Connected Vehicle Pilot Deployment Program Phase 2

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 are 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 2020 version of the document represents the "as built" system, which does not include system generated Distress Notifications.

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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 dedicated short-range communications (DSRC) 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 August 2020. This will be followed by a 12-month demonstration period in the third phase.

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.
- **Equip around 400 vehicles, a combination of fleet vehicles and commercial trucks, with on-board units (OBU).** Of the 400 vehicles, at least 75 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.
- **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, using Pikalert®[1] to provide for more accurate and road segment specific conditions to define better variable speed limits (VSLs), and improving road condition dissemination via 511, Dynamic Message Signs (DMS) and other WYDOT sources.

[1] Pikalert is a trademark of the University Corporation for Atmospheric Research.

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 Security Credentialing Management Systems (SCMS) can support secure communications as part of a larger security management framework developed for the proposed system.
- The Federal Communications Commission (FCC) will maintain the DSRC Spectrum for safety applications.

1.4 Constraints

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

- Polices 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 parties.
- 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.
- 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 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.
- Recruitment of fleet partners might be impacted by FCC's ruling on the DSRC Spectrum. Potential partners might be reluctant to join if they do not see a future for this technology.

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 the technology to be confident that they can achieve the objectives of the WYDOT CV 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. The FCC ruling on reallocating the DSRC spectrum also poses a risk, as it may impact the pilot and system's operation.

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)
    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 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 – Snow plow 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 as a result 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 new 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 snow plows, fleet vehicles (including light duty), 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 around 75 RSUs with DSRC connectivity** that are able to 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, DNs, 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).

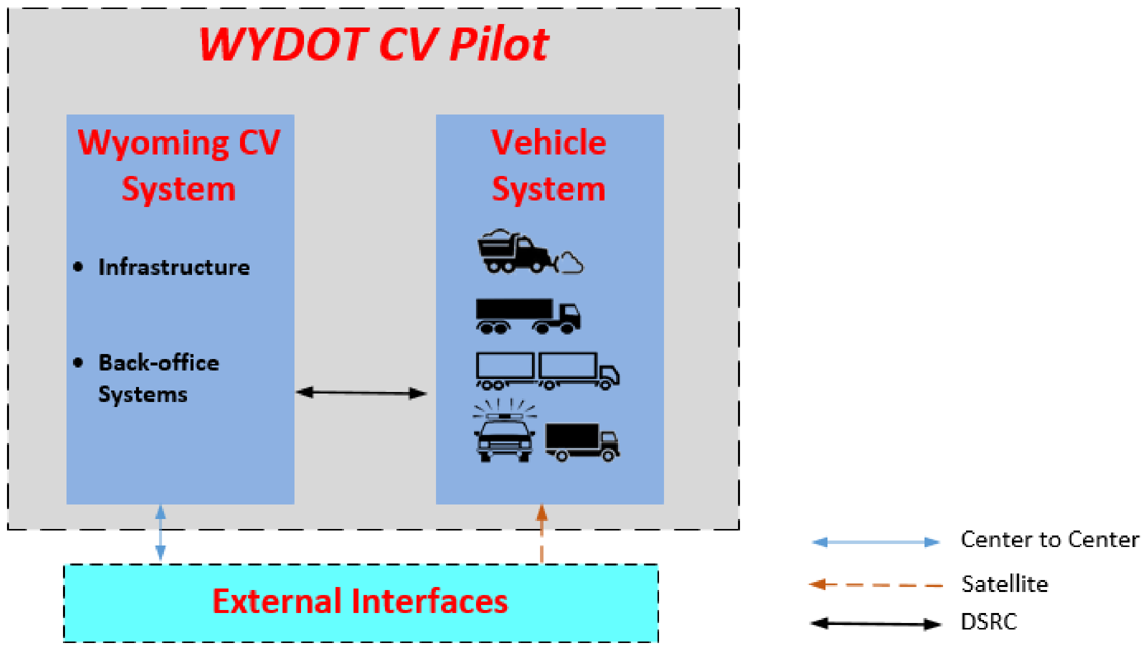

Figure 2-1 Wyoming CV Pilot System of Systems (Source: WYDOT).

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*).

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 and DNs) 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 and DNs (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.
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 Situation Data Exchange (SDX).
5. Store Data – Data generated are 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. 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.

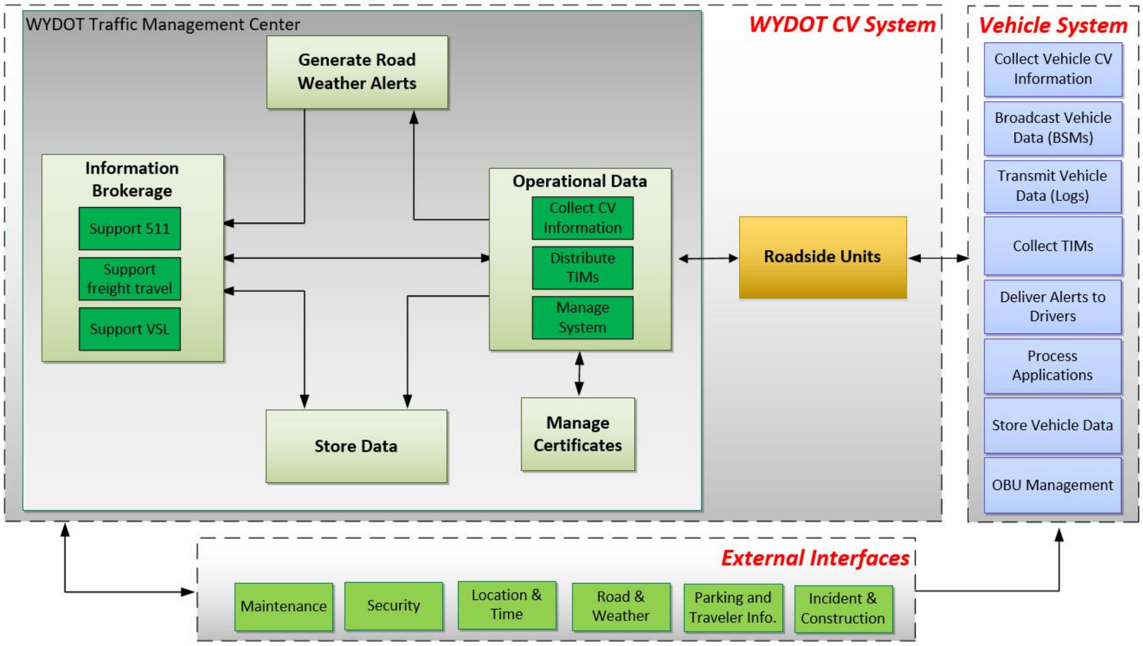

Figure 2-2. Functions of the Wyoming CV System and the Vehicle System. (Source: WYDOT)

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 five Sub-Systems:

- Roadside Units (RSUs)
- Operational Data Environment (ODE)
- Hardware Security Module (HSM)
- Pikalert System
- 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 DSRC 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 DSRC. 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 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 Hardware Security Module

The Wyoming CV Pilot uses the IIS/GHS[2] rented, black box hardware security module (HSM) in the Cheyenne TMC. In essence, the HSM will manage the Wyoming CV System's certifications. It has a Representational State Transfer (RESTful)[3] endpoint that receives an unsigned TIM and outputs a signed TIM. The HSM also has a link to the ISS/GHS Certificate Management System (CMS) to get updated certifications. It should be noted that its internal workings are a black box that is proprietary code, and therefore WYDOT will not have access to it. WYDOT will physically have two 1U rack[4] units that each have dual power supplies and are fail over in capability. The units also have a gig Ethernet connection with IPv4 and IPv6.

2.3.4 Pikalert System

The Pikalert System supports the integration and fusion of CV and non-CV weather data to develop alerts and advisories regarding adverse weather conditions along I-80. CV data are received from the ODE, while non-CV data derive from weather sources and the WYDOT DB. To generate the alerts and advisories, the Pikalert System assigns CV and non-CV data to 1-mile segments on I-80 every 5 minutes. The CV data is quality checked, then passed to Pikalert Road Weather Hazard module (RWH). The RWH uses these data to produce the alerts and advisories for adverse weather and for a 72-hour forecast of road weather conditions and hazards. The generated information is then shared with the DB for further distribution.

2.3.5 WYDOT Data Broker

WYDOT DB receives information from the ODE, Pikalert 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

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[2] IIS/GHS is the company hosting the pilot's certificate management system (i.e., INTEGRITY Software Services/Green Hills Software).

[3] https://en.wikipedia.org/wiki/Representational_state_transfer

[4] Rack height unit 1.75" (https://en.wikipedia.org/wiki/Rack_unit)

Traveler Information Messages (TIMs) to the RSUs and can also access historical data stored at the DW if needed.

2.3.6 WYDOT Data Warehouse

The WYDOT DW 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

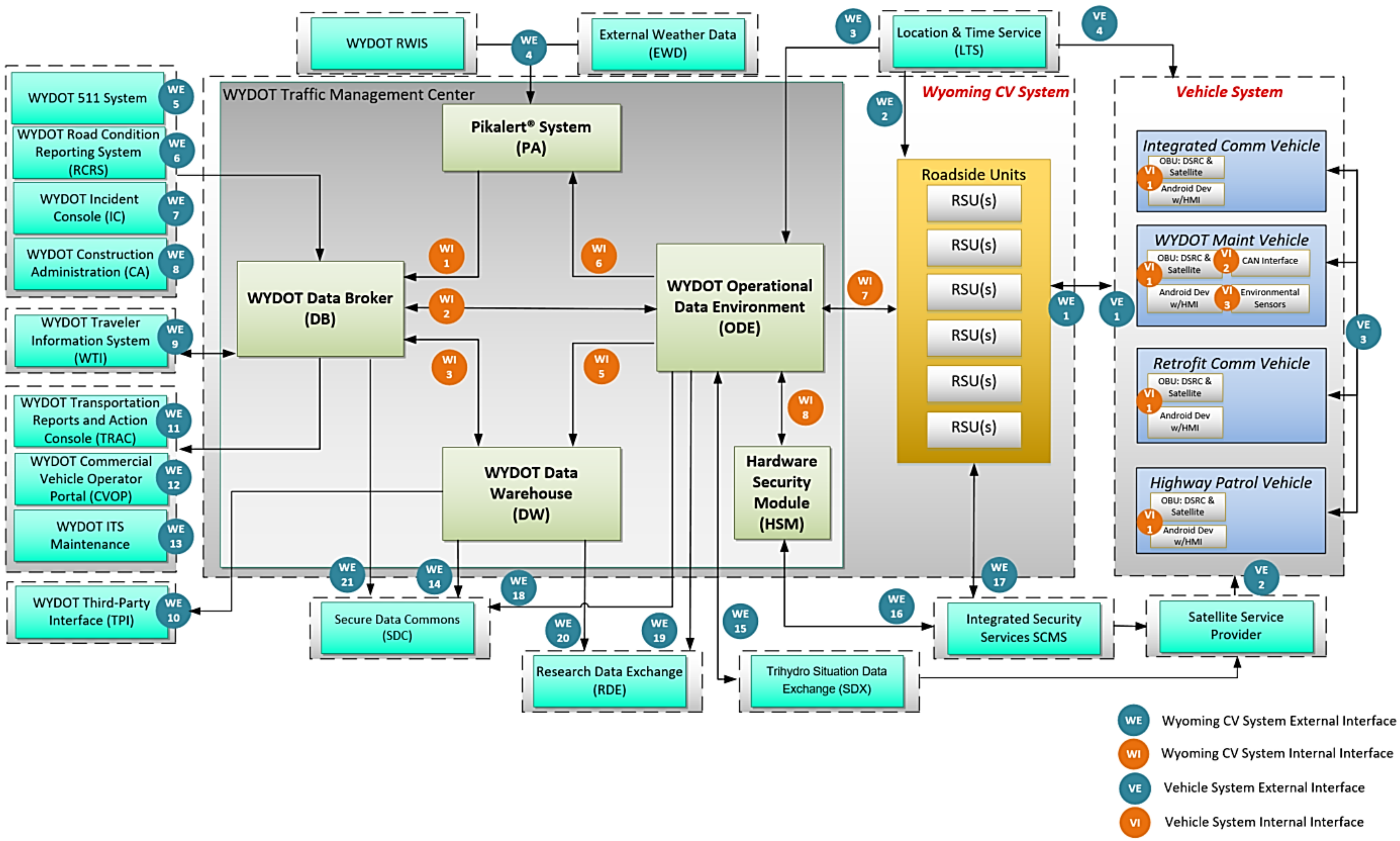
Figure 2-3 shows the physical architecture with interfaces numbered for reference and discussion here and in following sections. The Wyoming CV System includes the following external interfaces for exchanging data and information with external WYDOT and USDOT systems.[5]

- **I2V DSRC 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 and SAE J2945/1.
- **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.[6]
- **EWD and RWIS** (Interface WE4) – **EWD** provides regional weather data shared through data sources outside of WYDOT, such as the National Oceanic and Atmospheric Administration's Meteorological Assimilation Data Ingest System and USDOT. **RWIS** provides atmospheric and pavement condition information collected through Environmental Sensor Stations (ESS) deployed as part of the WYDOT RWIS network in the field.
- **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 I80.

[5] 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.

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

- **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 TPI** (Interface WE10) – A standardized interface based on the TMDD standard that can be used to support delivery of traveler information to external centers and information service providers.
- **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.
- **Secure Data Commons (SDC) / Research Data Exchange (RDE)** (Interfaces WE14, WE18, WE19, WE20, and WE21) **–** Provides WYDOT CV Pilot data to the independent evaluators and the RDE for use in independent analysis and impact evaluation across multiple CV pilots. Data will be collected, managed and shared utilizing the various WYDOT CV Pilot systems. Details of the data transfer are provided in the WYDOT CV Pilot SDD and the WYDOT CV Pilot ICD.
- **Trihydro Situation Data Exchange (SDX)** (Interface WE15) – A service based on the original USDOT SDX, operated by Trihydro that stores near real-time data and shares them 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.
- **Integrated Security Services 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 SCMS-related information.



NOTE: The Wyoming CV System Interface WI4 (PA→DW) and VI2 (OBU-CAN Bus) were not implemented in the final system design.

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

Additionally, several vehicles that are part of the *Vehicle System* have further capability. Based on this, the *Vehicle System* is divided into five Sub-Systems, which define the various vehicle types for this pilot based on their data collection and communication capabilities. Each Sub-System and its rationale are described below.

2.5.1 WYDOT Maintenance Vehicles

This Sub-System represents the maintenance fleets operated by WYDOT. This includes, but is not limited to, snow plow vehicles assigned to the I-80 corridor. These vehicles represent a set of vehicles over which WYDOT has full control as part of their operations. As such, some of the vehicles will be equipped with the full package of environmental sensors and equipment necessary to support the CV Pilot applications.
Around 60 vehicles are expected to be part of this sub-system, but not all with the same capabilities. Al vehicles will have the ability to:

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

Whereas 50 of them are expected to be able to:

- Collect weather sensor data.

2.5.2 WYDOT Highway Patrol Vehicles

This Sub-System represents the highway patrol fleet assigned to the I-80 corridor. While also operated by WYDOT, these vehicles represent a set over which WYDOT has less flexibility given the nature of their operations. Around 50 highway patrol vehicles are expected to be part of this subsystem, which will have the ability to:

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

2.5.3 Integrated Commercial Vehicles

This connected trucks Sub-System represents a subset of commercial trucks owned and operated by fleet partners involved in the pilot. Similar to Highway Patrol Vehicles, no external weather sensor data will be collected from these systems (i.e., only data from the vehicle) and there is no CAN Bus integration. To summarize, this Sub-system will include the abilities to:

- Receive BSM Parts I and II over DSRC.
- Broadcast BSM Parts I and II over DSRC.
- Receive TIMs via DSRC and Satellite (or other remote communication methods).

In essence, these vehicles represent the capability to use vehicle data collected from trucks in the pilot. WYDOT anticipates that about 200 trucks will have these functionalities.

2.5.4 Retrofit Commercial Vehicle

This Sub-system is intended to simulate a commercial-off-the-shelf system—which is different from the one installed on the integrated commercial vehicles—that enables a vehicle to communicate data through DSRC to other connected devices and receive TIMs through DSRC or satellite. About 50 vehicles are expected in this category and their abilities include:

- Receive BSM Parts I and II over DSRC.
- Receive TIMs via DSRC and Satellite (or other remote communication methods).
- Broadcast BSM Parts I and II over DSRC.

2.6 Pilot On-Board Applications Functionality

The WYDOT CV Pilot will develop five 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 as 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 snow plows 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.

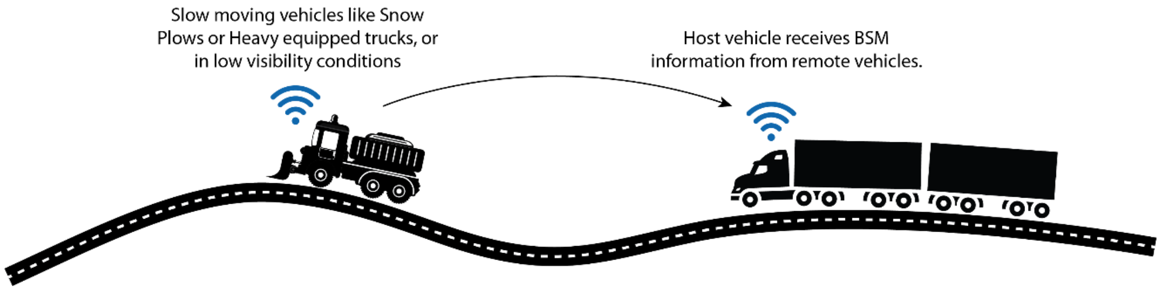


Figure 2-4. Forward Collision Warning Concept Diagram. (Source: WYDOT)

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 impact 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 communications that directly to drivers through both DSRC 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[7], 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 DSRC 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 DSRC communications. This application will follow the description from SAE J3067 August 2014 Section 2.9.3.6.

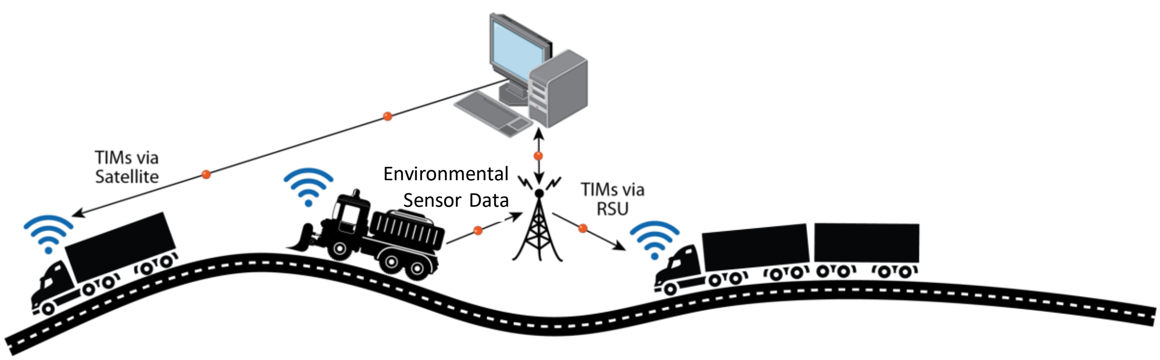


Figure 2-5. I2V Situational Awareness Concept Diagram. (Source: WYDOT)

[7] 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

2.6.3 Distress Notification (DN)

This application enables connected vehicles to communicate a distress status back to Wyoming CV System when ~~the vehicle's sensors detect an event that might require assistance from others (e.g., air bag deployed, vehicle disabled) or~~ the vehicle's operator manually initiates a distress status. The OBU generates and broadcasts a DN (e.g., Mayday) to the nearest RSU. The DN will include the location, time of message, distress message explanation, and vehicle category. The RSU forwards it on to the *Wyoming CV System* for notification of system operators and first responders.

Recognizing that this CV Pilot cannot provide continuous coverage of I-80 by RSUs, this application includes a V2V relay of DNs, illustrated in Figure 2-6. When a distressed vehicle (#1) is not within communication range of an RSU, the message is received by nearby connected vehicles (#2) traveling in the same and/or in opposite directions. These vehicles relay the Notification to the nearest RSU, whether upstream or downstream, which forwards it on to the *Wyoming CV System*. The relay function also enables vehicles traveling the opposite direction (#2), to inform vehicles upstream (#3), traveling in the same direction as the distressed vehicle, of the need for caution ahead.

Although this application is loosely based on the Mayday application description from SAE J3067 Section 3.5.9.2.1, it is built on a higher priority TIM communication using SAE J2735 March 2016, Section 5.16, Part 3, Integrated Transport Information System (ITIS) advisory elements.

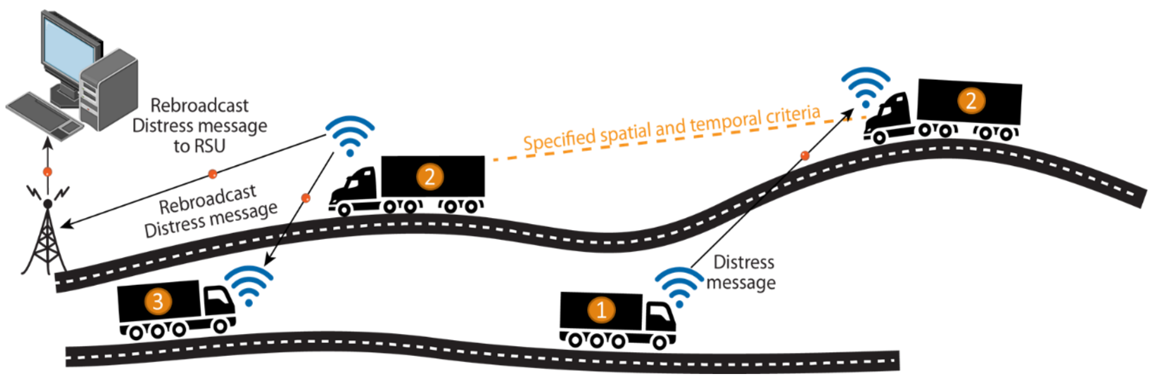


Figure 2-6 Distress Notification concept diagram (Source: WYDOT)

2.6.4 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 2-7). 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.

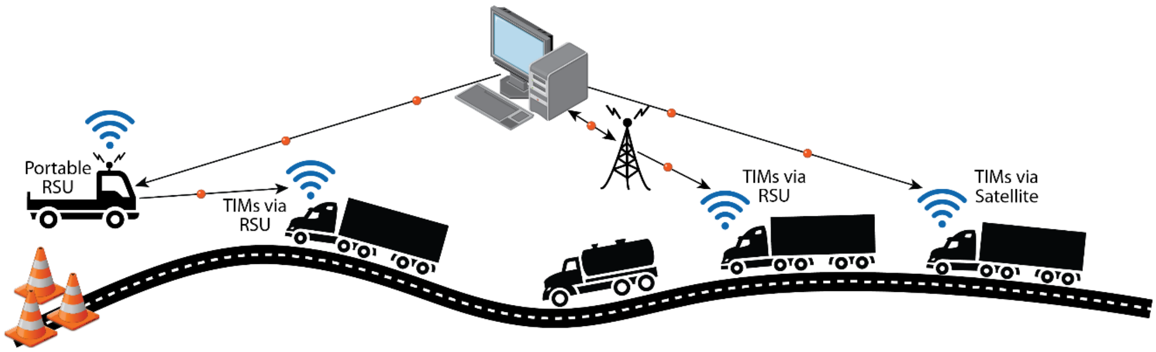


Figure 2-7. Work Zone Warning Concept Diagram. (Source: WYDOT)

2.6.5 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 2-8). 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.

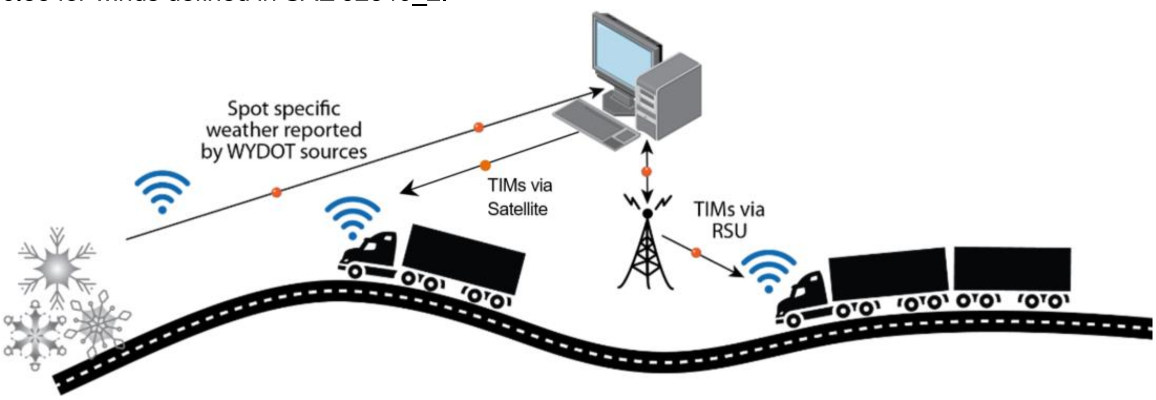


Figure 2-8 Spot Weather Impact Warning concept diagram (Source: WYDOT)

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, 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, Pikalert, 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 are 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 DSRC 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 2-9 shows the communication flows amongst the different components for the Forward Collision Warning application.

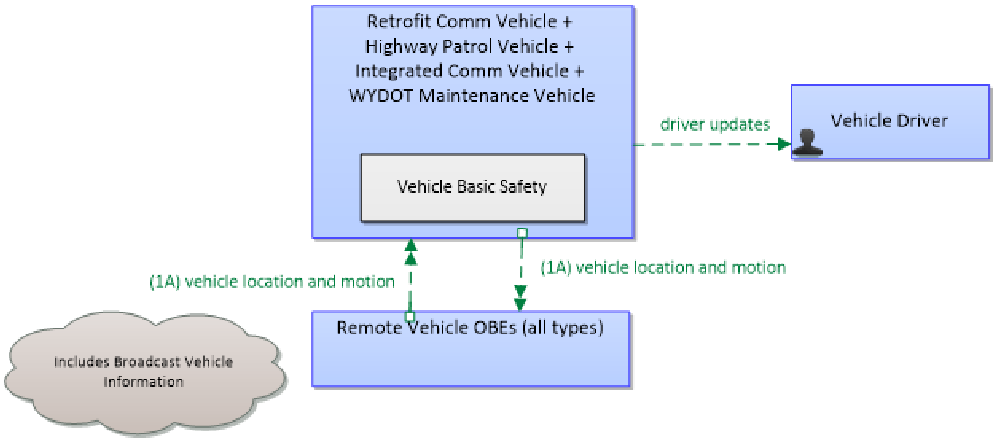


Figure 2-9. Forward Collision Warning Data Flows (Source: WYDOT).

2.9.1.2 OBU Functions

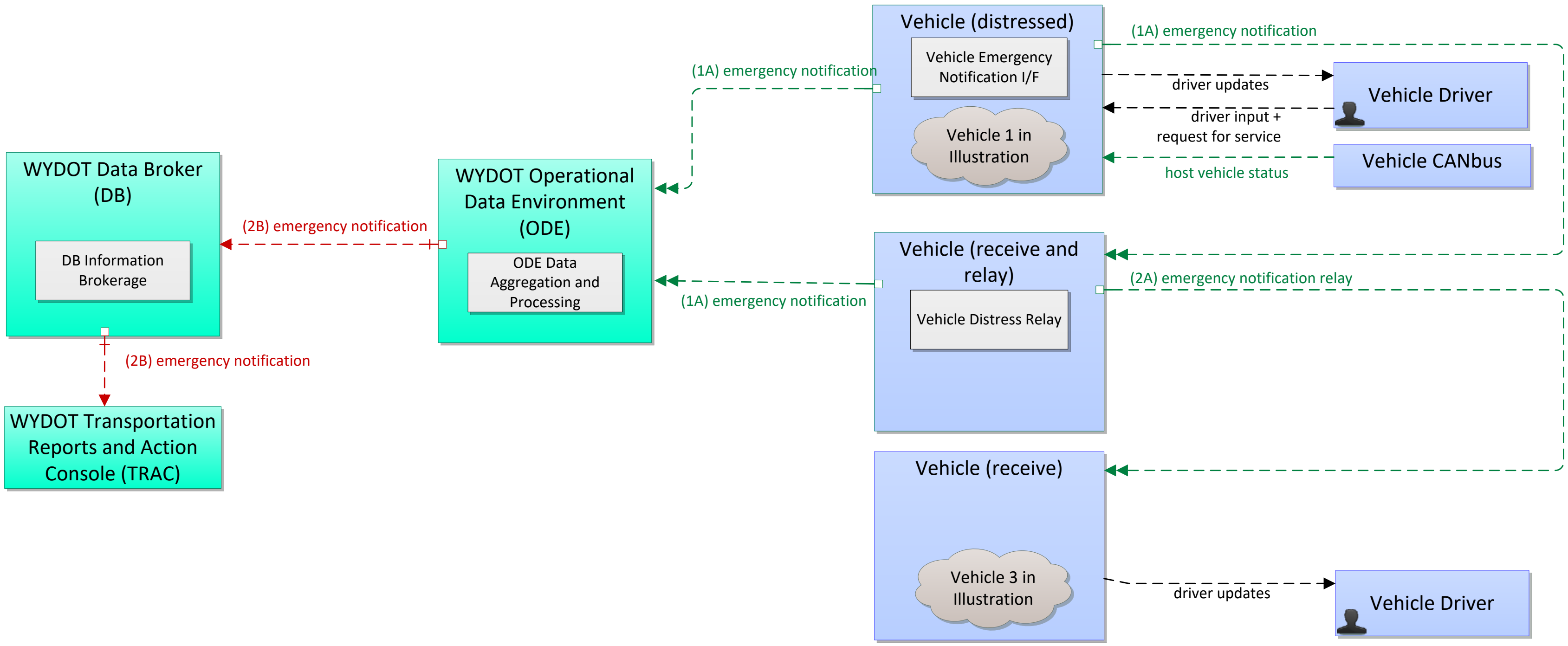
Functions responsible by the OBU for the forward collision warning application include monitoring BSMs from other connected vehicles traveling. If a speed difference is detected that would indicate a possible or imminent collision then an alert would be issued to the driver of the vehicle.

2.9.2 Distress Notification Application

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

2.9.2.1 System Level Design

Figure 2-10 shows the communication flows amongst the different components for the Distress Notification application.



NOTE: CANbus integration no longer applies to this Pilot.

Figure 2-10. Distress Notification Data Flows (Source: WYDOT).

2.9.2.2 OBU Functions

Functions responsible by the OBU for the distress notification application include detecting when a vehicle is in distress through the driver indicating that the vehicle is in distress~~ or when the vehicle's sensors detect an event that might require assistance from others (e.g., air bag deployed, vehicle disabled~~). The OBU will then be responsible for sending out a Distress Notification TIM message. This TIM will then be picked up by other OBUs that are then responsible for rebroadcasting the message over a defined time until the time elapses. Additionally, the OBU is responsible for uploading a DN TIM log and upload the log file through an RSU directly to the ODE for processing. The OBU is also responsible for notifying the drivers of all vehicles that receive the distress notification that a vehicle is in distress.

2.9.2.3 RSU Functions

The RSU will act as a pass-through for the Distress Notification message. This will allow the OBU to deposit the Distress Notification directly to the ODE.

2.9.2.4 ODE Functions

Functions responsible by the ODE for the distress notification application include making all Distress Notifications received available via a highly reliable and Kafka™ (application messaging) stream to the WYDOT Data Broker application.

2.9.2.5 DB Functions

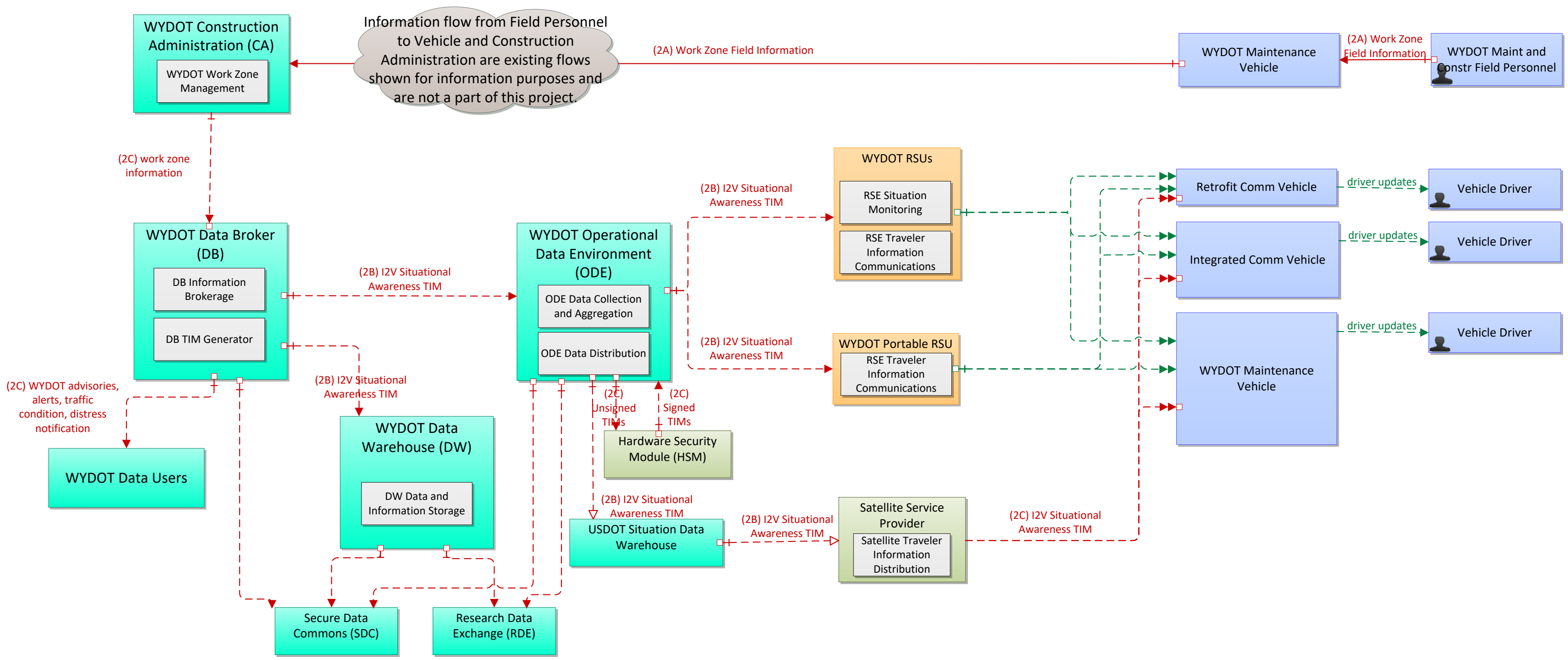
Functions responsible by the Data Broker for the distress notification application include notifying the TMC of any distress notification messages received by the ODE via the TRAC application.

2.9.3 Work Zone Warning

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

2.9.3.1 System Level Design

Figure 2-11 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.



NOTE: The figure is missing Highway Patrol Vehicles, which have the same communication capabilities as Integrated Commercial Vehicle.

Figure 2-11. Work Zone Warning flow diagram (Source: WYDOT)

2.9.3.2 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.

2.9.3.3 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.

2.9.3.4 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.

2.9.3.5 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 Situation Data Exchange 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.

2.9.3.6 RSU Functions

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

2.9.3.7 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.

2.9.3.8 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.

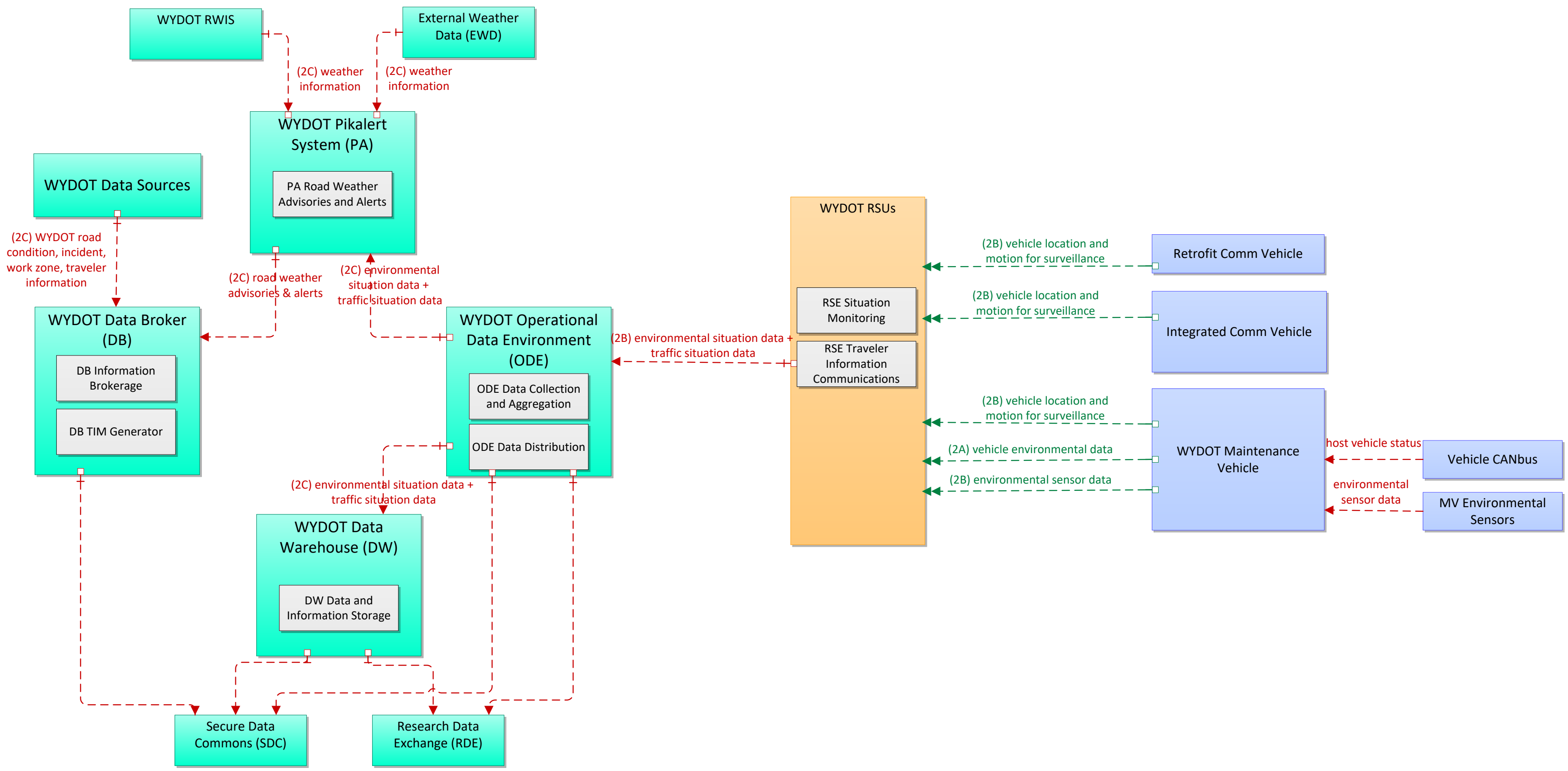
2.9.4 I2V Situational Awareness and Spot Weather Impact Warning Application

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.

2.9.4.1 System Level Design

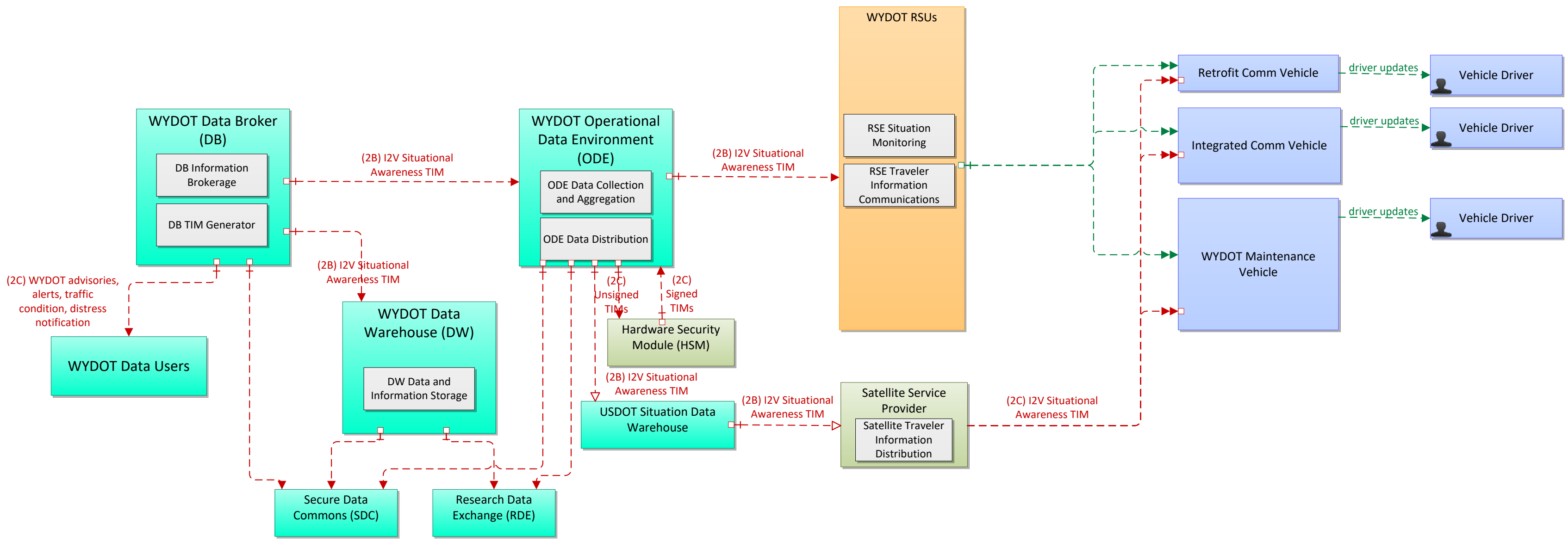
Figure 2-12 shows the communication flows into the Pikalert system. The Pikalert system will be responsible for providing the bulk of information that will be used to generate TIMs for the I2V Situational Awareness and Spot Weather Impact Warning application.

Figure 2-13 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.



NOTE: Vehicle CANBus integration is no longer part of this Pilot.

Figure 2-12. Pikalert inflow diagram (Source: WYDOT)



NOTE: The figure is missing Highway Patrol Vehicles, which have the same communication capabilities as Integrated Commercial Vehicle.

Figure 2-13. I2V outflow diagram (Source: WYDOT)

Figure 2-14 shows the communication flows for different applications within the TMC for the I2V situational awareness application.

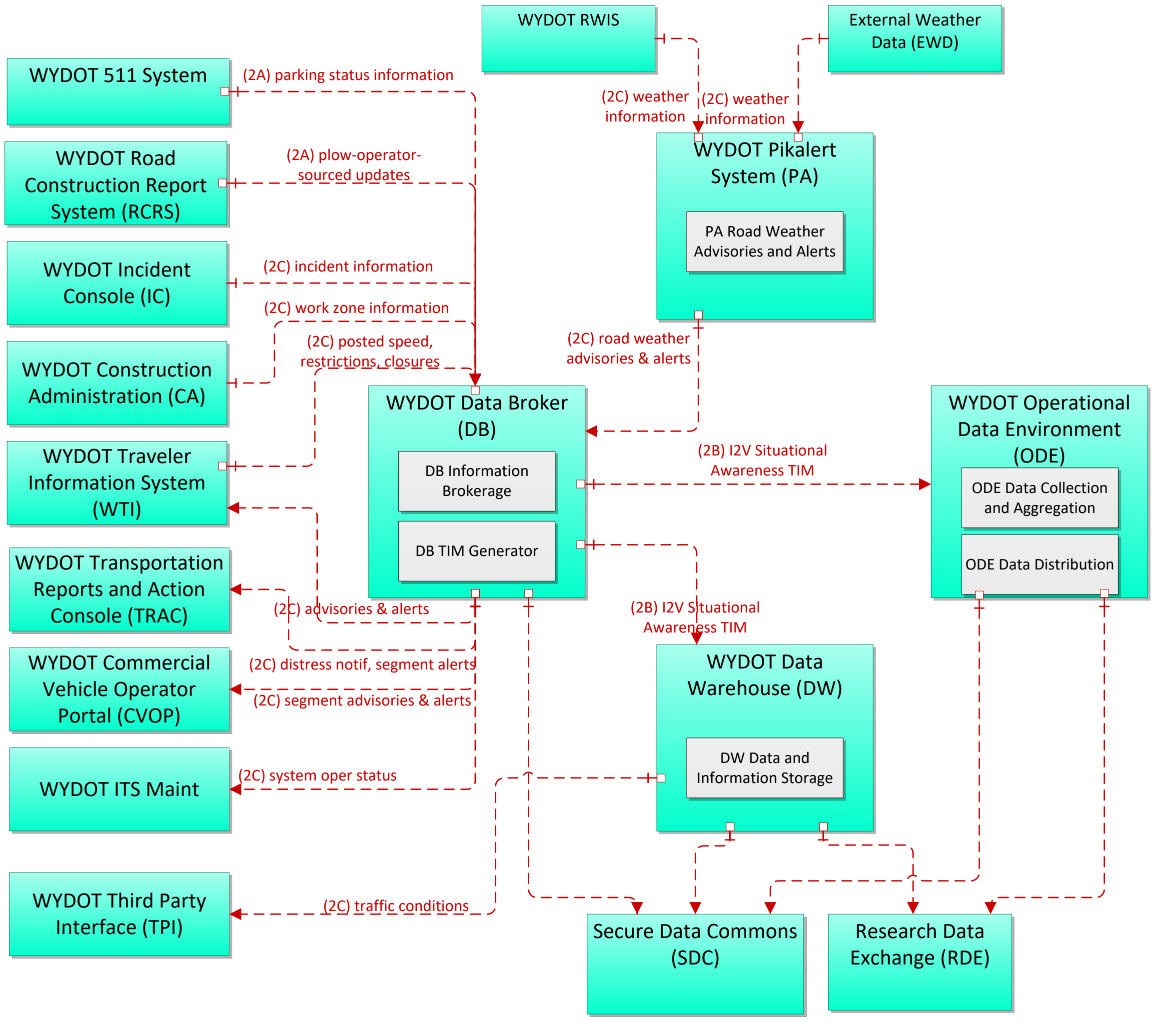


Figure 2-14. I2V TMC flow diagram (Source: WYDOT)

2.9.4.2 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.

2.9.4.3 RSU Functions

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

2.9.4.4 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 USDOT SDX when indicated.

2.9.4.5 Pikalert Functions

The Pikalert system functions for the I2V Situational Awareness application include ingesting weather data from BSM part 1 and part 2 and environmental data log streams provided by the ODE. This data will then be used to generate road weather and condition alerts when appropriate. The Pikalert system will be responsible for notifying the Data Broker application when new advisories/alerts are issued.

2.9.4.6 DB Functions

The Data Broker functions for the I2V Situational Awareness application include processing incoming warnings and alerts from the Pikalert system and then notifying the appropriate Application within the TMC to notify operators of the warning/alert. The Data Broker also provides functionality to allow TMC applications to post situational data to the data brokers for processing. The data broker is then responsible for determining the affected area and posting TIM messages to the ODE for appropriate RSUs.

2.9.4.7 DW Functions

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

2.9.4.8 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.

2.9.5 Truck Parking

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

2.9.5.1 System Level Design

Figure 2-15 shows the communication flows amongst the different components for the Truck Parking application.

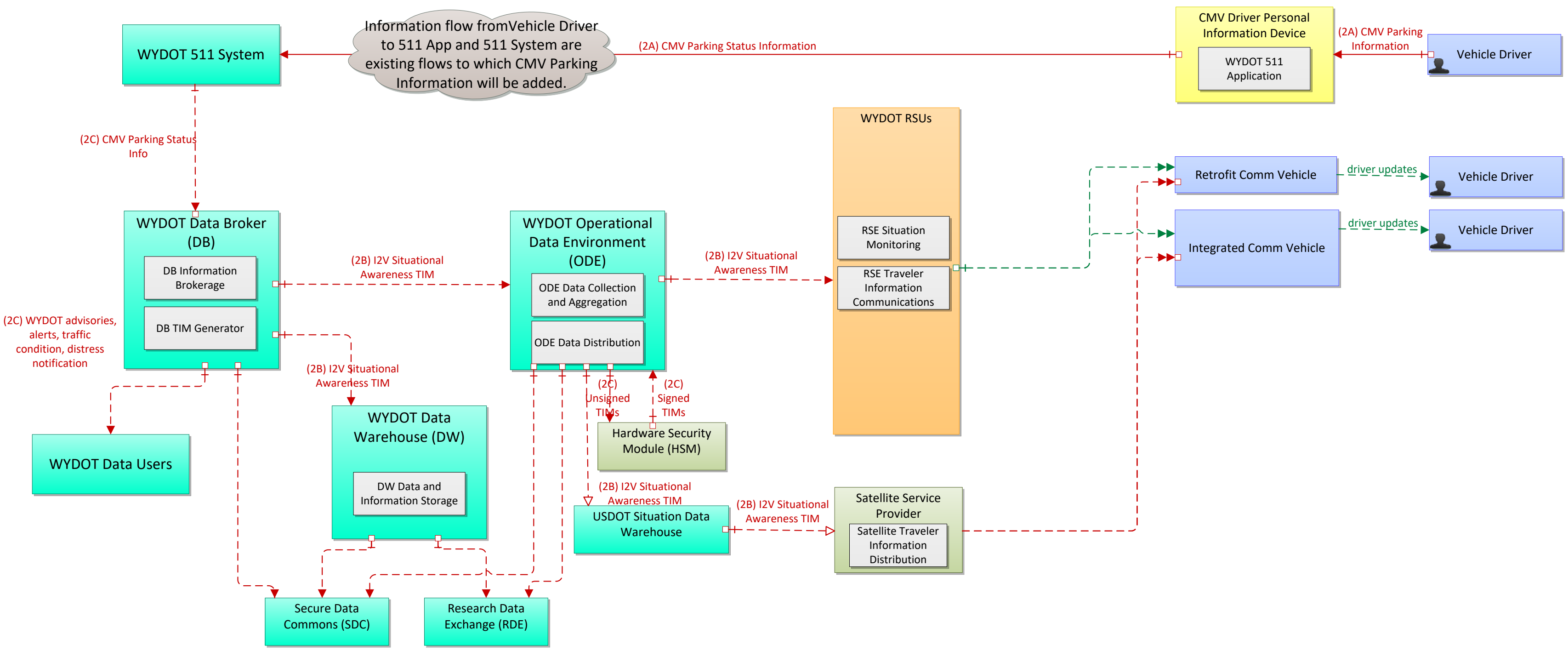


Figure 2-15. Truck Parking Data Flows (Source: WYDOT)

2.9.5.2 511 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.

2.9.5.3 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.

2.9.5.4 DW Functions

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

2.9.5.5 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.

2.9.5.6 RSU Functions

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

2.9.5.7 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.

2.9.5.8 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 2-16.

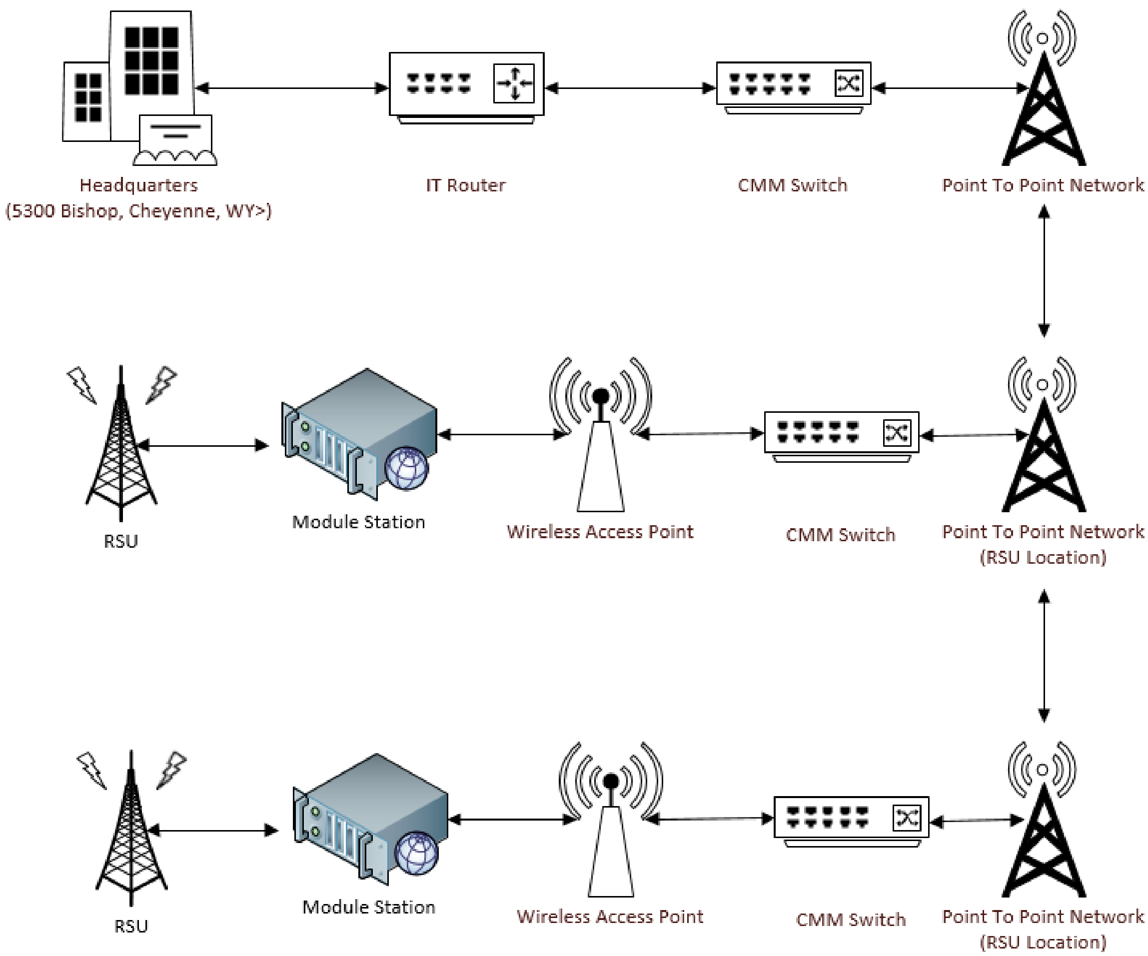


Figure 2-16. Simplified WYDOT Backhaul (Source: WYDOT).

The overall network for WYDOT can be viewed in Figure 2-17.

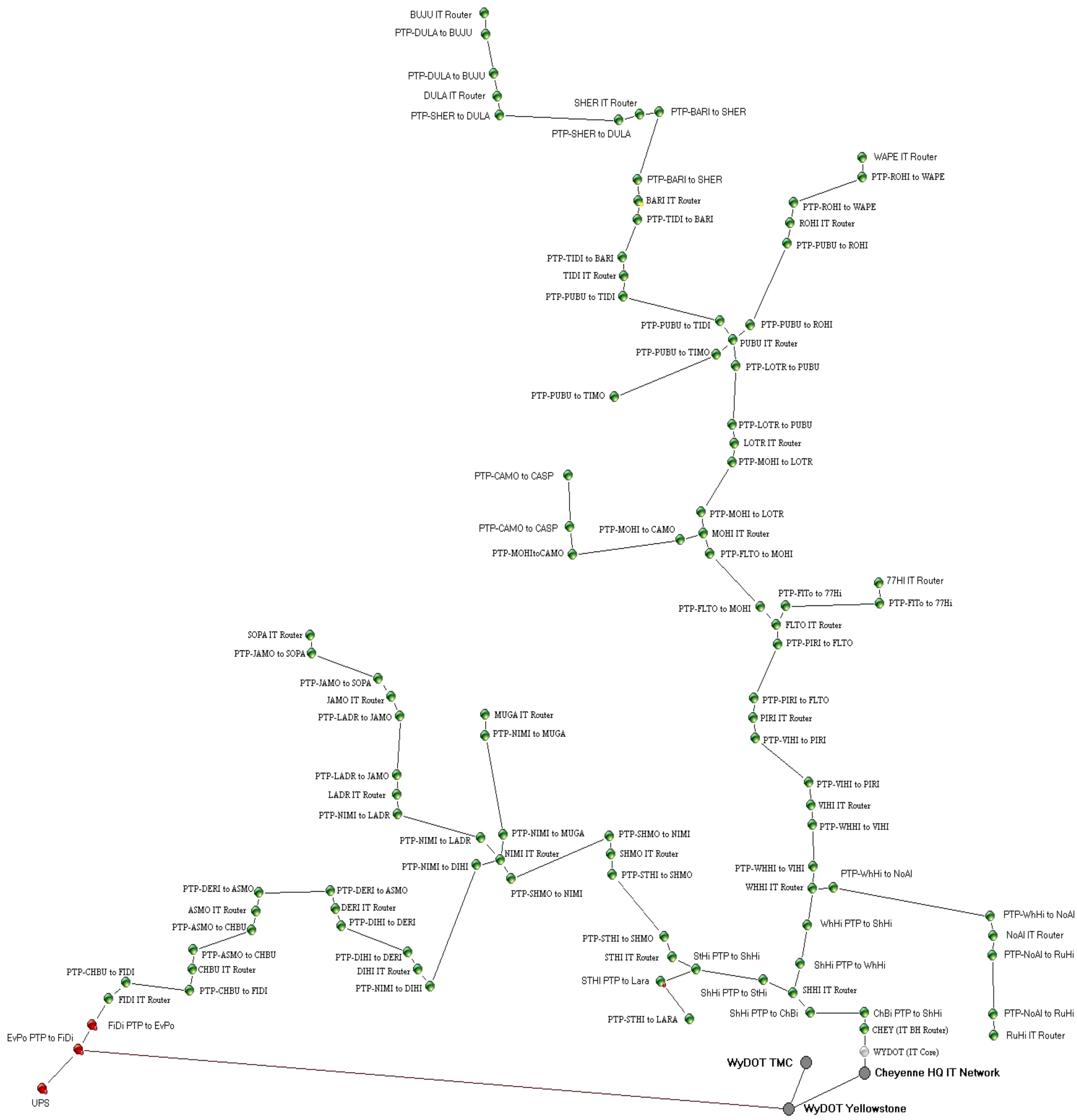


Figure 2-17. WYDOT Backhaul (Source: WYDOT)

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. Communications between REST services and the Oracle 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).

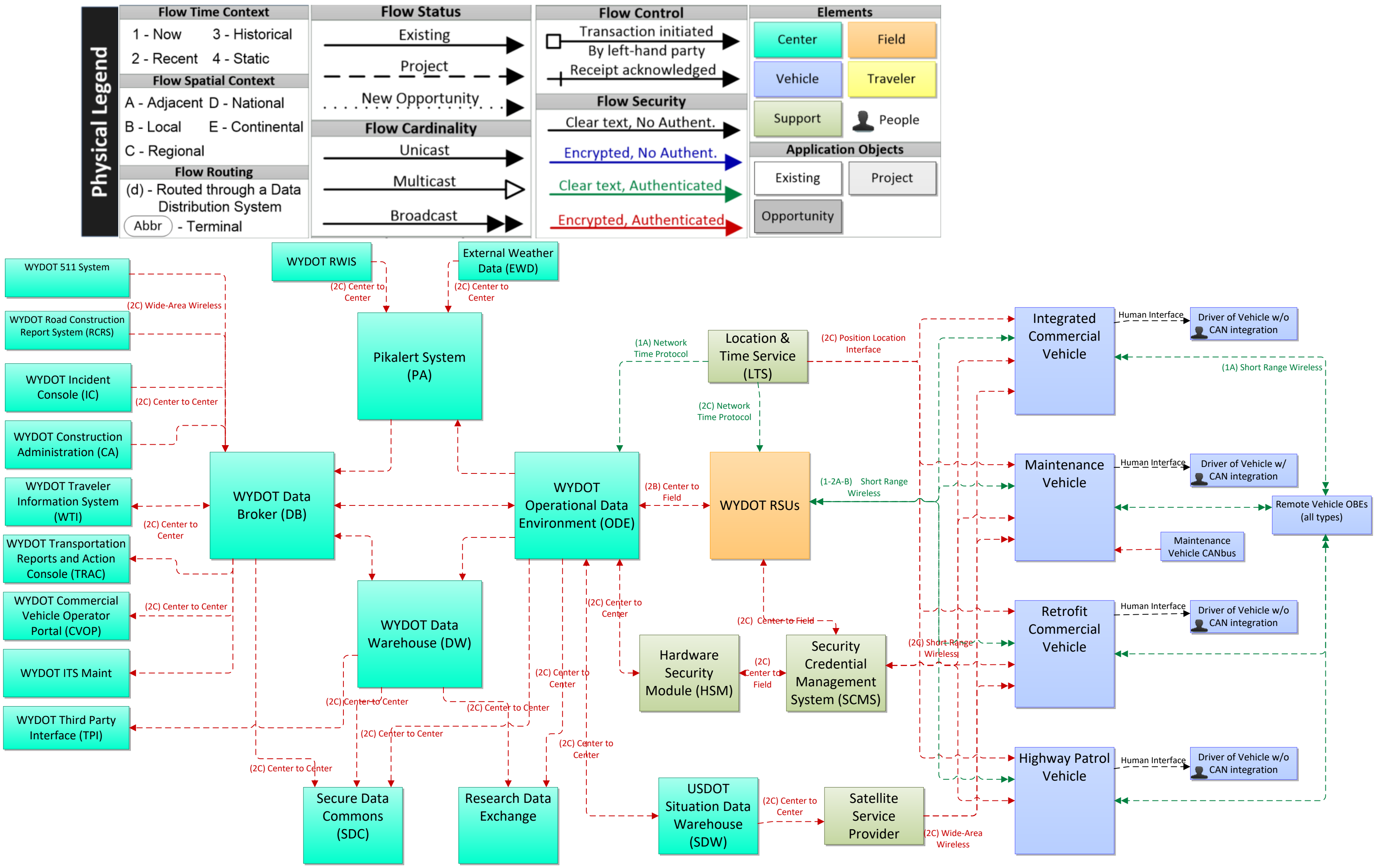
2.11.3 Communications Security Overview

Figure 2-18 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.

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 2-18 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. Figure 2-18 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. Figure 2-18 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 SCMS proof-of-concept system is an external system provided by the Federal government. 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 in order 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.



NOTE: CANBus integration is no longer part of this Pilot.

Figure 2-18. 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 DSRC radio communications the pilot will use the USDOT SCMS POC 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 Road Side Units that will be deployed for the WYDOT CV pilot system. Information in this section is provided by Lear as they are the chosen WYDOT RSU vendor.

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 in order 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, environmental situation data, 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, environmental situation data, SCMS certificates, and traffic situation data. BSMs are bundled and forwarded periodically without modification to the ODE. Environmental situation data passes through the RSU and gets pushed to the ODE for processing. SCMS certificates are pushed out to requesting OBUs.

3.1.1.2 RSU Hardware Platform

3.1.1.2.1 Vendor/manufacturer & model

Lear is the RSU manufacturer. The current RSU model is Locomate Roadstar RSU.

3.1.1.2.2 Picture and physical description of hardware

The Lear Locomate Roadstar RSU is encased in a weatherproof case and contains antennas for WiFi and DSRC connections. Additionally, the RSU unit comes with an integrated GPS and Sirius XM antenna. Figure 3-1 shows a Lear Locomate Roadstar RSU.

Figure 3-1. Locomate Roadstar RSU. (Source: WYDOT)

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

The RSU Unit has the following physical interfaces.

