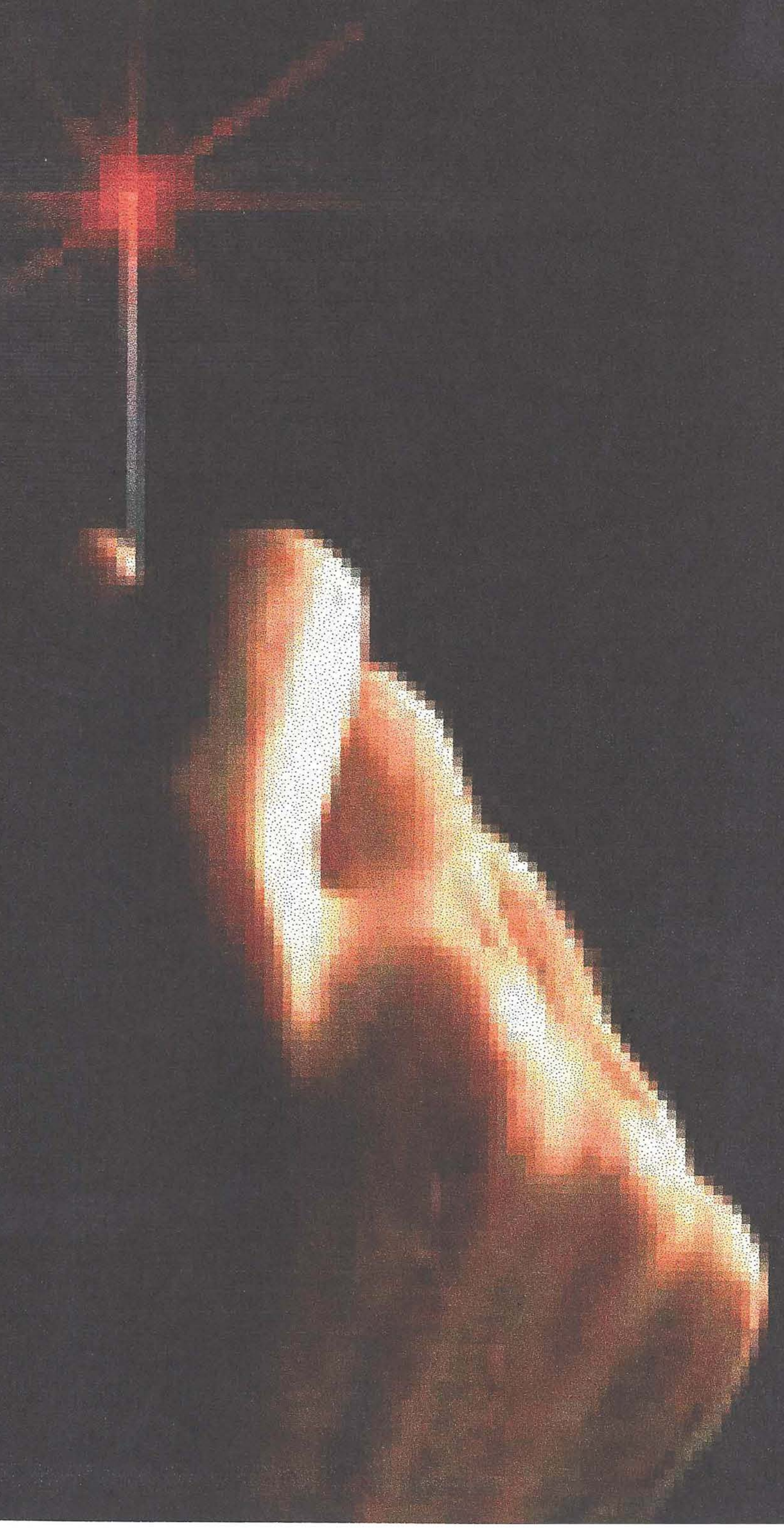
Fiber-Optic Communications Concept Plan for Miami-Dade County's Intelligent Transportation Infrastructure



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Prepared by:

CUTR

Center for Urban Transportation Research

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Prepared by the
Center for Urban Transportation Research
University of South Florida

For the
Miami-Dade Metropolitan Planning Organization

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EXECUTIVE SUMMARY

This report is intended to define a concept plan for a fiber-optic communications network that will support Miami-Dade County's intelligent transportation system infrastructure. At this time, this is a difficult task since all the components for the ITS infrastructure have not been defined and the fiber-optic network that currently exists does not have connections to all areas as it relates to transportation facilities. Consequently, the value of this report is in providing an introductory discussion on fiber-optic technology, a description of existing and planned fiber-optic networks within Miami-Dade County, case study examples of public-private partnerships and cost-sharing opportunities in fiber network development, and recommendations on how to move forward.

Since it first came into prominence in the early 1970s, optical fiber technology has allowed more information (voice, data, and video) to be transmitted faster, more reliably, and more economically than ever before. It is the medium of choice for the advanced telecommunication systems that exist today and are foreseen for tomorrow. However, there are many options to consider and evaluate when planning and designing such a system. Similar to the foresight and creativity required to properly plan and design a transportation system to move people and goods, a seamless communication system must receive the same level of attention to efficiently move information.

One existing and three planned fiber-optic networks can be identified within Miami-Dade County. Each address as specific concerns and needs, but an common objective is missing. Obstacles and tradeoffs exist, both legal and economic, that must be integrated into the network planning and design process. The findings in this report suggests a "countywide" shared resources agreement (the telecommunications version of a public-private partnership) must be developed quickly in lieu of the emerging fiber-networks. Perhaps the communications network currently envisioned (but stalled in implementation) for the county's advanced transportation management system (ATMS) can be the foundation for a comprehensive "countywide" communications network. However, greatest benefits for Miami-Dade County can not be realized without more coordination. <u>All</u> future communication needs must first be defined, then designed into a single communication network in order to maximize benefit to the county and potential private sector partners. It is anticipated that the general information contained in this report will stimulate discussion, focus, and decision toward the telecommunication solution for Miami-Dade County.

PURPOSE

The purpose of this report is to define a concept plan for a fiber-optic communications network that will support Miami-Dade County's intelligent transportation system (ITS) infrastructure. ITS infrastructure consists of components that send and/or receive information. If these individual components (and subsystems) operate only in isolation, the full benefit and effectiveness of ITS investment cannot be realized. These components must be linked and integrated to allow for real-time information (e.g., voice, video, and data) exchange between agencies responsible for providing mobility and safety, and transportation system users. Optical fiber (or lightwave transmission) is one medium used to facilitate real-time information exchange, and definition of the county's fiber-optic network will serve as the key enabler for the planned ITS program in Miami-Dade County. Moreover, definition of this concept plan will lead to a better understanding and appreciation of ITS functionality and compatibility.

The approach taken for concept plan development begins with a general discussion of fiber and fiber-optic systems, and fiber network evolvement within Miami-Dade County. A summary of communication needs assessment is presented for both FDOT District 6 (previously compiled by the FDOT Fiber-Optics Team), and a sampling of Miami-Dade County transportation-related agencies (compiled as part of this research effort). Wireless options for ITS infrastructure communication applications are briefly outlined and compared. Barriers to fiber-optic network deployment are identified. A major portion of this report summarizes case studies of several government-based partnerships that have resulted in the development of fiber systems. Cost-sharing opportunities for fiber system expansion also are presented. Finally, in consideration of the aforementioned information contained in the report, major steps toward development of a concept plan for fiber-optic communication serving ITS infrastructure are recommended.

BACKGROUND

Prior to beginning a general discussion of fiber and fiber-optic systems, one should first gain an appreciation of the importance associated with the communication medium for ITS infrastructure. Just as a physical travelway (or roadway/transit network) is intended to efficiently move people and goods, the communication medium (or fiber-optic network) is intended to efficiently move information. Likewise, maximum efficiency for both is obtained by determining what needs to be "connected," and then engineering the proper configuration, alignment, and extent of access along each link. Hubs, or nodes, are where major connections to the network are located. In the hierarchy of an efficient roadway/transit network, certain links are designed for high-capacity, limited access, through traffic, whereas other links are intended to serve simply as "local" collectors/distributors. This hierarchy is somewhat analogous to an efficient fiber-optic network. This is why, as will be illustrated later in this report, the existing fiber-optic network closely follows the attributes of the transportation system, both figuratively and literally. With the advent of optical fiber as a transmission medium, information can now be moved faster and more reliably than ever before. Consequently, coordinated planning for an information transmission system now becomes just as critical as transportation system planning. Once again, this report is intended to launch this coordinated planning effort.

Since 1956, Miami-Dade County has had in-house staff (five employees in 1956) responsible for improving data processing operations. Over the years, the growing demand for improved operations and advancements in communication technology necessitated periodic expansion of this in-house group. In October 1992, the Board of County Commissioners renamed this internal department to the Information Technology Department (ITD) to reflect the scope and diversity of the technologies which provide information services to the county and local community. ITD, with about 550 employees, is now one of 39 departments reporting to the County Manager. ITD's self-proclaimed mission is to integrate all the county's communication tools into an "enterprise information system", making government services more accessible and convenient.

ITD currently manages a fiber-optic network that provides telecommunications services to three major county facilities (Civic Center, Stephen P. Clark Building, and the ITD Communications Center.) The existing network is configured with approximately 12 miles of single-mode fiber cable in the center of the county, (See Network Map following page 15) and it is used to network mainframe and local network data. The County owns most of the telephone switches, which dramatically reduces the cost of its long distance voice communications and allows the county to control their own connections, rather than going through BellSouth.

The County's partner, Intermedia Corporation of Florida, Inc. (ICI), has installed approximately 60 miles of fiber cable, from which the county received 12 fiber strands in exchange for the use of right-of-way. (The contractual relationship with ICI entitles the County to receive 12 fiber-optic strands wherever ICI installs new fiber-optic cable). The existing 12 fiber strands are reserved and currently dark (or unused) awaiting the installation of a new, industry proven, Synchronous Optical Network (SONET) for data, voice, and video communications. The SONET fiber-optic network is being developed as a bi-directional telecommunications transmission ring by ITD, and it will connect eight major County facilities (TGK Correctional Center, Traffic Signals & Signs Center, Palmetto Rail Yard Center, Miami International Airport, MDTA Central Bus Station, Civic Center, Stephen P. Clark Building, and the ITD Communications Center.) The network protocol and access methodologies to the fiber network will be through standard telecommunication interfaces.

