5. DALLAS AREA-WIDE ITS ARCHITECTURE

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5.1 National Transportation Architecture

The National ITS Architecture uses a reference model that contains three layers: communications, transportation and socioeconomic. The transportation layer consists of nineteen interconnected subsystems. These subsystems align closely with existing jurisdictional and physical boundaries that characterize the operation and maintenance of existing transportation systems. Figure 5-1 illustrates the transportation and communication layers of the architecture by depicting both the subsystems (transportation layer elements) and the major communications interconnects (communication layer elements) required to support ITS services. The figure represents a fully deployed architecture in the twenty year time frame.

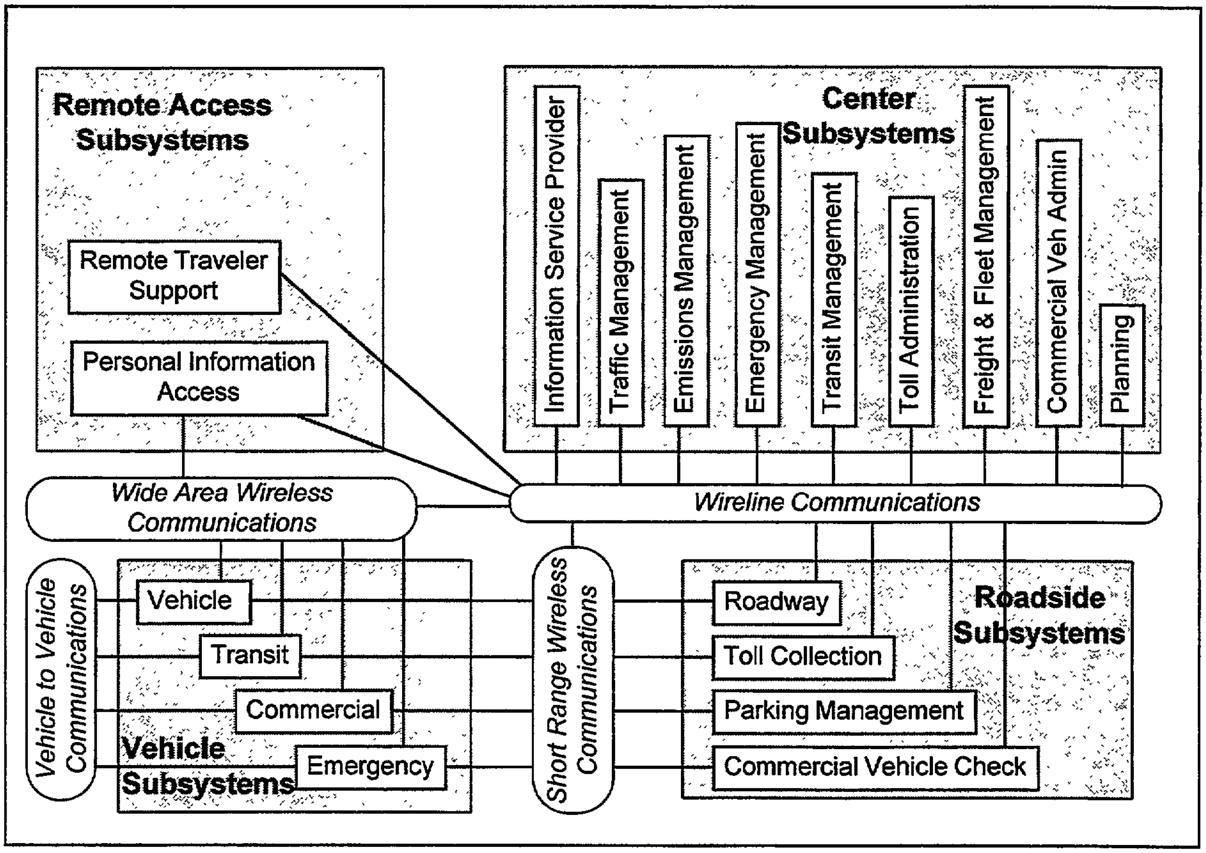

Figure 5-1. Twenty Year National Architecture

As illustrated in Figure 5-1, the ITS architecture subsystems may be grouped into four subsystem classes that share basic functional, deployment, and institutional characteristics. These classes (Center, Roadside, Vehicle, and Remote Access) are used to organize the following descriptions of ITS subsystems. The brief descriptions are summaries of more comprehensive treatments supplied to the FHWA at the June 1995 National Architecture Interim Program Review.

<u>Center Subsystems</u>

The center subsystems provide management, administration, and support functions for the transportation system.

- Commercial Vehicle Administration Subsystem

  The Commercial Vehicle Administration Subsystem will operate at one or more fixed locations within a region. This subsystem performs administrative functions supporting credentials, tax, and safety regulations.

- Emergency Management Subsystem

  The Emergency Management Subsystem operates in various emergency centers supporting public safety including police and fire stations, search and rescue special detachments, and HAZMAT response teams.

- Emissions Management Subsystem

  This subsystem provides the capabilities for air quality managers to monitor and manage air quality.

