



Module 19: On-Board Transit Management Systems

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1. Module Description

On-board Transit Management for buses covers technologies and systems that are located within transit vehicles that facilitate and automate operations, management, maintenance, safety and security functions of public transit systems. While there are currently few standards that govern receiving and transmitting the data and information generated by these systems, the use of the existing relevant Society of Automotive Engineers (SAE) standards facilitate the systems' operations and maintenance. An on-board system can include a vehicle area network (VAN), mobile data terminal (MDT), vehicle logic unit (VLU) (sometimes combined with an MDT), equipment for supervisor/support vehicles (e.g., ruggedized laptop), an Automated Vehicle Announcement (AVA) System (covered in Modules 6 and 7), an Automatic Passenger Counter (APC) System (covered in Modules 2 and 5), an Event Data Recorder System (EDRS) and Vehicle Component Monitoring (VCM) (covered in Modules 2 and 5), and On-board Video Surveillance System (covered in Modules 2 and 5).

Module 2 – Transit Management Standards, Part 1 of 2 and Module 5 – Transit Management Standards, Part 2 of 2 can be found respectively at

<https://www.pcb.its.dot.gov/StandardsTraining/Modules.aspx?Year1Transit=1&ModuleID=57#mod57> and

<https://www.pcb.its.dot.gov/StandardsTraining/Modules.aspx?Year1Transit=1&ModuleID=60#mod60>.

2. Introduction/Purpose

The purpose of Module 19 is to provide details of on-board hardware and software standards (in addition to Transit Communications Interface Profiles (TCIP) covered in Module 3 and Module 4). Examples will demonstrate how to procure systems that use these standards.

The information provided in this module will help participants further understand those standards that support On-board Transit Management functions for buses, specifically SAE J1587, J1708 and J1939 profiles, and how to procure systems using these standards. Topics covered in this module includes single point logon/logoff, data upload/download from an on-board device, and the use of an interface control document (ICD) (An ICD is the formal means of establishing, defining, and controlling interfaces and for documenting detailed interface design definitions. See Section 6 for the full definition of an ICD).

3. Samples/Examples

3.1. C2V Flows: Chattanooga Area Regional Transportation Authority (CARTA)

Beginning in 2006, CARTA required the inclusion of a multiplex system on all buses purchased. This system connected to the SAE J1939 data bus; monitored common engine, transmission, and braking faults transmitted on the data bus (e.g., high engine oil temperature, low oil pressure, high transmission oil temperature); and logged the data for later retrieval. The main purpose of this system was for integration with other planned in-vehicle equipment to eventually provide CARTA with a full remote diagnostics maintenance system. The system is now operational. In 2009, CARTA



implemented the daily upload via wireless local area networks (WLAN) of bus diagnostic information collected on-board to the Automatic Vehicle Monitoring (AVM) server, making these data available to maintenance staff. Prior to this, CARTA deployed on-board components for an AVM system on fixed route vehicles, including WLAN communications at both vehicle storage facilities to enable bulk data transfer with vehicles.

The 2009 rollout of the AVM system provided another example of CARTA's commitment to testing. The core infrastructure needed to support AVM – the on-board equipment, the WLAN for daily data uploads, and the AVM software – was in place early in 2008. However, it had been decided to focus 2008 ITS resources on implementing systems that would deliver the most direct and visible benefits most directly and visibly to riders, such as the next-stop announcements and the next-arrival-time predictions. After these systems came online in December 2008, CARTA shifted focus to rolling out AVM. By January 2009, the AVM system elements were integrated and the AVM system was receiving daily uploads of data from the buses. CARTA then conducted internal testing of the AVM system to confirm it was operating correctly before releasing it for use by the mechanics in March 2009.

CARTA included the requirements for the AVM system in the request for proposals (RFP) for their CAD/AVL system. In developing these specifications, they reviewed and selected the most appropriate standards that could facilitate the implementation of AVM. In their review, they assessed standards availability, applicability to their needs, maturity of the standards, and the vendors' use, experience, and acceptance of the standards. This led them to specify the use of either SAE J1708 or J1939 to facilitate the implementation of the AVM system.

After making this selection, they incorporated the requirement of SAE J1708 or J1939 into the specification in several places, as follows:

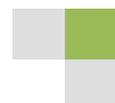
- Forming a vehicle area network (VAN) connecting the on-board mobile data terminal (MDT) with several other on-board devices (e.g., headsign):

The on-board Vehicle Area Network (VAN) shall support the functional capabilities of the interconnected equipment, as identified in the specifications, and conform to one of the following standards: (1) SAE J-1708/1587; (2) SAE J-1939; (3) IEEE 802.3 (i.e., Ethernet); or (4) IEEE 802.11g (i.e., Wi-Fi).

The supported Message IDs (MID) and Parameter IDs (PID), available for communications with future on-board devices using the J-1708/1587 interface, shall be fully documented (or equivalent information for a J-1939 interface).

The MDTs shall allow a single logon for all onboard equipment integrated over the VAN, including exterior variable signs, APCs, AAS and farebox.

The MDTs shall provide a single logon, as well as automatic updates for changes in route, run, block, trip, destination, and schedule direction, to all components integrated through the MDT via the VAN.



Each MDT shall be integrated with the mobile data communications equipment, including the maintenance of a Virtual Local Area Network (VLAN) over the mobile data communications system with the central systems.

The MDTs shall use the VAN to provide information to, and receive information from, other on-board equipment, including the automated annunciation/signage system, APC system, external variable signs, farebox and the vehicle maintenance controller.

The MDTs shall be integrated with the fixed voice radios, handset and speakers on fixed route and flexible route vehicles so as to allow the MDT to control when the operator can use the radio to send and receive.

All new vehicles currently being ordered by CARTA, including the last 10 fixed route vehicles ordered, have I/O Controls multiplex systems. The remaining fleet vehicles have standard OEM wiring harnesses, and onboard device monitoring shall support the communications protocols of the installed equipment. The devices to be monitored on a given vehicle could involve a mix of monitoring J1708/1587 or J1939 communications and monitoring discrete interfaces. Any additional details will be discussed during the design review process.

- Integrating the automatic passenger counting (APC) controller with the on-board MDT

The APC controller shall be integrated with the on-board MDT, using the VAN.

The APC sensors may alternatively be each connected directly to the VAN, to enable communications with the MDT without any intermediate APC controller.

- Integrating the on-board MDT with interior DMS

The AAS controller shall be integrated with the on-board MDT, using the VAN.

- Integrating the on-board MDT with the VAN to provide Vehicle Component Monitoring (VCM) (collecting codes from Engine Control Module, Transmission Control Module, and Automatic Braking System)

The MDT shall provide the on-vehicle features of Automatic Vehicle Monitoring.

The system shall collect transmitted fault and operational performance data from sub-systems on-board the vehicle via the J1708, J1939 and multiplex networks, simultaneously.

The MDT shall send and receive messages from all sub-systems actively communicating and connected to the J1708/CAN networks that conform to the SAE J1587/J1939 data definitions.

Multiplex systems shall be monitored via J1708/J1939 and/or RS232/485. It is the responsibility of CARTA to ensure that the vehicles are equipped with all necessary gateways configured to externalize data in a manner compatible with the MDT.



3.2. Capital District Transportation Authority (CDTA) Single-point Logon – Albany, NY

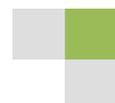
The Capital District Transportation Authority (CDTA) is New York State's Capital Region mobility company with an annual ridership of 17.2 million. CDTA provides express, park & ride, local, and paratransit services. CDTA operates 280 buses from three facilities and owns and operates rail stations in Saratoga Springs and Rensselaer. CDTA serves 55,000 customers on a typical weekday. Buses travel 25,000 miles each day along 50 individual routes.

