# EVALUATION AND IMPLEMENTATION OF THE NATIONAL TRANSPORTATION COMMUNICATION FOR ITS PROTOCOL AS A STANDARD FOR TXDOT: ANNUAL REPORT

## Abstract

Infrastructure agencies like TxDOT have a need to cost-effectively implement transportation user services that are required by the federal government and that are expected by TxDOT's customers. A true multi-vendor environment that provides interoperable equipment and systems is a basic building block of such a deployment.

This project evaluates the impact of the National Transportation Communications for ITS Protocol (NTCIP) on the implementation of transportation control systems within TxDOT, including ITS services and devices. The project will also provide implementation recommendations to assist TxDOT in the cost-effective deployment of these systems.

This report summarizes a number of implementation considerations developed during the second year of the work program.

## Keywords

- National Transportation Communications for ITS Protocol, NTCIP, ITS, ATC, NEMA, ITE

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EVALUATION AND IMPLEMENTATION OF THE NATIONAL TRANSPORTATION COMMUNICATIONS FOR ITS PROTOCOLS (NTCIP) AS A STANDARD FOR TxDOT: ANNUAL REPORT

by

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ACKNOWLEDGMENT

The national standards work performed as a part of this contract on behalf of the Texas Department of Transportation is indicative of the comprehensive perspective of TxDOT towards including Intelligent Transportation Systems (ITS) as a component of a complete transportation set of solutions. The author appreciates the willingness of TxDOT and the US Department of Transportation to assist in deriving a deployment solution for devices and systems that enables a national outcome incorporating regional needs.
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1. BACKGROUND

1.1 SCOPE OF PROJECT

Infrastructure agencies like TxDOT need to cost-effectively implement transportation user services required by the federal government and expected by TxDOT's customers. For Intelligent Transportation Systems (ITS), implementation and operational cost effectiveness is founded on the ability to share communications infrastructure and to provide interchangeability and interoperability for basic functionality.

Interchangeability is the ability to connect different brands of the same type of equipment to the same communications channel, e.g., the ability to connect several different brands of a traffic controller to the same channel and expect the same operation. Interoperability is the ability to connect different types of equipment to the same communications channel, e.g., the ability to connect a traffic controller, message sign controller, and environmental sensor station to the same communications channel.

Interchangeability offers TxDOT and other customers the means to increase the level of competition and hence obtain the best possible value in procuring products. Interoperability offers customers the means to use the communications channel, often the most costly component in an integrated system installation, for many different purposes. Prior to the National Transportation Communications for ITS Protocol (NTCIP), customers did not have either of these advantages.

The primary objective of NTCIP and this project is to provide a communications standard that ensures interoperability and interconnectivity of traffic control and Intelligent Transportation System devices, and to do so by utilizing existing communications standards and models to the greatest extent possible. As such TTI has been working on behalf of TxDOT to assist the national standards development efforts.

1.2 STRUCTURE OF REPORT

This report focuses on implementation issues which impact TxDOT. Technical details of approved and evolving standards are not generally incorporated in this report, but are available from standards development organizations either as white papers or standards.
2. NTCIP ISSUES AND IMPLEMENTATION OPTIONS

2.1 INTRODUCTION AND ISSUE SUMMARY

Section 2. describes issues associated with NTCIP that deserve specific attention by TxDOT. Table 1 summarizes the recommendations.

Table 1 TxDOT NTCIP Recommendations

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<td>Recommendation 2: Work through the NTCIP Joint Committee or separately with other states to develop a set of field management station data elements.</td>
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<td>Recommendation 5: Develop and implement a standards transition policy that describes investments and actions that over the course of a system’s life cycle will provide a standards based deployment.</td>
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<td>Recommendation 6: Monitor the IEEE sponsored data registry activity. Register unique TxDOT data elements either through the NTCIP private node number process or through the IEEE data registry process.</td>
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<td>Recommendation 7: Continue to work with the NTCIP Joint Committee to develop an ITS addressing scheme that can be implemented in Texas and that will facilitate ITS deployment.</td>
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2.2 FEDERAL RULE MAKING

2.2.1 Legislative Background

TEA-21 (the Transportation Equity Act for the 21st Century) contains language that ties ITS projects to conformance with the National ITS Architecture and standards. The following excerpt from that legislation illustrates the language.