- Fleet Management Subsystem

  The Fleet Management Subsystem provides the capability for commercial drivers and dispatchers to receive real-time routing information and access databases containing vehicle and cargo locations as well as carrier, vehicle, cargo, and driver information.

- Information Service Provider Subsystem

  This subsystem provides the capabilities to collect, process, store, and disseminate traveler information to subscribers and the public at large. It is likely that this subsystem will be deployed in various manifestations, some private and focused on specific services and market segments, others public and directed towards general public information delivery.

- Traffic Management Subsystem

  This subsystem communicates with the Roadway Subsystem to monitor and manage traffic flow.

- Toll Administration Subsystem

  The Toll Administration Subsystem provides general payment administration capabilities to support electronic assessment of tolls and other transportation usage fees.

- Transit Management Subsystem

  The Transit Management Subsystem provides the capability for determining accurate ridership levels and implementing corresponding fare structures.

<u>Roadside Subsystems</u>

These infrastructure subsystems provide the direct interface to vehicles traveling on the roadway network.

- Commercial Vehicle Inspection Subsystem

  The Commercial Vehicle Inspection Subsystem supports automated vehicle identification at mainline speeds for credential checking, roadside safety inspections, and weigh-in-motion.

- Parking Subsystem

  The Parking Subsystem provides the capability to provide parking availability and parking fee information, to allow for parking payment without the use of cash with a multiple use medium, and to support the detection, classification, and control of vehicles seeking parking.

- Roadway Subsystem

  This subsystem includes the equipment distributed on and along the roadway that monitors and controls traffic.

- Toll Collection Subsystem

  Using pricing structures for locally determined needs, including the capability to implement various road pricing policies, the Toll Collection Subsystem provides the capability for vehicle operators to pay tolls without stopping their vehicles.

Vehicle Subsystems

These subsystems are all vehicle-based and contain driver information, vehicle navigation, and advanced safety systems functions.

- Personal Vehicle Subsystem

  This subsystem resides in an automobile and provides the sensory, processing, storage, and communications functions necessary to support efficient, safe, and convenient travel by personal automobile.

- Commercial Vehicle Subsystem

  This subsystem resides in a commercial vehicle and provides the sensory, processing, storage, and communications functions necessary to support safe and efficient freight movement.

- Emergency Vehicle Subsystem

  This subsystem resides in an emergency vehicle and provides the sensory, processing, storage, and communications functions necessary to support safe and efficient emergency response.

- Transit Vehicle Subsystem

  This subsystem resides in a transit vehicle and provides the sensory, processing, storage, and communications functions necessary to support safe and efficient movement of passengers.

Remote Access Subsystems

The traveler subsystems include the equipment that is used by the traveler to gather information and to access other traveler services prior to a trip and while en-route.

- Personal Information Access Subsystem

  This subsystem accesses traveler information at home, at work, and other locations frequented by the traveler using personal fixed and portable devices over multiple types of electronic media.

- Remote Traveler Support Subsystem

  This subsystem provides access to traveler information at transit stations, transit stops, other fixed sites along travel routes, and at major trip generation locations, such as special event centers, hotels, office complexes, amusement parks, and theaters.

5.2 Communication Layer Architecture

Figure 5-l presents the relationship between the Communication Layer and the Transportation Layer. The communication architecture has two components: one wireless and one wireline. The applicable communications technologies are as follows.

- Wide Area Wireless Communications
  These systems are cell-based wireless infrastructures supporting wide-area information transfer (most data flows). The cell-based airlink, from a mobile terminal to one of a set of base stations, provides connections between mobile users or between mobile and fixed network-connected users (e.g., those connected to the telephone network). It is typified by the current cellular telephone network, the larger cells of Specialized Mobile Radio, and PCS.

- Short Range Wireless Communications
  Short-range airlink used for close-proximity (less than 15-30 meters) transmissions between a mobile user and a base station, typified by transfers of vehicle identification numbers at toll booths.

- Vehicle to Vehicle Communications
  Dedicated wireless system handling high data rate, with a low probability of error, line of sight transmission, and Automated Highway System (AHS)-related data flows, such as vehicle to vehicle transceiver radio systems.

- Wireline Communications
  Information transfer between two fixed entities. Typically, this interface will use one of the many alternative existing public or private networks that may physically include wireless (e.g., microwave) as well as wireline infrastructure. This infrastructure is typified by fixed (as compared to mobile) transmission sites.

5.3 Equipment Packages and Subsystems

Section 4.10 identified the National Architecture equipment packages relevant to the Dallas Area. The equipment package tables provided in that section of the document were selected based on the Steering Croup prioritization of ITS user services. Those tables organized the equipment packages based on broad “functional” categories of ITS service (ATIS, APTS, ATMS, AVSS, CVO, EM and ITS). These same equipment packages can be aggregated by subsystem as well. Table 5-l enumerates the relationships between equipment packages and the subsystems identified in Section 5.1.

These equipment package subsystem affiliations will be used in Section 5.4 to assist with describing architecture based deployment descriptions of ITS in the Dallas area.