CDTA is conducting a solicitation (beginning in April 2016) that is part of a larger initiative to upgrade CDTA's Computer Aided Dispatch/Automatic Vehicle Location (CAD/AVL) and radio communication system, and related Advanced Public Transportation Systems (APTS). These dated technologies will be replaced with current, state of the art Intelligent Transportation Systems (ITS) that more closely align themselves with the goals of CDTA. The objective of this project is to use a new and functional system to improve transit customer service, safety, reliability, and efficiency.

CDTA, like NTD, began their procurement by, in part, identifying system integration needs. Out of their 20 base system (high-level) requirements, they identified the following:

- Provide a fully integrated vehicle area network infrastructure to support integrated subsystems including passenger Wi-Fi, ITMS mobile equipment diagnostics, single sign on, monitoring, and diagnostic reporting.
- Integrate mobile data terminals with existing ITS systems including: SPX-Genfare FastFare™ Fareboxes, Twin Vision head signs, March Networks mobile digital video recorders, odometers, and GTT Opticom™ traffic signal priority emitters, among others.
- Provide an integrated automatic passenger counting (APC) system to count boarding and alighting events.
- Provide automated vehicle announcement audio/video displays on-board each revenue service vehicle to inform passengers about upcoming stops, major intersections, and landmarks.
- Implement Traffic Signal Priority (TSP) to be used in coordination with passenger load, schedule adherence, and route specific eligibility requirement information along premium service lines.
- Provide on-board passenger Wi-Fi functionality.
- Provide automated vehicle component monitoring of critical system components.

Out of 3 future system capabilities, one deals with on-board integration. The successful vendor/systems integrator shall partner with SPXGenfare to integrate open payments through CDTA's new FastFare® electronic Fareboxes via the Contractor's ITMS on-board mobile gateway router. The purpose of this interface is to provide customers with on-board payment card transactions in real time.



A slide in this module shows the systems to be integrated with the vehicle logic unit (VLU) using J1708/J1587. Also, this integration shall result in single-point logon, as mentioned in this module.

In April 2016, CDTA issued a Request for Proposals (RFP) for an Intelligent Transportation Management System (ITMS). In the specifications for the ITMS, there is a requirement to integrate the vehicle logic unit (VLU) through a bidirectional interface with CDTA's new FastFare™ electronic Fareboxes provided by SPX-Genfare (and Twin Vision head signs) to eliminate the need for multiple driver log-on processes. The language in the specification addressing this requirement is as follows:

“4.2.11.2.1 Farebox Integration

The ITSM shall support a bidirectional interface between the SPX-Genfare FastFare™ Farebox and the Contractor's MDT/VLU with a single point logon on all revenue service vehicles. The SPX-Genfare Farebox shall interface with the MDT and/or the VLU over J1708/1587 network to enable single point logon for the vehicle operator. The single point logon shall negate the need for operators to logon on to the MDT.

The existing SPX-Genfare Farebox login is automated through the use of the smart card reader on the SPX-Genfare FastFare®® Farebox. At minimum, this login includes the time, date, driver identification number, route, run, trip and/or pattern, real-time vehicle location, and vehicle number, which shall be interface transferred to the MDT/VLU through a bidirectional interface. If a change to the driver identification number, route, run, trip, and/or pattern is made either by the driver or remotely by dispatch through the MDT, this same information will update the SPXGenfare Farebox logon. Conversely, the Farebox shall update the MDT data when the operator makes a change.

The operator shall continue to be able to use all Farebox operator control unit (OCU) features, regardless of whether or not the operator has logged into a run using the MDT or whether the MDT is operational.

Upon request from the Farebox, the MDT shall send the current location. The MDT shall automatically provide to the Farebox the segmentation data for the beginning of each trip. The Farebox shall request at least once each day from the MDT the current date/time, and reset its internal clock when needed to synchronize with the MDT.

The MDT shall be able to send Farebox alarms data through to the central system. The Contractor shall provide the design specifications and demonstrate the Farebox integration for CDTA review at the Preliminary Design Review and approval at the Final Design Review.

4.2.11.2.2 Head Sign Integration

Through a bidirectional interface, the MDT software shall provide the time, date, driver identification number, route, run, trip and/or pattern, and vehicle number, along with the ability to control the destination text to be displayed on CDTA's existing head signs on all revenue Capital District Transportation Authority Intelligent Transportation Management System service vehicles. The VLU/MDT shall also automatically adjust the electronic



destination (head) signs based on GPS location. At a CDTA configurable distance before the start of each trip, the MDT shall change the head sign message to display a message that can be configured by CDTA. The head signs shall send to the MDT any hardware or software alarm codes for the head signs. These alarms will be sent to the ITMS CDS via the MDT.

The VLU shall interface with the electronic destination (head) signs provided by Twin Vision signs provided by Luminator Technology Group. Programming must include any route interlining that may accompany a vehicle route or block number with no additional driver or operator involvement. Additional electronic destination (head) sign programming shall be available to accommodate the display of the route name, route number, end terminal or end destination, and other messages, which may rotate through the head sign display based on programmable measures configurable by CDTA authorized staff. At minimum, the integration will allow for the head sign display, to show (left-justified) the route number followed by route name.

When the vehicle is logged into a run using the MDT but operating on a deadhead run from the garage to the first trip of the run, the MDT shall automatically command the head sign to display a message that can be configured by CDTA. This message could be "OUTBOUND", "INBOUND", "OUT OF SERVICE", "FROM GARAGE" or the message that will be displayed during the first trip.

When the vehicle is logged into a run using the MDT, but operating on deadhead to the garage from the final trip of the run, the MDT shall automatically command the head sign to display a message that can be configured by CDTA. This message could be "OUT OF SERVICE", "TO GARAGE" or the message that will be displayed during the final trip.

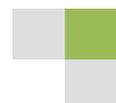
When the vehicle is logged into a run using the MDT, but operating on deadhead for interlining between trips in the course of a run, the MDT shall automatically command the head sign to display a message that can be configured by CDTA. This message could be "OUT OF SERVICE" or the message displayed during either the previous or upcoming trip.

When the vehicle is logged into a "special" run using the MDT, the MDT shall automatically command the head sign to display a message that can be configured by CDTA for that run (e.g., "OUT OF SERVICE", "IN TRAINING").

When the vehicle is logged into any run using the MDT, the vehicle operator shall be able to manually command the head sign to display one of a set of preconfigured messages that can be configured by CDTA (e.g., "OUT OF SERVICE", "IN TRAINING").

When the vehicle is in covert alarm mode, the MDT shall automatically command the head sign to display one of a set of preconfigured messages that can be configured by CDTA (e.g., "CALL POLICE" or "CALL 911-EMERGENCY").

All messages shall be adjustable manually by the operator without shutting down the vehicle to reset or refresh the system.



The head sign shall request at least once each day from the MDT the current date/time, and reset its internal clock when needed to synchronize with the MDT.

