



Chapter 5: COMMUNICATIONS REQUIREMENTS

5.1 INTRODUCTION

This Chapter outlines a communication plan for the region that will support transportation requirements for data, and video transmission.

The communication network will support communication required for ITS deployment between selected points in the region. It will provide a backbone communication system, as well as a distribution network to reach the individual devices or control locations.

The basic purpose of the communication network is to provide the communication links between various end points on the network. These end points are distributed across the region and can include everything from a CCTV camera to a Central Traffic Signal Server.

5.1.1 Methodology for Developing Eugene-Springfield Communications Plan

The methodology used to develop this communication plan is a “bottom-up” approach. The analysis begins with the current communication requirements and known additional requirements. These needs are combined with forecasted future growth and new technologies that should be supported in the future. This aspect of the planning is based on experience with similar systems and an understanding of the current trends in the industry.

All of the communication requirements (current and potential) are then used as the basis for developing a communication model for the entire network. This model establishes the general configuration of the communication network and the basic protocols that will be supported.

The final stage of the communication planning determines how the plan is applied to the actual deployment of the communication network.

The communication plan should be considered a “living document” that is updated on a regular basis, as the communication needs change, to follow improvements in technology, and to reflect the implementation of various portions of the network.

5.1.2 Communications Plan Guidelines

There are a number of guiding principles that have been used in the development of this communication plan. These principles must also be considered during the detailed design:

- **Reliability:** The system must provide a high level of reliability, achieved through the use of components with a high MTBF (Mean time between failures), combined with a redundancy in the network design.
- **Growth:** The network must be expected to grow gracefully. This requires the incorporation of a reasonable amount of unused capacity and a design approach that allows extra capacity to be provided by upgrading the transmission equipment.
- **Standards:** Communication protocols and component selection must use widely accepted standards that minimize ongoing operations and maintenance costs.
- **Flexibility:** The network configuration must be designed to maximize flexibility to accommodate future changes, rearrangements and equipment changes.
- **Decentralized:** As the network supports several agencies, it must be configured around several centers of control, and allow the control location to be changed according to current needs. This will support the concept of a virtual operations center.

5.1.3 Application of the Communication Plan

This Chapter defines a “high-level” planning approach to ITS communication for the region. This plan provides the guidelines to be used in the development of the detailed design for each section of the communication network. As the opportunity arises to construct a section of the network (through funding or provision of facilities by a third party), the detailed design for that section will be completed.

The regional plan addresses the configuration and implementation approach, but it does not determine exact routing, equipment selection and capacities. These aspects of the communication network are best finalized during detailed design as a section of the network is to be implemented, allowing the most up to date requirements to be incorporated in sizing, and current transmission equipment to be selected. In municipal networks, cost effective facility routing and equipment locations can be selected if the implementation considers the plans for road reconstruction, and construction or renovation of buildings that can be used for communication equipment.

The following approach is recommended for each detailed design:

5.1.3.1 Pre-Design Planning Review

Before the start of the detailed design, typically at the same time as the documents are prepared to seek budget funding for the design, a brief “Pre-Design Planning Review” should be prepared. This document would typically be no more than two pages and would address the following topics:

- a) Key elements of the design that are required by the Communication plan. These should include provisions for future growth and to provide for geographic areas outside that served by the particular detailed design.
- b) Aspects of the design that will not follow the communication plan, with justification for these changes.

The purpose of the pre-design planning review is to ensure that the concepts and principles of the communication plan are considered in the detailed design. For example, if a road is being reconstructed, and it is known to be on a planned backbone communication route, this approach will ensure that the detailed design (even if it is only a small section of the ultimate backbone) provides for the future needs. These provisions could accommodate the future capacity with the initial installation or provide conduit and equipment mounting space for future installation.

5.1.3.2 Final Planning Review

After the completion of the detailed design of the specific network segment, the pre-design planning review should be finalized to include any changes that have been made during the detailed design. The finalized review will document any provisions made in the detailed design to support the communication plan (for instance spare capacity, routing or configuration considerations). It will also justify deviations that have been made to the communication plan.

An important aspect of the final planning review will be to identify if there is a need to update the master communication plan, either in whole, or in part.

5.1.3.3 Communication Plan Updates

As sections of the network are implemented, and as technology and communication requirements change, the communication plan should be updated as required. At any given time the “current” communication plan will consist of the plan itself, and any Planning Reviews that have been conducted. A current list should be maintained with the communication plan, and updated as required.

5.2 EXISTING COMMUNICATION INFRASTRUCTURE

Chapter 1: Current & Future Transportation Conditions, includes a section on existing communication infrastructure. This section identified existing equipment and infrastructure that is owned and maintained by ODOT, City of Eugene, City of Springfield and Lane County, as well as the regional consortium known as Public Agency Network (PAN) and its participating agencies. This existing infrastructure is illustrated in Figure 5-1 and summarized in this section.

In addition to the existing infrastructure, each agency was asked about their near-term plans and future vision for communications—independent of the new requirements defined in this regional ITS planning effort. The results of this discussion are included in this section as well.

5.2.1.1 Public Agency Network (PAN)

The Eugene-Springfield Public Agency Network (PAN) is an intergovernmental cooperative network allowing multiple agencies to share fiber resources and maximize cost effective utilization of existing infrastructure. The Eugene Water and Electric Board (EWEB) is the executive authority of the PAN, whose other members include:

- City of Eugene
- City of Springfield
- Lane County
- Lane Council of Governments
- Lane Transit District
- Lane Community College
- Springfield Utility Board (SUB)
- Eugene School District 4J
- University of Oregon

PAN utilizes Dense Wavelength Division Multiplexing (DWDM) technology to achieve high bandwidth capacity on a limited amount of fiber plant¹. DWDM technology allows different agencies to utilize individual wavelengths of light (also referred to as “lambdas”) on the same fiber optic cable, allowing multiple agencies to share a single fiber. While this technology supports very efficient use of fiber plant, it is important to note that some data exchange requirements, or agency policies, may require that the data traffic be separate from other agency data traffic. These requirements need to be considered when determining whether utilization of the PAN is a suitable option.

Figure 5-1 illustrates the existing fiber optic cable owned by the PAN member agencies. This cable plant represents the physical layer of the PAN, however, most of the routes indicated are currently only being utilized by the agency that owns that segment of fiber (i.e. no PAN circuits). Approximately two dozen point-to-point DWDM (PAN) circuits on this network have been activated at this time.

Rates to use PAN are structured on a “lambda strand-miles” formula, used to cover system operations and maintenance cost of the fiber and the network. While the rates vary accordingly on a circuit-by-circuit basis, for planning purposes they are approximately \$500/month/lambda. Each agency is required to purchase their own network equipment.

As the cost for PAN is per lambda, most agencies have opted to use the facility for high-speed transmission, generally Gigabit Ethernet. Some agencies have used the fiber channels for lower speed services, including T-1 (DS-1) and 100 Mbps Ethernet.

5.2.1.2 ODOT

The Oregon Department of Transportation has several interconnected traffic signals, however, the twisted pair cable plant itself is owned and maintained by one of the local

¹ In a telecommunications network, the word “plant” refers to the physical infrastructure layer of the network, usually relating to fiber optic, copper or twisted pair cable. In the most general terms, it can be used to refer to the entire physical layer, including cable, poles, conduit, transmission equipment, etc. The term “Inside Plant” is often used to refer to cable and equipment inside a building, while “Outside Plant” is used to describe infrastructure outside of a building.

jurisdictions (either City of Eugene or City of Springfield) to support local operation of the controllers.

ODOT is in the process of establishing a high-bandwidth fiber optic connection between its Eugene facilities, and their statewide network, including the Northwest Traffic Operation Center (NWTOC) in Salem. It is likely that this fiber backbone will terminate locally at the University of Oregon, and utilize other local agency fiber to reach the new ODOT facility in Glenwood.

ODOT does not currently have any specific plans to build fiber optic plant in the Eugene-Springfield region, but the agency does have experience building, maintaining and operating fiber in the Portland Metro area and some other regions.

5.2.1.3 City of Eugene

The City of Eugene has an extensive network of twisted-pair copper plant utilized for signal interconnect on 186 signals throughout the city.

The city has acquired some fiber optic cable through agreements with long distance service providers Williams (96 fibers) and Level3 (12 fibers). The city is also a member of PAN, but does not currently use any of the PAN infrastructure for traffic data exchange.

The City of Eugene intends on upgrading their signal interconnect plant from twisted-pair copper to fiber optic cable in a phased program over the coming years. The first phase will connect the old traffic office at 858 Pearl Street to the new location² at 1902 Roosevelt. Subsequent phasing and priority corridors are still in preliminary planning stages.

The City of Eugene IS department has been deploying fiber to various city buildings to support telephone and data network requirements and reduce agency costs.

5.2.1.4 City of Springfield

The City of Springfield has a fairly extensive network of 12-pair twisted-pair copper plant utilized for signal interconnect throughout the city.

The city is also a member of PAN, but does not currently use any of the PAN infrastructure for traffic data exchange.

The City of Springfield traffic department does not have plans for deploying a fiber optic network in the foreseeable future.

5.2.1.5 Lane County

Lane County has mostly isolated signalized intersections and does not require traffic signal interconnect. The county is a member of PAN and the county office is connected to the PAN network. The county also utilizes a dial-up cellular connection to access video from a remote CCTV camera in Coburg.

² The City of Eugene traffic operations group was recently relocated from the 858 Pearl Street office to the maintenance office at 1902 Roosevelt.

Lane County would like to establish a higher bandwidth connection to their CCTV camera in Coburg, as the current cellular dial-up option is not very functional. The county does not have further plans to build interconnect or fiber to any field devices in the near future.

5.2.1.6 Lane Transit District

Lane Transit District utilizes a 450MHz radio network to communicate (voice and data) with the bus operators. The two data channels on this network are used to collect real-time vehicle location and passenger count data as part of LTD's newly implemented ITS and Computer Aided Dispatch (CAD) system.

LTD also uses an 802.11b wireless network for large batch data files such as schedule updates and voice annunciation files. This network supports short distance communications, and includes wireless antennas in the maintenance yard.

LTD has access to six fibers on the "fiber consortium" segments (also referred to locally as the "Gang of Six") and is a member of PAN.

Lane Transit District plans on deploying additional radio transmitters and receivers to improve radio coverage in several corridors that are currently poorly served. The agency has also shown interest in being able to access video from surveillance cameras at both the Eugene and Springfield transit centers and possibly future deployments. The agency is also considering future expansion of their 802.11 network to support high-bandwidth data transfers in a larger geographical coverage area.

5.2.1.7 Regional Wireless Network

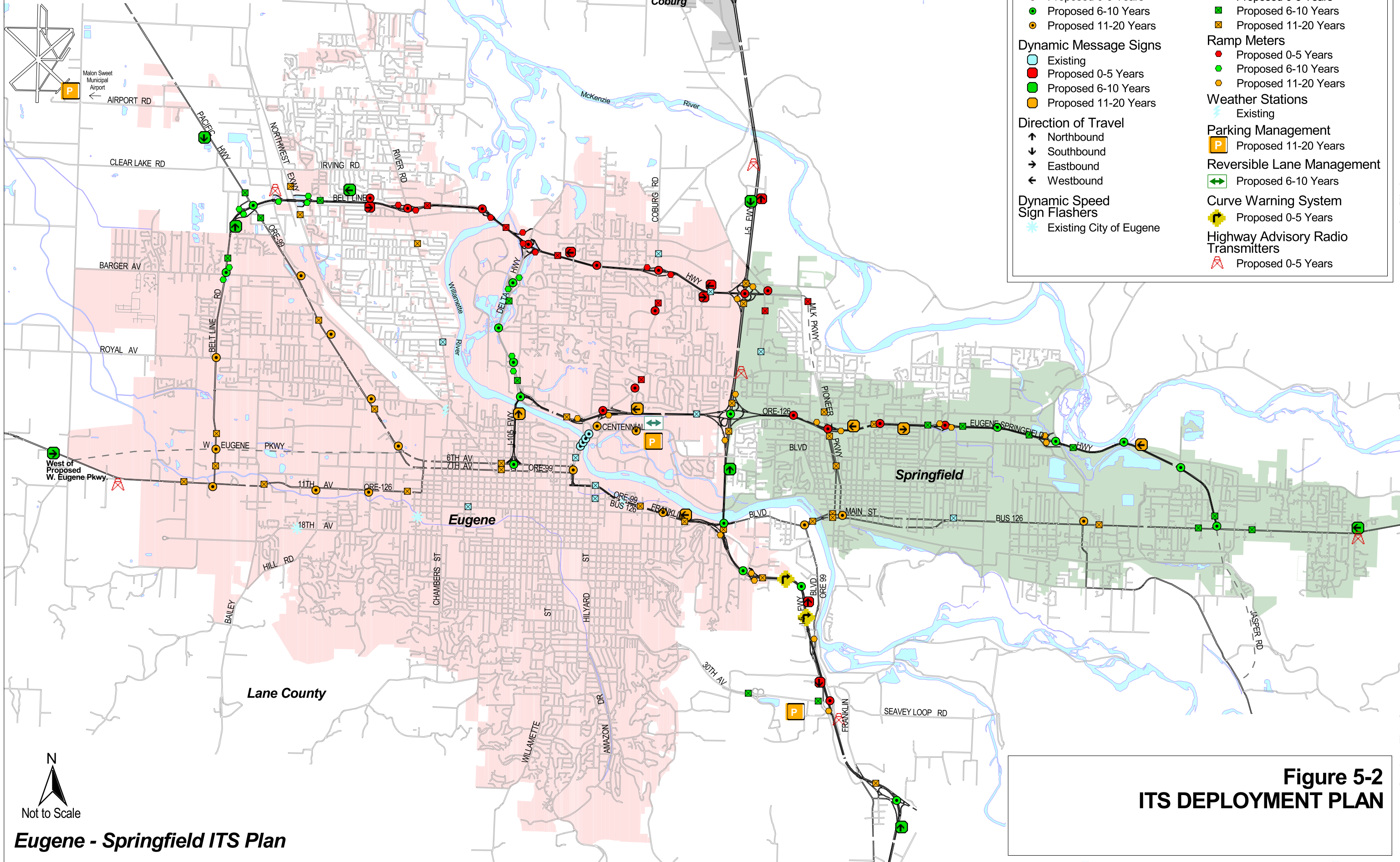
There has been some recent discussion in the Eugene-Springfield region regarding building a large scale, high-bandwidth wireless network. This network may be lead by several public agencies collaborating on design and construction or it may be lead by the private sector, who would then lease services to public sector agencies. Either way, if this network moves forward, it could provide extremely cost effective communications links to field devices and progress on this effort should be tracked closely.