Table 5-l. Dallas Area Equipment Packages Organized by Subsystem

Equipment Package	Subsystem
CV Safety Administration	Commercial Vehicle Administration
On-board Cargo Monitoring	Commercial Vehicle Subsystem
On-board CV Electronic Data	
Emergency Mayday & E-911 Interface	Emergency Management
Emergency Response Management	
Emergency Vehicle Routing & Communications	
On-board EV Safety	Emergency Vehicle Subsystem
On-board Trip Monitoring System	
Freight Administration & Management	Freight & Fleet Management
Fleet HAZMAT Management	
Basic Information Broadcast	Information Service Provider
ERMS Route Plan Information Dissemination	
Infrastructure Provided Dynamic Ridesharing	
Infrastructure Provided Route Selection	
Infrastructure Provided Yellow Pages & Reservation	
Interactive Infrastructure Information	
ISP Advanced Integrated Control Support	
ISP Probe Information Collection	
Parking Management	Parking Management
Personal Basic Information Reception	Personal Information Access
Personal Interactive Information Reception	
Personal Mayday Interface	
Data Collection and ITS Planning	Planning Subsystem
Remote Basic Information Reception	Remote Traveler Support
Remote Interactive Information Reception	
Remote Mayday Interface	
Remote Transit Fare Management	
Remote Transit Security Interface	
Transit Center Security	
Automated Road Signing	Roadway Subsystem
Roadside Fault Reporting	
Roadside Signal Priority	
Roadside Support for Freeway Control	
Roadway Advanced Signal Controls	
Roadway Basic Signal Control	
Roadway Basic Surveillance	
Roadway HOV Lane Usage	
Roadway Incident Detection	
Roadway Traffic Information Dissemination	
Probe Data Via Toll Collection	Toll Administration
Toll Administration	
Toll Plaza Toll Collection	Toll Collection

Table 5-1. Dallas Area Equipment Packages Organized by Subsystem - continued

Equipment Package	Subsystem
Collect Traffic Surveillance	Traffic Management
Distributed Road Management	
TMC / HOV Lane Management	
TMC / Toll Parking Coordination	
TMC Advanced Integrated Control	
TMC Advanced Signal Control	
TMC Basic Signal Control	
TMC Incident Detection	
TMC Incident Dispatch Coordination / Communication	
TMC Multi-modal Coordination	
TMC Probe Information Collection	
TMC Traffic Information Dissemination	
TMC Traffic Network Performance Evaluation	
Traffic Maintenance	
Fleet Maintenance Management	Transit Management
Transit Center Fare and Load Management	
Transit Center Fixed Route Operations	
Transit Center Multi-modal Coordination	
Transit Center Paratransit Operations	
Transit Center Tracking & Dispatch	
On-board Maintenance	Transit Vehicle Subsystem
On-board Signal Coordination	
On-board Transit Driver Interface	
On-board Transit Fare & Load Management	
On-board Transit Security	
On-board Trip Monitoring System	
Vehicle Dispatch Support	
Basic Vehicle Reception	Vehicle
Interactive Vehicle Reception	
Probe Vehicle Software	
Ridesharing	
Smart Probe	
Vehicle / Toll Parking Interface	
Vehicle Mayday Interface	

5.4 Architecture Representations of Dallas Area-Wide Deployment

The National Architecture development process is developing a common set of definitions, subsystems and data flows from which to describe ITS systems. As part of their work effort, the Teams are forming a representation of each ITS Service and each subsystem based upon these uniform definitions and upon the perspective of a twenty year build out (full ITS deployment). However, the Dallas Area-Wide Plan focuses on a near term deployment of ITS based upon Steering Group prioritization of ITS user services. In the near term, not all subsystems will be deployed. Initial emphasis will be placed on construction of core ATMS infrastructure, utilization of existing transit investments and integration of toll capabilities. Existing deployment might be characterized from an architectural subsystem and communications perspective as shown in Figure 5-2.

