# Integrated Vehicle-to-Infrastructure Prototype (IVP)

## V2I Hub Design

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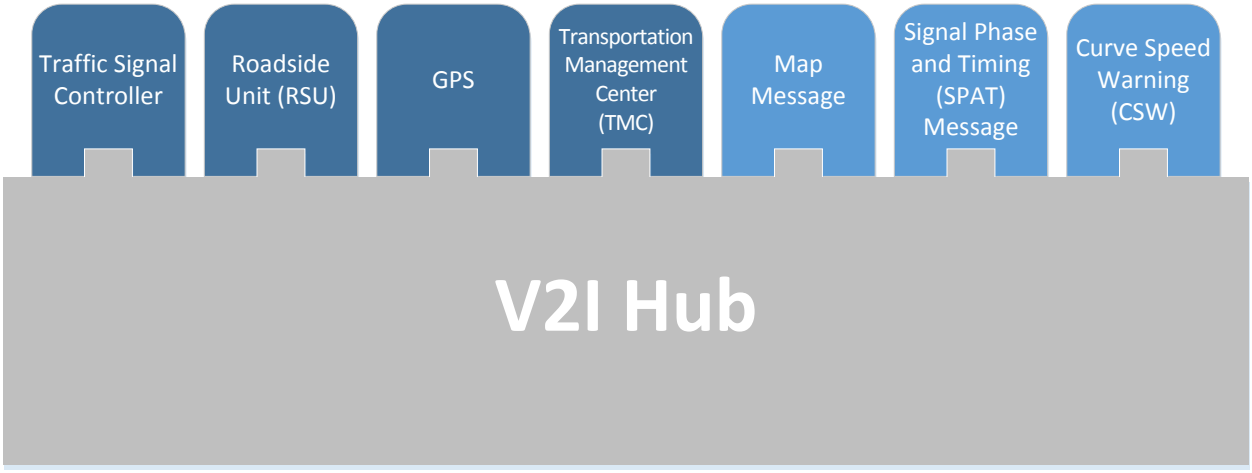
**Draft Report – May 2016**
**FHWA-JPO-16-TBD**

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**16. Abstract**

The Integrated Vehicle-to-Infrastructure Prototype (IVP), called V2I Hub, is part of USDOT's Vehicle-to-Infrastructure (V2I) Program and was developed to support jurisdictions in deploying V2I technology by reducing integration efforts and issues.

- V2I Hub is a software platform that enables connected vehicles to talk to existing traffic management hardware and systems, such as traffic signal controllers, Transportation Management Centers, pedestrian and vehicle sensors, road weather sensors, and dynamic message signs.
- V2I Hub simplifies integration by translating communication between different standards and protocols.
- Using a modular design, software plugins enable efficient connections to new hardware, custom connections to specialized systems, and Connected Vehicle Safety Apps to run on roadside equipment.

This report documents the Software Design Document (SDD) for the prototype development and demonstration of the V2I Hub. This SDD is a representation of a system/software design that is to be used for recording design information, addressing various design concerns, and communicating that information to the V2I Hub stakeholders.

This document provides a representation of the V2I Hub software system created to facilitate analysis, planning, implementation, and decision making. It is a blueprint or model of the V2I Hub software, communications, and to some extent, the hardware systems. The SDD is used as the primary medium for communicating design information.


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# Executive Summary

The Integrated Vehicle-to-Infrastructure Prototype (IVP), called V2I Hub, is part of USDOT's Vehicle-to-Infrastructure (V2I) Program and was developed to support jurisdictions in deploying V2I technology by reducing integration issues and enabling use of their existing transportation management hardware and systems. V2I Hub is a software platform that utilizes plugins to translate messages between different devices and run connected vehicle safety applications on roadside equipment. This document uses V2I Hub and IVP interchangeably.

This document presents a representation of a system/software design that is to be used for recording design information, addressing various design concerns, and communicating that information to the V2I Hub stakeholders. A representation of the V2I Hub software system has been created to facilitate analysis, planning, implementation, and decision making. A blueprint or model of the V2I Hub software, communications, and to some extent, the hardware systems are presented. The structure of the hardware and software system has been structured to satisfy the requirements identified in the V2I Hub requirements specification. It is a translation of requirements into a description of the structure and behavior of the system, the hardware and software components, the interfaces, and the data necessary for implementing the software solution.

# Chapter 1 Introduction

The Integrated Application Prototype concept incorporates vehicle-to-infrastructure (V2I), infrastructure-to-vehicle (I2V), and center-to-center communications (referred to collectively as V2X). The automated V2X communications are predicated on Dedicated Short-Range Communications (DSRC) capabilities and associated infrastructure, but communications are not constrained to DSRC. For example, operations centers will communicate with each other largely through secure telecommunications networks, while existing infrastructure will communicate using established protocols over serial connections.

This report documents the System Design Document (SDD) for the V2I Hub platform.

This SDD is a representation of a system/software design that is to be used for recording design information, addressing various design concerns, and communicating that information to the V2I Hub stakeholders.

This document provides a description of the V2I Hub software system created to facilitate analysis, planning, implementation, and decision making. It is a blueprint or model of the V2I Hub software, communications, and to some extent, the hardware systems. The SDD is used as the primary medium for communicating design information.

The SDD illustrates how the hardware and software system will be structured to satisfy the requirements identified in the V2I Hub requirements specification. It is a translation of requirements into a description of the structure and behavior of the system, the hardware and software components, the interfaces, and the data necessary for implementing the software solution.

The overall approach to this SDD is based on the guidance described in IEEE Std 1016-2009, the *IEEE Standard for Information Technology – Systems Design – Software Design Description*.

Chapter 2 presents an overview of the V2I Hub platform, focusing on the input and output messages of the core functionality. Chapter 3 presents a description of the system components, specifically message definition and routing, communication with infrastructure components and Internet-hosted services. Chapters 4 and 5 detail the core and plugin components respectively. Chapter 6 outlines the V2I Hub hardware components. Chapter 7 describes the details of the underlying configuration database.

# Chapter 2 Overview

## Project Objectives

The objective of the Integrated V2I Prototype (IVP) project is to identify, develop, implement, test, document and deploy a roadside prototype system that supports an integrated, interoperable deployment of multiple V2I safety, mobility, and environmental applications.

V2I Hub is an interface system supporting the collection, integration and dissemination of data between infrastructure and vehicles for a wide variety of applications:

- Signal Phase and Timing
- Mapping (Intersections and Road Segments)
- Other Roadside Equipment (i.e. signage, detectors)
- Positioning / Corrections
- Communications (DSRC, cellular)
- Security
- Road Condition and Weather Data

It is not the intention of this document to describe the details of each V2I application itself. Rather, this document is intended to describe the V2I Hub platform architecture capabilities to support these and other applications through an extensible message architecture. This document describes the core features of the V2I Hub architecture, as well as the implementation interfaces to a number of useful external subsystem components to the V2I Hub platform. This document also describes in some detail the interfaces between the listed V2I applications and the core of the V2I Hub platform, to the extent that those applications have been implemented, in the case of several simpler, utility features of the platform, or ported, as is the case with the INFLO and SPAT applications. The details of the interfaces to external subsystem components are described in the V2I Hub Interface Control Document (ICD), while the details of particular V2I applications can be found elsewhere.

## Supported Applications

Table 2-1 lists the applications and application groups that the V2I Hub platform is designed to support. Note that while the initial deployment of the V2I Hub platform will only implement a subset of DMA applications, nonetheless the V2I Hub platform has been designed to be readily extended to accommodate any of the listed applications using the techniques outlined in this document.

**Table 2-1. Supported V2I Applications**

| | |
|---|---|
| **Dynamic Mobility Applications**<br>• INFLO Speed Harmonization (SPD-HARM)<br>• INFLO Queue Warning (Q-WARN)<br>• RESCUME Incident Zone (INC-ZONE) - Low latency comm for V2V; High latency comm for V2I<br>• FRATIS – High latency communications<br><br>**Multi-Modal Intelligent Traffic Signal System**<br>• Intelligent Traffic Signal System<br>• Transit Signal Priority<br>• Pedestrian Mobility<br>• Freight Signal Priority<br>• Emergency Vehicle Priority<br><br>**AERIS Applications**<br>• Eco-Signal Operations<br>– Eco-Traffic Signal Timing<br>– Eco-Approach and Departure at Signalized Intersections<br>– Eco-Traffic Signal Priority<br>– Connected Eco-Driving<br>• Dynamic Low Emissions Zones<br>• Dynamic Eco-Lanes | **Transit Applications**<br>• Pedestrian Crossing Warning (PCW)<br><br>**V2I Safety Applications**<br>• Red-Light Violation Warning (RLVW)<br>• Stop Sign Gap Assist (SSGA)<br>• Curve Speed Warning (CSW)<br>• Stop Sign Violation Warning (SSVW)<br>• Railroad Crossing Violation Warning (RCVW)<br>• Spot Weather Information Warning (SWIW)<br>• Oversize Vehicle Warning (OVW)<br>• Reduced Speed Zone Warning (RSZW) – Speed Reduction and Lane Closure Advisories<br>• Reduced Speed Zone Warning (RSZW) – Lane Closure Alerts & Warnings<br><br>**Road Weather Connected Vehicle Applications**<br>• Enhanced Maintenance Decision Support System (MDSS).<br>• Information for Maintenance and Fleet Management Systems.<br>• Weather-Responsive Traffic Management.<br>• Motorist Advisories and Warnings.<br>• Information for Freight Carriers.<br>• Information and Routing Support for Emergency Responders. |

Source: Battelle

# User Needs

Multiple applications require a local communication and computational/processing platform for:

- Message Handling across Multiple Interfaces
  - Integrating data from multiple sources and compiling messages for delivery to vehicles and drivers and nomadic devices via multiple communication methods
  - Obtaining and aggregating data from multiple vehicles and nomadic devices and delivery to Traffic Management Entity
  - Distribution of TME messages to local vehicles

- Local Infrastructure Based Computation and Processing:
  - e.g., Local computation of safe speeds and safe stopping distances using real time weather and road condition data for crash imminent V2I safety scenario such as Reduced Speed (Work Zone) Warning and Spot Weather Information Warning
  - e.g., Aggregation of vehicle weather data for efficient communication to Traffic Management Entity for Weather Responsive Traffic Management
  - e.g., MMITSS “Intersection level” functions including MAP and SPAT broadcast manager, equipped vehicle tracker, priority request server, and interface to traffic signal controller

# Chapter 3 System Description

The Integrated system architecture is described in the *V2I Hub System Requirements and Architecture Document*. High-level details are repeated here for readability. For more detailed architecture information please consult the architecture.

## System Architecture

Figure 3-1 illustrates the physical components of the V2I Hub system.

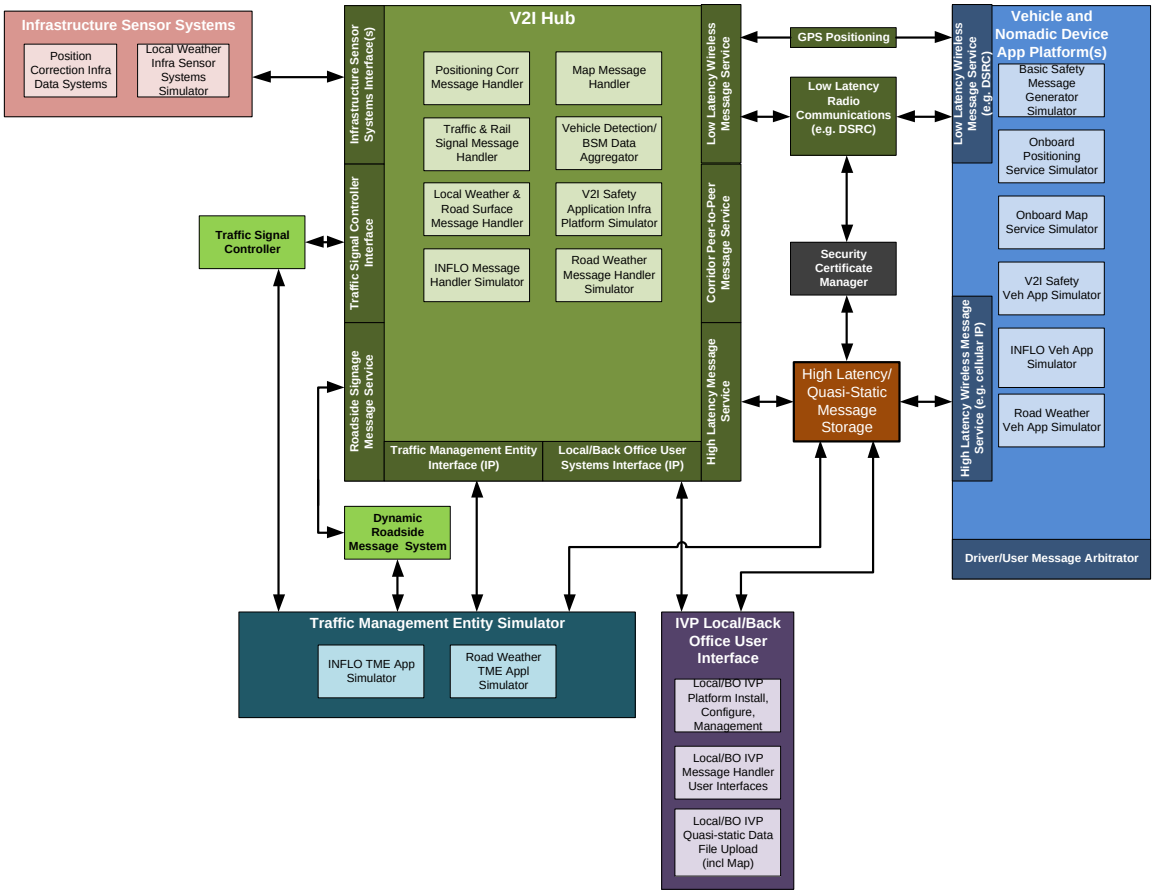


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**Figure 3-1. V2I Hub Detailed System View with Candidate Message Handlers**

The components of the V2I Hub architecture fall into two main categories:

- Core Components that are responsible for providing generic message routing capabilities
- Administrative details of the V2I Hub platform, and Extension Modules, or Plugins, which implement the functionality of specific V2I applications.

# Core Components

The core components of the V2I Hub platform architecture are application neutral blocks of functionality whose primary functions are to manage message routing among the application-specific components and support the infrastructure upon which the application specific components reside.

The core components are:

- V2I Hub Message Router – The C/C++ program that implements the Publish/Subscribe features of the V2I Hub platform
- V2I Hub System Monitor – The C/C++ program that oversees the behavior of the V2I Hub platform, including plugin status, user access, and overall system health
- Configuration and Status Database – A MySQL database that holds status information about each plugin, user accounts, and current system status exposed through the Admin Web Portal interface
- Admin Web Portal – The PHP web portal through which a remote user is able to configure, monitor, and manage the V2I Hub platform
- J2735:2009 Message Library – A support library that translates ASN.1 payloads that originate from and are destined to the DSRC radio into machine readable formats
- FHWA Battelle SPAT Message Library – A support library that translates Battelle-specific SPAT messages into machine readable formats
- V2I Hub plugin API – A library of entry points into the V2I Hub system code that simplifies development of plugin modules and allows access to system resources on the platform
- SSH Interface – Enables secure, remote access to the V2I Hub platform resources.

These components, illustrated with their connections to each other in Figure 3-2, are described in detail in Chapter 4.