. . . the Secretary shall ensure that intelligent transportation system projects carried out using funds made available from the Highway Trust Fund, including funds made available under this subtitle to deploy intelligent transportation system technologies, conform to the national architecture, applicable standards or provisional standards, and protocols. . . (1)
Of course the legislation contains some exceptions for this requirement. These include:

- certain research projects,
- the upgrade or expansion of an intelligent transportation system in existence on the date of enactment of the legislation, if the Secretary determines that the upgrade or expansion --
  (i) would not adversely affect the goals or purposes of this subtitle;
  (ii) is carried out before the end of the useful life of such system; and
  (iii) is cost-effective compared to alternatives that would meet the conformity requirement described in the legislation;
- funds used for operation or maintenance of an intelligent transportation system in existence on the date of enactment of this subtitle.

While developing the legislative directive for these standards, Congress delegated the decision about which standards would be included to the Secretary of Transportation. Wording from TEA-21 on this topic is as follows:

Not later than June 1, 1999, the Secretary shall identify which standards are critical to ensuring national interoperability and specify the status of the development of each standard identified.

If a standard identified as critical is not adopted and published by the appropriate standards development organization by January 1, 2001, the Secretary shall establish a provisional standard after consultation with affected parties.

2.2.2 Standards Community Position On Rule Making

The Joint Committee on NTCIP has taken the position that Congress and the United States Department of Transportation (US DOT) should not designate NTCIP and the other data element related standards as “critical,” but rather should consider them voluntary and act to encourage their use. The Committee does not believe the standards are “mature” at this time. According to the Joint Committee, a few of the key maturity milestones that should be reached before the US DOT should consider moving from a voluntary status include:

- testing or certification mechanisms have been developed;
- systems have been deployed that demonstrate interoperability between multiple manufacturers; and
- support for a broader array of communication infrastructures has been standardized.

The Joint Committee sent a letter to the Joint Program Office through both the Institute of Transportation Engineers (ITE) and the American Association of State Highway and Transportation Officials (AASHTO) to that effect in April and May 1998. This position was echoed again in July 1998 through AASHTO’s Subcommittee on Advanced Transportation Systems.
2.2.3 Potential TxDOT Implementation Actions

Standards imposed as a requirement (at the appropriate time when they have reached reasonable maturity) do facilitate interoperability and interchangeability and therefore enable cost effective delivery of ITS services. If standards are applied at the national level they create more opportunities for the marketplace to create competitive choices for user agencies. Given a mature set of “required” standards TxDOT can leverage these benefits, including potential cost reductions for capital and operating expenses.

Recommendation 1 summarizes this implementation recommendation. It differs from the standards community’s position that compliance should always be voluntary. Rather it defers the recommendation regarding “required” and/or “voluntary” standards to a later time.

Recommendation 1: Advocate voluntary usage of standards at the federal level at this time for traffic signal controllers and other field devices. Work within the national standards process to facilitate development of testing procedures, associated data elements and protocols, and evaluatory implementations. The goal of this work is to position the user community, including TxDOT, for a requirement to use standards as directed from either the federal or the state level.

2.3 STANDARDS TRANSITION STRATEGIES

The biggest barrier to upgrading an existing system will likely be the change to a new communications protocol and associated data elements. The following discussion provides some guidelines, facts, and alternatives for upgrading an existing field-based system to one that uses NTCIP.

2.3.1 Modification of Existing Field Equipment

It may not be feasible to modify old versions of traffic signal controllers or other field devices to make them NTCIP compatible. Constraints such as computing power, memory availability, and the cost of modification may well preclude such enhancements. If field devices cannot be upgraded or replaced, these systems will likely continue using unique protocols. However, current versions of traffic controllers can likely be modified to use NTCIP, and future versions could be purchased with an option for NTCIP compatibility. Although current versions of traffic signal controllers typically have this capability, it should be noted not all field devices generally have this capacity. Some are built with less capable microprocessors since their current implementations do not require more sophisticated communications capacity.