5.3 COMMUNICATIONS REQUIREMENTS

This section considers the end devices and centers to be supported on the network and the associated requirements for local communication facilities. All of these devices and centers, considered as a group, form the communication requirements for the region, which must be supported by the communication network. Figure 5-2 illustrates the existing and planned ITS devices (from agency interviews) as well as the proposed ITS devices that are identified in this regional ITS planning effort and discussed in more detail in Chapter 7.

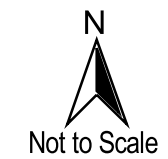
5.3.1 Requirements for Existing and Planned Devices

The network must be designed to support the various communication needs of the region; now, in the near future and for the long term. This section describes the current and near-term requirements for communication that the network must accommodate, including the existing and planned near-term devices (and independent of the results of this regional ITS planning effort). Section 5.3.2 will discuss the devices that are planned as part of this regional ITS planning effort.



LEGEND

<p>CCTV Cameras</p> <ul style="list-style-type: none"> ● Existing ● Proposed 0-5 Years ● Proposed 6-10 Years ● Proposed 11-20 Years 	<p>System Detectors</p> <ul style="list-style-type: none"> ■ Existing ■ Proposed 0-5 Years ■ Proposed 6-10 Years ■ Proposed 11-20 Years
<p>Dynamic Message Signs</p> <ul style="list-style-type: none"> ■ Existing ■ Proposed 0-5 Years ■ Proposed 6-10 Years ■ Proposed 11-20 Years 	<p>Ramp Meters</p> <ul style="list-style-type: none"> ● Proposed 0-5 Years ● Proposed 6-10 Years ● Proposed 11-20 Years
<p>Direction of Travel</p> <ul style="list-style-type: none"> ↑ Northbound ↓ Southbound → Eastbound ← Westbound 	<p>Weather Stations</p> <ul style="list-style-type: none"> ⚡ Existing
<p>Dynamic Speed Sign Flashers</p> <ul style="list-style-type: none"> ⚡ Existing City of Eugene 	<p>Parking Management</p> <ul style="list-style-type: none"> Ⓟ Proposed 11-20 Years
	<p>Reversible Lane Management</p> <ul style="list-style-type: none"> ↔ Proposed 6-10 Years
	<p>Curve Warning System</p> <ul style="list-style-type: none"> ⚠ Proposed 0-5 Years
	<p>Highway Advisory Radio Transmitters</p> <ul style="list-style-type: none"> ⓡ Proposed 0-5 Years



Eugene - Springfield ITS Plan

**Figure 5-2
ITS DEPLOYMENT PLAN**

The detailed design of any section of the network should support all current requirements, and provide for all anticipated requirements. Where the exact deployment of the anticipated equipment is not finalized, or in those cases where there is a significant incremental cost, the provision for these future requirements may be limited to the following:

- a) installation of appropriate cable sizes, or the installation of underground conduit for future cable installation,
- b) sizing of equipment enclosures, cabinets, and facility rooms to accommodate the future requirements,
- c) sizing provisions for power to include the load for future equipment, and
- d) choice of transmission systems that will allow modular expansion to support the anticipated future requirements.

5.3.1.1 Traffic Signals

Traffic Signals in the region are operated by four separate entities as shown Table 5-1. This table identifies how many signals are operated and maintained by each entity. It is important to note that 83 signals owned by ODOT are actually operated and maintained by Eugene and Springfield.

Table 5-1. Traffic Signals in the Region

Agency	Number of Signals	Controller Types	Software	Communication
City of Eugene	224	170,170A and 170E	BiTrans with QuicNet 4.1 central software	85% of signals are connected using twisted pair.
City of Springfield	66	170	BiTrans with QuicNet 4.1 central software	65% of signals are connected using twisted pair.
ODOT	9	170	Wapiti W4IKS	None
Lane County	17	170	Wapiti	One signal has cellular interface
TOTAL	316			

Communication to traffic signals requires a data channel between the traffic signal system computer and the controller for each intersection. The communication plan must support the existing systems and be capable of supporting migration to National Transportation Communications for ITS protocol (NTCIP) compliant communication in the future.

Current Requirements

The current communication approach has been an individual twisted pair to groups of up to seven controllers, with modems used to provide the communication link. Communication uses EIA/TIA-232 communication, commonly referred to by its original name, RS-232. This link is used to upload and download signal timing parameters, and allows monitoring of current status.

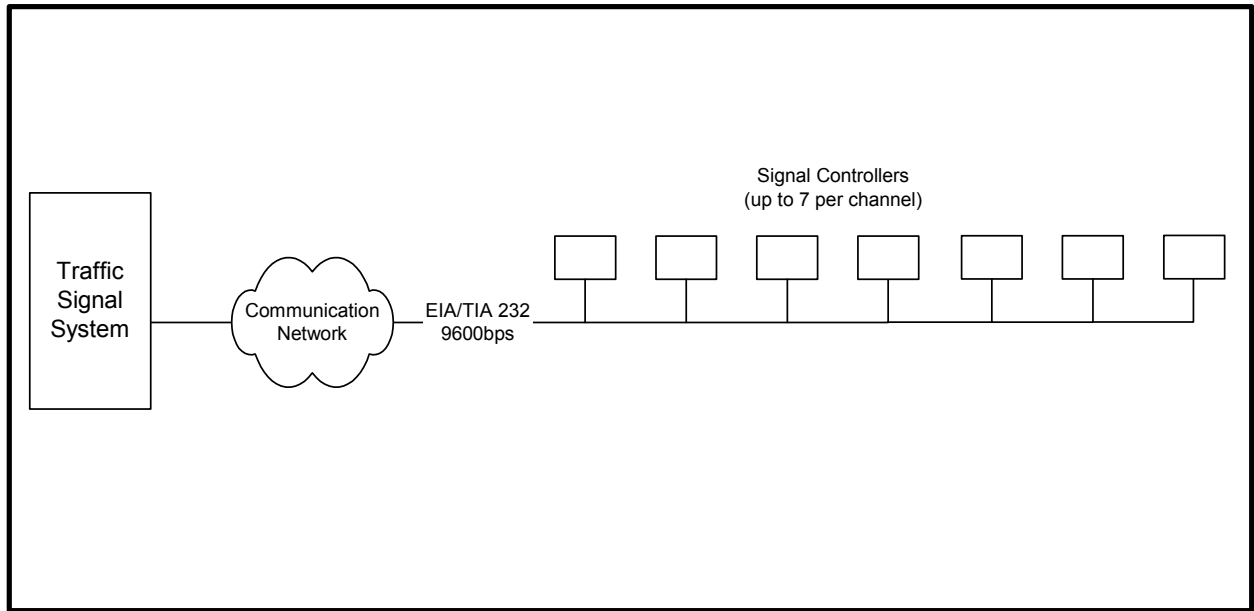


Figure 5-3. Traffic Signal Communication

The current requirements can be supported with RS-232 channels between the traffic signal system computers and the signal controller. The existing central software will allow channels to be shared so that seven controllers can utilize the same channel to the traffic signal controller as shown in Figure 5-3.

Anticipated Requirements

It is expected that eventually all signals will migrate to NTCIP communications at some point in the future. NTCIP protocols will allow RS-232 or Ethernet communication to each controller, but at this time all the development for Type 170 controllers is focused on RS-232 protocols for signal controllers. The data loading is dependant on the manufacturer’s implementation of the protocol, but as shown in Figure 5-3, a maximum of seven controllers on a shared EIA/TIA 232 channel operating at 9600 bps is a good basis for network design. Note that NTCIP has a significant amount of overhead data that needs to be transmitted (as compared to proprietary systems/communications which use less data and for which 9600 baud is more than sufficient). This limits the number of controllers that can share a channel.

Communication Provisions

The communication protocols used by traffic signal controllers can be supported by fiber optics, twisted pair or a combination of the two. The communication design should provide for two fibers for each controller. Groups of up to six controllers (five current and one spare) may share the same two fibers, connected in series. The change from seven controllers per channel to five plus one spare will support additional overhead required for NTCIP. It is not necessary to reorganize existing groups of controllers until NTCIP is implemented, but any new transmission hardware or cables should be sized to accommodate this change.

When cable is placed in the vicinity of the signal controller, it should support the communication to that device. Signals that are not on a current fiber path can be connected to this path using existing twisted pair cable as required, but fibers should be reserved in the main cables to accommodate those additional signals in the future.

Detailed design should anticipate additional intersections that may be installed. Where additional signals are likely, the number of intersections sharing a common channel should be reduced to allow for future intersections.

5.3.1.2 Vehicle Detection

Vehicle detection data may be collected through the traffic signal controllers or stand alone vehicle detection sites. For planning purposes, the communication requirements are identical with those of a traffic signal controller.

Current Requirements

The majority of vehicle detection occurs at signalized intersections and is handled by the signal controller. There are also several existing video detection sites in Eugene and Springfield.

ODOT, City of Eugene and City of Springfield each have a few system detectors or automatic traffic recorders.

Anticipated Requirements

Future requirements would arise from new signalized intersections, or isolated detection sights along major arterial roads. Video detection can be used locations where permanent loop installations are not recommended (e.g. in areas where future road work is anticipated), but it is not necessary to bring video feeds from video detection sites back to the TMC – only the detection data is required. If the selected video detection system provides a suitable image for monitoring traffic, the video signal may be supported in the same manner as a CCTV camera.

Communication Provisions

It is anticipated that the communication provisions for traffic signal control will also provide for the vehicle detection requirements. Where there is a known requirement for stand alone vehicle detection sites, these should be included in the design of the traffic signal control system, and treated simply as another controller on this system. Similarly, if the video from a video detection site is to be available for viewing, provisions should be made to provide a CCTV channel as described in the next section.

5.3.1.3 CCTV Video

CCTV monitoring requires transmission of a video signal, as well as a data channel for camera control. In most systems the camera control, used to provide pan/tilt/zoom (PTZ) and focus, is carried on an RS-232 or EIA/TIA 485 (commonly called RS-485) data channel, which can be digitized in an IP video stream or carried as a separate low speed data channel.

Current Requirements

In this system video signals are originated at cameras located in the field and transmitted to a Control Center, where a video switch and monitors are located.

Anticipated Requirements

It is likely that additional CCTV cameras will be provisioned in the future, and that cameras will be shared between agencies within the region. The video signals interfaced at a typical control center are shown in Figure 5-4.

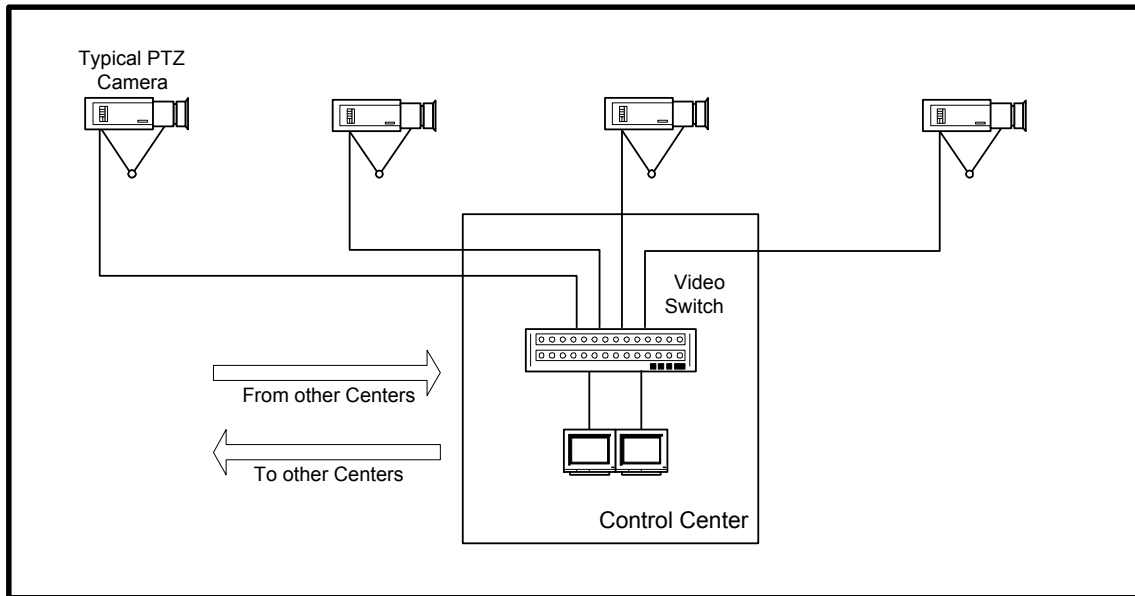


Figure 5-4. CCTV Video

Communication Provisions

CCTV video can be carried as an analog or digitized signal. The camera control channel must also be carried. There are several methods available, but IP video is recommended as described in Section 5.5.2.2. Two fibers will be provided at every camera site to provide an Ethernet link that would support the video and camera control requirements.

5.3.2 Future Requirements (supporting this Deployment Plan)

There are a number of possible future subsystems (discussed in more detail in Ch.7) that should be considered in the design of the communication system. These future requirements are expected, but not designed for a specific location, and provisions to support these needs can only be made as spare capacity. This section considers the type of ITS equipment that may be required in the future and based on the possible future requirements, recommends a spare capacity allocation to be included in the communication network plan to accommodate these devices.

5.3.2.1 Additional CCTV Video

Potential Requirements

As described above, there will be additional CCTV cameras installed within the region. Some of these are forecast for particular locations, and should be considered as anticipated requirements. Others will be located at undetermined locations throughout the region in accordance with changing traffic monitoring requirements.