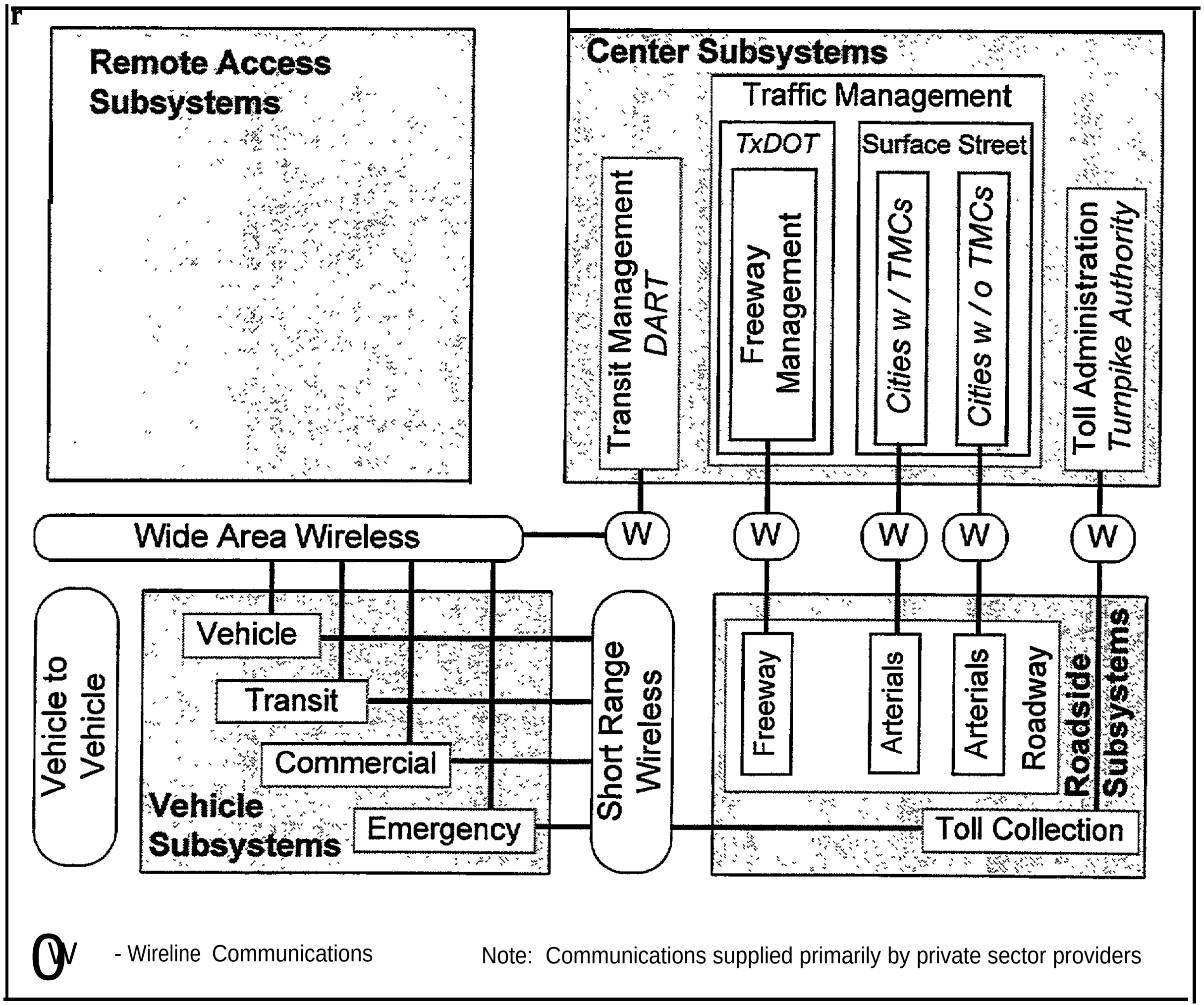

Figure 5-2. Existing Architecture in Terms of Subsystems and Communications

Figure 5-2 depicts the lack of interconnection between subsystems. It illustrates the dedicated subsystem to infrastructure communications that are currently deployed. Figure 5-3 illustrates the near term ITS deployment in the Dallas area and identifies agencies involved (those shown in italics).