2.3.2 Sharing Use of Communications Media

In general, NTCIP and non-NTCIP devices cannot be mixed on the same communications channel. Therefore all devices sharing a channel must be upgraded simultaneously. A field master that communicates with both NTCIP and non-NTCIP devices will need to use a different communications port for NTCIP devices than for non-NTCIP devices and will need to support both protocols. In traditional closed-loop traffic signal systems, the simplest solution is to limit each field master to one protocol. Only field masters with NTCIP-
compatible traffic signal controllers would be upgraded to support NTCIP. This avoids the need for field masters to simultaneously support two protocols on two separate ports.

In closed-loop traffic signal systems, the central computer could communicate with field masters using a different protocol than that used by the field master to communicate with controllers. Since no field master data elements are currently being developed through the NTCIP effort, this is an important consideration. The NTCIP Committee has developed a work task for "field management units" that will serve as a field master for traffic signals and other ITS devices. Caltrans (California Department of Transportation) has written a rough draft of a set of initial data elements for this device.

**Recommendation 2**: Work through the NTCIP Joint Committee or separately with other states to develop a set of field management station data elements.

As with field devices and field masters, the central computer software will require modification to support the NTCIP protocol if the standard is to be used for communications with field masters or directly with field devices.

Some vendors have suggested they will develop generalized solutions to upgrading typically deployed systems, e.g., closed loop traffic signal systems with dialup masters. Depending on the strategy taken by the vendor, it may be more cost effective to choose the vendor's upgrade path than require the vendor to establish a unique, agency specific upgrade solution.

### 2.3.3 Central System Considerations

One approach to the introduction of NTCIP standards is to operate two totally separate systems – one NTCIP and one non-NTCIP during a transition period. Field devices can gradually be switched over from one to the other as they are replaced or their software is upgraded. This may be the only choice if the current system is old and upgrading it for NTCIP is not practical. Such a transition might logically be done as part of a general system upgrade. Figure 1 illustrates the concept of such a "parallel systems" migration strategy. In this situation the legacy field devices are physically relocated from an existing infrastructure to an NTCIP-based infrastructure as the field devices are converted to NTCIP operation.

Since this choice might also mean there are discontinuities when coordinating field devices, it is important to consider linking the two central systems. Such a link might establish a common time reference for establishment of synchronized traffic signal timing operation and pass other database information between the central systems.
2.3.4 Dual Mode Field Devices

Even if a system continues to use a proprietary protocol, when purchasing new field devices and field masters or new software packages, the procuring agency could include NTCIP support as an option. Some vendors will support both their existing protocols and the NTCIP in the same device (sometimes called "dual mode" capability). Others might require a change of software to switch from one protocol to the other. This might be accomplished through replacement of a computer chip. Regardless of how it is done, the operating agency could ensure that NTCIP support is available for future use even if it is not needed immediately. This will maximize the useful life of new equipment and enable the introduction of NTCIP in the future without further upgrades to these devices.

Recommendation 3: Consider purchasing dual mode field devices that can both communicate using protocols compatible with existing deployed systems and with NTCIP.

2.3.5 Bandwidth Limitations

In many legacy UTCS traffic signal systems, communications speed is 1200 baud or lower. On these lines, eight intersections usually communicated their green status once every second. NTCIP with its greater communications overhead will likely be unable to provide this level of monitoring. However, most private line metallic cable plants are capable of communicating at 9600 to 19200 baud with the upgrade of modems. In addition, point to multi-point modems are currently available from multiple sources that can provide this communications speed.

Even though TxDOT doesn’t have UTCS-based deployments facing this issue, the lesson is still applicable – when upgrading field equipment to achieve NTCIP capability, modems
should be part of the decision process. Typical closed-loop traffic signal systems are similarly configured with multiple traffic signals dispersed on a physical communications link operating at relatively low speed. Faster modems permit NTCIP, with its greater overhead, to operate and can facilitate the addition of new ITS devices on a circuit.

