I-95 Corridor Coalition

Corridor-Wide Center-to-Center Communications Study

TECHNICAL MEMORANDUM

Final Report

August 1, 2008
5-14-3C
# Table of Acronyms

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<th>Description</th>
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<tbody>
<tr>
<td>AASHTO</td>
<td>American Association of State Highway and Transportation Officials</td>
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<tr>
<td>ADUS</td>
<td>Archived Data User Service</td>
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<tr>
<td>AMBER</td>
<td>America’s Missing Broadcast Emergency Response</td>
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<td>ANSI</td>
<td>American National Standards Institute</td>
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<tr>
<td>API</td>
<td>Applications Program Interface</td>
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<tr>
<td>ArcIMS</td>
<td>Arc Internet Map Server</td>
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<td>ASCII</td>
<td>American Standard Code for Information Interchange</td>
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<tr>
<td>ASN</td>
<td>Abstract Syntax Notation</td>
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<tr>
<td>ATM</td>
<td>Asynchronous Transfer Mode</td>
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<td>ATMS</td>
<td>Advanced Transportation Management System</td>
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<td>C2C</td>
<td>Center to Center</td>
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<td>C2F</td>
<td>Center to Field</td>
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<tr>
<td>CAD</td>
<td>Computer Aided Dispatch</td>
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<td>Caltrans</td>
<td>California Department of Transportation</td>
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<td>CARS</td>
<td>Condition Acquisition and Reporting System</td>
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<td>CATT</td>
<td>Center for Advanced Transportation Technology</td>
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<td>CCTV</td>
<td>Closed Circuit Television</td>
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<td>CORBA</td>
<td>Common Object Request Broker Architecture</td>
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<td>CRS</td>
<td>Condition Reporting System</td>
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<td>CVO</td>
<td>Commercial Vehicle Operation</td>
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<td>DATEX</td>
<td>Data Exchange</td>
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<td>DE</td>
<td>Data Element</td>
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<td>DelDOT</td>
<td>Delaware Department of Transportation</td>
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<td>DFD</td>
<td>Data Flow Diagram</td>
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<td>DMS</td>
<td>Dynamic Message Sign</td>
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<td>DOT</td>
<td>Department of Transportation</td>
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<td>DRBA</td>
<td>Delaware River and Bay Authority</td>
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<td>DRPA</td>
<td>Delaware River Port Authority</td>
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<td>DS</td>
<td>Digital Signal</td>
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<td>EMC</td>
<td>Emergency Management Center</td>
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<td>ERM</td>
<td>Event Report Message</td>
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<td>ETC</td>
<td>Electronic Toll Collection</td>
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<td>FCC</td>
<td>Federal Communications Commission</td>
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<td>FEU</td>
<td>Full Event Update</td>
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<td>FHWA</td>
<td>Federal Highway Administration</td>
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<td>FORETELL</td>
<td>Road and Weather Prediction System</td>
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<td>FTP</td>
<td>File Transfer Protocol</td>
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<td>Geographic Information System</td>
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<td>GUI</td>
<td>Graphical User Interface</td>
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<td>HAR</td>
<td>Highway Advisory Radio</td>
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<td>Abbreviation</td>
<td>Full Form</td>
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<td>HOGs</td>
<td>Highway Operations Group</td>
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<td>HTML</td>
<td>HyperText Markup Language</td>
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<td>HTTP</td>
<td>HyperText Transfer Protocol</td>
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<td>HTTPS</td>
<td>HyperText Transfer Protocol Secure</td>
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<td>IEEE</td>
<td>Institute of Electrical and Electronic Engineers</td>
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<td>IEN</td>
<td>Information Exchange Network</td>
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<td>IP</td>
<td>Internet Protocol</td>
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<td>IRVN</td>
<td>Interagency Remote Video Network</td>
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<td>ISN</td>
<td>Information System Network</td>
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<td>International Standards Organization</td>
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<td>Information Technology</td>
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<td>ITE</td>
<td>Institute of Transportation Engineers</td>
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<td>ITIS</td>
<td>International Traveler Information System</td>
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<td>Intelligent Transportation Systems</td>
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<td>JPO</td>
<td>Joint Program Office</td>
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<td>LAN</td>
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<td>LPFM</td>
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<td>MassHighway</td>
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<td>MPEG</td>
<td>Moving Picture Experts Group</td>
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<td>MWCOG</td>
<td>Metropolitan Washington Council of Governments</td>
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<td>NEMA</td>
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<td>NOC</td>
<td>Network Operations Center</td>
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<td>NTCIP</td>
<td>National Transportation Communication for ITS Protocol</td>
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<td>National Television System Committee</td>
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<td>NYSDOT</td>
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<td>OC</td>
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<td>OER</td>
<td>Octet Encoding Rules</td>
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<td>OpenGIS</td>
<td>Open Geographic Information System</td>
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<td>OSI</td>
<td>Open System Interconnection</td>
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<td>PennDOT</td>
<td>Pennsylvania Department of Transportation</td>
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<td>PICS</td>
<td>Profile Implementation Conformance Specification</td>
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<td>PSPEC</td>
<td>Process Specifications</td>
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<td>PTZ</td>
<td>Pan/Tilt/Zoom</td>
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<td>QoS</td>
<td>Quality of Service</td>
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<td>RA</td>
<td>Regional Architecture</td>
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<td>RIMUS</td>
<td>Regional Integrated Multi-Modal Information Sharing</td>
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<td>RITIS</td>
<td>Regional Integrated Transportation Information System</td>
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<td>SAE</td>
<td>Society of Automotive Engineers</td>
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<td>SDO</td>
<td>Standards Development Organization</td>
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<td>SmartNET</td>
<td>Syracuse Metropolitan Area Regional Transportation NETwork</td>
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<td>SOAP</td>
<td>Simple Object Access Protocol</td>
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<td>SONET</td>
<td>Synchronous Optical Network</td>
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<td>STIX</td>
<td>Southern Traffic Information Exchange</td>
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<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>STS</td>
<td>Synchronous Transport Signal</td>
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<td>TCC</td>
<td>Traffic Control Center</td>
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<tr>
<td>TCP</td>
<td>Transmission Control Protocol</td>
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<tr>
<td>TCP/IP</td>
<td>Transmission Control Protocol and the Internet Protocol</td>
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<td>TDM</td>
<td>Time Domain Multiplexing</td>
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<tr>
<td>TMC</td>
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<tr>
<td>TMDD</td>
<td>Traffic Management Data Dictionary</td>
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<td>Traffic Operations Center</td>
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<td>TRANSCOM</td>
<td>Transportation Operations Coordinating Committee</td>
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<td>TRANSMIT</td>
<td>TRANSCOM System for Managing Incidents and Traffic</td>
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<td>TRIO</td>
<td>Tri-State Traveler Information Online</td>
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<tr>
<td>UDDI</td>
<td>Universal Description Discovery and Integration</td>
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<tr>
<td>UDP</td>
<td>User Datagram Protocol</td>
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<tr>
<td>USDOT</td>
<td>U.S. Department of Transportation</td>
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<td>VBR</td>
<td>Variable Bit Rate</td>
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<tr>
<td>VSAT</td>
<td>Very Small Aperture Satellite Earth Terminals</td>
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<tr>
<td>W3C</td>
<td>World Wide Web Consortium</td>
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<tr>
<td>WAN</td>
<td>Wide Area Network</td>
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<tr>
<td>WSDL</td>
<td>Web Services Description Language</td>
</tr>
<tr>
<td>XML</td>
<td>eXtensible Markup Language</td>
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Executive Summary

The I-95 Corridor Coalition Corridor-Wide Center-to-Center (C2C) Communications Study project is structured to provide a technical report outlining a series of recommendations to employ a stable and reliable communications mechanism during, and subsequent to, catastrophic events between multiple transportation management centers along the I-95 Corridor. This study targets I-95 Corridor Coalition participating agencies looking to maintain an exchange of emergency management information to manage their operations when traditional communication means (e.g. landline, wireless and cellular phone) are not available. Generally, the communication system is, in most respects, the least failure prone element of an overall system, but potentially has a high risk of being disrupted in case of emergency situations or catastrophic events, such as terrorist attack, extreme weather, earthquake or hurricane. The communications between Transportation Management Centers (TMCs) or Traffic Control Centers (TCCs) of member agencies; emergency communications between TMCs/TCCs and public safety agencies or emergency management agencies, could be severely disrupted. Currently none of the existing information exchange systems in the I-95 Corridor Coalition systematically provides any emergency communication backup mechanism. The outcome of this study is a series of technical recommendations regarding a C2C communications mechanism to support the I-95 Corridor Coalition information exchange system, which will help participating agencies understand the C2C communication standards and backup mechanism for a stable and reliable information exchange system. This project includes total four task orders.

The Task Order One within the C2C Communications Study included outlining the current state of the C2C Intelligent Transportation System (ITS) standards as it relates to the National Transportation Communications for ITS Protocol (NTCIP) and the National ITS Architecture. The first task also included the identification of applicable communication network technologies for meeting C2C communication needs, which included: Synchronous Optical Network (SONET), Asynchronous Transfer Mode (ATM), and Ethernet (Standard, Fast Ethernet, or Gigabit Ethernet). It additionally provided a brief summary of the characteristics, advantages and disadvantages of each network technology.

The Task Order Two presented research of existing information sharing/exchange systems that currently exist along the I-95 corridor, including systems being utilized by Coalition members and others. Only systems that have the capability of C2C communications at a corridor-level were considered and the identified systems were representative of the best practices in ITS standards utilization.

The Task Order Three included an effort in reviewing the C2C guidelines (outlined in Task Order One) and the existing eleven information exchange systems with C2C deployments (identified as best practices in Task Order Two), undertook an analysis to identify the divergences from the National ITS Architecture C2C standards and also highlighted the gaps between the existing best practices in terms of the communication mechanism, interagency video sharing technology and the system functional
requirements. The purpose of this task was to identify problem areas in the existing systems and drove the technology recommendations to be defined in the Task Order Four of this project.

The Task Order Four represented an expansive effort in identifying, evaluating, and describing viable C2C communications standards and technologies based upon the research performed in Task Orders Two and Three. As a result of this task, a series of technical recommendations regarding a C2C communications mechanism to support the I-95 Corridor Coalition information exchange system were developed. The technical recommendations were focused on three major areas: C2C communication standards, system architecture and communication architecture, and the interagency video sharing technology. The advantages and disadvantages of each technology were also highlighted.

As a result of this project, the Internet networking protocols and standards are recommended for the I-95 Corridor Coalition information exchange system and its components: XML (eXtensible Markup Language) data structures based on ITS messaging standards, retrieved over the Internet using HTTP/HTTPS (Hypertext Transfer Protocol), are recommended to be the preferred means of publishing traffic and incident data information; The interfaces would be implemented as SOAP-based (Simple Object Access Protocol) Web services; Administrative user interfaces would be adequately implemented in HTML (HyperText Markup Language).

System architecture and communication architecture are recommended for the information exchange system in this project. Its logical architecture, functional architecture and physical architecture are also introduced: IP/Ethernet-based communication network architecture is recommended; Very Small Aperture Satellite Earth Terminals (VSAT) is recommended as the C2C communication backup in case of emergency situations. Several satellite Internet service providers and their various service plans (on-demand or regular plan) are available to meet the requirements of the I-95 Corridor Coalition information exchange system. The one-time installation and equipment cost is normally less than $20,000 per site, and the average monthly service cost is about $500 plus the usage-based charges if on-demand service is activated during emergency situations.

A hybrid architecture is recommended to share the video from both the existing legacy cameras and the IP-addressable cameras. All video encoding/decoding equipment in future deployments should be capable of transmitting both MPEG-2 and MPEG-4 (Moving Picture Experts Group) video streams. 100 Mbps Fast IP/Ethernet for the sharing of small number of video feeds (no more than ten video feeds) and 1,000 Mbps Gigabit IP/Ethernet for large number of shared video feeds (no more than one hundred video feeds) are recommended for future deployments.
1 Chapter 1 - Task One: National Intelligent Transportation Systems (ITS) Architecture/Center to Center (C2C) Standards

1.1 Task One Background

The I-95 Corridor Coalition Corridor-Wide C2C Communications Study project is structured to provide a technical report outlining a series of recommendations to employ a stable and reliable communications mechanism during, and subsequent to, catastrophic events between multiple transportation management centers along the I-95 Corridor. This study targets I-95 Corridor Coalition participating agencies looking to maintain an exchange of emergency management information to manage their operations when traditional communication means (e.g. landline and wireless) are not available. The outcome of this study will be a series of options that will help participating agencies understand how to efficiently manage information and increase mobility along the I-95 Corridor.

The first task within the C2C Communications Study includes production of this Technical Memorandum outlining the current state of the C2C ITS standards as it relates to the NTCIP and the National ITS Architecture. This report includes the identification of applicable communication network technologies for meeting C2C communication needs, which include: SONET, ATM, and Ethernet (Standard, Fast Ethernet, or Gigabit Ethernet), provides a brief summary of their characteristics, advantages and disadvantages, and presents the reader with a ready resource for existing guidelines on C2C technologies, including the communications hardware and software elements stipulated to support the communications between public transportation management agencies.

1.2 National ITS Architecture

1.2.1 Overview

ITS development is governed by the National ITS Architecture – a systems architecture that was developed under the direction of the U.S. Department of Transportation (USDOT) in June of 1996. The architecture was designed to provide a common framework for planning, defining, and integrating ITS.

The National ITS Architecture is a voluminous suite of documentation which guides the conception of intermodal and interoperable systems that will provide various levels of service to transportation management entities serving the traveling public. It is a mature product that reflects the contributions of a broad cross-section of the ITS community (transportation practitioners, systems engineers, system developers, technology specialists, consultants, etc.).
The following diagram provides a high level illustration of the National ITS Architecture:

![National ITS Architecture Diagram](image)

**Figure 1-1: National ITS Architecture**
(Source: The NTCIP Guide 9001)

This architecture demonstrates how ITS services can be incorporated into an existing infrastructure and support future technological advances by means of an open standard that enables the deployment of ITS components (regardless of the particular hardware or software vendor). The architecture defines the functions (e.g., gather traffic information or request a route) that must be performed to implement a given user service, the physical entities or subsystems where these functions reside (e.g., the roadside or the vehicle), the interfaces/information flows between the physical subsystems, and the communication requirements for the information flows (e.g., wireline or wireless). Additional information on the USDOT National ITS Architecture can be found on the Internet at the following address: http://www.its.dot.gov/arch/index.htm.

**1.2.2 Logical Architecture**

The Logical Architecture provides a functional view of the ITS services defined in the National ITS Architecture. It does not take into account any physical implementation and is not dependent on any technology. It defines the functions or process specifications that are required to perform specific ITS user services, and the information or data flows that need to be exchanged.
The logical architecture provides a decomposition of ITS functions and is generally represented by data flow diagrams (DFD) and process specifications (PSPEC). The DFDs are organized hierarchically to arrive at the fundamental ITS processes and activities. PSPECs are descriptions of the processes in the Logical Architecture and consist of an overview, a set of requirements, and a complete listing of inputs and outputs.

1.2.3 Physical Architecture

The Physical Architecture provides a structural view of all the processes and data flows in the Logical Architecture. It defines the physical elements (e.g. subsystems) that make up an Intelligent Transportation System and partitions the functions defined in the Logical Architecture based on the similarity of the PSPECs.

1.2.4 ITS Standards

The National ITS Architecture depends upon a series of standards that provide guidance for exchanging information within a consistent framework. ITS Standards define the interoperability among systems or subsystems by establishing a set of technical specifications without impeding innovation as technology advances, vendors change, and new approaches evolve. The development of standards is critical to achieving ITS compatibility and interoperability.

ITS standards have been grouped into five deployment-oriented categories (application areas) that focus on specific ITS services or systems. Each category has a set of ITS Standard documents developed by Standards Development Organizations (SDOs). These groups include:

- Center to Center Information Exchanges
The National ITS Architecture provides a means by which ITS standards activities can be managed and provides the framework that enables a means to detect gaps, overlaps, and inconsistencies in the ITS Standards. ITS standards are developed and published by SDOs and is being supported by USDOT ITS Joint Program Office (JPO) to facilitate the successful deployment of ITS in the United States.

To accelerate the development of ITS standards, the USDOT ITS Joint Program Office supports the following SDOs and their various standards:

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<th>ITS Standards Development Organizations</th>
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<tr>
<td>American Association of State Highway and Transportation Officials (AASHTO)</td>
</tr>
<tr>
<td>American National Standards Institute (ANSI) Accredited Standards Committee</td>
</tr>
<tr>
<td>American Society for Testing &amp; Materials (ASTM)</td>
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<tr>
<td>Institute of Electrical and Electronics Engineers (IEEE)</td>
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<tr>
<td>Institute of Transportation Engineers (ITE)</td>
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<tr>
<td>National Electrical Manufacturers Association (NEMA)</td>
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<td>Society of Automotive Engineers (SAE)</td>
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**Table 1-1: ITS Standards Development Organizations**

### 1.2.5 Implementation

One of the main goals for the creation of the National ITS Architecture was to define the key interfaces for standardization. Architecture flows (and their constituent detailed data flows) serve as the basis for much of the ITS standards, the majority of which have been developed, and whose mapping is detailed in the National ITS Architecture. Within the framework of the National ITS Architecture, ITS standards developers can identify the standards for development that will meet the user's needs, ITS planners can integrate regional ITS elements using these ITS standards and achieve their interoperability goals, and ITS deployers can select the standards that reduce risk to their deployment and thus help to manage costs and schedule.

