phase 4**
- VS-REQ-5 External Environment Sensor Data **Not part of Phase 4**
- VS-REQ-5.1 External Environment Sensor Data Configuration **Not part of Phase 4**
- VS-REQ-5.2 External Environment Sensor Data Management **Not part of Phase 4**
- VS-REQ-10.1 Safely Following a Vehicle
- VS-REQ-10.2 Passing a Stopped Vehicle
- VS-REQ-15 Distress Notification ID **Not part of Phase 4.**
- VS-REQ-15.1 Log **Not part of Phase 4.**
- VS-REQ-16 Create Distress Notification **Not part of Phase 4.**
- VS-REQ-23 IVAA Rank **Distress Message not included in Phase 4.**
- VS-REQ-24 IVAA Level **For Phase 4 we will use the off the shelf vendor alerting system.**
- VS-REQ-25 IVAA Priority Alert
- VS-REQ-26 IVAA FCW **During Phase 4 these will be based on the selected vendor standard for alerting, no customization required.**
- VS-REQ-27 IVAA DN **DN is not part of Phase 4.**
- VS-REQ-28 IVAA SA-Advisory
- VS-REQ-29 IVAA SA-VSL
- VS-REQ-30 IVAA SWIW
- VS-REQ-31 IVAA WZW
- VS-REQ-33 BCVI Messages **Phase 4 will use C-V2X rather than DSRC for wireless broadcasts of BSMs**
- VS-REQ-34 BCVI Distress **Phase 4 will not include BCVI Distress.**
- VS-REQ-34.1 Received Distress **Phase 4 will not include received distress messages.**
- VS-REQ-34.2 Generated Distress **Phase 4 will not include generated distress notifications.**
- VS-REQ-35 BCVI General Broadcast Requirements **Phase 4 will not include the broadcast of traveler information.**
- VS-REQ-36 Transmit Data **Phase 4 shall not use DSRC and should test Wi-Fi.**
- VS-REQ-36.1 Transmit Environmental Data **Phase 4 will not include transmitting of environmental data.**

- VS-REQ-36.2 TVI Data Management-Log **Phase 4 should transmit logs via Wi-Fi.**
- VS-REQ-38 SLD Information. **SLD information is not part of Phase 4.**
- VS-REQ-39 SLD Rolling Log **Vehicle Status Data not part of Phase 4.**
- VS-REQ-40 SLD Log Format
- VS-REQ-41 SLD Log Data **Phase 4 excludes distress messages.**
- VS-REQ-42 VSM SCMS
- VS-REQ-43 VSM SCMS Encryption **Phase 4 will not include any encryption of messages.**
- VS-REQ-44 VSM SCMS Sign
- VS-REQ-45 VSM SCMS Encryption-Log **Phase 4 will not include any encryption of messages**
- VS-REQ-46 VSM SCMS Sign-Log P**hase 4 will not include any signing of log files.**
- VS-REQ-47 VSM App Availability Log **Phase 4 will not include any app availability logs.**
- VS-REQ-48 VSM Updates
- VS-REQ-49 Architectural
- VS-REQ-50 Safety Communication
- VS-REQ-51 VS Equipment
- MCP-REQ-1 V2V Exchange of BSMs **In Phase 4 this will be C-V2X rather than DSRC.**
- MV-REQ-2 Can Bus **Not in Phase 4.**
- MV-REQ-3 Static Identifier **Not in Phase 4.**
- MV-REQ-4 Receive TIM over DSRC **Not in Phase 4.**
- MV-REQ-5 Receive TIM over Satellite **Not in Phase 4.**
- MV-REQ-6 OTA Updates **Not in Phase 4.**
- MV-REQ-7 Time **Not in Phase 4.**
- MV-REQ-8 Location **Not in Phase 4.**
- MV-REQ-9 General **Not in Phase 4.**
- MV-REQ-10 OBU Equipment **Not in Phase 4.v**
- HP-REQ-1 General **Not in Phase 4.**
- HP-REQ-2 Receive TIM over DSRC **Not in Phase 4.**
- HP-REQ-3 Time **Not in Phase 4.**
- HP-REQ-4 Location **Not in Phase 4.**
- HP-REQ-5 OBU Equipment **Not in Phase 4.**
- HP-REQ-6 Receive TIM over Satellite **Not in Phase 4.**
- HP-REQ-7 OTA Updates **Not in Phase 4**
- IT-REQ-1 Receive TIM over DSRC **Not in Phase 4.**
- IT-REQ-2 Receive TIM over Satellite **Not in Phase 4.**
- IT-REQ-3 OTA Updates **Not in Phase 4.**
- IT-REQ-4 Time **Not in Phase 4.**
- IT-REQ-5 Location **Not in Phase 4.**
- IT-REQ-6 General **Not in Phase 4.**
- IT-REQ-7 OBU Equipment **Not in Phase 4.**
- TV-REQ-1 Receive TIM over DSRC
- TV-REQ-2 Receive TIM over Satellite
- TV-REQ-3 Time
- TV-REQ-4 Location
- TV-REQ-5 General
- TV-REQ-6 OBU Equipment

- TV-REQ-7 OTA Updates

3.2.1.6 ICD Traceability

The following interfaces are applicable to this component and its design. A reference to the location of the interface within the ICD is also provided.

Interface	Action within Interface	Section No.
OBU <-> OBU	Connected Vehicles broadcast and receive BSMs	5.1.1
	OBUs broadcast and receive Distress Notifications	5.1.2
OBU <-> Vehicle Driver	Vehicle Driver inputs vehicle data to HMI (non-DN)	5.2.1
	Vehicle Driver Declares a Distress Situation using HMI	5.2.2
	OBU Alerts Vehicle Driver of Distressed Vehicle	5.2.3
	OBU Interface with Vehicle Driver regarding non-DN	5.2.4
OBU <-> Vehicle Location and Time System (VLTS)	OBU Incorporates Location and Time into BSM	5.3.1
OBU <-> Vehicle CAN bus	CAN bus Data Triggers Distress Notification	5.4.1
	CAN bus Periodically Delivers Host Vehicle Data to OBU	5.4.2
MV Environmental Sensors <-> WYDOT MV (HMI)	GroundTruth Android Application Function	5.5.1
OBU <-> RSU	OBU Broadcasts BSM (Part I & II) which is received by RSU	5.9.1
	RSU Broadcasts TIMs which are received by OBUs	5.9.2
	OBU Utilizes RSU Broadcast SCMS Services	5.9.3
USDOT Prototype SCMS <-> OBU	OBU Device Enrollment (Bootstrapping)	5.13.1
	OBU Pseudonym Certificate Provisioning	5.13.2
	OBU Security Policy and Networking Information	5.13.3
	OBU Misbehavior Reporting	5.13.4
	OBU Security Credential Revocations	5.13.5
ODE <-> OBU	OBU Copies Log File to ODE	5.16.1
	ODE Updates OBU Firmware OTA	5.16.2
ODE <-> WY Maintenance Vehicle (OBU)	OBU Copies Weather Environmental Data to ODE	5.17.1
Satellite <-> OBU	Delivery of Traveler Information to Vehicles	5.24.1
	Delivery of Latest Certificate Revocation List to Vehicles	5.24.2

3.2.2 Android™ Device Design

The Android™ Device that will be used in the vehicles to run the HMI will be supplied by Commsignia as part of the OBU package.

3.2.2.1 Function of the Component

The primary purpose of the Android™ tablet will be to run the Lear HMI application. This application is the primary interface to the user for notifications from TIMs and other applications such as Forward Collision Warnings.

3.2.2.1.1 Functions/Services Brief description
The Android tablet will serve as the primary devices that will house the HMI.

3.2.2.1.2 Input Data/Message Flows
Input flows to the tablet will include a WiFi connection to the OBU.

3.2.2.1.3 Output Data/Message Flows
All output data from the HMI will include messages and alerts to users.

3.2.2.2 Android™ Device Hardware Platform

Commsignia will be responsible for supplying the Android tablet hardware.

3.2.2.3 Requirements Traceability

There are no requirements applicable to the design of this component:

3.2.2.4 ICD Traceability
The following interfaces are applicable to this component and its design. A reference to the location of the interface within the ICD is also provided.

Interface	Action within Interface	Section No.
OBU <-> Vehicle Driver	Vehicle Driver inputs vehicle data to HMI (non-DN)	5.2.1
	Vehicle Driver Declares a Distress Situation using HMI	5.2.2
	OBU Alerts Vehicle Driver of Distressed Vehicle	5.2.3
	OBU Interface with Vehicle Driver regarding non-DN	5.2.4
MV Environmental Sensors <-> WYDOT MV (HMI)	GroundTruth Android Application Function	5.5.1

3.2.3 OBU Applications Design

3.2.3.1 OBU Spot Weather Impact Warning Application

3.2.3.1.1 Function of the Application
The sections below detail the functions of the spot weather impact warning application.

3.2.3.1.1.1 Functions/Services Brief description
This application provides the capability for vehicles and drivers to receive information on upcoming weather hazards, based on the vehicle's current location and direction of travel, from an RSU or satellite and display notices to the driver through the HMI.

3.2.3.1.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

Figure 3-35 shows the Spot Weather Impact Warning application communications along the highway.

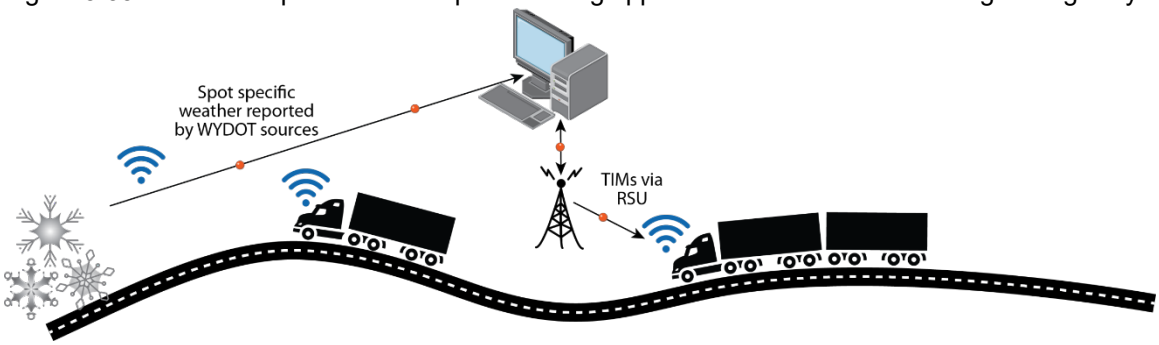


Figure 3-35. Spot Weather Impact Warning illustration.
Source: WYDOT

3.2.3.1.1.3 Input Data/Message Flows

A TIM message is required as the input for the applicable spot weather impact warning I2V processing application.

The TIM message contains the ITIS code for different V2I notifications. ITIS codes contain information regarding weather, atmosphere, curved road, Severe Weather, and permitted vehicle size (length, height, and width) for the road. Figure 3-36 shows the Input/Output data flows for processing Spot Weather Impact warnings.

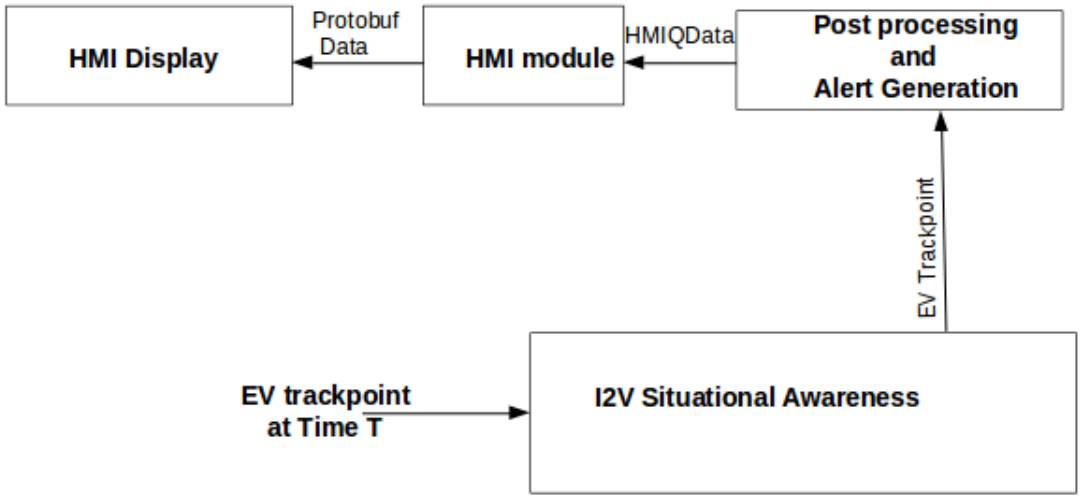


Figure 3-36. Input/Output data flows for I2V Processing.
Source: WYDOT

3.2.3.1.1.4 Output Data/Message Flows

A Severe Weather Icon (image) is the output data for the application.

3.2.3.1.2 Developer & version number

The Commsignia application development team is responsible for the development of this application.

3.2.3.1.3 Application Message and Alerts Descriptions

The sections below describe the messages and alert descriptions for the Spot Weather Impact Warning application.

3.2.3.1.3.1 Descriptions and illustrations of messages and alerts issued by application

There is no alert for spot weather impact warning notifications. It is a message and will show on the HMI along with any other V2V or V2I warnings and alerts.

3.2.3.1.3.2 Describe algorithm to determine when messages and alerts are issued

This message is raised when a TIM is received from the RSU and the OBU is in the area designated by the TIM message.

3.2.3.1.3.3 Summary tables of criteria for issuing messages and alerts

Table 3-27 shows the summary criteria for issuing a Spot Weather Impact Warning alert. Please note that Appendix A has a complete list of TIMs and their associated requirements.

Table 3-27. Spot Weather Warning Summary table for message criteria

Message or Alert	Issue Criteria
SevereWeather Notification	• Severe Weather notification TIM is received from an RSU.
Snow Notification	• Snow notification TIM is received from an RSU.
Rain Notification	• Rain notification TIM is received from an RSU.
FogArea Notification	• Fog Area notification TIM is received from an RSU.

3.2.3.1.3.4 Description of Operations/Driver Interface with illustrations

Please note that the current User Interface may be subject to change. Figure 3-37 shows the driver interface for the severe weather notification.

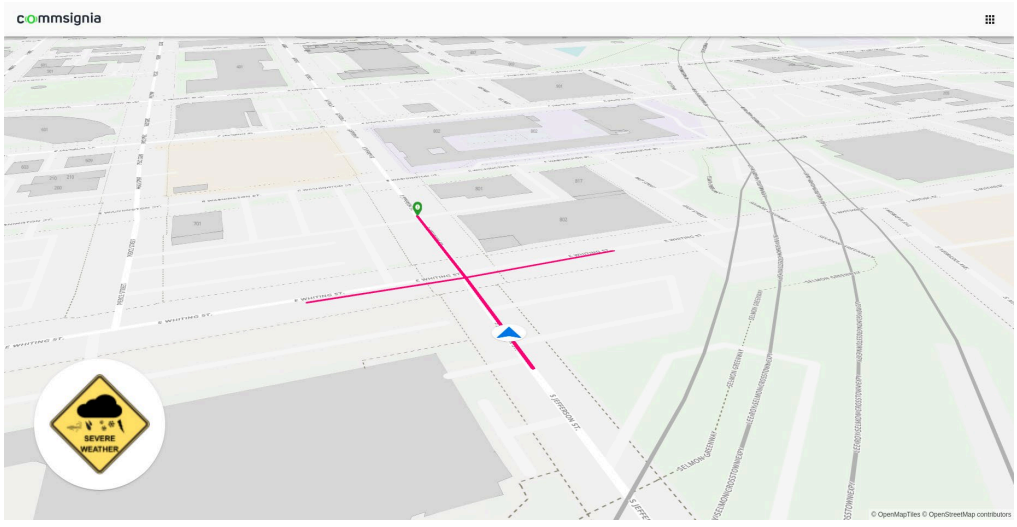


Figure 3-37. Severe Weather Notification.
Source: WYDOT

3.2.3.1.3.5 Description of Maintenance User Interface with illustrations
This application does not contain a maintenance user interface.

3.2.3.1.4 Requirements Traceability
The following requirements are applicable to this component and met by this design:

- VS-REQ-21 SWIW TIM
- VS-REQ-22 SWIW TIM-Region

3.2.3.1.5 ICD Traceability
The following interfaces are applicable to this component and its design. A reference to the location of the interface within the ICD is also provided.

Interface	Action within Interface	Section No.
OBU <-> Vehicle Driver	OBU Interface with Vehicle Driver regarding non-DN	5.2.4
OBU <-> Vehicle CAN bus	CAN bus Periodically Delivers Host Vehicle Data to OBU	5.4.2
OBU <-> RSU	OBU Broadcasts BSM (Part I & II) which is received by RSU	5.9.1
	RSU Broadcasts TIMs which are received by OBUs	5.9.2
Satellite <-> OBU	Delivery of Traveler Information to Vehicles	5.24.1

3.2.3.2 OBU Work Zone Warning

The following sections describe the application design for the OBU Work Zone Warning application.

3.2.3.2.1 Function of the Application
This application provides the capability for vehicles and drivers to receive information on upcoming work zones, based on the vehicle's current location and direction of travel, from an RSU or satellite and display notices to the driver through the HMI.

3.2.3.2.1.1 Functions/Services Brief description
This application belongs to I2V safety system. RSUs send Traveler information to OBUs. This application shows the Work Zone Icon on the HMI screen to notify the driver of the host vehicle (HV). Please note that Appendix A has a complete list of TIMs and their associated requirements.

3.2.3.2.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway
Figure 3-38 shows the work zone warning application communications on the highway.