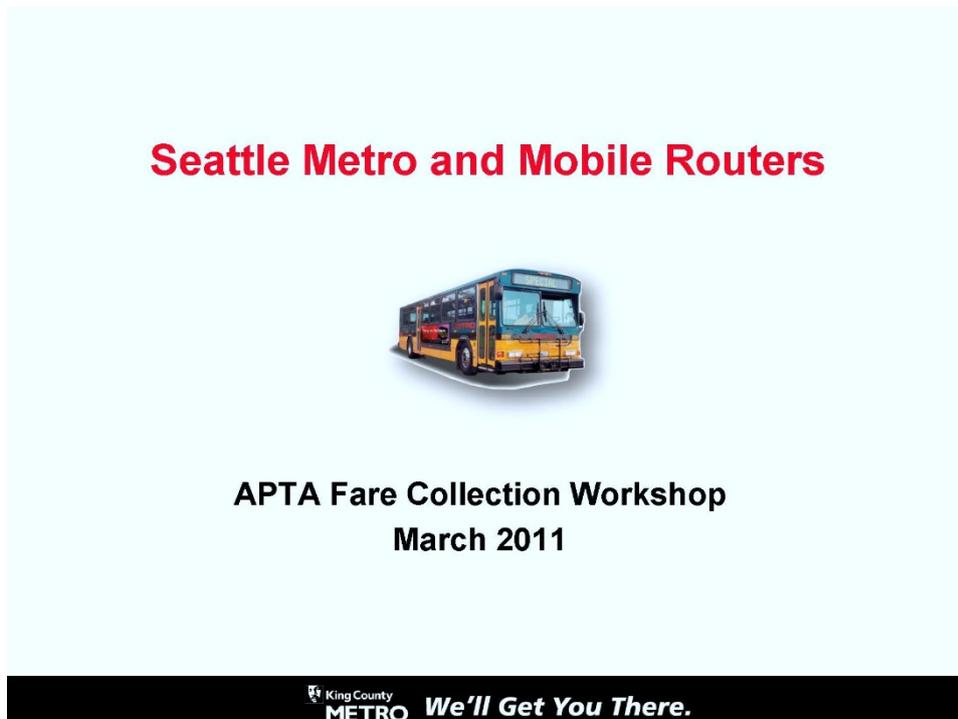
The Contractor shall confirm if any upgrades to the head sign or head sign controller firmware are needed to implement this interface.

The vehicle operator shall continue to be able to use all features of the existing head sign controller, regardless of whether or not the vehicle operator has logged into a run using the MDT or whether the MDT is operational.

The Contractor shall provide the design specifications and demonstrate the head sign integration for CDTA review at the Preliminary Design Review and approval at the Final Design Review.”¹

3.3. King County Single-point Logon

Information regarding King County Metro’s single-point logon is as follows.



¹ Capital District Transportation Authority (CDTA), Request for Proposals (RFP), Proposal Title: Intelligent Transportation Management System (ITMS), Proposal Number: CDTA IT-57-1000, <https://www.cdfa.org/procurements/intelligent-transportation-management-system-itms>, pages 4-107 through 4-109.



Presentation Overview



- ORCA fare collection system
- On-board systems project
- On-board integration
- Role of the mobile router

ORCA Fare Collection System



- 7 Agencies
- Regional fare products
- Ferry, bus, light rail, commuter rail
- 255,000 Average weekday ORCA boardings



Status



- Contract with ERG signed April 2003
- Public launch April 2009
- Full system acceptance April 2011
- 10-year Operating contract

On-Board Systems (OBS) Project



- INIT
- Smart bus concept
- GPS/odometer/gyroscope solution
- Stop announcements
- Next stop electronic displays
- Destination sign integration
- Automatic passenger counting
- Vehicle monitoring
- Installs in progress



Business Need for Integration



- Single logon for operators
- Automatic fare zone changes
- Space and power constraints
- Maintenance requirements
- Network infrastructure support
- Multiple hardware and software vendors
- Phased implementation

Evolution



- OBS should have come first but...
- ORCA became the integration platform
 - Driver Display Unit (DDU)
 - Wireless bridge (Cisco 1310)
- Regional requirements and agency-specific requirements
- Migrating to mobile router (MAR)

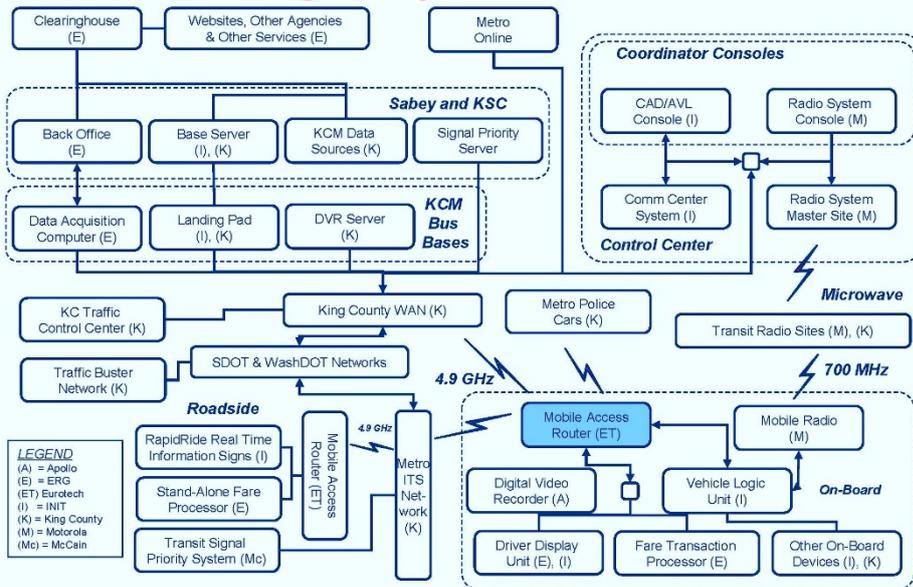


Driver Display Unit (DDU)

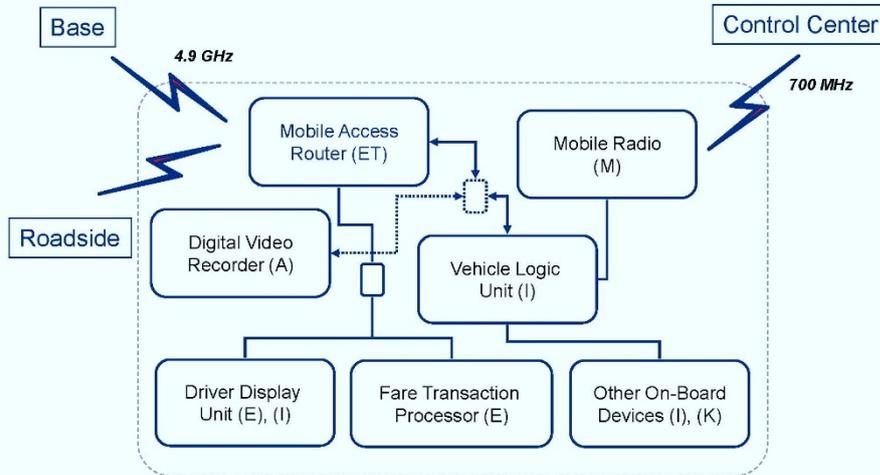
- Window CE operating system
- Software development kit and certification process part of contract



King County ITS Architecture



On-Board Architecture



Mobile Access Router (MAR)



- DuraMAR 2150 from Eurotech
- Configuration data
 - Schedule and trip details – OBS and ORCA need to match
 - Trigger points
 - Announcement text
 - Audio files
- Usage data
 - Fare transactions
 - Vehicle history
 - Schedule adherence
 - Passenger counts



Why a Mobile Router?