# Plugin Components

Plugin modules are the application specific pieces of code on the V2I Hub platform. Plugin modules are responsible for processing data extracted from external peripheral components, and generating status or other information that is published to the V2I Hub router, or, controlling or communicating with external components based on processing performed from messages received from other application plugins installed on the V2I Hub platform.

The plugin architecture addresses the user need for efficient computation and processing in the local infrastructure. The plugin API provides access to messages and data in an efficient manner. For example, a specific message routed through the system only needs sent once, but can be received by multiple plugins for further processing.

The currently implemented plugin components, shown with their connections to the core components of the V2I Hub platform in Figure 3-3, are described in detail in Chapter 5.

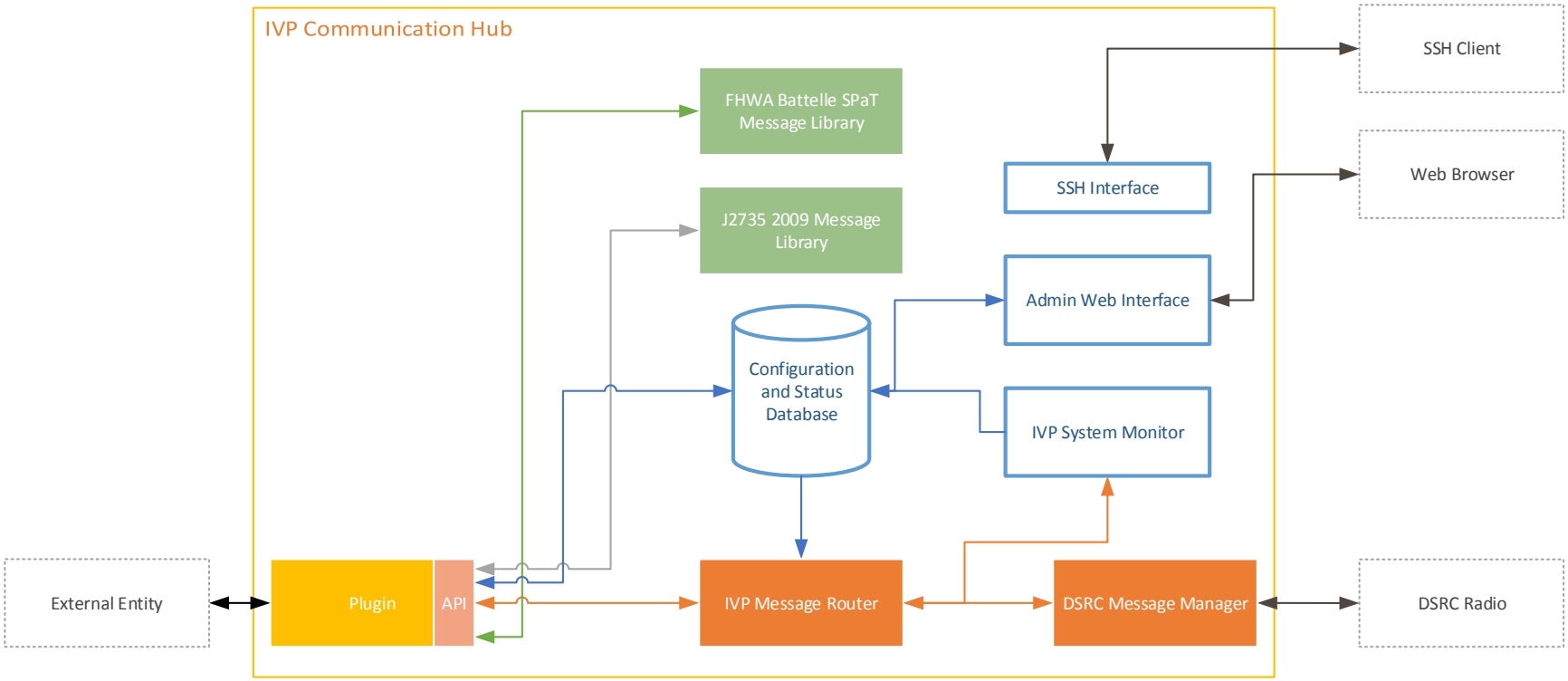


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**Figure 3-2. The V2I Hub Core Components**

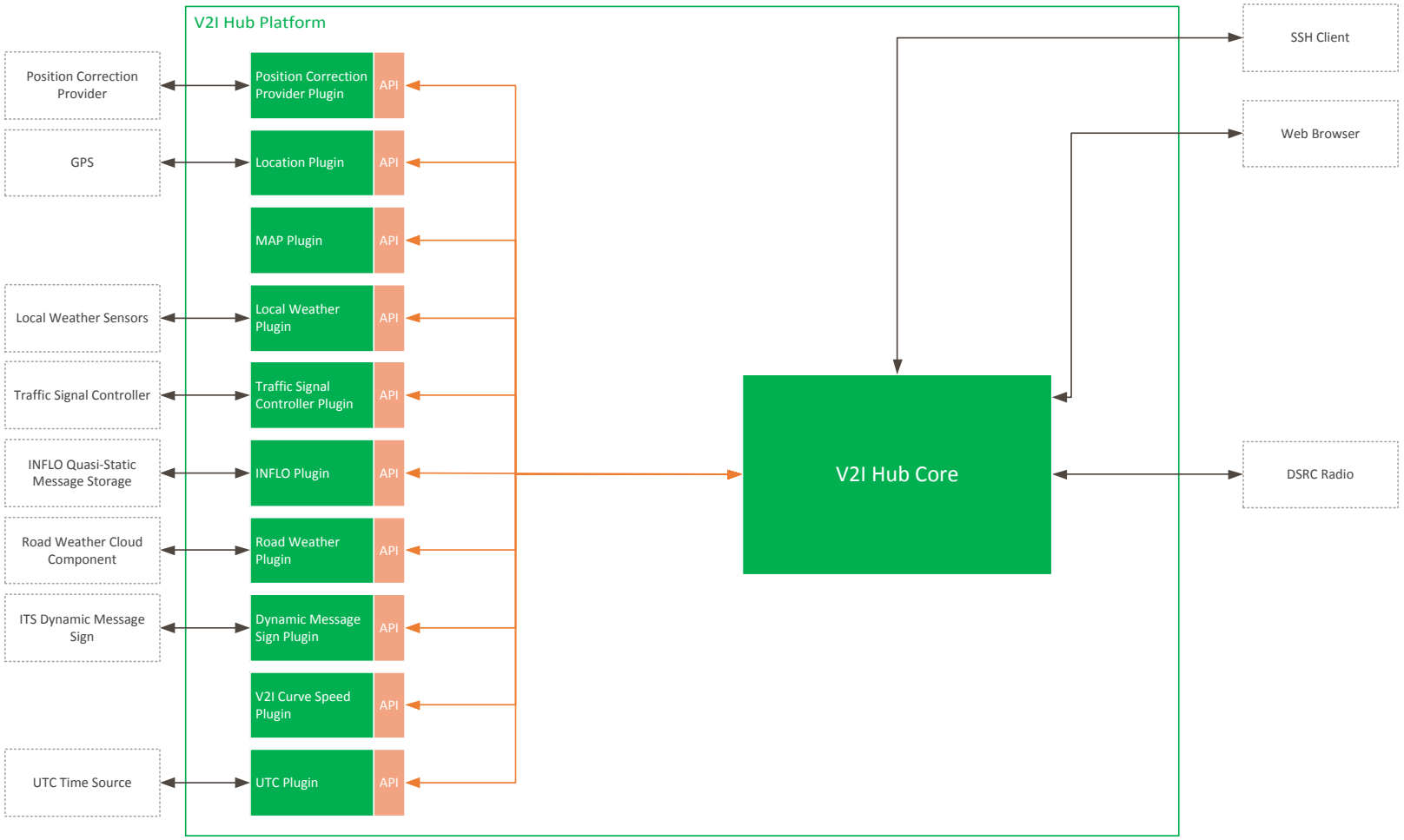


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**Figure 3-3. V2I Hub Plugin Components**

# External Subsystem Components

The V2I Hub platform interacts with a number of external subsystems through software plugin modules. This design document is intended to describe the interactions of the V2I Hub platform with those plugin modules. The details of the interfaces between the plugin modules and the external components described in this section are presented in the V2I Hub Interface Control Document (ICD). The following is a brief description of the external components which the V2I Hub platform that the initial development of the IVP project is intended to connect with.

## DSRC Radio

The Dedicated Short Range Communications (DSRC) radio is the primary means of achieving V2I communications for the V2I Hub platform. As a component of equipment positioned along highways, at traffic intersections and other locations to support wireless communications between connected vehicles and infrastructure, the V2I Hub platform's DSRC functionality is a critical feature of the RSU configuration demonstrated, but which may be implemented in many different ways that are not specified. The DSRC RSU must adhere to the RSU 3.1 specification.

## GPS Receiver

A Global Positioning System (GPS) receiver attached to the V2I Hub platform provides both location information and a precise time source for system that are deployed without continuous internet connectivity. Systems deploy with reliable internet connectivity may substitute a surveyed location plugin for GPS equipment, and use an internet-based NTP provider as the precision UTC time source required for system operation.

## Position Correction Provider

A source of data from a network of base stations providing in Radio Technical Commission for Maritime Services (RTCM) differential corrections for location and time position that allows rover to calculate a more accurate determination of position than an unassisted rover typically offers. Position data may be obtained from a server via an internet connection, or from a DSRC source using standardized J2735 messages to encapsulate position corrections.

## UTC Provider

If reliable internet connectivity is available, a precise source of Coordinated Universal Time (UTC) is provided by an internet-based Network Time Protocol (NTP) provider. If no reliable internet connectivity is available, an accurate source of UTC time may be delivered by external GPS equipment.

## Traffic Signal Controller

The initial implementation of the V2I Hub platform utilizes the Econolite TSC connected to the V2I Hub platform. As developed in previous work the TSC will transmit relevant phase and timing information on regular intervals to the V2I Hub platform. The TSC must send the Traffic Signal Controller Broadcast Message as defined in Table 4 of document 60606-018A_SPaT_ICD FINAL.

## Quasi-Static Message Storage

The Quasi-Static Message Storage (QMS) component's role may be occupied by a Traffic Management Entity (TME) or Traffic Management Center (TMC)-like entity. For the BCO demonstration, the QMS will be the recipient of INFLO messages for both the Queue Warning (Q-WARN) and Speed Harmonization (SPD-HARM) applications.

## ITS Dynamic Message Sign

A Dynamic Message Sign (DMS) is an electronic traffic sign on roadways used to give travelers information about special events. These events include traffic congestion, accidents, incidents, roadwork zones, or speed limits. During system development, a simulated DMS will be utilized.

## Local Weather Provider

The Local Weather Provider component may be fulfilled by an Environmental Sensor Station (ESS) consisting of meteorological instruments connected to the V2I Hub platform, or by internet-based road weather information system (RWIS) providing regional road weather data.

## Road Weather Data

Plugins can be created to communicate directly with a Road Weather Information System (RWIS) to collect road weather data from environmental sensors. This data can be used locally by the plugin or routed through the V2I Hub system for processing by other plugins.

# Chapter 4 Core Components

## V2I Hub Message Router

The V2I Hub Message Router is the central node for all communications in the V2I Hub platform. The V2I Hub Message Router allows plugins to connect to it, subscribe to messages, and publish messages for sharing to other plugins or external via the DSRC radio. The V2I Hub Message Router also has dedicated connections to the DSRC Message Manager for transmission over the DSRC Radio, and to the V2I Hub System Monitor for system analysis and statistics. The V2I Hub System Monitor logs key events to the database, but does not log messages. Message logging can be enabled on the RSU for transmission logs.

Plugins subscribe to data messages by message type. Messages are received by the plugin via a TCP / IP interface over a configurable port. The V2I Hub Message Router forwards all messages of a message type to plugins which have subscribed to messages of that message type. The V2I Hub Message Router also connects to the DSRC Message Manager and forwards all messages that have the dsrc_routing flag set to true, regardless of message type. Both low latency and high latency messages are routed to the DSRC radio when the dsrc_routing flag is true. The DSRC Message Manager has a queue to arbitrate multiple concurrent messages sent to the DSRC radio. Messages are sent in the order received.

The V2I Hub Message Router receives incoming messages from the DSRC Message Manager. The V2I Hub Message Router forwards all messages regardless of type to the Message Monitor.

The V2I Hub Message Router reads configuration parameters from a Configuration Database. Plugin properties such as subscribed messages types, message properties such as whether to route to the DSRC Message Manager, as well as various system characteristics, are stored in the Configuration Database.

Configuration Parameters

- Max Plugins (int)
- Plugin Port (int)

## V2I HUB JSON Message Structure

Internal communications between plugins in V2I Hub use the V2I HUB JSON Message Structure, as sample of which is illustrated in Figure 4-1. The message allows any type of payload formatted as a string to be sent through V2I Hub. The Header contains the needed information for recipients to decode the payload. The fields in the header are required. They are:

- source – String representing the creator of the message. Must be unique
- type – String representing the parent type of the payload. Examples: J2735, NEMA, etc.

- sub-Type – String representing the sub type of the payload. Examples for a J2735 message: RTCM, MAP, SPAT, etc.
- encoding – String representing the encoding of the payload. Examples: ASN.1, PER, BER, JSON, ASCI, etc.
- timestamp – UTC Timestamp in milliseconds from epoch, represented as a long
- dsrc_routing – Boolean letting the V2I Hub Message Router know if the message is to be sent out the DSRC radio

```
{
  "header": {
    "source": "Position Correction Plugin",
    "sub-type": "RTCM",
    "type": "J2735",
    "encoding": "ASN.1",
    "timestamp": 1404995791000,
    "dsrc_routing": true,
  },
  "payload": "data goes here"
}
```

Source: Battelle

**Figure 4-1. JSON Message Structure**

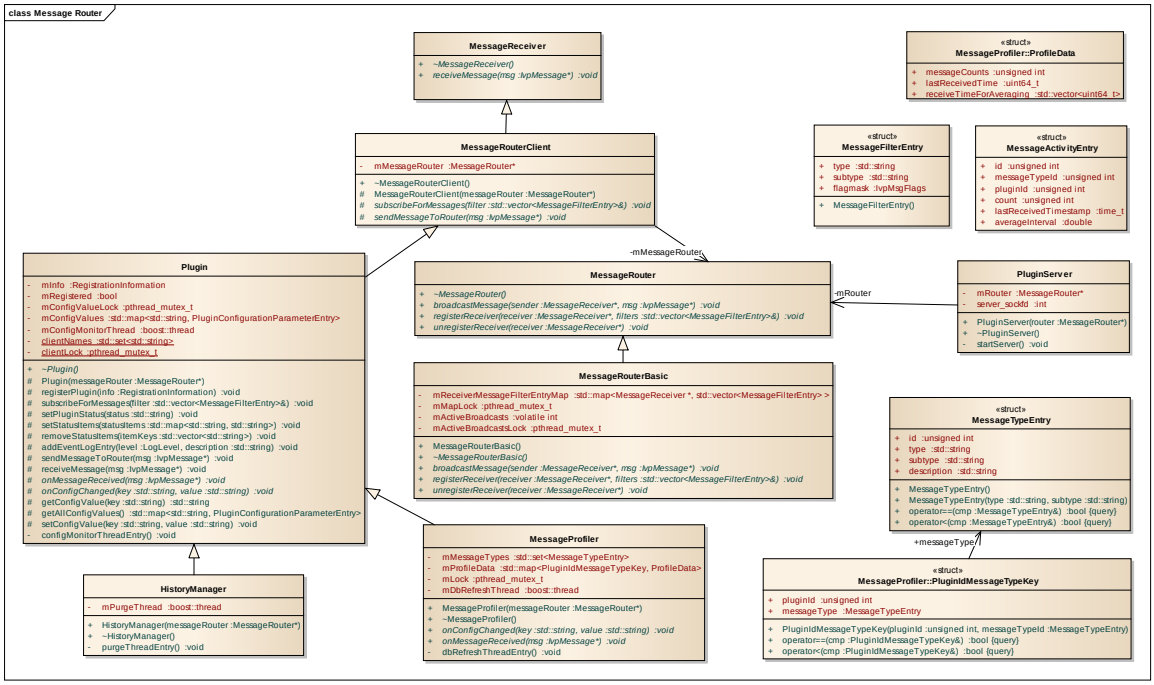
The payload of the message encoded in whatever format is required of the message definition. The V2I Hub JSON Message class structure is shown in Figure 4-3.

