INFLO PROTOTYPE - DESIGN WALKTHROUGH

December 18th, 2013

Texas A&M Transportation Institute

Battelle
The Business of Innovation

Agenda – Dec. 18th, 2013

9:00 AM	Welcome, Introductions & Walkthrough Process
9:15 AM	Background / Scope
9:30 AM	System Design Document Review
10:30 AM	Break
10:45 AM	System Design Document Review (cont.)
12:15 PM	Lunch (on your own)
1:00 PM	System Design Document Review (cont.)
2:15 PM	Break
2:30 PM	SPD-HARM and Q-WARN Algorithm Design Review
4:15 PM	Wrap-Up, Action Items and Next Step
4:30 PM	Adjourn

Welcome & Introductions

- Overview of INFLO Project by Govt. Task Monitor – Mohammed Yousuf
- Project Staff
  - ITS JPO DMA Program Manager – Kate Hartman
  - US DOT Technical Support – Meenakshy Vasudevan / Carl Kain (Noblis)
  - Battelle Project Manager – Ted Smith
  - Co-Principal Investigators
    - Tom Timcho (Battelle)
    - Kevin Balke (Texas A&M Transportation Inst.)
  - Software Architects
    - Scott Sheaf (Battelle)
    - Hassan Charara (TTI)
  - Subject Matter Experts
    - Srini Sunkari, Williams Gibbs

Roles

- Walkthrough Leader – Tom Timcho
- Recorder – Battelle Team
- Author – Hassan Charara, Scott Sheaf, Williams Gibbs, Tom Timcho
- Team Members – All participating in this meeting

Purpose

- Review the INFLO design, including the algorithms for SPD-HARM and Q-WARN
- Capture comments or Action Items (AIs)
- Agree upon the resolutions to the comments and AIs, wherever possible
- Set the schedule for updating and publishing the next update to the design and documentation

Approach to Review

- Large Volume of Data to Review
- Because of size of audience, asking for feedback through the chat window
- In order to keep things moving along, it may be necessary to skip some slides
- Asking for everyone to control mute from their end
- When Review Items has multiple ‘no’ results, should rank most important (1) to lowest (x)
- Inputs on design are welcome offline
  - Submit to USDOT and Battelle by COB Friday, December 27th
    - mohammed.yousuf@dot.gov
    - timchot@battelle.org

Review Items

- INFLO System Design Document
- Updated design document to be released in January 2014
- SPD-HARM and Q-WARN Algorithms

BACKGROUND

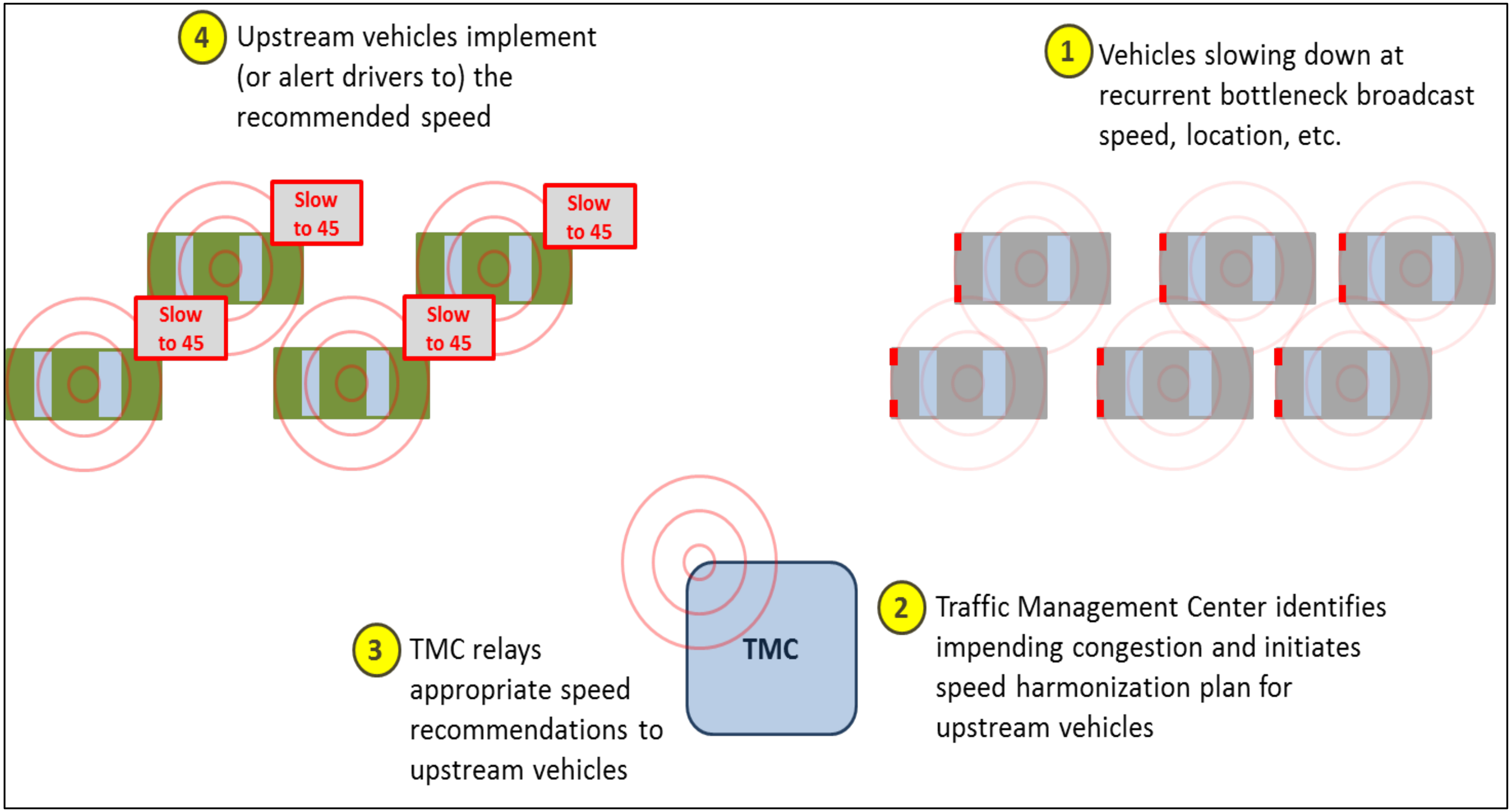
INFLO Applications

- Intelligent Network Flow Optimization (INFLO) represents a collection of three high-priority transformative applications identified by the United States Department of Transportation (USDOT) Mobility Program that relate to improving roadway throughput and reducing crashes through the utilization of frequently collected and rapidly disseminated multi-source data drawn from connected travelers, vehicles, and infrastructure.
- These three applications are queue warning (Q-WARN), dynamic speed harmonization (SPD-HARM), and cooperative adaptive cruise control (CACC).
- The purpose of this Prototype project is to develop and perform a small-scale demonstration of dynamic speed harmonization with queue warning (SPD-HARM with Q-WARN).

SPD-HARM

- The INFLO SPD-HARM application concept aims to maximize throughput and reduce crashes by
  - Utilizing infrastructure-to-vehicle (I2V) and vehicle-to-vehicle (V2V) communication to detect impending congestion that might necessitate speed harmonization
  - Generating appropriate target speed recommendation strategies for upstream traffic
  - Communicating the recommendations to the affected vehicles using either planned I2V communication technology, DSRC and LTE.
- Speed recommendation decisions are made at a Traffic Management Center (TMC) or a similar infrastructure-based entity, and then communicated to the affected traffic.
- Communication of target speed recommendations to the affected vehicles will always give priority to crash avoidance/mitigation safety applications when such applications determine that a safety alert is necessary.

SPD-HARM


4
Upstream vehicles implement (or alert drivers to) the recommended speed
Slow to 45
Slow to 45
Slow to 45
Slow to 45
1
Vehicles slowing down at recurrent bottleneck broadcast speed, location, etc.
TMC
2
Traffic Management Center identifies impending congestion and initiates speed harmonization plan for upstream vehicles
3
TMC relays appropriate speed recommendations to upstream vehicles

SPD-HARM Scenarios

- Fixed Point Breakdown Formation (External-to-Vehicle Processing; V2I-Dissemination)
- Non-Location Specific Breakdown Formation (External-to-Vehicle Processing; V2I-Dissemination)
- Weather-Related Speed Harmonization (External-to-Vehicle Processing; V2I-Dissemination)

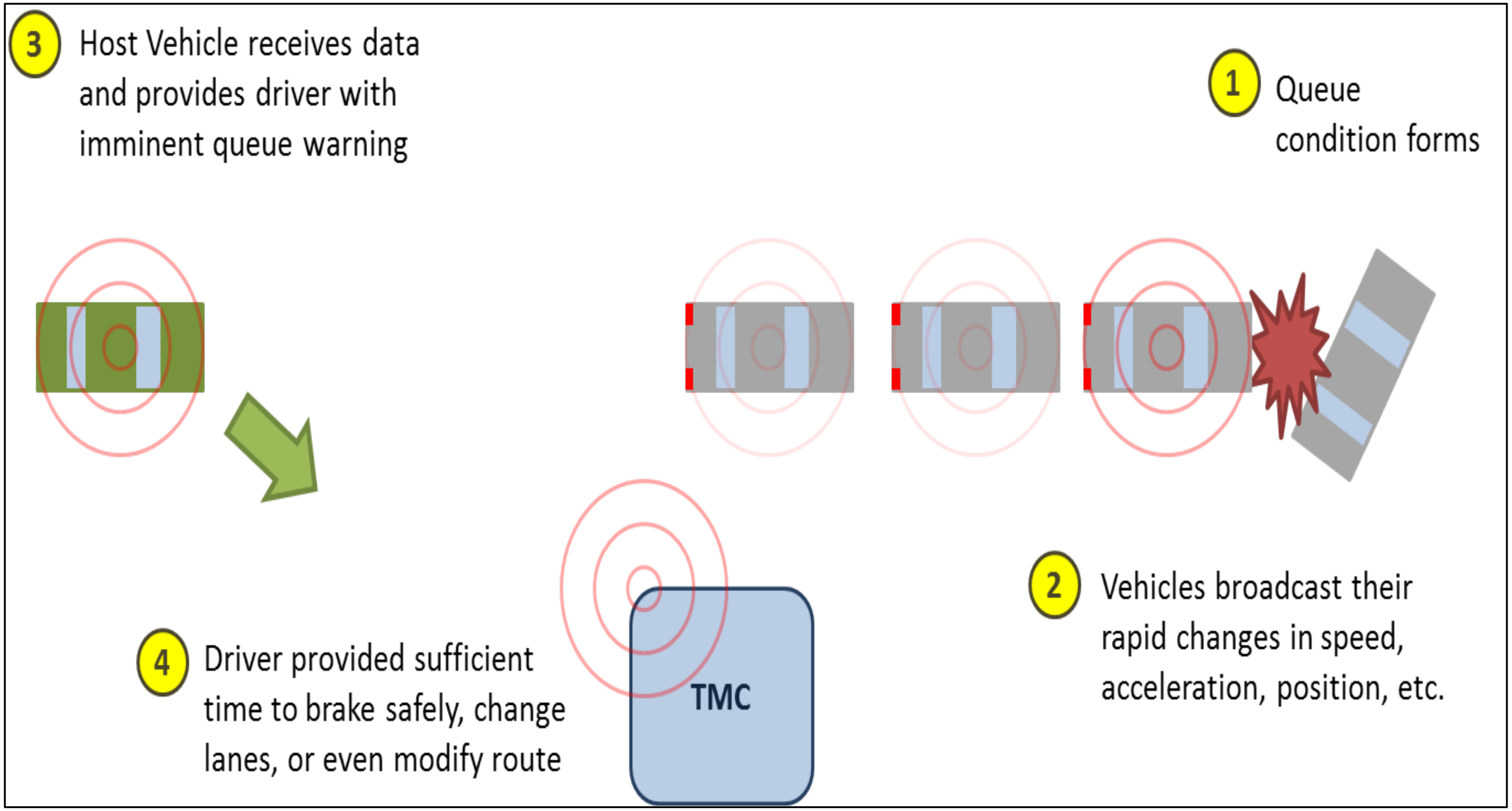
Q-WARN

- The INFLO Q-WARN application concept aims to minimize or prevent impacts of rear-end or secondary collisions by
  - Utilizing data obtained from both I2V and V2V communications to detect existing queues and/or predict impending queues
  - Communicate advisory queue warning messages to drivers in advance of roadway segments with existing or developing vehicle queues.
- The Q-WARN concept reflects an operational environment in which two essential tasks are performed:
  - Queue determination (detection and/or prediction)
  - Queue information dissemination.

Q-WARN

- The Q-WARN application may reside in the vehicle or within an infrastructure-based entity, or utilize a combination of both.
- The queue warning messages may either be communicated by the infrastructure-based entity using I2V communication or broadcast by vehicles that are in a queued state to nearby vehicles and infrastructure based entities.
- NOTE: the Q-WARN application concept is not intended to operate as a crash avoidance system (e.g., like the forward collision warning safety application). In contrast to such systems, Q-WARN will engage well in advance of any potential crash situation, providing messages and information to the driver in order to minimize the likelihood of a crash avoidance or mitigation actions later. As such, Q-WARN-related driver communication will always give priority to crash avoidance/mitigation safety applications when such applications determine that a safety-related alert is necessary.

Q-WARN


3
Host Vehicle receives data and provides driver with imminent queue warning
1
Queue condition forms
2
Vehicles broadcast their rapid changes in speed, acceleration, position, etc.
4
Driver provided sufficient time to brake safely, change lanes, or even modify route
TMC

Q-WARN Scenarios

- Scenario 1: Fixed Queue Generation Point Queue Warning (External-to-Vehicle Processing; I2V-Dissemination)
- Scenario 2: Non-Location Specific Queue Warning (Vehicle-Based Processing; V2V-Dissemination)
- Scenario 3: Weather-Related Queue Prediction and Warning (External-to-Vehicle Processing; I2V-Dissemination)

SCOPE OF THE PROTOTYPE

INFLO Concept of Operations

- The INFLO ConOps documents a fully featured set of capabilities that long-term INFLO applications could support.
- The features are organized into both Essential and Desirable subsystems.
- The INFLO Prototype includes all but one of these Essential subsystems.

Comparison of ConOps to Prototype

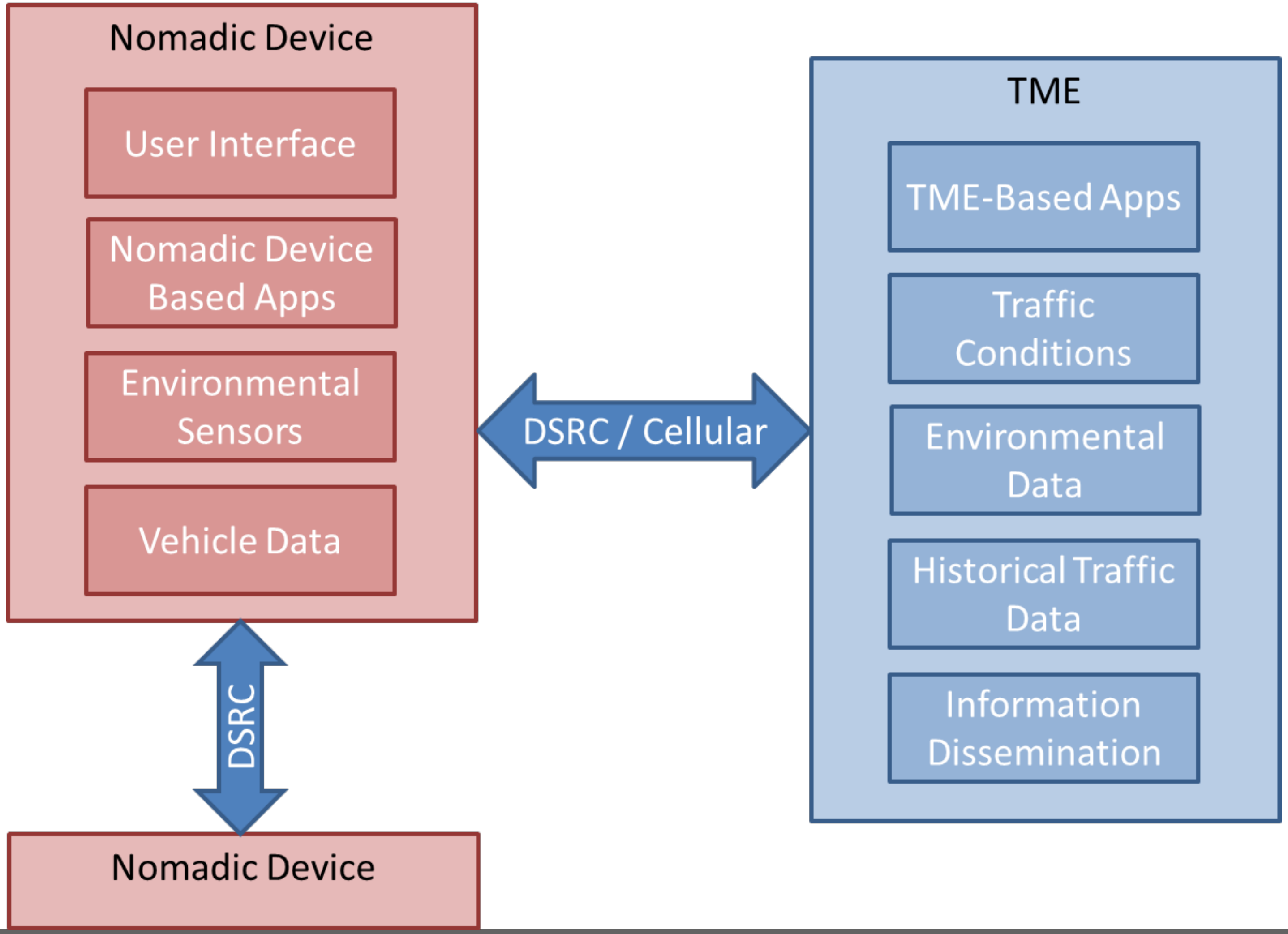
ConOps

- Traffic Information Collection
- Environmental Information Collection
- SPD-HARM Response Generation
- Queue Determination (detection and/or prediction)
- Information Dissemination (both I2V and V2V)
- Data Storage
- Service Monitoring

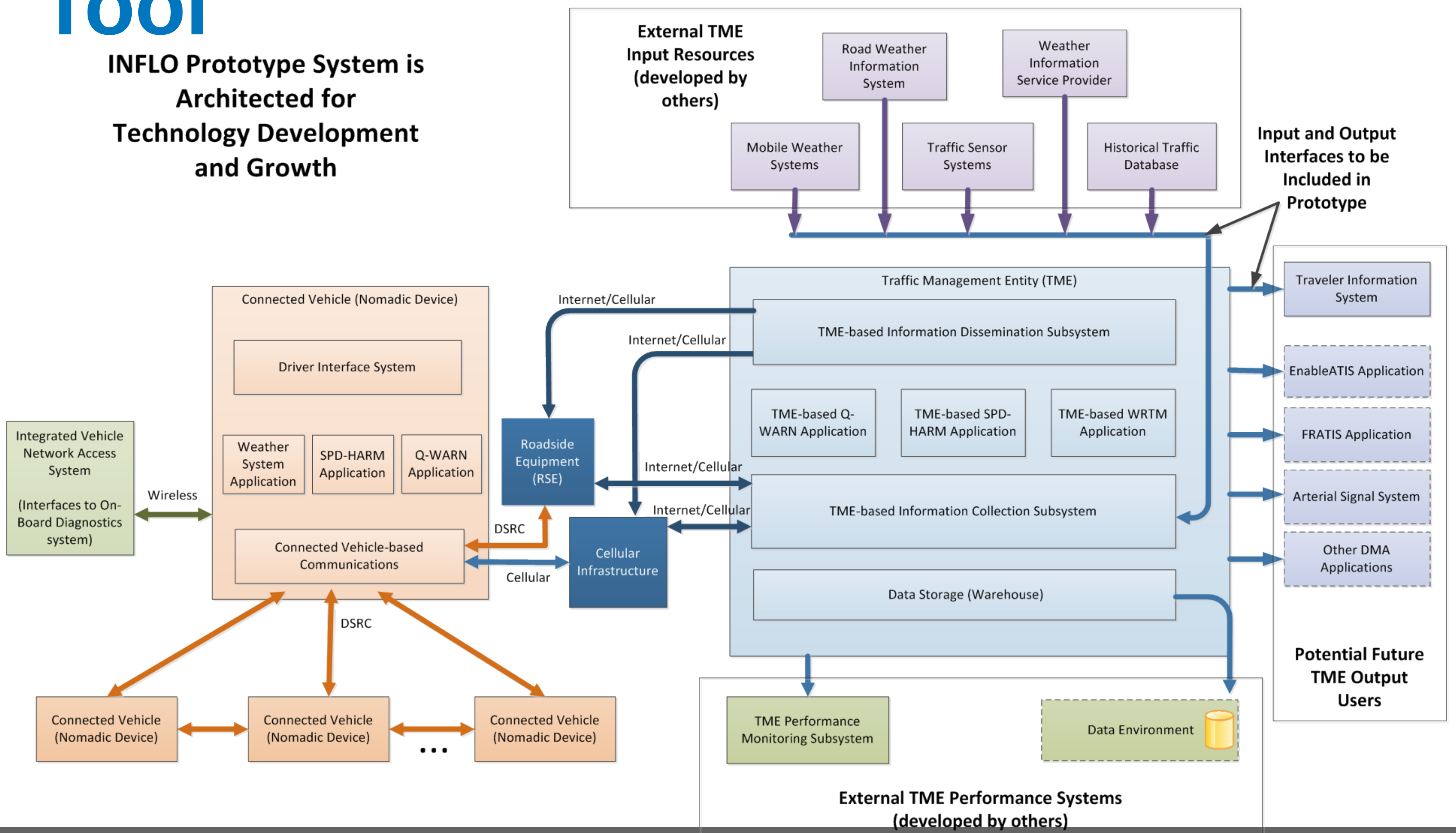
Prototype

- Traffic Information Collection
- Environmental Information Collection
- SPD-HARM Response Generation
- Queue Determination (detection ~~and/or prediction~~)
- Information Dissemination (both I2V and V2V)
- Data Storage
- ~~Service Monitoring~~

High Level Subsystems



Architected as a Development Tool



Connected Vehicle (Nomadic Device)

- The Nomadic Device will provide the following:
  - Both cellular and DSRC radios
  - Regular BSM/Probe data messages to the infrastructure
  - When located in vehicle, access to the vehicle OBD-II data via Bluetooth (for vehicle telemetry/weather related data)
  - When outside of vehicle, will provide simple weather data (temp., humidity, pressure)
  - Q-WARN capabilities for V2V environment
  - User Interface to demonstrate receipt of queue warning and speed harmonization alerts and indications.

Traffic Management Entity

- Houses TME-based Q-WARN, SPD-HARM and Weather Responsive Traffic Management (WRTM) algorithms
- Communicates Alerts/Warnings, etc. to Connected Vehicles and Traveler Information Systems
- Receives Connected Vehicle data via both DSRC and cellular
- Interfaces with existing data sources (i.e. traffic sensors, historic traffic data, road weather information systems (RWIS), weather info service providers and mobile weather systems)
- Open architecture supports future integration with other applications such as Performance Measures and other DMA applications (e.g. R.E.S.C.U.M.E.)
- Supports research activities through interface with the Research Data Exchange (RDE) and the Open Source Application Development Portal (OSADP)

Algorithms

- TME-Based Applications (SPD-HARM, Q-WARN and WRTM) shall utilize:
  - Existing infrastructure-based detectors
  - ‘Connected vehicle’ data
  - Forecasted weather conditions
  - Historical Traffic Data (both from Connected Vehicles and traditional fixed sensor). Prototype will demonstrate use of representative sample from agency developed data archiving system containing traffic sensor data.
  - Current road/weather conditions – using existing approaches and predefined data elements (i.e., coefficient of friction in BSM Part II). Prototype would support future development of new methodologies for using weather related information.

Algorithms (cont.)

- The TME-based algorithm will support potential future implementation of:
  - Forecasted traffic conditions
  - Performance Monitoring system – prototype will log the outputs of the algorithm that can be used in the future to evaluate the outcomes of deploying the strategies (i.e., impacts on travel time, travel time reliability, etc.)