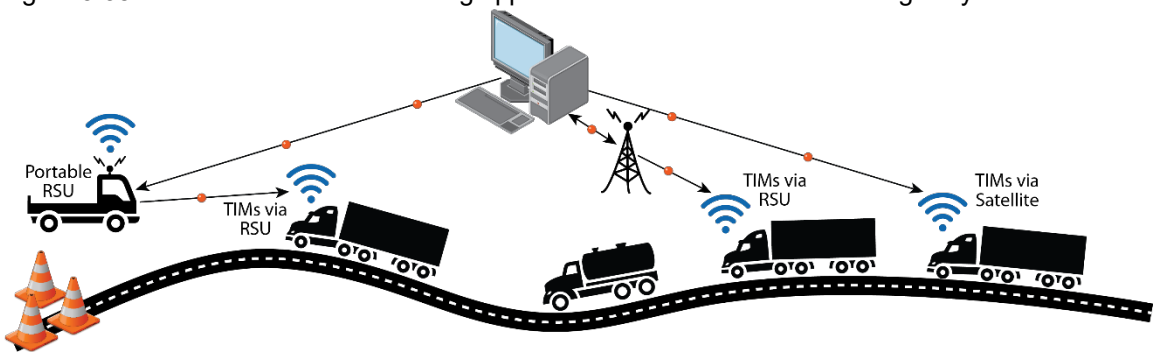


Figure 3-38. Work Zone Warning communications.
Source: WYDOT

3.2.3.2.1.3 Input Data/Message Flows
A TIM message is required as the input for "Work Zone Notification" I2V processing application.

The TIM message contains the ITIS code for different V2I notifications. ITIS codes contain information regarding weather, atmosphere, curved road, Work Zone, and permitted vehicle size (length, height, and width) for the road. Figure 3-39 shows the data flows for the Work Zone warning application.

3.2.3.2.1.4 Output Data/Message Flows
A Work Zone Icon (image) is the output data for the application.

3.2.3.2.2 Developer & version number
The Lear application development team is responsible for the development of this application.

3.2.3.2.3 Application Message and Alerts Descriptions
The sections below describe the messages and alert descriptions for the Work Zone Warning application.

3.2.3.2.3.1 Descriptions and illustrations of messages and alerts issued by application
There is no alert for Work Zone notification. It is a message and will show on the HMI along with any other V2V or V2I warnings and alerts.

3.2.3.2.3.2 Describe algorithm to determine when messages and alerts are issued
This message is raised when a TIM is received from the RSU.

3.2.3.2.3.3 Summary tables of criteria for issuing messages and alerts
Table 3-28 shows the summary criteria for issuing a Work Zone Warning alert.

Table 3-28. Work Zone Warning Summary table for message criteria

Message or Alert	Issue Criteria
Work Zone Notification	• Work Zone Warning TIM is received and OBU is in TIM defined area.

3.2.3.2.4 Application Design Description
Commsignia will be responsible for the application design.

3.2.3.2.4.1 Description of Operations/Driver Interface with illustrations
Figure 3-39 shows the driver interface for the work zone warning notification.

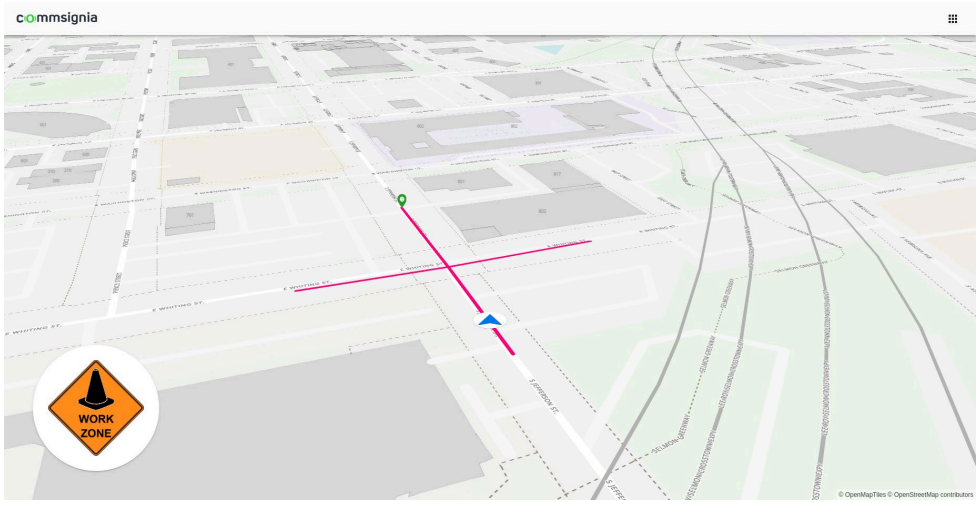


Figure 3-39. Work Zone Notification.
Source: WYDOT

3.2.3.2.4.2 Description of Maintenance User Interface with illustrations
This application does not contain a maintenance user interface.

3.2.3.2.5 Requirements Traceability
The following requirements are applicable to this component and met by this design:

- VS-REQ-19 WZW TIM
- VS-REQ-20 WZW TIM-Region
- VS-REQ-31 IVAA WZW

3.2.3.2.6 ICD Traceability
The following interfaces are applicable to this component and its design. A reference to the location of the interface within the ICD is also provided.

Interface	Action within Interface	Section No.
OBU <-> Vehicle Driver	OBU Interface with Vehicle Driver regarding non-DN	5.2.4
OBU <-> RSU	RSU Broadcasts TIMs which are received by OBUs	5.9.2
Satellite <-> OBU	Delivery of Traveler Information to Vehicles	5.24.1

3.2.3.3 OBU I2V Situational Awareness

3.2.3.3.1 Function of the Application
This application provides the capability for vehicles and drivers to receive general transportation information including weather alerts, speed restrictions, vehicle restrictions, road conditions, incidents, parking, and road closures from an RSU or satellite and display relevant notices to the driver through the HMI.

3.2.3.3.1.1 Functions/Services Brief description
This application belongs to the I2V safety system. This application shows icons on the HMI related to the type of alert received (speed restriction, road closure, etc.) to notify the driver of host vehicle (HV). Please note that Appendix A has a complete list of TIMs and their associated requirements.

3.2.3.3.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway
Figure 3-40 shows a graphical illustration of vehicle and infrastructure communications along the highway for this application.

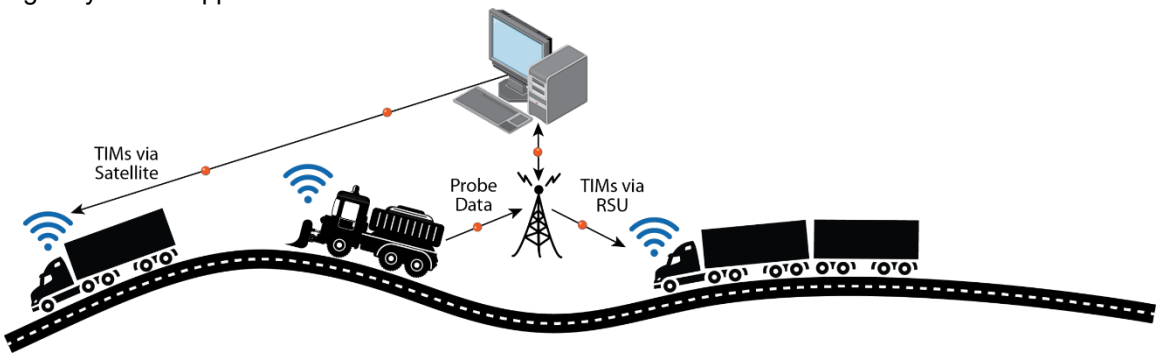


Figure 3-40. I2V Situational Awareness communications.
Source: WYDOT

3.2.3.3.1.3 Input Data/Message Flows
A TIM message is required as the input for the I2V Situational Awareness application.

The TIM message contains the ITIS code for different V2I notifications. ITIS codes contain information regarding weather, atmosphere, curved road, Road Closures, permitted vehicle size (length, height, and width) for the road, and other situational awareness applications.

3.2.3.3.1.4 Output Data/Message Flows
An Icon (image) is the output data for the application.

3.2.3.3.2 Developer & version number
The Commsignia application development team is responsible for the development of this application.

3.2.3.3.3 Application Message and Alerts Descriptions
The sections below describe the messages and alert descriptions for the I2V Situational Awareness application.

3.2.3.3.3.1 Descriptions and illustrations of messages and alerts issued by application
There is no alert for I2V Situational Awareness messages, instead these are considered notifications. A notification will show on the HMI along with any other V2V or V2I warnings and alerts.

3.2.3.3.3.2 Describe algorithm to determine when messages and alerts are issued
This message is raised when a TIM is received from the RSU.

3.2.3.3.3.3 Summary tables of criteria for issuing messages and alerts
Table 3-29 shows the summary criteria for I2V Situational Awareness notifications.

Table 3-29. I2V Situational Awareness Summary table for message criteria.

Message or Alert	Issue Criteria
Truck Parking Notification	• Truck Parking TIM is received from an RSU or satellite.

Message or Alert	Issue Criteria
Road Closure Notification	• Road Closure TIM is received from an RSU or satellite.
Speed Limit Notification	• Speed Limit TIM is received from an RSU or satellite.
No High Profile Vehicle Notification	• No High Profile Vehicle TIM is received from an RSU or satellite.
No Light Trailer Notification	• No Light Trailer TIM is received from an RSU or satellite.
Chain Require Notification	• Chain Requirement TIM is received from an RSU or satellite.

3.2.3.3.4 Application Design Description

The Commsignia group is responsible for the design of this application.

3.2.3.3.4.1 Description of Operations/Driver Interface with illustrations

Figure 3-41 shows the driver interface for the I2V Situational Awareness notification.

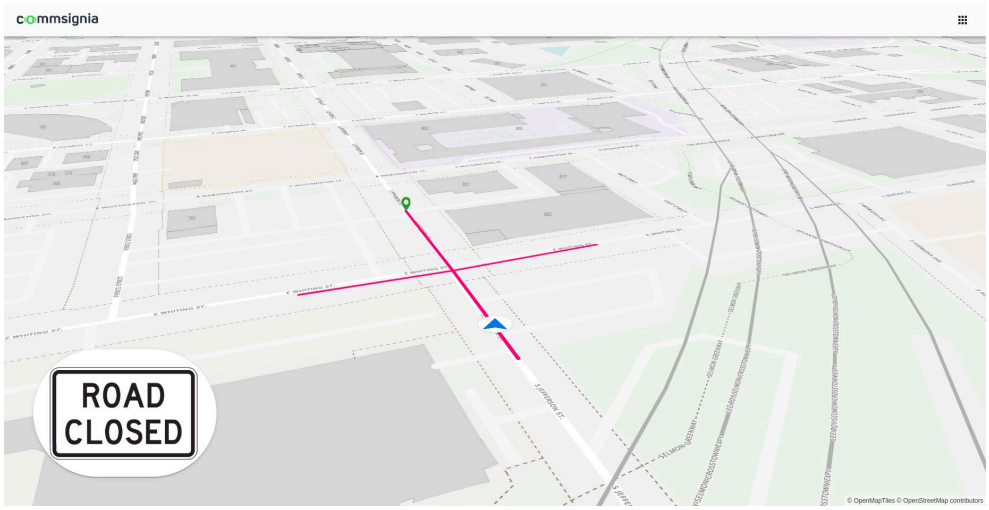


Figure 3-41. Road Closure Notification.
Source: WYDOT

3.2.3.3.4.2 Description of Maintenance User Interface with illustrations

This application does not contain a maintenance user interface.

3.2.3.3.5 Requirements Traceability

The following requirements are applicable to this component and met by this design:

- VS-REQ-11 SA TIM-Advisories
- VS-REQ-12 SA TIM-Speed Limit
- VS-REQ-13 SA TIM-Exit Services
- VS-REQ-14 SA TIM-Region
- I2VSAP-REQ-4 Message Display Geofence Beginning

3.2.3.3.6 ICD Traceability

The following interfaces are applicable to this component and its design. A reference to the location of the interface within the ICD is also provided.

Interface	Action within Interface	Section No.
OBU <-> Vehicle Driver	OBU Interface with Vehicle Driver regarding non-DN	5.2.4
OBU <-> RSU	RSU Broadcasts TIMs which are received by OBUs	5.9.2
Satellite <-> OBU	Delivery of Traveler Information to Vehicles	5.24.1

3.2.3.4 OBU Forward Collision Warning

3.2.3.4.1 Function of the Application

This application exchanges current vehicle location and motion information with other vehicles in the vicinity, uses that information to calculate vehicle paths, and warns the driver when the potential for an impending collision is detected. Vehicle location and motion broadcasts are also received by the infrastructure and used by the infrastructure to support a wide range of roadside safety and mobility applications including variable speed limit support and situational awareness support. This application implements a broad range of features ranging from basic Vehicle Awareness where only vehicle location and speed are broadcast and provide no driver warnings to advanced integrated safety systems that may, in addition to warning the driver, provide collision warning information to support automated control functions that can support control intervention. The specific applications used will be based on vendor selection for OBU's, at a minimum all OBU's will support situational awareness.

3.2.3.4.1.1 Functions/Services Brief description

This application belongs to the class of V2V safety system. It generates Forward Collision Warnings (FCW) to assist the driver of a host vehicle (HV) of a possible forward collision with a remote vehicle (RV). The host vehicle is also called an Ego Vehicle (EV).

3.2.3.4.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

Figure 3-42 shows a graphical description of the communication between the vehicles for the Forward Collision Warning. Please note that infrastructure communication is not art of this application.

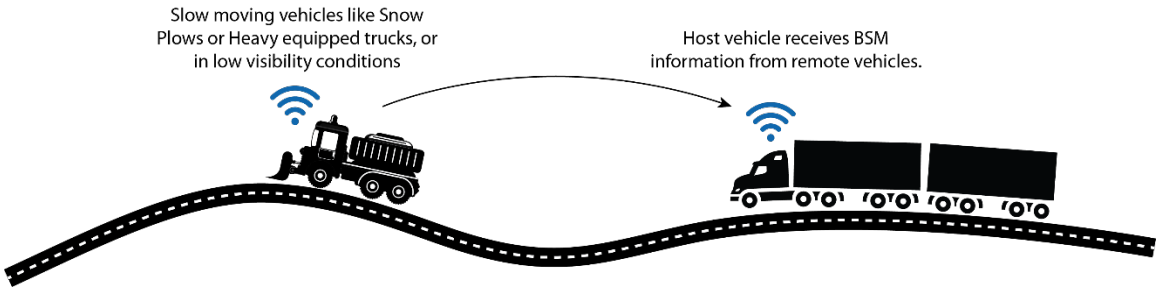


Figure 3-42. Forward Collision Warning Concept Diagram.
Source: WYDOT

3.2.3.4.1.3 Output Data/Message Flows

The only output flow from the FCW application is a generated alert to the HMI.

3.2.3.4.2 Developer & version number

This application is developed by the Commsignia team.

3.2.3.4.3 Application Message and Alerts Descriptions

This section describes the messages and alerts issued by the FCW application.

3.2.3.4.3.1 Descriptions and illustrations of messages and alerts issued by application

There are two levels of alert messages that are issued by the FCW application which include Advisory and Imminent.

The advisory alert is an advisory suggesting that there are chances of a collision with a vehicle ahead.

The imminent FCW alert s is generated when there is an imminent threat of forward collision with a vehicle ahead. Immediate action is required from the driver to avoid the collision when the imminent FCW alert is generated.

3.2.3.4.3.2 Describe algorithm to determine when messages and alerts are issued

FCW is generated when Ego Vehicle (EV) and Remote Vehicle (RV) are in same lane and the RV is in front of EV. Criteria for generating FCW is Time-To-Collision (TTC). If TTC is less than a threshold value then a FCW alert is generated. This threshold value is provided as a configuration parameter for the user to set.

3.2.3.4.3.3 Summary tables of criteria for issuing messages and alerts

Table 3-30 contains a summary of all alerts and messages issued to the user from the FCW application.

Table 3-30. Forward Collision Warning Alert Summary. (Source: Commsignia)

Message or Alert	Issue Criteria
FCW Alert	• TTC < threshold

3.2.3.4.4 Application Design Description

The Commsignia team is responsible for the application design of the Forward Collision Warning. The FCW application does not store any data within a database or by any other means.

3.2.3.4.5 Application Configuration Data

Table 3-31 describes all of the application configuration data for the FCW application.

Table 3-31. FCW Application Configuration Parameters. (Source: Commsignia)

Configuration Parameter	Description
TTC (time to collision)	The threshold (in seconds) for the FCW application to generate a warning trigger.
vMin (speed threshold)	The minimum speed threshold (in m/s) for the FCW application to generate a warning trigger. No warning is issued below this speed.
Targetlength (checking distance)	The threshold (in meters) for checking another vehicle in front of the ego vehicle that needs to be involved in FCW evaluation. Vehicles further away from the ego are excluded from the calculations.

3.2.3.4.6 Application User Interface(s)

This section describes what the user interface may look like for interactions with the FCW application. Please note that the user interface may change as more studies are done to determine the effectiveness of the current User Interface.

3.2.3.4.6.1 Description of Operations/Driver Interface with illustrations

Figure 3-43 shows a sample HMI screen shot for the advisory message from the Forward Collision Warning application.