Other CCTV video requirements could include video links to be installed from field cameras owned by outside agencies, but of interest to the region. An example of this could be a state owned camera positioned on an interstate through the region. It may be easier to intercept this video signal near the camera itself and route a secondary signal directly to a regional control center, than to use a center to center video link on a full time basis between the state and regional control centers.

Communication Provisions

As it is common to multiplex a number of video signals on a single fiber, it is not necessary to provide large numbers of fibers or video channels for future requirements. For this reason, it is recommended that a minimum of four spare fibers be included in distribution fiber optic cables to accommodate future CCTV video links.

5.3.2.2 Center-to-Center

A key element of a regional ITS operation is typically the use of center to center links. These links provide for sharing of video and data, and in some cases allow for the control of a complete control center from a backup location. Many jurisdictions are constructing emergency operations centers that typically use ITS video and data, and these requirements should also be anticipated. This requirement is particularly relevant to support for the virtual TOC concept described in more detail in chapter 6.

Potential Requirements

Although there are no plans in the near term for Traffic Operation Centers for Eugene or Springfield, there are other locations that should be considered as centers and served with appropriate communication links as identified in Table 5-2.

Table 5-2. Center-to-Center Links

From	To	Purpose	Type of Link
Traffic Signal System - Eugene	ODOT Control Center	Allow monitoring of ODOT owned Traffic Signals operated by Eugene	Ethernet or RS232
Traffic Signal System – Springfield	ODOT Control Center	Allow monitoring of ODOT owned Traffic Signals operated by Springfield	Ethernet or RS232
Emergency Operations Center (EOC)	Eugene and Springfield Traffic Systems and to ODOT	To allow monitoring and possibly control of activities in the region under emergency conditions. Links could include data and video	Should adhere to TCPIP Center to Center specifications.
911 Center	Emergency Operations Center (EOC)	To allow sharing of information during emergency situations.	Data on Ethernet channels. Could also consider voice communication as an emergency backup link.
911 Center	Eugene, Springfield, and ODOT Traffic Systems	Viewing of video images	RS 250B video channels
Traffic Signal System Computers	City Maintenance Yards	To allow remote access and monitoring of the traffic signal systems	Ethernet or RS232

Communication Provisions

During detailed design, fibers should be included in the main fiber runs to accommodate six fibers for each center-to-center link. This would provide two for high speed data transmission, two for video channels (based on 12 video channels per fiber), and two spare fibers.

5.3.2.3 DMS Signs

Potential Requirements

DMS or Arterial signing is a common ITS element that is added to many systems. The signs typically communicate using EIA/TIA 232 communication, and are commonly compliant with NTCIP standards. Communication requirements are similar to the traffic signal controllers, and a number of signs may be multidropped on a single channel.

Communication Provisions

Two fibers or a twisted pair would be sufficient for a VMS Sign Channel. Usually at least eight signs can share the same channel. For this reason it is recommended that two fibers or a twisted pair be included in all distribution or backbone cable installations for future DMS signs.

5.3.2.4 Other Traffic Subsystems

Other low data devices, such as road weather information systems, traffic beacons and highway advisory radio systems have similar communications requirements to the DMS devices.

5.3.2.5 Transit Signal Priority

Potential Requirements

Most transit signal priority systems use local communication between a roadside sensor and the traffic signal controller. The roadside sensor identifies the location of a transit vehicle and may provide signal priority as required.

In some municipalities a more centralized monitoring approach has been used, where the location of the transit vehicles is tracked, and the signal priorities changed system-wide in response to the congestion experienced by these vehicles. Such systems require field detectors that use wireless communication with transit vehicles to collect location information. They also require fast, reliable communication and a near-real time traffic signal control system.

Communication Provisions

Fiber would be the preferred communication media for vehicle location stations, as they typically operate using TCP/IP protocols. Where fiber cable is installed, two fibers should be included, and these fibers can serve any number of vehicle location stations.

5.3.2.6 Other Transit Subsystems

A number of systems are available for “next bus arrival,” providing time and/or routing information to transit riders for the next bus to arrive. Many of these systems operate using wireless technologies, but they could also use the wireline communication network if it is available. It is also possible that at strategic points in the region, there will be communication links to the transit vehicles. Although the final link to the vehicle would use

wireless technology, the communication backbone would support the link between a wireless antenna site and the control center.

Communication Provisions

Two fibers or one twisted pair should be allocated in distribution facilities for future transit links – either to roadside information signs or for communication to vehicles.

5.4 NETWORK ARCHITECTURE

In order to select a network architecture that is best suited to the needs of the region, it is important to consider the available options. This section describes the possible configurations and communication protocols at a higher level, including brief consideration of the strengths and weaknesses of each option.

A typical communication network is divided into three basic elements as shown in Figure 5-5:

- a) **Backbone:** The communication backbone is capable of carrying all types of the data traffic in the system. The backbone interconnects a number of nodes, which are central locations where the information can be inserted onto or removed from the backbone.
- b) **Distribution:** The distribution portion of the network provides a connection between the backbone node and a group of ITS devices or buildings. The distribution typically consists of a fiber optic cable running down the municipal road allowance from the node location, but it may also be an existing twisted pair cable or wireless link. Distribution electronics are commonly collocated with the backbone node equipment in a communications hub.³
- c) **Local:** The local portion of the network or “drop” that connects an end device or building to a distribution cable or directly to a node on a backbone.

The network must be designed to support data and video requirements to a wide variety of locations through the region. With particular types of communication equipment the video can also be converted to a data stream and carried on a common transmission medium, but for planning purposes it is typically more flexible to consider two independent networks:

- a) **Data:** The communication network to carry the data signals will consist of a high-speed backbone and local distribution that will feed the individual signals to the backbone.
- b) **Video:** The video network will carry single video channels and multi-channel video signals, generally to a control center. Single channel video will typically be carried in the distribution network, and video on the backbone usually combines a number of video signals into one multi-channel video signal.

³ For the purposes of this document, the terms node and hub can be considered interchangeable..

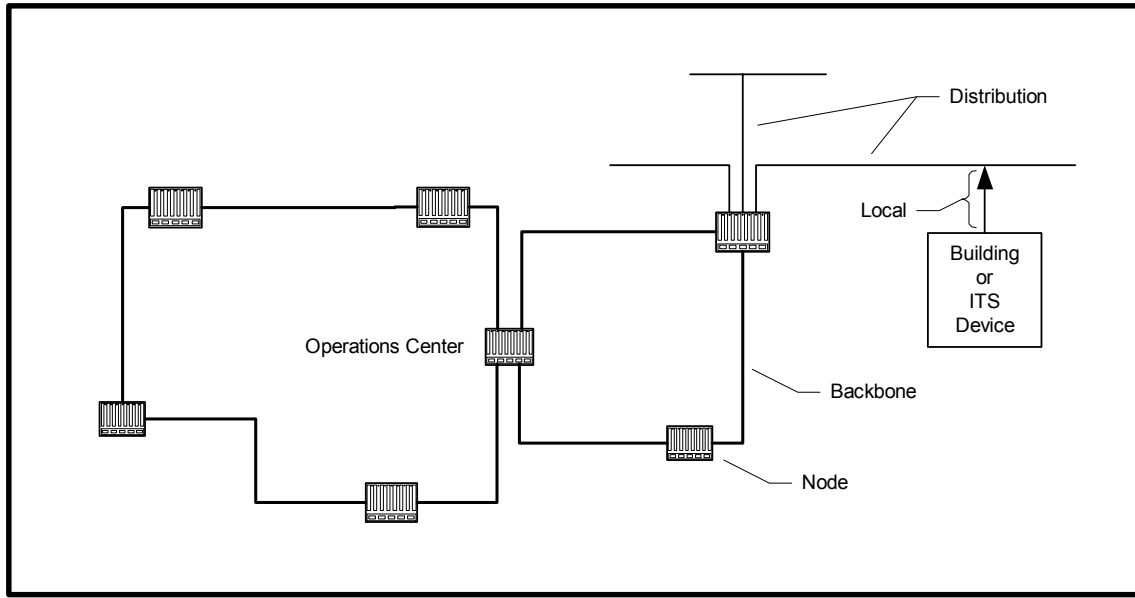


Figure 5-5. Communication Network Elements

There are a number of aspects of any network architecture that need to be considered:

- a) **Communications Technology Options – Plant Level:** At the Outside Plant level, the network architecture considers the links between elements in the network. There are a number of technologies that can be used to connect locations on the network, either cables or wireless links.
- b) **Physical Topologies:** The devices, centers and other facilities on a communication network can be connected in a number of different physical configurations or topologies, including star, ring, and/or mesh networks.
- c) **Backbone Communications Technology Options – Sub-network Level:** A key aspect of the network architecture is the type of transmission system used in the backbone to interconnect network nodes. Examples include ATM, SONET and Gigabit Ethernet (GigE) technologies. In newly constructed networks generally a single backbone transmission system is selected for the entire network.
- d) **Distribution Communications Technology Options – Sub-network Level:** There are a number of communication technologies that should be supported by the architecture for distribution systems such as Ethernet, RS-232/485, or propriety. Although it reduces complexity to minimize the number of distribution technologies, it is better not to design physical facilities that limit the use of a wide range of technologies.

5.4.1 Communications Technology Options – Plant Level

The plant level considers the physical plant used to interconnect points on the network. In traditional networks this would include the cable (fiber or twisted pair) between devices,

but in recent years, the introduction of wireless technologies have also allowed wireless equipment to provide a plant level link.

5.4.1.1 Twisted Pair

Twisted pair cable was the original physical plant used for communication networks. The widespread use of this technology by the telephone companies has resulted in robust cables that require little maintenance when installed correctly.

The most significant drawback of twisted pair plant is the narrow bandwidth it can provide. Although compression techniques have greatly improved data speeds, they are still generally limited to low speed data unless costly multiplexing equipment is utilized.

The region has a good quality twisted pair network that operates the traffic signal system. In many cases it may be feasible to intercept the twisted pair cables with the fiber optic distribution cable and connect low data ITS devices that are not located on the backbone or distribution routes using the existing twisted pair cables. Some technologies that may be considered support video over Twisted Pair, with varying degrees of quality and performance.

Utilization of the twisted pair plant in this manner could provide a cost effect method of serving some local, low data devices. It would also reduce the overall length of the twisted pair route, improving transmission quality. Utilizing existing twisted pair cable to communicate with low data devices can also decrease edge communications equipment costs, as many low data devices require costly intermediate equipment to transfer between fiber and their native communications protocol. All of these issues should be analyzed during detailed design of specific network segments.

5.4.1.2 Coax Copper

Coaxial cables were introduced to provide increased bandwidth and are still widely used to carry broadband video services by the Cable TV industry. In ITS systems they are used typically to make video connections where the cable is 500 feet or less in length, which does not require any transmission equipment.

Although coaxial cables can be used to transport video images for greater distances, the transmission of baseband video signals required in ITS systems is much more efficiently carried on fiber optic cable.

5.4.1.3 Fiber

Fiber optic cable has become the preferred choice of physical plant installations for ITS systems. Fiber optic systems can carry very large bandwidth on a single fiber, and cost effective transmission systems are available for CCTV video signals. Fiber has the advantage of low signal loss, allowing signals to be carried large distances without repeaters. Equipment is available that can carry a signal with any of the protocols described in this document between any two points in the city without repeaters. In recent years the cost of fiber optic cable has decreased, and it costs far less than a twisted pair of equivalent capacity.

5.4.1.4 Wireless

As the road allowances have become increasingly congested with cable plant, wireless systems have increased in suitability. Recent developments are making these systems more cost effective and increasing the bandwidth that they can carry.

Many options exist for low speed systems that do not require FCC licensing to operate. This simplifies their deployment, but does not reserve a particular frequency for use. In urban areas there is the increasing risk of interference between systems in use.

Some agencies use frequencies reserved for public safety for wireless transmissions, but are still experiencing interference with other wireless operators.

When compared to the high cost of cable installation, wireless systems are a viable choice. It is expected that they can provide the greatest cost benefit for low speed links in congested areas, and could be considered for short haul communication to ITS devices. Wireless communications may also be considered for remote, low data devices and possibly for phased implementation.

5.4.1.5 Leased Lines

Another Plant level option is to simply lease a twisted pair from a third party. Although there is other equipment that is likely in place on this link, it is not visible to the user, and the link can be considered as a physical plant link between two locations.

Leased links incur ongoing monthly charges, but do not require a large capital outlay to have installed. They carry the same data as a twisted pair cable. They are often used effectively to serve remote devices where it would be too costly to install a dedicated cable.

As a point of reference, a leased T-1 line can often run anywhere from \$500/month to over a \$1000/month, with a DS-3 often running approximately 10 times this amount. However, these costs can vary drastically from region to region and between service providers, and should be verified during detailed design.

5.4.1.6 Dark Fiber

Dark Fiber⁴ can be leased from the utilities in the region. These fibers are contained in cables owned by the utility, but would be segregated and leased exclusively for ITS use.

Although dark fibers incur monthly charges, they provide the full benefit of the fiber optic cable without the capital construction costs. Utilization of leased dark fiber may be particularly advantageous for phased network implementation, with the leased segments being replaced by new construction as network deployment proceeds.

EWEB and SUB indicated that dark fibers can be leased for approximately \$25-35/month/fiber pair/per mile, depending on the route and fiber availability.

5.4.1.7 Leased Wavelengths

The PAN network in the region provides the opportunity to lease a fiber optic channel between two points. As described in Section 5.2, the PAN network uses optical

⁴ The phrase “dark fiber” refers to fiber optic cable that has been installed, but is not currently activated or “lit”.

multiplexing equipment that can carry multiple wavelengths of light on a single fiber. It allows a single fiber to be shared as a connection between different backbone transmission equipment, and has specific modules designed for Gig E and SONET transmission.

The PAN network leases these channels, often called “lambdas” as they refer to particular wavelengths of light measured in lambdas. Although there is equipment in the PAN network, in a similar way to a leased line, the lambda can be considered a point to point plant link for the purposes of communication planning. There is some coordination required to ensure that the equipment connected to the PAN network uses the correct wavelengths, but specialized optics are not required.