Summary of INFLO Prototype

The INFLO Prototype will include the following features:

- Traffic Information Collection
- Environmental Information Collection
- SPD-HARM Response Generation
- Queue Determination
- Information Dissemination (both I2V and V2V)
- Data Storage

INFLO DESIGN ELEMENTS REVIEW

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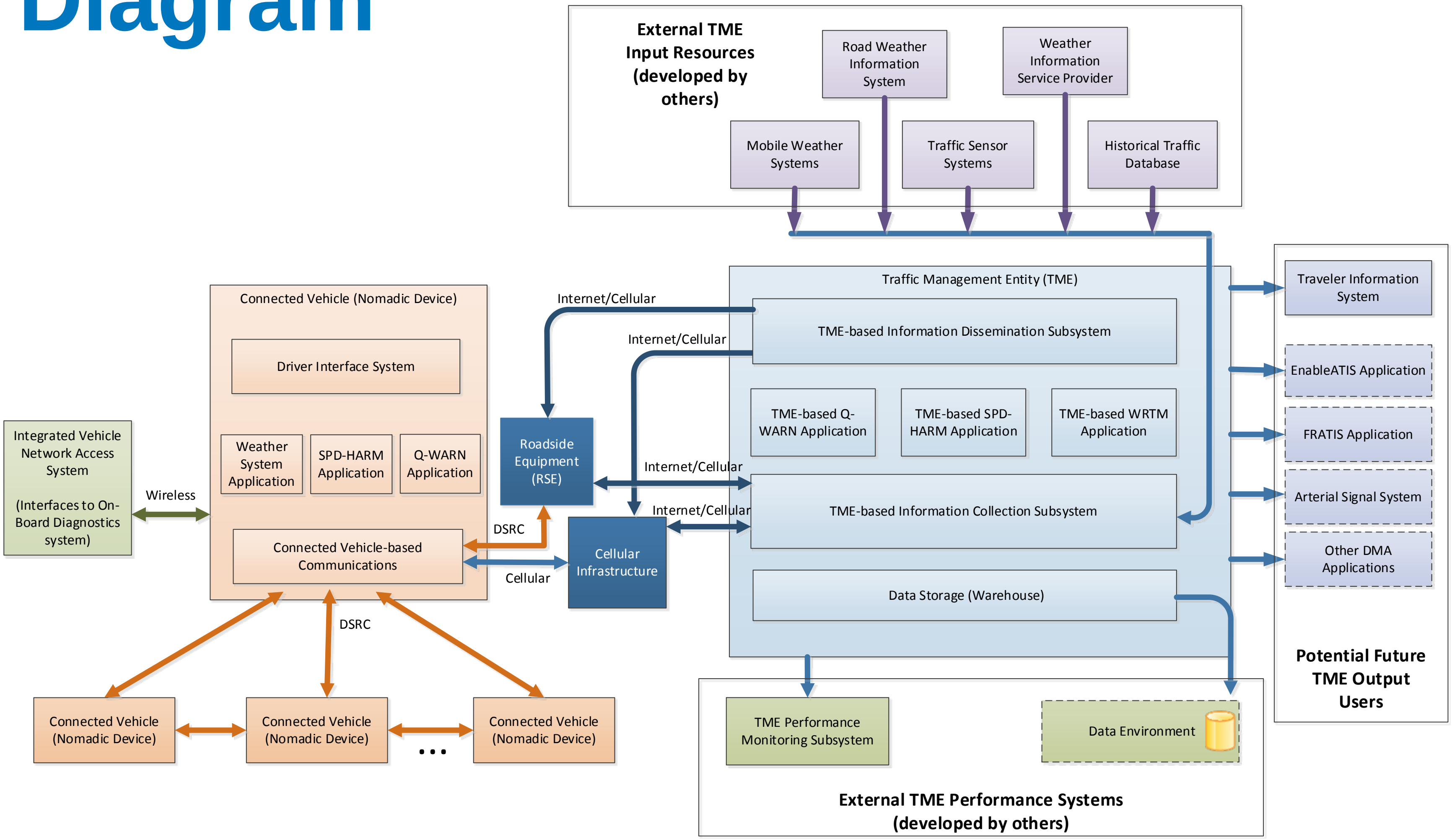
INFLO Design Components

- System Architectural Design
- Design Concerns
- Components Description
- Internal Interfaces
- External Interfaces
- Component Design

INFLO DESIGN ELEMENTS REVIEW:

SYSTEM ARCHITECTURAL DESIGN

INFLO Prototype System Diagram



Design Constraints

- The only known battery-operated DSRC radio, the Arada System's Locomate GO OBU radio contains only a single 5.9GHz radio
- Similarly, this same Locomate radio supports only a limited number of active Bluetooth connections
- Retrieving usable data from vehicles to the level for the BSM Part II is vehicle dependent. A good portion of the data required for the BSM Part II is proprietary data and is dependent on the year and make of the car.
- Data will be demonstrated thru use of an OBDII connection, however, without using an OEM supplied integrated vehicle, all of the data items may not be available. OEM OBD II data integration is not part of this task.

System Architectural Design

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

INFLO DESIGN ELEMENTS REVIEW:

DESIGN CONCERNS

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User Interfaces

- Connected Vehicle (Nomadic Device) Driver Interface System – This component will have a graphical user interface that displays not only Q-WARN and SPD-HARM information but it also needs the ability to support debug and diagnostics in the vehicle. It will be the primary user interface for operators and users while in the field.
- Road Side Equipment – This component will provide a simple user interface (possibly command line based through a network connection) to setup configuration parameters, monitor status, self-test, etc.
- Nomadic Device DSRC Radio Module – This component will provide a simple command-line user interface, via a network connection, to setup configuration parameters, monitor status, self-test, etc.
- Cloud Service – The cloud service(s) will provide a user interface to monitor the state of the TME, monitor the state of the connected vehicle network, allow configuration of parameters, etc.
- Traffic Management Entity – The TME will provide an interface to configure settings and monitor status and performance.

Design Concerns – User Interfaces

Content: See previous slide(s)

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Networking and Communications (1 of 3)

- The design of the INFLO networking architecture will strive to minimize the end-to-end latency of a single BSM message on its journey from a Nomadic Device to the TME. If the networking communications do not operate efficiently, a small bit of delay introduced at various hops along the way will accumulate into a significant amount by the time the BSM has reached its final destination at the TME. This amount of delay is compounded as more and more vehicles enter the system.
- Our strategy for profiling latency includes recording timestamps at each hop and later using comparative analysis techniques to identify bottlenecks in the system as network volume is increased.

Networking and Communications (2 of 3)

- The design should leverage parallel processing using multiple threads, and establish consumer/ producer queues to minimize the time spent waiting for physical data transfers to complete. A multi-threaded pipeline allows both receiving and sending tasks to be performed at the same time. The consumer/producer queues provide a means for tasks to be deferred temporarily until processor resources become available, essentially creating a flexible workflow that will adapt to the computing environment.

Networking and Communications (3 of 3)

- The INFLO networking architecture must scale well, such that as more vehicles are added to the system, more hardware resources are utilized to process the network load. Contingencies should be established for the situation when the network is overly saturated with BSMs, where the INFLO pipeline may be unable to keep up with the flow of inbound data. Due to hardware and bandwidth limitations, at some point of network saturation the INFLO system may be unable to send all BSM traffic to the TME in a timely manner. Key performance parameters (such as maximum end-to-end latency) must be identified in order to recognize when the system is in a saturated state and can automatically begin executing contingencies, such as dropping BSMs according to a pre-determined strategy in order to prioritize timeliness over volume.

Design Concerns – Networking and Communications

Content: See previous slide(s)

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External Interfaces

- Use of standards such as the SAE J2735:2009 Message Set for DSRC Communications will prescribe a common set of data elements and messages found in the transportation environment.
- Use of communications standards currently in place the ITS community, such as the NTCIP family of standards, as well as standards used in the broader global internet, standards such as TCP/IP (v6) and RESTful web services, will be used to remain consistent with the open architecture vision and not preclude integration with other external systems.

Design Concerns – External Interfaces

Content: See previous slide(s)

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Security

- US DOT, the vehicle OEMs and other industry partners have developed the foundational security. As such, no new security techniques will be developed under this work, but instead, will be fulfilled by current approaches.
- For purpose of the INFLO prototype, this OTA security will be implemented as exists today as part of the US DOT Safety Pilot Model Deployment using a security credential management system (SCMS) and a secure DSRC-stack. Details of this approach are available in the Security Credential Management System Design – April 12, 2012, available from US DOT, as well as the IEEE 1609 family of standards.

Security (cont.)

- Similar to DSRC, the application of digital certificates can be used for the cellular-based communications to be implemented along with industry best-practices for secure communications, such as the use of secure socket layers (SSL).
- All backhaul connections from either the roadside device, the virtual TME and the cellular provider will also implement similar industry best-practices for security, again through the use of SSL and similar.
- Finally, the cloud-based data repository and computing platform will also use industry-based best-practices. Microsoft Azure environment possesses a government-level certification, and provides the necessary mechanisms to demonstrate the application of security at this level within the INFLO prototype.

Design Concerns - Security

Content: See previous slide(s)

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Protection of Personally Identifiable Information

- All data sent to the US DOT Research Data Exchange (RDE) must be free of PII. However, the need to protect PII must go further than that, ensuring that PII/SPII is protected throughout the duration of the project and not just data sent to the RDE
- Battelle intends to use the Microsoft Azure cloud services to host the systems that will collect and temporarily house any potential PII data. The Azure services received the Federal Information Security Management Act of 2002 (FISMA) Authorization to Operate (ATO) in December 2010.

Protection of Personally Identifiable Information (cont.)

- Any devices used by participants will be paid for and supplied and by Battelle, and as such, no financial data will be collected for any participant nor will any devices be specifically associated with or identifiable to a participant. Also, as there is no need to associated participants with devices for purposes of the application demonstration, no data even associated with the participants will need to be store on the cloud or provided to the RDE.
- All collected cloud-based data will be de-identified and scrubbed for PII removal prior to transmittal to the RDE. Minimal data associated with particular device is captured, however techniques such as eliminating the initial and final two (2) minutes of a trip will protect a person's place of work or residence will still be employed. Similarly, any specific, traceable devices IDs or similar will be removed.

Design Concerns – Protection of PII

Content: See previous slide(s)

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Weather Sensing

- Weather related and weather relevant data will collected from the vehicles ODB-II port when available.
- Ambient conditions around the nomadic device will be collected through the use of a COTS sensor. NOTE: Sensing in vehicle environmental conditions like temperature and barometric pressure is of little value but when the device goes “nomadic” and is operating outside of the vehicle this kind of data may prove to be valuable not only for INFLO but for future US DOT programs.
- Integrate a low-cost Bluetooth enabled temperature/pressure sensor into the nomadic device. Interfacing via Bluetooth over industry standard protocols will allow easy transition to other sensing packages in the future if desired.

Design Concerns – Weather Sensing

Content: See previous slide(s)

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Packaging

- The two primary components that comprise the nomadic device are a smartphone and a battery-powered DSRC radio. Our intent is to remove the DSRC radio from its current, packaging,, and to house the single printed circuit board, along with an external battery, into a ‘backshell’ case that will then attach to the back of the smartphone in a manner similar to how many extended battery cases connect.
- Communications between the DSRC radio and the phone will be via Bluetooth, as is indicated elsewhere in this design document. Connections to provide power to both the phone and the radio will also be included in the backshell design.
- The weather sensor tag will also be integrated into this same backshell housing and will also communicate via Bluetooth. No external power is necessary for this device.
- The In-Vehicle Network Access System consists of the OBD-II connector to interface with the vehicle, and a Bluetooth capability to communicate with other devices.

Design Concerns - Packaging

Content: See previous slide(s)

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Power

- The nomadic device will be battery powered such that it can be removed from the vehicle power source and truly demonstrated as being nomadic. This includes the capability of the DSRC radio to continue transmitting Basic Safety Messages at the 10Hz frequency throughout this duration, along with an ability to perform the simple weather-related measurements.
- The main batteries (there are two – one for the smartphone and one for the DSRC radio) are rechargeable and are expected to last at least two hours without being recharged. NOTE: truly low-powered, mobile DSRC chipsets are only now being developed and our not available for this prototype.
- The device will also support operating/charging when installed in the vehicle through the use of a simple accessory power port cable, supplying power at 12VDC to the device via a micro-USB or similar off-the-shelf power connector. The time to fully recharge in this manner has not yet been determined, but is expected to be similar to times typical of current generation smartphones.

Power (cont.)

- The nomadic device will support charging from standard household outlets (110-120 VAC) using an AC-to-DC transformer.
- The weather sensor tag does not require external power, but is powered by an internal ‘watch’ battery. Specifications on this device indicate that the battery life should be sufficient to last the duration of the INFLO design and deployment activities.
- The In-Vehicle Network Access System will draw power from the vehicle directly through the OBD-II port. The module was designed specifically for semi-permanent installation in the vehicle, and as such, has a lower-power mode that will detect when the ignition is off and switch to this mode in order to preserve vehicle battery power when the device / vehicle is not in use.

Design Concerns - Power

Content: See previous slide(s)

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INFLO DESIGN ELEMENTS REVIEW:

COMPONENTS DESCRIPTION

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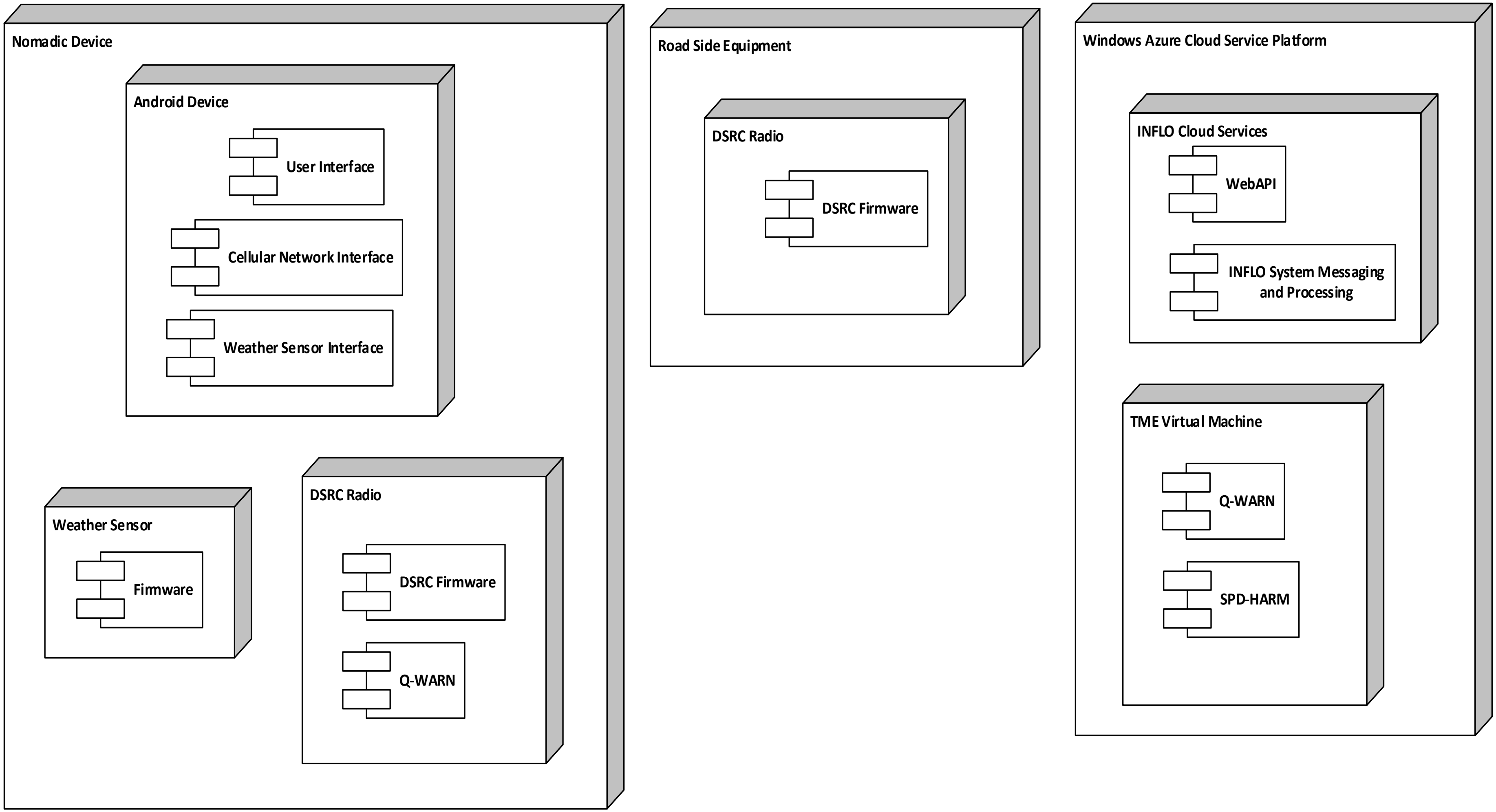
High Level Deployment Diagram



Component Selection

Component	Selection Specifics	Rationale
Android Device	Samsung Galaxy S4	• Support for Bluetooth Low Energy • Integrated temperature sensor if needed • Large high resolution display
Weather Sensor	Texas Instruments (TI) Sensor Tag	• Inexpensive • Easy to integrate • Little to no development needed
DSRC Radio	Arada System's LocoMate™ GO OBU	• Only available device that is portable and battery powered • Approved for use in other USDOT programs (Safety Pilot)
Roadside Equipment	Arada System's LocoMate™ RSE	• Commonality with Nomadic Device DSRC Radio (supports using the same firmware)
Cloud Services	Microsoft Windows Azure	• Commonality with other USDOT programs • Ease of use • Low cost • Mature tool chain

Components Description

Content: See previous slide(s)

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INFLO DESIGN ELEMENTS REVIEW:

INTERNAL INTERFACES

Weather Sensor

- The weather sensor component will expose a Bluetooth Smart (Bluetooth Low Energy) interface. The latest Bluetooth specification uses a service-based architecture based on the attribute protocol (ATT). All communication in low energy takes place over the Generic Attribute Profile (GATT). An application or another profile uses the GATT profile so a client and server can interact in a structured way.
- The server contains a number of attributes, and the GATT Profile defines how to use the Attribute Protocol to discover, read, write and obtain indications. The services are used as defined in the profile specifications. GATT enables you to expose service and characteristics defined in the profile specification. The following table details the services the weather sensor will expose.

Service	Service ID (short)	Service ID (Full)
Barometric Pressure	0xAA40	F0000000-0451-4000-B000-00000000-AA40
Accelerometer	0xAA10	F0000000-0451-4000-B000-00000000-AA10
Gyroscope	0xAA50	F0000000-0451-4000-B000-00000000-AA50
Magnetometer	0xAA30	F0000000-0451-4000-B000-00000000-AA30
Ambient Temperature	0xAA00	F0000000-0451-4000-B000-00000000-AA00
Ambient Humidity	0xAA20	F0000000-0451-4000-B000-00000000-AA20

**Elements such as data length, update rate, etc., are left out of this document for clarity but will be documented in the final ICDs for INFLO.*

Internal Interfaces – Weather Sensor

Content: See previous slide(s)

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Nomadic Device to Nomadic Device

- The Nomadic Device will operate in the same manner as any other vehicle equipped with DSRC radios. It will transmit both BSM Part 1 and Part 2. It will receive and process and BSM, RSA, TIM and MAP message that conform to the SAE J2735:2009 specification. In addition to the traditional V2V communications the nomadic device will transmit Q-WARN messages using the RSA, TIM and MAP messages as appropriate. The nomadic device will forward any Q-WARN or SPD-HARM messages from an RSE in the form of RSA, TIM and MAP messages to any other OBE in range.

Internal Interfaces – Nomadic Device to Nomadic Device

Content: See previous slide(s)

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Nomadic Device to RSE

- The Nomadic Device will receive and process and BSM, RSA, TIM and MAP message that conform to the SAE J2735 specification. In addition to the traditional I2V communications the nomadic device will transmit and Q-WARN messages in the form of RSA, TIM and MAP messages. The nomadic device will forward any Q-WARN or SPD-HARM messages from an RSE in the form of RSA, TIM and MAP messages to any other OBE in range.

Nomadic Device to RSE (cont.)

Message	
BSM Part One	• Transmitted message will conform to SAE J2735 specification
BSM Part Two	• Transmitted message will conform to SAE J2735 specification. Will fill the following information when available: Time, Location, Velocity (Speed), Heading, Barometric Pressure, Lateral Acceleration, Longitudinal Acceleration, Yaw Rate, Rate of change of steering wheel, Brake Status, Brake, Boost Status, Impact Sensor Status, Anti-lock braking status, External air temperature, Wiper status, Headlight status, Traction control status, Stability control status, Differential wheel, speed • Will add additional event for Queued State
Road Side Alert (RSA)	• Transmitted message will conform to SAE J2735 specification. • Transmitted from the nomadic device based on Q-WARN application.
Traveler Information Message (TIM)	• Transmitted message will conform to SAE J2735 specification. • Transmitted from the nomadic device based on Q-WARN application.

Internal Interfaces – Nomadic Device to RSE

Content: See previous slide(s)

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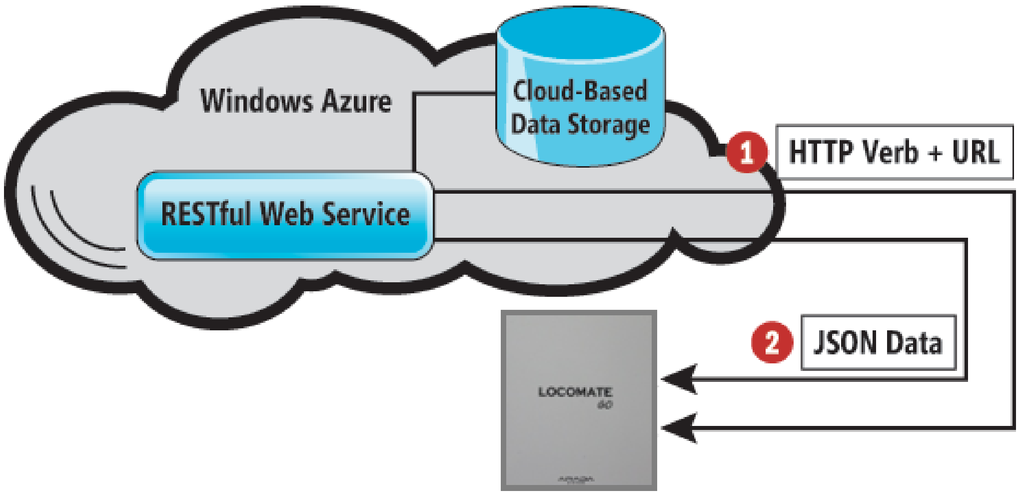
RSE to Cloud API

- The Cloud Service will host a secure Cloud Web Server over HTTPS protocol (Hypertext Transfer Protocol Secure). This secure Cloud Web Server will implement a simple Representational State Transfer (REST) architecture to service requests from the RSEs.



RSE to Cloud API (cont.)

- A RSE web client will request a persistent HTTPS connection (Keep-Alive) with the Cloud Web Server to reduce the overhead otherwise required to repeatedly open temporary HTTPS client connections.

Request	Resource	Parameters	Response
GET	I2V/MAP	Lat/Lon	Wrapper MAP object (JSON)
GET	I2V/TIM	Lat/Lon	Wrapper TIM object (JSON)
GET	I2V/RSA	Lat/Lon	Wrapper RSA object (JSON)

Request	Resource	Parameters	Content
POST	BSMBundle		Wrapper BSMBundle object (JSON)

Internal Interfaces – RESE to Cloud

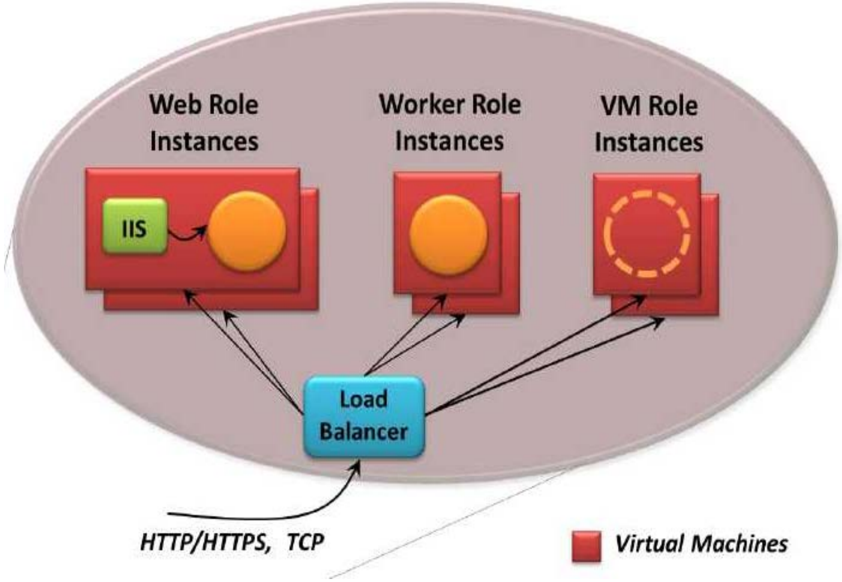
Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Cloud Service to TME

- The Cloud Service will host multiple Virtual Machines (VMs) that provide basic web server and back-end database worker functionality for the TME. In Microsoft Windows Azure, these VM instances are known as Web Roles and Worker Roles. The function of these roles is to service request from Internet clients over HTTPS. In the context of INFLO, these web roles will fulfill requests for I2V resources and update the database upon receiving BSM POSTs. All VMs have access to shared database storage.



- In addition to these web-related roles, the Cloud Service will also host an isolated internal Virtual Machine for running the main TME application, which is responsible for analyzing traffic data in real time and generating appropriate intelligent traffic alerts. This main TME application is expected to require significant computing resources to process the TME algorithms, and for this reason the TME application will be hosted on its own dedicated Virtual Machine.

