FINAL

MassDOT ITS Strategic Plan

Task 7: Provide Technical Assistance to Identify Protocols, Standards, and Best Practices for Supporting Statewide Interoperability.

Massachusetts Key ITS Standards v1.2

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1 INTRODUCTION

The purpose of this report, part of "Task 7: Provide Technical Assistance to Identify Protocols, Standards, and Best Practices for Supporting Statewide Interoperability" is to:

1) Identify key ITS standards used for information and control exchange between ITS systems in Massachusetts;
2) Develop a Massachusetts Statewide ITS Standards Framework;
3) Provide guidance on the use of ITS Standards.

Based on information in this report, training materials and a training course on using ITS standards have been developed and delivered.

1.1 Overview of ITS Standards

ITS standards establish a common way in which systems , devices, and vehicles connect and communicate with one another. By specifying how systems and components interconnect, the standards promote interoperability, allowing transportation agencies to implement systems that cost-effectively exchange pertinent data and accommodate equipment replacement, system upgrades, and system expansion.

Standards benefit the traveling public by providing products that will function consistently and reliably throughout a region or state. ITS standards facilitate regional interoperability, and promote an innovative and competitive market for transportation products and services.

Establishing regional and national standards for exchanging information among ITS systems is important not only from an interoperability point of view; it also reduces risk and cost since a region can select among multiple vendors for deployment products. Standards facilitate deployment of interoperable systems at local, regional, and national levels without impeding innovation as technology advances and new approaches evolve.

The U.S. Department of Transportation's (U.S. DOT) ITS Joint Program Office has been funding the development of ITS standards since 1996. From its beginning, the U.S. DOT has funded the development of the ITS standards by leveraging the existing processes within established Standards Development Organizations (SDOs). The SDOs that are involved in the development of ITS standards are:

- American Association of State Highway and Transportation Officials (AASHTO)
- American Public Transportation Association (APTA)
- Institute of Electrical and Electronics Engineers (IEEE)
- Institute of Transportation Engineers (ITE)
- National Electrical Manufacturers Association (NEMA)
- Society of Automotive Engineers (SAE)

The overall goal of the ITS Standards Program has been to promote the widespread deployment of integrated ITS through robust, non-proprietary standards.

1.2 Benefits of Using ITS Standards

The use of non-proprietary open standards offers transportation agencies increased flexibility and choice for operating ITS systems. For example, the NTCIP standards allow equipment of different types and different manufacturers to be mixed on the same communications line.

1.2.1 Providing a Choice of Vendor

There are numerous vendors of equipment and systems within the ITS industry. Each vendor has naturally defined specific features to allow differentiation among competitors. Nonetheless, there exists core functionality that is common across multiple vendors. The ITS standards community, from the start, has engaged the public sector, equipment manufacturers, system integrators, transportation consultants, and academia to identify and standardize the communication exchanges between systems that will lead to interoperability.

The result is a basic set of functionality described in standards, available regardless of vendor, with a common programming interfaces. Today, transportation agencies, through use of standards, have an easier path to change software and equipment provided by a single vendor to an entire system supported by multiple vendors.

1.2.2 Avoiding Early Obsolescence

While retrofitting legacy equipment and systems that support one or more ITS standards is not practical in most situations (due to cost), many manufacturers today offer systems that support open information and control exchange based on the ITS standards. A common industry practice is to integrate legacy equipment and systems with standards-based upgrades in a manner that ensures that an operating agency's systems and equipment remain useful and compatible long into the future. Over time legacy equipment will be replaced with standards-based solutions.

1.2.3 Phased Procurement and Deployment

Specifying ITS standards allows agencies to procure equipment and systems in phases, over several financial cycles. For example, many agencies procure a few signs one year, then a few more the next year, and so on. Sometimes devices are procured from one vendor, and sometimes from multiple vendors. Specifying ITS standards allows multiple deployment phases, over multiple years, to be integrated, with little difficulty. The initial deployment establishes an ITS communications infrastructure that can be leveraged by future deployment phases.

1.2.4 Enabling Interagency Coordination

Use of ITS standards allows agencies to exchange information, and with authorization basic commands, that enable any agency to monitor transportation-related conditions from other agencies' systems. For example, agencies can implement coordinated responses to incidents and other changes in field conditions when needed. Such data exchange and coordinated response can be implemented either manually or automatically. One agency can monitor, and issue basic commands, if authorized, to field devices operated by another agency, even though those devices may be from a different vendor than those used by the monitoring agency. Potential applications of interagency coordination include:

a) Coordinating timed transfers at a shared transit center,
b) Coordinating traffic signals across jurisdictional boundaries,
c) Providing traffic signal priority for selected, e.g., behind schedule, transit vehicles,

d) Coordinating and monitoring of incident response information,
e) Providing real-time information to a shared traveler information center,
f) Monitoring traffic volumes on another agency's roadway,
g) Coordinating the operation of a freeway ramp meter with an adjacent traffic signal, or
h) Posting a warning message on another agency's dynamic message sign.

1.2.5 Use of One Communications Network for Multiple Purposes

The communications network is usually one of the components of a transportation management system that requires the most resource investment. ITS standards provide a way to make that resource open to multiple purposes and increased operational and potentially financial benefit.

1.3 Approach to Identify Key ITS Standards for Massachusetts

The initial starting point for identification of the key ITS standards is a comprehensive review of existing and planned projects in Massachusetts (See Appendix A). This analysis resulted in a list of candidate key ITS standards (described in Section 1.4). Section 1.4 also provides a table with summary information about each standard. A standards framework diagram has been developed that illustrates the key ITS standards and their interrelationships. Section 2 of the report provides initial guidance on how ITS standards are used. Section 3 provides a more in-depth description of each key ITS standard, but has been written for a non-technical audience, or technical professionals whose area of expertise is not data communications.

1.4 MASSACHUSETTS KEY ITS STANDARDS

The table below is a list of the key ITS standards, with summary information for each. Additional detail is included in Section 3 of this report.

Table 1. Massachusetts Key ITS Standards

ITS Application Area	Key ITS Standard	Description/Purpose of Standard
Traffic Management	TMDD	The Traffic Management Data Dictionary provides for information and control exchanges related to roadway and traffic management operations.
Public Safety Communications	IEEE 1512	IEEE Standard for Traffic Incident Management Message Sets for Use by Emergency Management Centers focuses on the exchange of information about traffic and public safety agency resources used during traffic incident response.
Parking Traveler Information	SAE-J2354	The Message Set for Advanced Traveler Information System (ATIS) contains sections relevant to parking management and related traveler information.
Transit Management	TCIP	The Transit Communications Interface Profile covers transit operations and communications between centers, and centers and transit vehicles. Especially relevant are sections on Fare Collection, Passenger Counting, and Transit Priority.
	GTFS	The General Transit Feed Specification is a community-based standard developed outside of the USDOT Standards program. It is being widely deployed by transit agencies and is used to define transit schedule and real time transit service information.
Traffic Devices	NTCIP 1200 Series	The NTCIP 1200 Series contains definition of information elements for the configuration, status monitoring, and control of ITS field equipment related to traffic management (e.g., CCTV, Dynamic Message Signs, Environmental Sensor Stations, Traffic Sensors and Counters, to name a few.)
Center-to-Center Communications	NTCIP 2306	NTCIP 2306 defines encoding and transport of messages between transportation management centers including traffic management centers, transit management centers, and emergency management/public safety. The standard is based on the Web Services Architecture and standards of the World Wide Web Consortium.
Center-to-Field Communications	NTCIP 2301	NTCIP 2301 defines encoding and transport communication between a traffic management center and field device. The standard is based on Internet Engineering Task Force Simple Network Management Protocol (SNMP)
Internetworking	TCP/IP and UDP/IP	A protocol for the transmission of data across an internetwork.

A standards framework diagram showing the interrelationship of the key ITS standards is shown below.

