Report on Architecture Description for the INFLO Prototype

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16. Abstract This report documents the Architecture Description for the implementation of the Intelligent Network Flow Optimization (INFLO) Prototype bundle within the Dynamic Mobility Applications (DMA) portion of the Connected Vehicle Program. The intent is to describe, at a high level, the architectural components that make up the INFLO system and their respective interfaces. The approach is loosely based on ISO/IEC 42010:2007(e) Systems and software engineering – Recommended practice for architectural description of software intensive systems.		
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Chapter 1 Introduction

This report documents the high level architectural concept for the prototype development and demonstration of the Intelligent Network Flow Optimization (INFLO) application bundle, with a focus on the Speed Harmonization (SPD-HARM), Queue Warning (Q-WARN) and Weather Responsive Traffic Management (WRTM) applications. These two applications together comprise a tightly integrated bundle that is a key research activity within the Dynamic Mobility Applications (DMA) portion of the Connected Vehicle Program.

Identifying Information

Architecture Name: Intelligent Network Flow Optimization (INFLO) Architecture

System-Of-Interest: Intelligent Network Flow Optimization (INFLO) application bundle, including Speed Harmonization (SPD-HARM), Weather Responsive Traffic Management (WRTM) and Queue Warning (Q-WARN) services.

Approach

This Architecture Description Document is based on the format and requirements laid out in ISO/IEC/IEEE 42010, *Systems and software engineering – Architecture description* which is an international standard for the documentation of a system's architecture. The 42010 standard is designed to be used on large complex systems, however because the goal of INFLO is a prototype demonstration we take some liberties with the required rigor and detail typically contained in a 42010 type architecture document. For example, our models are expressed, for the most part, using simple block diagrams as opposed to an industry standard systems engineering based modeling language. 42010 does not necessarily prescribe a specific approach as long as the information is communicated effectively and this document upholds that spirit[1].

[1] This document was based on a template created by Rich Hilliard which can be found at http://www.iso-architecture.org/42010/templates/. The template is licensed under a Creative Commons Attribution 3.0 Unported License which can be found at http://creativecommons.org/licenses/by/3.0/.

Architecture Evaluations

In this section we document results from any evaluations of the INFLO Architecture being documented.

Date	Comment/Action	Sections Affected
10-16-2013	Revised based on comments received from the US DOT on 10-10-2013	Entire Document
1-10-2014	Revised based on comments received from US DOT walkthrough review conducted 10-23-2013	Figures 3.1, 4.1 & 4.2.

Rationale for Key Decisions

1. In order to save on development time and cost, the Nomadic Device will contain as much commercial off-the-shelf (COTS) hardware as possible. Ideally, the dedicated short-range communications (DSRC) radio, cellular radio, and user interface components would be combined into a single device but in lieu of this, the plan is to package a COTS mobile device (tablet or phone) together with a COTS DSRC radio. While this will increase the overall packaging and "one off" costs it will reduce development time, risk and overall cost.

2. The mobile device (tablet or phone) would likely have enough processing power to support running the vehicle based Q-WARN, WRTM and SPD-HARM support software, but the wealth of existing code and application programming interface (API) support on the DSRC radio makes it appealing (and reduces risk) to implement as much as possible directly on the DSRC radio and use the mobile device as:
    a. A cellular network interface – using a commercial off-the-shelf mobile device (tablet or phone) saves the cost of integrating a cellular device directly into the DSRC radio. The approach is to use a Bluetooth (or similar) connection to the tablet/phone from the DSRC device and then using the tablet/phone's cellular capabilities to gain access to the Internet, and therefore the Traffic Management Entity.
    b. User interface – Using the commercial off-the-shelf mobile device (tablet or phone) as the primary interface to the driver/user.

3. We will consider architectural support for authentication, security, data integrity, and personal information protection during design. The approach will be to use as much from industry standard and packaged support as possible while creating an architecture that allows for higher, more complex, levels of protection if needed once the program moves out of the prototype demonstration phase.

Chapter 2 Stakeholders and Concerns

For complete treatment of stakeholders and concerns see the document entitled *Concept Development and Needs Identification for Intelligent Network Flow Optimization (INFLO), Functional and Performance Requirements, and High-Level Data and Communication Needs*, November 1, 2012 (FHWA-JPO-13-013).

Chapter 3 System of Interest

Figure 3-1 shows the system-level diagram with arrows indicating the various information flows between the entities. A detailed description of each of these entities follows:

- **Connected Vehicle (Nomadic Device)** – dual-radio device that can move from car to transit to pedestrian and includes ability to collect weather data. This device contains the following subsystems:
  - **Driver Interface System (UI)** – the in-vehicle system that displays system output and receives user input.
  - **Q-WARN Application** – the core in-vehicle application that processes real-time data and either makes individual queue warning determinations or responds to the queue warning messaging from the traffic management entity (TME).
  - **Communication System** – the in-vehicle system that communicates wirelessly with infrastructure and other nomadic devices to send and receive data and instructions (DSRC and/or cellular communication).
  - **Weather System** – the Nomadic Device will need the ability to sense and disseminate environmental conditions (temperature, barometric pressure, etc.) The Weather System is responsible for providing those sensors. If the Nomadic Device is installed in a vehicle with access to the on-board diagnostics, and if the vehicle provides environmental data (pressure, external temperature, etc.) then the system will utilize that information. The Nomadic Device will also have on-board environmental sensors that will provide localized environmental sensing.
  - **Integrated Vehicle Network Access System** – the in-vehicle systems that reads real-time vehicle data (if available; speed, heading, temperature, etc.) to make it available to the INFLO applications.
- **Traffic Management Entity (TME)** – the generalized system (which could refer to a traffic management center [TMC]) that is responsible for (a.) making segment-specific and network-wide target speed recommendations for SPD-HARM-enabled Nomadic Devices (b.) creating Q-WARN recommendations and policies on the transportation network using safety and mobility measures (c.) creating WRTM recommendations and policies on the transportation network using safety and mobility measures (d.) collecting information to permit agencies to monitor and evaluate the effectiveness of the Q-WARN, WRTM and SPD-HARM applications information. The TME will communicate these recommendations to the Nomadic Devices via I2V communications. The TME is comprised of the following subsystems:

- **TME-based Q-WARN Application** – the core infrastructure-based application that processes real-time and historical transportation network data to generate queue warnings for a given road segment.

- **TME-based SPD-HARM Application** – the core infrastructure-based application that processes real-time and historical transportation network data to determine network efficient speed harmonization recommendations.

- **TME-based WRTM Application** – the core infrastructure-based application that processes real-time and historical transportation network data to determine weather responsive traffic management recommendations.

- **TME-based Information Dissemination Subsystem** – the subsystem that sends speed harmonization and queue warning recommendations to road users on specific segments of the road via I2V communications and/or traditional dynamic message signs (DMSs). Will manage outgoing messaging, high-level protocols, prioritization, routing, security, etc.