This new system will provide a transmission capacity rate of 2.48 billion bits per second (Gbps). The new fiber network is expected to be completed by the end of September 1998, and when funding is available, the Miami-Dade Seaport may become a fiber network node in the new SONET.

According to ITD, they continuously look for opportunities to share fibers and trenches with private entities for the County's fiber network, and very little budget exists to permit expansion without partnership with the private sector. It is their intention to transfer as much of the existing and new communication requirements of the County for voice, data, and video to the County's SONET fiber-optic network.

Two other fiber networks currently being planned will impact Miami-Dade County. The County's Public Works Department is currently designing the upgrade for the traffic control system, a system that will ultimately have the capacity to simultaneously manage 4,000 intersections throughout the entire county. The consultant for the Public Works Department (F.R. Aleman & Associates, Inc.) has presented their preliminary needs assessment to ITD. In addition, the Public Works Department has had "exploratory" meetings with Florida Power & Light and several local cable television operators to discuss partnerships for fiber networks. A discussion of the partnership activities of this project is contained in the case studies portion of this report. Additionally, the Florida Department of Transportation (FDOT) has examined the possibility of having a private company install fiber-optic cable along the interstate and turnpike system's right-of-way. The FDOT has decided that bartering an asset such as right-of-way with private industry telecommunication providers is a feasible way to achieve a high-capacity, low-cost communications system for the future. The future general consultant for FDOT communications will evaluate access to the non-FDOT fibers. A more detailed discussion of this project is also contained in the case studies portion of this report.

INTRODUCTION TO FIBER-OPTIC SYSTEMS

History of Fiber-Optics

Use of light as a means of communication dates back to several centuries. Ancient Egyptians used flares as a means of communication. Romans built flaring towers, changed the color of the flaring smoke, and sent information with smoking and smokeless flares. In the 17th century, the distance of effective communication covered by flare signaling even reached several miles.

James Tyndal, a British physicist in 1854, first demonstrated the basic principle of optical communications. He used a stream of water flowing from a tank and a bright light in his experiment. As water was allowed to flow, an arc of light followed the water stream. In 1966, Dr. Charles Kao of Standard Telecommunications Laboratories was the first to use a pure glass medium to transmit light. However, the pure glass could not retain the strength of transmitted light from one end to the other effectively because much of the light was lost in the glass medium itself. In 1970, Dr. Robert Maurer of Corning Inc. introduced the first low-loss optical glass fiber that is being used today.

Since its invention in the early 1970s, the use and demand of optical fiber has grown tremendously. The uses of optical fiber today are quite varied including telecommunications, medicine, transportation, military, automotive, and industrial. Currently, intelligent transportation systems (ITS) with advanced traffic control devices, roadside message signs, traveler information web sites and kiosks, automated tollbooths, and sophisticated traffic monitoring systems is the fastest growing market for fiber optics. (Source: An Introduction to Fiber Optics, Siecor Corporation, August 1977.)

Definition

Fiber optics is the technology of using electrical signals to transport information from one point to another as light. Unlike the copper form of transmission, fiber optics is not electrical in nature. Basic fiber optic system consists of a transmitting device, which generates the light signal; and optical fiber cable, which carries the light; and a receiver, which accepts the light signal transmitted. The fiber, made of ultra pure silica glass (200,000 times more pure than window glass), itself is passive and does not contain any active, generative properties. The typical cross-section of fiber, including the glass core and protective coverings, can range from about 250-900 micrometers. Comparatively speaking, the thickness of the human hair is approximately 70 micrometers, or 0.003 inches. The information transmission sequence for light wave transmission is illustrated in Figure 1.

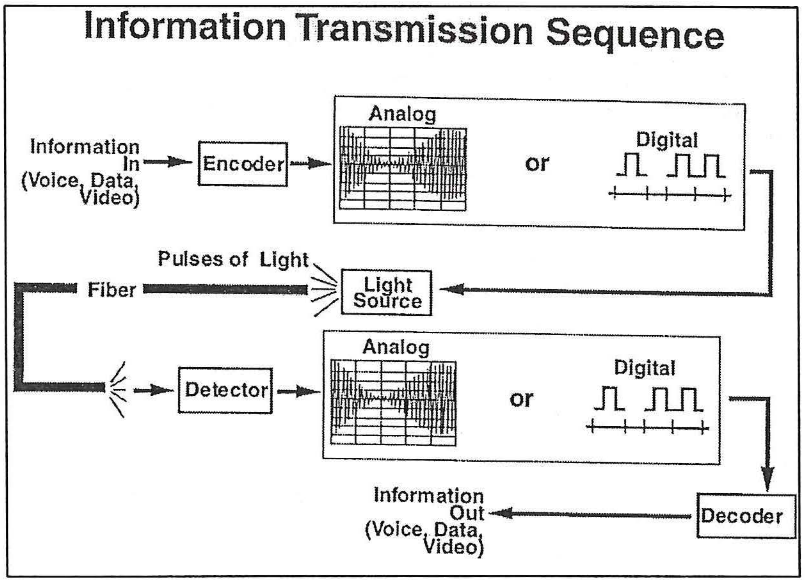


Figure 1- Basic Principle of Operation
Source: Siecor's Introduction to Fiber-Optics

Fiber is manufactured either as single-mode or multi-mode fiber cables. The multi-mode fiber was the first type of fiber to be commercially available and has a core (center) that is much larger than the single-mode counterpart. As its name suggests, multi-mode fiber can transmit multiple rays of light (or modes) simultaneously. On the other hand, single-mode fiber with a much smaller core can transmit only one mode of light at a time. While it may appear that multi-mode fiber has higher information-carrying capacity, in fact the opposite is true. Single-mode fiber retains the shape and definition of each pulse of light better, allowing more information to be transmitted over longer distances. The increased bandwidth capacity of single-mode fiber makes it a suitable transmission medium for advanced communications networks that require high data rates and future bandwidth upgradeability. (See Table 1) Well over 90 percent of fiber sold today for ITS communication system uses single-mode fiber.

Optical fiber, long the transmission medium of choice for Local Area Network (LAN) backbones, is gaining market share for communication cabling applications. While copper is still the most popular communication cable medium, an increasing number of Management Information System (MIS) managers are choosing fiber for their desktop cable, and an even larger number plan to use fiber in the next three to five years. Driving the decision to install fiber is the nation's growing commitment and dependence on high-speed LANs to support business requirements. In less than a decade, data rates have nearly doubled every year (according to Figure 2) as companies add more users to their networks and take advantage of more bandwidth intensive applications.

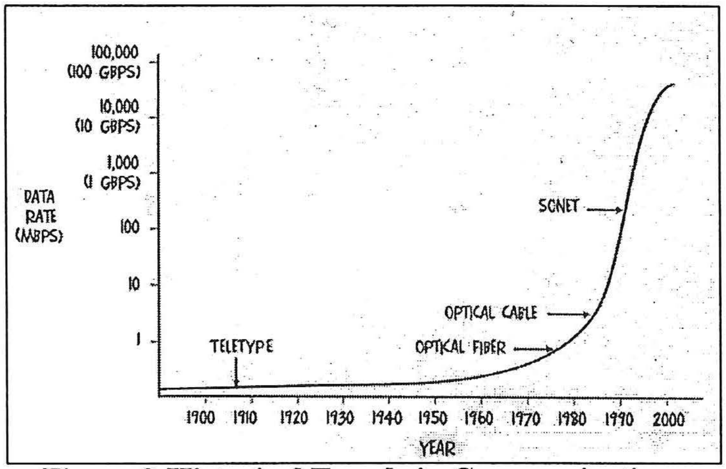


Figure 2-Historical Trends in Communications
Source: Traffic Technology Review '98

According to industry experts, an increasing number of communication network planners specify optical fiber cable for number of reasons. The most common reasons are:

1. ***Error-free transmission over longer distances.*** This results in fewer outages, less downtime and greater reliability. With longer link distances, network designers also have more flexibility in planning their networks, and are able to take advantage of new architectures.

2. ***Ability to support higher data rates.*** Fiber's high bandwidth gives flexibility to network designers to take advantage of existing and emerging high-speed network interfaces and protocols.

3. ***Ease of handling, installing, and testing.*** Fiber is now a proven and established medium that can be easily tested for performance at all data rates. Typically fiber requires only attenuation tests, since the bandwidth is unaffected by installation practices.

4. ***Long-term economic benefits.*** Over the lifetime of the network, optical fiber is typically a more economically viable choice than copper. For example, fiber's superior reliability reduces operating costs by minimizing network outages. Similarly, fiber's higher bandwidth can produce considerable savings by eliminating the need to pull new cable when the network is upgraded to support higher bandwidth applications. Also, fiber's high bandwidth and long distance capability allow all hub electronics to be centrally located, rather than distributed in closets throughout a building. Centralization reduces the cost of cabling and electronics, and reduces administration and maintenance efforts by making changes easier.

System Components

A typical fiber-optic network consists of transmitters, receivers, connectors, splices, and repeaters. Depending on the system specifications, auxiliary components such as wall mount cabinets, jumpers (termination panels to network equipment), protective fiber ducting (equipment to fiber terminal panels), manholes, cable assemblies, patch cords, closures, distribution panels, rectifiers (AC power raceways, outlets, etc.), terminal servers, battery plant (sufficient for a couple of hours backup), etc. exist as integral parts of the fiber-optic backbone.

As stated previously, the data, in the form of an electrical signal, are converted into near infrared light signals at the transmission end and launched into a fiber. An electronic device known as a transmitter does this conversion. The transmitter is usually a LED (Light Emitting Diode) or LD (Laser Diode, or Laser) source, as depicted in Figure 3. This light signal is decoded into the original electrical input at the receiver end. The support electronics processes that signal to perform its intended communications function. Every receiver incorporates a photodetector such as a photodiode to convert the incoming optical signal back to an electrical signal.