5.4.2 Physical Topologies

There are a number of physical topologies that can be used to interconnect locations on a communication network. This section introduces some example network topologies.

5.4.2.1 Star

Star configurations refer to a topology where each device has one connection to a central point as shown in Figure 5-6. Also called a “home run”, these links would be the sole communication path from the device to any other point in the network. This approach is often used in distribution networks, where each device has a single channel back to a node on the backbone. Local links are typically star configurations as well, between the distribution cable and the end device.

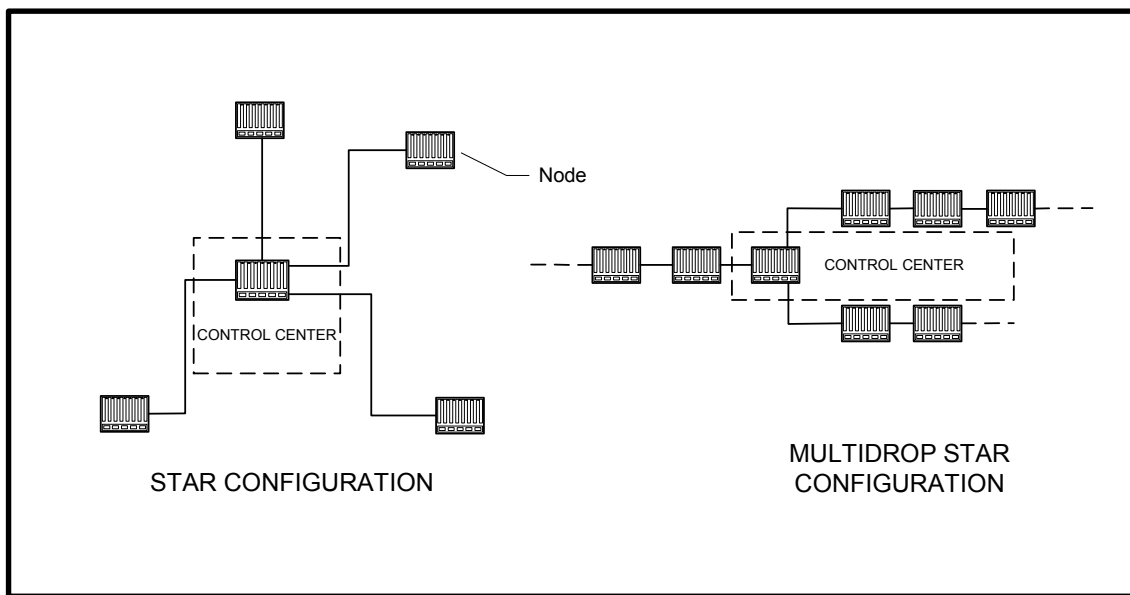


Figure 5-6. Generic Star and Multidrop Configuration

With some systems, more than one device can share a channel. If these devices are served in series (as illustrated in Figure 5-6) they can be called a multidropped star, where a number of devices share one communication path.

5.4.2.2 Ring

Ring configurations connect a number of devices or locations in a ring. This approach is often used in backbone networks that connect a number of nodes together as shown in Figure 5-5. Each node has two connections, primary and secondary. In this configuration, the failure of a single communication path or a single node allows the remainder of the devices to communicate without interruption.

The use of rings in distribution networks is also possible, although there are a fewer number of types of distribution electronics available to do this.

5.4.2.3 Mesh

In some backbone technologies, particularly TCP/IP, the equipment can accept many different connections (instead of just primary and secondary), and the firmware on the communication equipment can select the routing of the traffic between any two points on the network. (As compared to the ring where the hardware determines the routing). With this capability, a mesh configuration can be established where any number of connections may exist between any two points in the network, as shown in Figure 5-7.

This configuration can provide multiple redundant paths, and allows the system to balance traffic between the nodes in real time. It also provides increased flexibility and growth options for the network.

This configuration also provides advantages in a system where there are multiple control points. The virtual TMC concept would be well supported by this configuration.

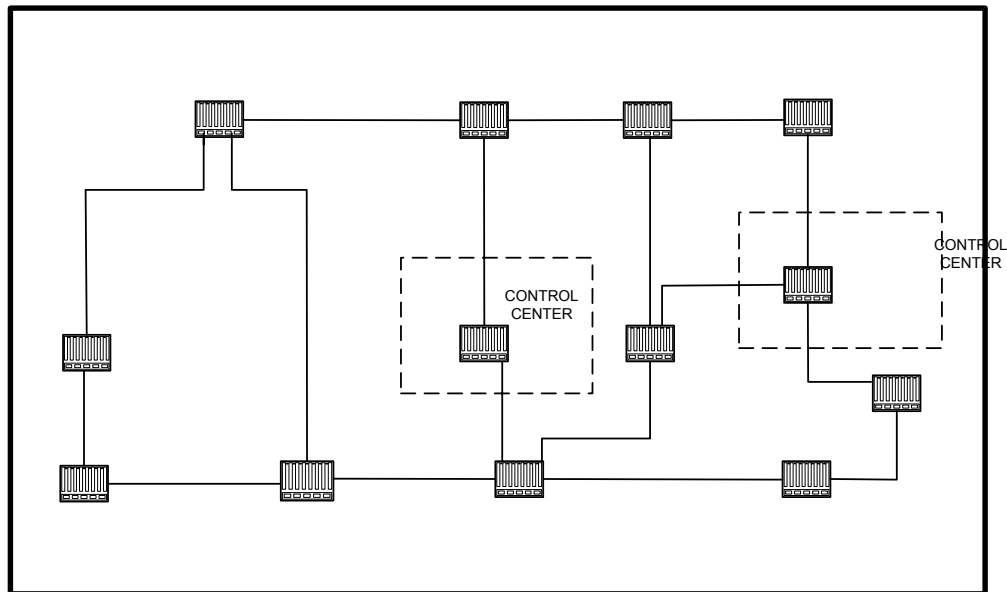


Figure 5-7 Generic Mesh Configuration

5.4.2.4 Hybrid

A Hybrid network combines one or more of the above technologies into a single network. The most common topology is a hybrid with a star distribution network and a mesh or ring backbone.

A hybrid approach is also typically used in backbones where a ring or mesh has a node that is connected by a spur in a star configuration as shown Figure 5-8. In this case the node on the spur has access to the backbone bandwidth, but does not have the redundancy that a node on the ring or mesh would have.

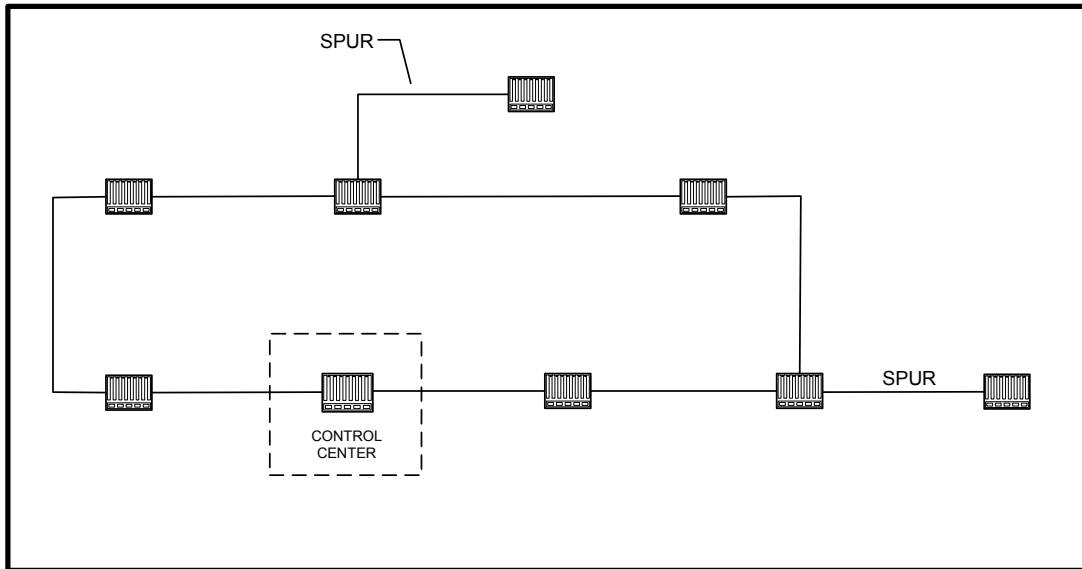


Figure 5-8 Generic Hybrid Configuration

This configuration also provides advantages in a system where there are multiple control points. The virtual TMC concept would be well supported by this configuration.

Another hybrid network is a redundant star as shown in Figure 5-9. In this configuration, each device is connected in a star configuration, but two channels are provided to make the connection. The two channels are contained in the same transmission media, providing redundancy should the electronics on one of the end points fail. As the communication path is common, however, this does not provide any redundancy to communication path failures such as cable cuts.

5.4.3 Backbone Communications Technology Options – Sub-Network Level

The most significant decision in the design of the communication network is the selection of the data backbone technology. The selection must consider the current needs, industry standards, and the developing standards.

At this time there are basically only three technologies that are widely used, for which there is a well established base of standards: ATM, SONET and Gigabit Ethernet. Other backbone systems exist, but they either do not have a full range of accepted standards, or there is not a variety of vendors providing interoperable equipment.

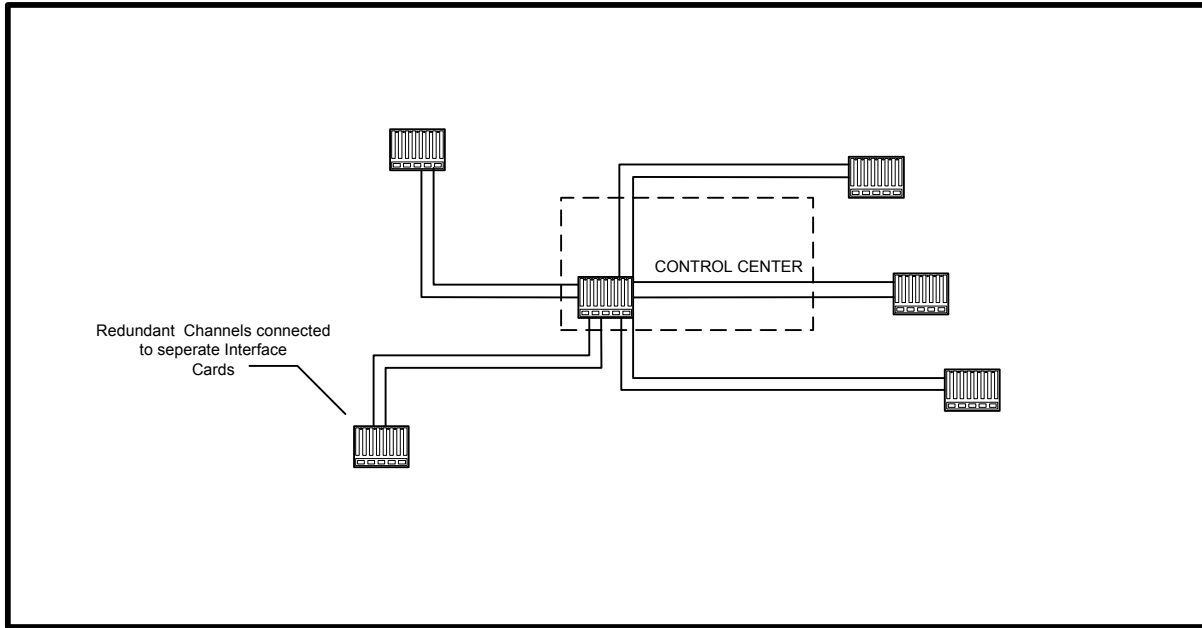


Figure 5-9. Generic Redundant Star Configuration

5.4.3.1 ATM

ATM backbones saw their greatest growth prior to the introduction of 100 and 1000Mbps Ethernet transmission. This equipment provided high speed connectivity and easily supported TCP/IP (Ethernet) transmission, making it a popular candidate for use in networks that had a high volume of TCP/IP traffic. The equipment provided routing and supported mesh configurations. ATM also provided the first variable bit rate solutions for transmission of video signals.

With the improvement of speeds provided on Ethernet equipment and new advances in digital video, the implementation of new ATM networks has virtually stopped. The same TCP/IP traffic that was the strength of the ATM equipment can be carried in native Ethernet equipment using Gigabit Ethernet (1000Mbps), without translation to ATM protocol. The most common digital video transmission protocols are also now based on TCP/IP protocol.

By eliminating the need for conversion to ATM protocol, Gigabit Ethernet has replaced ATM for use in new networks.

5.4.3.2 SONET

SONET technology is the traditional choice of telecommunication providers, for whom voice transmission is the majority of the traffic. The highly reliable system is based on the provision of established channels that are constantly open between each end point in the system.

The standards for SONET are firmly established and widely followed, and provide for the transport of serial data streams of 1.544 Mbps or higher in a number of protocols. Data services operating at lower speeds or different protocols can be accommodated by adding

communication components connected to the SONET network. Transmission equipment supporting pure implementations of SONET is interoperable between vendors.

SONET standards do not provide for Ethernet connections or data channels with lower speeds than 1.544 Mbps. Some vendors do provide multiplexers that will accept these protocols and transport them using SONET protocols and data rates, but these products are not “pure” SONET, and are not interoperable between vendors – each multiplexer must communicate with another multiplexer made by the same vendor.

An implementation of SONET in the backbone network for the region that would support TCP/IP (Ethernet) and low speed data would require routers at every node to convert the Ethernet signals into data channels that can be carried by SONET. It would also require multiplexers to combine the low speed data channels for ITS applications into a T1 signal (1.544 Mbps) that can be carried by the SONET multiplexer. These additions require a number of other components as shown in Figure 5-10 resulting in a very complicated network, increasing capital cost and complexity in network maintenance.