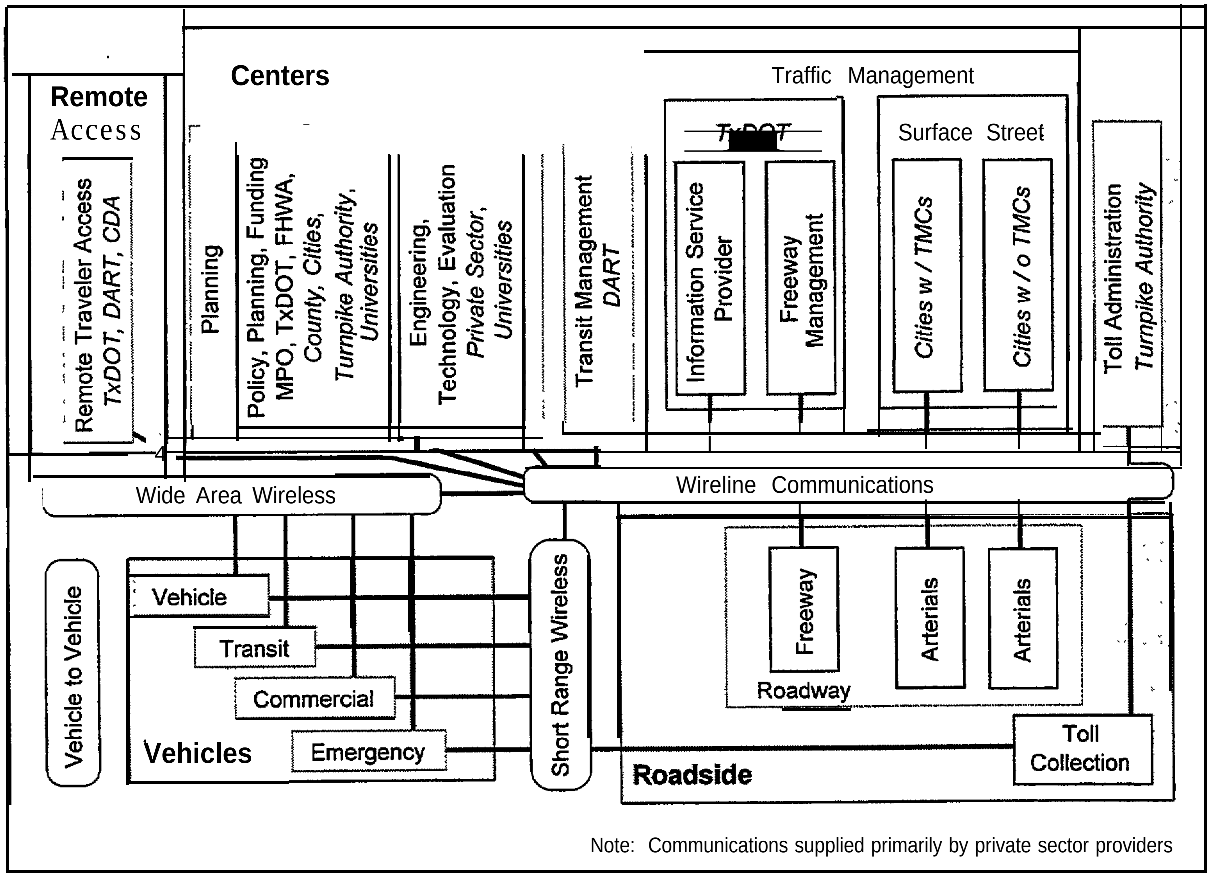

Figure 5-3. Near-Term Dallas ITS Architecture

The following two sections illustrate how these architecture concepts might be tailored to the Dallas area. The first section focuses on Traffic Management and the second on Incident Management. Each section contains a figure illustrating the applicable subsystems and the information flows between subsystems. Following each illustration is a description of the information flows cross-referenced to the numerically designated information flows on the diagrams. These diagrams were derived from National ITS Architecture document generalized user service block diagrams (1).

5.4.1 Traffic Management

Figure 5-4 illustrates the Traffic Control User Service as potentially deployed in the Dallas Area.

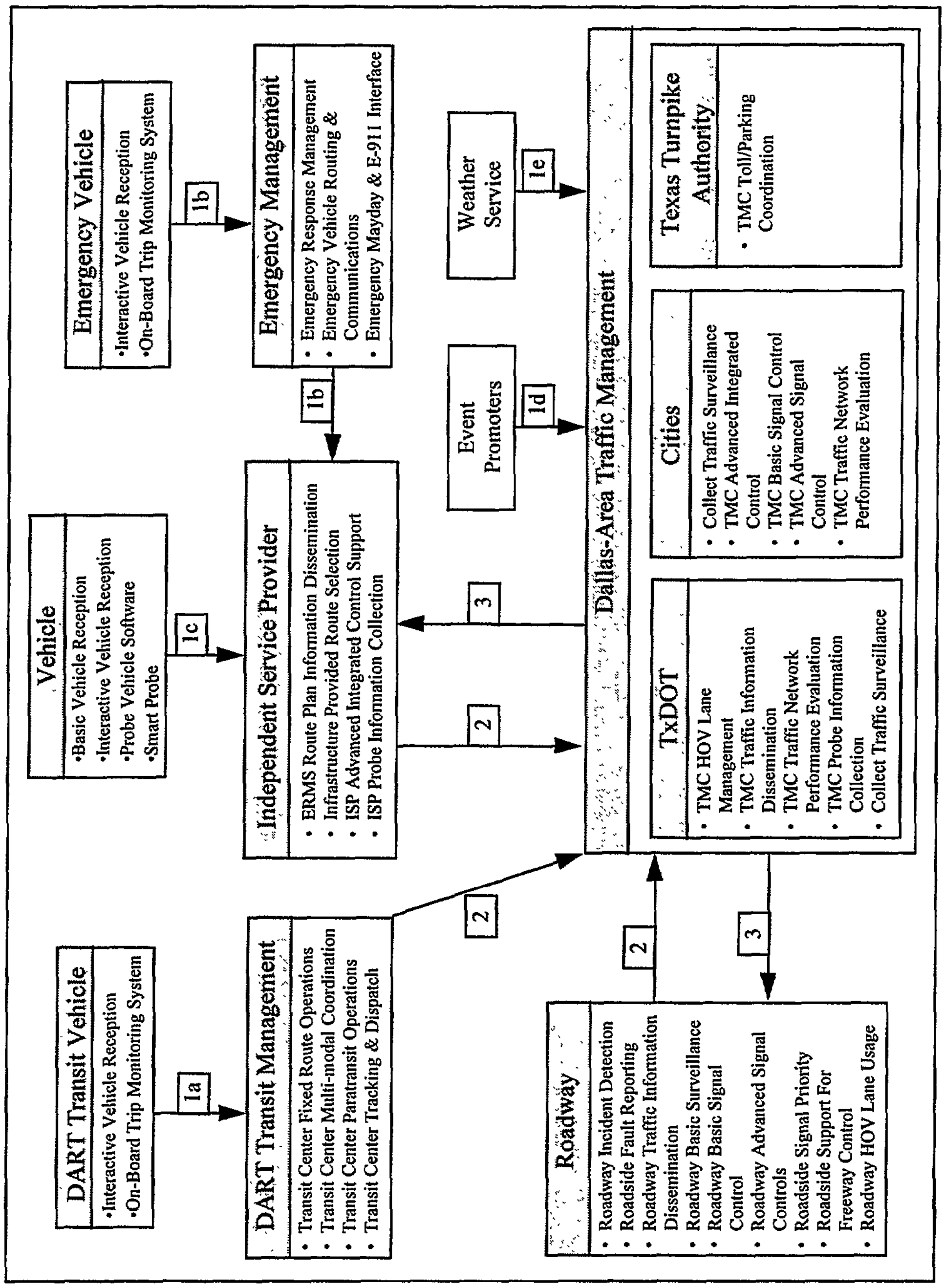

Figure 5-4. Dallas Area Traffic Control Architecture Representation

In this figure TxDOT will initially perform the Independent Service Provider (ISP) function. The information flows depicted in Figure 5-4 are summarized as follows.