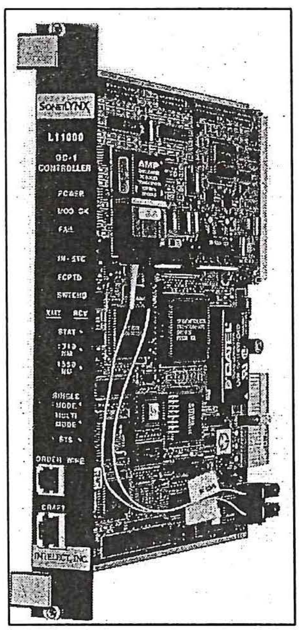


Figure 3-Data Transmission Module
Source: SonetLynx Information Pamphlet

Fiber and cables are not endless and therefore must eventually be joined. Fiber must be joined at both transmit and receive termination equipment, and may also be joined to distribution cables and splitters. Connectors are used as terminating fixtures for temporary non-fixed fiber joints. The function of a connector is to permit two fibers to be connected and disconnected easily, minimizing loss at the fiber ends. Similar to regular household electric plugs, the connectors are made to be plugged in and disconnected hundreds and possibly thousands of times. Since no one connector is ideal for every possible situation, a wide variety of connector styles and types (see Figure 4) have been developed over the short life of fiber communications.

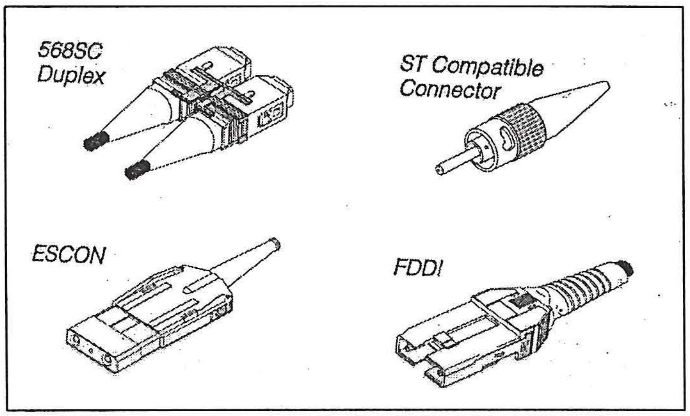


Figure 4-Commonly Used Connectors
Source: Siecor Design Guide

Splices are normally a permanent joint between two fibers. The fiber can be spliced either by fusion or mechanical techniques. Generally speaking, splices offer a lower return loss, lower attenuation, and greater strength than connectors do. Also, splices are usually less expensive per splice (or per joint) than connectors, require less labor, form a smaller joint for inclusion into splice closures, offer a better hermetic seal, and allow either individual or mass splicing.

Depending on the distance between the transmitter and the receiver, fiber optic system may require repeaters to generate optical signals to allow an increase in the signal strength. It is typical for optical systems to go over 100 kilometers (or about 62 miles) without repeaters.

Comparison to Other Transmission Mediums

Optical fiber is lightweight, offers extremely high data-carrying capacity, and easily upgradeable. These features have made it the most popular transmission medium. One mile of optical fiber core weighs under 2.5oz (71gm). A copper cable with the same information-carrying capacity (see Figure 5) would weigh 33 tons. According to Corning, Inc., over 120 million miles of fiber have been installed throughout the world since early 1980s, enough fiber to circle the earth more than 4,000 times.

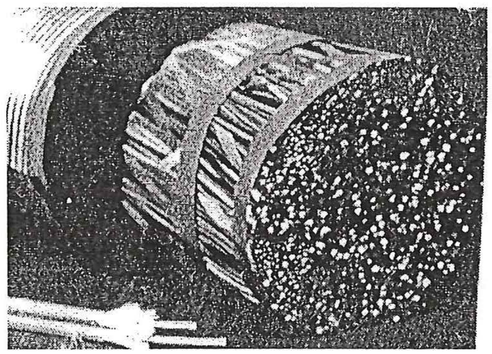


Figure 5-Fiber versus Copper Cables
(with similar data carrying capacity)

Low attenuation and superior signal integrity associated with fiber-optic systems allow much longer intervals of signal transmission than metallic-based systems. Since optical fiber does not contain any metallic components, it can be installed in areas with electromagnetic interference (EMI), including radio frequency interference. Areas with high EMI include utility lines and railroad tracks. Fiber-optic cables are also ideal for areas of high lightning-strike incidences. Unlike metallic-based systems, the dielectric nature of optical fiber makes it impossible to remotely detect the signal being transmitted within the cables. The only way to do so is by actually accessing the optical fiber itself. Accessing the fiber requires intervention that is easily detectable by security surveillance. This security feature has made fiber extremely attractive to government bodies, banks, and others with major security concerns. Moreover, at high-speed data transmission rates, a fiber network typically is 1,000 times more reliable compared with copper twisted pair.

Comparison of different wireless and wireline transmission mediums is listed in Table 1. The comparison is made with respect to the bandwidth, ability to transmit video, cost, and reliability. With a high bandwidth, compatible to transmit full-motion video, low cost (as measured in $ per bps), and high reliability, the single-mode fiber is the best transmission media.

Table 1-Comparison of Communication Media

	Medium range data speed (5+ miles)	Long range data speed (15+ miles)	Full-motion video compatible	Relative cost ($ per bps)	Reliability
Wireline					
Cooper twisted-pair	1.5 Mbps	1.5 Mbps	No	Low	High
Coaxial cable	100 Mbps	100 Mbps	Yes	Medium	Medium
Multi-mode fiber	500 Mbps	N/A	Yes	Low	Very High
Single-mode fiber	40 Gbps	40 Gbps	Yes	Very Low	Very High
Wireless					
Digital microwave	155 Mbps	155 Mbps	Yes	Medium	Medium
Digital Packet radio	250 Kbps	N/A	No	Medium	Medium
Cellular	19.2 Kbps	19.2 Kbps	No	High	Medium
Micro-cellular	N/A	N/A	Yes	Low	Medium-High

Source: "Benefits of Optical Fiber vs. Copper or Coaxial Transmission Media", ITS America Annual Meetings-Compendium of Papers, 1995.
Kbps=thousand bits per second, Mbps=million bits per second, Gbps=billion bits per second

Table 2 lists the standard SONET line capacity rates. The line capacity is a linear multiplier of the OC-1 format. Upgrading the end equipment (transmitter and receiver) to the required OC-format can increase the capacity of a fiber network. As mentioned previously, the County's existing fiber system is being upgraded to double current capacity from OC-24 to OC-48.

Table 2-SONET Digital Signal Hierarchy Standards

OC (Optical Carrier) Format	Line Rates
OC-1	51.84 Mbps
OC-3	155.52 Mbps
OC-12	622.08 Mbps
OC-24	1.244 Gbps
OC-48	2.488 Gbps
OC-192	9.953 Gbps

Perhaps the most compelling feature of fiber-optic systems can be seen in lightwave transmission cost trends since the early 1970s. Excerpted from a recent article in Traffic Technology International-Annual Review 1998, Figure 6 indicates over the last two decades transmission cost for lightwave transmission has decreased by a factor of 100 yet transmission rate capability over the same time period has become 55 times faster.

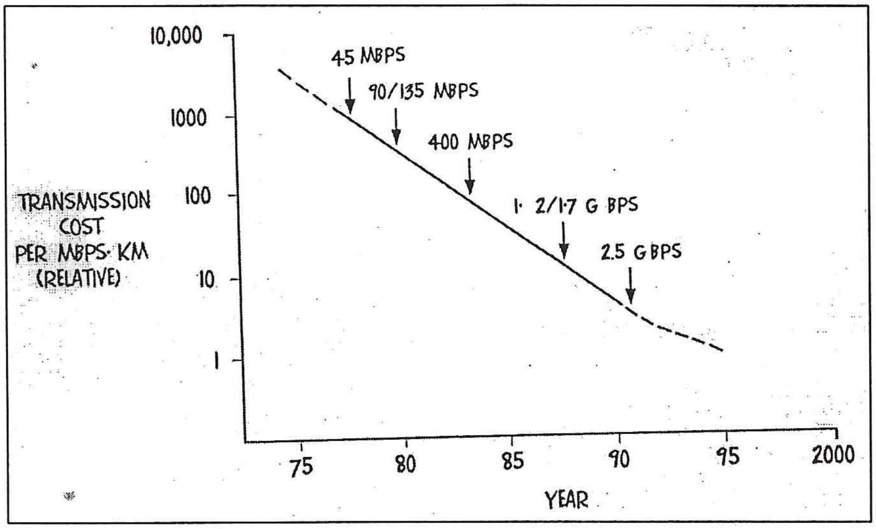


Figure 6-Cost Trends in Lightwave Transmission
Source: Traffic Technology International 98, Annual Review

MIAMI-DADE COUNTY'S FIBER-OPTIC NETWORK

Existing Network

Miami-Dade County's first fiber optic network was completed in December 1987 with two single-mode fiber optic cables (8 optical strands in each cable). Time Division Multiplexing (TDM) network architecture was implemented for high-speed telecommunication services. TDM is a communications technology that allows multiple messages to be integrated into a single lightwave form or light impulse. Running along the MetroRail, this network connects the ITD, MDC, and Justice Buildings. Four of the sixteen strands are used to connect the TDM point-to-point network equipment to support the ITD, MDC, and Justice Buildings. Savings from this network implementation amounts to about $200,000 per year in recurrent charges to the local telecommunication provider, BellSouth.