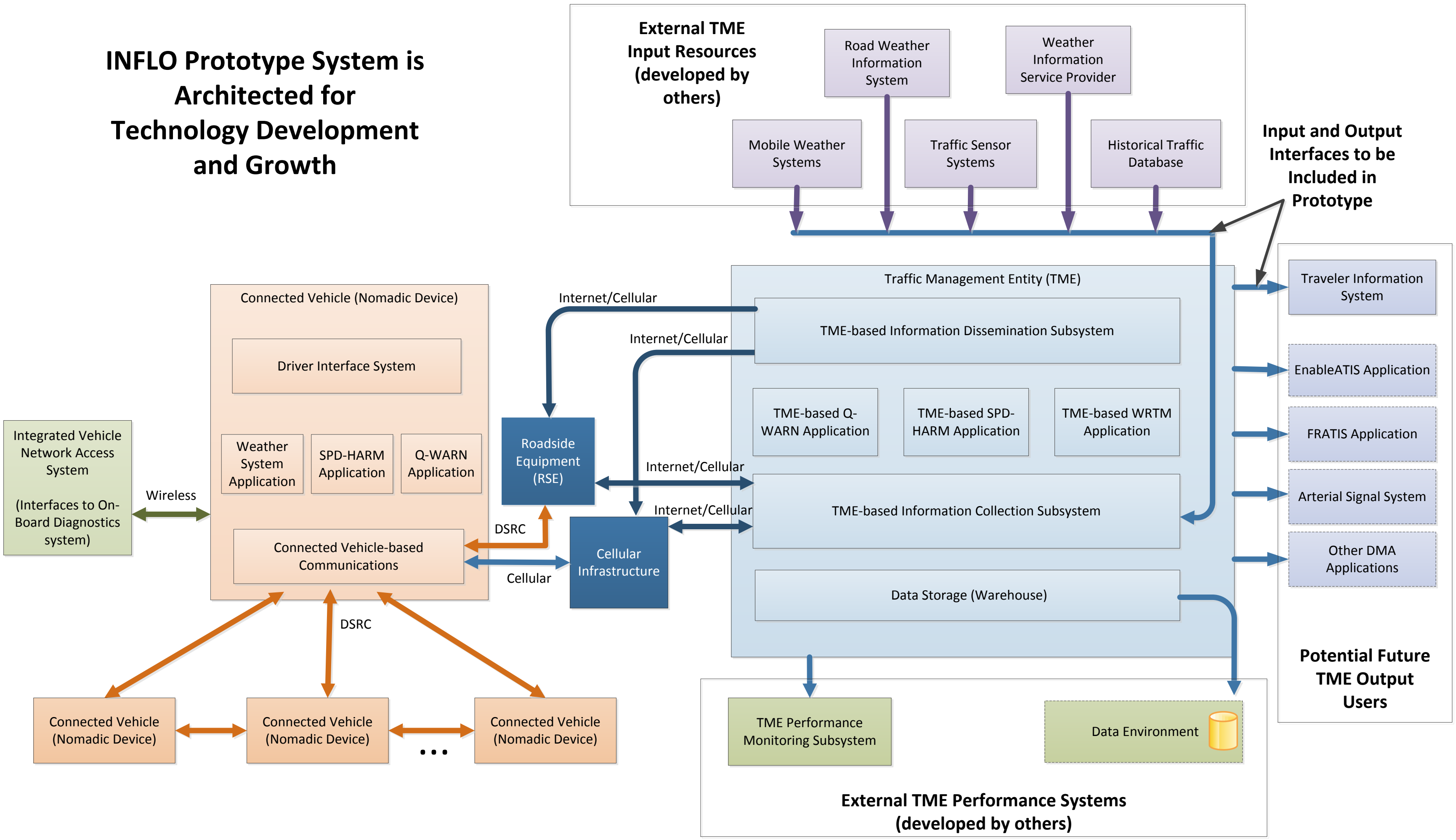
- **Data Storage (Warehouse)** – used to store data gathered from Nomadic Devices and fixed-location sensors as well as the data generated by the Q-WARN, WRTM and SPD-HARM applications to enable the Performance Monitoring Subsystem to measure the effectiveness of speed harmonization and queue warning heuristics, recommendations and policies on the transportation network using safety and mobility measures. This component also supports the Impacts Assessment (IA) element of the prototype project.
-
- **TME-based Information Collection** Subsystem – software and hardware in the TME that manages information input into the TME. Data can come from various external entities (Mobile Weather Systems, Traffic Sensor Systems, etc.) as well as the network of Nomadic Devices in the field.

- **Roadside Equipment** – the infrastructure-based communication systems that receive and send information between Nomadic Devices and the TME (may include DSRC and/or cellular communication).

- **TME Performance Monitoring Subsystem** – the subsystem of the TME that monitors the effectiveness of speed harmonization and queue warning heuristics, recommendations, and policies on the transportation network using safety and mobility measures. The TME-Performance Monitoring System will collect and store data that would potentially allow one to go back and determine if a need for increased enforcement might exist, but we don't envision it doing the assessment directly. What the system would include is the recommended target speed as well as the measured travel speed for each segment. By comparing these two measures, one could get a feel for the "level of compliance" that might exist. This would work for the queue warning and weather recommended target speeds that rely on conditions other than speed in making a target speed recommendation. This approach however probably will not work for the shockwave detection algorithm (i.e., SPD-HARM) because it uses measured speed to determine recommended target speeds.

- **Other Applications** – represents other applications that could contribute to and benefit from the data available for the SPD-HARM/Q-WARN/WRTM application.
  - ***Arterial Signal System***
  - ***Traveler Information Systems***
  - ***EnableATIS application***
  - ***FRATIS application***
  - ***Other DMA Applications***

- **Infrastructure-Based Detection Equipment** – existing, infrastructure-based sensors and other measurement equipment currently in use for queue, speed and weather/road condition detection purposes.
  - ***Mobile Weather Systems***
  - ***Road Weather Information System***
  - ***Traffic Sensor Systems***
  - ***Weather Information Service Provider***
  - ***Historical Traffic Database***



Source: Battelle/Texas A&M Transportation Institute

Figure 3-1. INFLO Prototype System Diagram

Chapter 4 Viewpoints, Views and Models

An Architecture Description Document typically contains multiple architecture views; each view adheres to the conventions of an architecture viewpoint. This section provides these architectural viewpoints, views and models thru the use of block diagrams. We will describe what architectural view(s) are important and document one or more models (block diagrams) appropriate for those view(s).

Physical View Description

The physical view model shown in Figure 4-1 represents the block diagram of the system. This is the most fundamental model of the architecture. Each block is a specific, tangible, physical entity in the system. The arrows represent logical connections between the individual entities.