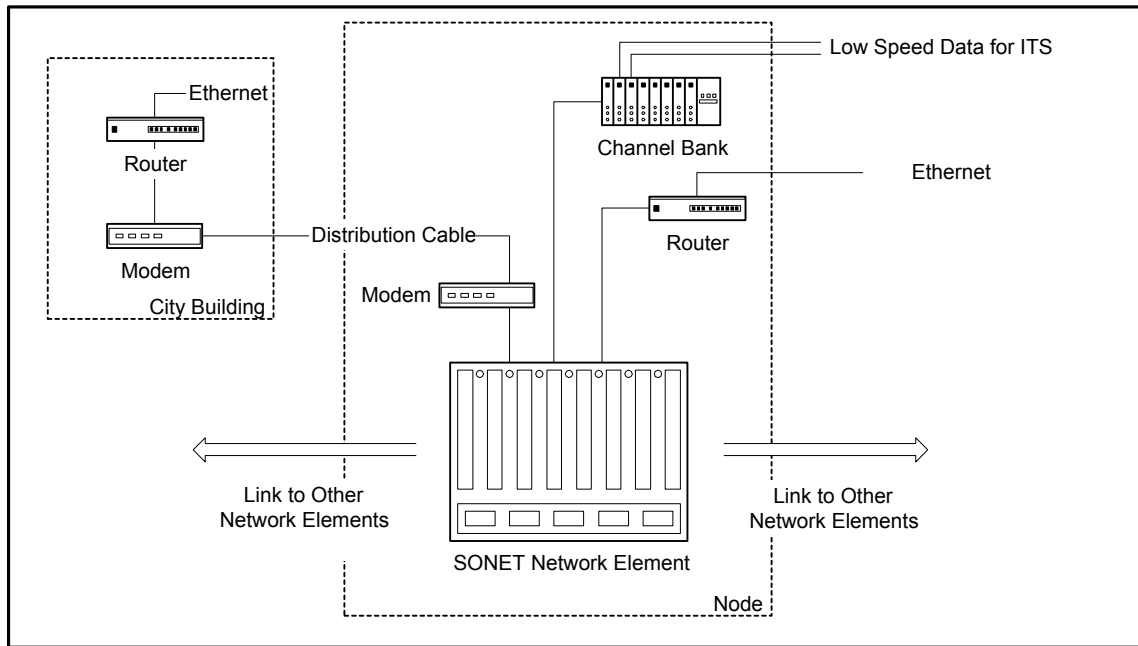


Figure 5-10. Required Equipment for SONET Backbone

The inherent requirement for SONET to assign all channels in a permanent manner can make the system inefficient, unless the transmission requirements are continuous and consistent, and the switching is done outside the backbone network. (This is the case in a traditional telco network.)

5.4.3.3 Ethernet/Gigabit Ethernet

A third network architecture that is increasing in use as the backbone in ITS networks is based on Gigabit Ethernet operating at 1000 Mbps, with support for all Ethernet standards commonly available today (10 Mbps, 100 Mbps and 1000 Mbps on twisted pair and fiber

optic cable). Standard TCP/IP protocols are used throughout the network, and the components are widely available and interoperable between vendors.

Gigabit Ethernet (Gig E) provides a number of advantages:

- a) Based on established standards.
- b) Provides direct TCP/IP connectivity for center-to-center connectivity.
- c) Allows a standard IP addressing scheme, and subnetting
- d) Supports Virtual Private Networking (VPN)
- e) Maintains the simple communication configuration.
- f) Supported by standard Network Interface (NIC) Cards and drivers, allowing direct connection to the backbone.
- g) Equipment is inter-operable between a number of vendors, and compatible with the equipment and systems installed in the region's facilities.
- h) The extensive use of Ethernet in communication networks worldwide ensures that it will continue in the future.

Under this configuration a serial hub or terminal server device would provide the low speed EIA/TIA 232 communication for existing ITS devices using EIA/TIA 232 communication, but this provides flexibility by allowing each port to be addressed with an IP address. Many new ITS devices may be procured with the Ethernet protocol in place of RS-232/422/485 and no serial hub or terminal server device is required. The routers are not required to convert the Ethernet traffic to other protocols for transport. The equipment at a node is greatly simplified as shown in Figure 5-11.

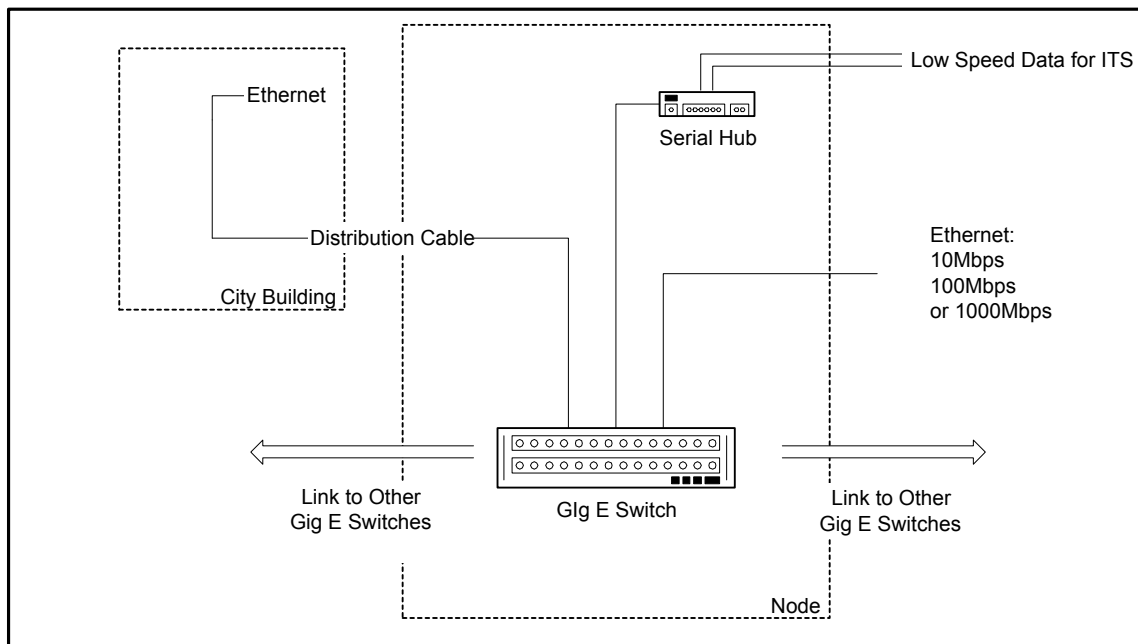


Figure 5-11. Required Equipment for Gigabit Ethernet Communication

5.4.4 Distribution Communications Technology Options – Sub-network Level

The options for communication in the distribution network are driven mainly by the communication protocol used by the ITS device. Most distribution networks support these protocols directly, however, some distribution systems convert signals in a number of protocols into a common channel that can be easily carried on the backbone network.

5.4.4.1 RS-232/422/485

The traditional low speed protocol used by ITS devices is RS-232. This protocol is still widely used, and is one of the two low speed protocols recognized by NTCIP as a standard. RS-422 and RS-485 are similar protocols, and are often found in the circuits used for camera control. These all provide low speed communication, typically operating at 9600 bps or 19,200 bps.

Each of these low-speed protocols was originally designed for twisted pair communication, but are now widely supported by fiber optic components. Although RS-232 is actually a point-to-point protocol, it can be supported as a multi-dropped protocol with certain fiber optic transceivers. RS-422 and RS-485 have similar interface requirements except that RS-422 is generally point-to-point and RS-485 is a multi-drop protocol.

In addition to simple point-to-point and multi-drop transmission, there are many options to combine and transport multiple RS-232/422/485 signals on the distribution network. Video/Data transceivers are also available that will carry these protocols and video signal over fiber so that a pair of transceivers can provide the video signal from a camera and the camera control data channel.

Some distribution networks use redundancy, and there are data transceivers that can be connected in a ring over fiber to provide redundancy in case of a fiber failure.

Communication for the ITS subsystems requires the provision of low speed links to the controllers for each device. A number of controllers can typically share each low speed channel, and with NTCIP compliant controllers, functions such as vehicle detection and VMS sign control signal can share the same channel.

As shown in Figure 5-12, the low speed channels can be carried on the distribution cable from the node to the device using fiber optic modems. These modems will carry the signal over a pair of fibers connected in series so that the same pair of fibers can serve a number of modems. When the signals are carried to the node, a modem converts the optical signal to an electrical signal that can be connected to node equipment.

5.4.4.2 Video Transmission

There are two economical methods of carrying the video signals from the field cameras to a Control Center, simple analog video transmission over fiber optic cables or digitized video carried by the backbone transmission equipment.

Analog video signals can be carried economically over the relatively short distances in the region, and provide a full motion video signal. Such transmitters could also carry the camera control signal as described above.

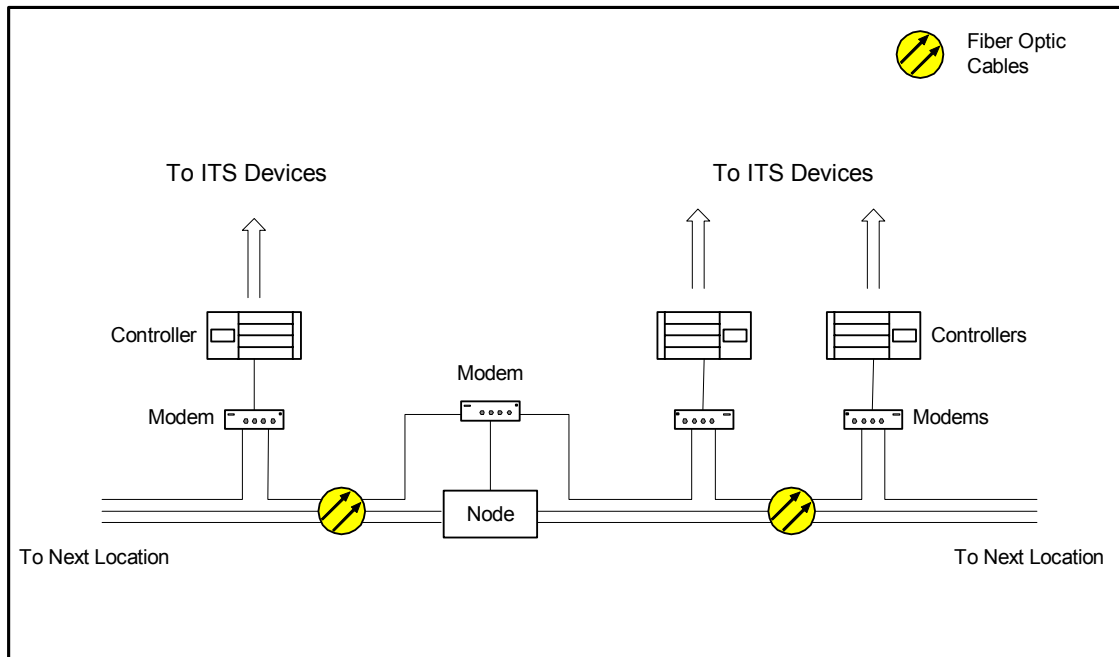


Figure 5-12. ITS Distribution – RS 232

A number of video signals can be multiplexed and transported over a single fiber. Such systems typically combine from four to twelve signals on a fiber, but systems with as many as 128 signals are available. These systems become economical when there are few fibers available or the transmission distances are greater.

Individual camera signals would be carried on single channel transmission systems to a node location. At the node, a number of camera signals will be multiplexed into one signal that can be carried over a fiber to the Control Center, as shown in Figure 5-13.

The trend in the ITS industry is towards digital video transmission equipment that will carry digitized video signals over a TCP/IP network (“IP Video”) as shown in Figure 5-14, and the quality of the video images can be equivalent to analog systems. There is significant development occurring in this area, with improved quality using less bandwidth, and the systems are becoming more cost effective.

A significant advantage of IP Video is the ability to transport and re-route signals as required. This can allow re-routing of video for a particular control center to another location for off-hours control from a secondary location, and will also easily support the virtual control center concept. A particular video signal can be accessed by IP address from a number of locations in the network.