In 1989 headed by ITD, the County entered into an agreement with Intermedia Communications of Florida, Inc. (ICI) to utilize existing County street conduits identified by the Public Works Department and the Metro-Dade Transit Department MetroRail and MetroMover guideways to deploy a metropolitan fiber-optics ring. With this public-private partnership agreement, the County received 12-fiber strands. This new network interconnects eight county government buildings. The 12 fiber stands are reserved for a new SONET-based network. The TDM technology currently supports communications for remote host terminal access, voice response unit (VRU) interfaces, private branch exchange (PBX) switch tie-line interconnection, electronic mail, office automation services, mainframe channel extensions, Geographical Information System (GIS) applications, LAN to LAN bridging, and the 800Mhz radio system.

Planned Network

ITD Upgrade
With the changes introduced in the federal Telecommunications Act of 1996, ICI has entered in to the local telephone business and is planning to expand their fiber optic network services for subscribers. According to the agreement with ICI, the County receives 12 fiber strands in this new network. The latest plan of the ITD is to use all the dark fiber in the current fiber route to create a high-speed multi-fiber redundant transmission system with SONET OC-48 architecture. This new network is expected to save the County an additional $2.5 million in annual charges for leased circuits from BellSouth.

ATMS
In May 1997, the Traffic Signals & Signs Division of the Miami-Dade Public Works Department received the communications network analysis report for a proposed Advanced Traffic Management System (ATMS) from their consultant F.R. Aleman & Associates. No suitable countywide communications infrastructure presently exists to serve their needs for the entire county. The ATMS will be replacing the existing 22-year old traffic control system that currently manages 2,048 traffic controllers (with 450 signals running off-line). The proposed communications network for the ATMS requires high-speed data, video, and voice transmission for up to 4,000 traffic signals across Miami-Dade County. This design calls for all traffic controllers to be connected via fiber-optic to eight strategically placed hubs, each capable of transmitting back to the traffic control center on N.W. 58th Street at a speed of 155 million bits per second. In October 1997, ITD reviewed the ATMS analysis report and recommended that the Public Works Department utilize the SONET network and locate their hubs at the eight major County buildings that will house the OC-48 SONET equipment. In addition, ITD (per Public Work's request) identified a preliminary fiber network grid for only the first 500 intersections (indicated on the network map as "proposed county ATMS" and also locally known as ATMS-Phase 2). Even though transmission costs under this option would be reduced (from the present $1.2 million annual BellSouth fee) according to F.R. Aleman, Public Works would still have to pay $500,000/year to ITD, and they would have to assume all the cost of direct connections to the SONET hubs. However, according to ITD, the County's annual recurring

charges ($500,000/year) will be greatly reduced if ITD is involved in the design and implementation stages of the ATMS project.

Given the current shortfall of ATMS funding from FDOT, and the growing attractiveness of partnering with other telecommunication providers at this time, it appears the ATMS project should proceed with or without ITD in order to maximize cost reductions. This network decision is particularly critical because of the enormous areawide coverage the ATMS fiber network creates within the County that many others could benefit from.

Other (Non-County) Networks

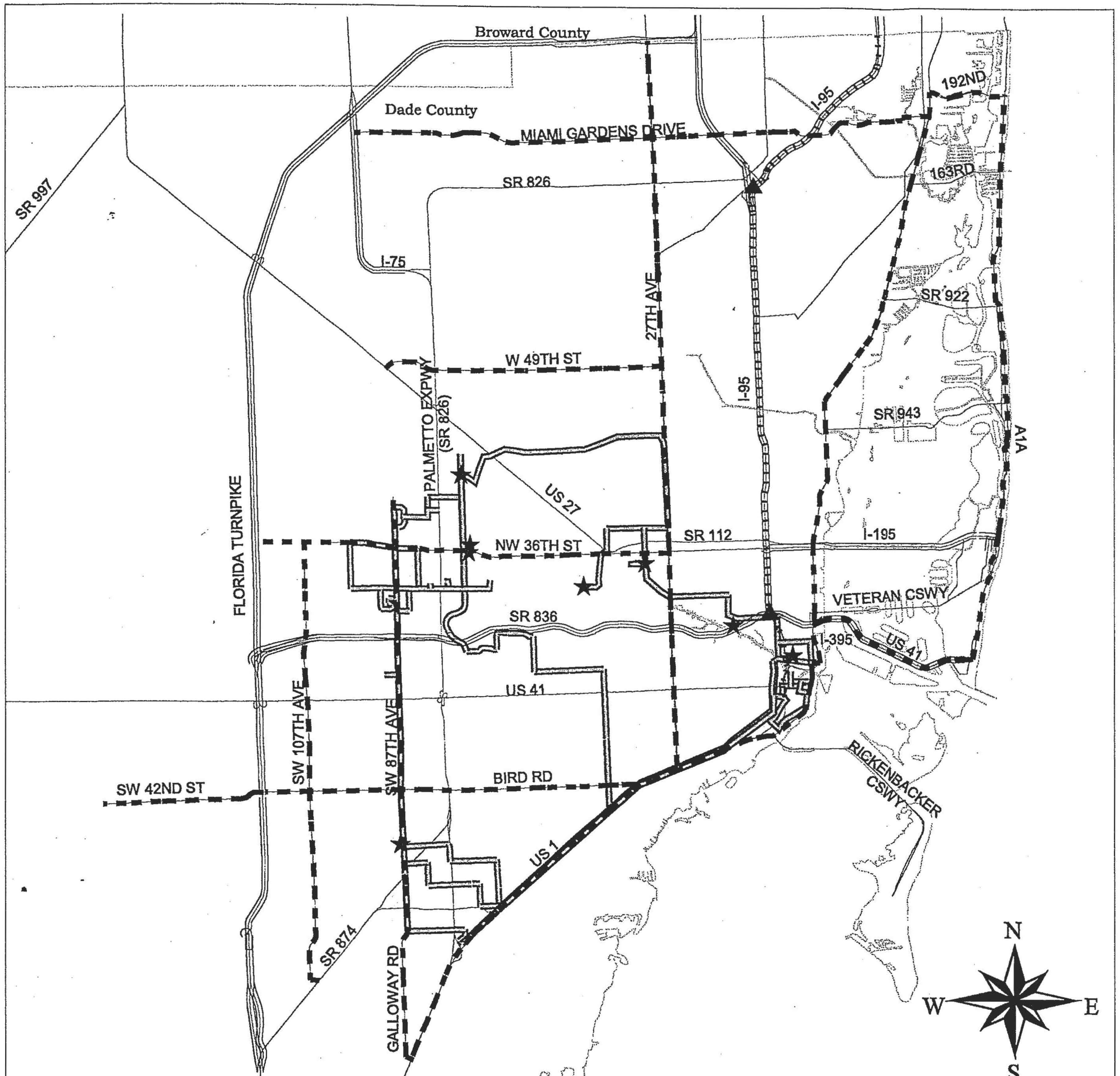
About seven major cable TV service providers exist in Miami-Dade County. It appears that only three (TCI of South Dade (south of US 41), TCI of South Florida in north Miami-Dade County, and Strategic Technologies in west-central Miami-Dade County) currently transmit TV signals through fiber-optic cables. The status of the others regarding extent of existing or planned fiber-based networks could not be confirmed. Strategic Technologies, Inc. (STI) has about 10 miles of fiber-optic cable in the Doral resort area. TCI of South Dade, Inc. has about 100 miles of fiber-optic cable. TCI recently approached the Public Works Department about partnership opportunities in fiber-optic network installation within all of their service areas (north Miami-Dade, city of Miami, Virginia Key, and Kendall).

The proposed Florida Fiber Network (FFN), as previously mentioned, will not reach the advertised RFP stage until July 1998. However, the importance of such a statewide network is undeniable. When and if the FFN becomes a reality, the current configuration plan is to have two "spare" fiber conduits in urban areas and one "spare" fiber conduit in rural areas along all of Florida's Interstate and Turnpike rights-of-way (SR 836 will also be covered by the FFN in Miami-Dade County). User access to the "spare" fiber conduits is totally undetermined at this time. The FDOT (24 fibers) and the state's Division of Management Systems (12 fibers) will occupy one additional conduit in each respective geographic area.

The FDOT Miami District office is awaiting the FFN outcome. Nevertheless, the District has its own plan for installing a fiber-optic communication network to begin to serve the needs of the S.E. Florida Intelligent Corridor System (ICS) project. To be completed by early 2000, this 96-fiber trunk (first phase of installing currently under construction) will be located along I-95 from the north county line south to US 1. Major hubs are also under construction at the Golden Glades interchange and SR 836. Conceptually, the District wants the FFN and ICS deployment (which is envisioned to link all the public sector development fiber lines, including that for the Miami-Dade County Signal System upgrade) to operate in a seamless fashion along the I-95 corridor.

The fiber system map for Miami-Dade County on the following page depicts the limits of all the aforementioned fiber networks, with the exception of the cable television fiber networks. Several

Dade County Fiber Network



Proposed Fiber Nodes (Hubs)
Existing Fiber Nodes (Hubs)
Proposed Florida Fiber Network
Proposed County ATMS
Proposed FDOT Dist. 6 Fiber
Existing County Fiber

Scale
1 inch = 2 miles

characteristics of this collective network are important to highlight. First, many of the major travel corridors have or will have fiber conduit installed along them. Second, there are several fiber systems that exist or are being planned within the same right-of-way. Third, each of four networks shown (one existing and three planned) are essentially being separately planned with somewhat different objectives in mind. Finally, no one entity or individual is intimately familiar with the details of all four systems. Therefore, it is highly likely that without a common base objective and coordinated planning soon in place, the full potential for connectivity, information sharing and economic savings will not be realized.

TRANSPORTATION COMMUNICATIONS INFRASTRUCTURE

NEEDS ASSESSMENT

It is critical to have a sense of (transportation) communication needs before determining the most appropriate and cost-effective (transportation) communications system. Again, following the analogy with a roadway/transitway network, we have to have a basic estimate of volume, origin-destination patterns, and type of traffic (through versus local) to design, build and maintain an efficient transportation system. Likewise, we must be able to define similar operating parameters for the communications (or information exchange) system. Two examples of transportation communications needs assessment have been summarized in this portion of the report; one compiled from a very simplified mailback survey of several Miami-Dade County departments, the other conducted by FDOT for District 6 as part of the FFN planning.