- Roaming and reduced authentication time supports TSP
- Licensed 4.9GHz spectrum
- Reduced interference
- Better yard coverage
- Simplified IP addressing
- Migration from in progress

3.4. Norwalk Transit District (NTD) Computer-aided Dispatch (CAD)/ Automatic Vehicle Location (AVL)

Figures 1 and 2 present the System and On-Board System Overviews. Figure 1 is the system overview including on-board and real time information systems. Figure 2 shows the on-board system overview for fixed-route and dual-use vehicles.

Once NTD documented the system integration requirements, the procurement process continued with proposers stating if they are in compliance, not in compliance or in compliance with modification with the specifications in their proposals. Sections of the specifications that addressed SAE J1708/J1587 were (1) Vehicle Area Network (VAN), (2) Farebox Integration, (3) Headsign Integration, (4) APC Installation/Integration, (5) Optional Vehicle Component Monitoring, (6) Integration with Interior DMS and (7) Optional Interface with Transit Signal Priority (TSP) Emitter (fixed-route only). The following language is directly from the specifications.

- Vehicle Area Network (VAN). “The Contractor shall install communications cabling and connections compliant with the Society of Automobile Engineers (SAE) J-1708/1587 or J-1939 network standard, to form a VAN connecting the MDT with farebox (when available), headsign, APC controller, DVR, AVA controller and interior DMS for AVA, for common login, operating control and other integrated functionalities. Further, MDTs shall be able to be integrated with optional on-board equipment (when purchased) that includes TSP emitters, on-board surveillance systems and maintenance network gateways for vehicle component monitoring.

“All supported Message IDs (MID) and Parameter IDs (PID), available for communications with on-board devices using the J-1708/1587 or J-1939 interface, shall be fully documented.”



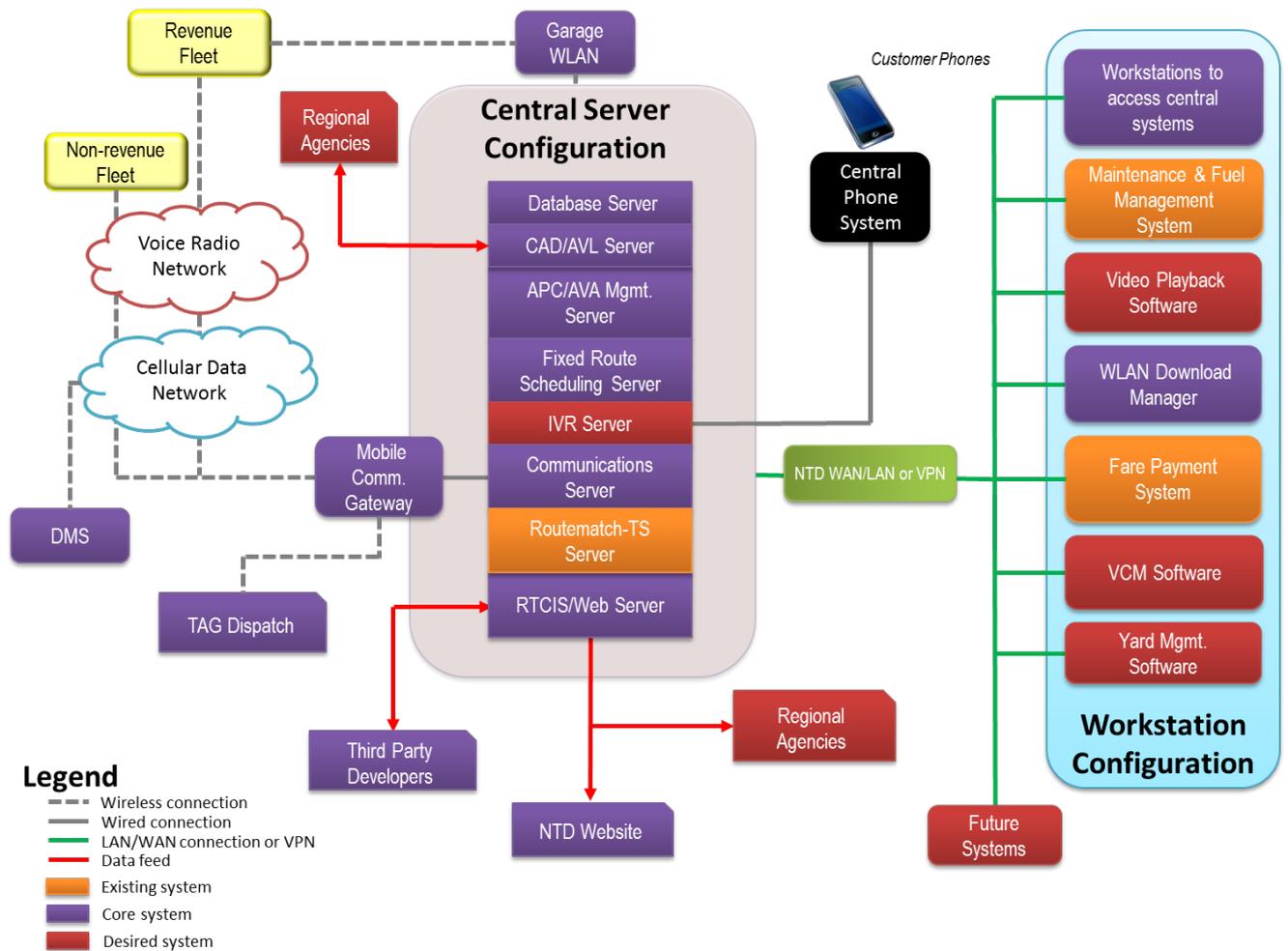
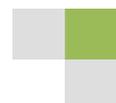


Figure 1. System Overview

- Farebox Integration. The MDT shall interface with the GFI farebox (for farebox equipped vehicles only) to enable single point logon for the vehicle operator. The single point logon shall override the current logon on the farebox
- Headsign Integration. The MDT software shall control the destination text to be displayed on the existing headsigns. The Contractor shall confirm if any upgrades to the headsign or headsign controller firmware are needed to implement this interface. NTD will coordinate these upgrades.
- APC Installation/Integration. “The APC controller shall be integrated with the on-board MDT, based on the standard SAE J-1708/J-1587 or J-1939 VAN.”
- Optional Vehicle Component Monitoring. “The MDT shall be integrated with existing J1708/1587 and J1939 network on the fixed-route fleet to collect codes from Engine Control Module, Transmission Control Module and Automatic Braking System.”
- Integration with Interior DMS. “The Contractor shall install new interior DMS that shall communicate with AVA controller over the J1708/1939 network.”