Vehicle – represents a vehicle networked infrastructure. When the Nomadic Device is used within an automobile that has the correct interfaces exposed, it can connect to the vehicle's on-board diagnostic system to retrieve the current state for certain vehicle components. This interface is optional as the Nomadic Device should be designed to work, albeit in a limited mode, when it is not being used in a vehicle, for example, on a bicycle or a train.

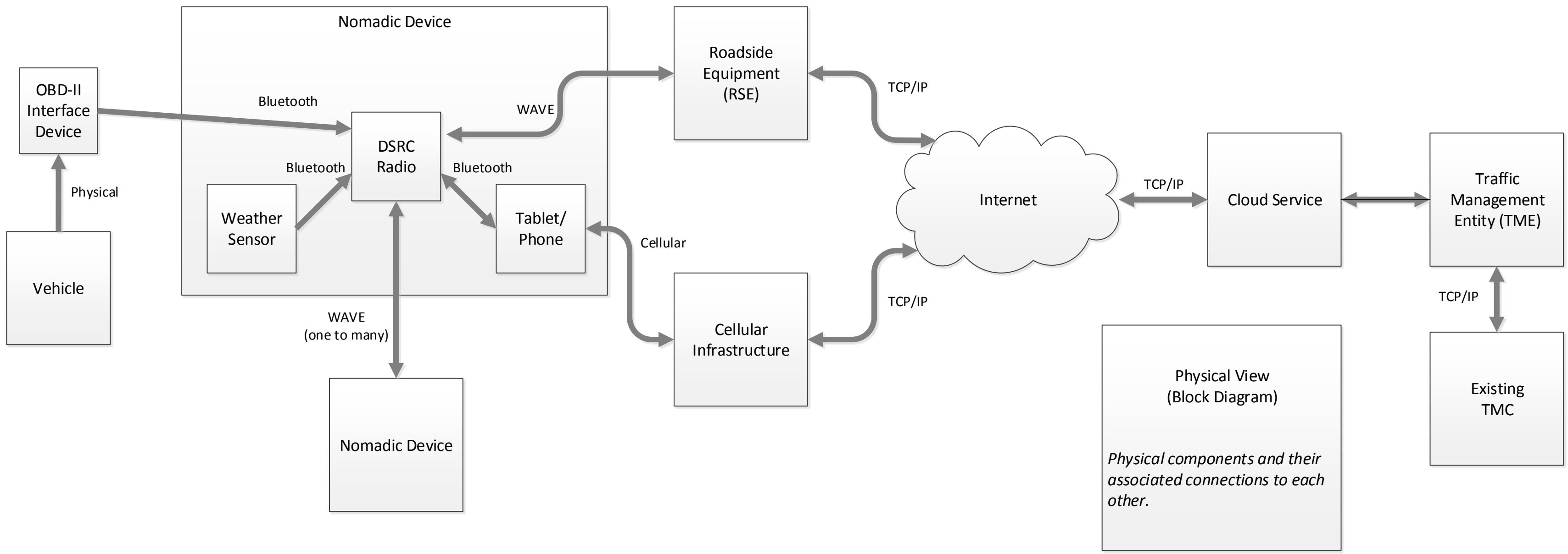
Nomadic Device – a dual-radio (cellular and DSRC) device that can move between vehicle, transit and pedestrian and includes ability to collect weather data. It also provides the primary user interface with the vehicle operator. It will host vehicle side Q-WARN algorithms. Nomadic devices themselves will communicate with each other by sending Q-WARN messages over the DSRC. The goal is for the V2V communications is to simply pass Q-WARN messages to DSRC radios in the vicinity and then for those vehicles to do the same. The plan is to implement a pretty simple N-Hop strategy to avoid getting into more complicated "mesh networking" types of implementations.

Roadside Equipment (RSE) – a system that will act as a bridge between the Nomadic Device and the Internet. The RSE will contain a DSRC radio and have back-haul connections to the TME. The firmware on the RSE will receive Basic Safety Messages and Road Side Alert messages from the Nomadic Devices, parse, and pass the information on to the TME. The TME will broadcast messages to the RSEs. The RSEs will convert those messages into DSRC-formatted packets and transmit to the in-range Nomadic Devices. For the prototype demonstration, the RSE will be connected to the Internet and we are assuming IP-based communications on that link between the RSE and the TME. In expanded demonstrations or full implementation a dedicated backhaul between the RSE and the TME could be used.

Cellular Infrastructure – standard TCP/IP over cellular infrastructure available to the Nomadic Devices to be used when not in range of a DSRC device, which is presumably faster and more reliable.

Cloud Service –cloud service for hosting the virtual TMC, for example, Microsoft® Windows Azure.

Traffic Management Entity (TME) – the host for the SPD-HARM, WRTM and Q-WARN components. The TME will receive information from each connected vehicle in the network. It will combine that information with historical data and external sensors sources (e.g., weather), synthesize this information and feed it to the SPD-HARM, WRTM and Q-WARN decision making systems. Results will be fed back to the connected vehicle network or to fixed infrastructure equipment (e.g., road signs).



Source: Battelle

Figure 4-1. Physical View

Communications View Description

The Communications View is represented in *Source: Battelle*
Figure 4-2 above. Each of the major components of this view are described below.