Internal Interfaces – Cloud Service to TME

Content: See previous slide(s)

Comments/Changes:

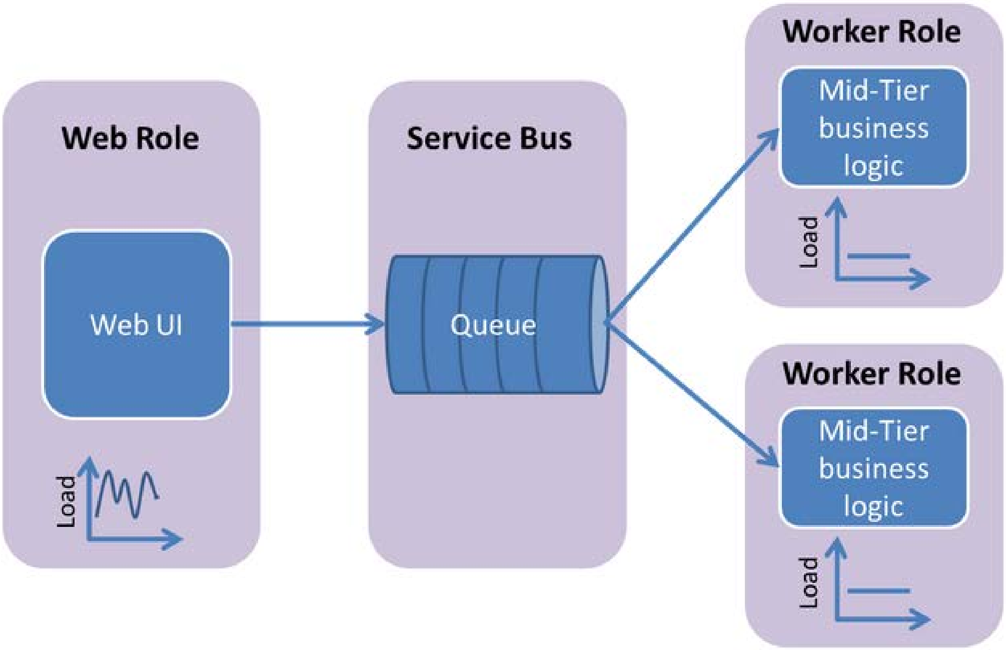
		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Cloud Service to Database

- The Cloud Service will provide all back-end functionality required to efficiently process inbound BSM bundles, using the pre-built functionality packaged with Azure Web Roles, Worker Roles, and Service Bus Queues.

Cloud Service to Database (cont.)

- Loading can be balanced and further parallelized by adding more Web Roles and Worker Roles to process the main Service Bus Queue.



Internal Interfaces –Cloud Service to Database

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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5	Can this design be improved?		

TME to Database (1 of 3)

- Traffic Sensor Systems (TSS) will provide the required traffic data from infrastructure based sensors like radars or loops. The data provided shall be by lane and include at a minimum the average speed, volume, and occupancy in a specific lane during the time interval requested.
- Environmental Sensor Stations (ESS) will provide weather data from infrastructure sensors.
- Mobile ESS will provide weather data from mobile maintenance vehicles that are equipped with weather sensors.

TME to Database (2 of 3)

- Weather Information Service Providers will provide weather alerts that will be used to determine the roadways that could be affected by severe weather conditions and to modify the weather data polling frequency from infrastructure ESS and mobile ESS systems.
- Connected Vehicle Cloud will provide connected vehicle traffic and weather data that was collected from connected vehicles.

TME to Database (3 of 3)

- A separate data aggregation module will be developed to interface with each one of the external data providers to listen/poll the required data at a frequency defined by the user or the application, perform the necessary data validation requirements and insure that the data collected is within the thresholds defined by the user, process the acquired inputs to generate the data required by the INFLO applications like determining the roadway link where a connected vehicle is located based on its mile marker location or if a roadway link is congested or queued, and finally write the raw data received from the external sources and the processed data into the INFLO database. The INFLO data aggregation modules will use the query language provided by the database and Ethernet TCP/IP protocols to write the collected data into the various tables in the database.
- The recommended link target speeds generated by the INFLO applications and the weather together with the queue and weather alerts disseminated to connected vehicles and infrastructure dynamic message signs will also be logged into the INFLO database to be used by the performance monitoring system.

Internal Interfaces – TME to Database

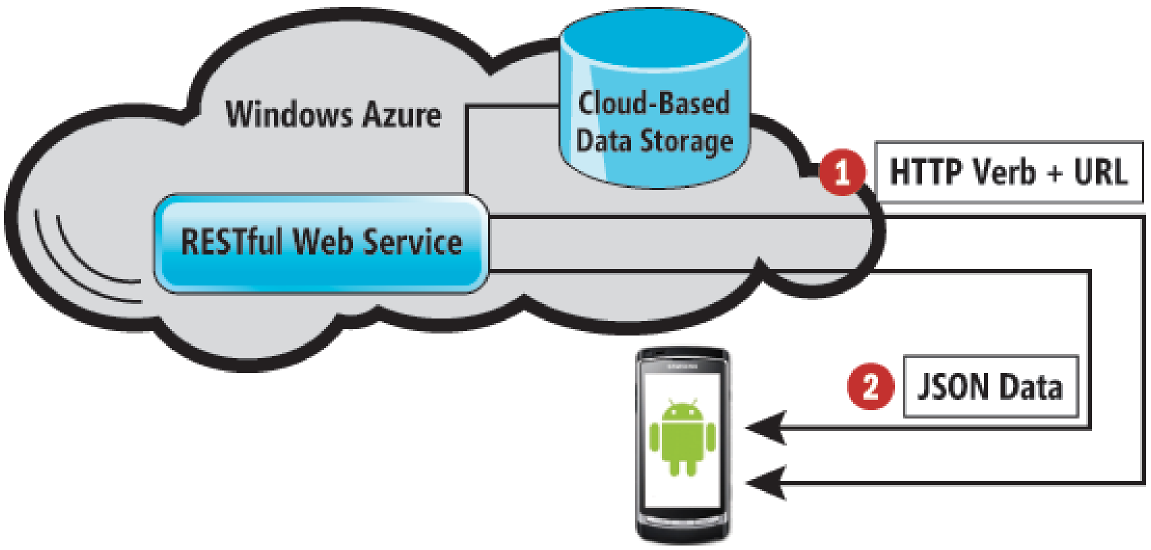
Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Tablet to Cloud Service

- The Cloud Service will host a secure web server over HTTPS protocol (Hypertext Transfer Protocol Secure). This secure web server will implement a simple Representational State Transfer (REST) architecture to service requests from the Nomadic Devices.



Tablet to Cloud Service (cont.)

- A Nomadic Device web client will request a persistent HTTPS connection (Keep-Alive) with the Cloud Web Server to reduce the overhead otherwise required to repeatedly open temporary HTTPS client connections.

Request	Resource	Parameters	Response
GET	I2V/MAP	Lat/Lon	Wrapper MAP object (JSON)
GET	I2V/TIM	Lat/Lon	Wrapper TIM object (JSON)
GET	I2V/RSA	Lat/Lon	Wrapper RSA object (JSON)

Request	Resource	Parameters	Content
POST	BSMBundle		Wrapper BSMBundle object (JSON)

Internal Interfaces – Tablet to Cloud Service

Content: See previous slide(s)

Comments/Changes:

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1	Is the design understandable?		
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5	Can this design be improved?		

15 Minute Break

INFLO DESIGN ELEMENTS REVIEW:

EXTERNAL INTERFACES

Vehicle Interface

- The Vehicle Interface will be a Bluetooth module that plugs into the OBD-II port on a vehicle. The Nomadic Device DSRC radio will then connect to this module to receive data available on the vehicle's OBD-II port.

External Interfaces - Vehicle

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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Variable Message Signage

- The INFLO TME will, in select locations, disseminate recommended roadway link target speeds and queue/weather alerts and warnings to all drivers through infrastructure based dynamic message signs and variable speed limit signs.
- The INFLO TME application will interface with these TME sign management application through existing C2C standards to display messages on the signs.
- This will be accomplished via NTCIP 1203.
- The 1203 NTCIP standard can be used with serial, TCP/IP, or UDP communications protocols to display messages on the signs.

External Interfaces – Variable Message Sign

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Mobile Environmental Sensor Station (Mobile ESS)

- The INFLO prototype will contain a data aggregation application to interface with Mobile ESS devices to acquire roadway link weather conditions. The frequency of accessing the Mobile ESS system will be either defined by the user or based on weather alerts received from Weather Information Service Providers like NOAA. The acquired information will be checked to verify that the data collected is valid and if it applies to the roadway network being monitored. The data will be saved into the INFLO database where it can be used by the WRTM module to generate weather alerts/warnings, and to determine the recommended target safe speed for each roadway link being monitored.

External Interfaces – Mobile ESS

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Environmental Sensor Station (ESS)

- The INFLO prototype will contain a data aggregation application that will interface with ESS infrastructure devices to acquire roadway link weather conditions. The frequency of accessing the ESS infrastructure devices will be either determined by the user or based on weather alerts received from Weather Information Service Providers like NOAA. The acquired information will be checked to verify that the data collected is valid and if it applies to the roadway network being monitored. The data will be saved into the INFLO database where it can be used by the WRTM module to generate weather alerts/warnings, and to determine the recommended target safe speed based on roadway conditions for each roadway link being monitored.

External Interfaces - ESS

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
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3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Traffic Sensor Systems (TSS)

- A dedicated data aggregation module will interface with the TSS collecting data from infrastructure traffic sensors installed in each lane of the roadway being monitored. The frequency of polling the TSS is user defined. The TSS will use NTCIP standard 1209 together with either Ethernet TCP/IP or UDP protocols to interface with the TSS. The data received from TSS for each lane detector should include volume, average speed, and occupancy for each lane for the requested time interval. The lane data is aggregated to calculate the average speed, volume, and average occupancy across all lanes for each detector station configured in the TSS. The detector station data will be used to further determine a roadway link local speed and if the link is queued or congested based on user defined threshold.

External Interfaces - TSS

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Weather Information Service Providers

- A dedicated data aggregation module will interface with the Weather Information Service Providers like NOAA to receive weather alerts. The weather alerts will be used to determine the affected roadway links and to modify the frequency of polling the infrastructure based ESS and mobile ESS devices during the weather alert specified time interval.

External Interfaces – Weather Information

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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INFLO DESIGN ELEMENTS REVIEW:

COMPONENT DESIGN

In Vehicle Network Access System

- The In Vehicle Network Access System (IVNAAS) will implement an OBD-II interface that will be handled by the VITAL module. The VITAL module is a proprietary Battelle module that plugs into the OBD-II port to obtain a vehicle's telemetry data and forward the messages using Bluetooth to a connected device. This module will allow the DSRC radio to receive vehicle dynamics to populate the Basic Safety Message Part II. The availability of data is vehicle dependent.

Component Design - In Vehicle Network Access System

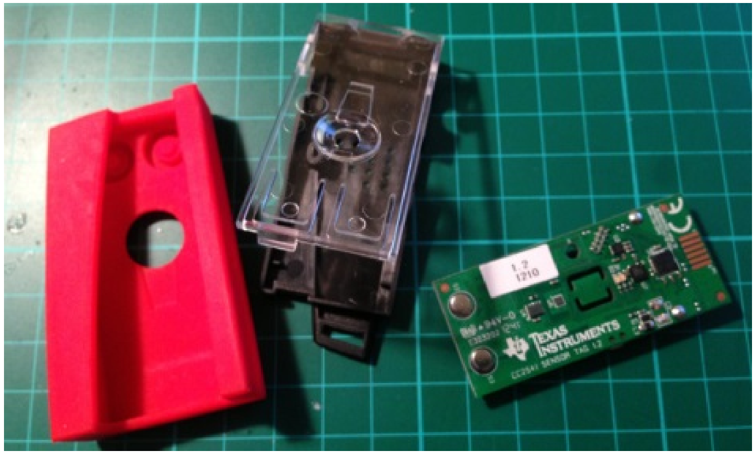
Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Weather Sensor

- The weather sensor will be based on the Texas Instruments CC2541 System-On-Chip. The CC2541 is a power-optimized true system-on-chip (SoC) solution for both Bluetooth low energy and proprietary 2.4-GHz applications. Texas Instruments offers a low-cost integrated sensor package called the CC2541 SensorTag that comes with integrated IR temperature, humidity, pressure, accelerometer, gyroscope, and magnetometer sensors.
- The SensorTag will be mounted to the external package of the nomadic device and powered by a battery. The off-the-shelf SensorTag firmware is sufficient for INFLO needs.



Component Design – Weather Sensor

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Nomadic Device User Interface Module

The Nomadic Device User Interface Module will be a mobile device (cell phone) running the Android operating system. The goals/features of this component are:

1. Provide an interface to the cellular network (i.e., the TME via the Internet)
2. Management of the connection back to the Microsoft Azure Web Service hosting the TME
3. Integrate and exposing the ambient weather sensor data
4. Graphical user interface to communicate the following to the user:
    - INFLO system state
    - Nomadic device system state
    - SPD-HARM messages (recommended speed for example)
    - Q-WARN messages (queue location, time to end of queue, etc.)
5. Interfacing with the DSRC radio module in the nomadic device via a Bluetooth connection to send weather data to the DSRC radio module and receive TME bound messages.

Component Design – Nomadic Device UI

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Platform

- The target platform is the Samsung Galaxy S4 which is a 5" Android based cell phone however the software developed for the Nomadic Device User Interface Module will run on any type of Android device as long as that device supports Android 4.3 (API Level 18).

Component Design – Nomadic Device Platform

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Development Stack

- The Nomadic Device User Interface Module will be built using Google's Android SDK and targeted at Android devices running at least Android 4.3 Jelly Bean (API level 18).

Component Design – Development Stack

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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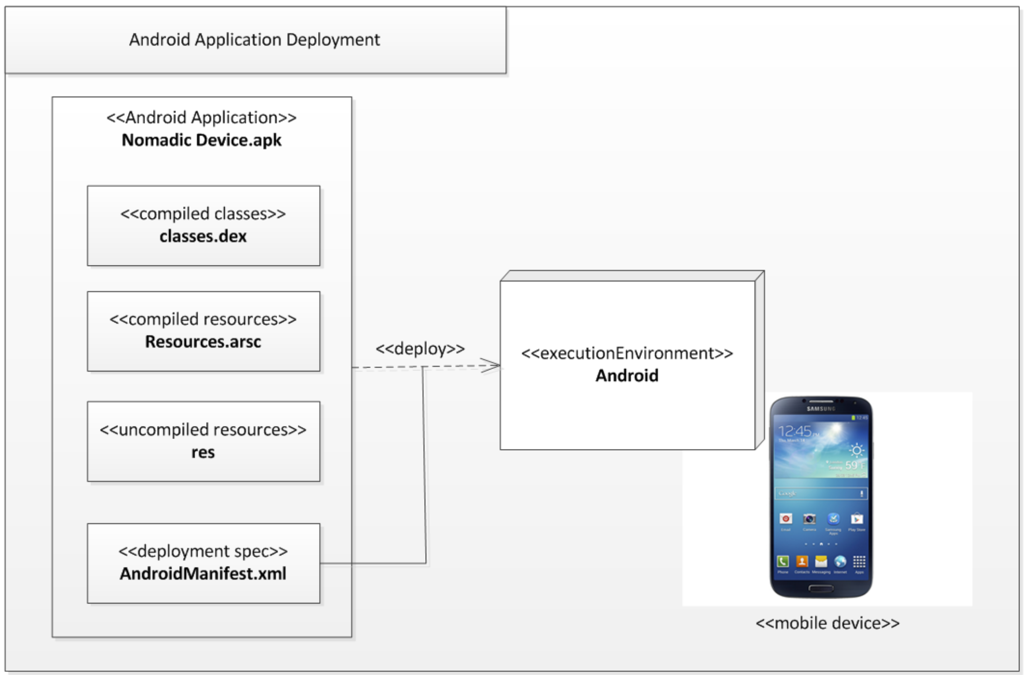
Deployment Diagram

- Figure shows the basic deployment diagram for the Nomadic Device User Interface Module. This is a standard deployment model used by most basic Android applications.



Component Design – Deployment Diagram

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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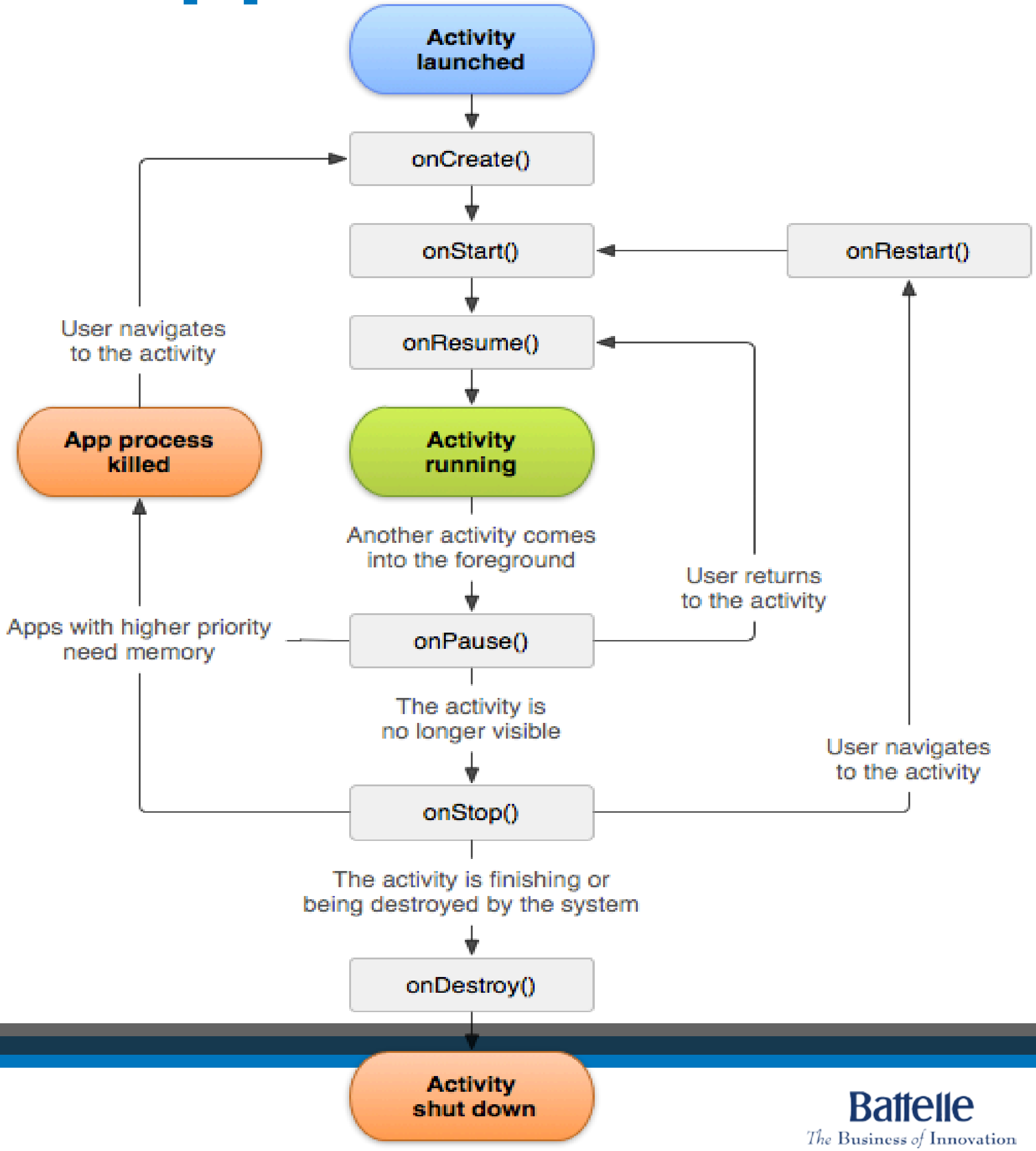
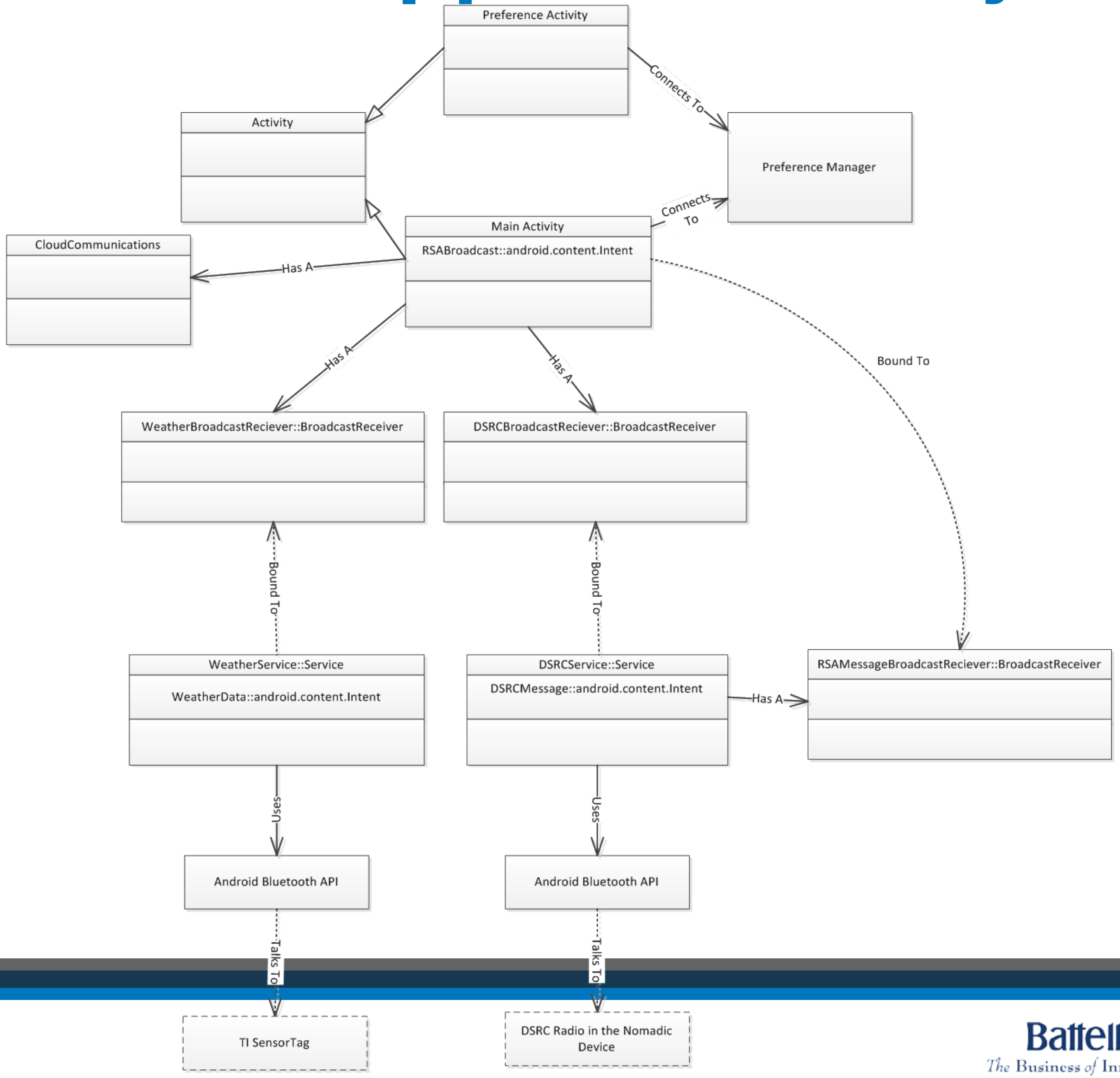
Application

- Most Android applications are composed of Activities. The activities normally live in a lifecycle controlled by the Android OS. The intent is that the INFLO application on the nomadic device is the only executing application on the device but the system must support the user switching to other activities (applications) or responding the operating system events.
- Figure on slide 110 shows the Nomadic Device User Interface Module lifecycle. This diagram shows the important state paths of an Activity. The square rectangles represent callback methods which will be implemented to perform operations when the Activity moves between states. The colored ovals are major states the Activity can be in. The subsequent figure shows a simplified object model for the Nomadic Device User Interface Application.