- 4 DSRC radio antenna connections
- 3 WiFi antennas connections
- 1 Power Over Ethernet (PoE) ethernet connection

- 1 Micro USB port
- 1 Global Navigation Satellite System (GNSS) connection
- 1 Sirius Satellite connection

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

The RSU will have the following equipment ordered as a single kit

- Dual DSRC radios
- GPS
- Bluetooth
- CPU
- IP Services (over DSRC)
- Wi-Fi
- Sirius XM
- Power Adapter
- GPS Antenna
- Sirius XM Antenna
- Dual DSRC Antennas
- Three years' hardware and software support

These devices will be installed along I-80 as well 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.

3.1.1.2.5 Hardware design description relevant to CV function and performance

Road Side Units (RSUs) include DSRC 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 DSRC and the ODE. About 75 RSUs are planned to be deployed in the pilot.

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 Vendor & version number

The OS Version is Linux kernel with version number is “3.10.17”.

3.1.1.3.2 Operating platform design description

The primary operating system is a lightweight Linux based Kernel operating system that provides the speed and functionality necessary to operate the RSU.

3.1.1.3.2.1 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.

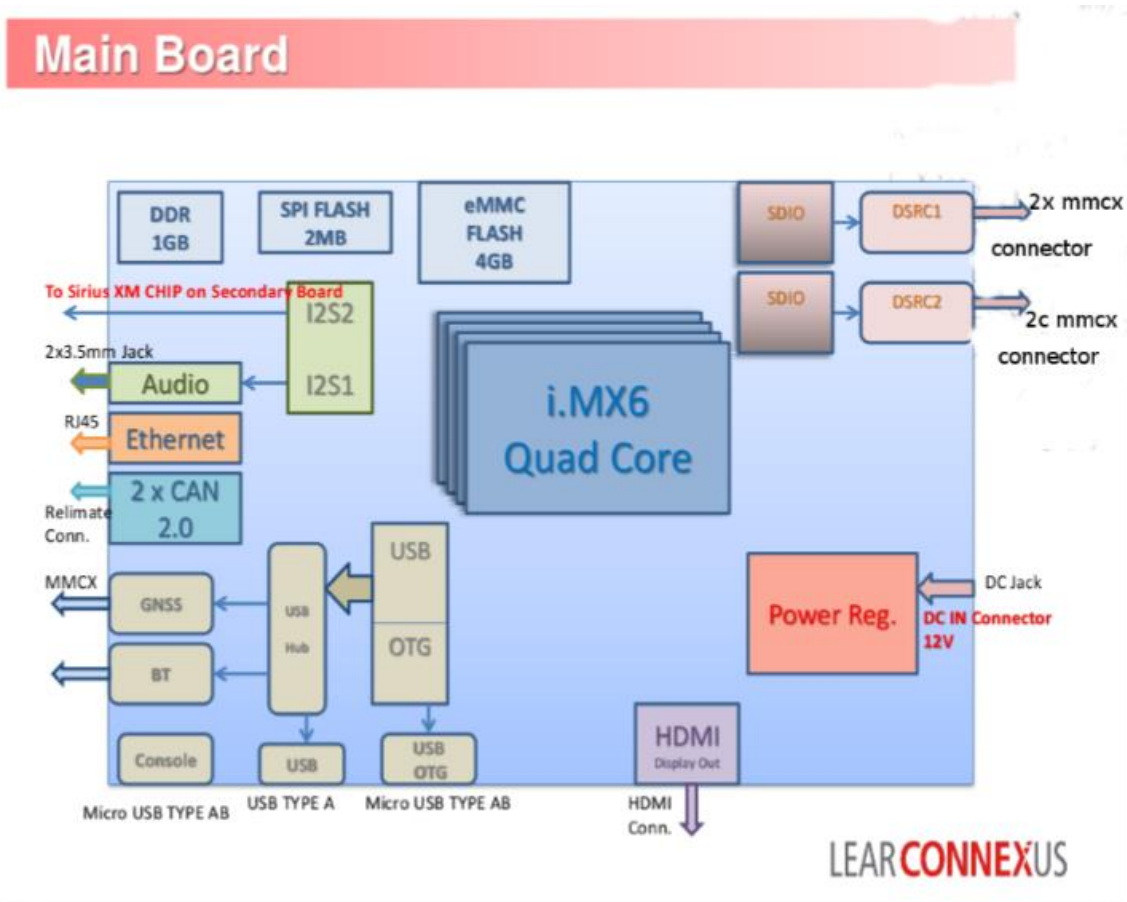


Figure 3-2. Block Diagram of RSU (Source: Lear)

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

Figure 3-3 shows the design diagram of different modules for User mode and Kernel mode within the RSU.

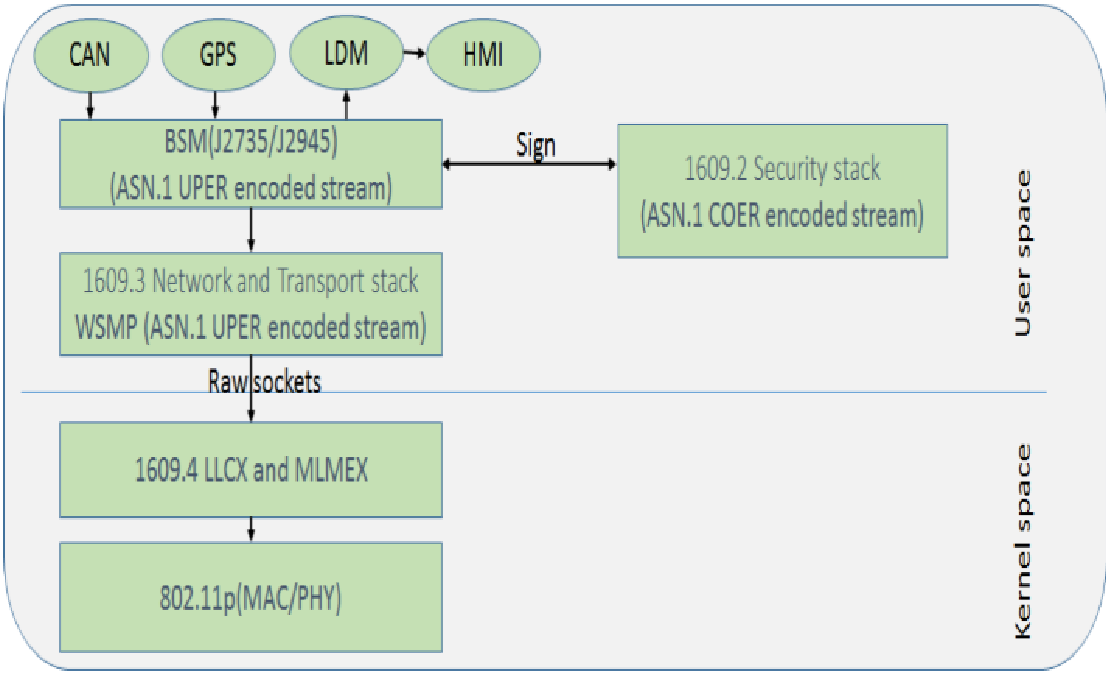


Figure 3-3. Flow Diagram of Modules within RSU (Source: Lear)

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

The RSU applications, which includes TIM, IPServices and PDM applications will run in user mode. Security for these messages is handled in the Security stack by signing the messages while transmitting and verifying them upon receiving the messages. Unique identifier to identify each application is the PSID, each application contains its own PSID. Based on the PSID values, the security profile will be applied for that given application and corresponding Relevance Checks and Certificate compliance operations will be handled in the Dot2 layer as per 1609.2 standards.

Dot3 application running in user space layer consists of a network and transport stack. Applications and the Dot3 layer communicate using a socket interface. Dot3 layer has WSMP Header and 1609.3 library, when application data accesses this layer, Dot3 requests the driver and registers the application with a corresponding PSID and channel info. For this, Dot3 interacts with library through the system calls. If the channel is available, then only it registers that channel with driver. Once the registration is done, the operations switches to kernel mode.

Data link layer (DOT4) running in the kernel mode. Applications will be using the NETLINK layer for communicating the configuring the Radio Driver and uses RAW sockets for Data transmission and reception. This layer implements the 1609.4 library and LLC layer header and MAC header. The MAC header size is 32 bytes of address, which is populated with the destination MAC of the device, channel, ID etc. This information along with payload that is coming from the previous layers. At physical layer using the modulation techniques, it will send the data in binary form to the air. Once the transmission is completed, the available devices listening on the same channel and PSID will receive these packets and do the reverse operation.

3.1.1.3.3 Operating Platform Configuration Data

On the device the application can be configured through clish. The configuration parameters may be either string or integer. While configuring if you enter ? , it will give whether it is integer/string along with some description about that parameter. Once the configuration is done those values are reflected in the “/var/config” file. Any configuration parameter changes have to be done through clish for that application. This change will get correspondingly reflected in “/var/config” file.

For BSM/SPAT/MAP/TIM/EGOPROCESS/IPSERVICE applications, the Syntax for the application configuration is:

config application <ACTION> <APPLICATION NAME> <PARAMETERS>

The ACTION, APPLICATION NAME and PARAMETERS configurations are explained below.
ACTION There are three actions are possible for applications.

1. Enable
2. Disable
3. Update

Enable To enable the APPLICATION. After enabling the application, that application should run on the board.

[Lear01FA2E:conf (0)] config application enable <APPLICATION NAME>

Disable To disable the APPLICATION. After disabling the application, that application should not run.

[Lear01FA2E:conf (0)] config application disable <APPLICATION NAME>

Update To update APPLICATION we use this update command. Make sure to update any application, first that application should be disable. In update there are several PARAMETERS are there, which explained in the following sections.

APPLICATION NAME The applications that are able to be configured on the device are:

1. BSM
2. SPAT
3. MAP
4. TIM
5. EGOPROCESS
6. IPSERVICE

PARAMETERS: Parameters can be configured through Update command only. General syntax is,

config application update <APPLICATION NAME> <PARAMETERS>

Parameters that need to configure are as follows.

wmeConfig
Following table contain different parameters included in the wmeConfig.

Table 3-1. WME Configuration Parameters

Parameter Name	Type	Description
psid	Unsigned integer	ID of the application
provider/user/channel	String	Selecting for specific arguments
timeslot	String	Selecting the timeslot (SCH/CCH/BOTH/NONE)
userreqtype	String	User request type(auto/no channel access)
srcmac	MAC(IPv6 address)	Providing source MAC address
advidentifier	String	matching advertise id string in WSA
linkquality	positive integer	Providing link quality value
immaccess	positive integer	immediate access value
wsatype	String	Selecting the security service
psc	String	provider service context
schan	Unsigned integer	service channel for registration
chaccess	String	Channel access for service
wsarepeatrate	Unsigned integer	Repeat rate of WSA's
dstmac	MAC(IPv6 address)	Destination device MAC address
wsachan	Unsigned integer	wsa Tx channel default CCH
ipservice	string	Enable/disable of Ipservice
serviceport	Positive integer	Mention the port number of service
serviceIpv6Addr	IPv6 address	Ipv6 adrress of the service
providermac	IPv6 address	MAC address of the provider service
rcpithresh	Positive integer	rcpi threshold value
wsacntthresh	Positive integer	WSA count threshold value
wsacountthinterval	Positive integer	WSA count threshold interval
infoelementind	Positive integer	info element indicator value
signlifetime	Positive integer	signal life time value

wsmConfig

The wsmConfig parameters are listed in following table

Table 3-2. WSM Configuration Parameters

Parameter Name	Type	Description
security	String	Security option(sign/encrypt/unsecured)
verifybypass	String	Security bypass verification status
timeslot	String	Selecting the timeslot (SCH/CCH/BOTH/NONE)
txchan	Unsigned integer	Transmission channel value
datarate	Float value	Providing data rate for transmission
txpower	Unsigned integer	Transmission power in dbm
chload	positive integer	channel load value
infoelementindicator	positive integer	info element indicator value
userpriority	positive integer	User priority value
repeatrate	Unsigned integer	Range 2Hz-20Hz, default 10Hz
expirytime	Positive integer	Expiry time
peermac	MAC(IPv6 address)	peer MAC address

otherConfig

The otherConfig parameters are listed in following table

Table 3-3. Other Configuration Parameters

Parameter Name	Type	Description
txrxmode	String	Mode(TX/RX/TXRX/NONE)
tempidrandstatus	String	temp ID control status
msgcount	Positive integer	message ID value
tempid	String	Temporary Id
srmfolder	String	srm folder name with path
portnumber	Positive integer	port number value
forwarddirection	String	remote forward direction value
logtype	String	Providing the logtype
remoteforwardip	String	remote server IP value
remoteforwardport	Positive integer	remote server port number value
filename	String	Remote file name
configFile	String	application specific config file name with path
filesize	Positive integer	Size of the file
remotedataforward	String	remote data forward value
remoteparamforward	String	remote forward paramter value
remoteeventforward	String	forward event value
loglevel	String	log level value
printencode	String	Enable/disable status
printdecode	String	Enable/disable status

saeConfig
The saeConfig parameters can be configure only in BSM application only. The parameters are listed in following table

Table 3-4. SAE Configuration Parameters

Parameter Name	Type	Description
vehicletype	String	vehicle type value
vehiclelength	Float value	vehicle length value in meters
vehiclewidth	Float value	vehicle width value in meters
vehicleheight	Float value	vehicle height in meters
vehicleclass	String	vehicle class value
vehiclerole	String	vehicle role value
vehiclefuel	String	vehicle fuel value
vehiclemass	Float value	Vehicle mass in kgs
frontbumperheight	Float value	vehicle front bumper height in meters
rearbumperheight	Float Value	vehicle rear bumper height in meters
vehicledisabled	String	Checking vehicle is disable or not

OFFLOAD Application
Offload is the application run on the ASD device. The syntax of this application is below.

config locos offload <status/update>

Status
By using this status we can start/stop the application.
Enable
To start the offload application we need to enable the status.
config locos offload status enable
Disable
To stop or configuring the application parameters, we need to disable the application.
config locos offload status disable
Update
There are two types of configuration parameters.

1. wmeConfig
2. OptConfig

wmeConfig
The parameters of the wmeConfig are listed below.

Table 3-5. WME Configuration Parameters

Parameter Name	Type	Description
appname	String	Application name
psid	Unsigned integer	Application psid
userRequestType	Unsigned integer	Application user request type
wsaType	Unsigned integer	WSA type value
psc	String	Configure Provider service context
serviceChannel	Unsigned integer	configuring service Channel value
advertiserIdentifier	String	Configure advertiser Identifier

OptConfig
The parameters of the OptConfig as listed below.

Table 3-6. Opt Configuration Parameters

Parameter Name	Type	Description
RemoteUserName	String	user name of backend machine
LocalSrcDir	String	Its is the path that files should be offloaded
RemoteDestDir	String	Path of directory that files should be offloaded.
retrycount	Unsigned integer	Retry count value for uploading files
ipaddress	IPv4/IPv6 address	backend machine IPv4/IPv6 address
uploadtime	Unsigned integer	Upload time in seconds
retryinterval	Unsigned integer	Retry interval value in seconds
threshold1	Unsigned integer	minimum size of the offload directory
threshold2	Unsigned integer	threshold2 value
threshold3	Unsigned integer	maximum size reached by offload directory

RSUOFFLOAD Application

RSUOffload is the application run on the RSU device. The syntax of this application is below.
config locos rsuoffload <status/update>

Status

By using this status we can start/stop the application.

Enable

To start the rsuoffload application we need to enable the status.
config locos rsuoffload status enable

Disable

To stop or configuring the application parameters, we need to disable the application.
config locos rsuoffload status disable

Update

There are two types of configuration parameters.

1. Partition
2. DIRECTORY

Partition

The parameters of the partition as listed below.

Table 3-7 Partition Configuration Parameters

Parameter Name	Type	Description
mountpoint	String	Application mount point
keyfile	String	SCP key file
sizethresholdcheckinterval	Signed integer	size threshold check interval in minutes
offloadinterval	Signed integer	offlaod interval in minutes
sizethreshold1	Signed integer	Minimum range of mount point
sizethreshold2	Signed integer	Size of threshold2
sizethreshold3	Signed integer	Maximum range of mount point

DIRECTORY

In this we have five directories. If we want to we can configure all directories. The parameters of the DIRECTORY as listed below.

Table 3-8. DIRECTORY Configuration Parameters

Parameter Name	Type	Description
action	String	Either add or delete
srcpath	String	Path of the source directory
serveraddr	IPv6 address	Address of the server.
serverport	Signed integer	Port number of the server
destdir	String	Destination directory path
serverusername	String	User name of the server
retrycount	Signed integer	offload retry count

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
- SCMS-REQ-1.1 SCMS Wyoming CV System Certificates
- SCMS-REQ-1.2 SCMS Wyoming CV System Misbehavior Reporting
- SCMS-REQ-1.3 SCMS Wyoming CV System Certificates Revocation List (CRL)
- SCMS-REQ-1.4 SCMS Wyoming CV System Rejection
- RSU-REQ-3 SCMS
- RSU-REQ-4 LTS
- RSU-REQ-6 Safety Communication
- RSU-REQ-7 Broadcast
- RSU-REQ-10 Management and Performance
- 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 3-9) and are broadcast on channels found in Table 3-10. 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 Locomate Roadstar RSU.

3.1.2.1.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway
Figure 3-4 shows the high-level communications for the RSU Roadway Traffic Information Dissemination along the highway.

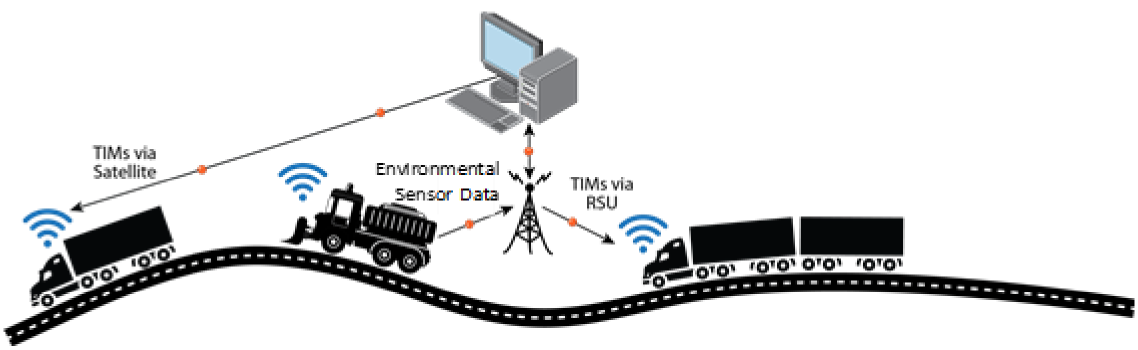


Figure 3-4. RSU Roadway Traffic Information Dissemination highway communications. (Source: WYDOT)

3.1.2.1.1.3 Input Data/Message Flows
The Traffic Information Dissemination application input flows consist of Immediate Forward Messages (IFM) or SNMP configuration input data streams. IFM messages are immediately pushed to the TIM application for publication and broadcast on the RSU while SNMP configuration messages go through a Store and Repeat module that will push to the TIM module. Figure 3-5 represents the data flow for inputs to the TIM application.

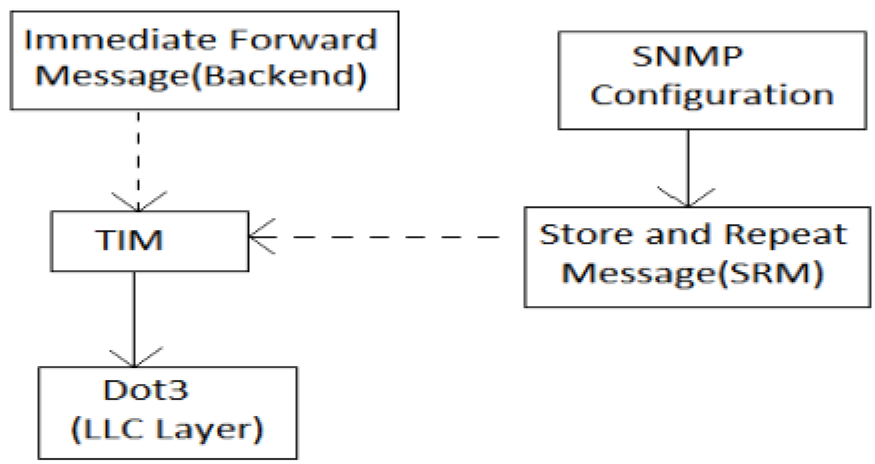


Figure 3-5. Traffic Information Dissemination Flows. (Source: Lear)

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. Figure 3-5 shows the output of the data flows for the Traffic Information Dissemination application.

3.1.2.1.2 Developer & version number

Lear 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 application

Table 3-9 shows the alerts and messages that are issued by the Traffic Information Dissemination application for broadcast to OBU's.

Table 3-9. 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

ITIS Code	Description	Category
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
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

ITIS Code	Description	Category
"Advices 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 of the messages that are issued by the Traffic Information Dissemination application in Table 3-9 follow the same algorithm used in the traffic information dissemination application. Once the TIM application receives a request from either the IFM or the SRM modules an alert or advisory is broadcast from the TIM application.

3.1.2.1.4 Application Design Description

The following sections describe the design of the Traffic Information Dissemination application.

3.1.2.1.4.1 Schematic of major modules/functions

Figure 3-4 shows the major modules and functions within the Traffic Information Dissemination application.

3.1.2.1.4.2 Description of modules/functions

Immediate Forward Message: This module receives an encoded payload and directly sends the message to the TIM application.

Store and Repeat Message: This module uses an SNMP configuration to encode and send messages for a specified period of time to the TIM application.

TIM: This module is used to transmit the received ITIS application on channel 174 through the Dot3 Logical Link Control layer.

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

Figure 3-5 shows the process flow between the algorithms for the major modules/functions in the Traffic Information Dissemination application. The process flow follows the same pattern as the indicated data flow diagram.

3.1.2.1.5 Application Configuration Data

Table 3-10 shows the configuration parameters for the different aspects of the RSU Traffic Information dissemination application.

Table 3-10. RSU Traffic Information Dissemination application parameters.

Parameter Group	Parameter Name	Possible Values	Description
WME	psid	131	Message type processed by the TIM application.
	service	provider, user, channel	Identifies the role that the application is configured for: psr Provider – supplies the service csr Channel – supplies the channel usr User – uses the service
	schan	174,176,180,182	Service channel that the TIM are broadcast on.
	slot	slot0, slot1, either	Defies the timeslot for the broadcast.
SM	security	unsecured, encrypt, sign	• Unsecured – no encryption or verification of messages • Sign – use certificates to sign outgoing and validate incoming messages • Encrypt – encrypt messages
	verifybypass	enable, disable	Determines if security certificates are used to verify the communication. Enable => skip message verification
	txchan	178	Control channel where availability of service is broadcast

	datarate	6.0, 9.0, 12.0, 18.0	Data rate Mbps
	txpower	0-23	Transmit Power for the TIM broadcast.
	userpriority	0 - 7	Application priority level used by Networking Services to decide which application gets preferred access to the communication services. Annex A of J2735 Lowest 0 highest 7
Other	txmode	tx, rx, txrx, none	Operating mode of the TIM application tx – transmitting only rx – receiving only txrx – transmitting and receiving none – not operating
	srmFolder	/var/SRM/AML/	Path where the files for each TIM are found.
	printencode	enable, disable	Encode received packets and print to console
	printdecode	enable, disable	Decode received packets and print to console

3.1.2.1.6 Requirements Traceability

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

- WCVS-REQ-8 Internal Brokerage
- WCVS-REQ-10 Distribute TIM
- WCVS-REQ-10.1 Distribute TIM to VS
- RSU-REQ-2 Distribute TIM to VS

3.1.2.1.7 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

3.1.2.2 RSU Distress Notification Application

Based on the updated design from Lear the incoming Distress Notification message from an OBU is passed through the RSU directly to a WYDOT server that is deposited to the ODE. Therefore, there is no need for an RSU Distress Notification application.

3.1.2.3 RSU Basic Safety Monitoring

This section describes the information flow and the responsibilities for each of the components involved with the RSU Basic Safety Monitoring application.

3.1.2.3.1 Function of the Application
The sections below describe the function of the RSU Basic Safety Monitoring application.

3.1.2.3.1.1 Functions/Services Brief description
This application monitors the basic safety messages that are broadcast from connected vehicles and filters this data into traffic flow measures that can be used to manage the network in combination with or in lieu of traffic data collected by infrastructure-based sensors. As connected vehicle penetration rates increase, the measures provided by this application can expand beyond vehicle speeds that are directly reported by vehicles to include estimated volume, occupancy, and other measures. This application will broadcast on channel 172 and have a PSID of 0x20.

3.1.2.3.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway
Figure 3-6 shows a graphical illustration of the Basic Safety Monitoring application communications along the highway.

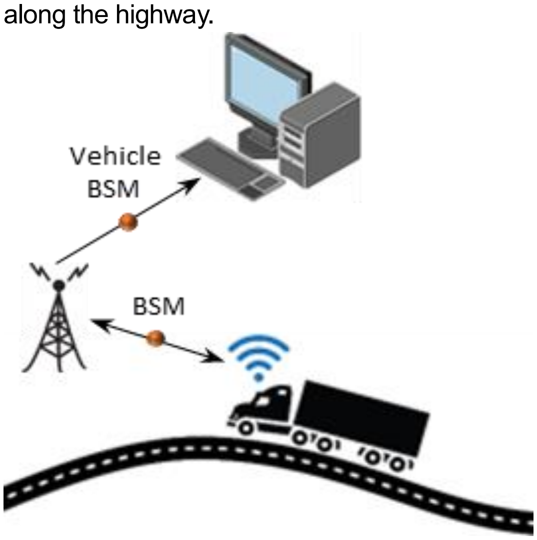


Figure 3-6. Basic Safety Monitoring application illustration. (Source: WYDOT)

3.1.2.3.1.3 Input Data/Message Flows
Input data for the Basic Safety Monitoring application consists of Basic Safety Messages (BSMs) from OBUs. The BSMs pass in through a Logical Link Control layer into a capture module and are forwarded on to the WSMPForward application. The WSMPForward application uses SNMP settings to then route incoming BSMs to a log file and then on to the TMC backend server. Figure 3-7 shows the input data flows for the Basic Safety Monitoring application.

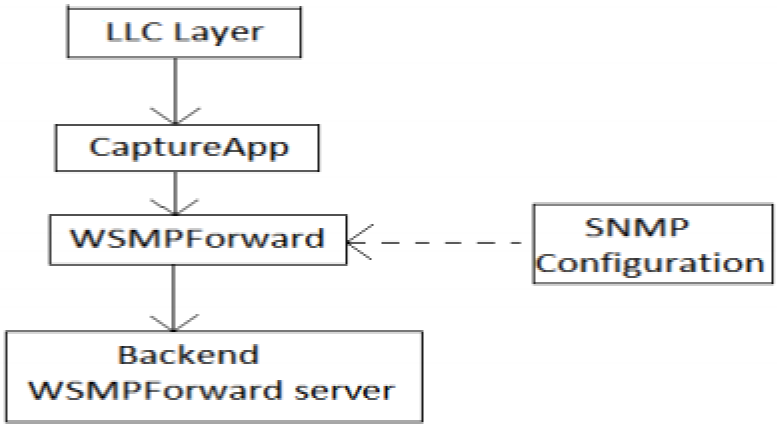


Figure 3-7. Basic Safety Monitoring Data Flows. (Source: Lear)

3.1.2.3.1.4 Output Data/Message Flows

Output data for the RSU Basic Safety monitoring application consists of BSM messages that are forwarded to a backend server (seen in Figure 3-7)

3.1.2.3.2 Developer & version number

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

3.1.2.3.3 Application Design Description

The following sections describe the design for the RSU Basic Safety Monitoring application.

3.1.2.3.3.1 Schematic of major modules/functions

Figure 3-8 through Figure 3-10 shows the different functions for the WSMPForward application that makes up the RSU Basic Safety Monitoring functionality.

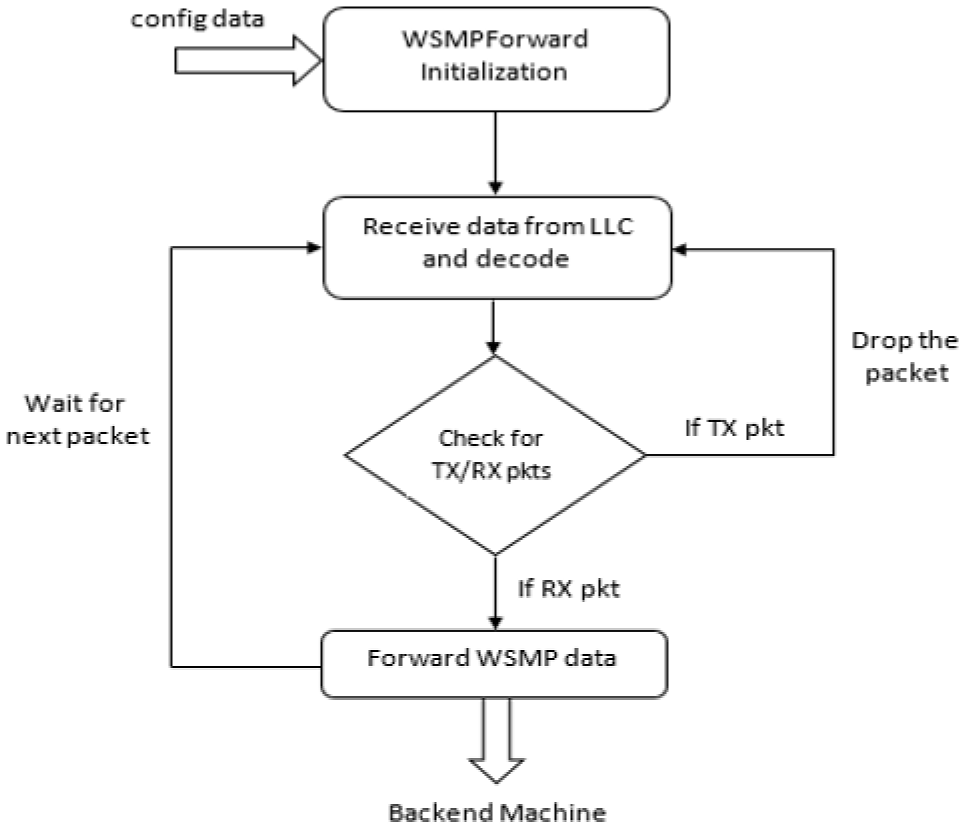


Figure 3-8. WSMPForward Initialization Function. (Source: Lear)

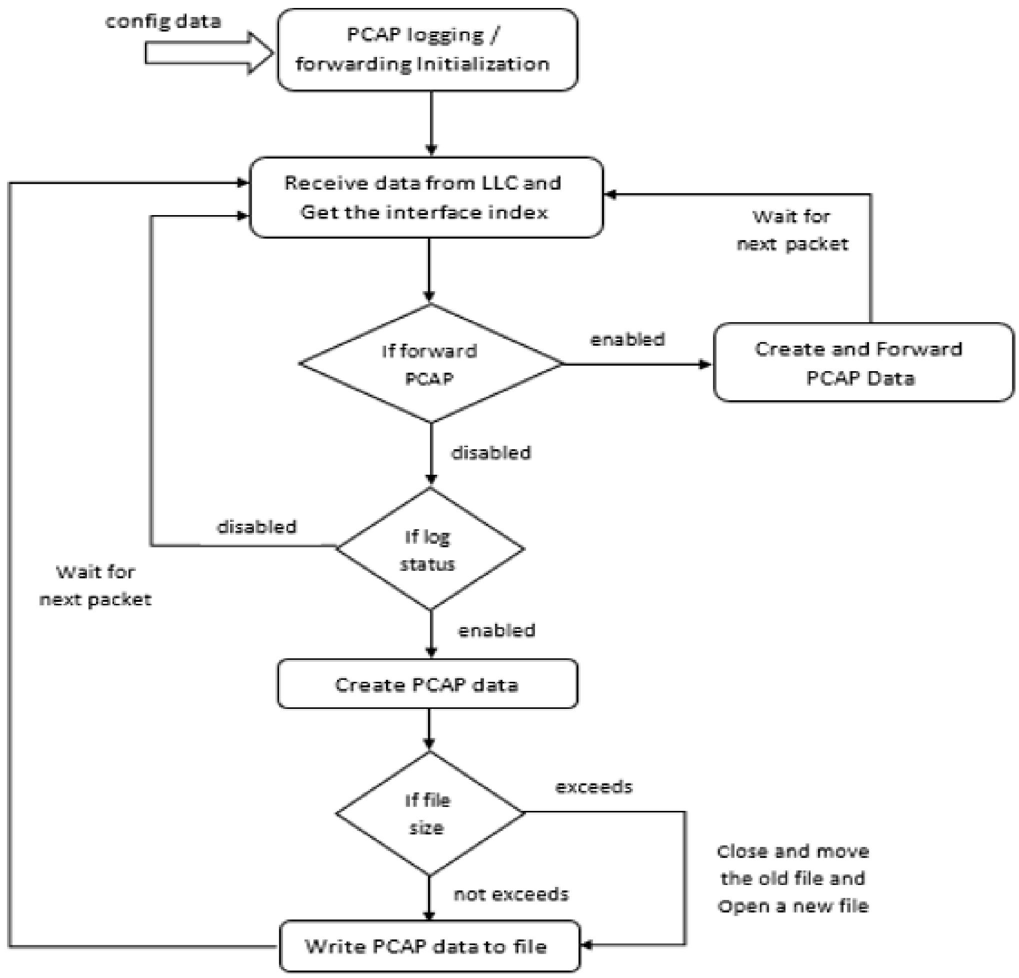


Figure 3-9. PCAP Logging function process flow. (Source: Lear)

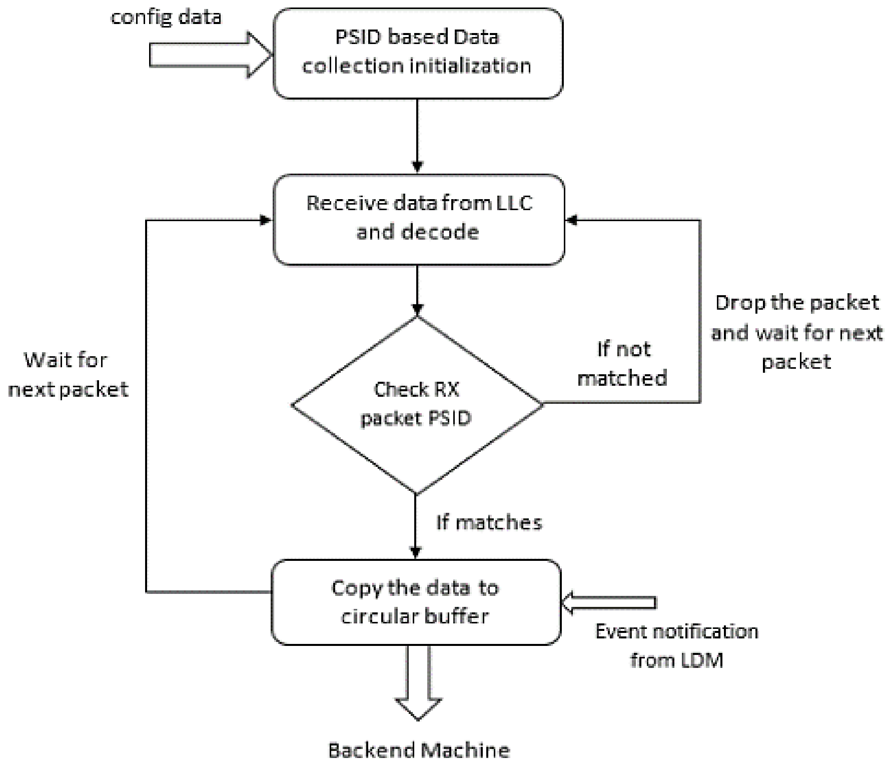


Figure 3-10. PSID function process flow. (Source: Lear)

3.1.2.3.3.2 Description of modules/functions

WSMPForward Initialization: Reads the WSMPForward configuration files and maintains the configurations in a table. Creates the sockets to forward the WSMP data to backend machine and update the respective table entries.

PCAP Forwarding/Logging Initialization: Reads the PCAP Forwarding/Logging configuration. If PCAP forwarding is enabled, PCAP logging feature won't work (even if PCAP logging is enabled). PCAP forwarding should be disabled to use the PCAP logging feature. If PCAP forwarding is enabled, CaptureApp creates a socket to forward the PCAP data to backend machine. If PCAP forwarding is disabled, CaptureApp creates files to log the PCAP data.

PSID based Data Collection Initialization: Reads the PSID based data collection configuration. Creates the socket to forward the collected data (before, during and after the event notification) to backend machine.

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

See figures Figure 3-8 through Figure 3-10 for process flow diagrams.

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

WSMP Forward Process Flow (Figure 3-8):

1. WSMPForward receives the packets from LLC layer and decodes the packets to get the WSMP header
2. Checks the configured data against the received packet WSMP data.

3. If the PSID and other configured parameters matches it will forward the received packet to the backend machine.
4. Else check the next configured entry in the table.
5. If none of the configured entries matches, wait for the next packet.

PCAP Forwarding Process Flow (Figure 3-9**):**
If PCAP forwarding is enabled, then logging won't work. PCAP logging will work only if PCAP forwarding is disabled. PCAP forwarding can be configured through CLISH and PCAP logging can be configured through SNMP/CLISH.

1) Receives the packets from LLC layer and strip off the unwanted headers to get the WSMP data
    a. For TX packet need to remove the ether header, TX control data, ether header and QoS control data from the received data to get the WSMP data.
    b. For RX packet needs to remove the ether header, RX stats control data and ether header from the received data to get the WSMP data.
2) Get the interface index based on the received packet and fill it in log header.
3) Updates the prism header with the Channel number, data rate, TX/RX packet, interface name, rssi and MAC address from the WSMP data.
4) PCAP data is a combination updated prism header, parsed WSMP data and log header.
5) If the PCAP forwarding is enabled, create the PCAP data and send it to backend machine (ODE Server) for ingesting CV Data.
6) If the PCAP forwarding is disable, check for the PCAP logging is enabled or not.
7) If PCAP logging is enabled, writes the PCAP data to the file.
8) If the file size reaches the maximum configured limit, close the PCAP file and create the new PCAP file and log it.
9) PCAP file creation can be controlled through interface log status and log direction.

PSID Forwarding Process Flow (Figure 3-10**):**
PSID based can be configured through CLISH. This application has the following process flow.

1) Receives the packets from LLC layer and decode the packets to get the WSMP header
2) Checks the configured data against the received packet WSMP data.
3) If the PSID and other configured parameters matches, store the 10 second data in a circular buffer.
4) If any event notification comes from LDM, store the 10 seconds data before the event, store all the received data during the event and store 10 seconds data after the event.
5) Then forward the collected data to backend machine.

3.1.2.3.4 Application Configuration Data

Table 3-11 shows the configuration parameters for the WSMPForward application.

Table 3-11. WSMPForward Configuration Parameters.

Parameter Name	Possible Values	Description
psid	32	Message type processed by the wsmpforward application.
ipaddr	<IPv6 address>	IPv6 address of the remote host. Example: 2001:11:22::1
port	8888	Port for the remote host application

channel	172	Channel to receive messages.

3.1.2.3.5 Requirements Traceability

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

- WCVS-REQ-1 Collect CV Data
- WCVS-REQ-1.1 Collect BSM Data
- RSU-REQ-1 Collect CV Data
- RSU-REQ-6 Safety Communication

3.1.2.3.6 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.

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
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 <-> OBU	OBU Copies Log File to ODE	5.16.1
ODE <-> WY Maint. Vehicle (OBU)	OBU Copies Weather Environmental Data to ODE	5.17.1

3.1.2.4 RSU Support Services

The following sections describe the application design for the RSU Support Services application.

3.1.2.4.1 Function of the Application

The sections below describe the functionality of the RSU Support Services application.

3.1.2.4.1.1 Functions/Services Brief description

This application provides foundational functions that support data collection, management, and distribution. It coordinates with Object Registration and Discovery to maintain its registration with respect to location/geographic scope and credentialing information. It maintains the necessary security credentials, authorizations, and associated keys to support communications in the connected vehicle environment. This application also checks for configuration updates for existing applications. Additionally, this application can track the location the RSU first and last communicated with OBU's to ensure the Radio Frequency (RF) range is correct and report back to the TMC through the ODE.

3.1.2.4.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

Figure 3-11 shows the communications along the highway for the RSU Support Services application.

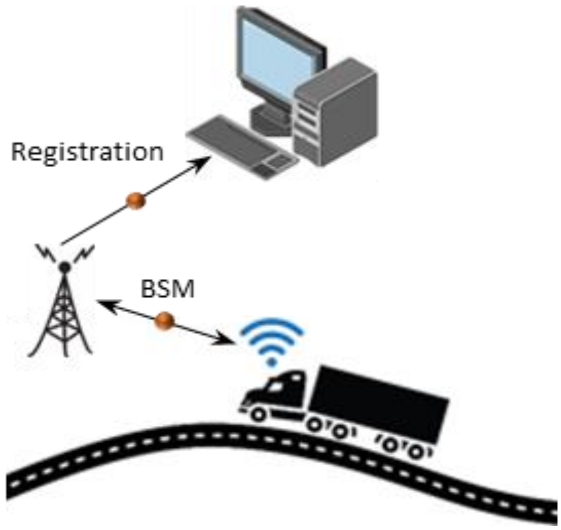


Figure 3-11. RSU Support Services Communications Illustration. (Source: WYDOT)

3.1.2.4.1.3 Input Data/Message Flows

The RSU 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 Lear. Figure 3-12 shows the data flows between different networking layers (modules and functions shown are defined in section 3.2.5.6.4).

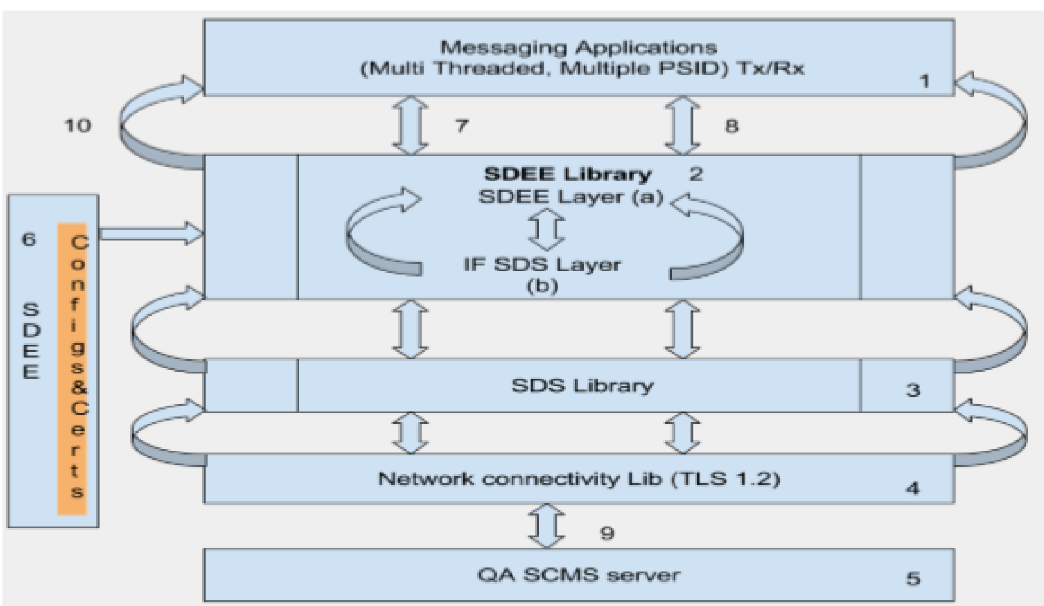


Figure 3-12. RSU Support Services Data Flows. (Source: Lear)

3.1.2.4.1.4 Output Data/Message Flows

Output data from the RSU Support service includes forwarding addresses for the SCMS server for OBU's to retrieve new Security certificates from the SCMS server.

3.1.2.4.2 Developer & version number

Lear is responsible for the development of this application.

3.1.2.4.3 Application Message and Alerts Descriptions

There are no messages or alerts issued by this application.

3.1.2.4.4 Application Design Description

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

3.1.2.4.4.1 Schematic of major modules/functions

Figure 3-106 shows a schematic of the major modules/functions for the OBU Support Services application. The primary module for support Services is the Secure Data Exchange Utility (SDEE).

3.1.2.4.4.2 Description of modules/functions

SDEE: The SDEE module supports multi-threaded applications to communicate simultaneously with the underlying security algorithm services and hence boost performance. Signing and verification operations are supported as asynchronous operations so that applications have no need to block on the Application Programming Interface (API) calls.

Location and Time Retrieval: The SDEE library provides functions to retrieve Location and Time Service (LTS) from the installed GPS (see ICD sections 5.10 and 5.10.1 for details).

Logging Functionality: The SDEE 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:

- Collect and transmit all received BSMs
  - Add time to each record for all BSMs (from 1609.2 header)
- Collect and transmit all connections to SCMS
  - Log connections to SCMS
- Collect and transmit System log
  - Boot and shutdown location/time
  - Application errors and re-starts
- Collect and transmit all received TIMs from ODE (and SiriusXM)
- No DNM logging as these will go straight from the OBU to the ODE.

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.csv.gzip). Log types will include Driver_Alert, BSM_30Second, BSM_Event, Received_Message, Environmental, DNM, 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 milliseconds 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 SDEE follow the design detailed in the SCMS Wiki (https://wiki.campllc.org/display/SCP/SCMS+CV+Pilots+Documentation).

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

Figure 3-106 show the process flow among the different components of the major modules/functions for the OBU Vehicle Support services application.

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

The process flows for Figure 3-12 are described below.

1. Applications

These are the applications utilizing security services. Application can be multi-threaded registers that may communicate for different PSID's at the same time with the SDEE module.

2. SDEE Library

a. The SDEE layer, exposes the API's to Applications. It also keeps track of the context of the application registered.

b. Interface SDS layer. This layered distinguishes the multiple stack support apart from the Lear security stack.

3. SDS Library

Secure data services library has the algorithms support to perform the sign, verification, encryption, and decryption operations. This Library/stack can be from Lear or other supported vendors.

4. Network connectivity Library

This library is responsible for the SCMS server connection establishment and secure data reception from servers using TLS1.2.

5. QA SCMS server

At present connectivity pilots Wave devices will communicate with a server to download the certificates.

6. SDEE Configs and certificates

This block contains the profile configurations, Global configurations for the applications with respective PSID. The preloaded certificates for the PSID are stored under this logical block. Tools like certAdmin/certadm are available and can be used to parse and load the certificates. This block also performs the certificate management.

7, 8. Concurrent operations

These arrows (Figure 3-12) depict the parallel communication by applications (BSM, TIM, SPAT, MAP) to the SDEE module and further down the stack. This multi-threading with asynchronous operation callbacks helps in stack performance improvement.

9. TLS communication

Stream socket communications to the SCMS server uses TLS 1.2 channel. The SDS layer utilizes this library for SCMS communications.

10. Callbacks
Callback arrows are part of the asynchronous operation handling. While registering for security services if callbacks are mentioned then signed, verification operations can be achieved asynchronously so that applications will not be blocked.

3.1.2.4.5 Requirements Traceability

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

- 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
- 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
- RSU-REQ-6 Safety Communication
- RSU-REQ-10 Management and Performance
- 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
- SCMS-REQ-1.1 SCMS Wyoming CV System Certificates
- SCMS-REQ-1.2 SCMS Wyoming CV System Misbehavior Reporting
- SCMS-REQ-1.3 SCMS Wyoming CV System Certificates Revocation List (CRL)
- SCMS-REQ-1.4 SCMS Wyoming CV System Rejection

3.1.2.4.6 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
RSU <-> Field Location and Time Source (FLTS)	RSU retrieves location and time from LTS	5.10.1
ODE <-> OBU	OBU Copies Log File to ODE	5.16.1
ODE <-> WY Maint. Vehicle (OBU)	OBU Copies Weather Environmental Data to ODE	5.17.1

3.1.2.5 RSU Trust Management

The following sections describe the design for the RSU Trust Management application.

3.1.2.5.1 Function of the Application

The sections below describe the functionality of the RSU Trust Management application.

3.1.2.5.1.1 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 to maintain a current, valid set of security certificates and keys and identifies, logs, and reports events that may indicate a threat to Connected Vehicle Environment security. This application is also used to verify communications from the TMC.

3.1.2.5.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

Figure 3-13 illustrates the communications along the highway for the RSU Trust Services application.

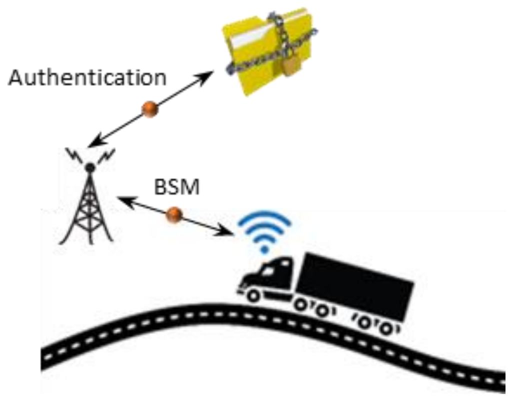


Figure 3-13. RSU Trust Services Communication. (Source: WYDOT)

3.1.2.5.1.3 Input Data/Message Flows

Input flows for the RSU Trust management application include inputs from the RSU Support Services application for SCMS certificates that will allow this application to sign BSM and TIM messages broadcast from the RSU. Unsigned BSM and TIM messages are also inputs to the RSU Trust Management application. Figure 3-14 shows the data flows for the RSU Trust Management application between the Secure Data Exchange Entity (SDEE) application and the SDEE library used for trust management.

Figure 3-14. RSU Trust Management Data Flows. (Source: Lear)

3.1.2.5.1.4 Output Data/Message Flows

Output from the RSU Trust Management application include signed BSM and TIM messages.

3.1.2.5.2 Developer & version number

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

3.1.2.5.3 Application Message and Alerts Descriptions

There are no messages or alerts issued by this application.

3.1.2.5.4 Application Design Description

The sections below describe the RSU Trust Management application design.

3.1.2.5.4.1 Schematic of major modules/functions

See Figure 3-14 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 RSU Trust Services.

3.1.2.5.4.2 Description of modules/functions

Each Messaging application defined on the RSU such as (BSM, SPAT, MAP, TIM) should use the flow in Figure 3-14, to register with the SDEE module. This allows the application the ability to use the security services. A sample program for usage can be accessed at http://support.aradasystems.com/file.php?tab=files&file=4536

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

Figure 3-14 shows the process flow diagrams for applications signing and validating messages.

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

The following is the process flow for applications to sign and validate messages with the SDEE service.

1. Registration

Applications are required to register with the security services. After registering the SDEE module returns the unique context handle for further communication. The unique handle allows signing/verification operations to be performed in the multi-threaded environment.

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.

3.1.2.5.5 Requirements Traceability

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

- RSU-REQ-3 SCMS
- SCMS-REQ-1 Wyoming CV System (WCVS) SCMS Use
- SCMS-REQ-1.1 SCMS Wyoming CV System Certificates
- SCMS-REQ-1.2 SCMS Wyoming CV System Misbehavior Reporting
- SCMS-REQ-1.3 SCMS Wyoming CV System Certificates Revocation List (CRL)
- SCMS-REQ-1.4 SCMS Wyoming CV System Rejection

3.1.2.5.6 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.

General Interface	Action within Interface	Section No.
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

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 TMDD third party interface, ODE, Pikalert weather simulation and prediction software as well as management software for the RSU's according to the system requirements. 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 compute 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).

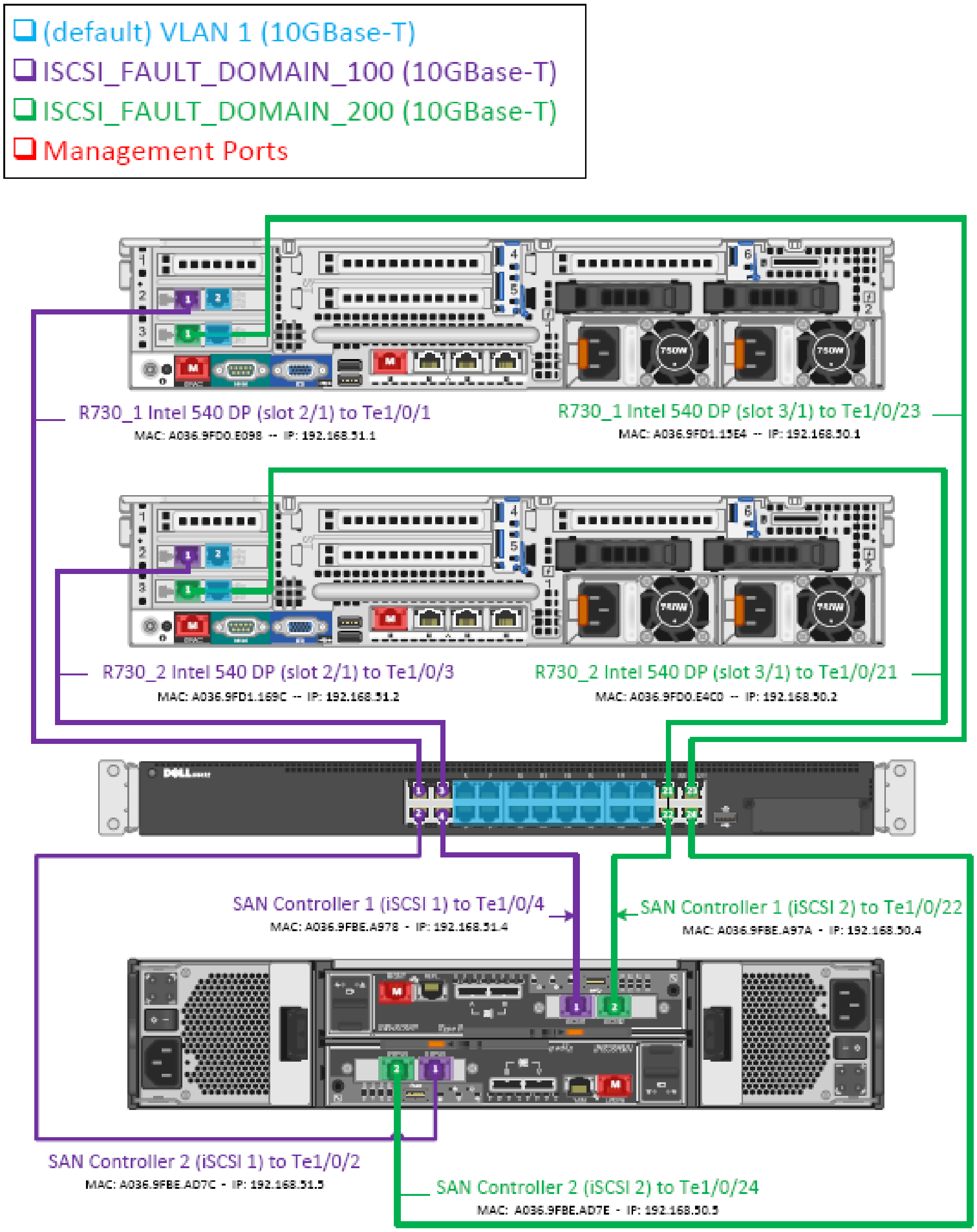


Figure 3-15. Storage Area Network (Source WYDOT)

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.

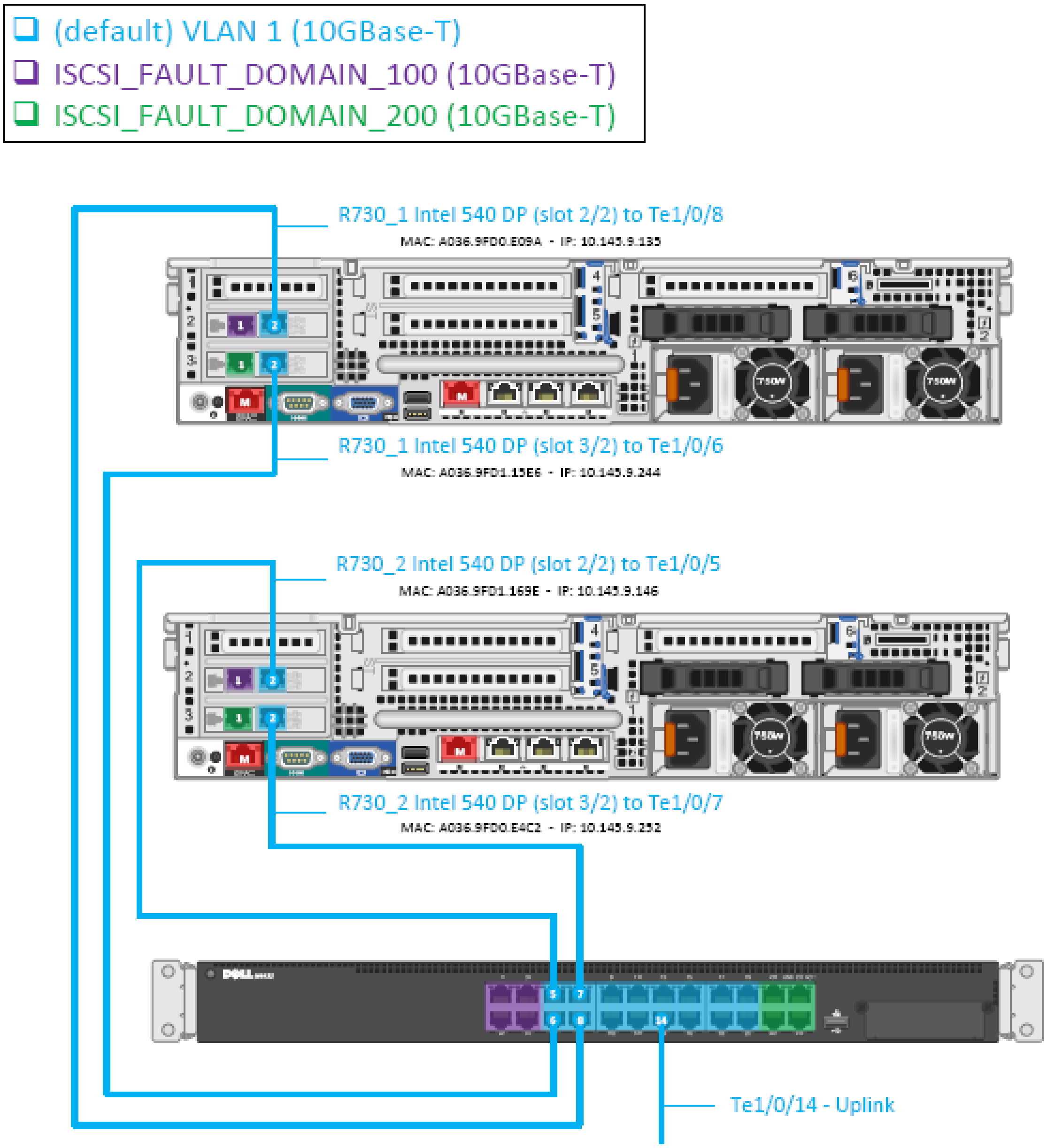


Figure 3-16. Server Cluster Network (Source WYDOT)

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, Pikalert weather simulation and prediction software as well as management software for the RSU's. The Third Party Interface which publishes TMDD data, the Operational Data Environment and the Pikalert weather software are integral components of the WYDOT Pilot.

3.1.3.2.1 Vendor/manufacturer & model number,

Table 3-12 describes the supporting hardware purchased for the CV pilot project.

Table 3-12. 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 3-17 shows the WYDOT server chosen to run the CV ODE, Pikalert, and other supporting applications.

Figure 3-17. Dell PowerEdge R730 Server (Source: Dell)

Figure 3-18 shows the WYDOT storage array chosen to store CV data.

Figure 3-18. Dell SCv2020 ISCSI Storage Array (Source: Dell)

Figure 3-19 shows the WYDOT network switch chosen to support the CV project.

Figure 3-19. Dell Networking N4032, 24x 10GBaset-T switch (Source: Dell)

Figure 3-20 shows the WYDOT Hardware Security Module chosen to support the CV project.

Figure 3-20. 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 TMDD third party interface, ODE, Pikalert weather simulation and prediction software 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 has the ability to check and digitally sign Traveler Information Messages at the TMC level and allows for delivery to 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 3-21 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.

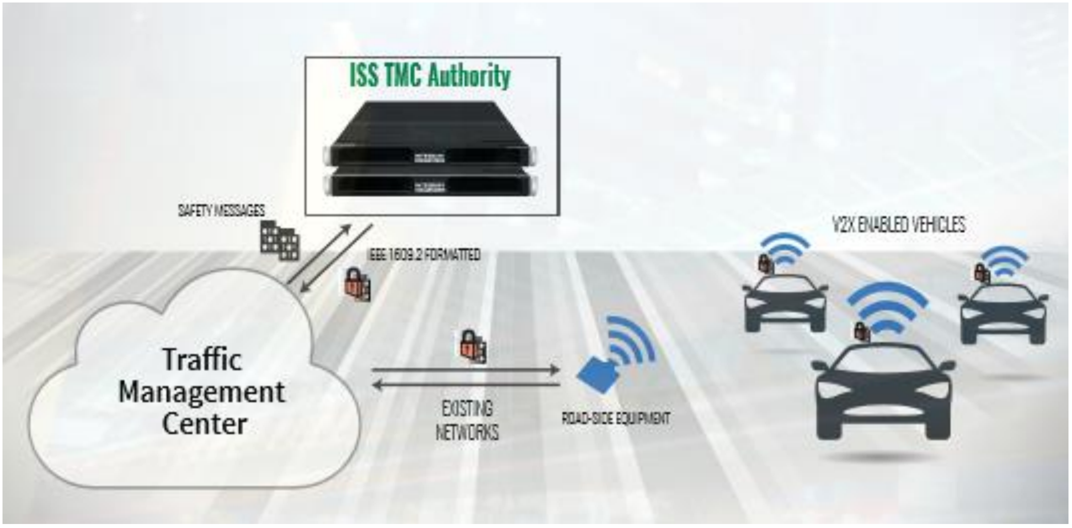


Figure 3-21. HSM working diagram (Source: Integrated Security Solutions)

3.1.3.2.5 Hardware Configuration Data

Table 3-13 shows the Hardware configuration data for the added hardware components of the CV system.

Table 3-13. 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
- WCVS-REQ-11.3 Store Distress Messages
- WCVS-REQ-12 Store Generated Alerts/Advisories
- 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
- 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
- DW-REQ-1.1.2 Store Alerts/Advisories-Road Condition Hazard
- DW-REQ-1.1.3 Store Alerts/Advisories-Visibility Hazard
- 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
- DW-REQ-2.2 Share Data with SDC
- DW-REQ-2.3 Share Data with RDE
- 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
- HSM-REQ-2 Share with ODE
- HSM-REQ-3 Receive from SCMS
- HSM-REQ-4 Share with SCMS

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 <-> Situation Data Exchange (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), and the Situation Data Exchange.

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 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 3-22 shows the data flow diagram for all available input and output for the ODE application.