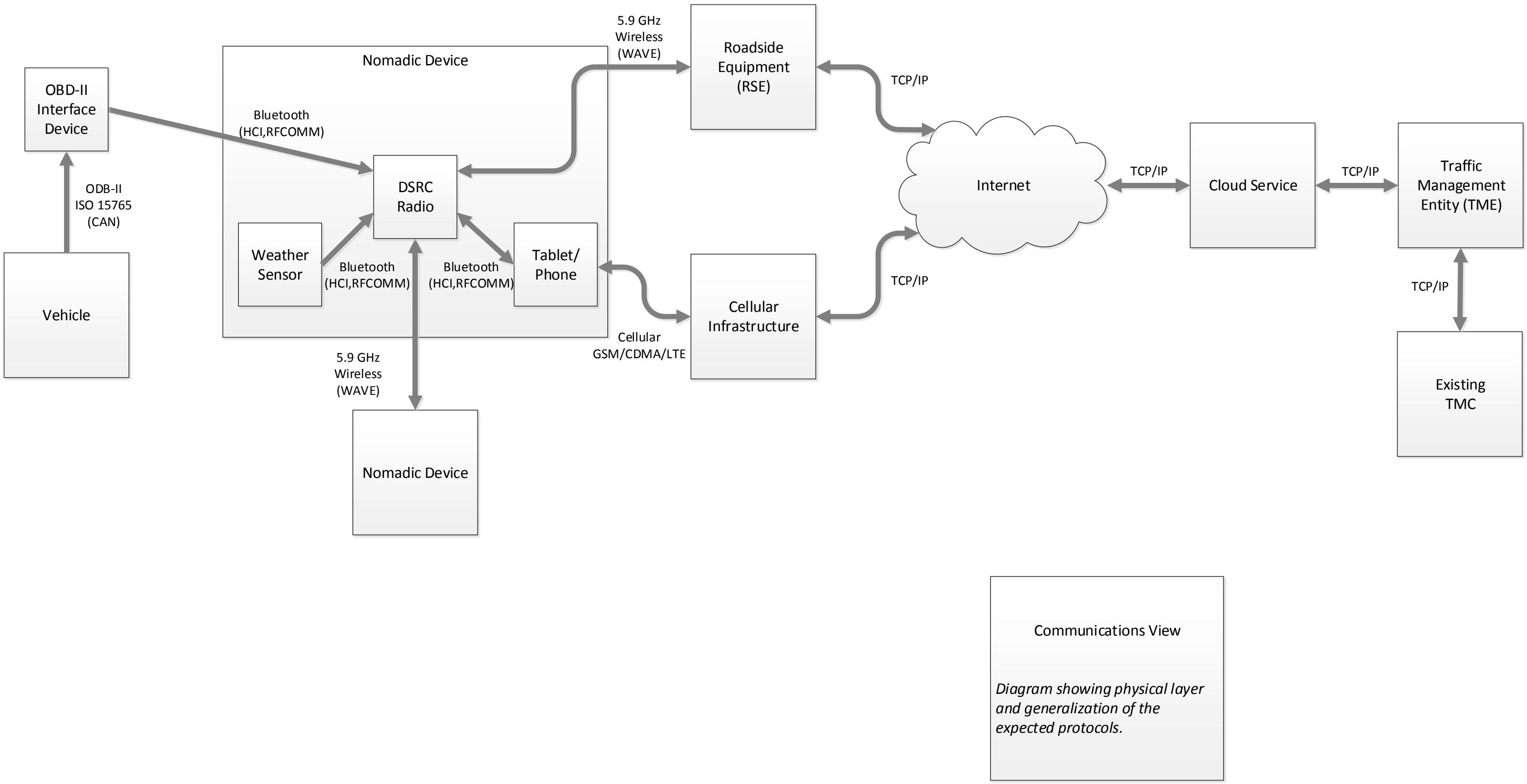
DSRC Communications – the DSRC network is made up of statically placed RSEs and a variable number of DSRC-enabled Nomadic Devices. A DSRC network is by its very nature a dynamic network where entities of the network (e.g., vehicles) come in and out of range of one another continuously. It is likely that extensions to the SAE J2735:2009 message set will be required for INFLO.

Each Nomadic Device will communicate on the DSRC network in two ways; first, to the TME via the RSE, and second to other vehicles within the Nomadic Devices DSRC radio range.

TCP/IP Internet Communications – The Nomadic Device will have the capability to send data to, and accept data from the TME over both the cellular and DSRC links. The TME itself will only see the TCP/IP based communications, but routing through the RSE or the cellular network will be accomplished based on best path and available connectivity. Because this prototype activity is focused on transportation domain problems, care must be taken to limit the amount of new networking work and focus should be on implementing workable solutions with minimal development time knowing that some performance may potentially be sacrificed by routing messages through both interfaces.

In this context, the RSE will act as a smart router. It will take DSRC-based messages from the Nomadic Device and convert them to a custom TCP/IP based protocol developed for INFLO and send those messages to the TME. Likewise, the messages coming from the TME through the RSE will need to be converted into DSRC formatted messages before being transmitted to the Nomadic Devices.

Vehicle Communications – The vehicles used in the prototype demonstration will expose an industry standard OBD-II connection. Data on the OBD-II bus will be exposed to the Nomadic Device via an OBD-II to Bluetooth (or similar) interface.



Source: Battelle

Figure 4-2. Communications View

Computational View Description

The purpose of the model(s) that make up the computational view is to enumerate both what computational components exists and where they are located in the system. In the context of the INFLO architecture, a computational component is a logically self-contained piece of software. In the non-cloud based contexts, each computational component is a process. In the cloud-based context it is not as clear since these are hosted services and the hosting model (web worker role within IIS, virtual machine hosted app, etc.) are details that will be defined during the design phase.

In Figure 4-3 components that are greyed out might have software, but the software is not being developed or modified as part of the INFLO project, and therefore these components are treated as black boxes and not addressed.

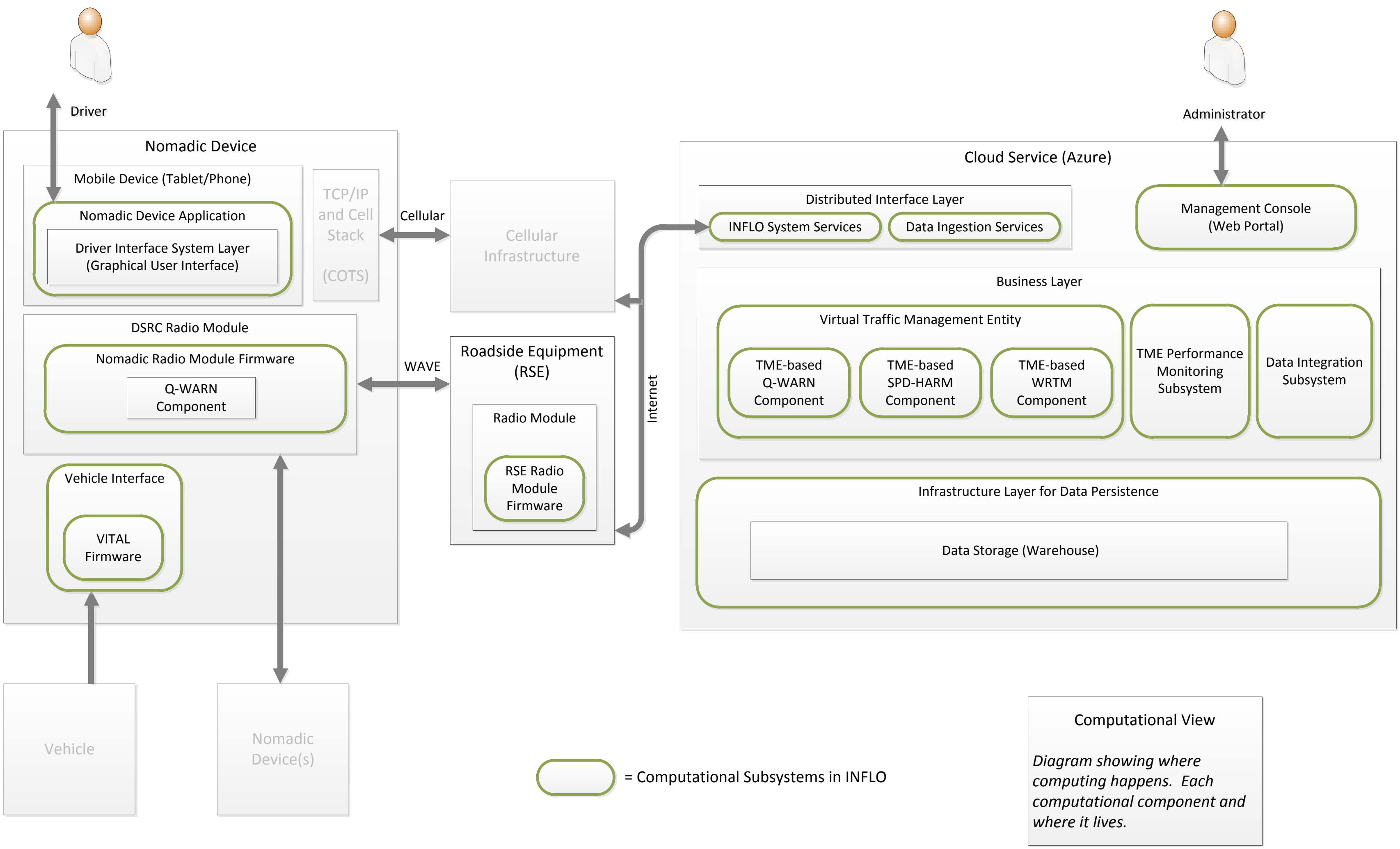
Nomadic Device Application – the Nomadic Device itself will likely be (or contain) a traditional mobile device platform (tablet or phone). The intent is to host the Nomadic Device Application on this mobile device. This application has two primary roles, acting as the user interface and providing a conduit to the cellular network.

