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Joint Committee on the NTCIP*

NTCIP 9001 version v04

National Transportation Communications for ITS Protocol The NTCIP Guide

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IN MEMORIAM

The Joint Committee on the NTCIP dedicates NTCIP 9001 v04, *The NTCIP Guide*, to the memory of G. Curtis Herrick.

FOREWORD

NTCIP 9001 v04 is an NTCIP standards publication, and NTCIP 9001 v04 is known colloquially as “The NTCIP Guide.” NTCIP 9001 v04 is an educational tool, created to assist planners, specification writers, and implementers in understanding the various NTCIP standard publications and how to use them. NTCIP 9001 v04 also explains the motivations behind the use of NTCIP. NTCIP 9001 v04 is an informative NTCIP publication, but NTCIP 9001 v04 is not an NTCIP standard and is, therefore, not to be considered binding.

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Section 1 INTRODUCTION

The National Transportation Communications for ITS Protocol (NTCIP) family of standards defines protocols and profiles that are open, consensus-based data communications standards. When used for remote control of roadside and other transportation management devices, NTCIP-based devices and software can help achieve interoperability and interchangeability. When used between transportation and emergency management centers, NTCIP standards facilitate agency coordination and information sharing.

Why are NTCIP standards needed? How are NTCIP standards used? What is interoperability and interchangeability? NTCIP 9001 v04, referenced as “The NTCIP Guide” here, explains these terms, and gives you the “why” and the “how” to specify and implement NTCIP standards in your ITS devices and systems.

1.1 PURPOSE OF *THE NTCIP GUIDE*

The NTCIP Guide is an educational tool, created to assist planners, specification writers, and implementers in understanding the various NTCIP standard publications and how to use them. The NTCIP Guide also explains the motivations behind the use of NTCIP. The NTCIP Guide is an informative NTCIP publication, but *The NTCIP Guide* is not an NTCIP standard and is, therefore, not to be considered binding.

The reader should understand that, in writing specifications or implementing systems, only the actual NTCIP standards govern and take precedence, not The NTCIP Guide. For updated information on NTCIP standards publications, please see the NTCIP website at www.ntcip.org.

1.2 PURPOSE OF NTCIP

The transportation industry has had a history of deploying systems with unique data definitions and proprietary communications protocols. Field devices and systems from one manufacturer or developer were not interoperable with those of other manufacturers or developers. As a result, expansion of the system after initial deployment can generally only be done using equipment of the same type and usually the same brand as in the initial deployment, unless there are investments in major systems integration efforts.

With proprietary protocols, there is little to no opportunity for realistic competitive bidding as additional field devices are added to the system, due to the lack of interchangeability. Nor, is there any opportunity for realistic competitive bidding to add additional types of field devices to the system, due to the lack of interoperability.

NTCIP is a family of open standards, defining common communications protocols and data definitions.

The NTCIP standards define common data definitions and open protocols. The proper use of NTCIP open-standards in an ITS deployment allows future expansion of the system to benefit from true competitive bidding, as well as allowing other types of field devices to be added. NTCIP is an entire family of standards designed to meet the communications needs of various fixed-asset roadside devices and traffic management centers. The open-standards approach is illustrated in Figure 1.

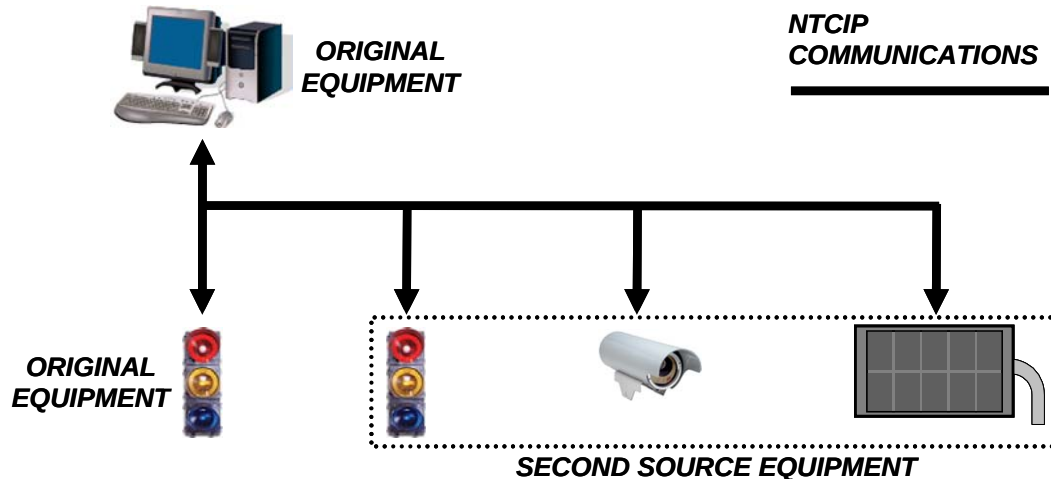


Figure 1 NTCIP Facilitates Interoperability and Interchangeability of Field Equipment

Interoperability and interchangeability are two key goals of the NTCIP open-standards effort. The terms interoperability and interchangeability generally reflect the ability to use multiple brands of a device on the same communications channel, along with the ability to swap them out. For example, the ability to put any brand of NTCIP-conformant traffic signal controller in the same system at the same time reflects interchangeability for that device type. It is for this reason that the NTCIP family of protocols is being widely embraced and specified in many new system deployments.

Interoperability and Interchangeability help to reduce the total life system expenditures (procurement, operations, and maintenance).

1.2.1 Interoperability

Interoperability reflects the ability of multiple center systems and devices of different types to exchange information for some common purpose. Interoperability allows system components from different vendors to communicate with each other to provide system functions and to work together as a whole system. For example, using the same communications infrastructure to interconnect a management system with traffic signal controllers, dynamic message signs, video surveillance controls and other devices to manage traffic reflects a real-world example of interoperability.

1.2.2 Interchangeability

Interchangeability reflects the capability to exchange devices of the same type on the same communications channel and have those devices interact with others devices of the same type using standards-based functions. With interchangeability, system components can be changed out (switched) with similar components from different vendors because they possess common functional and physical characteristics. An example of interchangeability is a signal controller from different manufacturers interacting with each other to provide traffic signal coordination along an arterial throughway.

1.3 NTCIP OVERVIEW

NTCIP is a family of communications standards for transmitting data and messages between computer systems used in Intelligent Transportation Systems (ITS). A communications standard specifies a set of rules for how messages are coded and transmitted between electronic devices. The equipment at each end of a data transmission uses the same specification to successfully communicate. It is a bit like human languages that have an alphabet, vocabulary and grammar rules used by everyone speaking that language.

1.3.1 Center to Field (C2F) Communications

NTCIP provides communications standards for two fundamentally different types of ITS communications. The first type is between a center system and multiple control or monitoring devices managed by that center. An example of a center system is a computer at city hall monitoring and controlling the operation of microprocessor-based roadside controllers at traffic signals within a city. The center system may send instructions to the traffic signal controllers to change signal timings as traffic conditions change and the controllers send status and traffic flow information to the computer.

Other examples of this type of communications include:

- a) An on-board vehicle transit system communicating with a traffic signal device to facilitate transit priority;
- b) A freeway management system communicating with detectors and ramp meters on freeways; and
- c) A traffic management system controlling roadway lighting, closed-circuit television (CCTV) cameras, dynamic message signs, advisory radio transmitters, environmental sensors and traffic count stations on roadways.

Since most applications of this type involve a center system communicating with various devices at the roadside or on agency vehicles, this type of communication is referred to as “center to field” (C2F). The NTCIP protocols intended for this communications application is often used in an environment where a center system routinely polls each field device, as in the most common case of multiple field devices sharing a communications channel.

1.3.2 Center to Center (C2C) Communications

The second type of communication involves messages sent between two or more center systems. This type of communication is referred to as center to center (C2C) communications, although two or more of the various systems may in fact be located within the same “center” or building, they are logically separate. C2C involves peer-to-peer communications between any number of center systems in a many-to-many network. This type of communication is similar to the Internet, in that any center can request information from, or provide information to, any number of other centers.

An example of C2C communications is two traffic management centers that exchange real-time information about the inventory and status of traffic control devices. This allows each center system to know what timing plan, for example, the other center system is running to allow traffic signal coordination across center geographic boundaries. Other examples of this type of communication include:

- a) Two or more traffic signal systems exchanging information (including second-by-second status changes) to achieve coordinated operation of traffic signals managed by the different systems and to enable personnel at one center to monitor the status of signals operated from another center;
- b) A transit system reporting schedule adherence exceptions to a transit customer information system and to a regional traveler information system, while also asking a traffic signal management system to instruct its signals to give priority to a behind-schedule transit vehicle;
- c) An emergency management system reporting an incident to a freeway management system, to a traffic signal management system, to two transit management systems and to a traveler information system;
- d) A freeway management system informing an emergency management system of a warning message just posted on a dynamic message sign on the freeway in response to its notification of an incident; and
- e) A weather monitoring system informing a freeway management system of ice forming on the roadway so that the freeway management system is able to post warning messages on dynamic message signs as appropriate.

1.4 NTCIP BENEFITS

NTCIP standards offer increased flexibility and choices for agencies operating transportation management systems. NTCIP standards usage removes barriers to interagency coordination and allows

equipment of different types and different manufacturers to be mixed on the same communications line. For these reasons, operating agencies benefit from specifying that NTCIP be included in all future acquisitions and upgrades, even if NTCIP is not initially used.

1.4.1 Avoiding Early Obsolescence

While retrofitting legacy equipment and systems with NTCIP support is not practical in most situations, most manufacturers offer NTCIP support in their ITS devices. It is possible to migrate a system gradually, since it is possible to operate a mixture of NTCIP and non-NTCIP devices in the same system, though not on the same communications line. Equipment may also continue to use a current protocol even though the device may also support NTCIP as a second protocol. Integrating legacy equipment and systems with NTCIP-conformant upgrades in this manner ensures that an operating agency's systems and equipment remain useful and compatible long into the future.