ITS planners, deployers and other stakeholders tailor the National ITS Architecture to create Regional and Project ITS Architectures that meet their specific needs. Regional ITS Architectures consist of functions within ITS elements and architecture flows that interconnect each of the ITS elements in (and outside) the region. Project ITS Architectures are implemented to develop specific ITS systems and take the region’s ITS architecture into account to define the overall design, providing a mapping to National ITS Architecture flows.
The following diagram illustrates the relationships between ITS Standards and the various levels of the National ITS Architecture:

![ITS Architecture Relationships Diagram](image-url)

**Figure 1-4: ITS Architecture Relationships**
(Source: National ITS Architecture, USDOT)
1.3 Center to Center (C2C)

1.3.1 Overview

Center to Center subsystems provide support for an ITS by facilitating the communications between physical entities to carry out transportation system related functions. The C2C concept suggests that disparate transportation systems can co-exist within a common ground for the purposes of information exchange and device control.

The following diagram illustrates the C2C concept at a high-level:

As noted in the above diagram, the C2C concept supports the integration of various agencies by means of sharing information over a universal channel. Information shared across agencies is characterized by standard message sets – categories of information that carry data and / or commands to be managed potentially by another center. The need to share and communicate this information implies that a standard mechanism is necessary; therefore the National ITS Architecture includes the design of a set of protocols and data definitions that would enable centers to effectively communicate with each other.
1.3.2 General Standards

C2C Standards describe guidelines for communicating data and commands in a C2C application / system. C2C communications span the entire ITS domain, covering the exchange of data between computers physically located in different transportation management center facilities (e.g., traffic management centers, transit management centers, and emergency management centers). C2C communication standards enable this data exchange, specifying what information is exchanged, how and when it is exchanged, and the underlying transport mechanisms. C2C standards can be divided into two categories: 1) the vocabulary (e.g., objects, data elements, and messages), and 2) the rules for exchanging the messages and data (protocols). The two categories work together to successfully exchange meaningful ITS-related information. The following table lists ITS standards commonly used in C2C applications:

<table>
<thead>
<tr>
<th>Standard Number</th>
<th>Standard Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSI TS285</td>
<td>Commercial Vehicle Safety and Credentials Information Exchange</td>
</tr>
<tr>
<td>ANSI TS286</td>
<td>Commercial Vehicle Credentials</td>
</tr>
<tr>
<td>ASTM AG</td>
<td>ADMS Standard Guidelines</td>
</tr>
<tr>
<td>ASTM DD</td>
<td>ADMS Data Dictionary Specifications</td>
</tr>
<tr>
<td>IEEE Std 1512-2000</td>
<td>Common Incident Management Message Sets (IMMS) for use by EMCs</td>
</tr>
<tr>
<td>IEEE P1512.1</td>
<td>Standard for Traffic Incident Management Message Sets for Use by EMCs</td>
</tr>
<tr>
<td>IEEE P1512.2</td>
<td>Standard for Public Safety IMMS for use by EMCs</td>
</tr>
<tr>
<td>IEEE P1512.3</td>
<td>Standard for Hazardous Material IMMS for use by EMCs</td>
</tr>
<tr>
<td>ITE TM 1.03</td>
<td>Standard for Functional Level Traffic Management Data Dictionary (TMDD)</td>
</tr>
<tr>
<td>ITE TM 2.01</td>
<td>Message Sets for External TMC Communication (MS/ETMCC)</td>
</tr>
<tr>
<td>ITE TM 3.0M</td>
<td>Traffic Management Business Area Standard</td>
</tr>
<tr>
<td>NTCIP 1102</td>
<td>Octet Encoding Rules (OER)</td>
</tr>
<tr>
<td>NTCIP 1210</td>
<td>Objects for Signal Systems Masters</td>
</tr>
<tr>
<td>NTCIP 1301</td>
<td>Weather Report Message Set for ESS</td>
</tr>
<tr>
<td>NTCIP 1401</td>
<td>Standard on Common Public Transportation (CPT) Objects</td>
</tr>
<tr>
<td>NTCIP 1402</td>
<td>Standard on Incident Management (IM) Object</td>
</tr>
<tr>
<td>NTCIP 1403</td>
<td>Standard on Passenger Information (PI) Objects</td>
</tr>
<tr>
<td>NTCIP 1404</td>
<td>Standard on Scheduling/Runcutting (SCH) Objects</td>
</tr>
<tr>
<td>NTCIP 1405</td>
<td>Standard on Spatial Representation (SP) Objects</td>
</tr>
<tr>
<td>NTCIP 1406</td>
<td>Standard on On-Board (OB) Objects</td>
</tr>
<tr>
<td>NTCIP 1407</td>
<td>Standard on Control Center (CC) Objects</td>
</tr>
<tr>
<td>NTCIP 1408</td>
<td>Standard on Fare Collection (FC) Objects</td>
</tr>
<tr>
<td>NTCIP 2104</td>
<td>Subnetwork Profile for Ethernet</td>
</tr>
<tr>
<td>NTCIP 2202</td>
<td>Transport Profile for Internet (TCP/IP and UDP/IP)</td>
</tr>
<tr>
<td>NTCIP 2303</td>
<td>Application Profile for File Transfer Protocol (FTP)</td>
</tr>
<tr>
<td>NTCIP 2304</td>
<td>Application Profile for Data Exchange ASN.1 (DATEX)</td>
</tr>
<tr>
<td>NTCIP 2306</td>
<td>Application Profile for XML Message Encoding in ITS C2C Comm</td>
</tr>
<tr>
<td>SAE J2353</td>
<td>Data Dictionary for Advanced Traveler Information System (ATIS)</td>
</tr>
<tr>
<td>SAE J2354</td>
<td>Message Set for Advanced Traveler Information System (ATIS)</td>
</tr>
<tr>
<td>SAE J2529</td>
<td>Rules for Standardizing Street Names and Route Ids</td>
</tr>
</tbody>
</table>

Table 1-2: Commonly Used C2C ITS Standards
1.3.3 NTCIP Standards

As noted in Table 1-2, National Transportation Communications for ITS Protocol occupies a major portion of the commonly used C2C standards. NTCIP is a family of communications protocols and data definition standards that have been designed to accommodate the diverse needs of various subsystems and user services of the National ITS Architecture.

AASHTO is the leading SDO in the AASHTO / ITE / National Electrical Manufacturers Association (NEMA) partnership for the development and enhancement of the NTCIP. The NTCIP family of standards primarily addresses the interface standards between a transportation management center (TMC), the ITS field devices it manages, and other centers. They provide both the vocabulary and the protocols necessary to communicate and exchange information between ITS systems.

NTCIP organizes its C2C standards using a layered approach, similar to the International Standards Organization’s (ISO) Open System Interconnection (OSI) framework model. While message/data standards address the Information Level, NTCIP C2C communications standards primarily address the Application, Transport, and Subnetwork Levels. At these levels, NTCIP leverage existing computer and telecommunications industry base standards, and specify what is mandatory and optional where alternatives are available for ITS applications. In some cases, the NTCIP standards have extended the industry base standard to meet the specific needs of the transportation community. In this manner, the NTCIP C2C communications standards are "profiles" of base standards and other standards.

The following diagram illustrates the NTCIP C2C standards levels being developed:

![Figure 1-6: NTCIP Center-to-Center Standard Levels](Source: The NTCIP Guide 9001)

The National ITS Architecture identifies four communication blocks to represent how ITS subsystems communicate with one another. The NTCIP C2C standards are mapped
to all Center-to-Center interfaces / links in the Wireline (Fixed-Point to Fixed-Point) Communications block within the National ITS Architecture (See Figure 1-1).

1.3.3.1 Information Level

The NTCIP Information Level standards define the messages and data (informational level dialogs), as well as the type of message encoding and naming rules. The information level standards follow the NTCIP numbering convention of "11xx", "12xx", "13xx", and "14xx". The various messages and the types of data (which make up a message) that can be exchanged between two centers include two broad categories: status and command / control.

Status Information is characterized by types of messages that contain information relative to status. Status information is sent to multiple centers in an identical fashion. Conceptually, these messages are a “one-to-many” connection to other centers.

Command/Control Information is characterized by types of messages that contain requests to perform a given command and obtain control of a resource at the center. Command / Control messages are exchanged between two centers directly – establishing a “one-to-one” connection between two centers as illustrated in the figure to the left.

Note: Command/Control Information messages are generally controlled by the receiving center prior to executing a specific request.
1.3.3.2 **Application Level**

The NTCIP Application Level standards define the rules and procedures for exchanging information data. These standards roughly equate to the Session, Presentation, and Application Layers that are defined in the OSI model. These application level standards follow the NTCIP numbering convention of "23xx."

Application Level standards include software components (web services) whose interfaces are described using the Web Service Description Language (WSDL). Software components abiding by these standards would provide a capability to communication of the Simple Object Access Protocol (SOAP) using eXtensible Markup Language (XML) encoding, Data Exchange ASN (DATEX-ASN) using either XML or Abstract Syntax Notation One (ASN.1), and FTP (File Transfer Protocol).

1.3.3.3 **Transport Level**

The NTCIP Transport Level standards define the rules and procedures for exchanging Application Level data between two or more points on a network, including routing and switching. In the OSI model, these standards equate to the Transport and Network Layers. These standards follow the NTCIP numbering convention of "22xx."

Transport Level standards include the User Datagram Protocol (UDP) over Internet Protocol (UDP/IP) for connectionless transport services and the Transmission Control Protocol over Internet Protocol (TCP/IP) for connection-oriented transport services. All Application Level standards (with the exception of the DATEX-ASN standard) can utilize TCP/IP. The DATEX-ASN standard is the only standard that can support both TCP/IP and UDP/IP applications.

1.3.3.4 **Sub-network Level**

The NTCIP Sub-network Level standards define the rules and procedures for encoding and decoding the information at the bit level to be transmitted and received between two points in a network. These standards equate to the Data Link and Physical Layers in the OSI model. Sub-network Level standards follow the NTCIP numbering convention of "21xx."

Sub-network Level standards include the high-bandwidth Ethernet and Point-to-Point over RS-232 Protocol standards. Although other industry standards such as ATM and SONET could be used, the bandwidth and reliability of Ethernet and RS-232 is the preferred standard.

1.3.4 **Communication Standards**

There are many available and emerging communications technologies and services (with associated standards) that are applicable for meeting center-to-center communication requirements. Within the framework of the National ITS Architecture, network technologies considered for C2C communication are standardized technologies that may consist of components available from multiple vendors. Available network technology options include SONET, ATM, and Ethernet (Standard, Fast Ethernet, or Gigabit Ethernet).
1.3.4.1 SONET

SONET is a data transmission technology designed to provide a universal transmission and multiplexing scheme. It is recognized by the ANSI and is the common standard for connecting digital and fiber-optic transmission systems. The SONET technology is capable of transmitting data at rates that are in the gigabit per second range.

SONET uses Time Domain Multiplexing (TDM), which allows multiple communications channels to be carved out of a single, digital transmission facility. Each channel supports a single bit stream, with each channel providing the level of bandwidth demanded by the application. Primary structure of SONET is built around Synchronous Transport Signal Level-1 (STS-1) transport through an Optical Carrier (OC) signal over fiber optics. An aggregate 51.84Mbps STS-1 bit stream, when converted from electrical to optical (fiber) is called Optical Carrier-1 (OC-1), and is comprised of a transmission of 810-byte (6,480 bits) frames.

The SONET OC-level structure follows a structure that maps to electrical hierarchies. Table 1-3 and Table 1-4 show the SONET speed hierarchy by OC-level, illustrating the number of DS-0s (Digital Signal 0), DS-1s, and DS-3s equivalents. DS-0, DS-1 and DS-3 are widely used standards in telecommunications in North America to transmit voice and data between devices. These standards permit the transmission of many low speed data channels over a single high-speed communication medium. Any types of services, ranging from voice, low-speed data and high-speed data and video can be integrated into one communication system, which reduces the complexity of the entire system.

The following table illustrates the types of DS, their bit rates and number of channels defined by the electrical standards.

<table>
<thead>
<tr>
<th>Type</th>
<th>Bit Rate</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fundamental Unit (DS-0)</td>
<td>64 Kbps</td>
<td>1 voice-grade channel</td>
</tr>
<tr>
<td>T-1 Channel (DS-1)</td>
<td>1.544Mbps</td>
<td>24 DS-0 Channels</td>
</tr>
<tr>
<td>T-3 Channel (DS-3)</td>
<td>44.736Mbps</td>
<td>28 DS-1 Channels</td>
</tr>
</tbody>
</table>

Table 1-3: Electrical Standards

The following table illustrates the levels of STS/OC, their bit rates and number of channels defined by the SONET standards.

<table>
<thead>
<tr>
<th>STS Level (Electrical)</th>
<th>OC Level (Optical)</th>
<th>Bit Rate</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>STS-1</td>
<td>OC-1</td>
<td>51.84Mbps</td>
<td>Encapsulates one DS-3</td>
</tr>
<tr>
<td>STS-3</td>
<td>OC-3</td>
<td>155.52Mbps</td>
<td>3 OC-1 Channels</td>
</tr>
<tr>
<td>STS-12</td>
<td>OC-12</td>
<td>622.08Mbps</td>
<td>12 OC-1 Channels</td>
</tr>
<tr>
<td>STS-48</td>
<td>OC-48</td>
<td>2.488Gbps</td>
<td>48 OC-1 Channels</td>
</tr>
</tbody>
</table>

Table 1-4: SONET Standards

SONET equipment today offers configurable integrated circuit devices allowing high-density bandwidth allocation, higher port density, support of many different interface types, as well as flexible bandwidth capabilities. The end result being many different
combinations of bandwidths and interface types (i.e., voice, video, Ethernet, 1-1, DS-3, low-speed data, etc.) are available, reducing the number of physical boxes (i.e., external equipment) that must be installed to solve multiplexing problems.

The increased configuration flexibility, scalability and bandwidth availability of SONET provides many advantages over older systems using proprietary architectures, equipment, multiplexing formats. SONET advantages include:

- Reduction in equipment requirements
- Increased network reliability / survivability;
- Provision for overhead and payload bytes
- Permitting individualized network management out to the field network device
- Facilitation of centralized fault segmenting
- Synchronous multiplexing format to carry lower level digital signals
- Simplified add/drop multiplexing
- Generic standards allowing various vendor products to connect interchangeably

### 1.3.4.2 ATM

ATM is widely deployed as a network backbone switching and multiplexing technology. This technology integrates easily with other technologies, offering sophisticated network management features that allow signal carriers to guarantee Quality of Service (QoS). ATM is also referred to as a cell relay because the network uses short, fixed length packets or cells for data transport. Information transmitted over ATM is divided into different cells, transmitted, and re-assembled at the receive end.

ATM is able to provide multimedia transport across the same medium primarily by ascribing a Quality of Service (QoS) mark to each cell transmitted. With SONET based solutions, the network is designed to provide enough bandwidth in each circuit or virtual circuit to handle the peak rate required by variable bit rate (VBR) applications. When the traffic is below the peak rate, the extra bandwidth is unused. With packet-switched networks (such as ATM, Ethernet, etc.) the network is engineered to provide enough bandwidth to handle the average rate required by the set of VBR applications that are running. The peaks are handled by providing QoS, which is intelligent statistical sharing of the extra bandwidth. This has been one of primary selling features of ATM for multimedia applications.

When an information source (such as TMC network equipment) petitions to communicate across an ATM network, the information source negotiates a contract with the network. Video traffic cells (which are extremely sensitive to delay) are granted priority over data cells (which are more sensitive to bit errors than to delay). This QoS prioritization process makes it feasible for multimedia applications available to the desktop. Therefore this process essentially provides “bandwidth on demand.”
Although ATM supports video, it is generally not as cost-effective, with the same level of video performance, as a SONET add/drop based system. ATM achieves its capability of supporting video by QoS giving top priority to digital video and for continuous real-time video. However, one of the advantages of integrating data, video and possibly voice over the same network is the efficiency and cost effectiveness of simplifying network management and personnel requirements.

ATM solutions are generally more expensive (however, equipment / ATM switch port costs are continuing to drop with an increasing number of vendors offering products), given the special interfaces required for the adaptation layer (cell creation or re-conversion). ATM was touted to be the seamless and scalable networking solution – to be used in LANs, backbones, and WANs.

1.3.4.3 Ethernet

Ethernet is a packet-based networking standard that provides a physical link between stations and provides a shared bandwidth pipe between multiple stations. Ethernet refers to a family of LAN implementations that include the following three principal categories: Standard Ethernet or 10BaseT (10Mbps over copper using Cat 5 cable); Fast Ethernet or 100BaseTX (100Mbps over copper using Cat 5 cable) and 100BaseFX (100Mbps using single of multi-mode fiber); Gigabit Ethernet or 1000BaseTX (1000Mbps Gigabit over copper using Cat 5 or Cat 5e cable), 1000BaseSX (1000Mbps Gigabit over multimode fiber) and 1000LX (1000Mbps Gigabit over single-mode fiber).