Driver Interface System Layer – this presents and manages Nomadic Device interactions with the driver (in-vehicle) or holder of the device (extra-vehicle). The intent is to present the user with a very crisp and easy to-understand user interface experience. As much as possible, this user interface design should be decoupled from the traffic management software components.

Nomadic Radio Module Firmware – the Nomadic Device will contain a DSRC radio, which will be used to communicate with other vehicles (V2V) and the TME (V2I). The DSRC radio is considered COTS equipment for INFLO, but the firmware will be customized. Within this customized application there will be SPD-HARM and Q-WARN components and software to interface with the DSRC networks (directly) and the cellular network (through the Nomadic Device Application). The firmware will have access to the services provided by the WAVE management entity through a manufacturer supplied API. This API will allow SAE J2735 messages to be created in the application and sent via the DSRC radio.

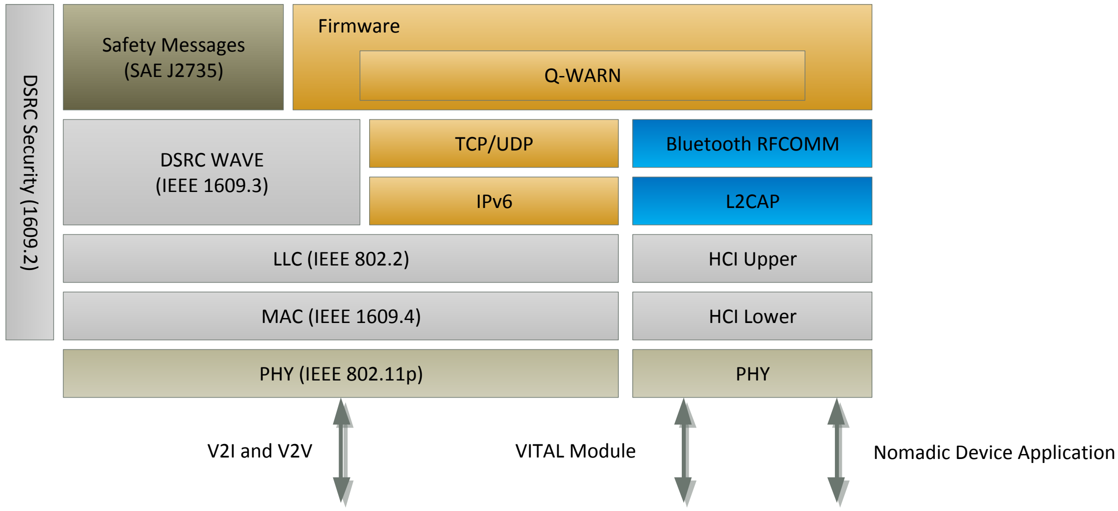
The firmware will be the main data collection system and will create all messages for the V2V and V2I communications. It will:

- Collect Basic Safety Message (BSM) from external vehicles that are in range and have INFLO Nomadic Devices. Notifications from the firmware on the DSRC will be sent to the Nomadic Device Application running on the tablet/cell phone via a Bluetooth interface for display.
- Receive vehicle data from the Integrated Vehicle Network Access System interface and use this information to populate the BSM and the Probe Messages.
- Receive SPD-HARM and Q-WARN messages from the infrastructure (V2I). These messages will be processed and display messages will be sent to the nomadic Device Application via the Bluetooth interface. Source: *Battelle*
- Figure 4-4 illustrates the firmware architecture.



Source: Battelle

Figure 4-3. Computational View



Source: Battelle

Figure 4-4. Nomadic Device DSRC Radio Based Firmware Architecture

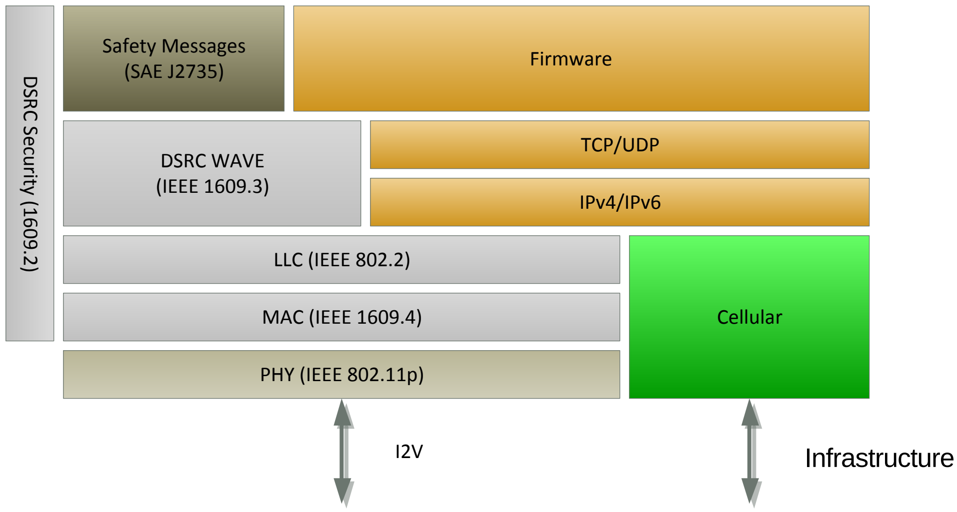
Q-WARN Component – this component will be responsible for managing the Q-WARN related activities on the Nomadic Device. It represents the application layer of the communications to and from the TME. It will implement any client side algorithms to augment the TME based Q-WARN algorithms. It is also responsible for computing and disseminating Q-WARN information. The Q-WARN capabilities will reside both on the TME and on the Nomadic Device.