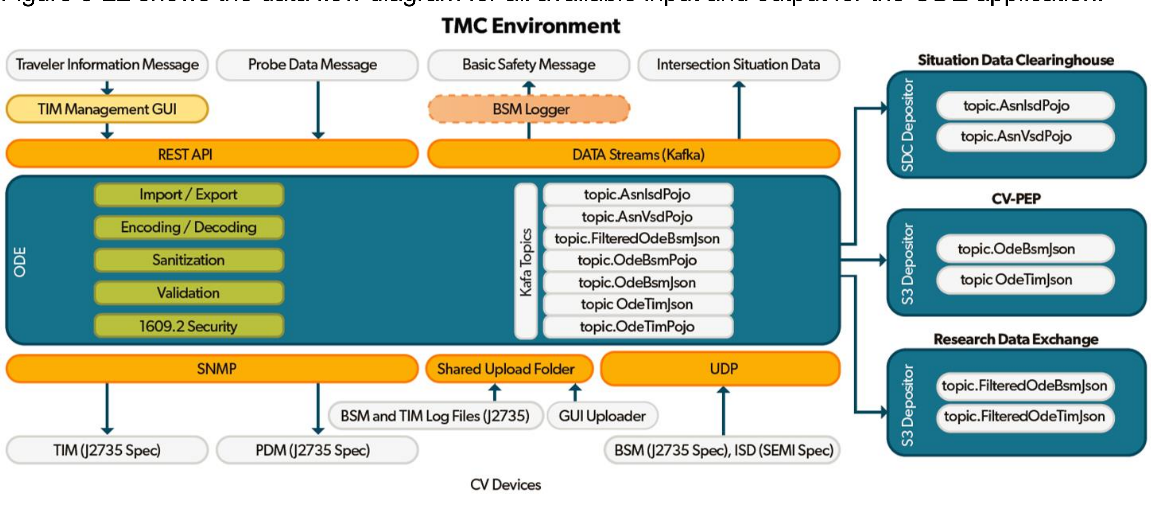


Figure 3-22. ODE Data Flow Diagram. (Source: USDOT)

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.[8]

- **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:** Through the use of 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 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 3-22 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 3-14 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.

Table 3-14. Messages and alerts issued by the ODE application

#	Message/Alert
0	Operation was successful
1	General error in file copy

[8] 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.

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 3-15 - File Copy Data Deposit Messages and Alerts

Message or Alert	Communication Method	Description
See Table 3-14 for “copy” function Messages and Alerts	Command exit code	See Table 3-14 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 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 3-16 describes the algorithm used to determine the error message issued.

Table 3-16 Algorithms for determining alerts

Message or Alert	Algorithm
See Table 3-14 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 3-17 shows the criteria used for issuing messages and alerts from the ODE.

Table 3-17 ODE Summary table for alerts

Message or Alert	Criteria
See Table 3-14 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[9] and service-oriented architectures.

The micro-services pattern consists of three major concepts:

1. *Separately deployed units*: As illustrated in Figure 3-23, 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.

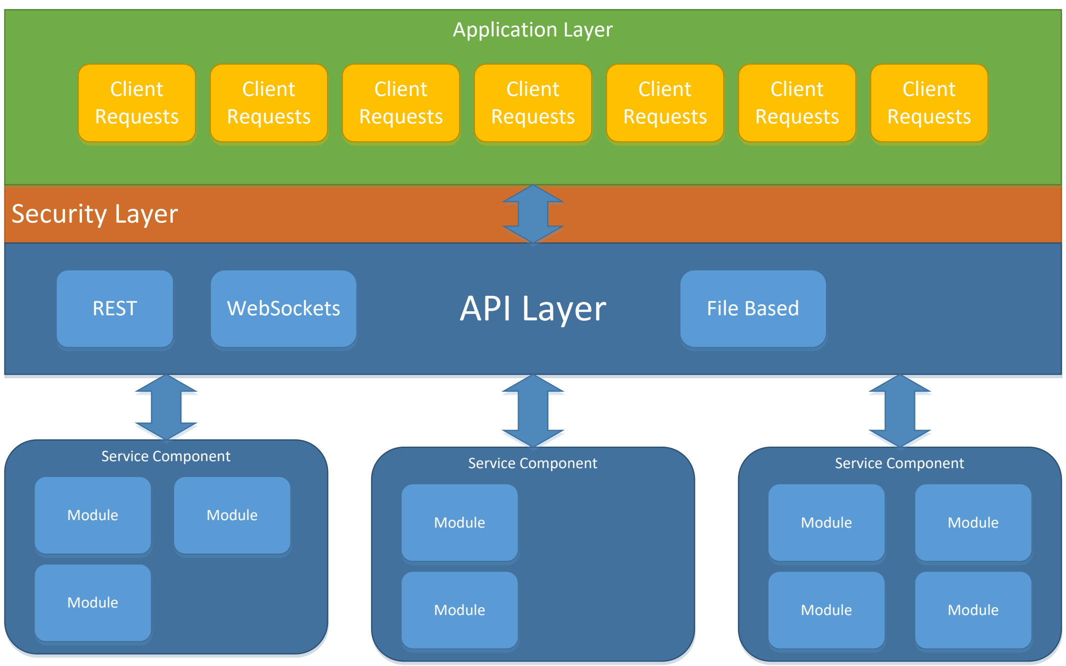


Figure 3-23 Basic Micro-services architecture pattern (Source: USDOT)

3.1.4.1.4.1 Description of modules/functions

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

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[9] 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**.

1. Managing SNMP Devices — over SNMP Protocol, the ODE can ping and assess the health of an existing Road Side 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. VSD Deposit to SDC — ODE sends VSD message to SDC using UDP protocol rather than Web Socket protocol. UDP protocol supports transfer of high volume data and is more scalable whereas web socket protocol is not intended for transferring high volume data. Unlike TCP, UDP is a best effort delivery service which means that the protocol does not worry about acknowledging whether the receiver actually received the message or not. The VSD depositor is implemented as a module in the ODE app and follows the VSD dialog mentioned below for depositing VSD message to SDC. Deposited TIMs shall be compliant with J3067 standards for TIM definition.
13. 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 3-24 for a diagram of the process flow between application layers within the ODE.

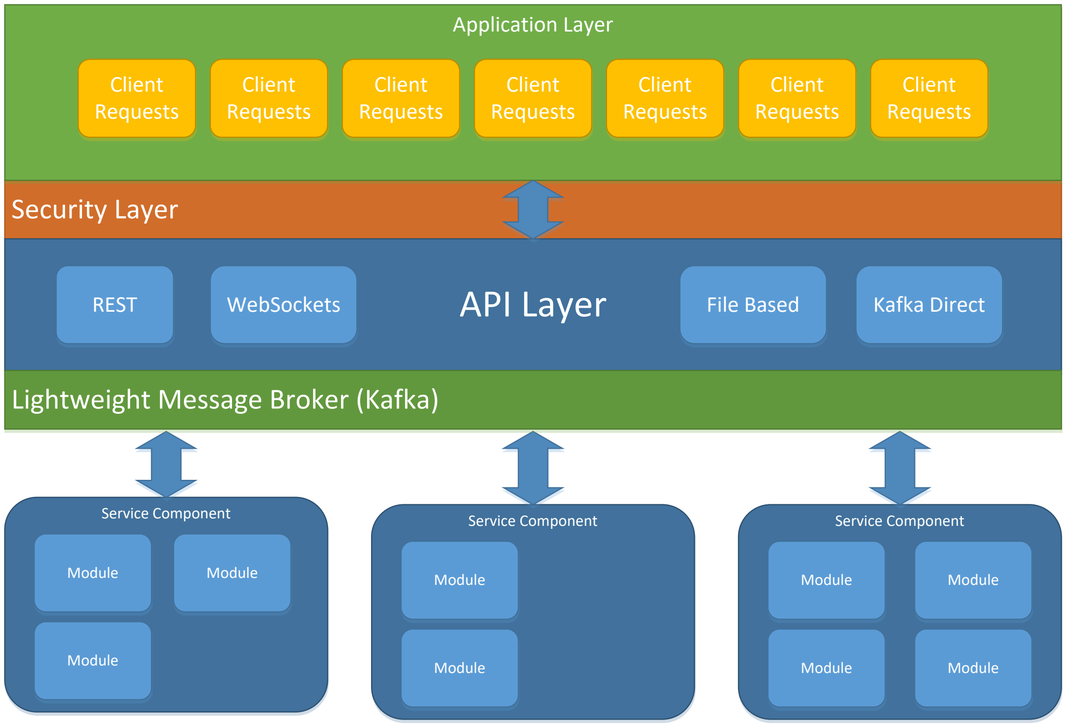


Figure 3-24- Centralized messaging topology (Source: USDOT)

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 3-25 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.

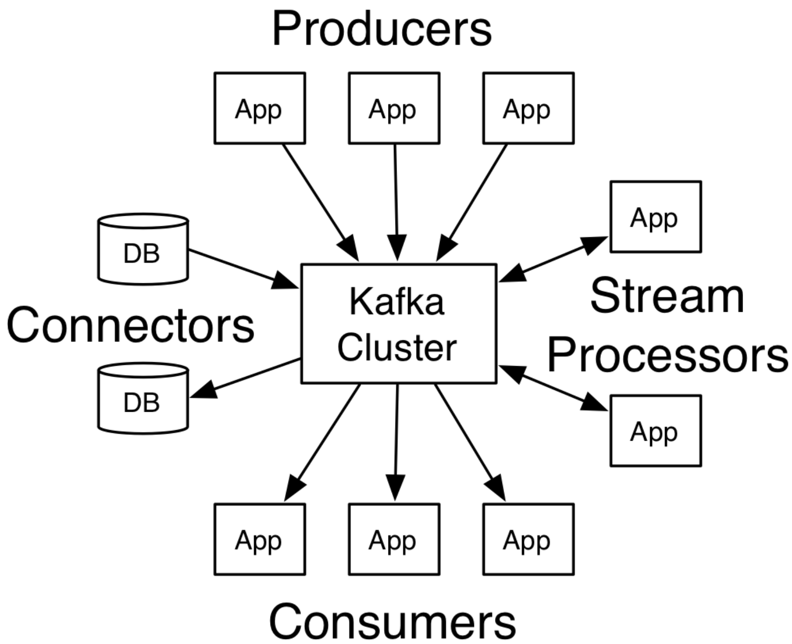


Figure 3-25 - Kafka Concepts (Source: USDOT)

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 3-26.

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

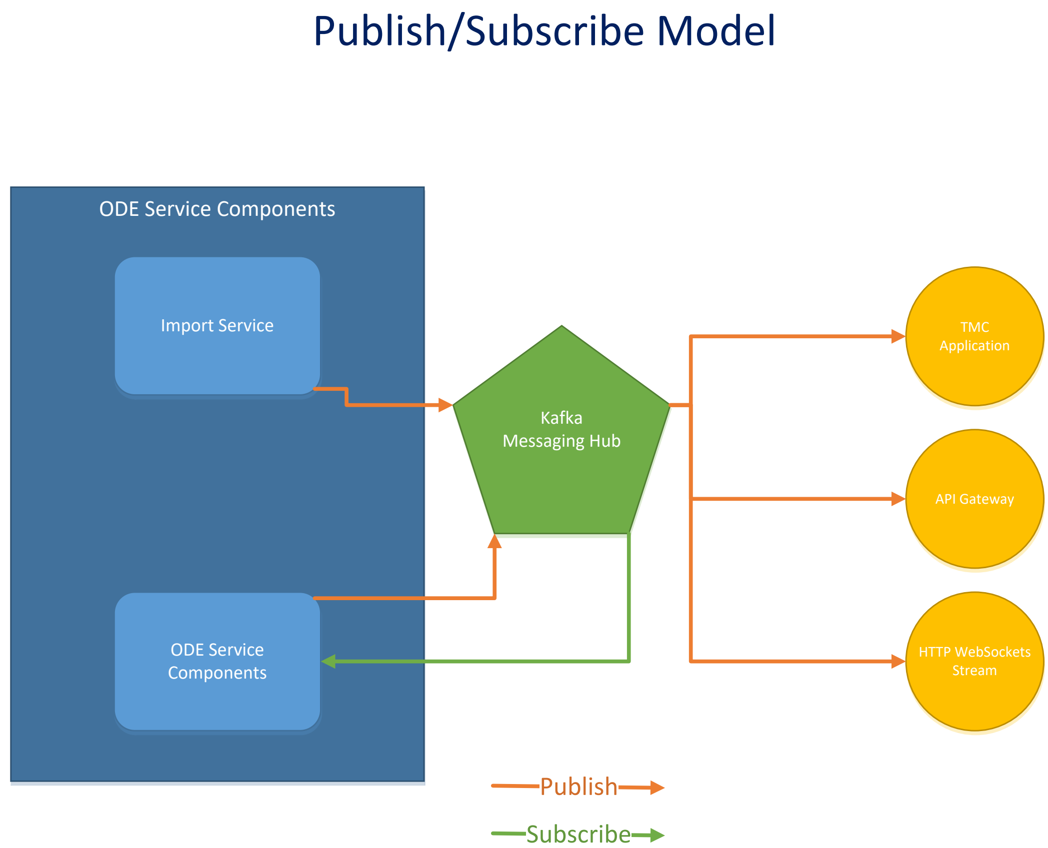


Figure 3-26 - Kafka Publish/Subscribe Model (Source: USDOT)

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 Configuration Data

Table 3-18 describes the ODE configuration properties for the ODE service

Table 3-18 Application configuration properties for the ODE service (file: application.properties)

Property	Default Value	Description
Ode.ddsCasUsername	<SDXUSERNAME>	The Situation Data Exchange (SDX) username for posting transactions from the ODE to the SDX
Ode.ddsCasPassword	<SDXPASSWORD>	The Situation Data Exchange (SDX) password for posting transactions from the ODE to the SDX

3.1.4.1.7 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.

3.1.4.1.7.1 Description of Operations/Driver Interface with illustrations

This application has no driver interface.

3.1.4.1.7.2 Description of Maintenance User Interface with illustrations

This application has no maintenance user interface.

3.1.4.1.8 Requirements Traceability

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

- SDC-REQ-1 Data Provided to the SDC
- RDE-REQ-1 Data Provided to the RDE
- 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 SDX
- ODE-REQ-3.3 Distribute to Pikalert
- 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
- ODE-REQ-3.4.3 Distribute to Data Warehouse-ES
- ODE-REQ-3.5 Distribute to Data Broker
- ODE-REQ-3.6 Distribute to SDC
- ODE-REQ-3.7 Distribute to RDE
- ODE-REQ-4 SCMS
- ODE-REQ-5 LTS
- ODE-REQ-6 OBU Update
- ODE-REQ-7 Receive from Data Broker
- VS-REQ-31 IVAA WZW
- SDX-REQ-1 Data Provided to the SDX
- SDX-REQ-2 Distribute TIM to VS
- WCVS-REQ-1.3 Collect Distress Messages
- WCVS-REQ-2 Validate Data
- WCVS-REQ-8 Internal Brokerage
- 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 SDX
- HSM-REQ-1 Receive from ODE
- HSM-REQ-2 Share with ODE

3.1.4.1.9 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.
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 <-> Situation Data Exchange (SDX)	ODE Transmits TIM to SDX	5.22.1

3.1.4.2 Pikalert System

3.1.4.2.1 Function of the Application

The Pikalert system will be used to ingest connected vehicle observations, blend them with other weather observations, and produce road weather hazard advisories, warnings, and forecasts that will then be used by other applications.

3.1.4.2.1.1 Functions/Services Brief description

Functions/Services provided by the Pikalert system include ingesting and quality checking vehicle data, blending vehicle data with weather observations, and producing current and forecast hazard alerts based on those data.

3.1.4.2.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

This application is not directly involved in any vehicle/infrastructure communications on the highway and is meant strictly for support purposes of management and tracking of the WYDOT CV pilot.

3.1.4.2.1.3 Input Data/Message Flows

Input data for the Pikalert system falls into two main categories: vehicle data and weather data. The vehicle data will be provided via the WYDOT Data Broker and will consist of data from the WeatherCloud external instrumentation along with any relevant native vehicle data that may be collected (to include RCRS data). Ingest data points from the environmental sensors can be found in the ICD section 7.7.

Weather data is collected via a variety of flows. Road Weather Information System (RWIS) station data are collected by WYDOT and will be provided to the Pikalert system via the FHWA’s Weather Data Environment. Other data sources are collected via Load Data Manager (LDM) or http connection and include a radar mosaic from the Multi-Radar Multi-Sensor (MRMS) system, Automated Surface Observing System (ASOS) and Automated Weather Observing System (AWOS) station METAR reports, and HRRR, GEM, GFS, NAM, and RAP numerical weather prediction model data.

Figure 3-27 shows the data flows for the Pikalert system.

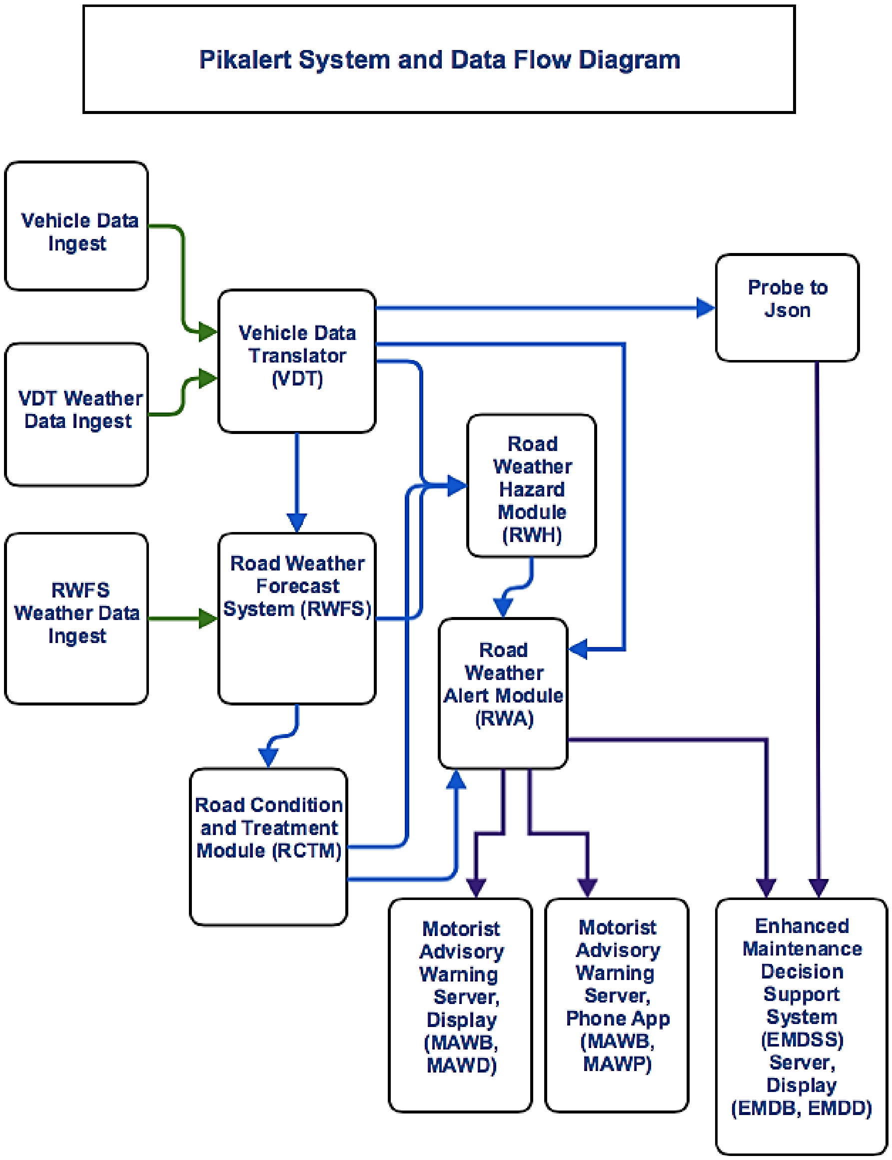


Figure 3-27 Data Flow of the Pikalert system (Source: WYDOT)

3.1.4.2.1.4 Output Data/Message Flows

Two main outputs come from the Pikalert system: current and future (forecast) hazards. In addition, more intermediate outputs are produced: vehicle observations (sensor logs), quality-checked vehicle observations, and road segment statistics. All Road Segments are identified by a starting and stopping milepost along I-80.

The intermediate files are produced using the ingested vehicle and weather observations. First, vehicle data are translated from their input format to netCDF format using a Python script. This file is called the probe message file. These data are then quality checked. These checks are listed in Table 3-19. The quality checked vehicle observations, along with corresponding weather data used in the quality checks, are entered into intermediate file quality-checked vehicle observations. This file includes only road segments that contain vehicle observations. The final intermediate file is the road segment statistics. All configured road segments are included in this file and contain weather observations as available at their location. Statistics for all vehicle observations that have a confidence value above the user-defined value are also included. Statistics depend on the observation type (continuous vs. discrete) but may include mean, median, interquartile values and ranges, and modal value (e.g., 5 wipers off, 4 wipers intermediate, 2 wipers low). The segment statistics file is what is used by all other Pikalert system modules.

Table 3-19 List of Pikalert quality check tests

Quality Check Test	Description
Anticipated Range Test	Observation is compared against a minimum and maximum expected value based on instrument specifications and/or typical realistic values (e.g., a speed of 300 mph is not realistic). Any observations outside this range are flagged.
Time Step Test	Observations that change unexpectedly through time (e.g., air temperature changes from 10 deg C to 30 deg C in less than an hour) are flagged.
Persistence Test	Observations that do not change through time, but are expected to be changing, are flagged.
Climate Range Test	Atmospheric variables are compared to climatological ranges for the given month of the year, with some tolerance for extreme/record events. Any observations outside this range are flagged.
Data Filtering Test	Certain observations may be filtered out as defined by the user, such as a latitude/longitude value that falls outside the Earth (e.g., latitude of -100 deg) or a defined missing value.
Spatial Test	Observations are compared to surrounding observations such as RWIS stations using a Barnes analysis or, when three or more observations fall within the user-defined radius from the vehicle observation, an interquartile range comparison. Values outside the user-defined tolerance compared to these nearby stations are flagged.
Neighboring Vehicle Test	Observations are compared to those of other nearby vehicles. Those falling outside a user-defined standard deviation from other vehicles are flagged.
Model Analysis Test	Atmospheric observations are compared against the background model used in the Pikalert system. Those outside a user-defined tolerance are flagged.
Combined Algorithm Test	After the above tests are performed, they are combined and weighted based on user-defined criteria to give a final confidence value of 0 to 1 for the vehicle observation. Those below the user-defined confidence level (e.g., below 0.8 confidence) are not used in subsequent RWH processing.

The Pikalert system generates reports for precipitation, road conditions, visibility, and sub-surface temperature along with treatment recommendation at 5 minute intervals. The updated feed is available for all road segments along I-80. Road segments are defined by WYDOT.

Pikalert calculates with the following variables for Subsurface temperature by the weather (not pavement) model in the same way air temperature and probability of precipitation are produced:

```
float T_bls(max_site_num, days, fc_times_per_day) ;
        T_bls:long_name = "sub-sfc temperature" ;
        T_bls:units = "Celsius" ;
 float T_lbls0(max_site_num, days, fc_times_per_day) ;
        T_lbls0:long_name = "0-10 cm layer sub-sfc temperature" ;
        T_lbls0:units = "Celsius" ;
 float T_lbls1(max_site_num, days, fc_times_per_day) ;
        T_lbls1:long_name = "10-40 cm layer sub-sfc temperature" ;
        T_lbls1:units = "Celsius" ;
 float T_lbls2(max_site_num, days, fc_times_per_day) ;
        T_lbls2:long_name = "40-100 cm layer sub-sfc temperature" ;
        T_lbls2:units = "Celsius" ;
 float T_lbls3(max_site_num, days, fc_times_per_day) ;
        T_lbls3:long_name = "100-200 cm layer sub-sfc temperature" ;
        T_lbls3:units = "Celsius" ;
```

Fuzzy logic for slickness within Pikalert is calculated using the following definition:

Slick Interest = 0.3*precip + 0.3*pavement + 0.2*stability controls + 0.1*IQR Yaw Rate + 0.1*Departure from Median Yaw Rate

Interest greater than or equal to 0.44 adds a slickness flag
Precipitation Type

- -1: None
- -0.5: Light Rain, Moderate Rain, Road Splash in Rain
- 0: Heavy Rain
- 0.5: Light Snow, Moderate Snow, Light Mixed, Moderate Mixed, Heavy Mixed, Road Splash in Mixed or Snow, Hail
- 1: Heavy Snow

Pavement Condition

- -1: Dry
- 0: Wet, Dry/Wet
- 0.5: Dry/Frozen
- 1: Snow or Ice

Stability Control

- 0: ABS, Traction Control, Stability Control either not activated or only 1 is activated.
- 1: Two of ABS, Traction Control, or Stability Control are activated

IQR of Yaw Rate

- Value of IQR of Yaw Rate if <=1
- 1: IQR >1

Departure from Median Yaw Rate

- Maximum of the difference between the observed yaw rate and the segment median yaw rate if <=1
- 1: Maximum of the difference between the observed yaw rate and the segment median yaw rate if >1

3.1.4.2.2 Developer & version number

Developers for this application include members of the National Center for Atmospheric Research.

3.1.4.2.3 Application Message and Alerts Descriptions

No additional messages or alerts are issued by the Pikalert application for the integration into the WYDOT environment.

3.1.4.2.3.1 Descriptions and illustrations of messages and alerts issued by application

No additional messages or alerts are issued by the Pikalert application for the integration into the WYDOT environment.

3.1.4.2.3.2 Describe algorithm to determine when messages and alerts are issued

No additional messages or alerts are issued by the Pikalert application for the integration into the WYDOT environment.

3.1.4.2.3.3 Summary tables of criteria for issuing messages and alerts

No additional messages or alerts are issued by the Pikalert application for the integration into the WYDOT environment.

3.1.4.2.4 Application Design Description

The sections below describe the overall design of the Pikalert system.

3.1.4.2.4.1 Schematic of major modules/functions

Major modules/functions of the Pikalert system are defined below. Figure 3-28 describes the activity diagram for the precipitation interference algorithm

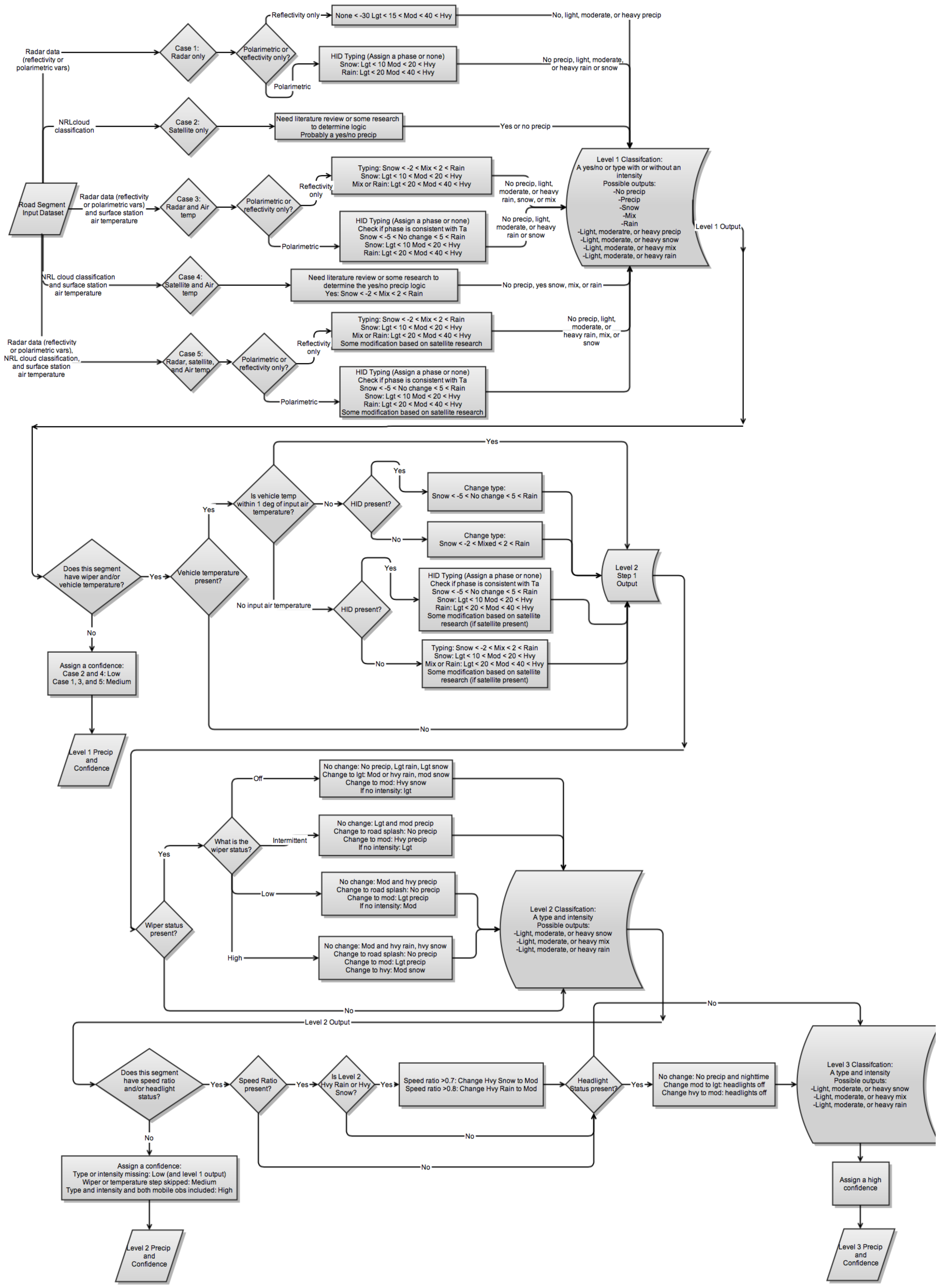


Figure 3-28. Activity diagram for the precipitation interference algorithm (Source: WYDOT)

Figure 3-29 shows an activity diagram for the pavement condition interference algorithm used in Pikalert.

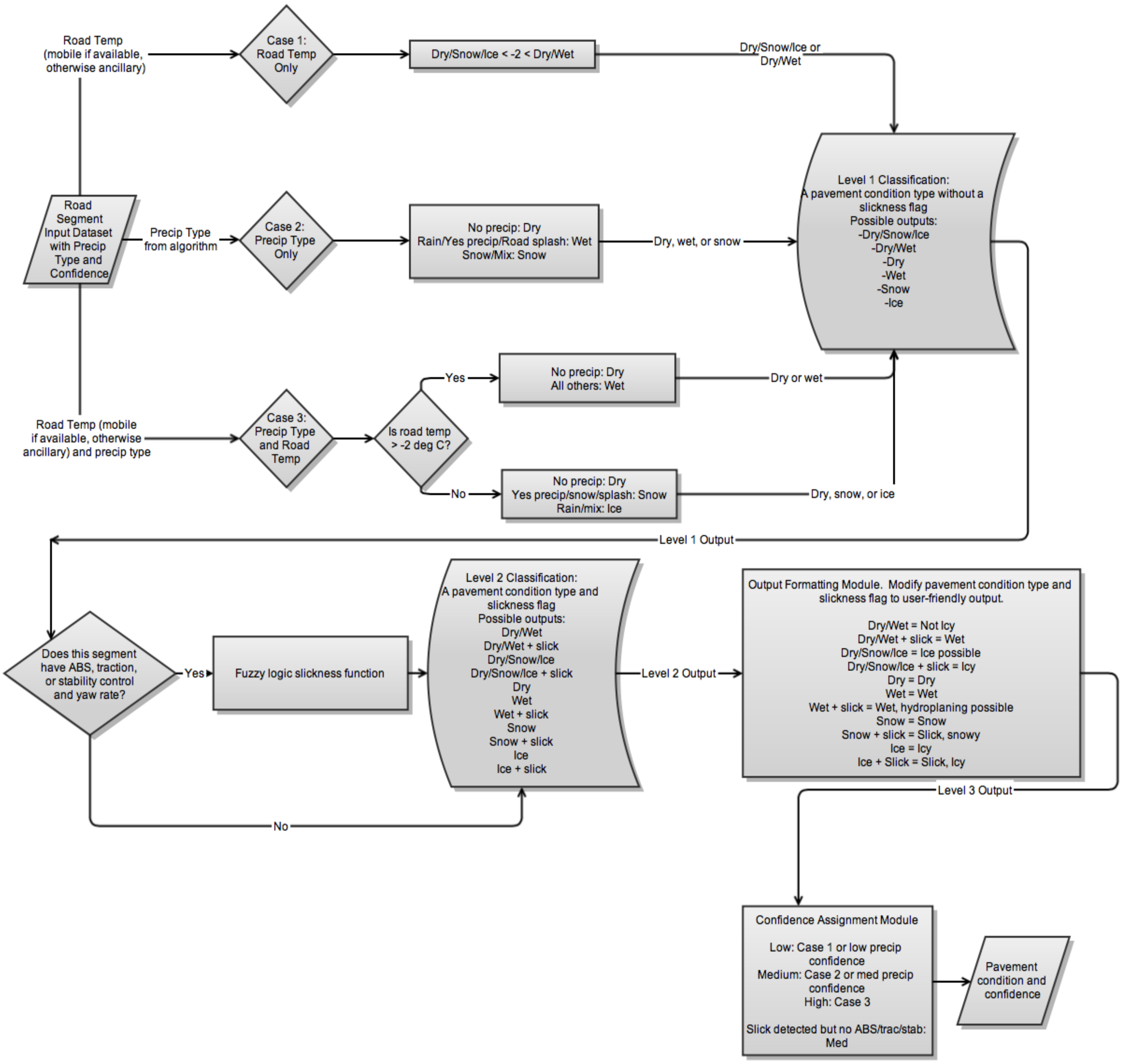


Figure 3-29. Activity diagram for the pavement condition interference algorithm (Source: WYDOT)

3.1.4.2.4.2 Description of modules/functions

Both the current and forecast hazards are produced by four algorithms in the RWH: precipitation, pavement condition, and visibility, along with blowover hazard which is being developed as part of the Pilot deployment. The main difference between the two is that the current hazards use the road segment statistics file as an input, whereas the forecast hazards use forecasts produced by the Road Weather Forecast System.

The Road Weather Hazard Assessment Module collects the segment statistics files output by the VDT at each time period, the output files from the Road Weather Forecast System atmospheric forecast and the Road Condition and Treatment Module road condition forecasts. The RWH then reads in its configuration file, forecast site list, and VDT road segments.
The RWH pulls out the required variables from the VDT segment statistics files and organizes them by road segment. The RWH also pulls out the required variables from the RWFS and RCTM files and organizes them by forecast site and lead time.

The RWH ingests the VDT segment statistics variables and performs the assessment on each road segment. The assessments that are performed are the following:

- Precipitation type
- Precipitation intensity
- Pavement condition
- Slickness flag
- Visibility

The RWH holds the resulting current assessments while the forecast assessments are run. The RWH then ingests the RWFS and RCTM variables and performs the assessment at each forecast site and for each lead time. The assessments that are performed are as follows identical to those listed above.

The current and forecast hazard assessments are matched together using the road segments and forecast site list and the RWH writes out the hazard assessments in one Network Common Data Form (netCDF) file containing the following:

- Time
- Road segment ID
- Precipitation type – Rain, Snow, Mix
- Precipitation intensity – None, Light, Moderate, Heavy, Road splash
- Road condition – Dry, Wet, Snow covered, Ice covered, Hydroplane potential Black ice, Dry/Wet, Ice possible
- Slickness flag - Not slick, Slick
- Visibility – Normal, Low, Heavy Rain, Heavy Snow, Blowing Snow, Fog
- Blowover Risk for regular vehicles, high profile-fully loaded vehicles, and high profile-light vehicles

Activity diagrams for the RWH as a whole and each individual algorithm are shown in Figure 3-28 through Figure 3-31. The Blowover Risk algorithm will be based on a set of fuzzy logic interest functions and weights for each of the three vehicle types and include wind direction and gust speed, the difference between wind gust and sustained wind speeds, and pavement slickness.

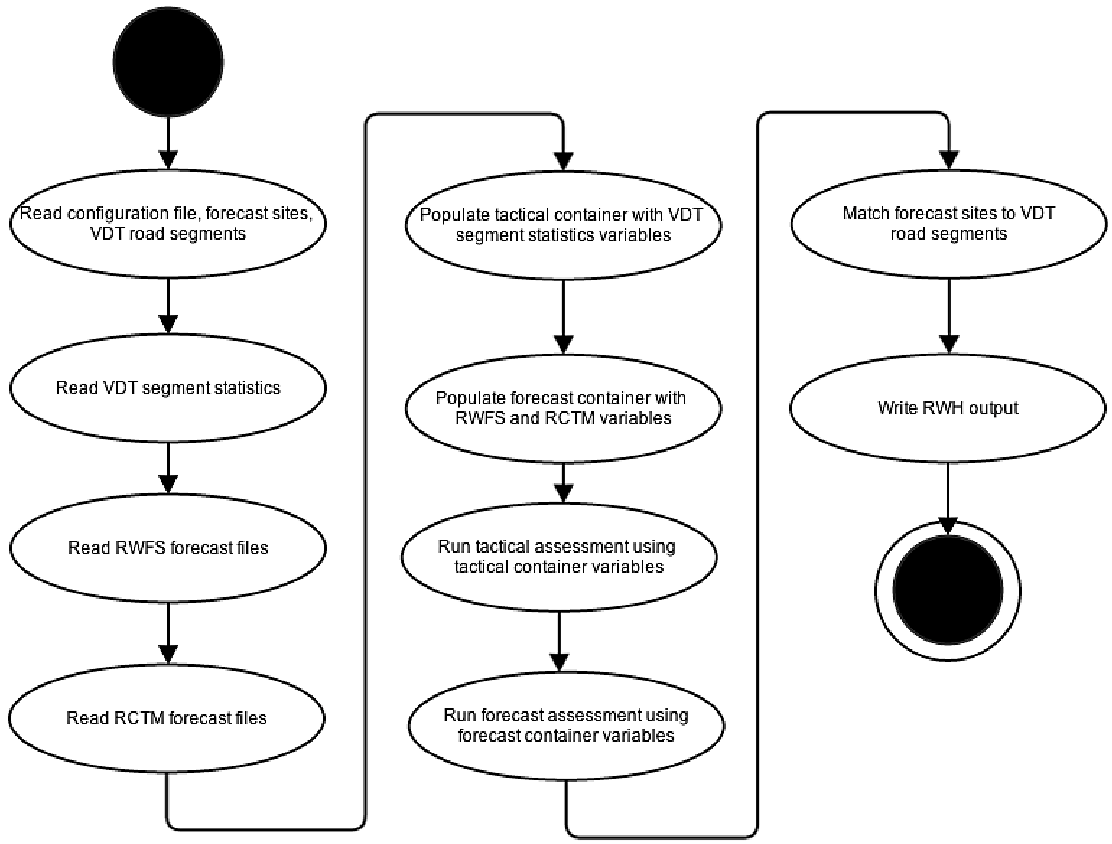


Figure 3-30. Activity diagram for the RWH (Source: WYDOT)

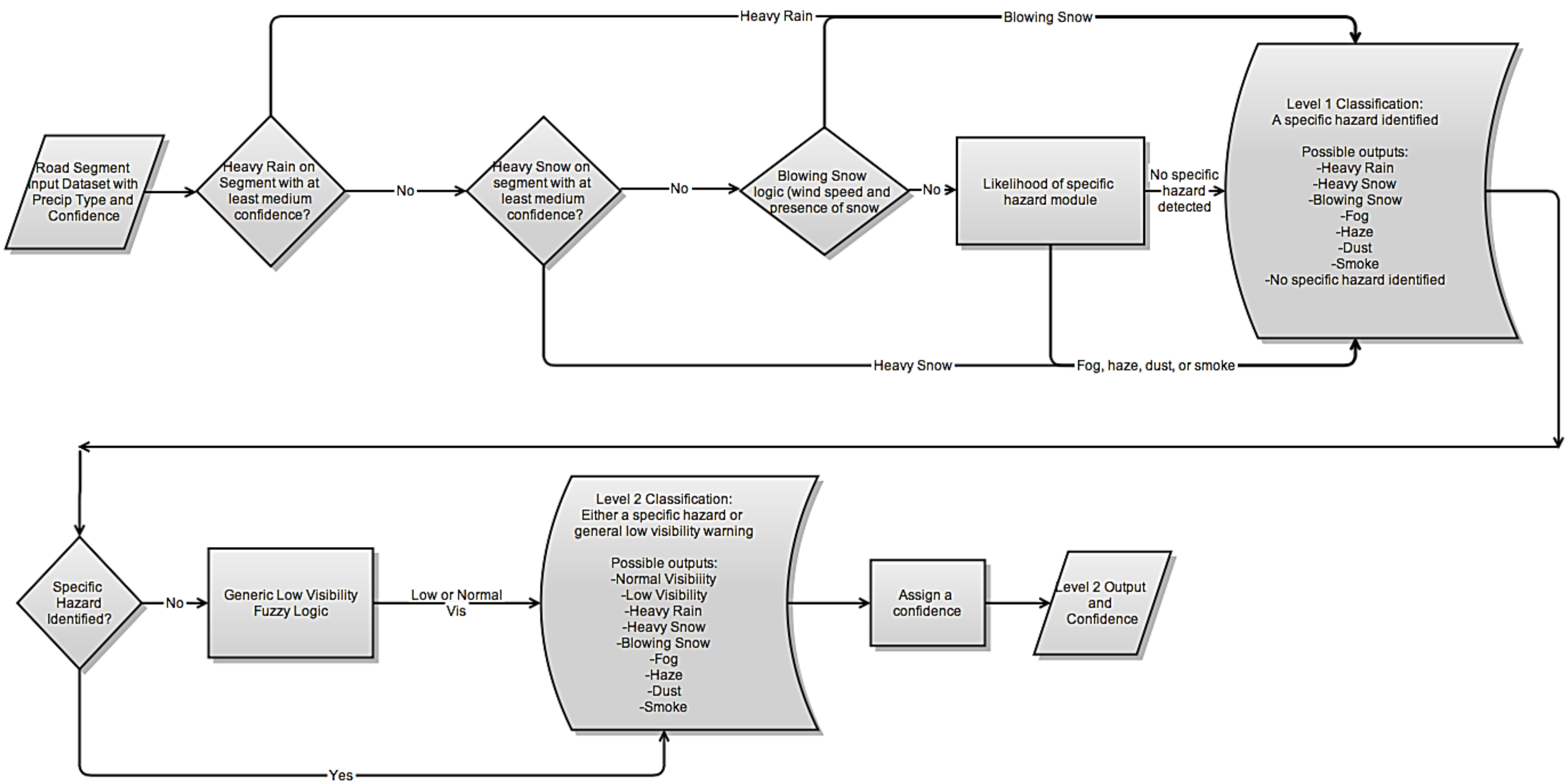


Figure 3-31. Activity diagram for the visibility interference algorithm (Source: WYDOT)

After the RWH has created the weather inferences, the Road Weather Alert (RWA) module collects the following information in order to create road segment specific alert output:

- Road segment hazard nowcast and forecast alerts from the RWH
- Road Weather Information Station (RWIS) nowcast and forecast alerts from RWH (note that alerts are made for RWIS as if they were road segments)
- Road treatment information from the treatment forecast file
- Road segment observation statistics from VDT
- Road segment and RWIS definitions from the PDS
- The RWA then creates alerts for RWIS locations and road segments based on user-defined settings in the configuration file. The following alerts are then output in JSON format:
- District alert information for road segments and RWIS in user defined districts
- Site-based road weather alert and treatment information used in the alert and treatment bar charts and pull downs in the EMDSS display
- Observation statistics information used in the EMDSS display pull-down menu for road segment observations
- MAW phone application files containing precipitation type alerts, pavement alerts, visibility alerts for road segments

The output for road weather alerts is given in a JSON file with the following parameters:
The district alerts are placed in JSON files according to the following scheme:
District alerts Each district has:

- District name
    - A string referencing the state or district in a state
- hr06_alert_summary_code
    - 0 to 6 hour forecasted alert summary code string for entire district
    - "missing", "clear", "warning", "alert"
- hr24_alert_summary_code
    - 6 to 24 hour forecasted alert summary code string for entire district
    - "missing", "clear", "warning", "alert"
- hr72_alert_summary_code
    - 24 to 72 hour forecasted alert summary code string for entire district
    - "missing", "clear", "warning", "alert"
- max_lat
    - maximum latitude for district in degrees (northern direction)
    - floating point number
- max_lon
    - maximum longitude for district in degrees(eastern direction)
    - floating point number
- min_lat
    - minimum latitude for district in degrees
    - floating point number
- min_lon
    - minimum longitude for district in degrees
    - floating point number
- obs_alert_summary_code
    - observation alert summary code string for entire district
    - "missing", "clear", "warning", "alert"
- Array of sites
    - desc

        - Description string for site
            - For example:
                - "LOVELAND PASS CO US CAIC"
- hr06_alert_code
    - 0 to 6 hour alert code string for site
    - "missing", "clear", "warning", "alert"
- hr24_alert_code
    - 6 to 24 hour alert code string for site
    - "missing", "clear", "warning", "alert"
- hr72_alert_code
    - 24 to 72 hour alert code string for site
    - "missing", "clear", "warning", "alert"
- is_road_cond_site
    - true or false based on whether site is a road segment
- is_rwis_site
    - true or false based on whether site is an RWIS station
- is_wx_obs_site
    - true or false based on whether site is a weather obs site
    - currently set to false

Each site also has time series information consisting of the following object(s)

- alert_code
    - "missing", "clear", "warning", "alert"
- chemical
    - none, apply chem
- pavement
    - dry, wet, snow_covered, ice_covered, hydroplane, black_ice, dry_wet, dry_frozen
- plow
    - none, plow precip none, light, moderate, heavy, road_splash
- road_temp
    - floating point temperature in fahrenheit
- time
    - yyyymmddhhmm string
- treatment_alert_code
    - "missing", "clear", "warning", "alert"
- Visibility
    - normal, low, heavy_rain, heavy_snow, blowing_snow, fog, haze, dust, smoke

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

Figure 3-32 shows the activity diagram for the RWA.

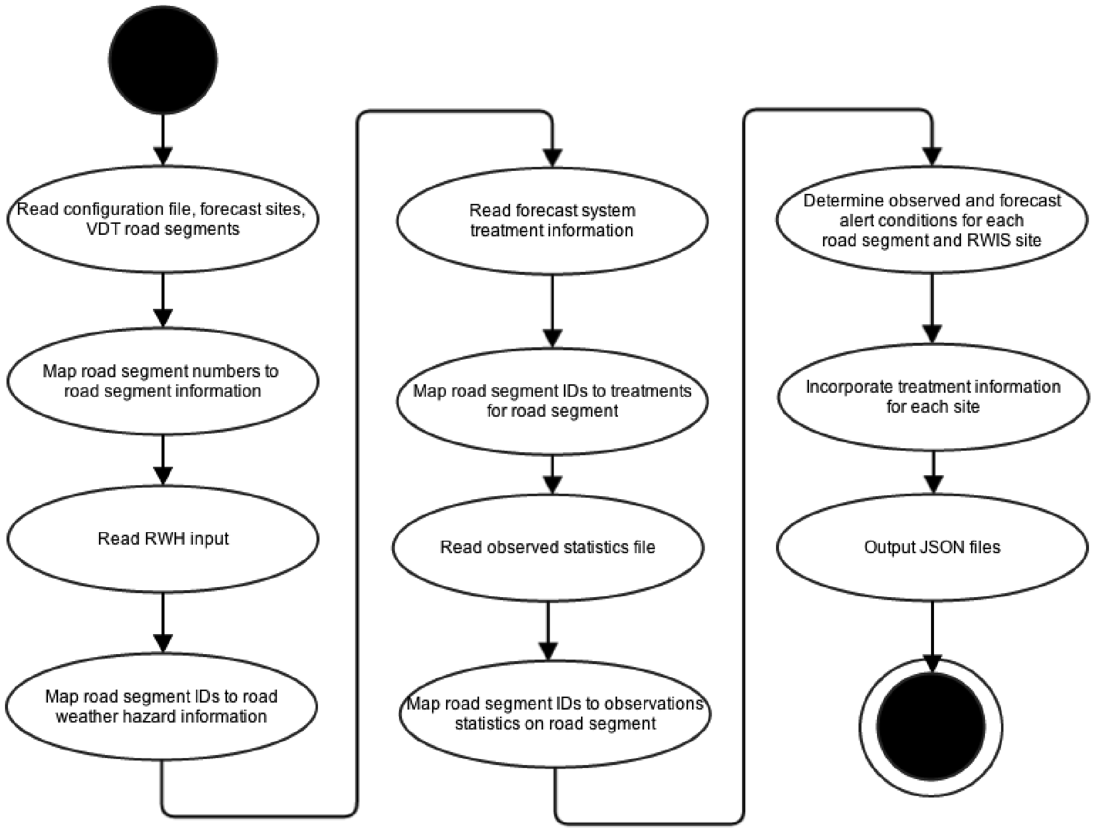


Figure 3-32. Activity diagram for the RWA (Source: WYDOT)

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

The processing steps for the RWA module are:

1. RWA reads its configuration file, the forecast system site list file, and the road segment definitions file.
2. RWA then maps road segment IDs to road segment information (such as road segment latitudes and longitudes).
3. RWA reads the RWH input file and maps road segment IDs to road weather hazard information.
4. RWA reads the plowing, apply chemical and road temperature fields from the forecast system treatment file and maps road segment IDs to treatments for the specific road segment.
5. RWA reads the observation statistics file and maps road segment IDs to observations statistics for the road segment.
6. RWA then determines the observed and forecast alert conditions for each road segment and RWIS location and incorporates treatment information for each site if available.

The RWA output is in JSON format.

3.1.4.2.5 Application Data Tables

The following sections provide details on the data produced by the Pikalert system. All data are stored in netCDF or JSON files and provided to the Data Broker for use in other applications.

3.1.4.2.5.1 Input data description tables

Table 3-20 and Table 3-21 describe the input data being ingested by the Pikalert system

Table 3-20. Description of connected vehicle data.

Data Name	Type	Units	Description
Air Temperature	Float	Deg C	Observed air temperature
Sfc Temperature	Float	Deg C	Observed surface temperature
Humidity	Float	%	Observed relative humidity
Wiper speed	Float	Hertz	Number of swipes of wipers across windshield per unit time
Stability	Integer		If available via BSM, the ABS, traction, or stability control status of a vehicle
Speed	Float	m/s	Vehicle speed
Yaw Rate	Float	Deg/s	If available via BSM, the rate of change of vehicle yaw
Headlights	Integer		If available via BSM, the on/off status of vehicle headlights, parking lights, and fog lights
Heading	Flat	Deg	If available, vehicle's heading

Table 3-21. Description of weather data.

Data Name	Type	Units	Description
Model Air Temperature	Float	Deg C	RTMA air temperature
Model Dewpoint Temperature	Float	Deg C	RTMA dewpoint temperature
Model Barometric Pressure	Float	hPa	RTMA surface air pressure
Nearby Air Temperature	Float	Deg C	Average air temperature from surrounding surface stations
Nearby Surface Temperature	Float	Deg C	Average road temperature from surround RWIS stations
Nearby Barometric Pressure	Float	hPa	Average surface air pressure from surrounding surface stations
Nearby Dewpoint Temperature	Float	Deg C	Average dewpoint temperature from surrounding surface stations
Nearby Hourly Precip	Float	mm	Average precipitation accumulation from surrounding surface stations
Nearby Visibility	Float	Km	Average visibility from surrounding surface stations
Nearby wind direction	Float	Deg	Average wind direction from surrounding surface stations
Nearby wind speed	Float	m/s	Average wind speed from surrounding surface stations
Radar reflectivity	Float	dBZ	Base reflectivity from MRMS mosaic radar reflectivity
Radar dual-pol hydrometeor classification	Integer		Hydrometeor classification (e.g., rain or snow) derived from dual-polarization radar

Road state	Integer		Modal RWIS-observed road surface condition from nearby stations

Input data derives from multiple sources including NWS data feeds, WYDOT Road Condition Reports Services (RCRS) app, CV BSM data, CV Environmental logs, and other Weather interfaces defined in section 3.4 of the System Requirements.

3.1.4.2.5.2 Output data description tables

Table 3-22 describes the output data of the Pikalert system.

Table 3-22. Output data for Pikalert

Data Name	Type	Description
Probe message	netCDF	This file contains vehicle observations that were converted into netCDF format for use in the Pikalert system
VDT output	netCDF	This file contains vehicle observations assigned to road segments, associated weather observations for that segment, and quality check test results
Segment statistics	netCDF	This file contains vehicle observation statistics (if available) and weather data statistics for every road segment configured in the system. Statistics vary by data type but may include mean, median, interquartile range, modal value, and standard deviation
RWH output	netCDF	This file contains the results of the RWH assessment and forecast hazards for all configured road segments
RWA output	JSON	The RWH output was converted into JSON format and includes alert levels and alert messages configured by the user
Road Weather Forecast	netCDF	Output from the Road Weather Forecast System for weather and road surface conditions
Recommended Treatment	netCDF	Output from the Road Condition and Treatment Module giving treatment recommendations based on the road weather forecast

3.1.4.2.5.3 Data/database storage description diagrams and tables

The Pikalert system's data storage will be performed via the Data Broker.

3.1.4.2.6 Application Configuration Data

The following is a list of configuration files applicable to the Pikalert system.

- wy_roads.nc: netCDF file containing definition of road segments used in the Pikalert system (lat/long points making up the segment, segment midpoint lat/lon, and road metadata such as segment name)
- wy_rwa.cfg: an ascii file containing message alert severity and alert text based on RWH outputs
- wy_cdf_config.cfg: an ascii file containing field names and definitions for netCDF files
- site_config.cfg: a list of sites used in EMDSS forecasts along with rules of practice for chemical application
- wy_vdt_config.cfg: an ascii files containing parameters used in quality check algorithms

3.1.4.2.7 Application User Interface(s)

This application does not have a user interface. However, an internal display will be used to help monitor system performance, while downstream applications will provide Pikalert outputs for end users. Screenshots of the internal display are shown below.

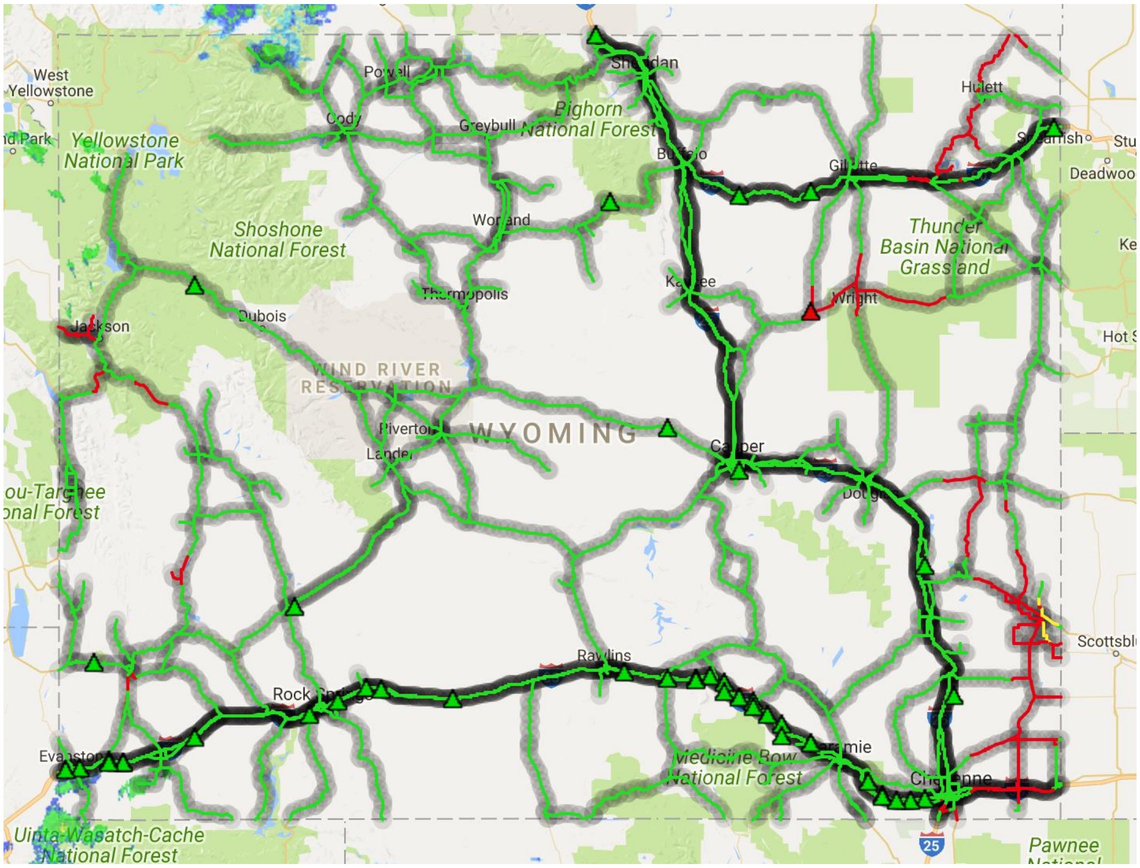
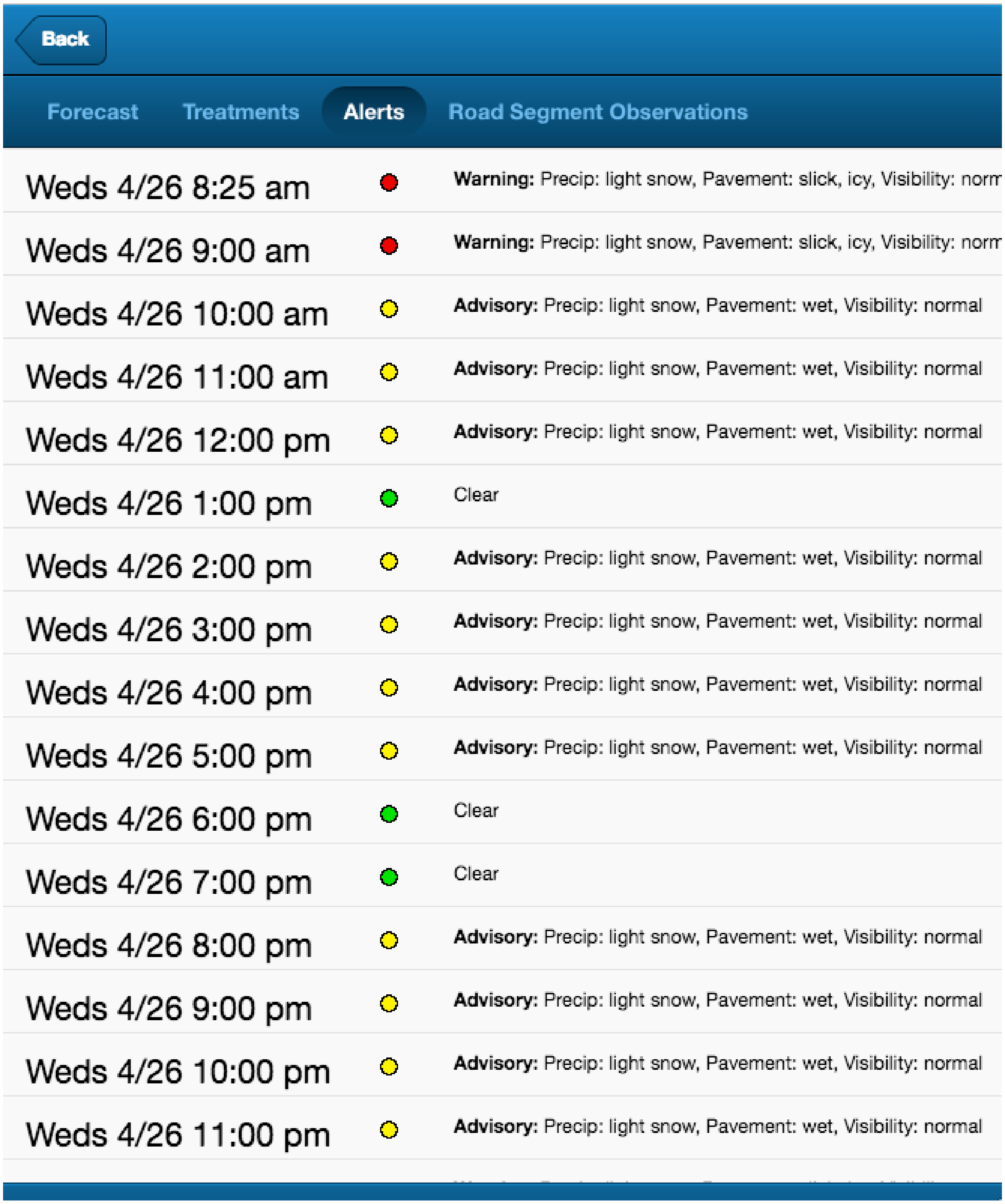
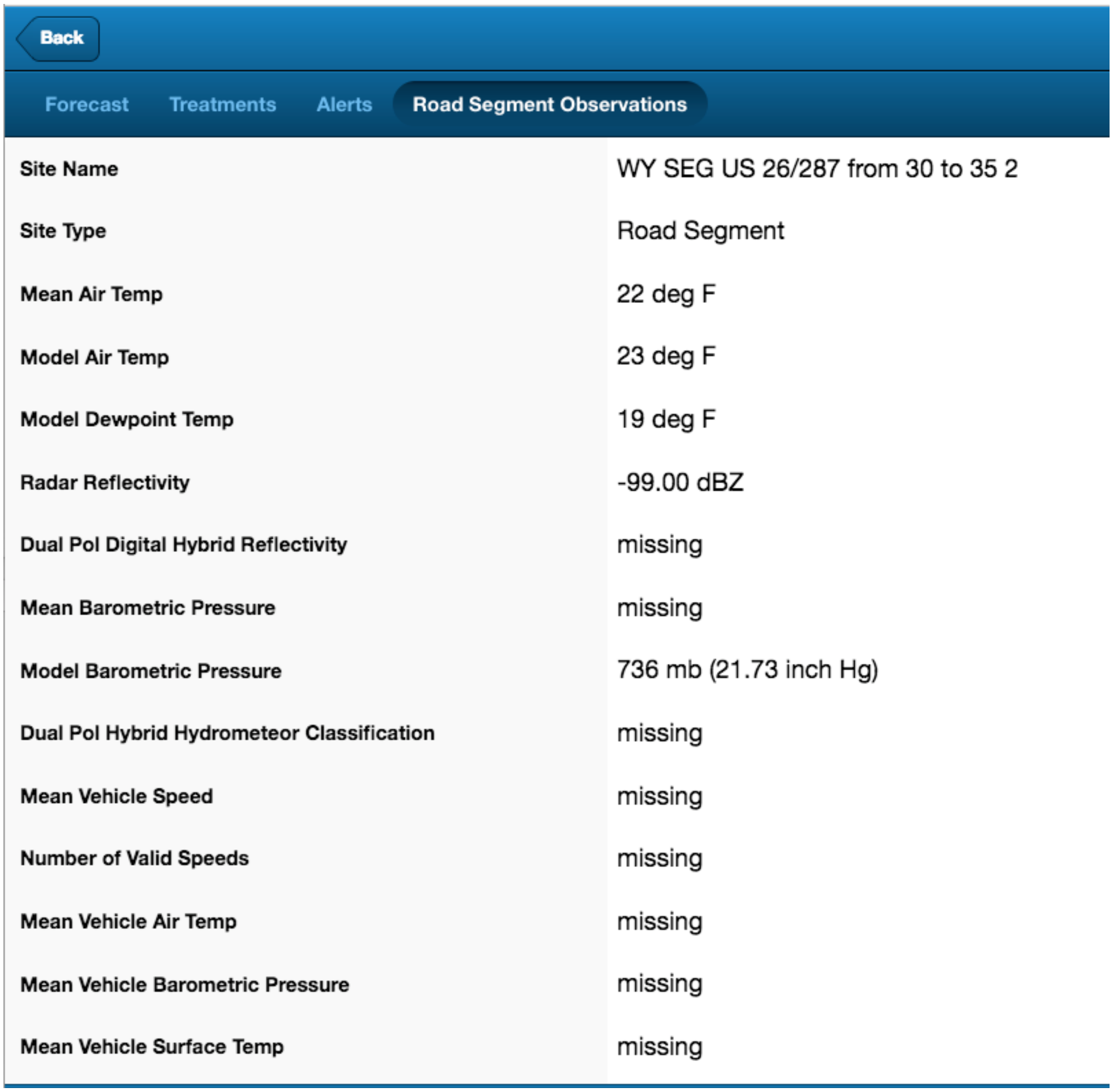


Figure 3-33. Main display. (Source: WYDOT)



Weds 4/26 8:25 am	**Warning:** Precip: light snow, Pavement: slick, icy, Visibility: norm
Weds 4/26 9:00 am	**Warning:** Precip: light snow, Pavement: slick, icy, Visibility: norm
Weds 4/26 10:00 am	**Advisory:** Precip: light snow, Pavement: wet, Visibility: normal
Weds 4/26 11:00 am	**Advisory:** Precip: light snow, Pavement: wet, Visibility: normal
Weds 4/26 12:00 pm	**Advisory:** Precip: light snow, Pavement: wet, Visibility: normal
Weds 4/26 1:00 pm	Clear
Weds 4/26 2:00 pm	**Advisory:** Precip: light snow, Pavement: wet, Visibility: normal
Weds 4/26 3:00 pm	**Advisory:** Precip: light snow, Pavement: wet, Visibility: normal
Weds 4/26 4:00 pm	**Advisory:** Precip: light snow, Pavement: wet, Visibility: normal
Weds 4/26 5:00 pm	**Advisory:** Precip: light snow, Pavement: wet, Visibility: normal
Weds 4/26 6:00 pm	Clear
Weds 4/26 7:00 pm	Clear
Weds 4/26 8:00 pm	**Advisory:** Precip: light snow, Pavement: wet, Visibility: normal
Weds 4/26 9:00 pm	**Advisory:** Precip: light snow, Pavement: wet, Visibility: normal
Weds 4/26 10:00 pm	**Advisory:** Precip: light snow, Pavement: wet, Visibility: normal
Weds 4/26 11:00 pm	**Advisory:** Precip: light snow, Pavement: wet, Visibility: normal

Figure 3-34. Detailed alert tab for a road segment (Source: WYDOT)



Site Name	WY SEG US 26/287 from 30 to 35 2
Site Type	Road Segment
Mean Air Temp	22 deg F
Model Air Temp	23 deg F
Model Dewpoint Temp	19 deg F
Radar Reflectivity	-99.00 dBZ
Dual Pol Digital Hybrid Reflectivity	missing
Mean Barometric Pressure	missing
Model Barometric Pressure	736 mb (21.73 inch Hg)
Dual Pol Hybrid Hydrometeor Classification	missing
Mean Vehicle Speed	missing
Number of Valid Speeds	missing
Mean Vehicle Air Temp	missing
Mean Vehicle Barometric Pressure	missing
Mean Vehicle Surface Temp	missing

Figure 3-35. Detailed road segment observations tab (Source: WYDOT)

3.1.4.2.7.1 Description of Operations/Driver Interface with illustrations

This application contains no driver interface operations.