Gigabit Ethernet (IEEE 802.3z) is the third generation Ethernet technology offering a speed of 1000Mbps. It is fully backed by the industry and is compatible with existing Ethernet infrastructure. Gigabit Ethernet employs the same protocol, same frame format and frame size as its predecessors. All applications that work on Ethernet (IEEE 802.3) will work on Gigabit Ethernet (IEEE 802.3z).

A major advantage to using Ethernet technologies is the very large installed user base. The equipment is readily available, well tested, and well supported. There are a wide variety of interfaces available, and adding new equipment can be as simple as setting a few parameters. In addition, there is a large amount of sophisticated network management software available, which will allow for easier, more cost effective maintenance to be performed – resulting in a lower cost of ownership and day-to-day network maintenance.

With TCP/IP providing integrations of different communication types, Ethernet becomes a viable solution for ITS networks and C2C communications. Transportation management applications requiring Video over IP (traffic monitoring, surveillance), audio over IP (HAR), voice over IP (dispatch, emergency call boxes) and low-speed data over IP (signal controllers, DMS, PTZ controllers) become feasible over existing infrastructure.
1.4 Summary

ITS development in the United States is guided by the National ITS Architecture. The National ITS Architecture depends upon ITS standards developed by Standards Development Organizations to provide guidance for exchanging information within a consistent framework. The C2C standards group is one of the five major standards bodies that has been established for the development and continued enhancement of National ITS standards.

The NTCIP is an important family of ITS standards. These standards occupy a major portion of the commonly used C2C standards. Specifically, the NTCIP defines the communications protocols and data definition standards that have been extensively used in the ITS industry.

There are a number of communication network technologies that meet the communications needs for a C2C implementation. The most applicable network technologies that meet these needs include: SONET, ATM, and Ethernet (Standard, Fast Ethernet, or Gigabit Ethernet). Although each technology has its own suite of characteristics, advantages and disadvantages, Ethernet has become the most viable solution for ITS networks and C2C communications due to the large installed user base (equipment readily available / supported) – making it a cost-effective solution for C2C deployments.
2 Chapter 2 - Task Two: C2C Best Practices

2.1 Task Two Background

Within the I-95 Corridor Coalition there are a wide range of local and regional systems for collecting incident data; for supporting incident and emergency management; and for providing traveler information. The purpose of this task is to undertake a research of existing and proposed information sharing/exchange systems in use by Coalition members and others along the I-95 corridor. Based on the covered jurisdictional boundaries these information sharing/exchange systems can be divided into three levels:

Single State Level

- Florida: Surface Transportation Security and Reliability Information System Model Deployment (iFlorida)
- New York: New York Condition Acquisition and Reporting System (CARS) Information Exchange Network
- New York: Syracuse Metropolitan Area Regional Transportation Network (SmartNET)
- Massachusetts: the Massachusetts Highway Department (MassHighway) Event Reporting System

Regional / Multi-State Level

- Maine/Vermont/New Hampshire: Tri-State Traveler Information Online (TRIO)
- Virginia/Maryland/District of Columbia: Regional Integrated Transportation Information System (RITIS)
- New Jersey/Pennsylvania: Regional Integrated Multi-Modal Information Sharing (RIMUS)
- Transportation Operations Coordinating Committee (TRANSOM) Regional System
- I-95 Corridor Coalition: Southern Traffic Information Exchange (STIX)

Corridor Level

- I-95 Corridor Coalition: Information Exchange Network (IEN)
- I-95 Corridor Coalition: Information System Network (ISN)

The list above is not a full list of all systems along the I-95 corridor and this task is not a comprehensive overview of all systems, but is a representation of best practices in information exchange. Only systems that have the capability of center-to-center (C2C) communications have been considered.
2.2 Best Practices

2.2.1 Surface Transportation Security and Reliability Information System Model Deployment (iFlorida) - Florida

In March 2003, Florida Department of Transportation (FDOT) was selected to participate in a highly innovative model deployment with the Federal Highway Administration (FHWA). The formal name of the program is the Surface Transportation Security and Reliability Information System Model Deployment. The objective of the model deployment – named iFlorida – is to demonstrate the wide variety of operational functions that are enabled or enhanced by a surface transportation security and reliability information system. iFlorida was a four-year statewide project with a metropolitan focus in Central Florida. The first two-year period was for infrastructure deployment, followed by a two-year operations and maintenance, and evaluation period. The project officially started in May 2003.

To meet the model deployment’s objective, iFlorida defined twenty-four integrated projects that build upon Florida’s institutional, operational and technical foundations, and leverage the collective experience, commitment and resources of the participating organizations. The model deployment solicitation specified nine component areas. iFlorida addressed each:

- Metropolitan Area Data and Information Systems – ten projects focused on the Orlando area
- Statewide Condition Reporting System (CRS) – four data collection and fusion projects for statewide data and information
- Security of Critical Infrastructure – four projects, focused on Central Florida and Jacksonville
- Non-Metropolitan Evacuation – two projects focused on the State Route 528 evacuation corridor between Brevard County and the Orlando area
- Weather Response – one project focused on Central Florida
- Multi-Modal Traveler Information – two projects, one focused on the Orlando area and the other statewide
- Data Availability – data available to public agencies and private firms
- Locally-Defined Components – a project focused on developing recommended practices associated with the evacuation of attractions and special event venues
- Cooperation With National Evaluation

The statewide CRS was one of the first stage initiatives. The iFlorida CRS is Florida’s implementation of CARS. CARS has been developed by a consortium of state transportation departments that now includes Minnesota, Iowa, Missouri, Alaska, Washington State, New Mexico, Kentucky, and Coalition members: Maine, New Hampshire, Vermont, and New York. CARS is a non-proprietary, standards based condition reporting system that allows authorized users to enter, view and disseminate critical road, travel, weather and traffic information. CARS users access the system from
I-95 Corridor Coalition 2-26 August 1, 2008

any location using a standard web browser (no local software is required). This allows
users to enter any condition reports or view reports entered by any other users around the
state. While CARS has been developed through a multi-state consortium, most
deployments have been undertaken on an individual state basis. CARS provides a useful
tool that allows information to be added and shared between registered users – typically
in public agencies. It can also be used to disseminate information to the public through
511 services, Dynamic Message Signs (DMS), and Highway Advisory Radio (HAR).
CARS uses the Event Report Message (ERM) set of C2C standards to send or receive
data and CARS does not utilize GIS-based (Geographic Information System) mapping

The purpose of iFlorida CRS is to develop and implement a road reporting system that
supports a multi-agency database of traffic events, including: construction, accidents,
road conditions, and delays. The iFlorida CRS deployment expands and integrates
existing data collection and monitoring systems, collects and shares data between
agencies, uses collected data to improve transportation system management, and
distributes data to motorists. Authorized staff uses the Internet to input traffic information
and travel conditions. Since extreme weather is a major concern in Florida, the CRS also
disseminates weather information.

The iFlorida CRS is composed of various different modules that each creates independent
pieces of software that plugs and plays using national ITS standards as C2C interfaces
between each module. These modules include DMS and Closed Circuit Television
(CCTV) software, 511 system, and 511 website. The use of national standards, which
provides plug-and-play interoperability with other systems, allows for expansion and
provide for interaction with other software programs.

Currently iFlorida is undergoing an extensive evaluation process, which includes:
articulating the successes and failures of the deployment strategies, documenting the
lessons learned, and evaluating impacts from the overall integration.

2.2.2 New York CARS Information Exchange Network - New York

The New York Information Exchange Network effort was focused on the adaptation of
CARS as the statewide source of information on highway conditions with linkage to
existing dispatch and incident systems throughout the state.

Similar to the iFlorida CRS, the New York State’s CARS is also composed of various
standards-compliant modules including DMS and CCTV software, 511 system, and 511
website.

This system gets data feeds from existing systems throughout the state in order to display
appropriate events in CARS. These systems include the New York State Department of
Transportation (NYSDOT) Winter Traveler Advisory System, as well as traffic camera
feeds and speed map data from the Albany/Capital region, with plans to expand to similar
systems throughout the state. All information is disseminated through 511 automated
phone system, LPFM (Low Power FM) radio and the New York 511 website. New York State’s CARS is also linked to Computer Aided Dispatch (CAD) systems and traffic management systems on an expanding basis.

Future enhancement includes statewide emergency management operations, which will have the capability to track resource deployments operating in response to emergency conditions and also track the status of the various transportation systems throughout the state (rail, transit, ferries, etc.).

2.2.3 Syracuse Metropolitan Area Regional Transportation Network (SmartNET) - New York

SmartNET is the Syracuse Metropolitan Area Regional Transportation Network. SmartNET is a web-based traffic management system which is developed for NYSDOT Region 3. The system supports operational management and data entry of incidents, construction events, and special events from transportation management centers (TMCs) and other off-site locations. As a web-based application, any authorized user with internet access can view or enter information in the system. Information is available to registered public sector users including traffic operations and maintenance personnel, safety personnel, and local government public works personnel. Users can view information from a map displaying a list of events and their descriptions.

The SmartNET system utilizes Arc Internet Map Server (ArcIMS) and could integrate any other GIS or mapping system. SmartNet uses the National Transportation Communication for ITS Protocol (NTCIP) C2C standards and the message sets included in the Traffic Management Data Dictionary (TMDD).

The Phase One system provided event submission and tracking, fax/pager/e-mail alerts, and an automated data interface with the County 911 center. Planned enhancements include the addition of real-time traffic volume and speed data from detectors, road-weather data from sensors, video-sharing capabilities, and a 511 interactive voice response system.

2.2.4 MassHighway Event Reporting System - Massachusetts

The Massachusetts Highway Department deployed a web-based event reporting system: the MassHighway Event Reporting System. This system provides detailed real-time transportation and security related events such as: construction closures, detours, restrictions, permit and weather information. Information is entered by Districts and other authorized users. Authorized users may include representatives from other operating agencies.

The user interacts with the system through a web browser. The main display combines a district level GIS-based zoomable map, aerial images, and events list. Overlaid on a map is a network of major roadways.
Currently the MassHighway Event Reporting System is in use for urgent situations, and it is planned to be used for construction events in the future.

2.2.5 Tri-State Traveler Information Online (TRIO) - Maine/Vermont/New Hampshire

The New England Tri-State Rural Advanced Traveler Information System, referred to as TRIO, is a partnership of three state tourism agencies, three state DOTs and the private sector. The three states include Maine, Vermont, and New Hampshire. The program is to develop and deploy a regional traveler information system. The TRIO program defines the staged implementation of a variety of systems through twelve project modules across three project generations.

Generation One of TRIO deployment provided travelers and tourists with accurate and real-time information of road conditions, lodging, and recreational activities. Travelers and tourists are able to make informed decisions about their travel patterns using the 511 system, the Internet, HAR, and DMS. Four major modules of Generation One: CARS, Road and Weather Prediction System (FORETELL), 511 system, and Travel Information Web Portals throughout the three states were deployed between 2001 and 2004. TRIO uses the ERM set of C2C standards to send or receive data via XML. The ERM messages support detailed, real-time event summaries or overviews for exchange between TMCs, and from TMCs to service providers or the public. This allows CARS to be integrated with other external ITS applications and systems.

Generation Two will include infrastructure deployments. Initial focus would be in the I-93 corridor in New Hampshire and the I-95 corridor in New Hampshire and Maine. Generation Three may be developed to further extend TRIO outreach, once the basic statewide and corridor components are in place. The phasing and extent of public investment in these modules would be determined based on user feedback and experience gained from the Generation One and Two deployments.

TRIO is capable of communicating with other regional systems like TRANSCOM and other agencies in New York and Massachusetts area. However, some issues still remain. Though the communication interface has been completed, institutional issues such as data ownership, as well as technical issues like firewall access to make the inbound information exchange operational still need to be addressed in the future enhancements.

2.2.6 Regional Integrated Transportation Information System (RITIS) – (Virginia/ Maryland/ District of Columbia)

RITIS is an information exchange system that is intended to integrate the existing transit and transportation management system data in Virginia, Maryland, and the District of Columbia. RITIS will emphasize data fusion and its relationship to data collection, regional transportation systems management, regional traveler information dissemination, and systems evaluation. RITIS will take data of regional interest and fuse that data into regional information that can be used to enhance regional traveler information and
transportation management functions performed by member agencies. RITIS will enhance on-going activities performed by individual agencies by providing each agency with real-time, regional information in an electronic, standardized format.

The RITIS project will advance regional data fusion and demonstrate how real-time regional information can be used to support transportation management, traveler information, emergency preparedness, emergency response, and other regional priorities. The project is a pilot, intended to demonstrate that the technical elements can be developed in a cost effective manner and provide significant benefit to the region. The project directly supports the Metropolitan Washington Region’s on-going and planned ITS activities and incubates the basic technical components that the region needs in order to improve transportation efficiency, safety, and security.

RITIS planning began in 2002 with a grant from the federal government issued to the Metropolitan Washington Council of Governments (MWCOG). The Center for Advanced Transportation Technology (CATT) Laboratory of the University of Maryland, College Park, began work on RITIS in 2006. Currently a project prototype is being developed.

2.2.7 Regional Integrated Multi-Modal Information Sharing (RIMUS) – (New Jersey/ Pennsylvania)

RIMUS is an information exchange network that is intended to link transportation agencies, emergency management agencies, information service providers, and other selected agencies in the greater Delaware Valley area. The primary emphasis of the RIMUS project is to implement a software platform that can be placed on computers in various operations centers. To improve current procedures for information sharing among agencies, a decentralized approach using a message based information exchange network has been selected as most appropriate.

While RIMUS is still in preliminary stages of development, certain needs have already been identified. Information to be shared includes incident notification, incident tracking, traffic and transit conditions, traffic control resources, and emergency support resources. Incidents include accidents, special events, adverse weather conditions, construction and maintenance activity, and emergency evacuation. Agencies will use RIMUS to notify each other about incidents, request incident updates from another agency, request the posting of traffic alerts, or request special assistance.

In the future, emerging technology may allow for the development of a portable RIMUS platform that may be taken into the field. The long-term vision of RIMUS is to establish a virtual database that will store incident information, traffic speeds, traffic volumes, transit schedules, and other real-time information through field detectors.

2.2.8 TRANSCOM

TRANSCOM is a coalition of eighteen transportation and public safety agencies in the New York/ New Jersey/ Connecticut metropolitan region. Several of TRANSCOM’s
members are also members of the I-95 Corridor Coalition. In 1998, the TRANSCOM Regional Architecture was developed to provide regional coordination in incident detection and incident sharing. This Regional Architecture is integrated with the TRANSCOM System for Managing Incidents and Traffic (TRANSMIT), which provides real-time travel time and incident alerts using Electronic Toll Collection (ETC) probe data, and the Trips 123 system which provides traveler information and transit trip planning. The TRANSCOM Regional Architecture also allows integration and distribution of GIS and mapping data and services.

In most recent events, the Regional Architecture is being changed from a client/server based application to a web-based application; known as the Regional Architecture (RA) Web Interface. The RA Web Interface allows users to create, update, close, receive, and distribute Regional Architecture incident, construction, special events, link data, object data, as well as view them on a map interface.

The configuration of the TRANSCOM architecture is shown in Figure 2-1. The model is relatively heterogeneous; allowing the agency's ITS systems to be as different as necessary to support their local missions. It also allows the integration of existing systems and their databases.

![Figure 2-1: TRANSCOM Regional Architecture Network](Source: Regional Integration, FHWA's Freeway Management and Operations Handbook)
All user access to the regional network is through workstations. Information is presented to the operators in an integrated fashion, combining graphical, text, and video formats. Graphical displays represent the primary mechanism for interfacing with and navigating through the regional database. The regional transportation network is displayed in a graphical map-based format providing a common, area wide reference for network conditions, the location of incidents, and the position of ITS devices.

The regional architecture uses national standards to communicate within its expansive network of servers and workstations and subsequently promotes future interoperability with systems that are external to the region, as external systems adopt national standards. The national standards include the use of the NTCIP DATEX (DATa EXchange) protocol for communications between centers or TMCs as well as the standard data dictionary such as TMDD.

Overlaying the data architecture is the Interagency Remote Video Network (IRVN), permitting full-motion video sharing between agencies. The IRVN system allows a TMC operator to interface with the video network and choose the cameras the operator wishes to view. The video encoders convert the video from the selected cameras (routed through the video switch) to Internet Protocol (IP) real-time streaming video. At the receiving TMC, video decoders convert the streaming video signal for display using a video capture card.