## V2I Hub Subscription Request Message Structure

When a plugin is installed on the V2I Hub platform, the plugin must communicate with V2I Hub Message Router to inform it of the messages it wishes to subscribe to. The V2I Hub Subscription Request Message is sent from a plugin on successful connection to the V2I Hub Message Router. The message contains a list of messages that a plugin wants to receive. An example is shown in Figure 4-2.

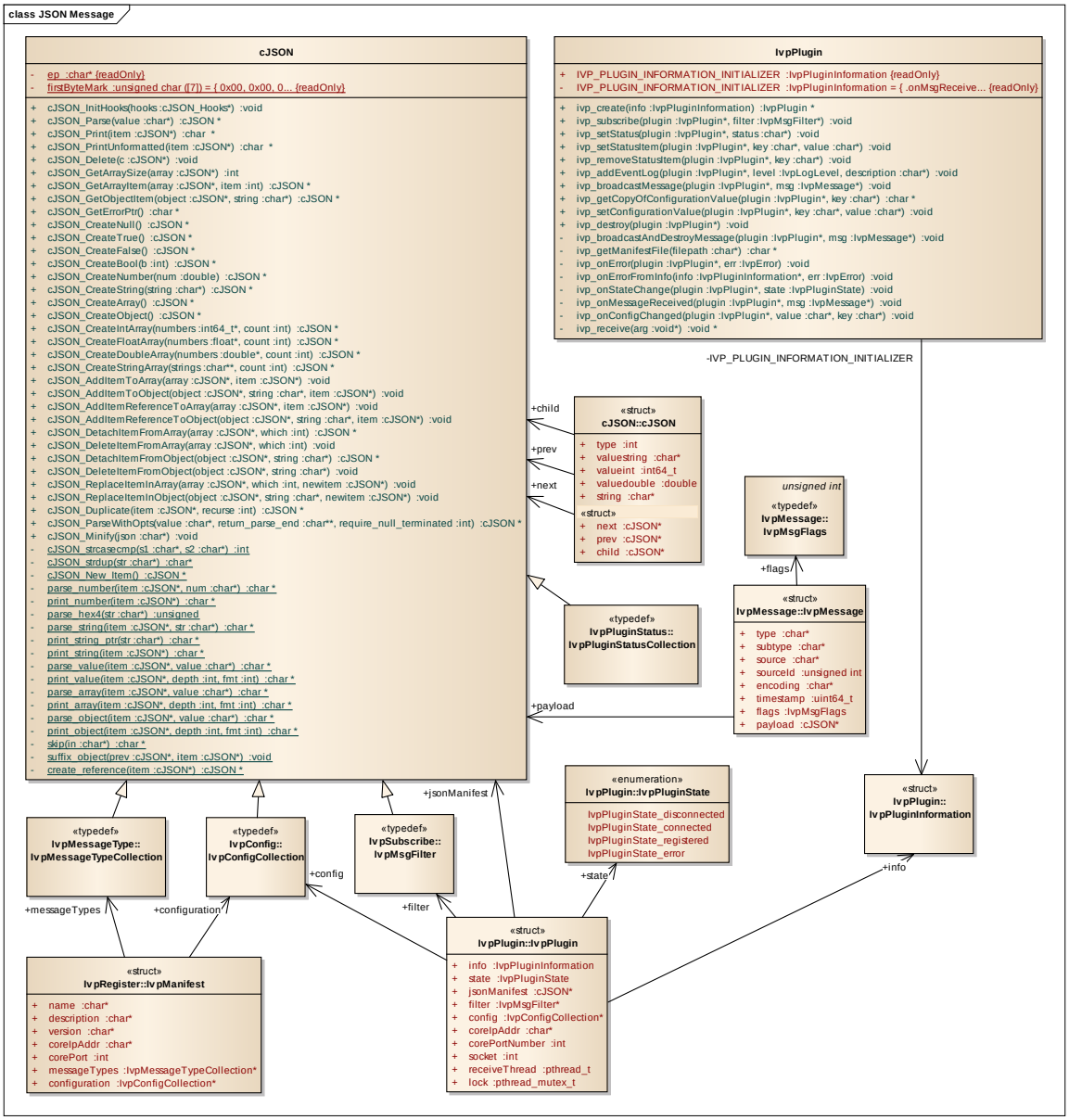
- messages – A list of message type names
- message – A message type name
- plugin_name – The name of the requesting plugin

The Message Router class structure is shown in Figure 4-2.




Source: Battelle

**Figure 4-2. Message Router Class Structure**



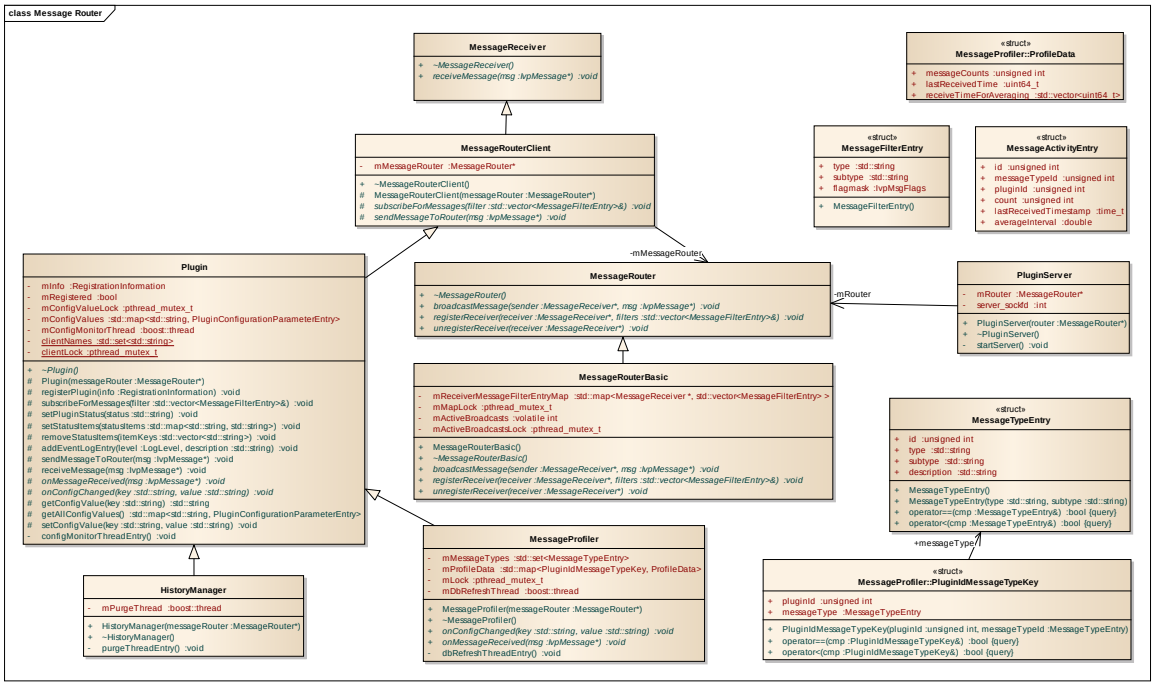

Source: Battelle

**Figure 4-3. V2I Hub JSON Message Class Structure**

```
{
  "messages": [
    "message type name 1",
    "message type name 2"
  ],
  "plugin_name": "My Plugin Name"
}
```

Source: Battelle

**Figure 4-4. V2I Hub Subscription Request Message**




Source: Battelle

**Figure 4-5. Message Router Class Structure**

# DSRC Message Manager

The DSRC Message Manager handles the communications to and from the V2I Hub Message Router and DSRC Radio. The DSRC Message Manager handles the packaging and un-packaging of DSRC messages for V2I Hub. Any DSRC messages that need rerouting back through the DSRC radio are handled by the DSRC Message Manager.

The DSRC Message Manager has a dedicated connection to both the V2I Hub Message Router and the DSRC Radio. The DSRC Message Manager receives messages from the V2I Hub Message Router, and prepares them to be sent to the DSRC radio, ensuring only properly formatted DSRC messages are send to the DSRC radio. The DSRC Message Manager receives incoming DSRC messages from the DSRC radio, unpacks the messages, formats them into the V2I HUB JSON message format described in Figure 4-3, and sends the results to the V2I Hub Message Router. The DSRC Message Manager relays any DSRC messages from the DSRC radio that are flagged as "relay."

# V2I Hub System Monitor

The V2I Hub System Monitor is an application running on the V2I Hub platform, a part of the V2I Hub Core, which monitors the status of each installed plugin in the system. It receives all data transmissions sent through the V2I Hub Message Router, analyses the data, and the updates statistics per message per plugin. If the V2I Hub Message Router detects that a plugin has not been active for some time, it will restart that plugin automatically.

The V2I Hub System Monitor has a dedicated connection to the V2I Hub Message Router and receives all data transmitted through the V2I Hub Message Router. The V2I Hub System Monitor logs the number of messages received and last received timestamp per message type since last boot per plugin in the messageActivity table in the Configuration and Status Database. The V2I Hub System Monitor logs the average time between messages in the messageActivity table by message type and source. The V2I Hub System Monitor monitors data message output of each plugin, and restarts a plugin if no message is received in the configurable amount of time. The V2I Hub System Monitor logs every startup time per plugin. The V2I Hub System Monitor monitors the event log and removes messages based on a configurable max size. The V2I Hub System Monitor starts the plugins on start up after a delay time so that the "core" is up and running.

Configuration Parameters

- Max Event Log Size

The class supporting the Plugin Support and V2I Hub System Monitor are shown in Figure 4-5 and Figure 4-6, respectively.

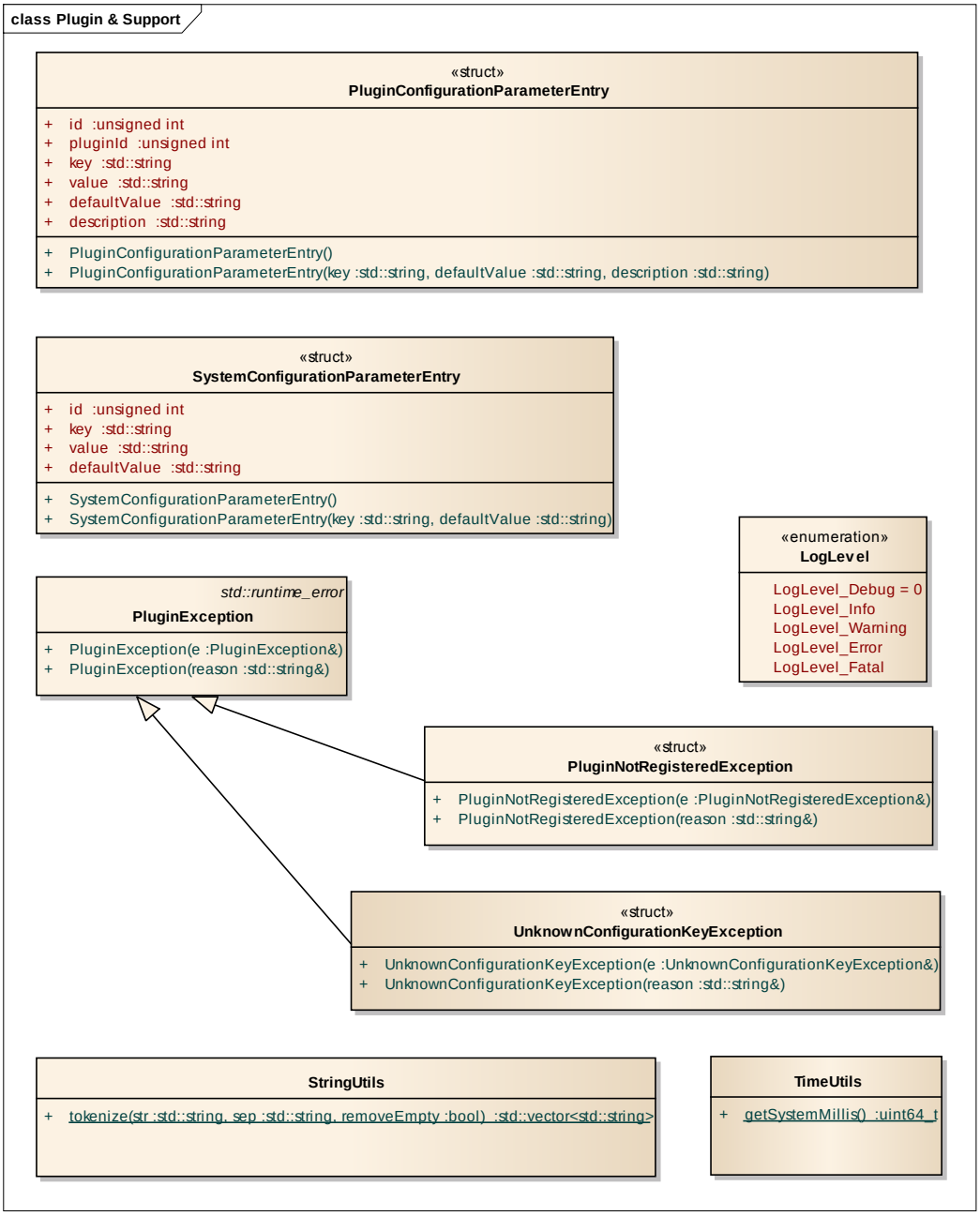



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**Figure 4-6. Message Router Class Structure**