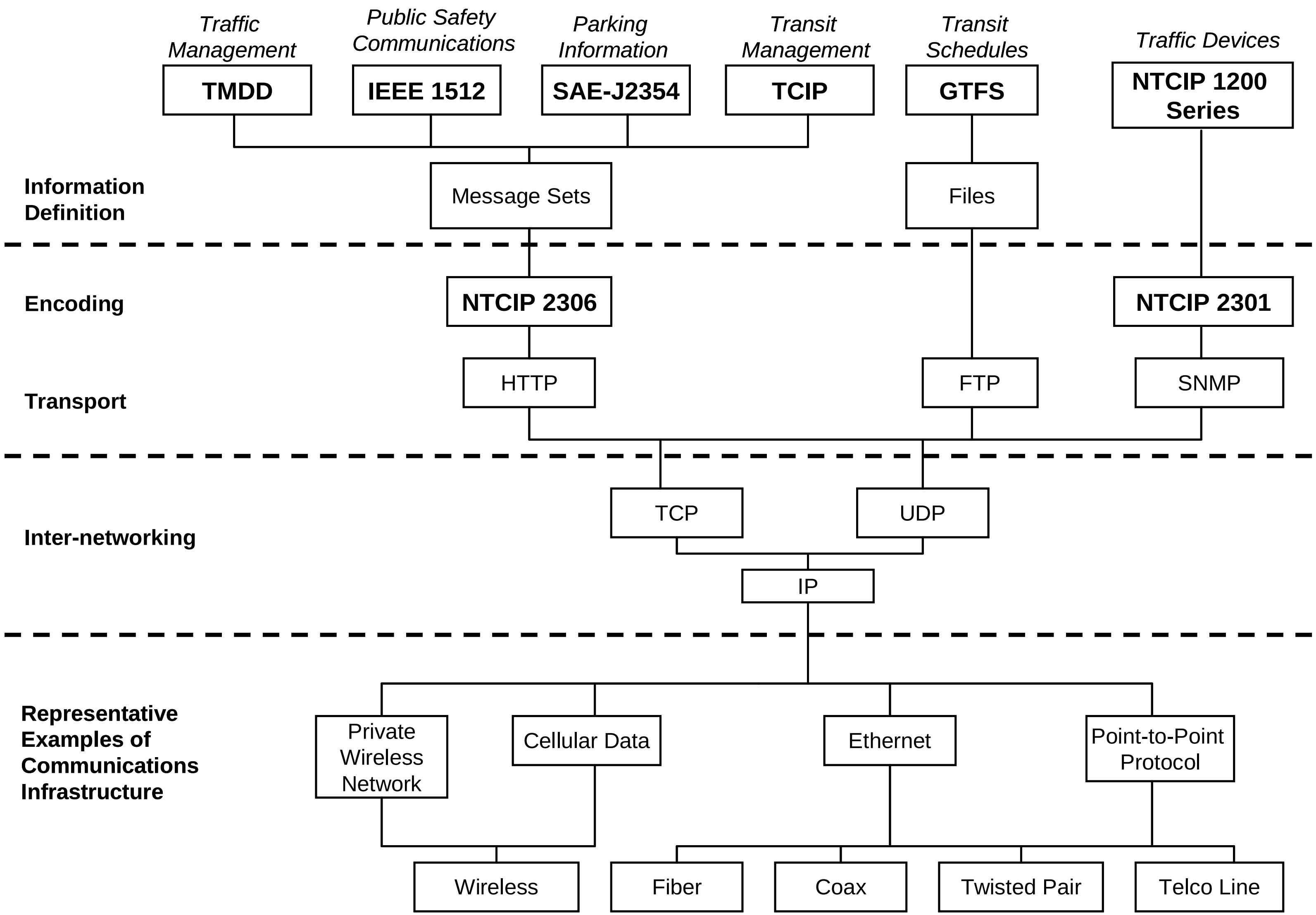

Figure 1. Massachusetts Key ITS Standards Framework

2 USING ITS STANDARDS

This section provides an brief overview of how to specify ITS standards for ITS projects.

2.1 Specify Which ITS Standards and System Interfaces are Required for the Project

An initial starting point for using ITS standards in projects is to understand that:

1. The key to success with ITS standards is specifying and requiring their use in project specifications (or, requiring that an ITS standards-based interface specification be developed as part of the project);
2. To clearly identify which system interfaces of the ITS project shall be based on ITS standards, and which standards should be applied for those interfaces.

System interfaces covered by standards include:

- Center-to-Center. Information exchanges between transportation management centers (whether inter- or intra-agency exchanges). For example, exchange of real-time roadway status information.
- Center-to-Field. Information exchanges between a center and field devices. For example, a traffic management center and a dynamic message signs.
- Vehicle-to-Infrastructure. Information exchanges between a center and a vehicle. For example, a transit management center and a bus.
- Traveler Information. Information exchanges between centers and travelers. For example, a real-time transit service status and a smart phone.

There is unfortunately no specific wording that can simply be copied into project specifications, because there is no single system design that is standard across the transportation industry. Available resources, needs, and requirements vary from agency to agency and as a result, system designs vary from agency to agency. While defining a system that encompasses all available functionality and options is an unwarranted burden on any agency, defining a system with minimal functionality may not meet the needs and requirements of any agency.

Agency specifications should not include over-simplified statements such as *"All components shall be NTCIP compliant,"* or *"The system shall use NTCIP as the communications protocol."* Neither of these statements, nor those that simply list the NTCIP publication numbers, provide sufficient information to manufacturers or systems integrators on the type, scope and functionality of the system or hardware an agency wishes to implement.

That said, if the use of standards is not included in procurement documents, they will likely not be deployed. There is no federal mandate to implement particular standards for particular interfaces, and many vendors have not incorporated standardized interfaces in their products. Therefore, if the use of ITS standards is desired, then as a minimum the procurement documents should specify which standards, and that development of a system interface specification be required as a project deliverable.

2.2 Develop a High-Level Communications Interface Specification

2.2.1 Identify Relevant and/or Mandatory Portions of Standards

The ITS standards contain mandatory and optional elements. Rarely will an agency need all the functions and messages that an ITS standard supports, thus the project specifications should specify the required information elements (whether center-to-field, center-to-center, or center-to-vehicle) for a project. This tailoring of the ITS standards will yield a project-specific version of the standard (or system interface specification).

To conform with an ITS standard, a system must support ALL the mandatory elements of that standard. But, the system is NOT required to support ANY of the optional elements. Thus the project specifications should specify which OPTIONAL elements are required to be implemented for the project. Moreover, an agency cannot develop a test plan without clearly defining what is required of the device, vehicle, or center system in a clear, concise and testable manner.

The following identifies a short-list of items that should be included in procurement documents (or required to be developed as part of the project):

- List of Standards the Project (system) shall reference in project-specific documentation. The list should be specific as to version, date of issue, etc.
- Ideally, which communications dialogs (information exchange sequences) shall define a system interface with a device, vehicle, or center.
- A Requirements Traceability Matrix (RTM) that identifies mandatory functional requirements and which optional elements are required for the project
- List of and value ranges for all data elements – for example, size of event logs, the number of DMS messages to be supported, and the number of special functions managed.

The result of this effort will be a project-specific standards-based communications interface specification suitable for procurement, that can be tested.

2.2.2 Maintenance Considerations

Agency specifications may need to address operational maintenance, version maintenance and subsequent device and/or software upgrades. Operational maintenance requirements accommodate the reality that ITS devices and component subsystems are often deployed over a wide geographical area, and potentially long time-frame (e.g., in phases). Agency specifications should consider addressing needs or requirements for fault detection, remote troubleshooting and diagnosis, and availability of service personnel and replacement parts.

2.3 Develop Communications Interface Test Documentation

2.3.1 Testing Phases

An agency's approach to testing for any deployment should consider the maturity of the ITS equipment or software being procured, the number of units being acquired and installed, the agency's ability to test, available expertise, and the relative significance of each agency specification requirement, among other factors.

The approach to testing should be tempered with the number of units to be acquired, unique agency or project implementation requirements, and the history of the ITS system (device, vehicle equipment, or center software), and the ITS standards involved. System testing is generally divided into the following phases: [adapted from NTCIP 9012]

a) Prototype test and inspection
b) Design approval test and inspection
c) Factory acceptance test
d) Incoming equipment test
e) Site acceptance test
f) Burn-in and observation test

Table 2 summarizes the relationship of these testing phases with the testing phases.

Table 2. Test Phases

Test Phase	Purpose	Number of Units	Test Location
Prototype Test and Inspection	Verify the electrical and mechanical design.	One prototype.	Test Laboratory
Design Approval Test and Inspection	Verify the final design.	Pre-production or a small percentage of the production units	Laboratory
Factory Acceptance Test	Verify production units are identical to the final design and production quality	A percentage of the production unit.	Production factory.
Incoming Equipment Test	Inspect for damage due to shipping and handling.	All delivered units, including spares	Agency.
Site Acceptance Test	Full functionality of the entire system.	All installed units.	Final location for operation.
Burn-in and Observation Test	Monitor proper operation of the installed unit.	All installed units.	Final location for operation.

2.3.2 Test Documentation

Test documentation is a key element of a testing program. Test documentation includes test plans, test cases and test procedures. Test documentation may be developed by the vendor, the agency, a test laboratory, a consultant, or perhaps it is based on test documentation used by another agency as part of their qualified products program. Testing is conducted by a combination of vendor, agency, and possibly an independent laboratory to verify that an ITS system complies with the agency specification.

Test documentation should include the following:

- Test Plan. Describes the scope, approach, resources, and schedule of testing activities
- Test Design. References the test cases applicable to a particular test plan associated with the test design. The test design also references the features (requirements) to be tested.
- Test Cases and Procedures. Describe the inputs, outputs, expected results, and procedures used to verify one or more requirements.
- Test Reports. Document the test plan execution.

Developing agency test documentation can take a significant amount of time and require coordination of many parties. It is recommended that test plan development begin after system interface requirements have been completed and approved. Test Design and development or Test Cases can begin after agency specification requirements have been approved and signed-off. Test Plan execution occurs throughout implementation. Test reports document test plan execution. Test documentation, as outlined, ensures that testing is thoroughly documented. In addition, test designs, test cases, and test procedures should be regularly reviewed based on past experience and results.