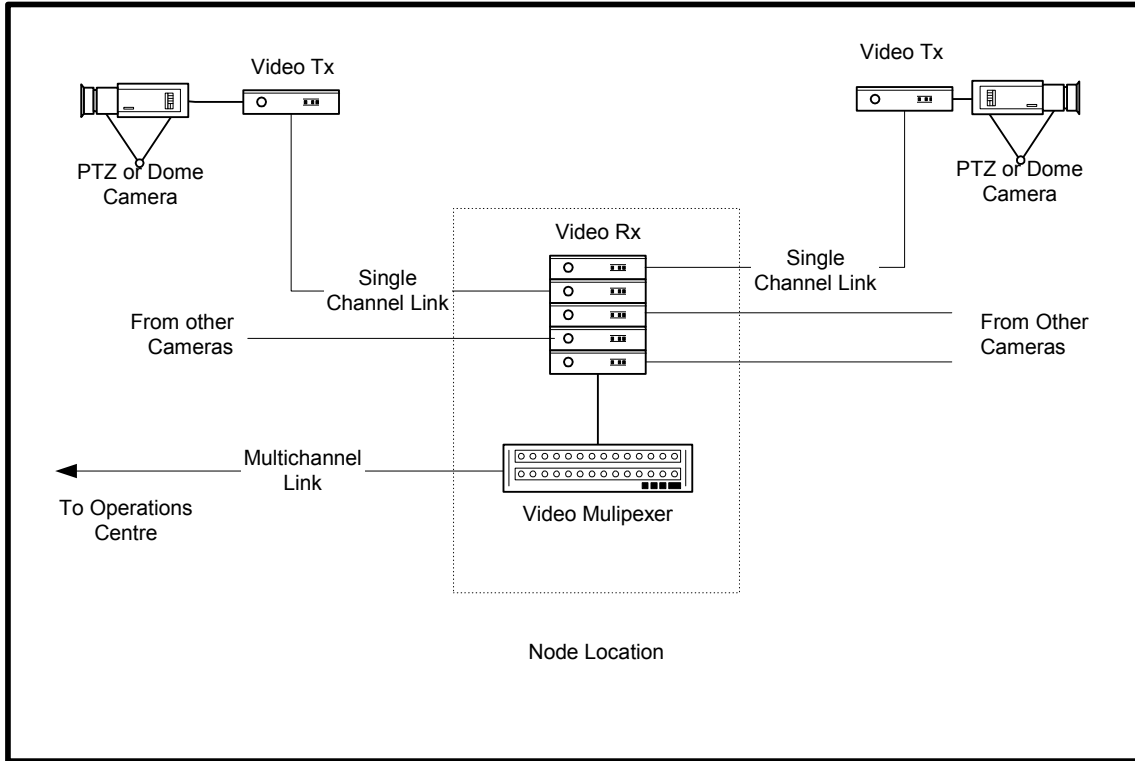


Figure 5-13. Video Links

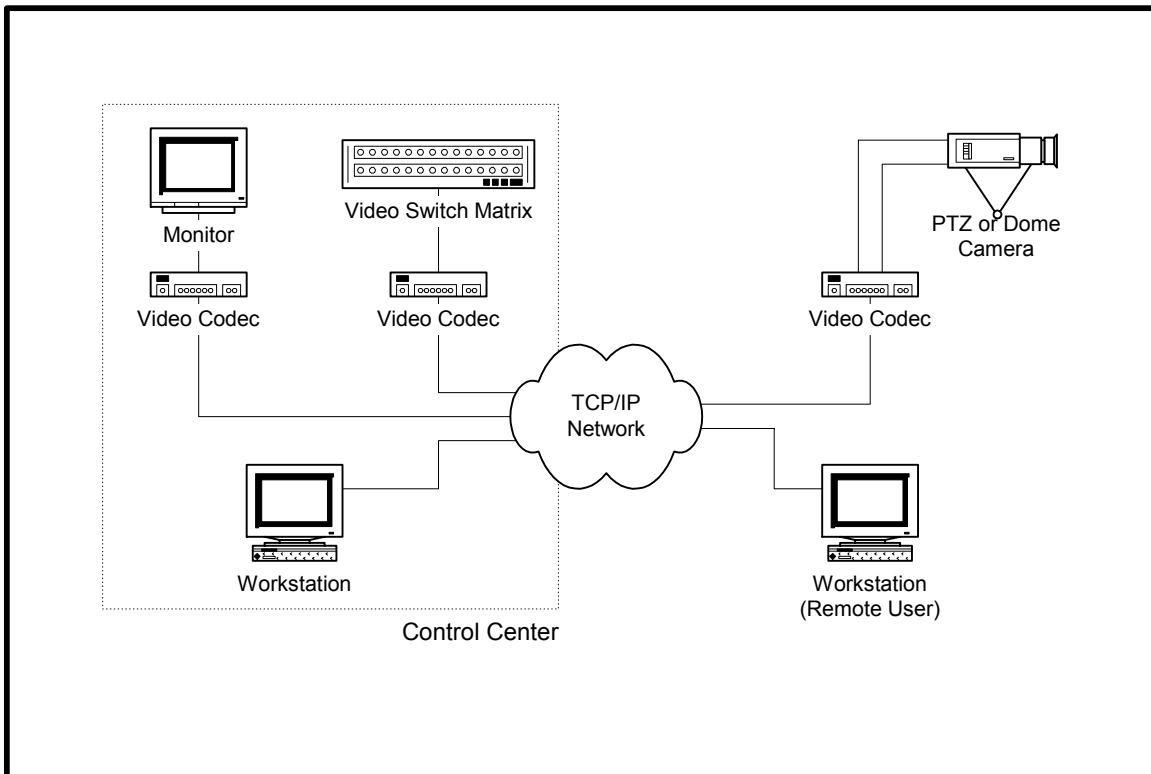


Figure 5-14. TCP/IP Network

5.4.4.3 Ethernet

With the proliferation of Ethernet (TCP/IP) communication in most computing equipment, this protocol is now appearing as an option in many ITS devices. Ethernet is a shared network providing a much wider bandwidth link to each device. (10Mbps Ethernet typically provides up to 2 Mbps of actual throughput and 100Mbps or “Fast Ethernet” provides over 22Mbps).

Ethernet is the second low speed protocol standardized under NTCIP, and is gaining use in this area because the increased connection speed is needed to support the overhead required by the NTCIP protocol. With Ethernet being the defacto standard for office networks and the Internet, it is clear that Ethernet equipment will be available for many years to come.

Where the backbone network is Gigabit Ethernet, the use of Ethernet for the distribution can result in a very simple and flexible network. Small serial hubs can be used to convert RS-232/422/485 signals to Ethernet traffic so that the network can support all data requirements. If IP video is also implemented, all network traffic can be carried as an Ethernet signal as shown in Figure 5-15.

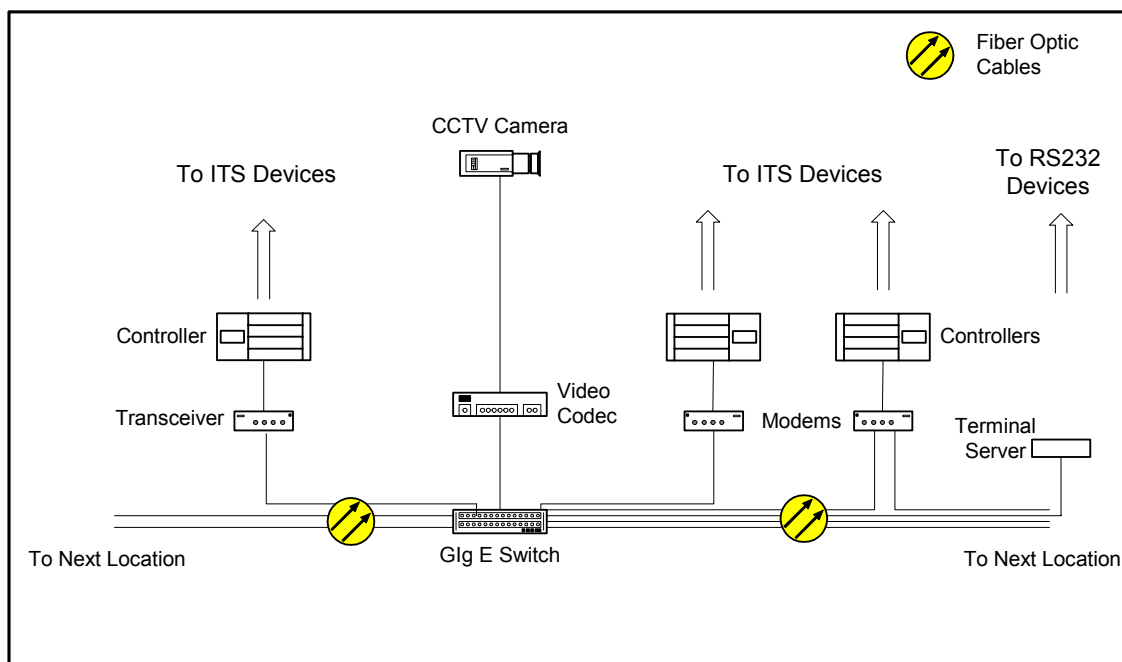


Figure 5-15. ITS Distribution

5.4.4.4 Wireless

Wireless communication is being used for distribution services for an increasing number of systems due to its advantage of not requiring a physical cable installation. Most wireless systems will carry RS-232/485 communication and can be used interchangeably with a pair of fibers and interconnecting fiber as described above.

Local leased wireless services are available to provide these services, and the region's radio systems could provide some limited connectivity.

Ethernet communication can also be accomplished over wireless links, and standards such as 802.11 are providing for interconnectivity between equipment from different vendors. Sections of an Ethernet Distribution system, or an entire distribution network could be implemented using wireless Ethernet

Microwave transmission is an option in many ITS networks, but the urban nature of this region will make it difficult to obtain the line of sight or spectrum allocation that would be required to make microwave networks economical. Limited use could be made for short video links, for example cameras on building roofs could be connected without use of cable through the building.

5.5 COMMUNICATIONS PLAN RECOMMENDATIONS

This section describes the communication plan recommendations, and the process used to reach these recommendations. This methodology starts with the areas to be connected, addresses the configuration to be used, and develops a logical plan to serve the entire area.

At this stage of the process, this plan is a high-level conceptual design of the network. Therefore, as the alternative technologies, architectures and approaches were considered, detailed cost estimating was not performed. Recommendations are based on industry experience, and a higher-level analysis combining the ability to meet requirements, cost, technical maturity, availability of equipment and services and a number of other factors.

It is highly recommended that this plan be considered a guide, and not a final design. It is further recommended that as each network segment enters planning and detailed design, all options be considered for connecting centers and field devices, including:

- Building new fiber optic cable,
- Utilizing existing twisted pair or other copper plant,
- Leasing communications services from private providers,
- Leasing communications services from public entities, including PAN, EWEB, SUB, etc.
- Building and/implementing new wireless communications links, and
- Leasing wireless communications services.

Finally, as discussed in Section 5.1, it is recommended that this plan be updated regularly, as various segments of the network are built, and if and as overall design philosophy changes.

5.5.1 Physical Topology

5.5.1.1 Backbone vs. Distribution

A two-tiered communication network is recommended for the region, consisting of a high-speed backbone and a local distribution network. Distribution networks will carry the communication channels from field devices to a field node location where it will be

combined into one aggregate signal that is carried on a pair of fibers in the backbone. This approach allows the backbone to be built with redundancy so that equipment failures or fiber cable cuts do not result in a complete loss of communication. It also minimizes the number of fiber channels required, reducing the number of channels (and associated monthly charges) that are required to carry the backbone traffic over leased lines, dark fiber or PAN channels.

The backbone will also have a node in each operations center or traffic system equipment location, to allow data to be accessed on the backbone, and to facilitate center-to-center communication. Physical redundancy in the backbone network is strongly recommended whenever possible.

The distribution network will connect field devices to each node in a star or multidrop star configuration. Although it would be possible to make these links redundant, the considerable increased cost, and network complexity are not justified for the number of devices involved.

5.5.1.2 Communication Corridors

From an operations viewpoint, it is preferable to configure networks such that the field equipment and associated communication networks are isolated from one another, with each group running their own network. The region however, has a patchwork of communication corridors operated by the three agencies as shown in Figure 5-16.

ODOT has four corridors that are linear and would not provide the opportunity to accommodate a redundant communication link unless facilities were installed on both sides of the highway. The Eugene corridors are generally a star that spreads out from downtown, with no opportunity for redundancy. The areas to be monitored in Springfield are isolated sections that are not interconnected.

5.5.1.3 Mesh Configuration

While the individual agency communication corridors do not support redundancy as stand alone corridors, when they are considered as a group, they provide the opportunity to construct a redundant network. This network is geographically a mesh that would allow most sections to be configured with redundancy as shown in Figure 5-16.

Although it would be possible to configure this network as a series of virtual rings, it would require more equipment than serving the area as a mesh. As is described in section 5.5.2.3, the mesh network is well suited to the technology that is proposed.

As it is unlikely that the network would be built in a single stage, it is expected that sections of this network would operate in a linear fashion with limited redundancy until the full network is deployed. A mesh network accommodates this approach without the need to reconfigure the system as new segments are constructed.

5.5.1.4 Redundant vs. Spur

Some sections of the proposed network do not easily allow interconnection in a redundant configuration. A decision must be made for each section to decide if it is to be built as a spur without redundancy or if a redundant link should be provided. The following may be considered when this decision is made:

- **I-5 Corridor** – The I-5 corridor outside of the core area is not redundant on the north or south side of the city. A common solution to this situation in highway networks is to install a network that has cables on both sides of the highway, but the density of field devices and/or redundancy requirements may not justify the cost of this approach for this specific corridor. Alternately, a leased wireless or fiber channel could be used.
- **Springfield** – Most of the network in Springfield is linear in the general vicinity of the Eugene-Springfield Highway. This section of the network is sufficiently long that a redundant route could be considered, as shown in Figure 5-16. The redundant path is shown passing through the isolated area with field devices on Main St (area S-4) in order to connect this section as well. This redundant link could be accomplished with a fiber link, or leased services.
- **Pacific Highway Corridor** –The northwest end of the Pacific Highway 99 corridor beyond Beltline Rd is a short section that does not have a natural redundant path. Short sections of this type are often treated as a spur.

5.5.2 Communications Technology

5.5.2.1 Plant Level

At the plant level, the preferred technology is fiber optic cable. The fiber may be owned by one of the agencies or leased as dark fibers from others. Leased channels on the PAN network would also fulfill the same requirement. A combination of any of these technologies could be used to support the backbone network. As each network segment goes to detailed design, both leased and new build options should be analyzed and a final decision made on a case-by-case basis.

Single Mode vs. Multimode Fiber

All of the leased fiber and fiber channels provided by the PAN will provide singlemode (SM) transmission. Although Multimode (MM) fiber transmission could be used for links with short lengths (generally the distribution from a node to the field devices) this would require the use of a hybrid SM/MM fiber cable that would be a custom order. It is recommended that the system utilize only SM fiber. This approach will standardize the transmission components and allow the procurement of the widely available SM fiber. It will also allow the PAN network to expand over the fibers provided for the backbone, and will ensure that all of the spare fibers in a cable could be used for any application. (In a hybrid cable spare MM fibers cannot be used for the longer distance links).

While fiber is the recommended technology for any new construction, some more cost effective distribution options may also be reviewed during detailed design, including using existing twisted pair plant and/or wireless links as discussed below.

Use of Existing Twisted Pair for Distribution

The existing twisted pair cable may be used for the distribution from the node to the field device. The twisted pairs allocated to each field device would be re-routed to a field node and terminated there. The multidrop modems currently used to connect up to seven traffic signal controllers over a twisted pair could be used to connect these same controllers to a node location. Other devices could also use low speed modems or Ethernet Transceivers (likely using VDSL technology) to provide communication between the node and the field device.

Wireless Distribution

Wireless communication is also a viable option for distribution services between the node and the field device. Since high capacity wireless systems (SONET OC-3 at 155 Mbps) can typically cost over \$60,000 per link, and they are not available at higher speeds, it is not anticipated that they would be a viable selection for backbone transmission. Wireless systems could be considered to provide redundancy for sections that are spurs, or to link sections through environmentally sensitive areas or those with particularly difficult obstacles. As discussed earlier in this chapter, there are some regional efforts underway to consider developing a multi-agency, high bandwidth wireless network throughout the region. If this network moves forward, this may be an opportunity for both distribution and possibly even some backbone, communications segments to utilize wireless communications.