Buying a field device or central control system that has no software available to support NTCIP is like buying a computer that has no software available to access the Internet. Even if agencies do not use the Internet now, Internet use is surely likely during the lifetime of the computer.

1.4.2 Providing a Choice of Vendor

Since a computer system that supports NTCIP can communicate with any device from other vendors that are NTCIP-conformant, the number of vendors and systems, field devices, or software that can be considered for procurement increases greatly.

While vendor-specific features may only be available to other software and ITS devices from the same vendor, the basic functionality described in an NTCIP standard is available regardless of vendor. This requires that agency specifications (procurement documents) adequately specify the mandatory and optional conformance requirements that support the agency's functional requirements. However, NTCIP makes it easier for an agency to gradually change its software, controllers and other field devices from one vendor to supporting multiple vendors for the entire system.

Agencies should also consider issues beyond the interoperability/interchangeability aspects inherent to the NTCIP family of standards. These include issues such as stocking replacement parts that are different from provider to provider, and the knowledge-base of ITS technicians who would have to become familiar with multiple vendors' devices.

1.4.3 Phased Procurement and Deployment

Specifying NTCIP allows agencies to procure devices and center 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 NTCIP standards means that multiple deployment phases, over multiple years, can be integrated, with little difficulty. The initial deployment establishes an ITS communications infrastructure that can be leveraged by future deployment phases resulting in improved cost/benefit for ITS projects.

1.4.4 Enabling Interagency Coordination

NTCIP allows agencies to exchange information and (with authorization) basic commands that enable any agency to monitor conditions in other agencies' systems, and to 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) Providing real-time information to a shared traveler information center,

- e) Monitoring traffic volumes on another agency's roadway,
- f) Coordinating the operation of a freeway ramp meter with an adjacent traffic signal, or
- g) Posting a warning message on another agency's dynamic message sign.

1.4.5 Use One Communications Network for All Purposes

NTCIP allows a management system to communicate with a mixture of device types on the same communications channel. For example, with the addition of appropriate application software in the system computer, a dynamic message sign could be installed near a signalized intersection, and the computer could communicate with the sign controller using the communications line or channel already in place for the traffic signal controller, if certain aspects of the communications protocols, that is, the Data Link and Physical layer protocols are the same. Similarly, a wide area network interface installed for communications with a system operated by another agency can be used for communications with any number of other systems, of any type, if NTCIP and the C2C Data Dictionaries and Message Sets of other efforts, such as the Traffic Management Data Dictionary (TMDD), are used. The communications network is usually one of the components of a transportation management system that requires the most resource investment. NTCIP ensures flexibility in the future use of that component.

1.5 U.S. DOT RITA ITS STANDARDS PROGRAM OVERVIEW

The U.S. DOT Research and Innovative Technology Administration (RITA) ITS Standards Program has supported the development and widespread use of standards to encourage the interoperability of ITS systems. Through cooperative agreements with five standards development organizations (SDOs), the U.S. DOT RITA ITS Standards Program accelerated the development of non-proprietary, industry- and consensus-based open ITS standards, and has encouraged public-sector participation in the development process. The five original cooperative agreement SDOs are: AASHTO, ASTM, ITE, IEEE, and SAE. NEMA and APTA joined the program through other agreements.

ITS practitioners are encouraged to use SDO-approved ITS standards when deploying ITS projects in their region. The use of ITS standards is necessary to provide integrated, open systems.

U.S. DOT continues to encourage stakeholders to test and evaluate developing standards, and where available, to use ITS standards in their deployment. In support of early deployment, the U.S. DOT RITA ITS Standards Program offers information and resources to those ITS project managers who decide to use ITS standards. A website, located at www.standards.its.dot.gov/, provides background information, testing results, and guides to deploying specific standards. In addition, links to contacts, training, and technical assistance resources are also located on this site.

1.6 ORGANIZATION OF THE NTCIP GUIDE

The NTCIP Guide is divided into seven sections as follows:

- a) **Section 1—Introduction** provides a brief overview of NTCIP as well as a discussion of the motivations that led to the development of NTCIP standards. It also discusses the issues associated with NTCIP use.
- b) **Section 2—Understanding NTCIP** provides a general purpose technical overview of NTCIP and the NTCIP Framework. It's a good starting point for anyone wishing to become better informed on the various technical aspects of the NTCIP approach.
- c) **Section 3—Procuring NTCIP** is intended principally for agency specification writers. This section presents an overview of the procurement process and issues related to procurement.
- d) **Section 4—Agency Requirements and Specifications** is intended principally for agency specification writers. This section outlines elements of NTCIP standards and how to use them in developing agency requirements and specifications.
- e) **Section 5—Designing NTCIP** is intended principally for those faced with the task of designing the communications element of transportation systems that use NTCIP protocols. This section, together with the material in Annex E, provides a detailed discussion on bandwidth analysis and system timing.

- f) **Section 6—Implementing NTCIP** is intended for systems implementers, including software and hardware developers for field equipment, traffic management center software and hardware developers and systems integrators. In particular, some of the lessons learned and common pitfalls encountered during actual deployments are discussed, with suggested solutions.
- g) **Section 7—NTCIP Testing** is intended principally for test documentation developers. The information presented is a summary of NTCIP 9012 v01, Testing Guide for NTCIP Center-to-Field Communications.

1.7 ADDITIONAL NTCIP INFORMATION

More information about NTCIP standards can be found on the NTCIP Website at www.ntcip.org. Those without access to the World Wide Web may contact:

NTCIP Coordinator
National Electrical Manufacturers Association
1300 North 17th Street, Suite 1752
Rosslyn, Virginia 22209-3801
e-mail: ntcip@nema.org

NTCIP standards are developed with input from users and other interested parties. Such input was also sought and evaluated for the development of *The NTCIP Guide*. Anyone interested in making written inquiries, comments, and proposed or recommended revisions should submit them to the NTCIP Coordinator at the above address. Please include the following information in your correspondence:

- a) NTCIP Document Number:
- b) Version Number:
- c) Section Number:
- d) Paragraph:
- e) Comment (including Suggested Alternative Language):
- f) Your Name:
- g) Your Address:
- h) Your Organization

1.8 NTCIP STYLE CONVENTIONS

Within *The NTCIP Guide*, as well as within other NTCIP standards publications, certain conventions are used with respect to document self-reference, acronym and abbreviation usage, and normative and informative references.

1.8.1 Self-Reference Within NTCIP Standards Publications

When an NTCIP standards publication references itself or is referenced in another standard, the style of that reference is: NTCIP XXXX vZZ. Specifically, “XXXX” is the NTCIP publication designation number, and “ZZ” refers to the major version number.

NOTE—Prior to 2008, NTCIP standards used the following reference style: NTCIP XXXX:YYYY, where “XXXX” was the NTCIP publication number, and “YYYY” referred to the year. For those NTCIP standards published prior to 2008, the cover of the published NTCIP standard or document governs the style of the self-reference, and these publications should be cited as: NTCIP XXXX:YYYY.

NOTE—Following this convention, NTCIP 9001 v04 should refer to itself as NTCIP 9001 v04; however, to make NTCIP 9001 v04 more “user-friendly,” NTCIP 9001 v04 refers to itself as “*The NTCIP Guide*.”

1.8.2 Abbreviation and Acronym Usage

Various abbreviations and acronyms are used throughout the family of NTCIP standards and publications. For a list of abbreviations and acronyms commonly used in NTCIP standards and publications, as well as a glossary of common terms, see Annex A.

Within NTCIP standards and publications, abbreviations or acronyms are usually spelled out on first use, with the abbreviation or acronym following in parentheses. On subsequent use, the abbreviation or acronym is used alone, without parentheses.

Section 2 UNDERSTANDING NTCIP

2.1 TYPES OF SYSTEMS AND DEVICES SUPPORTED BY NTCIP

NTCIP defines a family of general-purpose communications protocols and transportation-specific data dictionaries/message sets that support most types of computer systems and field devices used in transportation management. Applications for NTCIP are generally divided into two categories: C2F and C2C. The former, C2F, normally involves devices at the roadside, communicating with management software on a central computer. The latter, C2C, usually involves computer-to-computer communications where the computers can be in the same room, in management centers operated by adjacent agencies, or across the country.

For both C2F and C2C applications, NTCIP supports systems and devices used in traffic, transit, emergency management, traveler information, and planning (data archiving) systems. Figure 2 illustrates how various transportation management systems and devices can be integrated using NTCIP.

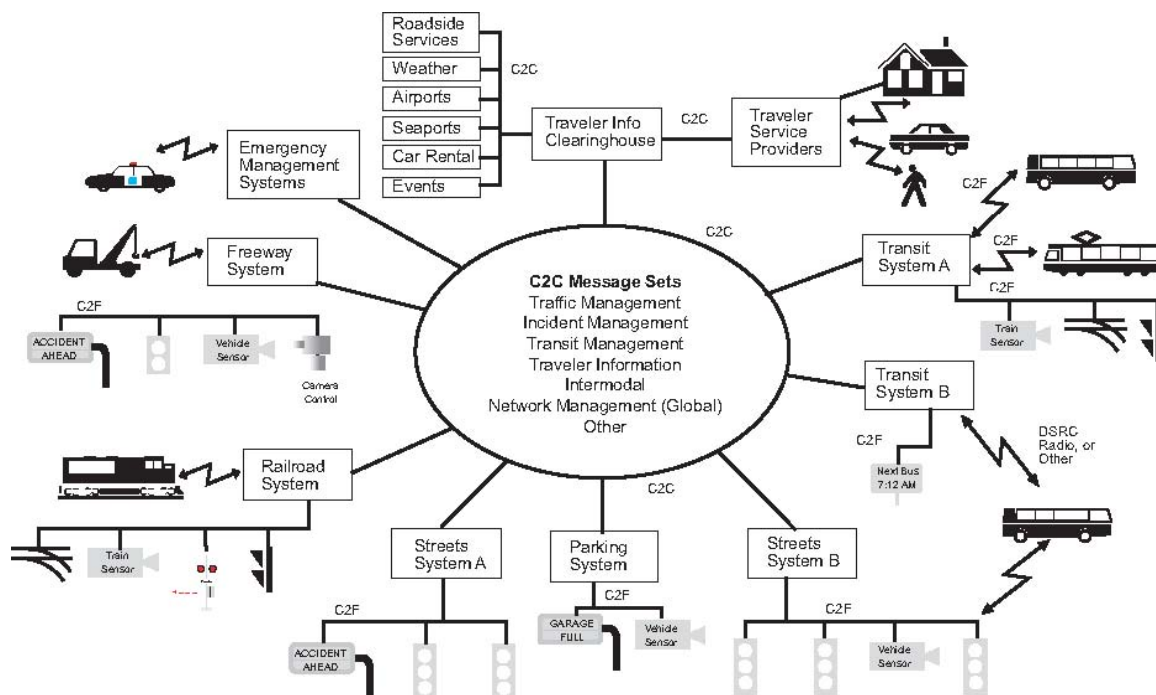
The following are examples of systems and devices that can take advantage of NTCIP:

a) C2F

- Dynamic message signs
- Traffic signals
- Field masters (closed loop systems)
- Data collection and monitoring devices such as traffic counter, traffic classifiers and weigh-in-motion stations
- On-board sensors and controllers
- Environmental sensors
- Ramp meters
- Vehicle detectors
- Closed circuit television cameras (camera control only)
- Video switches
- Highway lighting control

b) C2C

- | | |
|--|--|
| • Traffic management (freeway/surface street, urban/rural) | • Parking management |
| • Transit management (bus/rail/other) | • Traveler information (all modes) |
| • Incident management | • Commercial vehicle operations regulation |
| • Emergency management | • Any mix of these |



Communications Links/Systems not shown include Toll/fare collection, commercial vehicle regulation, on-vehicle, video, vehicle-to-vehicle, automated highway.

Legend: C2F=NTCIP Center-to-Field Protocol
C2C=NTCIP Center-to-Center Protocol

Figure 2 Example—ITS Integration Using NTCIP

Many applications of NTCIP are related to near real-time communications and involve continuous, automated transmissions of data or commands. NTCIP also supports human to-remote-machine/system transmissions. Historical data can also be sent using NTCIP, but other communication standards, especially electronic mail and file transfer protocols developed for the Internet, may also be suitable for this purpose. Human-to-human communications are generally better served by fax/telephone and Internet protocols, for example, e-mail, but basic support is also provided in the NTCIP C2C protocols.

2.2 APPLICATIONS NOT ADDRESSED BY NTCIP

The NTCIP family of standards is intended for use in all types of management systems dealing with the transportation environment, including those for freeways, traffic signals, transit, emergency management, traveler information, and data archiving. NTCIP is intended for fixed-point to fixed-point communications between computers in different systems or different management centers, and between a computer and devices at the roadside. Current NTCIP standards are not intended for use in devices owned by individual travelers; other standards either currently exist or are in development for those purposes.

Some of the data transfers involved in ITS have special needs that are the subject of other standards development efforts. The NTCIP effort is coordinating with the activities of these other groups to the extent practical. These other standards efforts include:

- A roadside device reading and/or writing to an electronic tag on a vehicle. This involves very fast and compact wireless data transfers over short distances of a few meters during the few milliseconds that a passing vehicle's tag is within that reception range. However, NTCIP is suited to C2F communications between the roadside tag reader and a central computer;
- Full motion video images transmitted from a camera or recorded media. This involves specialized protocols able to accommodate the large volume of continuous streaming information making up a video signal, and several such industry standards already exist, for example, NTSC. However, NTCIP

is suited to C2F transmission of video camera control commands and switch control data using a separate communications channel;

- c) Transmission of traveler information data to privately owned vehicles. This involves special broadcast and limited bandwidth protocols such as those that work in conjunction with the FM radio standards or cellular radio. However, NTCIP is suited to sending the information from various data sources to the traveler information service provider, using C2C communications;
- d) Communications for financial transactions. This involves special security measures not currently supported in NTCIP;
- e) In-vehicle communications for operations monitoring, advanced vehicle control, and safety. This involves specialized protocols for very high speed and fail-safe transmissions between devices housed on the same vehicle; and
- f) In-cabinet communications between a controller and other electronic devices in a roadside cabinet. This involves specialized protocols for very fast high-volume data transmissions over short distances. The ITS industry is currently addressing these requirements in the Advanced Transportation Controller (ATC) efforts, via three standards: the ATC Cabinet standard, the ATC Controller standard, and the ATC Application Programming Interface (API) standard.

Other communications standards are available, or under development, to serve each of these specialized needs.

2.3 RELATIONSHIP TO THE NATIONAL ITS ARCHITECTURE

The U.S. National ITS Architecture defines a common framework for ITS integration, and the ITS standards define how the system components operate within this framework. By specifying how systems and components interconnect, standards allow for interoperability. To expedite deployment of nationally interoperable ITS systems and services, the U.S. DOT supports specific ITS standards initiatives, especially in those areas that have significant public benefit.

The role of NTCIP in the National ITS Architecture is illustrated in Figure 3.

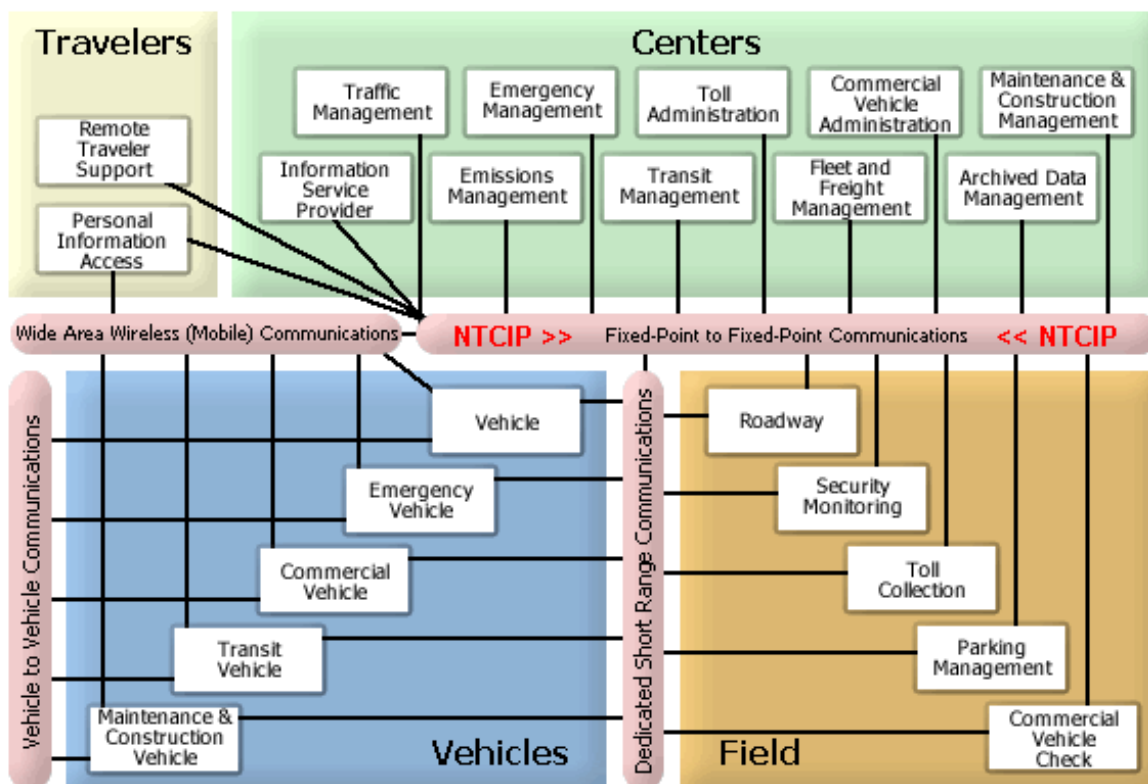


Figure 3 NTCIP and the U.S. National ITS Architecture

2.4 NTCIP FRAMEWORK

The NTCIP Framework, shown in Figure 4, uses a layered or modular approach to communications standards, similar to the layering approach adopted by the Internet and the International Organization of Standards (ISO). In general, data communications between two computers or other electronic devices can be considered to involve the following primary layers, called “levels” in NTCIP, to distinguish them from those defined by the International Organization for Standardization (ISO) and the Internet. The five levels are: information level, application level, transport level, subnetwork level, and plant level.

The levels in the NTCIP framework are somewhat different from communication stack layers defined by ISO’s Open Systems Interconnect (OSI) seven-layer reference model and other standards developing organizations. The OSI model breaks the communications process into seven well-defined layers. Each layer has a defined purpose, generally independent of adjacent layers. Although OSI communications protocols are not widely used, the layered model remains.

With the many diverse requirements of NTCIP, it is not surprising that the NTCIP family of standards looked at the ISO OSI Basic Reference model to help define its framework. However, the NTCIP stack extends beyond the communications stack to include informational data and interfaces to the physical communications infrastructure. The levels and terminology used in NTCIP were chosen for simplicity and ease of understanding by lay readers, and relevance to typical applications in the transportation industry. The OSI layers and terminology are often referenced in later technical sections of this publication and in many of the standards defined by NTCIP. Figure 5 shows how the NTCIP Information, Application, Transport, Subnetwork, and Plant Levels loosely relate to the OSI model.