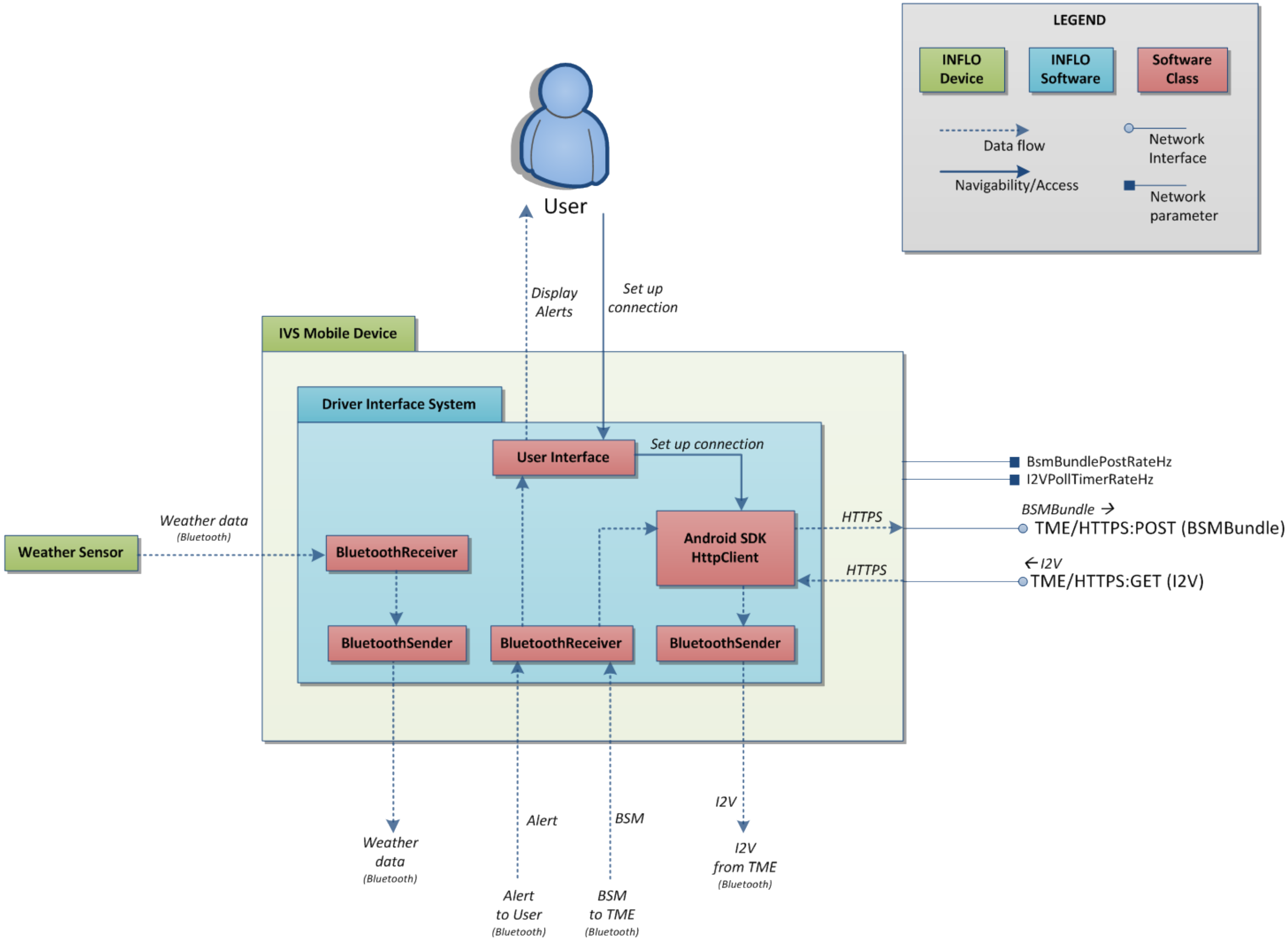
User Interface Application Lifecycle



User Interface Application Object Model



Mobile Device Data Flow



Component Design – Nomadic Device Application

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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Application - Bluetooth Interfaces

- To support communications between the mobile device and both the weather sensor (Bluetooth Low Energy) and the nomadic device's integrated DSRC radio (classic Bluetooth) the application will leverage the Android support for the Bluetooth network stack, which allows a device to wirelessly exchange data with other Bluetooth devices (see Figure to follow). The application framework provides access to the Bluetooth functionality through the Android Bluetooth APIs (for both Bluetooth Low Energy and standard Bluetooth). These APIs let applications wirelessly connect to other Bluetooth devices, enabling point-to-point and multipoint wireless features.
- Support for interfacing with the weather sensor and the integrated DSRC radio will be handled by two Android services. The Android Service object supports developers by providing a way to manage long running or persistent operations while not blocking the main user interface activities. In other words, it is a facility for the application to tell the system about something it wants to be doing in the background (even when the user is not directly interacting with the application).

Application - Bluetooth Interfaces (cont.)

- The WeatherService will manage collecting ambient weather information from the TI SensorTag over Bluetooth Low Energy. The Android device will be “Bluetooth Smart Ready.” This is a one-way link where data, once subscribed, will flow from the SensorTag to the Android device.
- The DSRCService will implement and support bi-directional communications between the Android device and the DSRC radio. The DSRC radio in the nomadic device will be responsible for much of the INFLO processing that is not handled by the TME. When not in range of road side equipment, data bound for the DSRC radio in the nomadic device will come through the cellular link provided by the Android device and pass, essentially unchanged, to the DSRC radio. Similarly, data bound for the TME will flow through the DSRCService to the Android device’s cellular connection to the TME.

Component Design – Bluetooth Interfaces

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
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Application - Intents and Broadcast Receivers

- An Intent in Android is an abstract description of an operation to be performed. It can be sent to any interested component who implements a BroadcastReceiver.
- The MainActivity in this design will expose a BroadcastReceiver for both the WeatherService and the DSRCService. It will, via the CloudCommunications object, send incoming RSA information to the DSRC radio component via the same mechanism.

Component Design – Application Intents and Broadcast Receivers

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Application - CloudCommunications

- The CloudCommunications component acts as a cellular network bridge and is responsible for synchronous communications with the INFLO Windows Azure WebAPI interfaces. There will be a configurable timer that essentially polls the WebAPI. Each call will post status packets (BSM's for example) to the WebAPI and at the same time query for location specific data (RSA's for example). When BSM's are not available/valid this interface will continue to the poll the TME for location specific updates. Note that this interface is only active when the nomadic device is not in range of RSE.

Component Design – Cloud Communications

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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Application - User Interface

- In the mockups the screens are made as simple as possible with the goal of displaying:
  - Recommended speed (SPD-HARM)
  - Distance to an approaching queue (Q-WARN)
  - Some level of color based warning for distance to queue and/or current speed relative to recommended speed
- The Android application's user interface will contain settings and debug/diagnostic screens as well.

Application - User Interface (cont.)

Nomadic Device User Interface Module

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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Nomadic Device DSRC Radio Module

- The nomadic device DSRC radio will be a small portable unit that can run on battery power. The unit will be the main processing for the nomadic device. The unit will receive messaging from the DSRC radio and the cellular network. It will process all messages and supply any needed information for
- The unit will interface to the User Interface Module via Bluetooth. The radio will receive both V2V and I2V communications. The radio will transmit Basic Safety Messages (Part I and Part II) to other DSRC radios that are in range. The DSRC radio will also host the Connected Vehicle-based Q-WARN Application which is 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 TME.

Nomadic Device DSRC Radio Module (cont.)

- The Nomadic Device will transmit both Basic Safety Messages Part One and Basic Safety Messages Part Two. The part two data will be populated by data from the vehicle, data from the onboard GPS and data collected by weather sensors. The BSM will be transmitted at 10 Hz with the Part Two Being transmitted at 1HZ. The Nomadic Device will also transmit any Q-WARN indicators calculated in the onboard Q-WARN Application (as part of the BSM Part Two). The radio will also forward any Q-WARN message received from the TME.
- The Nomadic device will receive messages from other vehicles (V2V) and from the infrastructure (I2V). The nomadic device will receive and process any BSMs from surrounding vehicles and supply the data to the Q-WARN application. The Nomadic device will also receive and process at a minimum the following messages from the infrastructure whether it is from a local DSRC radio or the cellular connection: MAP, Road Side Alert (RSA) and Traveler Information Message (TIM). The preceding messages will be forwarded to any other nomadic device within range.

Nomadic Device – DSRC Module

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
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DSRC Platform

- The nomadic DSRC radio will use an Arada System's LocoMate™ GO OBU battery powered unit. The LocoMate™ GO OBU comes in a tiny form factor for in-vehicle deployment with a full DSRC WAVE software solution and applications for integration with smart phones to ease the human-user-interface. The solution is integrated with GPS (better than 1 meter accuracy), Bluetooth and high-power 802.11p radios. It is fully compliant with Omni-Air's certification and used in worldwide deployments including the US Department of Transportations' Safety Pilot in Ann Arbor, Michigan.

Nomadic Device – DSRC Module Platform

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
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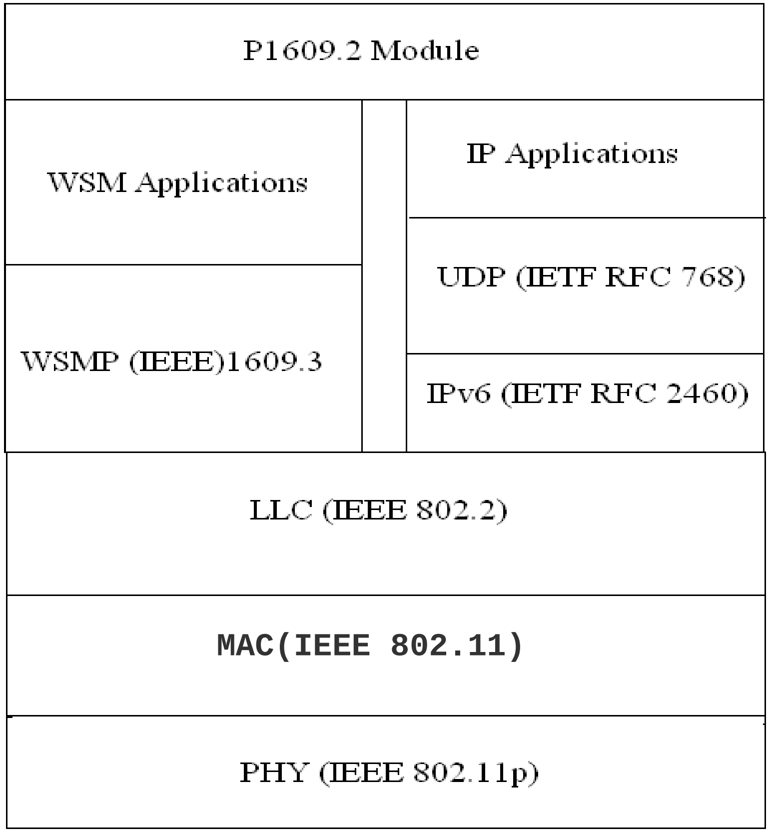
5	Can this design be improved?		

Development Stack

- The Nomadic Device DSRC application will be written in C using interfaces supplied by the manufacturer. The development for the application that resides on the DSRC will use Arada's WAVE API version 1.86. The application will be built to execute on a Linux operating system using the LocoMate™ tool chain version 1.42. This API includes Security, GPS positioning and SAE J2735 messaging. Figure shows the WAVE stack as included on the Arada DSRC devices.



Nomadic Device – DSRC Module Platform Development Platform

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
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5	Can this design be improved?		

Application

- The application will be based on Arada's example code for the On-Board Equipment deployment. This example implements the messaging, logging and security for the WAVE messages. Additional functionality will be added to this application to incorporate the following.
- Q-WARN on board application
- Vehicle Data integration into the BSM Part II message
- Weather Data integration into the BSM Part II message
- User Interface messaging
- Cellular Communications via Bluetooth
- Queued State determination and integration into the BSM Part II message
- Alert Forwarding via DSRC

Nomadic Device – DSRC Module Platform Application

Content: See previous slide(s)

Comments/Changes:

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1	Is the design understandable?		
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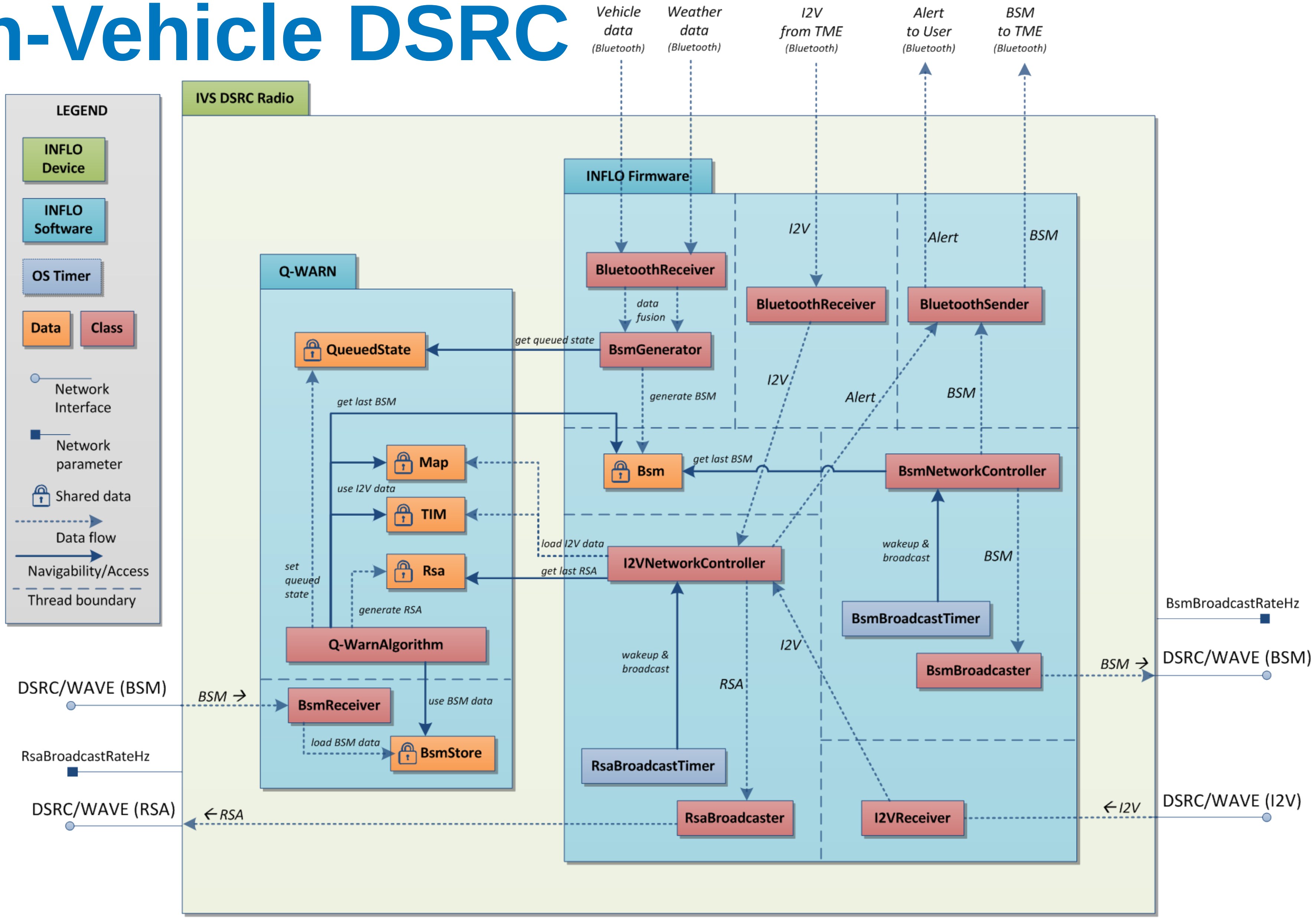
In-Vehicle DSRC



Texas A&M Transportation Institute

Battelle
The Business of Innovation

Nomadic Device – In-vehicle DSRC

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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5	Can this design be improved?		

In-Vehicle Application - Q-WARN

- The Q-WARN application is the core in-vehicle application that processes real-time data and makes individual queue warning determinations from the data provided. This application will take BSM Messages from surrounding vehicles and determine the queue state of the vehicle and fill in an event indicator on the outgoing BSM Part II messages.

Application – Q-WARN Application

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Application - Vehicle Data and Weather Bluetooth Receiver

- The vehicle data will be collected from a Bluetooth link to an OBD-II module that will allow the application to determine specific states of the vehicle. The receiver will connect to the module and receive raw OBD-II messages from the vehicle. The messages will then be decoded to extract the vehicle status. When the device is in nomadic mode the vehicle data for the BSM Part II will not be populated. The data that will be received from the vehicle is listed to the right.
- This Bluetooth receiver will also receive the weather data from the Nomadic Device User Interface Module. All of this data is passed to the BSM Generator for inclusion into the Basic Safety Message Part II.

Data Elements
Time
Location
Velocity (Speed)
Heading
Barometric Pressure
Lateral Acceleration
Longitudinal Acceleration
Yaw Rate
Rate of change of steering wheel
Brake Status
Brake Boost Status
Impact Sensor Status
Anti-lock braking status
External air temperature
Wiper status
Headlight status
Traction control status
Stability control status
Differential wheel speed

Application – Q-WARN Application

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Application - I2V Bluetooth Receiver

- The Infrastructure to vehicle receiver will handle any incoming message from the TME over the cellular link. The messages that will be received are the Road Side Alert, Traveler Information and Map Data. The messages will be received in ASCII and they will be converted to a binary ASN.1 format. The messages will then be processed by the existing Arada message handlers.

Application – Bluetooth Receiver

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Application - Alert Bluetooth Sender

- The Alert Bluetooth Sender will relay messages to the User Interface to be displayed to the user. The alert will come from either the TME or the on-board Q-WARN application. The alert will contain ITIS Codes for the text display that the user interface will use a table lookup to decode.

Application – Alert Bluetooth Sender

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Application - Message Bluetooth Sender

- The Message Bluetooth sender will send Basic Safety Message Part Two to the TME. The Basic Safety Messages will be received internally from the BSM Network Controller and will send them to the Nomadic Device User Interface Module for transmission on the cellular network. These Basic Safety Messages will only be sent via the cellular network when the Nomadic Device DSRC is not in range of a RSE.

Application – Message Bluetooth Sender

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Application - Basic Safety Message Generator

- The Basic Safety Message Generator will fill all applicable fields in the BSM from data that it receives from multiple inputs. The weather data will be filled in from data received from the Nomadic Device User Interface Module. The vehicle data, when the nomadic device is installed as an OBE, will be used to populate the appropriate fields. The time and GPS position will be retrieved from the integrated GPS receiver.

Application – BSM Generator

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Application - I2V Network Controller

- The Infrastructure to Vehicle Network Controller will handle all messages between the infrastructure and the nomadic device.

Application – I2V Network Controller

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Application - I2V Receiver

- The Infrastructure to Vehicle Receiver will receive any messages from an RSE over the DSRC radio. All messages will be sent to the I2V Network Controller for handling.

Application – I2V Receiver

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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5	Can this design be improved?		

Application - BSM Network Controller

- The Basic Safety Message Controller will be responsible for deciding where and when to send the BSM messages. When the Nomadic Device is within range of an RSE it will only send the BSM Part II message through the DSRC radio. When the Nomadic Device is not in range of an RSE it will send the BSM Part II message to the Nomadic Device User Interface Module for transmission on the cellular network. The BSM Part I message will only be sent through the DSRC radio.

Application – BSM Network Controller

Content: See previous slide(s)

Comments/Changes:

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5	Can this design be improved?		

Application - BSM Receiver

- The Basic Safety Message Receiver will receive any BSM from surrounding DSRC transmissions. These messages will be stored for use by the Q-WARN Application.

Application – BSM Receiver

Content: See previous slide(s)

Comments/Changes:

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1	Is the design understandable?		
2	Does the design contain the necessary information?		
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5	Can this design be improved?		

Application - BSM Broadcaster

- The Basic Safety Message Broadcaster will broadcast the current BSM over the DSRC radio to any other DSRC radio within range. The Basic Safety Message Part I will be broadcast at 10 Hz and the Basic Safety Message Part II will be broadcast at 1 Hz.

Application – BSM Broadcaster

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Application - RSA, MAP and TIM Broadcaster

- The Road Side Alert Broadcaster will broadcast a Q-WARN RSA or TIM message to any other DSRC within range. The messages will be populated from the on-board Q-WARN application and will contain data concerning the queue. The broadcaster will transmit a MAP message if any is available for the geographic location.

Application – RSA, MAP and TIM Broadcaster

Content: See previous slide(s)

Comments/Changes:

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1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

User Interface

- The user interface to the LocoMate™ GO is through a Bluetooth telnet connection. Once a user has logged into the device a command line interface is used to configure the device using standard Linux commands. A command line interface is provided by Arada that will allow the user to manage the operation of the DSRC radio and its external interfaces.

User Interface

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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1 Hour for Lunch

Agenda – Dec. 18th, 2013

9:00 AM	Welcome, Introductions & Walkthrough Process
9:15 AM	Background / Scope
9:30 AM	System Design Document Review
10:30 AM	Break
10:45 AM	System Design Document Review (cont.)
12:15 PM	Lunch (on your own)
1:00 PM	System Design Document Review (cont.)
2:15 PM	Break
2:30 PM	SPD-HARM and Q-WARN Algorithm Design Review
4:15 PM	Wrap-Up, Action Items and Next Step
4:30 PM	Adjourn

Road Side Equipment

- The Road Side Equipment will be an Arada LocoMate™ RSU which will handle all communications from the TME to vehicles and nomadic devices and communications from the vehicles to the TME. The Road Side Equipment will forward any warnings from the TME to all devices within its range. The RSE will also collect BSM Part II messages and send a batch of messages back to the TME for inclusion in calculations.

Road Side Equipment

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

RSE Platform

- The Road Side Equipment will be an Arada LocoMate™ RSU which comes in an industrial outdoor NEMA rated enclosure that allows for seamless outdoor deployments with a full DSRC WAVE software solution. The solution is integrated with GPS, Bluetooth and high-power 802.11p radios. It is fully compliant with Omni-Air's certification and used in worldwide deployments including the US Department of Transportations' Safety Pilot in Ann Arbor, Michigan.

RSE Platform

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Development Stack

- The Nomadic Device DSRC application will be written in C using interfaces supplied by the manufacturer. The development for the application that resides on the DSRC will use Arada's WAVE API version 1.86. The application will be built to execute on a Linux operating system using the LocoMate™ tool chain version 1.42. This API includes Security, GPS positioning and SAE J2735 messaging.

RSE Development Stack

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

RSE Application

- The Road Side Equipment will forward any messages received from the TME to any DSRC radios within range. These messages must conform to the SAE J2735 specification. The RSE will also receive Basic Safety Messages received by any DSRC within range. The application will queue the BSM Part II messages and send them in a block to the TME. The queue will allow the RSE to send a block of messages to the TME at a slower rate than sending them one at a time. The design of the RSE software can be seen in the following figure.

RSE Applications

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
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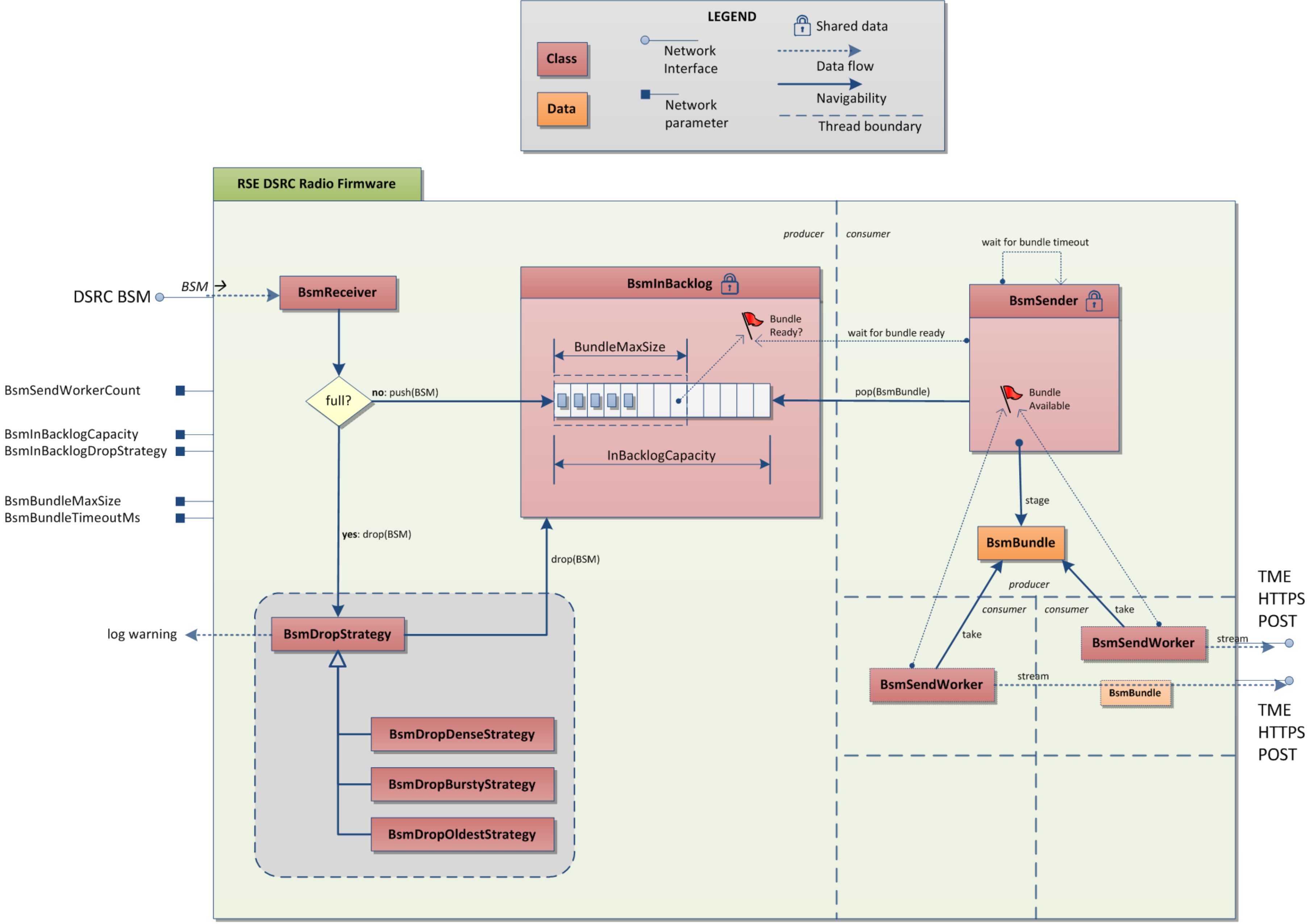
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		



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RSE Design

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
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4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Application - BSM Receiver

- The Basic Safety Message Receiver will receive any BSM from surrounding DSRC transmissions. If the Basic Safety Message is a Part II then the receiver will attempt to add the message to the send queue. If the send queue is full then the message will be sent to the BSM Drop Strategy to determine which messages should be in the queue.