3 DESCRIPTION OF MASSACHUSETTS KEY ITS STANDARDS

3.1 Information Definition Standards

Information definition standards specify the structure and meaning of information and control exchanges.

3.1.1 ITE Traffic Management Data Dictionary

The Traffic Management Data Dictionary covers management center communications related to traffic management operations. It is subdivided into the following areas:

- Center Connection Management
- Center Entity Naming and Identification
- Security Data
- Manage Center Entities
- Provide Information on Organization and Contacts
- Events Information Sharing (e.g., incidents, construction, and planned events)
- Roadway Network Data (e.g., speed, volume, location, routes, stop points, device and incident location)
- Traffic Device Inventory, Status and Control
- Roadway Weather
- Archived Data

The TMDD references the SAE Location Referencing Message Specification (LRMS) to describe a link and node roadway network.

3.1.2 IEEE 1512 Family of Standards (Emergency and Public Safety Communications)

IEEE 1512 is not a single standard, but a series of five standards. Here is an overview of each volume:

- IEEE 1512-2006, IEEE Standard for Common Incident Management Message Sets for Use by Emergency Management Centers. Foundation of the series and includes general introductory material about IEEE Std 1512 and a message set that focuses on the exchange of information about traffic incidents.
- IEEE 1512.1-2003, IEEE Standard for Traffic Incident Management Message Sets for Use by Emergency Management Centers. This volume focuses on the exchange of information about traffic and public safety agency resources used during traffic incident response.
- IEEE 1512.2-2004, Public Safety Incident Management Message Sets for Use by Emergency Management Centers. Covers the exchange of information necessary to support traffic incident response.
- IEEE 1512.3-2006, Hazardous Material (HAZMAT) Incident Management Message Sets for Use by Emergency Management Centers. Covers the exchange of information where hazardous materials have been released on or near a roadway.
- IEEE 1512.4 (Draft), Common Traffic Incident Management Sets for Use in Entities External to Centers. While unpublished, this volume specifies message sets which support the exchange of information between a mobile asset and the emergency management center. [IEEE 1512 Implementation Guide.]

IEEE 1512 contains data concepts for emergency vehicle location and trips. The IEEE 1512 references the SAE LRMS.

3.1.3 Transit Management

3.1.3.1 APTA Transit Communications Interface Profile

There are several standards that support transit information in the U.S. including APTA's Transit Communications Interface Profiles (TCIP). TCIP is closely coupled with the SAE J2354 ATIS standard and its family of standards. Implementing one of these standards necessitates the application of several SAE standards. TCIP may be more integrated with general non public transport related trip planning; however, it has not been deployed in a widespread manner yet. Both standards can be implemented using a prescribed set of message request/response pairs as defined in NTCIP 2306. TCIP does not have a specified transport layer; it does specify the use of ASN.1 or XML as the encoding format.

The APTA TCIP, being a standard for transit information, contains data concepts for transit vehicle location, passenger loading, and transit schedule information (route, trip, direction/headsign, stop, and timepoint data).

TCIP provides building blocks for interfaces for several business areas:

- Common Public Transport
- Scheduling
- Passenger Information
- Transit Signal Priority
- Control Center
- Onboard Systems
- Spatial Referencing
- Fare Collection

3.1.3.2 GTFS – General Transit Feed Specification

The information in this section is summarized from the GTFS developers web site: https://developers.google.com/transit/gtfs/

The General Transit Feed Specification (GTFS) defines a common format for public transportation schedules and associated geographic information. GTFS feeds allow public transit agencies to publish their transit data and developers to write applications that consume that data in an interoperable way.

A GTFS feed is composed of a series of text files collected in a ZIP file. Each file models a particular aspect of transit information: stops, routes, trips, and other schedule data. A transit agency can produce a GTFS feed to share their public transit information with developers, who write tools that consume GTFS feeds to incorporate public transit information into their applications. GTFS can be used to power trip planners, time table publishers, and a variety of applications, too diverse to list here, that use public transit information in some way.

3.1.3.3 GTFS Static Feed Files

This specification defines the following files along with their associated content:

Table 3. General Transit Feed Specification Files

Filename	Required	Defines
agency.txt	Required	One or more transit agencies that provide the data in this feed.
stops.txt	Required	Individual locations where vehicles pick up or drop off passengers.
routes.txt	Required	Transit routes. A route is a group of trips that are displayed to riders as a single service.
trips.txt	Required	Trips for each route. A trip is a sequence of two or more stops that occurs at specific time.
stop_times.txt	Required	Times that a vehicle arrives at and departs from individual stops for each trip.
calendar.txt	Required	Dates for service IDs using a weekly schedule. Specify when service starts and ends, as well as days of the week where service is available.
calendar_dates.txt	Optional	Exceptions for the service IDs defined in the calendar.txt file. If calendar_dates.txt includes ALL dates of service, this file may be specified instead of calendar.txt.
fare_attributes.txt	Optional	Fare information for a transit organization's routes.
fare_rules.txt	Optional	Rules for applying fare information for a transit organization's routes.
shapes.txt	Optional	Rules for drawing lines on a map to represent a transit organization's routes.
frequencies.txt	Optional	Headway (time between trips) for routes with variable frequency of service.
transfers.txt	Optional	Rules for making connections at transfer points between routes.
feed_info.txt	Optional	Additional information about the feed itself, including publisher, version, and expiration information.

3.1.3.4 GTFS-realtime

The information in this section is summarized from the GTFS developers web site: https://developers.google.com/transit/gtfs-realtime/

GTFS-realtime is a feed specification that allows public transportation agencies to provide real time updates about their fleet to application developers. It is an extension to GTFS (General Transit Feed Specification), an open data format for public transportation schedules and associated geographic information. GTFS-realtime was designed around ease of implementation, good GTFS interoperability and a focus on passenger information.

The specification currently supports the following types of information:

- Trip updates - delays, cancellations, changed routes
- Service alerts - stop moved, unforeseen events affecting a station, route or the entire network
- Vehicle positions - information about the vehicles including location and congestion level

Updates of each type are provided in a separate feed. Feeds are served via HTTP and updated frequently. The file itself is a regular binary file, so any type of webserver can host and serve the file (other transfer protocols might be used as well). Alternatively, web application servers could also be used which as a response to a valid HTTP GET request will return the feed. There are no constraints on how frequently nor on the exact method of how the feed should be updated or retrieved.

Because GTFS-realtime allows you to present the actual status of your fleet, the feed needs to be updated regularly - preferably whenever new data comes in from your Automatic Vehicle Location system.

3.1.4 SAE-J2354 Parking Traveler Information

The SAE-J2354 Message Set for Advanced Traveler Information System (ATIS) standard is organized into seven primary groupings shown below. A summary of the contents of each is provided before examining the traveler information group further.

- Mayday Functions. Vehicle and personal distress alerting messages
- Tight Bandwidth. Message formats for narrow bandwidth devices
- Preference Settings. User preference settings and session control messages
- Directory Services. Spatially aware yellow pages and searching messages
- Parking Data. Information about parking lots, prices, capacities, and reservations
- Trip Guidance. Multi-modal trip planning and step by step guidance services
- Traveler Information. Information about road conditions, events, weather and travel in general

The section on Parking Data is most relevant to ITS projects in Massachusetts, and described in more detail below.

The Parking Data section of SAE-J2354 contains a set of messages used to request and receive information about various types of parking locations and lots including both public and private run lots, long term and temporary parking areas, and temporary parking that may be associated with a special event. The messages cover information about the lot itself (locations, directions to it, prices, and various types of capabilities and amenities).

3.1.5 NTCIP 1200 Series Center to Traffic Management Device

The field deployment of interoperable field devices has been a success for the past decade because NTCIP has enabled the communication and command/control of equipment from different manufacturers to be specified, procured, deployed, and tested.

The NTCIP 1200 series of standards defines the information content between a traffic management center and a field device. The data element definitions may include syntax, allowable ranges, and may also include valid sequences for transmitting data elements. A brief description of each of the standards that make up the NTCIP 1200 Series is included below [www.ntcip.org:

- NTCIP 1201 - Global Object (GO) Definitions. NTCIP 1201 is a data dictionary standard defining those data elements which may be used by a wide variety of ITS devices, such as data related to device identification, time, scheduling capabilities, event reporting, auxiliary device monitoring and control, and security.
- NTCIP 1202 Actuated Signal Controllers (ASC). The NTCIP 1202 defines the information elements for configuration, control, and status associated with the functions of a traffic

signal controller. The functions addressed include: Phases, Rings and Sequence; Detectors; Special Functions; Coordination; Time Base Control; Preemption; Overlaps; and Upload and Download.