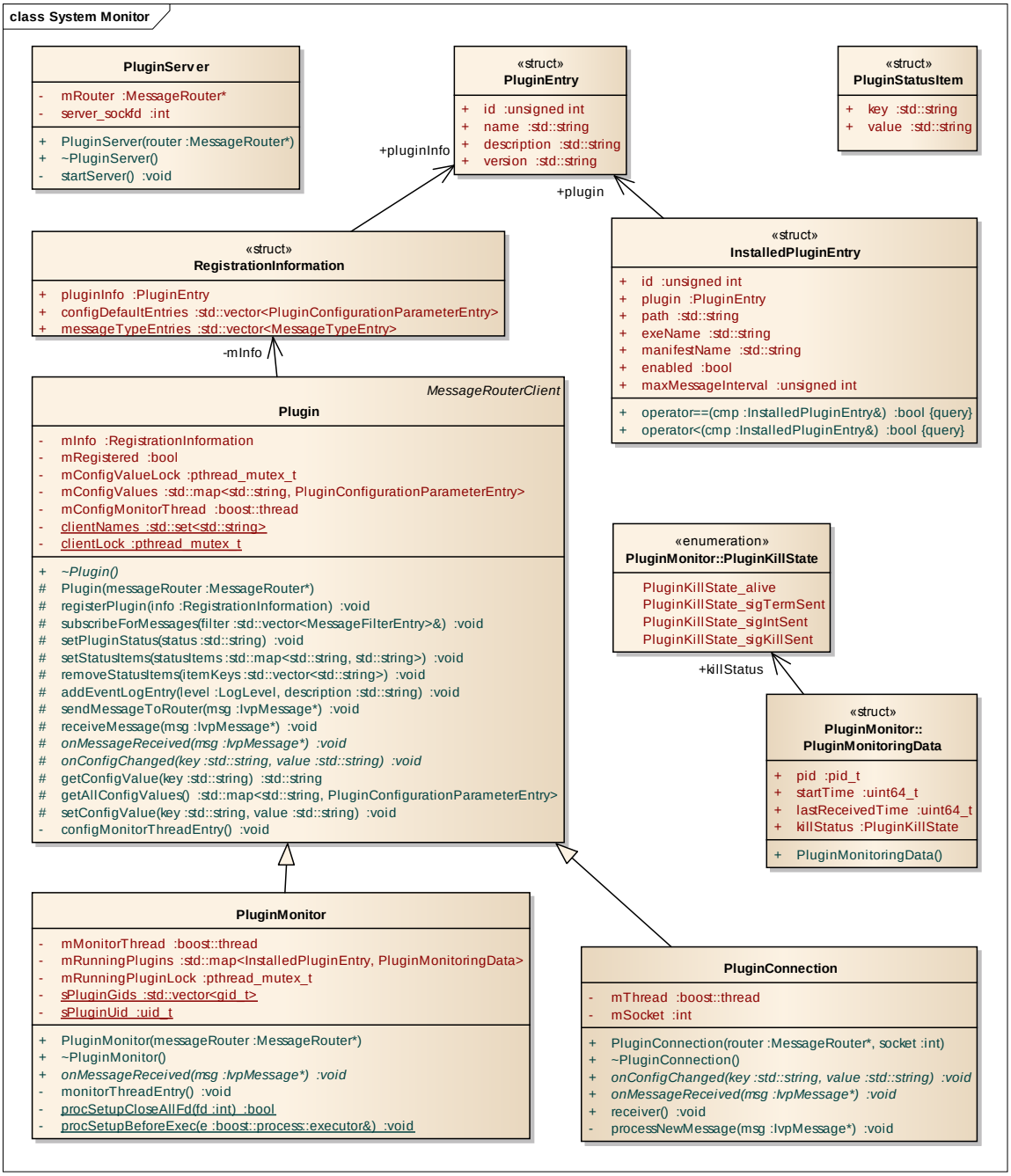


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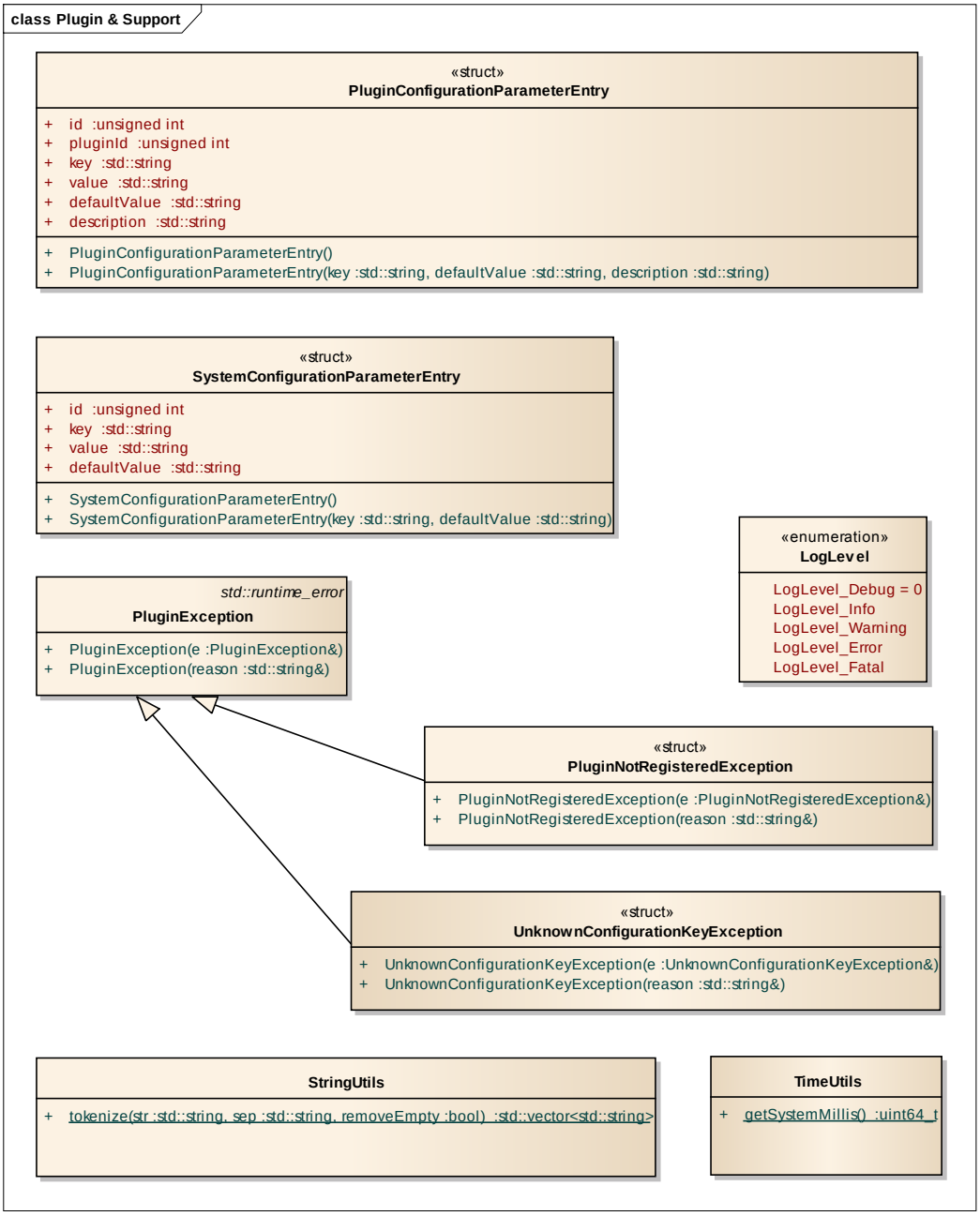
**Figure 4-7. System Monitor Class Structure**




Source: Battelle

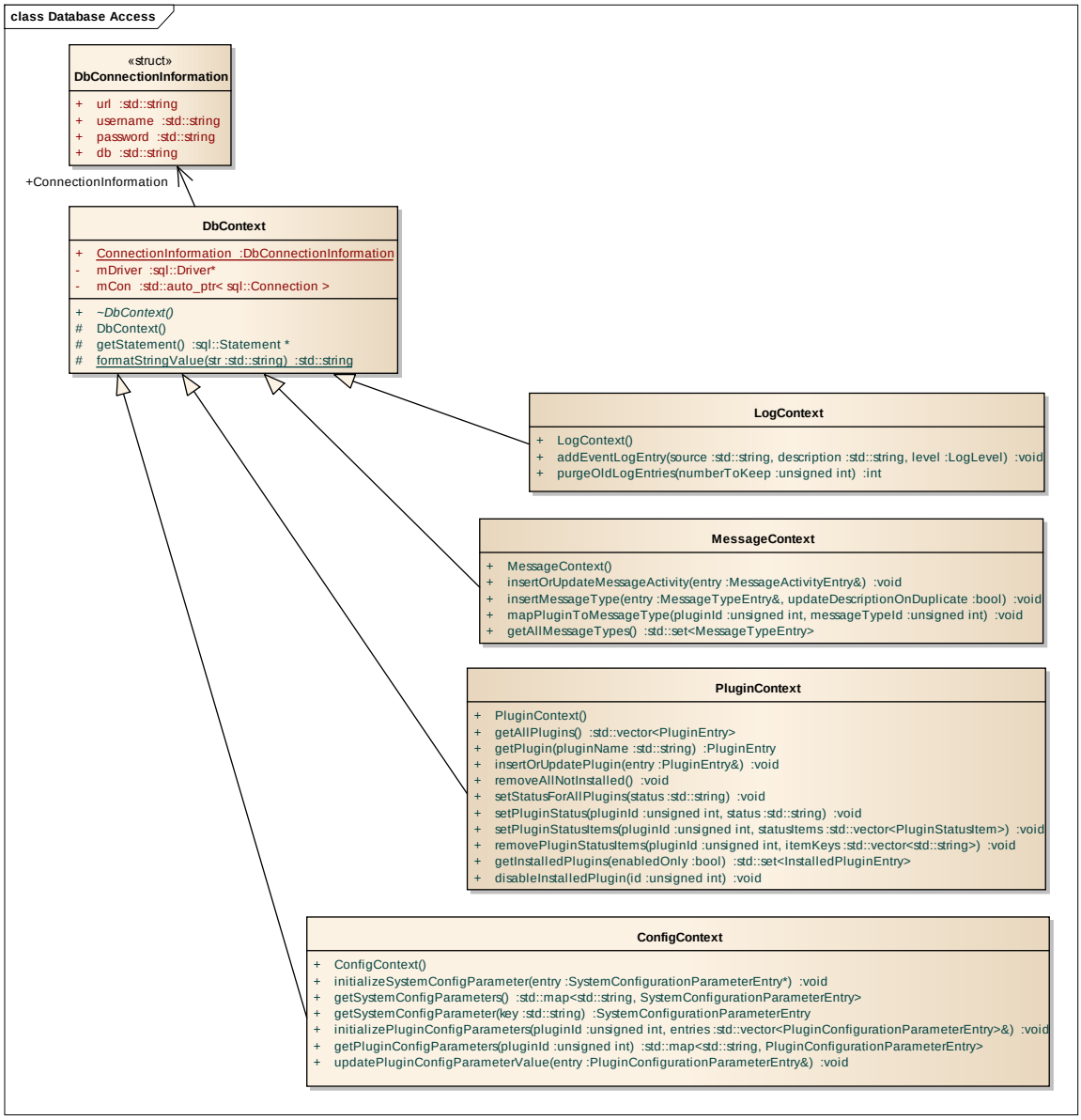
**Figure 4-8. Plugin & Support Class Structure**

# Configuration and Status Database

The Configuration and Status Database is the database for V2I Hub. Entries for each of the plugins installed on V2I Hub are recorded in the database along with their configuration and the configuration

of the V2I Hub Core. Statistics and status are also stored in the Configuration and Status Database which show a snapshot of the data being sent through the

Figure 4-9 shows the classes implementing the access layer to the MySQL configuration and status database.




Source: Battelle

**Figure 4-9. Database Context Class Structure**

# Admin Web Interface

The Admin Web Interface has two distinct functions. The administration side allows the deployment of new plugins, the configuration of plugins on the system including enabling the plugin and any parameters needed, and the configuration of the system. Another function of the administration side of the Admin Web Interface is the ability to remotely reboot the system. The status side of the Admin Web Interface shows the current status of the system including the plugins currently running, and statistics on the data being sent by each plugin.

The Admin Web Interface has an authentication method to limit access to this functionality of the V2I Hub platform. The Admin Web Interface authenticates against credentials in the Admin Users table of the Configuration and Status Database.

The Admin Web Interface allows a user with admin privileges to deploy and configure new plugins to the V2I Hub platform. The Admin Web Interface allows the configuration the name, location, and command line parameters for a new plugin. These configuration items are subsequently stored in the Configuration and Status Database.

The Admin Web Interface lists all plugins installed on the system, and their status. Plugins can be enabled and disable through the Admin Web Interface. The Admin Web Interface allows a user with admin privileges to reboot the system. The Admin Web Interface displays information from the Message Activity Table in the Configuration and Status Database

The web browser can be any major web browser (Internet Explorer, Firefox, and Chrome) used to view the Administration Web Interface of the V2I Hub platform.

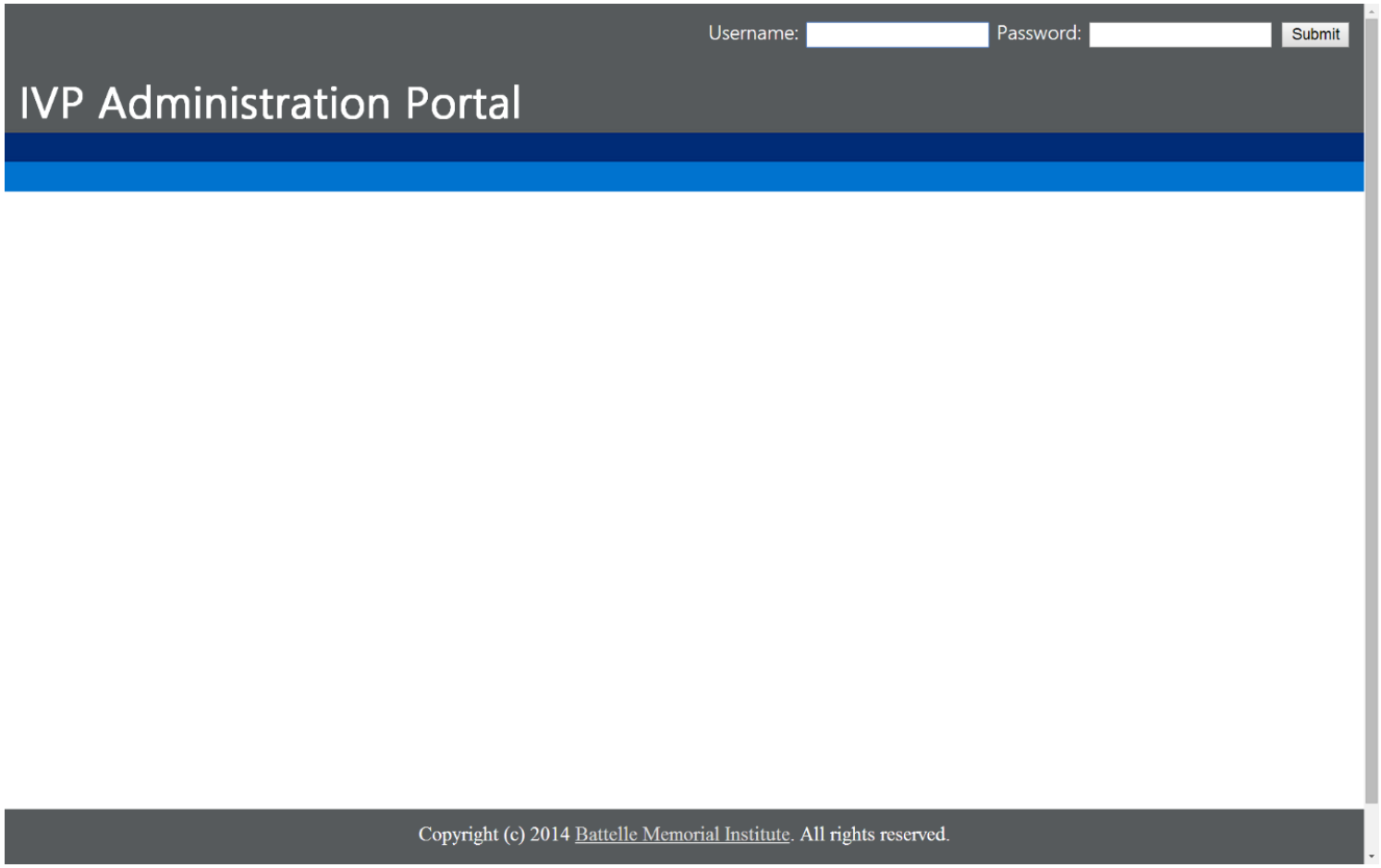
User interactions with the web portal are divided into three access levels, as follows:

View only

- Login to portal: The user is presented with a form for entering a username and password. (See Figure 4-10)
- Logout of portal: Logs the user out and returns to the login page. (See Figure 4-11)
- View event log: A user may view log data from oldest to most recent, displaying the log severity, the source plugin module of the message, and the log message description, color coded by severity:
    - Warning: Black font on canary yellow (#FFFF99) background
    - Error: Black font on salmon pink (#FF9999) background
    - Fatal: Tomato red (#FF4444) font on a black background
    - Data for this portal display is refreshed from the V2I Hub MySQLdatabase every two seconds. (Figure 4-12)
- View message activity: A user may view a summary of all log messages recorded in the V2I Hub MySQLdatabase. Each message displayed includes the name of the plugin module that issued the message, the message type and subtype, a count of the number of messages seen since the last restart of the V2I Hub Core, the data/time of the last message seen, and the average interval between messages. (See Figure 4-13)

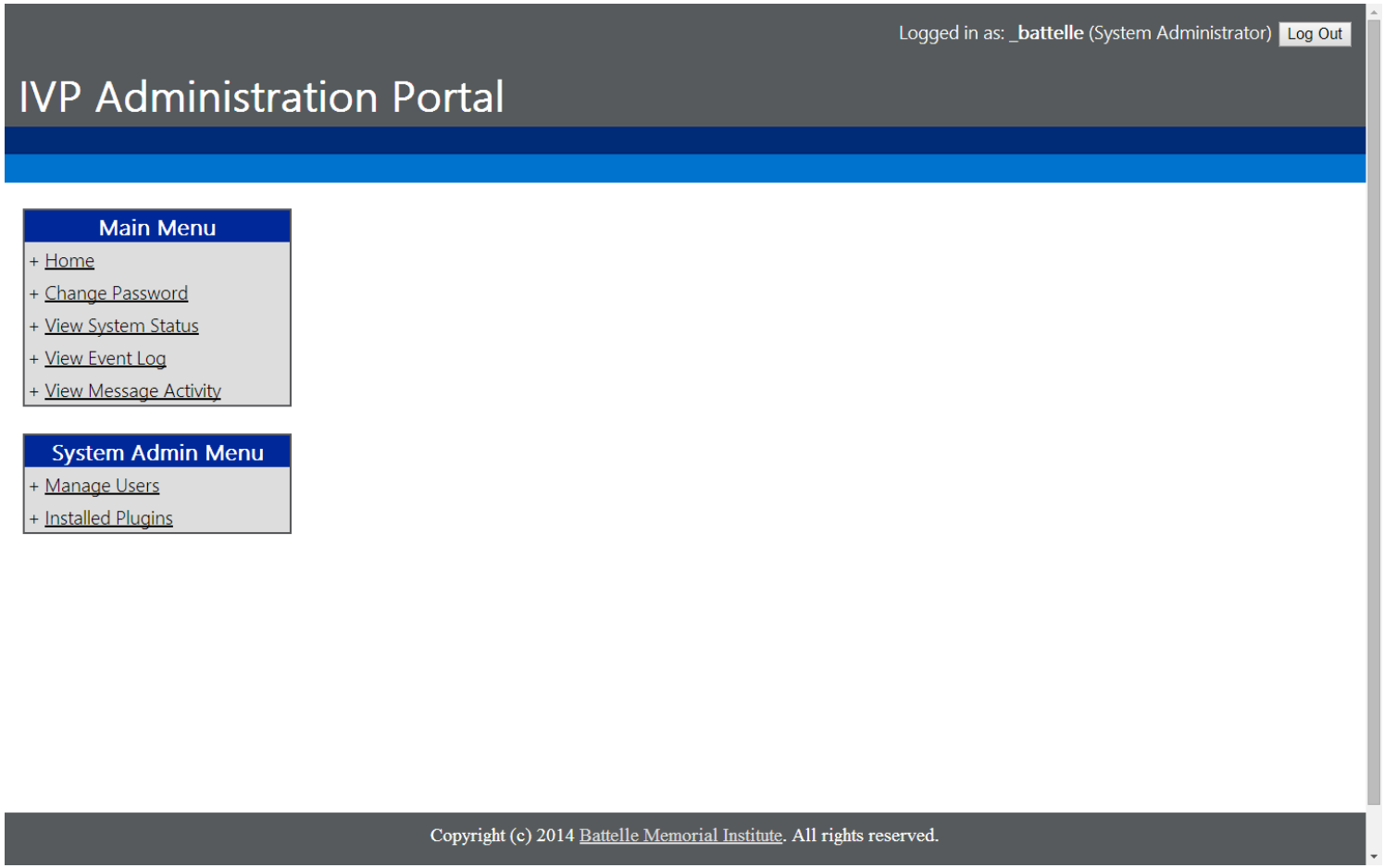
Application Administration

- View V2I Hub system status: The system status includes the name, description, version, whether or not the plugin is enabled, and status for each plugin installed on the local V2I Hub system. (See Figure 4-14)
- View module status: Enables an application administrator to view the configuration parameters and status fields for a single plugin module. Configuration parameters are display with their default and current values. Status fields are listed as key/value pairs, where the key is the unique identifier within the plugin for the status, and the value is the key's current value. All values for module status are extracted from the underlying V2I Hub MySQLdatabase.