Miami-Dade County Survey Results

Based on feedback from ITD and the MPO, nine transportation-related departments were selected for the communication needs survey. The survey contained 16 questions that address the current and future communication needs of each department. The survey included a basic quantitative inventory of employees and different communication devices, and a qualitative assessment of type of communication (i.e., voice, video, data) and extent (i.e., inside versus outside Miami-Dade County). In years past, ITD conducted surveys of this nature but they are no longer done countywide. More detailed surveys, beyond that conducted for this project, are required to obtain communication needs for <u>future</u> planning. Eight of the nine surveys were completed and returned, with the findings summarized in Table 3.

Table 3-Miami-Miami-Dade County Communications Inventory

Agency/ Department	Total Employees	PCs Networked	PCs Non-networked	Modems	Phones	Cellular Phones	Two-way Radios	Pagers	Fax Machine	Control/ Dispatch Centers
Fire Rescue	1938	378	28	42	900	86	1867	467	53	1
Solid Waste Management	1055	111	7	30	472	14	300	158	20	4
Police	4232	1104	481	297	2757	375	3683	3151	111	25
MDTA	3272	29	217	29	1238	10	13	236	300	3
Port of Miami	204	79	25	19	115	5	96	79	13	-
Emergency Management	24	24	2	6	100	3	36	18	8	-
Aviation	1537	900	-	24	5145	87	850	390	141	6
Public Works	656	190	6	5	394	19	182	200	16	5
Planning, Development & Regulation	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Upon review of Table 3, it is interesting to make several comparisons. On the average, about one in every four employees has a personal computer (79 percent of the computers are networked, 13 percent have modems). On the average, 86 percent of the employees have a telephone, 54 percent have two-way radios, 36 percent have pagers, and just under 5 percent have a cellular phone. There is about one fax machine for every 20 employees. The number of department communication control centers varies from none (for the Port and Emergency Management) to 25 (for Police). Qualitatively speaking (and not indicated in Table 3), with the exception of the Miami-Dade Transit Agency, the responding departments indicated a high degree of outside county communication needs. All indicated many intra-county departments with which they regularly communicate. Unfortunately, only two departments indicated that they even have permanently installed communication devices in the field (and those are very limited). Finally, only two departments (Aviation and Transit) have regular voice, data, and video communication needs at the present time.

This preliminary survey reflects an inventory of current activity rather than future needs. (The sample survey is included at the end of this report, following the Project Contacts.) However, based on this limited survey, it appears that the departments have adequate (not full) communication capability between themselves now, but almost no capability to send and receive information (due to lack of field devices and interconnected control centers) directly to the general public.

FDOT District 6 Needs Assessment

This assessment primarily focused on future transportation communication needs, and can serve as an example for future more comprehensive surveys conducted with Miami-Dade County departments. During July-August 1996, the FDOT fiber-optic technical team visited the eight FDOT district offices to gather communication needs information, and they were able to translate this information into specific communication design parameters. For the fiber network design purposes, the information gathered was broken into two categories: telephony and ITS communication needs, as summarized (for District 6) in Table 4. This information should not be misread as the total needs of the District. These were only the needs that the proposed Florida Fiber Network could accommodate. The District plans to utilize the FFN infrastructure to the maximum extent and add on to it as needed.

Table 4-FDOT District 6 Current Telecommunication Needs by Facility

		Facility					Total
		Miami District Office	South Dade Maintenance	North Dade Maintenance	602 Building	Marathon Office	
Employees	Office	600	163	90	22	25	900
Phones	Trunks	670	92	8	36	16	822
	Sets	300	71	33	35	24	463
PCs	Network	260	25	10	25	40	360
	Non-net	-	25	-	-	10	35
Faxes		40	2	1	1	3	47
Modems		17	8	10	10	10	55

Telephone calls among FDOT district facilities were assumed to represent the major portion of the telephony communication traffic. A preliminary analysis revealed that this traffic could be transported with less than a DS-1 network. As an aggregated state communications traffic model, the team decided to initially support telephony requirements of the FDOT on a SONET based DS-3 service to each district office. If the communication traffic patterns grow, upgrading the end equipment would increase overall system capacity.

A typical density of the most common ITS devices on limited access roadway was prepared that would represent a typical full ITS deployment scenario. This density reflected two variable message signs (VMSs) per mile, one closed-circuit television (CCTV) per mile, one detector per 0.33 mile, one Highway Advisory Radio (HAR), call box, and "other" ITS device each per 0.5 mile in an urban setting. From this sizing rationale, the basic ITS device needs were established for District 6 (as shown in Table 5).

Table 5-ITS Devices in District 6

ITS Model	Length	VMS	CCTV	Detectors	HAR	Call Box	Other Devices
Urban Suburb Rural	29 0 0	58	29	87	58	58	58
	Total Devices	58	29	87	58	58	58
	Device B/W	19.2K	3.33M	14.4K	64K	64K	19.2K
	% of Utilization	0.5	0.2	1	0.2	0.1	1
	Total Device B/W	0.556	19.314	1.253	0.742	0.371	1.114

FDOT Needs Assessment

To develop a set of viable network design requirements (from an ITS perspective) providing for a realistic planning horizon, the FDOT team assumed that:

- *No more than 20 percent of the CCTV will be transported at any given time and viewed at any facility (i.e., traffic operation center).*
- *Fifty percent of the VMSs, 20 percent of the HAR base stations, and 10 percent of call boxes within a district will be transmitting at any given time.*

Based on the above assumptions, estimated peak total ITS bandwidth requirements were calculated for each district. This lead to an estimated 23.35 Mpbs total bandwidth for District 6, while the estimated highest bandwidth (155.66 Mbps) was calculated for District 8. The maximum bandwidth requirement can be satisfied by an OC-3 SONET multiplexer.

WIRELESS COMMUNICATION APPLICATIONS

ITS-Specific Needs

Many ITS projects rely on communication linkages with moving vehicles (e.g., delivering accurate traffic advisory reports and route guidance to commuters), real-time video display traffic kiosks and Internet web sites, roadside message boards, and traffic signals. Other ITS projects require a continuous stream of status data from roadway sensors throughout a metropolitan area. Often, wireless communications presents the best method for quickly getting the information where it is needed. Five general classes of mobile communication services have been identified as follows:

(1) office-to-field communication,
(2) in-vehicle communication with motorists,
(3) data transmission from remote sensors,
(4) continuous vehicle tracking, and
(5) wireless relays to trigger equipment for immediate and automatic response to incidents.

What are the Options?

At the present time, lower regulatory barriers are encouraging the trial of innovative applications for wireless technologies. Some of these new mobile communications services will ultimately fail, but industry analysts expect that the eventual outcome will create more technological choices available for reliable wireless communications. One of the most significant breakthroughs has been the advent of digital transmission techniques that have revamped the entire broadcast environment. Basically, digital transmission makes it possible to compress wide bandwidth signals into narrow radio channels improving reception quality. Beyond digital transmission improvements, advances in image display systems, rechargeable batteries, and computer chip design opened up new communications potential, as evidenced by low-Earth-orbit satellites and meteor-burst systems. The net effect is that the old mobile communication systems have been reshaped and to some extent replaced by the proliferation of new wireless networks.

As the Miami-Dade MPO considers the wireless component of its transportation communication infrastructure, six distinguishing features should be kept in mind: reliability, coverage, transmission speed, equipment and airtime costs, security, and one-way versus two-way service. Any technology that requires multiple broadcasts to deliver a message, no matter how fast the speed, will prove to be unreliable. Seamless reception over a broad coverage is preferred for many ITS applications, but many of the newer wireless networks serve only metropolitan areas. Transmission speed and throughput (amount of message-specific data that reaches recipients in a given period of time) affect the efficiency and acceptance of employees using mobile communication systems. There are few situations in which wireless technologies are cheaper to employ than traditional wired networks. Wireless communications will always carry a premium cost. The transition to digital techniques has made it easier to send encrypted messages, but depending on the specific ITS application some messaging is not worth the premium price for digital (e.g., travel advisory reports intended for all travelers). Two-way communication demands greater bandwidth and is more expensive than one-way communication. The following table highlights some of the most distinguishing characteristics of the wireless technologies available or emerging at the present time.

Table 6-Wireless Technology Characteristics

Cellular	• Data transfer speeds of 9.6 Kbps • Digital airtime rates cheaper than analog charges • Does not reach beyond suburban areas • Cellular digital packet data (CDPD) will support data transfer rates as high as 19.2 Kbps • CDPD uses vacant space on cellular radio channels, so its coverage area does not extend Beyond the cellular network • Personal communication services (PCS) use greatly reduced transmitter power so phones are smaller, lighter, and able to operate longer on a single charge • PCS could cost less than analog or digital, but has not yet established proven reliability
Radiopaging	• Primarily an urban service • Traditionally just a one-way service • Simple technology • Competition among providers is creating a wide selection of options for users • Tone and voice message models are available
Land Mobile Radio	• Less high-tech than other wireless services for voice communications • Has existed for almost 40 years • Rugged, dependable, proven • Low airtime costs, with set-aside frequencies • Only by switching to a digital data transmission could call scanning be eliminated
Radio Data Networks	• RDN cannot carry voice communications • Provides mobile data networking at fairly slow data transmission speeds • Very limited coverage into rural locations • Airtime rates difficult to calculate and modems are expensive
Micro-Cellular	• Another newer version of RDN • Uses spread-spectrum transmission (unlicensed frequencies between 902-928 MHz) • Faster data transfer rate (up to 77 Kbps) than standard RDN • May be susceptible to interference problems because of sharing frequencies • Lower equipment and airtime rates than standard RDN
Radio Frequency and Infrared Local Area Networks	• Substitutes radio or infrared connections for traditional LAN cabling • Designed primarily for indoor office communications, where PCs are frequently moved • Most offer data transfer rates of 1 Mbps • Very limited transmission range (less than 1,000 feet) • Infrared does not require FCC license • Infrared is unaffected by radio frequency transmissions
Microwave	• Ideal for transmission of large quantities of voice, data, or video • Less microwave congestion outside metropolitan areas • Microwave requires clear line-of-sight between sending and receiving antennas • Most operate at 25-mile distances between transmission towers • Transmission is very reliable and secured • Service can be leased from many common carriers
Satellites	• Geostationary satellites (about 22,300 miles high) offer wide coverage, but airtime is expensive • Geostationary satellites offer high-quality and service reliability for voice communication • Newly emerging low earth orbit satellites (about 500 miles high) offer less interference and Much cheaper airtime than fixed satellites • Handsets for low earth orbit satellite communication require less power, but continuous coverage Requires more satellites to be deployed
Meteor Bursts	• No airtime costs • Usable meteor trails (acting as natural satellite relays) are not always available, so Delays in messaging can occur • Best for short data messaging to remote locations not requiring real-time communication

Source: Wireless Communications for Intelligent Transportation Systems

TECHNOLOGICAL AND INSTITUTIONAL OBSTACLES

Legislation

The Florida Legislature passed a bill that would impose some restrictions to county, municipal, or local government planing to provide telecommunication service. The bill *HB 313* addresses several issues pertaining to telecommunications provider that is a county, municipality, or other entity of local government. These telecommunications providers are subjected to all local requirements applicable to other private telecommunications companies, including paying taxes for the services provided to the public. However, the bill does not alter current billing/taxation requirements for the telecommunication services provided for internal operational needs of a county, municipality, or other entity of local government.