TRANSCOM has become a nationally-recognized test-bed for the implementation of intelligent transportation technologies in a multi-jurisdictional environment. TRANSCOM has now installed regional information servers for up to forty-seven centers at its member agencies and provides the following functions:

- Disseminating information on incidents, construction, and other unusual events to affected agencies and other interested parties, including private entities.
- Serving as an interface to the media and private traffic reporting entities regarding incidents and other events that impact the regional transportation network.
- Analyzing the real-time incident information, determining the nature and extent of any regional impacts, developing response scenarios for mitigating these projected problems, and helping to marshal regional resources for response.
- Developing and disseminating a weekly regional summary of the member agencies' major closures and planned construction activities. Also maintaining a long-term database of projected construction projects. This regional construction coordination program helps member agencies to avoid unknowingly restricting capacity on adjacent facilities or routes.
- Clearinghouse of real-time information covering all critical routes and modes. This database integrates available information from agency-specific systems and TMCs to provide a composite picture of the real-time status of the surface transportation network. This information is made available to all member agencies, TMCs, other operating entities, and private traffic reporting entities.
- Regional coordination support between TMCs, transportation agencies, and public safety agencies during major incidents and events.
2.2.9 Southern Traffic Information Exchange (STIX) - I-95 Corridor Coalition

The I-95 Corridor Coalition is currently working on the Southern Traffic Information Exchange Program (STIX) across the four Southern States (Florida, Georgia, North Carolina and South Carolina). The STIX Program will be the newest addition to the I-95 Corridor Coalition incident management network. This project will develop interstate incident notification, information sharing, and inter-jurisdictional coordination between the Southern States, similar to the IEN coordinated by TRANSCOM.

The Georgia TMC will be the “hub” for all STIX Program information, as shown in Figure 2-2 and will receive and disseminate information to all southern stakeholders as well as report information directly to the I-95 Corridor Coalition incident management network.

All recommended standards, specifications, and technologies for the STIX Program are fully compatible with the current I-95 Corridor incident management network, which would benefit the interconnection with the I-95 Corridor incident management network in the future.

Recently the Concept of Operations has been developed and the next phase of this project will consider software implementation options.

Figure 2-2: STIX System Architecture
(Source: STIX Concept of Operations)
2.2.10 Information Exchange Network (IEN) - I-95 Corridor Coalition

The I-95 Corridor Coalition IEN project is developed to fulfill the I-95 Corridor Coalition member agencies need for an electronic communication/information exchange network in the early 90s. The IEN was developed as a client/server application supporting member agencies in the New York, New Jersey, and Connecticut regional area and was connected through dial-up service. System development for the IEN project started in 1994 and completed in 1997. The IEN currently serves the East Coast from New England through the Mid-Atlantic with planned services to the Southern States of the I-95 corridor. The IEN consists of computer workstations and servers connected by a wide-area network (WAN) as illustrated in Figure 2-3. The system uses a distributed hierarchical architecture – a hybrid of centralized and distributed architectures. The wide area network is composed of dial-up telephone between the workstations and the servers, frame relay between the servers themselves, and frame relay between sites that supply information from other systems.

![Figure 2-3: IEN Architecture Diagram](Source: I-95 Corridor Coalition Information Exchange Network)

While the IEN was being developed, Coalition agencies expressed a desire to designate a central location where information could be collected and disseminated for those
incidents having regional impacts. TRANSCOM was asked to provide those services. Since then TRANSCOM has been providing services to the Coalition to provide regional coordination in incident detection and incident information sharing throughout the majority of the Coalition.

User access to the IEN is through workstations located at Coalition members' facilities and Traffic Operations Centers (TOC). These workstations allow users to input and display current operational corridor-wide information in a graphical environment incorporating both data and maps. So far approximately fifty-two IEN workstations have been installed in this project.

The overall goal of the IEN was to facilitate information sharing among member agencies and users of transportation facilities, and to promote coordination of agency activities and resources. The IEN functions and applications are described below:

- **Incident Tracking and Management**
  An important function of the IEN is to facilitate the exchange of real-time information of incidents and their impacts, and to support coordinated incident management activities. Information on major incidents including location, type of incident, estimated duration, category (i.e. local, regional, and corridor), impact and status, and other descriptive information are input to the IEN and regularly updated by the member agencies.

- **Construction Events**
  The construction advisory application allows agencies to share information about planned construction activities, including their location and coverage, schedule, lane closures and vehicle restrictions, diversion routes and contact persons. This information facilitates the implementation of regional diversions, construction planning and scheduling.

- **DMS/HAR**
  The IEN supports the exchange of information regarding the location and usage of DMS and HAR operated by the Coalition member agencies. DMS/HAR information includes locations and types of equipment, status and availability, and current messages.

- **Traffic Condition and Status**
  Information on real-time traffic conditions including volumes, speeds, congestion levels, and transit schedule is extracted from agency-specific systems, processed and aggregated by the IEN, and displayed on map of the Corridor. The traffic flow conditions are represented by different colors and/or symbols associated with the roadway and transit segments.

- **Historic Data**
  The IEN logs and stores the information elements noted above for subsequent use and analyses such as transportation planning and congestion management.
User Interface
The Windows-based user interface includes graphical map displays, “Click-on” icons denoting locations of incidents and transportation management devices, text-based description screens, and summary browsers; all linked together. This interface will be upgraded to a web-based application with GIS-based map in the future IEN enhancement.

Traveler Information (Future Enhancement)
The IEN database, consisting of information and graphics noted above will be made available to private entities for subsequent added value and dissemination to travelers via radio and television broadcasts, public kiosks, computer bulletin boards at home/office, and in-vehicle devices. Moreover, this information transfer is planned to be two-way, with the private entities providing selected information to the IEN database that is not available from the Coalition members themselves.

Commercial Vehicle Operations (CVO, Future Enhancement)
The IEN will function as the communications backbone in support of CVO services including eliminating unnecessary and duplicate inspections, enhancing the permitting process across state lines, and supporting on-line access to credential database.

2.2.11 Information System Network (ISN) - I-95 Corridor Coalition

The goal of the ISN project is to develop an architecture that will support real-time data sharing both within and across regional boundaries throughout the I-95 corridor. The vision is that all related information exchange systems throughout the Corridor will connect to the ISN to provide information that is relevant to other systems, and to receive information that could impact its users. It is anticipated that by provision of a single, standards-compliant interface, any existing or new system will be able to access appropriate real-time information throughout the corridor.

The main purpose of the ISN is to provide effective means for diverse public agencies and jurisdictions along the I-95 corridor to share information affecting regional transportation operations. Operators will have access to information about events that may impact their area of control, independent of which agency’s monitoring system(s) are gathering the data. Emergency responders will have a consistent and reliable means of obtaining information about events and traffic, especially in disaster scenarios that may fall into multiple jurisdictions. This will allow motorists traveling the I-95 corridor to perceive it as a seamless transportation system providing consistent information along their entire route. Transportation system managers and traveler information providers will also be able to provide these capabilities with minimal new investment and development time, leveraging their existing systems as much as possible.

The ISN is best thought of as a network of transportation information services. It is not a new information center, or a dedicated workstation, or a specific software package to be
distributed to ISN users, although all these may be components of the deployed ISN. The network consists of the existing systems along the I-95 corridor, with new standardized interfaces, and of new management components and policies needed to make it coherent and cohesive. The existing systems and new management components are services on the ISN. Any particular system can be a data provider, a data consumer, or both. All participating systems will be registered on the network as providers and/or users of particular classes of information.

The ISN and its components will be built on existing Internet networking protocols and standards. XML data structures based on ITS messaging standards, retrieved over the Internet using HTTP/HTTPS, will be the preferred means of publishing traffic and incident data information. The interfaces of the STIX Program will be implemented as SOAP-based Web services. Administrative user interfaces will be adequately implemented in HTML.

The basic functions and features proposed for the ISN in Phase One of this project are listed below:

- Ability to get essential data from other systems. Essential data includes: speed/volume/occupancy
- Ability to publish essential data to other systems
- Ability to get alerts from other systems
- Ability to publish alerts to other systems
- Register users and services. Establishes and defines the extent of the network
- Authenticate users and services. Assures that messages are to and from legitimate registered users and services
- Authorize users and services
- Implement standard publishing format(s)
- Provide network event “browser”. Provides human interface to the network registry and data
- Establish ISN administrative policies and procedures

The ISN project started in 2003 and had three phases:

- Phase One: development of a concept of operations and system architecture
- Phase Two: development of system requirements
- Phase Three: development of design documentation, building and testing of the ISN, and deployment and assessment of an initial ISN

The ISN is an ongoing project and is currently in the 2nd phase. Figure 2-4 shows the basic conceptual diagram for ISN physical configuration.
Figure 2-4: ISN Physical Architecture
(Source: ISN System Architecture Description)
2.3 Findings

2.3.1 Commonality of Existing Systems

The systems that have been discussed in previous sections are often standards-based information exchange systems that allow authorized users to enter, view, and disseminate critical road, travel, weather, and traffic information through a Graphical User Interface (GUI). These systems can cover single state, multiple states, or mixed jurisdiction regions. They are typically operated by the State departments of transportation, although some regional consortiums are active in this area. These systems provide many of the same functions and features on a regional basis that are provided by a TMC and its field infrastructure. The regional systems in many cases, however, also obtain and redistribute information from various TMCs within that region. In that sense, the regional systems are users of the other systems. The data housed in a statewide information exchange system can be generated by automated or manual methods. Manual data entry into the system and data management is often accomplished through web-based user interface. These information exchange systems can serve as a collection point for real-time transportation system information from various stakeholders including the state police, motorist assist, metropolitan planning organizations, and local maintenance and construction crews. These systems can also capture planned events.

These systems typically provide the following features on a broad geographic basis:

- Ability to enter and update event information
- Ability to record planned events
- Serve as information source for traveler information systems
- Serve as a means of communicating and displaying event information with the covered region; and
- Serve as an information source for other systems

These systems typically capture and distribute a wide variety of transportation data. The level of data collected and distributed is often dependent on the level of maturity of the information exchange system. Systems which were initially designed for manual event entry are being expanded to handle real-time data from other sensor systems and generate corresponding events. Typical data available includes:

- Construction and maintenance work zones
- Road closures
- Lane closures
- Travel restrictions
- Special/planned events
- Congestion
- Delays
- Hazards
- Contact details
- Travel speeds
The following functions have already been developed in most information exchange systems in the I-95 Corridor Coalition and could be shared and integrated in others’ systems as needed:

- Web-based solutions for users to create and share messages about relevant events using web browser with GIS-based map and appropriate national ITS standards such as XML-based protocol and TMDD
- Solutions for interfacing with common GIS databases, tools and location referencing technique
- Solutions for importing and utilizing data from automated sources such as traffic operations centers and public safety 911 centers, as well as manual data entry
- Solutions for outputting data to other ITS applications such as traveler information system, 511 system and 511 website, HAR and DMS

2.3.2 Future Enhancements

2.3.2.1 Automated Web-based Information Exchange with GIS Mapping

Most currently existing web-based information exchange along I-95 corridor is semi-automated such as the TRANSCOM/IEN Regional Architecture Web Interface. Semi-automated information exchange normally requires manual data/information re-entry into another processing system during the C2C information exchange. Suggestion for future enhancement is the move to fully automated web-based information exchange by using XML-based protocols and data vocabularies. Although there are many technologies that could be used for the web-based C2C communication, three families of technologies have been widely utilized by the ITS industry: the International Standards Organization’s DATEX-ASN protocol (used by TRANSCOM), the Object Management Group’s CORBA standard, and the W3C-based XML protocol. The three technologies have their respective advantages and disadvantages. However, the NTCIP 9010 Standard recommends the W3C-based XML protocol for the C2C communication. One of its primary benefits is that it is comprised of vendor neutral technologies and is well supported in the Information Technology (IT) industry.

Potential future enhancements of automated web-based information exchange include the following:

- XML-based vocabularies as a supplement to or replacement for ANSI electronic data interchange standards (for example: ANSI TS285 - Commercial Vehicle Safety and Credentials Information Exchange, etc.).

- XML-based traveler information: the Society of Automotive Engineers (SAE) Advanced Traveler Information Systems (ATIS) Committee published a standard
in 2004: SAE J2630 - Converting ATIS Message Standards from ASN to XML, for transforming an ASN message set definition into an XML schema. A number of systems are now using XML on the server side to prepare web pages and are publishing the XML-based information as well, for reprocessing by others.

- Location referencing: the Open Geographic Information Systems (OpenGIS) Consortium developed an XML-based standard for web-based exchange of geographic information and the latest revision was released in 2007. It is a recommended standard to encode or markup spatial and non-spatial information in XML format by the OpenGIS Consortium. Currently in I-95 Corridor Coalition not all participating agencies have the ability to geo-locate incidents and events. Therefore, a comprehensive web-based regional map showing real-time status of transportation facilities or devices with GIS-based data would be preferred in the future enhancement. Agencies without mapping capabilities that want to see incident information on a map can use the web interface.

- Archived data exchange: Archived Data User Service (ADUS) was added to the National ITS Architecture in 1999. Information collected for real-time operations has many additional uses. XML can be used to exchange ADUS information by systems providing archived data, which will be a new enhancement of web-based information exchange.

### 2.3.2.2 Corridor-Wide 511 Information Sharing

511 systems collect and share information concerning the transportation system and the effects that changing conditions have on that system. This information can be used by long and short distance travelers to plan their trip. Information collected from various sources and distributed to travelers through the 511 system includes:

- Active and planned work zone activities (lane closures)
- Major incidents and their expected duration
- Weather and road conditions (icy or snow covered roads)
- Planned special events

511 systems manually or automatically update their traveler information content. This information can also include floodgate messages concerning severe travel restrictions or AMBER (America’s Missing Broadcast Emergency Response) Alerts. Some 511 systems also act as data sources for their companion 511 web sites.

Currently multiple 511 Traveler Information Systems exist within the I-95 corridor. As of February 2008, nine out of sixteen Coalition member states (Florida, Georgia, Maine, New Hampshire, New Jersey, North Carolina, Rhode Island, Vermont, and Virginia) have deployed a 511 system statewide. The 511 information exchange among the Coalition member agencies is mainly via a 511 E-mail group, which now has more than seventy members and has been used effectively by members seeking answers and information related to 511. The I-95 Corridor Coalition also maintains a 511 website.
resource that links to and showcases member agency 511 and travel information web sites. However, the emphasis of current 511 systems to date has been on metro area or statewide system deployments. No systematic exploration of use of 511 for multi-state trip planning has been considered. The I-95 Corridor Coalition extends from Maine to Florida. There are many overlapping commuter jurisdictions as well as nine of the top twenty-five metropolitan areas located within the corridor. A multi-modal corridor-wide 511 has the potential to provide travelers with a unique set of travel options improving their overall travel experience and it also has the potential to reduce highway congestion and secondary incidents, thus improving overall mobility in the I-95 corridor. The I-95 Corridor Coalition has realized the importance. In 2003 the Coalition began a program called the 511 Support Services Program within its Travel Information Program Track Committee to facilitate the deployment of 511 in its member agencies.

Systematic corridor-wide 511 information sharing requires a corridor-wide information exchange system, which should be capable of facilitating corridor-wide highway traveler information and sharing data with state and local governments and the public. The information exchange system should also support long-distance traveler information application and major incident, emergency, or disaster notification to public sector operators.

A corridor-wide 511 system will then use information from the corridor-wide information exchange system to develop messages that will be included in a 511 call. These messages may be in the form of informational advisories concerning major events several hours or states away including anticipated delays and expected clearance times. Alternate route advisories may also be offered during the duration of the event. In the case of major road closures lasting for long periods of time, flood gate messages may also be posted on the 511 system. This can assist in mitigating the effects of major incidents or road closures along the I-95 corridor.

### 2.3.2.3 Regional Video Sharing

A primary goal of the I-95 Corridor Coalition’s Coordinated Incident Management Program Track Committee is to facilitate, support, and enhance the coordination and implementation of interagency incident response along the I-95 corridor so that safety is improved and impact on the public is minimized. The interagency distribution and sharing of CCTV traffic video during major incidents has been determined to help achieve this goal. The interagency sharing of the video should be limited to I-95 Corridor Coalition member agencies and is not intended to be available to the public. The increased video distribution will improve traffic responsiveness in three ways:

- By increasing traffic monitoring capability of agencies during major incidents within the region
- By improving interagency incident response capabilities
- By providing senior management agency officials more direct access to traffic conditions during major incidents
In 2000 the I-95 Corridor Coalition started a pilot project: Delaware Valley Video Sharing Project. This project included two phases. The first phase of this project was to determine the feasibility and usefulness of sharing video from selected locations within the Delaware Valley Region. Based on the traffic video surveillance resources of the interested agencies, a qualitative analysis of alternative video sharing methods was generated and presented to the participating agencies, and a decision was made by the Delaware Valley Regional Highway Operations Group (HOGs) that it was desirable to proceed with implementation. The second phase of this project was to develop the equipment specifications and perform the system integration needed to implement the video sharing system at the following five agencies: Delaware Department of Transportation (DelDOT), Delaware River and Bay Authority (DRBA), Delaware River Port Authority (DRPA), New Jersey Department of Transportation (NJDOT), and Pennsylvania Department of Transportation (PennDOT).

The Delaware Valley video sharing system uses a decentralized architecture to deliver software-encoded video via the Internet. Each of the five agencies that supply video operates its own separate video sharing subsystem from its own TOC. Each agency’s subsystem encodes that agency’s video feeds into a format that can readily pass over an IP network. In addition this subsystem includes the video distribution server that delivers the agency’s encoded video streams in response to an end user’s request. Essentially each agency has its own independently configured and operated video sharing system. The five transmitting agencies’ video sharing subsystems are tied together by the Delaware Valley video sharing system’s GUI. The GUI is an HTML based web page that the end user will access via the Internet. This web page is password protected to limit access to the Delaware Valley video sharing system to only authorized personnel. In addition the system should be configured so that only PCs with specific IP addresses can access the web page. All future cameras deployed will be IP addressed and existing cameras will be switched over.