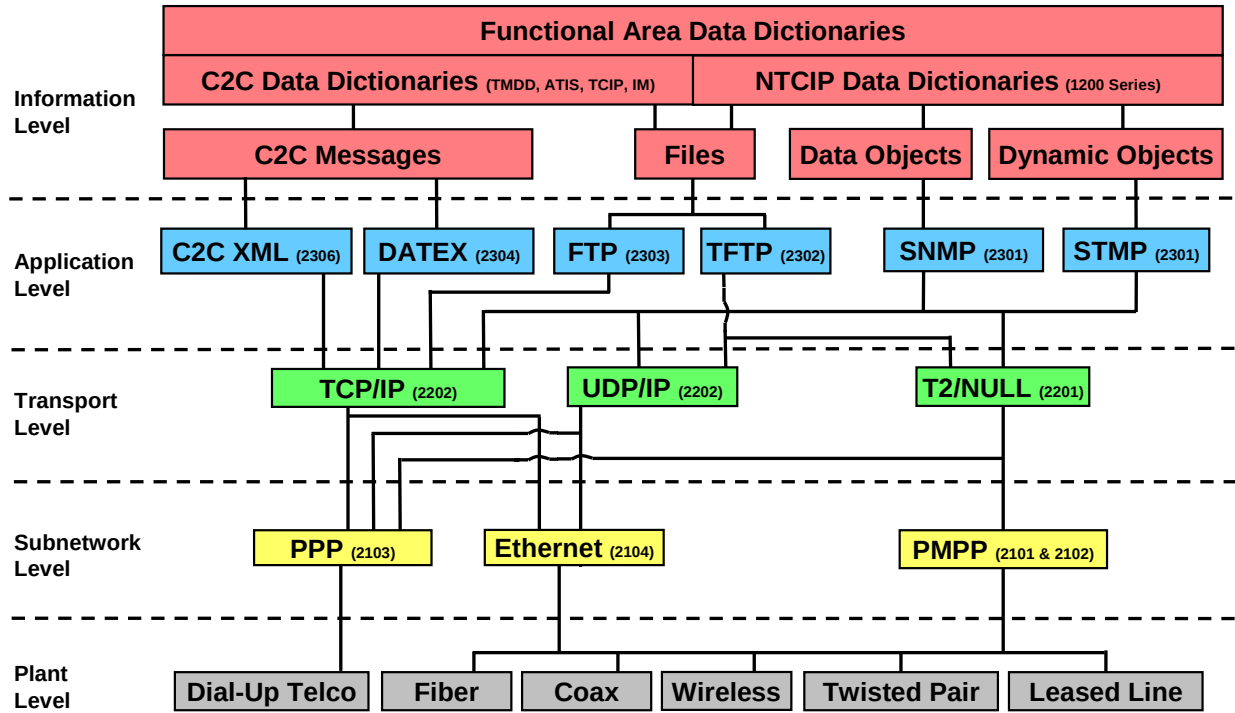


Figure 4 NTCIP Framework

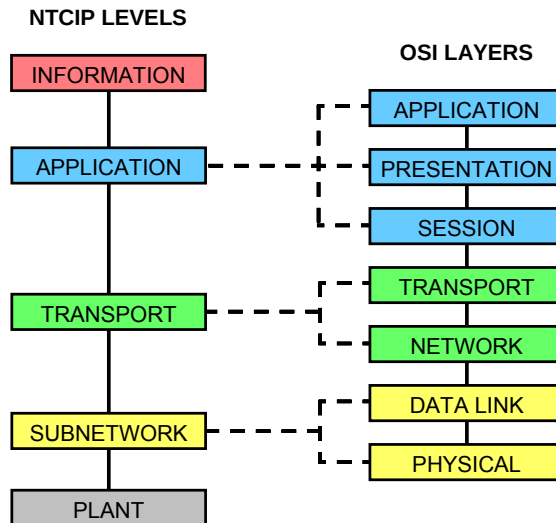


Figure 5 OSI Layer to NTCIP Level Mapping

- a) **NTCIP Information Level**—Information standards define the meaning of data and messages and generally deal with ITS information (rather than information about the communications network). This is similar to defining a dictionary and phrase list within a language. These standards are above the traditional ISO seven-layer model. Information level standards represent the functionality of the system to be implemented.
- b) **NTCIP Application Level**—Application standards define the rules and procedures for exchanging information data. The rules may include definitions of proper grammar and syntax of a single statement, as well as the sequence of allowed statements. This is similar to combining words and phrases to form a sentence, or a complete thought, and defining the rules for greeting each other and exchanging information. These standards are roughly equivalent to the Session, Presentation and Application Layers of the OSI model.
- c) **NTCIP Transport Level**—Transport standards define the rules and procedures for exchanging the Application data between point 'A' and point 'X' on a network, including any necessary routing, message disassembly/re-assembly and network management functions. This is similar to the rules and procedures used by the telephone company to connect two remotely located telephones. Transportation level standards are roughly equivalent to the Transport and Network Layers of the OSI model.
- d) **NTCIP Subnetwork Level**—Subnetwork standards define the rules and procedures for exchanging data between two 'adjacent' devices over some communications media. This is equivalent to the rules used by the telephone company to exchange data over a cellular link versus the rules used to exchange data over a twisted pair copper wire. These standards are roughly equivalent to the Data Link and Physical Layers of the OSI model.
- e) **NTCIP Plant Level**—The Plant Level is shown in the NTCIP Framework only as a means of providing a point of reference to those learning about NTCIP. The Plant Level includes the communications infrastructure over which NTCIP communications standards are to be used and has a direct impact on the selection of an appropriate Subnetwork Level for use over the selected communications infrastructure. The NTCIP standards do not prescribe any one media type over another. In most cases, communications media selections are made early in the design phase.

Deployers should select and specify at least one NTCIP protocol or profile at the information, application, transport and subnetwork level for a system.

The NTCIP Framework does not preclude combinations beyond those expressly indicated on the diagram. For example, some C2C deployments are exchanging eXtensible Markup Language (XML) messages across Data Exchange Protocol (DATEX). Also, device deployments have implemented a protocol stack of Data Objects → SNMP → T2/Null → PMPP → Dial-Up Telco.

To ensure a working system, deployers should select and specify at least one NTCIP protocol or profile at each level. A discussion of each level, and NTCIP standards that apply at that level, follows.

A complete and current list of the protocols and profiles defined by the NTCIP family of standards can be found at www.ntcip.org.

2.5 PROTOCOL STANDARDS—NTCIP 1100 SERIES

The NTCIP 1100 series of standards are the protocol, cross-cutting foundation standards that may be referenced by any other NTCIP standard. These standards are not shown on the NTCIP Framework.

2.6 INFORMATION PROFILES—NTCIP 1200 SERIES

The NTCIP 1200 series of standards defines the information content between a management center and a field device, or other center. The data element definitions may include syntax, allowable ranges, and may also include valid sequences for transmitting data elements.

NOTE—NTCIP 1201 v03, Global Object (GO) Definitions, is considered a supporting standard, not a primary standard, because NTCIP 1201 v03 can be used for multiple types of field devices.

2.7 APPLICATION PROFILES—NTCIP 2300 SERIES

NTCIP application profiles can be categorized into three areas: application profiles specific to C2F communications, application profiles specific to C2C communications, and application profiles adopted directly from the Internet (per the Internet Engineering Task Force (IETF)).

2.7.1 Application Profiles for Center to Field (C2F) Communications

As of the publication of NTCIP 9001 v04, two application profiles are supported by NTCIP for C2F communications, Simple Network Management Protocol (SNMP) and Simple Transportation Management Protocol (STMP).

2.7.1.1 SNMP Overview

SNMP is a communication protocol widely used in computer networks for managing network devices. For transportation communications, SNMP is the essential protocol 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 access the field device appropriately.

Stacks based on SNMP provide a simple, but bandwidth inefficient, protocol for C2F applications, based on the Internet protocol of the same name (SNMP). It is suitable only for networks with high bandwidth, or low volumes of messages. SNMP has been designed by the Internet community to run over User Datagram Protocol/Internet Protocol (UDP/IP), but SNMP can be forced to run over Transmission Control Protocol/Internet Protocol (TCP/IP) or T2/NULL.

2.7.1.2 STMP Overview

STMP is an extension of SNMP in which the central system and the field device dynamically establish composite messages (typically when they are first connected) made up of a set of the field device data elements. The composite messages are still sent using SNMP but with greatly reduced overhead over sending the data elements individually. STMP is ideal for low-bandwidth communication media such as 9600 serial communication.

STMP was developed specifically for use in the transportation industry. It is an extension of SNMP that allows C2F messages to be sent more efficiently using dynamic composite objects. Stacks based on this protocol are suitable for networks with low bandwidth and high volumes of messages, including such traffic signal systems where a central computer is directly connected to field devices, without the need to route the information through some other device such as an on-street master in a closed loop system. STMP has been designed to run over T2/Null since STMP supports low bandwidth links, but STMP could also be used over UDP/IP or TCP/IP if sufficient bandwidth is available.

2.7.1.3 Comparison of SNMP and STMP

NTCIP provides two application level protocol choices for C2F communications: the Internet’s SNMP and STMP. These base protocols use the get/set messaging paradigm used in SNMP. These choices use the same base data elements, as defined in the NTCIP 1200 series of standards. They differ in the level of complexity to implement and the types of services offered. Table 1 summarizes the services offered and implementation requirements.

Table 1 Center to Field (C2F) Protocol Comparison

	SNMP	STMP
Can send any base data element?	Yes	Yes
Bandwidth Efficiency – inverse of packet overhead	Worse	Better (uses dynamic objects)
Supports routing & dial-up	Options	Options
Message Set	Supported	Limited to 13
Ease of Implementation	Easier	Harder

STMP is the most bandwidth efficient option currently available and includes full support of SNMP for infrequent messaging demands. It includes SNMP as a subset, so that any management system that implements STMP can also communicate with a device that supports only SNMP. It also requires the use of SNMP to define dynamic objects. Occasional messages requiring additional security can be sent using SNMP. The greatest advantage of STMP is its support for dynamic objects which, when combined with a more efficient encoding scheme, dramatically reduce the packet overhead relative to SNMP. Dynamic objects also enable users to define custom messages that are composed of any number of individual data elements. However, these data elements have to be defined in both the central computer and the field devices to work properly. STMP is the most flexible and bandwidth efficient option.

2.7.1.4 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.

See Annex C for more information on traps and exception based reporting.

2.7.1.5 Data Encoding

Data encoding refers to the procedures for representing the bits and bytes representation of information content to be transferred. For C2F communications, data encoding of information is governed by:

- a) **Basic Encoding Rules (BER)**—BER is a series of procedures for the representation of data octets to be transferred. BER is used only in conjunction with the SNMP Application Profile; and
- b) **Octet Encoding Rules (OER)**—OER is a variation of BER developed for use on low bandwidth communications links. OER can be used in conjunction with the SNMP and STMP Application Profiles.