Two subsections of Section 253 of the Federal Telecommunications Act of 1996 have created a great deal of discussion and varying interpretation. These subsections deal with the ability of state or local government to offer public rights-of-way for private telecommunication providers to install fiber or coaxial lines, and are as follows:

> *"No state or local statute or regulation, or other state or local legal requirement, may prohibit or have the effect of prohibiting the ability of any entity to provide any interstate or intrastate telecommunications service."*

> *"A state or local government has the authority to manage the public rights-of-way or to require fair and reasonable compensation from telecommunications providers, on a competitively neutral and nondiscriminatory basis, for use of public rights-of-way on a nondiscriminatory basis, if the compensation required is publicly disclosed by such government."*

Many state and local government agencies have established public-private partnerships to use the existing rights-of-way to install telecommunication mediums. This type of arrangement is also commonly known as "shared resource project." These agencies, in general, have agreed to limit the use of these rights-of-way to others not in the initial partnership list. In exchange for allowing access to the rights-of-way, the state or local government would get part of the telecommunication medium at reduced or no cost. Given the ambiguity of the two subsections, several private telecommunication service providers have taken action in court to bar state and local government agencies from limiting access to the rights-of-way already contracted out. For example, in June 1988, the Minnesota Telephone Association with co-plaintiff MEANS Telcom, filed a lawsuit (despite numerous offers to resolve differences) seeking a permanent injunction against the State's project ("Connecting Minnesota") to bring more of the information superhighway to more of Minnesota. This fiber-optic communication networked, valued at $125 million, will reserve 20 percent of network-capacity for public sector use.

Threshold issues are those that determine whether shared resource projects are viable options for state and local highway agencies. These are the issues that must be addressed at the outset of a program for shared resource projects. Primarily legal and political, issues range from statutory or regulatory constraints on access to public rights-of-way for communications purposes, to political opposition to competition between public and private communications systems. Shared resource projects are developing in an atmosphere of significant political and legislative activity. Several important telecommunications bills have recently come up before the United States Congress and Florida legislature which, if enacted in their entirety, would significantly affect the telecommunications industry and have associated ramifications for shared resource projects. These bills would measurably alter the market structure for telecommunications services and thus the relationship among service providers. Provisions in such bills may also affect the ability of local governments to negotiate specific public benefits in return for allowing access to a given telecommunications provider (e.g., offering exclusive right-of-way access to one vendor, or the telecommunications carriers that use public rights-of-way offering preferential rates to public institutions).

Economic vs. Efficiency Tradeoffs

Economic versus efficiency tradeoffs in designing and implementing a fiber-optic communications system covers a broad array of considerations. From the type of fiber used to the network configuration and transmission protocol, and finally to the area of coverage and determination of ultimate users, economic savings and technical efficiencies can be gained or lost due to decisions made at the early planning stages. For example, even though multi-mode fiber has some cost advantages when compared to single-mode fiber (easier splicing and connecting to end equipment), multi-mode fiber's susceptibility to greater transmission interference in a major urban setting would require more repeaters and amplifiers for comparable transmission quality and reliability.

At about $2 per foot ($6.50/meter), the cost of a fiber strand itself is relatively inexpensive compared to the support equipment required for transmission and routing. System configuration and transmission protocol is determined by several operating parameters. Communication data rate that will be needed (e.g., real-time, two-way voice, video, and data for all users versus delayed one-way transmission for data only to a limited number of users), the number of ultimate end users to the network, the number of centralized communication centers versus, the number of individual communication devices in the field, and the extent of built-in redundancy and expansion capability are some of these critical parameters. Recent estimates from F.R. Aleman indicated that non-fiber material costs could constitute about 75 percent of the total construction cost for a fiber communications system.

Once again, the analogy of comparing the design and construction of a communication system to a transportation system is appropriate. For example, a transportation engineer certainly knows at the outset whether an interstate or local collector road is to be designed. The transportation engineer also predetermines the location and access type (interchanges vs. at-grade intersections) in his design, allowing for some future expansion and/or upgrading. Financing options and sources of funding for the facility are also identified early. Likewise, a good communication system design approach would follow all of the same principles to minimize costs and look for efficiencies.

Overcoming the Barriers

The Institute of Electronic and Electrical Engineers (IEEE) has recently proposed a Recommended Practice for Selection and Installation of Fiber-Optic Cable in Intelligent Transportation (*IEEE-P1435*), which is currently under discussion among groups such as ITS America and the Federal Highway Administration. This recommendation is expected to provide guidelines for selection, installation approach, splicing, major hub connections, and performance acceptance testing of fiber-optic cable.

Finding the right private sector partners for shared resource ventures is very important for any government agency. The American Association of State Highway and Transportation Officials (AASHTO) lists three basic steps involved in this process:

1. *Identify potential partners and their needs*
2. *Determine conditions for partnership*
3. *Enlist participation*

For many government agencies, steps 2 and 3 represents a paradigm shift in addressing transportation needs because they emphasize a collaborative approach rather than the more traditional procurement process. The initial contacts for fiber-optic projects between public and private agency may occur in one of the two ways. Private partners may approach public agency on their own, or the public agency can initiate the process of exploring shared resources projects. Since a competitive environment can increase the ultimate value of a project, the public agency can benefit from systematic outreach to potential private sector partners.

Given the mandate by the Telecommunications Act of 1996, the public agency should effectively advertise the available shared resource opportunities and actively solicit private sector input into the partnership selection process (as the state is about to do for the FFN). The public agency may contact private agencies by holding public and/or one-on-one meetings, or workshops and technical forums (which the state has also done as a prelude for its upcoming RFP).

Partnership conditions between public and private agencies are critical for a successful shared resource project. Often times the partnership conditions can be a function of private agency preference, public agency needs and policy decisions, and legal and technical constraints that limit choices. Since these conditions may affect partner interest, AASHTO recommends that following issues must be addressed and articulated as agency policy before partners are selected:

- *Form(s) of compensation*
- *Number of initial partners*
- *Treatment of subsequent partnership applications*
- *Re-marketing and sublease conditions*
- *Use of design standards and guidelines*
- *Geographic scope*

The public agency may receive goods and services, cash, or a combination of both as form of compensation for the use of its right-of-way. An option to include additional partners to the shared resource project should be formulated to be compliant with the Telecommunications Act of 1996 (to ensure that there are no barriers to entry). The public agency has four options in this regard, and the advantages and disadvantages of each option are listed in Table 7.

Table 7-Options to Include Additional Partners

Approach	Advantage	Disadvantage
One-time window of opportunity	Imposes time limit on administrative involvement with partner selection. Construction on specific ROW segments minimized by installing infrastructure at one time.	Total number of partners and therefore total compensation to public agency may be restricted, possibly interpreted as barriers to entry.
Limited window of opportunity	Imposes time limit on administrative involvement with partner selection; construction on specific ROW segments minimized by installing infrastructure at one time; allows expansion later at public agency's discretion.	Total number of partners, and therefore total compensation to public agency, may be restricted (possibly interpreted as barriers to entry).
Open application period	Clearly a non-discriminatory and no-barriers approach; probably enhances total compensation received by public agency.	Extends period of construction/ installation on ROW posing safety concerns and danger of damage to existing infrastructure and ongoing administrative burden.
Planned excess physical capacity	Easy to accommodate subsequent applications without disruptive construction on ROW.	Can impose some financial burden on initial partners (though costs of incremental capacity are a fraction of total costs); may discourage primary tenant(s) if perceived as threat to their customer base (diversion of demand to subsequent applicants).

Source: AASHTO's Guidance on Sharing Freeway and Highway Rights-of-Way for Telecommunications.

CASE STUDIES OF GOVERNMENT-BASED PARTNERSHIP FOR DEVELOPMENT OF FIBER SYSTEMS

In order to further understand the development process of public-private partnerships in telecommunications, this report has summarized some of the better-publicized examples below. These case study examples are intended to provide a comparison (and perhaps some insight) for Miami-Dade County activities, which has also been included.

City of Leesburg, Florida

In early 1992, Knight Enterprises and the City of Leesburg discussed a potential fiber-optic network that would connect the city with other major Florida cities. Consequently, the City of Leesburg and Alternative Communications Networks (ACN), a subsidiary of Knight Enterprises entered into a joint venture to develop such a network in the Leesburg Utilities territory. The main attractions of the city to ANC were its utility right-of-way, electric poles for fiber attachment, approximately thirty-five miles of existing fiber cable, and central location within the state.

According to the agreement, the City would provide the right-of-way and funding for construction, while Knight and ACN would provide design and construction, acquire customers, and handle billing. This proposal was driven by the local hospital's need to connect several of their various buildings throughout the city.