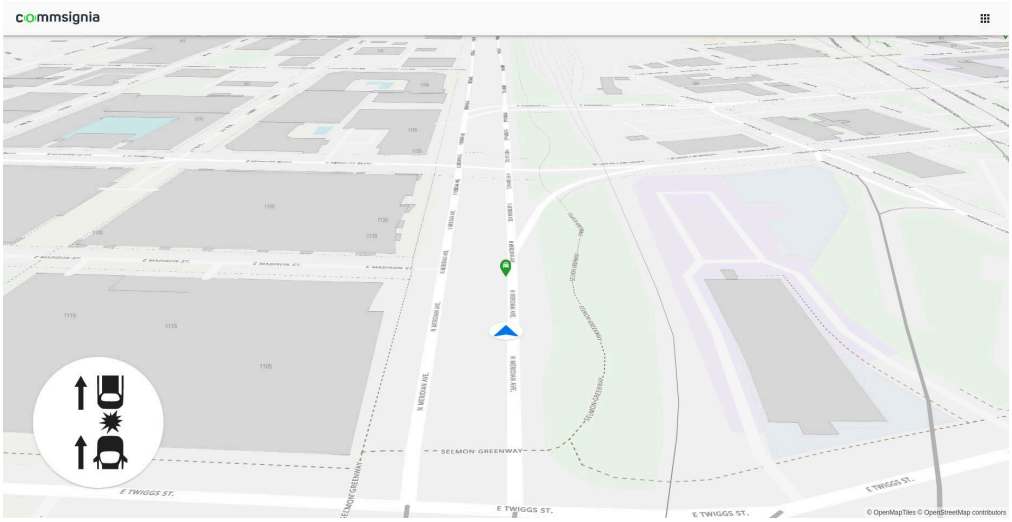


Figure 3-43. FCW Screenshot in Driving mode.
Source: Commsignia

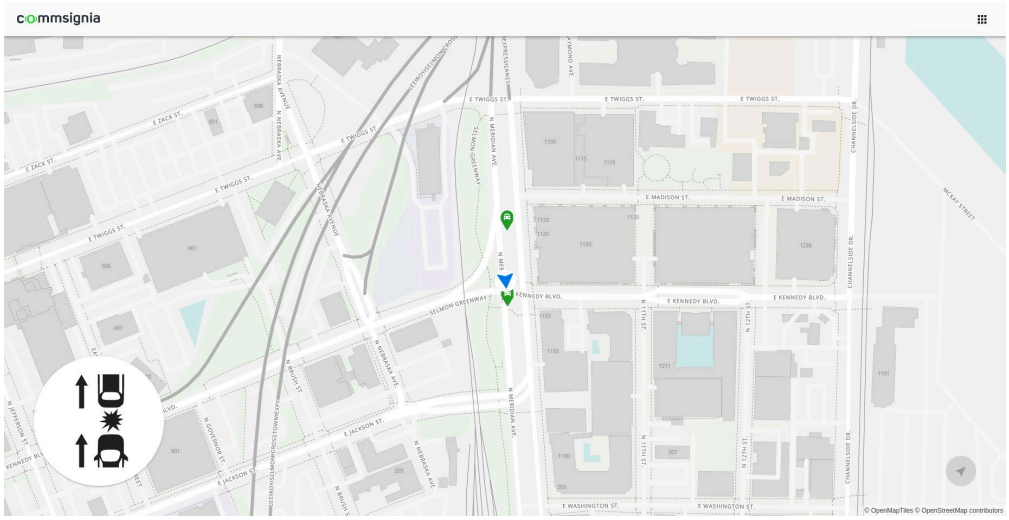


Figure 3-44. FCW Screenshot in Explore mode.
Source: Commsignia

3.2.3.4.6.2 Description of Maintenance User Interface with illustrations

There are no User Interface options.

3.2.3.4.7 Requirements Traceability

The following requirements are applicable to this component and met by this design:

- VS-REQ-6 FCW Stopped Vehicles
- VS-REQ-7 FCW Decelerating/Slow Moving Vehicles
- VS-REQ-8 FCW Stopped and Obstructed Vehicles
- VS-REQ-9 FCW Rear-End Crash
- VS-REQ-9.1 FCW Rear-End Crash in Straight Road
- VS-REQ-9.2 FCW Rear-End Crash in Curved Road
- VS-REQ-10 FCW No Warnings
- VS-REQ-10.1 Safely Following a Vehicle
- VS-REQ-10.2 Passing a Stopped Vehicle

3.2.3.4.8 ICD Traceability

The following interfaces are applicable to this component and its design. A reference to the location of the interface within the ICD is also provided.

Interface	Action within Interface	Section No.
OBU <-> OBU	Connected Vehicles broadcast and receive BSMs	5.1.1
OBU <-> Vehicle Driver	OBU Interface with Vehicle Driver regarding non-DN	5.2.4

3.2.3.5 OBU Vehicle Support Services

The following sections describe the design for the OBU Vehicle Support Services application.

3.2.3.5.1 Function of the Application

The sections below describe the functions of the Vehicle Support Services application.

3.2.3.5.1.1 Functions/Services Brief description

This application provides foundational functions that support data collection, management, and distribution. It coordinates with Object Registration and Discovery to acquire necessary communications information and prioritize data. It maintains the necessary security credentials, authorizations, and associated keys to support communications in the connected vehicle environment. This application also checks for updates of software (operating system, firmware, and applications) as well as configuration updates for existing applications that change log data collection frequency and event limits allowing for over the air updates. Additionally, this application will be used for log file transfers of environmental log data.

3.2.3.5.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

Figure 3-45 shows the highway communications for the OBU Support services application along the highway.

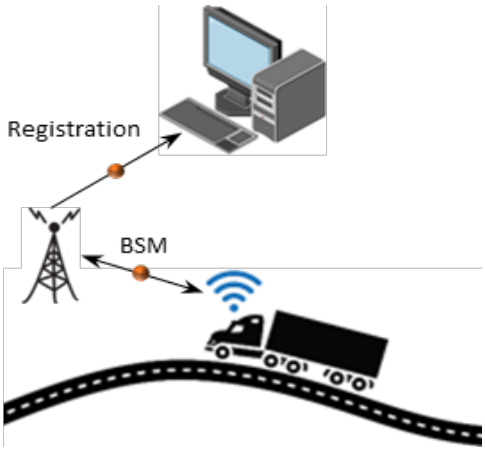


Figure 3-45. OBU Support Services Communications.
Source: WYDOT

3.2.3.5.1.3 Input Data/Message Flows

The OBU Vehicle Support Services input flows consist of new SCMS certificates from the SCMS service and firmware updates. The SCMS certificates retrieved from the SCMS system use the RSU as a router to the SCMS system. The updates for the OBU firmware shall be retrieved through the RSU via a proprietary solution from Commsignia. Figure 3-46 shows the data flows between different network elements to enable IP connectivity for different services (modules and functions shown are defined in section 3.2.3.5.4).

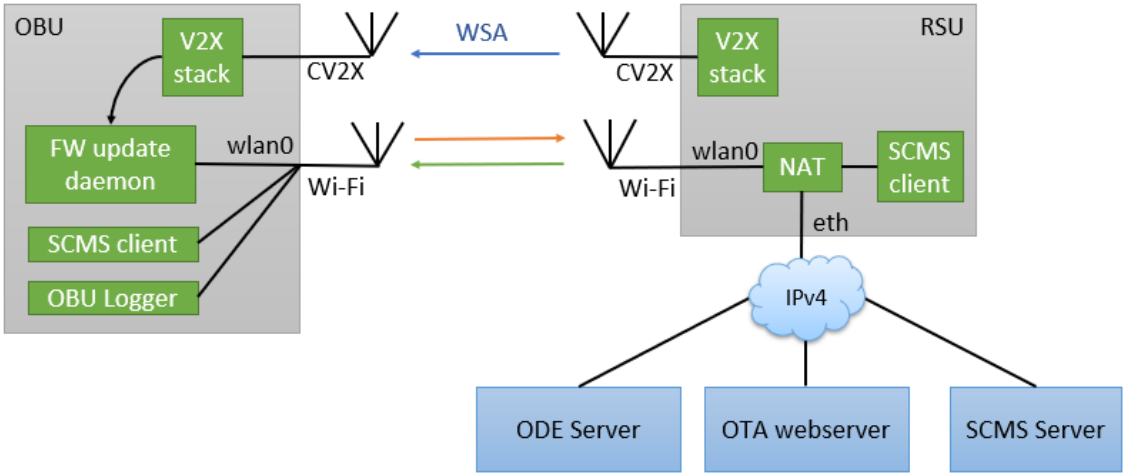


Figure 3-46. Vehicle Support Services Data Flows.
Source: Commsignia

3.2.3.5.1.4 Output Data/Message Flows

The output flows for the OBU Vehicle Support Services application consist of log file transfers from the OBU to the ODE server. Log files from the OBU are transferred to the ODE through a WiFi AP (which can be configured on the RSU itself).

3.2.3.5.2 Developer & version number

The Commsignia application development team is responsible for the development of this application.

3.2.3.5.3 Application Message and Alerts Descriptions

There are no messages or alerts issued by this application.

3.2.3.5.4 Application Design Description

The following sections describe the design of the OBU Support Services application.

3.2.3.5.4.1 Schematic of major modules/functions

Figure 3-46 shows a schematic of the major modules/functions for the OBU Support Services application.

3.2.3.5.4.2 Description of modules/functions

FW update daemon: This background service starts upon boot and runs continuously on each Commsignia OBU. It is responsible for initiating download of new OBU firmware once the OBU established connection with the OTA server via Wi-Fi. Connection setup is controlled by Wireless Access in Vehicular Environments (WAVE) Service Advertisement (WSA) message sending from the RSU that triggers the OBU Wi-Fi to be switched from AP mode (serving the HMI app on a tablet) into client mode connecting to the Wi-Fi hotspot provided by the RSU (alternatively a separate hotspot can be configured).

Logging Functionality: The **OBU Logger module** is responsible for data collection and transmission of Event Logs. Data Collection and transmission is configurable but will have the following settings for the pilot project:

- Log all alerts that were not given because of a higher priority alert.
  - Location, time, alert (FCW, TIM)
- BSM once every 30 seconds
  - Add time to each record for all BSMs (from 1609.2 header).
- BSMs for event (10 seconds before, event, 10 seconds after all at 10 Hz) (purge first)
  - Driver alert
  - Received BSMs from remote vehicle(s), also record host vehicle BSMs.
  - Add time to each record for all BSMs (from 1609.2 header).
- Received messages
  - TIMs from RSU and Satellite, message, location, method of reception (Sat/RSU) and time, only log messages within 20-mile radius and only log first time message is received.
- Environmental Log
  - Location, time, environmental log
  - Second priority for sending this log
- OBU upgrades
  - Log success/fail of firmware updates
  - Log availability of firmware updates
- SCMS
  - Log connections to SCMS (top-up)
- System log
  - Boot and shutdown location/time
  - Application errors and re-starts
- OBU unique identifier

Logs will be kept under 100kb in size. Each log file will have a file name with integrated time/date stamp (time of log file creation), IPv6 OBU address and type of log (type_millisecondsUTC_IPv6address.gzip). Log types will include Driver_Alert, BSM_30Second, BSM_Event, Received_Message, Environmental, RSU_BSM. Each log file will be zipped (gzip) and protected with private key (ODE will keep all public keys using SSH key not SCMS). Time for log files

will be in UTC in 1 millisecond from UNIX epoch (this time will be from the logging OBU system time sync'd to GPS, so not from the 1609.2 header based approach from the generating system security header). All TIMs and BSMs that are logged need to have signatures validated and the log file needs to note if the validations passed or failed (for RSUs and OBUs). Logs will be deleted if over 7 days old. Logs will have the purge order defined below for automated purging by OBU firmware to protect storage:

- Logs will be deleted after they are sent to ODE
- Logs will be retained through reboots

SCMS Certificate Management: All certificates downloaded through the SCMS client follow the design detailed in the SCMS Wiki (https://wiki.campllc.org/display/SCP/SCMS+CV+Pilots+Documentation). SCMS server connection establishment and secure data reception from servers are using TLS1.2. Certificates are stored locally on the OBU flash drive.

3.2.3.5.4.3 Diagram of process flow/algorithms between major modules/functions
Figure 3-46 show the process flow among the different components of the major modules/functions for the OBU Vehicle Support services application among different network elements (OBU, RSU, WiFi AP, Servers).

3.2.3.5.5 Requirements Traceability
The following requirements are applicable to this component and met by this design:

- LTS-REQ-4 VS LTS Time
- LTS-REQ-5 VS LTS Time Standard
- LTS-REQ-6 VS LTS Location
- VS-REQ-35 BCVI General Broadcast Requirements **Phase 4 will not include the broadcast of traveler information.**
- VS-REQ-36 Transmit Data **Phase 4 shall not use DSRC and should test Wi-Fi.**
- VS-REQ-36.1 Transmit Environmental Data **Phase 4 will not include transmitting of environmental data.**
- VS-REQ-36.2 TVI Data Management-Log **Phase 4 should transmit logs via Wi-Fi.**
- VS-REQ-49 Architectural
- VS-REQ-50 Safety Communication

3.2.3.5.6 ICD Traceability
The following interfaces are applicable to this component and its design. A reference to the location of the interface within the ICD is also provided.

Interface	Action within Interface	Section No.
ODE <-> OBU	OBU Copies Log File to ODE	5.16.1
	ODE Updates OBU Firmware OTA	5.16.2

3.2.3.6 OBU Vehicle Trust Management

The following sections describe the design for the OBU Vehicle Trust Management application.

3.2.3.6.1 Function of the Application
The sections below describe the functions of the Vehicle Trust Management application.

3.2.3.6.1.1 Functions/Services Brief description

This application manages the certificates and associated keys that are used to sign, encrypt, decrypt, and authenticate messages. It communicates with the Security and Credentials Management System through the RSU Trust Management application to maintain a current, valid set of security certificates and identifies, logs, and reports events that may indicate a threat to the Connected Vehicle Environment security.

3.2.3.6.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

Figure 3-47 illustrates highway communications for the OBU Trust Management application.

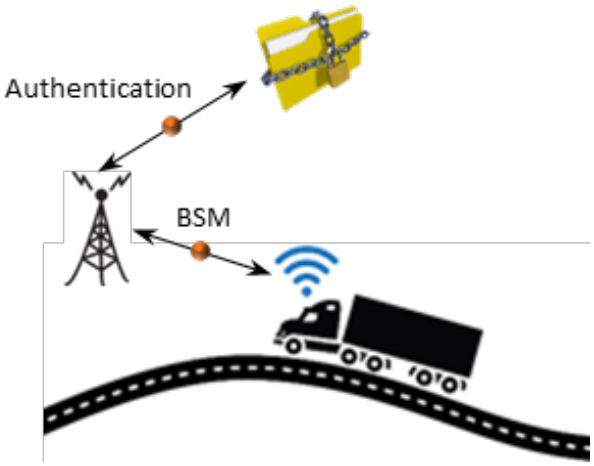


Figure 3-47. OBU Trust Management highway communications.
Source: WYDOT

3.2.3.6.1.3 Input Data/Message Flows

Input flows for the OBU Trust management application include inputs from the OBU Support Services application for SCMS certificates that will allow this application to sign BSM and TIM messages broadcast from the OBU. Unsigned BSM and TIM messages are also inputs to the OBU Trust Management application. Figure 3-48 shows the data flows for the Vehicle Trust Management application between the Secure Data Exchange Entity (SDEE) application and the SDEE library used for trust management.

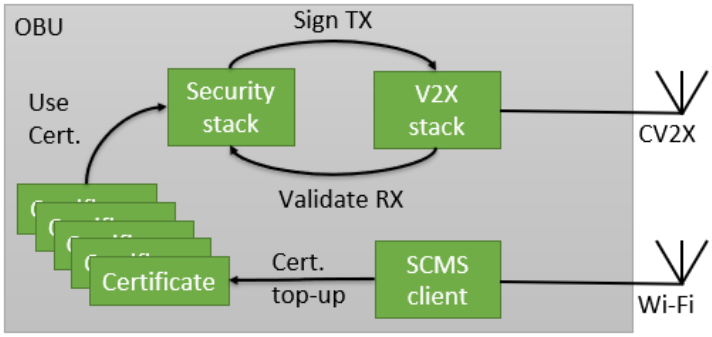


Figure 3-48. OBU Trust Management process flows.
Source: Commsignia

3.2.3.6.1.4 Output Data/Message Flows
Output from the OBU Trust Management application includes signed BSM and TIM messages.

3.2.3.6.2 Developer & version number
The Lear application development team is responsible for the development of this application.

3.2.3.6.3 Application Message and Alerts Descriptions
There are no messages or alerts issued by this application.

3.2.3.6.4 Application Design Description
The sections below describe the OBU Trust Management application design.

3.2.3.6.4.1 Schematic of major modules/functions
See Figure 3-48 for a schematic of the process flow between SDEE applications and the SDEE library. The SDEE library is the only major module defined for the OBU Trust Services.

3.2.3.6.4.2 Description of modules/functions
Each Messaging application defined on the OBU such as (BSM, SPAT, MAP, TIM) should use the flow in Figure 3-46, to register with the SDEE module. This allows the application the ability to use the security services.

3.2.3.6.4.3 Diagram of process flow/algorithms between major modules/functions
Figure 3-46 shows the process flow diagrams for applications signing and validating messages.

3.2.3.6.4.4 Descriptions of process flow/algorithms between major modules/functions
The following is the process flow for applications to sign and validate messages with the Security stack.

1. Registration
Applications are required to register with the security services.

2. Signing/Verification
a. Creates 1609.2 signed payload using ECDSA algorithm. A ContexthandleID is passed to identify the registered application uniquely with a signed payload. If a Bypass argument is specified in the call set, then an unsecured payload will be created (i.e., the signing operation is bypassed).
b. Verifies the signed payload. A ContexthandleID is passed to identify the registered application uniquely with the verified payload. If a Bypass argument is in the call set, then verification operations will be bypassed.

3. Certificate Change
A certificate change request can be triggered by the application at an appropriate time interval. This triggers the certificate change completion callback after certificate changes have been successfully completed.

4. Unregister
The call removes the registered information with the SDEE module and all context and resources allocated will be freed up.

3.2.3.6.5 Requirements Traceability
The following requirements are applicable to this component and met by this design:

- SCMS-REQ-2 Vehicle System SCMS Use **Phase 4 will use the ISS SCMS.**

- SCMS-REQ-2.1 SCMS Vehicle System Certificates **Phase 4 will use the ISS SCMS.**
- SCMS-REQ-2.2 SCMS Vehicle System Misbehavior Reporting **This is outside the scope of Phase 4.**
- SCMS-REQ-2.3 SCMS Vehicle System Certificates Revocation List (CRL) **This is outside the scope of Phase 4.**
- SCMS-REQ-2.4 SCMS Vehicle System Rejection **This is outside the scope of Phase 4.**

3.2.3.6.6 ICD Traceability
The following interfaces are applicable to this component and its design. A reference to the location of the interface within the ICD is also provided.