2.7.1.6 Data Transmission

Data transmission for C2F communications is handled by the Transport and Subnetwork profiles.

2.7.2 Information Profiles for Center to Center (C2C) Communications

To date, NTCIP has not developed an information profile for C2C communications. Other standards development organizations have developed functional area data dictionaries that can use NTCIP

standards for communications. The functional area data dictionaries (TMDD, ATIS, TCIP, IM) are shown on the NTCIP framework diagram and described briefly as:

- a) TMDD—The TMDD Standard for Traffic Management Center-to-Center Communications covers the functional area of traffic management, and is a joint standard of ITE and AASHTO.
- b) ATIS—The Message Sets for Advanced Traveler Information Systems, SAE J2354, is a standard of the Society of Automotive Engineers.
- c) TCIP—The Transit Communications Interface Profile (TCIP) is an American Public Transit Association (APTA) standard to allow transit agencies and transit suppliers to create standardized tailored interfaces. TCIP is based on the earlier NTCIP 1400-series standards.
- d) IM—The incident management (IM) standards of IEEE, IEEE 1512 series, have been developed to standardize communications between transportation and emergency management centers.

2.7.3 Application Profiles for Center to Center (C2C) Communications

C2C communications require a peer-to-peer network connection between the involved computers. This is typically a local area network, a wide area network, or a dial-up connection. Local area networks typically use agency-owned twisted pair cable or fiber optic cable. Wide area networks typically use commercial telecommunications links such as frame-relay, fractional T1 leased lines, packet radio, or leased “virtual private networks.” Dial-up connections typically use ISDN, V.90, or similar modems over “plain-old telephone” lines. Any type of communication link can be used, as long as it enables use of the Internet transport and routing protocols (TCP/IP and UDP/IP) and has sufficient bandwidth for the planned communications load to achieve the desired operational performance—based upon frequency, size of messages to be exchanged, and latency issues encountered when using C2C systems).

At publication, NTCIP supports two application profiles for C2C communications; DATEX and XML. NTCIP previously supported a third application profile, CORBA; however, that standard was withdrawn.

2.7.3.1 DATEX Overview

DATEX, commonly referenced as “Application Profile for DATEX-ASN (AP-DATEX),” is referenced in ISO 14827. ISO 14827 defines the rules for message exchanges, encoding, and transport for ASN.1-based communications definitions. DATEX is based on the assumption that two centers are always connected. Therefore, common dialogs for connecting, logging in, and disconnecting are defined and required. Once connected, two centers share information using a request-response message pattern or subscription-publication pattern.

DATEX was designed to provide simple, resource-effective solutions for basic needs. It is especially well suited for:

- a) Systems requiring real-time, fast data transfer, for example, traffic signal status data;
- b) Systems with limited communications bandwidth, but high data transfer load;
- c) Systems with infrequent event-driven exchanges over dial-up links; and
- d) Non-object oriented systems.

C2C networks allow each system to request any available information from any or all other systems. Each system can be configured to either accept or reject any request. The “data” sent can be informational or can constitute a “command” to take some action. Consider a message sent from one traffic signal system to another and containing a signal timing pattern number. In DATEX, for example, depending on the message type, the message could represent a command to implement that timing pattern at a particular traffic signal or group of signals, or the message could represent a status report indicating that this timing pattern was just implemented at a particular traffic signal or group of signals.

The user can also establish standing subscriptions for data, if the user wants the same data sent repeatedly. In DATEX, these subscriptions can specify that data be sent one-time-only, periodically, or repeatedly on occurrence of some event as defined in the subscription. Each subscription message has a corresponding publication message. Unless the subscription is a one-time request, the data continue to

be automatically “published” repeatedly until the subscription is cancelled, or until a predefined end date specified in the subscription.

2.7.3.2 C2C XML Overview

The application profile for C2C XML is based on the rules of message encoding and transport of the W3C’s (World Wide Web Consortium) Web Services Architecture. C2C XML provides a way to define messages (using XML Schema) and dialogs (using the Web Services Definition Language (WSDL)).

C2C XML provides a way to specify WSDL for the following combinations of message encoding and transport:

- a) **Simple Access Application Protocol (SOAP)**—Using SOAP encoded messages over the hypertext transfer protocol (HTTP), centers are able to describe and deploy center interfaces that support the request-response and subscription-publication message patterns.
- b) **eXtensible Markup Language (XML)**—Using XML encoded messages over HTTP, centers are able to describe and deploy interfaces that support the request-response (via HTTP POST), AND request-only message patterns (via HTTP GET and file transfer protocol (FTP)).

2.7.3.3 Comparison of DATEX and Center to Center (C2C) XML

NTCIP provides two alternative application level protocol choices for C2C communications, DATEX-ASN and C2C XML. These two different protocols were found necessary to meet the variety of requirements for inter-system data exchanges. Table 2 provides a comparison between the two application profiles.

Table 2 Center to Center (C2C) Protocol Comparison

	DATEX	C2C XML
Support for Message Sets	Yes	Yes
Bandwidth Efficiency – inverse of packet overhead	Better	Worse
Ease of Implementation	Harder	Easier

2.7.3.4 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.

2.7.3.5 Data Encoding

Data encoding refers to the procedures for representing the bits and bytes representation of information content to be transferred. In C2C communications, messages are encoded into the bit-byte representation prior to the start of network transfer regardless of how the information is represented in the originating and destination systems. The message encoding formats of C2C XML and DATEX are described as:

- a) **C2C XML**—specifies two information encoding formats: XML and SOAP, both standards of the W3C, and an encoding format for compression, GZip, a standard of the IETF.

- b) **DATEX**—specifies information encoding of ASN.1. These include Basic Encoding Rules (BER) and NTCIP 1102:2004, Octet Encoding Rules (OER) Base Protocol. In addition, projects have been encoding message content as XML.

2.7.3.6 Data Transmission

Data transmission for DATEX and C2C XML is supported by TCP/IP. In both cases a well-known socket is defined and used by TCP/IP. The data transmission mechanisms (TCP/IP applications) used in DATEX and C2C XML are described below:

- a) **C2C XML**—describes two message transport mechanisms: HTTP and FTP, both standards of the IETF.
- b) **DATEX**—specifies a transport mechanism based on the TCP Socket API. Clients and servers exchange messages in DATEX over TCP Socket 355.

2.7.4 Application Profiles Adopted from the Internet

2.7.4.1 File Transfer Protocol (FTP)

File Transfer Protocol (FTP) is a widely used protocol to exchange files between computing devices. It uses TCP.

2.7.4.2 Trivial File Transfer Protocol (TFTP)

Trivial File Transfer Protocol (TFTP) is a protocol used to exchange files between computing devices. It is less capable than FTP. TFTP uses UDP.

2.8 TRANSPORT PROFILES—NTCIP 2200 SERIES

NTCIP C2F protocol stacks can be used in management systems of any configuration or complexity. If the Transmission Control Protocol/User Datagram Protocol Internet Protocol (TCP/UDP IP) transport standards are implemented, then support for message routing through intermediate communications hubs or field masters is inherently included. However, a particular implementation of a C2F protocol stack may not provide support for such immediate or future options unless specifically requested at the time of procurement.

2.8.1 Transmission Control Protocol/Internet Protocol (TCP/IP)

TCP/IP is made up of two protocols, Transmission Control Protocol (TCP) and Internet Protocol (IP). TCP/IP is the most widely used protocol for internet communications. TCP/IP is used for routed networks that require a reliable protocol. A reliable protocol, in this context, means that the protocol attempts to detect and recover from transmission errors. The additional reliability also results in reduced efficiency due to overhead within the packet and more processing required. SNMP performs error handling at the application level, making UDP/IP sufficient for most NTCIP applications that use routed networks.

2.8.2 User Datagram Protocol/Internet Protocol (UDP/IP)

UDP/IP is made up of two protocols, User Datagram Protocol (UDP) and Internet Protocol (IP). 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 should be done at a higher layer. Because of this, UDP/IP communications are more efficient than TCP/IP due to reduced overhead and processing requirements. UDP/IP is recommended for NTCIP in routed networks unless the application explicitly requires TCP/IP.

2.8.3 T2/NULL

T2/NULL is a non-routed serial communication protocol. T2/Null provides multiplexing on a single serial channel and works with half or full duplex.

2.9 SUBNETWORK PROFILES—NTCIP 2100 SERIES

Devices that use any particular subnetwork protocol can share the same communications line with other devices using the same subnetwork protocol. It doesn't matter whether such devices are from different manufacturers or are totally different devices, for example, a traffic signal and a dynamic message sign. Each device is assigned an address that is unique on that line or channel. The management system can communicate with any of the devices at any time by sending a message addressed to that device. However, when using Point-to-MultiPoint Protocol, the management system can communicate with only one of the devices on the line or channel at a time. As a function of SNMP and STMP, devices can only send a message to the management system when requested to do so by the management system. NTCIP protocols enable broadcast messages intended for all devices, for example, a time clock update. No devices can reply to a broadcast message. At present, NTCIP devices cannot communicate peer-to-peer with each other exclusive of a central facility. The identification of needs and requirements for this capability are under consideration.

2.9.1.1 Ethernet

This subnetwork profile specifies the provisions for a connectionless and connection-oriented data link service and the physical interface between an end system and other compatible end systems. It has specific reference when these services are used through the Internet Protocol (IP) connectionless network service. "Ethernet" is somewhat of a misnomer. More precisely, NTCIP network-type communications are based on IEEE 802 network communications, which are similar to Ethernet but also include Logical Link Control (LLC) and Media Access Control (MAC) layers.

2.9.1.2 Point-to-Point Protocol (PPP)

Point-to-Point Protocol (PPP) is a protocol that operates in a point-to-point configuration where exactly two devices (called peers) are connected by a communications link. PPP is intended to provide an interoperability standard for transportation related devices for dialed-up circuits using V Series Modems.

2.9.1.3 Point-to-Multipoint Protocol (PMPP)

Point-to-Multipoint Protocol (PMPP) is a protocol that operates in a primary/secondary configuration where one device is the designated primary while one or more other devices are connected to one communication channel acting as secondaries. PMPP is intended to provide an interoperability standard for transportation related devices using frequency shift keying (FSK) modems.