Application – BSM Receiver

Content: See previous slide(s)

Comments/Changes:

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1	Is the design understandable?		
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Application - BSM Drop Strategy

- The BSM Drop Strategy will determine which messages should remain and/or be added to the queue when the queue becomes full. There are three strategies that can be employed to determine which messages to keep in the queue.

BSM Drop Dense Strategy

- This strategy will drop a message from a closely grouped set of messages. The closeness of the messages indicates a low rate of travel or being stopped. Many messages from the same area do no contribute much to the applications running on the TME.

BSM Drop Bursty Strategy

- This strategy will drop messages that are sent very close together. This will allow a nice distribution of data to time.

BSM Drop Oldest Strategy

- This strategy will drop the oldest message in the queue. This will allow the messages that get sent to the TME to be the latest available.

Application – BSM Drop Strategy

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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5	Can this design be improved?		

Application - BSM Sender

- The Basic Safety Message Sender is responsible for sending any queued BSM messages to the TME. It will send the bundled messages to a BSMSendWorker that will send the messages to the TME.

Application – BSM Sender

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Application - Message Handler

- The Message Handler is responsible for receiving any messages from the TME and forwarding them to the DSRC radio to be sent to any other DSRC radios that are in range. The messages must be J2735 compliant.

Application – Message Handler

Content: See previous slide(s)
Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
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4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

User Interface

- The user interface to the Arada LocoMate™ RSU is through a Bluetooth telnet connection. Once a user has logged into the device a command line interface is used to configure the device using standard Linux commands. A command line interface is provided by Arada that will allow the user to manage the operation of the DSRC radio and its external interfaces.

User Interface

Content: See previous slide(s)

Comments/Changes:

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1	Is the design understandable?		
2	Does the design contain the necessary information?		
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Cloud Service

- The Cloud Service will be a Microsoft Azure Cloud Service comprised of the following components:
  - SQL Database
  - Web Role (TME Web Server)
  - Web Role (Admin Portal)
  - Worker Role (Database Worker)
  - Virtual Machine Role (TME Application)

Cloud Service

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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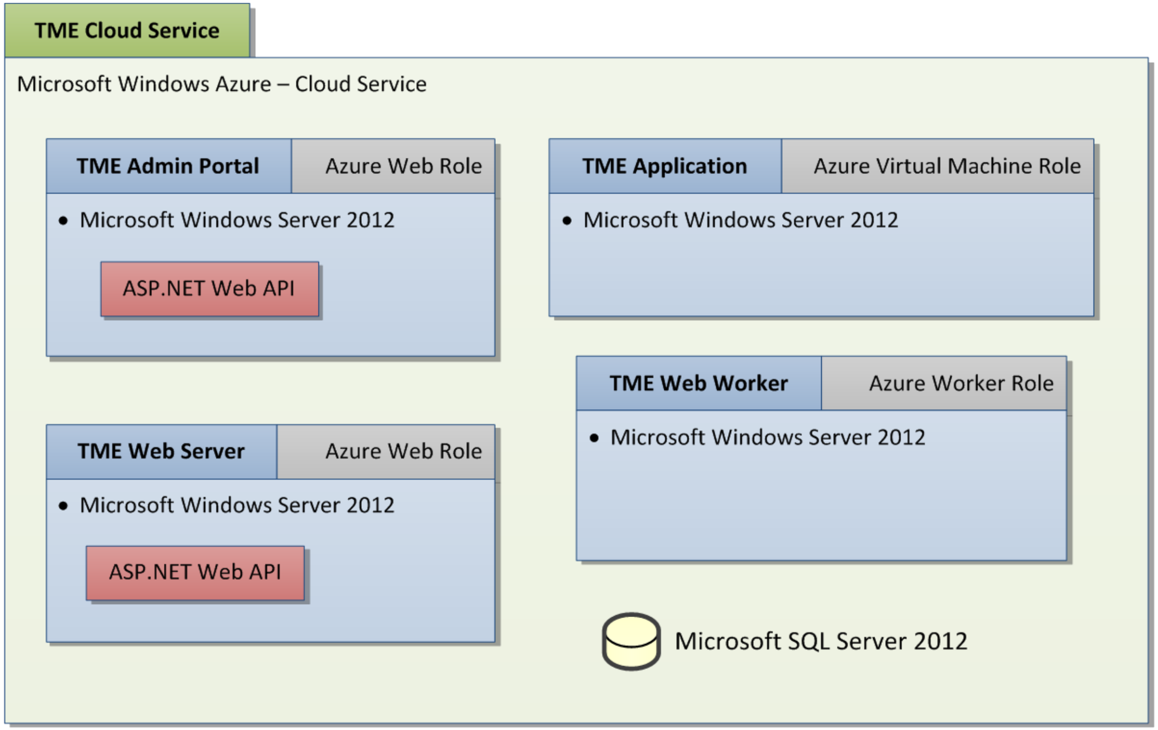
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Platform

- The computing platforms for each VM in the Azure Cloud Service is as shown.



Cloud Service Platform

Content: See previous slide(s)

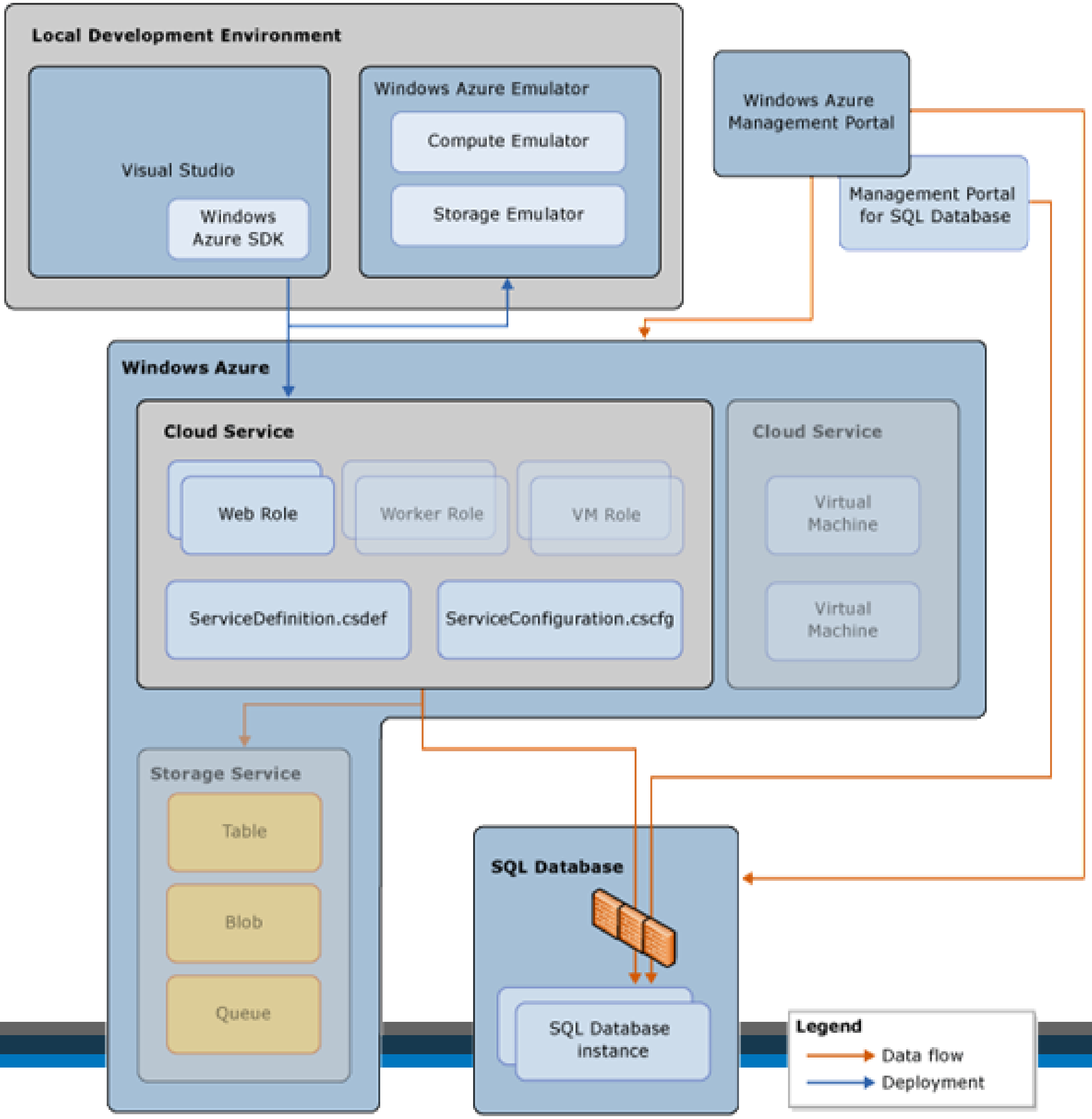
Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Development Stack

- The Azure software developer will use Microsoft Visual Studio 2012 with the Windows Azure SDK installed. The Azure SDK provides an Azure Emulator for local unit testing. The Windows Azure Management Portal provides most configuration capabilities via an interactive web site interface.

Windows Azure Development Stack



Cloud Service Development Stack

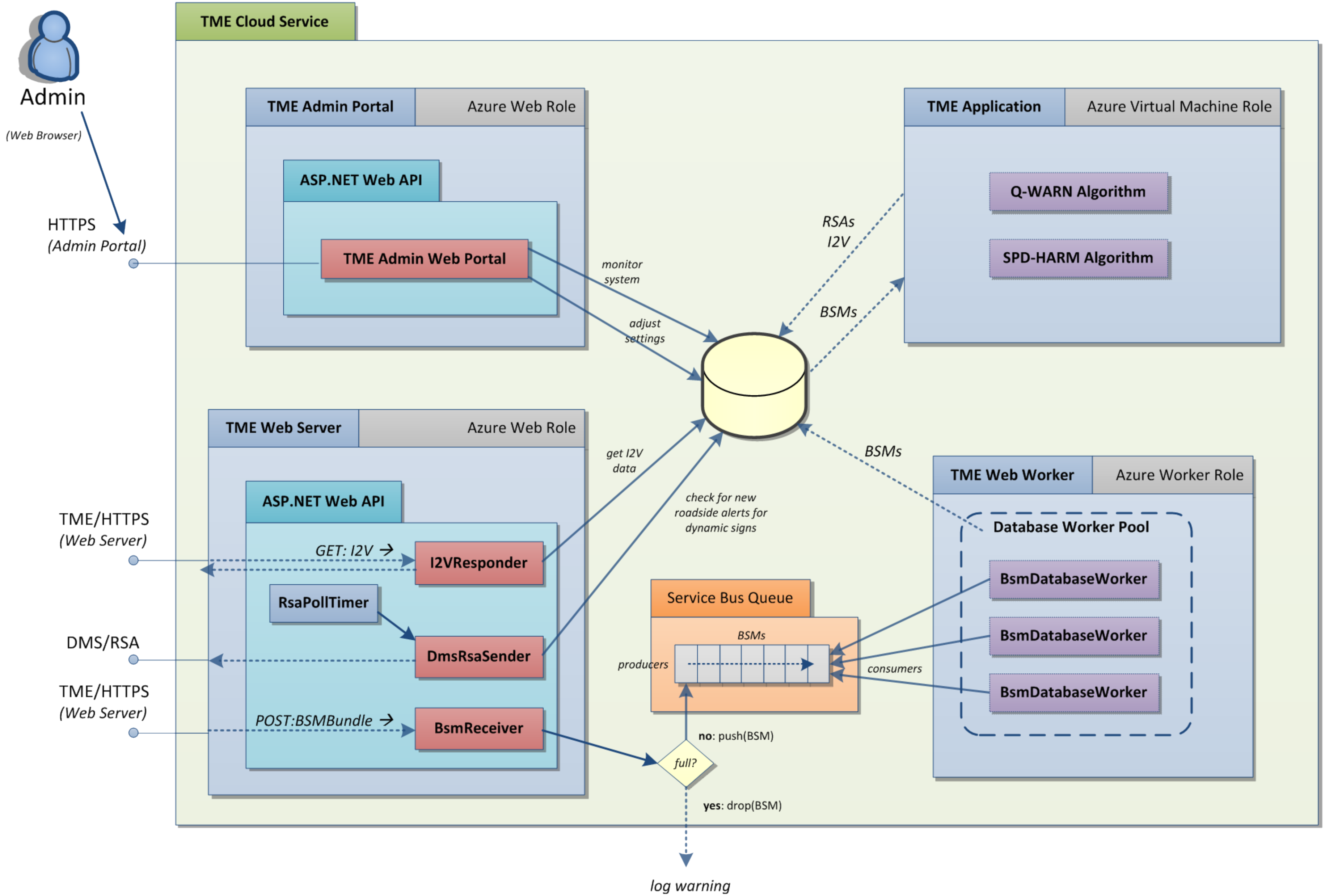
Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Processes

- The internal design of the Cloud Service is depicted in the following Figure. The SQL Database is at the center of the process flow. A Service Bus Queue will be established to separate the process of receiving BSMs (coming from web clients in the Web Role), from the process of updating the database using a pool of database worker threads in the Worker Role. The TME Application will poll the database as needed to gather BSM data for analyzing the traffic system, and will generate I2V messages if a Q-WARN or SPD-HARM condition is determined. The Web Role for the TME Web Server will respond to requests for I2V messages; upon receiving a GET I2V request, the Web Role will check the database and retrieve the requested I2V message if present given the request parameters (I2V region/location).



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Cloud Service Processes

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

User Interface

- The user interface to the Microsoft Azure Cloud Service is the Microsoft Windows Azure Management Portal, which is an interactive web site located at the following URL: https://account.windowsazure.com.
- The Azure Portal provides Remote Desktop (RDP) access to all virtual machines, primarily for development and diagnostic purposes.
- An INFLO Admin Portal will provide real-time diagnostic information about the TME to the INFLO Administrator via a simple web portal interface. The INFLO Admin will need to be able to modify values in a reserved configuration settings table in the database to adjust the TME algorithms. Due to project constraints, it may be adequate to provide the Admin with direct access to the SQL database using SQL Server Management Console by having the Admin connect to an Azure VM via RDP, which would allow the Admin to view and modify specific reserved tables in the database to adjust the TME algorithms.

Cloud Service User Interface

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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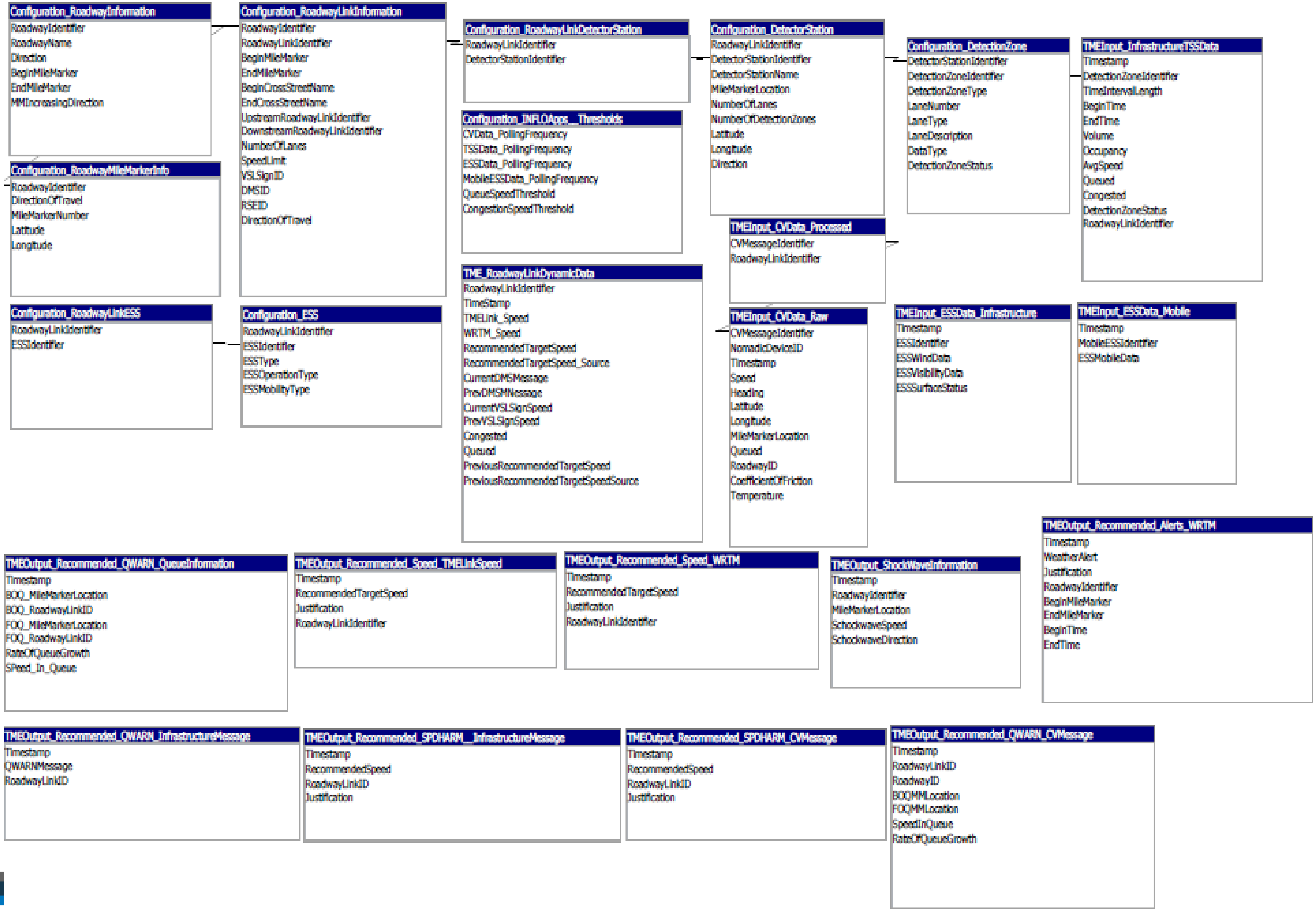
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

INFLO Database

- The database lives in the Windows Azure INFLO cloud service. It will hold incoming data from the nomadic devices (BSM type of data), road side alerts, settings, etc. It sits between the web service layer and the TME.


Configuration_RoadwayInformation
RoadwayIdentifier
RoadwayName
Direction
BeginMileMarker
EndMileMarker
MMIncreasingDirection
Configuration_RoadwayLinkInformation
RoadwayIdentifier
RoadwayLinkIdentifier
BeginMileMarker
EndMileMarker
BeginCrossStreetName
EndCrossStreetName
UpstreamRoadwayLinkIdentifier
DownstreamRoadwayLinkIdentifier
NumberOfLanes
SpeedLimit
VSLSignID
DMSID
RSEID
DirectionOfTravel
Configuration_RoadwayLinkDetectorStation
RoadwayLinkIdentifier
DetectorStationIdentifier
Configuration_DetectorStation
RoadwayLinkIdentifier
DetectorStationIdentifier
DetectorStationName
MileMarkerLocation
NumberOfLanes
NumberOfDetectionZones
Latitude
Longitude
Direction
Configuration_DetectionZone
DetectorStationIdentifier
DetectionZoneIdentifier
DetectionZoneType
LaneNumber
LaneType
LaneDescription
DataType
DetectionZoneStatus
TMEInput_InfrastructureTSSData
Timestamp
DetectionZoneIdentifier
TimeIntervalLength
BeginTime
EndTime
Volume
Occupancy
AvgSpeed
Queued
Congested
DetectionZoneStatus
RoadwayLinkIdentifier
Configuration_RoadwayMileMarkerInfo
RoadwayIdentifier
DirectionOfTravel
MileMarkerNumber
Latitude
Longitude
Configuration_INFLOApps_Thresholds
CVData_PollingFrequency
TSSData_PollingFrequency
ESSData_PollingFrequency
MobileESSData_PollingFrequency
QueueSpeedThreshold
CongestionSpeedThreshold
TMEInput_CVData_Processed
CVMessageIdentifier
RoadwayLinkIdentifier
TME_RoadwayLinkDynamicData
RoadwayLinkIdentifier
TimeStamp
TMELink_Speed
WRTM_Speed
RecommendedTargetSpeed
RecommendedTargetSpeed_Source
CurrentDMSMessage
PrevDMSMessage
CurrentVSLSignSpeed
PrevVSLSignSpeed
Congested
Queued
PreviousRecommendedTargetSpeed
PreviousRecommendedTargetSpeedSource
Configuration_RoadwayLinkESS
RoadwayLinkIdentifier
ESSIdentifier
Configuration_ESS
RoadwayLinkIdentifier
ESSIdentifier
ESSType
ESSOperationType
ESSMobilityType
TMEInput_CVData_Raw
CVMessageIdentifier
NomadicDeviceID
Timestamp
Speed
Heading
Latitude
Longitude
MileMarkerLocation
Queued
RoadwayID
CoefficientOfFriction
Temperature
TMEInput_ESSData_Infrastructure
Timestamp
ESSIdentifier
ESSWindData
ESSVisibilityData
ESSSurfaceStatus
TMEInput_ESSData_Mobile
Timestamp
MobileESSIdentifier
ESSMobileData
TMEOutput_Recommended_Alerts_WRTM
Timestamp
WeatherAlert
Justification
RoadwayIdentifier
BeginMileMarker
EndMileMarker
BeginTime
EndTime
TMEOutput_Recommended_QWARN_QueueInformation
Timestamp
BOQ_MileMarkerLocation
BOQ_RoadwayLinkID
FOQ_MileMarkerLocation
FOQ_RoadwayLinkID
RateOfQueueGrowth
SPeed_In_Queue
TMEOutput_Recommended_Speed_TMELinkSpeed
Timestamp
RecommendedTargetSpeed
Justification
RoadwayLinkIdentifier
TMEOutput_Recommended_Speed_WRTM
Timestamp
RecommendedTargetSpeed
Justification
RoadwayLinkIdentifier
TMEOutput_ShockWaveInformation
Timestamp
RoadwayIdentifier
MileMarkerLocation
SchockwaveSpeed
SchockwaveDirection
TMEOutput_Recommended_QWARN_InfrastructureMessage
Timestamp
QWARNMessage
RoadwayLinkID
TMEOutput_Recommended_SPDHARM__InfrastructureMessage
Timestamp
RecommendedSpeed
RoadwayLinkID
Justification
TMEOutput_Recommended_SPDHARM_CVMessage
Timestamp
RecommendedSpeed
RoadwayLinkID
Justification
TMEOutput_Recommended_QWARN_CVMessage
Timestamp
RoadwayLinkID
RoadwayID
BOQMMLocation
FOQMMLocation
SpeedInQueue
RateOfQueueGrowth

Database

Content: See previous slide(s)

Comments/Changes:

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Data Dictionary (1 of 15)

Data Element	Required	Type	Unit of Measure	Refresh Rate	Standard/ References	Description
Configuration_INFLOApps_Thresholds						
CVDATA_PollingFrequency	Yes	Number-Integer	seconds		TMDD	Frequency of vehicle broadcasting BSM and weather data to TME Cloud
CVDATA_TMECloud_PollingFrequency	Yes	Number-Integer	seconds		TMDD	Frequency of polling connected vehicle data from the TME Cloud
TSSData_PollingFrequency	Yes	Number-Integer	seconds		TMDD	Frequency of polling the infrastructure traffic sensor data
ESSData_PollingFrequency	Yes	Number-Integer	minutes		TMDD	Frequency of polling the infrastructure ESS data
MobileESSData_PollingFrequency	Yes	Number-Integer	minutes		TMDD	Frequency of polling the mobile ESS data
QueueSpreedThreshold	Yes	Number-Integer	miles per hour		TMDD	Speed threshold used to determine if roadway links are queued based on infrastructure traffic sensor data
CongestionSpeedThreshold	Yes	Number-Integer	miles per hour		TMDD	Speed threshold used to determine if a roadway link is congested based on infrastructure traffic sensor data

Data Dictionary (2 of 15)

Data Element	Required	Type	Unit of Measure	Refresh Rate	Standard/ Reference s	Description
Configuration_RoadwayInformation						
RoadwayIdentifier	Yes	Text		Static	TMDD	A unique ID identifying a roadway name with a specific direction. Example, RoadwayID = 1 identifies I-35 North
RoadwayName	Yes	Text		Static	TMDD	Road name
Direction	Yes	Text		Static	TMDD	Direction of travel of roadway
BeginMileMarker	Yes	Number-Double	miles	Static	TMDD	Roadway beginning mile marker (TMDD – roadway-linear-reference) Accuracy of 1/10th of a mile.
EndMileMarker	Yes	Number-Double	miles	Static	TMDD	Roadway ending line marker (TMDD – roadway-linear-reference) Accuracy of 1/10th of a mile.
MMIncreasingDirection	Yes	Text		static	TMDD	Direction of increasing mile marker numbering for the roadway (Example: south/north/east/west)
Configuration_RoadwayLinkInformation						
RoadwayIdentifier	Yes	Text		static	TMDD	Identifier of the roadway the link belongs to
RoadwayLinkIdentifier	Yes	text		static	TMDD	A unique ID identifying a section of roadway
BeginMileMarker	Yes	Number-Double	miles	static	TMDD	Roadway link beginning mile marker
EndMileMarker	Yes	Number-Double	miles	static	TMDD	Roadway link ending mile marker