Interface	Action within Interface	Section No.
ODE <-> OBU	OBU Device Enrollment (Bootstrapping)	5.13.1
	OBU Pseudonym Certificate Provisioning	5.13.2
	OBU Security Policy and Networking Information	5.13.3
	OBU Misbehavior Reporting	5.13.4
	OBU Security Credential Revocations	5.13.5
Satellite <-> OBU	Delivery of Latest Certificate Revocation List to Vehicles	5.24.2

3.2.4 Mobile Applications Design

3.2.4.1 WYDOT 511 integration (Android & iOS)

The section describes the design of the 511 app updates for the CV Pilot project.

3.2.4.1.1 Function of the Application
This application provides drivers with personalized traveler information including traffic and road conditions, transit information, maintenance and construction information, multimodal information, event information, and weather information. The provided information is tailored based on driver requests. Both one-time requests for information and on-going information streams based on a submitted traveler profile and preferences are supported. This application will be extended to support updated data feeds available from the CV project such as work zone warnings, road weather advisories, SPOT Weather impacts, and parking availability. Users of the application will be able to subscribe to these data feeds based on their location. Additionally, the app will be updated to allow for users to submit information on truck parking availability for parking locations.

3.2.4.1.1.1 Functions/Services Brief description
Functions and services that this application will provide as enhancements to the 511 app include additional CV sourced road condition information and a crowd sourced truck parking availability and reporting feature. The additional CV sourced road condition information will be included in the current road condition feed so no development will be required for this enhancement.

3.2.4.1.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway
This application is not directly involved in any vehicle/infrastructure communications on the highway.

3.2.4.1.1.3 Input Data/Message Flows
Input data for the 511 App updates include CV Sourced road condition information including road closures, spot weather impact warnings, and truck blow over warnings. The other input flow included

is truck parking availability information for truck parking locations along I-80. Figure 3-49 shows the CV related 511 app message flows.

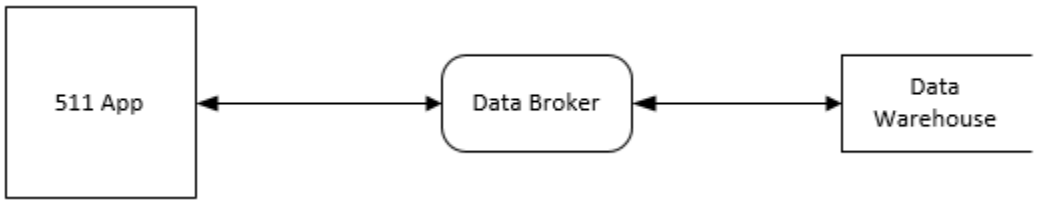


Figure 3-49. 511 App Message Flows.
Source WYDOT

3.2.4.1.1.4 Output Data/Message Flows
Output data from the 511 app includes truck parking availability data. 511 App users will be able to select form a list of available options to describe the current parking availability at a truck parking location. Users will be able to submit this data to the WYDOT TMC for review and posting of updated data so other truckers can tell how many spaces are available at upcoming truck parking locations. Figure 3-49 shows the output flow of the parking 511 app to the Data Broker and on to the Data Warehouse for review by the TMC.

3.2.4.1.2 Developer & version number
The Timmons development group is currently planned as the development team for this application.

3.2.4.1.3 Application Message and Alerts Descriptions
Messages and alerts issued by this application are described in the sections below.

3.2.4.1.3.1 Descriptions and illustrations of messages and alerts issued by application
Table 3-32 describes the messages and alerts of the CV enhancement issued by the 511 application.

Table 3-32. 511 App Alerts and Descriptions

Message or Alert	Communication Method	Description
Unable to upload parking availability	Http Response	• Error: “Unable to submit truck parking availability”

3.2.4.1.3.2 Describe algorithm to determine when messages and alerts are issued
Unable to upload parking availability
This error is displayed to the user when a user attempts to submit truck parking availability and is unsuccessful. The application will attempt to connect to the Data Broker REST service for parking submissions. If there is no internet connectivity, the service is unresponsive, or the service returns and error upon submission this message is displayed to the user requesting they try again in a little while.

3.2.4.1.3.3 Summary tables of criteria for issuing messages and alerts
Table 3-33 contains a summary of information for criteria to submit messages/alerts for the 511 app.

Table 3-33. 511 App Messages/Alerts Criteria Summary

Message or Alert	Issue Criteria
Unable to upload parking availability	• No internet connectivity is found • The Data Broker is unresponsive • The Data Broker returns an error upon submission

3.2.4.1.4 Application Design Description

The sections below describe the 511 app design for truck parking availability enhancements

3.2.4.1.4.1 Schematic of major modules/functions

Figure 3-50 shows the major module that will be created for the 511 application.

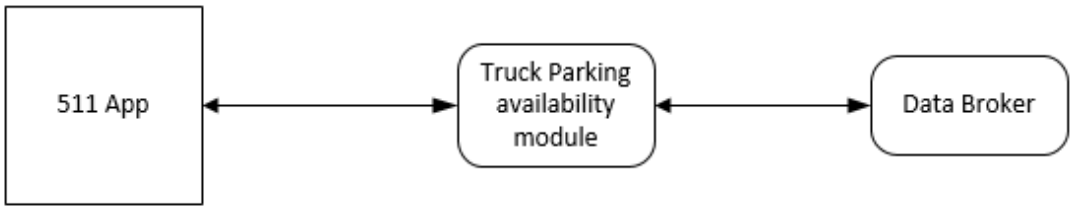


Figure 3-50. Major Truck Parking Availability modules/functions.
Source WYDOT

3.2.4.1.4.2 Description of modules/functions

The only major module that will be created for the 511 app is the truck parking availability module. This module will be responsible for handling the user interface and the submission of the truck parking availability to the WYDOT Data Broker service. It will also be responsible for handling any errors that are returned from the Data Broker service.

3.2.4.1.4.3 Diagram of process flow/algorithms between major modules/functions

Figure 3-50 shows the process flows between the major updated modules/functions within the 511 app and the WYDOT Data Broker REST service.

3.2.4.1.4.4 Descriptions of process flow/algorithms between major modules/functions

The process flow for truck parking availability submissions will be as follows. The map within the app will add a layer for truck parking sites. Users will be able to toggle the layer on/off from the layer menu within the map view of the app. Once the layer is toggled on truck parking locations will be visible within the map as icons located along the roadway. Clicking on the icon will allow the user to view basic information regarding the parking area including total number of parking spaces, last know availability, images (if a web cam is available), and an option to submit updated availability information. If the user selects the option to submit an updated availability, then a short for would come up allowing the user to select an availability option from a list of options (spaces available, only a few spaces available, full parking lot). After a user submits the data, it is then submitted to the WYDOT Data Broker service for storage, validation, and processing by the TMC.

3.2.4.1.5 Application Data Tables

The sections below describe the input and output data for the 511 app.

3.2.4.1.5.1 Input data description tables

Table 3-34. Input Truck Parking availability data for the 511 App shows the input data for the truck parking enhancements on the WYDOT 511 App.

Table 3-34. Input Truck Parking availability data for the 511 App.

Data Name	Type	Description
Parking Name	String	A unique valid name for each truck parking location
Latitude	Double	The latitude of the truck parking location
Longitude	Double	The longitude of the truck parking location
Availability	String	The last reported truck parking availability
Total Spaces	Int	The total number of parking spaces for the location
Cam Images URL	String	The URL to the cam images for the parking area
Parking ID	Int	The Parking area identifier

3.2.4.1.5.2 Output data description tables

Table 3-35. Output Truck Parking availability data for the 511 App shows the output data for the truck parking enhancements on the WYDOT 511 App.

Table 3-35. Output Truck Parking availability data for the 511 App.

Data Name	Type	Description
Parking ID	Int	The truck parking area unique identifier
Availability	String	The user submitted parking availability

3.2.4.1.5.3 Data/database storage description diagrams and tables

The database storage for this application will extend the data tables currently in use by WYDOT (i.e., 1 new field will be added to the parking area table within the WYDOT database.

3.2.4.1.6 Application Configuration Data

No additional configuration data is needed for this application.

3.2.4.1.7 Application User Interface(s)

The following mockups represent initial design ideas for the 511 app enhancements. Please note that these mockups may be changed to improve the look and feel as well as the usability of the app.

Figure 3-51 is a mockup of the user's ability to select a new Truck Parking layer from the Map options menu.

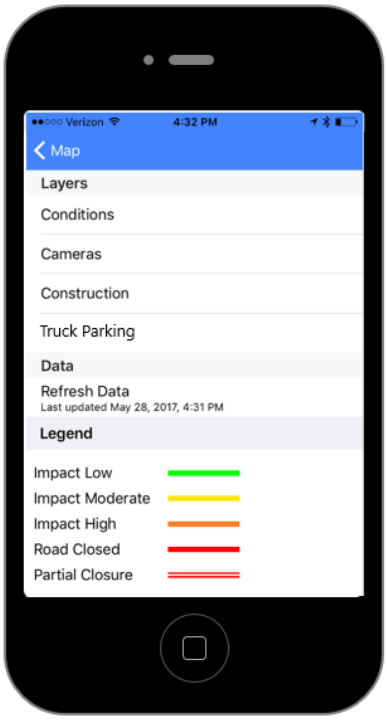


Figure 3-51. Select Truck Parking Layer.
Source WYDOT

Figure 3-52 shows the parking details that should be displayed to a user after clicking on a parking area.

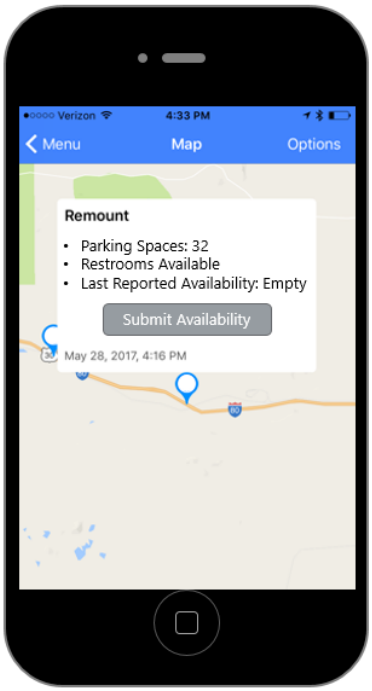


Figure 3-52. View Parking Details.
Source WYDOT

Figure 3-53 shows what the potential user interface for submitting a truck parking availability report to WYDOT would look like.

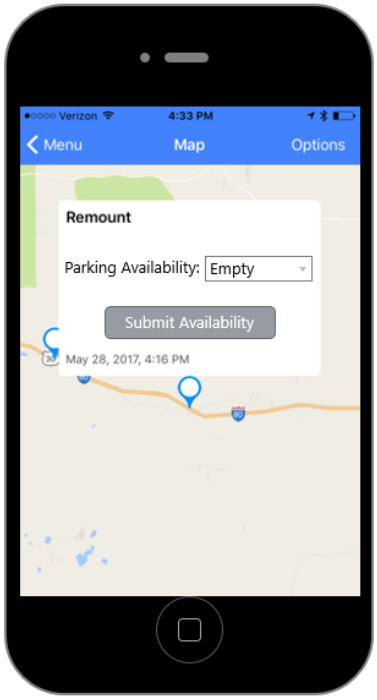


Figure 3-53. Truck Parking Availability Submission.
Source WYDOT

3.2.4.1.7.1 Description of Operations/Driver Interface with illustrations
This application contains no driver interface operations.

3.2.4.1.7.2 Description of Maintenance User Interface with illustrations
This application contains no maintenance interface operations.

3.2.4.1.8 Requirements Traceability
The following requirements are applicable to this component and met by this design:

- 511-REQ-1 511App Parking Data Collection
- 511-REQ-1.1 Availability
- 511-REQ-1.2 Default
- 511-REQ-1.3 Time
- 511-REQ-1.4 Location
- 511-REQ-1.5 Protocol
- 511-REQ-1.6 Schema
- 511-REQ-2 Timeframe

3.2.4.1.9 ICD Traceability
The following interfaces are applicable to this component and its design. A reference to the location of the interface within the ICD is also provided.

Interface	Action within Interface	Section No.
CMV Driver PID <-> Vehicle Driver	Vehicle Driver Enters Parking Data into PID	5.6.1
CMV Driver PID <-> WYDOT 511 System	CMV Driver PID Sends Parking Data to WYDOT 511 System	5.7.1

3.2.4.2 Vehicle Messaging Display/Interface (HMI Design)

The following sections describe the design for the Vehicle Messaging Display/HMI application.

3.2.4.2.1 Function of the Application

The sections below define the functionality for the HMI app.

3.2.4.2.1.1 Functions/Services Brief description

This application will provide a hands-free and eye-free interface setting for drivers to display information related to an upcoming warning. The exact specifics of the interface will be determined by available products that comply with the hands-free and eyes-free requirements. This application will be capable of audio and visual alerts as well as displaying different messages to drivers including hazardous weather advisories, local variable speed limits, incidents, SPOT weather advisories, road closures, and other information deemed necessary for drivers to consider while driving through the I-80 corridor. Though this application will be deployed in pilot vehicles it will be built using a mobile development platform.

The User Interface (UI) for the HMI is designed to be user friendly and consistent in display and layout. Part of this design includes adequately designed icons. User-friendly designed icons can influence a human machine interface positively in several ways: First, they can be found and recognized quicker, they need much less space than text, they are more memorable, and are not bound to a specific language. If the meaning of the respective icons is not obvious and captured entirely, an increasing error rate could result. For icons as part of an in-vehicle driver information or assistance system, the most important criteria are task adequacy, self-descriptiveness, conformity to expectations, and learning supportiveness.

For each content (alert, warning or information), three colors are used to convey importance (red, yellow and grey respectively). Also, widely used traffic icons have been reused in order to represent the information on the HMI so that the Driver can easily recognize the meaning of the content.

Along with displaying information to drivers the HMI app is also used as a mechanism for drivers to input details of any trailers the driver may be towing along with basic information on those trailers.

3.2.4.2.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

This application does not involve any direct communications along the highway.

3.2.4.2.1.3 Input Data/Message Flows

Inputs to the HMI app include messages and alerts generated by the OBU. Once a message or alert is received it is processed within the HMI app and then sent as output to the user interface.

3.2.4.2.1.4 Output Data/Message Flows

The HMI Frontend block displays TIM messages as well as alerts after receiving data from the OBU device. Display of the messages are done appropriately based on their priority and the user

preferences. Designated layout and icons are shown on the user interface to provide the user with the necessary information.

3.2.4.2.2 Developer & version number

The Commsignia Application Development Team is responsible for the development of this application.

3.2.4.2.3 Application Message and Alerts Descriptions

A vehicle with an active Commsignia app connected with On-Board Unit will display Host Vehicle Speed and all the Remote Vehicles (RV's) and/or Road Side Units (RSU's) which are transmitting the SAE J2735 safety messages, within the specified range of the DSRC radio of the On-Board Unit.

The entire HMI user interface has been divided into multiple blocks. Figure 3-54 displays the different blocks of the application:

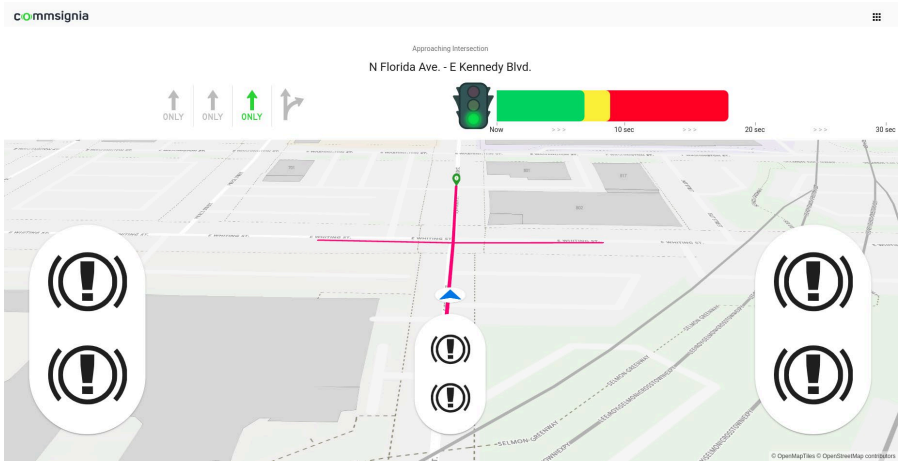


Figure 3-54. HMI Display Blocks.
Source: Commsignia

3.2.4.2.3.1 Descriptions and illustrations of messages and alerts issued by application

V2V Block (Vehicle to Vehicle) This block is designed to alert the automotive vehicle driver when one or more vehicles are approaching and/or are in the vicinity of the automobile. The driver of the vehicle will be made aware of one or more approaching vehicle from any direction and at multiple distances. The location of these warnings is configurable, so the user can decide whether V2V warnings shall show up on the left or right side of the screen (but they must not be configured to the same side as the V2I warnings for proper separation of safety and informational messages).

This block is divided into layers each displaying certain components.

Vehicle Display block

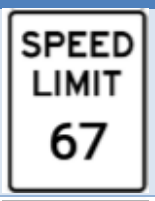
- Vehicle position indicator showing heading with a triangle shaped arrow
- Lane / trace markings on the live map
  - Displayed over the map tiles
  - Show the TIM traces on the map
- EV (host vehicle) and RV (remote vehicles):
  - Host vehicle is displayed with a blue triangle inside a white circle
  - RVs are displayed with green markers on the live map

V2I Block (Vehicle to Infrastructure)

The icons displaying V2I information are shown at relevant locations which can be configurable so the user can decide whether V2I warnings shall show up on the left or right side of the screen.

The icons are displayed in a static manner, see Table 3-36.

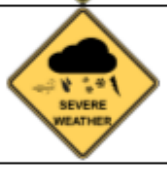
Table 3-36. V2I (Left Block) display icons.