2.9.1.4 Communication Links Using Tunneling

Tunneling describes the encapsulating or embedding of one protocol within another. A common example is tunneling of PMPP through an Ethernet network. In this example, both the central management station and the field device are "talking" PMPP, but at least part of the link between them involves encapsulating the PMPP packets within Ethernet packets. A device called a terminal server (also called an Ethernet-serial converter, port server, or other name) is used to convert the PMPP serial data to and from Ethernet. At the management station, this conversion may be performed within software on a computer in a process often called (serial) port replication. This avoids the need for multiple serial ports and terminal servers at the management station.

When serial data are tunneled through an Ethernet network, each field device (e.g., controller) may have its own terminal server (the Ethernet network extends to each cabinet). Some field devices may even have a terminal server built into the device. Alternatively, multiple field devices may share a serial multi-drop channel with one terminal server for the channel. In any case, field devices still communicate via a serial port.

As long as the protocol conversion devices or processes and the Ethernet network have adequate buffering, reliability, and low latency, such tunneling can be considered part of the physical layer and has no impact on the NTCIP-related project requirements. Both the management station and the field devices operate as if using a direct Point-to-Multipoint Protocol serial channel without the intermediate protocol conversion.

The NTCIP Framework (see Figure 4) does not attempt to illustrate the use of tunneling.

Tunneling of serial communications via an Ethernet network is quite different from using an end-to-end Ethernet link between the management station and a field device. The latter does not involve serial communications or conversion between protocols. In this case, the field device has a built-in Ethernet port and native support for the Ethernet protocol and related protocols such as TCP, UDP, and IP.

2.10 OTHER NTCIP SERIES STANDARDS

The NTCIP 8000-series documents cover Process, Control & Information Management Policy. The NTCIP 9000-series documents are informational reports.

NOTE—The previously-designated NTCIP 1400-series standards are transit standards, which were moved to APTA and are no longer maintained by or under NTCIP.

2.11 USING THE NTCIP FRAMEWORK

When a user wants to deploy an NTCIP-based system, the user chooses the protocols the user wants to deploy. A stack is a subset of the overall NTCIP framework—a selected route through the levels, given the choices available. Some stacks include two standards at some levels, which usually mean the protocol can use either of the optional standards. NTCIP protocols generally offer further options within most of the standards. The highlighted portion of Figure 6 illustrates an example of a C2F protocol stack choice that can be defined using NTCIP standards. Additional examples are included in Annex D.

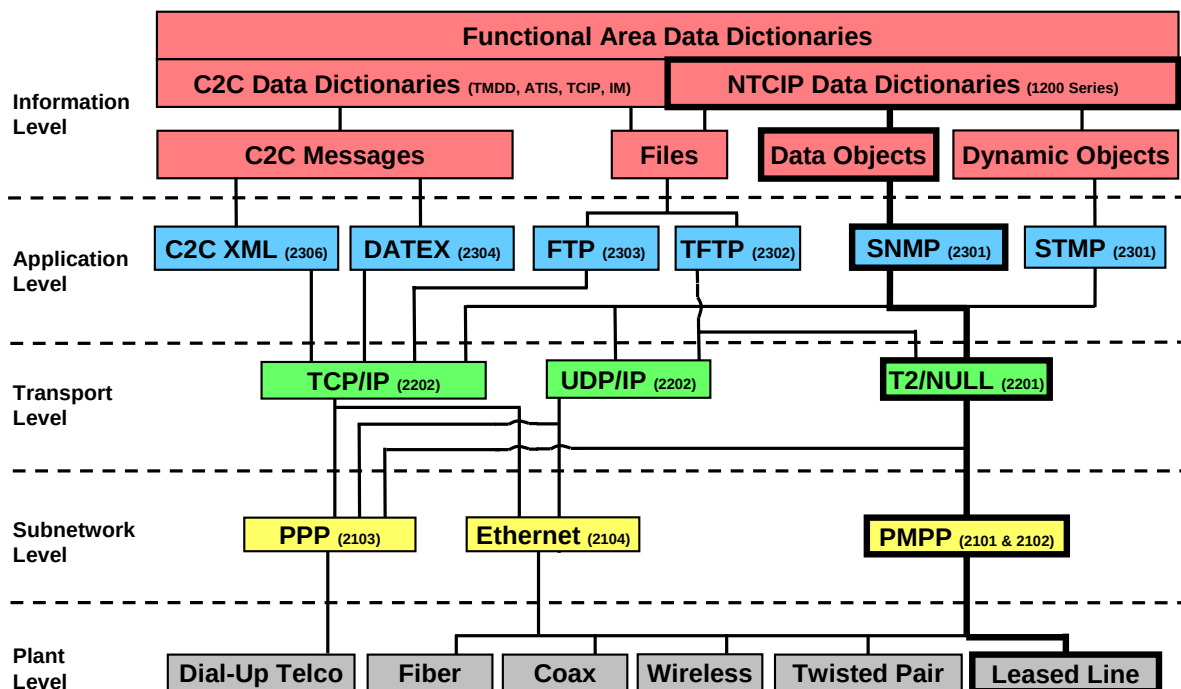


Figure 6 Example—Center to Field (C2F) Stack

The process flowchart defined in Figure 7 can help determine which NTCIP communication profiles should be used in different systems and different communications networks. The colors and document numbers in Figure 7 correspond with the NTCIP Framework diagram (see Figure 4).

The flowchart in Figure 7 can guide the user, specification writer, or developer when selecting the most appropriate NTCIP standard to use when specifying different communications infrastructure and field devices. In Figure 7, diamond shapes identify the decision points. The progression of decision points are identified by a number in brackets, for example [1]. Boxes with a curved bottom line represent documents, namely the NTCIP standards publications. These boxes are color-coded to correspond with the colors of the NTCIP Framework diagram (Figure 4): blue for application level standard, green for transport level, and blue for subnetwork level. Agency specifications should identify the major version number for each NTCIP standards publication they wish to use. The ovals represent the start point and end point of the decision path taken for selecting the NTCIP standards publications.

Further explanation of the questions and considerations within each decision point follows:

- a) **Device Uses Ethernet [1]?**—Is the primary communications port on the device an RJ-45 connector? If the answer is YES, it should be verified that the device is not using an internal terminal server, which could accept an Ethernet data packet, but internally strips the Ethernet header/footer to deliver a serial data packet to the field device application. If the device does not use Ethernet communications, then the answer is NO. If the answer is NO, then proceed with the question “Device Uses Serial [2]?”.
- b) **Device Uses Serial [2]?**—If the answer to the first question (Ethernet) is NO, then the device uses a serial interface, a dial-up interface, or a non-NTCIP-defined interface. If the device is supposed to conform to NTCIP, then the answer is YES. If the device is something different, then the answer is NO. If the answer to the first question (Ethernet) is NO, and the answer to this question (Serial) is NO, then there are no NTCIP standards for the communications configuration in question.
- c) **Using Dial-Up [3]?**—If the answer to the second question (Serial) is YES, the device uses either a serial interface or a dial-up interface. If the device uses an RS-232 interface, then it is likely that the answer is NO. If the device has an internal dial-up modem or connects to an external dial-up modem, then the answer is YES.
- d) **FSK Modem [4]?**—If the interface to the device is serial, the user decides whether an FSK modem (also known as Bell 202) is to be used. Even though an external FSK modem, which typically contains a regular RS-232 port into the device, is used, a user could decide to answer this question NO. If external FSK modems are used on both ends, the answer is also NO. It is a matter of where NTCIP conformance is measured, on the outside or the inside of the external FSK modem.
- e) **File Transfer Required [5]?**—There is currently no NTCIP-conformant device type that solely operates using a file transfer mechanism. Agencies deploying a system should ask the central system developer and field device vendors to determine whether a particular system requires file transfers. If the system requires file transfers, the answer is YES; otherwise, the answer is NO.
- f) **Ack Required [6]?**—A decision has to be made whether UDP/IP or TCP/IP is to be supported. If the file transfer protocol is FTP, then the answer is YES. If TFTP is to be supported, then the answer is NO. FTP is more commonly used but FTP requires more communication bandwidth and more processing capabilities. If neither FTP nor TFTP are used, either TCP or UDP may be used; however, UDP is recommended due to the improved efficiency.
- g) **STMP Required [7]?**—STMP is a protocol that is only supported by Actuated Signal Control (ASC) devices at this time. The need to use STMP is based on system bandwidth requirements and the media used.