3.1.4.2.7.2 Description of Maintenance User Interface with illustrations

This application contains no maintenance user interface.

3.1.4.2.8 Requirements Traceability

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

- PA-REQ-1 External Weather Data
- PA-REQ-2 Wyoming CV Sub-Systems Data
- PA-REQ-2.1 ODE Data
- PA-REQ-2.2 TMC Data
- PA-REQ-3 Generate Alerts/Advisories and Forecasts
- PA-REQ-4 Distribute Alerts/Advisories and Forecasts
- PA-REQ-4.1 Distribute to DB

- WI-REQ-1 External Data Acquisition
- WI-REQ-2 Fixed Data Acquisition
- WCVS-REQ-3 Ingest Data for Road Weather information
- WCVS-REQ-4 Contents of Alerts and Advisories
- WCVS-REQ-4.1 Precipitation Hazard
- WCVS-REQ-4.2 Road Condition Hazard
- WCVS-REQ-4.3 Visibility Hazard
- WCVS-REQ-5 Forecast Conditions
- WCVS-REQ-5.1 Atmospheric Forecasts
- WCVS-REQ-5.2 Road Weather Forecasts
- WCVS-REQ-5.3 Forecast Time
- WCVS-REQ-5.4 Forecast Update
- WCVS-REQ-6 Associate Alerts and Forecast to Segments
- WCVS-REQ-8 Internal Brokerage

3.1.4.2.9 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.
ODE <-> Pikalert	ODE Sends Vehicle Environmental Data to Pikalert System	5.19.1
	ODE Sends Environmental Situation Data to Pikalert System	5.19.2
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

3.1.4.3 TMC Data Brokerage (WTIDB)

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

3.1.4.3.1 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 handle data inputs for mayday alerts from the ODE, data inputs for weather forecast, weather alerts and advisories from Pikalert and support new data exports to keep the CVOP current and the ODE for TIMs. The details for these data processing systems are defined below.

3.1.4.3.1.1 Functions/Services Brief description

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

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

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

- Weather Alerts from the Pikalert System
- Weather and road Forecast from the Pikalert system
- 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.

3.1.4.3.1.4 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
- Manual upload of all data to the SDC

All output flows above shall be either responses

3.1.4.3.2 Developer & version number
The Developers working with the Data Broker application include Ivan Yourshaw and David Rush.

3.1.4.3.3 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.

3.1.4.3.3.1 Descriptions and illustrations of messages and alerts issued by application
Table 3-23 describes all messages and alerts that may be issued by the WTIDB application related to the CV features.

Table 3-23 Descriptions of messages and alerts issued by WTIDB.

Message or Alert	Communication Method	Description
Pikalert Inaccessible	Http Response	Error: “Unable to connect to Pikalert endpoint”
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
Emergency Notification (via Distress Notification)	Http Request	This message will be sent to the TRAC System to notify a TMC operator of the received Distress Notification.
Truck Parking Availability Update	Http Request	Message notifying TRAC system of a new crowd sourced parking availability submission

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

Pikalert Inaccessible: A REST request is sent to the Pikalert REST service to retrieve Pikalert information. If a timeout response is received from the request the error is raised and returned as the response.

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.

Road Weather Alert: This road weather alert is generated when the Data Broker application is contacted by the Pikalert system and notified of a new generated Road Weather Alert. The application notifies the TMC TRAC application with the newly generated Road Weather Alert.

Emergency Notification: This alert message is generated when the Data Broker receives a new Distress Notification message via a Kafka feed from the ODE. The message is then created and pushed to the TMC TRAC system for an Operator to handle.

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.

3.1.4.3.3.3 Summary tables of criteria for issuing messages and alerts

Table 3-24 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 3-24. List of criteria for issuing messages and alerts

Message or Alert	Issue Criteria
Pikalert Inaccessible	• Communication failure when calling the Pikalert service
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
Road Weather Alert	• Pikalert issues a new Road Weather alert
Emergency Notification (via Distress Notification)	• ODE receives a new Distress Notification • Data Broker detects DN message via Kafka Stream
Truck Parking Availability Update	• 511 app user submits a new parking availability update for a given (specified) parking area. • 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

3.1.4.3.4 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, ODE, and Pikalert systems. The Data Broker will extend its current REST interface to include functions allowing users to push/pull data meant for the Pikalert forecasting and 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 3-36 below shows interactions with the different applications that the Data Broker shall perform.

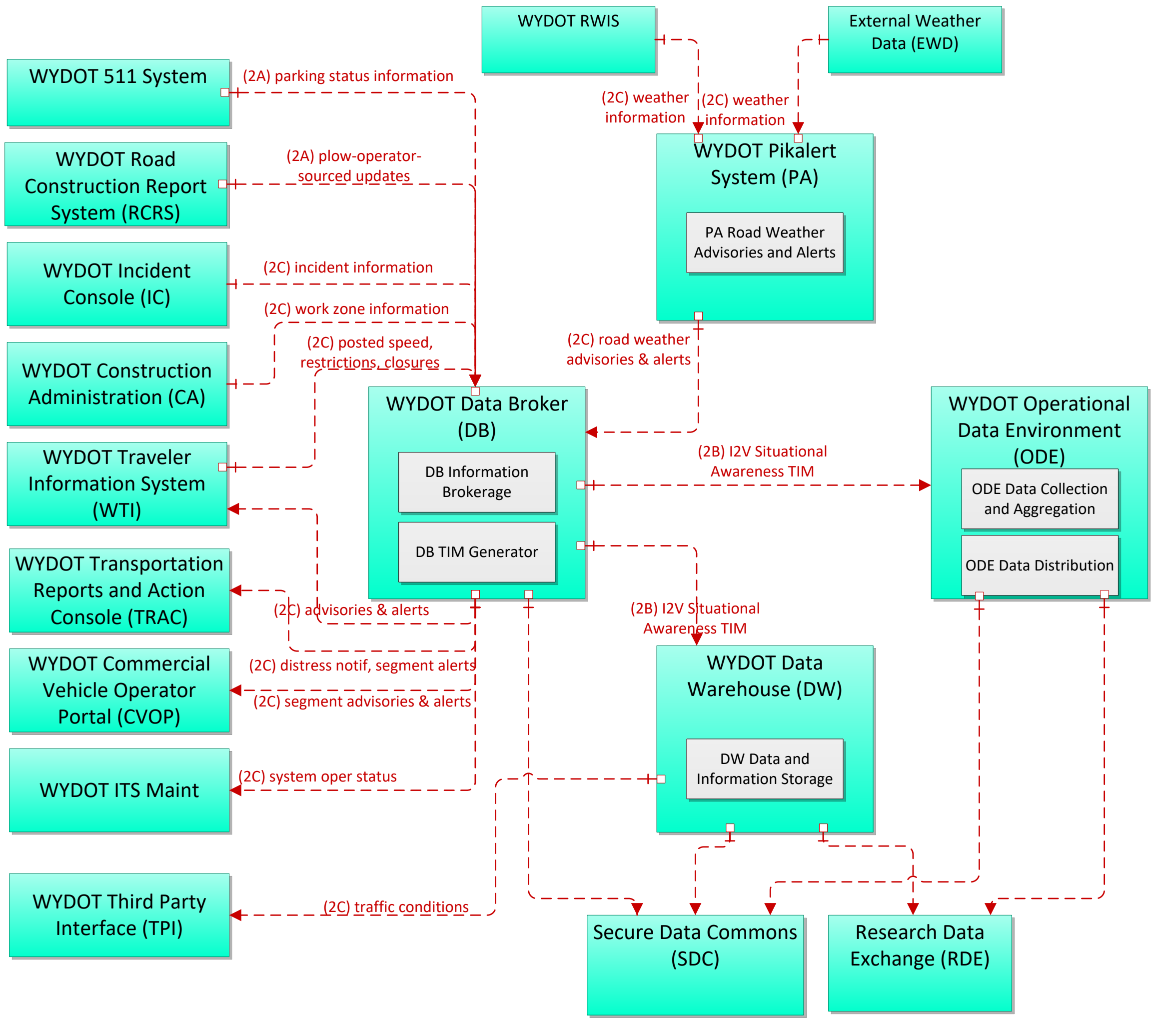


Figure 3-36 Data Broker CV Integration (Source: WYDOT)

All interactions shall be performed over a RESTful service interface with the exception of 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.

3.1.4.3.4.1 Schematic of major modules/functions

See Figure 3-36 for the major modules of the Data Broker application which include a TIM_Generator and an Information Brokerage module.

3.1.4.3.4.2 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 3-253-26 below.

Table 3-253-26 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).
GetPikalertForecast	This function will retrieve forecasts for all road segments within Wyoming and aggregate the forecasts from the 1 mile segments given by the Pikalert system to existing WYDOT road segments. The aggregation algorithm will smooth the forecast for the overall road segment amongst the 1 mile segment forecasts provided by Pikalert to apply to the overall road segment. The exact algorithm has yet to be worked out and will be provided in an updated version of the SDD. Forecasts retrieved include a 12, 24, 48, and 72 hour forecast for road conditions.
SetForecast	This function stores original Pikalert forecasts. Additionally, this function will save the updated forecast from the local meteorologist changes.

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 3-27 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 3-27 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.
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)

Hazard Monitor Module: This module will periodically monitor (at a configurable time) the Pikalert system for new Pikalert issued warnings and hazards including the following:

- Alerts and Advisories
- Precipitation Hazards
- Road Condition Hazards
- Visibility Hazards

Additionally, this module is also responsible for monitoring the ODE for incoming Distress Notification messages.

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 and to the Pikalert system. Event logs are written to the database as soon as they are received from the ODE (maximum of 5 minute processing time).

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

Figure 3-37 shows the process flow between the different applications for the Data Broker Information Brokerage module.

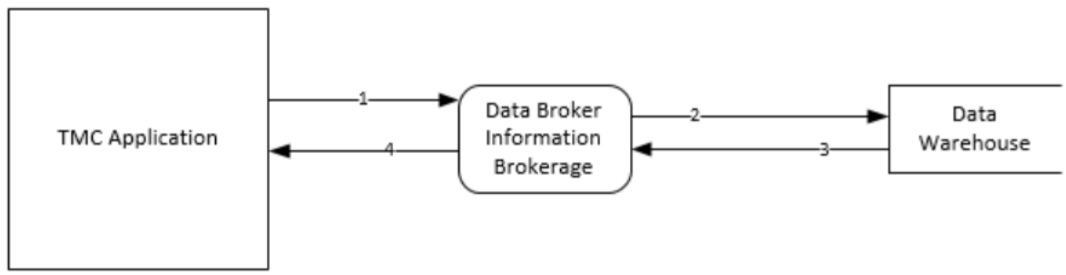


Figure 3-37 Information Brokerage module process flow (Source: WYDOT)

Figure 3-38 shows the process flow between the different applications for the Data Broker TIM_Generator module.

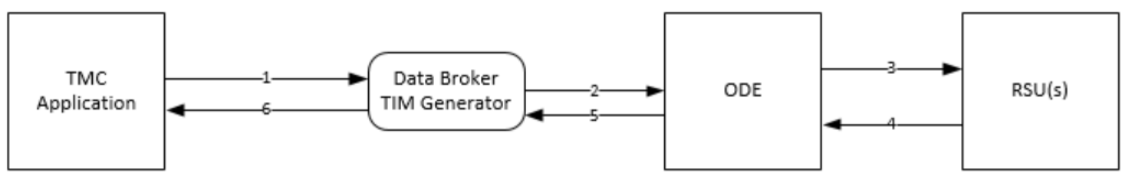


Figure 3-38 Data Broker TIM_Generator process flow (Source: WYDOT)

Figure 3-39 shows the process flow between different applications for the generation of a road weather hazard. Please note that all messages sent to the TRAC system for Road Weather Alerts are sent in less than one second from the time they are received by the Hazard Monitor.

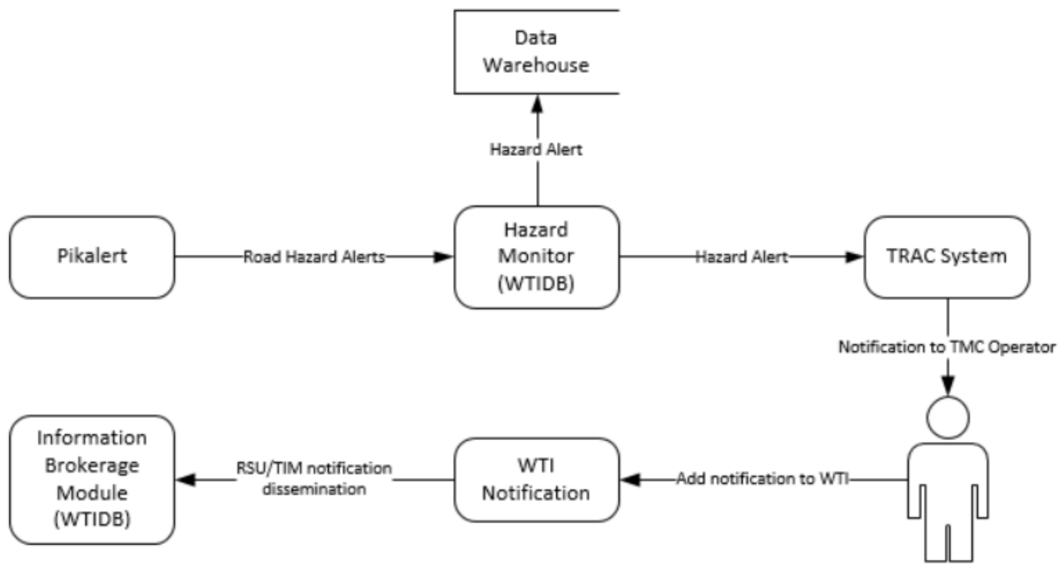


Figure 3-39 Hazard Alert notification and generation (Source: WYDOT)

Figure 3-40 shows the process flow of the Hazard Monitor monitoring for distress notification alerts that are incoming. Please note that all messages sent to the TRAC system for Distress Notifications are sent in less than one second from the time they are received by the Hazard Monitor.

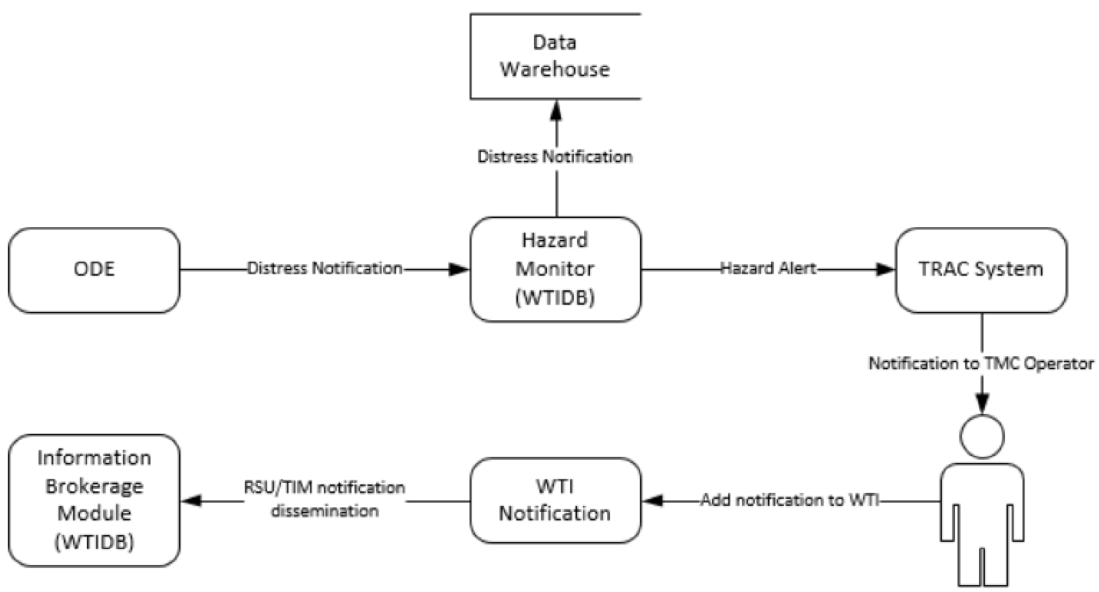


Figure 3-40 Distress Notification Alert notification. (Source: WYDOT)

3.1.4.3.4.4 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 3-37: 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 3-38: 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.

The process flow for the Hazard Monitor module within the WTIDB application (shown in Figure 3-39) consists of the following: 1) Pikalert generates road weather alerts and outputs the data in a JSON format. 2) The Hazard Monitor module requests the Pikalert hazard alert information periodically (initially set to every 5 minutes but is configurable). 3) When new alerts are generated the monitor adds the generated alert to the data warehouse and then sends a request to the TRAC system for TMC operators to review. 4) TMC operators review the hazard alert and generate a new notification via existing WTI interface. 5) WTI submits hazard alert through existing interface to WTIDB information brokerage module. 6) Information brokerage sends a JSON object to the TIM_Generator module (see process flow for TIM_Generator Module for dissemination information). Additionally, the Hazard Monitor is also responsible for monitoring the ODE for incoming distress notifications (see Figure 3-40) and notifying the TMC of notifications via the TRAC system. This process is almost identical to the Pikalert alert/warning notification so will not be described in detail other than the source monitor is done continuously instead of periodically.

3.1.4.3.5 Application Data Tables

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

3.1.4.3.5.1 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 3-41).

3.1.4.3.5.2 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.

3.1.4.3.5.3 Data/database storage description diagrams and tables

Figure 3-41 below shows the new ERD to hold TIM message data (both outbound and inbound Distress Notification data).

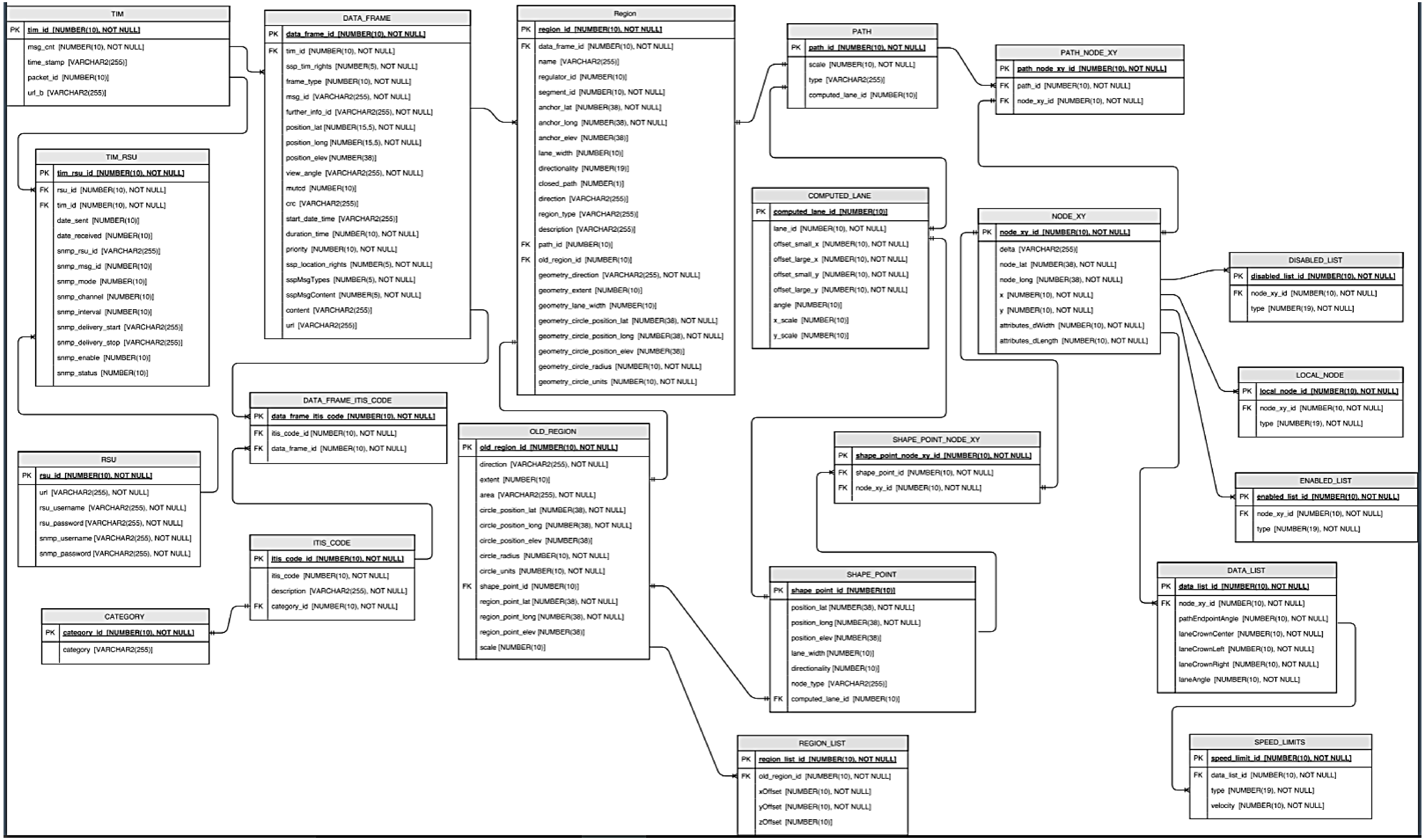


Figure 3-41 TIM message ERD (Source: WYDOT)

3.1.4.3.6 Application User Interface(s)

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

3.1.4.3.6.1 Description of Operations/Driver Interface with illustrations

This application contains no driver interface operations.

3.1.4.3.6.2 Description of Maintenance User Interface with illustrations

This application contains no maintenance interface operations.

3.1.4.3.7 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
- DB-REQ-4 Receive from Pikalert
- DB-REQ-4.1 Receive Alerts and Advisories
- DB-REQ-4.2 Receive Forecast
- DB-REQ-5 Distribute to ODE
- DB-REQ-6 Receive from ODE
- DB-REQ-7 Distribute to Data Warehouse
- 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
- TRAC-REQ-1.1 Distress Notification
- TRAC-REQ-1.1.1 Transmission Time
- TRAC-REQ-1.2 Segment Alerts
- TRAC-REQ-1.2.1 Transmission Time
- TRAC-REQ-1.2.2 Segment Alerts-Pikalert
- 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
- WTI-REQ-1.1 Current Segment Alerts
- WTI-REQ-1.1.1 Transmission Time
- WTI-REQ-1.2 Forecast Segment Alerts
- WTI-REQ-1.2.1 Forecast Time
- WTI-REQ-1.2.2 Forecast Update

- 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
- CVOP-REQ-1.2.1 Forecast Time
- CVOP-REQ-1.2.2 Forecast Update
- 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
- WCVS-REQ-8 Internal Brokerage
- DW-REQ-2.4 Share Data with DB

3.1.4.3.8 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
	DB Sends Emergency Notification to TRAC	5.28.1

WYDOT DB <-> WYDOT TRAC	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

3.1.4.4 WYDOT Third Party Interface (TPI)

The sections below describe the application design for the Third Party Interface (TPI), which serves WYDOT Traffic and Road Condition information with Commercial Vehicle Operators.

3.1.4.4.1 Function of the Application

The TPI is a standardized interface based on ITE / AASHTO Traffic Management Data Dictionary (TMDD) v03.03c that can be used to support delivery of traveler information to external centers and information service providers.

3.1.4.4.1.1 Functions/Services Brief description

The TPI REST service retrieves fresh data from the central WYDOT Oracle database every 5 minutes. Commercial vehicle operators may request data from the service as often as they choose to. The RESTful end-point is password protected and runs over SSL. SSL protects the user's credentials which are passed using HTTP Basic Authentication.

User authentication leverages existing accounts from WYDOT's Commercial Vehicle Operator Portal (CVOP). The CVOP user credentials are stored in WYDOT’s Oracle database.
The TPI data feed is in JSON format and consists of data structures defined in the ITE / AASHTO TMDD Standard, v03.03c. The TMDD structures each distinct traffic condition, closure, advisory, incident, road condition into what it calls an "event".

3.1.4.4.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

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

3.1.4.4.1.3 Input Data/Message Flows

Oracle Database to REST Service: WYDOT events as XML file & 8 files which make up the XSD schema.
User to REST Service: HTTP GET Request with Basic Authentication Credentials.

3.1.4.4.2 Output Data/Message Flows
REST Service to User: WYDOT events as JSON HTTP response.

3.1.4.4.3 Developer & version number

The WYDOT development team is responsible for this application.

3.1.4.4.4 Application Message and Alerts Descriptions

There are no new messages or alerts issued by this application for the CV project.

3.1.4.4.5 Descriptions and illustrations of messages and alerts issued by application
There are no new messages or alerts issued by this application for the CV project.

3.1.4.4.6 Describe algorithm to determine when messages and alerts are issued
There are no new messages or alerts issued by this application for the CV project.

3.1.4.4.7 Summary tables of criteria for issuing messages and alerts
There are no new messages or alerts issued by this application for the CV project.

3.1.4.4.8 Application Design Description

The following sections describe the Application Design for the Third Party Interface application.

3.1.4.4.9 Schematic of major modules/functions
The following component diagram shows the major modules of the Third Party Interface. The TMDD Web App consists of a public facing REST Service and a thread which imports TMDD event data from an XML file. The Oracle Database (WYDOT Data Warehouse) hosts a stored procedure which regularly exports WYDOT traveler event to an XML file using the TMDD schema.

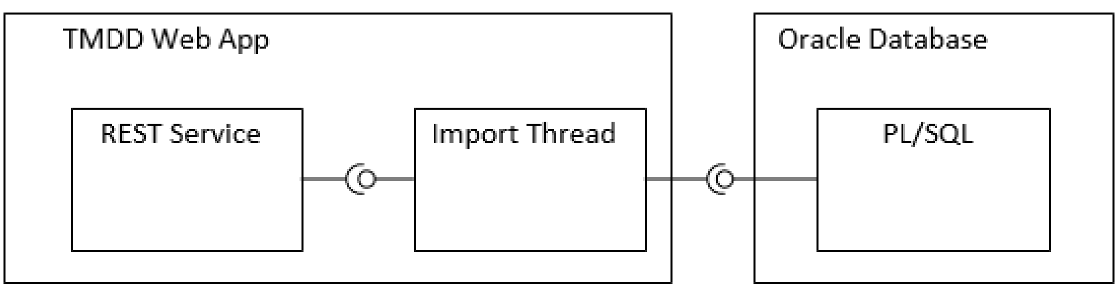


Figure 3-42. Component Diagram: Third Party Interface (Source: WYDOT)

3.1.4.4.10 Description of modules/functions
An Oracle Stored Procedure periodically (currently every 5 minutes) collects a snapshot of all active Wyoming 8, 9 & 10 codes. It converts these records into TMDD event records and exports them to an XML file in a location known to the TMDD REST Service Web Application.

A background thread on the REST Service Web Application polls the XML file changes. When an updated XML file is detected the file is read in and its contents are validated against the TMDD XSD schema. Assuming the XML is valid, the TMDD event records are extracted and saved to Java representation (POJO) and stored in a singleton data structure which is the source data for the REST service.

The REST Service Web Application follows the Java Servlet Specification but is implemented using REST Easy framework running on an Apache Tomcat web server. In practical terms, this means the REST Service source code is an annotated Java method which is invoked by Tomcat for HTTP GET requests. The Apache server manages the SSL handshake based on WYDOT's public/private key configuration. BASIC Authentication for the REST service is handled in the Tomcat server. The user credentials are stored in Oracle and Tomcat is configured to automatically perform user password validation on all incoming HTTP requests. When the GET method of the REST Service is eventually called, the service obtains the singleton Java object representing the complete set of WYDOT events, serializes it to JSON and returns the JSON in the HTTP Response.

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

The following sequence diagram shows how the WYDOT Traveler Events are exported from the Oracle Database every 5 minutes as an XML file using the TMDD schema.

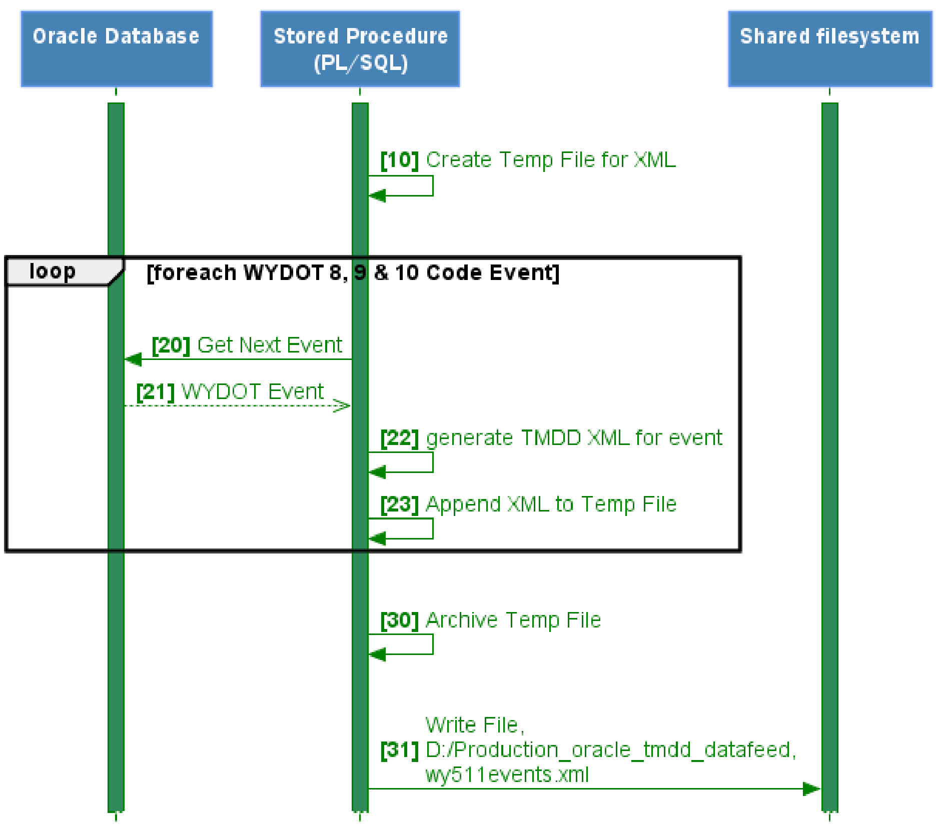


Figure 3-43. WYDOT Events Exported to XML every 5 minutes (Source: WYDOT)

The following sequence diagram shows how a background process owned by the REST service consumes the latest XML data.

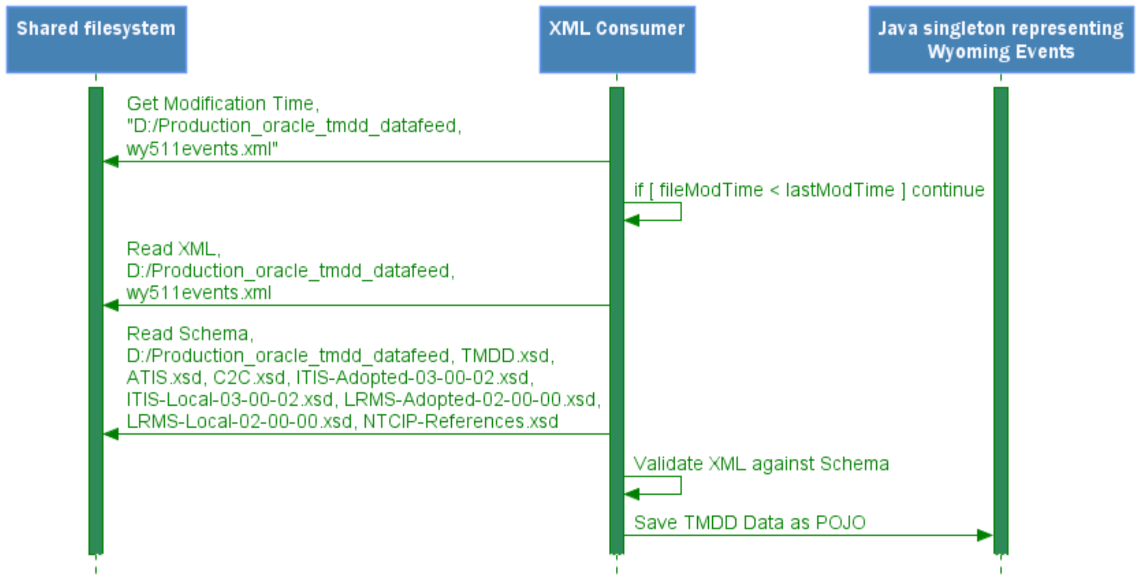


Figure 3-44. WYDOT REST Service Imports Events from XML (Source: WYDOT)

The following diagram shows how the REST Service processes a request.

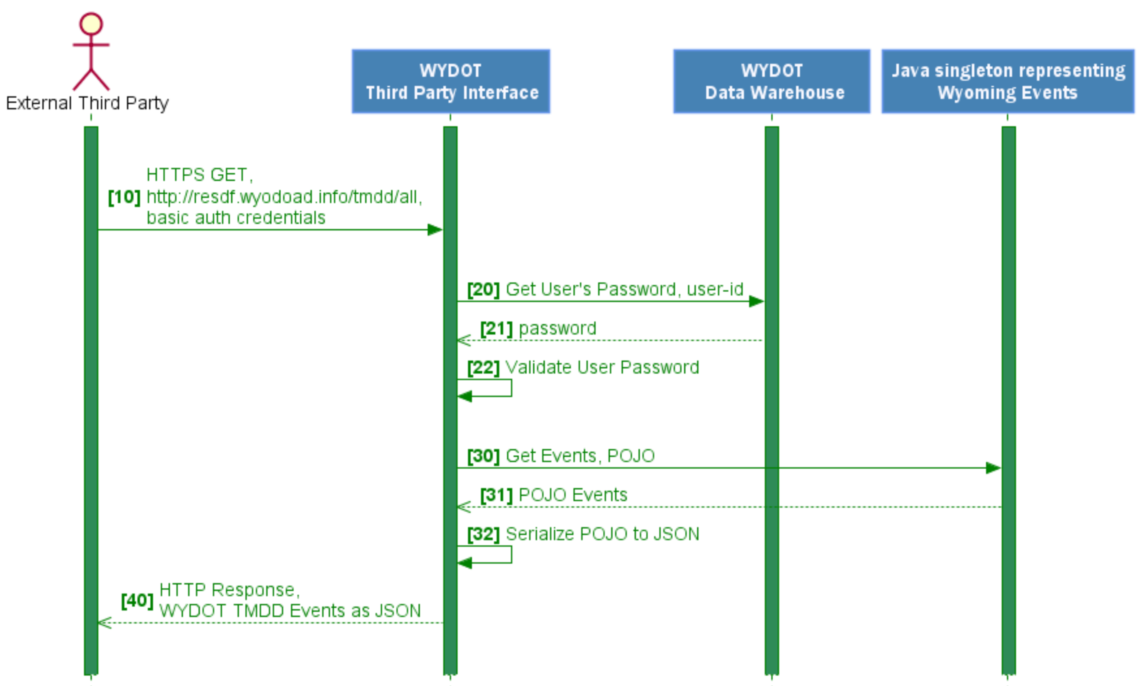


Figure 3-45. WYDOT REST Service Handles Request (Source: WYDOT)

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

The Oracle Stored Procedure which exports the Wyoming 8, 9 & 10 codes to XML file must translate WYDOT specific event types into ITIS codes from the TMDD standard dictionary. The ICD contains tables which show the mappings between WYDOT event types and ITIS codes in the TMDD standard dictionary. For details see Tables:

- 0-9: TMDD ITIS codes for WYDOT Road Conditions, Advisories and Closures
- 0-10: WYDOT Incident Problem Codes to ITIS Codes
- 0-12: WYDOT Incident Action Codes to ITIS Codes

3.1.4.4.12 Application Data Tables

No new data tables were created for this application for the CV project.

3.1.4.4.13 Input data description tables

No new data tables were created for this application for the CV project.

3.1.4.4.14 Output data description tables

No new data tables were created for this application for the CV project.

3.1.4.4.14.1 Data/database storage description diagrams and tables

No new data tables were created for this application for the CV project.

3.1.4.4.15 Application Configuration Data

The following table shows configuration parameters used during the build of the REST Service.

Table 3-28. Build Configuration Settings for the REST Service

Java Build Configuration Parameter	Value	Description
tmdd.xsd.fname	TMDD.xsd	TMDD XSD schema file name.
tmdd.xsd.path	D:/Production_oracle_tmdd_datafeed	Path to TMDD XSD schema
tmdd.xml.fpath	D:/Production_oracle_tmdd_datafeed/wy511events.xml	Path to input XML file

3.1.4.4.16 Application User Interface(s)

The following represents the public, HTTP GET request to return the complete list of Wyoming events. A valid request is shown below (with authentication data obscured with italic bold):

```
GET /tmdd/all HTTP/1.1
Host: resdf.wyoroad.info
Accept: application/json
Content-Transfer-Encoding: application/gzip
Authorization: Basic <XXXXXXX>
Cache-Control: no-cache
```

3.1.4.4.16.1 Description of Operations/Driver Interface with illustrations

This application has no driver user interface.

3.1.4.4.16.2 Description of Maintenance User Interface with illustrations

This application has no maintenance user interface.

3.1.4.4.17 Requirements Traceability

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

- TPI-REQ-1 TPI Data

3.1.4.4.18 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 DW <-> Third Party Interface (TPI)	Third Party retrieves WYDOT traffic and road conditions	5.36.1

3.1.4.5 Service Monitor Device Management

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

3.1.4.5.1 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.

3.1.4.5.1.1 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

3.1.4.5.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

Figure 3-46 shows how over the air updates would be handled from RSUs to OBUs.

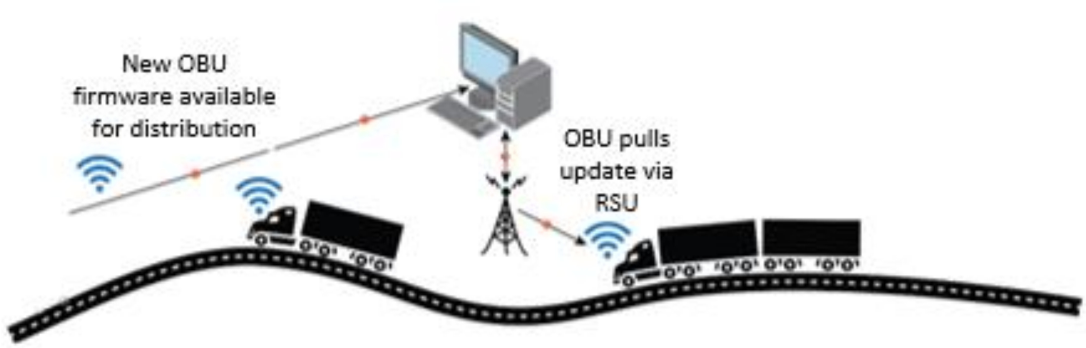


Figure 3-46. Over the air updates from RSUs to OBUs (Source: WYDOT)

3.1.4.5.2 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

3.1.4.5.3 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 3-47.

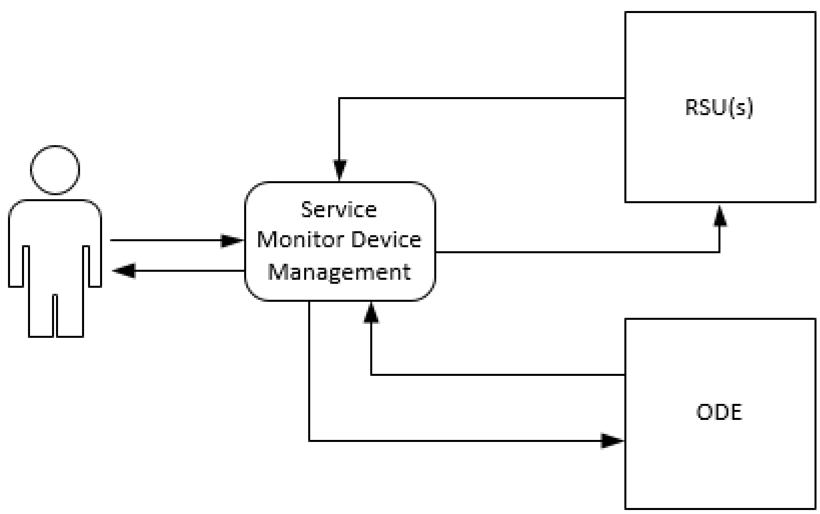


Figure 3-47. Service Monitor Device Management data flows (Source: WYDOT)

3.1.4.5.4 Developer & version number

Developers responsible for the Service Monitor Device Management service include Rick Smith and Tim Frye.

3.1.4.5.5 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.

3.1.4.5.5.1 Descriptions and illustrations of messages and alerts issued by application

Table 3-29 describes the messages and alerts returned from the Service Monitor Device Management service.

Table 3-29. Service Monitor Device Management message and alerts

Message or Alert	Communication Method	Description
ODE Inaccessible	Http Response	Error: "Failed accessing ODE endpoint"
OBU Update Error	Http Response	Error: "Failed updating OBU" – additional details will be provided of the exact error received from the OBU
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"

3.1.4.5.5.2 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.

OBU Update Error: A request is sent to update an OBU. A python script is run as a background process to update the OBU 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. Over the air updates for OBUs will be handled by the RSU. RSUs will broadcast update availability and will download firmware updates to the OBU via a passthrough from a Lear Server to the OBU. The OBU will prompt users for available updates.

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.

3.1.4.5.6 Summary tables of criteria for issuing messages and alerts

Table 3-30 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 3-30. List of criteria for issuing messages and alerts

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

3.1.4.5.7 Application Design Description

The following sections describe the design for the Service Monitor Device Management REST service. Please note that over the air updates for OBUs will be included in the functionality of this service. However, they are not included in the functional details below as WYDOT has yet to receive details on over the air updates from the Lear team.

3.1.4.5.7.1 Schematic of major modules/functions

Figure 3-48 shows the major components of the Service Monitor Device Management REST service. Please note that the development of the RSU and OBU scripts are part of the design for this application and are described in the sections below.

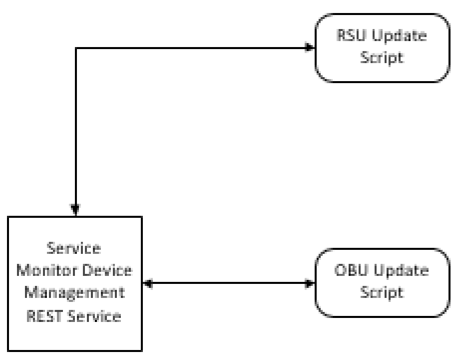


Figure 3-48. Service Monitor Device Management Module Design (Source: WYDOT)

3.1.4.5.8 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 3-31. 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 3-31. 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 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.
UpdateOBU	Attempts to Update an OBU to a given version of firmware. This function kicks off a python script that will update the OBU. Any errors encountered are returned in the response to the user.
GetSDXStatus	Retrieves the current status and space available within the WYDOT SDX.

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

Figure 3-48 shows the process flow for the major modules/functions within the Service Monitor Device Management REST service.

3.1.4.5.8.2 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.

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

Please note that at the moment 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.

3.1.4.5.9 Application Data Tables

The following sections describe the data input and output for the different functions within the service.

3.1.4.5.9.1 Input data description tables

Table 3-32 describes the input parameters for the function calls to the rest service.

Table 3-32. 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
UpdateOBU	OBU_IPs	String [ ]	The list of OBU IP addresses to update.
UpdateOBU	Version	String	The version number of the firmware to upgrade the OBUs to

3.1.4.5.9.2 Output data description tables

Table 3-33 describes the output parameters for the function calls from the REST service.

Table 3-33. 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

Function Name	Parameter	Type	Description
			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.
UpdateOBU	Success	Boolean	Returns true if the function succeeded otherwise false.
UpdateOBU	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.

3.1.4.5.9.3 Data/database storage description diagrams and tables

Figure 3-49 shows the ERD for the Service Monitor Device Management REST service.

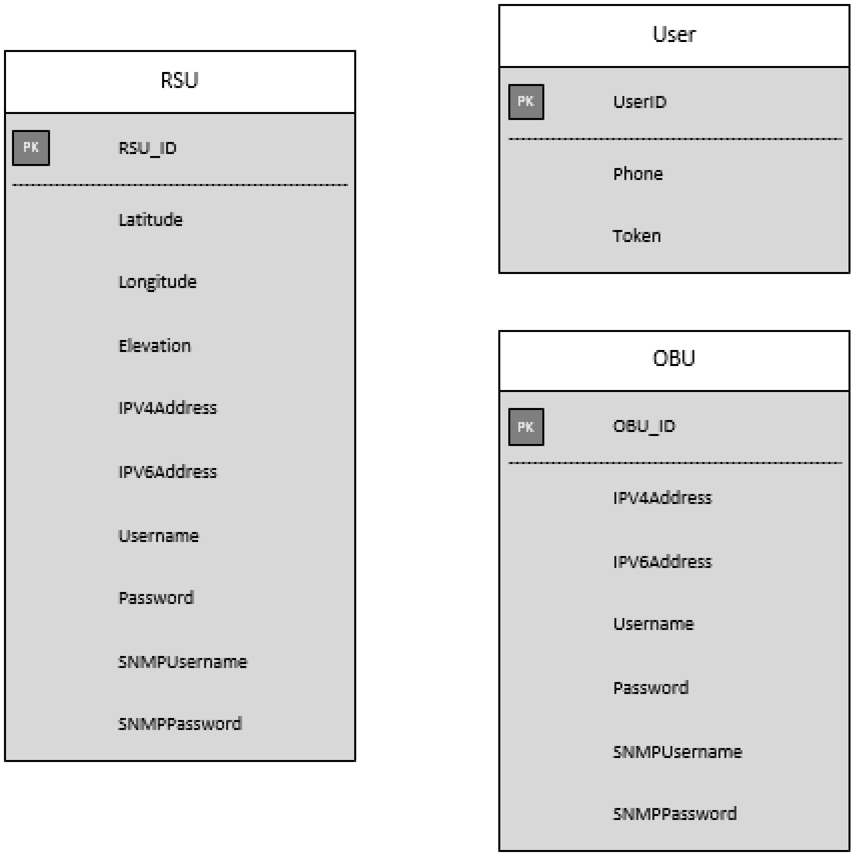


Figure 3-49. Service Monitor Device Management ERD (Source: WYDOT)

3.1.4.5.10 Application User Interface(s)

This application is a service and does not contain any user interfaces.

3.1.4.5.10.1 Description of Operations/Driver Interface with illustrations

This application contains no driver interface operations.

3.1.4.5.10.2 Description of Maintenance User Interface with illustrations

This application contains no maintenance user interface operations.

3.1.4.5.11 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
- 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

3.1.4.5.12 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 CVOP Website updates (Extension & Interface)

3.1.5.1.1 Function of the Application

This application is responsible for extending the current CVOP site to allow for updating content based on the TMC Road Weather Advisories and Warnings service. Updates to the CVOP site will include a section where current conditions by road segment will be available and the site will include updates for responsive web design making the website more user friendly on mobile devices. Additionally, the CVOP forecasting will incorporate Pikalert forecasted conditions.

3.1.5.1.1.1 Functions/Services Brief description

Functions/Services provided by the CVOP web application include providing a web application that allows commercial vehicle operators (CVOs) to view forecasts for many highways within Wyoming. All forecasts are stored within an Oracle database. The website has the ability for a WYDOT on-staff meteorologist to create and update forecasts for all interstates and some other highways within Wyoming. Forecasting information from the Pikalert system shall be integrated within the forecasting section of the website and shall allow for all major highways within Wyoming to contain forecast information.

The CVOP website is only available to registered users. Table 3-34 defines the three roles for the CVOP web application.

Table 3-34. List of user roles and permissions.

Role	Permissions
Commercial Vehicle Operator	• View current forecasts
WYDOT Meteorologist	• View current forecasts • Add/Edit/Delete forecasts
WYDOT Administrator	• View current forecasts • Add/Edit Delete Commercial Vehicle Operators • Approve or Reject commercial vehicle operators' requests for access

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

3.1.5.1.1.3 Input Data/Message Flows
There are two input flows for the CVOP website, authentication data and forecasting data. The user provides authentication data during login to confirm the identity of the user. The other input flow consists of forecasts for road segments within Wyoming.

Authentication data for the CVOP website consists of an email address and password. All authentication is done through Tomcat web authentication services.

Forecast data shall consist of data originating from both the Pikalert application as well as a meteorologist on the WYDOT staff that has permissions to the CVOP website. A section of the website shall allow the WYDOT meteorologist to edit Pikalert forecasting recommendations. Forecasting data consists of specific data related to forecasts for Wyoming road conditions up to 72 hours in advance. The only additional data flow that will be developed for the CV pilot project is the data flow to/from the Pikalert service.

Figure 3-50 shows the data flows for the CVOP application.

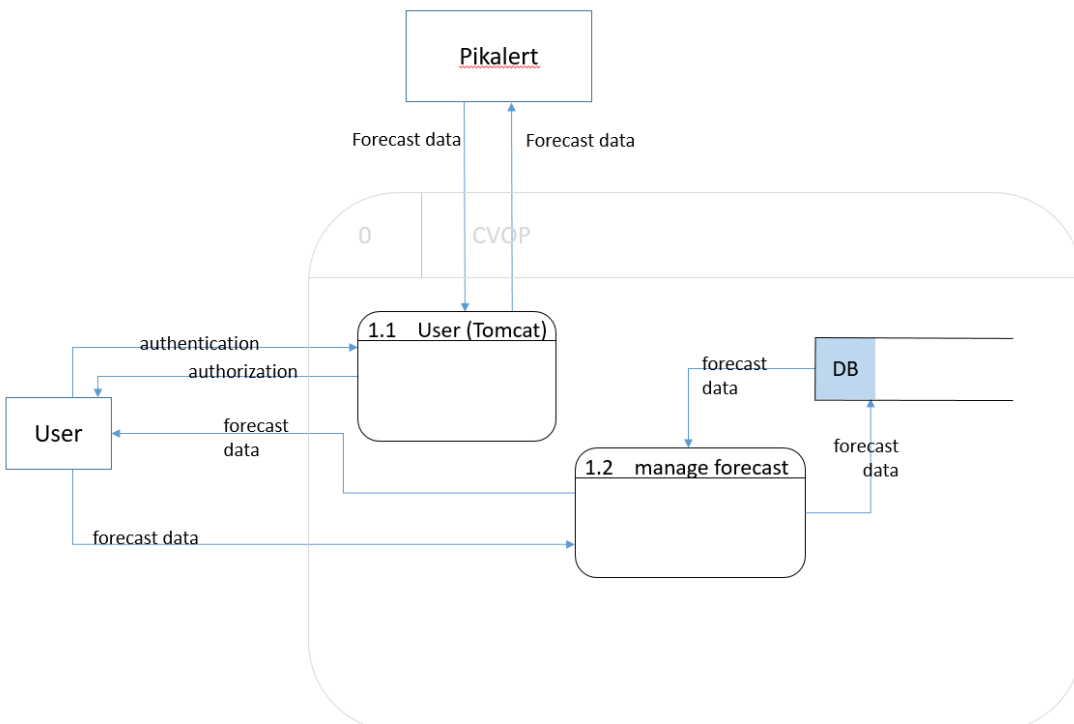


Figure 3-50. CVOP Data Flows (Source: WYDOT)

3.1.5.1.1.4 Output Data/Message Flows
The output data flow from the CVOP website will primarily be forecast data and current road condition data. Different forecast data shall be provided to different sources as requested by users with different roles. Users with the *WYDOT Meteorologist* role will have the ability to update forecasts for road segments. Additionally, road segments coming from the Pikalert system will be consolidated from one-

mile segments to larger predefined road segments in order to reduce alerts sent to Commercial Vehicle Operators.

3.1.5.1.2 Developer & version number

David Rush with WYDOT is the primary developer for this application.

3.1.5.1.3 Application Message and Alerts Descriptions

The following sections describe the application messages and alerts this application may generate.

3.1.5.1.3.1 Descriptions and illustrations of messages and alerts issued by application

Table 3-35 shows a list of messages and alerts that may be issued by the CVOP application.

Table 3-35. Descriptions of messages and alerts issued by CVOP.

Message or Alert	Communication Method	Description
RecordNotFoundException	Http Response	• Status Code: 404 • Error: “Unable to find forecast information”
PikalertException	Http Response	• Status Code 403 • Error: Pikalert service unavailable

3.1.5.1.3.2 Describe algorithm to determine when messages and alerts are issued

RecordNotFoundException

The REST web application portion of the CVOP provides basic validation checks when updating or deleting any resource data. If a resource record is to be updated or deleted, and the specified record does not exist then then a RecordNotFoundException is generated. This error is communicated to the user with a specific error status and error text in the http response header returned from the offending request.

PikalertException

This exception is thrown when access to the Pikalert system is unavailable or unreachable for any reason. Any additional information regarding the error is also provided in the response to the user.

3.1.5.1.3.3 Summary tables of criteria for issuing messages and alerts

Table 3-36 describes the algorithms used to determine issuance of a message or alert.

Table 3-36. List of criteria for issuing messages and alerts

Message or Alert	Issue Criteria
RecordNotFoundException	• During an update or delete of a resource object record, no record matching the specified id is found
PikalertException	• Unable to retrieve data from the Pikalert service • Accessing the Pikalert service times out.

3.1.5.1.4 Application Design Description

The overall application design for the CVOP website updates will encompass adding a new Java Servlet REST service that will access data from the Pikalert system to prepopulate forecasting information in the CVOP forecast website. The CVOP website will also add a current conditions map so users may view the current road condition information from within the website. The database structure will remain the same but additional data will be stored for performance measurements against the existing forecasting already being performed. Though this application will not be setup to automatically update forecast information initially the WYDOT meteorologist is responsible for reviewing Pikalert recommendations and pushing forecast updates every 12 hours from the system.

3.1.5.1.4.1 Schematic of major modules/functions

Figure 3-51 shows the major modules within the CVOP Application.

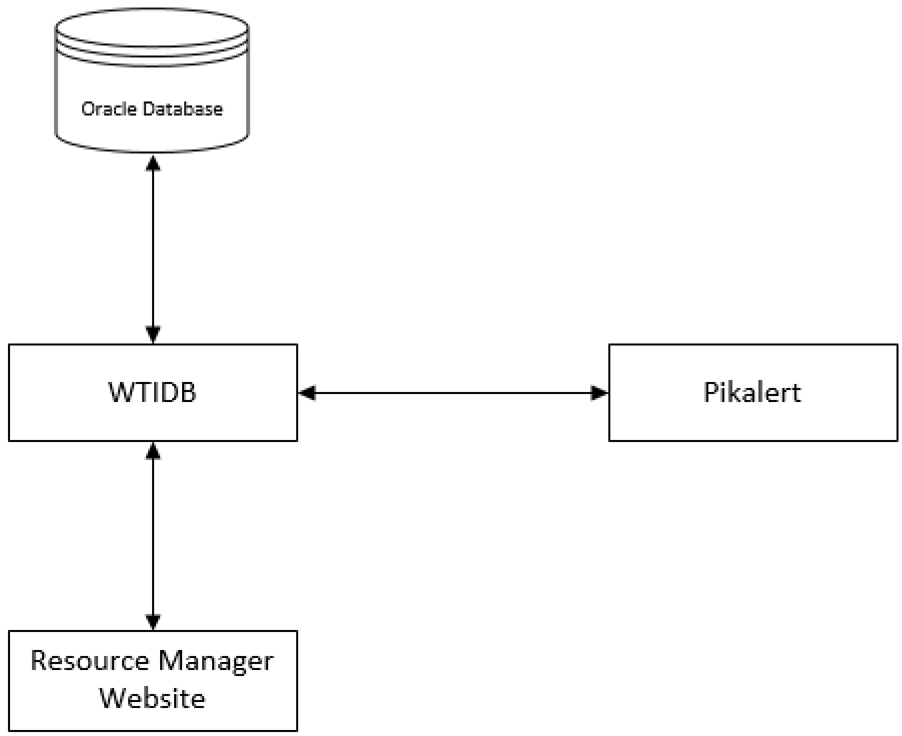


Figure 3-51. CVOP Modules (Source: WYDOT)

3.1.5.1.4.2 Description of modules/functions

New features that shall be implemented for the CVOP website updates include adding current conditions map, integrating Pikalert forecasting information, and storing forecasting information from Pikalert as well as meteorologist updates to the Pikalert forecast. The newly added conditions map will be the same source code used for the WYOROAD.INFO conditions map. The WTIDB Service will house the functions for retrieving and aggregating Pikalert forecasts. Functions for the new WTIDB REST service are defined in the WTIDB section.

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

Figure 3-52 shows the process flows between the major modules for the CVOP enhancements.

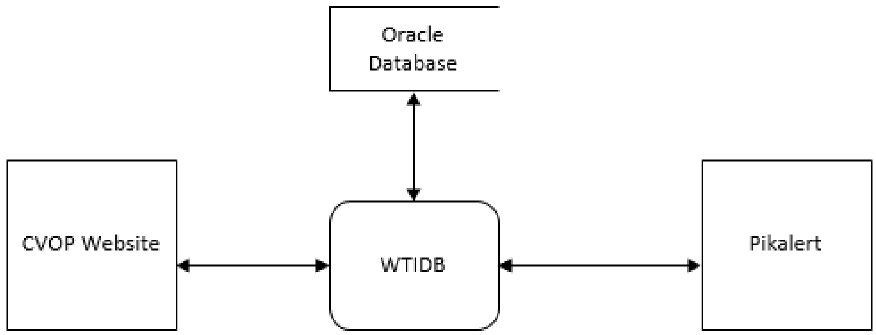


Figure 3-52. CVOP functional data flows (Source: WYDOT)

3.1.5.1.4.4 Descriptions of process flow/algorithms between major modules/functions
Process flow/algorithms between the major modules/functions are described below.

CVOP and WTIDB Service: This process flow begins with CVOP requesting forecast information from Pikalert so that it can prepopulate forecasts for the local WYDOT meteorologist to review and update as needed. After updates have been made another call to the WTIDB REST service saves the data to the existing forecast data tables along with the changes made by the WYDOT meteorologist. Here the WTIDB is responsible for polling the Pikalert system every 5 minutes to process and input information the database. As soon as this information is added to the Database the segment alert and forecast information is also reflected within the CVOP website. Please note that the meteorologist from WYDOT will still need to approve the segment alerts before they are distributed to the CVOP system. As soon as they are approved segment alerts are sent out to all registered CVOP users and are reflected in the CVOP system.

WTIDB and Oracle Database: This process flow consists of the WTIDB REST service saving and retrieving forecasts from the Oracle database.

WTIDB and Pikalert: This process flow consists of the REST service querying the Pikalert system for forecasts and then aggregating the forecasts for specific WYDOT road segments.

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 of application configuration parameters, including defaults

3.1.5.1.7 Application User Interface(s)

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 user interface.

3.1.5.1.8 Requirements Traceability

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

- 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
- CVOP-REQ-1.2.1 Forecast Time
- CVOP-REQ-1.2.2 Forecast Update

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 CVOP	DB sends segment advisories and alerts to CVOP	5.29.1
	CVOP Manages Road Weather Forecast Data Using DB	5.29.2

3.1.5.2 WYDOT Transportation Reports and Action Console (TRAC)

The following sections describe the design for the TRAC application

3.1.5.2.1 Function of the Application

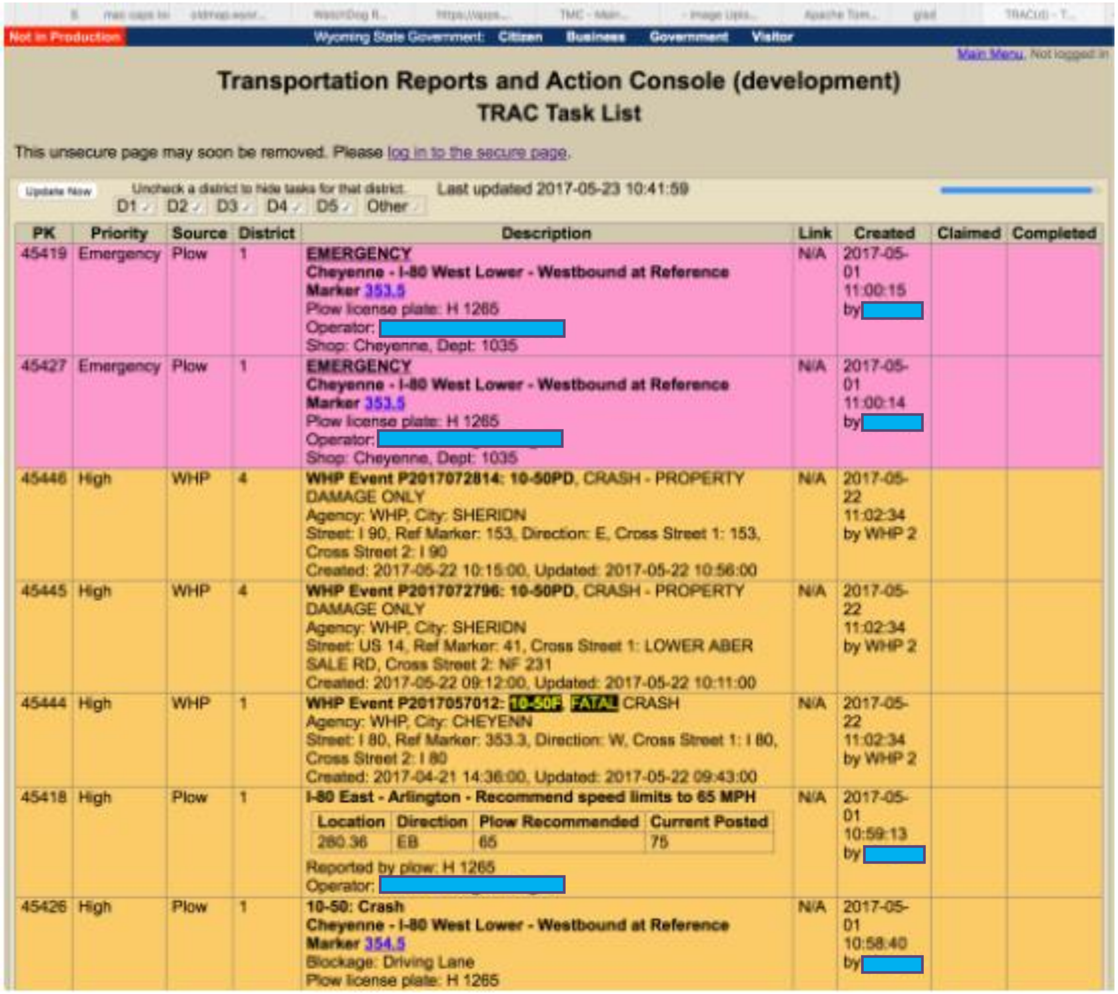
The TRAC is an operator console used in the TMC to monitor and manage planned, ongoing, and forecast events and actions on facilities monitored by the TMC. The TRAC provides a tabular list of actions that require operator attention. As events progress, operators mark actions as complete. The TRAC receives 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.