**Recommendation 4:** Consider upgrading modems when transitioning to NTCIP.

### 2.3.6 Standards Transition Policy

With these comments in mind, it could be useful for TxDOT to establish a standards transition guideline document that describes the investments and actions that will lead to a standards based deployment as the life cycle of systems progress.

**Recommendation 5:** Develop and implement a standards transition policy that describes investments and actions that over the course of a system’s life cycle will provide a standards based deployment.

### 2.4 TESTING

In the traditional traffic control system environment, few roadside devices are tested for complete functionality. While it is common to validate compliance for environmental hardiness, especially temperature extremes, testing of functionality is limited. This is especially true for complex applications such as traffic signals. Instead agencies tend to rely on vendor self-certification and warranties to ensure valid functional operation.

The ITS perspective of “standard” data elements and protocols has raised the expectation for *interchangeability* and *interoperability*; and therefore, raised the expectation for testing functionality. Tempering that expectation is experience in testing functionality in other domains, e.g., rail industry. The observation of the NTCIP support consultants to the Joint Committee is that experience in these domains highlights the extreme complexity of testing functionality.

The path to functionality will require (a) testing devices to ensure compliance with protocol transmission rules; (b) testing the devices for robust operation in typically configured active operational scenarios, (c) testing read/write capability to validate that data element values can be deposited to, and read from, devices using the transmission rules; and (d) testing functionality associated with data element values. Judging from experience in other industries, ITS testing procedures should follow the previously mentioned path from protocol readiness to data integrity and to functionality validation. Further, functionality testing may be limited in more complex devices.

### 2.5 ASSIGNED NUMBERS DOCUMENT

#### 2.5.1 Background

One of the potential new NTCIP documents is labeled *National Transportation Communications for ITS Protocol (NTCIP) Assigned Numbers.* This document,
designated TS 3.AN-199x, is available for downloading from the NTCIP web site (www.ntcip.org).

One of the topics this document covers is assignment of node numbers on the ISO global name tree. For instance in this tree structure, organizations have "private node numbers" assigned as follows:

1.3.6.1.4.1.1206.3.1  PEEK – TRANSYT Corp.
1.3.6.1.4.1.1206.3.2  NAZTEC, Inc.
1.3.6.1.4.1.1206.3.3  Eagle Traffic Control Systems
1.3.6.1.4.1.1206.3.4  Viggen Corporation
1.3.6.1.4.1.1206.3.5  Econolite Control Products, Inc.
1.3.6.1.4.1.1206.3.6  PB Farradyne Inc.

These node numbers serve as locations from which organizations can begin cataloging data elements for unique features of their applications and products. This is an important capability that allows vendors the opportunity to be innovative and responsive to their customers. In addition to vendors, public agencies could also apply and receive a node number for cataloging any unique data elements associated with their "requirements."

2.5.2 Data Element Registration for Functionality Not Contained in the Standards

A principle intent of ITS standards is to provide a consistent set of data elements for describing and communicating application functionality. With this objective in mind the initial set of standards currently being deployed contains data elements for commonly applied practices. However, each standard’s list of data elements is not exhaustive and is likely to be extended as deployments begin. TxDOT may want to request a node number from which they can begin cataloging data elements associated with TxDOT functionality.

However, the development of a public “data registry” might provide a better forum in which to register data elements that will be publicly described. While vendors may find it useful to have a private numbering scheme for which they control access, public agencies are likely to desire public registration of data elements used in specifying their systems.

IEEE is initiating the development of a “data registry” which will allow any agency to submit and record data elements (and likely message sets as well) for general public reference. While the details of this data registry are still evolving, the specifics should be agreed to in the next few months. Depending on the details of the registry mechanisms, TxDOT may prefer to use the IEEE registry as its cataloging mechanism.

Recommendation 6: Monitor the IEEE sponsored data registry activity. Register unique TxDOT data elements either through the NTCIP private node number process or through the IEEE data registry process.