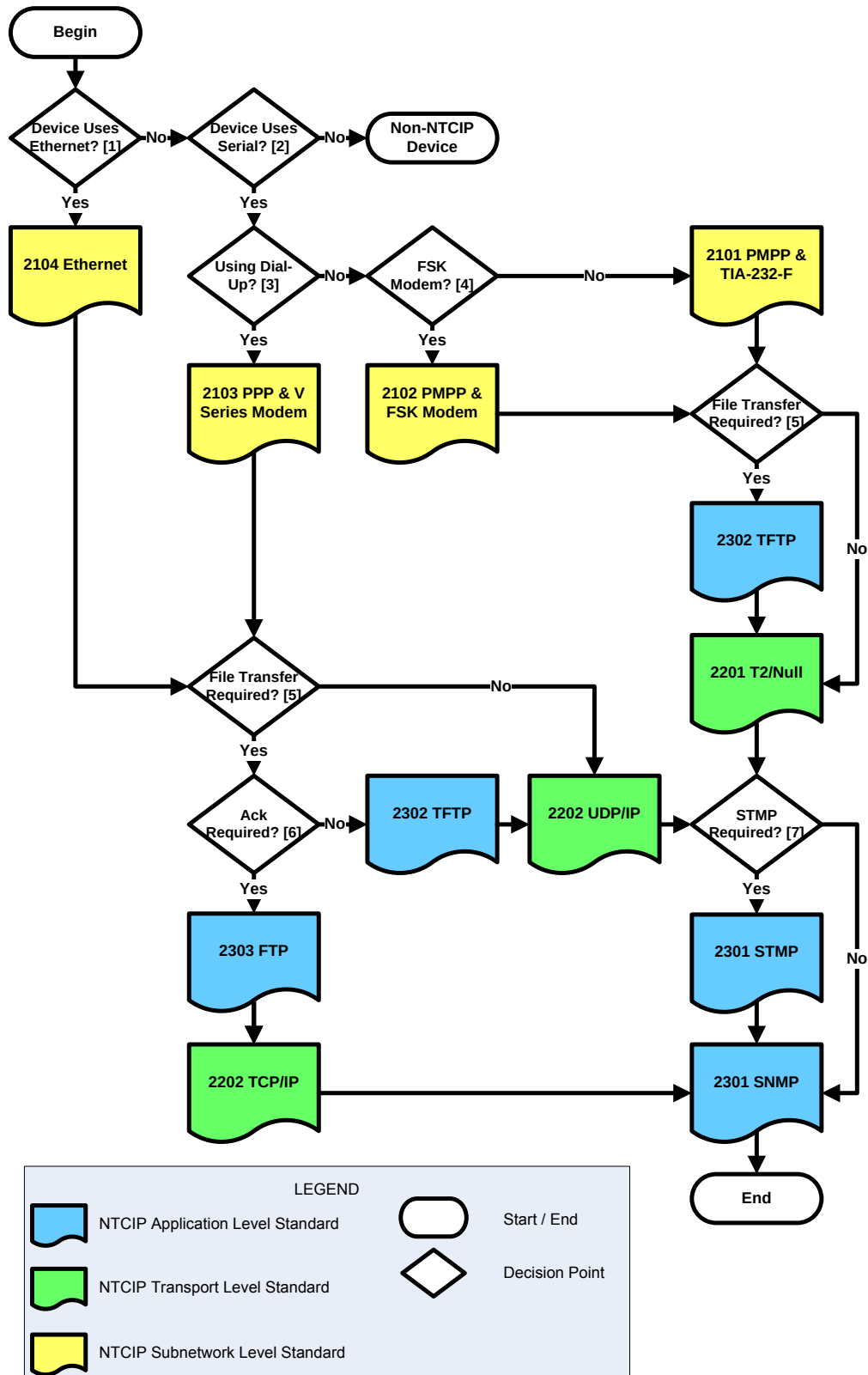


Figure 7 NTCIP Profile Selection Flowchart

Figure 8 illustrates an example C2C protocol stack choice that can be defined using the NTCIP standards. Additional examples are included in Annex D.

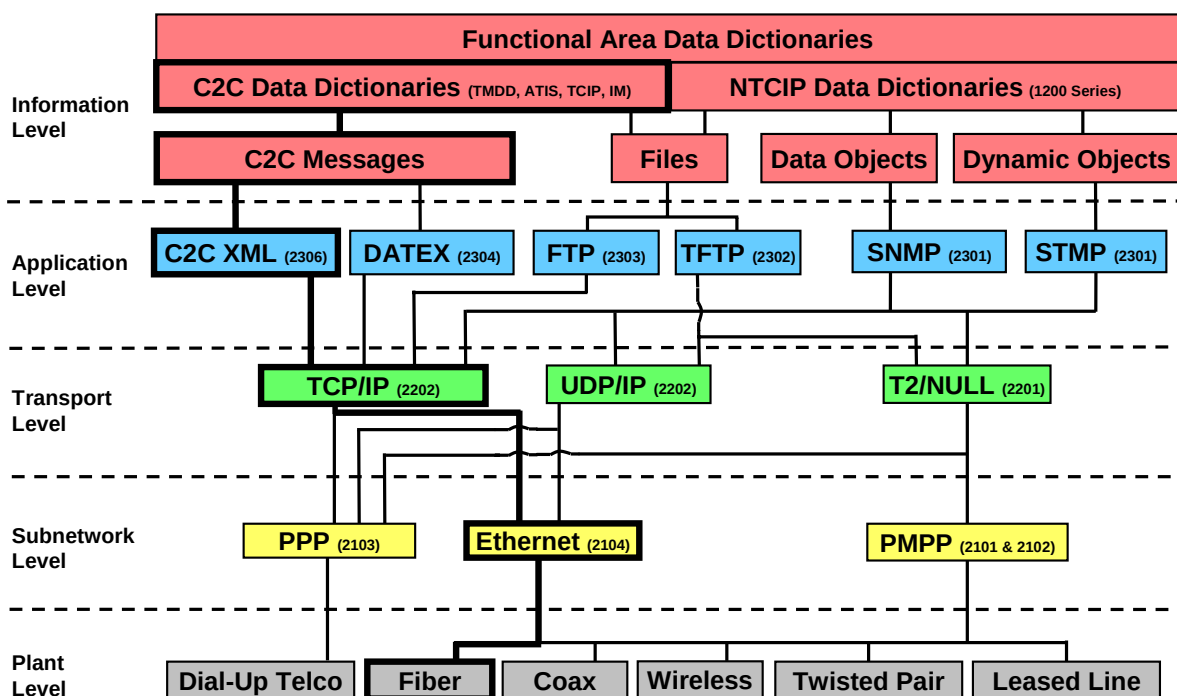


Figure 8 Example—Center to Center (C2C) Stack

2.12 CONFORMANCE

Each NTCIP standard contains a section addressing “Conformance” which clearly states the requirements for conformance to the standard by implementations that embody that standard. The ease or difficulty of determining conformance depends on the complexity of the standard and the resulting implementation.

- **Standards Conformance**—When an item fulfills all of the mandatory requirements as defined by a standard.
- **Specification Compliance**—When an item fulfills all the requirements of an agency specification.

Conformance differs from compliance. The term compliance is most often used in contractual language to assess the legal determination of meeting or not meeting an agency’s specifications of the contract. An agency creating a specification, based on NTCIP standards, is necessary to ensure that all optional elements in the standard are required for your deployment. An agency specification allows for the explicit removal of optional elements of the NTCIP standards that do not apply.

Therefore, while a vendor may state that their devices are “NTCIP conformant,” meeting conformance with the minimal mandatory requirements of an NTCIP standard may not be sufficient to fulfill agency project requirements, or to achieve compliance with an agency specification.

2.13 OPTIONS AND CONFORMANCE LEVELS

In addition to specifying a protocol stack, the system designer should also choose between alternatives available in the selected stack. These options exist in both C2C and C2F protocol stacks. Major options, such as which protocol(s) to support at each level in the communications stack, are sometimes grouped according to conformance levels, while others are individually selectable. Most manufacturers and system

suppliers typically offer features that go beyond the standard. To make use of such features, it is necessary to specify the inclusion of manufacturer-specific data elements or messages as extensions of the standards when procuring a management system.

An agency decision to use features above and beyond the standard should be made only with the understanding of the potential impacts. These impacts could be considerable in the long term. These options may, in effect, result in the acquisition of proprietary systems. Part of the agency decision should include the number of such features allowed.

Details on options and conformance levels, and how to specify your selection, are presented in later sections of *The NTCIP Guide*.

Section 3 PROCURING NTCIP

3.1 INTRODUCTION

Procuring transportation related systems that use NTCIP communications involves additional considerations beyond what is required for non-NTCIP systems. When procuring systems that use proprietary non-NTCIP communications, the system vendor is normally responsible for ensuring that both ends of the communications link can communicate and support system features. In contrast, when procuring NTCIP systems, the agency is responsible for specifying the appropriate NTCIP communications requirements. It is not sufficient to simply say, "The device shall be NTCIP compliant." Section 3 describes the additional procurement considerations for specifying NTCIP communications requirements.

Agencies acquiring transportation transportation-related systems want the system to have specific features that meet agency requirements. For a system feature to be available across a communication link, the components on each end of the link should support that feature and also support communications related to that feature. The goal of the communications portion of an agency specification is to ensure that communications support the desired features and that both ends of the communications link are compatible with each other.

Section 3 describes how to identify which NTCIP standards are applicable and how to generate the communications portion of an agency specification. Section 3 also highlights some agency specification considerations that are not unique to NTCIP.

3.2 DETERMINING APPLICABLE NTCIP STANDARDS

NTCIP is a family of standards addressing different levels or layers of the communication hierarchy. This hierarchy, with associated series of NTCIP standards, is described in Section 2. For C2F applications, a good starting place for defining NTCIP requirements is at the information level using an NTCIP 1200-series standard. For C2C applications, the information level standards are defined outside of the NTCIP program, and an agency should refer to the appropriate standard for information on how to specify the information level. Therefore, the NTCIP portion of an agency specification for C2C should begin at the application level.

3.3 DEVELOPING NTCIP SPECIFICATIONS

If an agency is planning to prepare detailed specifications for NTCIP-based systems, the agency should select the appropriate standards from each level within the NTCIP Framework. To effectively make these selections, a good understanding of agency resources and operational capabilities is needed, as well as any existing communications constraints, such as existing communications infrastructure and equipment. System requirements describe a set of desired functionality that satisfies an agency's operational and user needs plus communications and infrastructure constraints.

Specifications for NTCIP communications are just one part of a complete agency specification.

NTCIP communications specifications are just one necessary part of the specification an agency produces to procure a transportation-related system. Other specifications include: the physical construction, environmental requirements, installation requirements, testing requirements, warranties, etc.

Section 4 describes the systems engineering process (SEP) that is helpful to follow when procuring a complex system. NTCIP communication requirements derive from an agency's operational and user needs. If an agency intends to procure a commercial off the shelf (COTS) system rather than specify a

custom designed system, the agency should compare their communications and non-communications requirements with the capabilities of commercially available ITS devices before finalizing an agency specification.

Many NTCIP standards are designed around SEP. Section 4 describes how to produce an agency specification for NTCIP communications standards. Other NTCIP standards are not designed around SEP. The following process describes how to produce an agency specification for NTCIP communications standards.

To effectively prepare detailed agency specifications for an NTCIP-based system, the systems planner/specification writer should consider and document the agency's functional and operational needs, so that a deployed system satisfies those needs.

Some of the newer NTCIP standards are designed around a systems engineering process. Section 4 addresses how to specify those NTCIP standards using the systems engineering process.