Currently, the fiber is being used to connect 14 city buildings together to provide high-speed computer system connections, and in some cases, additional telephone extensions. In addition, the local hospital has nine buildings connected with fiber for high-speed data communications.
Today, Knight Enterprises/ACN has all but abandoned the Leesburg project so that they can pursue contracts with Time Warner Cable Company. This is strictly a business decision, given that Time Warner represents several million dollars of business a year to Knight, and the City of Leesburg represented only a few thousand. The city is in the process of taking over all of Knight's tasks in the original partnership. This represents an example of a situation a public-private partnership may face when there is only a limited customer base to serve.

State of Maryland

Maryland is engaged in a shared resource project to install 80 miles of fiber-optic cable in its right-of-way. The agreement involves MCI and Teleport Communications Group (TCG). Maryland is allowing MCI access to 80 miles of right-of-way for 25 years (with options for renewal), in which MCI may lay as many conduits as feasible and pull fiber as needed afterward. In return, MDOT received 72 dark fibers and 25 percent increase in bandwidth capacity from MCI. MCI is acting as the lead contractor in building the system and providing routine maintenance. MCI has installed two conduits in the Baltimore-Washington Corridor segment of I-95, one for itself and one for Maryland DOT, with no excess capacity. TCG, which entered the arrangement as a subcontractor to MCI, will pay MCI to install and maintain fiber for TCG's use in the privately held conduits. In return for access, TCG is providing the state with equipment necessary to light the original 24 dark fibers, plus an additional 24 dark fibers for public sector use. Each of the three partners retains ownership of the fiber dedicated to its use. As the party responsible for construction and maintenance, however, only MCI will physically access the system. Maryland set up this shared resource project strictly as a procurement, purchasing telecommunications capacity with right-of-way access. The state also disaggregated its fiber-optics backbone geographically. Bidders could invest in right-of-way routes of specific interest to them. The right-of-way for this agreement is part of the I-95 corridor that runs between Washington, D.C., and New York City, an area in which telecommunications redundancy can be valuable. Railroad and other utility rights-of-way are competitive options in the corridor.

Although the rights granted to MCI and TCG are technically not exclusive, the private partners have "practical exclusivity" because the state does not want repeated construction projects in the right-of-way. The shared resource arrangement also provides for relocation cost sharing. That is, the state will pay for the necessary duct for the fiber-optic cables if and when construction or reconstruction of the roadway requires relocation of the duct. MCI will relocate and provide ancillary equipment to reestablish the network connectivity to operate at "pre-move" performance levels. Potential contractors requested that the state commit not to require relocation for at least five years from the contract date. Although the state did not expect to move facilities within that term, it would not commit contractually to refrain from doing so. At this time, it is unclear whether MCI will be responsible for relocation if the state installs an ITS application. The state's liability is limited to repair of any facilities that it damages. MCI has indemnified the state for any dissemination of information pertaining to the contract and for any negligent performance of its services under the contract. According to state sources, this was a significant issue in the negotiation of the contract. MDOT also has recently announced the Phase II Fiber Optic RFP for 700 miles of rights-of-way and has not yet received any qualified proposals.

Ohio Turnpike Commission

In late 1980s, the Ohio Turnpike Commission entered into a number of licensing agreements. These agreements are expressly non-exclusive and licenses extend for a 25-year period. Litel has 200 miles of fiber and MCI less than 75 miles of fiber along the Turnpike. Other firms have also been granted licenses. The Ohio Turnpike Commission receives a fixed per-mile fee for the use of its right-of-way. In return for allowing access, the Commission receives a license fee of $1,600 per mile of installed fiber, as well as rights to use the fiber-optics for Turnpike purposes at minimal or no cost. At present, the Commission uses relatively little of the capacity available. Valuation of the right-of-way was determined with information from market studies conducted prior to the 1980's.

The Ohio Turnpike agreement requires relocation, alteration, or protection of the telecommunications facility, at the licensees' sole expense, in order to avoid interference with the operation, reconstruction, improvement, or widening of the Turnpike. From a strictly legal perspective, the agreement contains excellent, broadly drafted indemnities. The licensees are required to maintain specified levels of insurance and to hold the Turnpike Commission harmless from losses, costs, claims, damages, and expenses arising out of or related to any claims as a result of the agreement. The Commission has the right to defense by its own counsel and to control any claims made against it. The agreement also requires licensees to indemnify the Commission for bodily injury and property damage, to the extent of the licensees' negligence. The Commission is only liable to the extent that damage to its system is caused by its own gross negligence.

State of Missouri

In 1994, Missouri entered into a contract with Digital Teleport, Inc. (DTI) for the installation of a statewide backbone system of more than 1,300 miles of fiber-optics. More than 300 miles have been installed and activated, and an additional 100 miles of conduit have been installed to date. In return for allowing access to the right-of-way, Missouri receives six-lighted fibers for state highway use as well as DTI maintenance of the system. Missouri's arrangement offers two strong advantages: (a) it gives exclusivity to one telecommunications firm, although that firm can lease access to other telecommunications firms on its lines; and (b) there is limited or no serious competition from alternative right-of-way locations, such as railroads, in the areas of greatest interest to the bidders.

Missouri, like Maryland, set up its shared resource project strictly as a procurement, purchasing telecommunications capacity with right-of-way access. Although DTI can also locate within the standard utility corridor, the exclusivity provision does not apply to that portion of the right-of-way. The provision permits other firm's fiber-optic cables to cross DTI's easement at an approximate right angle, but only upon mutual agreement of the Missouri Highway and Transportation Commission (MHTC) and DTI regarding the location. Nothing in the agreement limits the Commission's authority to install its own fiber-optics cable for highway purposes within MHTC air space.

The state is to bear the cost of relocating. MHTC may either acquire additional right-of-way for the fiber-optic cable corridor in some fashion acceptable to DTI, or remove and relocate other utilities at its own expense so that DTI may place its system in the utility corridor if necessary. DTI assumes responsibility for all warranties and liabilities for service and performance, and maintains insurance for bodily injury and property damage, product, and completed operation (with underground property damage endorsement, commercial automobile insurance, and worker's compensation insurance). MHTC is not responsible for any liability incurred by DTI. DTI is responsible for all injury or damage for its negligent acts or omissions and saves harmless MHTC for any expense or liability deriving from such acts or omissions, whether on its part or on the part of its subcontractors or agents. MHTC is liable for actual repair costs if its personnel, contractors, or subcontractors damage or destroy any part of the fiber system or equipment installed by DTI, but it is not liable for lost revenues or other incidental or consequential damages sustained by DTI.

San Francisco Bay Area Rapid Transit

In this three-party agreement concluded in 1995, San Francisco Bay Area Rapid Transit (BART) procured a new fiber-optic system for use in operating its rail transit facilities. In addition to installing approximately $45 million worth of capital improvements procured by BART for its own system, MFS Network Technologies will invest $3 million to install additional conduit throughout the BART system. MFS will then rent that conduit space to any carrier that wishes to pull its own fiber. BART will receive 91 percent of the rental returns, and MFS will receive the remaining nine percent. BART anticipates that these revenues will cover all but $2 million of the cost including operations, maintenance, and interest on debt for its train control and communication system over the 15-year period.

BART had investigated developing its own fiber system but determined that ownership of fiber or conduit might trigger its regulation as a public utility, which it preferred to avoid. This prompted BART to search for a joint development partner. BART's right-of-way gains value from the fact that it is a closed system and generally well protected from intrusion. Railroads are the main competition for right-of-way lessees. For example, Southern Pacific owns substantial right-of-way leased to telecommunications carriers.

The BART agreement also involves the California DOT (Caltrans) as a silent partner. Of the 100 miles of right-of-way included in BART's current and planned extensions, 25 miles are actually owned by Caltrans, which conceded control but not ownership to BART. Thus, Caltrans is also a lessor and, for the airspace lease it negotiated with BART, will receive a portion of the revenues generated from MFS conduit leases after BART has fully paid for its telecommunications system. BART divides its revenues by facility segment and will pay Caltrans 25 percent of the revenues it receives from conduit leases on those segments of right-of-way shared with Caltrans (which are considered relatively lower value for telecommunications use). Caltrans also receives in-kind compensations of BART's 48 strands of fiber-optics along the full 100 miles of the BART system, with access to 15 strategic locations. In fact, this in-kind compensation was the dominant attraction for Caltrans. Caltrans has estimated that this in-kind benefit is equivalent to $812 million in avoided costs for independent construction of Caltrans infrastructure or $960,000 per year in lease costs for comparable fiber.

Caltrans' lease of air space to BART appears to be exclusive for the conduit system. BART's license to MFS does not provide exclusivity, however, as long as the conduit system between two adjacent BART stations has unoccupied capacity and MFS is not in default under the agreement, BART has agreed that it will not grant any other provider a license to install a communications system between these points. Once system capacity has been reached this exception will cease, even if space later becomes vacant. However, BART must give MFS right of first refusal if BART wants to add conduit capacity. BART is obligated to designate a new route for the conduit if it must be relocated, and all relocation costs not paid for by a third party are to be paid by BART. MFS is not obligated to indemnify BART for BART's own negligence or willful misconduct. Both BART and MFS waived consequential, incidental, speculative, and indirect damages, lost profits, and the like. The agreement includes the form of license to be used by MFS in marketing excess capacity to third party customers. It requires the user to insure MFS, free MFS from liability for service interruptions, and indemnify MFS.

MCI of Washington, D.C.

MCI of Washington, D.C. has announced a new SONET-based data service that combines its long-distance network and its local facilities in 22 metropolitan areas. The new service, which MCI is calling a nationwide first, will enable businesses to exchange information at high speeds from location to location without any intermediary such as the incumbent local exchange carrier. The company's SONET technology, called network MCI Broadband Connections, has speeds from 45 to 155 Mbps. The service connects directly into the long-distance network via MCI's local metro fiber facilities.