Vehicle Interface (VITAL) – the vehicle interface component is a self-contained device with embedded firmware that reads vehicle diagnostic information from the vehicle's OBD-II port. When installed in a host vehicle, it provides a wireless (most likely Bluetooth) interface into the OBD-II vehicle network. It is considered an optional part of the Nomadic Device to be used when in-vehicle.

VITAL Firmware – the firmware running on the VITAL component. VITAL is considered a COTS component as far as INFLO is concerned, but there is a possibility of the need for firmware upgrades to support extended or custom messages so it is included in the architecture.

RSE Radio Module Firmware – RSE units used in INFLO will contain a DSRC radio, which will be used to communicate with vehicles using DSRC and the TME over the Internet. The DSRC radio is considered COTS equipment for INFLO, but the firmware will be customized. Unlike the firmware customization in the Nomadic Radio Module Firmware, the customizations here should be minimal.

The firmware will receive DSRC messages from the vehicles and forward any Probe Messages to the TME via the cellular interface essentially acting as a DSRC to Internet gateway for the INFLO system. The firmware will send any SPD-HARM, WRTM and Q-WARN messages from the TME through the DSRC radio to any equipped vehicle. *Source: Battelle*
Figure 4-5 illustrates the various functions and layers.



Source: Battelle

Figure 4-5. RSE Device DSRC Radio Based Firmware Architecture

Distributed Interface Layer – most likely a WebAPI (or similar) interface but could be a simple socket based service hosted in a cloud-based system. The external, Internet accessible, interfaces will be hosted in this service layer. The intent is for this layer to be extensible as new service interfaces are needed.

INFLO System Services – the fundamental API for the INFLO system. This interface will expose methods to accept INFLO data from the nomadic device network. It will also, ideally, provide a way to asynchronously send data back to the nomadic devices in the network. The technical feasibility of such an approach is in question and needs explored. The fall back is to implement a polling protocol. Those decisions will be dealt with during detailed design.

Data Ingestion Services – details of the data ingestion services are TBD as work progresses to define the external data sources available. The concept is to provide a mechanism to inject external data into the INFLO algorithm pipeline, e.g., weather data.

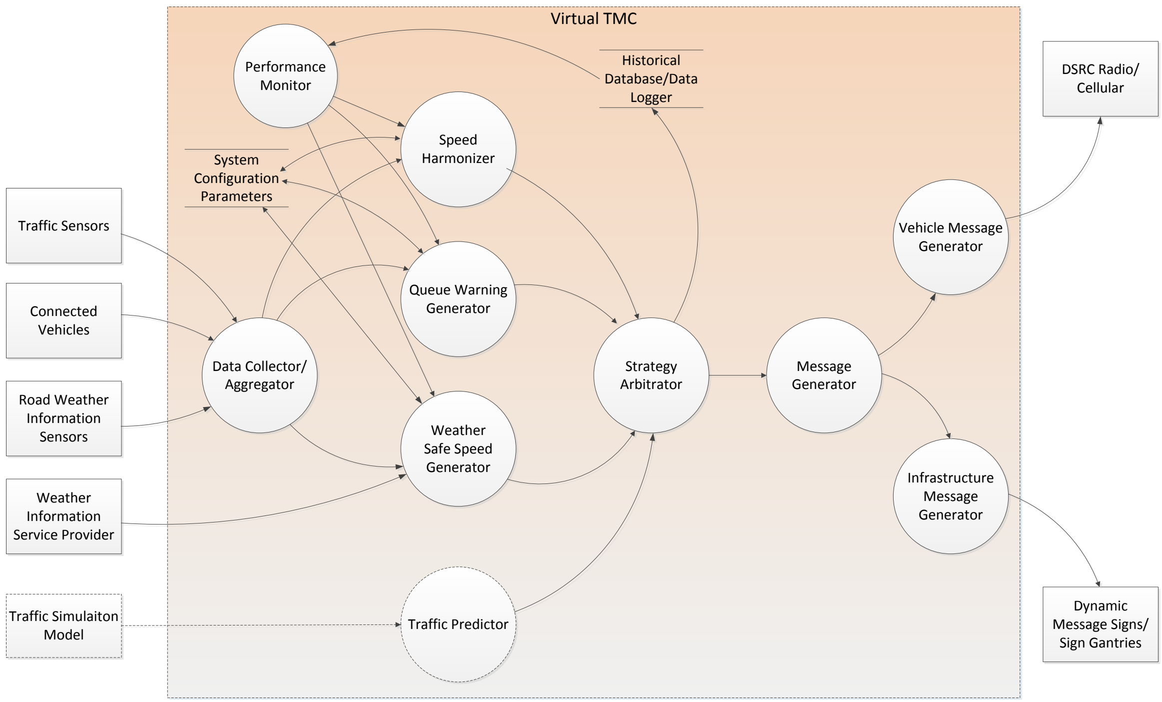
Management Console (Web Portal) – browser based user interface, which will act as the monitoring and administration console for the TME.

Data Integration Subsystem – the requirements for injecting and exposing non-INFLO generated data are unclear. The Data Integration Subsystem is a placeholder for the services that support input of external data into the INFLO data environment. Fundamentally, this layer provides the business logic for data ingestion. It will provide a to-be-determined set of services for accepting, converting, and appropriately storing this data. This subsystem should be designed to facilitate extensibility as new data sources are needed.

Infrastructure Layer for Data Persistence – architecturally this layer represents the INFLO database. It will most likely contain a relational database designed to house the real-time data flowing from the connected vehicle network, the external data sources, derived data from the TME algorithms, performance metrics, etc.

Virtual TMC Description – Source: *Texas A&M Transportation Institute/Battelle*

Figure 4-6 provides a logical view of the Virtual TMC. This logical view shows the processes and data flows associated with the Virtual TMC. The blocks represent external data sources while the circles represent processes inside the virtual TMC. The arrows represent data flows between the individual processes.



Source: Texas A&M Transportation Institute/Battelle

Figure 4-6. Logical Architecture of INFLO Virtual TMC

Data Collector/Aggregator – this process is responsible for obtaining, processing, formatting and distributing the data used by the various processes in the INFLO algorithm. The Data Collector/Aggregator will obtain speed, volume and/or occupancy data from the Traffic Sensors; BSM data from Connected Vehicles; and road surface and weather condition information from Road Weather Information System (RWIS) stations deployed in the corridor. This process will also be responsible for performing quality assurances checks on the data before sending the data on to other processes.