- NTCIP 1203 Dynamic Message Signs (DMS). NTCIP 1203 defines the information elements for control and monitoring of DMS. The standard also introduced a markup language, called MULTI, that allow rich definition messages and attributes (e.g., color, spacing, and font). The term DMS is a general term that applies to a variety of electronic message signs and displays found on roadways including: variable message signs, changeable message signs, blank out signs, arrow signs, and drum signs.
- NTCIP 1204 Environmental Sensor Stations (ESS). This standard defines information elements for configuration, control, and status in roadway weather information stations and air quality sensors.
- NTCIP 1205 Closed Circuit Television Cameras (CCTV). This standard defines those data elements required to control video cameras. Control features include: pan/tilt, iris control, focus, zoom, and presets.
- NTCIP 1206 Data Collection and Monitoring (DCM) systems. NTCIP 1206 defines data elements used for the configuration, control, and status monitoring of transportation data collection devices. DCM equipment processes sensor signals to yield information about the traffic passing over a sensor array. Traffic information is stored in the DCM equipment as data files for future retrieval. The DCM equipment may be portable to set up at a site for a data collection period as short as one day, or the equipment may be installed permanently for continuous monitoring.
- NTCIP 1207 Ramp meters. The NTCIP 1207 standard provides definition of information required to monitor and control a ramp meter. The standard encompasses scenarios for single and multi-lane ramps and scheduling.
- NTCIP 1208 Video switches. NTCIP 1208 defines data elements used for the control and status monitoring of CCTV video switching devices. The data elements that control CCTV cameras, lens, the pan/tilt units, and camera-generated titles and labels are defined in NTCIP 1205. Video switches are deployed in traffic management centers to switch video sources (such as cameras, VCR playback, and digital video decoders) to video destination devices (such as monitors, projectors, and VCR recording inputs). The NTCIP 1208 switching standard controls the switching of video inputs to outputs, including the block switching of input and output groups, and the time-sequenced programming of multiple inputs.
- NTCIP 1209 Transportation Sensor Systems (TSS). The NTCIP 1209 defines the information elements to acquire timely and accurate information on traffic flow. A traffic management center communicates with a TSS device (controller) which captures traffic parameters in zones. A zone is an abstract representation of an area that is independent of technology.
- NTCIP 1210 Field Master Station (FMS). The NTCIP 1210 defines an information level communications interface between a management station and a Signal System Master (SSM). This standard would only apply to projects intending to deploy multi-tier traffic signal control.
- NTCIP 1211 Signal Control Priority (SCP). This NTCIP data dictionary defines the management information base for Signal Control and Prioritization (SCP) systems through parameters that represent the configuration, status, and control information. NTCIP 1211 defines the functional entities of a Priority Request Generator and a Priority Request Server, which respectively originates and performs triage on requests. After performing triage in terms of importance and priority, the requests are sent to the Coordinator entity in a Traffic Signal Controller. This standard was developed with participation of the transit community,

though the scenarios described in the concept of operations may apply for emergency vehicle preemption.

- NTCIP 1213 Electrical and Lighting Management Systems (ELMS). This NTCIP standards defines the management information for roadside electrical and lighting management systems through parameters that represent the configuration, status, and control (e.g., power level and usage, illumination characteristics). [adapted from www.ntcip.org]

With the exception of ramp meters, each of the standards may play a role in Massachusetts ITS projects.

3.2 Information Encoding and Transport Standards

Whereas the Information Definition standards define what information must be included in communications across an interface that connects two systems, the information encoding and transport standards define the encoding (i.e., format) of the information, and protocols to transport the encoded message between one system and another.

The NTCIP 2300 series of standards for encoding and transport of information. Two standards are identified as key for Massachusetts:

- NTCIP 2301 – The Simple Transportation Management Framework (STMF) is for center-to-field communications
- NTCIP 2306 - XML in ITS Center to Center Communications is for center-to-center and wide area wireless communications.

These two standards are described in further detail below.

3.2.1 NTCIP 2301 – The Simple Transportation Management Framework (STMF)

The Simple Transportation Management Framework (STMF) was developed to standardize communications between a management center and a field device, and is based largely on the Simple Network Management Protocol (SNMP).

3.2.1.1 Simple Network Management Protocol (SNMP)

SNMP is a communication protocol widely used in computer networks for managing network devices. SNMP is a standard of the Internet Engineering Task Force (IETF) and runs over User Datagram Protocol/Internet Protocol (UDP/IP). [Note: UDP/IP is described in the Section below entitled – Internetworking Standards.] As a result, the same software used to access and control a network router can be used to access and control an ITS device.

For transportation communications, SNMP is used by all NTCIP compliant field devices. SNMP uses a client-server communications model where the central computer acts as the client and the field devices act as servers. The client uses four types of messages: “Set,” “Get,” “Get Next,” and an NTCIP-defined Trap to configure, control, and monitor data elements in field devices. SNMP uses Abstract Syntax Notation 1 (ASN.1) notation to specify and encode data elements in a Management Information Base (MIB) for each compliant field device. A copy of the field device’s MIB is on the central system so that the central system may communicate with the field device.

3.2.1.2 Communications Patterns

Communications patterns are used to describe the general sequence of communications between two entities on a network. Three basic communications patterns, or simple dialogs, can handle a wide variety of situations. The three basic communications patterns are:

a) Request-Response. This communications pattern supports sending of data followed by a response. This pattern implements a synchronous pattern of message communications.
b) Dynamic Objects. This pattern supports a subscriber application (center) performing an initial request-response to set up future asynchronous responses from a device.
c) Traps. The main feature of traps is that communication is initiated by the field device to the center system when the field device has something to report. This means traps are much more efficient than polled-response communication, but traps have a key disadvantage, in that it is not immediately apparent when field communications have a problem. [NTCIP 9001]

3.2.1.3 Data Encoding

Data encoding refers to the procedures for representing the bits and bytes representation of information content to be transferred. SNMP uses data encoding governed by the Basic Encoding Rules (BER) standard, which defines a series of procedures for the representation of the data to be transferred.

3.2.2 NTCIP 2306 – XML in Center-to-Center Communications

The XML in Center-to-Center Communications standard was developed to standardize communications between two transportation management centers, and is based largely on the Web Services Architecture, and associated standards, of the World Wide Web Consortium (W3C). The NTCIP 2306 was developed in close association with the SDOs and developers of the functional area data dictionaries (TMDD, SAE-J2354, APTA TCIP, and IEEE 1512), and is applicable for encoding and transport of messages from these standards.

3.2.2.1 Overview of Center-to-Center Communications

Successful data exchange between centers requires the involved centers to agree on several key items such as the following:

- The mechanism, or message patterns, by which a message is requested or triggered (e.g., The Incident Message is sent only when a new incident is first created and thereafter when a change in status occurs, and only to those centers that previously sent a subscription message requesting incident data). Message patterns support the implementation of message dialogs, which define the sequence of message exchanges.
- The structure of the message, which defines the data elements that make up a message, (e.g., Incident Message contains three elements – Incident ID, Incident Type, and Incident Status in that order) are catalogued in a message set.
- The definition of data elements in the requested message (e.g., Incident Type 3 means an accident involving at least one fatality). Data elements are defined in a data dictionary. ITS Standards Development Organizations, or SDOs, have defined data dictionaries for various transportation functional areas (transit, traffic management, traveler information, archived data, and emergency/incident management).
- The rules used to encode the data into computer readable format (e.g., Incident Type is encoded as an enumerated short integer, with valid values lying between 0 and 8 and a default value of 0 if the element is missing from the message). XML is encoded in text

format. The valid tags that can be used in an XML document for a specific area of application are specified in the XML Schema. [NTCIP 9010]

3.2.2.2 Communications Patterns

Communications (or message) patterns are used to describe the general sequence of communications between two entities on a network. Three basic communications patterns, or simple dialogs, can handle a wide variety of situations. The three basic communications patterns are:

a) Request-Response—This communications pattern supports sending a message followed by a response. This pattern implements a synchronous pattern of message communications.
b) Subscription-Publication—This communications pattern supports a subscriber application performing an initial request-response to set up future asynchronous responses from an information publisher application.
c) One-way—This communications pattern reflects a concept intended for bulk data transfer. This pattern implements a request of a file by name. [NTCIP 9001]

3.2.2.3 Encoding and Transport

The NTCIP 2306 standard is based on the rules of message encoding and transport of the W3C's (World Wide Web Consortium) Web Services Architecture. It specifies a way to: 1) define the structure of messages (using XML Schema), and 2) the sequence of message exchanges (called dialogs), using the Web Services Description Language.

Messages are encoded using the eXtensible Markup Language (XML), and transported using the HyperText Transfer Protocol (HTTP) or File Transport Protocol (FTP). Both the HTTP and FTP are standards of the Internet Engineering Transport.

The HTTP and FTP protocols transmit data over the Transmission Control Protocol and the Internet Protocol (TCP/IP).

The NTCIP 2306 also provides a mechanism for message compression, based on the GZIP standard, suitable for sending large files over FTP, or sending XML messages over a wide area wireless network.