3.1.5.2.1.1 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 in order to reduce the amount of "noise" that an operator will be exposed to.

3.1.5.2.1.2 Graphical illustration of the Application from the Users Perspective

Figure 3-53 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.



Not in Production | Wyoming State Government: Citizen Business Government Visitor

Main Menu, Not logged in

Transportation Reports and Action Console (development)

TRAC Task List

This unsecure page may soon be removed. Please log in to the secure page.

Update Now | Uncheck a district to hide tasks for that district. D1 D2 D3 D4 D5 Other | Last updated 2017-05-23 10:41:59

PK	Priority	Source	District	Description	Link	Created	Claimed	Completed
45419	Emergency	Plow	1	**EMERGENCY** **Cheyenne - I-80 West Lower - Westbound at Reference Marker** 353.5 Plow license plate: H 1265 Operator: [redacted] Shop: Cheyenne, Dept: 1035	N/A	2017-05-01 11:00:15 by [redacted]		
45427	Emergency	Plow	1	**EMERGENCY** **Cheyenne - I-80 West Lower - Westbound at Reference Marker** 353.5 Plow license plate: H 1265 Operator: [redacted] Shop: Cheyenne, Dept: 1035	N/A	2017-05-01 11:00:14 by [redacted]		
45446	High	WHP	4	**WHP Event P2017072814: 10-50PD**, CRASH - PROPERTY DAMAGE ONLY Agency: WHP, City: SHERIDN Street: I 90, Ref Marker: 153, Direction: E, Cross Street 1: 153, Cross Street 2: I 90 Created: 2017-05-22 10:15:00, Updated: 2017-05-22 10:56:00	N/A	2017-05-22 11:02:34 by WHP 2		
45445	High	WHP	4	**WHP Event P2017072796: 10-50PD**, CRASH - PROPERTY DAMAGE ONLY Agency: WHP, City: SHERIDN Street: US 14, Ref Marker: 41, Cross Street 1: LOWER ABER SALE RD, Cross Street 2: NF 231 Created: 2017-05-22 09:12:00, Updated: 2017-05-22 10:11:00	N/A	2017-05-22 11:02:34 by WHP 2		
45444	High	WHP	1	**WHP Event P2017057012: 10-50F**, **FATAL** CRASH Agency: WHP, City: CHEYENN Street: I 80, Ref Marker: 353.3, Direction: W, Cross Street 1: I 80, Cross Street 2: I 80 Created: 2017-04-21 14:36:00, Updated: 2017-05-22 09:43:00	N/A	2017-05-22 11:02:34 by WHP 2		
45418	High	Plow	1	**I-80 East - Arlington - Recommend speed limits to 65 MPH** Location: 280.36, Direction: EB, Plow Recommended: 65, Current Posted: 75 Reported by plow: H 1265 Operator: [redacted]	N/A	2017-05-01 10:59:13 by [redacted]		
45426	High	Plow	1	**10-50: Crash** **Cheyenne - I-80 West Lower - Westbound at Reference Marker** 354.5 Blockage: Driving Lane Plow license plate: H 1265	N/A	2017-05-01 10:58:40 by [redacted]		

Figure 3-53. TRAC User Interface (Source: WYDOT)

3.1.5.2.1.3 Input Data/Message Flows

Figure 3-54 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.

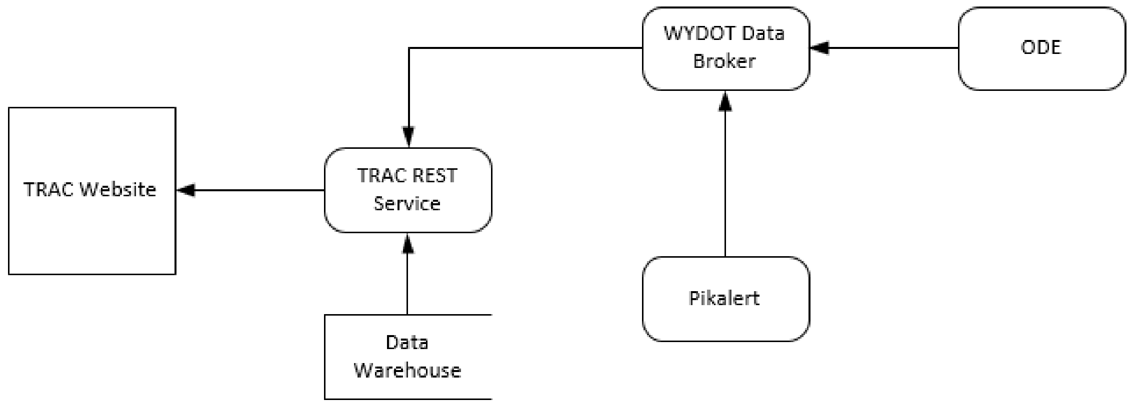


Figure 3-54. TRAC Input Data Flows (Source: WYDOT)

3.1.5.2.1.4 Output Data/Message Flows

Figure 3-55 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.

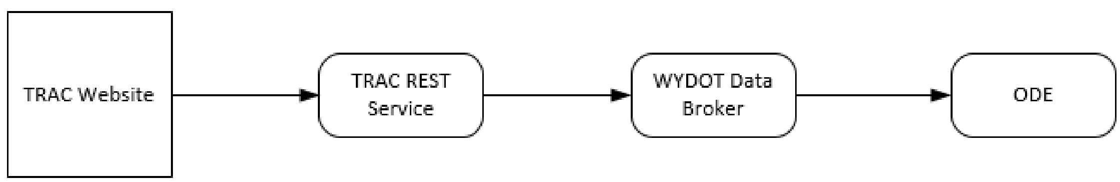


Figure 3-55. TRAC Output flows (Source: WYDOT)

3.1.5.2.2 Developer & version number

The primary developer for the TRAC enhancements will be David Rush

3.1.5.2.3 Application Message and Alerts Descriptions

The sections below describe the Messages and alerts issued by this application with the updated CV interface.

3.1.5.2.3.1 Descriptions and illustrations of messages and alerts issued by application

Table 3-37 describes the messages and alerts issued by CVOP

Table 3-37 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.
Distress Notification	Http Response	This is an Emergency priority message that the TRAC system displays to TMC operators.

Message or Alert	Communication Method	Description
Weather Alert	Http Response	This is a High priority message displayed in the TRAC system originating from the Pikalert system.
VSL Update Notification	Http Response	This is a High priority message displayed in the TRAC system originating from the Pikalert system.
Road Closure Recommendation	Http Response	This is a High priority message displayed in the TRAC system originating from the Pikalert system.

3.1.5.2.3.2 Describe algorithm to determine when messages and alerts are issued

Table 3-38 describes the algorithms used to determine when a message or alert is issued to the TRAC user.

Table 3-38. 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.
Distress Notification	A new Distress Notification message is received from the Data Broker application
Weather Alert	A new Weather Alert is issued by the Pikalert system
VSL Update Notification	A new VSL recommendation is issued from the Pikalert system.
Road Closure Recommendation	A new Road Closure recommendation is issued from the Pikalert system.

3.1.5.2.3.3 Summary tables of criteria for issuing messages and alerts

Table 3-38 summarizes the messages and alerts as well as the criteria used to issue them.

3.1.5.2.4 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.

3.1.5.2.4.1 Schematic of major modules/functions

Figure 3-56 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 3-56. Parking availability (Source: WYDOT)

3.1.5.2.4.2 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.

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

See Figure 3-56 for a process flow between the major modules for the truck parking availability.

3.1.5.2.4.4 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.

3.1.5.2.5 Application Data Tables

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

3.1.5.2.5.1 Input data description tables

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

3.1.5.2.5.2 Output data description tables

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

3.1.5.2.5.3 Data/database storage description diagrams and tables

This application has no proposed changes to the existing database schema

3.1.5.2.6 Application Configuration Data

Table 3-39 shows the new configuration parameters that will be added to the TRAC application.

Table 3-39. TRAC Configuration Parameters

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

3.1.5.2.7 Application User Interface(s)

Figure 3-57 shows the TRAC application interface.

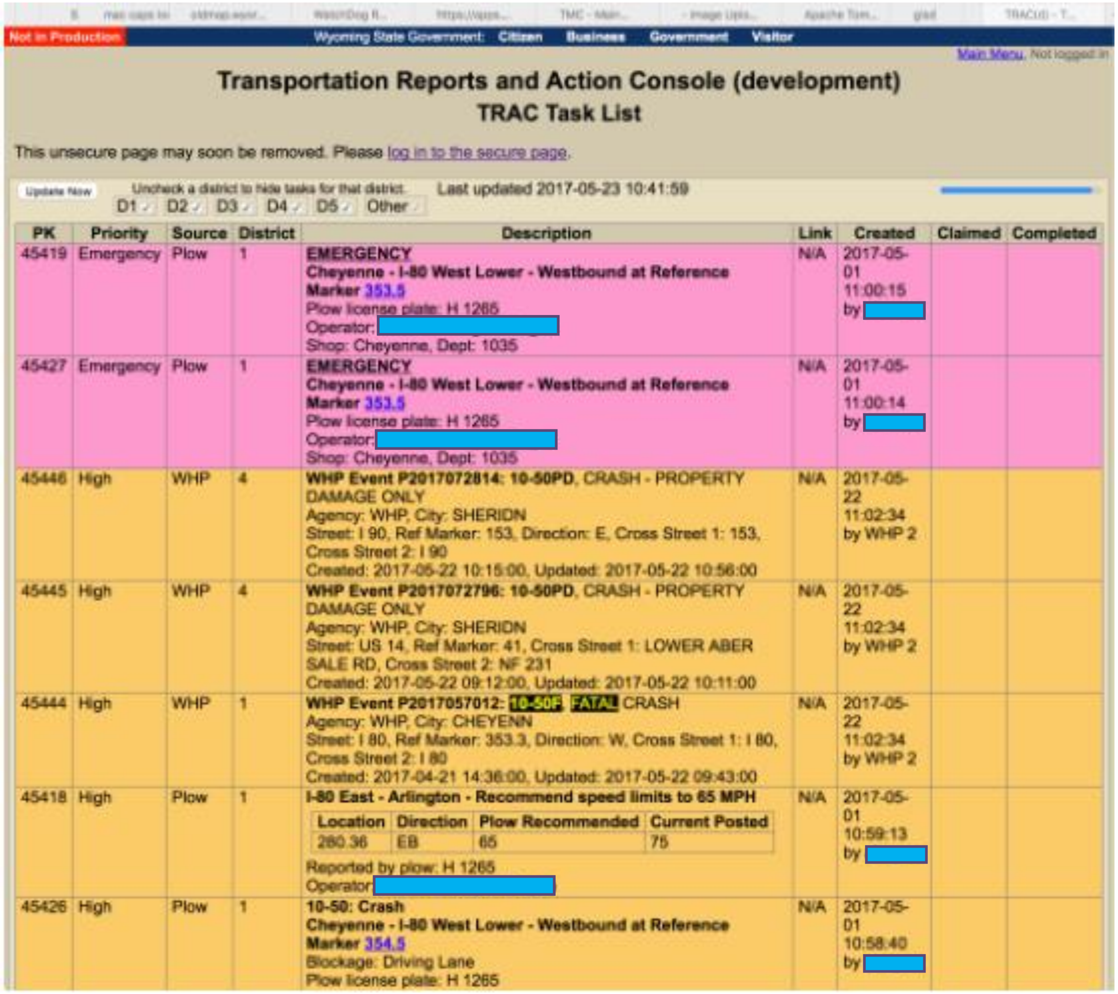


Figure 3-57. TRAC application interface (Source: WYDOT)

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:

- TRAC-REQ-1 TRAC Updates
- TRAC-REQ-1.1 Distress Notification
- TRAC-REQ-1.1.1 Transmission Time
- TRAC-REQ-1.2 Segment Alerts
- TRAC-REQ-1.2.1 Transmission Time
- TRAC-REQ-1.2.2 Segment Alerts-Pikalert

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 TRAC	DB Sends Emergency Notification to TRAC	5.28.1
	DB Sends Road Weather Alert from Pikalert to TRAC	5.28.2

3.1.5.3 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.

3.1.5.3.1 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.

3.1.5.3.1.1 Functions/Services Brief description

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

Pikalert Notifications for VSL Updates: New functionality shall allow the WTI application to notify TMC Operators of suggested updates to VSL zones. Operators

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.

Pikalert Notifications for road conditions: New functionality shall allow TMC operators to view CV related data for road condition information including slick spots and road closure recommendations originating from the Pikalert system.

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 to the WTI application consist of weather related alerts and notifications from the Pikalert application and 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 3-58.

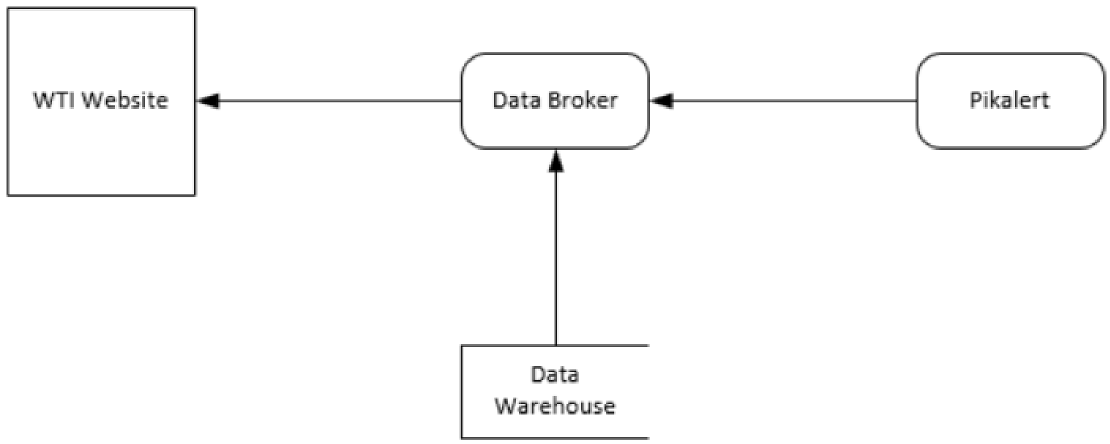


Figure 3-58. Input Data Flows for WTI (Source: WYDOT)

3.1.5.3.1.4 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 3-59 shows the output data/message flow for the WTI application.

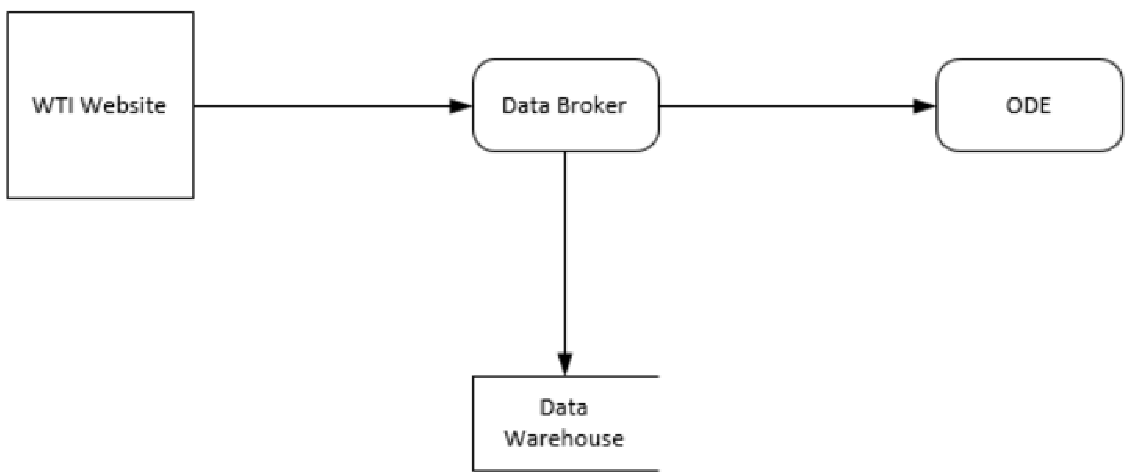


Figure 3-59. WTI Output Data/Message Flows (Source: WYDOT)

3.1.5.3.2 Developer & version number

WYDOT will be responsible for development of this application.

3.1.5.3.3 Application Message and Alerts Descriptions

The following sections describe the messages/alerts specific to the CV integration for the WTI application.

3.1.5.3.3.1 Descriptions and illustrations of messages and alerts issued by application

Table 3-40 describes messages and alerts that may be issued by the WTI application related to the CV project enhancements.

Table 3-40. WTI CV Messages and Alerts

Message or Alert	Communication Method	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

3.1.5.3.3.2 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.

3.1.5.3.3.3 Summary tables of criteria for issuing messages and alerts

Table 3-41 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 3-41. 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

3.1.5.3.4 Application Design Description

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

3.1.5.3.4.1 Schematic of major modules/functions

Figure 3-60 shows the Major Modules/Functions associated the CV integration in the WTI application.

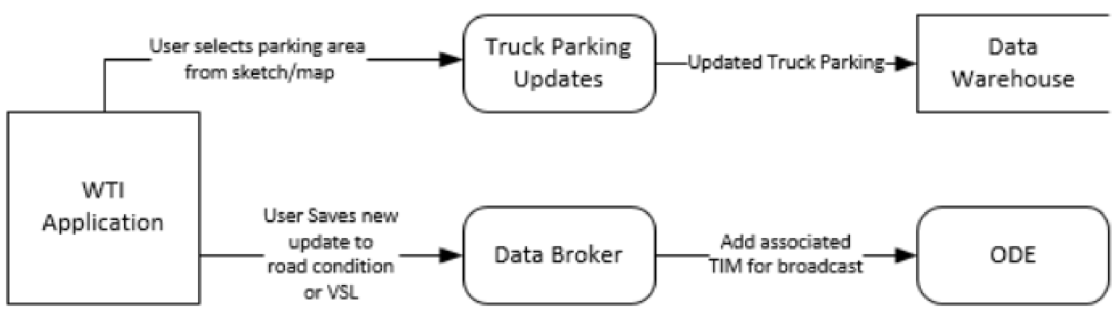


Figure 3-60. WTI Major Modules/Functions (Source: WYDOT)

3.1.5.3.4.2 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.

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

Figure 3-60 shows the process flow/algorithms between the major modules/function for the CV integration in WTI.

3.1.5.3.4.4 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.

3.1.5.3.5 Application Data Tables

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

3.1.5.3.5.1 Input data description tables

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

3.1.5.3.5.2 Output data description tables

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

3.1.5.3.5.3 Data/database storage description diagrams and tables

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

3.1.5.3.6 Application Configuration Data

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

3.1.5.3.7 Application User Interface(s)

Figure 3-61 shows a mockup of the WTI interface for truck parking.

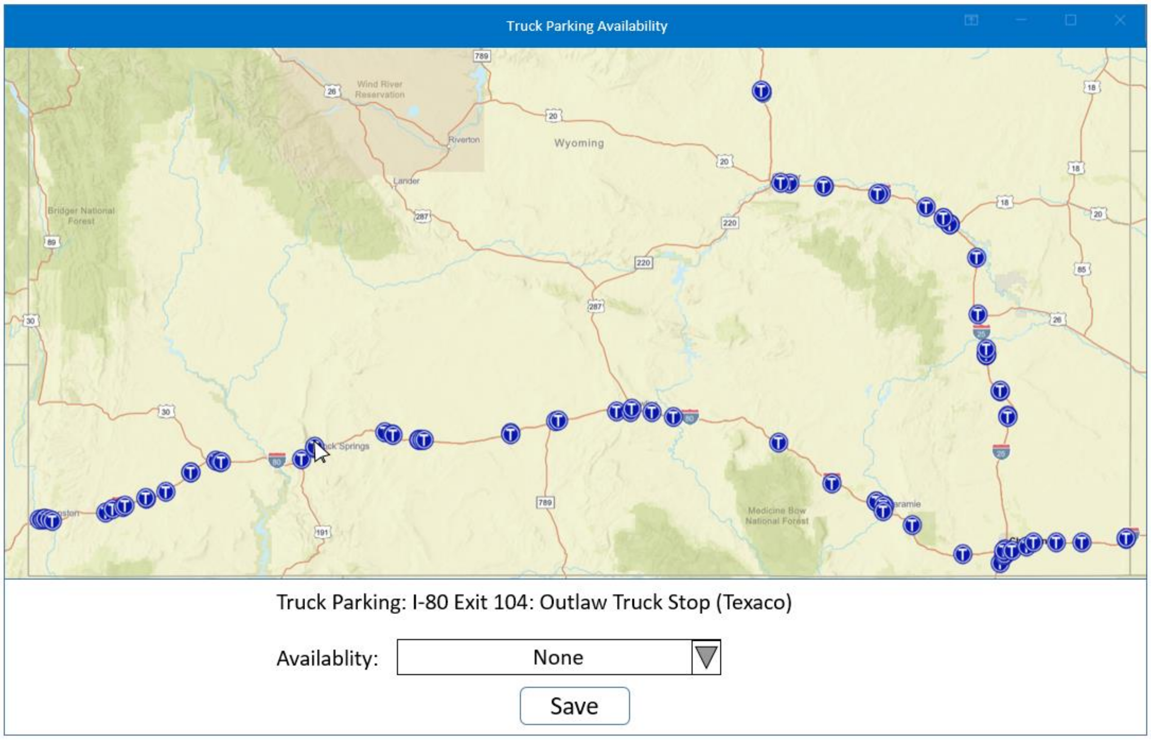


Figure 3-61. WTI Truck Parking window mockup (Source: WYDOT)

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:

- WTI-REQ-1 WTI Inputs
- WTI-REQ-1.1 Current Segment Alerts
- WTI-REQ-1.1.1 Transmission Time
- WTI-REQ-1.2 Forecast Segment Alerts
- WTI-REQ-1.2.1 Forecast Time
- WTI-REQ-1.2.2 Forecast Update
- 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

3.1.5.3.9 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 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

3.1.5.4 WYDOT Construction Administration (CA)

3.1.5.4.1 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.

3.1.5.4.1.1 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.

3.1.5.4.1.2 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

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.

3.1.5.4.1.4 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.

3.1.5.4.2 Developer & version number

WYDOT will be responsible for development of this application.

3.1.5.4.3 Application Message and Alerts Descriptions

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

3.1.5.4.3.1 Descriptions and illustrations of messages and alerts issued by application

Table 3-42 describes the messages and alerts that are issued by the ConAdmin application.

Table 3-42. 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

3.1.5.4.3.2 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.

3.1.5.4.3.3 Summary tables of criteria for issuing messages and alerts

Table 3-43 is a summary table of message and alerts along with the criteria for issuance for the ConAdmin application.

Table 3-43. 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

3.1.5.4.4 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.

3.1.5.4.4.1 Schematic of major modules/functions

Figure 3-62 shows the major functions that will be built in order to integrate the existing ConAdmin application into the new CV environment.

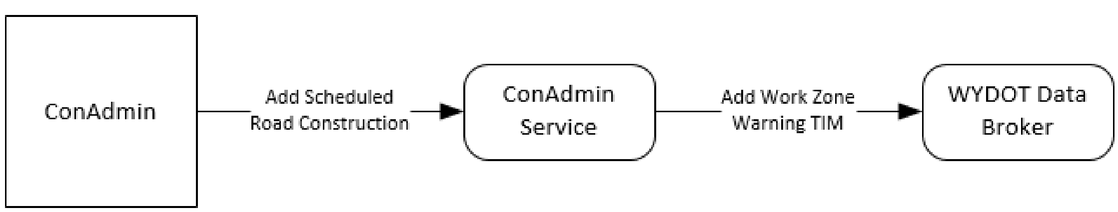


Figure 3-62. Schematic of Major ConAdmin CV Functions (Source: WYDOT)

3.1.5.4.4.2 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.

3.1.5.4.4.3 Diagram of process flow/algorithms between major modules/functions
Figure 3-62 shows the process flow amongst the different modules/functions for the ConAdmin application.

3.1.5.4.4.4 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 in 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.

3.1.5.4.5 Application Data Tables
The following sections describe affected input/output data tables for the ConAdmin application.

3.1.5.4.5.1 Input data description tables
Table 3-44 describes the functional input parameters for the new ConAdmin CV integration.

Table 3-44. 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.

3.1.5.4.5.2 Output data description tables
Table 3-45 shows all of the ConAdmin output parameters for the new CV functions.

Table 3-45. 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.

3.1.5.4.5.3 Data/database storage description diagrams and tables

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

3.1.5.4.6 Application Configuration Data

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

3.1.5.4.7 Application User Interface(s)

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

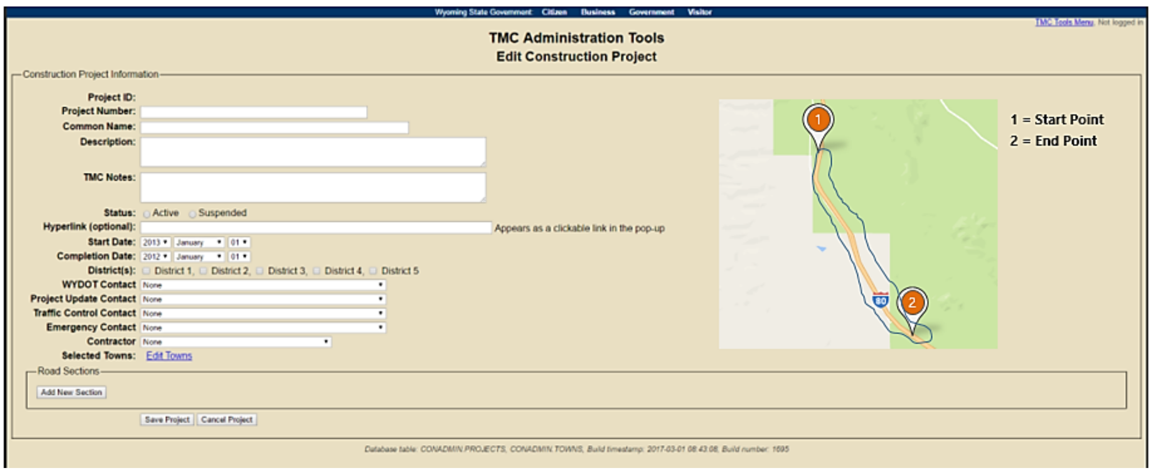


Figure 3-63. Work Zone Area mockup (Source: WYDOT)

3.1.5.4.7.1 Description of Operations/Driver Interface with illustrations

This application contains no driver interface operations.

3.1.5.4.7.2 Description of Maintenance User Interface with illustrations

This application contains no maintenance interface operations.

3.1.5.4.8 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

3.1.5.4.9 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

3.1.5.5 WYOROAD.INFO Website (Extension & Interface)

3.1.5.5.1 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.

3.1.5.5.1.1 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.

3.1.5.5.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

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

3.1.5.5.1.3 Input Data/Message Flows

Figure 3-64 shows the input flows related to updated CV road condition and truck parking information.

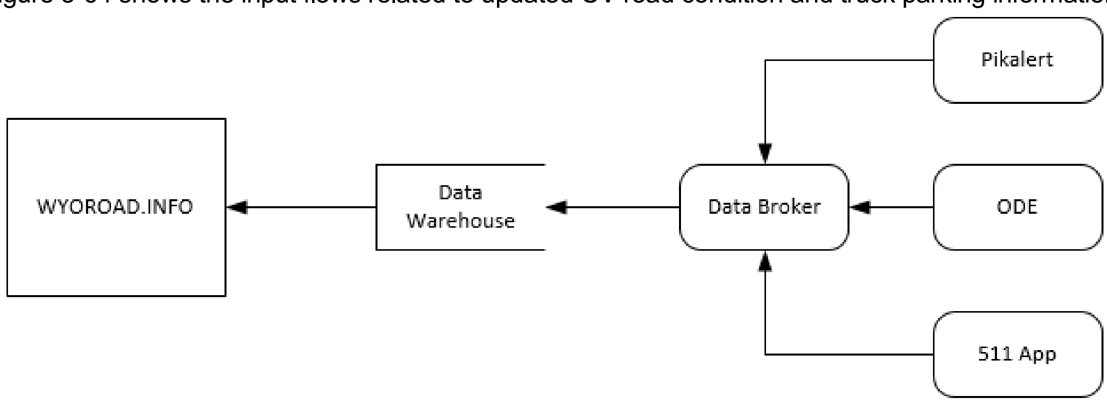


Figure 3-64. WYOROAD.INFO Input flows (Source: WYDOT)

3.1.5.5.1.4 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.

3.1.5.5.2 Developer & version number

This application was developed and is maintained by WYDOT

3.1.5.5.3 Application Message and Alerts Descriptions

No additional messages or alerts will be developed for this application related to the CV project.

3.1.5.5.3.1 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.

3.1.5.5.3.2 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.

3.1.5.5.3.3 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.

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

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

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

3.1.5.5.4.3 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.

3.1.5.5.4.4 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.

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

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

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

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

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

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

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

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

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

3.1.5.6 OBU/RSU Management Application

The following sections describe the design for the OBU/RSU management website.

3.1.5.6.1 Function of the Application
This application will allow CV developers (WYDOT developers and contractors in charge of testing the system) to test and manage applications for vehicle on board unit and roadside unit. It will be also allowing CV developers to query current equipment inventory and add new equipment for connected vehicle inventory management. Additionally, this application will allow CV developers to track, monitor, and perform updates (applications, firmware, and operating systems) for OBU and RSU software. For OBU's it will be a pull based system as we will not have direct access to OBU's.

3.1.5.6.1.1 Functions/Services Brief description
This website will perform the following functions:

- **Manage CV Equipment -** The website will allow users to add/edit/delete equipment inventory.
- **Monitor CV Equipment –** The website will have the ability to view the current state of all RSUs on a map along with a color-coded indication of current availability.
- **Test CV Equipment –** The website will also allow users to test the RSUs and OBUs by allowing a series of Python testing scripts to be run on an RSU or OBU and results of the test returned to the user.
- **Track CV Equipment –** The website will allow users to view locations for all RSU's and locations for OBUs that are within range of an RSU.
- **Update CV Equipment –** The website will allow users to push out updates to the RSU/OBU firmware.

3.1.5.6.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway
Figure 3-65 shows a simple illustration of OBU communications to pull firmware updates along the roadway from RSUs.

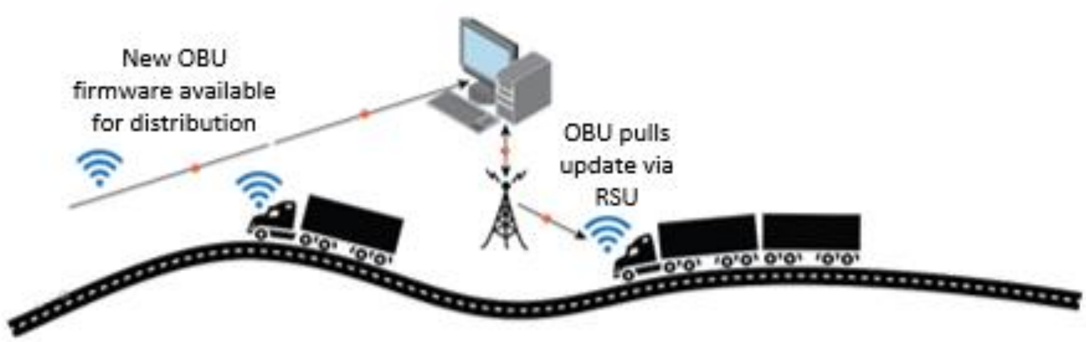


Figure 3-65. OBU Over the Air Updates (Source: WYDOT)

3.1.5.6.1.3 Input Data/Message Flows
Input flows for the OBU/RSU management website will include input sources from the Service Monitor Device Management REST service. All input flows for the Service Monitor Device Management REST

service can be seen in section 3.1.4.5. Essentially, the primary input flows will be from the ODE and the RSUs for managing, monitoring, testing, and updating CV equipment. Additionally, an input flow will be from an Auth0 authentication service that shall be used to authenticate users. Please note that the Over the Air updates for OBUs are a proprietary solution from Lear.

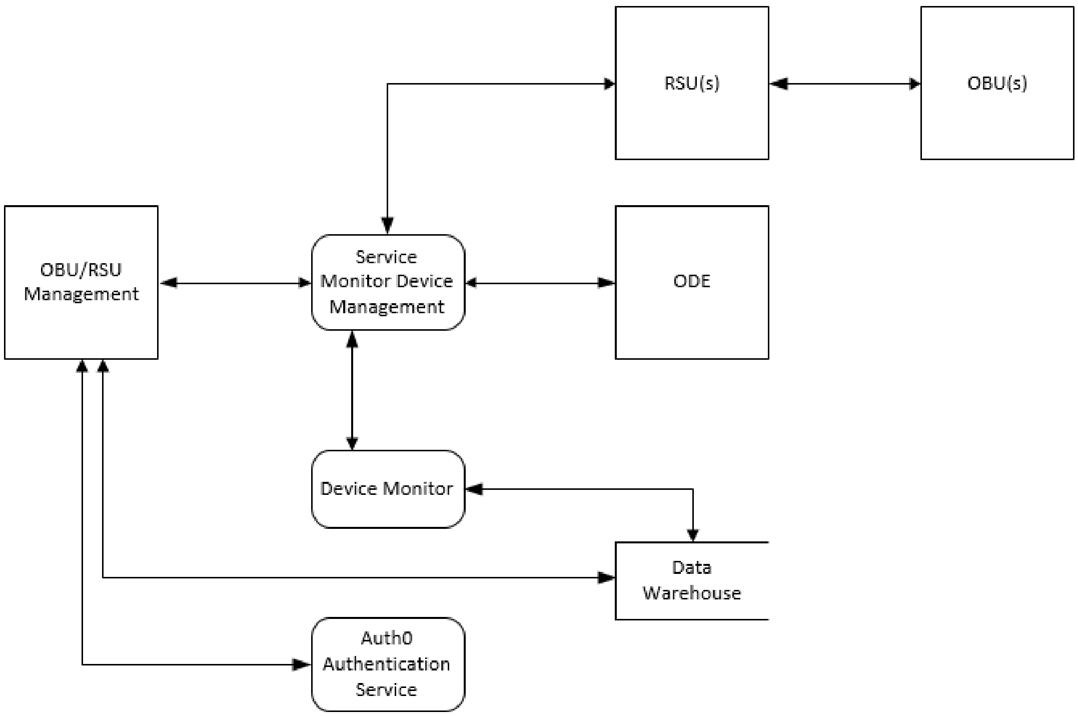


Figure 3-66. OBU/RSU Management flows (Source: WYDOT)

3.1.5.6.1.4 Output Data/Message Flows

The primary output data flows for the OBU/RSU management website consist of updates to RSU/OBU inventory data and firmware updates. Additional output data flows consist of user authentication data and pings to the ODE to determine uptime/current performance status. Figure 3-66 shows the output flows for the OBU/RSU management application.

3.1.5.6.2 Developer & version number

This application will be developed by the Trihydro development team. WYDOT is working with the other pilot sites I order to determine if a collaborative, open source solution to this application is possible.

3.1.5.6.3 Application Message and Alerts Descriptions

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

3.1.5.6.3.1 Descriptions and illustrations of messages and alerts issued by application

Table 3-46 shows all messages and alerts that may be issued by the OBU/RSU management application.

Table 3-46. Messages and Alerts issued by the OBU/RSU Management application

Message or Alert	Communication Method	Description
RecordNotFoundException	Http Response	• Status Code: 404 • Error: “Unable to find RSU/OBU”
ServiceAccessException	Http Response	• Status Code: 424 • Error: “Failed accessing Auth0 user data endpoint”
AuthorizationException	Http Response	• Status Code 403 • Authorization failure
Required Data Field Validation	Web page highlight	• JavaScript Validation • Database constraint
Field Type Validation	Web page highlight	• JavaScript Validation • Database Constraint
User Registration Validation	Web Page Redirect	• Auth0 validation exception

3.1.5.6.3.2 Describe algorithm to determine when messages and alerts are issued

RecordNotFoundException

The Service Monitor Device Management (SMDM) REST Service acts as the backend of the OBU/RSU management website. The SMDM provides basic validation checks when updating or deleting any resource data. If a resource record is to be updated or deleted, and the specified record does not exist then then a RecordNotFoundException is generated. This error is communicated to the user with a specific error status and error text in the http response header returned from the offending request.

ServiceAccessException

The OBU/RSU Management website shall communicate with the Auth0 user authentication service. If there is any communication failure with the Auth0 service, or the data returned from user authentication service is not what was expected, a ServiceAccessException 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.

AuthorizationException

The SMDM REST web application 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.

Required Data Field Validation

The front-end of the OBU/RSU website includes logic to validate the user input data. Certain data elements are required when adding new equipment into the OBU/RSU Manager. When the user submits data for new equipment, validation logic confirms all required data elements have been input. If any required fields are missing then the submission is rejected and the missing data fields are highlighted on the submission form.

Field Type Validation

The web front-end of the OBU/RSU management website includes logic to validate the user input data. Certain data elements are limited to specific types, for example, latitude and longitude must be numeric decimal values. If an invalid value is entered into a limited type field then a pop-up warning is generated for the user and the invalid value is not accepted as input.

User Registration Validation

The user authentication portion of the OBU/RSU management website includes logic to validate a user during the user registration and login process. Each user's login is based on their email address. An administrator user for the OBU/RSU management website creates a new user entry that includes the user's email address. Upon creation of a new user, a time sensitive invitation is emailed to the new user. If the new user attempts to register after the invitation period expires, or the user entry has been removed (by an OBU/RSU management website administrator), then the new user is not allowed to register and a login failure page is displayed to the user instead. If an existing user's account is removed by the OBU/RSU management website admin, then upon attempted login, a login failure is displayed to the user.

ODE Inaccessible

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

OBU Update Error

A request is sent to update an OBU. A python script is run as a background process to update the OBU 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. Over the air updates for OBUs will be handled by the RSU.

RSU Update Error

A request is sent to update an RSU. The SMDM service updates 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.

3.1.5.6.3.3 Summary tables of criteria for issuing messages and alerts

Table 3-47 shows the criteria used for issuing messages and alerts to the user.

Table 3-47. Summary criteria for OBU/RSU website messages/alerts

Message or Alert	Issue Criteria
RecordNotFoundException	• During an update or delete of an inventory record, no record matching the specified id is found
ServiceAccessException	• Communication failure when calling an Auth0 service • Parse failure of the expected data returned from an Auth0 service call
AuthorizationException	• Invalid or missing id token in an http request
Required Data Field Validation	• Required field on web page form has no data
Field Type Validation	• Non-numeric data entered into a numeric field on a web page form
User Registration Validation	• User invitation is invoked beyond the valid invitation period • A user that has been removed or blocked attempts to login
ODE Inaccessible	• A request to the ODE timed out

OBU Update Error	• A request to update an OBU returned an error from the SMDM • A request to send over the air updates to OBUs returned an error from the SMDM
RSU Update Error	• A request to update an RSU returned an error from the SMDM

3.1.5.6.4 Application Design Description

The following sections describe the over design of the OBU/RSU management website.

3.1.5.6.4.1 Schematic of major modules/functions

The OBU/RSU management website shall be built using Angular 2 JavaScript framework which follows the Model View Control (MVC) design pattern. Figure 3-67 shows the different views/modules that shall be built for the OBU/RSU management website.

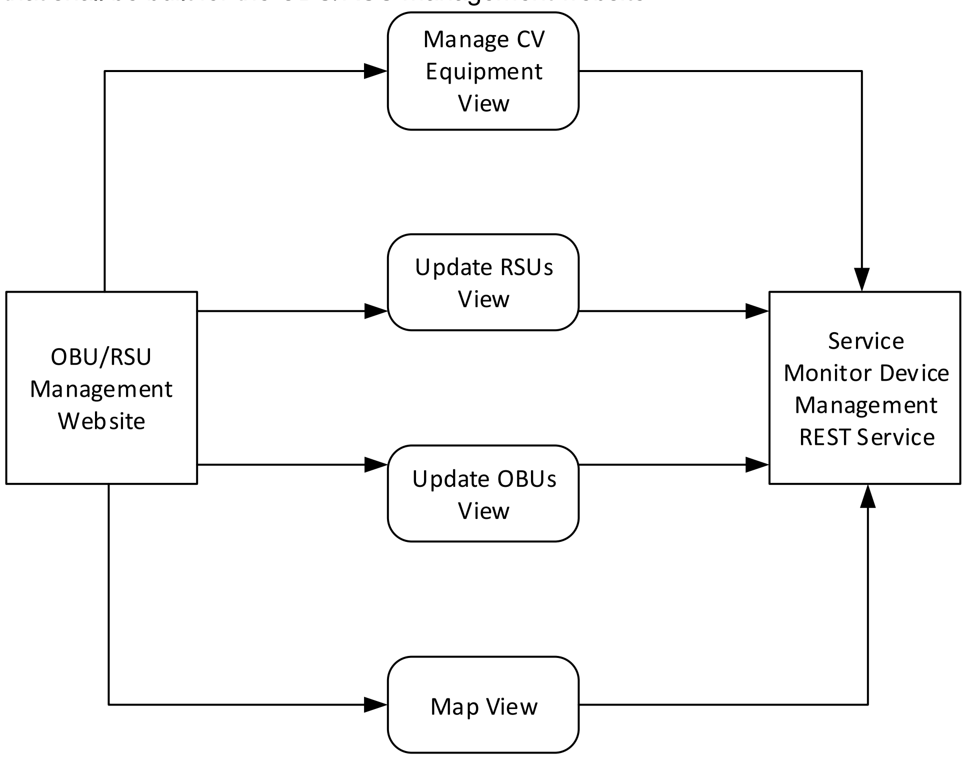


Figure 3-67. OBU/RSU Major Views. (Source: WYDOT)

Figure 3-68 shows the major modules for the RSU/OBU application. The major modules consist of the website itself and a device monitoring service that is used to periodically (at a configurable timeframe) check the status of the RSUs and ODE within the CV environment.

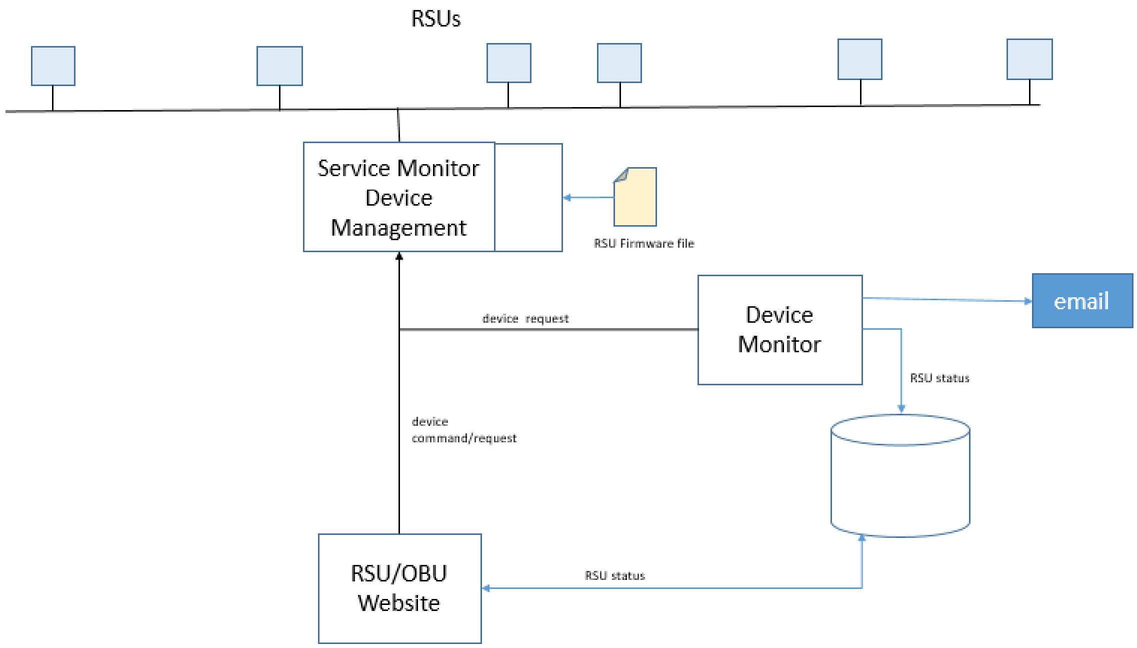


Figure 3-68. RSU/OBU Major Modules.

3.1.5.6.4.2 Description of modules/functions

The following views/modules will be built within the OBU/RSU management website. All users that have access to the OBU/RSU Management website will be able to have all of the functionality listed below.

Manage CV Equipment View

This view shall allow users to add/edit/delete all RSUs and OBUs inventory within WYDOT. The SMDM service shall contain all of the functions necessary to manage the CV inventory. This view will require an authenticated user to access.

Update RSUs View

This view will allow users to view the current version of all firmware for RSUs on the WYDOT network. The view will also allow users to update all of the RSUs or just a select few RSUs to a different version of the firmware. Additionally, this view will allow users to upload new versions of firmware for RSUs. This view will call the SMDM REST service in order to perform the firmware updates. This view will require an authenticated user to access.

Update OBUs View

This view will allow users to update an OBU that is currently on the WYDOT network (hardwired for testing purposes). The view shall also allow users to push out new over the air updates for OBUs to RSUs. Please note that WYDOT is still awaiting details from Lear on how the over the air updates will be performed. This view will require an authenticated user to access.

Map View

This view will allow user to view all RSUs on a map along with aggregated OBU data (number of OBU passes, average speed, other stats yet to be determined) for communications along the I80 corridor.

Device Monitor
This service/module is responsible to monitoring the status of RSUs and OBUs via the Service Monitor Device Management (SMDM) REST service. The module will periodically call the SMDM service to retrieve the current status for all RSUs as well as the ODE. Results of the calls will be recorded in the WYDOT Situation Data Exchange. Additionally, this service is responsible for notifications that will be sent out if any part of the CV system is found to be down or unresponsive. Notifications sent by this service include the following:

- Email notifications for an RSU(s) unresponsive or misbehaving
- Email notifications for the ODE unresponsive or misbehaving
- Email notifications for SDX unresponsive or misbehaving
- Text notification for RSU(s) unresponsive or misbehaving
- Text notification for the ODE unresponsive or misbehaving
- Text notification for SDX unresponsive or misbehaving

3.1.5.6.4.3 Diagram of process flow/algorithms between major modules/functions
Figure 3-69 shows the process flows between major modules/functions within the OBU/RSU management website. By design the views within the OBU/RSU management website are encapsulated so that there is no cross communication amongst the views. The business logic for the OBU/RSU management website is all performed within the SMDM REST service. The website acts as a viewing portal for the data/functions provided by the SMDM service.

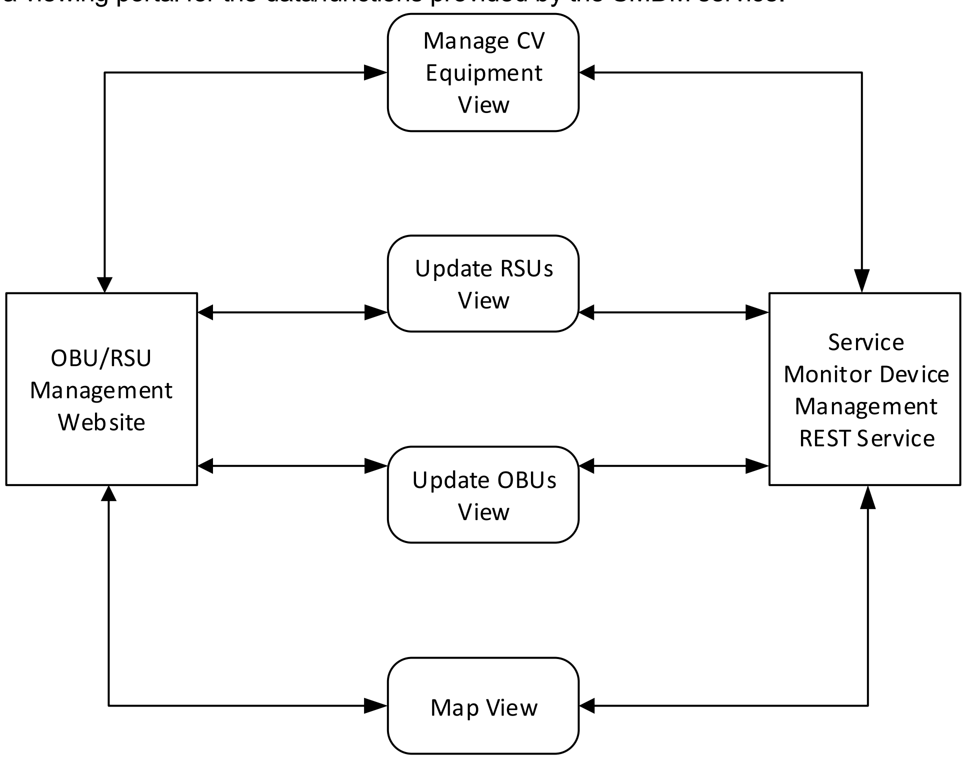


Figure 3-69. Process Flow between OBU/RSU website Modules/Functions (Source: WYDOT)

Figure 3-70 shows the monitoring module process flows for monitoring all of the RSUs within the Wyoming CV System.

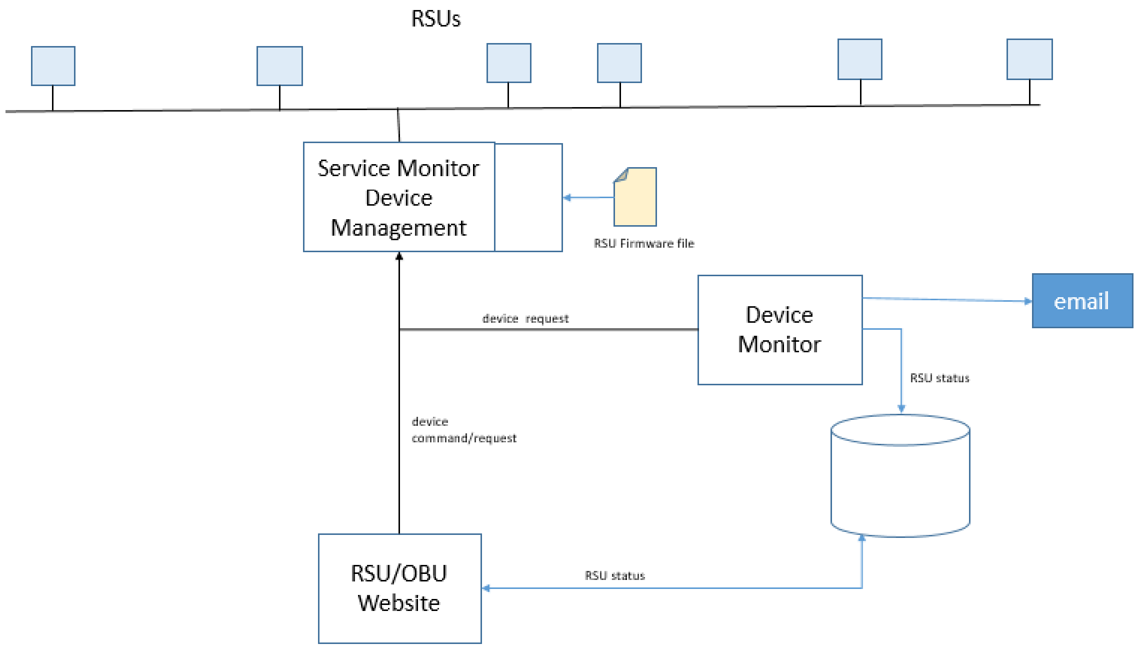


Figure 3-70. Process Flow for Monitoring Modules. (Source: WYDOT)

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

Equipment View

The Equipment view shall query RSU and OBU equipment from the SMDM REST service. The SMDM REST service performs the add/update/delete operations for all requests coming from the Equipment View of the OBU/RSU management website. All calls for equipment management require a valid authenticated user.

Update RSUs View

The Update RSUs view shall query RSUs status from the SMDM REST service. The SMDM REST service performs the update firmware/view current state operations for all requests coming from the Update RSUs View of the OBU/RSU management website. All calls to the Update RSUs View require a valid authenticated user.

Update RSUs View

The Update RSUs view shall query RSUs status from the SMDM REST service. The SMDM REST service performs the update firmware/view current state operations for all requests coming from the Update RSUs View of the OBU/RSU management website. All calls to the Update RSUs View require a valid authenticated user.

Map View

GIS dashboard(s) (on web and mobile interfaces) show a map overlaid with RSU locations and per-device properties such as on-line status, number of unique vehicles passing in some interval and approximate traffic speeds for example. The SMDM REST service would provide all of the data on the RSUs/OBUs. The Map shall be created using ArcGIS maps from ESRI.

Device Monitor
This service/module periodically calls the Service Monitor Device Management (SMDM) REST service to retrieve the current status for all RSUs as well as the ODE. Results of the calls will be recorded in the WYDOT Situation Data Exchange. If any of the CV components are found to be unresponsive or misbehaving the Device monitor will be responsible for sending email or text notifications out to a configurable list of recipients. All sent alerts are dispersed as soon as an issue is found and at least one notification recipient has been setup in the configuration file. All monitoring data shall also be stored within the Oracle CV database. Data stored shall include the type of monitoring done, the equipment monitored, the time of the monitor, the result of the monitoring (success/failure), and the email contents (including recipient/content) for any related notifications sent out.

3.1.5.6.5 Application Data Tables

The following sections describe the data input and output for the OBU/RSU Management website.

3.1.5.6.5.1 Input data description tables

The following tables describe the different input data tables that the OBU/RSU website will interact with. Please note that the SMDM REST service will be the conduit for the storage and retrieval of all data from the database.

Table 3-48. User Authentication Data Table

Data Name	Type	Description
Username	String	A unique valid email for each user.
Password	String	A password string.
Two Factor Id	String	A generated id value, typically a numeric string.

Table 3-49. Equipment Inventory Data Table

Data Name	Type	Units	Description
description	String		Text describing the equipment
assetId	String		Id from the asset tag of the equipment
equipmentTypeId	Integer		Id referencing the type of equipment
serialNumber	String		Serial number of the equipment.
modelNumber	String		Model number identifier for the equipment.
wan	String		Wide Area Network id for the equipment.
latitude	Float	Decimal deg.	Latitude for equipment installed at a location or null for mobile equipment
longitude	Float	Decimal deg.	Longitude for equipment installed at a location or null for mobile equipment
elevation	Float	Feet	Elevation above sea-level for equipment installed at a location or null for mobile equipment
height	Float	Feet	Height above roadway for equipment installed at a location or null for mobile equipment
dateInstalled	Date		Date equipment was installed at a location or in vehicle or null for equipment not yet installed. Format YYYY-MM-DD example 2017-02-08
firmwareVersion	String		The currently installed firmware version.

notes	String		Text field for any user specified information about the equipment.

3.1.5.6.5.2 Output data description tables

Table 3-50 shows the output data description tables for the OBU/RSU website.

Table 3-50. OBU/RSU website Output Data Tables

Data Name	Type	Description
Access Token	String	A unique time constrained token provided to the user client software after a successful login by a user. The access token is subsequently added to every request made to the SMDM REST service by that user client. No request is authorized unless it includes a valid access token.

Table 3-51. CV Component Operating Status Data Table

Data Name	Type	Units	Description
StatusId	Integer		Unique identifier
assetId	String		Id from the asset tag of the equipment (for RSUs)
equipmentTypeId	Integer		Id referencing the type of equipment
StatusDate	DateTime		DateTime of the status entry
ObservedStatusId	Integer		Id referencing the current observed status of the CV equipment (ex. OK, unpingable, slow, etc)

3.1.5.6.5.3 Data/database storage description diagrams and tables

Figure 3-71 shows the ERD for the OBU/RSU management website. Please note that this is the ERD for the database that the SMDM REST service interacts with.

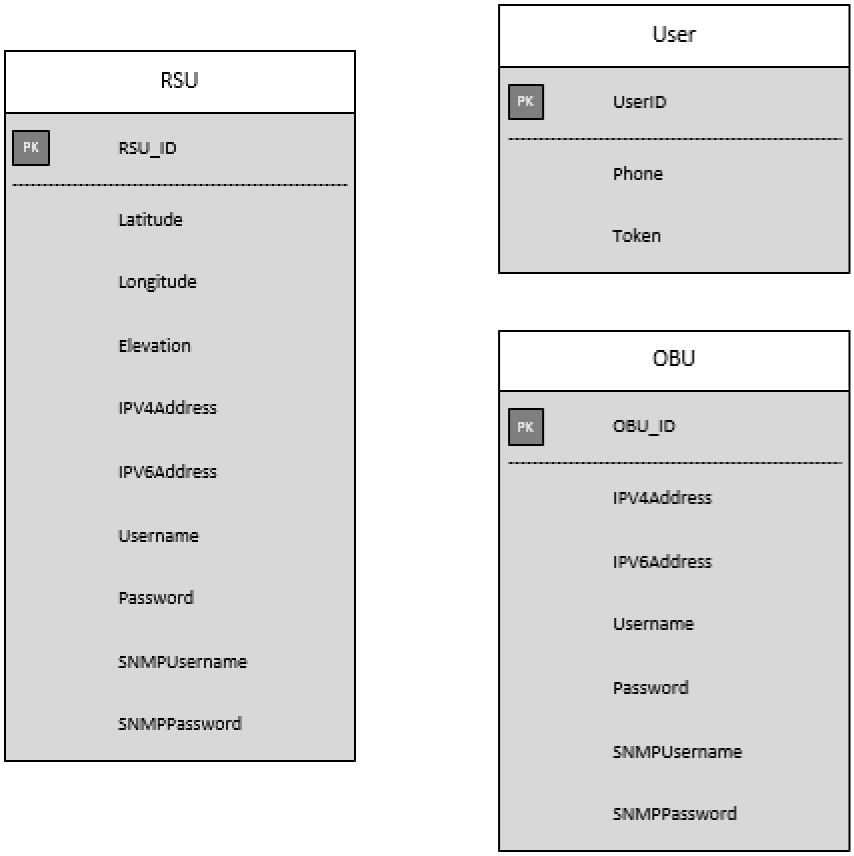


Figure 3-71. OBU/RSU management ERD (Source: WYDOT)

3.1.5.6.6 Application Configuration Data

Table 3-52 shows the configuration parameters available for the OBU/RSU management website.

Table 3-52. OBU/RSU Configuration Data

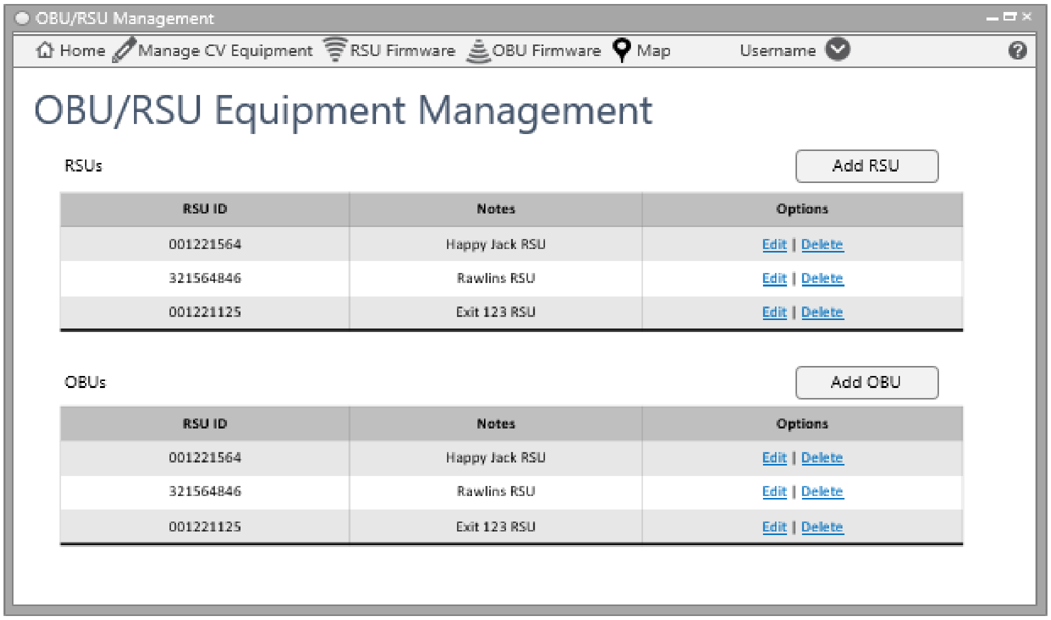
Property	Default Value	Description
auth0.apiClientId	<client id>	Id for client configured on Auth0 to handle the admin service calls for the Resource Manager application.
auth0.apiClientSecret	<client secret>	Secret generated by Auth0 associated with the client to handle admin service calls for the Resource Manager application.
auth0.domain	cvrm-its-dot.auth0.com	Domain to use to reference the account set up on Auth0 for Resource Manager user authentication.
auth0.issuer	https://cvrm-its-dot.auth0.com	Base URL for connection to the Auth0 authentication service.

auth0.clientId	<client id>	Id for client configured on Auth0 to handle the user service calls for the Resource Manager application.
auth0.clientSecret	<client secret>	Secret generated by Auth0 associated with the client to handle user service calls for the Resource Manager application.
auth0.securedRoute	NOT_USED	Turns off the secured route option for Auth0 endpoint security.
auth0.base64EncodedSecret	false	Determines if the secret is base64encoded.
auth0.authorityStrategy	ROLES	Indicates that users include ROLES that define the access authority for each user.
auth0.defaultAuth0ApiSecurityEnabled	false	Turns off Auth0 authentication
auth0.signingAlgorithm	HS256	Algorithm used to sign the user id token. Options: HS256, RS256
DeviceMonitorPeriodicity	5	Frequency (in minutes) to check the status of all CV devices
RSUDownNotificationList	<WYDOT support email>	Email address(s) for WYDOT IT support services
ODEDownNotificationList	<WYDOT support email>	Email address(s) for WYDOT IT support services
RSUDownTextList	<WYDOT support phone>	Phone number and carrier list for WYDOT IT support services
ODEDownTextList	<WYDOT support phone>	Phone number and carrier list for WYDOT IT support services

3.1.5.6.7 Application User Interface(s)

The following figures are mockups for the OBU/RSU Management website. Please note that these images are just Mockups and may not represent the final look and feel of the application or all of the functionality described for this application.