2.5.3 Assigned Network Addresses

At this time for environments using a Network Layer, the NTCIP standards are recommending use of IP version 4. This means that NTCIP-based networks should only
acquire IP addresses for those nodes that will require such uniqueness, e.g., those which
might communicate over the Internet or outside the ITS domain.

As a solution for this limitation of addressing space which confronts the entire IP
environment, the document (National Transportation Communications for ITS Protocol
(NTCIP) Assigned Numbers) recommends use of an "intranet" IP addressing scheme.
Section 7 of this document recommends an IP addressing range for each state. It further
recommends that some agency in the state be responsible for "dividing the state domain into
subdivisions for local, county, and state department use." (2)

The methodology used to assign the recommended intranet address space was based on
population for each state. In the case of Texas with almost 19 million people, the
recommendation is as follows:

**IP Addresses for Regional Field Devices:** 10.11.0.0 – 10.39.255.255
This yields 1,900,544 addresses for nodes that act as regionally networked
field devices.

**IP Addresses for Centers:** 172.18.24.0 – 172.18.96.255
This yields 18,688 addresses for nodes that act as networked centers.

**IP Addresses for Nodes Not Expected For Use Outside a Local Jurisdiction:**
192.168.0.0 – 192.168.255.255
This yields 65,536 addresses for each local jurisdiction to use for devices they
never intend to share in a network outside of their own.

It is likely that short of a legislative requirement at the state level, it will be impractical to
implement such a strict IP address assignment across the agencies involved in ITS.

Another viewpoint for addressing ITS implementations is to consider the "applications" as
opposed to the "devices". That is, the critical issue, at least for regional and center based
applications is to know the "identity" of the application not necessarily the physical location
of the devices(s) that manage the application. In fact the devices that handle the application
may change over time as technology evolves. An example of this is the advanced
transportation controller (ATC) that may serve as a device to handle multiple functionality.
Current practice typically uses a separate filed device for each ITS application like camera
control, traffic signal operation, and dynamic message sign operation. The ATC may permit
various combinations of these applications to perform this functionality. From a system
management and communications routing perspective it might be advantageous to develop a
"virtual addressing" scheme that is oriented towards applications and not address tied to
physical devices.

**Recommendation 7:** Continue to work with the NTCIP Joint Committee to develop
an ITS addressing scheme that can be implemented in Texas and that will facilitate
ITS deployment.
3. STATUS OF SELECTED NTCIP STANDARDS

A number of NTCIP standards have been approved by the Standards Development Organizations of AASHTO, ITE and NEMA. These standards describe data elements for specific roadside applications and define the communications rules for moving those data elements. As with any maturing technology, emerging deployments are highlighting modifications and interpretations to the standards. The following table lists the status of selected standards and identifies are:

<table>
<thead>
<tr>
<th>Standard</th>
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<tr>
<td>Table 2 Status of Selected Standards - Continued</td>
<td></td>
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<tr>
<td>-----------------------------------------------</td>
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<tr>
<td><strong>TS 3.8CC</strong>, National Transportation Communications for ITS Protocols (NTCIP) Object Definitions for Video Camera Control.</td>
<td>A Working Group Draft is scheduled for submission to the NTCIP Joint Committee in October 1998 for elevation to User Comment Status. If recommended for User Comment, the draft document will be posted on the NTCIP web site <a href="http://ntcip.org/library/index.asp">http://ntcip.org/library/index.asp</a>, and the Standards Development Organizations of AASHTO, ITE and NEMA will use their organizational processes to solicit user comments.</td>
</tr>
<tr>
<td><strong>TS 3.RMC</strong>, National Transportation Communications for ITS Protocols (NTCIP) Object Definitions for Ramp Metering Control.</td>
<td>A Working Group Draft is scheduled for submission to the NTCIP Joint Committee in October 1998 for elevation to User Comment Status. If recommended for User Comment, the draft document will be posted on the NTCIP web site <a href="http://ntcip.org/library/index.asp">http://ntcip.org/library/index.asp</a>, and the Standards Development Organizations of AASHTO, ITE and NEMA will use their organizational processes to solicit user comments.</td>
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4. STANDARDS PERSPECTIVE

4.1 A FRAMEWORK FOR STANDARDS

The following subsections describe how ITS standards are related to the National ITS Architecture and to the application-specific domain knowledge of practitioners. This concept was developed by the author and validated through use in NTCIP presentations and a World Wide Web Internet posting (3).