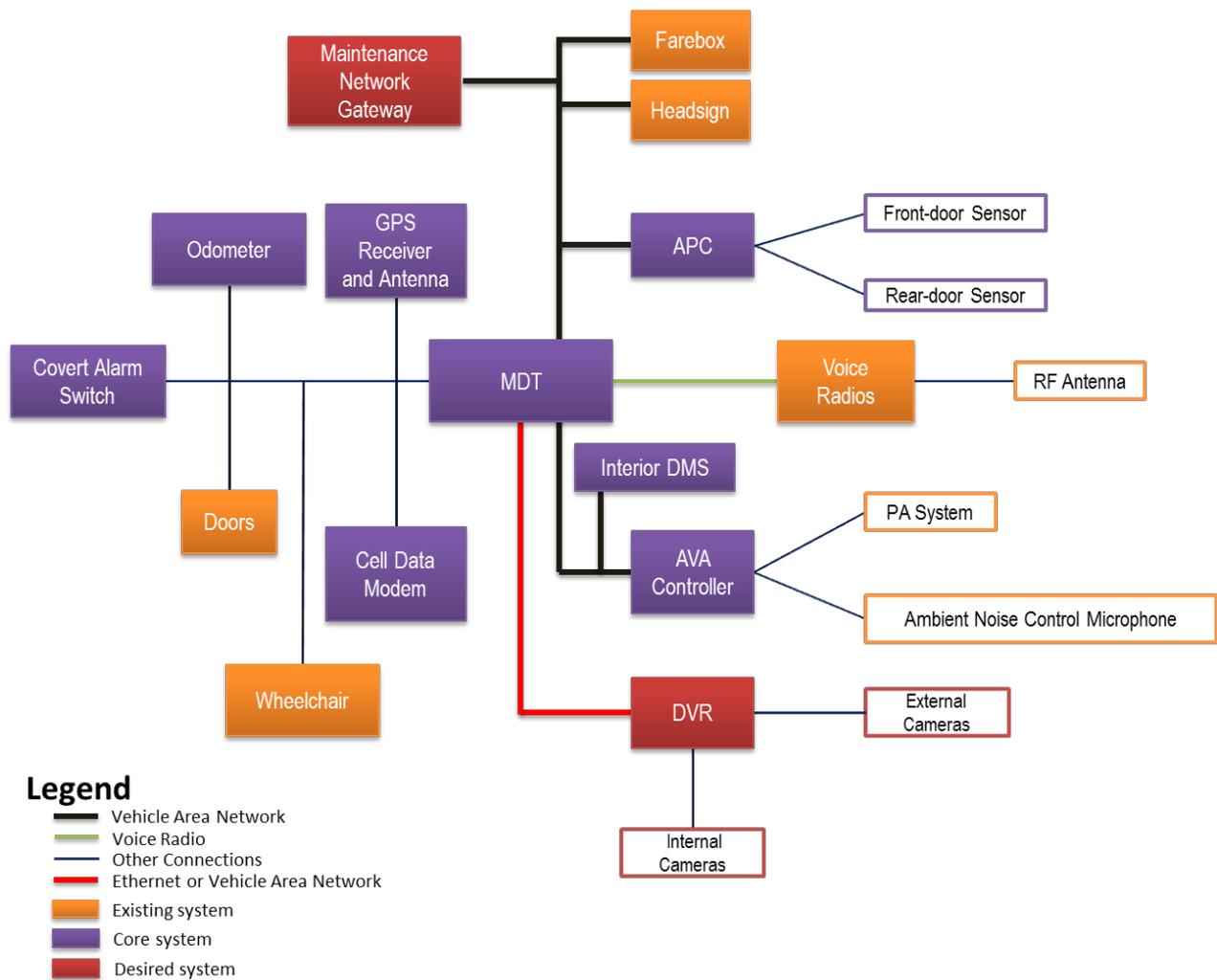


Figure 2. On-board System Overview for Fixed-Route and Dual-Use Vehicles

- Optional Interface with Transit Signal Priority (TSP) Emitter (fixed-route only). “The MDT shall be interfaced with signal priority emitters using the standard VAN. The Contractor shall obtain from the emitter vendor the standard interface, protocols and messages applicable to the emitter for communication with the MDT.”

3.5. Ann Arbor Area Transportation Authority (AAATA) Computer-aided Dispatch (CAD)/ Automatic Vehicle Location (AVL)

The following bullets are from portions of the AAATA’s specifications that address SAE J1708 or J1939:

- The Contractor shall install communications cabling and connections compliant with the Society of Automobile Engineers (SAE) J-1708/1587 or J-1939 network standard, to form a VAN connecting the MDT with farebox, headsign, APC controller, DVR [optional], AVA controller and interior DMS for AVA, for common login, operating control and other integrated functionalities.



All supported Message IDs (MID) and Parameter IDs (PID), available for communications with on-board devices using the J-1708/1587 or J-1939 interface, shall be fully documented.

- The APC controller shall be integrated with the on-board MDT, based on the standard SAE J-1708/J-1587 or J-1939 VAN.
- The MDT shall interface with the existing GFI farebox over J1939 network to enable single point logon for the vehicle operator. The single point logon shall negate the need for operators to logon on the farebox
- The Contractor shall install new interior DMS that shall communicate with AVA controller over the J1708/1939 network.
- The MDT shall be integrated with existing J1708/1587 and J1939 network on the fixed-route fleet to collect codes from Engine Control Module, Transmission Control Module and Automatic Braking System.

4. Reference to Other Standards

There are a few other standards related to the on-board transit standards described in this module. The following subsections explain these additional standards.

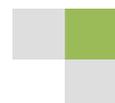
4.1. Open System Interconnection (OSI)

While this is not a standard, it is critical to understand Open System Interconnection (OSI). OSI is an ISO standard for worldwide communications that defines a networking framework for implementing protocols in seven layers. Control is passed from one layer to the next, starting at the application layer in one station, proceed to the bottom layer, over the channel to the next station and back up the hierarchy.

The 7 layers are defined as follows²:

- Physical (Layer 1): This layer conveys the bit stream - electrical impulse, light or radio signal - through the network at the electrical and mechanical level. It provides the hardware means of sending and receiving data on a carrier, including defining cables, cards and physical aspects.
- Data Link (Layer 2): At this layer, data packets are encoded and decoded into bits. It furnishes transmission protocol knowledge and management and handles errors in the physical layer, flow control and frame synchronization. The data link layer is divided into two sub layers: The Media Access Control (MAC) layer and the Logical Link Control (LLC) layer. The MAC sub layer controls how a computer on the network gains access to the data and

² <http://www.webopedia.com/TERM/O/OSI.html> and http://www.webopedia.com/quick_ref/OSI_Layers.asp



permission to transmit it. The LLC layer controls frame synchronization, flow control and error checking

- Network (Layer 3): This layer provides switching and routing technologies, creating logical paths, known as virtual circuits, for transmitting data from node to node. Routing and forwarding are functions of this layer, as well as addressing, internetworking, error handling, congestion control and packet sequencing.
- Transport (Layer 4): This layer provides transparent transfer of data between end systems, or hosts, and is responsible for end-to-end error recovery and flow control. It ensures complete data transfer.
- Session (Layer 5): This layer establishes, manages and terminates connections between applications. The session layer sets up, coordinates, and terminates conversations, exchanges, and dialogues between the applications at each end. It deals with session and connection coordination.
- Presentation (Layer 6): This layer provides independence from differences in data representation (e.g., encryption) by translating from application to network format, and vice versa. The presentation layer works to transform data into the form that the application layer can accept. This layer formats and encrypts data to be sent across a network, providing freedom from compatibility problems. It is sometimes called the syntax layer.
- Application (Layer 7): This layer supports application and end-user processes. Communication partners are identified, quality of service is identified, user authentication and privacy are considered, and any constraints on data syntax are identified. Everything at this layer is application-specific. This layer provides application services for file transfers, e-mail, and other network software services. Telnet and FTP are applications that exist entirely in the application level. Tiered application architectures are part of this layer.

4.2. Society of Automotive Engineers (SAE) J1939 Documents

SAE J1939 is defined by a series of documents shown on Table 1 that describe various aspects of the standard. For example, the physical layer (J1939/11) describes the electrical interface to the bus (bus being a shared digital pathway between resources and devices). The data link layer (J1939/21) describes the rules for constructing a message, accessing the bus, and detecting transmission errors. The application layer (J1939/71 and J1939/73) defines the specific data contained within each message sent across the network.