The choice of wireless or twisted pair transmission would be determined during detailed design, and is specific to the local site conditions and facility availability.

5.5.2.2 Video Transmission

It is recommended that the video signals on the network be transported as IP video. In order to support implementation of the virtual control center concept video must be converted to IP data at some point in the network.⁵ By using IP video transmission throughout the network the video is converted to IP traffic at the camera location and can be easily routed to users at any point on the network.

The use of IP Video also supports a single backbone transmission system, instead of two (analog video and data transmission). This minimizes the number of fibers that are required, and would introduce cost savings in cases where fiber channels are leased on the PAN or dark fibers are utilized.

With multiple agencies covering the region, it is expected that several video images will be of interest to more than one agency. This will occur where ODOT corridors intersect with city corridors, as well as along routes that are shared between agencies, such as the Eugene-Springfield highway where one agency is responsible for signal control while a separate agency is responsible for incident Response. In these circumstances one video image is commonly required at more than one control center. With IP video this is

⁵ Analog transmission cannot be used since it requires a separate network and video receivers at the users location. Since these receivers cannot be moved easily to accommodate the “virtual control center”, the video is converted to IP traffic that can easily be directed to the users IP address, no matter where they are connected in the network.

accomplished simply by multicasting⁶ the IP stream, where analog systems require distribution amplifiers and additional video channels between control centers.

IP Video transmission should adhere to a current MPEG standard. At this time, the most widely used standard is MPEG-2, which would support traditional video display devices, and also allow standard web browsers to view the video stream over an Ethernet connection to the backbone network. The most current and appropriate compression technology should be reviewed as the communication plan is updated on a regular basis.

5.5.2.3 Backbone

Gigabit Ethernet transmission is recommended for backbone transmission. The primary reasons for this recommendation are as follows:

- The opportunity to use leased services provides the greatest cost benefit when all services are carried on one backbone. This is possible with GigE and IP Video.
- The mesh network of the geographical areas served is well suited to GigE deployment.
- GigE provides flexible bandwidth allocation, supporting the virtual control centers
- GigE will support transmission of the recommended IP Video without any additional transmission equipment.
- GigE will directly support NTCIP standards for center to center communication, as well as NTCIP communication over Ethernet to field devices.
- GigE is mid-span compatible⁷ between vendors, allowing different agencies to select different hardware for their portion of the network, and allowing open procurement.
- GigE provides Quality of Service (QoS) levels that can assign a priority (or QoS) to data from different ports. This allows prioritization of the services to be provided if the network is operating in a failure mode or peak traffic period.

Reasons GigE is recommended over SONET

SONET transmission offers very fast switchover to redundant rings and dedicated channel capacity to any point in the network. It does not provide the advantages of GigE in the following areas however:

- A "pure" SONET implementation does not support TCP/IP traffic that is specified in the NTCIP standards, or the low speed data channels. In these cases, additional channel banks or multiplexing/encoding hardware would be required.
- Proprietary SONET implementations will support Video, Ethernet and low speed data directly, but once a type of equipment is selected for the ring, the same vendor must be used elsewhere. This could be a problem in multi-agency networks.
- The corridors in the region do not easily provide logical large-scale rings for SONET implementation. This would require additional hardware to interface multiple smaller

⁶ Most IP traffic uses unicasts, where traffic is sent from one IP address to another. With Video, the traffic can be multicast, from one address (the camera) to a number of receivers in one transmission. This reduces network traffic by sending the data only once to two or more receiving locations. A third transmission mode, broadcast, sends from one address to all other addresses. Broadcast transmission is typically only used for short messages to all devices, and must be used with caution if the receiving devices must respond to the broadcast command, as they can easily overload the communication network.

⁷ When equipment is mid span compatible, products from different vendors with function fully when inter-connected.

rings, and may require additional fiber between nodes were more than one ring must be installed in parallel.

- SONET networks set up channels and reserve bandwidth between points on the network. Where the data requirements change, particularly as routing for video is changed, the channels would have to be re-routed through the nodes. Standard SONET implementations do not do this automatically, or in a user-friendly manner; it must be completed through changes at the network management system.
- Generally, SONET has a higher cost per node, particularly when the equipment required to convert the low speed RS232 signals for transport on the SONET network are included.
- Overall cost and complexity of SONET network (due to the points discussed above) is not justified by regional redundancy requirements.

ATM

ATM is not recommended as it has generally been superseded by Gigabit Ethernet in new installations.

5.5.2.4 Distribution

At this time, the recommended protocol for distribution to most devices is RS-232 communication, but all detailed design should support a migration to 10/100Mbps Ethernet. This recommendation is based on the large installed base of RS232 controllers, and the fact that Ethernet based controllers using NTCIP protocols are not yet widely available for ITS devices. As new versions of controllers are made available in the market, Ethernet communication should be considered, as it will likely become the standard in the future.

A specific implication of this recommendation is that the current maximum of seven controllers per channel would be reduced to allow for the use of NTCIP protocols in the future. It is recommended that detailed design accommodate a future maximum of five controllers plus one spare per RS-232 channel. Detailed design should not make rearrangements to existing multidropped channels with seven controllers unless it is cost effective to do so at the time. Provisions should be made however to provide spare cable pairs or fibers and transmission equipment to allow these rearrangements to be made in the future.

To provide RS-232 distribution to field devices over the GigE network, small terminal servers or serial hubs should be used. These devices are up linked to the Ethernet network on the backbone, and provide a number of RS-232/485/422 ports, each addressable with a unique IP address. The central computer would communicate over the Ethernet network to the serial hub, where the data would be converted. From the hub to the end device, fiber optic links, wireless links or twisted pairs could be used as determined in detailed design.

Distribution facilities should multidrop the connected RS-232 devices as described in Section 5.4.4.1. The distribution links can be fiber, twisted pair or wireless links as shown in Figure 5-17. Where Ethernet communication is required, fiber optic transceivers can be used to connect in a series of roadside cabinets.

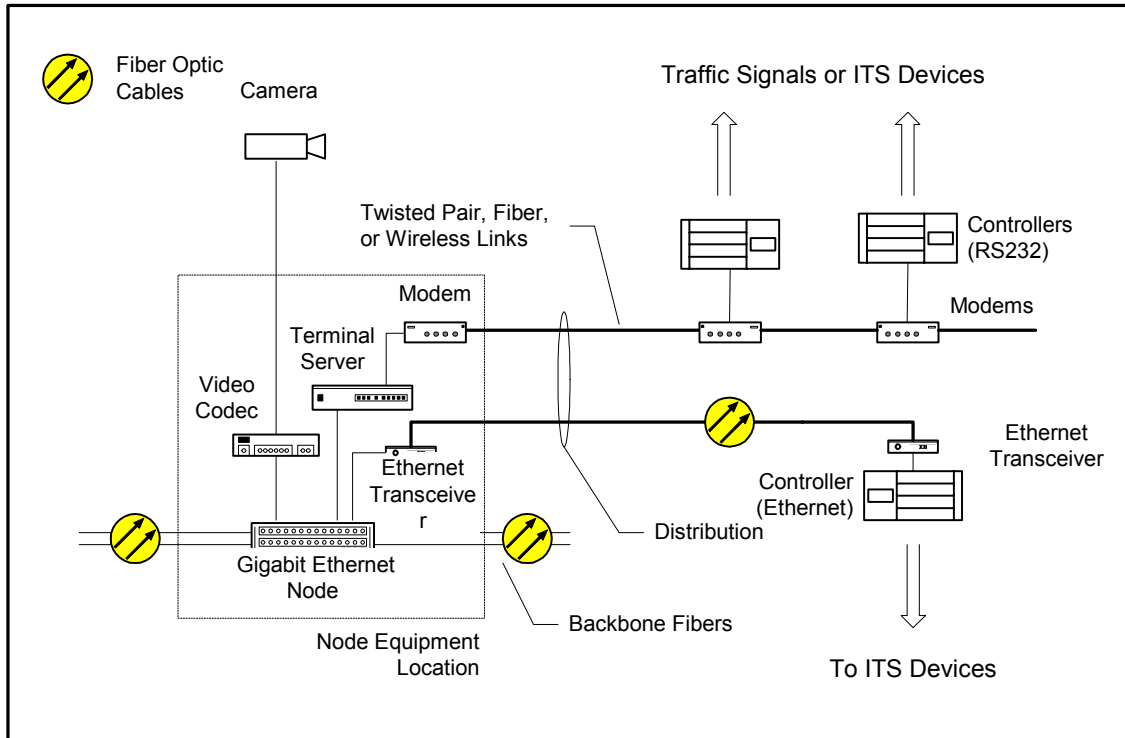


Figure 5-17. Distribution Links

Where possible, field nodes would be co-located at video camera locations, allowing video to be encoded and directly inserted on the backbone. When this is not possible, the video signal must be carried on the distribution network. It is recommended that the video image could be converted to IP video at the base of the pole, and transported using video transceivers to the node. This approach eases a later migration to Ethernet.

Alternatively, hubs may be located on or near intersection points with the PAN, primarily to support use of the PAN or member agency fiber, either during phased construction or as a redundant route.



5.5.3 Map of Proposed Communications System

5.5.3.1 Backbone Routes

The backbone routes should be ultimately planned to cover all of the communications corridors illustrated in Figure 5-16, however, it is anticipated that the networks will be constructed in phases, either as funding becomes available or in coordination with roadway improvement projects. One way to cost effectively support this phased construction process may be to build new fiber within the boundaries of the specific project and utilize leased services (either PAN or dark fiber) for hub to hub and/or hub to center connectivity.

When fiber cable is installed on any of these routes, sufficient fibers to support the ultimate network should be included, even if the current build is only a section of the backbone. Isolated backbone sections could be connected by leased fiber or PAN channels as shown in Figure 5-18. When the interconnection sections of the corridor are constructed the leased service would be replaced with backbone fiber as appropriate.

LEGEND

-  - Initial Fiber Construction
-  - Lease Utility or PAN Fiber

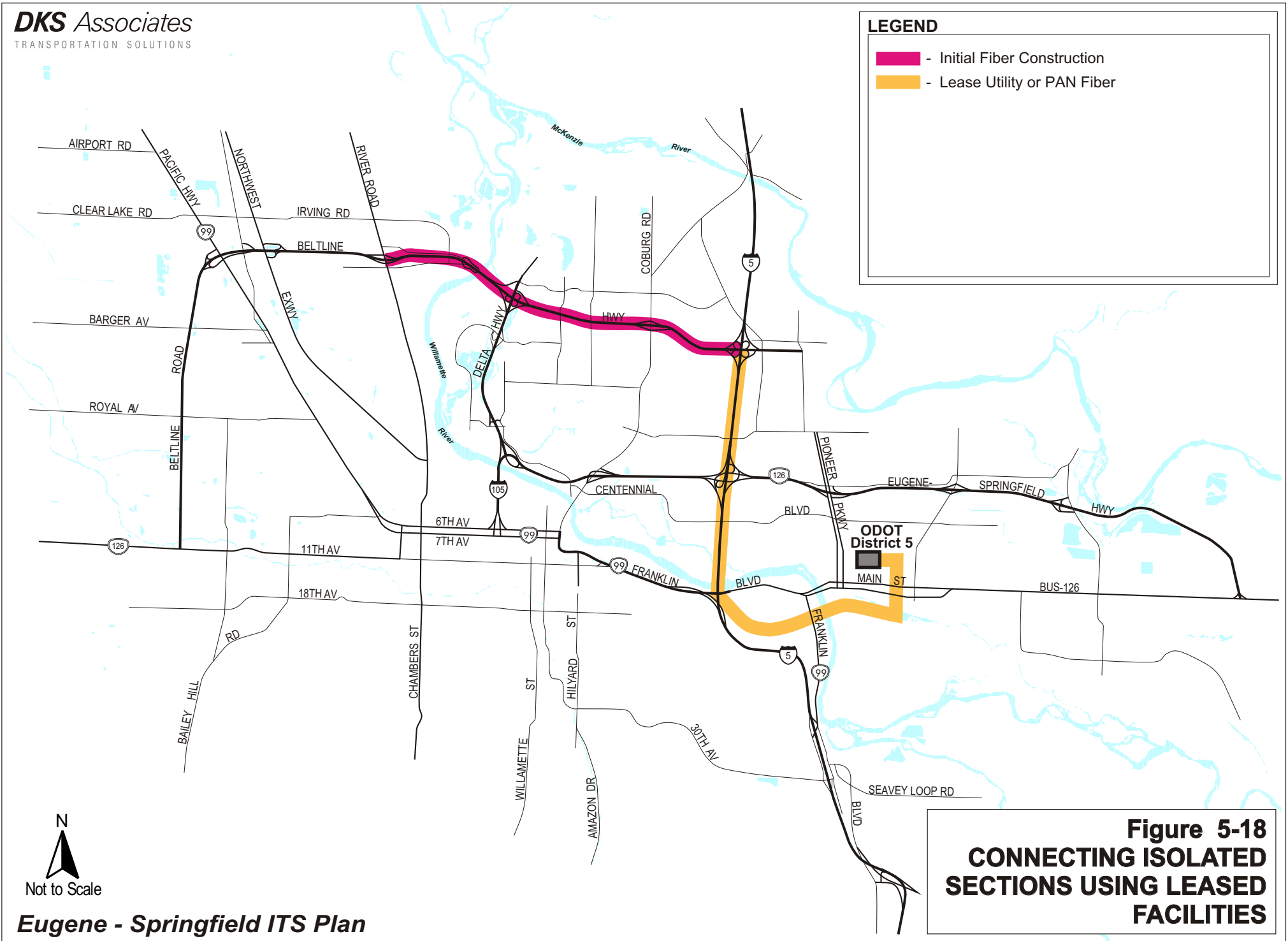


Figure 5-18
CONNECTING ISOLATED
SECTIONS USING LEASED
FACILITIES

5.5.3.2 Logical Device Groupings and Hubs

To develop the overall communication plan, all of the planned ITS devices were mapped, and the resulting clusters of equipment were then divided into logical groups as shown in the enclosed foldout map. Each of these groups is a preliminary group of equipment to be served by a backbone node. Although ITS devices are owned and operated by five agencies, the majority of the proposed roadside devices will be owned and maintained by Eugene, Springfield and ODOT. It is envisioned that these three agencies would be responsible for hubs and groups of equipment selected so that a single agency is responsible for the entire group of devices including the communication hub. This preliminary grouping results in a quantity of devices by type as shown in Table 5-3.