4.1.1 Architecture & Application Perspectives

In looking at the overall NTCIP effort from the interdependent ITS perspective, NTCIP is two things: (a) a set of data element definitions for devices and systems and (b) a set of rules for moving these data elements between devices and systems. These data elements are the fundamental data building blocks of NTCIP. They are the vocabulary of devices and systems. The rules for moving the data, (a.k.a. protocols), are the keys to sharing communications infrastructure with other systems and other applications.

This is the nature of the ITS motivated standards that are being developed by SDOs. Most initiatives define one or more of the following product categories:

- data elements that can be viewed as dictionaries (or databases if you prefer an information technology term);
- groupings of related data elements (a.k.a., message sets); and/or
- rules for communications of the data (or protocols if you prefer a communications technology term).

The objective of these standards is to facilitate the deployment and effective use of the interdependent ITS subsystems described in the National ITS Architecture. The National ITS Architecture describes the future transportation community as interconnected subsystems of “centers,” “roadside devices,” “vehicles” and “travelers.” In that web of subsystems, which includes customers, providers and technologies, information must flow and be interpreted and acted upon. The National Architecture provides a comprehensive view of the data flows that must occur between the subsystems to deliver the customer desired functionalities and accommodate the application interdependencies. These standards-based dictionaries and communications rules enable this interdependent interaction. With these standards in place, there will be a common understanding of information (data elements) and a common method of transmitting the information.

Figure 2 illustrates the relationships involved between Architecture, applications, and standards initiatives. From the ground up, data elements are defined for specific applications. For example, NTCIP has defined a set of standard data elements for traffic signals, another set for dynamic message signs, traditionally referred to as (VMS) variable message signs or (CMS) changeable message signs, and another set for environmental sensors, and so on. In the same manner, the TCIP effort has defined data elements for passenger information, scheduling/runcutting, and others. The driving force for these bottom-up activities is the perspective of the individuals who design, build, operate, and manage these systems and devices—that is, the people who have the domain knowledge and understand the current
needs of these applications (sometimes referred to as business areas). Their knowledge of core business areas yields rich, detailed dictionaries that reflect current industry practices. Typically they also incorporate data elements that could solve pressing issues commonly acknowledged throughout their business area. For example, state and municipal transportation engineers, traffic signal manufacturers, and system integrators across the country collectively developed NTCIP data elements for actuated traffic signal controllers (ASC).

Figure 2. Architecture & Application Perspectives

From the top down, the Architecture data flows define the “interdependent” needs of ITS subsystems. An architecture data flow is the information that can be transmitted between ITS subsystems according to the National ITS Architecture framework. They establish the linkages between subsystems that are required in order to create the synergistic, interdependent ITS services that will enable very effective use of transportation resources. Within the context of a shared vision of “user services,” the ITS Architecture was designed using a systems engineering approach in conjunction with users. While meeting the needs for defining system and subsystem interactions, this top down approach did not develop detailed data dictionaries for the data flows. Instead, the ITS Architecture effort recommended a series of standards development activities to support deployment of these ITS user services.
The challenge is to reconcile the top down and bottom up approaches so we can build a complete communications infrastructure that provides the capabilities of contemporary applications and enables the benefits of an interdependent ITS world. In many cases this reconciliation will occur when ITS Architecture-based message sets must be reconciled with application-based data elements. Figure 3 illustrates these concepts. Some data elements from the application perspective are only used within a subsystem for the application—that is, they are not needed from the ITS Architecture's perspective for subsystem to subsystem communications. Other data elements might not have been defined within an application, but are needed to completely define a message involved in subsystem to subsystem communications.