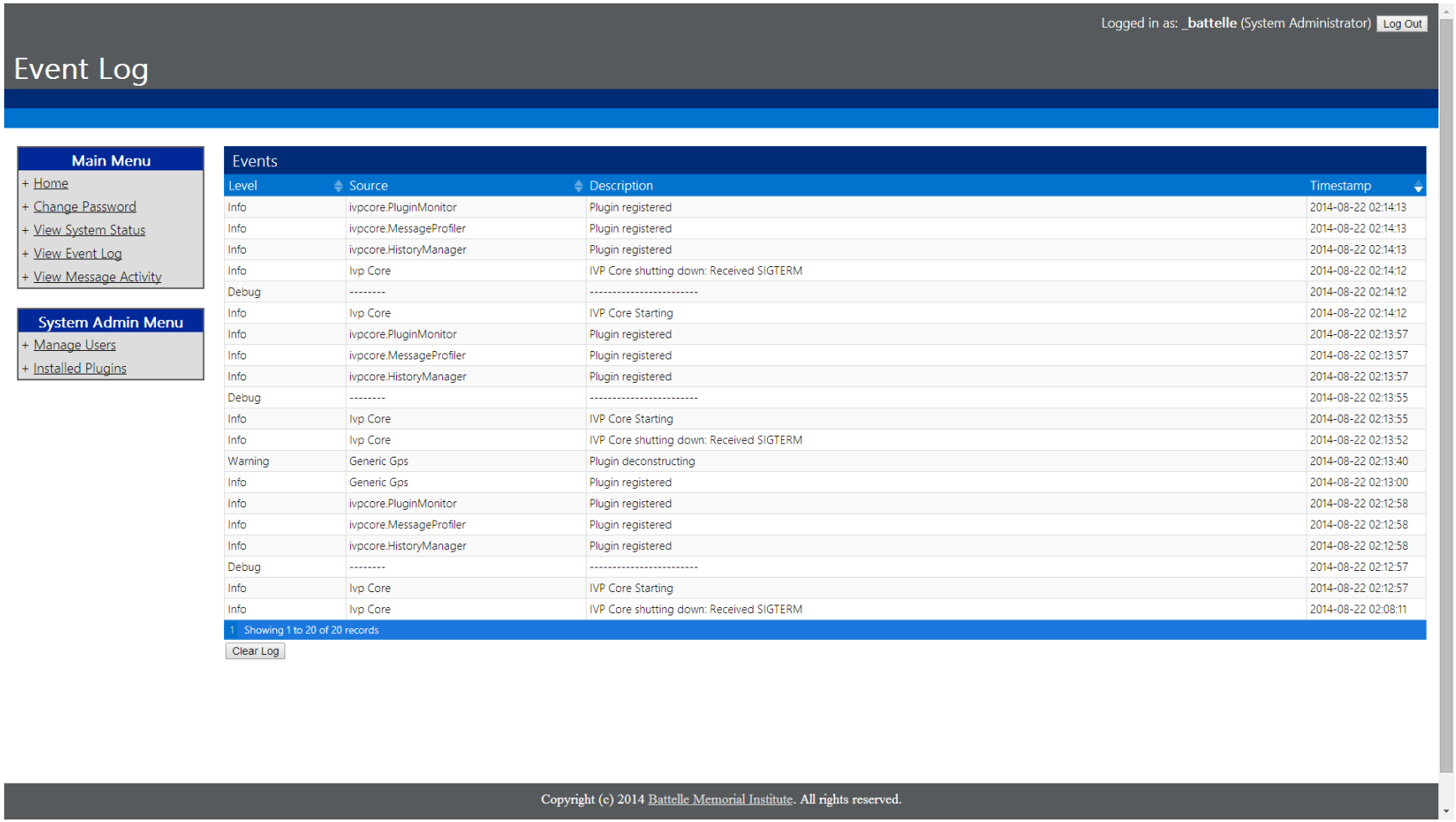

Source: Battelle

**Figure 4-10. The V2I Hub Administration Portal Login**



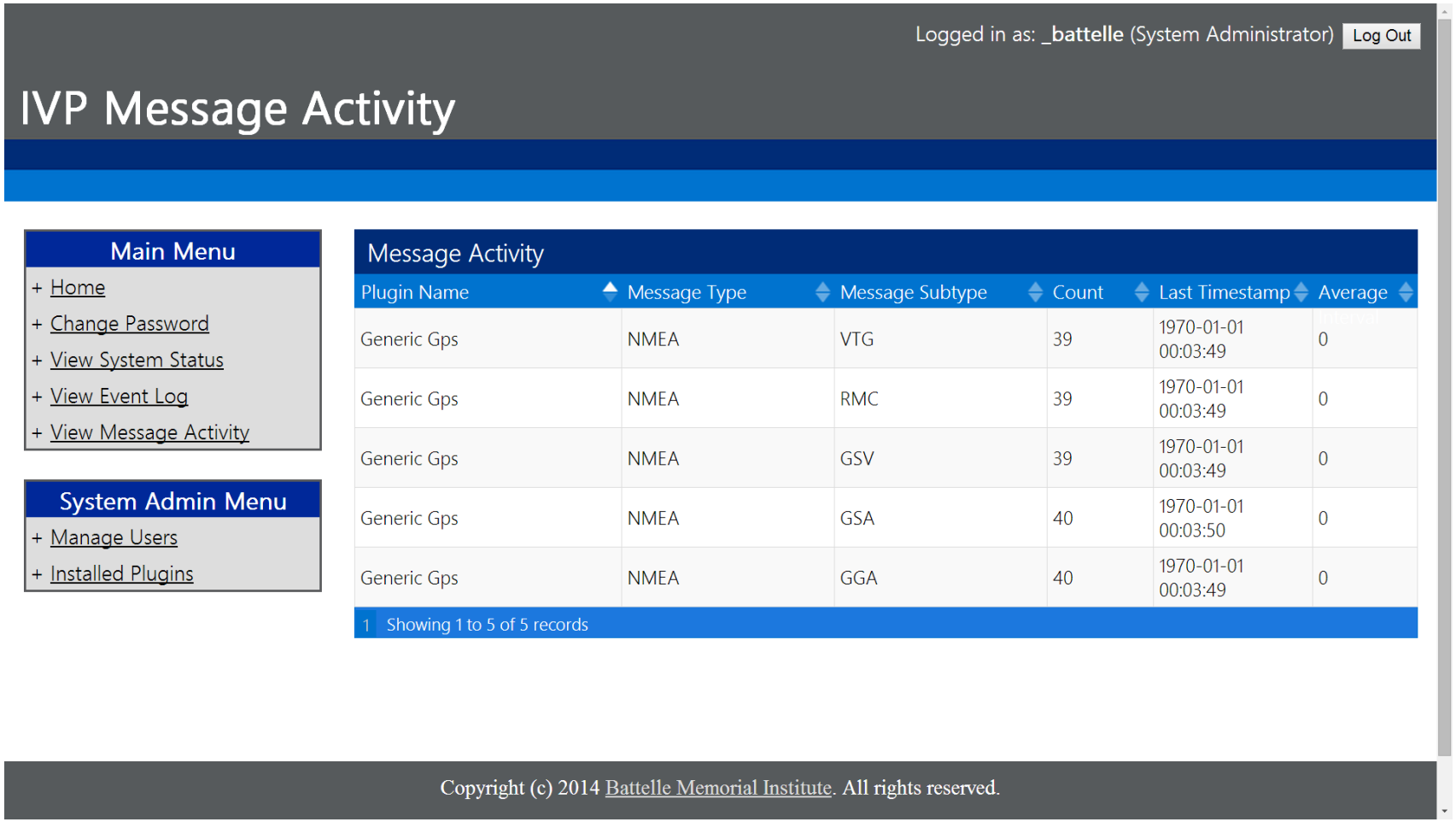

Source: Battelle

**Figure 4-11. The V2I Hub Administration Portal**



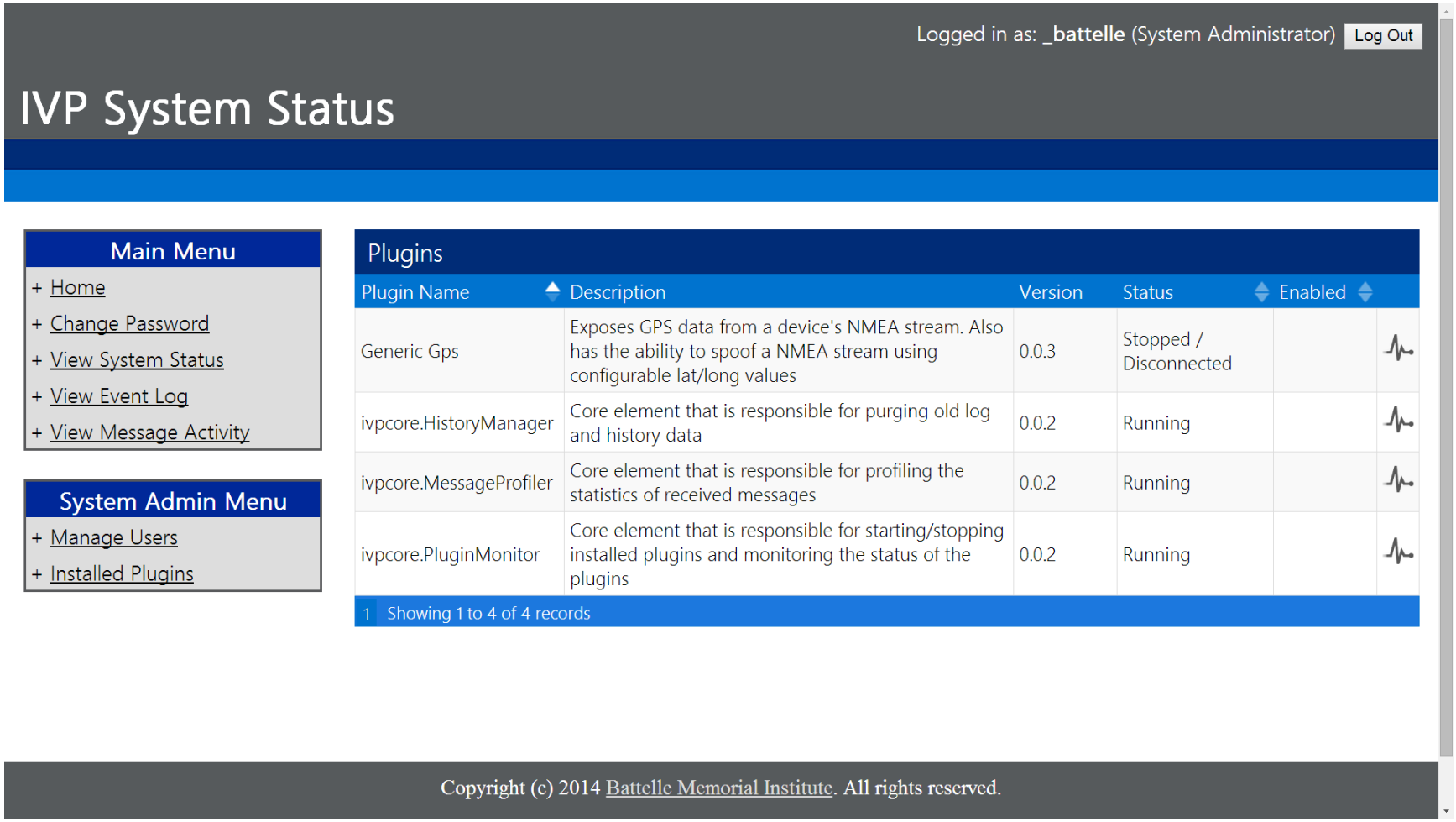

Source: Battelle

**Figure 4-12. The V2I Hub Event Log Page**




Source: Battelle

**Figure 4-13. The V2I Hub Message Activity Page**




Source: Battelle

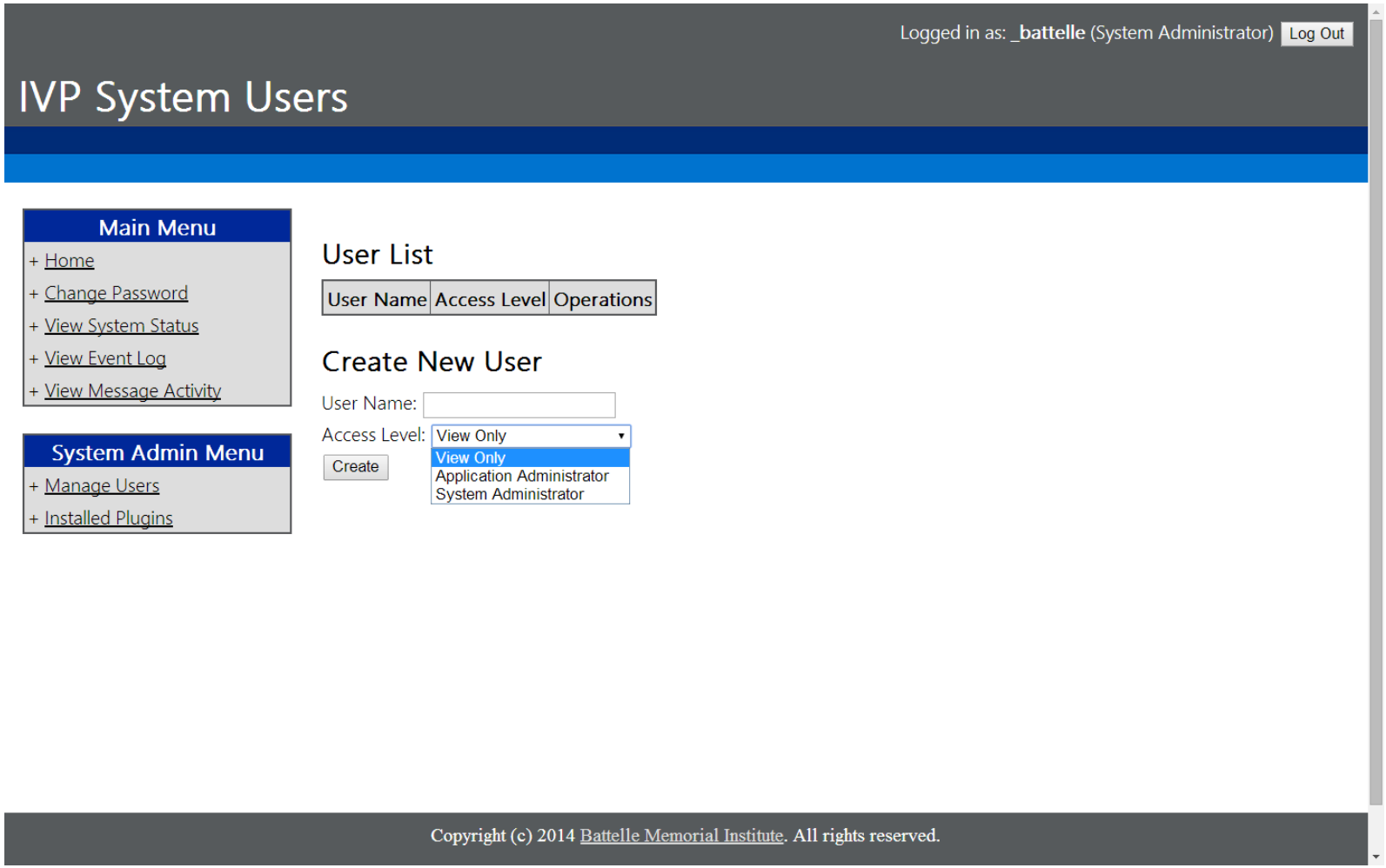
**Figure 4-14. The V2I Hub System Status Page**

# System Administration

- Clear Event Log: Allows a system administrator to completely clear the V2I Hub event log, without restarting the V2I Hub Core. The administrator is prompted for a confirmation before this action is taken.
- Change access level: Allows an administrator to promote or demote the access level of a user. The valid access levels recognized by the V2I Hub platform are:
  - View Only – Allows the user the ability to view system and plugin status only
  - Application Administration – Provides the user with the ability to install, remove, and manage plugin modules on the V2I Hub platform
  - System Administration – Elevates the user to have access to user administration functions.
- Change password
- Create new user account: Allows a system administrator to create a new user account. The administrator must specify the new account name, typically an email address, and select the new user's access level, as described above. (See Figure 4-15)
- Edit user account
- Remove user account: Enables a system administrator to delete a user's account from the system. The system administrator is prompted for confirmation before deleting the specified account.
- Reset password: Enables a system administrator to set the password of any user defined in the system to a random 8-character string consisting of only lower case letters and/or the digits from 0 to 9.
- Display user account list: The current user is shown a list of all user accounts defined in the system, along with each user's access level and operations.

## The V2I Hub Admin Web Portal API

In order to provide a more secure interface for the V2I Hub platform, all access to the V2I Hub Configuration and Status Database from the portal pages is mediated by the V2I Hub Admin Web Portal API. This arrangement reduces the potential for certain types of web site hacking attempts and attacks known as "SQL injection" attacks. This arrangement also serves to encourage separation of visual interface components from processing components, and allow for a more robust and manageable model/view/controller (MVC) design for the portal code.




Source: Battelle

**Figure 4-15. The V2I Hub Administration Portal User Administration Page**

# J2735:2015 Message Library

The payloads of messages destined for or originating from the DSRC radio are almost entirely encoded in the ASN.1 formats defined by the J2735:2015 standard. In order for plugin modules to conveniently access the data in the message payloads encoded this way, the V2I Hub platform includes a library that performs the necessary translations to and from the standard format.

The library's functions are accessed by plugin modules through calls to the V2I Hub platform API.

# Networking

The V2I Hub Connection supports both IPv4 and IPv6, but all external components do not. The DSRC Message Manager supports both IPv4 and IPv6 communications to the RSU. The Signal Controller only supports IPv4.

# Security

The V2I Hub Connection will be accessible on a Virtual Private Network (VPN) using secure shell (SSH) network protocol for secure data communications. This connection will allow users to make changes to the V2I Hub software without the need for physical access.

This interface provides administrator's with remote access to V2I Hub. The interface is secure, uses standard off-the-shelf components, and allows administrators to do more than through the Admin Web Interface.

The SSH Interface is a COTS product that allows secure access to the V2I Hub platform's underlying OS. This capability is only accessed by users with appropriate credentials.

Network security to the V2I Hub Connection is handled by the installing agency. For our testing and demonstration purposes, a VPN server with certificate access was used to restrict access to the V2I Hub Connection.

Over-the-air security is provided using certificates and signing of the DSRC messages. The DSRC Message Manager Plugin has a Boolean configuration parameter "Signature" that is passed to the radio to specify whether messages are signed and encrypted.

# The V2I Hub plugin API

The Plugin API is the foundation of all plugins in the V2I Hub platform. The API has the functionality to communicate to the V2I Hub Message Router, subscribe and publish messages, read configuration information, and encode and decode messages using the message libraries.

# Chapter 5 Plugin Components

Plugin modules are the means of extending the functionality of the V2I Hub platform.

## Generic Plugin Structure

All V2I Hub platform plugin modules have the same general structure and interact with the core of the V2I Hub platform via standard means. In order to successfully be installed and execute on the V2I Hub platform, a plugin module is required to have:

- A unique name, taken from the name of the deployment zip file for the plugin
- A manifest file, containing the configuration parameters for the plugin and their default values
- An executable file
- A zip file for deployment, containing the manifest file and the executable file for the plugin itself

Plugins on the V2I Hub platform are deployed in a standard location in the platform's directory structure. The directory structure where the plugin is deployed is generated automatically by the system during installation. The name of the plugin deployment directory is taken from the name of the plugin's zip file.

When a plugin is removed (deleted) from the system, the deployment directory and all data associated to the plugin is removed from the file system as well. Log data specific to the plugin is removed, however the record of messages published to the V2I Hub Message Router is retained in the V2I Hub Message Router log files.

```
{
        "name":"EmptyPlugin",
        "description":"...",
        "version":"0.0.1",
        "exeLocation":"/Debug/EmptyPlugin",
        "coreIpAddr":"127.0.0.1",
        "corePort":24601,
        "messageTypes":[
                {
                        "type":"...",
                        "subtype":"...",
                        "description":"..."
                }
        ],
        "configuration":[
                {
                        "key":"...",
                        "default":"...",
                        "description":"..."
                }

        ]
}
```

Source: Battelle

**Figure 5-1. An "Empty" manifest file**

The manifest file is a JavaScript Object Notation (JSON) text file that defines the characteristics of the plugin that are known to the V2I Hub platform, configuration parameters that are required by the V2I Hub platform, and any configuration parameters specific to the particular plugin. The JSON representation for an "empty" plugin module is shown in Figure 5-1. The fields defined in the manifest file are:

- Name – The name of the plugin. This string is required to be unique within the plugins installed in the V2I Hub platform, unless the user intends to replace (update) an existing plugin module. The name is limited to 50 characters, and may not be empty.
- Description – A brief description of the plugin module. This value is represented in the V2I Hub database as a 'TEXT' data type which may be as large as 65,535 characters in length. The description may not be empty.
- Version – The plugin's version number. No validity checking is performed on the version number.
- Executable Location – The location in the file system where the executable for the plugin can be found.
- Core IP Address – The IPV 4 address of the V2I Hub Core.
- Core Port – The port number for the V2I Hub Core.
- Message Types – The type definitions of the messages that this extension plugin will publish to the V2I Hub platform.
- Configuration parameters – The parameters required to configure the plugin and their default values.

When a plugin is successfully installed on the V2I Hub platform, the manifest file is read. The configuration parameters and their required default values are recorded in the V2I Hub Platform's Configuration and Status database. The values stored in the database can be edited through the Admin Web Portal by a user with appropriate access rights. However, default values for a plugin's configuration parameters cannot be changed through the Admin Web Portal. These may only be changed by edits to the manifest file itself, preferably as updates to the zip file contents prior to being uploaded into the V2I Hub platform. Edits made to a manifest file once the plugin has been installed are not recognized by the V2I Hub platform until the plugin is halted and re-enabled.

# Generic GPS Plugin

The Generic GPS plugin interacts with a connected GPS receiver to supply V2I Hub with real time positioning information in NEMA GPGGA format. The plugin does not provide any locally generated GPS corrections.

The GPS plugin receives location information from the external GPS receiver through a serial port on the V2I Hub platform, if one is attached, or reads static location information from a local configuration file. The GPS plugin publishes location information as an NEMA GPGGA formatted payload to the V2I Hub Message Router. The manifest file for the Location Plugin is shown in Figure 5-2 and Figure 5-3.

.

```
"name":"Generic Gps",
        "description":"Exposes GPS data from a device's
                NMEA stream.  Also has the ability to spoof
                a NMEA stream using configurable lat/long values",
        "version":"0.0.4",
        "exeLocation":"/Debug/GenericGpsPlugin",
        "coreIpAddr":"127.0.0.1",
        "corePort":24601,
        "messageTypes":[
                {
                        "type":"NMEA",
                        "subtype":"GGA",
                        "description":"Global Positioning System
                                Fix Data. Time, position and fix related
                                data for a GPS receiver."
                },
                {
                        "type":"NMEA",
                        "subtype":"GGL",
                        "description":"Geographic position,
                                latitude / longitude"
                },
                {
                        "type":"NMEA",
                        "subtype":"GSA",
                        "description":"GPS DOP and active satellites"
                },
                {
                        "type":"NMEA",
                        "subtype":"GSV",
                        "description":"GPS Satellites in view"
                },
                {
                        "type":"NMEA",
                        "subtype":"RMC",
                        "description":"Recommended minimum specific
                                GPS/Transit data"
                }
        ],
```

Source:  Battelle

**Figure 5-2.  The Manifest File for the Generic GPS Plugin**

```
"configuration":[
                {
                        "key":"Device Stream File",
                        "default":"/dev/ttyACM0",
                        "description":"The device stream file
                                of the GPS device."
                },
                {
                        "key":"Mode",
                        "default":"SPOOFED",
                        "description":"Options are: 'SPOOFED' or 'LIVE'.
                                The field is NOT case sensitive."
                },
                {
                        "key":"Spoofed Latitude",
                        "default":"0.0000",
                        "description":"+- decimal degrees"
                },
                {
                        "key":"Spoofed Longitude",
                        "default":"0.0000",
                        "description":"+- decimal degrees"
                },
                {
                        "key":"Spoofed Elevation",
                        "default":"0.0000",
                        "description":"+- meters"
                },
                {
                        "key":"Spoofed Speed",
                        "default":"0.0000",
                        "description":"m/s"
                },
                {
                        "key":"Spoofed Course",
                        "default":"0.0000",
                        "description":"degrees"
                }
        ]
}
```