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Data Dictionary (3 of 15)

Data Element	Required	Type	Unit of Measure	Refresh Rate	Standard/ References	Description
BeginCrossStreetName		Text		static	TMDD	Name of the nearest cross street close to the beginning of the roadway link
EndCrossStreetName		Text		static	TMDD	Name of the nearest cross street close to the end of the roadway link
UpstreamRoadwayLinkIdentifier		Text		static	TMDD	Identifier of the adjacent upstream roadway link
DownstreamRoadwayLinkIdentifier		Text		static	TMDD	Identifier of the adjacent downstream roadway link
NumberOfLanes		Number-Integer			TMDD	Number of lanes in this roadway link
SpeedLimit	Yes	Number-Integer	miles per hour		TMDD	posted speed limit for this section of roadway
VLSSignID		Text		static	TMDD	Identifier of the variable speed limit sign associated with the roadway link
DMSID		Text		static	TMDD	Identifier of the Dynamic Message sign associated with the roadway link
Direction	Yes	Text		static	TMDD	Direction of travel of the roadway link

Data Dictionary (4 of 15)

Data Element	Required	Type	Unit of Measure	Refresh Rate	Standard/ References	Description
Configuration_RoadwayLinkDetectorStation						
RoadwayLinkIdentifier	Yes	Text		static	TMDD	A unique ID identifying a roadway link
DetectorStationIdentifier	Yes	Text		static	TMDD	A unique ID that identifies the location and other information associated with a detector station installed in a roadway link
Configuration_DetectorStation						
DetectorStationIdentifier	Yes	Text		static	TMDD	A unique ID that identifies the location and other information associated with a detector station within an agency's infrastructure devices inventory
DetectorStationName		Text		static	TMDD	Name of closest street or area where the detector station is located
MileMarkerLocation		Number-Double	miles	static	TMDD	Mile marker location of the detector station
NumberOfLanes		Number-Integer			TMDD	Number of lanes monitored by the detector station detection zones
NumberOfDeteectionZones		Number-Integer			TMDD	Number of detection zones installed or defined in the detection device/s that are part of the detector station
Latitude		Number-Double		static	TMDD	Geographical location of the detector station

Data Dictionary (5 of 15)

Data Element	Required	Type	Unit of Measure	Refresh Rate	Standard/ References	Description
Longitude		Number-Double		static	TMDD	Geographical location of the detector station
Direction		Text		static	TMDD	Direction of travel monitored by the detector station detection zones
Configuration_DetectionZone						
DetectorStationIdentifier	Yes	Text		static	TMDD	A unique ID that identifies the location and other information associated with a detector station within an agency's infrastructure devices inventory
DetectionZoneIdentifier	Yes	Text		static	TMDD	A unique ID that identifies a detection zone within a detector station
DetectionZoneType		Text		static	TMDD	Detector technology used type: loop, radar, magnetometers, video, etc.
LaneNumber		Number-Integer		static	TMDD	Number of lane the detection zone is monitoring
LaneType		Text		static	TMDD	Exit/Entrance/Through/Toll/HOT/HOV/Shoulder/etc.
LaneDescription		Text				Includes any additional information about a lane
DataType		Text		static	TMDD	Actual, reconstructed, historical, predicted, smoothed, averaged, estimated
DetectionZoneStatus		Text			TMDD	On, off, out-of-service, unavailable, unknown, marginal, failed

Data Dictionary (6 of 15)

Data Element	Required	Type	Unit of Measure	Refresh Rate	Standard/ References	Description
Configuration_RoadwayLinkESS						
RoadwayLinkIdentifier	Yes	Text		static	TMDD	A unique ID identifying a roadway link
ESSIdentifier	Yes	Text		static	TMDD	A unique identifier that is assigned to an infrastructure ESS or mobile ESS by the operating agency
Configuration_ESS						
ESSIdentifier	Yes	Text		static	TMDD	A unique identifier that is assigned to the ESS by the operating agency
ESSType	Yes	Text		static	TMDD	Atmospheric, wind, temperature, precipitation, visibility, pavement, subsurface, other, unknown
ESSOperationType		Text		static	TMDD	Staffed, automatic, unknown, other
ESSMobilityType	Yes	Text		static	TMDD	Permanent, transportable, mobile, other
Configuration_RoadwayMileMarkerInfo						
RoadwayIdentifier	Yes	Text		static	TMDD	A unique ID identifying a roadway name with a specific direction. Example, RoadwayID = 1 identifies I-35 North
DirectionOfTravel	Yes	Text		static	TMDD	Direction of roadway travel
MileMarkerNumber	Yes	Number-Double	miles	static	TMDD	Linear reference location information
Latitude	Yes	Number-Double		static	TMDD	Geographical location of the mile marker

Data Dictionary (7 of 15)

Data Element	Required	Type	Unit of Measure	Refresh Rate	Standard/ References	Description
Longitude	Yes	Number-Double		static	TMDD	Geographical location of the mile marker
TME_RoadwayLinkDynamicData						
Timestamp	Yes	DateTime			TMDD	Local time zone date and time when the recommendation was generated
RoadwayLinkIdentifier	Yes	Text			TMDD	Identifier of the roadway link the speed applies to
TMELink_Speed		Number-Integer			TMDD	Roadway link local speed recommended by the TMELinkSpeed application
WRTMSpeed		Number-Integer			TMDD	Roadway link local speed recommended by the WRTM application
RecommendedTargetSpeed	Yes	Number-Integer			TMDD	The selected recommended target speed
RecommendedTargetSpeedSource	Yes	Text			TMDD	The application (Q_WARN, SPD-HARM, or WRTM) local speed that was selected for the roadway link
DMSSignMessage		Text			TMDD	Current message displayed on the DMS associated with the roadway link
VLSSignSpeed		Text			TMDD	Current speed displayed on the VLS associated with the roadway link

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Data Dictionary (8 of 15)

Data Element	Required	Type	Unit of Measure	Refresh Rate	Standard/ References	Description
Congested	Yes	Yes/No				Yes if the roadway link local speed is below the Congested speed threshold
Queued	Yes	Yes/No				Yes if the roadway link local speed is below the queued speed threshold
PreviousRecommendedTargetSpeed	Yes	Number-Integer			TMDD	Previous roadway link recommended target speed
PreviousRecommendedTargetSpeedSource	Yes	Text			TMDD	previous roadway link recommended speed source
TMEInput_CVData_Raw						
CVMessageIdentifier	Yes	Number-Integer				An automatic unique number assigned to each message received from connected vehicle by the TME
NomadicDeviceIdentifier		Text				The nomadic device unique identifier. This data element is tracked and used only in the prototype testing for evaluation purposes.
Timestamp	Yes	DateTime			TMDD	The local time zone date and time when the message was generated by the nomadic device
Speed	Yes	Number-Integer			TMDD	Speed of the vehicle when the message was generated
Heading	Yes	Number-Double				Heading of the vehicle when the message was generated

Data Dictionary (9 of 15)

Data Element	Required	Type	Unit of Measure	Refresh Rate	Standard/ References	Description
Latitude	Yes	Number-Double			TMDD	Geographical location of the vehicle when the message was generated
Longitude	Yes	Number-Double			TMDD	Geographical location of the vehicle when the message was generated
MileMarkerLocation	Yes	Number-Double			TMDD	Mile marker location when the message was generated
Queued	Yes	Yes/NO				The queued state (Yes/No) of theehcle when the message was generated
RoadwayIdentifier		Text			TMDD	Identifier of the roadway where the vehicle was traveling when the message was generated
CoefficientOfFriction		Number-Double			TMDD	Coefficient of friction of the pavement where the vehicle was traveling when the message was generated
Temperature		Number-Integer			TMDD	Outside the vehicle temperature when the message was generated

Data Dictionary (10 of 15)

Data Element	Required	Type	Unit of Measure	Refresh Rate	Standard/ References	Description
TMEInput_CVData_Processed						
CVMessageIdentifier	Yes	Number-Integer				An automatic unique number assigned to each message received from connected vehicle by the TME
RoadwayLinkIdentifier	Yes	Text			TMDD	Roadway link where the vehicle was traveling when it generated the message sent to TME
TMEInput_InfrastructureTSSData						
Timestamp	Yes	DateTime			TMDD	Local time zone date and time when traffic data was received from the Infrastructure TSS
DetectionZoneIdentifier	Yes	Text			TMDD	Detection zone unique id
TimeIntervalLength	Yes	Number-Integer	Seconds		TMDD	Length of time interval traffic data was requested for from the TSS
BeginTimestamp		DateTime			TMDD	Beginning date and time of the interval traffic data was requested for from the TSS
EndTimestamp		DateTime			TMDD	Ending Date and time of the interval traffic data was requested for from the TSS
Volume	Yes	Number-Integer	count		TMDD	Detection zone vehicle count during the time interval traffic data was requested for from the TSS
Occupancy	Yes	Number-Double			TMDD	Detection zone occupancy during the time interval traffic data was requested for from the TSS

Data Dictionary (11 of 15)

Data Element	Required	Type	Unit of Measure	Refresh Rate	Standard/ References	Description
AvgSpeed	Yes	Number-Integer	miles per hour		TMDD	Detection zone average speed during the time interval traffic data was requested for from the TSS
Queued	Yes	Yes/No				Queued state of detection zone. Yes if avgspeed during requested time interval falls below the queue speed threshold
Congested	Yes	Yes/No				Congested state of detection zone. Yes if avgspeed during requested time interval falls below the congestion speed threshold
DetectionZoneStatus	Yes	Text			TMDD	On, off, out-of-service, unavailable, unknown, marginal, failed
RoadwayLinkIdentifier	Yes	Text			TMDD	Roadway link the detection zone is associated with
TMEInput_ESSData_Infrastructure						
Timestamp	Yes	DateTime			TMDD	Local time zone date and time when weather data was received from the Infrastructure ESS
ESSIdentifier	Yes	Text			TMDD	Environmental Sensor Station identifier
EssWindData	Yes	Text			NTCIP 1204 Weather Block	The NTCIP 1204 Wind data will be used to generate a wind advisory alert
EssVisibilityData	Yes	Text			NTCIP 1204 Weather Block	The NTCIP 1204 Visibility data will be used to calculate the current visibility

Data Dictionary (12 of 15)

Data Element	Required	Type	Unit of Measure	Refresh Rate	Standard/ References	Description
EssSurfaceStatus	Yes	Text			NTCIP 1204 Pavement Sensor	The 1204 Surface data will be used to calculate a pavement coefficient of friction
TMEInput_ESSData_Mobile						
Timestamp	Yes	DateTime			TMDD	Local time zone date and time when weather data was received from the Mobile ESS
ESSIdentifier	Yes	Text			TMDD	Mobile Environmental Sensor Station identifier
EssMobileData		Number-Double			NTCIP 1204 Mobile Block	The NTCIP 1204 Mobile data block will be used to calculate a pavement coefficient of friction
TMEOutput_Recommendation_Alerts_WRTM						
Timestamp	Yes	DateTime		Minutes	TMDD	Date and time the weather alert was generated
WeatherAlert	Yes	Text		Minutes	IT IS Codes	Weather alert message to send to connected vehicles and infrastructure signs due to severe weather conditions
Justification		Text		Minutes	IT IS Codes	Justification for the weather alert
RoadwayIdentifier	Yes	Text		Minutes	TMDD	Identifier of the roadway affected by the weather alert
BeginMileMarker	Yes	Number-Double	miles	Minutes	TMDD	Beginning mile marker of the roadway links affected by the weather alert

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Data Dictionary (13 of 15)

Data Element	Required	Type	Unit of Measure	Refresh Rate	Standard/ References	Description
EndMileMarker	Yes	Number-Double	miles	Minutes	TMDD	Ending mile marker of the roadway links affected by the weather alert
BeginTime	Yes	DateTime		Minutes	TMDD	The start time when the weather alert will apply for the affected roadway links
EndTime	Yes	DateTime		Minutes	TMDD	The end time when the weather alert will expire for the affected links
TMEOutput_Recommendation_Speed_TMELinkSpeed						
Timestamp	Yes	DateTime		1 Minute	TMDD	Local time zone date and time when the recommendation was generated
RecommendedTargetSpeed	Yes	Number-Integer		1 Minute	TMDD	Recommended safge speed generated by the Q_WARN application for the roadway links that are queued
Justification		Text		1 Minute	TMDD	Justification for the recommended target speed for the affected roadway links
RoadwayLinkIdentifier	Yes	Text		1 Minute	TMDD	Identifier of the roadway with the reduced speed links

Data Dictionary (14 of 15)

Data Element	Required	Type	Unit of Measure	Refresh Rate	Standard/ References	Description
TMEOutput_Recommendation_Speed_WRTM						
Timestamp	Yes	DateTime		1 Minute	TMDD	Local time zone date and time when the recommendation was generated
RecommendedTargetSpeed	Yes	Number-Integer		1 Minute	TMDD	Recommended safe speed generated by the WRTM application for the roadway links affected by severe weather conditions
Justification		Text		1 Minute		Justification for the recommended target speed for the affected roadway links
RoadwayLinkIdentifier	Yes	Text		1 Minute	TMDD	Identifier of the roadway with the reduced speed links
TMEOutput_ShockwaveInformation						
Timestamp	Yes	DateTime		1 Minute	TMDD	Local time zone date and time when the shockwave was detected
RoadwayIdentifier	Yes	Text		1 Minute	TMDD	Identifier of the roadway where the shockwave was detected
MileMarkerLocation	Yes	Number-Double	miles	1 Minute	TMDD	Roadway mile marker location where the shockwave was detected
SchockwaveSpeed	Yes	Number-Integer		1 Minute	TMDD	Speed of the detected shockwave
SchockwaveDirection	Yes	Text		1 Minute	TMDD	Direction the shockwave is moving

Data Dictionary (15 of 15)

Data Element	Required	Type	Unit of Measure	Refresh Rate	Standard/ References	Description
TMEOutput_QWARN_QueueInformation						
Timestamp	Yes	DateTime		1 Minute	TMDD	Local time zone date and time when the queue was detected
BOQ_MileMarker_Location	Yes	Text		1 Minute	TMDD	Back of detected queue mile marker location
BOQ_RoadwayLinkIdentifier	Yes	Number-Integer		1 Minute	TMDD	Identifier of the roadway where the back of detected queue is located
FOQ_MileMarkerLocation	Yes	Text		1 Minute	TMDD	Front of detected queue mile marker location
FOQ_RoadwayLinkIdentifier	Yes	Number-Integer		1 Minute	TMDD	Identifier of the roadway where the front of the detected queue is located
RateOfQueueGrowth		Number-Double		1 Minute		Rate of growth of the queue from one time interval to another. It can positive indicating a growing queue or negative indicating a dissipating queue
SpeedInQueue		Number-Integer		1 Minute	TMDD	The average speed of the vehicles in the queue

Data Dictionary

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Virtual Traffic Management Entity

- The Virtual TME consists of a Microsoft Windows virtual server that will be used to host the TME based INFLO applications and support software. The Virtual TME will also include a database system like Microsoft SQL server database to log the input data acquired by the various INFLO applications, recommendations generated by the INFLO applications, and the system configuration information. Configuration information includes the roadway network configuration, user entered settings, and threshold used by the INFLO applications in making decisions and generating recommendations. The following sections provide a brief description of the major components of the virtual TME. The interfaces used to collect and aggregate input data required by the INFLO applications from connected vehicles and other infrastructure based sensors are described in section 6 under External Interfaces.

Virtual TME

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
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4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

TME Weather Application

- The TME Weather Application is responsible for developing recommended roadway target speeds as well as road weather alerts and warnings based on measured weather conditions. The TME Weather Application will interface with INFLO database to obtain road weather information provided by the infrastructure-based ESSs, mobile ESSs, and connected vehicles. Road weather information will be extracted from the INFLO database every 15 minutes. Forecast weather information will be used to active the TME Weather application

TME Weather Application

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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5	Can this design be improved?		

TME Q-Warn Application

- The TME Q-Warn application is responsible for developing detecting queues in the traffic stream and for generating appropriate queue warning messages. The TME Q-Warn application will interface with the INFLO database to extract both connected vehicle data and infrastructure-based traffic data to determine information about the queue. The application will consist of two processes running in parallel: one process for detecting queues using connected vehicle data and the other for detecting queues using information based traffic data. The TME Q-Warn application will use the queue state data element in both the connected vehicle and infrastructure-based traffic data to determine the links in the network operating in a queue state. The TME Q-Warn application will then produce information about the queue (i.e., the location of the back of the queue, the speed and direction of the queue growth, etc.) by monitoring the links and sublinks defined to be operating in a queued state. The TME Q-Warn application will then forward information about the queue to the TME Message Generator, which will then use the information to generate appropriate queue warning alerts for display on infrastructure-based dynamic message signs and for broadcast to connected vehicles.

TME Q-WARN Application

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

TME Message Generator

- The TME Message Generator application is responsible for producing and formatting speed recommendations and alert message for display on infrastructure-based dynamic message signs and for broadcast to connected vehicles. The TME Message Generators will interface with the TME WRTM, TME Link Speed Arbitrator, and the TME Q-Warn applications to receive road weather alerts, harmonized link speed, and with the queue characteristics information. Using the information from these applications, the TME Message Generator interface with a TMCs DMS control software to format and transmit an appropriate Center-to-Center (C2C) message for displaying alerts and speed recommendation of the TMC’s dynamic message signs. The TME Message Generator will also be responsible for developing and formatting an appropriate J2735 alert message for broadcast to connected vehicle. The TME Message Generator will send the appropriate J2735 message to the connected vehicle cloud for broadcast to connected vehicles.

TME Message Generator

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

TME Link-Speed Arbitrator

- The TME Link-Speed Arbitrator is an application that is responsible for providing "harmonized" link speeds to the TME Message Generator. The TME Link-Speed Arbitrator will receive local link speed recommendations from both the TME_WRTM and the TME Link Speed applications. The TME_WRTM application will produce recommended link speeds appropriate for the prevailing weather conditions in the corridor. The TME Link Speed application produces recommended target speed for detected traffic congestion and queuing situations. The goal/purpose of the TME Link-Speed Arbitrator is to take these speed recommendations and determine which the appropriate speeds for each link on the roadway network. The application will apply user defined priority rules to select the appropriate speeds. Once the recommended link target speeds have been selected, the TME Link-Speed Arbitrator will then group target speeds into troupes and then apply harmonization rules for transitions speeds between recommended troupes. The TME Link-Speed Arbitrator will then pass the harmonized speed recommendation to the TME Message Generator for formatting for displaying on infrastructure-based dynamic message signs and for broadcasting to connected vehicles.

TME Link Speed Arbitrator

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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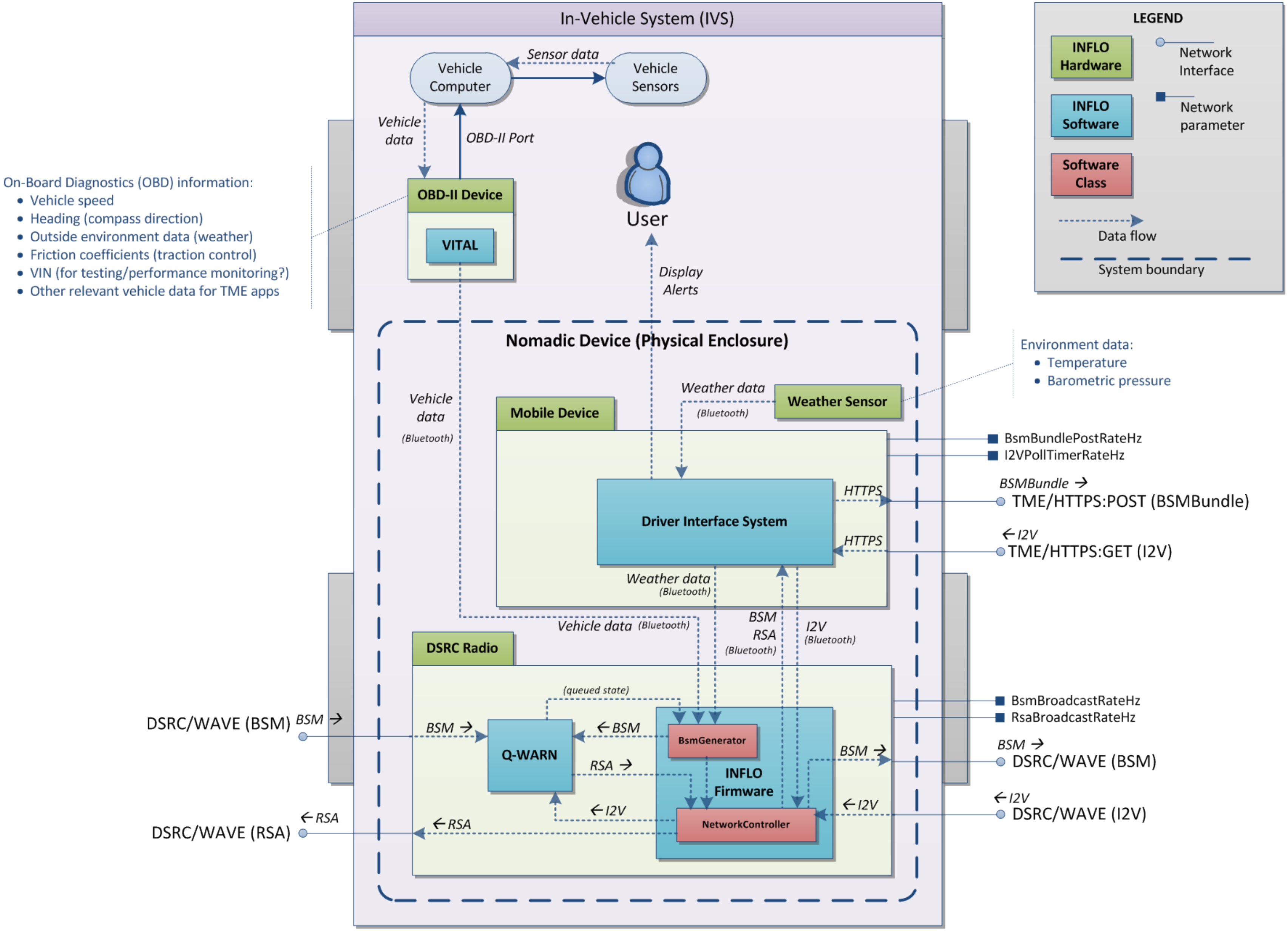
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

Networking/Topology Diagrams

- Following figures show the networking both from the nomadic device perspective, as well as from the infrastructure. These diagrams capture the extent of the messages flows between the various components of the INFLO prototype system.