3.3 Internetworking Standards

The Transmission Control Protocol (TCP), User Datagram Protocol (UDP), and Internet Protocol (IP) are standards of the Internet Engineering Task Force, and referred to more commonly as either TCP/IP or UDP/IP. These communications protocols provides a mechanism for internetworking. Internetworking, a combination of the words *inter* (between) and *networking*, is the practice of connecting a computer network with other networks through the use of gateways that provide a common method of routing information packets between the networks. [Wikipedia entry on Internetworking]

Internetworking provides for the routing of information across multiple networks, whether a wide are network, local area network, regardless of transmission media, including wireless and radio.

The TCP/IP provides for reliable transmission across routed networks. A reliable protocol, in this context, means that the protocol attempts to detect and recover from transmission errors.

UDP/IP is used for routed networks that do not require a reliable protocol (also known as non-reliable). A non-reliable protocol, in this context, means that the protocol does not make any attempt to detect or recover from transmission errors. Any detection and error recovery must be done at a higher layer. This freedom from error detection and handling makes UDP/IP communications more efficient than TCP/IP. SNMP performs error handling at the application level, making UDP/IP sufficient for most NTCIP applications that use routed networks. [adapted from NTCIP 9001].

Another selling feature of the TCP/IP and UDP/IP is a simple application programmers interface (API) called "sockets" that allows software to interface with the network.

3.4 Communications Infrastructure Standards

The communications infrastructure generally refers to the physical network and devices (e.g., fiber, cables, radio modems, cell towers, routers, etc.) used in a communications network. Based on the discussion in the section above titled Internetworking Standards, the key consideration for the communications infrastructure is whether the plant level infrastructure can manage TCP/IP and UDP/IP communications.

3.5 ITS Hardware Standards

The FHWA has gathered a group of users interested in furthering the development of open architecture hardware and software to meet the future needs of ITS. Section 4.1 through 4.4 of this report provide an overview of the communications interface standards to support interoperability of information and control exchanges between ITS systems. A separate initiative is focusing on ITS hardware, namely, controllers and cabinets. The Advanced Transportation Controller (ATC) user group continues work in developing standards for the Advanced Transportation Controller (ATC) Family of Standards. The ATC Standards are being developed and maintained under the direction of the ATC Joint Committee (JC) which is made up of representatives from the American Association of State Highway and Transportation Officials (AASHTO), the Institute of Transportation Engineers (ITE) and the National Electrical Manufacturers Association (NEMA).

To date the ATC Group has generated three standards:

- Advanced Transportation Controller
- ATC Application Programming Interface Standard
- ITS Cabinet

The following sections provide an overview of these ITS hardware standards.

3.5.1 Advanced Transportation Controller

The goal of the ATC standard is to provide an open architecture design for the next generation of transportation controller applications. The ATC standard describes a family of advanced, ruggedized controllers that are configurable for a variety of transportation management applications. An ATC is a special function computer that must be able to operate remotely in a largely unattended mode in the harsh environment of field deployments throughout the United States.

These controllers are modular in design and intended to be compatible with or inclusive of existing (present day) traffic controller capabilities. First, the design specified in this standard is based on the concentration of computing power in a single component (the engine board) that is interchangeable with engine boards designed by other manufacturers. Second, the standard provides for required and optional features, all of which are based on open standard, common protocol communication standards. Key Elements of the ATC Standard are described below.

3.5.1.1 Form/Fit/Function

The ATC provides for easy hardware upgrades to adapt to newer processors, operating systems and increased memory size and speed. It does this by requiring that the engine board (CPU module) conform to a designated specific physical form and pin-out interface.

While the ATC packaging is ultimately left open to allow manufacturers to be responsive to special needs, this standard describes packaging and interfaces that allow the ATC to be deployed in industry standard cabinet configurations.

The overall ATC physical design allows for either rack mount or shelf mount cabinet configurations.

- If used in the new ITS Cabinet standard or Model 332 cabinet, the controller unit shall be capable of being mounted in rack cabinet.
- If used in standard NEMA TS1 or TS2 cabinets, the controller unit shall be shelf mounted.

3.5.1.2 Engine Board

All computational functions are concentrated on an engine board within the ATC that meets designated minimum requirements on:

- CPU and RAM memory
- FLASH memory storage
- Serial ports
- Ethernet interface
- Standardized (form, fit and function) pin out interface
- Clock/calendar maintenance
- Board support package

3.5.1.3 Communications and User Interfaces

This standard requires at least one and at most two communications interface slots be provided by an ATC. This standard does not require that either of these slots be populated. The standard also defines the required front panel interfaces of the ATC and defines the allowable optional interfaces.

3.5.1.4 Parallel and Serial I/O

This standard also requires a minimum of one synchronous serial port to interface to the ITS Cabinet or a TS2 Type 1 Cabinet. Optional interface modules defined in this standard include:

- Serial to parallel interface module for connection to NEMA TS1 or TS2 type 2 cabinet
- Serial to parallel interface module for connection to Model 332 cabinet

3.5.1.5 Operating System & Board Support Package Requirements

The ATC shall use a Linux operating system (O/S) and shall include standard POSIX libraries for application support including real-time extensions of POSIX 1003. To facilitate application level access to the ATC hardware, a Board Support Package (BSP) shall be provided for access to hardware-specific drivers.

After boot-up the ATC Linux O/S shall make available to applications, access to the low level drivers (block, character and network) provided by the kernel (subject to current open source requirements) or through kernel modules. [Adapted from ATC Standard v5.2]

3.5.2 ATC Application Programming Interface Standard

The Advanced Transportation Controller (ATC) Standards are intended to provide an open architecture hardware and software platform that can support a wide variety of Intelligent Transportation Systems (ITS) applications including traffic management, safety, security and other applications.

The ATC API standard defines a software interface for application programs intended to operate on an ATC controller unit.

The ATC Controller Standard defines a controller that can grow with technology. It is made up of a central processing unit (CPU), an operating system, memory, external and internal interfaces and other associated hardware necessary to create an embedded transportation computing platform. The goal of the application programming interface is to define a software platform that, when combined with the ATC O/S, forms a universal interface for application programs. This interface allows application programs to be written so that they may run on any ATC controller unit regardless of the manufacturer. It also defines a software environment that allows multiple application programs to be interoperable on a single controller unit by sharing the fixed resources of the controller. [Adapted from ATC API Standard v0206.]

3.5.3 ITS Cabinet

The Advanced Transportation Controller (ATC) is being developed to provide an open architecture hardware and software platform for a wide variety of ITS applications. In this context, the words "open architecture" mean that the platform may include both public and private sector developers, and it supports modular software cooperatively running on standardized and shared modular hardware components. This provides cost-effective ITS functionality for a wide variety of applications. To accomplish this goal the platform needs to provide the maximum flexibility for many different system configurations and installations. The general concept and model for the ATC is the PC computer. However, the ATC controller unit is a field-hardened, general-purpose computer for embedded applications which, with the appropriate software and hardware modules, can be asked to perform many different duties.

The ATC standards development committee has focused initially on the more traditional traffic control applications: traffic signal control, ramp control, traffic surveillance, lane use signals, field masters, general ITS beacons, lane control and access control. As a result, the modular structure focuses on providing rack space, power management and serial buses for the classic traffic control input devices, load switching and cabinet monitoring to ensure that the ITS cabinet is consistent with past practices. In addition, the serial control and monitoring bus arrangement is modular in nature and supports the development of additional special function oriented assemblies to support a variety of ITS functions.

3.5.3.1 Cabinet Overview

The ATC cabinet melds concepts from both the NEMA and Model 170 traffic signal equipment. From the Model 170, it takes the concept of rack-mounted subassemblies. From NEMA, it borrows the basic serial connections between the controller and subassemblies.

The cabinet is much more than a weatherproof housing for a collection of electronic boxes. The cabinet provides the communications paths between the various subsystems, as well as a system to monitor their operation. Further, the cabinet provides power supplies suitable for the various electronic subassemblies mounted throughout the cabinet. In general, the ITS cabinet is an extension of the original cabinet used for the Model 170 controller in that it is based upon the EIA/TIA standard 19-inch equipment rack. In this rack, the subsystems that comprise the field controller assembly are mounted in a manner so as to facilitate user access. The controller and other subassemblies are also similar in concept to the Model 170 system in that they are essentially interchangeable circuit cards or device cages. However, this does not preclude other cabinet constructs that may be proposed for inclusion in this standard at some later date. An example might be that retrofitting to existing NEMA TS1 and TS2 type cabinets or other more specialized cabinets might one day be accommodated, so long as the architecture of the serial buses is maintained.

Each of the subassemblies is connected to the controller using a serial bus, similar to that used in the NEMA TS2 Type 1 specification. Using a serial interconnection between subassemblies allows for easy system expansion. The system supports up to 28 switch packs (also know as solid state load switches) in six and 16 switch-pack increments and 96 detector channels in 24 channel increments. This serial bus may also be extended using inexpensive fiber optic transceivers, as an example, insomuch as multiple remote switching/data collection cabinets can be supported from a single controller. [Adapted from ITS Cabinet Standard v01.02.17b]

3.6 Tolling Management Standards

3.6.1 E-ZPass Group

National interoperability of tolling equipment (e.g., tags and readers) is emerging only recently. Until now, regions, such as the Northeast, and states such as Florida and Texas, have had to create consortiums and quasi-government transportation authorities to ensure interoperability of toll equipment.