Source: Battelle

**Figure 5-3. The Manifest File for the Generic GPS Plugin (cont.)**

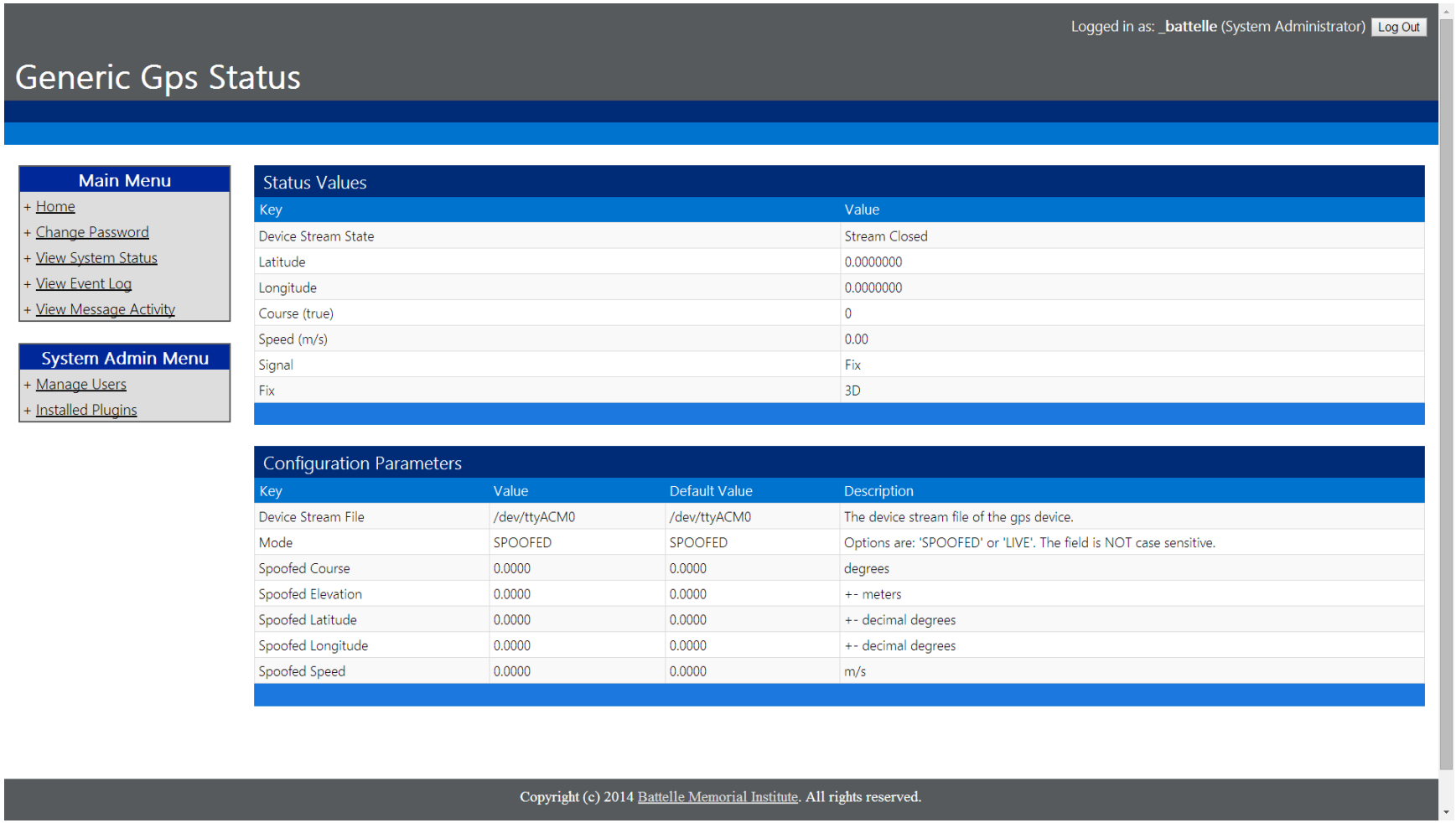
The fields defined in the Generic GPS Plugin file show the five (5) message subtypes published by the plugin. All of the messages published by the GPS Plugin conform to NMEA 0183 Standard definitions. They are:

- NMEA GAA strings – Global Positioning System Fix Data.
- NMEA GLL strings – Geographic Position, Latitude and Longitude
- NMEA GSA strings – GPS DOP and Active Satellites
- NMEA GSV strings – GPS Satellites in View
- NMEA RCM strings – Recommended Minimum Specific GPS/Transit data

The configuration parameters required by the Generic GPS plugin are:

- The Device Stream File – This parameter defines the serial port from which the plugin can read the GPS data.
- Mode – Determines whether the plugin is to read actual data from a GPS receiver over the serial port, or use a "spoofed" location defined by other parameters.
- Spoofed Latitude, Longitude, Elevation, Speed and Course – These five parameters define the data required to construct the NMEA strings necessary for a predefined location.

Figure 5-4 shows the presentation of the status values and configuration parameter values for the Generic GPS Plugin after it has been installed and enabled. This screen is visible to any logged in user with application or system administration access.




Source: Battelle

**Figure 5-4. The Generic GPS Status Page**

# Position Correction Plugin

The Position Correction Provider supplies V2I Hub with real time differential GPS correction data, using an Ntrip (Networked Transport of RTCM via Internet Protocol) client to receive differential GPS data over the internet in Radio Technical Commission for Maritime Services (RTCM) format.

The Position Correction Plugin receives correction information over an internet connection after supplying the Position Correction Provider its current location information. The position correction information is converted into a J2735 RTCM message and published to the V2I Hub Message Router. The Position Correction Plugin may also receive J2735 RTCM Messages from the V2I Hub Message Router, and if the source of those messages is not itself, the Position Correction Plugin will stop asking for position correction data from the Position Correction Provider until the RTCM messages stop. This strategy allows the V2I Hub platform to act either as a publisher or subscriber of position correction data as dictated by the local environment.

As shown in the manifest file of Figure 5-5, The Position Correction Plugin publishes RTCM 2.3 messages.

The configuration parameters required by the position correction plugin are:

- Endpoint IP Address – This is the V2I Hub-4 address of the source of the RTCM stream
- Endpoint Port – The port address corresponding to the RTCM source.
- Username – The subscriber account username for the RTCM service
- Password – The unencrypted password of the subscriber account
- Mount Point – This identifies the desired type of correction data provided by the position correction provider.

```
{
        "name":"NTRIP",
        "description":"",
        "version":"0.0.1",
        "exeLocation":"/Debug/NtripPlugin",
        "coreIpAddr":"127.0.0.1",
        "corePort":24601,
        "messageTypes":[
                {
                        "type":"RTCM",
                        "subtype":"2.3"
                }
        ],
        "configuration":[
                {
                        "key":"Endpoint IP",
                        "default":"156.63.133.118",
                        "description":""
                },
                {
                        "key":"Endpoint Port",
                        "default":"2101",
                        "description":""
                },
                {
                        "key":"Username",
                        "default":"battelle2",
                        "description":""
                },
                {
                        "key":"Password",
                        "default":"rtkPass",
                        "description":""
                },
                {
                        "key":"Mountpoint",
                        "default":"ODOT_RTCM23",
                        "description":""
                }

        ]
}
```

Source: Battelle

**Figure 5-5. The Manifest File for the Position Correction Plugin**

# UTC Plugin

The UTC plugin is the source of Universal Coordinated Time for plugin modules installed on the V2I Hub platform. Depending on the configuration of the UTC plugin, the time source for the system's local time is synchronized with either timestamps from an installed GPS receiver, or from a Network Time Protocol (NTP) server, in the case that no GPS receiver is available and the V2I Hub platform has a reliable source of internet connectivity. The manifest file for the UTC plugin is shown in Figure 5-6.

```
{
        "name":"UTC Time",
        "description":"Provides the current UTC time.",
        "version":"0.0.1",
        "exeLocation":"/Debug/UtcPlugin",
        "coreIpAddr":"127.0.0.1",
        "corePort":24601,
        "messageTypes":[
                {
                        "type":"Time",
                        "subtype":"MS_UTC",
                        "description":"Current UTC time since
                                Epoch in milliseconds."
                },
                {
                        "type":"Time",
                        "subtype":"Formatted_UTC",
                        "description":"Current UTC time formatted
                                into month, day, year,
                                hour, minute, second."
                }
        ],
        "configuration":[
                {
                        "key":"Time Server",
                        "default":"localhost",
                        "description":"The time server or localhost
                                to get time from the V2I Hub host."
                },
                {
                        "key":"Frequency",
                        "default":"1000",
                        "description":"Millisecond frequency to
                                send the time."
                }
        ]
}
```

Source: Battelle

**Figure 5-6. The Manifest File for the UTC Plugin**

Regardless of the source of the system's local time, the UTC plugin extracts the local server time and formats it into several messages that are published to the V2I Hub Message Router.

# MAP Plugin

The MAP Plugin publishes a J2735 MAP Message containing data to describe complex intersections, curve outlines, and roadway segments which are used by a variety of other J2735 messages. An input to the MAP Plugin is an XML file containing the intersection geometry. Procedures for provisioning of an XML file are contained in the V2I Hub User Document. The manifest file for the MAP plugin is shown in Source: Battelle

Figure 5-7.

```
{
        "name":"MAP",
        "description":"Provides the intersection geometry.",
        "version":"0.0.1",
        "exeLocation":"/Debug/MapPlugin",
        "coreIpAddr":"127.0.0.1",
        "corePort":24601,
        "messageTypes":[
                {
                        "type":"J2735",
                        "subtype":"MAP",
                        "description":"Intersection geometry in J2735 format."
                }
        ],
        "configuration":[
        ]
}
```

Source: Battelle

**Figure 5-7. The Manifest File for the MAP Plugin**

# SPAT Generator Plugin

J2735 SPAT message is published from the SPAT Generator Plugin using the information obtained by the Traffic Signal Controller. The manifest file for the SPAT Generator plugin is shown in Figure 5-8.

```
{
        "name":"SPAT Generator",
        "description":"",
        "version":"0.0.1",
        "exeLocation":"/Debug/SpatGeneratorPlugin",
        "coreIpAddr":"127.0.0.1",
        "corePort":24601,
        "messageTypes":[
                {
                        "type":"J2735",
                        "subtype":"SPAT"
                }
        ],
        "configuration":[]
}
```

Source: Battelle

**Figure 5-8. The Manifest File for the SPAT Generator Plugin**

# DSRC Message Manager Plugin

The DSRC Message Manager Plugin is responsible for taking internal messages flagged for transmission and ensuring they are sent out via the DSRC radio. Communications to the RSU will be UDP messages as defined in the RSU 3.1 specification. A sample message to immediately send a MAP message is shown below in Figure 5-9Figure .

```
Version=0.5
Type=MAP
PSID=0xBFF0
Priority=7
TxMode=CONT
TxChannel=172
TxInterval=0
DeliveryStart=
DeliveryStop=
Signature=True
Encryption=False
Payload=3081DE8001108109000000000000001000830101A481C63081C3800102A11BA119A01080
0418054A3B8104CE3585DF82020D06810200408201028202070B8303061621840270D00850102A61
080041804FD888104CE35C39E82020CF68702016E880100A93C303A80020040A234A032A3300404
1C6BCDB304040420EC2B0404FAC8EC280404EF79F1210404EBC4FD660404E65310690404F9621
AA50404095B3F31AA3AA0383006A004800235293006A0048002010C3006A004800231383006A00
4800222113006A0048002010C3006A004800231483006A004800222118502100l
```

Source: LocoMate USersGuid_V1.26.pdf, section D2

**Figure 5-9. Sample UDP DSRC Message**

# INFLO Plugin

The INFLO Plugin retrieves Queue Warnings and Speed Harm TIM messages from the cloud computing system and sends the TIM messages out the DSRC radio. It also supplies BSM messages to the cloud computing system for processing. The manifest file for the INFO Plugin is shown in Figure 5-10.

```
{
	"name":"INFLO",
	"description":"The INFLO Plugin retrieves Queue Warnings and Speed Harm TIM
messages from the cloud computing system and sends the TIM messages out the DSRC radio.
The INFLO Plugin also supplies BSM messages to the cloud computing system for processing.",
	"version":"1.0.0",
	"exeLocation":"/Debug/InfloPlugin",
	"coreIpAddr":"127.0.0.1",
	"corePort":24601,
	"messageTypes":[
	],
	"configuration":[
		{
			"key":"BSM Web API",
			"default":"http://inflotst-cloud-roles.cloudapp.net/api/bsm",
			"description":"URL of the BSM Web API"
		},
		{
			"key":"TIM Web API",
			"default":"http://inflotst-cloud-roles.cloudapp.net/api/tim",
			"description":"URL of the TIM Web API"
		},
		{
			"key":"Roadway ID",
			"default":"0",
			"description":"ID of the INFLO Roadway"
		},
		{
			"key":"Roadway MM",
			"default":"0.0",
			"description":"Milemarker location on INFLO Roadway"
		}
	]
}
```


Source: Battelle

**Figure 5-10. The Manifest File for the INFLO Plugin**

# Chapter 6 Hardware

The hardware selected to support the initial V2I Hub platform development and deployment was the Advantech UNO-2184G. This unit is an example of an industrial grade, commercial off the shelf (COTS) automation computer, providing extensive I/O functionality as well as ample processing power to handle the needs of the targeted V2I applications as well as the message routing and administrative needs of the core V2I Hub platform functionality. Key specifications of the hardware and software are listed in Figure 6-1.