Figure 3-72 shows a potential mockup for the RSU/OBU inventory management page.



RSU ID	Notes	Options
001221564	Happy Jack RSU	Edit | Delete
321564846	Rawlins RSU	Edit | Delete
001221125	Exit 123 RSU	Edit | Delete

RSU ID	Notes	Options
001221564	Happy Jack RSU	Edit | Delete
321564846	Rawlins RSU	Edit | Delete
001221125	Exit 123 RSU	Edit | Delete

Figure 3-72. OBU/RSU Inventory Management Mockup (Source: WYDOT)

Figure 3-73 shows a mockup of the map view for the OBU/RSU management application.

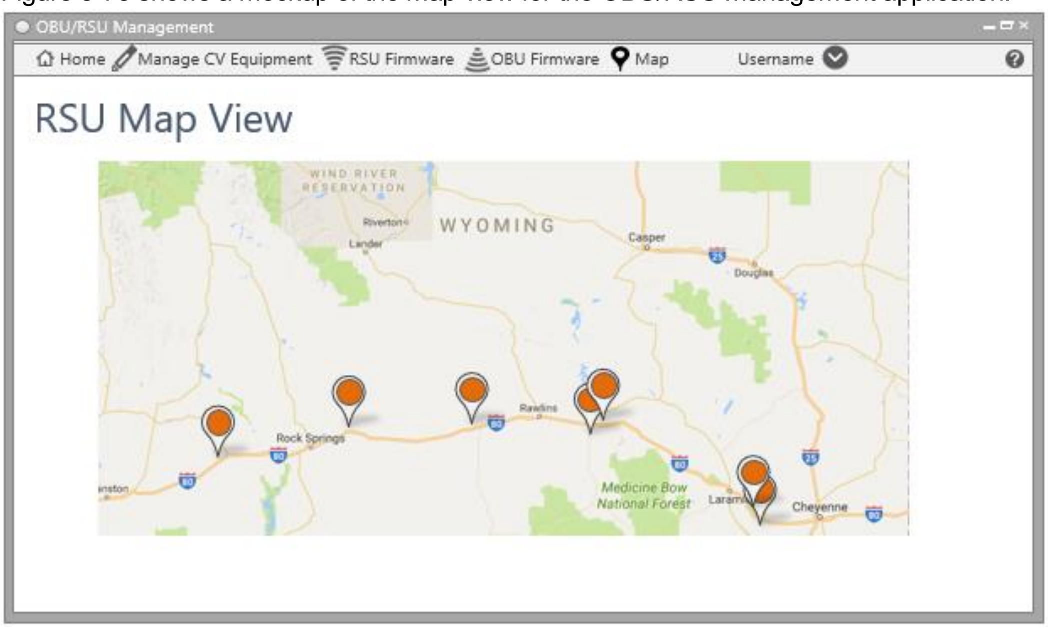


Figure 3-73. OBU/RSU Map View (Source: WYDOT)

3.1.5.6.7.1 Description of Operations/Driver Interface with illustrations

This application contains no driver interface operations.

3.1.5.6.7.2 Description of Maintenance User Interface with illustrations

This application contains no maintenance interface operations.

3.1.5.6.8 Requirements Traceability

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

- WCVS-REQ-7 External Brokerage with WYDOT Interfaces
- WCVS-REQ-7.2 Distribute to WYDOT External Interfaces
- 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

3.1.5.6.9 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.
ODE <-> OBU	ODE Updates OBU Firmware OTA	5.16.2

3.1.5.7 Resource Manager Application

3.1.5.7.1 Function of the Application

This application will manage the training, vehicle, and driver information for all participants of the connected vehicle program, keeping all private and confidential information secure. The system will allow new participants to be added and participants to be removed from the system. All information for this application shall be kept private and confidential.

Please note that the website was initially named Participant Tracker in previous documents it has been renamed to Connected Vehicle Resource Manager (CVRM) as there were concerns that the Participant Tracker name may give the wrong idea to potential participants of what the website is used for.

3.1.5.7.1.1 Functions/Services Brief description

Functions/Services provided by the Resource Manager application include providing a secure and central storage for all participant information including associated vehicles, equipment, and training. All participant information is stored within an encrypted Oracle database. REST services using the Spring framework shall be developed to allow for the website to securely retrieve and update participant information.

3.1.5.7.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

This application is not directly involved in any vehicle/infrastructure communications on the highway and is meant strictly for support purposes of management and tracking of the WYDOT CV pilot.

3.1.5.7.1.3 Input Data/Message Flows

There are two input data flows for the Resource Manager, authentication data and resource data. The user provides authentication data during login to confirm the identity of the user. The user adds resource data as they input details on specific resources they want the Resource Manager to track.

Authentication data for the Resource Manager has two primary elements, user data and second factor authentication data. User data consists of the user's login name and password. The second factor authentication is a time sensitive code generated for the user during login. Authentication shall be provided by Auth0 authentication and is considered an off the shelf solution for authentication.

Resource data consists of the specific data elements for the primary resources being managed. Each primary resource type has a defined set of data elements that can be input for that resource. For equipment, the important features are what type of equipment it is, along with installation information, where it was installed and when it was installed. Equipment can also be broken down into a set of components that make up each installed unit. Data for vehicles includes identifying information such as make and model as well as the specific DOT vehicle class. Any equipment installed in a vehicle as part of the CV program is also part of the input vehicle data. Participant data includes identity information for participants such as their name, email and organization they are associated with. As part of the CV project participants complete specific training; each participant's training history is part of the participant data. All CV participants are drivers for the vehicles that are part of the project, so the set of vehicles a given participant may drive are included as part of the participant data.

Figure 3-74 shows the data flows for the entire Resource Manager website.

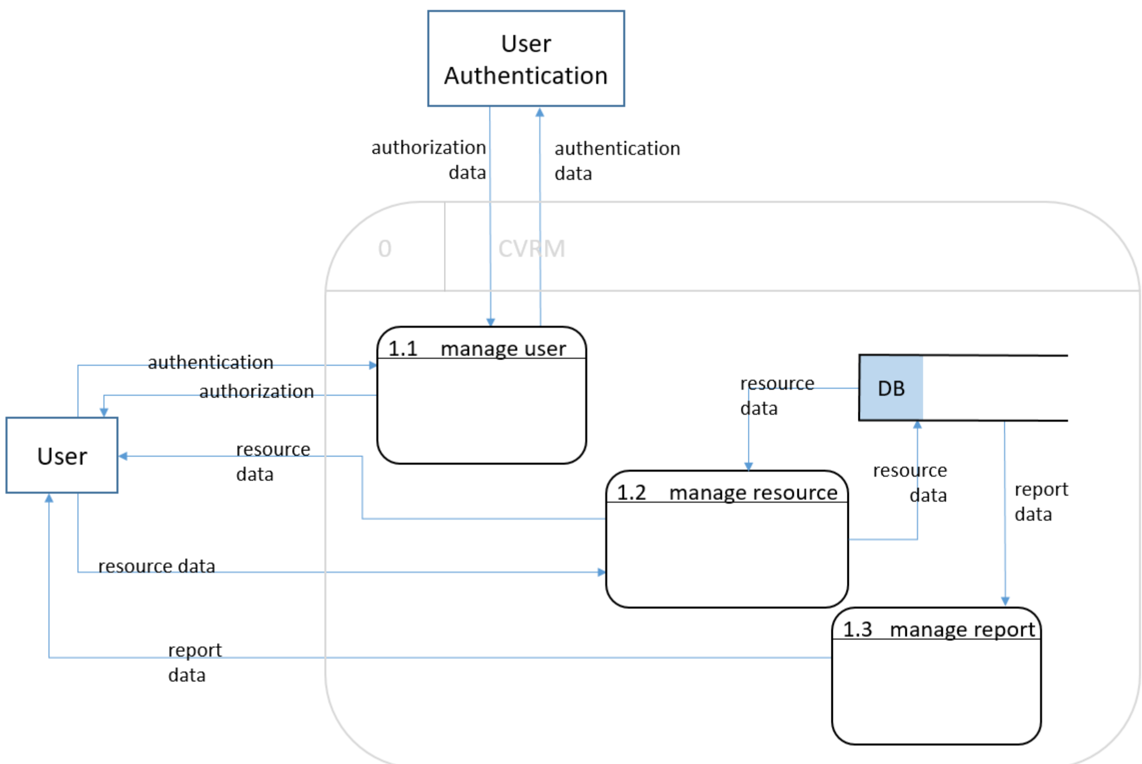


Figure 3-74. Data flow of the Resource Manager website. (Source: WYDOT)

3.1.5.7.1.4 Output Data/Message Flows

There are three output data flows for the Resource Manager website, authorization data, resource data, and report data. The user receives authorization data as part of the login process. Based on user requests, data on the various resources tracked by the Resource Manager website is output. Data for predefined reports are output based on a user's request.

Authorization data is output to the user as a result of the login process. The authorization data is an encoded token string that verifies the user's identity and access permissions. This token is required to validate each request by the user. The authorization token is time sensitive and expires after a defined validity period.

Resource data consist of specific data elements for the resources being managed. Each primary resource type has a defined set of data elements that can be output for that resource. Depending on the user's access permission (described in Table 3-53), some resource data may be redacted. For example, a user having read only access cannot see identifying information on participants (i.e. first name, last name, email).

Table 3-53. List of user roles and permissions

Role	Permissions
Super User	• Access to all data, only used by developers
Administrator	• View basic participant data (PII is redacted) • Add/Edit/Delete Vehicles • Add/Edit/Delete Components • Add/Edit/Delete Equipment • Add/Edit/Delete Training modules • Run Reports
Participant Trainer	• Add/Edit/Delete Participants • Add/Edit Delete Training modules • Associate Participants to Training (record training performed) • Associate Participants to Vehicles • View Vehicle/Component/Equipment information • Run Reports
Vehicle Manager	• Add/Edit/Delete vehicles • Associate Equipment/Components to vehicles • Run Reports
Read only	• View equipment • View components • View Vehicle/Participants (PII redacted) • Run Reports

Important data elements for equipment are what type of equipment it is, along with installation information, where it was installed and when it was installed. Equipment can also be broken down into a set of components that make up each installed unit. Data for vehicles includes identifying information such as make and model as well as the specific DOT vehicle class. Any equipment installed in a vehicle as part of the CV program is also part of the output vehicle data. Participant data includes contact information for participants such as their name, email and organization they are associated with. As part of the CV project participants complete specific training; each participant's training history is part of the participant data. All CV participants are drivers for the vehicles that are part of the project, so the set of vehicles a given participant may drive are included as part of the participant data.

Report data are generated from the resource data entered into the Resource Manager. Each set of report data is a response to a predefined report query and summarizes data for specific resources. For example, the percent of equipment installed report data provide a count of each equipment of a specific type that are installed vs the total count of that equipment type.

3.1.5.7.2 Developer & version number

Developers for this application include Rick Smith and Kim Perry for Trihydro. Shane Zumpf with Trihydro is the technical lead for the application design and development.

Current Version: 1.0

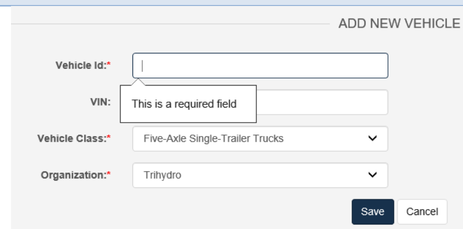
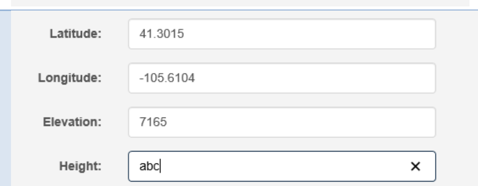
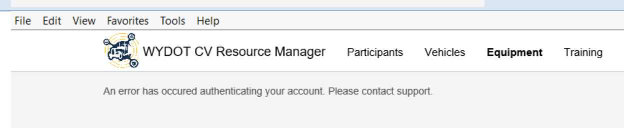
3.1.5.7.3 Application Message and Alerts Descriptions

The following sections describe the application messages and alerts this application may generate. Please note that this application is a website meant to track participant information so has no direct contact with any participant while traveling on the road.

3.1.5.7.3.1 Descriptions and illustrations of messages and alerts issued by application

Table 3-54 describes all messages and alerts that may be issued by the Resource Manager application.

Table 3-54. Descriptions of messages and alerts issued by Resource Manager.

Message or Alert	Communication Method	Description
RecordNotFoundException	Http Response	• Status Code: 404 • Error: “Unable to find equipment using reference equipment_id=5”
ServiceAccessException	Http Response	• Status Code: 424 • Error: “Failed accessing Auth0 user data endpoint”
AuthorizationException	Http Response	• Status Code 403 • Authorization failure
Required Data Field Validation	Web page highlight	
Field Type Validation	Web page highlight	
User Registration Validation	Web Page Redirect	

3.1.5.7.3.2 Describe algorithm to determine when messages and alerts are issued

RecordNotFoundException
The REST web application portion of the Resource Manager provides basic validation checks when updating or deleting any resource data. If a resource record is to be updated or deleted, and the specified record does not exist then then a RecordNotFoundException is generated. This error is communicated to the user with a specific error status and error text in the http response header returned from the offending request.

ServiceAccessException
The REST web application portion of the Resource Manager communicates with the Auth0 user authentication service. If there is any communication failure with the Auth0 service, or the data returned from user authentication service is not what was expected, a ServiceAccessException 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.

AuthorizationException
The REST web application 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.

Required Data Field Validation
The web front-end of the Resource Manager includes logic to validate the user input data. Certain data elements are required when adding a new resource into the Resource Manager. When the user submits data for a new resource, validation logic confirms all required data elements have been input. If any required fields are missing then the submission is rejected and the missing data fields are highlighted on the submission form.

Field Type Validation
The web front-end of the Resource Manager includes logic to validate the user input data. Certain data elements are limited to specific types, for example, latitude and longitude must be numeric decimal values. If an invalid value is entered into a limited type field then a pop-up warning is generated for the user and the invalid value is not accepted as input.
Type checking fields:

- equipment.latitude
- equipment.longitude
- equipment.elevation
- equipment.height
- equipment_component.count
- participant_training.time_to_complete

User Registration Validation
The user authentication portion of the Resource Manager includes logic to validate a user during the user registration and login process. Each user’s login is based on their email address. An administrator user for the Resource Manager creates a new user entry that includes the user’s email address. Upon creation of a new user, a time sensitive invitation is emailed to the new user. If the new user attempts to register after the invitation period expires, or the user entry has been removed (by a

Resource Manager administrator), then the new user is not allowed to register and a login failure page is displayed to the user instead. If an existing user's account is removed by the Resource Manager admin, then upon attempted login, a login failure is displayed to the user.

3.1.5.7.3.3 Summary tables of criteria for issuing messages and alerts

Table 3-55 displays a list of messages and alerts that may be raised by the Resource Manager application given the criteria is met. The table describes the message as well as corresponding criteria.

Table 3-55. List of criteria for issuing messages and alerts

Message or Alert	Issue Criteria
RecordNotFoundException	• During an update or delete of a resource object record, no record matching the specified id is found
ServiceAccessException	• Communication failure when calling an Auth0 service • Parse failure of the expected data returned from an Auth0 service call
AuthorizationException	• Invalid or missing id token in an http request
Required Data Field Validation	• Required field on web page form has no data
Field Type Validation	• Non-numeric data entered into a numeric field on a web page form
User Registration Validation	• User invitation is invoked beyond the valid invitation period • A user that has been removed or blocked attempts to login

3.1.5.7.4 Application Design Description

The overall application design for the Resource Manager website follows the n-tier design for websites that isolated the data storage, business logic, and user interface into tiers. The data tier is composed of an Oracle database that stores all of the data related to the Resource Manager website. The next tier is comprised of a REST service that encompasses the business logic as well as the data access layer for the application. The REST service tier uses the Java Spring framework with Maven for automating builds. The next tier is the User Interface tier. This tier comprises the main website. The website was built using the Angular 2 JavaScript framework and goes through the REST service for all data and business logic related functionality.

3.1.5.7.4.1 Schematic of major modules/functions

Figure 3-75 shows the major modules within the Application and how the modules communicate. Please note that the Resource Manager REST service contains the bulk of the functionality and most of the Business Logic for the application by design. The Auth0 authentication service does contain some business logic for authentication and is isolated within the Auth0 service.

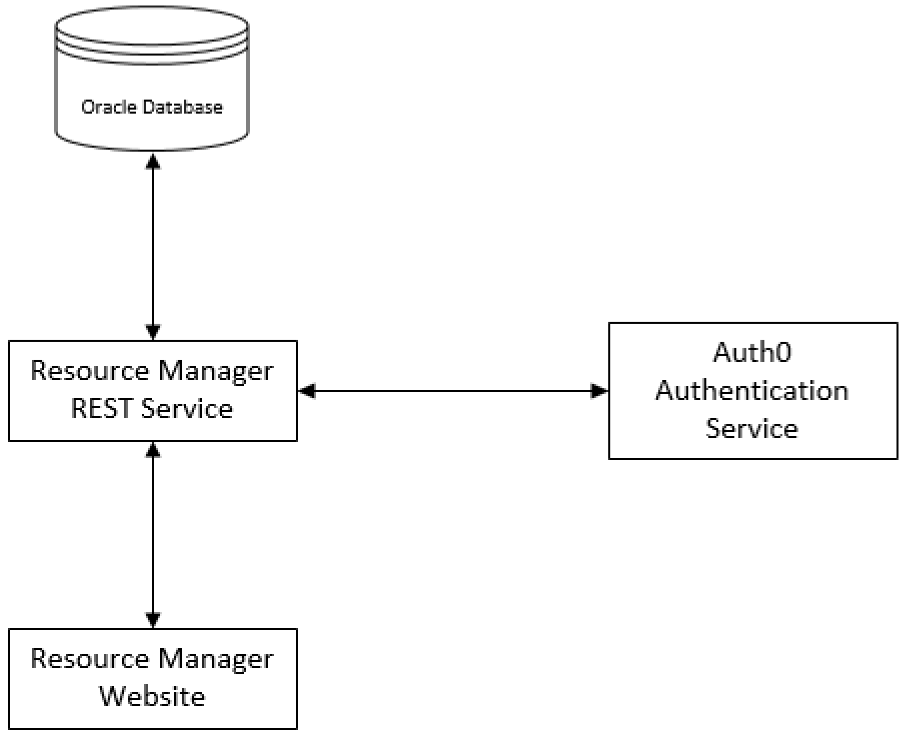


Figure 3-75. Major modules within the Resource Manager Application. (Source: WYDOT)

3.1.5.7.4.2 Description of modules/functions

The following describes the major modules/functions that make up the design of the Resource manager website.

Resource Manager REST Service:

This REST service provides all of the functionality needed to add, edit, delete, and view data within the Oracle database for information on participants, vehicles, equipment, and training. This module also contains all of the business logic needed to validate data going to/from the database including verifying user roles and validating permissions through the Auth0 authentication service.

Resource Manager Website:

This website displays participant information to the user and allows for interaction of the data including add/edit/delete/view. The website is responsible for some data validation and communicating with the REST service to perform all database operations.

Auth0 Authentication Service:

This REST service provides the business logic to perform all user authentication. All user login information is stored within this 3rd party tool. Auth0 provides a secure way to store user information as well as permissions associated with users. All token authentication is generated and validated through the Auth0 service. Auth0 is a 3rd party application that allows open source projects to use their product free of charge. This application is Open Source and falls under a free license agreement with Auth0.

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

Figure 3-76 shows the overall process flow between the major components of the Resource Manager application.

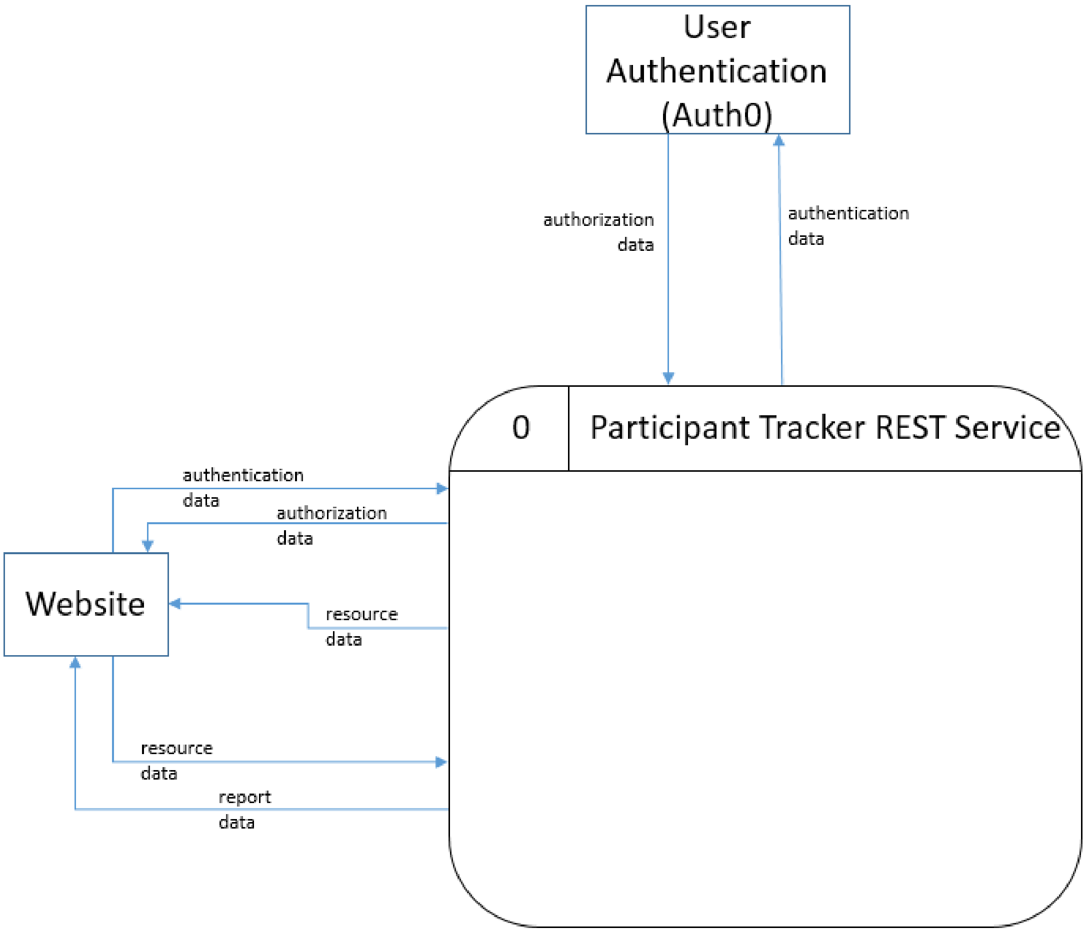


Figure 3-76. Process flow/algorithms between major modules/functions (Source: WYDOT)

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

Resource Manager REST Service <-> Auth0:
This flow consists of authentication data including user/pass and token authentication after a user has logged into the website.

Website <-> Resource Manager REST Service
This flow consists of authentication data as well as participant data and relationship data.

3.1.5.7.5 Application Data Tables

The following sections provide details on the data stored within the Resource Manager website. All data shall be stored within an Oracle database. All data for this website shall be encrypted en-route to/from and within the Oracle database using an encrypted tablespace.

3.1.5.7.5.1 Input data description tables

Table 3-56 through Table 3-60 describe the input data being managed by the Resource Manager for user authentication, equipment, vehicle, participant and training resources.

Table 3-56. Description of the user authentication input data for the Resource Manager.

Data Name	Type	Description
Username	String	A unique valid email for each user.
Password	String	A password string.
Two Factor Id	String	A generated id value, typically a numeric string.

Table 3-57. Resource Manager input data for the equipment resources being managed.

Data Table	Column	Type	Units	Description
Equipment	description	String		Text describing the equipment
	assetId	String		Id from the asset tag of the equipment
	equipmentTypeId	Integer		Id referencing the type of equipment
	serialNumber	String		Serial number of the equipment.
	modelNumber	String		Model number identifier for the equipment.
	wan	String		Wide Area Network id for the equipment.
	latitude	Float	Decimal deg.	Latitude for equipment installed at a location or null for mobile equipment
	longitude	Float	Decimal deg.	Longitude for equipment installed at a location or null for mobile equipment
	elevation	Float	Feet	Elevation above sea-level for equipment installed at a location or null for mobile equipment
	height	Float	Feet	Height above roadway for equipment installed at a location or null for mobile equipment
	dateInstalled	Date		Date equipment was installed at a location or in vehicle or null for equipment not yet

Data Table	Column	Type	Units	Description
				installed. Format YYYY-MM-DD example 2017-02-08
	notes	String		Text field for any user specified information about the equipment.
EquipmentComponent	equipmentComponentTypeId	Integer		Id referencing the type of equipment component.
	equipmentId			Id referencing the equipment that this component is part of.
	description	String		Text describing the equipment component.
	serialNumber	String		Serial number of the equipment component.
	modelNumber	String		Model number identifier for the equipment.
	version	String		Any version identifier for the component. Example software version numbers: 1.2
	count	Integer		The count of these components that are incorporated into a single piece of equipment.

Table 3-58. Resource Manager input data for the vehicle resources being managed.

Data Table	Column	Type	Description
Vehicle	id	String	A specific Id that uniquely identifies a vehicle. Example license plate number.
	vehicleClassId	Integer	Id referencing the vehicle class for this vehicle.
	organizationId	Integer	Id referencing the organization for this vehicle.
	vin	String	Vehicle Id Number
	make	String	Vehicle make.
	model	String	Vehicle model.
	notes	String	Text field for any user specified information about the vehicle.

VehicleEquipment	vehicleId	Integer	Id referencing the vehicle for this vehicle equipment installation.
	equipmentId	Integer	Id referencing the equipment for this vehicle equipment installation.

Table 3-59. Resource Manager input data for the participant resources being managed.

Data Table	Column	Type	Units	Description
Participant	firstName	String		Participant given name.
	lastName	String		Participant family name.
	organizationId	Integer		Id referencing the organization this participant is affiliated with.
	email	String		Email address for this participant.
	startDate	Date		Date participant enrolled as a member of the CV project. Format YYYY-MM-DD example 2017-02-08
	endDate	Date		Date participant ended enrollment in the CV project. Format YYYY-MM-DD example 2018-10-06
ParticipantVehicle	participantId	Integer		Id referencing the participant for this participant vehicle pairing.
	vehicleId	Integer		Id referencing the vehicle for this participant vehicle pairing.
	isPrimary	String		Flag identifying the vehicle that is the primary vehicle associated with this participant/driver. Format ‘Y’ for yes and ‘N’ for no.
ParticipantTraining	participantId	Integer		Id referencing the participant for this participant training.
	trainingId	Integer		Id referencing the training for this participant training.
	timeToComplete	Integer	minutes	Total time recorded for participant to complete a specific training.
	dateCompleted	Date		Date on which the participant completed the specific training. Format YYYY-MM-DD example 2018-02-08

Table 3-60. Resource Manager input data for the training resources being managed.

Data Table	Column	Type	Units	Description
Training	training	String		Text description of this training course.
	courseId	String		A unique id for this training course.
	trainingTypeId	Integer		Id referencing the training type of this training.
	notes	String		Text field for any user specified information about the training course.

	startDate	Date		Date participant enrolled as a member of the CV project. Format YYYY-MM-DD example 2017-02-08
	endDate	Date		Date participant ended enrollment in the CV project. Format YYYY-MM-DD example 2018-10-06

3.1.5.7.5.2 Output data description tables

Table 3-61 through Table 3-64 describes the authorization, record count, record percent count and record vehicle organization output data for the Resource Manager. The output resource data is the same data and type as the input resource data described in the previous section (see tables in Section 3.1.5.7.5.1).

Table 3-61. Authorization output data for the Resource Manager.

Data Name	Type	Description
Access Token	String	A unique time constrained token provided to the user client software after a successful login by a user. The access token is subsequently added to every request made to the Resource Manager REST service by that user client. No request is authorized unless it includes a valid access token.

Output report data consists of sets of generic record types. For example, a set of record counts may be provided to support a report that lists the count of each type of equipment associated with the CV project. A description of the report outputs for record counts can be found in Table 3-62 for equipment counts and Table 3-63 for equipment percent.

Table 3-62. Record count report output data for the Resource Manager.

Data Name	Type	Description
type	String	A reference to a specific type. For example, the type could reference a specific type of equipment.
count	Integer	A count value associated with the specified type. For example, if the type was RSU then the count value might represent the total number of RSU existing in the database.

Table 3-63. Record percent count report output data for the Resource Manager.

Data Name	Type	Description
type	String	A reference to a specific type. For example, the type could reference a specific type of equipment.
totalCount	Integer	A count value associated with the specified type. For example, if the type was RSU then the count value might represent the total number of RSU existing in the database.
percentCount	Integer	A selective count value associated with the specified type. For example, if the type was RSU and the total count represented all RSU in the system, then the percentCount value could represent the total number of RSU currently installed (e.g. RSU's non-null install date).

The RecordVehicleOrganization data structure is defined to specifically support a particular report display, the visualization of the total population of each vehicle type and associated organizations. Output data for this report consists of a set of RecordVehicleOrganization records one record for each combination of vehicle class and organization. A description of all fields in the report is found in Table 3-64.

Table 3-64. Record vehicle organization report output data for the Resource Manager

Data Name	Type	Description
rowId	String	A unique id for this combination of organization and vehicle class
organizationName	String	An organization with vehicles of the specified vehicle class
vehicleClass	String	The name of a DOT vehicle class
vehicleCount	Integer	The count of vehicles of the given class associated with the given organization.

3.1.5.7.5.3 Data/database storage description diagrams and tables

The Entity Relationship Diagram (ERD) in Figure 3-77 is provided to show the data storage design for the data maintained by this application.

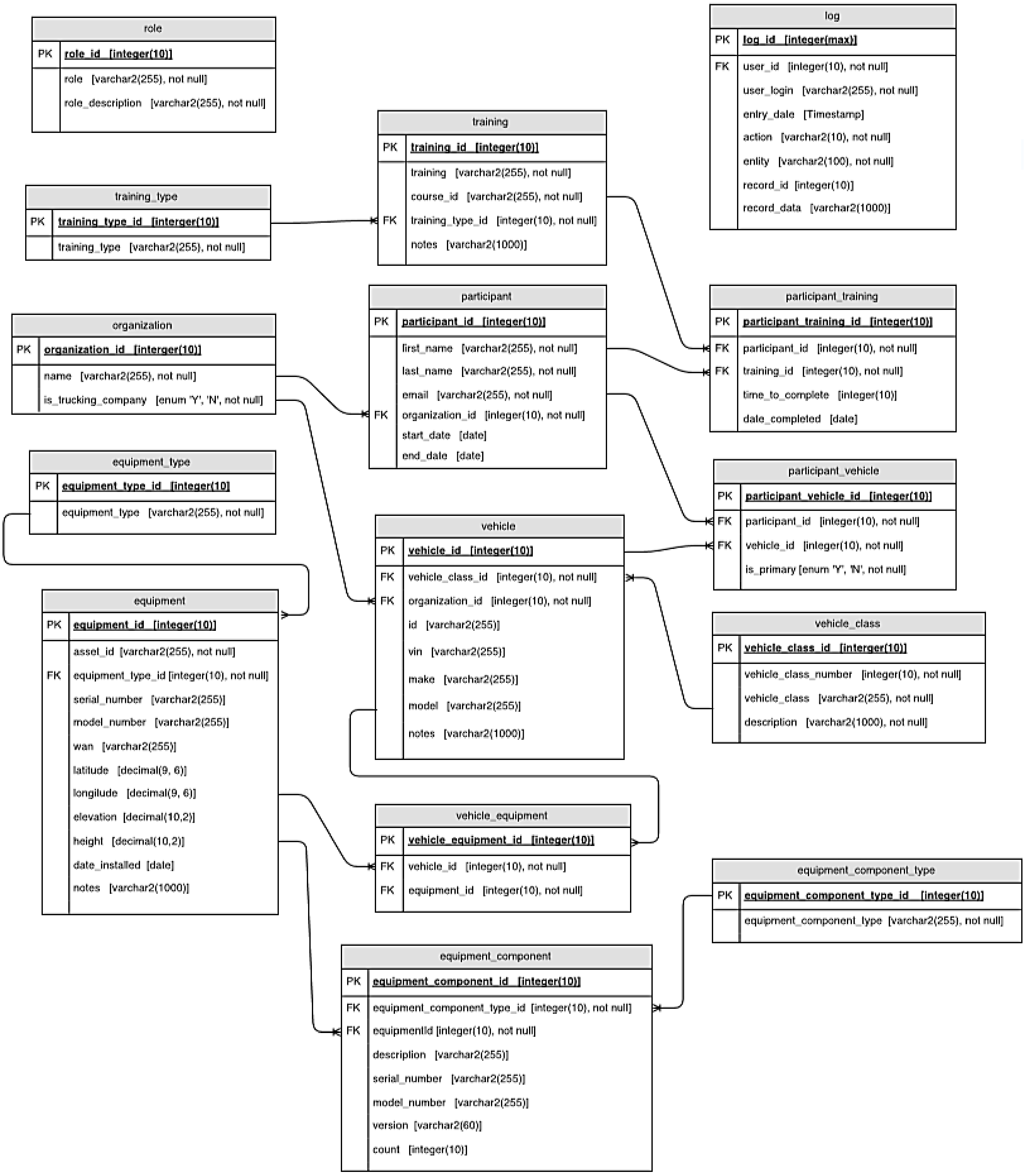


Figure 3-77. Data storage design for Resource Manager Application. (Source: WYDOT)

3.1.5.7.6 Application Configuration Data

The following tables describe the configuration setting for the CVRM website and what the purpose of the configuration setting is. Table 3-65 describes configuration settings for the REST Service. Table 3-66 describes configuration settings for the Resource manager website.

Table 3-65. Application configuration properties for the REST service (file location: /service/src/main/resources/).

Property	Default Value	Description
auth0.apiClientId	<client id>	Id for client configured on Auth0 to handle the admin service calls for the Resource Manager application.
auth0.apiClientSecret	<client secret>	Secret generated by Auth0 associated with the client to handle admin service calls for the Resource Manager application.
auth0.domain	cvrm-its-dot.auth0.com	Domain to use to reference the account set up on Auth0 for Resource Manager user authentication.
auth0.issuer	https://cvrm-its-dot.auth0.com	Base URL for connection to the Auth0 authentication service.
auth0.clientId	<client id>	Id for client configured on Auth0 to handle the user service calls for the Resource Manager application.
auth0.clientSecret	<client secret>	Secret generated by Auth0 associated with the client to handle user service calls for the Resource Manager application.
auth0.securedRoute	NOT_USED	Turns off the secured route option for Auth0 endpoint security.
auth0.base64EncodedSecret	false	Determines if the secret is base64encoded.
auth0.authorityStrategy	ROLES	Indicates that users include ROLES that define the access authority for each user.
auth0.defaultAuth0ApiSecurityEnabled	false	
auth0.signingAlgorithm	HS256	Algorithm used to sign the user id token. Options: HS256, RS256
logging.level.org.springframework.web	INFO	Logging level for messages about normal web processing
logging.level.org.springframework.security	INFO	Logging level for security related processing.
oracle.url	jdbc:oracle:oci8:@CVRMDB_DEV	Connection string for Resource Manager Oracle database. Note, the final field must match a defined connection name from the tnsnames.ora file configured for the local Oracle Net Client.
oracle.username	<login>	Oracle login for Resource Manager data
oracle.password	<password>	Password
server.port	9000	http port the Resource Manager REST service is listening on

Property	Default Value	Description
server.ssl.key-store	classpath:cvrmkey.jks	Path to the Java key-store file
server.ssl.key-store-password	<password>	The password to access the key-store
server.ssl.keyStoreType	PKCS12	Type for the java key-store options: PKCS12,
server.ssl.keyAlias	tomcat	Name for the key in the key-store
spring.mvc.throw-exception-if-no-handler-found	true	Configuration for the REST service to throw an exception if a request is made to an undefined endpoint.
spring.resources.add-mappings	false	A flag to specify that static files should be served by the dispatch servlet associated with the REST service.
spring.datasource.testWhileIdle	true	Flag specifies if a test query is issued during idle periods to make sure the database connection remains alive.
spring.datasource.validationQuery	SELECT 1 FROM DUAL	Test query to use during idle periods.
spring.jpa.show-sql	false	Flag indicates if generated SQL queries should be written to the console during operation. Useful to debug the repository operation.
spring.jpa.hibernate.naming-strategy	org.hibernate.cfg.ImprovedNamingStrategy	Hibernate configuration parameter on how it generates SQL names.
spring.jpa.properties.hibernate.dialect	org.hibernate.dialect.Oracle12cDialect	Hibernate configuration parameter to have it generate SQL syntax optimized for Oracle12c
spring.mail.host	10.145.9.29	SMTP mail server to use for sending user invitation email for user registration process.
spring.mail.port	25	Port number on mail server for SMTP connection.

Table 3-66. Configuration files and parameters for Resource Manager website.

File	Parameter	Default	Description
/website/src/main/website/package.jason	build	"ng build --env=dev"	Indicates which environment configuration should be used with the ng build process. Options: prod, test, dev
/website/src/main/website/src/environments/environment.ts	envName	test	There are a set of environment files in this directory, each one defines Urls for configuring the website and where to reach the REST

			service. The environment names match the –env name configured in the package.json file.
	baseUrl	'https://cvptdp01:9000'	Url to reach the Resource Manager REST service
	webUrl	'https://cvptdp01:8443/cvpt'	Url for the website

3.1.5.7.7 *Application User Interface(s)*

The following figures are screenshots of the Resource Manager website. The screenshots show the different functionality available within the website as well as the look and feel of the website. All pages within the website are built with responsive web design in mind so they will work on mobile devices just as well as standard computer monitors.

Figure 3-78 shows the Resource Manager dashboard.

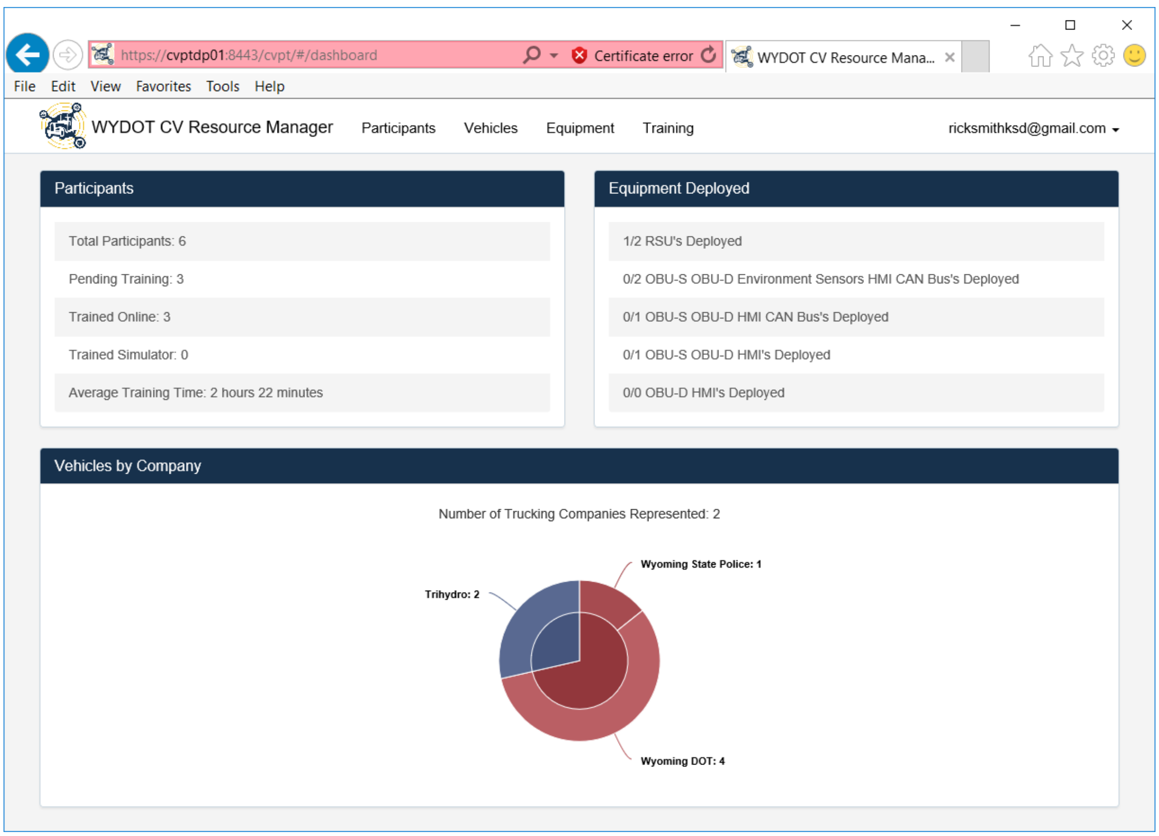


Figure 3-78. Resource Manager Dashboard. (Source: WYDOT)

Figure 3-79 shows the participant management page. This page allows users with permissions to view participant information as well as Add/Edit/Delete participants.

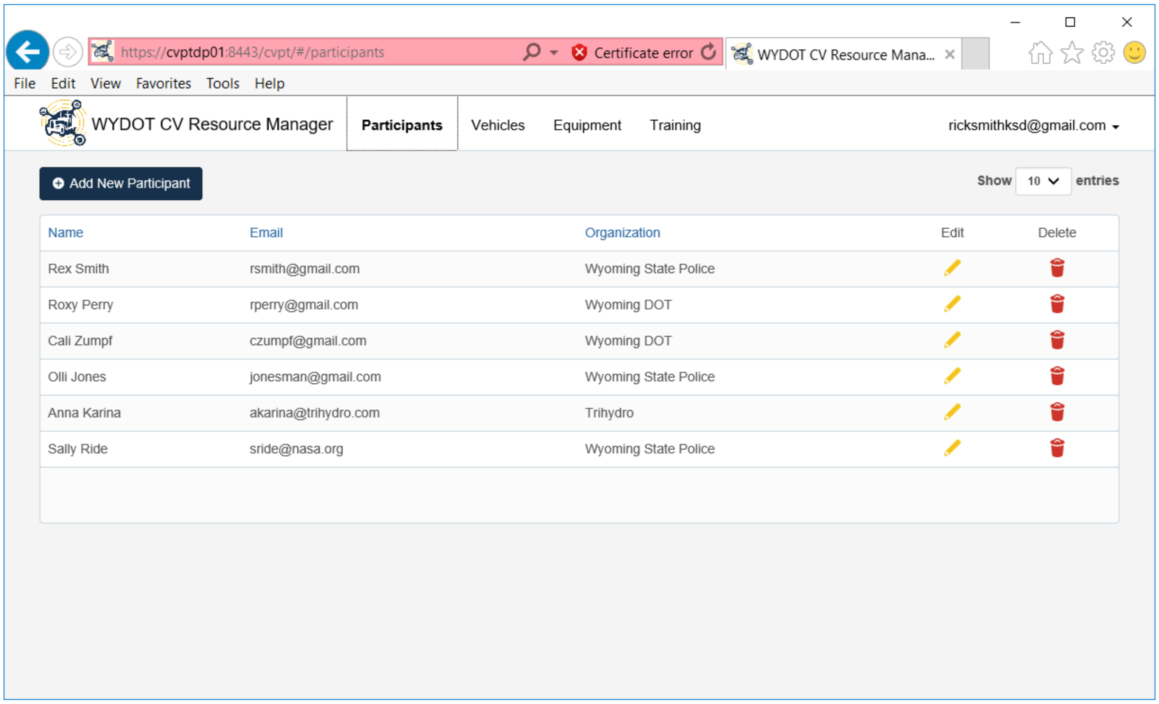


Figure 3-79. Participant management page (Source: WYDOT)

Figure 3-80 shows the Vehicle management page. This page allows users with permissions to add/edit/delete vehicle information.

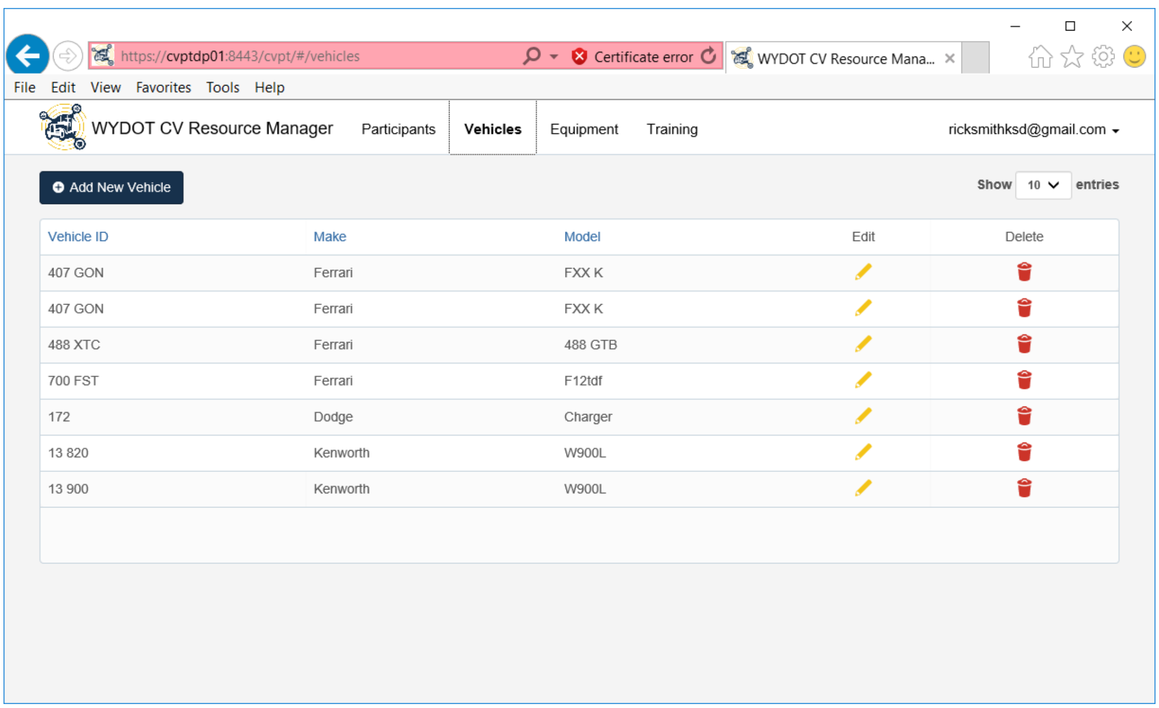


Figure 3-80. Vehicle management page. (Source: WYDOT)

Figure 3-81 shows the training management page. This page allows users with permission to add/edit/delete training modules within the resource manager website.

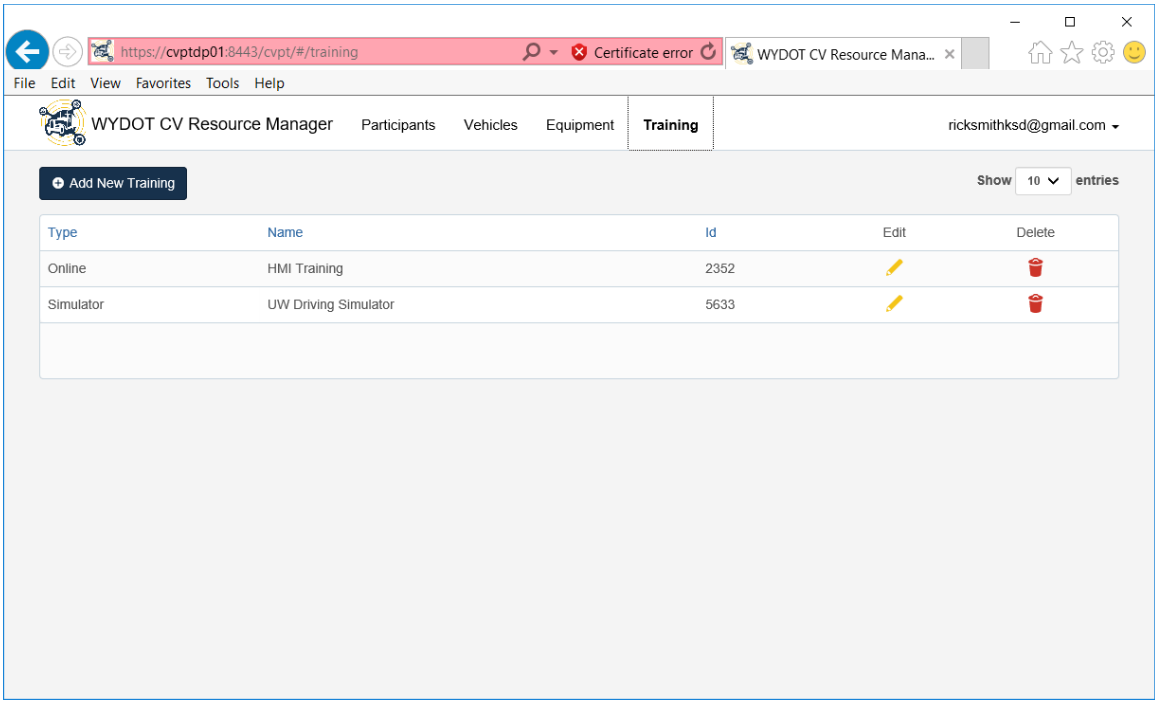


Figure 3-81. Training management page. (Source: WYDOT)

Figure 3-82 shows the equipment management page. This page allows user to add/edit/delete equipment that will be used within the Wyoming CV pilot project. This includes all RSU's, OBU's, and all related components.

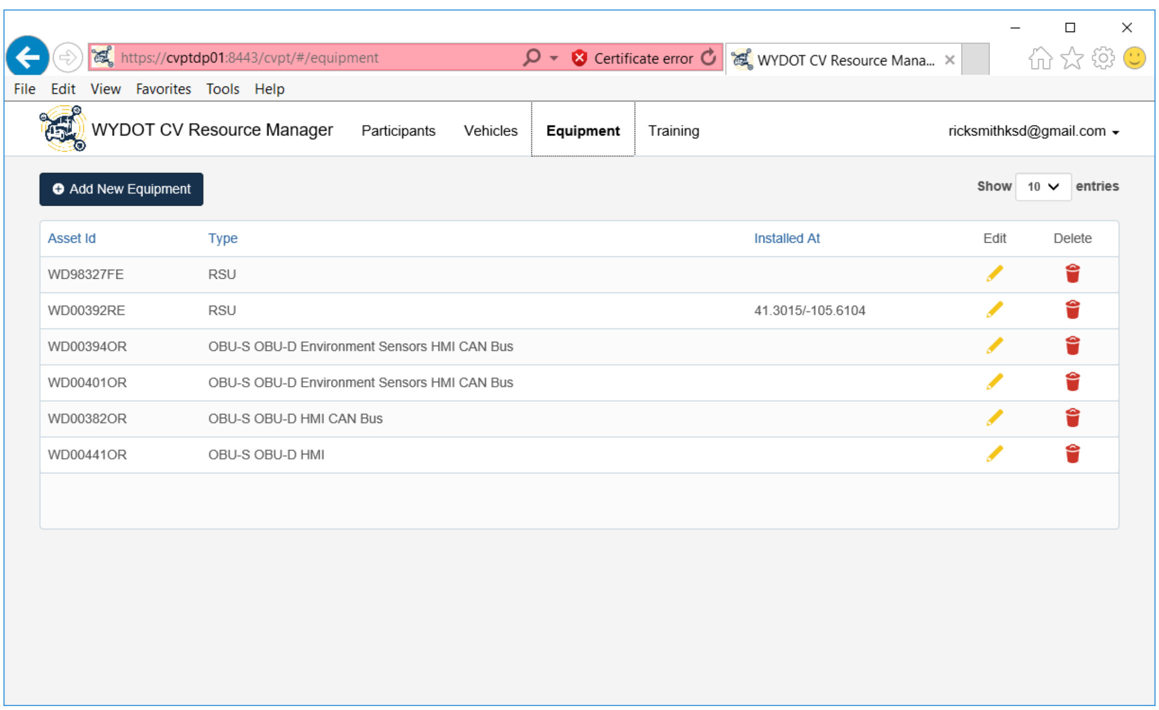


Figure 3-82. Equipment management page. (Source: WYDOT)

3.1.5.7.7.1 Description of Operations/Driver Interface with illustrations

This application contains no driver interface operations.

3.1.5.7.7.2 Description of Maintenance User Interface with illustrations

This application contains no maintenance user interface.

3.1.5.7.8 Requirements Traceability

There were no requirements related to this application identified in the System Requirements document.

3.1.5.7.9 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 & Satellite OBU Design (Lear)

This OBU type is a Lear Locomate Roadstar Premium model. This OBU hardware is planned to be installed on

- Integrated Commercial Vehicles
- 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.
- Integrate with the vehicle network via a Controller Area Network (CAN bus) connection. *Note that this capability will not be used in this Pilot.*
- Receive BSM Parts I and II.
- Broadcast BSM Parts I and II.
- Broadcast TIMs via DSRC for Distress Notification
- Transmit weather sensor data.

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 and will be used to display I2V Situational awareness, Work Zone Warning, and Spot Weather Impact Warning applications. Additionally, this OBU has the capability of packaging and sending weather data to RSUs from Weather sensors installed on the vehicle.

3.2.1.1.3 Output Data/Message Flows

Output flows for the OBU include BSM and TIM messages. BSM messages are transmitted continuously and are used for the Forward Collision Warning application.

3.2.1.2 OBU Hardware Platform

This design information will be added when it is received from Lear and submitted in a later version of the SDD.

3.2.1.2.1 Vendor/manufacturer & model number,

The manufacturer of the OBU is Lear. The model name for this OBU is the Locomate Roadstar Premium.

3.2.1.2.2 Picture and physical description of hardware

The Lear Locomate Roadstar Premium OBU is comprised of a magnetic antenna and the main OBU housed in a separate waterproof box that mounts under the hood of a vehicle and can either plug into a power source or be wired into the vehicle power. The OBU can be seen in Figure 3-83.

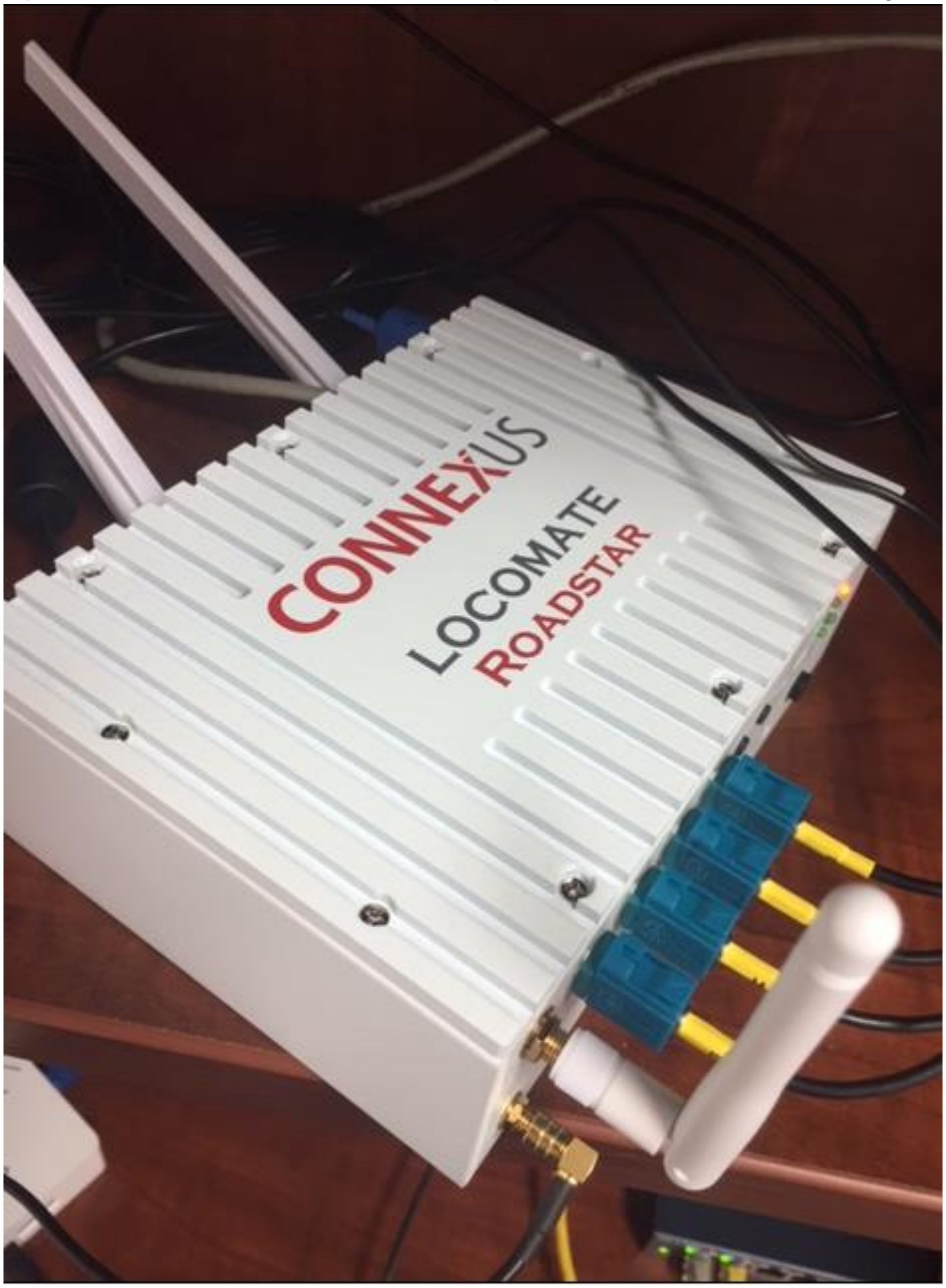


Figure 3-83. Lear Locomate Roadstar Premium OBU (Source WYDOT)

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

The Lear Locomate Roadstar Premium OBU contains the following interfaces.

- 4 Antenna ports
- 1 Sirius XM satellite reception port
- 1 HDMI port

- 1 USB port
- 3 ports for WiFi antennas
- 1 port for a Bluetooth antenna

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

This information has not yet been provided by Lear and will be added in a later revision of this document after it has been received.

3.2.1.2.5 Hardware design description relevant to CV function and performance

This information has not yet been provided by Lear and will be added in a later revision of this document after it has been received.

3.2.1.3 OBU Operating Platform/ Development Stack

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

3.2.1.3.1 Vendor & version number

The OS Version is Linux kernel with version number is "3.10.17".

3.2.1.3.2 Operating platform design description

Figure 3-84 shows the design diagram of different modules for User mode and Kernel mode within the RSU.

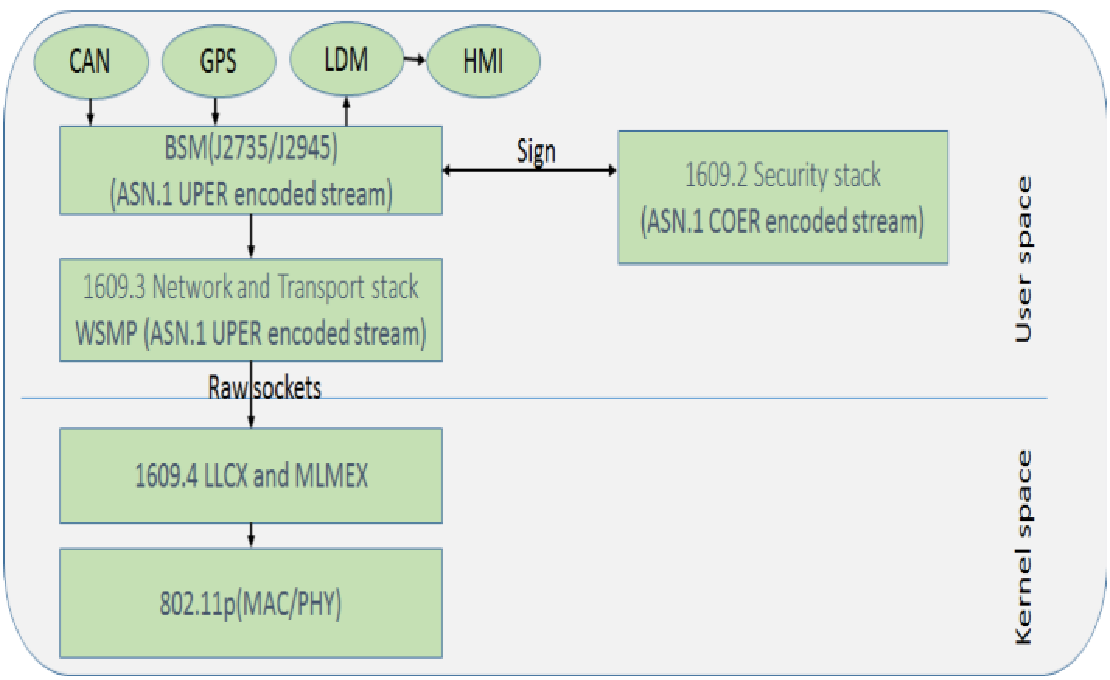


Figure 3-84. Flow Diagram of Modules within OBU. (Source: Lear)

The OBU applications, which include BSM, SPAT, MAP, TIM, CAN, GPS, HMI, LDM, OFFLOAD, and Security Stack run in user mode. Security is handled in the security stack by signing the packets while

transmitting or receiving the data. To differentiate between the applications, each application contains their own PSID's. Based on the PSID values, the security or signing operations are handled in the Dot2 layer using the 1609.2 standards.
In the user space, a Dot3 layer lies, which consists of a network and transport stack. Applications and the Dot3 layer communicate using a sockets interface. Dot3 layer has WSMP Header and 1609.3 library, when application data accesses this layer, Dot3 requests the driver and registers the application with a corresponding PSID and channel info. For this, Dot3 interacts with library through the system calls. If the channel is available, then only it registers that channel with driver. Once the registration is done, the OS switches to kernel mode.

The kernel mode comes under the data link layer (DOT4). Within the Dot4 layer the NETLINK and raw sockets reside. These are used to provide communication between user space and kernel space. This layer implements the 1609.4 library and LLC layer header and MAC header. The MAC header size is 32 bytes of address, which is populated with the destination MAC of the device, channel, ID, etc. This information along with payload that is coming from the previous layers. At physical layer using the modulation techniques, it will send the data in binary form to the air. Once the transmission is completed, the available devices having same channel and PSID will receive these packets and do the reverse operation.

3.2.1.3.3 Operating Platform Configuration Data

On the device the application can be configured through clish. The configuration parameters may be either string or integer. While configuring if you enter "?", it will give whether it is integer/string along with some description about that parameter. Once the configuration is done those values are reflected in the "/var/config" file. Any configuration parameter changes have to be done through clish for that application. This change will get correspondingly reflected in "/var/config" file.

For BSM/SPAT/MAP/TIM/EGOPROCESS/IPSERVICE applications, the Syntax for the application configuration is:

config application <ACTION> <APPLICATION NAME> <PARAMETERS>

The ACTION, APPLICATION NAME and PARAMETERS configurations are explained below.
ACTION There are three actions are possible for applications.

1. Enable
2. Disable
3. Update

Enable To enable the APPLICATION. After enabling the application, that application should run on the board.

[Lear01FA2E:conf (0)] config application enable <APPLICATION NAME>

Disable To disable the APPLICATION. After disabling the application, that application should not run.

[Lear01FA2E:conf (0)] config application disable <APPLICATION NAME>

Update To update APPLICATION we use this update command. Make sure to update any application, first that application should be disable. In update there are several PARAMETERS are there, which explained in the following sections.