The Northeastern U.S. (States from Maryland to Maine – including Massachusetts, and west as far as Illinois) formed the E-ZPass Group (formerly Inter-Agency Group - IAG) to manage standardized interfaces for tag and tag readers, and between Customer Service Centers. The E-ZPass Group is an association of 24 toll agencies in 14 states that operates the E-ZPass electronic toll collection program. E-ZPass is the world leader in toll interoperability, with more than 22 million E-ZPass devices in circulation. [Source: www.e-zpassiag.com]

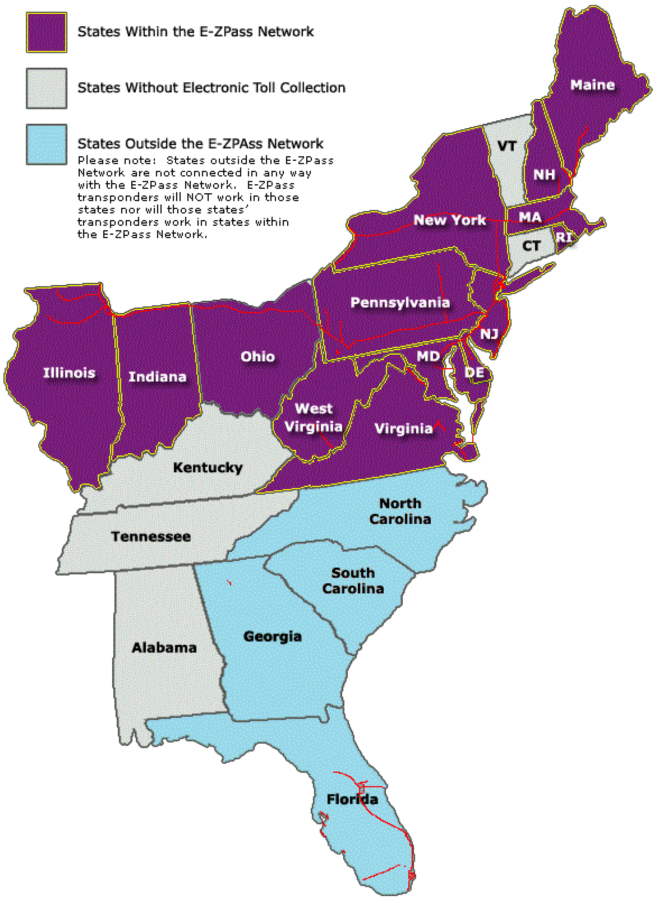

Figure 2. E-ZPass Group Region

MassDOT is a members of the E-ZPass Group and through the E-ZPass Group is involved in supporting standards for national toll interoperability. National toll interoperability, led by a group called OmniAir, is discussed in the following section.

3.6.2 OmniAir

The OmniAir Consortium, Inc. (OmniAir), formed in 2004, is an independent, not-for-profit trade association borne of IBTTA's late 5.9GHz DSRC Next Generation Task Force. OmniAir's mission is to advance the deployment of Dedicated Short Range Communications (DSRC) telematics by educating stakeholders and providing third-party certification services that ensure standards-compliance and enable interoperability of DSRC applications and transactions. [Source: www.onmiair.org]

Recently, OmniAir spun off a group called OmniAir Certification Service (OSC) whose mission is to become a certification program for tolling and connected vehicle interoperability. The interoperability standard of choice is the ISO 18000-6C standard (6C), a mature standard with worldwide deployments. A goal of the program is to make available a price point for tags of $1.50 or less, and tag readers at $7,000 each or less.

The drive for national interoperability in electronic toll collection is focusing increasingly on the ISO 18000 6C standard (6C) so far only implemented in states relatively smaller in tolling - Georgia, Washington, Colorado and Utah. A 6C User Group comprising tollers in the four early 6C adopter states has ensured that it will be the first toll technology to go to independent certification under OmniAir. And the E-ZPass Group sees 6C as having mayor potential for North American interoperability.

The E-ZPass Group has shown interest in the potential of 6C to provide a single tag usable thoughout North America, and is the reason behind a "Request for Information (12-22) ISO 18000-6C Communication Standard" issued June 1 by MTA Bridges and Tunnels providing procurement service for the E-ZPass Group as a whole. [Source: http://www.tollroadsnews.com/node/5984].

3.7 Emerging Standards of the Connected Vehicle Program

The U.S. DOT is the major sponsor of the Connected Vehicle program. Connected Vehicle focuses on localized Vehicle-to-Vehicle, Vehicle-to-Infrastructure and Vehicle-to-Device Systems (V2X) to support safety, mobility and environmental applications using vehicle Dedicated Short Range Communications (DSRC)\Wireless Access for Vehicular Environments (WAVE). This program has support from most of the automakers and a number of state departments of transportation.
In 1997, ITS America petitioned the Federal Communications Commission (FCC) to allocate spectrum dedicated to Intelligent Transportation Systems (ITS). In 1999, the FCC allocated 75 MHz of spectrum at 5.9GHz for DSRC. In 2004, the FCC adopted technical and service rules for Dedicated Short Range Communications (DSRC) to ensure interoperability. DSRC standards suite, similar to Wi-Fi and developed by the Institute of Electrical and Electronics Engineers (IEEE), is also commonly referred as 802.11p in standards development organizations.

Wireless Access in Vehicular Environments (WAVE) are a set of standards within the DSRC suite to allow cooperative and safety critical applications to be supported. DSRC is based on Wi-Fi, and is the core set of standards to support cooperative, safety-critical V2X applications. Such applications include Forward Collision Warning, Intersection Collision Warning, and many other vehicle safety services. Furthermore, DSRC is flexible enough to support mobility and environmental applications, such as tolling, traffic, weather, commercial vehicle credentialing and a host of new and existing services.

As new gains from improved crash worthiness of vehicles are harder to come by, crash avoidance technologies, especially ones that interact cooperatively through DSRC, represents the next great technological opportunity to reduce injuries and fatalities on US highways. Currently, U.S. DOT is constructing a large scale pilot to demonstrate effectiveness of DSRC with a mix of passenger, freight and transit vehicles, with the goal of accelerating the introduction and commercialization of DSRC.

This pilot is being managed by the University of Michigan and a consortium of automobile manufacturers, to include GM, Ford and Toyota among others.

Currently, USDOT is constructing a large scale pilot to demonstrate effectiveness of DSRC with a mix of light, heavy and transit vehicles, with the goal of accelerating the introduction and commercialization of DSRC. The anticipated results are an evaluation of the benefits of 10 or more applications across many vehicle, infrastructure, and device categories, using up to 3,000 vehicles. USDOT anticipates that aftermarket DSRC beacons, incorporated into connected personal navigation devices, for example, will be deployed in existing cars in the beginning to ensure that there is a critical mass of DSRC equipped vehicles to ensure early success of introductory Vehicle-to-Vehicle (V2V) applications.

This DSRC cooperative "Safety Pilot" will help USDOT and industry evaluate the scalability, security, and interoperability of all DSRC devices and applications. The pilot also plans to explore public acceptance through "driver clinics" designed to gauge reaction of drivers to new devices, applications and services. USDOT will use data collected from the pilot to support a potential National Highway Traffic Safety Administration (NHTSA) 2013 rulemaking, and to jumpstart commercialization in the automotive and consumer electronics. [Source: ITS America, http://www.itsa.org/industryforums/connectedvehicle]

4 APPENDIX A – MAPPING OF KEY ITS STANDARDS TO MASSACHUSETTS ITS PROJECTS

This appendix contains a mapping of ITS standards to ITS projects identified within the ITS Strategic Plan, organized by region.

CENTRAL REGION PROJECTS

Responsible Agency	Project Name	Stage	Location	Project Type	Relevant ITS Strategic Plan Goal(s)	Candidate ITS Standards	Comment/Question
MassDOT - Highway Division	Expansion of CCTV,VMS and Traffic Sensors	Programmed	I-290	Roadway Traveler Information, Surveillance, Roadway Operation Data	Coordination, Reliability and Efficiency, User Friendly	NTCIP 1205 (CCTV) NTCIP 1203 (DMS) NTCIP 1206 (Traffic Counters) NTCIP 1209 (Sensors) TMDD for C2C Exchanges	
MassDOT - Highway Division	Expand Statewide Fiber Network	Programmed	More Information Needed	Communications Infrastructure	Coordination	NA	This is not covered specifically by ITS standards, but fiber communications should be able to transport data across a TCP/IP connection.
MassDOT - Highway Division	Highway Assistance Patrols - Area 5	Programmed	More Information Needed	Incident Response	Safety and Security, User Friendly	IEEE 1512	
MassDOT - Highway Division	Integration Between Weather Stations and ERS	Programmed	More Information Needed	Weather Data Collection	Safety and Security, User Friendly	NTCIP 1204 (Environmental Sensor Stations) TMDD for exchange of roadway weather data between TMCs and TMCs and Weather Information Providers.	TMDD V3.0 incorporated Clarus.
City of Fitchburg	Emergency and Traffic Signal Preemption	Planned	More Information Needed	Emergency Signal Priority, Traffic Signal Priority	Coordination, Safety and Security, User Friendly	NA	ITS standards do not cover this particular functionality.
City of Worcester	Work Zone Safety Improvements	Programmed	More Information Needed	Maintenance and Construction	Safety and Security	NTCIP 1203 (Portable DMS) NTCIP 1205 (Portable	NTCIP does not cover equipment that may be applied in workzones such as

Responsible Agency	Project Name	Stage	Location	Project Type	Relevant ITS Strategic Plan Goal(s)	Candidate ITS Standards	Comment/Question
						CCTV) NTCIP 1206 and 1209 for Traffic Counters and Sensors TMDD for C2C	light curtains.