1. Various vehicle traffic management service requirements are collected:

    a. DART Transit vehicles report their status (including location, a timestamp and occupancy) to the Dallas-Area Transit Management subsystem. The Transit Management subsystem processes this data to determine general transit vehicle priority needs as well an individual transit vehicle priority needs.

    b. Similarly, Emergency Vehicles report their current position and selected routes to an Emergency Management Center (EM) which forwards this information (message lb) to the ISP.

    c. Other vehicles communicate their selected routes and updated locations to the ISP.

    d. Event promoters report "Event Info" to the TM for large traffic generators.

    e. Weather Service "Current and Predicted Weather" is delivered to the TM.

2. The DART Transit Management and the Information Service Provider subsystems send current position and expected routes and occupancies of vehicles to the Dallas Area-Wide Traffic Management subsystem. Roadway based surveillance data is also sent to the TM. Along with traditional surveillance data are messages about emergency vehicle preemption requests received 'directly from those vehicles at specific roadway locations. Also, field retrieved travel data generated from ETTM tags will be delivered to the TM.

3. The Dallas Area-Wide Traffic Management Center simultaneously processes the real-time routes required by emergency, DART, and other participating vehicles; determines an appropriate signal coordination strategy and sends this to the Roadway subsystems; updates its predicted traffic model; and sends this to the ISP.

5.4.2 Incident Management

Figure 5-5 illustrates the Incident Management User Service as potentially deployed in the Dallas area.