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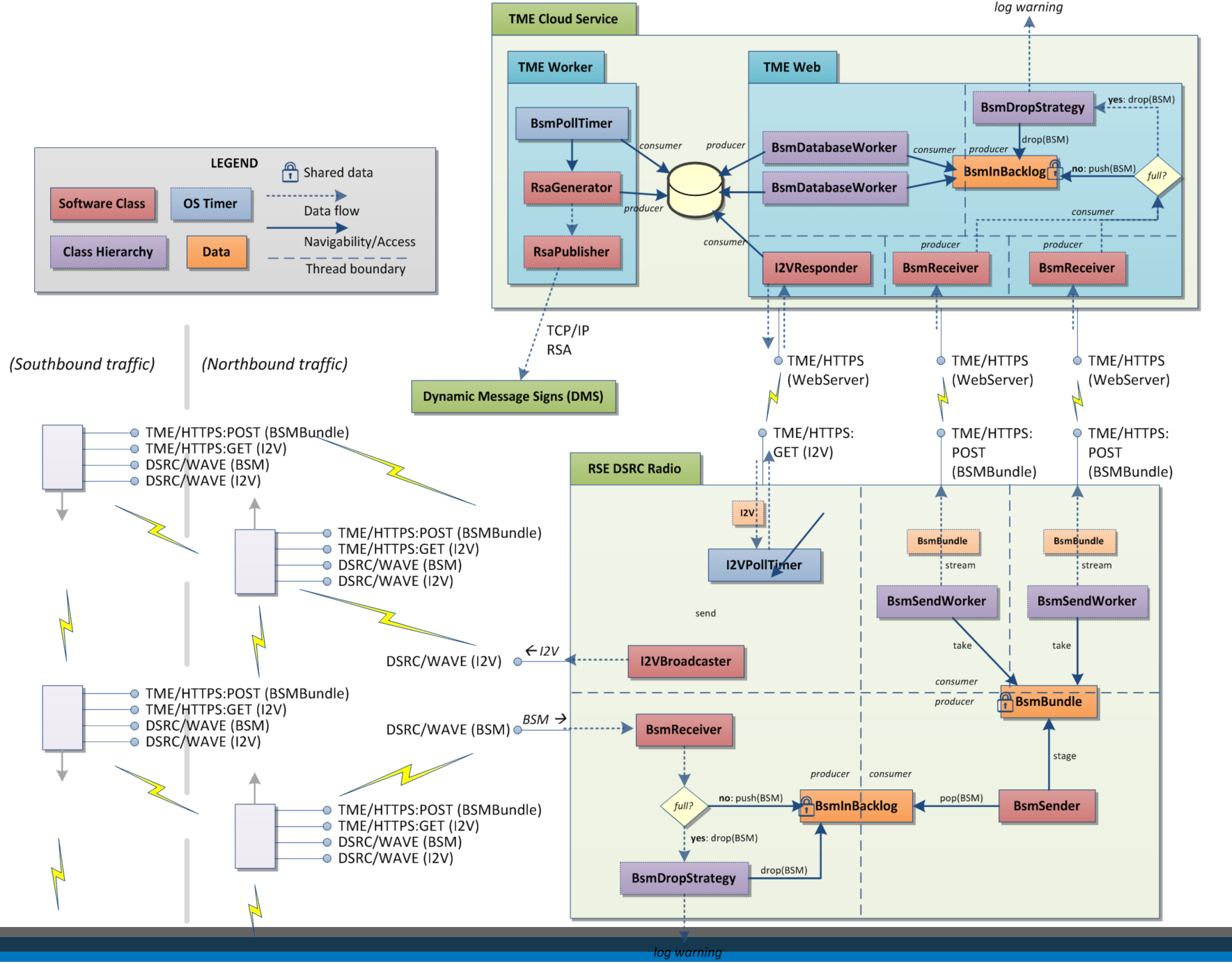
TME Cloud Service
log warning
TME Worker
TME Web
BsmPollTimer
RsaGenerator
RsaPublisher
consumer
producer
BsmDatabaseWorker
BsmDatabaseWorker
BsmDropStrategy
yes: drop(BSM)
drop(BSM)
consumer
producer
BsmInBacklog
no: push(BSM)
full?
consumer
I2VResponder
BsmReceiver
BsmReceiver
LEGEND
Shared data
Software Class
OS Timer
Data flow
Navigability/Access
Class Hierarchy
Data
Thread boundary
TCP/IP
RSA
Dynamic Message Signs (DMS)
(Southbound traffic)
(Northbound traffic)
TME/HTTPS (WebServer)
TME/HTTPS: GET (I2V)
TME/HTTPS: POST (BSMBundle)
TME/HTTPS:POST (BSMBundle)
TME/HTTPS:GET (I2V)
DSRC/WAVE (BSM)
DSRC/WAVE (I2V)
RSE DSRC Radio
I2V
I2VPollTimer
BsmBundle
stream
BsmSendWorker
send
take
I2VBroadcaster
← I2V
DSRC/WAVE (I2V)
DSRC/WAVE (BSM)
BSM →
BsmReceiver
BsmBundle
stage
full?
no: push(BSM)
BsmInBacklog
pop(BSM)
BsmSender
yes: drop(BSM)
BsmDropStrategy
drop(BSM)
log warning

Network Topology Diagrams

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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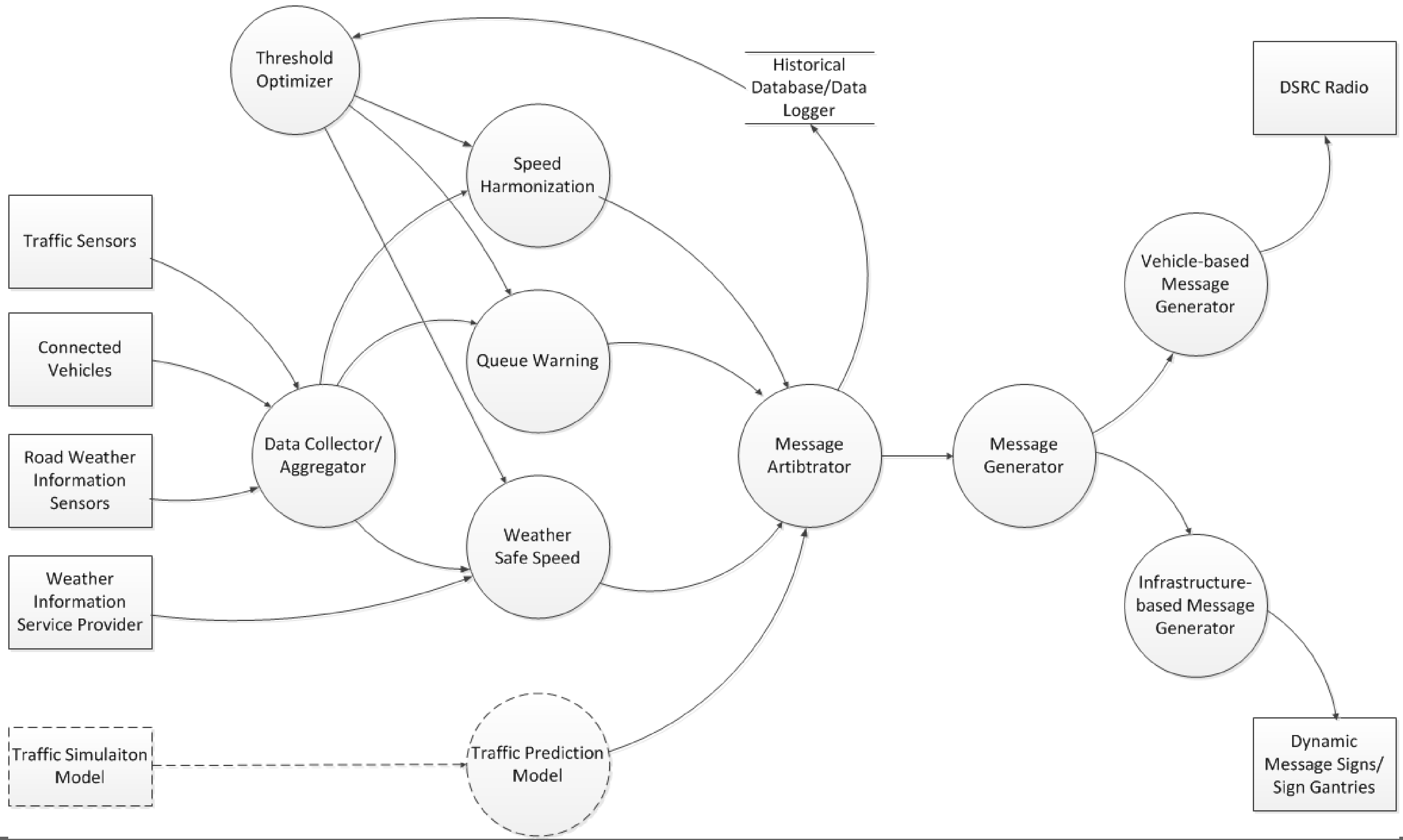
15 Minute Break

ALGORITHM DESIGN REVIEW

Overview of Algorithm Presentation

- TME System Architecture
- Infrastructure Assumptions
- Data Aggregators - Infrastructure, CV, Weather
- Steps for determining Link Speed
- Steps for determining Queue Warn
  - Infrastructure
  - V2V
    - Cloud Based
    - Non-Cloud based
- Steps for determining Speed Harmonization

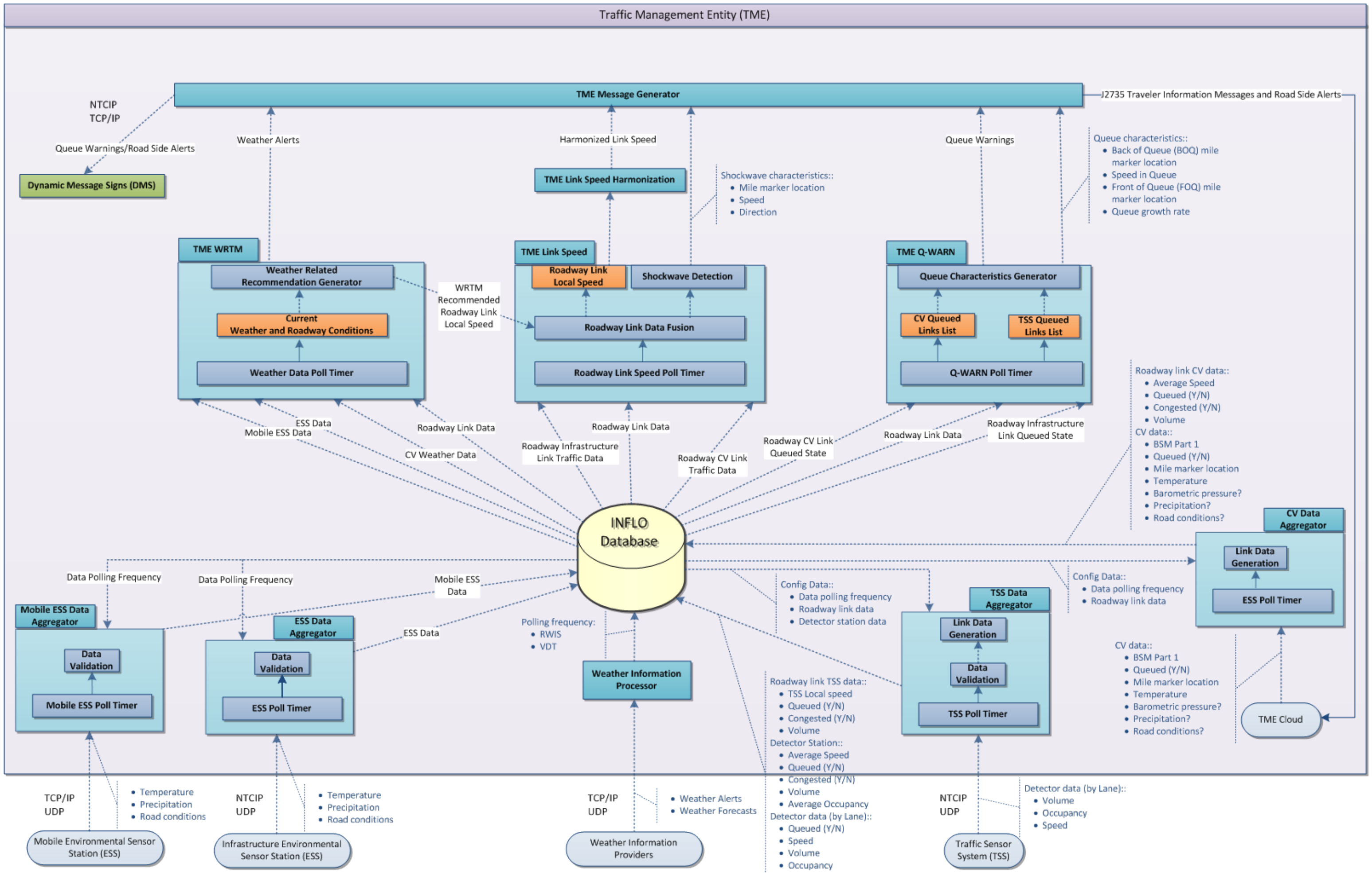
Overview TME-based Processes



Algorithm Design Principles

1. Each algorithm has been designed to function independently and in a modular fashion.
2. The algorithms must function with and without infrastructure and/or connected vehicle information.
3. The information displayed to the driver must be consistent between the infrastructure and CV.
4. Connected vehicles (CVs) can determine vehicle queued state.
5. CVs can determine mile marker location based on mile marker linear reference information.
6. CVs can broadcast BSM, queued state, and mile marker location every second.
7. CVs have a vehicle-based application that can receive Back-of-Queue (BOQ) messages generated from multiple sources and generate warning messages based on the location of vehicle with respect to BOQ.

Virtual TME System Architecture



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DETERMINING QUEUED STATE OF CONNECTED VEHICLE

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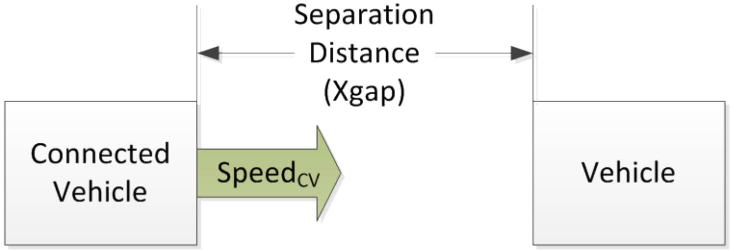
Determine CV Queued State



<u>Connected Vehicle is in Queue State if the following conditions are satisfied:</u>
1) Speed of Connected Vehicle ($Speed_{CV}$)<= Threshold Speed, AND
2) If the Separation Distance (Xgap) <= Threshold Separation Distance

- Determine separation distance to downstream vehicle with same heading
- Determine CV speed
- Determine CV queued state by comparing separation distance and speed to thresholds
- If CV is unable to determine separation distance (downstream vehicle is not a CV and CV has no on-board safety systems), compare CV speed to thresholds to determine queued state
- A queued state indicator can be added to BSM by using one of the unused data elements in BSM Part II message.

Determine CV Queued State

Content: See previous slide(s)

Comments/Changes:

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DATA AGGREGATION PROCESS

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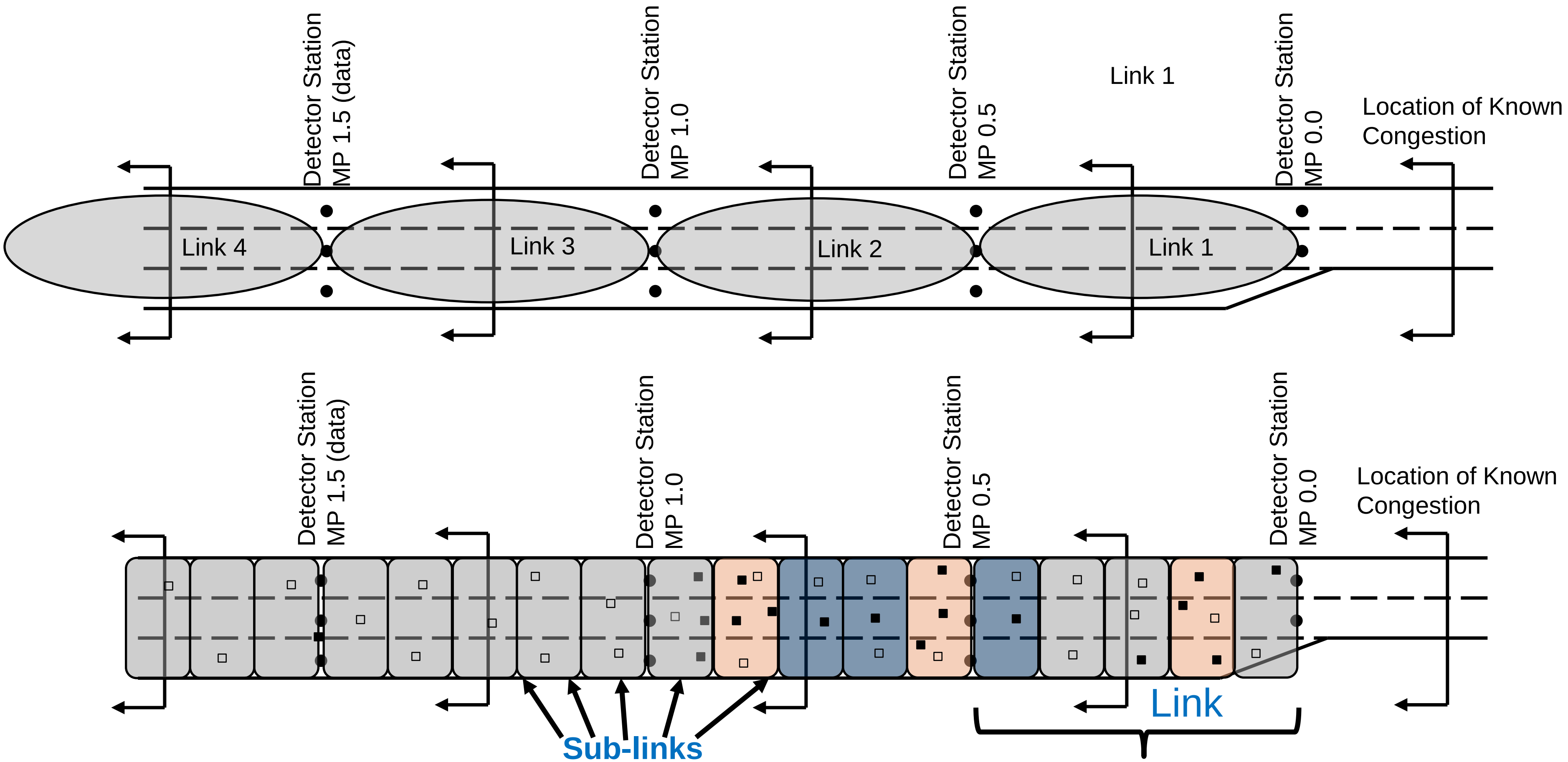
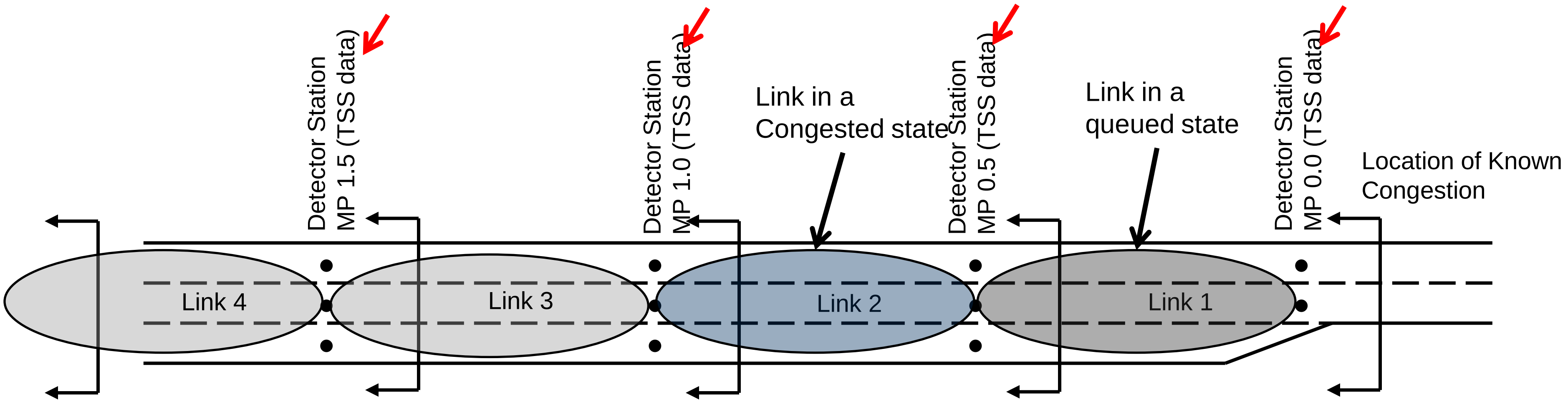
Aggregation of Data

- Purpose:
  - Combine Infrastructure, CV, and Weather data
  - Determine operating state of roadway
    - Queued State → Queue Warning
    - Congested State → Shockwave Detection/Speed harmonization
- Process
  - Get data from Infrastructure, CV and Weather
  - Determine operating state of sub-links
  - Generate average speed for sub-links

Definition of Links and Sub-links



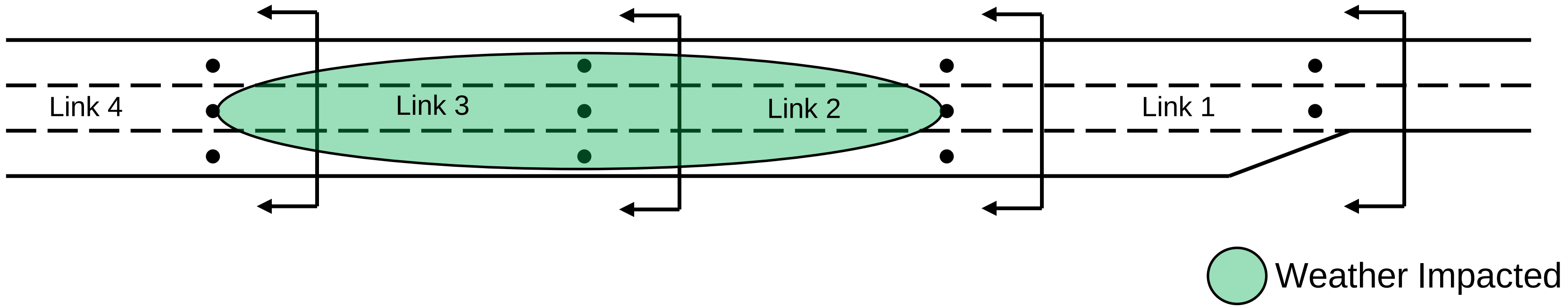
Processing of Infrastructure Data



Step 1. Get TSS Data (Average Speed, Volume, Occupancy)
Step 2. Compare average speeds from links with user thresholds
Step 3. Identify links that are queued and not queued.
Step 4. Identify links that are congested

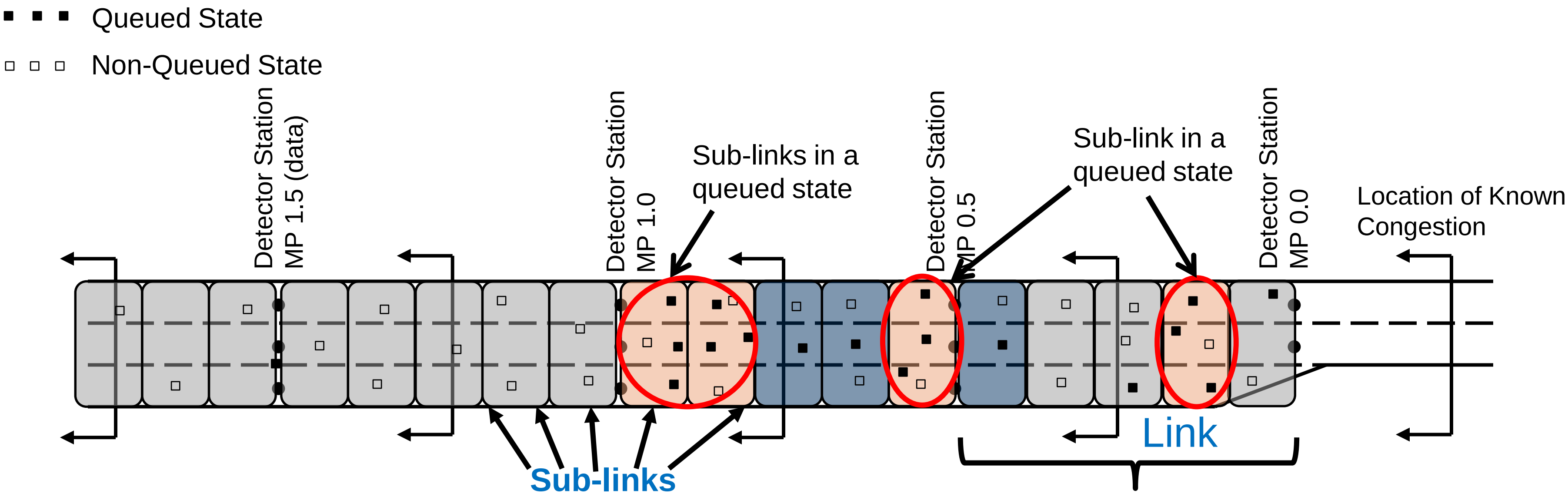
OUTPUT: Queued State (Link) = Y/N
Congested State (Link) = Y/N
Average Link Speed

Processing of Weather Data



- Purpose: Determine recommended link speed based on prevailing weather conditions
- Sources of Weather Data : Environmental Sensor Stations (ESS), Mobile ESS, Connected Vehicle/Nomadic Device, Weather Information Service Providers
- Assumptions:
  - Infrastructure ESS applies to entire corridor
  - Link speed = f(visibility, pavement surface state)
- Two Strategies for determining Link Speed
  - Table Lookup
  - Direct Computation

Processing of CV Data



Step 1. Get connected vehicle data from each vehicle every t seconds (speed, position, queued state)

Step 2. Categorize each vehicle's data for each second in each sub-link

Step 3. If P% of vehicles in a sub-link are in a queued state, then the sub-link is in queued state.