![Architecture/Application Reconciliation](image)

**Figure 3. Architecture/Application Reconciliation**

### 4.1.2 Standards Perspective

The National ITS Architecture recommended three broad categories of standards initiatives:

1. **Data element standards** (collections of data definitions that can be conceptualized as dictionaries);
2. **Message set standards** (collections of related data definitions); and
3. **Communications standards** (rules for moving the data).

The concept is straightforward. Domain experts in the application business areas can identify the data needed to support current industry practices. Parallel initiatives can identify the message sets needed to provide the ITS interdependent functionality. In collaboration, holes in both processes can be reconciled so the communications interfaces will accommodate the needs of both the domain business users and the community derived vision of ITS. Finally, the rules to transport these messages and data elements can be derived to promote shared use by applications of typical communications infrastructure (a.k.a. interoperability).

Figure 4 identifies some of the ITS derived standards initiatives and their associated sponsor SDOs. For instance, in conjunction with NEMA, ITE and AASHTO are sponsoring data
element dictionaries for NTCIP and TCIP. Society for Automotive Engineers (SAE) is
developing message definitions and data elements for ATIS (Advanced Traveler Information
Systems). The guiding framework for structuring and formatting both the data dictionaries
and the message sets is sponsored by IEEE. American Society for Testing and Materials
(ASTM) is developing communications standards for dedicated short-range communications
(DSRC). NTCIP is developing a series of protocols (rules for moving data) based on an
industry standard framework anchored on IP (Internet Protocol).

Figure 4. Standards Activities and Responsible SDOs
The following bullets highlight a "roadmap" of NTCIP mechanics. This description is partially derived from an article written by the author appearing in a newsletter sponsored by ITE, AASHTO and NEMA pertaining to NTCIP, _NTCIPnews_ (4).

NTCIP calls the building blocks of its subject matter dictionaries "objects" or "data elements." Like a word in a traditional dictionary, there is structure to the way an object is defined. Word definitions in a traditional language dictionary follow a well-known structure. The first part of the definition contains information pertaining to the syllabic spelling and pronunciation of the word. Then spelling for plurals and other forms of the work follow. Next, the dictionary presents the historical definition of the word followed by the meaning of the word.

Likewise, the NTCIP subject matter dictionaries follow a consistent structure, known as Abstract Syntax Notation One (ASN.1). This structure defines an object using descriptive fields. ASN.1 is an existing well-deployed standard for describing data. The NTCIP effort did not develop the structure; it adopted it as the descriptive language of choice. In addition, NTCIP will define its data elements according to the evolving IEEE 1489 standard for data element definition. The ASN.1 version serves to readily facilitate automated communications processes while the IEEE 1489 standard facilitates detailed, unambiguous definitions and database processes.

For example, one of the ASN.1 fields addresses whether the object is required or optional. This is an important concept NTCIP is using to build the subject matter dictionaries. These dictionaries are inclusive in nature and will contain sets of objects that provide a reasonably comprehensive range of functionality.

In most installations, agencies will only deploy a subset of the entire functionality defined in the standard. For example, the traffic signal controller dictionary (designated as NEMA TS 3.5) contains objects to support "time-based operation" and once-per-second "UTCS" control. Because an agency may choose not to operate in both of these modes, it is not necessary to require both capabilities. Therefore, many of the dictionary objects for the signal controller are optional. When procuring a system, agencies should specify which optional objects they wish to implement.

Traditional language dictionaries arrange words (data elements) in alphabetical order. If someone wants to find the definition of a word that begins with the letter "c," they know it is toward the front of the dictionary. The NTCIP dictionary arranges the data elements, or objects, by function in a hierarchical organization, not in alphabetical order.

For example, in a traffic signal subject matter dictionary, traffic signal coordination timing objects are in one section of the dictionary while preemption objects are in another section. To locate an object in the dictionary, transportation professionals typically reference the index in the front of the standard. The index shows the functional and hierarchical structure of the objects in the standard. After locating an object in the index, the page number reference allows one to quickly access the definition.
Like ASN.1, the hierarchical structure of the dictionaries is an existing standard borrowed from the International Standards Organization (ISO). This organization developed a "tree" structure and numbering configuration for standards. This results in each object being assigned a unique identification number. These unique object identifications facilitate the process of building NTCIP object databases from the subject matter dictionaries.