Table 5-3. Quantity of Devices by Logical Group

Comm Hub/ Node Group	Traffic Signals	Signal w/ Video Detection	CCTV	Ramp Meters	System Detectors	RWIS	Beacons	VMS	HAR
1	1	0	1	0	0	0	0	1	0
2	0	0	0	0	0	0	0	2	0
3	0	0	3	4	4	0	0	1	0
4	0	0	1	2	2	0	0	1	0
5	5	0	3	4	4	0	0	1	0
6	2	0	3	0	0	0	0	2	0
7	0	0	2	0	0	0	0	0	0
8	2	0	2	7	7	0	0	1	0
9	0	0	2	2	2	0	0	1	0
10	0	0	3	4	4	0	0	0	0
11	5	5	0	0	2	0	0	0	0
12	0	0	4	4	4	0	0	0	0
13	0	0	1	2	2	0	0	1	0
14	7	0	2	0	2	0	0	0	0
15	0	0	1	2	2	0	0	1	0
16	0	0	1	4	4	0	0	0	0
17	0	0	2	0	0	0	0	1	0
18	1	0	0	0	1	0	0	1	0
19	6	0	3	0	2	0	0	0	0
20	12	0	3	0	0	0	0	0	0
21	32	1	1	0	2	0	0	0	0
22	0	0	1	0	0	0	0	1	0
23	2	0	5	0	1	0	0	0	0
24	1	1	1	0	0	0	0	0	0
25	12	0	1	0	4	1	0	1	0
26	9	2	1	0	3	0	0	0	0
27	2	7	0	0	0	0	0	0	0
28	1	0	1	0	1	0	0	0	0
Stand-alone ⁸						1	2	1	
Totals	100	16	48	35	53	2	2	17	0

⁸ Isolated field equipment not appropriate to be included in a logical group served by a hub. These devices will likely be linked by a stand-alone data link.

For planning purposes the logical groups have been selected so that they are the smallest area appropriate to be served by a node. This approach maximizes the flexibility of the design and ensures that the design can serve a fully deployed ITS system. Note that this grouping is for planning purposes only, and that detailed design and project phasing could result in modifications to the grouping. Each logical group could be served by one backbone node in the future, or more than one group could be served by a node. Similarly, a string of three groups could be re-divided into two groups served by a node.

Based on the data in Table 5-4, the “standard” field node configuration would consist of the following equipment:

Table 5-4. Standard Node Requirements

Communication Channel	Type	Description	Maximum No. of Channels Required	Approximate Maximum Bandwidth
CCTV Cameras	Video	1 to 3 video cameras per group	3	30Mbps
CCTV Camera Control	RS232 or 485	One common channel for all cameras	1	9.6kbps
Traffic Signal Control	RS232 or Ethernet	Up to six intersections per channel	2	19.2kbps
System Detectors	RS232 or Ethernet	Up to six detectors per channel	1	9.6kbps
VMS or Arterial Signs	RS232 or Ethernet	Up to four signs per channel	1	9.6kbps
Ramp Meter	RS232	Up to six ramps per channel	1	9.6kbps
Other (HAR RWIS Beacons)	RS232		1	9.6kbps
Total				30.1Mbps

A test of the logical groupings that have been selected is to verify that all the backbone nodes that would serve the groups would have a bandwidth that is approximately equal. This approach often allows for a common design approach to be applied to the system, simplifying the network configuration and maintenance. Comparing the logical groups to the standard node, there are only four nodes that would not adhere to the standard configuration for data channels, and in each case the total number of data channels required is still less than the seven channels itemized in Table 5-4. Two nodes would have more than the three video channels for a standard node configuration and could be split into double nodes if required during detailed design.

5.5.4 Fiber Cable Sizing

Fiber cable sizing must support the current known requirements as well as a suitable quantity of spare fibers for future growth. As noted above, when fiber cable is installed along a particular route it should include all fibers contained in this plan, even if they are not all utilized on the initial installation. In particular, even if the existing twisted pair cables are used in the initial design, the fiber cable should be sized to allow these services to be transferred to optical transmission in the future.

5.5.4.1 Distribution Fiber Sizing

As described above, there are a number of possible future expansions to the range of subsystems that the communication network supports. The expansions that can be foreseen at this time would require a total of ten fibers, and an additional 2 spare fibers are recommended for a total of 12 spare fibers in each distribution cable:

Category	Spare Fibers
CCTV	4
DMS Signs	2
Transit Signal Priority	2
Transit Systems	2
<u>Undefined</u>	<u>2</u>
Total Spare Fibers	12

This spare fiber quantity can then be added to the number of fibers required for the standard node as described above:

Service	Fibers
CCTV Cameras	6
CCTV Camera Control	2
Traffic Signals	4
System Detectors	2
VMS or Arterial Signs	2
Ramp Meter	2
Other ITS	2
<u>Spare</u>	<u>12</u>
Total Distribution	32

5.5.4.2 Backbone Fiber Sizing

When fiber cable is installed on a backbone route, it should include the basic backbone requirements, additional center-to-center fibers, and spare fibers. Under the proposed Gigabit Ethernet backbone, only two fibers are required for each link between nodes, but it is quite common to have two links in the same cable leaving a node in a mesh network. It is recommended that two fibers be assigned for additional data links, and two reserved for network maintenance, commonly referred to as “hot backup”. As there is a great number of point-to-point services that could be required on the backbone in the future, an additional spare capacity of 8 fibers is also recommended, for a total of

Category	Spare Fibers
Primary Gig E link	2
Secondary Gig E link	2
Additional Link fibers	2
Hot Backup	2
<u>Undefined</u>	<u>8</u>
Total base	12

To this base number of fibers in a backbone run, an additional 6 fibers for center-to-center links should be allocated as described in Section 5.3.2.2 above. These fibers should be included for every route identified.

5.5.4.3 Final Fiber Cable Sizing

The backbone links will typically parallel certain distribution links, and in most cases the fibers for backbone links and distribution links can be carried in the same sheath. The final fiber optic cable size should be based on requirements for backbone, distribution and center to center as follows:

Service	Fibers
Distribution	12
Backbone	32
<u>Center to Center</u>	<u>6 per link</u>
Total Fibers	44 plus 6 per link

Fiber cable sizes are typically ordered in multiples of 12, so the total cable size determined above would be rounded up to the next multiple of 12. In most cases a 48 count fiber cable will be sufficient, but where a backbone should support one or more center to center links, an 60 count fiber cable should be provided.

5.6 MAINTENANCE & OPERATIONS

Figure 5-19 indicates the primary components of a generic regional communications network, and will be used to illustrate some of the Maintenance and Operations issues related to the communication network.

This figure assumes a network configuration in which agency specific fiber may be located in the same bundle or sheath as fiber that is utilized for the regional communications backbone. It also assumes that regional communication equipment (such as hubs, routers, multiplexers, transmitters, receivers, etc) may be located in agencies facilities as well as agency owned field devices, such as controller cabinets. Under this scenario, a number of different maintenance and operational issues need to be addressed and a series of recommendations are included below.

5.6.1 Fiber and Equipment Design

5.6.1.1 Communications Equipment Standards

It is recommended that communications equipment such as fiber optic cable, splice cabinets and enclosures, hubs, routers, multiplexers and modems, be standardized to the extent possible. It should be encouraged that agencies utilize this standard equipment for their “agency owned” portion of the communications network as well as the backbone communications network. This would support equipment bulk purchasing, stocking of spare equipment, training of operations and maintenance personnel, as well as network expansion and overall interoperability.

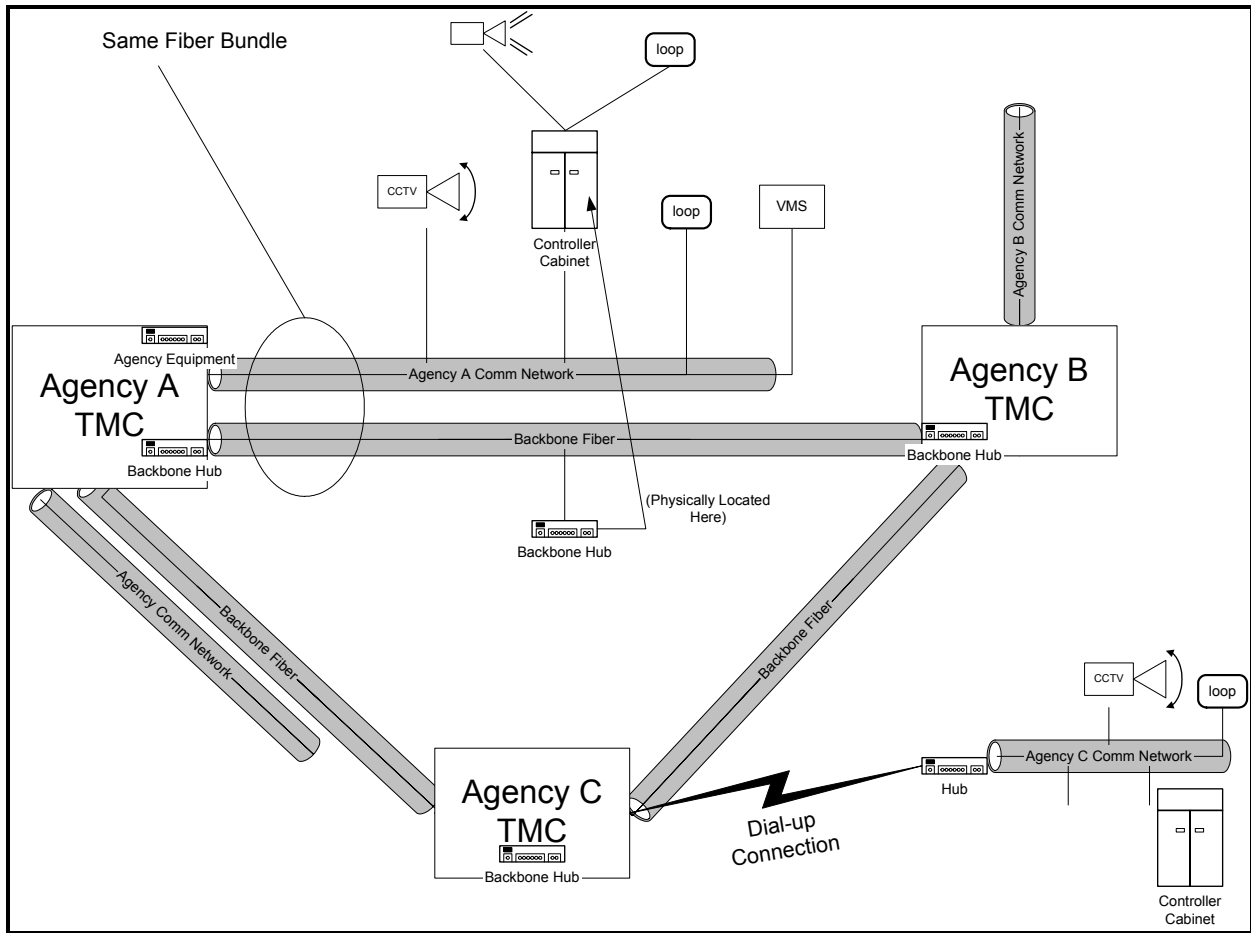


Figure 5-19. Conceptual Communications Network

5.6.2 Operations and Maintenance of Communications Equipment

Many agencies have found that the cost of maintaining their own fiber optic networks—including equipment, training, and allocated staff—can be quite prohibitive. The rate of equipment or cable failure is so low that the trained personnel often do not get the opportunity to use the training on a small system, making them ineffective when repairs are needed. Often a group of regional agencies have instead pooled their resources, developed necessary agreements, and either selected a lead agency or a preferred contractor to maintain the network.

In the case of PAN, EWEB is responsible for maintaining the backbone electronics and optronics (DWDM equipment), as part of their responsibility as the Executive Operating Authority of PAN. However, each agency that owns fiber in the PAN is responsible for maintenance of their individual fiber segments.

Any final maintenance agreements will need to address the following issues.

5.6.2.1 O&M of Agency Dedicated Fiber

This would identify each agency's responsibility for maintaining and operating fiber that connects to their own field devices.

5.6.2.2 O&M of Backbone Fiber

This would identify each agency's responsibility for maintaining and operating fiber that is used for the regional communications backbone.

5.6.2.3 O&M of Equipment Located in Agency Facilities

This would identify each agency's responsibility for operating and maintaining equipment that is located in an agency's facility (such as the TOC.) It is assumed that both agency specific communications equipment, as well as backbone communications equipment, will be included in agency facilities, and the responsibilities for operating and maintaining both sets of equipment need to be established.

5.6.2.4 O&M of Equipment Located in Agency Field Devices

This would identify each agency's responsibility for operating and maintaining equipment that is located in an agency's field device (such as a controller cabinet or splice vault.) It is assumed that both agency specific communications equipment, as well as backbone communications equipment, will occasionally be included in agency field device, and the responsibilities for operating and maintaining both sets of equipment need to be established.

5.6.3 Service Level Agreements

Once an agency (or group of agencies) has been determined as the lead agency(ies) for ongoing maintenance and operations of the network, agreement needs to be reached on level of service. Service Level Agreements (LSA's) include issues such as response time for a network outage to be repaired, prioritization of bringing equipment/fibers back on-line after an outage, availability of the network (acceptable amount of downtime per year), etc.

5.6.4 Utilization of Dial-Up and Leased Line Connections

Some agencies currently use (or may plan to use) leased line connections to field devices. Opportunities to replace these connections with agency owned infrastructure and/or purchase bulk telecommunications services from service providers should be examined, and regional rules-of-thumb developed.