Step 4. Calculate average speed of the all data points in a sub-link (average sub-link speed)

Step 5. Based on user thresholds, identify congested sub-links

OUTPUT: Queued State (Sub-link)
Congested State (Sub-link)
Average Speed (Sub-link)

Data Aggregation Process

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
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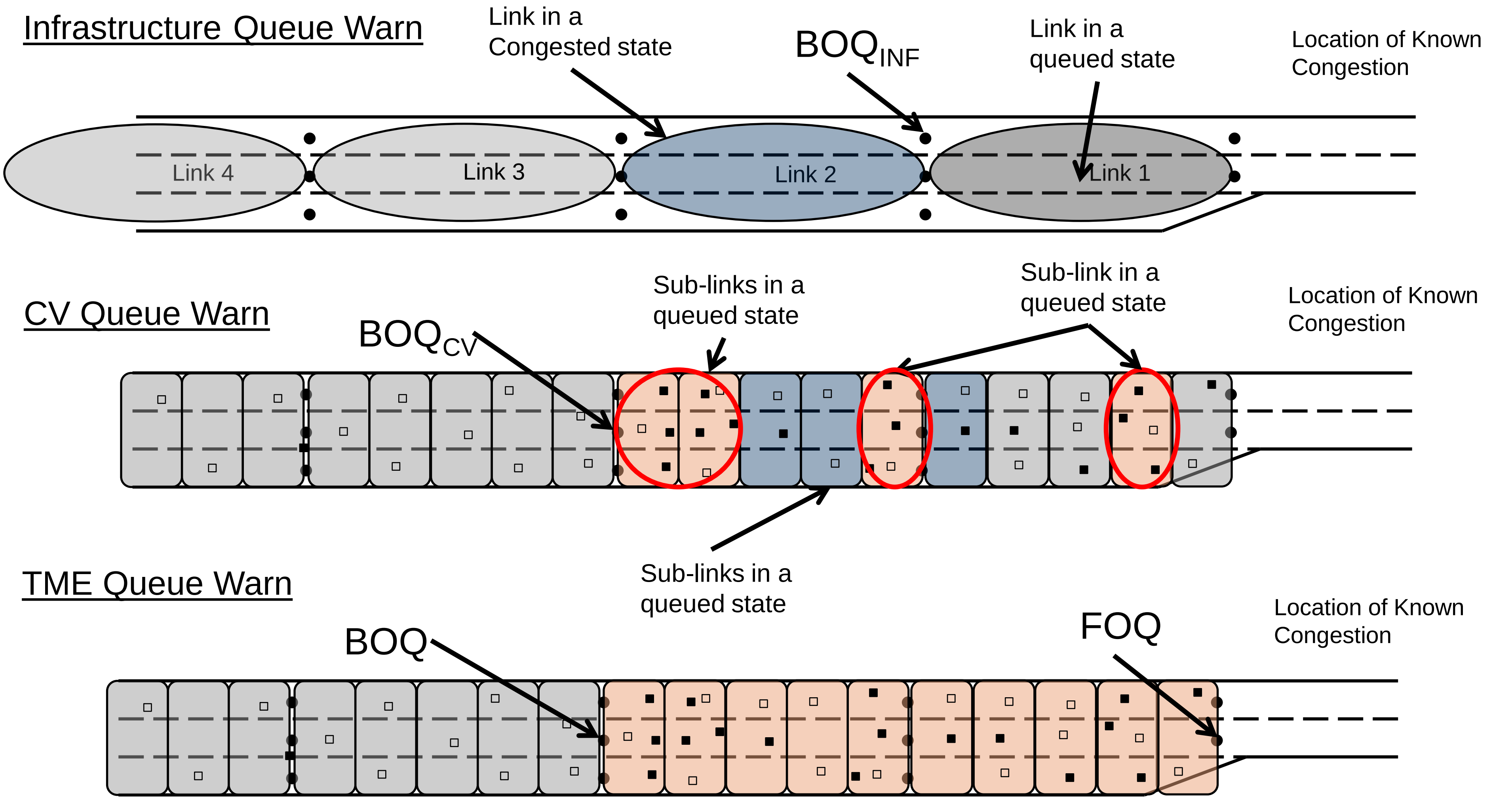
5	Can this design be improved?		

GENERATION OF QUEUE WARNING MESSAGES

TME Queue Warn



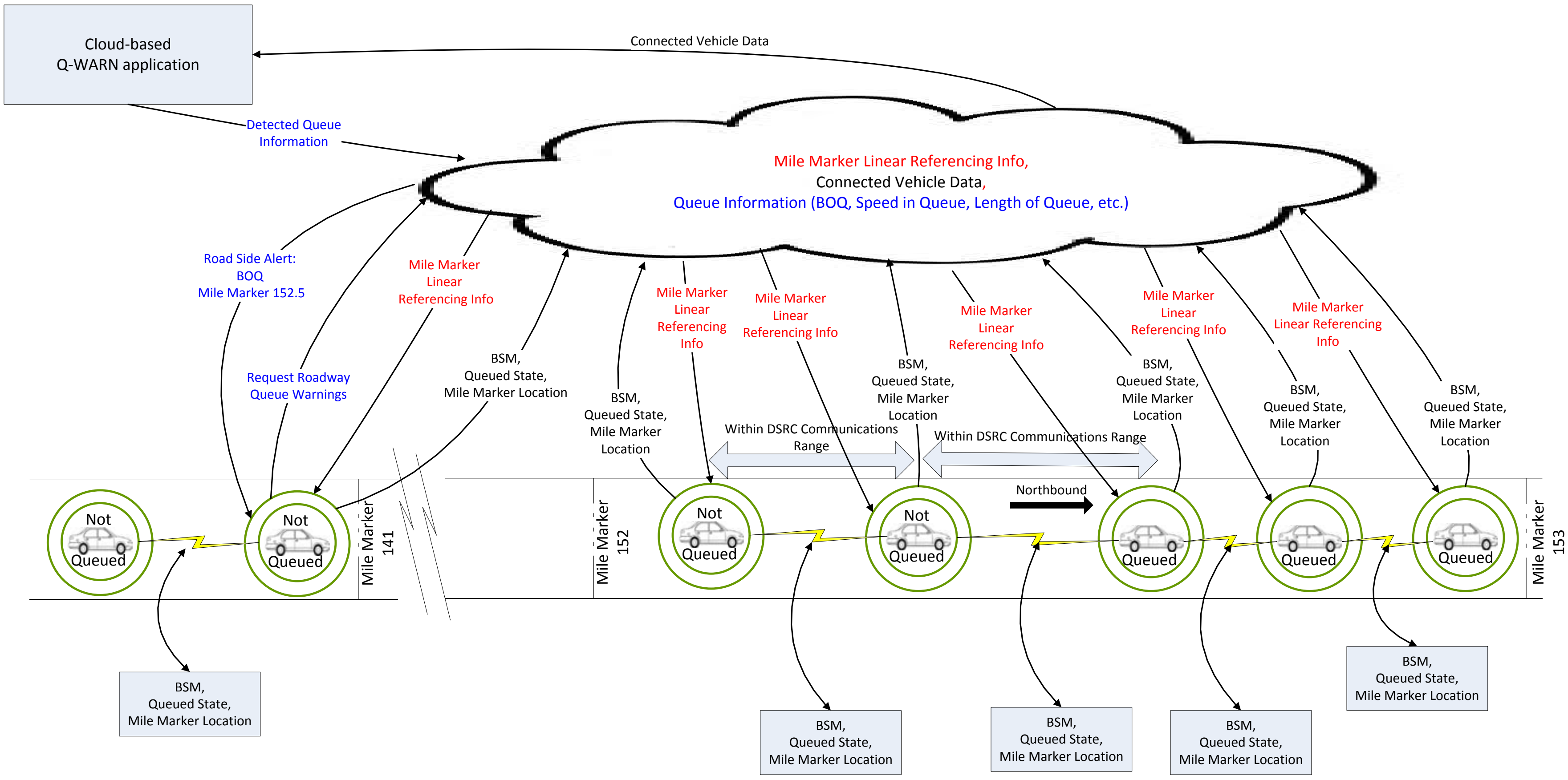
Steps for Determining Queue Warn

- Identify BOQ by comparing BOQ_{INF} and BOQ_{CV}
  - BOQ is the furthest one upstream
- Calculate the speed in queue from average sub-link speeds from FOQ to BOQ
- If BOQ changes for subsequent intervals, calculate rate of change of queue.

Vehicle Based Queue Warn

- Cloud Based Queue Warm System
  - Data transmitted to the cloud using cellular
- V2V Queue Warm System
  - Data transmitted to other vehicles using DSRC
- Data transmitted
  - BSM
  - Queued state of the vehicle
  - Mile marker location of the vehicle

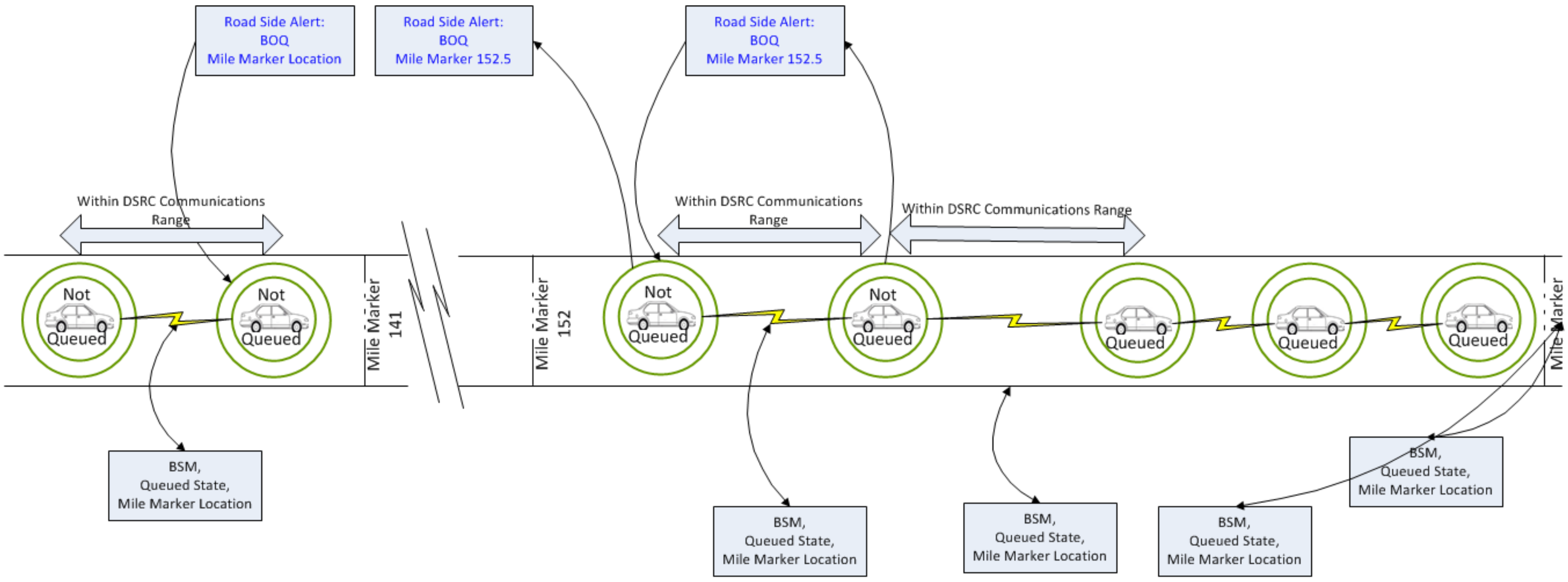
Cloud Based Queue Warn System



Steps in Cloud Based Queue Warn Application

- Retrieve connected vehicle data received during the last t seconds (BSM, queued state, mile marker location)
- Sort the connected vehicles based on their mile marker location into the proper roadway sub-links
- If P% of vehicles in a sub-link are in a queued state, then the sub-link is in queued state
- Determine BOQ, length of queue, speed in queue, rate of growth of queue
- Transmit BOQ message to vehicles in affected roadway link segments

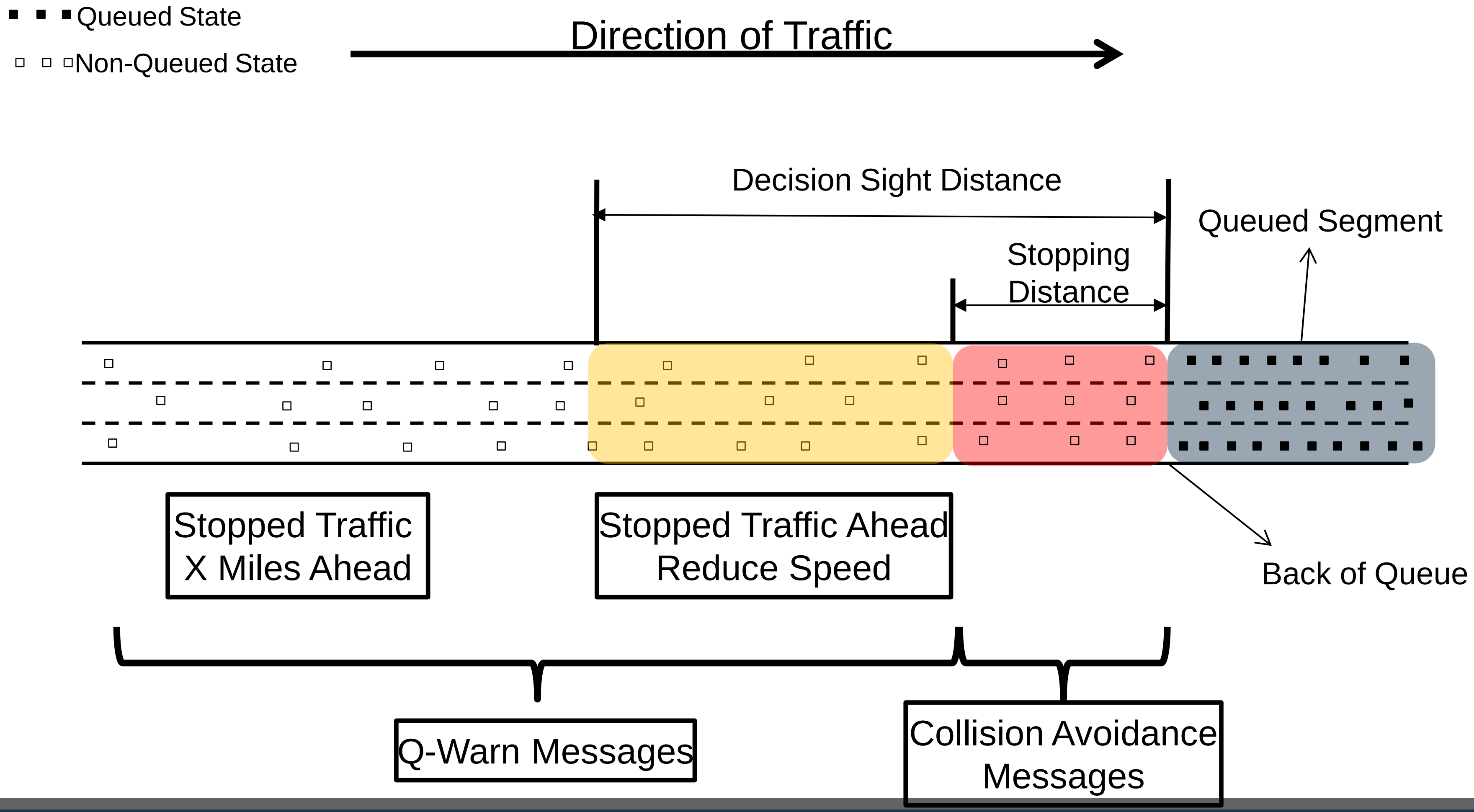
V2V Based Queue Warn System



V2V Based Queue Warn Application

- CV will determine its queued state
- CV will determine its mile marker location
- CV will transmit BSM, queued state, mile marker location to other vehicles
- If CV not in a queued state, determine BOQ ONLY from downstream vehicles
- Broadcast BOQ message
- If BOQ message received, display proper queue warning message to driver
- Upstream vehicles will re-transmit the BOQ message
- Upstream vehicles with distance more than X miles from BOQ can ignore the BOQ message

Displaying Queue Warning Messages



Generation of Q-WARN Messages

Content: See previous slide(s)

Comments/Changes:

		Yes	No/Rank
1	Is the design understandable?		
2	Does the design contain the necessary information?		
3	Does the design convey the necessary information in an appropriate manner?		
4	Does the design convey the necessary information at the appropriate level?		
5	Can this design be improved?		

GENERATION OF RECOMMENDED TRAVEL SPEEDS

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Speed Harmonization Process

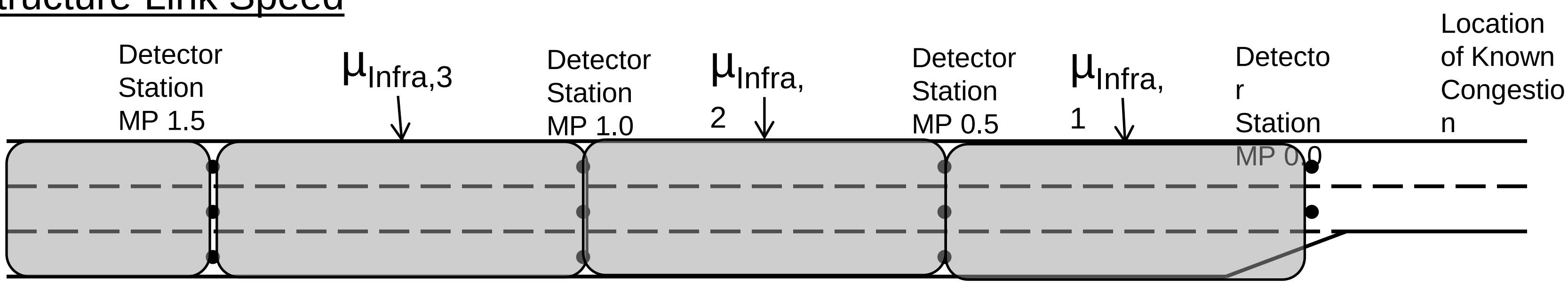
- Purpose: Provide recommend travel speed for broadcast/display to driver
- Process
  - Merging of recommended travel speed from three source: Infrastructure, CV, and Weather
  - Generate troupes of “Like” speeds
  - Generate recommended travel speeds for CV and DMS display

Merging Sub-link Speeds

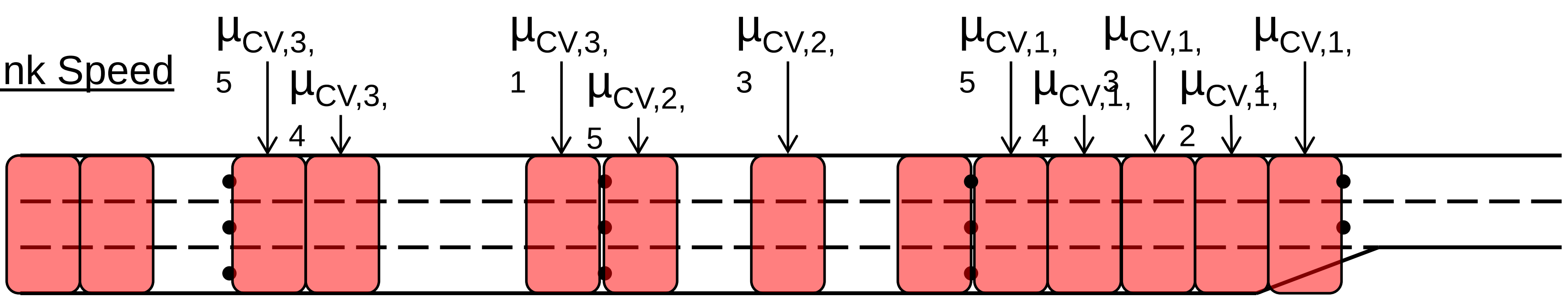
- Get average current speeds
  - Infrastructure link speed for detector station (μ_{Infra}) from database
  - Average CV sub-link speed (μ_{CV}) from database
  - Recommend WRTM link speed (μ_{WRTM})
  - Historical sub-link (μ_{HIST})
- Set Sub-link Speed = $\min\{\mu_{Infra}, \mu_{CV}, \mu_{WRTM}, \mu_{HIST}\}$
- Smooth speeds over time
  - Infrastructure data being updated every 20 seconds (approx.)
  - CV data being updated every 5 seconds (approx.)
  - TME Link Speeds being updated every 5 seconds
  - Rolling average of the previous n intervals (4 – 6)

TME Sub-link Speed

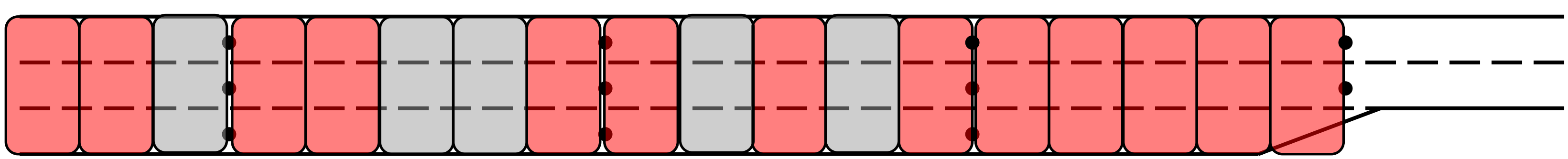
Infrastructure Link Speed



CV Link Speed



TME Sub-link Speed



Trouping of Sub-link Speeds

- Roadway section having common speed characteristics
- Start from the upstream end of the roadway
- Uses Troupe Range to qualify if a downstream sub-link can join a troupe
- Uses the maximum and minimum values of sub-link speeds within a troupe
- Checks the minimum troupe size (uses decision sight distance (DCD) criteria)
- Calculate troupe speed
  - Average and round it up to the nearest 5 mph

Illustration of Trouping Process

Troupe Range = 5 mph (12 mph in Seattle)

Mile Posts	MM 1.1	MM 1.2	MM 1.3	MM 1.4	MM 1.5	MM 1.6	MM 1.7	MM 1.8	MM 1.9	MM 2.0	MM 2.1	MM 2.2
Sub-Link ID	i	j	k	l	m	n	o	p	q	r	s	t
TME Link Speed	65	68	64	63	58	63	59	56	59	53	55	53
Maximum – TR		60	63	63	63	53	58	58	51	54	54	54
Minimum + TR		70	70	69	68	63	63	63	61	61	58	58
Troupe ID	A	A	A	A	B	B	B	C	C	C	C	D
Troupe Speed	65 mph				60 mph			60 mph				

- Sub-link joins a troupe
  - If the TME Link speed is between the maximum troupe speed - Troupe range and the minimum troupe range + Troupe range
  - Length of the sub-link is less than the DCD for the average troupe speed

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Generation of CV-based Recommended Speeds

- Start from the downstream end
- Use the troupe speed for the sub-links in the troupe
- Ensure that increment in speed is not greater than 5 mph between adjacent sub-links
- Ensure that lengths of sub-links having a common speeds is not less than the Decision Sight Distance (DSD) for that speed
- Ensure that speeds in a sub-link is not varied for a time of not less than 15 seconds (DSD time)

Example: CV-Based Recommended Speeds

Direction of travel →

Mileposts	MM 1.1	MM 1.2	MM 1.3	MM 1.4	MM 1.5	MM 1.6	MM 1.7	MM 1.8	MM 1.9	MM 2.0	MM 2.1	MM 2.2	MM 2.3	MM 2.4	MM 2.5	MM 2.6	MM 2.7	MM 2.8	MM 2.9	MM 3.0	MM 3.1	MM 3.2	MM 3.3	MM 3.4	MM 3.5	MM 3.6
TME Link Speed (mph)	66	71	67	69	63	64	67	62	64	63	58	56	54	57	53	44	44	46	42	39	40	36	31	33	32	30
Sub-link ID	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z	a1	b1	c1	d1	e1	f1	g1	h1
Max - Troupe Range		61	66	66	66	58	59	62	62	62	62	53	53	53	53	53	39	39	41	37	37	37	31	31	31	31
Troupe ID	A	A	A	A	B	B	B	B	B	B	C	C	C	C	C	D	D	D	E	E	E	F	F	F	F	F
Min + Troupe Range		71	71	71	71	68	68	68	67	67	67	63	61	59	59	58	49	49	49	47	44	44	41	36	36	36
Troupe Speed (mph)	70				65						60					45			45			35				
Troupe Range =	5	mph																								
CV Recommended Speed	70	70	70	65	65	65	60	60	60	55	55	55	50	50	50	45	45	45	45	45	45	40	40	40	40	40

Generating Infrastructure-Based Recommended Speeds

- If gantries are present
  - Start from the downstream end
  - Gantries should display the speed that is consistent with the CV recommended speeds
    - The CV Recommended speeds should match the gantry recommended speeds for at least the DCD after the gantry
    - If not, adjust the CV Recommended Speeds to adjust to the location of the gantries
  - Do not change the display for at least 15 seconds

Example: Infrastructure-Based Recommended Speeds

Direction of travel →

Mileposts	MM 1.1	MM 1.2	MM 1.3	MM 1.4	MM 1.5	MM 1.6	MM 1.7	MM 1.8	MM 1.9	MM 2.0	MM 2.1	MM 2.2	MM 2.3	MM 2.4	MM 2.5	MM 2.6	MM 2.7	MM 2.8	MM 2.9	MM 3.0	MM 3.1	MM 3.2	MM 3.3	MM 3.4	MM 3.5	MM 3.6
TME Link Speed (mph)	66	71	67	69	63	64	67	62	64	63	58	56	54	57	53	44	44	46	42	39	40	36	31	33	32	30
Sub-link ID	i	j	k	l	m	n	o	p	q	r	s	t	u	v	w	x	y	z	a1	b1	c1	d1	e1	f1	g1	h1
Max - Troupe Range		61	66	66	66	58	59	62	62	62	62	53	53	53	53	53	39	39	41	37	37	37	31	31	31	31
Troupe ID	A	A	A	A	B	B	B	B	B	B	C	C	C	C	C	D	D	D	E	E	E	F	F	F	F	F
Min + Troupe Range		71	71	71	71	68	68	68	67	67	67	63	61	59	59	58	49	49	49	47	44	44	41	36	36	36
Troupe Speed (mph)	70				65						60					45			45			35				
Troupe Range =	5	mph																								
CV Recommended Speed	70	70	70	65	65	60	60	60	60	55	55	55	50	50	50	45	45	45	45	45	45	40	40	40	40	40
Infrastructure Recommended Speeds					Gantry 4	60 mph						Gantry 3	50 mph				Gantry 2	45 mph					Gantry 1	40 mph		

Generation of Recommended Travel Speeds

Content: See previous slide(s)

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WRAP-UP

Comment Matrix

#	Author	Category	Priority	Reference	Anomaly Description	Action Item	Assignee
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Next Steps

Additional Comments / Inputs

- Please provide any final comments to USDOT and Battelle by COB Friday, December 27th
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  - timchot@battelle.org