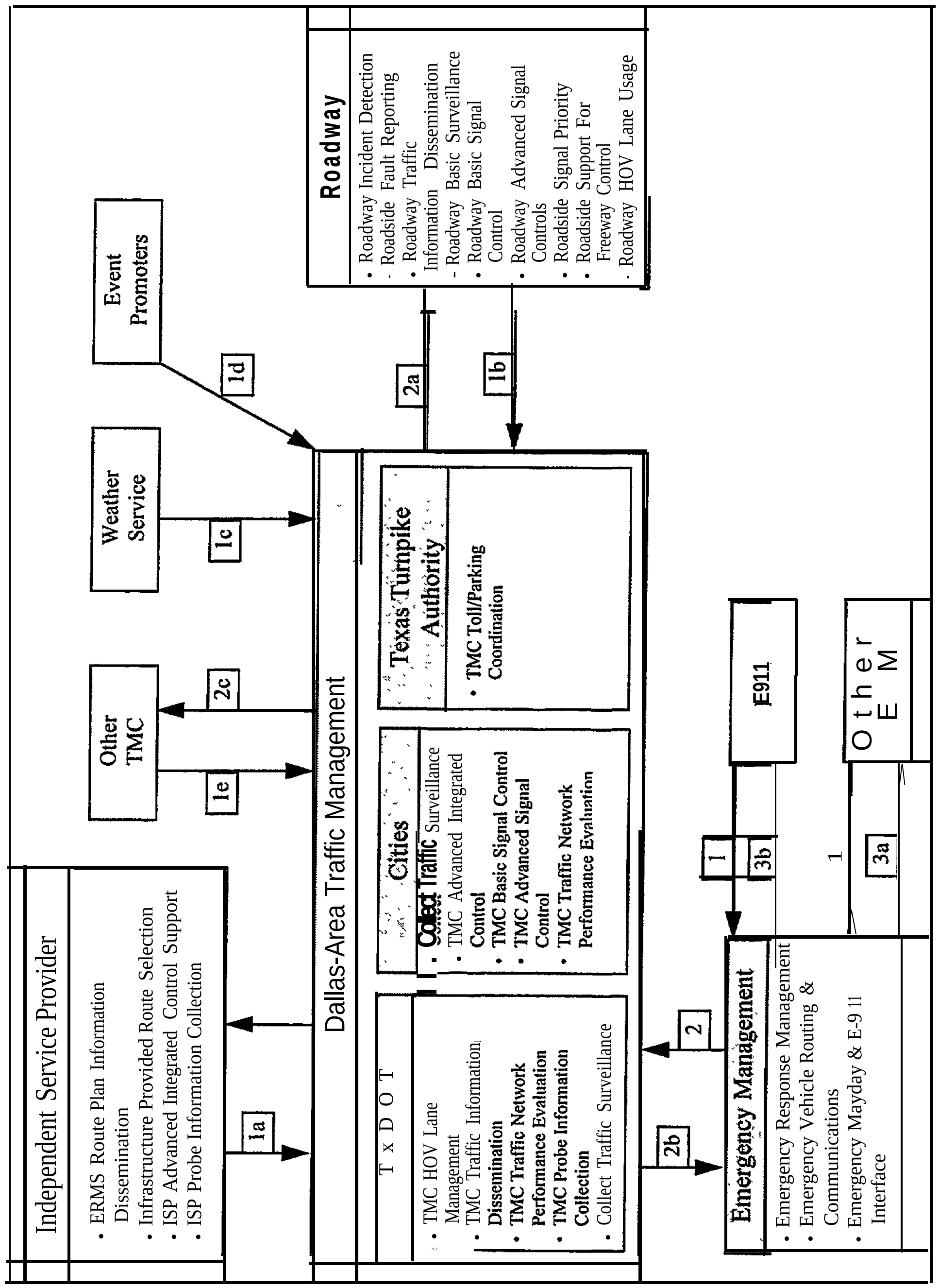

Figure 5-5. Dallas Area Incident Management Architecture Representation

In this figure the Independent Service Provider (ISP) function will initially be performed by TxDOT. The information flows depicted in Figure 5-5 are summarized as follows.

1. The TM continuously collects data from:

   a. ISP;

   b. Traffic sensors;

   c. Weather service data;

   d. Event promoter data about upcoming events; and

   e. Incident alerts from other TMs.

2. When an incident is verified, an appropriate incident response is prepared and messages are sent to:

   a. Roadway subsystems to set VMS and actuators;

   b. EMS to alert them to the incident and begin an incident clearance operation; and

   c. Other TMs to alert them to the incident and to participate in the incident clearance.

3. On receipt of a TM Incident Alert message, the EMs will notify with an Incident Alert message:

   a. Other EMs; and

   b. E-91 1 system.

5.5 Standards

Figure 5-6 was prepared in conjunction with the Rockwell International ITS Architecture Team. The drawing recommends standards for economies of scale between the centers that will be operating in the Dallas area. It suggests standards from the center subsystems to the roadside devices in order to facilitate regional interoperability. Finally, it identifies the adoption of standards from vehicles to roadside systems or to centers in order to achieve national interoperability.