Currently some Coalition member agencies have no or very limited regional video sharing and some have already proposed regional video sharing implementation in their future enhancements. This pilot project can serve as a demonstration of potential of interagency video sharing, in anticipation of a future enhanced web-based information exchange system. The deliverables of this project can be applied to other regional systems in terms of:

- Methodology, including a survey of existing field video sources and a qualitative analysis of alternative video sharing methods to determine feasibility and cost of implementation
- Equipment specifications, procurement report, and implementation plan
- System integration approach for the regional IP-based video sharing system
2.3.3 Lessons Learned

Lesson One: Develop information exchange systems using open national ITS standards and established guidelines and integrate with the National ITS Architecture

The existing information exchange systems throughout the I-95 corridor, described in Section 2, share very little information between systems. Communications about events that cross agency lines occur between operations personnel in the agencies as needed. In the best cases, agencies have established cooperative agreements for information sharing and may have policies and procedures in place for emergency and incident management. However, interagency communication mainly depends on human interaction to get information from one set of systems to another. One of the main reasons caused the interoperability difficulty is that not all information exchange systems are designed and developed by using open national ITS standards and established guidelines.

Take the TRIO project for example: in order to achieve interoperability between the three states’ CARS and the I-95 Corridor Coalition’s IEN for sharing incident/event information as well as information on the use/status of various ITS components such as HAR and DMS, the TRIO project had to extend an additional task for IEN integration, which upgraded the TRIO CARS from its ERM standard to the new Full Event Update (FEU) Message standard from TMDD, via a staged implementation process. Generally it is necessary to add protocol converters or ‘bridge’ standards to a legacy system to facilitate its information exchange with ITS standards-compliant systems seamlessly. A legacy system is, by definition, a closed system with proprietary interfaces, databases, or protocols. However, for some cases, it is neither feasible nor cost-effective to modify some older legacy systems to make them standards-compliant. In such cases, non-compliant legacy systems would be required to run separately from those which are standards-compliant. This approach would promote the simultaneous upgrade of non-compliant systems in the future.

In early 2007, the I-95 Corridor Coalition conducted a survey of its member agencies to define the performance requirements for a new information exchange system. Respondents were asked whether and over what distances they wanted to exchange information about major accidents and events. The survey found that member agencies strongly preferred automated information exchange among member agency traffic management centers and with travel information service providers and the public; without the need for major modification on existing systems and additional data entry. In an ideal circumstance, the system would allow any agency to see information from anywhere along the corridor as if the information were native to that agency’s own systems, without the need for human intervention to get the data from one system to the other.

Therefore, any conceptual framework of a new information exchange system or enhancement for I-95 Corridor Coalition should be developed by using open national standards to ensure uniformity and compatibility with the National ITS Architecture. This
way, integration with other systems will be more easily achieved. We will discuss more
details about the national ITS standards in the next task order of this project.

Lesson Two: Develop a stable and reliable communications mechanism during
emergency situations or catastrophic events such as hurricanes and major winter
storms, specifically when traditional communication means (landline or wireless) are
not available.

The overall objectives of the information exchange system in terms of system operations
are to:

- Be informed of risks (e.g., hazardous materials, weather, and terror) so that they
can be monitored appropriately
- Improve timeliness and accuracy in monitoring risks
- Reduce operating risks to travelers, operators, and maintenance personnel (e.g.,
  work zones, secondary collisions)
- Communicate risks to travelers, operators, and maintenance personnel

Therefore, communicating risks among member agencies is an important role of the
information exchange system. The same survey mentioned previously also found that the
Coalition member agencies were most interested in information exchange and sharing
during emergency situations or catastrophic events, which would eventually require that
the information exchange system should be capable of supporting the following
operations:

- Backup communications between TMCs or TCCs of member agencies
- Emergency communications between TMCs/TCCs and public safety agencies or
  emergency management agencies
- Temporary communications between mobile TMCs and fixed-site TMCs/TCCs if
  fixed-site TMCs/TCCs have to be evacuated or abandoned and mobile TMCs
  need to be used during emergency situations

Currently none of the systems discussed in this task systematically provide any
emergency communication mechanism during emergency situations or catastrophic
events. Therefore, the communication network architecture of any new information
exchange system or enhancement will have to take this into consideration.

Although landline communications have predominated in C2C and center-to-field (C2F)
communications, recent technological advances make wireless communications
increasingly attractive, specifically for emergency situations. New wireless data
communications technologies have the greatest potential for influencing future ITS
communication. In addition to traditional wireless media such as radio frequency and
microwave, other available options include: cellular networks, satellite transmission,
packet radio, spread spectrum radio, etc.
For large distance (C2C) communication and the communication in rural area (C2F) satellite communication has been proved to be capable of rapid deployment (within days or even hours) and cost-effective, specifically when it serves as a backup for the landline communications in catastrophic events such as earthquake or hurricane, which may severely disrupt normal communications between communication centers.

The use of VSAT may be a typical satellite communication application for C2C and C2F communications. A VSAT is a two-way satellite ground station with a dish antenna that is smaller than three meters. VSATs access satellites in geosynchronous orbit to relay data from small remote earth stations (terminals) to other terminals or master earth station hubs. The California Department of Transportation (Caltrans) has successfully deployed and tested the VSAT application in several pilot projects. During these projects, satellite communication was successfully established between two TMCs (one mobile TMC and one fixed-site TMC). The Advanced Transportation Management System (ATMS) was successfully transmitted to the mobile TMC for remote usage. In addition, the mobile TMC was able to successfully receive live video and data from field devices.

Satellite communication will be considered as a recommended technology for I-95 Corridor Coalition C2C communications and discussed more in the next task of this project.

**Lesson Three: Coordinate across jurisdictions/regions for institutional issues and future enhancements to reduce costs and delays**

By agreement of the participating agencies, an information exchange system is used as a tool to help agencies perform their functions, but it does not alter the lines of legal or operational responsibility for incident management, traffic management, or other aspects of transportation. Data collection from and maintenance of field devices remain the responsibility of the participating agencies. Information exchange system compiles and distributes traffic and transit information, but it does not actively manage traffic or transportation operations and incidents independent of existing lines of authority.

Most organizations already perform some level of incident management information exchange and may not see the potential benefits in working in a structured, coordinated fashion with other agencies that do not share a common goal. The participating agencies must perceive that there is a benefit to changing the status quo. The first step in gaining buy-in from all participants is to develop a common program goal that recognizes the different priorities among agencies. For example, DOTs may be more interested in the safe and efficient restoration of traffic flow, while fire departments may focus more on the individual safety of their personnel while clearing an incident. This difference of interests can result in different information data customization and filtering. When agencies request that they not receive all available data, limiting their data to, for example, specific types of incidents or incidents only in a given location, this might introduce a liability issue if agencies do not receive critical incident related information. By working together in an atmosphere of mutual respect and trust, all participating
agencies should be able to come to new agreements about how to meet each agency's goals while working toward a common goal of information sharing and exchange.

An information exchange system provides data to and extracts data from multiple systems at multiple agencies. This requires review of information systems policies at the agency level to determine appropriate interface requirements and logistics. Policies related to this coordination must be established to avoid conflicting data and response, and to best manage incidents that cross jurisdictional and modal boundaries. Policies on data ownership, privacy, security and agency network firewalls need to be examined to allow information to flow in and out while preventing system incursions, as well the need to restrict safety-sensitive data such as that from CAD systems. Other institutional technical issue such as the control of ITS devices (CCTV cameras, DMSs, etc.) will also need to be addressed before implementation. It would be most logical for the device owner to have the primary control of its device. For example, CCTV video can be shared among multiple agencies. Camera control (pan, tilt, and zoom) should remain exclusively with its owner. Shared control of cameras should not be allowed in order to avoid conflict in real-time operations. However, this may be changed under certain circumstances by agreement of the participating agencies.

It also needs to be determined how an information exchange system will be operated and maintained. In particular, all participating agencies must decide how these activities will be funded, how operation and maintenance responsibilities will be shared, and how operation and maintenance decisions will be made.

Furthermore, by coordinating future technology and infrastructure enhancements regionally rather than locally, benefits related to interoperability of technology and infrastructure management can be addressed prior to implementation, helping to reduce future costs and delays. Some common future enhancements mentioned previously have been planned or proposed by I-95 Corridor Coalition members, but are too frequently neglected by incident management leaders. This institutional bridge building helps to create better interagency coordination and avoid wasteful duplication for deployment.
3 Chapter 3 - Task Three: C2C Gap Analysis

3.1 Task Three Background

This task (Task Order Three) includes an effort in reviewing the C2C guidelines (outlined in Task Order One) and the existing eleven information exchange systems with C2C deployments (identified as best practices in Task Order Two), undertakes an analysis to identify the divergences from the National ITS Architecture C2C standards and also highlights the gaps between the existing best practices in terms of the communication mechanism, interagency video sharing technology and the system functional requirements. The purpose of this task is to identify problem areas in the existing systems and drive the technology recommendations to be defined in the Task Order Four of this project.

3.2 Gap Analysis

Several key elements are considered when analyzing the eleven information exchange systems of best practices, including:

- C2C standards including the data dictionaries and protocols

  In order to share data across subsystems and between systems, a standardized data dictionary is necessary. A data dictionary provides a rigorous, unambiguous definition of the form of data that will be stored in a computer or other processor. It includes items such as: a unique descriptive name, a domain-specific description, range of values, permissible values, minimum and maximum size, relationship to other data elements in the data dictionary, data type of element (integer, real, character), and format. Data dictionary elements are bundled into messages that can be transferred between computers. These messages comprise the data flows within the architecture. Without a standardized data dictionary, a uniform interpretation of messages and their meanings is not possible. In a simple analogy, message sets are the sentences, whereas the data elements in the dictionary are the individual words.

  A protocol is defined as a set of rules or conventions formulated to govern the exchange of information (i.e., data, messages) between two computers or two information exchange systems. Basic elements of a protocol include data format, message sequence, and maintenance of data integrity.

- Communication network architecture: In the context of ITS, the communication network architecture describes what and how information is exchanged among transportation agencies and their respective transportation management systems and centers, how the C2C connections and communications are accomplished, and the additional functionality of this integrated information provides to users.
Interagency video sharing technology: the interagency video distribution and sharing can provide increased information to the respective agencies for incident management and improve traffic responsiveness in many ways. Many Coalition members have realized the importance; however the difficulty is that each member agency uses different types of video equipment operated on various platforms. Therefore, to enable the interagency video sharing, a common information sharing platform and the associated video format conversion have to be considered.

System functional requirements: information exchange system captures and distributes a wide variety of transportation data. The type and level of data collected and distributed are dependent on the different agency needs. All these data and system functions are presented to the users through the GUI on workstations. Therefore our analysis is focused on the system functional requirements in terms of the data available to users and the user interface.

### 3.2.1 C2C Standards Analysis

C2C Standards describe guidelines for communicating data and commands in a C2C application / system. C2C communications span the entire ITS domain, covering the exchange of data between computers physically located in different transportation management center facilities (e.g., traffic management centers, transit management centers, and emergency management centers). C2C communication standards enable this data exchange, specifying what information is exchanged, how and when it is exchanged, and the underlying transport mechanisms. C2C standards can be divided into two categories: 1) the vocabulary (data dictionaries and messages), and 2) the rules for exchanging the messages and data (protocols). The two categories work together to successfully exchange meaningful ITS-related information.

#### 3.2.1.1 Vocabulary Standards

Data dictionaries and message sets are essential components in the operation of computer-based intelligent transportation systems. Data dictionaries provide the basic definitions, generally described as data elements (DEs), that make up the specific content of a message used to convey information among ITS systems. In a simple analogy, messages are the sentences and DEs are the individual words. A message set provides a series or set of individual messages, established in a strict format, for exchanging information on a given topic. Thus, an agreed-upon data dictionary and message set with unambiguous definitions are essential to exchange information between TMCs, or between a TMC and other ITS centers and/or sources of traffic data.

Some examples of commonly used vocabulary standards in the existing information exchange systems based on their functional areas include:
AASHTO-ITE TM 2.1: Standards for Traffic Management Center-to-Center Communications

The data dictionary and messages set standard, AASHTO-ITE TM 2.1: Standards for Traffic Management Center-to-Center Communications, was developed for ITS systems that manage traffic. The data dictionary standard, AASHTO-ITE TM 1.03, TMDD, and its companion message set standard AASHTO-ITE TM 2.01, Message Set for External Traffic Management Center Communications, were combined into the single standard in 2006, AASHTO-ITE TM 2.1. These data elements and message sets were developed as a joint AASHTO-ITE effort under the oversight of a national steering committee composed of formal representatives of both organizations. The AASHTO-ITE TM 2.1 is comprised of both a functional level data dictionary and a message set, and is designed to be independent of any specific communications protocol.

The data dictionary consists of and defines a set of data elements necessary to support data exchange within and among traffic management systems. Specifically, it provides meta-attributes for each DE including definitions (semantics) and specific format (syntax).

The message sets include three message groups (i.e., Manage Assets, Manage Transportation Related Information and Remote Operational Control of Traffic Control Devices) necessary to convey key data within and between traffic management centers and other ITS centers. It provides a list of specific data elements for each message plus other format information such as message name, message number, and other mandatory and optional message attributes.

The traffic management functional area data dictionary (as distinguished from an application-specific data dictionary) provides a national standard for an agreed-upon set of data elements for traffic management systems. Similarly, the message set provides a national standard for messages involving traffic operations. The data dictionary and message set become the basis for design and implementation of traffic management communications. Typically, these standards will be implemented in an Applications Program Interface (API) allowing communication to and from the traffic management center or application. Thus, the data dictionary and message set defined in this standard are intended to act as the core set of DEs and the core sets of messages, respectively, that will be used by all ITS-based traffic management systems. Both the data dictionary and message set may be augmented in specific applications as necessary to support additional local functions or conventions not contained in the standards.

The traffic management messages and DEs should be implemented in conjunction with the selected C2C communications profile standards. In addition, an interface specification should be defined consistent with the AASHTO-ITE TM 2.1.
Currently all the eleven information exchange systems use this standard.

- **SAE J2354 - Message Set for Advanced Traveler Information System (ATIS)**

  This standard provides the messages and data elements that are exchanged among traveler information providers (data providers) and travelers (data consumers). The most recent revisions to the standard includes the integrated use of the International Traveler Information System (ITIS) phrase lists for communicating event information, addition of XML-based versions of each entry, and reuse of data elements from other functional area data dictionaries (e.g., TMDD). Any information exchange system providing traveler information shall use this standard, such as the TRANSCOM Regional Architecture, TRIO and iFlorida, etc.

- **IEEE 1512 - Family of Standards for Incident Management Message Sets**

  This IEEE 1512 family of standards supports the exchange of incident-related data between transportation, public safety, and other responding agencies. The IEEE 1512 family consists of a base (or common) standard and several subject-area standards:

  - **IEEE Std 1512-2000**, Common Incident Management Message Sets for Use by Emergency Management Centers is the base standard that defines basic information - such as a description of the incident - that is exchanged for any incident.
  - **IEEE Std 1512.1-2003**, Traffic Incident Management Message Sets for Use by Emergency Management Centers defines messages needed to respond to traffic-related incidents, including information about traffic flow, traffic control equipment, and coordination of cleanup and repair.
  - **IEEE Std 1512.2-2004**, Public Safety Incident Management Message Sets for Use by Emergency Management Centers supports coordination among public safety agencies including warning information, situation awareness, plan dissemination, and interagency asset management.
  - **IEEE Std 1512.3-2002**, Hazardous Material Incident Management Message Sets for Use by Emergency Management Centers includes messages needed by responders to hazmat spills and other incidents related to commercial vehicles and homeland security.
  - **IEEE Std P1512.4 - Standard for Common Traffic Incident Management Message Sets for Use in Entities External to Centers** addresses the exchange of incident management information between centers and mobile data terminals.

  The subject area standards (1512.1 through 1512.4) are often referred to as "companion volumes" and must be used in conjunction with the base standard. Each standard defines messages and includes a data dictionary that defines the
data elements that each message contains. Each message is defined in ASN.1 and in XML.

### 3.2.1.2 Protocol Standards

Communications protocols work in conjunction with message sets and data dictionaries. Protocol standards describe how messages are encoded for transmission and then transmitted and received by other systems.

Although there are many technologies that could be used for C2C communication protocol, three families of technologies have been widely utilized by the ITS industry: the International Standards Organization’s DATEX-ASN protocol (NTCIP 2304: Application Profile for DATEX-ASN, used by TRANSCOM, etc.), the Object Management Group’s Common Object Reference Broker Architecture (CORBA) standard (NTCIP 2305: Application Profile for CORBA), and the W3C-based (World Wide Web Consortium) XML protocol (NTCIP 2306: Application Profile for XML Message Encoding and Transport in ITS C2C Communications). All three families of standards can share a common set of vocabulary standards for data element definitions (data dictionaries), and description of message dialogs. Based on feedback from the transportation community, the FHWA and the Standards Development Organizations (SDOs) have decided not to pursue further development of the CORBA standard.