Speed Harmonizer – this process is responsible for performing the speed harmonization process for the system. This involves obtaining both infrastructure-based and vehicle-based information from the Data Collector/Aggregator and processing the data to determine the local speed for each freeway segment. The Speed Harmonizer contains the logic for generating smooth transitions of speed from free flow to congested flow regimes. The output of the Speed Harmonizer feeds to the Message Arbitrator where it is compared to the output of other processes to determine which speed governs individual freeway segments.

Queue Warning Generator – this process is responsible for processing the traffic sensor data delivered by the Data Collector/Aggregator to detect the presence of queues in the freeway segments. The process is responsible for producing estimates of the back-of-queue location, the rate of growth/dissipation of the queue, the length of the queue and other information necessary to produce a queue warning for both infrastructure devices as well as connected vehicles.

Weather Safe Speed Generator – this process is responsible for generating safe speeds for measured and/or forecasted weather conditions. This process will first use forecasted weather conditions to determine when weather information should be obtained from RWIS sensors. This process would then use real-time measures of road surface conditions, visibility, and precipitation to determine the safe travel speeds for the weather conditions.

Strategy Arbitrator – the Strategy Arbitrator is a process that receives the results of the various INFLO algorithms and selects the critical message to be sent out to the road users. The critical message is usually the lowest advisory speed among the speeds recommended by the various INFLO algorithms. The Strategy Arbitrator will use user-defined rules to determine which of the speed recommendations has priority to be displayed to road users.

Message Generator – this process is responsible for determining the appropriate speed messages to be displayed for each section of the freeway. This process will start with the controlling section, and then adjust speed message upstream to provide a smooth transition from free flow to congested speed. The message generator will also determine the content of the messages to be displayed on DMS.

Infrastructure Message Generator – this process is responsible for formatting and coding the messages to be displayed on the infrastructure devices. It will compose the queue warning messages and speed advisory messages to be displayed in the systems dynamic message signs. The process will also be responsible for generating and managing the speed indications of the variable speed signs.

Vehicle Message Generator – this process is responsible for formatting and coding the messages to be disseminated to in-vehicle displays.

Traffic Predictor –this process is responsible for developing speed and queue warnings based on forecasted traffic conditions. It will utilize real-time data as well as the results of traffic simulation models to predict when and where speed harmonization and queues are likely to form. This process may not be developed as part of the prototype development given schedule and funding constraints, but is shown here to communicate to the designer the need for this type of extensibility.

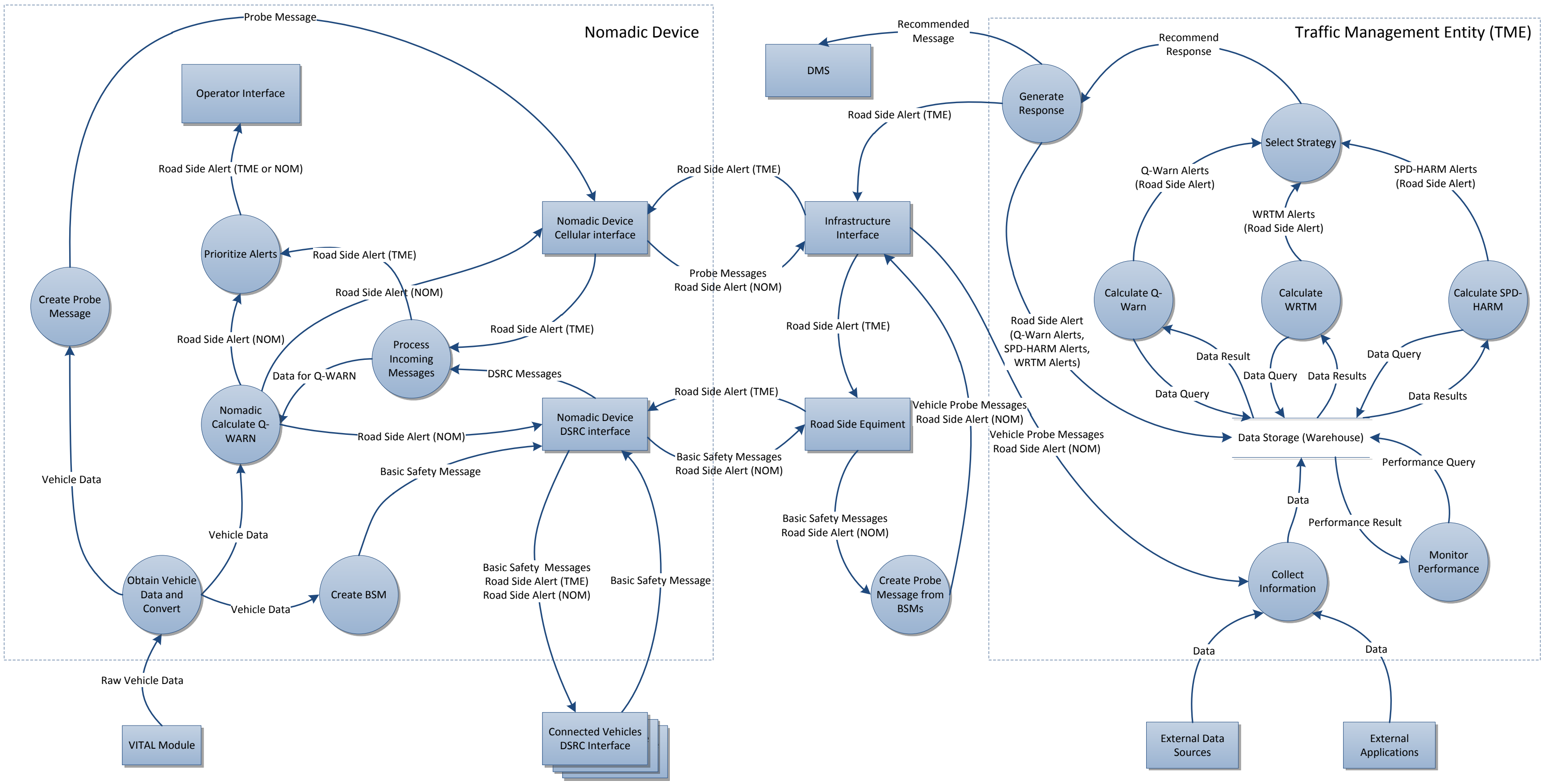
Performance Monitor – this process is responsible for producing performance measure reports. This process will use historical data to generate performance trends, which can be used to refine queue warning, speed harmonization and adverse weather speed thresholds. The process is also responsible for providing a means to identify, track, and analyze unidentified or mis-identified shockwave/breakdown formation events.

Historical Database/Data Logger – the historical database holds data received from the Nomadic Devices and fixed-location sensors, the recommendations generated by the algorithms that is disseminated to vehicles and signs and the static and dynamic configuration parameters used in making these recommendations. The historical database will be used by the Performance Monitoring subsystem to generate performance reports about the recommendations made by the INFLO algorithms and to refine the thresholds used by the algorithms.