The NTCIP effort then arranges these data elements (objects) into dictionaries organized by subject matter. These standard dictionaries represent unique business areas for which there are users, product/service providers, implementers, and other involved participants. Some of the NTCIP and TCIP dictionaries either approved or pending approval include the following business areas.

- Actuated Traffic Signals
- Dynamic Message Signs
- Environmental Sensor Stations
- Common Public Transportation (for Transit)
- Passenger Information (for Transit)
- Scheduling/Runcutting (for Transit)
- Incident Management (for Transit)
- Spatial Representation (for Transit)

The subset of the dictionary needed by a specific agency for a specific application, e.g., time-based traffic signal functionality for "City A" along "Main Street," is then extracted from the dictionary standard and loaded into a database. The database is known as a MIB module (Management Information Base). This database structure can be compiled, read from devices, and written to devices by computer programs. The products that structure the reading and writing of the database values are called SNMP (Simple Network Management Protocol). SNMP is an industry standard mechanism for reading and writing objects structured in MIB databases. This process of reading and writing data, which is the basis from which the application carries out its functionality, is sometimes denoted as "management." The controlling subsystem is often referred to as the management station while the application performing the functionality is often referred to as the management agent.

Once the data elements (objects) and message sets have been selected, they are ready for transporting to/from the management agent applications so that they can be "managed" using SNMP (Simple Network Management Protocol).

These management agent applications are field devices like traffic signals in the case of many roadside applications. The rules for moving the data are called protocols. NTCIP has chosen to use existing, industry recognized standards based on the same rules that are the foundations for the Internet. Using these network protocols enables practitioners to effectively use communications media, networks and devices commonly available.

These rules are structured using a seven-layer hierarchy called the Open Systems Interconnect (OSI) Model. The OSI model breaks the responsibility of transmitting data into various tasks. Some of the task rules are associated with the physical media—that is,
whether the communications path is twisted pair copper, coaxial cable, fiber optic, etc. The rules associated with the media are called “physical network” rules. Other task rules are associated with moving the data in a network along various routes and where other applications may also be moving data.

Think of the physical media rules as choosing whether to send a report to a work associate using a paper document, a voice tape, or a computer disk. In any case, we follow a set of rules for placing the information on the media that we choose. Next we choose which mailing system to use. Choices include the US Postal Service, various overnight services, trucking companies, etc. The choice of a mailing system determines the requirements for packaging, addressing, and so forth. In a similar sense, the physical network rules of the OSI establish how the communications system “gets the bits across the connection.”

Once we have chosen the media on which to send a report to an associate, we need to “package” our data consistent with the rules of the mailing system. In the case of the US Postal Service we have a relatively wide variety of envelope and packaging options. In the case of an overnight delivery service, we might be required to use their packages.

The task-rules for packaging electronic data are defined as physical network rules in the OSI model. The prevalent rules are called HDLC (High Level Data Link Control) framing protocols. This packaging technique adds “flag” bit patterns which designate the beginning and ending of a package (after all, ones and zeros in digital communications tend look a lot alike if you’re not careful). HDLC also adds some error checking to help ensure the integrity of the package.

Once a package containing the data has been built and the rules for moving it on the wire are formulated, the OSI model provides a series of rules for routing the data to its destination. These “data transport” rules are where the Internet Protocol is identified. The transport rules even contain procedures for repackaging the data into smaller packages and reassembling them after the transmission is complete.

Finally, after the management agent, e.g., field device, has received the data, it is deposited in the application using the SNMP rules mentioned above.
REFERENCES

2. Draft “National Transportation Communications for ITS Protocol (NTCIP) Assigned Numbers” version 98.01.01, AASHTO / ITE / NEMA Standards Committee, March 27, 1998, Section 7.1.