APPLICATION NAME The applications that are able to be configured on the device are:
1. BSM
2. SPAT
3. MAP
4. TIM
5. EGOPROCESS
6. IPSERVICE

PARAMETERS: Parameters can be configured through Update command only. General syntax is,

config application update <APPLICATION NAME> <PARAMETERS>

Parameters that need to configure are as follows.

wmeConfig
Following table contain different parameters included in the wmeConfig.

Table 3-67. WME Configuration Parameters

Parameter Name	Type	Description
psid	Unsigned integer	ID of the application
provider/user/channel	String	Selecting for specific arguments
timeslot	String	Selecting the timeslot (SCH/CCH/BOTH/NONE)
userreqtype	String	User request type(auto/no channel access)
srcmac	MAC(IPv6 address)	Providing source MAC address
advidentifier	String	matching advertise id string in WSA
linkquality	positive integer	Providing link quality value
immaccess	positive integer	immediate access value
wsatype	String	Selecting the security service
psc	String	provider service context
schan	Unsigned integer	service channel for registration
chaccess	String	Channel access for service
wsarepeatrate	Unsigned integer	Repeat rate of WSA's
dstmac	MAC(IPv6 address)	Destination device MAC address
wsachan	Unsigned integer	wsa Tx channel default CCH
ipservice	string	Enable/disable of Ipservice
serviceport	Positive integer	Mention the port number of service
serviceIpv6Addr	IPv6 address	Ipv6 adrress of the service
providermac	IPv6 address	MAC address of the provider service
rcpithresh	Positive integer	rcpi threshold value
wsacntthresh	Positive integer	WSA count threshold value
wsacountthinterval	Positive integer	WSA count threshold interval
infoelementind	Positive integer	info element indicator value
signlifetime	Positive integer	signal life time value

wsmConfig
The wsmConfig parameters are listed in following table

Table 3-68. WSM Configuration Parameters

Parameter Name	Type	Description
security	String	Security option(sign/encrypt/unsecured)
verifybypass	String	Security bypass verification status
timeslot	String	Selecting the timeslot (SCH/CCH/BOTH/NONE)
txchan	Unsigned integer	Transmission channel value
datarate	Float value	Providing data rate for transmission
txpower	Unsigned integer	Transmission power in dbm
chload	positive integer	channel load value
infoelementindicator	positive integer	info element indicator value
userpriority	positive integer	User priority value
repeatrate	Unsigned integer	Range 2Hz-20Hz, default 10Hz
expirytime	Positive integer	Expiry time
peermac	MAC(IPv6 address)	peer MAC address

otherConfig

The otherConfig parameters are listed in following table

Table 3-69. Other Configuration Parameters

Parameter Name	Type	Description
txrxmode	String	Mode(TX/RX/TXRX/NONE)
tempidrandstatus	String	temp ID control status
msgcount	Positive integer	message ID value
tempid	String	Temporary Id
srmfolder	String	srm folder name with path
portnumber	Positive integer	port number value
forwarddirection	String	remote forward direction value
logtype	String	Providing the logtype
remoteforwardip	String	remote server IP value
remoteforwardport	Positive integer	remote server port number value
filename	String	Remote file name
configFile	String	application specific config file name with path
filesize	Positive integer	Size of the file
remotedataforward	String	remote data forward value
remoteparamforward	String	remote forward paramter value
remoteeventforward	String	forward event value
loglevel	String	log level value
printencode	String	Enable/disable status
printdecode	String	Enable/disable status

saeConfig

The saeConfig parameters can be configure only in BSM application only. The parameters are listed in following table

Table 3-70. SAE Configuration Parameters

Parameter Name	Type	Description
vehicletype	String	Vehicle type value
vehiclelength	Float Value	Vehicle length value in meters
vehiclewidth	Float Value	Vehicle width value in meters
vehicleheight	Float Value	Vehicle class value
vehicleclass	String	Vehicle role value
vehiclerole	String	Vehicle fuel value
Vehiclefuel	String	Vehicle mass in kgs
Vehiclemass	Float Value	Vehicle front bumper height in meters
Frontbumperheight	Float Value	Vehicle rear bumper height in meters
Rearbumperheight	Float Value	Vehicle rear bumper height in meters
Vehicledisabled	String	Checking vehicle is disabled or not

OFFLOAD Application
Offload is the application run on the ASD device. The syntax of this application is below.
config locos offload <status/update>

Status
By using this status we can start/stop the application.
Enable
To start the offload application we need to enable the status.
config locos offload status enable
Disable
To stop or configuring the application parameters, we need to disable the application.
config locos offload status disable
Update
There are two types of configuration parameters.

3. wmeConfig
4. OptConfig

wmeConfig
The parameters of the wmeConfig are listed below.

Table 3-71. WME Configuration Parameters

Parameter Name	Type	Description
Appname	String	Application name
Psid	Unsigned integer	Application psid
userRequestType	Unsigned integer	Application user request type
wsaType	Unsigned integer	WSA type value
Psc	String	Configure Provider service context
serviceChannel	Unsigned integer	Configuring service Channel value
advertiserIdentifier	String	Configure advertiser Identifier

OptConfig

The parameters of the OptConfig as listed below.

Table 3-72. Opt Configuration Parameters

Parameter Name	Type	Description
RemoteUserName	String	User name of backend machine
LocalSrcDIR	String	It is the path that files should be offloaded
RemoteDestDir	String	Path of directory that files should be offloaded.
Retrycount	Unsigned integer	Retry count value for uploading files
Ipaddress	IPv4/IPv6 address	Backend machine IPv4/IPv6
Uploadtime	Unsigned integer	Upload time in seconds
Retryinterval	Unsigned integer	Retry interval value in seconds
threshold1	Unsigned integer	minimum size of the offload directory
threshold2	Unsigned integer	threshold2 value
threshold3	Unsigned integer	maximum size reached by offload directory

3.2.1.4 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~~ *[This no longer applies to this Pilot]*
- 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.

3.2.1.5 OBU Messages

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

3.2.1.6 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
- VS-REQ-2 Receive TIM
- VS-REQ-2.1 Receive TIM through DSRC

- VS-REQ-2.2 Receive TIM through Satellite
- VS-REQ-3 Receive Distress Information
- VS-REQ-4 Collect Vehicle Data
- VS-REQ-4.1 Collect Vehicle Status Data
- VS-REQ-4.2 Collect Dimension Data
- VS-REQ-4.2.1 Vehicle Dimension Data
- VS-REQ-4.2.2 Vehicle Trailer Data
- VS-REQ-5 External Environment Sensor Data
- VS-REQ-5.1 External Environment Sensor Data Configuration
- VS-REQ-5.2 External Environment Sensor Data Management
- VS-REQ-10.1 Safely Following a Vehicle
- VS-REQ-10.2 Passing a Stopped Vehicle
- VS-REQ-15 Distress Notification ID
- VS-REQ-15.1 Log
- VS-REQ-16 Create Distress Notification
- VS-REQ-23 IVAA Rank
- VS-REQ-24 IVAA Level
- VS-REQ-25 IVAA Priority Alert
- VS-REQ-26 IVAA FCW
- VS-REQ-27 IVAA DN
- 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
- VS-REQ-34 BCVI Distress
- VS-REQ-34.1 Received Distress
- VS-REQ-34.2 Generated Distress
- VS-REQ-35 BCVI General Broadcast Requirements
- VS-REQ-36 Transmit Data
- VS-REQ-36.1 Transmit Environmental Data
- VS-REQ-36.2 TVI Data Management-Log
- VS-REQ-38 SLD Information
- VS-REQ-39 SLD Rolling Log
- VS-REQ-40 SLD Log Format
- VS-REQ-41 SLD Log Data
- VS-REQ-42 VSM SCMS
- VS-REQ-43 VSM SCMS Encryption
- VS-REQ-44 VSM SCMS Sign
- VS-REQ-45 VSM SCMS Encryption-Log
- VS-REQ-46 VSM SCMS Sign-Log
- VS-REQ-47 VSM App Availability Log
- 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
- ~~MV-REQ-2 Can Bus~~

- MV-REQ-3 Static Identifier
- MV-REQ-4 Receive TIM over DSRC
- MV-REQ-5 Receive TIM over Satellite
- MV-REQ-6 OTA Updates
- MV-REQ-7 Time
- MV-REQ-8 Location
- MV-REQ-9 General
- MV-REQ-10 OBU Equipment
- HP-REQ-1 General
- HP-REQ-2 Receive TIM over DSRC
- HP-REQ-3 Time
- HP-REQ-4 Location
- HP-REQ-5 OBU Equipment
- HP-REQ-6 Receive TIM over Satellite
- HP-REQ-7 OTA Updates
- IT-REQ-1 Receive TIM over DSRC
- IT-REQ-2 Receive TIM over Satellite
- IT-REQ-3 OTA Updates
- IT-REQ-4 Time
- IT-REQ-5 Location
- IT-REQ-6 General
- IT-REQ-7 OBU Equipment

3.2.1.7 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 DSRC & Satellite OBU Design (Sirius XM)

This OBU type is a Sirius XM Commercial Off the Shelf (COTS) model. This OBU hardware is planned to be installed on

- Retrofit Commercial Vehicle

3.2.2.1 Function of the Component

This Sub-System is for trucks and other fleet vehicles that do not include integration with CAN bus data integration. This Sub-System intends to test the interaction between the systems within the WYDOT CV Pilot and external/commercial devices that are not developed as part of this pilot. In this manner, this Sub-System is intended to “simulate” a commercial-off-the-shelf (COTS) system that enables a vehicle to communicate data through DSRC to other connected devices and receive TIMs through DSRC or satellite. The design for this OBU shall meet the sensitivity requirements specified in J2945-1 section 6.4.2.

3.2.2.1.1 Functions/Services Brief description

This OBU sub-system has the ability to:

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

3.2.2.1.2 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 and will be used to display I2V Situational awareness, Work Zone Warning, and Spot Weather Impact Warning applications.

3.2.2.1.3 Output Data/Message Flows

Output flows for the OBU include BSM. BSM messages are transmitted continuously and are used for the Forward Collision Warning application.

3.2.2.2 OBU Hardware Platform

3.2.2.2.1 Vendor/manufacturer & model number

The Vendor for this OBU is Sirius XM. No model number is known yet.

3.2.2.2.2 Picture and physical description of hardware

Figure 3-85 shows the Sirius XM hardware that will be used to demonstrate a COTS solution for OBUs within Wyoming. The unit consists of three pieces of hardware including a display, Under Dash Module and a magnetic antenna for roof mounting.

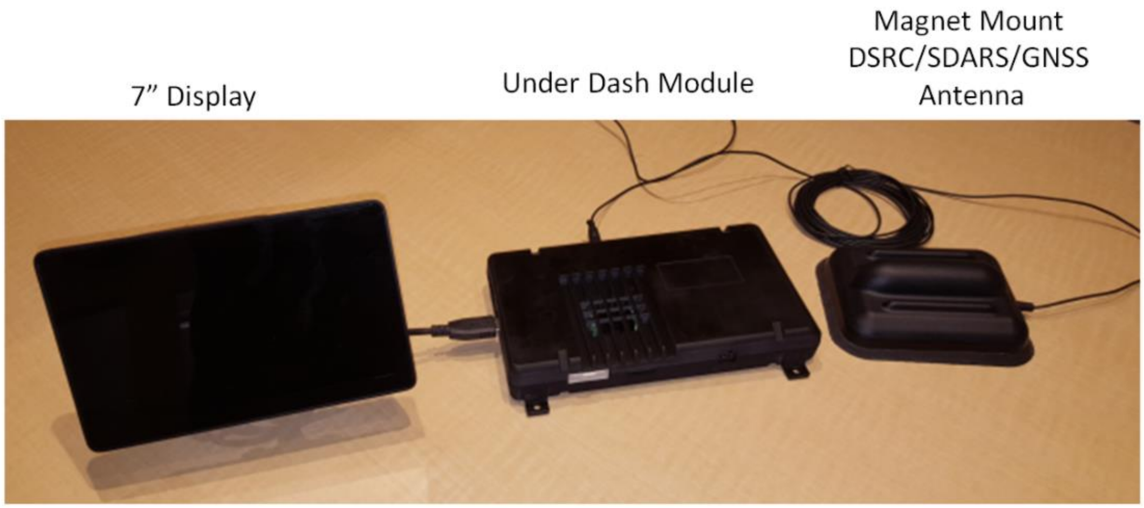


Figure 3-85. Sirius XM OBU (Source WYDOT)

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

The under-dash module contains an interface to both the display (via USB) and to the Antenna. Additionally, a port is available for sound to plug directly into the vehicles audio system.

3.2.2.3 User Interface(s)

This information has not yet been provided by Sirius and will be added in a later revision of this document after it has been received.

3.2.2.4 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
- VS-REQ-2 Receive TIM
- VS-REQ-2.1 Receive TIM through DSRC
- VS-REQ-2.2 Receive TIM through Satellite
- VS-REQ-4 Collect Vehicle Data
- VS-REQ-4.2 Collect Dimension Data
- VS-REQ-4.2.1 Vehicle Dimension Data

- VS-REQ-4.2.2 Vehicle Trailer Data
- 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 in Straight Road
- VS-REQ-10 FCW Rear-End Crash in Curved Road
- 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
- VS-REQ-24 IVAA Level
- VS-REQ-25 IVAA Priority Alert
- VS-REQ-26 IVAA FCW
- 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
- VS-REQ-35 BCVI General Broadcast Requirements
- VS-REQ-36 Transmit Data
- VS-REQ-36.2 TVI Data Management-Log
- VS-REQ-38 SLD Information
- VS-REQ-39 SLD Rolling Log
- VS-REQ-40 SLD Log Format
- VS-REQ-41 SLD Log Data
- VS-REQ-42 VSM SCMS
- VS-REQ-43 VSM SCMS Encryption
- VS-REQ-44 VSM SCMS Sign
- VS-REQ-45 VSM SCMS Encryption-Log
- VS-REQ-46 VSM SCMS Sign-Log
- VS-REQ-47 VSM App Availability Log
- 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
- RFV-REQ-2 Receive TIM over Satellite
- RFV-REQ-3 Time
- RFV-REQ-4 Location
- RFV-REQ-5 General
- RFV-REQ-6 OBU Equipment
- RFV-REQ-7 OTA Updates
- MCP-REQ-1 V2V Exchange of BSMs

3.2.2.5 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 <-> OBU	Connected Vehicles broadcast and receive BSMs	5.1.1
OBU <-> Vehicle Location and Time System (VLTS)	OBU Incorporates Location and Time into BSM	5.3.1
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 Security Credential Revocations	5.13.5
Satellite <-> OBU	Delivery of Traveler Information to Vehicles	5.24.1
	Delivery of Latest Certificate Revocation List to Vehicles	5.24.2

3.2.3 Android™ Device Design

The Android™ Device that will be used in the vehicles to run the HMI and the GroundTruth Weather Cloud apps will be a Samsung Galaxy Tab A, Android™ based tablet or a Samsung Galaxy A50 smart phone.

3.2.3.1 Function of the Component

The primary purpose of the Android™ tablet and smart phone 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.

3.2.3.1.1 Functions/Services Brief description

The Android tablet and smart phone will serve as the primary devices that will house the HMI.

3.2.3.1.2 Input Data/Message Flows

Input flows to the tablet will include a WiFi connection to the OBU and when weather sensors are present a Bluetooth connection will also be an input from locally installed weather sensors.

3.2.3.1.3 Output Data/Message Flows

All output data from the HMI will include messages and alerts to users as well as weather sensor data (when applicable) to the OBU.

3.2.3.2 Android™ Device Hardware Platform

The following sections describe the Android tablet hardware.

3.2.3.2.1 Vendor/manufacturer & model number

The Manufacturer for this Tablet is Samsung and the Model number is SM-T580. The manufacturer for this smart phone is Samsung and the model number SM-A50SF/DS.

3.2.3.2.2 Picture and physical description of hardware

This device is a Samsung Galaxy Tab A running Android™ 6.0-10. A picture of the device can be seen in Figure 3-86.

Figure 3-86. Samsung Galaxy Tab A (Source WYDOT)

Additionally a Samsung Galaxy A50 device running Android™ 9.0 may also be used and can be seen in Figure 3-87.

Figure 3-87 Samsung A50 (Source Samsung)

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

The Samsung Galaxy Tab A has the following physical interfaces:

- Micro SD port
- USB v2.0 port

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

Hardware specifications for the table from the vendor include:

- Operating System – Android™ 6.0 Marshmallow
- Processor – Exynos 7870, Octa-Core (1.6 GHz)
- Memory – 2GB RAM, 16 GB ROM
- WiFi - Wi-Fi 802.11 a/b/g/n/ac, 2.4GHz +5.0GHz, VHT80
- Location Technology – GPS, Glonass
- Bluetooth – v4.2
- USB – v2.0
- External Memory – Capacity Up to 200 GB (microSD™ card)

Hardware specifications for the smart phone from the vendor include:

- Operating System – Android™ 9.0
- Battery information : 4000mAh Li-Ion Polymer (non-removable)
- Bluetooth profiles : A2DP, AVRCP, DI, HID, HOGP, HFP, HSP, MAP, OPP, PBAP, PAN, SPP
- Dimensions : 6.2" x 2.9" x .03"
- Display : 6.4" FHD+ Super Amoled
- Keyboard : Capacitive
- Memory : Internal Memory: 4GB RAM / 64GB ROM External memory - supports up to 512GB micro SD card
- Operating system : Android 9.0
- Processor : 2.3GHz Octa-Core Processor (Exynos 9610)
- Weight : 5.92 oz

3.2.3.2.5 Hardware design description relevant to CV function and performance

The Samsung Tab A tablet and Samsung Galaxy A50 smart phone has been chosen for the CV project

3.2.3.3 Android™ Device Operating Platform/ Development Stack

3.2.3.3.1 Vendor & version number

The Operating System vendor is Google and the Platform is Android™ Marshmallow (v6.0) or Android™ 9.0

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

Platform specifications related to the CV function and performance include the following:

- Display Size: 10.1”
- Display Technology: WUXGA
- Display Resolution: 1920x1200

For the Samsung Galaxy A50 the following specifications will be used:

- Dimensions : 6.2" x 2.9" x .03"
- Display : 6.4" FHD+ Super Amoled

3.2.3.4 Android Device Communication Interfaces

The Android™ tablet will communicate with the OBU through a WiFi communication link.

3.2.3.5 User Interface(s)

The User Interface for the Android™ tablet is the Marshmallow Android™ Operating System. The User Interface for the Samsung Galaxy A50 is the Android™ 9.0 Operating System.

3.2.3.6 Requirements Traceability

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

3.2.3.7 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

3.2.4 Environmental Sensors Design

To be installed on WYDOT Maintenance Vehicle.

3.2.4.1 Function of the Component

This section describes the function for the Weather Cloud environmental sensor.

3.2.4.1.1 Functions/Services Brief description

The Weather Cloud Environmental Sensors will collect and transmit data to the Android Tablet using the Weather Cloud GroundTruth application. The GroundTruth app is designed to be the gateway between the sensors and the HMI device. The GroundTruth app connects to the sensors using Bluetooth Low Energy (BLE) and writes the sensor data to a local file on the HMI.

3.2.4.1.2 Input Data/Message Flows

Input data for the WeatherCloud Environmental sensors include environmental data points. All data points are defined in the Interface Control document section 5.5.1.

3.2.4.1.3 Output Data/Message Flows

The version 1.4.X of GroundTruth Android Application Connects to vehicle mounted Bluetooth 4.1 sensor packs to receive real-time weather data from the sensor's readings. The GroundTruth app logs the data in JSON format in a file called "WYC(UTC time and date stamp).TXT" in the "Downloads/WC" directory of the HMI (the WC is a configurable directory location). The GroundTruth app will create an entry in the file every 30 seconds when vehicle speed is over "Z" MPH, a new file will be created every "X" entries with "X" being a configurable parameter.

The GroundTruth app will delete files older than "Y" days with "Y" being a configurable parameter.

The initial thought is to use 6 for "X", 7 for "Y", and 5 for "Z". So, a new file is created every 5 minutes (every 10 entries at 30 seconds per entry), files older than a week are deleted and records are only created when the vehicle is moving over 5 MPH.

The following additional Vehicle identification information can be turned on or off (configurable via text file) to include:

- Vehicle ID
- MAC bumper
- MAC sky
- RSSI bumper
- RSSI sky
- Status bumper
- Status sky
- Android software version
- Application name

3.2.4.2 Environmental Sensors Hardware Platform

3.2.4.2.1 Vendor/manufacturer & model number

The Vendor for this hardware is Weather Cloud no current model number is provided

3.2.4.2.2 Picture and physical description of hardware

The environmental sensor hardware consists of a sky sensor, and a road environmental sensor. An image of the sensors along with related wiring hardware can be seen in Figure 3-88.

Figure 3-88. Weather Cloud Environmental Sensor hardware (Source WYDOT)

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

The Weather Cloud sensors do not contain any physical interfaces outside of power inputs.

3.2.4.3 Environmental Sensors Operating Platform/ Development Stack

3.2.4.3.1 Vendor & version number

The Vendor for this hardware is Weather Cloud, no version is given for this hardware.

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

The GroundTruth Android app is designed to be the gateway between the sensors and the HMI device. The GroundTruth app connects to the sensors using Bluetooth Low Energy (BLE) and writes the sensor data to a local file on the HMI.

3.2.4.3.3 Operating Platform Configuration Data

When the Weather Cloud application starts, it reads an ASCII configuration file which tells the application:

- directory on tablet to save sensor log files
- maximum history of log files to keep, measured in days
- number of records per log file

3.2.4.4 Environmental Sensors Communication Interfaces

Environmental sensors connect to the Android GroundTruth app using Bluetooth Low Energy (BLE) communication protocol.

3.2.4.5 Environmental Sensors Device Messages

- Brief description of Messages exchanged by Component with references to applicable Triples Instances

3.2.4.6 Requirements Traceability

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

- VS-REQ-5 External Environment Sensor Data
- VS-REQ-5.1 External Environment Sensor Data Configuration
- VS-REQ-5.2 External Environment Sensor Data Management
- MV-REQ-1 Environmental Sensors
- MV-REQ-1.1 Environmental Sensor Equipment

3.2.4.7 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.
MV Environmental Sensors <-> WYDOT MV (HMI)	GroundTruth Android Application Function	5.5.1

3.2.5 OBU Applications Design

3.2.5.1 OBU Spot Weather Impact Warning Application

3.2.5.1.1 Function of the Application

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

3.2.5.1.1.1 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.

3.2.5.1.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

Figure 3-89 shows the Spot Weather Impact Warning application communications along the highway.

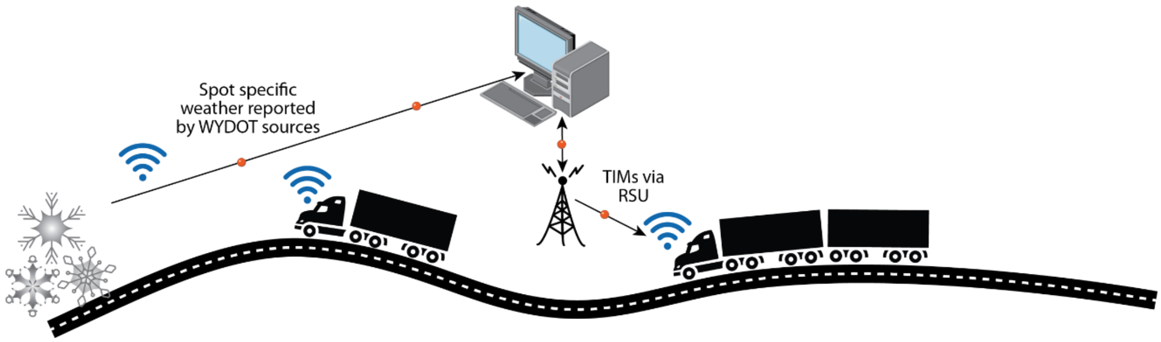


Figure 3-89. Spot Weather Impact Warning illustration (Source: WYDOT)

3.2.5.1.1.3 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 3-90 shows the Input/Output data flows for processing Spot Weather Impact warnings.

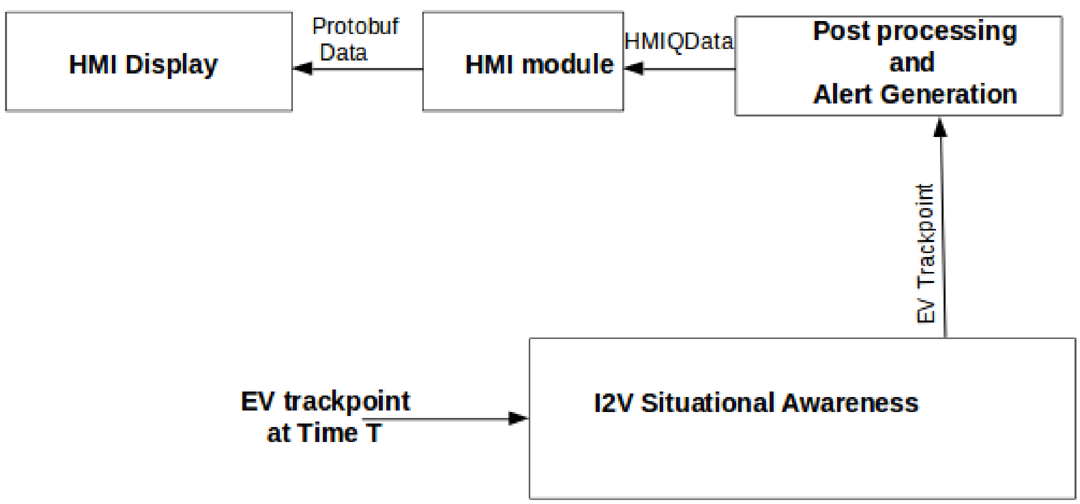


Figure 3-90. Input/Output data flows for I2V Processing (Source: WYDOT)

3.2.5.1.1.4 Output Data/Message Flows

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

3.2.5.1.2 Developer & version number

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

3.2.5.1.3 Application Message and Alerts Descriptions

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

3.2.5.1.3.1 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.

3.2.5.1.3.2 Describe algorithm to determine when messages and alerts are issued

This message is raised when a TIM is received from the RSU.

3.2.5.1.3.3 Summary tables of criteria for issuing messages and alerts

Table 3-73 shows the summary criteria for issuing a Spot Weather Impact Warning alert. Please note that Table A-1 has a complete list of TIMs and their associated requirements.

Table 3-73. 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.

3.2.5.1.4 Application Design Description

The sections below describe the Spot Weather Notification application design.

3.2.5.1.4.1 Schematic of major modules/functions

Figure 3-90 shows the major modules/functions that make up the design for the Spot Weather Impact Warning application.

3.2.5.1.4.2 Description of modules/functions

I2V Situational Awareness: This function forwards the input Ego Vehicle (EV) trackpoints (used to determine direction of travel) along with ITIS code to a post-processing and alert generation function.

Post Processing and Alert Generation: This function generates HMIQData and forwards it along with the IT IS code to the "HMI module".

HMI module: This module generates Protobuf data and forwards it along with the ITIS code to the "HMI display" block.

HMI display: Compares ITIS code with the different notifications. If it matches with ITIS code of the corresponding Spot Weather Impact Warning then the HMI displays the appropriate icon.

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

Figure 3-90 shows the process flow between modules/functions for the Spot Weather Impact Warning application.

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

I2V Situational Awareness: This function forwards the input EV trackpoints along with ITIS code to a post-processing and alert generation function.

Post Processing and Alert Generation: This function generates HMIQData and forwards it along with the IT IS code to the "HMI module".

HMI module: This module generates Protobuf data and forwards it along with the ITIS code to the "HMI display" block.

HMI display: Compares ITIS code with the different notifications. If it matches with ITIS code of the corresponding Spot Weather Impact Warning then the HMI displays the appropriate icon.

3.2.5.1.5 Application Data Tables

The sections below describe the application data tables for the Spot Weather Impact warning application.

3.2.5.1.5.1 Input data description tables

Table 3-74 shows the input data for the spot weather impact warning application.

Table 3-74. Description of input data for Spot Weather Impact Warning application

Data Name	Type	Unit	Description
Member Count	uint8_t	-	Number of ITIS codes in this message
ITISDataList[16]	union	-	List of ITIS data
ITISCode	uin8_t	-	ITIS codes within this message, in the format defined in part 3 of TIM message J2735.

3.2.5.1.5.2 Output data description tables

Table 3-75 shows the output data from the Spot Weather Impact Warning application.

Table 3-75. Output Data from Spot Weather Impact Warning application

Data Name	Type	Unit	Description
Icon	PNG image	-	Image displayed on the HMI

3.2.5.1.5.3 Data/database storage description diagrams and tables

No database is used with these applications.

3.2.5.1.6 Application Configuration Data

There is no configuration data for this application.

3.2.5.1.7 Application User Interface(s)

This application has no user interface. It does output icons to the HMI for display. Those are seen below.

3.2.5.1.7.1 Description of Operations/Driver Interface with illustrations

Please note that the current User Interface may be subject to change. Figure 3-91 shows the driver interface for the severe weather notification.

Figure 3-91. Severe Weather Notification (Source: WYDOT)

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

3.2.5.1.8 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

3.2.5.1.9 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.
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

3.2.5.2 OBU Work Zone Warning

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

3.2.5.2.1 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.

3.2.5.2.1.1 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 Table A-1 has a complete list of TIMs and their associated requirements.

3.2.5.2.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

Figure 3-92 shows the work zone warning application communications on the highway.

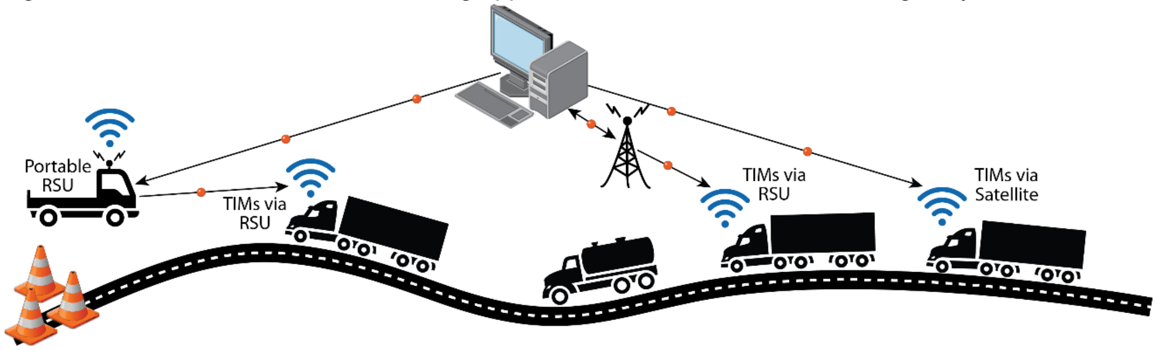


Figure 3-92. Work Zone Warning communications (Source: WYDOT)

3.2.5.2.1.3 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 3-93 shows the data flows for the Work Zone warning application.

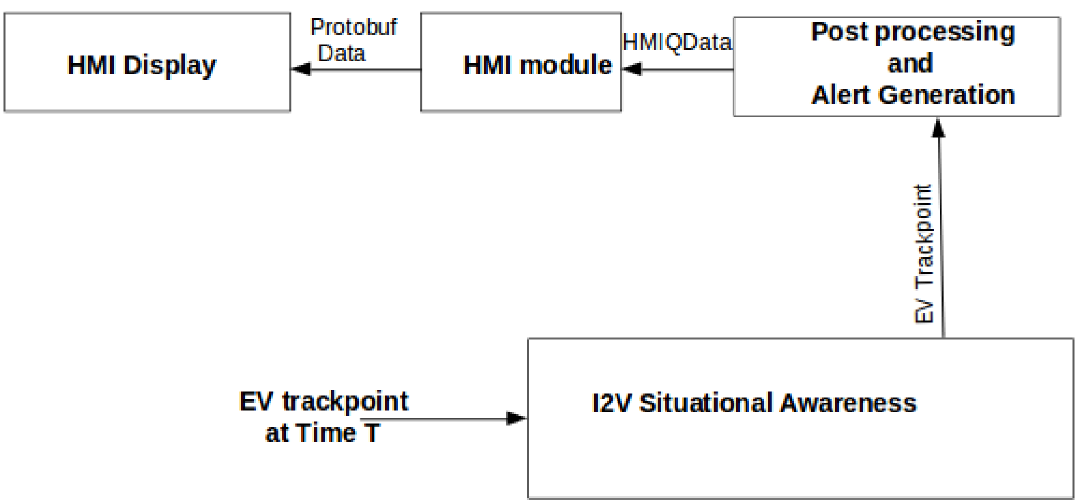


Figure 3-93. Work Zone Warning Data flows (Source: WYDOT)

3.2.5.2.1.4 Output Data/Message Flows

A Work Zone Icon (png image) is the output data for the application.

3.2.5.2.2 Developer & version number

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

3.2.5.2.3 Application Message and Alerts Descriptions

The sections below describe the messages and alert descriptions for the Work Zone Warning application.

3.2.5.2.3.1 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.

3.2.5.2.3.2 Describe algorithm to determine when messages and alerts are issued

This message is raised when a TIM is received from the RSU.

3.2.5.2.3.3 Summary tables of criteria for issuing messages and alerts

Table 3-76 shows the summary criteria for issuing a Work Zone Warning alert.

Table 3-76. Work Zone Warning Summary table for message criteria

Message or Alert	Issue Criteria
Work Zone Notification	• Work Zone Warning TIM is received from an RSU.

3.2.5.2.4 Application Design Description

The sections below describe the Work Zone Warning application design.

3.2.5.2.4.1 Schematic of major modules/functions

Figure 3-93 shows the major modules/functions that make up the design for the Work Zone Warning application.

3.2.5.2.4.2 Description of modules/functions

I2V Situational Awareness: This function forwards the input EV trackpoints along with ITIS code to a post-processing and alert generation function.

Post Processing and Alert Generation: This function generates HMIQData and forwards it along with the IT IS code to the "HMI module".

HMI module: This module generates Protobuf data and forwards it along with the ITIS code to the "HMI display" block.

HMI display: Compares ITIS code with the different notifications. If it matches with ITIS code of "Work Zone Warning" then the HMI displays the icon for Work Zone Warning.

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

Figure 3-93 shows the process flow between modules/functions for the Work Zone Warning application.

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

I2V Situational Awareness: This function forwards the input EV trackpoints along with ITIS code to a post-processing and alert generation function.

Post Processing and Alert Generation: This function generates HMIQData and forwards it along with the IT IS code to the "HMI module".

HMI module: This module generates Protobuf data and forwards it along with the ITIS code to the "HMI display" block.
HMI display: Compares ITIS code with the different notifications. If it matches with ITIS code of "Work Zone Warning" then the HMI displays the icon for Work Zone Warning.

3.2.5.2.5 Application Data Tables

The sections below describe the application data tables for the Work Zone warning application.

3.2.5.2.5.1 Input data description tables

Table 3-77 shows the input data for the Work Zone warning application.

Table 3-77. Description of input data for Work Zone Warning application

Data Name	Type	Unit	Description
Member Count	uint8_t	-	Number of ITIS codes in this message
ITISDataList[16]	union	-	List of ITIS data
ITISCode	uin8_t	-	ITIS codes within this message, in the format defined in part 3 of TIM message J2735.

3.2.5.2.5.2 Output data description tables

Table 3-78 shows the output data from the Work Zone Warning application.

Table 3-78. Output Data from Work Zone Warning application (Source: WYDOT)

Data Name	Type	Unit	Description
Icon	PNG image	-	Work Zone Warning image displayed on the HMI

3.2.5.2.5.3 Data/database storage description diagrams and tables

No database is used with these applications.

3.2.5.2.6 Application Configuration Data

There is no configuration data for this application.

3.2.5.2.7 Application User Interface(s)

This application has no user interface. It does output icons to the HMI for display. Those are seen below.

3.2.5.2.7.1 Description of Operations/Driver Interface with illustrations

Figure 3-94 shows the driver interface for the work zone warning notification.

Figure 3-94. Work Zone Notification (Source: WYDOT)

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

3.2.5.2.8 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

3.2.5.2.9 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.
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

3.2.5.3 OBU I2V Situational Awareness

3.2.5.3.1 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.

3.2.5.3.1.1 Functions/Services Brief description

This application belongs to 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 Table A-1 has a complete list of TIMs and their associated requirements.

3.2.5.3.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

Figure 3-95 shows a graphical illustration of vehicle and infrastructure communications along the highway for this application.

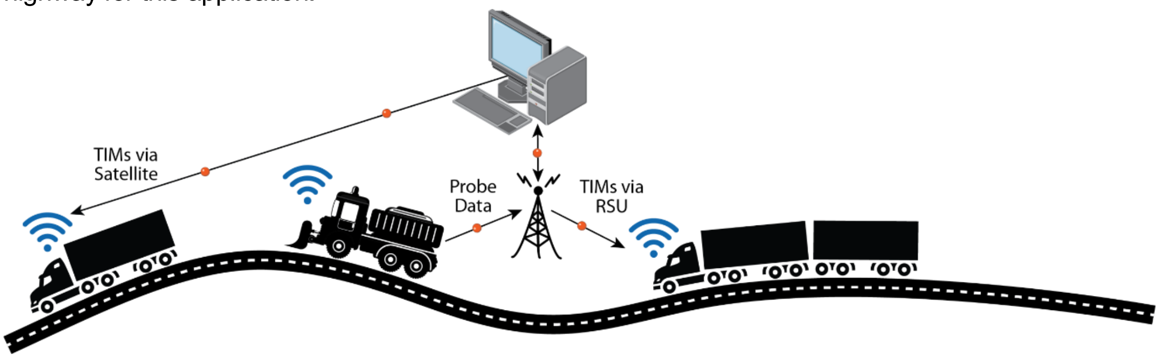


Figure 3-95. I2V Situational Awareness communications (Source: WYDOT)

3.2.5.3.1.3 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. Figure 3-96 shows the data flows for the I2V Situational Awareness application.

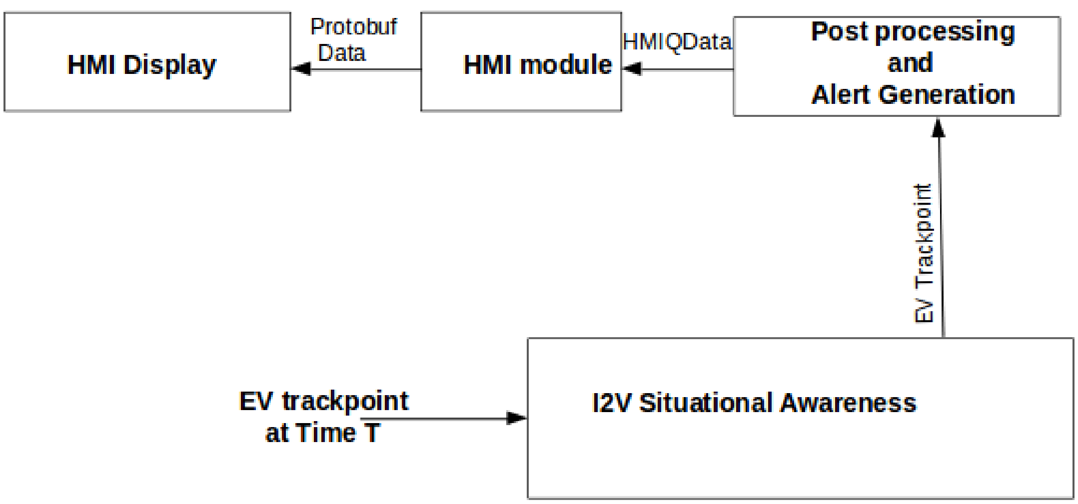


Figure 3-96. I2V Situational Awareness Data flows (Source: WYDOT)

3.2.5.3.1.4 Output Data/Message Flows

An Icon (png image) is the output data for the application.

3.2.5.3.2 Developer & version number

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

3.2.5.3.3 Application Message and Alerts Descriptions

The sections below describe the messages and alert descriptions for the I2V Situational Awareness application.

3.2.5.3.3.1 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 and will show on the HMI along with any other V2V or V2I warnings and alerts.

3.2.5.3.3.2 Describe algorithm to determine when messages and alerts are issued

This message is raised when a TIM is received from the RSU.

3.2.5.3.3.3 Summary tables of criteria for issuing messages and alerts

Table 3-79 shows the summary criteria for I2V Situational Awareness notifications.

Table 3-79. 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.
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.

3.2.5.3.4 Application Design Description

The sections below describe the I2V Situational Awareness application design.

3.2.5.3.4.1 Schematic of major modules/functions

Figure 3-96 shows the major modules/functions that make up the design for the I2V Situational Awareness application.

3.2.5.3.4.2 Description of modules/functions

I2V Situational Awareness: This function forwards the input EV trackpoints along with ITIS code to a post-processing and alert generation function.

Post Processing and Alert Generation: This function generates HMIQData and forwards it along with the IT IS code to the "HMI module".

HMI module: This module generates Protobuf data and forwards it along with the ITIS code to the "HMI display" block.

HMI display: Compares ITIS code with the different notifications. The appropriate icon based on the ITIS code is then displayed on the HMI.

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

Figure 3-96 shows the process flow between modules/functions for the I2V Situational Awareness application.

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

I2V Situational Awareness: This function forwards the input EV trackpoints along with ITIS code to a post-processing and alert generation function.

Post Processing and Alert Generation: This function generates HMIQData and forwards it along with the IT IS code to the "HMI module".
HMI module: This module generates Protobuf data and forwards it along with the ITIS code to the "HMI display" block.

HMI display: Compares ITIS code with the different notifications. The appropriate icon based on the ITIS code is then displayed on the HMI.

3.2.5.3.5 Application Data Tables

The sections below describe the application data tables for the I2V Situational Awareness application.

3.2.5.3.5.1 Input data description tables

Table 3-80 shows the input data for the I2V Situational Awareness application.

Table 3-80. Description of input data for I2V Situational Awareness application

Data Name	Type	Unit	Description
Member Count	uint8_t	-	Number of ITIS codes in this message
ITISDataList[16]	union	-	List of ITIS data
ITISCode	uin8_t	-	ITIS codes within this message, in the format defined in part 3 of TIM message J2735.

3.2.5.3.5.2 Output data description tables

Table 3-81 shows the output data from the Work Zone Warning application.

Table 3-81. Output Data from Work Zone Warning application

Data Name	Type	Unit	Description
Icon	PNG image	-	Corresponding I2V Situational Awareness image displayed on the HMI

3.2.5.3.5.3 Data/database storage description diagrams and tables

No database is used with these applications.

3.2.5.3.6 Application Configuration Data

There is no configuration data for this application.

3.2.5.3.7 Application User Interface(s)

This application has no user interface. It does output icons to the HMI for display. Those are seen below.

3.2.5.3.7.1 Description of Operations/Driver Interface with illustrations

Figure 3-97 shows the driver interface for the I2V Situational Awareness notification.

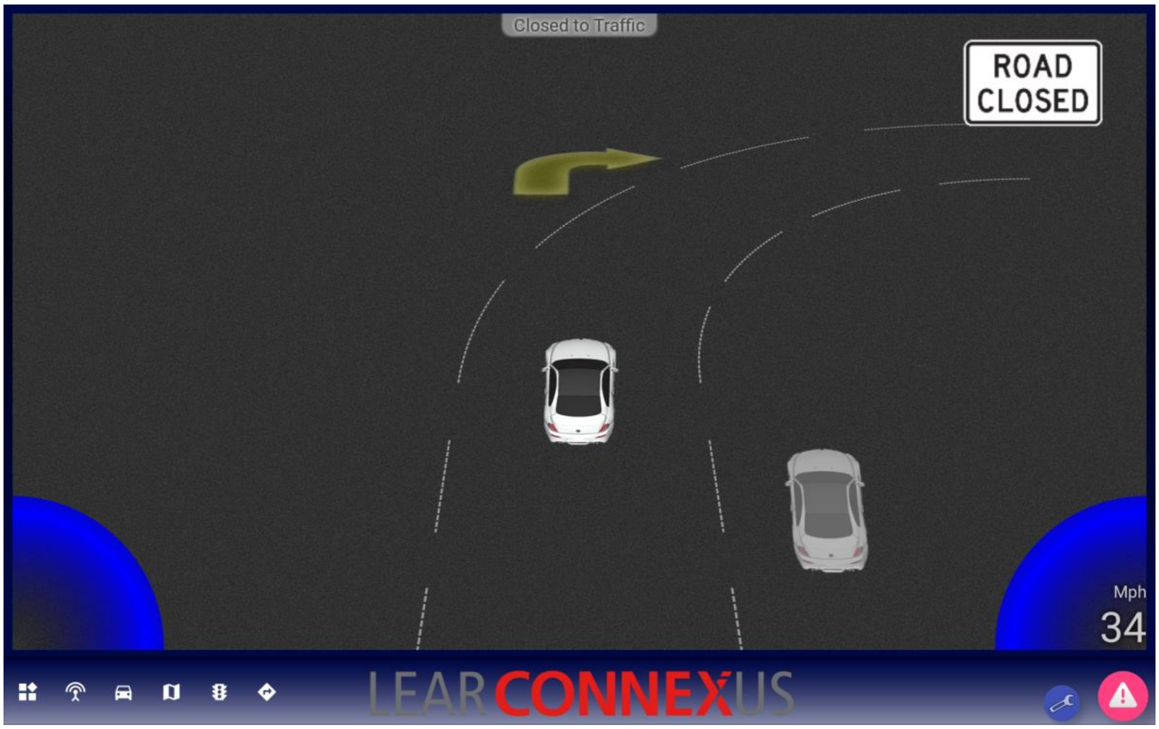


Figure 3-97. Road Closure Notification (Source: WYDOT)

3.2.5.3.7.2 Description of Maintenance User Interface with illustrations

This application does not contain a maintenance user interface.

3.2.5.3.8 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

3.2.5.3.9 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.
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

3.2.5.4 OBU Distress Notification Application

3.2.5.4.1 Function of the Application

The sections below describe the functions of the Distress Notification application.

3.2.5.4.1.1 Functions/Services Brief description

This application enables connected vehicles to communicate a distress status defined as:

- ~~When the vehicle's sensors detect an air bag deployment or vehicle disabled over the CAN bus~~ *[This no longer applies to this Pilot]*
- The vehicle's operator manually initiates a distress status with a selection from the Human Machine Interface (HMI)

The vehicle then generates and broadcasts a distress message (e.g., Mayday) to the nearest RSU. When an RSU is not within communication range, the message is received by connected vehicles that are in the vicinity and forwarded to an RSU that forwards it to the Wyoming CV System. The Distress Message will include the location, time of message, distress message explanation (e.g., air bag deployed, vehicle disabled, operator initiated), and vehicle type. Additionally, the distress notification received by nearby connected vehicles is broadcast to notify oncoming vehicles that a distressed vehicle is ahead. Although this application is loosely based on the Mayday application description from J3067 Section 2.5.3.3, it is built on a higher priority TIM communication using J2735 March 2016, Section 5.16, Part 3, Integrated Transport Information System (ITIS) advisory elements.

3.2.5.4.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

Figure 3-98 shows communications for the distress notification along the highway.

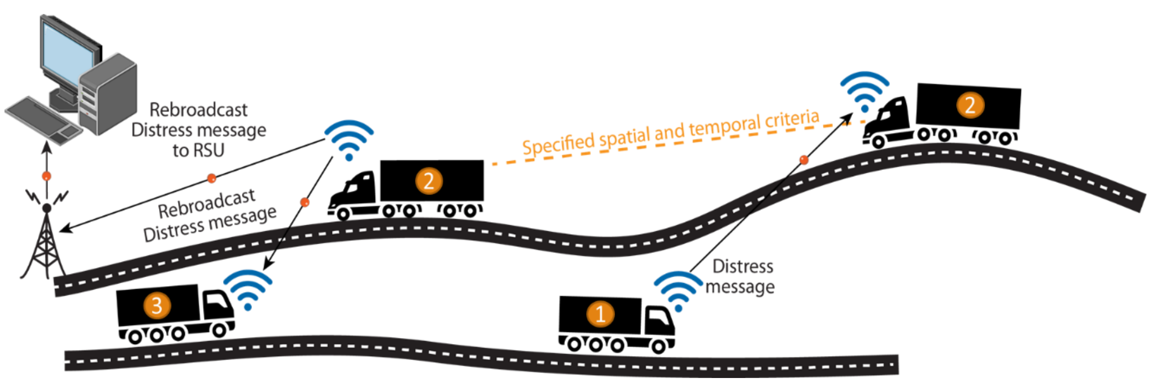


Figure 3-98. Distress Notification highway communications (Source: WYDOT)

3.2.5.4.1.3 Input Data/Message Flows

There are two types of input data for the Distress Notification application. These include a ~~system generated distress~~ user generated distress and distress TIM received from another vehicle. ~~The system generated distress notification is triggered from the continuous monitoring for the CAN Bus AIR_BAG_DEPLOYMENT event for the vehicle.~~ *[This no longer applies to this Pilot].*

The user generated distress originates from a button the user presses on the HMI. Figure 3-99 shows the input and the output flows for the distress notification application.

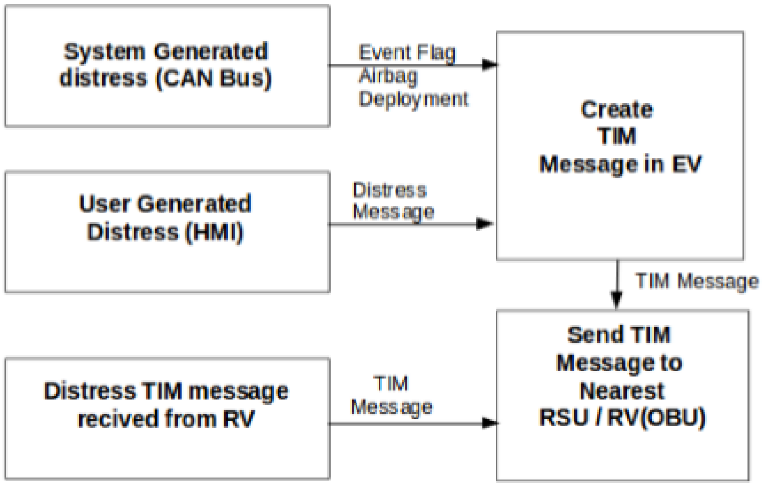


Figure 3-99. Input/Output flows for the Distress Notification application. (Source: Lear)
[NOTE: System generated distress (CAN Bus) no longer applies to this Pilot.]

3.2.5.4.1.4 Output Data/Message Flows

Output for the Distress Notification application consists of an encoded TIM message that contains the following data elements: the distressed vehicles location data, the distress timestamp, and the reason for the distress (e.g. vehicle breakdown, accident, etc.). Figure 3-99 shows the output flows for the Distress Notification application.

3.2.5.4.2 Developer & version number

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

3.2.5.4.3 Application Message and Alerts Descriptions

The following sections describe the alerts and messages issued by the OBU Distress Notification application.

3.2.5.4.3.1 Descriptions and illustrations of messages and alerts issued by application

Distress Notification Verification: This message asks the user to verify that they wish to initiate a distress notification. A mockup of this message can be seen in Figure 3-100.

Figure 3-100. Verify Distress Notification. (Source: Lear)

OBU Receives Distress Notification When a remote DN TIM is received, a check is made to determine if the current vehicle is moving towards the distressed vehicle or away from it. If the vehicle is moving towards the distressed vehicle, this info is displayed on HMI informing the driver about the accident. Whereas if we are moving away from the distressed vehicle, we broadcast the received DN TIM on channel 172 at a configurable rate for next 10 minutes or 5 miles. Once the vehicle crosses 5 miles or 10 minutes, the DN relay will stop until a RSU with DN service is detected.

Any time after receiving a remote DN TIM, the relay vehicle continuously keeps monitoring for the presence of RSU with DN service. Whenever it is available, DN TIM(s) are relayed on channel 172 once and then relay function stops.

3.2.5.4.3.2 Describe algorithm to determine when messages and alerts are issued

Distress Notification Verification: This message is issued to the user when they have clicked on a button in the HMI to issue a new Distress Notification.

OBU Receives Distress Notification: Issued when a new Distress Notification is received from an OBU.

Apart from the reason for the distress the vehicle’s location, path information, and the timestamp of distress is also encoded in the broadcasted TIM message. This DN TIM message is broadcast on channel 172 at configurable rate which will be received by nearby OBUs and RSU (if available in DSRC vicinity).

3.2.5.4.3.3 Summary tables of criteria for issuing messages and alerts

Table 3-82 shows the alerts/messages issued by the Distress Notification application along with issuance criteria.

Table 3-82. Distress Notification Messages and Alerts

Message or Alert	Issue Criteria
Verify Distress Notification	• User clicks on HMI Distress Notification Button.
Display Received Distress Notification	• OBU receives a new Distress Notification.

3.2.5.4.4 Application Design Description

The following sections describe the Application design for the Distress Notification application.

3.2.5.4.4.1 Schematic of major modules/functions

The schematic of major modules within the Distress Notification can be seen in Figure 3-99. Input/Output flows for the Distress Notification application.

3.2.5.4.4.2 Description of modules/functions

~~**System generated distress –** The CAN bus is continuously monitored. If it reports event AIR BAG DEPLOYMENT, this indicates that the vehicle has been involved in an accident and a new TIM message is created with an ITIS code~~. *[This no longer applies to this Pilot]*

User generated distress – In cases where there is a vehicle breakdown ~~or the vehicle is not equipped with a CAN bus~~, the user can initiate a distress notification manually from the HMI. In this case, a new TIM message is created with ITIS code 531 (incident).

TIM Reception - If a distress TIM is received from a nearby OBU, that means there is no RSU providing DN service in the vicinity of distressed vehicle. In this case an attempt will be made to send this TIM to an RSU providing DN service.

TIM Transmission - Before sending the locally created distress TIM or the received distress TIM, a check is made to see if there is a RSU present nearby proving DN service. If available, a TIM is sent to the RSU. If such RSU is not available in the DSRC vicinity, the TIM is then forwarded to other nearby OBUs. This process is repeated (for the next 5 Kilometers) until the distress TIM is successfully transmitted to a RSU proving DN service.

3.2.5.4.5 Application Data Tables

The sections below describe the data used within the Distress Notification application.

3.2.5.4.5.1 Input data description tables

Table 3-83 shows the input data fields for the Distress Notification application.

Table 3-83. Input data Description table for Distress Notification application

Data Name	Type	Unit	Description
Timestamp	Double	Seconds	Unix time in seconds
Latitude	Double	Decimal-Degrees	Vehicles latitude from GPS sensor
Longitude	Double	Decimal-Degrees	Vehicles longitude from GPS sensor
Altitude	Double	Meters	Vehicles altitude from GPS sensor

Data Name	Type	Unit	Description
Course	Double	Degrees from north	Vehicles heading from GPS sensor
~~EventFlags~~	~~Uint16_t~~	~~NIL~~	~~Airbag deployment event from CAN bus~~
Distress	DistressMsg	NIL	Distress Message sent from HMI by user
EncodedTIM	WsmMsg	NIL	Encoded TIM payload received from other vehicle

3.2.5.4.5.2 Output data description tables

Table 3-84 shows the output data fields for the Distress Notification application.

Table 3-84. Output data Description tables for Distress Notification application.

Data Name	Type	Unit	Description
WsmReq	p16093WSMTxRequest	NIL	Message Frame containing Encoded TIM

3.2.5.4.6 Application User Interface(s)

The following sections describe the User interface for the OBU Distress Notification application.

3.2.5.4.6.1 Description of Operations/Driver Interface with illustrations

Figure 3-100 shows the user interface for the verification of manually initiating a Distress Notification message.

3.2.5.4.7 Requirements Traceability

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

- VS-REQ-15 Distress Notification ID
- VS-REQ-15.1 Log
- VS-REQ-16 Create Distress Notification
- ~~VS-REQ-16.1 System-Generated Distress Notification~~
- VS-REQ-16.2 Driver-Generated Distress Notification
- VS-REQ-17 DNM-Region
- VS-REQ-18 DN PSID

3.2.5.4.8 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	OBUs broadcast and receive Distress Notifications	5.1.2
OBU <-> Vehicle Driver	Vehicle Driver Declares a Distress Situation using HMI	5.2.2
	OBU Alerts Vehicle Driver of Distressed Vehicle	5.2.3

3.2.5.5 OBU Forward Collision Warning

3.2.5.5.1 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.

3.2.5.5.1.1 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).

3.2.5.5.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

Figure 3-101 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.

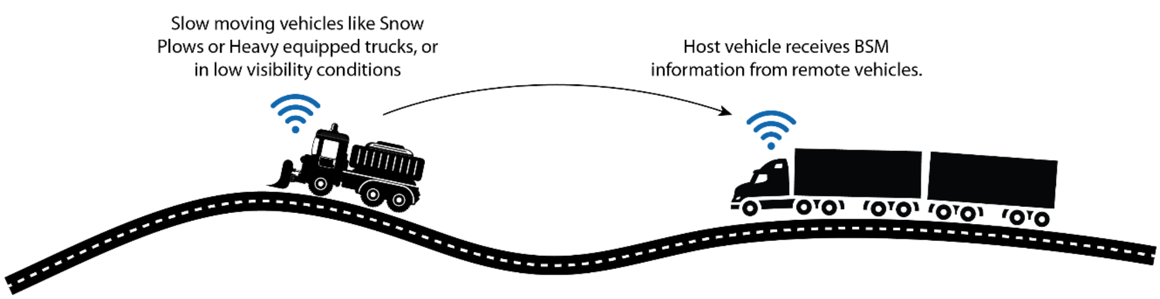


Figure 3-101. Forward Collision Warning Concept Diagram (Source: WYDOT).

3.2.5.5.1.3 Input Data/Message Flows

Two types of data are required at the input of FCW application configuration data and vehicle data.

Configuration data is read from a configuration file. This data contains information about user configured parameters for the FCW application.

Vehicle data contains information about EV and RV trackpoints at a particular time - T. A vehicle trackpoint contains vehicle identification information, GPS information of vehicle, and the path history information of vehicle.

A "Distance and time relevance check" block processes the input EV and RV track points to compute following information and fills in a "TrackStatus" structure with the computed results. Computed results consist of relative position of RV with respect to EV, heading alignment of RV with respect to EV, and distance between EV and RV.

Both EV and RV trackpoints as well the TrackStatus structure is then passed to a “Trace And Lane Relevance Check” for further processing. This module computes the Relative lane of RV with respect to EV and writes this information to the TrackStatus structure. EV-RV trackpoints and TrackStatus information is then passed to a Post-Processing/Alert-generation module. This module makes the final decision about generation of alert. Figure 3-102 shows the input/output flows for the forward collisions warning design.

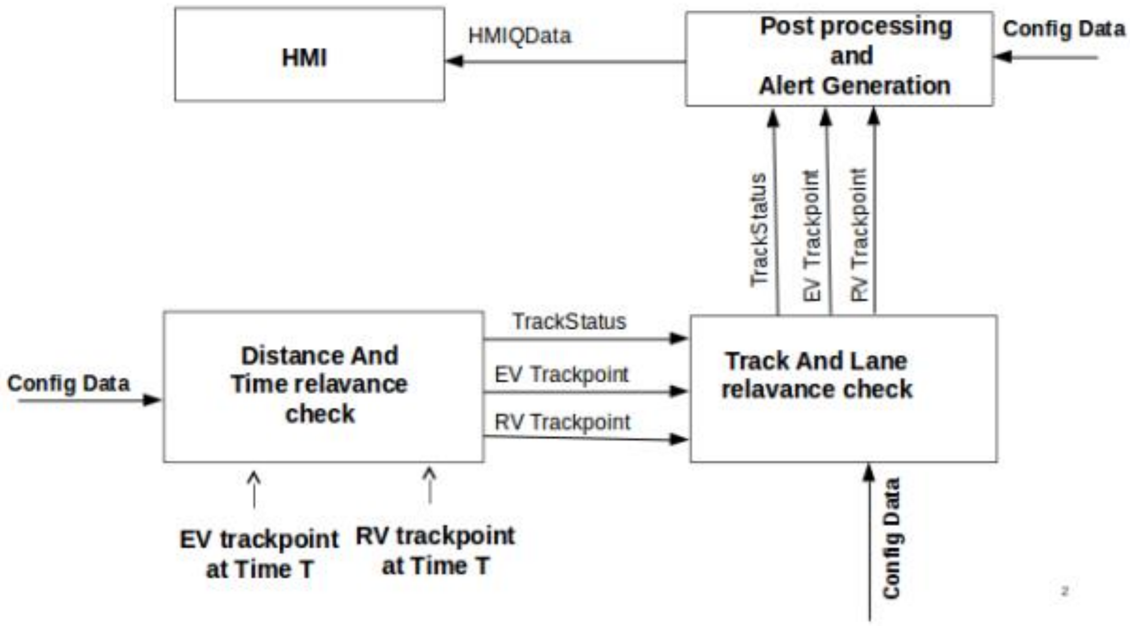


Figure 3-102. Forward Collision Warning Input/Output figure. (Source: Lear)

3.2.5.5.1.4 Output Data/Message Flows

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

3.2.5.5.2 Developer & version number

This application is developed by Lear’s DSRC-Safety Applications team

Version # 1.0

3.2.5.5.3 Application Message and Alerts Descriptions

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

3.2.5.5.3.1 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.

3.2.5.5.3.2 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.

3.2.5.5.3.3 Summary tables of criteria for issuing messages and alerts
Table 3-85 contains a summary of all alerts and messages issued to the user from the FCW application.

Table 3-85. Forward Collision Warning Alert Summary. (Source: Lear)

Message or Alert	Issue Criteria
Advisory Alert	• TTC > imminent threshold • TTC < advisory threshold
Imminent Alert	• TTC < imminent threshold

3.2.5.5.4 Application Design Description

3.2.5.5.4.1 Schematic of major modules/functions
3.2.5.5.4.2 Description of modules/functions
3.2.5.5.4.3 Diagram of process flow/algorithms between major modules/functions
3.2.5.5.4.4 Descriptions of process flow/algorithms between major modules/functions

3.2.5.5.5 Application Data Tables
This section described all of the data for input and output to the FCW application.

3.2.5.5.5.1 Input data description tables
Table 3-86 describes all of the input data descriptions for the FCW application.

Table 3-86. Input Data to FCW application. (Source: Lear)

Data Name	Type	Unit	Description
Vehicle Data	Structure	N/A	Represents the track point of the vehicle
Vehicle Id	Uint32_t	N/A	Represents the vehicle identifier
UTC Time	Double	Seconds	Represents the time T for Vehicle data, part of the GPS data
Latitude	Double	Radian	Part of GPS data.
Longitude	Double	Radian	Part of GPS data.
Elevation	Double	Radian	Part of GPS data.
Speed	Double	Meters/sec	The speed of the vehicle, part of the GPS data.
NoOfPathHistoryPoints	Uint8_t	N/A	Number of path history points for a track point
Array of path history	GPS Data Structure	N/A	Contains the previous GPS data of vehicle

3.2.5.5.5.2 Output data description tables
Table 3-87 describes all of the output data descriptions for the FCW application.

Table 3-87. Output data from FCW application. (Source: Lear)

Data Name	Type	Unit	Description
Track Status	Structure	N/A	Represents the status of RV track point, contains flags related to FCW.
Track Id	Uint32_t	N/A	Represents the RV vehicle
Time Stamp	Double	Seconds	Represents the time T for RV vehicle data
IsFCW	Uint8_t	N/A	The flag for FCW
Relative Position	Enum	N/A	Represents the position of RV with regards to EV
Relative Lane	Enum	N/A	Represents the lane of RV with regards to EV
Heading Alignment	Double	Seconds	Represents the heading alignment of RV with regards to EV
Time To Collision	Double	Seconds	Represents the time to collision of EV with RV.

3.2.5.5.5.3 Data/database storage description diagrams and tables

The FCW application does not store any data within a database or by any other means.

3.2.5.5.6 Application Configuration Data

Table 3-88 describes all of the application configuration data for the FCW application.