The next step in the process is to identify the mandatory and optional elements within each NTCIP standard that are needed to ensure that an agency's identified functionality needs are met. An optional element in an NTCIP standard that is required for an agency project becomes mandatory in an agency specification. The optional and mandatory elements of an NTCIP standard are documented in its Profile Requirements List (PRL), which an agency should tailor to satisfy a particular project's needs.

NOTE—Earlier versions of NTCIP standards contained conformance groups, which PRLs replace.

PRLs, in turn, define the “features” of NTCIP standards. These features of NTCIP standards enable the requested functionality within an implementation. Using a top-down approach, the system's functional requirements determine which elements of the PRL (previously conformance groups) are mandatory to provide the features that enable that stated functionality.

Once the applicable requirements are selected, and their included data element/object sets are identified, realistic value ranges are defined for each of the data elements, or data objects. These value range choices are based on the functional requirements of agency device specifications. It is important to remember that detailed NTCIP design elements can, and should be, tailored to meet the intended needs of the system being implemented. Otherwise, an agency may expend resources unnecessarily to acquire more functionality than is truly needed.

An entire NTCIP *stack* should be defined, with identification of NTCIP (or other) standards required at each level. This process should be repeated for each level of the NTCIP framework. NTCIP standards that are not designed around SEP contain an information profile listing the conformance groups with their objects. An agency can use this profile to select which conformance groups and objects are required. This completed form is then called a Profile Implementation Conformance Statement (PICS). An agency should use this completed form to specify the NTCIP communications requirements of the system.

If the system or ITS device being procured are to interface with an existing system, the agency may want to include a copy of the existing MIB as part of the agency specification to ensure compatibility of both ends of the communications link. Examples of this situation include adding new field devices to an existing central system or upgrading a central system to operate with existing field devices.

The process for NTCIP standards that are designed around SEP is slightly different and is described in Section 4.

3.4 ADDITIONAL PROCUREMENT CONSIDERATIONS

The project scope, deliverables and agency specifications should also include information related to hardware and/or devices, systems integration, testing and device configuration. Agency specifications

should also address the ownership, re-distribution and/ or re-use rights of the MIB, as well as requirements for documenting and obtaining the MIB.

Agency specifications should address ownership, re-distribution, documentation and/or re-use rights of the MIB.

Agencies should obtain final electronic and paper copies of the MIB(s) used in their system, including both standardized data elements and manufacturer-specific data elements. Re-distribution and/or re-use rights should be clearly spelled out at the onset of the project so that future expansion and integration issues can be minimized. Overall, a comprehensive set of system requirements, as well as design and other elements of agency specifications, helps the system/hardware implementation proceed more smoothly and with less ambiguity.

3.4.1 Software Acquisition

When agencies move to implement or upgrade center-based systems, the bulk of the work involves the acquisition of software. In the case of C2C communications, software is developed to provide a means of communicating between two central systems.

The National Highway Institute (NHI) has developed an ITS software acquisition course, based on the U.S. Department of Transportation Federal Highway Administration (FHWA) *The Road to Successful ITS Software Acquisition*, that lays out a successful approach to acquiring software. The ITS software acquisition course presents a variety of themes that are useful in any project, but are especially important in a software acquisition project. The main themes presented in the NHI course include:

- a) System Themes—relating directly to the final product
 - 1) Break the project up into “bite-size” pieces
 - 2) Consider COTS software whenever possible
- b) Management Themes—managing the acquisition
 - 1) Up-front planning is essential
 - 2) Maintain flexibility throughout the process
 - 3) There are no “silver bullets” or magical cures for troubled software projects
- c) People Themes – partnering and team building
 - 1) Maintain active customer involvement
 - 2) Maintain good collaboration
 - 3) Open communications is essential
 - 4) Team building is important

The NHI—ITS software acquisition course also presents the concept of a requirements walkthrough as a means of describing essential elements of the acquisition that should be well documented at the onset of the project.

Important factors affecting ITS standards-based implementations include:

- a) **Property Rights and Permissions**—Who owns the software being implemented? What rights do I have as a user? It is important to understand the difference between ownership and right to use. Right to use licensing implies restricted rights of use and distribution, while ownership may only be minimal or nonexistent. There are important implications to consider when evaluating which approach is right for your agency. Remember that intellectual property rights issues should be resolved prior to signing a contract.
- b) **Delivery**—What is my timeline for system delivery? Does the schedule adequately reflect time needed for software development (hurried software development can lead to implementation problems)? What is my method of acquisition and delivery (for example, software delivery may be acquired via a professional services arrangement)?
- c) **Acceptance Testing**—How is the system tested? How can an agency determine whether agency specifications are met? How can an agency determine whether the requirements of the pertinent standards are met? Are staff resources used to do system testing or is this outsourced? Is a good test

plan generated from agency specifications and the pertinent NTCIP (or other) standards? What tools are available within the agency, and what tools are needed to perform adequate testing?

Other important factors to consider in the procurement of NTCIP or other standards-based systems that may have a profound affect on post implementation include:

- a) **Maintenance and Support**—Once the system is built, how does an agency maintain the system in good working order? What kind of support is needed to maintain the system (e.g. additional staff, vendor contracts, etc.)? Standards are often undergoing initial development or revision, and the use of draft standards brings risks of substantive change prior to acceptance and publication—how can an agency upgrade to the final standard if the agency was involved in a lead deployment based on draft standards?
- b) **Documentation and Training**—What documentation does an agency need to have on hand to ensure that staff adequately understands the system? What are agency training needs (consider both operations and maintenance)? Are additional agency staff resources needed with specialty training?
- c) **Warranty Considerations**—What is the warranty period? What resources and benefits are associated with extended warranties?

For NHI course information, see www.nhi.fhwa.dot.gov. FHWA's *The Road to Successful ITS Software Acquisition* is at www.fhwa.dot.gov/tfhrc/safety/toc.htm.

3.4.2 Procurement Methods

When procuring NTCIP standards-based transportation system, agencies typically use existing procurement processes, selecting one depending on what the agency is procuring. Agency procurement processes for hardware may differ from those for software, field installation, or construction, as examples. For software development, the agency process for procuring technical services may be used.

When procuring ITS systems that include software development, an agency's information technology section may provide assistance.

When procuring ITS systems, the agency needs to determine the most appropriate process or combination of processes for the particular procurement at hand. If the traffic engineering section of the agency is not familiar with procuring software, the agency's information technology section may have such experience and could provide assistance.

As one example, the agency may wish to procure additional field devices to operate with an existing central system. In this case, the agency develops specifications for the field devices, including NTCIP-based communications requirements.

If the agency wants a contractor to install the devices in the field, along with electrical wiring and support structures, an agency could include the field devices with the field construction to be let as part of a construction project; however, it is often desirable for the agency to procure field devices separately from the construction aspects of a project. Separating field device procurement from the construction project allows the agency to deal directly with the field device vendor to resolve any issues, and avoids making a construction contractor responsible for installation tasks that are outside of the normal construction skill set. The agency's options include:

- a) The construction contractor installs agency-provided field devices or
- b) The agency installs field devices into cabinets and onto supports that the electrical contractor has installed.

As another example, the agency may wish to procure software for a center system or for C2C communications. Considerations include:

- a) If COTS software exists that meets most of the agency's needs, the agency may want to license the software.

- b) If no COTS software exists, the agency can either develop custom software internally or procure the development of custom software. Development of custom software often has high risks for achieving desired functionality and reliability, meeting the project schedule, and staying within project budget.
- c) For a large center with many software applications, it may be more effective to develop and maintain software using agency employees.
- d) For smaller operations without full time agency employees with software expertise, the agency may choose to procure outside technical services for software development. See 3.4.1.

Two alternative approaches can be used when preparing to procure NTCIP systems and devices.

One agency procurement approach is for the agency to solicit proposals and allow respondents (the manufacturer, vendor, developer, or systems integrator) to present detailed information on how their proposed system or device meets agency requirements or conforms to elements of NTCIP standards. This relies on the preparation of requirements during the initial stages. These requirements should be as detailed as possible to ensure that resulting responses provide sufficient information for fair and even comparisons among competing alternatives. At some point, either during selection or after award, the agency solicits (for approval), a detailed proposal from the respondents (systems developer or integrator) that presents information as to which standards, conformance groups (PRL or PICS), data elements and range values can be provided to meet the agency specification requirements. Other pertinent information should be included. This approach might be somewhat iterative, depending on agency requirements. This approach, however, is not appropriate for the procurement of additional field devices to operate with pre-existing central system software.

The second agency procurement approach involves the preparation of an agency specification, which includes detailed NTCIP system (or device) based and agency functional requirements. This approach requires knowledge of both NTCIP standards and the device or system functionality an agency requires to meet agency needs. This approach requires the agency to make appropriate selections at all levels within the NTCIP Framework and identify an NTCIP stack that meets agency needs. The agency identifies specific NTCIP standards, PRLs, PICS, data elements and range values. This approach requires agency expertise in communications and systems design, as well as identification of agency-specific needs and requirements.

While either approach may be used for initial procurement, the second approach is appropriate when existing central system software is to be re-used without modification.

3.4.3 Procurement Request

The procurement request can take many forms. Additional steps may be added to traditional procurement processes to ensure an adequate understanding of the requirements, and means used to evaluate conformance to elements of NTCIP standards and agency specifications.

3.4.4 Procurement Response

To ensure a thorough understanding of agency specification requirements, the agency should request a proposal (for agency approval) that reflects an understanding of and acknowledges the various issues addressed through the development of detailed design plans and requirements using the systems engineering approach. This proposal should address issues such as conformance requirements statements and range values, where appropriate, and any requirements that are unique to agency specification for a project.

If proposals deviate from agency specifications, the agency decides whether or not to allow such exceptions. If exceptions are allowed, the agency should identify the impact of these exceptions. Exceptions should be reflected within agency specifications to ensure that future procurements are interoperable and/or interchangeable. A good practice includes review of exceptions by all parties involved—both internal and external to the agency.

Exceptions may reflect options provided within a standard, or exceptions may render an implementation non-conformant. Working within the context of what is allowed within a standard promotes and enhances