Table 1. Core J1939 Standards

J1939	Recommended Practice for a Serial Control and Communications Vehicle Network
J1939-01	Recommended Practice for Control and Communications Network for On-Highway Equipment



J1939-02	Agricultural and Forestry Off-Road Machinery Control and Communication Network
J1939-03	On Board Diagnostics Implementation Guide
J1939-05	Marine Stern Drive and Inboard Spark-Ignition Engine On-Board Diagnostics Implementation Guide
J1939-11	Physical Layer – 250k bits per second, Twisted Shielded Pair
J1939-13	Off-Board Diagnostic Connector
J1939-15	Reduced Physical Layer, 250K Bits/sec, Un-Shielded Twisted Pair (UTP)
J1939-21	Data Link Layer
J1939-31	Network Layer
J1939-71	Vehicle Application Layer
J1939-73	Application Layer – Diagnostics
J1939-74	Application – Configurable Messaging
J1939-75	Application Layer – Generator Sets and Industrial
J1939-81	Network Management
J1939-82	Compliance – Truck and Bus
J1939-84	OBD Communications Compliance Test Cases for Heavy Duty Components and Vehicles

4.3. Society of Automotive Engineers (SAE) J1587

An example of a J1587 message was provided in the slides. The example was a J1587 message for battery voltage. See Figure 3.

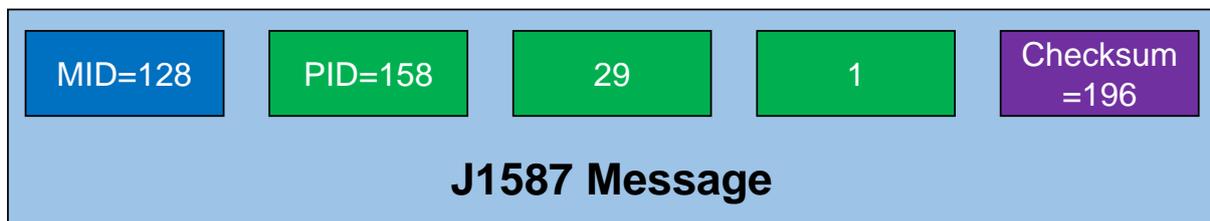
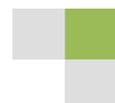


Figure 3. J1587 Example

The Battery Voltage, which is PID 158, is specified as follows:

- Parameter Data Length: 2 Characters (which is equal to 2 bytes in this protocol)
- Data Type: Unsigned integer
- Bit Resolution: 0.05 V
- Maximum Range: 0.0 to 3276.75 V
- Transmission Update Period: On request
- Message Priority: 8

Now, look for PID = 158 in the message and extract the data characters according to the specification above. Due to the specification there are two characters of data and they should be



treated like an unsigned integer (16 bits where the bits are grouped into 8 bits and sent in reverse order). The interpretation of the data bytes 29 and 1 as an unsigned integer is $(1 \cdot 2^8) + (29 \cdot 2^0) = 285$. The result must then be scaled by the bit resolution ($=0.05V$ per bit), i.e. $285 \cdot 0.05 = 14.25V$ which is the voltage level at the engine ECU.

Every PID is followed by a number of parameter data bytes. Their number and interpretation depend on the value of the PID.

4.4. Society of Automotive Engineers (SAE) J1708

An example of a J1708 message was provided in the slides. The example is sending a message from the node at the brakes of a transit bus (MID = 8). See Figure 4.

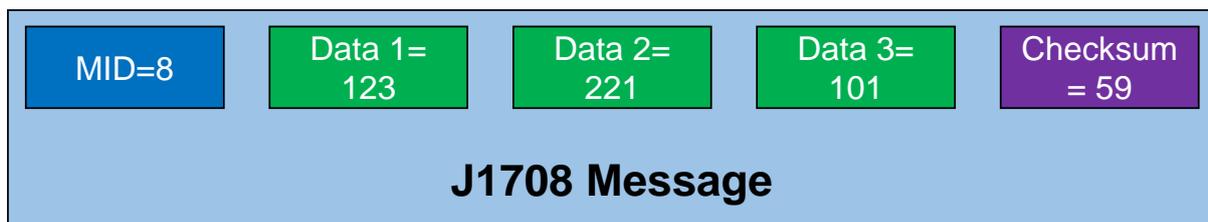


Figure 4. J1708 Example

The messages are byte-oriented, that is to say constructed of a number of bytes. Every byte consists of a start bit eight data bits and a stop bit. The start bit is of logical low level and the stop bit is a logical high level. The eight data bits are sent with the least significant bit first. This follows a standard serial UART (Universal Asynchronous Receiver/ Transmitter) communication. A message is always preceded by an idle time which is at least the shortest bus access time. The time between two bytes in a message is not allowed to be more than two bit times.

The information to send is 123, 221 and 101 from the node at the brakes of a transit bus (MID = 8). The sum of these gives $8 + 123 + 221 + 101 = 453 = (1C5)_{16}$. Mask the 8 least significant bits $\Rightarrow (C5)_{16} = (11000101)_2$. Take the two's complement: $(00111010)_2 + 1 = (00111011)_2 = 59$. The complete message to be sent will now be: 8, 123, 221, 101, 59. The reason why the checksum is calculated as described is that it becomes easy in the receiver to detect an error in the message. The receiver will just have to add all the characters in the message (including the checksum) and make sure that the eight least significant bits of the sum are equal to zero

4.5. Institute of Electrical and Electronics Engineers (IEEE) 802.3

“Ethernet, defined under IEEE 802.3, is one of today's most widely used data communications standards, and it finds its major use in Local Area Network (LAN) applications. Ethernet, IEEE 802.3 offers a considerable degree of flexibility in terms of the network topologies that are allowed. Furthermore as it is in widespread use in LANs, it has been developed into a robust system that meets the needs to wide number of networking requirements.

“The Ethernet IEEE 802.3 LAN can be considered to consist of two main elements:



- Interconnecting media: The media through which the signals propagate is of great importance within the Ethernet network system. It governs the majority of the properties that determine the speed at which the data may be transmitted. There are a number of options that may be used:
 - Coaxial cable: This was one of the first types of interconnecting media to be used for Ethernet. Typically the characteristic impedance was around 110 ohms and therefore the cables normally used for radio frequency applications were not applicable.
 - Twisted Pair Cables Type types of twisted pair may be used: Unshielded Twisted Pair (UTP) or a Shielded Twisted Pair (STP). Generally the shielded types are better as they limit stray pickup more and therefore data errors are reduced.
 - Fibre optic cable: Fibre optic cable is being used increasingly as it provides very high immunity to pick up and radiation as well as allowing very high data rates to be communicated.
- The network nodes are the points to and from which the communication takes place. The network nodes also fall into categories:
 - Data Terminal Equipment - DTE: These devices are either the source or destination of the data being sent. Devices such as PCs, file servers, print servers and the like fall into this category.
 - Data Communications Equipment - DCE: Devices that fall into this category receive and forward the data frames across the network, and they may often be referred to as 'Intermediate Network Devices' or Intermediate Nodes. They include items such as repeaters, routers, switches or even modems and other communications interface units.”³

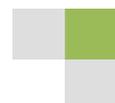
4.6. IEEE 802.11

“802.11 [and 802.11x] refers to a family of specifications developed by the IEEE for wireless [local area network] LAN (WLAN) technology. 802.11 specifies an over-the-air interface between a wireless client and a base station or between two wireless clients.

“There are several specifications in the 802.11 family:

- 802.11 — applies to wireless LANs and provides 1 or 2 [megabits per second] Mbps transmission in the 2.4 [gigahertz] GHz band using either frequency hopping spread spectrum (FHSS) or direct sequence spread spectrum (DSSS).