BOSTON REGION PROJECTS

Responsible Agency	Project Name	Stage	Location	Project Type	Relevant ITS Strategic Plan Goal(s)	Candidate ITS Standards	Comment/Question
MassDOT - Highway Division	I-495 ITS Fiber Project	Programmed	I-495	Communications Infrastructure	Reliability and Efficiency, Coordination	NA	This is not covered specifically by ITS standards, but fiber communications should be able to transport data across a TCP/IP connection.
MassDOT - Highway Division	Route 140 in Franklin	Programmed	Route 140	Emergency Signal Preemption	Reliability and Efficiency, Safety and Security	TMDD (interconnected traffic signals) NTCIP 1202 (Actuated Traffic Signal Controllers) NTCIP 1213 (Electrical Lighting Management Systems)	The project includes lighting systems, installation of interconnected traffic signals, with emergency preemption system.
MassDOT - Highway Division	I-95 ITS Expansion	Programmed	I-95	Surveillance, Traveler Information, Traffic Signals	Safety and Security, Coordination, User Friendly, Reliability and Efficiency	TMDD NTCIP 1203 (DMS) NTCIP 1205 (CCTV) NTCIP 1202 (Traffic Signals)	CCTV, VMS & and upgrade and expansion of the traffic signal (In this case depending on number of devices and expected return on investment, may just purchase additional of what you have) IF you are locked into a single vendor would recommend looking at introduction of standards approached)
MassDOT - Highway Division	ITS System Installation on Haverhill	Programmed	I-495 and Route 125	More Information Needed	More Information Needed	TMDD & NTCIP address ITS Systems C2C and Center to Field	
MassDOT - Highway Division	MassHighway HELP AVL	Programmed	More Information Needed	Automatic Vehicle Location	Reliability and Efficiency	IEEE1512	
MassDOT - Highway Division	ITS Revenue Collection Equipment in Brockton	Planned	City of Brockton	Revenue Collection Equipment	Reliability and Efficiency	IAG	This is a Northeast U.S. regional standard for

Responsible Agency	Project Name	Stage	Location	Project Type	Relevant ITS Strategic Plan Goal(s)	Candidate ITS Standards	Comment/Question
							toll equipment (readers and tags), plus a reciprocity network for exchange of account information.
BAT	Transit Signal Priority	Programmed	BAT Region	Transit Signal Priority	User Friendly, Reliability and Efficiency, Coordination	TCIP / NTCIP 1211	
BAT	Automatic Vehicle Location	Programmed	BAT Region	Automatic Vehicle Location	Reliability and Efficiency, User Friendly	TCIP / GTFS	
MBTA	Automated Fare Collection, Stage I	Programmed	MBTA Region	Automated Fare Collection	Reliability and Efficiency, User Friendly	TCIP	
MBTA	Commuter Rail Next Stop Announcements	Programmed	MBTA Region	Traveler Information	Reliability and Efficiency, User Friendly	TCIP / GTFS	Schedule Adherence
MBTA	Train and Bus Arrival Announcements	Programmed	MBTA Region	Traveler Information	Reliability and Efficiency, User Friendly	TCIP / GTFS	Schedule Adherence
MBTA	Automated Passenger Counters on Buses	Programmed	MBTA Region	Automated Passenger Counting	Reliability and Efficiency	TCIP	
MBTA	Automated Fare Collection, Phase II	Programmed	MBTA Region	Automated Fare Collection	Reliability and Efficiency, User Friendly	TCIP	

SOUTHEASTERN REGION PROJECTS

Responsible Agency	Project Name	Stage	Location	Project Type	Relevant ITS Strategic Plan Goal(s)	Candidate ITS Standards	Comment/Question
MassDOT - Highway Division	Outer Cape ITS Operations Control Center	Programmed	Outer Cape Cod	Operations Control Center	Reliability and Efficiency, Safety and Security, Coordination	TMDD for TMC	
MassDOT - Highway Division	Cape Cod VMS Phase I	Programmed	More Information Needed	Traveler Information	User Friendly, Reliability and Efficiency, Safety and Security, Coordination	NTCIP 1203 (Dynamic Message Signs)	
MassDOT - Highway Division	Cape Cod CCTV	Programmed	More Information Needed	Surveillance	Safety and Security	NTCIP 1205 (CCTV) NTCIP 1206 (Traffic Counters) NTCIP 1209 (Sensors)	
MassDOT - Highway Division	Cape Cod HAR	Programmed	More Information Needed	Traveler Information	Reliability and Efficiency, Safety and Security, User Friendly, Coordination	TMDD (There is no standard for HAR control)	
MassDOT - Highway Division	Cape Cod VMS Phase 2	Programmed	More Information Needed	Traveler Information	User Friendly, Reliability and Efficiency, Safety and Security, Coordination	NTCIP 1203 (Dynamic Message Signs)	
MassDOT - Highway Division	Cape Cod Real Time Data Collection	Programmed	Cape Cod	Real-Time Data Collection, Traveler Information	Reliability and Efficiency, Safety and Security, User Friendly, Coordination	TMDD NTCIP 1206 (Sensors) NTCIP 1209 (Traffic Counters)	
MassDOT - Highway Division	Cape-Wide ITS	Planned	Cape Cod	Real-Time Data Collection, Traveler Information	Safety and Security, User Friendly, Reliability and Efficiency, Coordination	TMDD	
MassDOT - Highway Division	Canal Area ITS	Planned	More Information Needed	Surveillance, Traveler Information, Real-Time Data Collection	Reliability and Efficiency, Safety and Security, User Friendly	NTCIP 1205 (CCTV) NTCIP 1206 (Traffic Counters) NTCIP 1209 (Sensors) TMDD	
MassDOT - Highway Division	Permanent Traffic Counting Stations in Cape Cod	Programmed	More Information Needed	Traffic Counting Stations	Reliability and Efficiency	NTCIP 1206 (Traffic Counters)	
MassDOT - Highway Division	Cape Cod Transportation	Planned	More Information Needed	Traffic Management Center	Safety and Security, Reliability and	TMDD	

Responsible Agency	Project Name	Stage	Location	Project Type	Relevant ITS Strategic Plan Goal(s)	Candidate ITS Standards	Comment/Question
	Management Center				Efficiency, Coordination, User Friendly		
MassDOT - Highway Division	Variable Message Signs - Cape Cod	Programmed	Route 6, Route 28, Route 25, Route 3	Traveler Information	Reliability and Efficiency, User Friendly	NTCIP 1203 (Dynamic Message Signs)	
MassDOT - Highway Division	Public Safety Signal Preemption	Planned	More Information Needed	Signal Preemption	Safety and Security	TCIP / NTCIP 1211 (Signal Priority)	
MassDOT - Highway Division	Upper/Mid Cape Real Time Traffic Information System	Planned	More Information Needed	Traveler Information	Reliability and Efficiency, User Friendly	TMDD	
Cape Cod Commission	Red Light Cameras	Planned	More Information Needed	Traffic Safety Enforcement	Safety and Security	NA	This is not covered by ITS standards.
Cape Cod Commission	Congestion Management	Planned	More Information Needed	Roadway Pricing	Reliability and Efficiency	TMDD	
CCRTA	Transit Enhancements	Programmed	CCRTA Region	Traveler Information	Reliability and Efficiency, User Friendly	TCIP / GTFS-realtime	
CCRTA	Information Kiosks	Planned	CCRTA Region	Traveler Information	Reliability and Efficiency, User Friendly	TCIP / GTFS-realtime	
CCRTA	Upgrade Radio System	Programmed	CCRTA Region	Communications Infrastructure	Reliability and Efficiency, Coordination	NA	This is not covered specifically by ITS standards, but radio communications should be able to transport data across a wireless TCP/IP connection.
CCRTA	Expansion of Next-Gen Mobile Data Terminals to Paratransit	Planned	CCRTA Region	Transit Communications Infrastructure	Reliability and Efficiency, Coordination	TCIP / GTFS-realtime	
CCRTA	Next Bus Stop Announcements and Automatic Passenger Counting	Planned	CCRTA Region	Traveler Information	Reliability and Efficiency, User Friendly	TCIP / GTFS	Schedule adherence, ridership
CCRTA	Web 2.0 Integrated Intermodal Traveler Information	Planned	CCRTA Region	Traveler Information	Reliability and Efficiency, User Friendly	TCIP / GTFS-realtime	This project would implement internet-based intermodal trip planning, displays at malls and terminals to provide real-time