IT IS Code	Description	Icon
NA	MAP message containing Speed Limit for the lane in which the host vehicle is in.	
7712 followed by 268	ADVISORY_SPEED SPEED_LIMIT	

- Top of the screen:
  - Traffic signal with traffic signal bar (with respective colors of the current signal state and the bar length decreasing with the remaining time counting down similar to a status bar).
  - Allowed maneuvers for each lane when the vehicle approaches an intersection (based on the received MAP message).
  - Matched lane (based on the received MAP message and the current vehicle position coming from the GPS).
  - These visual indicators only appear when the vehicle enters into an ingress lane for a received MAP message, at an intersection.

The icons will be displayed on either side of the Traffic Signal Space (Table 3-37).

Table 3-37. Traffic Information Icons and Codes (V2I Right Block).

ITIS Code	Description	Icons
13609	RIGHT_CURVE	
5127	STRONG_WINDS	
2575	LENGTH_LIMIT	
13610	LEFT_CURVE	
513	ACCIDENT	
532	STALLED_VEHICLE	
4865	SEVERE_WEATHER	
8230	OVERPASS	Combined with vehicle restrictions
1025	ROAD_CONSTRUCT	Combined work zone

ITIS Code	Description	Icons
1028	CONSTRUCT_WORK	
777	REDUCED_ONE_LANE	
771	CLOSED_AHEAD	
12299	WORKZONE	
2573	WIDTH_LIMIT	
5378	FOG	
769	CLOSED_TO_TRAFFIC	
2574	HEIGHT_LIMIT	

ITIS Code	Description	Icons
5906	ICE	
2568	NO_TRAILERS	
6148	CHAINS_REQUIRED	
4868	SNOW	
4885	RAIN	

- Miscellaneous (Table 3-38 and Table 3-39)
  - Includes information like parking, trailer info, etc.… (Either side of the HMI screen based on V2I warning configuration)

Table 3-38. Miscellaneous ITIS *Codes* and Information

ITIS Code	Description	Icons
11064	EMERGENCY	Text only
11030	EVACUATION	Text only
8468	EVACUATION_ROUTE	Text only
8467	EMERGENCY_SNOW_ROUTE	Text only

Table 3-39 Miscellaneous ITIS Codes and Information

ITS Code	Description	Icons
4120	PARKING	
4104	FEW_SPACES_AVBL	Combine with parking

ITS Code	Description	Icons
9227	TRUCK	Combine with parking

3.2.4.2.3.2 Describe algorithm to determine when messages and alerts are issued
Messages and alerts are displayed on the HMI after they are received from the OBU device.

3.2.4.2.4 Application Design Description
The HMI is primarily responsible for receiving and displaying alerts and warnings delivered via a TIM appropriately.

3.2.4.2.5 Application Configuration Data
The HMI configuration is stored on the tablet device and can be accessed from the UI of the HMI application under the Settings menu. All safety notification settings (e.g.: FCW) and informational notifications (TIM based) are configured with a default set of notification rules and icon set as per WYDOT specifications. These settings can be changed later from the UI for example:

- Modifying the matching ITIS code sequence for a certain trigger
- Uploading custom icons and setting them for certain informational warnings

3.2.4.2.6 Application User Interface(s)

3.2.4.2.6.1 Description of Operations/Driver Interface with illustrations
Forward Collision Warning (FCW): Forward Collision Warning alerts you if an object in your path has suddenly stopped or slowed down, so you can react faster. FCW will significantly reduce the chance of a crash or a fatal accident. Figure 3-55 and Figure 3-56 show the forward collision warnings in action on the HMI. The HMI also provides an audio warning along with the configured FCW icon being displayed. This audio file can also be replaced with custom audio.

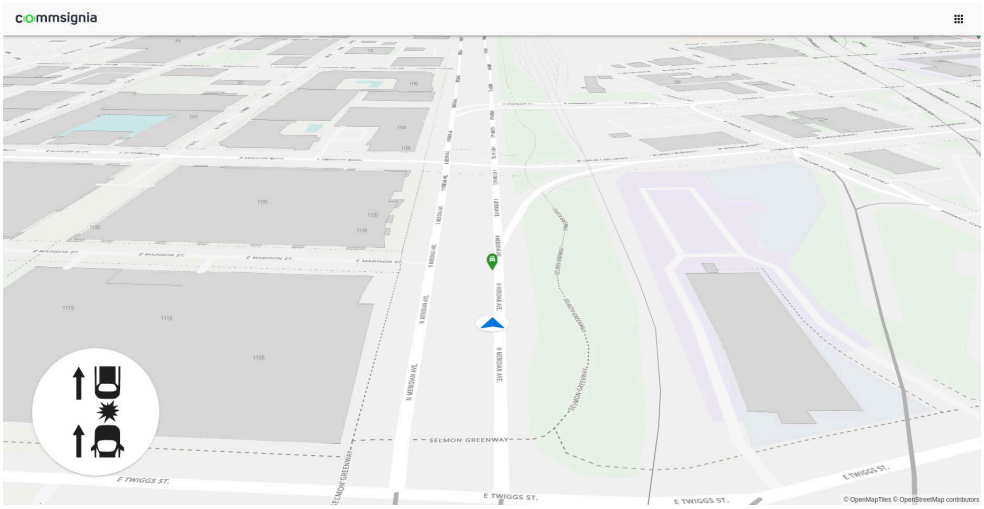


Figure 3-55. Forward Collision Warning (Driving mode).
Source: Commsignia

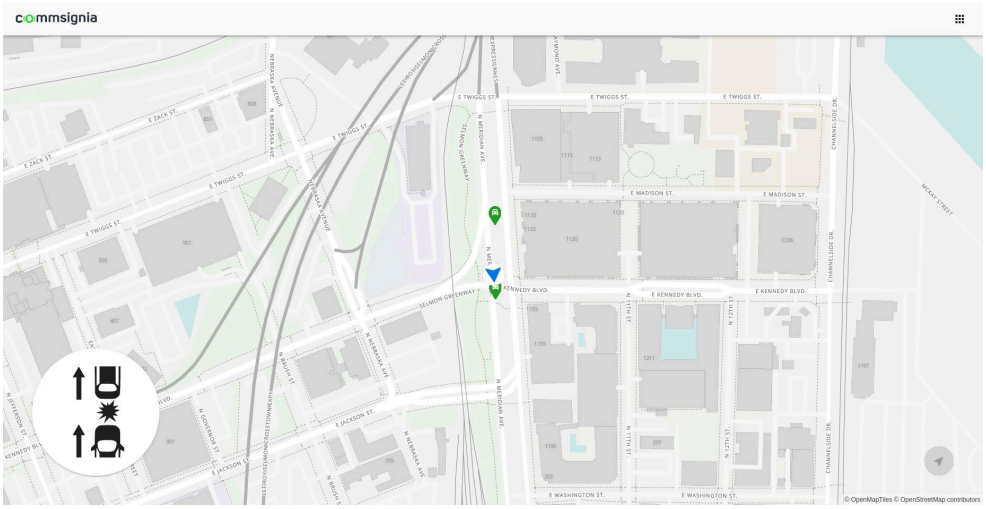


Figure 3-56. Forward Collision Warning (Explore mode).
Source: Commsignia

3.2.4.2.6.2 Description of Maintenance User Interface with illustrations

The HMI application enables a user set different HMI setting to influence how the HMI reacts to specific OBU safety warning.

Currently, the HMI home screen () contains the following buttons:

- Drive (more)
- Explore V2X (explore mode)
- Manage Locations (offline map download)
- Settings (HMI settings menu)

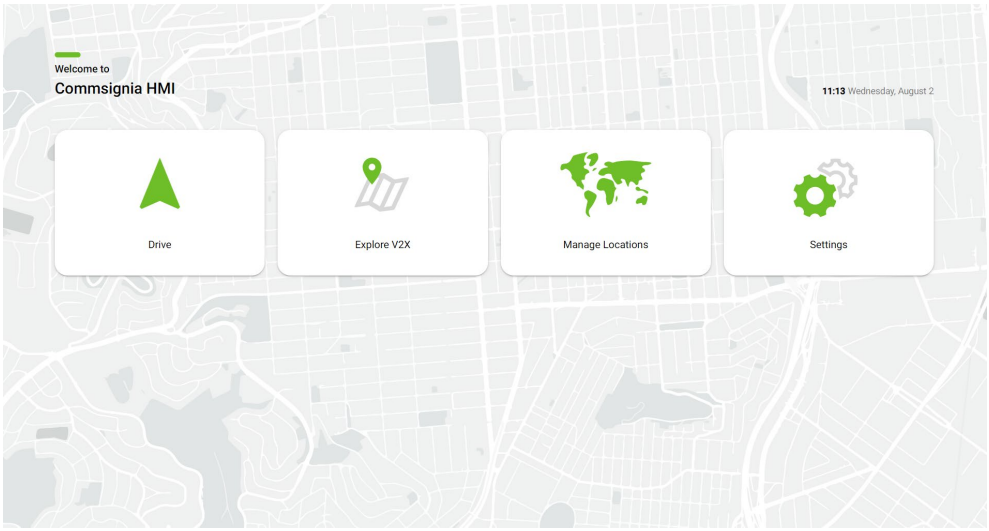


Figure 3-57. HMI Main Screen.
Source: Commsignia

Under the Settings menu, the following sub menus are available:

- General Connection Settings

- Account
- Diagnostics

- Driving Assistance
  - Safety notification rules
  - Road info notification rules
  - Entity notification rules
  - Icon library
  - Audio library

The HMI Connection settings can be found in the General connection settings menu. The tablet device must be connected to the OBU's Wi-Fi access point, and the OBU's default IPv4 address (assigned to the Wi-Fi interface) is configured by default in the OBU Address field as shown in Figure 3-58.

Further settings are available for the user account (e.g.: setting light/dark theme) and for diagnostic log collection under the corresponding sub-menus.

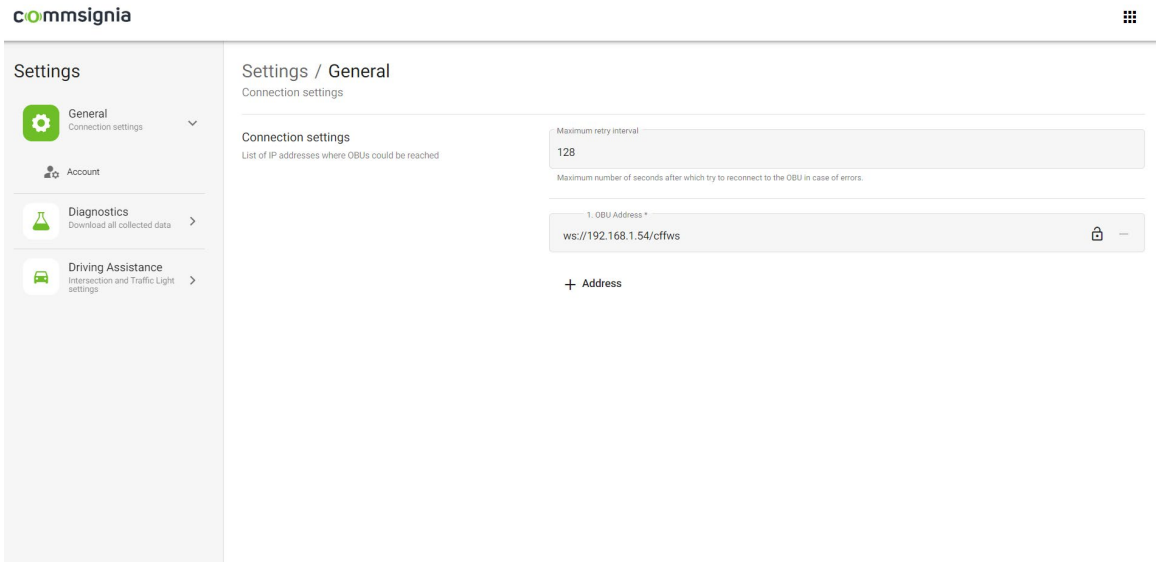


Figure 3-58. HMI OBU Connection Settings.
Source: Commsignia

FCW application settings can be modified in the Driving Assistance > Safety Notification Rules menu among all other supported safety application warnings.

The FCW safety warning related settings can be found in the list by scrolling down to the Forward Collision Warning field. Figure 3-59 shows the default screen with the Blind Spot Warning and Control Loss Warning settings being on the top of the list.

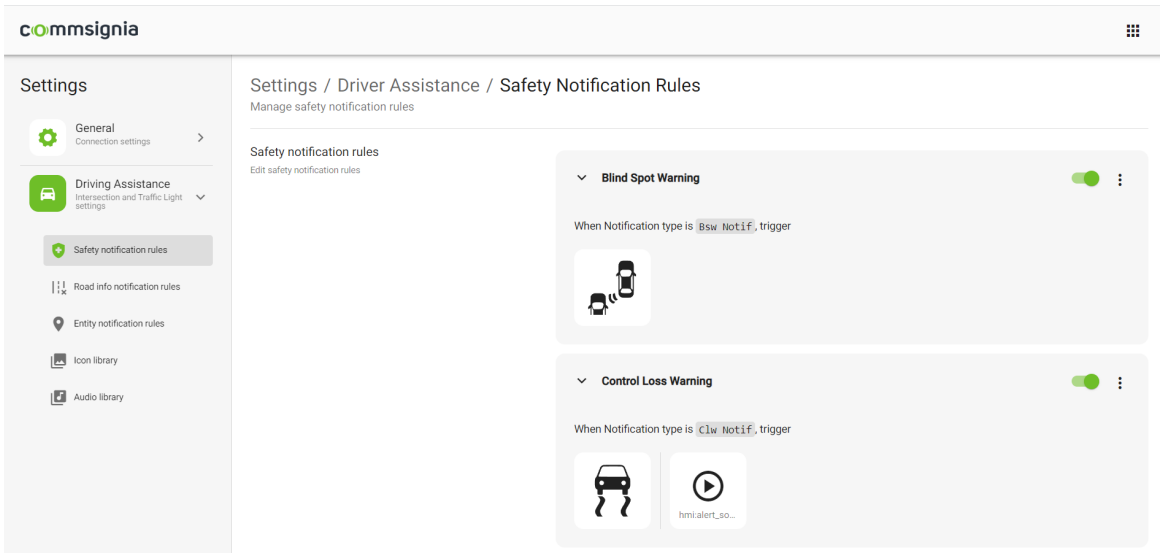


Figure 3-59. HMI FCW settings.
Source: Commsignia

3.2.4.2.7 Requirements Traceability

The following requirements are applicable to this component and met by this design:

- VS-REQ-4.2 Collect Dimension Data **Not part of Phase 4.**
- VS-REQ-4.2.1 Vehicle Dimension Data **Not part of Phase 4.**
- VS-REQ-4.2.2 Vehicle Trailer Data **Not part of Phase 4.**
- VS-REQ-16 Create Distress Notification **Not part of Phase 4.**
- VS-REQ-16.2 Driver-Generated Distress Notification **Not part of Phase 4.**
- VS-REQ-32 Human-Machine Interface
- VS-REQ-32.1 HMI-Location
- VS-REQ-32.2 HMI-Distraction
- VS-REQ-32.3 HMI-Readability
- VS-REQ-32.4 Visual and Auditory Interface
- VS-REQ-32.4.1 Visual Consistency
- VS-REQ-32.4.2 Audio Signals
- VS-REQ-32.5 Customizations
- VS-REQ-32.6 System Status
- VS-REQ-32.6.1 Power Status
- VS-REQ-32.6.2 System Settings
- VS-REQ-32.6.3 Application Availability
- VS-REQ-32.6.4 Pending Update Status
- VS-REQ-32.7 Distress Notification **Phase 4 will not include distress notification.**
- VS-REQ-32.8 Non-Distress Information **Phase 4 will not include non-distress information.**

3.2.4.2.8 ICD Traceability

The following interfaces are applicable to this component and its design. A reference to the location of the interface within the ICD is also provided.

Interface	Action within Interface	Section No.
CMV Driver PID <-> Vehicle Driver	Vehicle Driver Enters Parking Data into PID	5.6.1

4 Acronyms

The following table details the acronyms used in this document.

Table 4-1. Acronym List.

Acronym/ Abbreviation	Definition
ABS	Anti-lock Braking System
BSM	Basic Safety Message
DB	Data Broker
DW	Data Warehouse
CA	Construction Administration
CAN bus	Controller Area Network bus
ConOps	Concept of Operations
CRL	Certificates Revocation List
CV	Connected Vehicle
CVOP	Commercial Vehicle Operator Portal
CVRIA	Connected Vehicle Reference Implementation Architecture
DMS	Dynamic Message Signs
DN	Distress Notification
DOT	Department of Transportation
DSRC	Dedicated Short Range Communications
ESS	Environmental Sensor Station
FCW	Forward Collision Warning
FHWA	Federal Highway Administration
GIS	Geographic Information System
GPS	Global Positioning System
HMI	Human-Machine Interface
HSM	Hardware Security Module
I2V	Infrastructure-to-vehicle
I-80	Interstate 80
IC	Incident Console
ICD	Interface Control Document
IE	Independent Evaluator
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IRB	Institutional Review Board
ISO	International Organization for Standardization

Acronym/ Abbreviation	Definition
ITIS	Integrated Transport Information System
ITS	Intelligent Transportation System
LTS	Location and Time Service
MAP	Mapping for Intersection
MoU	Memorandum of Understanding
NCAR	National Center for Atmospheric Research
NWS	National Weather Service
OBU	On-Board Unit
ODE	Operational Data Environment
OSADP	Open-Source Application Development Portal
RCRS	Road Condition Reporting System
RDE	Research Data Exchange
RSU	Roadside Units
RWH	Road Weather Hazard
RWIS	Road Weather Information System
SAE	Society of Automotive Engineers
SCMS	Security Credential Management System
SDC	Secure Data Commons
SDW	Situation Data Warehouse
SDX	Trihydro Situation Data Exchange
SET-IT	Systems Engineering Tool for Intelligent Transportation
SPaT	Signal Phase and Timing
SSP	Satellite Service Provider
SWIW	Spot Weather Impact Warning
SyRS	System Requirements Specification
TIM	Traveler Information Message
TMC	Transportation Management Center
TMDD	Traffic Management Data Dictionary
TPI	Third-Party Interface
TRAC	Transportation Reports and Action Console
UoW	University of Wyoming
V2I	Vehicle-to-infrastructure
V2V	Vehicle-to-vehicle
VSL	Variable Speed Limit
WHP	Wyoming Highway Patrol
WYDOT	Wyoming Department of Transportation
WTI	Wyoming Traveler Information system
WZW	Work Zone Warning

5 References

The following table details the references used to create this document.