Orlando-Orange County Expressway Authority

Orlando Orange County Expressway Authority (OOCEA) is planning to install fiber optic cables along its expressways to join every toll plaza and the *E-PASS* service center to a central office. OOCEA has 10 main toll plazas, 38 ramp plazas, and a single service center. The Authority's right-of-way is a total of 79 centerline miles. All the cables except to the service center will be underground and secured in eight conduits. The service center will be connected to the fiber backbone by aerial cables. The conduits will contain 72, single-mode fiber strands that will be connected by SONET network end equipment. The optical signal from OOCEA headquarters to the main toll plazas will be transmitted via the 72-fiber backbone cable in a self-healing ring configuration. Signal from the OOCEA headquarters to the ramp plaza will be conveyed via the 72-fiber backbone cable and 12 fiber drop cables in a closed loop configuration.

The Request for Proposal for Design-Build Services was advertised in March 1997. Despite the announcement of private-public partnership opportunities for this fiber cable network, OOCEA has not yet been able to attract any private or public agency into this venture. As a result, the OOCEA has decided to bear the cost of construction and maintenance of the project. However, they expect new customers (especially private industry) will lease some of their fiber in the future.

Toronto, Canada

MetroNet Communications is planning to use a 17-km, fiber-optic network to provide businesses in Toronto with a choice in local telecommunications services. They are under an agreement with the city to install a fiber-optic network throughout business, financial, and governmental areas of the downtown. The facilities-based provider of local telephone service also recently opened a Toronto based network operations center to monitor its nationwide network.

Roseville, California

Electric Lightwave Inc. (ELI), a full-service competitive communications provider, has agreed with the California Public Utility to provide competitive local telephone service to businesses in the City of Roseville, CA. Roseville businesses have a high demand for bandwidth and ELI has installed more than 200 miles of fiber-optic cable in the metropolitan Sacramento area, and they plan to add another 40 miles in Roseville.

Miami-New York

A long haul, fiber-optic network from Miami to New York City has been started by BTI of Raleigh, North Carolina. The company is installing opto-electronics and OC-192 (10 Gbps) capacity on 3,500 miles of dark fiber it recently bought from the Qwest International Corporation. They have also started construction on a 15-mile addition to its 65-mile fiber-optic network in North Carolina's Research Triangle Park. The new section is scheduled to go on-line by the end of 1998.

State of Illinois

The Illinois State Toll Highway Authority has a public-private partnership with MFS to build a 276-mile, fiber-optic system along their the rights-of-way. The network will provide digital voice, data, and other communications services for the authority; aid in the establishment of the authority's *I-PASS* electronic toll collection program; and serve as a continuing source of revenue for both the authority and MFS through leasing of excess fiber capacity to third-party users. Construction is to be completed by summer 1999. Both MFS and the authority are sharing all risks.

City of Palo Alto, California

The City of Palo Alto has constructed a fiber-optic network using the existing electric poles and conduits. Cost of construction and maintenance was financed by the city itself. The city expects to lease dark fibers to telecommunications service providers, and network developers would use their fiber to gain access to potential Palo Alto customers. With about 60 Internet service providers, Palo Alto has one of the greatest numbers of providers of any other city for this type of service. One private telecommunication company already has licensed to use portion of fiber, and discussions are underway with other telecommunication carriers and Internet service providers.

State of Iowa

A statewide, fiber-optic backbone administered by Iowa Communications Network (ICN) transmits real time video, voice, and data to its customers. This state- administered backbone has connected every county in the state. The fiber-optic network was designed in several parts. Parts I and II of the network became operational in November 1993, with additional sites being added constantly. Part III of the design will connect 474 sites, mainly K-12 schools and libraries throughout the state. Implementation of this part began in 1996, with a seven-year lease for 439 of the sites and ownership of 35 of the site connections. Leases for Part III are with a number of private vendors and are on site-by-site or merged geographic area basis. More than 1,000 additional users will be permitted to access the statewide network. For example, the National Guard is constructing a $10 million project that will link 57 classrooms (in 50 armories throughout the state) onto the network. When these classrooms are not in use by the Guard for training, the classrooms will be available to authorized users in the community. The federal government is constructing a project that will link 22 more sites to this statewide network.

Florida Fiber-Optic Network (FFN)

With the emergence of ITS and therefore needs for a high capacity communication system, Florida Department of Transportation (FDOT) is actively considering installing a Florida fiber network (FFN). FDOT plans to create a public-private partnership for the 2,000-mile FFN. Public agency partners include FDOT and Department of Management Services (DMS) while the private partner would be a telecommunication provider. The telecommunication partner can install any number of fiber-strands/cables as it may want during the construction. FDOT will grant a right-of-way lease agreement with a 20-99 year term limit to the successful proposer. All the high priority sections of the network will be completed within first 3 years of the agreement. The entire communications infrastructure will be completed within the first seven years of the agreement. The contractor will be responsible for installation, testing, maintenance, and future relocation (necessitated by highway reconstruction or expansion) of the fiber network throughout the state.

The evaluation of proposals, expected to begin approximately three months after the July 1998 RFP advertisement, will involve no numerical scoring. Instead, proposals are to be evaluated and compared based on the extent of "enhanced" services added that would benefit FDOT and DMS. Enhancements would likely include optical end equipment, sharing of optical end equipment, additional fiber strands, periodic equipment upgrades, added switching and routing capabilities, and cash. At the time of award, FDOT and DMS will determine the financial savings DMS obtains if it accepts the successful proposer's offer. One-half of these savings will be credited against FDOT's overall SUNCOM charges, the other half of the savings will be passed on to all SUNCOM users, including FDOT. FDOT will continue to receive these savings as long as telecommunication service providers use the FFN to provide their services.

Miami-Dade County Advanced Traffic Management System (ATMS)

The present system of traffic control is about 22 years old, includes obsolete equipment non-conforming to current standards, suffers from frequent failures, continues to be extremely expensive to maintain, and cannot handle the growth of Miami-Dade County. Present BellSouth service cannot accommodate the projected 4,000-signal network and future bandwidth required for full ITS capabilities. A comprehensive communications network study has been completed, most of the system hardware purchased, and software development is progressing. However, the overall project timetable has been slipping, and any further delays will add to the $48 million total system upgrade cost. These costs could be substantially reduced if adequate partnering can be secured in a timely fashion, without jeopardizing FDOT funding and governmental obligations.

The Public Works Department has been recently discussing and considering public-private partnership arrangements with Florida Power & Light and at least one local cable television provider. Five options for a potential partnering arrangement are being reviewed by the County Attorney's office, but attractive opportunities for partnerships may be lost as the department awaits legal scrutiny. Perhaps the following table and review of this report's previous section on "Overcoming the Barriers" can offer some suggestions.

Table 8-Lessons Learned from Case Studies
Source: FDOT Communication Needs Assessment, April 1995

- *Make sure that the private agency has a large enough customer base in th area where the fiber is going to be used.*
- *Solicit the entire project, including all the areas of fiber-optic coverage needed, in one procurement effort.*
- *Scale down the capacity requirement by realizing that not all the signals are used all the time.*
- *System bandwidth capacity may not be driven by the mere number of fibers, but rather the electronic end-equipment which can always be upgraded.*
- *Fiber is the low-cost component of the system, therefore, install as many fiber strands as possible during the initial construction.*
- *State and local government agencies are significant customers of telecommunication companies. (This may present a problem to outside companies if excessive fibers are relinquished to the telecommunication needs of the state and local government agencies by the contract vendor).*
- *Assess rights-of-way value up front to establish a starting point in negotiating an agreement.*
- *Because of their available rights-of-way, railroad and power companies are the major competitors to the state and local government's rights-of-way.*
- *Partnership agreements can be structured in many ways, but state and federal legislative actions (as well as local ordinances) may have an impact on the procurement process.*

CONCLUSIONS

This report has identified one existing and three planned major fiber-optic communication systems in Miami-Dade County. This demonstrates the demand in major growing metropolitan areas for higher speed communication networks. However, the full benefit and cost-effectiveness to users and providers will not be realized if planning and design of these networks continues to proceed without coordination. The intelligent transportation infrastructure being planned for Miami-Dade County is in the process of being defined, but unfortunately the communications backbone to integrate all the components is rapidly evolving now (albeit in piecemeal fashion). Based on the level of information able to be gathered in this report, the following plan of action is suggested:

1. Consolidate all telecommunication planning and design activities.
One county-level department position should be assigned the full-time duties of Communications Coordinator. This department position should have an understanding of ALL communication needs of the county, as well as a keen sense of transportation infrastructure needs. This department position must be responsible for preparing the county's telecommunications master plan (and regular updates). Coordination with and input from the Mayor's Telecity 2000 panel is also imperative. This department position would serve as the single-source of all telecommunication project information in the county, and proactively seek input from all concerned parties (particularly those agencies responsible for transportation safety and mobility.)

2. Define a "countywide" shared resources agreement for telecommunications.
With the "big picture" in mind for ALL telecommunication needs of the county, the value of right-of-way access for potential private providers can be more accurately and attractively presented. This implies that a stronger, clearer commitment to ITS-related projects for the county has to be made at the highest level. Otherwise, ITS projects (and their respective communications networks) will be disconnected. Additional attractiveness to the private sector can be gained if the needs of Broward and Palm Beach counties are included in this agreement.

3. Move current telecommunication projects to implementation.
The county's ATMS will essentially define the "arterial/collector" communication network for the ITS infrastructure, just as the ICS will identify the "freeway/expressway" aspects of the county's ITS communication network. Each has to be done with the other in mind, but both are equally vital. The county's Communication Coordinator must be capable of making both networks reach a timely implementation, with the best interests of the county in mind (a difficult task at best).

4. Bring the future better into focus.
Communication managers within the various county departments must be willing to proactively define and substantiate future growth and service needs regarding information exchange. In particular, ITS infrastructure communication needs that will benefit the county as a whole (e.g., emergency response, traveler advisory information, congestion management, etc.) must be easily understood by the public and policy makers. Generally, if one understands the "why do we need it," they will be more willing to contribute to the "how do we get it done." General awareness can also be initiated with open forum discussions led by ITD, fiber technology consultants and vendors, and FDOT.

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