Responsible Agency	Project Name	Stage	Location	Project Type	Relevant ITS Strategic Plan Goal(s)	Candidate ITS Standards	Comment/Question
							mapping of transit vehicles, as well as transit vehicle ETAs. In addition, the project would include real-time displays for major destinations and terminals, ETAs at bus shelters and smartphone applications.
CCRTA	Construction of Enhanced Bus Shelters	Planned	CCRTA Region	Traveler Information	Reliability and Efficiency, User Friendly	TCIP / GTFS	Includes traveler information at shelter
City of New Bedford	New Bedford ITS - Phase I	Programmed	I-195, Route 140	Multi-Modal Coordination	Coordination, User Friendly, Reliability and Efficiency	For Parking Mgmt SAE-J2354 Parking Availability	Phase I of the project will include video surveillance, VMS, traffic and parking management, an interim operations center, and integration of the interim operations center with the Massachusetts Interagency Video and Information System.
City of New Bedford	New Bedford ITS - Phase II	Programmed	I-195, Route 140	Multi-Modal Coordination	Coordination, User Friendly, Reliability and Efficiency		Phase II of the project will expand the video surveillance system and include a construction permitting system, vessel detection system, and a transit management system.
City of New Bedford	New Bedford ITS - Phase III	Planned	I-195, Route 140	Multi-Modal Coordination	Coordination, User Friendly, Reliability and Efficiency		Phase III of the project will include an Aircraft Detection Alert System, a Truck Appointment System, an expansion of VMS, and Aerial Video

Responsible Agency	Project Name	Stage	Location	Project Type	Relevant ITS Strategic Plan Goal(s)	Candidate ITS Standards	Comment/Question
							Coverage.
City of New Bedford	Emergency Signal Preemption	Planned	More Information Needed	Emergency Vehicle Signal Preemption	Safety and Security	NA. May consider NTCIP 1211 for guidance.	This is not covered by ITS standards.
GATRA	Transit Signal Priority	Programmed	GATRA Region	Transit Signal Priority	User Friendly, Coordination, Reliability and Efficiency	TCIP and NTCIP 1211	
GATRA	SmartCard Fare Collection	Planned	GATRA Region	Advanced Payment Systems	User Friendly, Coordination, Reliability and Efficiency	TCIP and/or GTFS for static trip fare data exchanges between center systems.	Consider creating a regional standard similar to that created by IAG for tolling.
MEMA	Integrated Emergency Management CAD System	Programmed	More Information Needed	Computer Aided Dispatch	Safety and Security, Coordination, Reliability and Efficiency	IEEE1512	
NRTA	Automated Fare Payment	Planned	NRTA Region	Automated Fare Payment	Reliability and Efficiency, User Friendly	TCIP	
OpenCape Corporation	OpenCape	Programmed	Cape Cod	Communication Infrastructure	Reliability and Efficiency, Coordination	NA	This is not covered specifically by ITS standards, but radio communications should be able to transport data across a wireless TCP/IP connection.
SRTA	AVL Coordination	Programmed	SRTA Region	Automatic Vehicle Location	Reliability and Efficiency	TCIP / GTFS-realtime	
SRTA	Transit Signal Priority	Programmed	SRTA Region	Transit Signal Priority	Reliability and Efficiency, Coordination, User Friendly	TCIP / NTCIP 1211	
SRTA	Regional Fare Integration	Programmed	SRTA Region	Fare System Integration	Reliability and Efficiency, Coordination, User Friendly	TCIP / GTFS	GTFS / TCIP
SRTA	SmartCard Fare Collection	Planned	SRTA Region	Automated Fare Payment	Reliability and Efficiency, User Friendly	TCIP / GTFS for interagency exchanges	

WESTERN REGION PROJECTS

Responsible Agency	Project Name	Stage	Location	Project Type	Relevant ITS Strategic Plan Goal(s)	Candidate ITS Standards	Comment/Question
MassDOT - Highway Division	Transit Signal Priority in Northhampton	Programmed	Route 9	Transit Signal Priority	Reliability and Efficiency, Safety and Security, User Friendly, Coordination	TCIP / NTCIP 1211	
FRTA	Fixed Route AVL	Programmed	FRTA Region	Automatic Vehicle Location for Transit	Reliability and Efficiency, Safety and Security, User Friendly, Coordination	TCIP / GTFS	
Pioneer Valley Planning Commission	Interactive Voice Response	Programmed	PVTA Region	Traveler Information	Reliability and Efficiency, User Friendly	TCIP / GTFS-realtime	
PVTA	System Integration	Planned	PVTA Region	Transit Back End Infrastructure	Reliability and Efficiency	TCIP / GTFS	
PVTA	Automatic Vehicle Location	Planned	PVTA Region	AVL for Transit	Reliability and Efficiency, User Friendly, Safety and Security, Coordination	TCIP / GTFS-realtime	
PVTA	Traveler Information	Planned	PVTA Region	Transit Traveler Information	Reliability and Efficiency, User Friendly	TCIP / GTFS-realtime	

5 APPENDIX B – ACRONYMS AND ABBREVIATIONS

This appendix contains a listing of acronyms and abbreviations used in this report.

Table 4. Acronyms and Abbreviations

Acronym/Abbreviation	Definition
AASHTO	American Association of State Highway and Transportation Officials
AP	Application Profile
API	Application Programming Interface
APTA	American Public Transportation Association
ASC	Actuated Signal Control
ASCII	American Standard Code for Information Interchange
ASN.1	Abstract Syntax Notation 1
ATC	Advanced Transportation Controller
ATMS	Advanced Traffic Management System
AVL	Automatic Vehicle Location
BER	Basic Encoding Rules or Bit Error Rate
C2C	Center to Center
CCTV	Closed-circuit television
COTS	Commercial Off The Shelf
DCM	Data Collection and Monitoring
DMS	Dynamic Message Sign
ELMS	Electrical and Lighting Management Systems
DSRC	Dedicated Short-Range Communications
ESS	Environmental Sensor Systems
FCC	Federal Communications Commission
FHWA	Federal Highway Administration
FMS	Field Management Station
FTP	File Transfer Protocol
GIS	Geographic Information System
GPS	Global Positioning System
HAR	Highway Advisory Radio
HTTP	Hyper-text Transfer Protocol
IEEE	Institute of Electrical and Electronic Engineers
IETF	Internet Engineering Task Force
IP	Internet Protocol
ISO	International Organization for Standardization
ITE	Institute of Transportation Engineers
ITS	Intelligent Transportation Systems
ITSA	Intelligent Transportation Society of America
MIB	Management Information Base

Acronym/Abbreviation	Definition
MULTI	Mark-Up Language for Transportation Information
NEMA	National Electrical Manufacturers Association
NTCIP	National Transportation Communication for ITS Protocol
OER	Octet Encoding Rules
OET	Outreach, Education and Training
OID	Object Identifier
OSI	Open Systems Interconnection
PMPP	Point-to-Multi Point Protocol
PRL	Profile Requirements List
PPP	Point-to-Point Protocol
RFC	Request For Comment
RMC	Ramp Metering Control
RWIS	Road Weather Information System (see also ESS)
SAE	Society of Automotive Engineers
SCP	Signal Control and Prioritization
SDO	Standards Development Organization
SEP	Systems Engineering Process
SNMP	Simple Network Management Protocol
SOAP	Simple Object Access Protocol
TCIP	Transit Communications Interface Protocol
TCP	Transmission Control Protocol
TCP/IP	Transmission Control Protocol/Internet Protocol
TFTP	Trivial File Transfer Protocol
TMC	Transportation Management Center
TMDD	Traffic Management Data Dictionary
UDP	User Datagram Protocol
UDP/IP	User Datagram Protocol/Internet Protocol
VMS	Variable Message Sign
WAN	Wide Area Network
WIM	Weigh In Motion
XML	eXtensible Markup Language

6 APPENDIX C – REFERENCE MATERIALS

This appendix contains a list and links to information about key ITS standards.

Standard	Document	Publisher	Link
NTCIP	NTCIP 9001 – The NTCIP Guide	NTCIP	http://www.ntcip.org/library/standards/default.asp?documents=yes&qreport=no&standard=9001
NTCIP	NTCIP 9012 – Testing Guide for Center-to-Field Communications	NTCIP	http://www.ntcip.org/library/standards/default.asp?documents=yes&qreport=no&standard=9012
TMDD	TMDD Guide	ITE	http://www.ite.org/standards/TMDDstandardv03Guide.pdf
IEEE 1512	IEEE 1512 Implementation Guide	IEEE	http://grouper.ieee.org/groups/scc32/imwg/guide.pdf
TCIP	TCIP Standard	APTA	http://www.aptatcip.org
GTFS	General Transit Feed Specification	GTFS Community	https://developers.google.com/transit/gtfs/reference
E-ZPass	E-ZPass Group	E-ZPass Group	http://www.e-zpassiag.com/interoperability