System Configuration Parameters – the system configuration parameters include information necessary for the INFLO modules to establish communications with the data input sources and the devices with which they need communications. Configuration parameters also provide information about the static and dynamic freeway segments monitored by the system including: boundaries, length, maximum speeds, free flow speeds, associated sign and detectors, adjacent freeway segments, etc. The configuration parameters provide the user with the ability to alter the behavior of the INFLO algorithms. This can be accomplished by modifying the thresholds and other operational parameters. These thresholds or parameters can be either changed by the user or dynamically generated by the Performance Monitoring subsystem based on historical data that is collected by the various INFLO algorithms.

Data Flow Diagram

A Level 1 data flow diagram (DFD) expands on the context diagram by decomposing the system into a more detailed diagram that includes specific process areas and data stores. A single, detailed Level 1 DFD, expanding on the information of the System Context Diagram, has been developed for this effort. The processes, shown as circles in *Source: Texas A&M Transportation Institute/Battelle*
Figure 4-7, represent the high-level functionality of the system, expressed in an implementation-independent manner. Additionally, this diagram shows the general content and direction of each of the data flows associated with this system, as well as location for data store, represented by two parallel lines. Following the diagram is a breakdown of the diagram elements and a short description for each.



Source: Texas A&M Transportation Institute/Battelle

Figure 4-7. INFLO High Level Data Flow Diagram

Sub-System	Description / Purpose
Calculate SPD-HARM	Application that creates speed harmonization instructions or warnings
Calculate Q-Warn	Application that computes Q-Warnings
Calculate WRTM	Application that creates Weather Responsive Traffic Management (WRTM) warnings.
Collect Information	Process that collects all information and stores it in the data repository.
Connected Vehicles DSRC Interface	0..n connected vehicles that the nomadic device can communicate with.
Create BSM	Creates a Basic Safety Message (BSM) using data from the vehicle
Create Probe Messages	Creates J2735 Probe messages that will be sent to the TME through the cellular interface when not in range of road side equipment.
Create Probe Message from BSMs	Creates probe snapshots for connected vehicles that is sent to the infrastructure as a probe message.
Data Storage (Warehouse)	Data base that is the data repository for the system
DMS	Dynamic Messaging System
External Applications	External applications that supply data to the data repository
External Data Sources	External sources that will send data to be stored in the data repository
Generate Response	Creates the appropriate response message based on the selected strategy.
Infrastructure Interface	Data interface to communicate to the nomadic device.
Monitor Performance	Performance monitor for the system
Nomadic Calculate Q-WARN	Calculates the current Q-WARN status using the data from incoming DSRC data and vehicle data. Sends warning to be prioritized
Nomadic Device Cellular Interface	Cellular interface in the nomadic device that allows the applications to transmit and receive data
Nomadic Device DSRC Interface	DSRC radio that allows the nomadic applications to receive and send data.
Obtain Vehicle Data and Convert	Obtains the raw vehicle data from the vehicle and performs any scaling and conversions for use in the Probe messages, Basic Safety Messages and the Nomadic Q-WARN application
Operator Interface	Display that the operator can see the warning messages.
Prioritize Alerts	Prioritizes any current warnings and sends the warning with the highest priority to be displayed on the Operator Interface.

Process Incoming Messages	Receives incoming messages and routes the contents to the appropriate location based on the message type. This will receive messages from both the DSRC radio and the cellular infrastructure.
Road Side Equipment	Road Side Equipment (RSE) DSRC that communicates to the connected vehicles through DSRC and to the TME via an internet connection.
Select Strategy	Process whereby the recommended target speeds results of the each of the three strategy generation processes (SP_HARM, Q-WARM, and WRTM processes) are compared to determine which one should be implemented. There will be “rules” or criteria that would be applied that would cause one strategy to be selected over the following.
VITAL Module	Module that plugs into the OBD port on a vehicle and transfers the data via Bluetooth

Data Flow	Description / Purpose
Basic Safety Message	Basic Safety Message (BSM) that is created using the SAE J2735 Specification and is sent and received by the DSRC radio. The data in the outgoing Basic Safety Message will be populated from the vehicle data.
Data	Information from a source or formatted from a source.
Data for Q-WARN	Any data from the DSRC data that is needed for the Q-WARN nomadic application.
Data Query	Request for information to the data repository to retrieve specific information.
Data Response	Data that is returned from a Data Query.
DSRC Messages	Any SAE J2735 messages received from a DSRC radio.
Probe Message	Probe Message that is created using the SAE J2735 Specification. Will be used to transport the vehicle status to the TME.
Performance Query	Request for performance specific information to the data repository to retrieve specific information.
Performance Result	Data that is returned from a Performance Query.
Q-Warn Alerts (Road Side Alert)	Road Side Alert that contains a Q-Warning.
Raw Vehicle Data	Raw CAN data received from the VITAL module from the vehicle OBD II port.
Recommended Message	Recommended alert or warning being sent based on applications.
Recommended Response	Recommended response that will be used to create RSA message to be sent vehicles and signage.
Road Side Alert (NOM)	Road Side Alert Message created by the Nomadic Device (NOM) Q-WARN application using the SAE J2735 Specification. The messages will convey the Q-WARN warnings.
Road Side Alert (TME)	Road Side Alert Message created by the Traffic Management Entity (TME) using the SAE J2735 Specification. The messages will convey the Q-WARN, WRTM and SPD-HARM warnings and recommendations.
SPD-HARM Alerts (Road Side Alert)	Road Side Alert that contains a Speed Harmonization instruction or warning.
Vehicle Data	Data from the vehicle that has been parsed and converted to the proper units.
Vehicle Probe Message	A SAE J2735 Probe message that contains snapshots from a vehicle.
WRTM Alerts (Road Side Alert)	Weather Responsive Traffic Management alerts.

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Appendix A. List of Abbreviations and Acronyms

API	Application programming interface
BSM	Basic Safety Message
CAN	Controller area network
COTS	Commercial Off-the-Shelf
DMA	Dynamic Mobility Applications
DMS	Dynamic Message Sign
DSRC	Dedicated short-range communications
IA	Impacts Assessment
IIS	Internet Information Services
I2V	Infrastructure-to-Vehicle
INFLO	Intelligent Network Flow Optimization
OBD-II	Standard for vehicle based On-board diagnostics
Q-WARN	Queue Warning
RSE	Road side equipment
RWIS	Road Weather Information System
SAE	Society of Automotive Engineers
SPD-HARM	Speed Harmonization
TCP/IP	Transmission Control Protocol (TCP) and the Internet Protocol (IP)
TMC	Traffic Management Center
TME	Traffic management entity
V2I	Vehicle-to-Infrastructure
V2V	Vehicle-to-Vehicle
WRTM	Weather Responsive Traffic Management

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