- **NTCIP 2304: Application Profile for Data Exchange ASN (DATEX-ASN)**

  The NTCIP 2304 standard is one of the C2C data communication protocols defined by the NTCIP. This standard is applicable to communications between any two management subsystems within the ITS environment. It lists the requirements for a traditional approach for data exchange among systems. This standard specifies how DATEX-ASN is to be used within the United States. DATEX-ASN is also an international standard (ISO 14827 Parts 1 and 2) developed by the NTCIP Center-to-Center Working Group in cooperation with the ISO. This standard serves primarily as a pointer to detailed requirements in the ISO 14827 protocol standard. The main DATEX-ASN specification permits various options; this standard ensures all implementations of DATEX-ASN within the United States use the same base options and therefore can be made interoperable.

  Users refer to this standard to determine which DATEX-ASN options are appropriate for their applications. Of particular importance are the requirements for use of octet encoding rules (OER) for message encoding. The document also provides a profile requirements list, which is a checklist that can be used to choose between the various secondary options allowed by DATEX-ASN. The result is a Profile Implementation Conformance Specification (PICS). The format of this checklist enables the user to see the interdependencies between options so that compatible options can be chosen.
The TRANSCOM Regional Architecture and the Syracuse Metropolitan Area Regional Transportation NETwork (SmartNET) use this standard.

- **NTCIP 2306: Application Profile for XML Message Encoding in ITS C2C Communications**

The NTCIP 2306 Standard: Application Profile for XML Message Encoding and Transport in ITS C2C Communications (C2C XML) provides a mechanism for the implementation of communications interfaces defining the message form, usage and protocol used for transmitting information encoded in the XML between centers. XML is a standard of the W3C. XML is a means by which one computer can encode some information (data) so that another computer receiving that encoded information will be able to understand its contents and act on that content (e.g., process the information, display the information to a human, store the information in a database, issue a command to a field device, etc.). Unlike most computer encoding standards, there is no single set of encoding rules for XML. Instead, XML encoding rules are customized for different applications. Furthermore, XML encoding rules include a mechanism for identifying each element of an XML document or message. This standard defines mandatory requirements for implementing C2C, and also defines optional and conditional requirements that may be applicable in specific environments. Specifically, it defines mechanisms for using the SOAP and the WSDL to support customer-initiated requests for information from a central system. Compliant systems will implement these requirements to ensure compatibility with compliant applications.

- **NTCIP 9010: XML in ITS Center-to-Center Communications**

The NTCIP 9010 Standard recommends the W3C-based XML protocol (NTCIP 2306) for C2C communications although the other two standards have their respective advantages. One of its primary benefits is that it is comprised of vendor neutral technologies and is well supported in the IT industry. As a matter of fact, almost all existing systems are currently using the NTCIP 2306 as their primary C2C communication standard.

The first generation specifications for Web services were released by the W3C in 2000 with the adoption of SOAP. This XML-based messaging format established a transmission framework for inter-application (or inter-service) communication via HTTP. This was followed by the WSDL specification, which supplied a language for describing the interface of Web services and the Universal Description, Discovery, and Integration (UDDI) specification, which provides a standard mechanism for the dynamic discovery of service descriptions.

The following Table 3-1 summarizes the comparison of the major standards used to specify the various components for each of the three C2C communications standard families.
### Communications Protocol

<table>
<thead>
<tr>
<th>Data Dictionaries</th>
<th>DATEX-ASN</th>
<th>CORBA</th>
<th>W3C-based XML Protocol</th>
<th>XML Direct Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Message Dialogs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rules for Defining Messages/Objects</td>
<td>ASN.1 (Abstract Syntax Notation) e.g., MS-ETMCC, TCIP, ATIS, IM, etc.</td>
<td>CORBA IDL (Interface Definition Language)</td>
<td>XML Schema Language • SAE ASN.1 to XML Encoding Rules • WSDL (Web Services Description Language)</td>
<td>XML Schema Language • SAE ASN.1 to XML Encoding Rules</td>
</tr>
<tr>
<td>Encoding Rules for Transmission of Data/Objects</td>
<td>OER (Octet Encoding Rules)</td>
<td>CDR (Common Data Representation)</td>
<td>XML is encoded as ASCII text • Functional area XML Schemas define valid tags</td>
<td></td>
</tr>
<tr>
<td>Application Protocol (handshaking, message framing, etc.)</td>
<td>DATEX-ASN</td>
<td>IOP (Internet Inter-ORB Protocol)</td>
<td>SOAP (Simple Object Access Protocol) over HTTP for the W3C Approach.</td>
<td>XML Direct - FTP and HTTP</td>
</tr>
<tr>
<td>Other Services (e.g., discovery, security, aggregation, subscriptions, etc.)</td>
<td>DATEX-ASN supports a robust subscription-based service and administrative messages</td>
<td>CORBA services, Near Real-Time Data Service, Administrative Objects, Naming Service, Trader Service</td>
<td>Possibly UDDI (Universal Description, Discovery and Integration). An OASIS Group Standard, for Discovery.</td>
<td></td>
</tr>
<tr>
<td>Transport Protocol</td>
<td></td>
<td></td>
<td></td>
<td>TCP/IP and UDP/IP</td>
</tr>
</tbody>
</table>

Table 3-1: Standards Comparison
(Source: the NTCIP 9010)

### 3.2.2 Communication Analysis

#### 3.2.2.1 Network Technology

A communication network basically consists of two primary application types: Local Area Network (LAN) and Wide Area Network (WAN). The LAN covers smaller geographic area whereas the WAN covers a larger area (county, district, or region). WANs typically consist of multiple LANs interconnected through a high-speed data network.
Common topologies for communication networks include the point-to-point, star, ring, and hybrid topologies. A typical traditional information exchange system network such as TRANSCOM / IEN is normally configured as a hybrid of star and multiple point-to-point architectures as shown in Figure 3-1.

![Figure 3-1: Traditional Communication Network Architecture](image)

The star topology is basically configured for communications between workstations and the server in a LAN. All user access to the information exchange system is through workstations. A multi-line, parallel configuration of dial-up circuits or local agency Ethernet network permits the server to connect, and transmit messages simultaneously to multiple workstations; and also to receive information from workstations. Dial-up circuits are suitable only for infrequent and low bandwidth transmissions, specifically, incident status, construction schedule updates, and other text messages. The information that is received is not always real-time.

Multiple point-to-point topology is configured for communications between the servers in a WAN. Each agency server has a point-to-point dedicated high-speed circuit to the information exchange functional server. These circuits are normally 56 Kbps or greater dedicated service by using SONET, ATM or some form of dedicated service. This traditional hybrid topology has been changed and simplified due to the use of Ethernet technology combined with the IP in the ITS industry, specifically the use of
Gigabit Ethernet technology for the WAN communications. The communication network architecture with Ethernet technology is shown in Figure 3-2.

Figure 3-2: Communication Network Architecture with IP/Ethernet

All communications between workstations and the server, and between the servers are via Ethernet network. As discussed in the Task Order One of this project, Ethernet includes the following three principal categories: Standard Ethernet or 10BaseT (10 Mbps over copper using Cat 5 cable); Fast Ethernet or 100BaseTX (100 Mbps over copper using Cat 5 cable) and 100BaseFX (100 Mbps using single of multi-mode fiber); Gigabit Ethernet or 1000BaseTX (1000 Mbps Gigabit over copper using Cat 5 or Cat 5e cable), 1000BaseSX (1000 Mbps Gigabit over multimode fiber) and 1000LX (1000 Mbps Gigabit over single-mode fiber). It is worth noting that the 10 Gigabit Ethernet (10GigE) standard draft was complete in 2002, which will be capable of delivering 10 Gbps data rate with extension to 40 Gbps in the near future. Fast Ethernet (100 Mbps) is typically configured for communications between workstations and the server in a LAN. Gigabit Ethernet (1000 Mbps) is ideal for communications between the servers in a WAN, specifically if a high-speed data rate is required to transfer and share a large amount of data such as: real-time traffic data and video between agencies. With the combination of IP and Ethernet technology, Ethernet network becomes a viable solution for ITS networks and C2C communications. Interagency information sharing requiring high-speed data over IP (traffic monitoring, surveillance), and low-speed data over IP (traffic data, devices control) becomes feasible and cost-effective over Ethernet network.
Agency can use either private agency-owned networks or leased networks for connection. The agency-owned network is generally part of communication facilities which are designed, constructed, and operated by the agency. The leased communication network could be a mixture of media leased from a private sector telecommunications provider. The use of a leased network is a communications option utilized by many public agencies. The private agency-owned network may not be cost-effective for only information exchange purpose but could be implemented between specific systems if security justifies the cost.

A major advantage to using Ethernet technologies is the very large installed user base. The equipment is readily available, well tested, and well supported. There are a wide variety of interfaces available, and adding new equipment can be as simple as setting a few parameters. In addition, there is many sophisticated network management software available, which will allow for easier, more cost effective maintenance to be performed – resulting in a lower cost of ownership and day-to-day network maintenance. SONET and ATM solutions for WAN communications are generally more expensive, considering a variety of factors such as availability of service and providers, future expansion capability, and reliability, etc.

### 3.2.2.2 Network Redundancy

Generally the communication system is, in most respects, the least failure prone element of an overall system, but potentially has a high risk of being disrupted by outside forces. Each network communication technology has its redundancy mechanism. Ethernet network as an example has relied primarily on its protocols to provide a certain level of redundancy, typically for a single point or link failure. When there is a failure in the network, the Ethernet switches detect the failure and generate a series of control protocols to reroute the data to avoid the failed link. Unfortunately, this convergence can only eliminate single points of failure. In case of emergency situation or catastrophic event, such as earthquake or hurricane, which may severely disrupt the entire communication network, this level of redundancy is obviously not sufficient.

None of the existing eleven information exchange systems in the I-95 Corridor Coalition systematically provides any emergency communication mechanism during emergency situations or catastrophic events when traditional communication means are not available. It is critical for the I-95 Corridor Coalition agencies to be able to support the following operations during emergency situations: backup communications between TMCs or TCCs of member agencies; emergency communications between TMCs/TCCs and public safety agencies or emergency management agencies; temporary communications between mobile TMCs and fixed-site TMCs/TCCs if some fixed-site TMCs/TCCs have to be evacuated or abandoned and mobile TMCs need to be used.

In the previous task order we recommended the use of VSAT as a C2C communication backup in case of emergency situations. The communication network architecture with satellite communication backup is illustrated in Figure 3-3. We will discuss more details
in the next task order of this project: C2C Communication Technologies and Recommendations.

**Figure 3-3: Communication Network Architecture with Satellite Communication Backup**

### 3.2.3 Video Sharing Technology Analysis

In the previous task order we discussed that the interagency distribution and sharing of CCTV traffic video during major incidents provides increased information to the respective agencies for incident management in the Delaware Valley Region and improves traffic responsiveness in many ways. Many Coalition members have already proposed new regional video sharing implementations or expansions in their future enhancements.

The pilot project: the Delaware Valley Video Sharing Project is a great example of how the I-95 Corridor Coalition projects are very beneficial. In this instance, three states are brought together to identify and work through issues and ultimately successfully share video images, which can serve as a demonstration of potential of interagency video sharing among other member agencies, in anticipation of a future enhanced web-based information exchange system.

The Delaware Valley video sharing system uses a decentralized architecture to deliver software-encoded video via the Internet: a common information sharing platform. Each of the five agencies (DelDOT, DRBA, DRPA, NJDOT, and PennDOT) that supply video
operates its own separate video sharing subsystem from its own TOC. Each agency’s subsystem encodes that agency’s video feeds into a format that can readily pass over an IP network. In addition this subsystem includes the video distribution server that delivers the agency’s encoded video streams in response to an end user’s request. Essentially each agency has its own independently configured and operated video sharing system. The five transmitting agencies’ video sharing subsystems are tied together by the Delaware Valley video sharing system’s GUI. The GUI is an HTML based web page that the end user will access via the Internet. This web page is password protected to limit access to the Delaware Valley video sharing system to only authorized personnel. Once logged into the GUI the end user is presented with both a map based and list based means of selecting one of the five transmitting agencies’ traffic cameras. The end user selects a camera either by clicking on the appropriate camera icon on the map or by selecting the camera from a list displayed on the GUI. Selecting a camera by either of these methods through the GUI causes the end user’s PC to send a message to the appropriate transmitting agency’s video distribution server requesting access to that specific camera’s video stream. The video distribution server in response sends the video to the end user’s PC where the video is displayed. The overall video sharing system architecture is shown in Figure 3-4.

The typical configuration of an agency’s video sharing subsystem is illustrated in Figure 3-5. The main components of each video sharing subsystem are the video encoders, these are devices or PCs which are configured to digitize and compress analog video feeds. The distribution server is to send the compressed and formatted video, usually called video streams, from the video encoders and to deliver these streams to the end user via the Internet.

This project however only demonstrated the interagency video sharing solution for the existing legacy cameras, which are not IP-addressable. Eventually all future cameras deployed will be IP-addressable and the existing legacy cameras will be switched over. During the transition period, both types of cameras coexist. This project did not address how to solve this issue. Other issues such as communication bandwidth and institutional network also need to be addressed. The greater the bandwidth, the greater the quality and number of video feeds that can be transmitted and shared. However the greater the bandwidth, the greater the operation and maintenance costs that must be funded by the individual member agency. There must be a best trade off between quality and cost. Furthermore, the video sharing system subsystem can either be integrated with or isolated from the agency network. Agencies may have different choices based on their IT policies. Therefore additional firewall hardware and network configuration may be needed. We will discuss more details about the solutions for these issues in the next task order of this project: C2C Communication Technologies and Recommendations.
Figure 3-4: Overall Video Sharing System Architecture
(Source: Delaware Valley Video Sharing Project Final Design)

Figure 3-5: Typical Agency Video Sharing Subsystem
(Source: Delaware Valley Video Sharing Project Final Design)
3.2.4 Functional Analysis

3.2.4.1 Available Information/Data

Each of the eleven systems identified in Task Order Two serves primarily as a tool to gather, share, display and archive traffic information and data across multiple jurisdictions. These systems are standards-based information exchange systems that allow authorized users to enter, view, and disseminate critical road, travel, weather, and traffic information through a GUI. These systems provide many of the same functions and features on a regional basis that are provided by a TMC and its field infrastructure. The regional systems in many cases, however, also obtain and redistribute information from various TMCs within that region. These systems typically capture and distribute a wide variety of transportation data. The type and level of data collected and distributed are dependent on the level of maturity of the information exchange system and the agency needs. Typical data available to users includes, but not limited to:

- Traffic speed, volume and occupancy
- Incident data (road closures, lane closures, travel restrictions)
- Alternative routes
- Weather conditions
- Transit status
- Transit schedules
- Construction/Work zone data
- Video

A detailed comparison of the information/data available to users for the eleven information exchange systems is summarized in Table 3-2.

3.2.4.2 User Interface

All user access to the information exchange system is through workstations. Information is presented to the users through the GUI in an integrated fashion, combining graphical, text, and video formats (some systems only). Typically the GUI is either web-based interface or client-server based interface. Most of the current systems are using web-based applications. This allows the authorized users to enter any condition reports or view reports entered by any other users from any location. The transportation network is displayed in a graphical map-based format providing a common, area-wide reference for network conditions, the location of incidents, and the position of ITS devices. Most of the current systems are using GIS-based location referencing technique from several major software vendors. The detailed comparison is included in Table 3-2.

Two examples of the TRANSCOM user interface are shown in Figures 3-6 and 3-7.

The TRANSCOM Regional Architecture interface screen shows the Map Viewer screen. The screen is split, with the left side showing real-time traffic flow conditions (via color code), incident locations, and DMS locations along the George Washington Bridge and
approaches. The right side shows the same type of information for the Verrazano Narrows Bridge.

Figure 3-6: TRANSCOM Regional Architecture Map Viewer Interface
(Source: Regional Integration, FHWA's Freeway Management and Operations Handbook)

Figure 3-7: TRANSCOM Regional Architecture Event Tracking Interface
(Source: Regional Integration, FHWA's Freeway Management and Operations Handbook)
The TRANSCOM Regional Architecture Event Tracking Interface screen shows the Incident Tracking Highway View screen. It includes fields for Reported by, State, Contact Number, Responding, User's Name, Incident Type, Facility / Route, Article, Direction, Detail, From / To, and Description. It also includes tabs for Details, Actions, Links, Open Incidents, and Closed Incidents.