Table 5-1. References

#	Documents, Sources Referenced
1	SAE. (2014). J3067: Candidate Improvements to Dedicated Short Range Communications (DSRC) Message Set Dictionary [SAE J2735] Using Systems Engineering Methods. SAE International.
2	SAE. (2016a). J2945/1: Dedicated Short Range Communication (DSRC) Minimum Performance Requirements. SAE International.
3	SAE. (2016b). J2735: Dedicated Short Range Communications (DSRC) Message Set Dictionary. SAE International.
4	CV Reference Implementation Architecture (CVRIA), Version 2.1, www.iteris.com/cvria.
5	Systems Engineering Tool for Intelligent Transportation (SET-IT) Version 2.1.
6	IEEE. (2016a). 1609.2-2016 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Security Services for Applications and Management Messages. IEEE Vehicular Technology Society.
7	IEEE. (2016b). 1609.3-2016 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Networking Services. IEEE Vehicular Technology Society.
8	IEEE. (2016c). 1609.4-2016 - IEEE Standard for Wireless Access in Vehicular Environments (WAVE) - Multi-Channel Operation. IEEE Vehicular Technology Society.
9	Deepak Gopalakrishna, et al. (2015). *CV Pilot Deployment Program Phase 1, Concept of Operations (ConOps), ICF/Wyoming (FHWA-JPO-16-287)*. US Department of Transportation.
10	Research and Innovative Technology Administration (2011). "*5.9GHz DSRC Aftermarket Safety" Device Specification, Version 3.* US DOT. Washington, DC.
11	Leidos (2016). *DSRC Roadside Unit (RSU) Specifications Document 4.1.* US DOT Federal Highway Administration. Washington, DC.
12	Research and Innovative Technology Administration (2012). *5.9GHz DSRC Vehicle Awareness Device Specification, Version 3.6.* US DOT. Washington, DC.
13	USDOT, National ITS Architecture, Version 7.1
14	Deepak Gopalakrishna, et al. (2016a). *Connected Vehicle Pilot Deployment Program Phase 1, Application Deployment Plan – ICF/Wyoming (FHWA-JPO-16-292).* U.S Department of Transportation.
15	Deepak Gopalakrishna, et al. (2016b). *Connected Vehicle Pilot Deployment Program Phase 1, System Requirements Specification (FHWA-JPO-16-291) – ICF/Wyoming.* U.S Department of Transportation.
16	NCAR (2014). *Motorist Alert and Warning Application, Detailed System Requirements, Final Report — Feb 28, 2014.* Federal Highway Administration. Washington, DC.
17	CAMP - Vehicle Safety Communications 5 Consortium Proprietary (2016). *Security Credential Management System Proof–of–Concept Implementation, EE Requirements and Specifications Supporting SCMS Software Release 1.1 (as of May 2016).* National Highway Traffic Safety Administration
18	SCMS CV Pilots Documentation - Security Credential Management System Proof–of–Concept Implementation EE Requirements and Specifications Supporting SCMS Software Release 1.2, Crash Avoidance Metrics Partners (CAMP LLC) Vehicle Safety Communications 5 (VSC5) Consortium, (Website) as of July 3,2017 https://wiki.campllc.org/display/SCP/SCMS+CV+Pilots+Documentation

#	Documents, Sources Referenced
19	ITE/AASHTO (2014). *TMDD Standard v03.03c. Traffic Management Data Dictionary (TMDD) Standard for the Center to Center Communications. Volume I Concept of Operations and Requirements.*
20	Booz Allen Hamilton (2015). Southeast Michigan Test Bed Advanced Data Capture Field Testing. Task 4: Operational Data Environment - Concept of Operations.
21	SAE (2009). J2540-2 ITIS Phrase Lists (International Traveler Information Systems). SAE International.
22	DENSO International America (March, 2014). Connected Commercial Vehicles—Retrofit Safety Device Kit Project, Safety Applications and Development Plan (FHWA-JPO-14-106). FHWA.
23	FHWA (2014). Traffic Monitoring Guide – Vehicle Type. Retrieved from: https://www.fhwa.dot.gov/policyinformation/tmguide/tmg_2013/vehicle-types.cfm
24	University of Wyoming (2016). IRB Proposal Form. Institutional Review Board.
25	Office of the Assistant Secretary for Research and Technology (ver. 10/10/2016). *Connected Vehicle Reference Implementation Architecture (CVRIA).* http://local.iteris.com/cvria/index.html. USDOT
26	ISO/IEC & IEEE (2011). 42010: Systems and software engineering — Architecture description.
27	FHWA (2014). Traffic Monitoring Guide – Vehicle Type. Retrieved from: https://www.fhwa.dot.gov/policyinformation/tmguide/tmg_2013/vehicle-types.cfm
28	University of Wyoming (2016). IRB Proposal Form. Institutional Review Board
29	Kitchener, et al. (2016), *Connected Vehicle Pilot Deployment Program Phase 1, Performance Measurement and Evaluation Support Plan (version 2) – ICF/Wyoming (FHWA-JPO-16-290).* U.S. Department of Transportation.
30	Kitchener, et al. (2017), *Connected Vehicle Pilot Deployment Program Phase 2, Data Management Plan – Wyoming (FHWA-JPO-17-470).* U.S. Department of Transportation.
31	Deepak Gopalakrishna, et al. (2017). *Connected Vehicle Pilot Deployment Program Phase 2, Application Development Schedule, Wyoming*. U.S Department of Transportation.
32	Deepak Gopalakrishna, et al. (2016). *Connected Vehicle Pilot Deployment Program Phase 2, Deployment Comprehensive Acquisition Plan, Wyoming*. U.S Department of Transportation.
33	Deepak Gopalakrishna, et al. (2017). *Connected Vehicle Pilot Deployment Program Phase 2, System Architecture Design, Wyoming*. U.S Department of Transportation.
34	Wyoming Department of Transportation (WYDOT), Interface Control Document (ICD) – Wyoming CV Pilot, Version 2, June 17, 2017

6 Requirements Traceability Matrix

The following table provides traceability between the system requirements and design.

Table 6-1. Traceability of the System Requirement to the Design

System	Subsystem/ Component	Application	Req ID	Req Title
Wyoming CV System	Roadside Units Design	RSU	SCMS-REQ-1	Wyoming CV System (WCVS) SCMS Use **Phase 4 will use the ISS SCMS**.
			SCMS-REQ-1.1	SCMS Wyoming CV System Certificates **Phase 4 will use the ISS SCMS**.
			SCMS-REQ-1.2	SCMS Wyoming CV System Misbehavior Reporting **This is outside the scope of Phase 4.**
			SCMS-REQ-1.3	SCMS Wyoming CV System Certificates Revocation List (CRL) **This is outside the scope of Phase 4.**
			SCMS-REQ-1.4	SCMS Wyoming CV System Rejection **This is outside the scope of Phase 4.**
			RSU-REQ-3	SCMS **Phase 4 will use the ISS SCMS**.
			RSU-REQ-4	LTS
			RSU-REQ-6	Safety Communication
			RSU-REQ-7	Broadcast
			RSU-REQ-10	Management and Performance **Phase 4 will not include management and performance data collection.**
			RSU-REQ-11	Distribute to ODE
			RSU-REQ-12	Receive Update
			RSU-REQ-13	RSU Equipment
	RSU Application Design	RSU Roadway Traffic Information Dissemination	WCVS-REQ-8	Internal Brokerage **PA-REQ-2 and PA-REQ-4 are not supported with Phase 4**
			WCVS-REQ-10	Distribute TIM
			WCVS-REQ-10.1	Distribute TIM to VS
			RSU-REQ-2	Distribute TIM to VS
		RSU Distress Notification Application	N/A	#N/A **Distress Notification not part of Phase 4**
			WCVS-REQ-1	Collect CV Data

System	Subsystem/ Component	Application	Req ID	Req Title
		RSU Basic Safety Monitoring	WCVS-REQ-1.1	Collect BSM Data
			RSU-REQ-1	Collect CV Data
			RSU-REQ-6	Safety Communication
		RSU Support Services	WCVS-REQ-16	Monitored Functions
			WCVS-REQ-16.1	Sub-System Availability
			WCVS-REQ-16.2	Timeliness of Alerts
			WCVS-REQ-16.3	Availability for Interfaces
			WCVS-REQ-16.4	Availability for Data Storage
			WCVS-REQ-18	Management and Performance Policy **Performance measures and performance data will not be part of Phase 4.**
			WCVS-REQ-20	Manage Safe Communications
			WCVS-REQ-21	Manage CV Equipment
			WCVS-REQ-22	Test CV Equipment
			WCVS-REQ-23	Track CV Equipment
			WCVS-REQ-24	Update WCVS Equipment
			RSU-REQ-3	SCMS **Phase 4 will use the ISS SCMS**.
			RSU-REQ-6	Safety Communication
			RSU-REQ-10	Management and Performance **Phase 4 will not include management and performance data collection.**
			LTS-REQ-1	WCVS Time
			LTS-REQ-1.1	WCVS LTS Time
			LTS-REQ-1.2	WCVS Time Synchronization
			LTS-REQ-2	WCVS LTS Time Standard
			LTS-REQ-3	WCVS LTS Location
			SCMS-REQ-1	Wyoming CV System (WCVS) SCMS Use **Phase 4 will use the ISS SCMS**.
			SCMS-REQ-1.1	SCMS Wyoming CV System Certificates **Phase 4 will use the ISS SCMS**.

System	Subsystem/ Component	Application	Req ID	Req Title
			SCMS-REQ-1.2	SCMS Wyoming CV System Misbehavior Reporting **This is outside the scope of Phase 4.**
			SCMS-REQ-1.3	SCMS Wyoming CV System Certificates Revocation List (CRL) **This is outside the scope of Phase 4.**
			SCMS-REQ-1.4	SCMS Wyoming CV System Rejection **This is outside the scope of Phase 4.**
		RSU Trust Management	RSU-REQ-3	SCMS **Phase 4 will use the ISS SCMS**.
			SCMS-REQ-1	Wyoming CV System (WCVS) SCMS Use **Phase 4 will use the ISS SCMS**.
			SCMS-REQ-1.1	SCMS Wyoming CV System Certificates **Phase 4 will use the ISS SCMS**.
			SCMS-REQ-1.2	SCMS Wyoming CV System Misbehavior Reporting **This is outside the scope of Phase 4.**
			SCMS-REQ-1.3	SCMS Wyoming CV System Certificates Revocation List (CRL) **This is outside the scope of Phase 4.**
			SCMS-REQ-1.4	SCMS Wyoming CV System Rejection **This is outside the scope of Phase 4.**
	TMC Design	TMC		
			WCVS-REQ-11	Store VS Data
			WCVS-REQ-11.1	Store BSM
			WCVS-REQ-11.2	Store Environment Sensor Data
			WCVS-REQ-11.3	Store Distress Messages **Distress Messages will not be part of Phase 4**
			WCVS-REQ-12	Store Generated Alerts/Advisories **Not part of Phase 4**
			WCVS-REQ-13	Store TIM
			WCVS-REQ-14	Store System Monitoring Data
			WCVS-REQ-16	Monitored Functions
			WCVS-REQ-16.1	Sub-System Availability
			WCVS-REQ-16.2	Sub-System Performance

System	Subsystem/ Component	Application	Req ID	Req Title
			WCVS-REQ-16.3	Availability for Interfaces
			WCVS-REQ-16.4	Availability for Data Storage
			WCVS-REQ-17	Archive Data
			WCVS-REQ-18	Management and Performance Policy **Performance measures and performance data will not be part of Phase 4**
			WCVS-REQ-20	Manage Safe Communications
			WCVS-REQ-21	Manage CV Equipment
			WCVS-REQ-22	Test CV Equipment
			WCVS-REQ-23	Track CV Equipment
			WCVS-REQ-24	Update WCVS Equipment
			WCVS-REQ-25	Update VS Equipment
			DW-REQ-1	Store Data
			DW-REQ-1.1	Store Alerts/Advisories
			DW-REQ-1.1.1	Store Alerts/Advisories- Precipitation Hazard **Not in Phase 4**
			DW-REQ-1.1.2	Store Alerts/Advisories- Road Condition Hazard **Not in Phase 4**
			DW-REQ-1.1.3	Store Alerts/Advisories- Visibility Hazard **Not in Phase 4**
			DW-REQ-1.1.4	Store Alerts/Advisories- Work Zone Hazard
			DW-REQ-1.1.5	Store Alerts/Advisories- Incident Hazard
			DW-REQ-1.1.6	Store Alerts/Advisories- Parking
			DW-REQ-1.2	Store Vehicle System Data
			DW-REQ-1.3	Store TIM
			DW-REQ-1.4	Store System Monitoring Data
			DW-REQ-2	Share Data
			DW-REQ-2.1	Share Data with TPI **Not in Phase 4**
			DW-REQ-2.2	Share Data with SDC **The SDC will not be part of Phase 4**

System	Subsystem/ Component	Application	Req ID	Req Title
			DW-REQ-2.3	Share Data with RDE **The RDE will not be part of Phase 4**
			DW-REQ-3	Data Storage Administration
			DW-REQ-3.1	Maintain System Data Tables
			DW-REQ-3.1.1	CVE Data
			DW-REQ-3.2	Manage Data Storage Security
			DW-REQ-3.2.1	User Access
			DW-REQ-3.2.2	Unauthorized Access
			DW-REQ-3.3	Manage Data System
			DW-REQ-3.3.1	System Back-ups
			DW-REQ-3.3.2	Import/Export
			DW-REQ-3.3.3	Version Control
			DW-REQ-3.4	Manage Data Archive
			DW-REQ-4	Receive Data
			HSM-REQ-1	Receive from ODE **Not in Phase 4**
			HSM-REQ-2	Share with ODE **Not in Phase 4**
			HSM-REQ-3	Receive from SCMS **Not in Phase 4**
			HSM-REQ-4	Share with SCMS **Not in Phase 4**
	TMC Services Applications Design	Operational Data Environment (ODE)	SDC-REQ-1	Data Provided to the SDC **The SDC will not be supported in Phase 4**
			RDE-REQ-1	Data Provided to the RDE **The RDE will not be supported in Phase 4**
			ODE-REQ-1	Collect CV Data
			ODE-REQ-2	Data Processing
			ODE-REQ-3	Distribute Data
			ODE-REQ-3.1	Distribute TIM to RSU
			ODE-REQ-3.2	Distribute TIM to SDW
			ODE-REQ-3.3	Distribute to Pikalert **Pikalert will not be part of Phase 4**
			ODE-REQ-3.4	Distribute to Data Warehouse

System	Subsystem/ Component	Application	Req ID	Req Title
			ODE-REQ-3.4.1	Distribute to Data Warehouse-BSM
			ODE-REQ-3.4.2	Distribute to Data Warehouse-DNM **Phase 4 will not include distress notification messages**
			ODE-REQ-3.4.3	Distribute to Data Warehouse-ES **Environmental sensor data will not be part of Phase 4.**
			ODE-REQ-3.5	Distribute to Data Broker
			ODE-REQ-3.6	Distribute to SDC **The SDC will not be part of Phase 4.**
			ODE-REQ-3.7	Distribute to RDE **The RDE will not be part of Phase 4.**
			ODE-REQ-4	SCMS
			ODE-REQ-5	LTS
			ODE-REQ-6	OBU Update **The ODE will not be part of OTA firmware updates in Phase 4**
			ODE-REQ-7	Receive from Data Broker
			HSM-REQ-1	Receive from ODE **Not in Phase 4**
			HSM-REQ-2	Share with ODE **Not in Phase 4**
			VS-REQ-31	IVAA WZW
			SDX-REQ-1	Data Provided to the SDX
			WCVS-REQ-1.3	Collect Distress Messages **Distress Messages will not be part of Phase 4.**
			WCVS-REQ-2	Validate Data
			WCVS-REQ-8	Internal Brokerage **PA-REQ-2 and PA-REQ-4 are not supported with Phase 4.**
			WCVS-REQ-9	Create TIM
			WCVS-REQ-10	Distribute TIM
			WCVS-REQ-10.1	Distribute TIM to VS
			WCVS-REQ-10.2	Distribute TIM to SDW
		Pikalert System **Not in Phase 4**	PA-REQ-1	External Weather Data **Not in Phase 4**
			PA-REQ-2	Wyoming CV Sub-Systems Data **Not in Phase 4**
			PA-REQ-2.1	ODE Data **Not in Phase 4**