³ http://www.radio-electronics.com/info/telecommunications_networks/ethernet/ethernet-ieee-802-3-tutorial.php



- 802.11a — an extension to 802.11 that applies to wireless LANs and provides up to 54-Mbps in the 5GHz band. 802.11a uses an orthogonal frequency division multiplexing encoding scheme rather than FHSS or DSSS.
- 802.11b (also referred to as 802.11 High Rate or Wi-Fi) — an extension to 802.11 that applies to wireless LANs and provides 11 Mbps transmission (with a fallback to 5.5, 2 and 1-Mbps) in the 2.4 GHz band. 802.11b uses only DSSS. 802.11b was a 1999 ratification to the original 802.11 standard, allowing wireless functionality comparable to Ethernet.
- 802.11e — a wireless draft standard that defines the Quality of Service (QoS) support for LANs, and is an enhancement to the 802.11a and 802.11b wireless LAN (WLAN) specifications. 802.11e adds QoS features and multimedia support to the existing IEEE 802.11b and IEEE 802.11a wireless standards, while maintaining full backward compatibility with these standards.
- 802.11g — applies to wireless LANs and is used for transmission over short distances at up to 54-Mbps in the 2.4 GHz bands.
- 802.11n — 802.11n builds upon previous 802.11 standards by adding multiple-input multiple-output (MIMO). The additional transmitter and receiver antennas allow for increased data throughput through spatial multiplexing and increased range by exploiting the spatial diversity through coding schemes like Alamouti coding. The real speed would be 100 Mbit/s (even 250 Mbit/s in PHY level), and so up to 4-5 times faster than 802.11g.
- 802.11ac — 802.11ac builds upon previous 802.11 standards, particularly the 802.11n standard, to deliver data rates of 433Mbps per spatial stream, or 1.3Gbps in a three-antenna (three stream) design. The 802.11ac specification operates only in the 5 GHz frequency range and features support for wider channels (80MHz and 160MHz) and beamforming capabilities by default to help achieve its higher wireless speeds. This standard is being used currently for new wireless access points (WAPs) in transit garages and facilities in order to upload or download data and software updates.
- 802.11ac Wave 2 — 802.11ac Wave 2 is an update for the original 802.11ac spec that uses [multiple user] MU-MIMO technology and other advancements to help increase theoretical maximum wireless speeds for the spec to 6.93 Gbps.
- 802.11ad — 802.11ad is a wireless specification under development that will operate in the 60GHz frequency band and offer much higher transfer rates than previous 802.11 specs, with a theoretical maximum transfer rate of up to 7Gbps (Gigabits per second).
- 802.11ah— Also known as Wi-Fi HaLow, 802.11ah is the first Wi-Fi specification to operate in frequency bands below one gigahertz (900 MHz), and it has a range of nearly twice that of other Wi-Fi technologies. It's also able to penetrate walls and other barriers considerably better than previous Wi-Fi standards.



- 802.11r - 802.11r, also called Fast Basic Service Set (BSS) Transition, supports VoWi-Fi handoff between access points to enable VoIP roaming on a Wi-Fi network with 802.1X authentication.
- 802.1X — Not to be confused with 802.11x (which is the term used to describe the family of 802.11 standards) 802.1X is an IEEE standard for port-based Network Access Control that allows network administrators to restricted use of IEEE 802 LAN service access points to secure communication between authenticated and authorized devices.”⁴
- “802.11p is one of the recent approved amendments to the IEEE 802.11 standard to add wireless access in vehicular environments (WAVE). It appended some enhancements to the latest version of 802.11 that required to support applications of Intelligent Transportation Systems (ITS). This includes data exchange between high-speed vehicles and between the vehicles and the roadside infrastructure in the licensed ITS band.”⁵

5. Glossary

To include additional **descriptions/acronyms** used primarily in the module.
List out in alphabetical order.

Term	Definition
Checksum	A count of the number of bits in a transmission unit that is included with the unit so that the receiver can check to see whether the same number of bits arrived.
Controller Area Network (CAN)	A serial bus network of microcontrollers that connects devices, sensors and actuators in a system or sub-system for real-time control applications. There is no addressing scheme used in controller area networks, as in the sense of conventional addressing in networks (such as Ethernet). Rather, messages are broadcast to all the nodes in the network using an identifier unique to the network. Based on the identifier, the individual nodes decide whether or not to process the message and also determine the priority of the message in terms of competition for bus access. This method allows for uninterrupted transmission when a collision is detected, unlike Ethernets that will stop transmission upon collision detection.
Interface Class	In order for a subsystem to communicate with other subsystems, one or more of the telecommunication connections would be used to make a link between the subsystems. Subsystem to subsystem communications are categorized by the communicating subsystem category, or interface classes. For example, the communication between a "center" subsystem and another "center" subsystem (such as a traffic management

⁴ http://www.webopedia.com/TERM/8/802_11.html

⁵ http://www.iaeng.org/publication/WCECS2014/WCECS2014_pp691-698.pdf



Term	Definition
	center communication with a transit management center) belongs to the center-to-center (C2C) interface class. Other communications interface classes include center-to-field (C2F), center-to-vehicle, center-to-traveler, roadside-to-vehicle, and roadside-to-roadside.
Interface Control Document (ICD)	ICDs are the formal means of establishing, defining, and controlling interfaces and for documenting detailed interface design definitions. In other words, an ICD describes the interworking of two elements of a system that share a common interface. For example, a communications interface is described in terms of data items and messages passed, protocols observed and timing and sequencing of events. An ICD may also describe the interaction between a user and the system, a software component and a hardware device or two software components.
Open System Interconnection (OSI)	An International Organization For Standardization (ISO) standard for worldwide communications that defines a networking framework for implementing protocols in seven layers. Control is passed from one layer to the next, starting at the application layer in one station, proceed to the bottom layer, over the channel to the next station and back up the hierarchy.
SAE J1587	SAE J1587 is a specification which defines messages that are transmitted on a SAE J1708 network. J1708 specifies the data link and physical layers, while J1587 specifies the transport, network, and application layers.
SAE J1708	The SAE J1708 specification specifies a differential serial communications bus for inter-connecting electronic control units (ECUs) on heavy-duty and commercial vehicles. It does this by standardizes a hardware and software protocol for sending messages.
SAE J1939	SAE J1939 is used in the commercial vehicle area for communication in the commercial vehicle. In this application note, the properties of SAE J1939 should be described in brief. SAE J1939 uses CAN (Controller Area Network, ISO11998) as physical layer. It is a recommended practice that defines which and how the data is communicated between the ECUs within a vehicle network. Typical controllers are the Engine, Brake, Transmission, etc.
Systems Engineering Process (SEP)	Systems Engineering is an interdisciplinary approach and means to enable the realization of successful systems. It focuses on defining customer needs and required functionality early in the development cycle, documenting requirements, then proceeding with design synthesis and system validation while considering the complete problem.
Vehicle Area Network (VAN)	A local area network in and around a moving vehicle. It enables devices in and around the vehicle to communicate, either directly connected or through wireless protocols over the Internet.