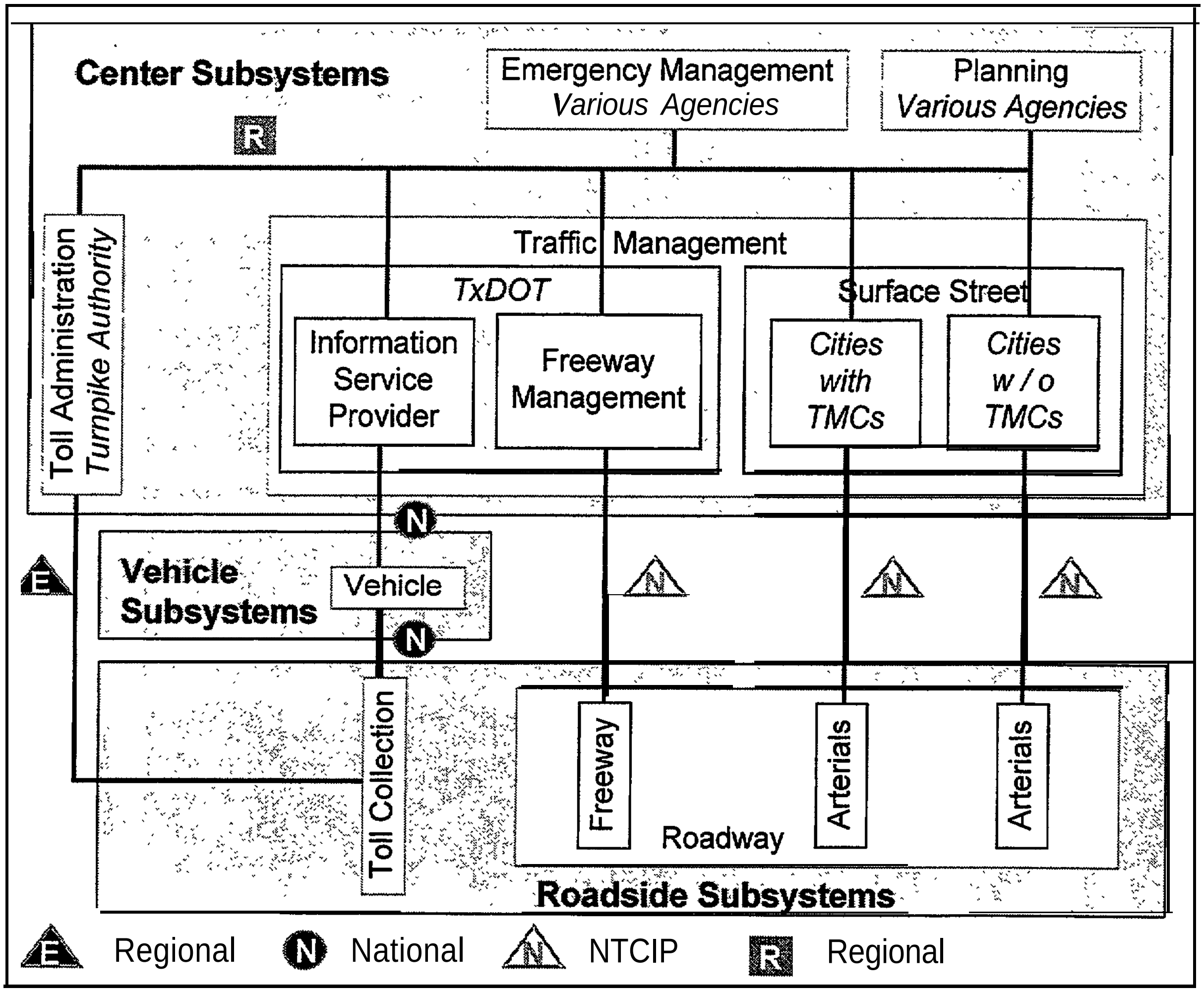

Figure 5-6. Recommended Dallas Area-Wide Standards

5.6 Communications Protocols

Communications protocols are key elements in implementing an ATMS/ITS system. Currently, in the traffic signal local controller technology arena, there does not exist a common set of protocols for communications. Therefore, it is difficult to develop an integrated system that provides interoperability between manufacturers' products. Furthermore, there is a desire by customers to view local controllers as "field processors" acting as a communications and control node performing more than traffic duties (2). These additional functions could include: changeable message sign displays, surveillance camera control, sprinkler system control and air quality monitoring.

NEMA traffic control equipment manufacturers began to formulate a National Traffic Control / ITS Communications Protocol (NTCIP) shortly after finalizing the TS 2 traffic control hardware standard in 1992. Among other considerations, TS 2 Standards addressed communications between equipment components within the cabinet (3). However, it did not pertain to communications protocols between traffic signal local controllers and other devices external to the cabinet.

As NEMA's discussions proceeded, the FHWA sponsored a Signal Manufacturers Symposium in Washington, D.C., in May 1993. The participants included NEMA members, the FHWA, states, cities and other industry representatives. The conclusion of the Symposium was to identify five priority issues for action (4). They were as follows:

- Development of a communications standard;
- Designation of the local controller as a "field processor" for various control applications;
- Simplification of operations and maintenance of traffic signal control equipment;
- Improvement of procurement practices; and
- Deployment of options with identified funding.

These issues were consistent with published objectives for ITS and also consistent with prior FHWA reports on the following related topics:

- Report on *Operation and Maintenance of Traffic Control Systems (5);*
- Expert panel report on *Traffic Control Systems Operations and Maintenance (6); and*
- Report on *Traffic Control Systems Operations and Maintenance* - *A Plan of Action (7);*

Specific issues relevant to communications standards that have been emphasized by NEMA in their NTCIP design efforts are (8):

- Develop a design that is fully documented and that could serve as an "open standard;"
- Keep communications separate from applications;
- Define a protocol that can be implemented;
- Allow multiple vendor's products shared use of the same communications path (connectivity);
- Share common functions between like products (interoperability); and

- Enable development of "field processors" that are communications and control nodes in an ITS network (not just local controllers).

The NTCIP design approach is based upon network models that have been designed for other non-transportation systems. Therefore, it is a goal for the protocol to conform to existing network methods and standards. The standards that have been chosen are:

- HDLC - High Level Link Data Control (IS0 3309 and IS0 4335) at the link level (9, 10); and

- Internet Protocol (IP) at network level (11, 12).

The NEMA Traffic Control Systems Section chose these models because (l3):

> models were chosen because the communications requirements for traffic control and traffic management generally fall into two levels. These are referred to as link level and network level communications. At the link level, a communication protocol must deal with passing data between directly connected devices such as a traffic controller connected to an arterial master. At the network level, a protocol must deal with end-to-end oriented communications where data may have to pass through several intervening devices to reach its destination. For example, a telephone conversation passes through several switching stations before reaching the destination party. In a traffic control application, the scenario might be a central computer downloading a controller database through an arterial master.

Both of these standards are based on the seven layer IS0 (International Organization for Standardization) network model (l4). The seven layers of the IS0 model are: physical, data link, network, transport, session, presentation and applications.

Significant progress for developing a publicly available NTCIP occurred during 1994 and the first half of 1995. For almost two years, the Technical Committee of the NEMA Traffic Control Systems Section worked closely with representatives of the May 1993 Signal Manufacturers Symposium Steering Committee to facilitate definition of the protocol. In May 1994 at the recommendation of the Symposium Steering Committee, FHWA asked Oak Ridge National Laboratory (ORNL) to evaluate the work-in-progress draft protocol definition. As a result, ORNL retained a consultant, Opus One, to review the draft and to search for software sources to support the NTCIP. Opus One's conclusion was that no suitable software was available and that it would be cost effective to develop the required software.

From June 1994 through December 1995, the NEMA Technical Committee refined the NTCIP protocol definition so that it was nearly complete. Concurrently, ARINC has been contracted by FHWA to write a public domain software code for NTCIP. At the January 1996 TRB meeting, a proof of concept demonstration of the NTCIP code was exhibited. The schedule for completion of the NTCIP is to have the communications protocol complete by April 1996 and to have object definitions for traffic actuated controllers available by June or July 1996.

5.7 References

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