System	Subsystem/ Component	Application	Req ID	Req Title
			PA-REQ-2.2	TMC Data **Not in Phase 4**
			PA-REQ-3	Generate Alerts/Advisories and Forecasts **Not in Phase 4**
			PA-REQ-4	Distribute Alerts/Advisories and Forecasts **Not in Phase 4**
			PA-REQ-4.1	Distribute to DB **Not in Phase 4**
			WI-REQ-1	External Data Acquisition **The External Data Acquisition will not be part of Phase 4.**
			WI-REQ-2	Fixed Data Acquisition **Fixed Data Acquisition will not be part of Phase 4.**
			WCVS-REQ-3	Ingest Data for Road Weather information . **WI-REQ-1 and WI-REQ-2 is not part of Phase 4.**
			WCVS-REQ-4	Contents of Alerts and Advisories
			WCVS-REQ-4.1	Precipitation Hazard **Not part of Phase 4.**
			WCVS-REQ-4.2	Road Condition Hazard **Not part of Phase 4.**
			WCVS-REQ-4.3	Visibility Hazard **Not part of Phase 4.**
			WCVS-REQ-5	Forecast Conditions **Not part of Phase 4.**
			WCVS-REQ-5.1	Atmospheric Forecasts **Not part of Phase 4.**
			WCVS-REQ-5.2	Road Weather Forecasts **Not part of Phase 4.**
			WCVS-REQ-5.3	Forecast Time **Not part of Phase 4.**
			WCVS-REQ-5.4	Forecast Update **Not part of Phase 4.**
			WCVS-REQ-6	Associate Alerts and Forecast to Segments **Not part of Phase 4.**
			WCVS-REQ-8	Internal Brokerage **PA-REQ-2 and PA-REQ-4 are not supported with Phase 4.**
		TMC Data Brokerage (WTIDB)	DB-REQ-1	Receive from External Interfaces
			DB-REQ-2	Distribute to External Interfaces **TPI-REQ-1 is not part of Phase 4.**
			DB-REQ-4	Receive from Pikalert **Pikalert will not be part of Phase 4.**
			DB-REQ-4.1	Receive Alerts and Advisories **Not in Phase 4**

System	Subsystem/ Component	Application	Req ID	Req Title
			DB-REQ-4.2	Receive Forecast **Not in Phase 4**
			DB-REQ-5	Distribute to ODE
			DB-REQ-6	Receive from ODE **Distress information will not be part of Phase 4.**
			DB-REQ-7	Distribute to Data Warehouse **Distress Notification and Forecast are not part of Phase 4.**
			DB-REQ-8	Receive Data from DW
			DB-REQ-9	Distribute to SDC
			DW-REQ-2.4	Share Data with DB
			511-REQ-1	511App Parking Data Collection
			511-REQ-1.1	Availability
			511-REQ-1.2	Default
			511-REQ-1.3	Time
			511-REQ-1.4	Location
			511-REQ-1.5	Protocol
			511-REQ-1.6	Schema
			511-REQ-2	Timeframe
			TRAC-REQ-1	TRAC Updates **Not part of Phase 4.**
			TRAC-REQ-1.1	Distress Notification **Not part of Phase 4.**
			TRAC-REQ-1.1.1	Transmission Time **Not part of Phase 4.**
			TRAC-REQ-1.2	Segment Alerts **Not part of Phase 4.**
			TRAC-REQ-1.2.1	Transmission Time **Not part of Phase 4.**
			TRAC-REQ-1.2.2	Segment Alerts-Pikalert **Not part of Phase 4.**
			RCRS-REQ-1	RCRS Data Sharing
			RCRS-REQ-1.1	Road Condition
			RCRS-REQ-1.2	Weather
			RCRS-REQ-1.3	Other Road Condition
			RCRS-REQ-1.4	Report Time
			RCRS-REQ-1.5	Location

System	Subsystem/ Component	Application	Req ID	Req Title
			RCRS-REQ-1.6	Transmit Time
			WTI-REQ-1	WTI Inputs **Not part of Phase 4.**
			WTI-REQ-1.1	Current Segment Alerts **Not part of Phase 4.**
			WTI-REQ-1.1.1	Transmission Time **Not part of Phase 4.**
			WTI-REQ-1.2	Forecast Segment Alerts **Not part of Phase 4.**
			WTI-REQ-1.2.1	Forecast Time **Not part of Phase 4.**
			WTI-REQ-1.2.2	Forecast Update **Not part of Phase 4.**
			WTI-REQ-2	WTI Outputs
			WTI-REQ-2.1	Posted Speed
			WTI-REQ-2.2	Vehicle Restrictions
			WTI-REQ-2.2.1	Restriction Information
			WTI-REQ-2.2.2	Restriction Start Time
			WTI-REQ-2.3	Posted Messages
			WTI-REQ-2.3.1	Message Information
			WTI-REQ-2.4	Posted Closures
			WTI-REQ-2.4.1	Closure Beginning
			WTI-REQ-2.4.2	Closure End
			WTI-REQ-2.4.3	Closure Start Time
			CVOP-REQ-1	CVOP Inputs
			CVOP-REQ-1.1	Current Segment Alerts
			CVOP-REQ-1.1.1	Transmission Time
			CVOP-REQ-1.2	Forecast Segment Alerts **Not part of Phase 4.**
			CVOP-REQ-1.2.1	Forecast Time **Not part of Phase 4.**
			CVOP-REQ-1.2.2	Forecast Update **Not part of Phase 4.**
			IC-REQ-1	IC Data Sharing
			IC-REQ-2	Protocol
			IC-REQ-3	Schema
			IC-REQ-4	Transmission
			CA-REQ-1	CA Data Sharing

System	Subsystem/ Component	Application	Req ID	Req Title
			CA-REQ-2	Protocol
			CA-REQ-3	Schema
			CA-REQ-4	Transmission
			ITSM-REQ-1	WYDOT ITS Alerts
			WCVS-REQ-4.5	Incident Hazard
			WCVS-REQ-4.6	Parking
			WCVS-REQ-7	External Brokerage with WYDOT Interfaces
			WCVS-REQ-7.1	Receive from WYDOT External Interfaces
			WCVS-REQ-7.2	Distribute to WYDOT External Interfaces **TPI-REQ-1 is not supported with Phase 4**
			WCVS-REQ-8	Internal Brokerage **PA-REQ-2 and PA-REQ-4 are not supported with Phase 4.**
		WYDOT Third Party Interface (TPI)	TPI-REQ-1	TPI Data **This is outside the scope of Phase 4.**
		Service Monitor Device Management	WCVS-REQ-15	Notifications
			WCVS-REQ-16	Monitored Functions
			WCVS-REQ-16.1	Sub-System Availability
			WCVS-REQ-16.2	Sub-System Performance
			WCVS-REQ-16.3	Availability for Interfaces
			WCVS-REQ-16.4	Availability for Data Storage
			WCVS-REQ-17	Archive Data
			WCVS-REQ-18	Management and Performance Policy **Performance measures and performance data will not be part of Phase 4**
			WCVS-REQ-20	Manage Safe Communications
			WCVS-REQ-21	Manage CV Equipment
			WCVS-REQ-22	Test CV Equipment
			WCVS-REQ-23	Track CV Equipment
			WCVS-REQ-24	Update WCVS Equipment
			WCVS-REQ-25	Update VS Equipment

System	Subsystem/ Component	Application	Req ID	Req Title
			ITSM-REQ-1	WYDOT ITS Alerts
	TMC Website/Desktop Applications Design	CVOP Website updates (Extension & Interface)	CVOP-REQ-1	CVOP Inputs
			CVOP-REQ-1.1	Current Segment Alerts
			CVOP-REQ-1.1.1	Transmission Time
			CVOP-REQ-1.2	Forecast Segment Alerts **Not part of Phase 4.**
			CVOP-REQ-1.2.1	Forecast Time **Not part of Phase 4.**
			CVOP-REQ-1.2.2	Forecast Update **Not part of Phase 4.**
		WYDOT Transportation Reports and Action Console (TRAC)	TRAC-REQ-1	TRAC Updates **Not part of Phase 4.**
			TRAC-REQ-1.1	Distress Notification **Not part of Phase 4.**
			TRAC-REQ-1.1.1	Transmission Time **Not part of Phase 4.**
			TRAC-REQ-1.2	Segment Alerts **Not part of Phase 4.**
			TRAC-REQ-1.2.1	Transmission Time **Not part of Phase 4.**
			TRAC-REQ-1.2.2	Segment Alerts-Pikalert **Not part of Phase 4.**
		WYDOT Wyoming Traveler Information (WTI)	WTI-REQ-1	WTI Inputs **Not part of Phase 4.**
			WTI-REQ-1.1	Current Segment Alerts **Not part of Phase 4.**
			WTI-REQ-1.1.1	Transmission Time **Not part of Phase 4.**
			WTI-REQ-1.2	Forecast Segment Alerts **Not part of Phase 4.**
			WTI-REQ-1.2.1	Forecast Time **Not part of Phase 4.**
			WTI-REQ-1.2.2	Forecast Update **Not part of Phase 4.**
			WTI-REQ-2	WTI Outputs
			WTI-REQ-2.1	Posted Speed
			WTI-REQ-2.2	Vehicle Restrictions
			WTI-REQ-2.2.1	Restriction Information
			WTI-REQ-2.2.2	Restriction Start Time
			WTI-REQ-2.3	Posted Messages
			WTI-REQ-2.3.1	Message Information
			WTI-REQ-2.4	Posted Closures
			WTI-REQ-2.4.1	Closure Beginning
			WTI-REQ-2.4.2	Closure End

System	Subsystem/ Component	Application	Req ID	Req Title
			WTI-REQ-2.4.3	Closure Start Time
		WYDOT Construction Administration (CA)	CA-REQ-1	CA Data Sharing
			CA-REQ-2	Protocol
			CA-REQ-3	Schema
			CA-REQ-4	Transmission
			WCVS-REQ-4.4	Work Zone Hazard
		WYOROAD.INFO Website (Extension & Interface)	N/A	#N/A
		OBU/RSU Management Application	WCVS-REQ-7	External Brokerage with WYDOT Interfaces
			WCVS-REQ-7.2	Distribute to WYDOT External Interfaces **TPI-REQ-1 is not supported with Phase 4.**
			WCVS-REQ-14	Store System Monitoring Data
			WCVS-REQ-15	Notifications
			WCVS-REQ-16	Monitored Functions
			WCVS-REQ-16.1	Sub-System Availability
			WCVS-REQ-16.2	Sub-System Performance
			WCVS-REQ-16.3	Availability for Interfaces
			WCVS-REQ-16.4	Availability for Data Storage
			WCVS-REQ-21	Manage CV Equipment
			WCVS-REQ-22	Test CV Equipment
			WCVS-REQ-23	Track CV Equipment
			WCVS-REQ-24	Update WCVS Equipment
			WCVS-REQ-25	Update VS Equipment
		Resource Manager Application	N/A	#N/A
Vehicle System	DSRC & Satellite OBU Design	Lear OBU	LTS-REQ-4	VS LTS Time
			LTS-REQ-5	VS LTS Time Standard
			LTS-REQ-6	VS LTS Location

System	Subsystem/ Component	Application	Req ID	Req Title
			VS-REQ-1	Receive BSM **In Phase 4 this will be done with C-V2X rather than DSRC**.
			VS-REQ-2	Receive TIM
			VS-REQ-2.1	Receive TIM through DSRC **In Phase 4 this will be done with C-V2X rather than DSRC**
			VS-REQ-2.2	Receive TIM through Satellite
			VS-REQ-3	Receive Distress Information **Distress information will not be part of Phase 4.**
			VS-REQ-4	Collect Vehicle Data **Not part of Phase 4.**
			VS-REQ-4.1	Collect Vehicle Status Data **Not part of Phase 4.**
			VS-REQ-4.2	Collect Dimension Data **Not part of Phase 4.**
			VS-REQ-4.2.1	Vehicle Dimension Data **Not part of Phase 4.**
			VS-REQ-4.2.2	Vehicle Trailer Data **Not part of Phase 4.**
			VS-REQ-5	External Environment Sensor Data **Not part of Phase 4.**
			VS-REQ-5.1	External Environment Sensor Data Configuration **Not part of Phase 4.**
			VS-REQ-5.2	External Environment Sensor Data Management **Not part of Phase 4.**
			VS-REQ-10	FCW No Warnings
			VS-REQ-10.1	Safely Following a Vehicle
			VS-REQ-10.2	Passing a Stopped Vehicle
			VS-REQ-15	Distress Notification ID **Not part of Phase 4.**
			VS-REQ-15.1	Log **Not part of Phase 4.**
			VS-REQ-16	Create Distress Notification **Not part of Phase 4.**
			VS-REQ-23	IVAA Rank **Distress Message not included in Phase 4.**
			VS-REQ-24	IVAA Level **For Phase 4 we will use the off the shelf vendor alerting system.**
			VS-REQ-25	IVAA Priority Alert

System	Subsystem/ Component	Application	Req ID	Req Title
			VS-REQ-26	IVAA FCW **During Phase 4 these will be based on the selected vendor standard for alerting, no customization required.**
			VS-REQ-27	IVAA DN **DN is not part of Phase 4.**
			VS-REQ-28	IVAA SA-Advisory
			VS-REQ-29	IVAA SA-VSL
			VS-REQ-30	IVAA SWIW
			VS-REQ-31	IVAA WZW
			VS-REQ-33	BCVI Messages **Phase 4 will use C-V2X rather than DSRC for wireless broadcasts of BSMs.**
			VS-REQ-34	BCVI Distress **Phase 4 will not include BCVI Distress.**
			VS-REQ-34.1	Received Distress **Phase 4 will not include received distress messages.**
			VS-REQ-34.2	Generated Distress **Phase 4 will not include generated distress notifications.**
			VS-REQ-35	BCVI General Broadcast Requirements **Phase 4 will not include the broadcast of traveler information.**
			VS-REQ-36	Transmit Data **Phase 4 shall not use DSRC and should test Wi-Fi.**
			VS-REQ-36.1	Transmit Environmental Data **Phase 4 will not include transmitting of environmental data.**
			VS-REQ-36.2	TVI Data Management-Log **Phase 4 should transmit logs via Wi-Fi**
			VS-REQ-38	SLD Information **SLD information is not part of Phase 4.**
			VS-REQ-39	**SLD Rolling Log Vehicle Status Data not part of Phase 4.**
			VS-REQ-40	SLD Log Format
			VS-REQ-41	SLD Log Data **Phase 4 excludes distress messages.**

System	Subsystem/ Component	Application	Req ID	Req Title
			VS-REQ-42	VSM SCMS
			VS-REQ-43	VSM SCMS Encryption **Phase 4 will not include any encryption of messages.**
			VS-REQ-44	VSM SCMS Sign
			VS-REQ-45	VSM SCMS Encryption-Log **Phase 4 will not include any encryption of messages.**
			VS-REQ-46	VSM SCMS Sign-Log P**hase 4 will not include any signing of log files.**
			VS-REQ-47	VSM App Availability Log **Phase 4 will not include any app availability logs.**
			VS-REQ-48	VSM Updates
			VS-REQ-49	Architectural
			VS-REQ-50	Safety Communication
			VS-REQ-51	VS Equipment
				This requirement no longer applies to this system
			MV-REQ-3	Static Identifier **Not in Phase 4.**
			MV-REQ-4	Receive TIM over DSRC **Not in Phase 4.**
			MV-REQ-5	Receive TIM over Satellite **Not in Phase 4.**
			MV-REQ-6	OTA Updates **Not in Phase 4.**
			MV-REQ-7	Time **Not in Phase 4.**
			MV-REQ-8	Location **Not in Phase 4.**
			MV-REQ-9	General **Not in Phase 4.**
			MV-REQ-10	OBU Equipment **Not in Phase 4.**
			HP-REQ-1	General **Not in Phase 4.**
			HP-REQ-2	Receive TIM over DSRC **Not in Phase 4.**
			HP-REQ-3	Time **Not in Phase 4.**
			HP-REQ-4	Location **Not in Phase 4.**
			HP-REQ-5	OBU Equipment **Not in Phase 4.**
			HP-REQ-6	Receive TIM over Satellite **Not in Phase 4.**
			HP-REQ-7	OTA Updates **Not in Phase 4.**

System	Subsystem/ Component	Application	Req ID	Req Title
			IT-REQ-1	Receive TIM over DSRC **Not in Phase 4.**
			IT-REQ-2	Receive TIM over Satellite **Not in Phase 4.**
			IT-REQ-3	OTA Updates **Not in Phase 4.**
			IT-REQ-4	Time **Not in Phase 4.**
			IT-REQ-5	Location **Not in Phase 4.**
			IT-REQ-6	General **Not in Phase 4.**
			IT-REQ-7	OBU Equipment **Not in Phase 4.**
			TV-REQ-1	***Receive TIM over C-V2X***
			TV-REQ-2	***Receive TIM over Satellite***
			TV-REQ-3	***Time***
			TV-REQ-4	***Location***
			TV-REQ-5	***General***
			TV-REQ-6	***OBU Equipment***
			TV-REQ-7	***OTA Updates***
		SiriusXM OBU	LTS-REQ-4	VS LTS Time
			LTS-REQ-5	VS LTS Time Standard
			LTS-REQ-6	VS LTS Location
			VS-REQ-1	Receive BSM **In Phase 4 this will be done with C-V2X rather than DSRC**.
			VS-REQ-2	Receive TIM
			VS-REQ-2.1	Receive TIM through DSRC **In Phase 4 this will be done with C-V2X rather than DSRC**
			VS-REQ-2.2	Receive TIM through Satellite
			VS-REQ-4	Collect Vehicle Data **Not part of Phase 4.**
			VS-REQ-4.2	Collect Dimension Data **Not part of Phase 4.**
			VS-REQ-4.2.1	Vehicle Dimension Data **Not part of Phase 4.**
			VS-REQ-4.2.2	Vehicle Trailer Data **Not part of Phase 4.**
			VS-REQ-6	FCW Stopped Vehicles
			VS-REQ-7	FCW Decelerating/Slow Moving Vehicles