6. References

Shinyoung Cho, "Vehicle Area Networks,"

<http://www3.cs.stonybrook.edu/~bjchoi/teaching/cse534/resources/VAN.pdf>

"Controller Area Network," http://www.webopedia.com/TERM/C/controller_area_network.html

"RoadRecorder® 7000 NVR J1939 Implementation Specification," Version: 1, Revision: 2, ©2014

"What is Systems Engineering," <http://www.incose.org/AboutSE/WhatIsSE>

"Consolidation of On-Board Ancillary Equipment for Metrobus," <http://itsmd.org/wp-content/uploads/Jonathan-Walker-WMATAs-Consolidation-of-On-Board-Bus-Equipment.pdf>

Road Recorder 6000 Pro, J1939 Implementation Specification

Kvaser, "Introduction to SAE J1587," <https://www.kvaser.com/about-can/can-standards/j1587/>

SAE International, "J1587: Electronic Data Interchange between Microcomputer Systems in Heavy-Duty Vehicle Applications," http://standards.sae.org/j1587_201301/

Simma Software, "J1587 Introduction," <http://www.simmasoftware.com/j1587-introduction.pdf>

"In-Vehicle Networking," Lecture 6 Introduction to SAE J1587, BAE 5030 – 003, Fall 2008, Instructor: Marvin Stone, Biosystems and Agricultural Engineering, Oklahoma State University

Kvaser, "Introduction to SAE J1708," <https://www.kvaser.com/about-can/can-standards/j1708/>

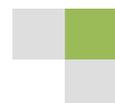
Texas Instruments, "AN-915 Automotive Physical Layer SAE J1708 and the DS36277," <http://www.ti.com/lit/an/snla038b/snla038b.pdf>

Simma Software, "J1708 | SAE J1708 Software, Protocol Stack, Source Code," <http://www.simmasoftware.com/j1708.html>

John Toone, "Seattle Metro and Mobile Routers," presented at APTA Fare Collection Workshop, March 2011, <http://www.apta.com/mc/fctt/previous/2011fare/program/Presentations/Seattle%20Metro%20and%20mobile%20routers.pdf>

John Toone, "King County Metro RapidRide ITS: Technology Review and Lessons Learned," <https://www.apta.com/mc/its/previous/2015-april/presentations/Presentations/King%20County%20Metro%20RapidRide%20ITS%20Technology%20Review%20and%20Lessons%20Learned%20-%20John%20Toone.pdf>

John Toone, "King County Metro RapidRide: Transit Signal Priority in a Connected Vehicles Environment,"



http://www.signalsystems.org.vt.edu/documents/July2013AnnualMeeting/Toone_Metro_TSP_TRB2_013.pdf

Ben Hoffman, "New Eagle J1939 Blockset for MotoHawk," June 19, 2014,

https://www.neweagle.net/wp-content/uploads/2014/06/NewEagle_J1939_Seminar_6_19.pdf

Fetah Basic, "Vehicle Network Gateway (VNG) (With emphasis on the j1850 interface),"

<http://ece.utah.edu/~cs3992/archive/2004/VNG-final-prop.pdf>

Doug J. Parker, "AVL Systems for Bus Transit: Update," TCRP Synthesis 73, Sponsored by the Federal Transit Administration, 2008, <http://www.tcrponline.org/PDFDocuments/tsyn73.pdf>

Bill Brown, Avail and Patrick Dietrich, Connect Tech, "Case Study: Location-Aware Public Transit Drives Custom I/O Controller Card Development | Transportation Systems,"

<http://eecatalog.com/transportation/2013/06/07/case-study-location-aware-public-transit-drives-custom-io-controller-card-development/>

SAE, "The SAE J1939 Communications Network: An overview of the J1939 family of standards and how they are used," <http://www.sae.org/misc/pdfs/J1939.pdf>

Simma Software, Inc., "Understanding SAE J1939," <http://www.simmasoftware.com/j1939-presentation.pdf>

Simma Software, Inc., "J1708 Introduction," <http://www.simmasoftware.com/j1708-introduction.pdf>

Vector, "Introduction to J1939," Version 1.1, 2010-04-27, Application Note AN-ION-1-3100, http://vector.com/portal/medien/cmc/application_notes/AN-ION-1-3100_Introduction_to_J1939.pdf

Motor Coach Industries, "Maintenance Matters: Driving the Data Bus," February 2009, <http://www.mcicoach.com/fyiFromMci/maintMatters/0209.htm>

John J. Schiavone, "Understanding and Applying Advanced On-Board Bus Electronics," TCRP Report 43, 1999, http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_43.pdf

R. Haas, E. Perry and J. Rephlo, "A Case Study on Applying the Systems Engineering Approach: Best Practices and Lessons Learned from the Chattanooga SmartBus Project," prepared for United States Department of Transportation, ITS Joint Program Office, Research and Innovative Technology Administration (RITA), November 2009, http://ntl.bts.gov/lib/32000/32600/32672/61027_se.pdf

John Carney, "APTA Bus Maintenance Webinar Series: Remote Diagnostics,"

<http://www.docfoc.com/2012-apta-bus-roadeo-maintenance-vehicle-inspection-guidelines-sponsored-by-fraser-guage>

"A Brief Introduction to SAE J1708 and J1587," <http://copperhilltech.com/a-brief-introduction-to-sae-j-1708-and-j-1587/>



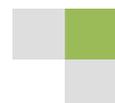
Ann Arbor Area Transportation Authority, Request for Proposal (RFP) #2015-09 for: INTELLIGENT TRANSPORTATION SYSTEMS (ITS) COMPUTER AIDED DISPATCH (CAD/AVL), October 20, 2014, [http://www.mitn.info/xfer/PublicSolicitation_Docs/SDIR~136985/0-RFP%202015-09%20ITS%20\(CAD-AVL\)%20System.pdf](http://www.mitn.info/xfer/PublicSolicitation_Docs/SDIR~136985/0-RFP%202015-09%20ITS%20(CAD-AVL)%20System.pdf)

Norwalk Transit District, Request for Proposals (RFP), "Purchase, Installation and Support of An Intelligent Transportation System," July 22, 2013, <http://www.norwalktransit.com/documents/1-proposalprocedure.doc>

Capital District Transportation Authority (CDTA), Request for Proposals (RFP), "INTELLIGENT TRANSPORTATION MANAGEMENT SYSTEM (ITMS)," Proposal Number: CDTA IT-57-1000, issued April 8, 2016, <https://www.cdta.org/procurements/intelligent-transportation-management-system-itms> (requires registration)

7. Study Questions

1. Which one of these is not a layer within Open System Interconnection (OSI) model?
 - a) Application
 - b) Data
 - c) Service
 - d) Physical
2. Which one of these differences between SAE J1939 and J1708 is not true?
 - a) J1939 is much faster than J1708
 - b) J1939 permits a connection of more units than J1708
 - c) J1939 is based on the Controller Area Network (CAN)
 - d) J1939 covers the same number of OSI layers as J1708
3. What is an interface control document (ICD)?
 - a) Documents and tracks necessary information to define system's interface
 - b) Communicates inputs and outputs for all potential actions whether internal to system or transparent
 - c) Helps ensure compatibility between system segments and components
 - d) All of the above



8. Icon Guide

The following icons are used throughout the module to visually indicate the corresponding learning concept listed out below, and/or to highlight a specific point in the training material.

- 1) **Background information:** General knowledge that is available elsewhere and is outside the module being presented. This will be used primarily in the beginning of slide set when reviewing information readers are expected to already know.



- 2) **Tools/Applications:** An industry-specific item a person would use to accomplish a specific task, and applying that tool to fit your need.



- 3) **Remember:** Used when referencing something already discussed in the module that is necessary to recount.



- 4) **Refer to Student Supplement:** Items or information that are further explained/detailed in the Student Supplement.



- 5) **Example:** Can be real-world (case study), hypothetical, a sample of a table, etc.



- 6) **Checklist:** Use to indicate a process that is being laid out sequentially.