3.2.4.3 Functional Comparison

The complete functional comparison for the eleven information exchange systems is summarized in Table 3-2. Other functions such as the information dissemination and data archiving are also included. Among the eleven systems, the functional requirements for the STIX and the ISN are at the design stage of the systems engineering phase of the project, hence are not currently available.
<table>
<thead>
<tr>
<th>Best Practices</th>
<th>Speed</th>
<th>Volume</th>
<th>Incident data</th>
<th>Alternative routes</th>
<th>Weather conditions</th>
<th>Transit status</th>
<th>Transit schedules</th>
<th>Work zone data</th>
<th>Video sharing</th>
<th>GIS Compatible</th>
<th>Web-based or client-server based</th>
<th>Information Disseminated to the Public through</th>
<th>Data Archiving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Florida: iFlorida</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Web-based</td>
<td>511 system, public website, DMS</td>
<td>Yes</td>
</tr>
<tr>
<td>New York: CARS</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Unique location referencing technique</td>
<td>Both</td>
<td>511 system, public website, DMS, HAR and LPFM (Low Power FM) radio</td>
<td>Yes</td>
</tr>
<tr>
<td>New York: SmartNET</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Web-based</td>
<td>511 System</td>
<td>Yes</td>
</tr>
<tr>
<td>Massachusetts: the MassHighway Event Reporting System</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Web-based</td>
<td>Information not disseminated to the public</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Maine/Vermont/New Hampshire: TRIO</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Unique location referencing technique</td>
<td>Both</td>
<td>511 system, public website, DMS, HAR</td>
<td>Yes</td>
</tr>
<tr>
<td>Virginia/Maryland/District of Columbia: RITIS (Proposed)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Web-based</td>
<td>511 system, public website, DMS</td>
<td>Yes</td>
</tr>
<tr>
<td>New Jersey Pennsylvania: RIMUS (Proposed)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Not specified</td>
<td>Not specified</td>
<td>Yes</td>
</tr>
<tr>
<td>TRANSCOM</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes, through IRVN</td>
<td>Web-based (RA Web Interface)</td>
<td>TRANSMIT and Trips123</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>I-95 Corridor Coalition: STIX (Proposed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Functional requirements not available yet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-95 Corridor Coalition: IEN</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Will upgrade to web-based</td>
<td>Traveler information and CVO (future)</td>
<td>Yes</td>
</tr>
<tr>
<td>I-95 Corridor Coalition: ISN (Proposed)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Functional requirements not available yet</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3-2: Functional Comparison
3.3 Summary

Four key elements of the current information exchange systems are analyzed in this task to identify problem areas. The four elements include: C2C standards, communication network architecture, interagency video sharing technology, and the system functional requirements.

Three families of communication standards have been widely utilized for information exchange: the International Standards Organization’s DATEX-ASN protocol, the Object Management Group’s CORBA standard, and the W3C-based XML protocol. The three technologies have their respective advantages and disadvantages. The NTCIP 9010 Standard recommends the W3C-based XML protocol for C2C communications. Some commonly used vocabulary standards in C2C communication have also been introduced in this task. It is worth noting that all three families of standards can share a common set of vocabulary standards for data element definitions (data dictionaries), and description of message dialogs.

It is critical for the I-95 Corridor Coalition agencies to be able to communicate with each other seamlessly during both normal and emergency situations. However, none of the eleven information exchange systems systematically provides any backup communications, emergency communications or temporary communications mechanism. The use of VSAT is recommended as a C2C communication backup during emergency situations when traditional communication means (landline or wireless) are not available.

Interagency video sharing plays an important role in improving traffic responsiveness for incident management. The Delaware Valley Video Sharing Project provides a great demonstration of the interagency video sharing technology and the institutional coordination as well. However, some issues still need to be addressed such as the bandwidth utilization and the institutional network security and firewall, etc.

A system functional comparison in terms of the data available to users and the GUIs, etc was also conducted for the eleven systems in this task order. Supplementing this comparison is the I-95 Corridor Coalition's Information Systems Network project, which addresses a complete functional comparison of current state systems in the Corridor.
Chapter 4 - Task Four: C2C Technical Recommendations

4.1 Task Four Background

This task (Task Order Four) represents an expansive effort in identifying, evaluating, and describing viable C2C communications standards and technologies based upon the research performed in Task Orders Two and Three. As a result of this task, a series of technical recommendations regarding a C2C communications mechanism to support the I-95 Corridor Coalition information exchange system are developed. The technical recommendations are focused on three major areas: C2C communication standards, system architecture and communication architecture, and the interagency video sharing technology. The advantages and disadvantages of each technology are also highlighted.

4.2 Technical Recommendations

4.2.1 C2C Standards Recommendation

4.2.1.1 Protocol Standard

As we discussed in the previous task orders, C2C standards can be divided into two categories: 1) the vocabulary (data dictionaries and messages), and 2) the rules for exchanging the messages and data (protocols). The two categories work together to successfully exchange meaningful ITS-related information.

Three families of communication protocol technologies have been utilized by the ITS industry: the International Standards Organization’s DATEX-ASN protocol (NTCIP 2304: Application Profile for DATEX-ASN, used by TRANSCOM, etc.), the Object Management Group’s Common Object Reference Broker Architecture (CORBA) standard (NTCIP 2305: Application Profile for CORBA), and the W3C-based XML protocol (NTCIP 2306: Application Profile for XML Message Encoding and Transport in ITS C2C Communications). The three technologies have their respective advantages and disadvantages. However, we recommend the W3C-based XML protocol (NTCIP 2306) for the C2C communication based on the recommendation of the NTCIP 9010 Standard.

- NTCIP 2306: Application Profile for XML Message Encoding in ITS C2C Communication

The NTCIP 2306 Standard: Application Profile for XML Message Encoding and Transport in ITS C2C Communications (C2C XML), provides a mechanism for the implementation of communications interfaces defining the message form, usage and protocol used for transmitting information encoded in the XML between centers. Specifically, it defines mechanisms for using the SOAP and the WSDL, which supplies a language for describing the interface of web services.
and the UDDI specification, to support customer-initiated requests for information from a central system.

Figure 4-1 illustrates the relationship between these standards. This model is recommended to be used as a foundation for the new information exchange system standard architecture.

![Figure 4-1: Web Services Specifications](Source: the NTCIP 2306)

Table 4-1 shows the XML C2C protocol map to the different communication protocol layers. This protocol framework is recommended to be the basis for the information exchange across the new proposed system.

<table>
<thead>
<tr>
<th>Communications Protocol</th>
<th>W3C-Based XML Protocol</th>
<th>XML Direct Protocol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Dictionaries</td>
<td>• Functional Area Data Dictionaries</td>
<td></td>
</tr>
<tr>
<td>Message Dialogs</td>
<td>• Defined in sequence diagrams in the functional area standards</td>
<td></td>
</tr>
<tr>
<td>Rules for Defining</td>
<td>• XML Schema Language</td>
<td>• Description Language</td>
</tr>
<tr>
<td>Messages/Objects</td>
<td>• SAE ASN.1 to XML</td>
<td>• XML Schema Language</td>
</tr>
<tr>
<td></td>
<td>encoding Rules</td>
<td>• SAE ASN.1 to XML encoding Rules</td>
</tr>
<tr>
<td>Encoding Rules for</td>
<td>• XML is encoded as ASCII text</td>
<td></td>
</tr>
<tr>
<td>Transmission of Data/Objects</td>
<td>• Functional area XML Schemas define valid-tags</td>
<td></td>
</tr>
<tr>
<td>Application Protocol</td>
<td>• SOAP (Simple Object</td>
<td>• XML Direct – FTP and HTTP</td>
</tr>
<tr>
<td>(handshaking,</td>
<td>Access Protocol) over HTTP</td>
<td></td>
</tr>
<tr>
<td>message framing, etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Services (e.g.,</td>
<td>• UDDI (Universal Description, Discovery and Integration)</td>
<td></td>
</tr>
<tr>
<td>discovery, security,</td>
<td></td>
<td></td>
</tr>
<tr>
<td>aggregation, subscriptions, etc.)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport Protocol</td>
<td>• TCP/IP</td>
<td></td>
</tr>
</tbody>
</table>
The C2C Protocol Map shown in Table 4-1 can be positioned within the NTCIP Standards Framework as shown in Table 4-2. NTCIP organizes its C2C standards using a layered approach, similar to the International Standards Organization’s Open System Interconnection framework model. The NTCIP Standards Framework as illustrated in Figure 4-2, is defined in the NTCIP 9001 Standard. While message/data standards address the Information Level, NTCIP C2C communications standards primarily address the Application, Transport, and Subnetwork Levels.

<table>
<thead>
<tr>
<th>NTCIP Standards Framework</th>
<th>C2C Protocol Map</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information Level</td>
<td>• Data Dictionaries</td>
</tr>
<tr>
<td></td>
<td>• Message Dialogs</td>
</tr>
<tr>
<td></td>
<td>• Rules for defining messages/objects</td>
</tr>
<tr>
<td></td>
<td>• Encoding rules for transmission of data/objects</td>
</tr>
<tr>
<td>Application Level</td>
<td>• Application Protocol</td>
</tr>
<tr>
<td></td>
<td>• Web services</td>
</tr>
<tr>
<td>Transportation Level</td>
<td>• Transport Protocol</td>
</tr>
<tr>
<td>Sub-network Level / Plant Level</td>
<td>• Ethernet Protocol</td>
</tr>
</tbody>
</table>

**Table 4-2: NTCIP Standards Framework Map**
(Source: the NTCIP 9001)

*Not all combinations between the Subnetwork and Plant Levels are feasible.*
NTCIP 9010: XML in ITS Center-to-Center Communications

The NTCIP 9010 Standard recommends the W3C-based XML protocol (NTCIP 2306) for the C2C communication. Other than this, it also recommends the following compatible development tools and server software:

- **XML and XML Schema Development Tools:**
  - XML Spy
  - XRay2

- **SOAP Servers:**
  - SOAP Lite: PERL – programming language-based SOAP Server, runs under Windows/Unix, compatible with Apache and Microsoft IIS Web servers
  - Microsoft SOAP – BizTalk Server, runs only on Microsoft IIS Web servers, supports Visual Basic, C++, and C#
  - Tomcat: java-based programming, JavaServer Pages, AXIS is a SOAP handler add-on, runs under Windows/Unix, compatible with Apache and Microsoft IIS Web servers
  - Apache SOAP – runs under Windows/Unix/Linux, compatible with Apache Web servers

### 4.2.1.2 Benefits and Challenges of XML

- **Existing Support**
  XML and related protocols are commonly used for web-based communications and are very broadly supported in the general computing and information technology industry. Experienced personnel, off-the-shelf software, and support tools are readily available and relatively inexpensive.

- **Human Readable**
  Because XML data are exchanged in a tagged text format, it is possible to directly read and understand the message content. This can help during system development and debugging, and allows direct review of the system interfaces at any time.

- **Bandwidth and Latency**
  The bytes in an XML transmission use American Standard Code for Information Interchange (ASCII) encoding and human readable names for data types and attributes. Since the data are transmitted in text format, it takes more bandwidth to transmit the data than binary encoding formats. In addition, there is overhead involved in the encoding and decoding of the textual format. This can add latency to the delivery and processing of a message. Compression schemes are available to reduce message size but add complexity and cost, and have interoperability considerations. In addition, the time taken to compress and de-compress...
information content will increase communications latency. The degree to which this is a significant issue depends on the application.

Bandwidth and latency issues are not a problem for many C2C applications, but may be a problem for some real-time applications such as second-by-second traffic signal status monitoring, and remote control of pan-tilt-zoom CCTV cameras.

- **Security**
  Different C2C applications have different security requirements. Security in this context relates to issues such as prevention of unauthorized access to the data being transmitted, and prevention of unauthorized introduction of spurious data or commands. XML itself has no provision for security, but various off-the-shelf security services can be used to deliver XML messages and for private use of the Internet. On the other hand, if security is not a concern, a potential benefit of using XML over a protocol such as HTTP is that the messages will pass through a standard firewall, whereas protocols used with CORBA and DATEX require special measures. This can be particularly significant when using the Internet for C2C communications.

- **Connectionless and Stateless**
  Web protocols such as HTTP commonly used with XML, are connectionless. This is not a problem for typical one-way data transmission, but can add complexity for transaction-type exchanges. Depending on the application context, this can require all messages to maintain any and all information required to carry out a request. Although this is a logical requirement, the technique to maintain the state of information across a number of requests can add complexity and overhead.

- **Scalability**
  Some protocols or web services commonly used with XML have constraints that can impact the scalability of a C2C network. For example, the HTTP relies on a well-known single port for the start of all messages, potentially causing an overload of this port as network traffic increases. There are techniques for managing this problem.

### 4.2.1.3 Other standards

Commonly used ITS standards and specifications applicable to the information exchange system are shown in Table 4-3.

<table>
<thead>
<tr>
<th>Standard Number</th>
<th>Standard Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANSI TS285</td>
<td>Commercial Vehicle Safety and Credentials Information Exchange</td>
</tr>
<tr>
<td>ANSI TS286</td>
<td>Commercial Vehicle Credentials</td>
</tr>
<tr>
<td>ASTM AG</td>
<td>ADMS Standard Guidelines</td>
</tr>
<tr>
<td>Standard</td>
<td>Description</td>
</tr>
<tr>
<td>----------</td>
<td>-------------</td>
</tr>
<tr>
<td>ASTM DD</td>
<td>ADMS Data Dictionary Specifications</td>
</tr>
<tr>
<td>IEEE Std 1512-2000</td>
<td>Standard for Common Incident Management Message Sets (IMMS) for use by EMCS</td>
</tr>
<tr>
<td>IEEE P1512.1</td>
<td>Standard for Traffic Incident Management Message Sets for Use by EMCS</td>
</tr>
<tr>
<td>IEEE P1512.2</td>
<td>Standard for Public Safety IMMS for use by EMCS</td>
</tr>
<tr>
<td>IEEE P1512.3</td>
<td>Standard for Hazardous Material IMMS for use by EMCS</td>
</tr>
<tr>
<td>IEEE P1512.4</td>
<td>Standard for Common Traffic Incident Management Message Sets for Use in Entities External to Centers</td>
</tr>
<tr>
<td>ITE TM 2.1</td>
<td>Standards for Traffic Management Center-to-Center Communications</td>
</tr>
<tr>
<td>ITE TM 3.TM</td>
<td>Traffic Management Business Area Standard</td>
</tr>
<tr>
<td>NTCIP 1102</td>
<td>Octet Encoding Rules (OER)</td>
</tr>
<tr>
<td>NTCIP 1301</td>
<td>Weather Report Message Set for ESS</td>
</tr>
<tr>
<td>NTCIP 1401</td>
<td>Standard on Common Public Transportation (CPT) Objects</td>
</tr>
<tr>
<td>NTCIP 1402</td>
<td>Standard on Incident Management (IM) Object</td>
</tr>
<tr>
<td>NTCIP 1403</td>
<td>Standard on Passenger Information (PI) Objects</td>
</tr>
<tr>
<td>NTCIP 1404</td>
<td>Standard on Scheduling/Runcutting (SCH) Objects</td>
</tr>
<tr>
<td>NTCIP 1405</td>
<td>Standard on Spatial Representation (SP) Objects</td>
</tr>
<tr>
<td>NTCIP 1407</td>
<td>Standard on Control Center (CC) Objects</td>
</tr>
<tr>
<td>NTCIP 2104</td>
<td>Subnetwork Profile for Ethernet</td>
</tr>
<tr>
<td>NTCIP 2202</td>
<td>Transport Profile for Internet (TCP/IP and UDP/IP)</td>
</tr>
<tr>
<td>NTCIP 2303</td>
<td>Application Profile for File Transfer Protocol (FTP)</td>
</tr>
<tr>
<td>NTCIP 2306</td>
<td>Application Profile for XML Message Encoding and Transport in ITS Center-to-Center Communications (C2C XML)</td>
</tr>
<tr>
<td>NTCIP 9010</td>
<td>XML in ITS Center-to-Center Communications</td>
</tr>
<tr>
<td>SAE J2353</td>
<td>Data Dictionary for Advanced Traveler Information System (ATIS)</td>
</tr>
<tr>
<td>SAE J2354</td>
<td>Message Set for Advanced Traveler Information System (ATIS)</td>
</tr>
<tr>
<td>SAE J2529</td>
<td>Rules for Standardizing Street Names and Route Ids</td>
</tr>
<tr>
<td>SAE J2540</td>
<td>Messages for Handling Strings and Look-up Tables in ATIS Standards</td>
</tr>
</tbody>
</table>

Table 4-3: Standards Applicable

4.2.2 System Architecture Recommendation

4.2.2.1 Logical Architecture

The logical architecture provides an overview of the software modules, program interactions / behavior, and interfaces that form the information exchange system.

Figure 4-3 illustrates the flow of traffic and incident data from (and back to) the contributing agencies. Traffic and incident data are collected in contributing transportation agencies by TMC systems, emergency response agencies by CAD systems, and all associated personnel. The traffic and incident data are consolidated by the information exchange system and disseminated as appropriate to contributors and other agencies.
The exchange of information between participants in the information exchange system represents a layered publish-and-subscribe model. Providers publish information that is authorized by the information exchange system. The information exchange system consolidates the data from its subscriptions and republishes the data for users subscribing to its information service. This publish-and-subscribe model can be implemented in a variety of forms, depending on the preferences of the participating agencies. One strategy is to push the published information directly to subscribers, similar to having mail delivered to an inbox. The opposing extreme is to require subscribers to explicitly ask for an event summary every time they want information. Neither of these, however, is an optimal solution by itself, and it is likely that participating agencies will need options between the two extremes. We would recommend either of the two extremes for the participating agencies depending on their internal policies and architectural preferences.

Although it is intended that the existing TMC and CAD systems will provide most of the information services, there are several shared services needed to tie the network together. Registration services will provide a directory of services and users participating in the information exchange system. In addition, authentication services may be provided to assure that users and services “are who they say they are.” In an open network of services, this function assures that a request for information is not coming from someone other than the registered user, or that information pushed from a service is actually coming from the known and trusted source. Alternatively, an authorization service is
recommended for users to log into a service before published information would be made available to them.