Table 3-88. FCW Application Configuration Parameters. (Source: Lear)

Configuration Parameter	Description
Threshold_TTC_ForAdvisoryFCW	The threshold (in seconds) for the Advisory message to be issued prior to impact with RV
Threshold_TTC_ForImminentFCW	The threshold (in seconds) for the Imminent collision message to be issued prior to impact with RV

3.2.5.5.7 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.

3.2.5.5.7.1 Description of Operations/Driver Interface with illustrations

Figure 3-103 shows a sample HMI screen shot for the advisory message from the Forward Collision Warning application.

Figure 3-103. FCW Advisory Screenshot. (Source: Lear)

Figure 3-104. FCW Imminent Collision Screenshot. (Source: Lear)

3.2.5.5.7.2 Description of Maintenance User Interface with illustrations
There are no User Interface options

3.2.5.5.8 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

3.2.5.5.9 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.
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

3.2.5.6 OBU Vehicle Support Services

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

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

3.2.5.6.1.1 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 prioritization of 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 application 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.

3.2.5.6.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway
Figure 3-105 shows the highway communications for the OBU Support services application along the highway.

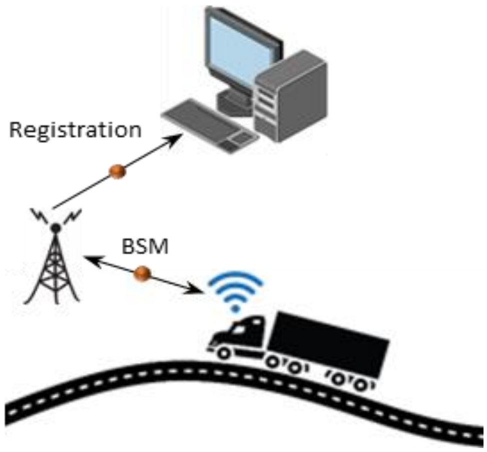


Figure 3-105. OBU Support Services Communications. (Source: WYDOT)

3.2.5.6.1.3 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 Lear. Figure 3-106 shows the data flows between different networking layers (modules and functions shown are defined in section 3.2.5.6.4).

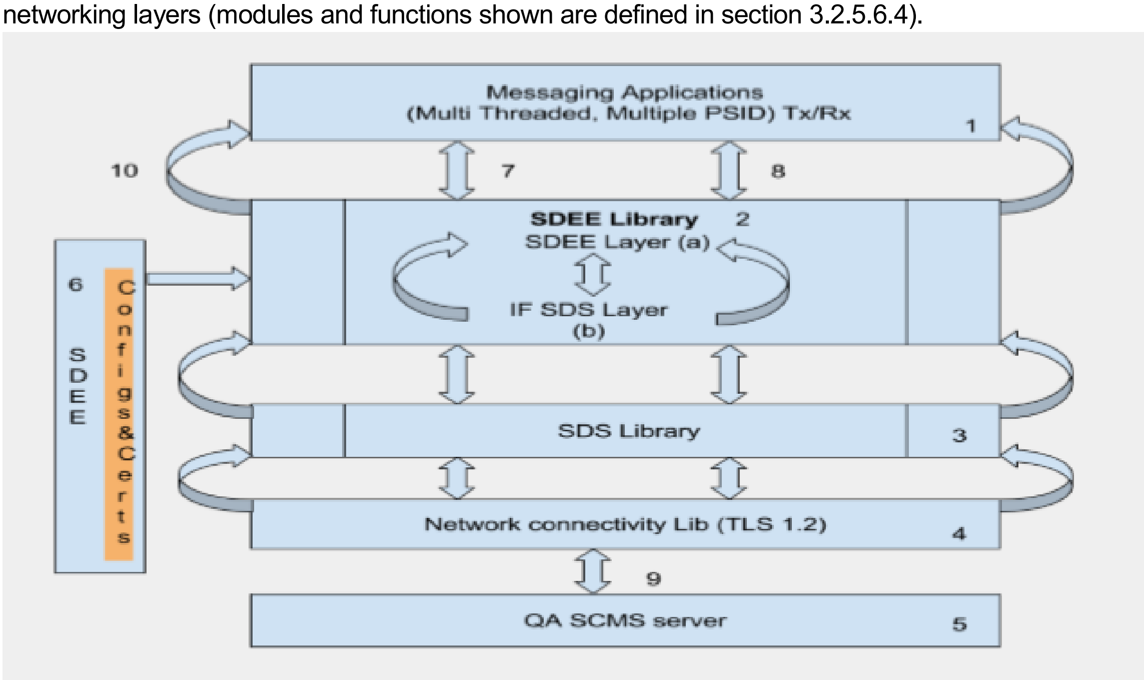


Figure 3-106. Vehicle Support Services Data Flows. (Source: Lear)

3.2.5.6.1.4 Output Data/Message Flows

The output flows for the OBU Vehicle Support Services application consist of log file transfers from the HMI to the ODE server. Log files from environmental sensors are deposited on the HMI and then transferred from the OBU to the ODE through the RSU (used as a router).

3.2.5.6.2 Developer & version number

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

3.2.5.6.3 Application Message and Alerts Descriptions

There are no messages or alerts issued by this application.

3.2.5.6.4 Application Design Description

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

3.2.5.6.4.1 Schematic of major modules/functions

Figure 3-106 shows a schematic of the major modules/functions for the OBU Support Services application. The primary module for support Services is the Secure Data Exchange Utility (SDEE).

3.2.5.6.4.2 Description of modules/functions

SDEE: The SDEE module supports multi-threaded applications to communicate simultaneously with the underlying security algorithm services and hence boost performance. Signing and verification operations are supported as asynchronous operations so that applications have no need to block on the Application Programming Interface (API) calls.

Location and Time Retrieval: The SDEE library provides functions to retrieve Location and Time Service (LTS) from the installed GPS (see ICD LTS interface for details).

Logging Functionality: The SDEE 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 (purge ninth)
  - Location, time, alert (FCW, TIM, not DNM)
- BSM once every 30 seconds (purge second)
  - 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
  - If event is longer than 1-minute drop to 1 Hz for host and remove vehicles
  - Add time to each record for all BSMs (from 1609.2 header)
- Received messages (purge third)
  - 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 (purge seventh)
  - Location, time, environmental log
  - Second priority for sending this log
- DNM (purge eight)
  - Location, time, DNM (log first unique DNM for Distressed vehicle and for each relay/received vehicle)
  - Top priority for sending this log
- OBU upgrades (purge fourth)
  - Log success/fail of firmware updates
  - Log availability of firmware updates
- SCMS (purge fifth)
  - Log connections to SCMS
- System log (very PII sensitive, just for internal use and will have to be locked down and encrypted, may want to exclude collection of this once the pilot is working well) (purge sixth)

- 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.csv.gzip). Log types will include Driver_Alert, BSM_30Second, BSM_Event, Received_Message, Environmental, DNM, 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 milliseconds 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 SDEE follow the design detailed in the SCMS Wiki (https://wiki.campllc.org/display/SCP/SCMS+CV+Pilots+Documentation).

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

Figure 3-106 show the process flow among the different components of the major modules/functions for the OBU Vehicle Support services application.

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

The process flows for Figure 3-106 are described below.

1. Applications

These are the applications utilizing security services. Application can be multi-threaded registers that may communicate for different PSID's at the same time with the SDEE module.

2. SDEE Library

a. The SDEE layer, exposes the API's to Applications. It also keeps track of the context of the application registered.

b. Interface SDS layer. This layered distinguishes the multiple stack support apart from the Lear security stack.

3. SDS Library

Secure data services library has the algorithms support to perform the sign, verification, encryption, and decryption operations. This Library/stack can be from Lear or other supported vendors.

4. Network connectivity Library This library is responsible for the SCMS server connection establishment and secure data reception from servers using TLS1.2.

5. QA SCMS server

At present connectivity pilots Wave devices will communicate with a server to download the certificates.

6. SDEE Configs and certificates
This block contains the profile configurations, Global configurations for the applications with respective PSID. The preloaded certificates for the PSID are stored under this logical block. Tools like certAdmin/certadm are available and can be used to parse and load the certificates. This block also performs the certificate management.

7, 8. Concurrent operations
These arrows (Figure 3-106) depict the parallel communication by applications (BSM, TIM, SPAT, MAP) to the SDEE module and further down the stack. This multi-threading with asynchronous operation callbacks helps in stack performance improvement.

9. TLS communication
Stream socket communications to the SCMS server uses TLS 1.2 channel. The SDS layer utilizes this library for SCMS communications.

10. Callbacks
Callback arrows are part of the asynchronous operation handling. While registering for security services if callbacks are mentioned then signed, verification operations can be achieved asynchronously so that applications will not be blocked.

3.2.5.6.5 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
- VS-REQ-36 Transmit Data
- VS-REQ-36.1 Transmit Environmental Data
- VS-REQ-36.2 TVI Data Management-Log
- VS-REQ-49 Architectural
- VS-REQ-50 Safety Communication

3.2.5.6.6 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 Copies Log File to ODE	5.16.1
	ODE Updates OBU Firmware OTA	5.16.2

3.2.5.7 OBU Vehicle Trust Management

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

3.2.5.7.1 Function of the Application

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

3.2.5.7.1.1 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.

3.2.5.7.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

Figure 3-107 illustrates highway communications for the OBU Trust Management application.

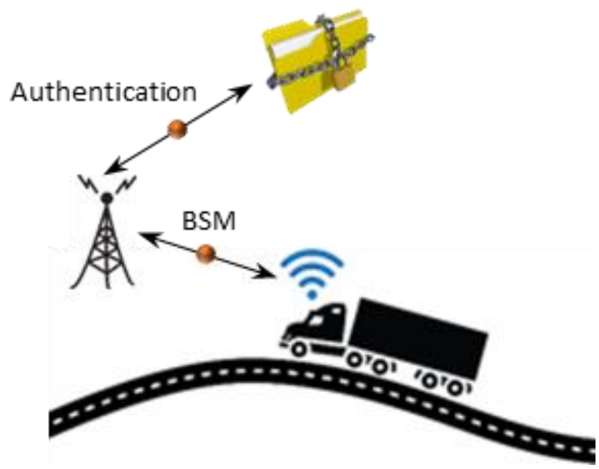


Figure 3-107. OBU Trust Management highway communications. (Source: WYDOT)

3.2.5.7.1.3 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 3-108 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 3-108. OBU Vehicle Trust Management Data Flows. (Source: Lear)

3.2.5.7.1.4 Output Data/Message Flows

Output from the OBU Trust Management application include signed BSM and TIM messages.

3.2.5.7.2 Developer & version number

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

3.2.5.7.3 Application Message and Alerts Descriptions

There are no messages or alerts issued by this application.

3.2.5.7.4 Application Design Description

The sections below describe the OBU Trust Management application design.

3.2.5.7.4.1 Schematic of major modules/functions

See Figure 3-108 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.

3.2.5.7.4.2 Description of modules/functions

Each Messaging application defined on the OBU such as (BSM, SPAT, MAP, TIM) should use the flow in Figure 3-106, to register with the SDEE module. This allows the application the ability to use the security services. A sample program for usage can be accessed at http://support.aradasystems.com/file.php?tab=files&file=4536

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

Figure 3-106 shows the process flow diagrams for applications signing and validating messages.

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

The following is the process flow for applications to sign and validate messages with the SDEE service.

1. Registration
Applications are required to register with the security services. After registering the SDEE module returns the unique context handle for further communication. The unique handle allows signing/verification operations to be performed in the multi-threaded environment.

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.

3.2.5.7.5 Requirements Traceability

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

- SCMS-REQ-2 Vehicle System SCMS Use
- SCMS-REQ-2.1 SCMS Vehicle System Certificates
- SCMS-REQ-2.2 SCMS Vehicle System Misbehavior Reporting
- SCMS-REQ-2.3 SCMS Vehicle System Certificates Revocation List (CRL)
- SCMS-REQ-2.4 SCMS Vehicle System Rejection

3.2.5.7.6 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

3.2.6 Mobile Applications Design

3.2.6.1 WYDOT 511 integration (Android & iOS)

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

3.2.6.1.1 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.

3.2.6.1.1.1 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.

3.2.6.1.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

This application is not directly involved in any vehicle/infrastructure communications on the highway.

3.2.6.1.1.3 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 blowover warnings. The other input flow included is truck parking availability information for truck parking locations along I80. Figure 3-109 shows the CV related 511 app message flows.

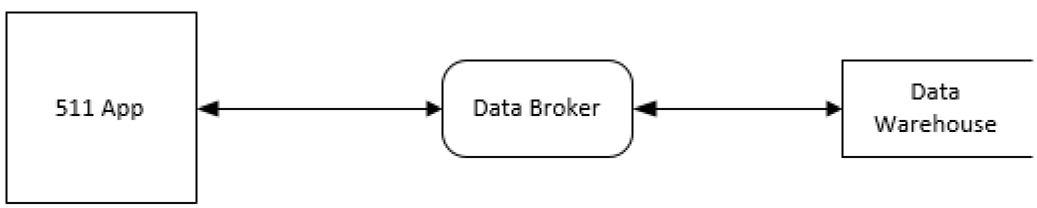


Figure 3-109. 511 App Message Flows (Source WYDOT)

3.2.6.1.1.4 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 3-109 shows the output flow of the parking 511 app to the Data Broker and on to the Data Warehouse for review by the TMC.

3.2.6.1.2 Developer & version number

The Timmons development group is currently planned as the development team for this application.

3.2.6.1.3 Application Message and Alerts Descriptions

Messages and alerts issued by this application are described in the sections below.

3.2.6.1.3.1 Descriptions and illustrations of messages and alerts issued by application
Table 3-89 describes the messages and alerts of the CV enhancement issued by the 511 application.

Table 3-89. 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”

3.2.6.1.3.2 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.

3.2.6.1.3.3 Summary tables of criteria for issuing messages and alerts
Contains a summary of information for criteria to submit messages/alerts for the 511 app.

Table 3-90. 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

3.2.6.1.4 Application Design Description
The sections below describe the 511 app design for truck parking availability enhancements

3.2.6.1.4.1 Schematic of major modules/functions
Figure 3-110 shows the major module that will be created for the 511 application.

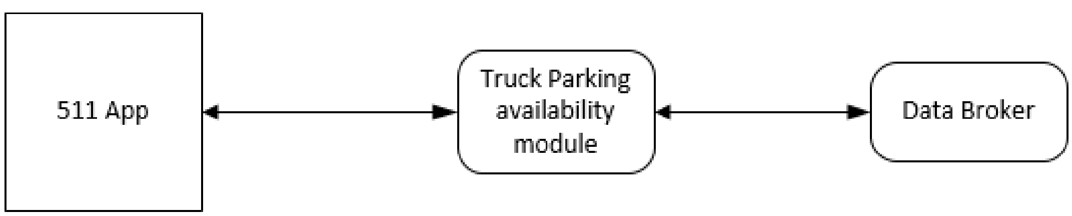


Figure 3-110. Major Truck Parking Availability modules/functions (Source WYDOT)

3.2.6.1.4.2 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.

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

Figure 3-110 shows the process flows between the major updated modules/functions within the 511 app and the WYDOT Data Broker REST service.

3.2.6.1.4.4 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.

3.2.6.1.5 Application Data Tables

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

3.2.6.1.5.1 Input data description tables

Table 3-91. Input Truck Parking availability data for the 511 App shows the input data for the truck parking enhancements on the WYDOT 511 App.

Table 3-91. 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

3.2.6.1.5.2 Output data description tables

Table 3-92. Output Truck Parking availability data for the 511 App shows the output data for the truck parking enhancements on the WYDOT 511 App.

Table 3-92. 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

3.2.6.1.5.3 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.

3.2.6.1.6 Application Configuration Data

No additional configuration data is needed for this application.

3.2.6.1.7 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 3-111. Select Truck Parking Layer is a mockup of the user's ability to select a new Truck Parking layer from the Map options menu.

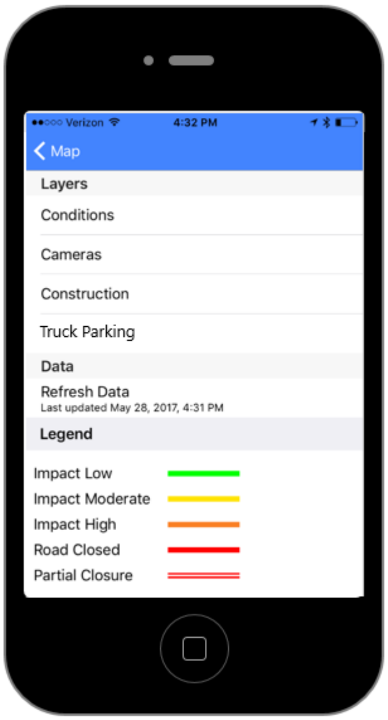


Figure 3-111. Select Truck Parking Layer (Source WYDOT)

Figure 3-112 shows the parking details that should be displayed to a user after clicking on a parking area.

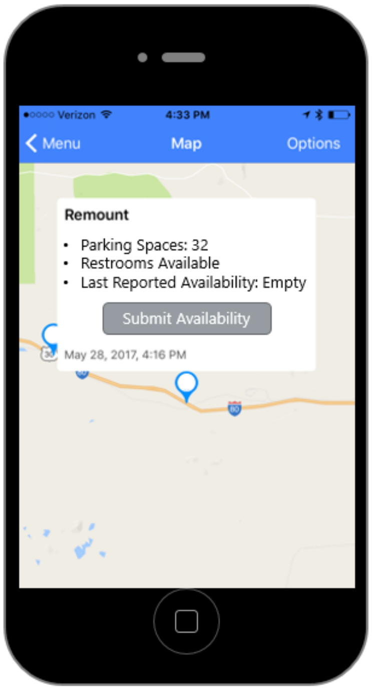


Figure 3-112. View Parking Details (Source WYDOT)

Figure 3-113 shows what the potential user interface for submitting a truck parking availability report to WYDOT would look like.

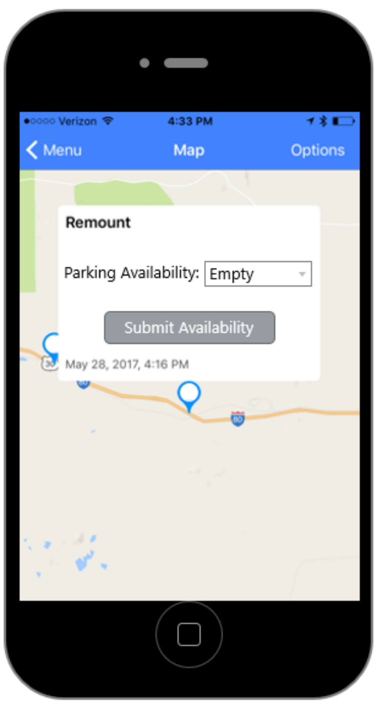


Figure 3-113. Truck Parking Availability Submission (Source WYDOT)

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

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

3.2.6.1.8 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

3.2.6.1.9 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

3.2.6.2 Vehicle Messaging Display/Interface (HMI Design)

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

3.2.6.2.1 Function of the Application
The sections below define the functionality for the HMI app.

3.2.6.2.1.1 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.

3.2.6.2.1.2 Graphical illustration showing vehicle and infrastructure communications on the highway

This application is not involved in any direct communications along the highway.

3.2.6.2.1.3 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.

3.2.6.2.1.4 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.

3.2.6.2.2 Developer & version number

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

3.2.6.2.3 Application Message and Alerts Descriptions

A vehicle with an active LearConnexus HMI 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 3-114 displays the different blocks of the application:

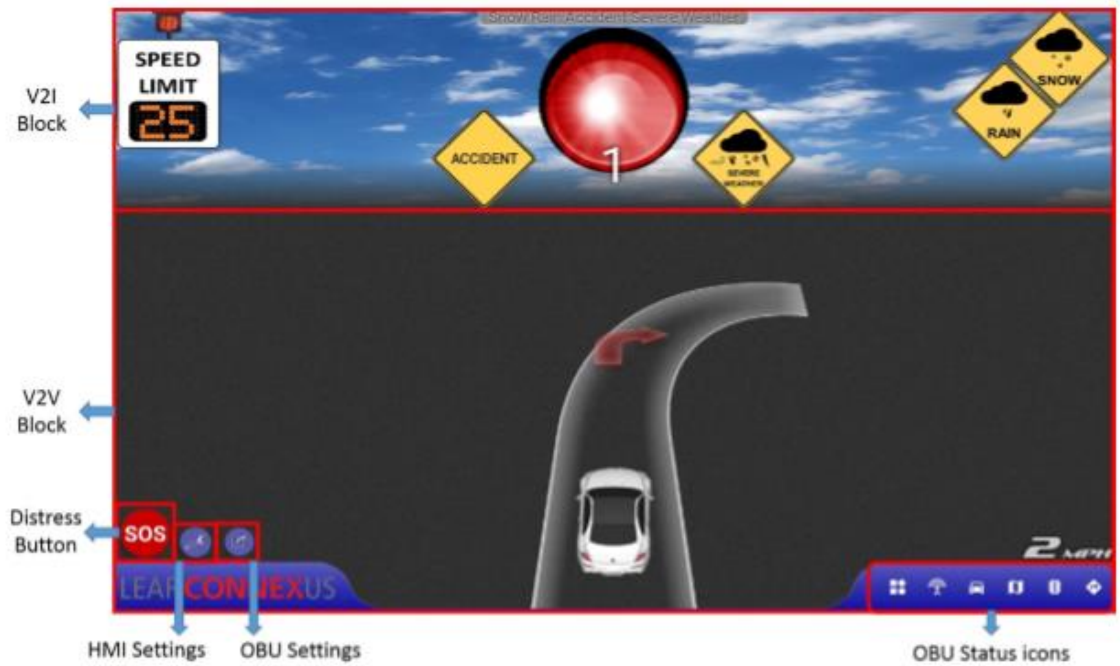


Figure 3-114. HMI Display Blocks. (Source: Lear)

3.2.6.2.3.1 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.

This block is divided into layers each displaying certain components.

Vehicle Display block

- Lane Path Indicator
  - During imminent and advisory alerts, the lane indicators are displayed in red and yellow colors respectively.
  - The Indicators denote:
    - Straight path
    - Intersection
    - Left curved path
    - Right curved path
- Lane arrows
  - Displayed over the lane path.
  - During imminent and advisory alerts, the lane arrows are displayed in red and yellow colors respectively.
  - The lane arrows denote:
    - Straight allowed
    - Left allowed
    - Right allowed
    - U-turn allowed
- EV (host vehicle) and RV (remote vehicles):
  - RVs are displayed based on their relative location with respect to the EV.
    - Ahead, ahead left, ahead right

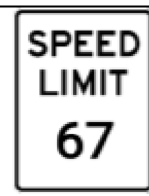
        - Far ahead, far ahead left, far ahead right
        - Behind, behind left, behind right
        - Oncoming, oncoming left, oncoming right
        - Far oncoming, far oncoming left, far oncoming right
        - Approaching left, approaching right
        - Far approaching left, far approaching right
    - RV Classification: Displays all the RVs
    - Ripple effect: During alerts, a ripple effect is shown for every RV along with the EV.
    - Based on the current alert type (Imminent or advisory), the color of the RVs as well as the ripples are shown as red or yellow respectively.
- EV speed: The EV speed received from the OBU is shown at the bottom right corner of the screen.

V2I Block (Vehicle to Infrastructure)
The icons displaying V2I information are shown at relevant locations.

- The information is displayed dynamically under specific layers:
    - Left:
        - Speed – Includes the maximum speed(MAP) as well Dynamic Speed limit (TIM based).

The icons are displayed in a static manner (Table 3-93).

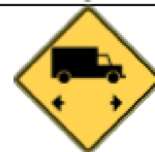
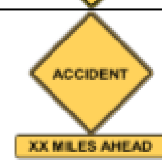
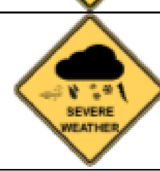
Table 3-93. V2I (Left Block) display icons

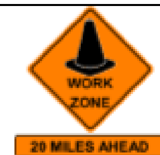
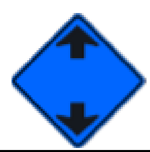
ITIS Code	*Description*	*Icons*
NA	MAP message containing Speed Limit for the Lane in which the Host Vehicle is in.	
7712 followed by 268	*ADVISORY_SPEED SPEED_LIMIT*	

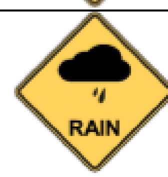
    - Center:
        - Traffic signal with traffic signal countdown
        - Priority alerts – Includes information like accident, severe weather, distressed vehicle, etc.…
        - Road information – Includes information like road closed, red light violation, pedestrian crossing, etc. (Over Lane Path Indicator)

The icons will be displayed on either side of the Traffic Signal Space (Table 3-94).

Table 3-94. 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 3-95 and Table 3-96)
  - Includes information like parking, trailer info, etc.… (Either side of dividers)

  The icons are displayed in fixed locations.

- ITIS text: Displayed at the top of the screen.
- ITIS speech: Text to speech can be enabled/disabled using settings.

Table 3-95. 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 3-96 Miscellaneous ITIS Codes and Information

ITS Code	Description	Icons
4120	PARKING	
4104	FEW_SPACES_AVBL	Combine with parking
9227	TRUCK	Combine with parking

Status Block
This block shows the OBU current connection status. Displays OBU status icons and logo at the bottom of the screen.

- Connection status: Wi-Fi/Bluetooth/Demo mode
- Host data information status: Available/Unavailable
- Remote data information status: Available/Unavailable
- MAP status: Available/Unavailable
- SPaT status: Available/Unavailable
- TIM status: Available/Unavailable

3.2.6.2.3.2 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. Driver alerts prioritization follows the same prioritization as what Figure 3-114 shows.

A distress signal or distress notification call is an internationally recognized means for obtaining help. Distress signals are communicated by transmitting radio signals, displaying a visually observable item or illumination, or making a sound audible from a distance.

A distress signal indicates that a person or group of people, ship, aircraft, or other vehicle is threatened by serious and/or imminent danger and requires immediate assistance. An urgency signal is available to request assistance in less critical situations.

- An “SOS” button is provided to the user at the bottom left corner.
- User can manually initiate a Distress Message.
- User can dismiss the generated distress message under the following scenario:
    - As long as the DN is being transmitted, Figure 3-115 is displayed and the user can cancel the generated distress.
- ~~Vehicle Generated DN messages are also displayed on the HMI (as seen in Figure 3-116)~~

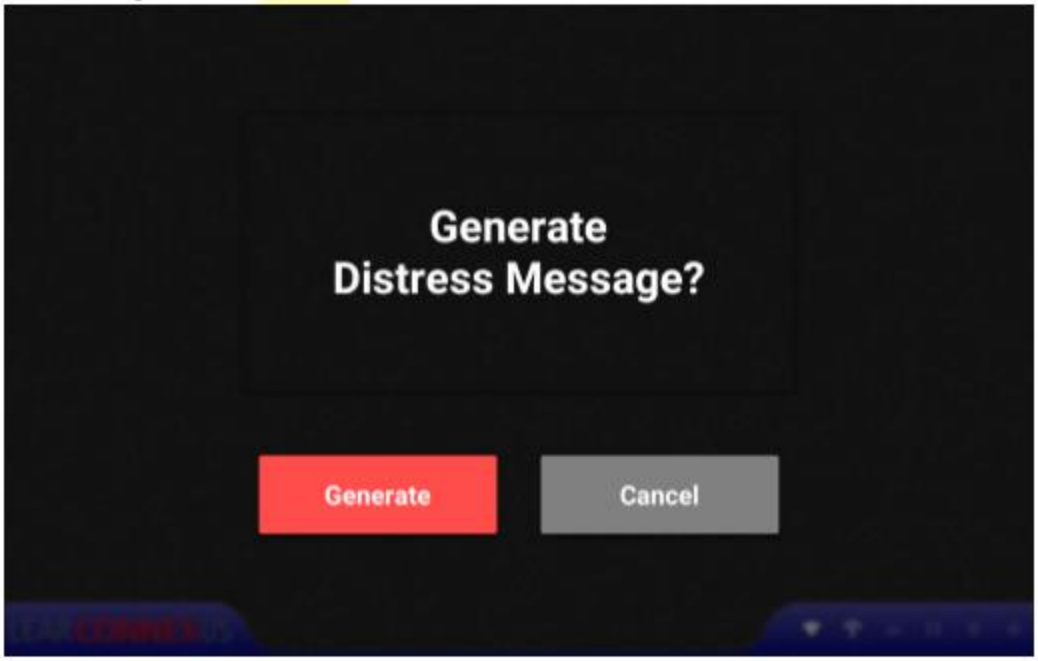
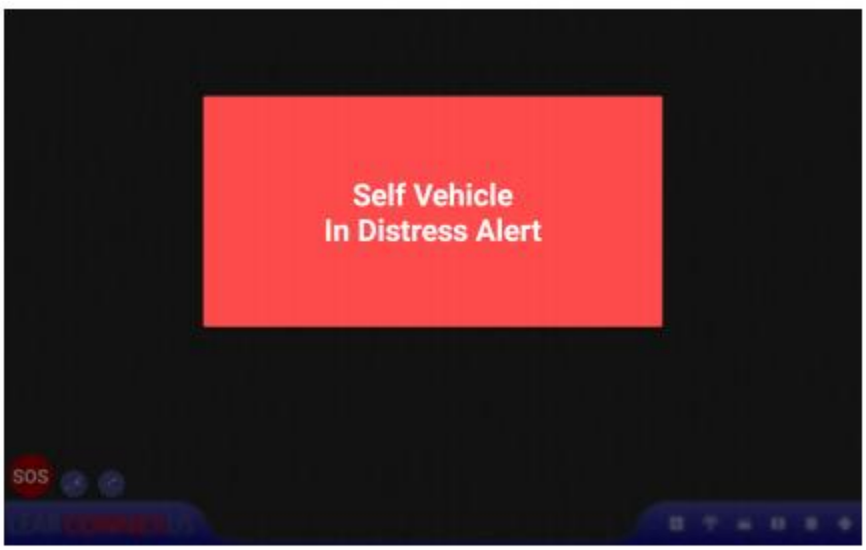


Figure 3-115. HMI Distress Notification verification confirmation. (Source: Lear)



~~Figure 3-116. CAN Generated Distress Notification display (Source: Lear)~~
[NOTE: This no longer applies to this Pilot]

3.2.6.2.4 Application Design Description

The HMI is primarily responsible for receiving and displaying the protobuf data generated by the HMI module appropriately. It also allows the user to set initial user preferences that can be used throughout the application.

3.2.6.2.4.1 Schematic of major modules/functions

Figure 3-117 shows the data flow between all of the Major Modules within the HMI application.

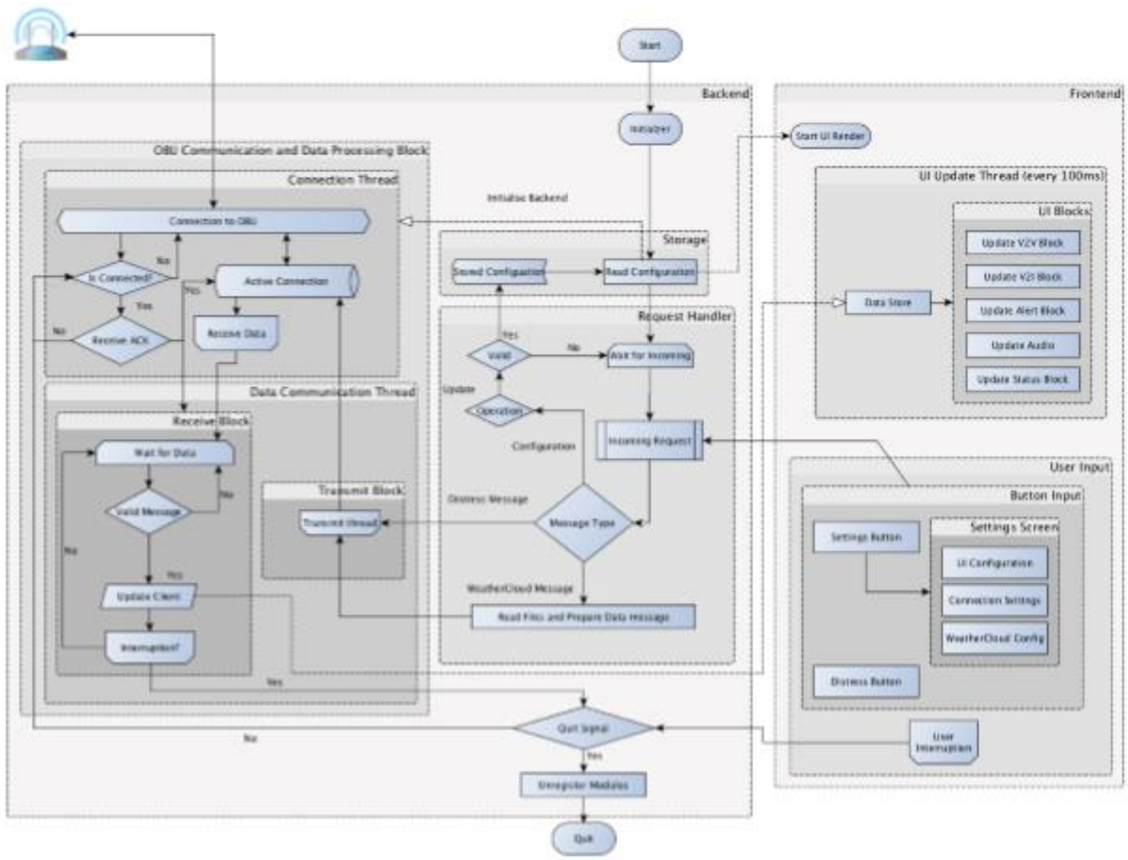


Figure 3-117. Data Flow Diagram of HMI major modules/functions. (Source: Lear)

3.2.6.2.4.2 Description of modules/functions

Connection Layer

This takes care of connection to the OBU and then verifying the connection is valid and active or not. This can be a generic module which can connect using multiple modes like Bluetooth, Wi-Fi, USB, etc., and then provide a bridge between the upper layers. This would be the core thread which takes care of connecting to the OBU in the mode that is configured (e.g., USB or Wi-Fi). Once the connection is established, it makes sure that it is a valid connection by sending and receiving an acknowledgement. Once this is done, it would update the data communication layer to start listening to data. If there is any interruption in data receive, or if timeout is triggered, this would be invoked to verify the connection status and reconnect if required.

Data Processing Layer

This can be synonymous to Connection layer, but takes care of decoding the data received from the Connection layer and forwarding it to the relevant registered applications. Once the data is received by this thread, it would be decoded into understandable format (in this case GPB) and then validated whether it is proper message or not. If validation is passed, this would be forwarded to the registered clients (applications) for this message type. In case there is any interruption in terms of invalid message it would discard the message, or in terms of connection, the connection thread is invoked to see if there is a disconnection from the OBU.

UI Updater
This module takes care of updating the UI by picking up the latest information that is available with the application. This module can operate at regular time interval of minimum 100 milliseconds or can be invoked upon receiving the data from the backend. Once the data is received / updated, various screen components would be updated and then the screen is updated in the main thread, for the end user.

UI Input
This block handles various kinds of User inputs on the HMI. Its further divided into multiple blocks:

3.2.6.2.5 Application Configuration Data

- UI settings: Allows user to
    - Determine the color of RV to be displayed according the alert type.
    - Choose required data unit for speed – Imperial and Metric.
    - Enable/Disable speaking out of ITIS codes.
    - Choose Imminent & Advisory alerts audio: Disable/Audio/Text to Speech.
        - Audio: Different intensity and duration of beep sounds according to alert type
        - Text to Speech: Speaks out the alert type
- Application settings: Allows user to
    - Choose connection mode – Wi-Fi/Bluetooth/Demo.
    - Set IP and port of OBU config server.
    - Set Port, Data and Connection timeouts.
    - Enable/Disable data and ADB logging.
- Trailer Settings: Allows user to
    - Choose the number of trailers the vehicle may be towing – this value is set to 0 for no trailers being towed.
    - Set trailer pivot offsets
    - Input Height, weights, and width of the attached trailers
- Weather Cloud: These settings allow the user to specify a location from which weather cloud files can be uploaded to the OBU
    - File path: Directory (can be chosen using browse) containing weather cloud files.
    - File filter: File filter to choose the kind of file to be uploaded.
    - Transfer interval: File upload takes place according to the mentioned interval.
    - Maximum file size
- Logging: These settings allow the user to specify a location from which log files can be uploaded to the OBU
    - File path: Directory (can be chosen using browse) containing log files.
    - File filter: File filter to choose the kind of file to be uploaded.
    - Transfer interval: File upload takes place according to the mentioned interval.
    - Maximum file size

3.2.6.2.6 Application User Interface(s)

3.2.6.2.6.1 Description of Operations/Driver Interface with illustrations

A distress signal is used to send a Distress Message to the nearby Traffic Center, when there is a critical situation, and the Driver is in need of help. ~~There is an automatic Distress Message generated when the OBU detects that the airbags are deployed.~~ The Driver can manually generate a Distress Signal by clicking the SOS button on the HMI, to transmit message wirelessly over to the Traffic Control Center, and also to notify the Vehicles coming in the direction of the Distressed Vehicle.

The manually generated Distress can be cancelled by clicking the X button displayed on the HMI. Figure 3-118 shows the Distress Notification confirmation screen for the HMI.

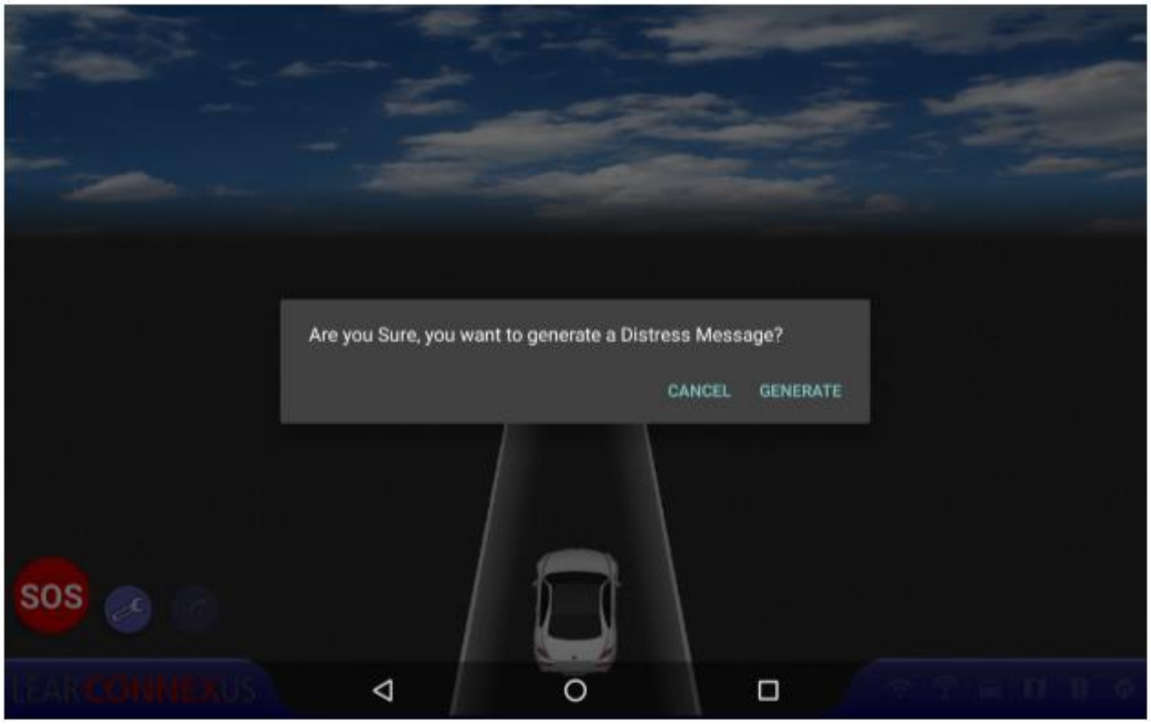


Figure 3-118. User Generated Distress Notification. (Source: Lear)

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 3-119 and Figure 3-120 show the forward collision warnings in action on the HMI.

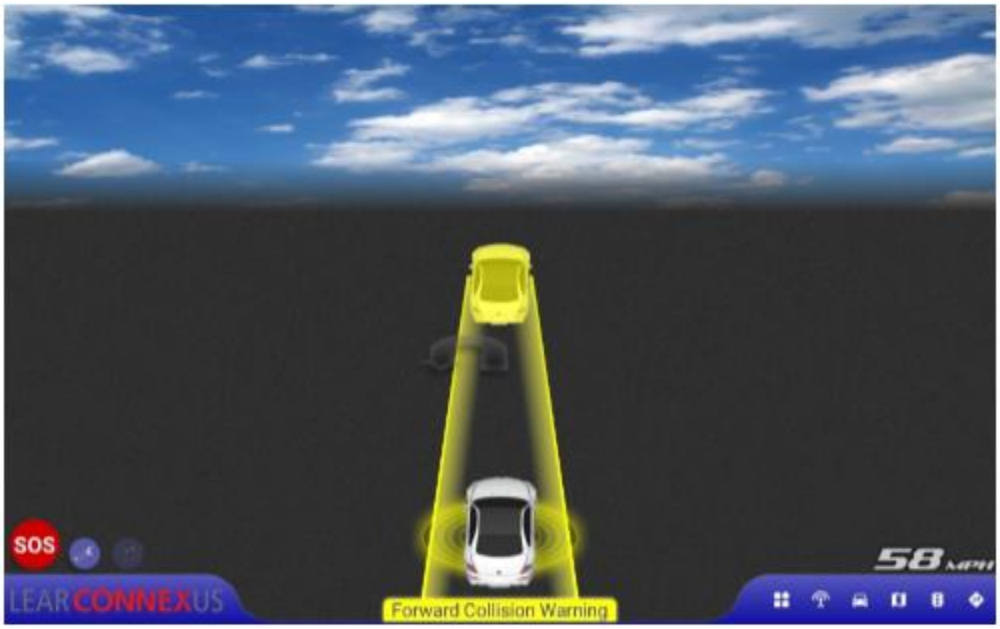


Figure 3-119. Forward Collision Warning. (Source: Lear)

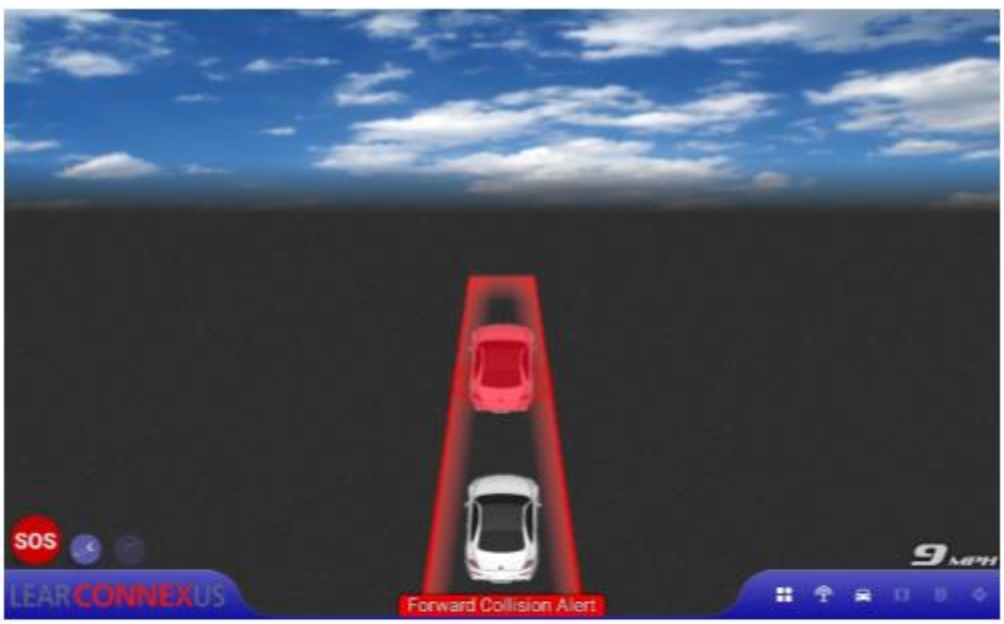


Figure 3-120. Forward Collision Warning (Imminent). (Source: Lear)

3.2.6.2.6.2 Description of Maintenance User Interface with illustrations

The HMI application enables a user set OBU config settings as well as receive them from the configured OBU. Users are required to enter in a password before being able to modify OBU settings.

The OBU settings will be fetched from the configured OBU once the user clicks the button present in the home screen. Currently, under OBU settings, there is are options given to the user to configure:

- Trailer settings.

- HMI settings.
- Safety apps settings.

Trailer Settings: (show in Figure 3-121)

- Trailer count: The max and min count is received from the OBU server. The minimum here is 0, the maximum is 4.
- "Pivoting Allowed" parameter will change based on the trailer count. If trailer count is 0, the parameter will be set as false. And, it will be set as true if count is greater than 0.
- Separate tabs are created according to the trailer count.
- Each trailer contains 3 configurable parameters: Trailer width, trailer height and trailer length. Each of them have a defined max and min value that the HMI receives from the OBU server. The minimum length for each trailer should be 2, the maximum should be 40. The minimum height for a trailer should be 1, the maximum should be 6. The minimum width for a trailer should be 1, the maximum should be 4. Please note that these values are in meters.

Figure 3-121. HMI Trailer Configuration Interface. (Source: Lear)

Connection: WiFi and Bluetooth Configuration (Figure 3-122)
The OBU settings denote the currently set configuration (WiFi or Bluetooth). Users are allowed to change the connection according to his/her choice.

- WiFi Configuration: A total of 3 parameters are user configurable under WiFi:
  - Port
  - Destination IP
  - Transmit Interval

The maximum, minimum and interval value for transmit interval, connection timeout and data timeout are defined by the HMI data definition that is received from the OBU config.

- Bluetooth Configuration: A total of 3 parameters are user configurable under Bluetooth:
    - Destination MAC
    - UUID
    - Transmit Interval

The maximum, minimum and interval value for transmit interval, connection timeout and data timeout are defined by the HMI data definition that is received from the OBU config.

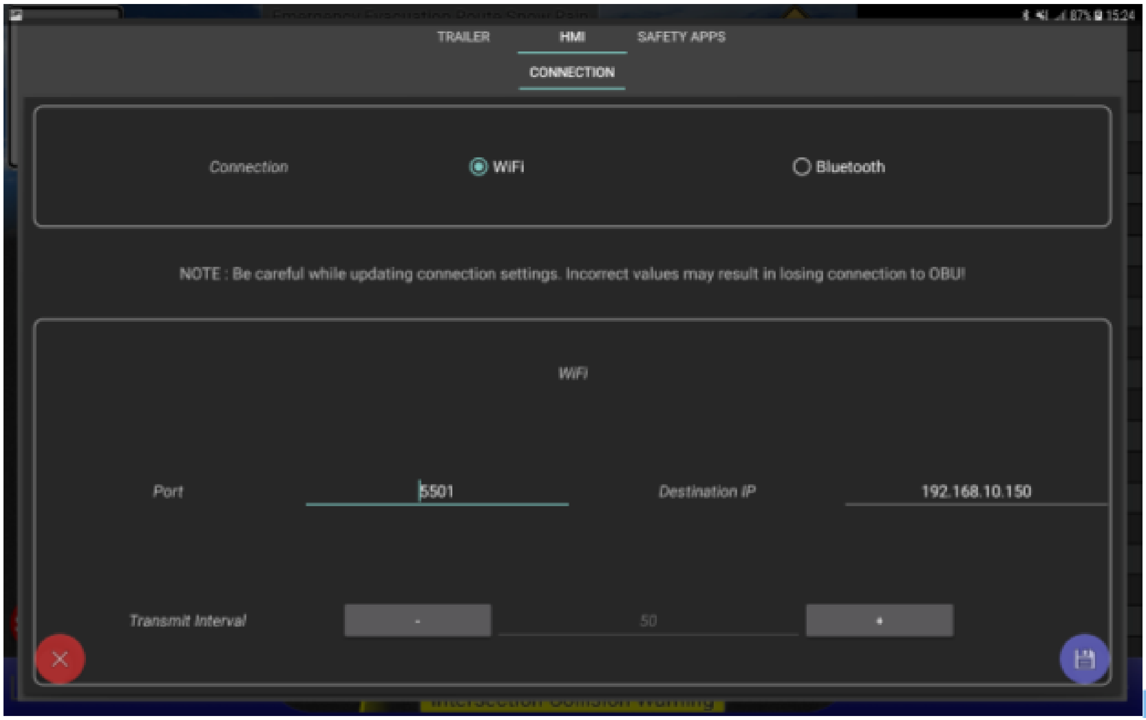


Figure 3-122. HMI OBU Connection Settings. (Source: Lear)

Safety app settings:

FCW setting
For Advisory:

Figure 3-123. HMI FCW settings. (Source: Lear)

3.2.6.2.7 Requirements Traceability

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

- VS-REQ-4.2 Collect Dimension Data
- VS-REQ-4.2.1 Vehicle Dimension Data
- VS-REQ-4.2.2 Vehicle Trailer Data
- VS-REQ-16 Create Distress Notification
- VS-REQ-16.2 Driver-Generated Distress Notification
- 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
- VS-REQ-32.8 Non-Distress Information

3.2.6.2.8 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
SDX	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
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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.
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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
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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
			SCMS-REQ-1.1	SCMS Wyoming CV System Certificates
			SCMS-REQ-1.2	SCMS Wyoming CV System Misbehavior Reporting
			SCMS-REQ-1.3	SCMS Wyoming CV System Certificates Revocation List (CRL)
			SCMS-REQ-1.4	SCMS Wyoming CV System Rejection
			RSU-REQ-3	SCMS
			RSU-REQ-4	LTS
			RSU-REQ-6	Safety Communication
			RSU-REQ-7	Broadcast
			RSU-REQ-10	Management and Performance
			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
			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
		RSU Basic Safety Monitoring	WCVS-REQ-1	Collect CV Data
			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
		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
		RSU-REQ-6	Safety Communication
		RSU-REQ-10	Management and Performance
		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
		SCMS-REQ-1.1	SCMS Wyoming CV System Certificates
		SCMS-REQ-1.2	SCMS Wyoming CV System Misbehavior Reporting
		SCMS-REQ-1.3	SCMS Wyoming CV System Certificates Revocation List (CRL)
		SCMS-REQ-1.4	SCMS Wyoming CV System Rejection
	RSU Trust Management	RSU-REQ-3	SCMS
		SCMS-REQ-1	Wyoming CV System (WCVS) SCMS Use
		SCMS-REQ-1.1	SCMS Wyoming CV System Certificates
		SCMS-REQ-1.2	SCMS Wyoming CV System Misbehavior Reporting
		SCMS-REQ-1.3	SCMS Wyoming CV System Certificates Revocation List (CRL)
		SCMS-REQ-1.4	SCMS Wyoming CV System Rejection
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
	WCVS-REQ-12	Store Generated Alerts/Advisories
	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
	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
	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
	DW-REQ-1.1.2	Store Alerts/Advisories- Road Condition Hazard
	DW-REQ-1.1.3	Store Alerts/Advisories- Visibility Hazard
	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
		DW-REQ-2.2	Share Data with SDC
		DW-REQ-2.3	Share Data with RDE
		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
		HSM-REQ-2	Share with ODE
		HSM-REQ-3	Receive from SCMS
		HSM-REQ-4	Share with SCMS
TMC Services Applications Design	Operational Data Environment (ODE)	SDC-REQ-1	Data Provided to the SDC
		RDE-REQ-1	Data Provided to the RDE
		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 SDX
		ODE-REQ-3.3	Distribute to Pikalert
		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

		ODE-REQ-3.4.3	Distribute to Data Warehouse-ES
		ODE-REQ-3.5	Distribute to Data Broker
		ODE-REQ-3.6	Distribute to SDC
		ODE-REQ-3.7	Distribute to RDE
		ODE-REQ-4	SCMS
		ODE-REQ-5	LTS
		ODE-REQ-6	OBU Update
		ODE-REQ-7	Receive from Data Broker
		HSM-REQ-1	Receive from ODE
		HSM-REQ-2	Share with ODE
		VS-REQ-31	IVAA WZW
		SDX-REQ-1	Data Provided to the SDX
		SDX-REQ-2	Distribute TIM to VS
		WCVS-REQ-1.3	Collect Distress Messages
		WCVS-REQ-2	Validate Data
		WCVS-REQ-8	Internal Brokerage
		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 SDX
	Pikalert System	PA-REQ-1	External Weather Data
		PA-REQ-2	Wyoming CV Sub-Systems Data
		PA-REQ-2.1	ODE Data
		PA-REQ-2.2	TMC Data
		PA-REQ-3	Generate Alerts/Advisories and Forecasts
		PA-REQ-4	Distribute Alerts/Advisories and Forecasts
		PA-REQ-4.1	Distribute to DB
		WI-REQ-1	External Data Acquisition
		WI-REQ-2	Fixed Data Acquisition
		WCVS-REQ-3	Ingest Data for Road Weather information
		WCVS-REQ-4	Contents of Alerts and Advisories

		WCVS-REQ-4.1	Precipitation Hazard
		WCVS-REQ-4.2	Road Condition Hazard
		WCVS-REQ-4.3	Visibility Hazard
		WCVS-REQ-5	Forecast Conditions
		WCVS-REQ-5.1	Atmospheric Forecasts
		WCVS-REQ-5.2	Road Weather Forecasts
		WCVS-REQ-5.3	Forecast Time
		WCVS-REQ-5.4	Forecast Update
		WCVS-REQ-6	Associate Alerts and Forecast to Segments
		WCVS-REQ-8	Internal Brokerage
	TMC Data Brokerage (WTIDB)	DB-REQ-1	Receive from External Interfaces
		DB-REQ-2	Distribute to External Interfaces
		DB-REQ-4	Receive from Pikalert
		DB-REQ-4.1	Receive Alerts and Advisories
		DB-REQ-4.2	Receive Forecast
		DB-REQ-5	Distribute to ODE
		DB-REQ-6	Receive from ODE
		DB-REQ-7	Distribute to Data Warehouse
		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
		TRAC-REQ-1.1	Distress Notification

	TRAC-REQ-1.1.1	Transmission Time
	TRAC-REQ-1.2	Segment Alerts
	TRAC-REQ-1.2.1	Transmission Time
	TRAC-REQ-1.2.2	Segment Alerts-Pikalert
	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
	WTI-REQ-1.1	Current Segment Alerts
	WTI-REQ-1.1.1	Transmission Time
	WTI-REQ-1.2	Forecast Segment Alerts
	WTI-REQ-1.2.1	Forecast Time
	WTI-REQ-1.2.2	Forecast Update
	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
		CVOP-REQ-1.2.1	Forecast Time
		CVOP-REQ-1.2.2	Forecast Update
		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
		WCVS-REQ-8	Internal Brokerage
	WYDOT Third Party Interface (TPI)	TPI-REQ-1	TPI Data
	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
		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
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
		CVOP-REQ-1.2.1	Forecast Time
		CVOP-REQ-1.2.2	Forecast Update
	WYDOT Transportation Reports and Action Console (TRAC)	TRAC-REQ-1	TRAC Updates
		TRAC-REQ-1.1	Distress Notification
		TRAC-REQ-1.1.1	Transmission Time
		TRAC-REQ-1.2	Segment Alerts
		TRAC-REQ-1.2.1	Transmission Time
		TRAC-REQ-1.2.2	Segment Alerts-Pikalert
	WYDOT Wyoming Traveler Information (WTI)	WTI-REQ-1	WTI Inputs
		WTI-REQ-1.1	Current Segment Alerts
		WTI-REQ-1.1.1	Transmission Time
		WTI-REQ-1.2	Forecast Segment Alerts
		WTI-REQ-1.2.1	Forecast Time
		WTI-REQ-1.2.2	Forecast Update
		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
		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
			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
			VS-REQ-1	Receive BSM
			VS-REQ-2	Receive TIM

	VS-REQ-2.1	Receive TIM through DSRC
	VS-REQ-2.2	Receive TIM through Satellite
	VS-REQ-3	Receive Distress Information
	VS-REQ-4	Collect Vehicle Data
	VS-REQ-4.1	Collect Vehicle Status Data
	VS-REQ-4.2	Collect Dimension Data
	VS-REQ-4.2.1	Vehicle Dimension Data
	VS-REQ-4.2.2	Vehicle Trailer Data
	VS-REQ-5	External Environment Sensor Data
	VS-REQ-5.1	External Environment Sensor Data Configuration
	VS-REQ-5.2	External Environment Sensor Data Management
	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
	VS-REQ-15.1	Log
	VS-REQ-16	Create Distress Notification
	VS-REQ-23	IVAA Rank
	VS-REQ-24	IVAA Level
	VS-REQ-25	IVAA Priority Alert
	VS-REQ-26	IVAA FCW
	VS-REQ-27	IVAA DN
	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
	VS-REQ-34	BCVI Distress
	VS-REQ-34.1	Received Distress
	VS-REQ-34.2	Generated Distress
	VS-REQ-35	BCVI General Broadcast Requirements

	VS-REQ-36	Transmit Data
	VS-REQ-36.1	Transmit Environmental Data
	VS-REQ-36.2	TVI Data Management-Log
	VS-REQ-38	SLD Information
	VS-REQ-39	SLD Rolling Log
	VS-REQ-40	SLD Log Format
	VS-REQ-41	SLD Log Data
	VS-REQ-42	VSM SCMS
	VS-REQ-43	VSM SCMS Encryption
	VS-REQ-44	VSM SCMS Sign
	VS-REQ-45	VSM SCMS Encryption-Log
	VS-REQ-46	VSM SCMS Sign-Log
	VS-REQ-47	VSM App Availability Log
	VS-REQ-48	VSM Updates
	VS-REQ-49	Architectural
	VS-REQ-50	Safety Communication
	VS-REQ-51	VS Equipment
	~~MV-REQ-2~~	~~Can Bus~~
	MV-REQ-3	Static Identifier
	MV-REQ-4	Receive TIM over DSRC
	MV-REQ-5	Receive TIM over Satellite
	MV-REQ-6	OTA Updates
	MV-REQ-7	Time
	MV-REQ-8	Location
	MV-REQ-9	General
	MV-REQ-10	OBU Equipment
	HP-REQ-1	General
	HP-REQ-2	Receive TIM over DSRC
	HP-REQ-3	Time
	HP-REQ-4	Location
	HP-REQ-5	OBU Equipment

		HP-REQ-6	Receive TIM over Satellite
		HP-REQ-7	OTA Updates
		IT-REQ-1	Receive TIM over DSRC
		IT-REQ-2	Receive TIM over Satellite
		IT-REQ-3	OTA Updates
		IT-REQ-4	Time
		IT-REQ-5	Location
		IT-REQ-6	General
		IT-REQ-7	OBU Equipment
	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
		VS-REQ-2	Receive TIM
		VS-REQ-2.1	Receive TIM through DSRC
		VS-REQ-2.2	Receive TIM through Satellite
		VS-REQ-4	Collect Vehicle Data
		VS-REQ-4.2	Collect Dimension Data
		VS-REQ-4.2.1	Vehicle Dimension Data
		VS-REQ-4.2.2	Vehicle Trailer Data
		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-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
	VS-REQ-24	IVAA Level
	VS-REQ-25	IVAA Priority Alert
	VS-REQ-26	IVAA FCW
	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
	VS-REQ-35	BCVI General Broadcast Requirements
	VS-REQ-36	Transmit Data
	VS-REQ-36.2	TVI Data Management-Log
	VS-REQ-38	SLD Information
	VS-REQ-39	SLD Rolling Log
	VS-REQ-40	SLD Log Format
	VS-REQ-41	SLD Log Data
	VS-REQ-42	VSM SCMS
	VS-REQ-43	VSM SCMS Encryption
	VS-REQ-44	VSM SCMS Sign
	VS-REQ-45	VSM SCMS Encryption-Log
	VS-REQ-46	VSM SCMS Sign-Log
	VS-REQ-47	VSM App Availability Log
	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
	RFV-REQ-2	Receive TIM over Satellite
	RFV-REQ-3	Time

			RFV-REQ-4	Location
			RFV-REQ-5	General
			RFV-REQ-6	OBU Equipment
			RFV-REQ-7	OTA Updates
			MCP-REQ-1	V2V Exchange of BSMs
	Android Device Design	Android Device Design	-	#N/A
	Environmental Sensors Design	Environmental Sensors Design	VS-REQ-5	External Environment Sensor Data
			VS-REQ-5.1	External Environment Sensor Data Configuration
			VS-REQ-5.2	External Environment Sensor Data Management
			MV-REQ-1	Environmental Sensors
			MV-REQ-1.1	Environmental Sensor Equipment
	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	VS-REQ-15	Distress Notification ID
			VS-REQ-15.1	Log
			VS-REQ-16	Create Distress Notification
			~~VS-REQ-16.1~~	~~System-Generated Distress Notification~~
			VS-REQ-16.2	Driver-Generated Distress Notification
			VS-REQ-17	DNM-Region
			VS-REQ-18	DN PSID
		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
		VS-REQ-36	Transmit Data
		VS-REQ-36.1	Transmit Environmental Data
		VS-REQ-36.2	TVI Data Management-Log
		VS-REQ-49	Architectural
		VS-REQ-50	Safety Communication
	OBU Vehicle Trust Management	SCMS-REQ-2	Vehicle System SCMS Use
		SCMS-REQ-2.1	SCMS Vehicle System Certificates
		SCMS-REQ-2.2	SCMS Vehicle System Misbehavior Reporting
		SCMS-REQ-2.3	SCMS Vehicle System Certificates Revocation List (CRL)
		SCMS-REQ-2.4	SCMS Vehicle System Rejection
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
		VS-REQ-4.2	Collect Dimension Data

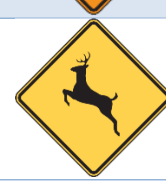
	Vehicle Messaging Display/Interface (HMI Design)	VS-REQ-4.2.1	Vehicle Dimension Data
		VS-REQ-4.2.2	Vehicle Trailer Data
		VS-REQ-16	Create Distress Notification
		VS-REQ-16.2	Driver-Generated Distress Notification
		VS-REQ-32	Human Machine Interface
		VS-REQ-32.1	HMI-Location
		VS-REQ-32.2	HMI-Distraction
		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
		VS-REQ-32.8	Non-Distress Information

Appendix A. WYDOT TIM Requirements

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.

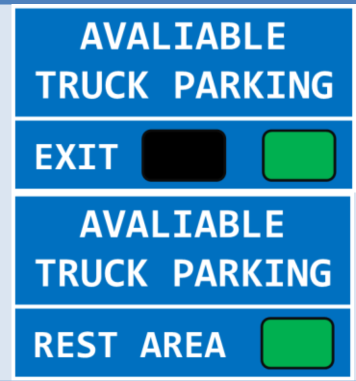
Table A-1. TIM Requirements

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)	

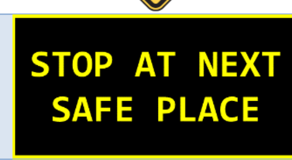
ITIS Code	Description	TIM Message Pattern to Detect	Image(s)
1309	Rockfall	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
1310	Landslide	Only appears in a TIM which has `content=advisory` containing a single ITIS code (this code)	
1537	Delays	Only appears 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)	 R14-5
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)	 

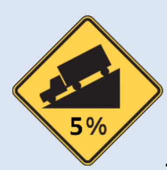
ITIS Code	Description	TIM Message Pattern to Detect	Image(s)
4105	Spaces Available	Only appears in a TIM which has `content=exitService` and the following ITIS codes: Parking spaces available (4105) Rest Area (7986) or Exit Number (11794) If Exit Number it will be followed by the name of the exit (ex. 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)	
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 1^{st} 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 1^{st} 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 1^{st} 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 1^{st} 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 1^{st} 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 1^{st} 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 1^{st} 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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