System	Subsystem/ Component	Application	Req ID	Req Title
			VS-REQ-8	FCW Stopped and Obstructed Vehicles
			VS-REQ-9	FCW Rear-End Crash
			VS-REQ-10	FCW No Warnings
			VS-REQ-11	SA TIM-Advisories
			VS-REQ-12	SA TIM-Speed Limit
			VS-REQ-13	SA TIM-Exit Services
			VS-REQ-14	SA TIM-Region
			VS-REQ-19	WZW TIM
			VS-REQ-20	WZW TIM-Region
			VS-REQ-21	SWIW TIM
			VS-REQ-22	SWIW TIM-Region
			VS-REQ-23	IVAA Rank **Distress Message not included in Phase 4.**
			VS-REQ-24	IVAA Level **For Phase 4 we will use the off the shelf vendor alerting system.**
			VS-REQ-25	IVAA Priority Alert
			VS-REQ-26	IVAA FCW **During Phase 4 these will be based on the selected vendor standard for alerting, no customization required.**
			VS-REQ-28	IVAA SA-Advisory
			VS-REQ-29	IVAA SA-VSL
			VS-REQ-30	IVAA SWIW
			VS-REQ-31	IVAA WZW
			VS-REQ-33	BCVI Messages **Phase 4 will use C-V2X rather than DSRC for wireless broadcasts of BSMs.**
			VS-REQ-35	BCVI General Broadcast Requirements **Phase 4 will not include the broadcast of traveler information.**
			VS-REQ-36	Transmit Data **Phase 4 shall not use DSRC and should test Wi-Fi.**

System	Subsystem/ Component	Application	Req ID	Req Title
			VS-REQ-36.2	TVI Data Management-Log **Phase 4 should transmit logs via Wi-Fi**
			VS-REQ-38	SLD Information **SLD information is not part of Phase 4.**
			VS-REQ-39	SLD Rolling Log **Vehicle Status Data not part of Phase 4.**
			VS-REQ-40	SLD Log Format
			VS-REQ-41	SLD Log Data **Phase 4 excludes distress messages.**
			VS-REQ-42	VSM SCMS
			VS-REQ-43	VSM SCMS Encryption **Phase 4 will not include any encryption of messages.**
			VS-REQ-44	VSM SCMS Sign
			VS-REQ-45	VSM SCMS Encryption-Log **Phase 4 will not include any encryption of messages.**
			VS-REQ-46	VSM SCMS Sign-Log **Phase 4 will not include any signing of log files.**
			VS-REQ-47	VSM App Availability Log **Phase 4 will not include any app availability logs.**
			VS-REQ-48	VSM Updates
			VS-REQ-49	Architectural
			VS-REQ-50	Safety Communication
			VS-REQ-51	VS Equipment
			RFV-REQ-1	Receive TIM over DSRC **Not in Phase 4.**
			RFV-REQ-2	Receive TIM over Satellite **Not in Phase 4.**
			RFV-REQ-3	Time **Not in Phase 4.**
			RFV-REQ-4	Location **Not in Phase 4.**
			RFV-REQ-5	General **Not in Phase 4.**
			RFV-REQ-6	OBU Equipment **Not in Phase 4.**
			RFV-REQ-7	OTA Updates **Not in Phase 4.**

System	Subsystem/ Component	Application	Req ID	Req Title
			MCP-REQ-1	V2V Exchange of BSMs **In Phase 4 this will be C-V2X rather than DSRC.**
	Android Device Design	Android Device Design	-	#N/A
	Environmental Sensors Design	Environmental Sensors Design **Not part of Phase 4.**	VS-REQ-5	External Environment Sensor Data **Not part of Phase 4.**
			VS-REQ-5.1	External Environment Sensor Data Configuration **Not part of Phase 4.**
			VS-REQ-5.2	External Environment Sensor Data Management **Not part of Phase 4.**
			MV-REQ-1	Environmental Sensors **Not part of Phase 4.**
			MV-REQ-1.1	Environmental Sensor Equipment **Not part of Phase 4.**
	OBU Applications Design	OBU Spot Weather Impact Warning Application	VS-REQ-21	SWIW TIM
			VS-REQ-22	SWIW TIM-Region
		OBU Work Zone Warning	VS-REQ-19	WZW TIM
			VS-REQ-20	WZW TIM-Region
			VS-REQ-31	IVAA WZW
		OBU I2V Situational Awareness	VS-REQ-11	SA TIM-Advisories
			VS-REQ-12	SA TIM-Speed Limit
			VS-REQ-13	SA TIM-Exit Services
			VS-REQ-14	SA TIM-Region
			I2VSAP-REQ-4	Message Display Geofence Beginning
		OBU Distress Notification Application **Not part of Phase 4.**	VS-REQ-15	Distress Notification ID **Not part of Phase 4.**
			VS-REQ-15.1	Log **Not part of Phase 4.**
			VS-REQ-16	Create Distress Notification **Not part of Phase 4.**
			VS-REQ-16.1	System-Generated Distress Notification **Not part of Phase 4.**
			VS-REQ-16.2	Driver-Generated Distress Notification **Not part of Phase 4.**

System	Subsystem/ Component	Application	Req ID	Req Title
			VS-REQ-17	DNM-Region **Not part of Phase 4.**
			VS-REQ-18	DN PSID **Not part of Phase 4.**
		OBU Forward Collision Warning	VS-REQ-6	FCW Stopped Vehicles
			VS-REQ-7	FCW Decelerating/Slow Moving Vehicles
			VS-REQ-8	FCW Stopped and Obstructed Vehicles
			VS-REQ-9	FCW Rear-End Crash
			VS-REQ-9.1	FCW Rear-End Crash in Straight Road
			VS-REQ-9.2	FCW Rear-End Crash in Curved Road
			VS-REQ-10	FCW No Warnings
			VS-REQ-10.1	Safely Following a Vehicle
			VS-REQ-10.2	Passing a Stopped Vehicle
		OBU Vehicle Support Services	LTS-REQ-4	VS LTS Time
			LTS-REQ-5	VS LTS Time Standard
			LTS-REQ-6	VS LTS Location
			VS-REQ-35	BCVI General Broadcast Requirements **Phase 4 will not include the broadcast of traveler information.**
			VS-REQ-36	Transmit Data **Phase 4 shall not use DSRC and should test Wi-Fi.**
			VS-REQ-36.1	Transmit Environmental Data **Phase 4 will not include transmitting of environmental data.**
			VS-REQ-36.2	TVI Data Management-Log **Phase 4 should transmit logs via Wi-Fi.**
			VS-REQ-49	Architectural
			VS-REQ-50	Safety Communication
		OBU Vehicle Trust Management	SCMS-REQ-2	Vehicle System SCMS Use **Phase 4 will use the ISS SCMS.**
			SCMS-REQ-2.1	SCMS Vehicle System Certificates **Phase 4 will use the ISS SCMS.**
			SCMS-REQ-2.2	SCMS Vehicle System Misbehavior Reporting **This is outside the scope of Phase 4.**

System	Subsystem/ Component	Application	Req ID	Req Title
			SCMS-REQ-2.3	SCMS Vehicle System Certificates Revocation List (CRL) **This is outside the scope of Phase 4.**
			SCMS-REQ-2.4	SCMS Vehicle System Rejection **This is outside the scope of Phase 4.**
	Mobile Applications Design	WYDOT 511 integration (Android & iOS)	511-REQ-1	511App Parking Data Collection
			511-REQ-1.1	Availability
			511-REQ-1.2	Default
			511-REQ-1.3	Time
			511-REQ-1.4	Location
			511-REQ-1.5	Protocol
			511-REQ-1.6	Schema
			511-REQ-2	Timeframe
		Vehicle Messaging Display/Interface (HMI Design)	VS-REQ-4.2	Collect Dimension Data **Not part of Phase 4.**
			VS-REQ-4.2.1	Vehicle Dimension Data **Not part of Phase 4.**
			VS-REQ-4.2.2	Vehicle Trailer Data **Not part of Phase 4.**
			VS-REQ-16	Create Distress Notification **Not part of Phase 4.**
			VS-REQ-16.2	Driver-Generated Distress Notification **Not part of Phase 4.**
			VS-REQ-32	Human Machine Interface
			VS-REQ-32.1	HMI-Location
			VS-REQ-32.2	HMI-Distraction
			VS-REQ-32.3	HMI-Readability
			VS-REQ-32.4	Visual and Auditory Interface
			VS-REQ-32.4.1	Visual Consistency
			VS-REQ-32.4.2	Audio Signals
			VS-REQ-32.5	Customizations
			VS-REQ-32.6	System Status
			VS-REQ-32.6.1	Power Status
			VS-REQ-32.6.2	System Settings

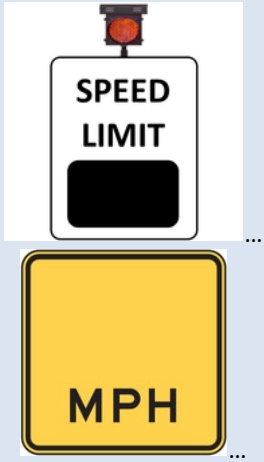
System	Subsystem/ Component	Application	Req ID	Req Title
			VS-REQ-32.6.3	Application Availability
			VS-REQ-32.6.4	Pending Update Status
			VS-REQ-32.7	Distress Notification **Phase 4 will not include distress notification.**
			VS-REQ-32.8	Non-Distress Information **Phase 4 will not include non-distress information**

Appendix A. WYDOT TIM Requirements

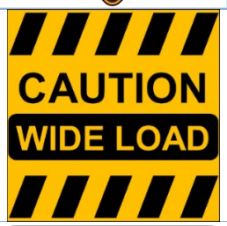
A.1 Introduction

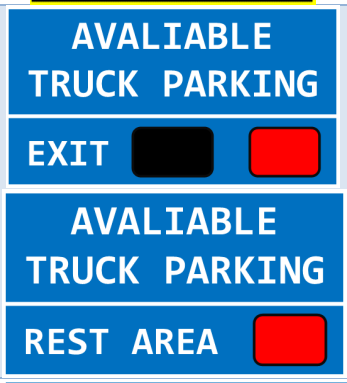
Table A-1 contains the full list of all supported TIMs along with images to be displayed and rules for how the TIM will be formatted.

Table A-1. TIM Requirements

ITIS Code	Description	TIM Message Pattern to Detect	Image(s)
268	Speed Limit	Only appears in a TIM which has `content=speedLimit` containing the following 3 ITIS codes: speedLimit (268) <number> (e.g. 12579) MPH (8720) *From J2540-2(2009) Section 9.11* *Note: Regulatory speed limit should be displayed when the frameType = roadSignage and the roadSignID->mutcdCode = regulatory.* *Advisory sign will bedisplayed when the framType=advisory and the roadSignID->mutcdCode=warning* The number representing the speed limit should be placed in the signs with the best represented font available to match the given signs. Font color on the regulatory sign should be yellow, font color on the advisory should be black.	
513	Accident	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
531	Incident	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	

ITIS Code	Description	TIM Message Pattern to Detect	Image(s)
550	Hazardous material spill	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
770	Closed	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
774	Closed for the season	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
777	Reduced to one lane	Only appears in a TIM which has `content=workzone` containing the following ITIS codes: Reduced to One Lane (777) Right (13579)/Left (13580) The 13579/13580 will determine which image is displayed. The image on the left is displayed when ITIS code 13580 is present.	
1042	Avalanche control activities	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
1025	Road Construction	Only appears in a TIM which has `content=workzone` containing a single ITIS code (this code)	
1292	Herd of animals on roadway	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	

ITIS Code	Description	TIM Message Pattern to Detect	Image(s)
1309	Rockfall	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
1310	Landslide	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
1537	Delays	Only appears in a TIM which has `content=workzone` containing the following ITIS codes: Delay (1537) <number> (e.g. 12579) minutes (8728)	
2050	Wide load	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
2568	No trailers	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
2573	Width Limit	Only appears in a TIM which has `content=advisory` containing the following 3 ITIS codes: widthLimit (2573) <number> (e.g. 12579) inches (8710) *From J2540-2(2009) Section 6.17 (comment says "typically followed by a number and a unit value")* *Application will need to take inches as an input and add text to the image representing the number in feet/inches*	

ITIS Code	Description	TIM Message Pattern to Detect	Image(s)
2574	Height Limit	Only appears in a TIM which has `content=advisory` containing the following 3 ITIS codes: heightLimit (2574) <number> (e.g. 12579) inches (8710) *From J2540-2(2009) Section 6.17 (comment says "typically followed by a number and a unit value")* *Application will need to take inches as an input and add text to the image representing the number in feet/inches*	
3084	Wildfire	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
3201	Weather emergency	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
3841	Major event	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
4103	No parking spaces available	Only appears in a TIM which has `content=exitService` and the following ITIS codes: No parking spaces available (4103) Rest Area (7986) or Exit Number (11794) If Exit Number it will be followed by the name of the exit (ex. 112 or 112b)	
4104	Only a few parking spaces available	Only appears in a TIM which has `content=exitService` and the following ITIS codes: Few spaces available (4104) Rest Area (7986) or Exit Number (11794) If Exit Number it will be followed by the name of the exit (ex. 112 or 112b)	

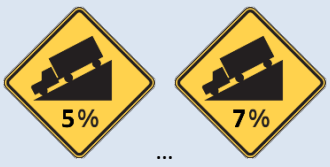
ITIS Code	Description	TIM Message Pattern to Detect	Image(s)
4105	Spaces Available	Only appears in a TIM which has `content=exitService` and the following ITIS codes: Parking spaces available (4105) Rest Area (7986) or Exit Number (11794) If Exit Number it will be followed by the name of the exit (ex. 112 or 112b)	
4223	No parking information available	Only appears in a TIM which has `content=exitService` and the following ITIS codes: No parking information available (4223) Rest Area (7986) or Exit Number (11794) If Exit Number it will be followed by the name of the exit (ex. 112 or 112b)	
4865	Severe weather	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	 Severe Weather.png
4868	Snow	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	 Snow.png
4871	Winter Storm	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
4885	Rain	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	 Rain.png

ITIS Code	Description	TIM Message Pattern to Detect	Image(s)
5127	Strong winds	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	 Strong Winds.png
5378	Fog	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
5383	Visibility reduced	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
5385	Blowing snow	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
5908	Black ice	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
5895	Wet pavement	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
5906	Ice	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
5907	Icy patches	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
5927	Snow drifts	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	

ITIS Code	Description	TIM Message Pattern to Detect	Image(s)
5933	Gravel Road Surface	Only appears in a TIM which has `content=workzone` containing a single ITIS code (this code)	
6011	Dry pavement	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
6016	Dirt Road Surface	Only appears in a TIM which has `content=workzone` containing a single ITIS code (this code)	
6017	Milled Road Surface	Only appears in a TIM which has `content=workzone` containing a single ITIS code (this code)	
6156	Snow tires or chains required	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
6952	Look out for workers	Only appears in a TIM which has `content=workzone` containing a single ITIS code (this code)	
7425	Keep to right	Only appears in a TIM which has `content=workzone` containing a single ITIS code (this code)	
7426	Keep to left	Only appears in a TIM which has `content=workzone` containing a single ITIS code (this code)	

ITIS Code	Description	TIM Message Pattern to Detect	Image(s)
7443	Reduce your speed	Only appears in a TIM which has `content=speedLimit` containing the following ITIS codes: reducedSpeed (7443) <number> (e.g. 12579) MPH (8720)	
7169	Drive carefully	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
7170	Drive with extreme caution	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
7173	Increase normal following distance	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
7186	Prepare to stop	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
7188	Stop at next safe place	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
7189	Only travel if absolutely necessary	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
12037	Falling rocks	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
Below are advisory strings up to 500 characters, used due to not equivalent in J2540			

ITIS Code	Description	TIM Message Pattern to Detect	Image(s)
"Extreme blow over risk"	Extreme blow over risk	Only appears in a TIM which has `content=advisory` containing a single ITIStext (the text in the 1st column)	
"Closed to light, high profile vehicles"	Closed to light, high profile vehicles	Only appears in a TIM which has `content=advisory` containing a single ITIStext (the text in the 1st column)	
"Advise no light trailers"	Advise no light trailers	Only appears in a TIM which has `content=advisory` containing a single ITIStext (the text in the 1st column)	
"Closed due to border state request from Colorado"	closed due to border state request from Colorado	Only appears in a TIM which has `content=advisory` containing a single ITIStext (the text in the 1st column)	
"Closed due to border state request from Idaho"	closed due to border state request from Idaho	Only appears in a TIM which has `content=advisory` containing a single ITIStext (the text in the 1st column)	
"Closed due to border state request from Montana"	closed due to border state request from Montana	Only appears in a TIM which has `content=advisory` containing a single ITIStext (the text in the 1st column)	
"Closed due to border state request from Nebraska"	closed due to border state request from Nebraska	Only appears in a TIM which has `content=advisory` containing a single ITIStext (the text in the 1st column)	

ITIS Code	Description	TIM Message Pattern to Detect	Image(s)
"Closed due to border state request from South Dakota"	closed due to border state request from South Dakota	Only appears in a TIM which has `content=advisory` containing a single ITIStext (the text in the 1st column)	
"Closed due to border state request from Utah"	closed due to border state request from Utah	Only appears in a TIM which has `content=advisory` containing a single ITIStext (the text in the 1st column)	
"Closed due to border state request from Multiple States"	closed due to border state request from Multiple States	Only appears in a TIM which has `content=advisory` containing a single ITIStext (the text in the 1st column)	
"Closed due to law enforcement request"	closed due to law enforcement request	Only appears in a TIM which has `content=advisory` containing a single ITIStext (the text in the 1st column)	
"Closed due to local authority request"	closed due to local authority request	Only appears in a TIM which has `content=advisory` containing a single ITIStext (the text in the 1st column)	
"Steep downgrade ahead"	Steep downgrade	Only appears in a TIM which has `content=advisory` containing the following IT IS codes: ITIStext (the text in the 1st column) <number> (e.g. 12579) Increasing direction • grade =5% MP20 to MP22 Decreasing direction • grade =6.6% MP191 to 191.5 (7% sign) • grade = 6.2% MP 271.7 to 271.85 (6% sign	 …

ITIS Code	Description	TIM Message Pattern to Detect	Image(s)
"Sharp curve ahead"	Left and Right turns	When deflection angle is greater than 40 degrees. Only appears in a TIM which has `content=advisory` containing the following IT IS codes: ITIStext (the text in the 1st column) Right (13579)/Left (13580) The 13579/13580 will determine which image is displayed. The image on the left is displayed when ITIS code 13580 is present.	 …
"Several Reverse curves ahead"	Winding road		

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