- UNO-2184G-D44E

4 x 10/100/1000Base-T RJ-45 ports
  - Intel Core i7-2655LE 2.2GHz
  - 4 GB DDR3 SDRAM
  - 80 GB SSD HD
  - 2 x RS-232 ports with DB9 Connectors
  - 2 x RS-232/422/485 with DB9 Connectors
  - 6 x USB 2.0

- Ubuntu 14
  - mySQL Server
  - Apache Web Server

Source: Advantech

**Figure 6-1. Platform Hardware and Specifications**

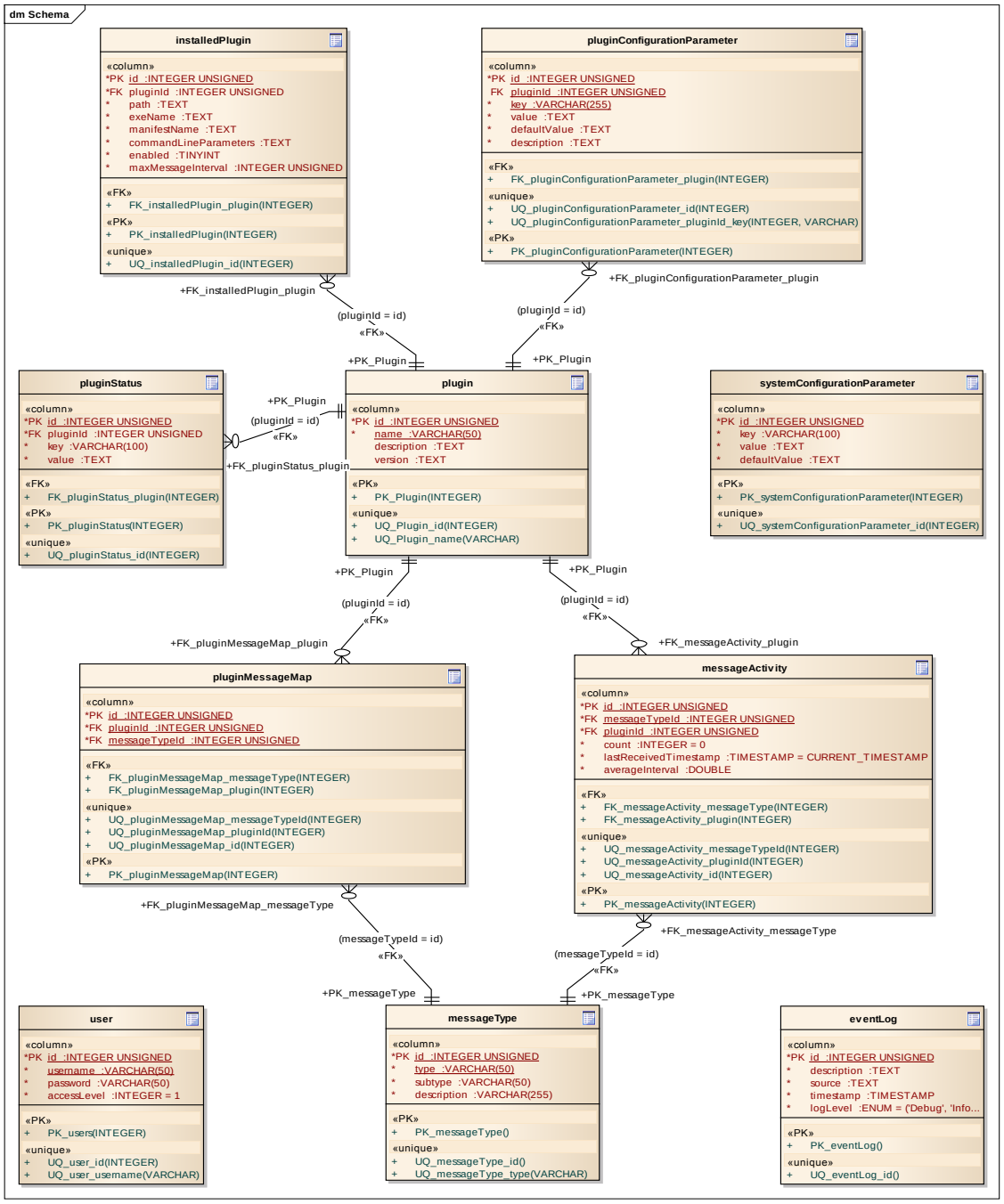
The DSRC (Dedicated short-range communications) radio will be used to relay messages from the infrastructure (RSU) to connected vehicles (OBU). The specific hardware selected for this function will vary with deployment. For our setup we are using Arada radios for both the RSU and OBU. The Arada RSU will be an Arada System's LocoMate™ Commando. The DSRC radio used as a proxy for deployed hardware during the development of the V2I Hub platform is an Arada System's LocoMate™ GO OBU battery powered unit, shown in Figure 6-2 unit will receive messaging from the DSRC radio. Refer to Arada Systems' documentation for recommended antenna configurations.

The solution integrates GPS, Bluetooth and high-power 802.11p radios. It is fully compliant with Omni-Air's certification and used in worldwide deployments including the U.S. DOT's Safety Pilot in Ann Arbor, Michigan.


Source: Arada Systems

**Figure 6-2. The Arada Systems' LocoMate™ GO OBU**

# Chapter 7 Database Schema




Source: Battelle

**Figure 7-1. Database Schema**

# installedPlugin

**Table 7-1. installedPlugin Relational Database Table Columns**

| PK | Name | Type | Not Null | Unique | Len | Notes |
|---|---|---|---|---|---|---|
| True | id | INTEGER | True | True | | Primary key |
| False | pluginId | INTEGER | True | False | | Foreign key into plugin table. |
| False | path | TEXT | True | False | | The location of the plugin executable in the file system. |
| False | exeName | TEXT | True | False | | The name of the plugin's executable. |
| False | manifestName | TEXT | True | False | | The name of the manifest file describing this plugin's characteristics |
| False | commandLineParameters | TEXT | True | False | | |
| False | enabled | TINYINT | True | False | | |
| False | maxMessageInterval | INTEGER | True | False | | |

Source: Battelle

**Table 7-2. installedPlugin Table Column Constraints**

| Name | Type | Columns |
|---|---|---|
| FK_installedPlugin_plugin | Public | pluginId |
| PK_installedPlugin | Public | id |
| UQ_installedPlugin_id | Public | id |

Source: Battelle

**Table 7-3. installedPlugin Table Relationships**

| Columns | Association | |
|---|---|---|
| (pluginId = id) | **0..*** | installedPlugin.FK_installedPlugin_plugin |
| | **1** | plugin.PK_Plugin |

Source: Battelle

# pluginStatus

**Table 7-4. pluginStatus Relational Database Table Columns**

| PK | Name | Type | Not Null | Unique | Len | Notes |
|---|---|---|---|---|---|---|
| True | id | INTEGER | True | True | | Primary key |
| False | pluginId | INTEGER | True | False | | Foreign key into plugin table |
| False | key | VARCHAR | True | False | 100 | |
| False | value | TEXT | True | False | | |

Source: Battelle

**Table 7-5. pluginStatus Table Column Constraints**

| Name | Type | Columns |
|---|---|---|
| FK_pluginStatus_plugin | Public | pluginId |
| PK_pluginStatus | Public | id |
| UQ_pluginStatus_id | Public | id |

Source: Battelle

**Table 7-6. pluginStatus Table Relationships**

| Columns | Association | |
|---|---|---|
| (pluginId = id) | **0..*** | pluginStatus.FK_pluginStatus_plugin |
| | **1** | plugin.PK_Plugin |

Source: Battelle

# systemConfigurationParameter

This table lists the V2I Hub system configuration parameters used by both core components and plugins to control the behavior of the system.

**Table 7-7. systemConfigurationParameter Relational Database Table Columns**

| PK | Name | Type | Not Null | Unique | Len | Notes |
|---|---|---|---|---|---|---|
| True | id | INTEGER | True | True | | Primary key |
| False | key | VARCHAR | True | False | 100 | The name of a configuration parameter. |
| False | value | TEXT | True | False | | The value of a configuration parameter |
| False | defaultValue | TEXT | True | False | | |

Source: Battelle

**Table 7-8. systemConfigurationParameter Table Column Constraints**

| Name | Type | Columns |
|---|---|---|
| PK_systemConfigurationParameter | Public | id |
| UQ_systemConfigurationParameter_id | Public | id |

Source: Battelle

This table does not have any foreign keys; therefore, no relationship table exists.

# pluginConfigurationParameter

This table lists the V2I Hub system configuration parameters used by both core components and plugins to control the behavior of the system.

**Table 7-9. pluginConfigurationParameter Relational Database Table Columns**

| PK | Name | Type | Not Null | Unique | Len | Notes |
|---|---|---|---|---|---|---|
| True | id | INTEGER | True | True | | Primary key |
| False | pluginId | INTEGER | False | True | | Foreign key into plugin table. |
| False | key | VARCHAR | True | True | 255 | The name of a configuration parameter. |
| False | value | TEXT | True | False | | The value of a configuration parameter |
| False | defaultValue | TEXT | True | False | | Default setting of a configuration parameter. |
| False | description | TEXT | True | False | | A brief description of the parameter's purpose. |

Source: Battelle

**Table 7-10. pluginConfigurationParameter Table Column Constraints**

| Name | Type | Columns |
|---|---|---|
| FK_pluginConfigurationParameter_plugin | Public | pluginId |
| UQ_pluginConfigurationParameter_id | Public | id |
| UQ_pluginConfigurationParameter_pluginId_key | Public | pluginId<br>key |
| PK_pluginConfigurationParameter | Public | id |

Source: Battelle

**Table 7-11. pluginConfigurationParameter Table Relationships**

| Columns | Association | |
|---|---|---|
| (pluginId = id) | **0..*** | pluginConfigurationParameter.FK_pluginConfigurationParameter_plugin |
| | **1** | plugin.PK_Plugin |

Source: Battelle

# plugin

This table lists the plugins loaded and available to run on the V2I Hub platform.

**Table 7-12. plugin Relational Database Table Columns**

| PK | Name | Type | Not Null | Unique | Len | Notes |
|---|---|---|---|---|---|---|
| True | id | INTEGER | True | True | | Primary key |
| False | name | VARCHAR | True | True | 50 | A unique plugin name |
| False | description | TEXT | False | False | | |
| False | version | TEXT | False | False | | |

Source: Battelle

**Table 7-13. plugin Table Column Constraints**

| Name | Type | Columns |
|---|---|---|
| PK_Plugin | Public | id |
| UQ_Plugin_id | Public | id |
| UQ_Plugin_name | Public | name |

Source: Battelle

**Table 7-14. plugin Table Relationships**

| Columns | Association | |
|---|---|---|
| (pluginId = id) | **0..*** | pluginMessageMap.FK_pluginMessageMap_plugin |
| | **1** | plugin.PK_Plugin |
| (pluginId = id) | **0..*** | messageActivity.FK_messageActivity_plugin |
| | **1** | plugin.PK_Plugin |
| (pluginId = id) | **0..*** | pluginConfigurationParameter.FK_pluginConfigurationParameter_plugin |
| | **1** | plugin.PK_Plugin |
| (pluginId = id) | **0..*** | installedPlugin.FK_installedPlugin_plugin |
| | **1** | plugin.PK_Plugin |
| (pluginId = id) | **0..*** | pluginStatus.FK_pluginStatus_plugin |
| | **1** | plugin.PK_Plugin |

Source: Battelle

# messageType

This table lists the valid message types of every plugin loaded on the V2I Hub platform.

**Table 7-15. messageType Relational Database Table Columns**

| PK | Name | Type | Not Null | Unique | Len | Notes |
|---|---|---|---|---|---|---|
| True | id | INTEGER | True | True | 0 | Primary key |
| False | type | VARCHAR | True | True | 50 | A unique message type name |
| False | subtype | VARCHAR | True | False | 50 | |
| False | description | VARCHAR | True | False | 255 | A description of the message type |

Source: Battelle

**Table 7-16. messageType Table Column Constraints**

| Name | Type | Columns |
|---|---|---|
| PK_messageType | Public | id |
| UQ_messageType_id | Public | id |
| UQ_messageType_type | Public | type |

Source: Battelle

**Table 7-17. messageType Table Relationships**

| Columns | Association | |
|---|---|---|
| (messageTypeId = id) | **0..*** | messageActivity.FK_messageActivity_messageType |
| | **1** | messageType.PK_messageType |
| (messageTypeId = id) | **0..*** | pluginMessageMap.FK_pluginMessageMap_messageType |
| | **1** | messageType.PK_messageType |

Source: Battelle

# pluginMessageMap

This table identifies the types of messages generated by each plugin.

**Table 7-18. pluginMessageMap Relational Database Table Columns**

| PK | Name | Type | Not Null | Unique | Len | Notes |
|---|---|---|---|---|---|---|
| True | id | INTEGER | True | True | | Primary key |
| False | pluginId | INTEGER | True | True | | Foreign key into the plugin table |
| False | messageTypeId | INTEGER | True | True | | Foreign key into the messageType table. |

Source: Battelle

**Table 7-19. pluginMessageMap Table Column Constraints**

| Name | Type | Columns |
|---|---|---|
| FK_pluginMessageMap_messageType | Public | messageTypeId |
| UQ_pluginMessageMap_messageTypeId | Public | messageTypeId |
| UQ_pluginMessageMap_pluginId | Public | pluginId |
| PK_pluginMessageMap | Public | id |
| UQ_pluginMessageMap_id | Public | id |
| FK_pluginMessageMap_plugin | Public | pluginId |

Source: Battelle

**Table 7-20. pluginMessageMap Table Relationships**

| Columns | Association | |
|---|---|---|
| (pluginId = id) | **0..*** | pluginMessageMap.FK_pluginMessageMap_plugin |
| | **1** | plugin.PK_Plugin |
| (messageTypeId = id) | **0..*** | pluginMessageMap.FK_pluginMessageMap_messageType |
| | **1** | messageType.PK_messageType |

Source: Battelle

# eventLog

This table records events generated by every V2I Hub Core component and plugin in the V2I Hub platform.

**Table 7-21. eventLog Relational Database Table Columns**

| PK | Name | Type | Not Null | Unique | Len | Notes |
|---|---|---|---|---|---|---|
| True | id | INTEGER | True | True | 0 | Primary key |
| False | description | TEXT | True | False | | The log message content |
| False | source | TEXT | True | False | | The name of the plugin or other agent that logged the event |
| False | timestamp | TIMESTAMP | True | False | | The date and time of the event in UTC |
| False | logLevel | ENUM | True | False | | The type of event being logged, one of<br>• Debug<br>• Info<br>• Warning<br>• Error<br>• Fatal |

Source: Battelle

**Table 7-22. eventLog Table Column Constraints**

| Name | Type | Columns |
|---|---|---|
| PK_eventLog | Public | Id |
| UQ_eventLog_id | Public | id |

Source: Battelle

# messageActivity

This table records the most recent message activity of each active plugin in the V2I Hub system. The data in this table is updated by the V2I Hub plugin monitor core component for every message the plugin monitor receives.

**Table 7-23. messageActivity Relational Database Table Columns**

| PK | Name | Type | Not Null | Unique | Len | Notes |
|---|---|---|---|---|---|---|
| True | id | INTEGER | True | True | | Primary key |
| False | messageTypeId | INTEGER | True | True | | Foreign key into the messageType table |
| False | pluginId | INTEGER | True | True | | Foreign key into the plugin table |
| False | count | INTEGER | True | False | | Records the total number of messages of a single message type emitted by a plugin. |
| False | lastReceivedTimestamp | TIMESTAMP | True | False | | The date and time of the most recent message of a type in UTC. |
| False | averageInterval | DOUBLE | True | False | | The rolling average of the interval between most recent set of messages of a single message type emitted by a plugin, measured in milliseconds. |

Source: Battelle

**Table 7-24. messageActivity Table Column Constraints**

| Name | Type | Columns |
|---|---|---|
| FK_messageActivity_messageType | Public | messageTypeId |
| UQ_messageActivity_messageTypeId | Public | messageTypeId |
| UQ_messageActivity_pluginId | Public | pluginId |
| PK_messageActivity | Public | id |
| UQ_messageActivity_id | Public | id |
| FK_messageActivity_plugin | Public | pluginId |

Source: Battelle

**Table 7-25. messageActivity Table Relationships**

| Columns | Association | |
|---|---|---|
| (pluginId = id) | **0..*** | messageActivity.FK_messageActivity_plugin |
| | **1** | plugin.PK_Plugin |
| (messageTypeId = id) | **0..*** | messageActivity.FK_messageActivity_messageType |
| | **1** | messageType.PK_messageType |

Source: Battelle

## user

The list of accounts that can access the V2I Hub platform via the administrative portal is held in the users table.

**Table 7-26. user Relational Database Table Columns**

| PK | Name | Type | Not Null | Unique | Len | Notes |
|---|---|---|---|---|---|---|
| True | id | INTEGER | True | True | | Primary key |
| False | username | VARCHAR | True | True | 50 | The account name for the user, typically an email address |
| False | password | VARCHAR | True | False | 50 | An encrypted password |
| False | accessLevel | INTEGER | True | False | | The access level permitted for this user, one of:<br>1. read-only access to portal<br>2. application administrator access<br>3. system administrator, all access |

Source: Battelle

**Table 7-27. user Table Column Constraints**

| Name | Type | Columns |
|---|---|---|
| PK_users | Public | id |
| UQ_user_id | Public | id |
| UQ_user_username | Public | username |

Source: Battelle

This table does not have any foreign keys; therefore, no relationship table exists.

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