### 4.2.2.2 Functional Architecture

The activities that occur inside the interface boundaries of the information exchange system are shown in Figure 4-4. The diagram provides more detail about what operations the information exchange system is actually performing in collecting, storing, and disseminating traffic and incident data.

Several of the component functions in Figure 4-4 may be thought of as sets of services. Obtaining, standardizing, formatting, and sending data are sets of services because each function has a different form for a particular data format interface. A set of services is required to properly interpret and transform all the incoming and outgoing information. The particular function needed to perform a transformation depends on the origin and destination of the data.

Obtaining data for the information exchange system involves collecting traffic and incident data from the contributing systems through both push and pull methods. The information exchange system must understand the particular data format used by the contributor. The standardization function is responsible for extracting the traffic and incident data and passing it to the storage function.

The formatting and sending functions format traffic and incident data to fulfill requests and information subscriptions for end users. Each of these components represents a set of services, with each individual service supporting a particular data format or destination.

The administration function supports the information exchange system by maintaining information about data providers and users that is stored in the registry. This function also manages the system configuration and rules for the other functions. Data transactions and system operational statistics are logged here as well.
4.2.2.3 Physical Architecture

The physical architecture provides an overview of the planning structures for the hardware, communications, and operational support for the information exchange system, as shown in Figure 4-5. No particular preferences or distinctions need be made in this architecture with respect to selection of operating system or hardware. The software features needed to support the information exchange system functionality are standard within the Microsoft Windows® operating system, the open source Linux operating system, and the Mac® system.

Figure 4-5 shows the basic conceptual diagram for the information exchange system physical configuration. As shown in the figure, each of the major functions could be provided by its own dedicated server, allowing the configuration of that server to be tailored specifically to that function. Distribution functions, for example, are well suited to a separate Web application server. These implementation decisions can be deferred to the detailed design phase with no impact on other functions.
Since the Internet will be used for data transport in and out of the information exchange system, each member agency will require an Internet connection (most of them already have). Each Internet connection should have a firewall consistent with the policies of the agency or center needing the connection.

4.2.2.4 Communication Architecture

4.2.2.4.1 VSAT Communication Architecture

In the previous task orders we recommended the IP/Ethernet-based communication network architecture and the use of VSAT as a C2C communication backup in case of emergency situations. The recommended IP/Ethernet-based communication network architecture with satellite communication backup is illustrated in Figure 4-6.
A VSAT is a two-way satellite ground station with a dish antenna that is smaller than 3 meters (most VSAT antennas range from 75 cm to 1.2 m). VSAT data rates typically range from narrowband up to 4 Mbps for the provision of Satellite Internet access to remote locations, Voice-over-IP or video. As shown in Figure 4-7, satellite communications architecture uses earth stations to transmit and receive data via a geosynchronous (i.e., appears to remain in a fixed position in space) satellite positioned approximately 22,300 miles above earth. Specifically, an earth station:

- Modulates the base band signal to the appropriate power and transmission frequency, then
- Radiates the signal to the satellite

The satellite:
- Shifts the received signal's frequency
- Amplifies it, then
- Reradiates the signal back to earth where it can be received by earth stations in the coverage area

Figure 4-6: Communication Network Architecture with Satellite Communication Backup
The Federal Communications Commission (FCC) allocates the following frequencies for satellite communications:

- C band (i.e., 5.925-6.425 GHz uplink and 3.700-4.200 GHz downlink), and
- Ku band (i.e., 14.0-14.5 GHz uplink and 11.7-12.2 GHz downlink)

VSAT networks are configured in one of these topologies:

- A star topology, using a central uplink site, such as a Network Operations Center (NOC), to transport data back and forth to each VSAT terminal via satellite,
- A mesh topology, where each VSAT terminal relays data via satellite to another terminal by acting as a hub, minimizing the need for a centralized uplink site,
- A combination of both star and mesh topologies. VSAT networks are configured by having several centralized uplink sites (and VSAT terminals stemming from it) connected in a multi-star topology with each star (and each terminal in each star) connected to each other in a mesh topology. Others configured in only a single star topology sometimes have each terminal connected to each other as well, resulting in each terminal acting as a central hub. These configurations are utilized to minimize the overall cost of the network, and to alleviate the amount of data that has to be relayed through a central uplink site (or sites) of a star or multi-star network.
4.2.2.4.2 Benefits and Challenges of VSAT

- **Benefits**
  - **Availability:** VSAT services can be deployed anywhere having a clear view of the southern sky.
  - **Diversity:** VSAT provides a wireless link completely independent of the local terrestrial/wireline infrastructure - especially important for backup or disaster recovery services.
  - **Deployability:** VSAT services can be deployed in hours or even minutes (with auto-acquisition antennas).
  - **Homogeneity:** VSAT enables customers to get the same speeds and service level agreements at all locations across their entire network regardless of location.
  - **Acceleration:** Most modern VSAT systems use onboard acceleration of protocols such as TCP ("spoofing" of acknowledgement packets) and HTTP (pre-fetching of recognized HTTP objects); this delivers high-quality Internet performance regardless of latency.
  - **Multicast:** Most current VSAT systems use a broadcast download scheme which enables them to deliver the same content to tens or thousands of locations simultaneously at no additional cost.
  - **Security:** Corporate-grade VSAT networks are private layer-2 networks over the air.

- **Challenges**
  - **Latency:** Since they relay signals off a satellite in geosynchronous orbit 22,300 miles above the Earth, VSAT links are subject to a minimum latency of approximately 500 milliseconds round-trip.
  - **Environmental concerns:** VSATs are subject to signal attenuation due to weather ("Rain Fade"); the effect is typically far less than that experienced by one-way TV systems that use smaller dishes, but is still a function of antenna size and transmitter power and frequency band.
  - **Installation:** VSAT services require an outdoor antenna installation with a clear view of the southern sky (assuming the location is in the northern hemisphere). This makes installation in urban environments or locations where a customer does not have "roof rights" problematic. The vehicle-mount dish antenna may be used under such circumstances.

4.2.2.4.3 Satellite Internet Service

Nearly all VSAT systems are now based on IP with a very broad spectrum of Internet applications. To receive the satellite Internet service, a satellite communication modem and a fixed-mount or vehicle-mount dish antenna are required. The vehicle-mount antenna can be mounted on a truck, van, railroad car, trailer, etc. and can be deployed within minutes in case of emergency situations. We recommend the vehicle-mount...
antenna for the satellite Internet in this project for the purpose of quick deployment and its mobility. Typically there are three antennas sizes (.75-meter, .98-meter and 1.2-meter) used in the VSAT service industry. The larger dishes provide for better reception and more importantly support much higher bandwidth service offerings. The antenna size has a direct correlation with bandwidth capability (especially in regards to upload capacity). A 1.2-meter satellite antenna can overcome bad atmospheric weather conditions, while retaining extreme bandwidth rates. The 1.2-meter system is ideal for customers that need the highest bandwidth rates.

Some satellite Internet service providers provide on-demand service plans besides the regular service plans. The on-demand service plan allows customers to pay a low monthly charge in normal situation for having the VSAT system as hot-standby service. When the backup connection is used, usage-based charges apply. It is an ideal solution for organizations such as the I-95 Corridor Coalition seeking a C2C communication backup service during emergency situations or catastrophic events, such as earthquake or hurricane, when traditional communication means are not available. Some service providers also provide emergency rental plans if there is an urgent need for broadband Internet service on an immediate or short term basis. Mobile broadband satellite Internet equipment can be rented on a daily, weekly, or monthly basis.

Major satellite Internet service providers in the United States include HughesNet, SpaceNet and SkyCasters, etc. A detailed comparison for the three service providers is summarized in Table 4-4.

<table>
<thead>
<tr>
<th>Service Provider</th>
<th>HughesNet</th>
<th>SpaceNet</th>
<th>SkyCasters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Package</td>
<td>Regular monthly service</td>
<td>On-demand service</td>
<td>On-demand service and Rental Service</td>
</tr>
<tr>
<td>Frequency Band</td>
<td>Ku</td>
<td>Ku</td>
<td>C and Ku</td>
</tr>
<tr>
<td>Dish Size (meter)</td>
<td>.98 / 1.2</td>
<td>.75 / 1.2</td>
<td>.75 / .98 / 1.2</td>
</tr>
<tr>
<td>Max Data Rate (Uplink / Downlink)</td>
<td>500 kbps / 2 Mbps</td>
<td>1 Mbps / 3 Mbps</td>
<td>1 Mbps / 3 Mbps</td>
</tr>
<tr>
<td>One time Installation/Equipment Cost</td>
<td>$10,000</td>
<td>$16,000</td>
<td>$18,000</td>
</tr>
<tr>
<td>Monthly Cost</td>
<td>$200</td>
<td>$500</td>
<td>$500</td>
</tr>
</tbody>
</table>

Table 4-4: Satellite Internet Service Comparison

4.2.3 Video Sharing Technology Recommendation

In the previous task orders we discussed that the Delaware Valley video sharing system uses a decentralized architecture to deliver software-encoded video via the Internet and share the video within the five agencies (DelDOT, DRBA, DRPA, NJDOT, and PennDOT). However, several major issues still remain. In this section we will provide the recommendations and solutions for addressing these issues.
4.2.3.1 Video Sharing System Architecture Recommendation

The Delaware Valley video sharing project only demonstrated the interagency video sharing solution for the existing legacy cameras, which are not IP-addressable. Eventually all future cameras deployed will be IP-addressable and the existing legacy cameras will be switched over. During the transition period, both types of cameras coexist. This project did not address how to solve this issue.

Our recommendation is to use a hybrid architecture to share the video from both the existing legacy cameras and the IP-addressable cameras as illustrated in Figure 4-8. The IP-addressable cameras connect to the IP/Ethernet network via network switch. The network switch can be either a Fast Ethernet switch or a Gigabit Ethernet switch based on the bandwidth need and the number of cameras. A Gigabit Ethernet switch is recommended for better video quality and future expansion.

![Figure 4-8: Hybrid Video Sharing System Architecture](Based on: the Delaware Video Sharing Project Final Design)

4.2.3.2 Bandwidth and Encoding Recommendation

As a pilot project the Delaware Valley video sharing project was initially designed to allow each of the transmitting agencies to share only four video streams (40-64 Kbps per stream) using a communication connection less than or equal to 256 kbps. It was a decision based on all agencies’ preferences and the Operations and Maintenances (O&M)
costs. However, with more future camera deployments and the interagency video sharing, the amount of bandwidth and the number of shared video are obviously not sufficient.

In order to transfer video onto the Internet, it must be digitized and then compressed to meet the bandwidth capacity that is available. This is accomplished via a video encoding/decoding process using appropriate compression standards. Currently the commonly used standards for the Internet streaming video are MPEG-2 and MPEG-4. The MPEG-2 is the compression standard selected by the FCC to provide the digital replacement for the National Television System Committee (NTSC). It was not originally designed for the Internet streaming video. However, many manufactures have adapted this standard to create a real-time video transmission via the Internet. The MPEG-4 standard was specifically developed for Internet streaming video. Generally, the normal data rate of a full-motion digital video stream encoded by the MPEG-2 standard ranges from 3 Mbps to 5 Mbps and the normal data rate encoded by the MPEG-4 standard is up to 2 Mbps according to different image qualities. Therefore, the MPEG-4 compressed video has lower bandwidth requirement and is ideal for the Internet transmission. The MPEG-2 compressed video however has better image quality due to less image quality lost in the conversion and compression processes and is ideal for video wall display or mission-critical monitoring in the TMC or other control centers.

Our recommendation is that all video encoding/decoding equipment in future deployments should be capable of transmitting both MPEG-2 and MPEG-4 video streams. Video stream should be user-selectable based on different application scenarios.

In this pilot project a communication connection of 256 Kbps was designed to share only four video streams between agencies. It is obviously not sufficient considering more future camera deployments and interagency video sharing. Full-motion video typically changes the image 30 frames per second (30 fps). In this project the data rate of the video stream is only 40-64 Kbps per stream and therefore the video is not full-motion. This type of slow-motion video is usually called slow-scan video. The slow-scan video sacrifices the video frame rate (frame per second) to meet the lower bandwidth need.

Our recommendation is to use 100 Mbps Fast IP/Ethernet for the sharing of small number of video feeds (no more than ten video feeds) and 1000 Mbps Gigabit IP/Ethernet for large number of shared video feeds (no more than one hundred video feeds) in future deployments.

The full capacity for a Fast Ethernet network is 100 Mbps based on the 100BaseT and 100BaseFL Fast Ethernet Standard. However, not all the capacity can be utilized to carry useful data. The reason is: in Ethernet network, messages navigate through the network based on information contained within each message or packet. This information is embodied in the TCP/IP protocol. The protocols used on Ethernet impose on overhead. The information included in each packet consumes capacity. Because of the overhead associated with TCP/IP, in practice, good network design suggests that this capacity should be further limited to about 50 percent loading. This provides a capacity of recommended maximum ten video streams per Fast Ethernet connection assuming the
average date rate of the shared digital video stream is 5 Mbps per camera. For the same reason, the recommended maximum video streams per Gigabit Ethernet connection is one hundred.

### 4.2.3.3 Network Configuration Recommendation

The video sharing system subsystem can either be integrated with or isolated from the rest of the agency’s network as shown in Figure 4-8 and Figure 4-9 respectively. Agencies may have different choices based on their own preferences. Our recommendation is to have the video distribution server and video encoders that make up their video sharing subsystem reside on their own agency network, as shown in Figure 4-8, this reduces the cost of network hardware as the existing routers, switches, and firewalls that are already part of their network will be used. Outside PCs in other member agencies can access the video distribution server through a router which handles the translation between public and private IP addresses.

![Has been added here](image)

**Figure 4-9: Isolated Video Sharing System Architecture**

*(Based on: the Delaware Video Sharing Project Final Design)*

Figure 4-9 shows an entirely autonomous network that only houses the video encoders, the video distribution server, and the network equipment (routers, firewalls, etc) that are needed to support them. This video sharing network is isolated from the rest of the agency’s network. This configuration could increase the security of the system, as there is
no direct IP link between the rest of agency network and the video sharing subsystem. However this requires additional costs associated with firewall hardware and the configuration of the new network.

4.3 Summary

The Internet networking protocols and standards are recommended for the I-95 Corridor Coalition information exchange system and its components. XML data structures based on ITS messaging standards, retrieved over the Internet using HTTP/HTTPS, are recommended to be the preferred means of publishing traffic and incident data information. The interfaces would be implemented as SOAP-based Web services. Administrative user interfaces would be adequately implemented in HTML.

System architecture and communication architecture are recommended for the information exchange system in this task. Its logical architecture, functional architecture and physical architecture are also introduced. IP/Ethernet-based communication network architecture is recommended for this project. VSAT is recommended as the C2C communication backup in case of emergency situations. Several satellite Internet service providers and their various service plans are available to meet the requirements of the I-95 Corridor Coalition information exchange system.

A hybrid architecture is recommended to share the video from both the existing legacy cameras and the IP-addressable cameras. Some issues of the Delaware Valley video sharing pilot project such as bandwidth utilization and network configuration, etc have also been addressed in this task.
Conclusions

The I-95 Corridor Coalition Corridor-Wide Center-to-Center Communications Study is a project sponsored by the I-95 Corridor Coalition and is structured to provide a technical report outlining a series of recommendations to employ a stable and reliable communications mechanism during, and subsequent to, catastrophic events between multiple transportation management centers along the I-95 Corridor. This study targets I-95 Corridor Coalition participating agencies looking to maintain an exchange of emergency management information to manage their operations when traditional communication means (e.g. landline and wireless) are not available. Currently none of the existing information exchange systems in the I-95 Corridor Coalition systematically provides any emergency communication backup mechanism. This project includes total four task orders: National ITS Architecture/C2C Standards Study, C2C Communications Best Practices, C2C Communications Gap Analysis, and C2C Communications Technical Recommendations.

As a result of this project, the Internet networking protocols and standards are recommended for the I-95 Corridor Coalition information exchange system and its components: XML data structures based on ITS messaging standards, retrieved over the Internet using HTTP/HTTPS, are recommended to be the preferred means of publishing traffic and incident data information; The interfaces would be implemented as SOAP-based Web services; Administrative user interfaces would be adequately implemented in HTML.

System architecture and communication architecture are recommended for the information exchange system in this project. Its logical architecture, functional architecture and physical architecture are also introduced: IP/Ethernet-based communication network architecture is recommended; VSAT is recommended as the C2C communication backup in case of emergency situations. Several satellite Internet service providers and their various service plans (on-demand or regular plan) are available to meet the requirements of the I-95 Corridor Coalition information exchange system. The one-time installation and equipment cost is normally less than $20,000 per site, and the average monthly service cost is about $500 plus the usage-based charges if on-demand service is activated during emergency situations.

A hybrid architecture is recommended to share the video from both the existing legacy cameras and the IP-addressable cameras. All video encoding/decoding equipment in future deployments should be capable of transmitting both MPEG-2 and MPEG-4 video streams. 100 Mbps Fast IP/Ethernet for the sharing of small number of video feeds (no more than ten video feeds) and 1,000 Mbps Gigabit IP/Ethernet for large number of shared video feeds (no more than one hundred video feeds) are recommended for future deployments.