Migrating to FDDI

In this report:

Fiber Optics—The Promised Medium .... -103

What is FDDI? .... -103

Characteristics of Optical Fiber .... -105

FDDI and OSI .... -106

FDDI on Twisted Pair .... -106

Switching to FDDI ..... -106

Is FDDI Really for You? .... -109

Editor's Note

Fiber Distributed Data Interface (FDDI) is a specification for a fiber optic-based local area network (LAN) operating at 100M bps. Although Ethernet, token-ring, and (to a lesser extent) Arcnet are the dominant LAN technologies today, FDDI is expected to grow dramatically as new LAN applications drive user needs for higher bandwidth.

Report Highlights

The migration from Ethernet, token-ring, and Arcnet LANs to FDDI-based LANs is just beginning. As with any new technology, the cost of entry is high. Although the benefits of FDDI (higher bandwidth, better security) are well known, justifying those entry costs can be difficult.

This report is designed to help the reader decide whether the migration to FDDI is necessary and/or possible. It will help determine whether fiber optics is a suitable medium for the network. It will examine the benfits of mixing FDDI with existing LAN technologies. It will assist in evaluating the costs of migrating to FDDI. Finally, if the migration is necessary, it will help formulate a migration plan.

This report was prepared exclusively for Datapro by Anand V. Rao. Mr. Rao is president of Rao Communications, a technology reporting service based in New York City. Rao Communications specializes in technical documentation, market analysis, and reporting.

Growing Demands on Networks

Network managers, in their unending quest to meet increased user expectations, are often forced to yield to vendor pressure and put their faith in untested technology, choosing hardware and software whose performance may not live up to promises made in the vendor's sales presentation.

The network manager is often called upon to take chances on new technology, which at first glance appears quite promising, but in reality is full of controversial elements and drawbacks. Whether an investment in a particular new technology is worth the risk—in terms of the money spent on it and the faith instilled in it—is often dictated by the specific demands of the organization. However, this is a dilemma that no technology manager can claim to have successfully overcome without suffering at least some misgivings.

This is especially true in networking and is complicated further by the changing roles of data processing and networking. Data processing has moved closer to the cost centers, and MIS managers now sit in the boardroom. Computers have increased in processing capacity and speed, and distributed computing is the norm rather than the exception. The traditional dependence on a single large computer (i.e., mainframe) for all processing needs is giving way to the development of applications that access enterprise-wide computing facilities. This has resulted in the demand for technological means to move large amounts of data efficiently and accurately through the organization.

Consequently, existing networking technology is being expanded to accommodate additional features and capabilities. These include media independence, higher bandwidth, greater spans, more connection options, integration of increasingly complex computer architectures and their implementation options, and integration of incompatible systems and faster computing engines. Network managers have to contend with all these issues to ensure continued user satisfaction with network services.

Rise of Distributed Processing

The traditional method of feeding data into one computer and trying to get all the answers from it is giving way to the distributed processing concept. Computing tasks are being broken down into smaller tasks that smaller, appropriately configured computers can handle. Applications are being written to access the services provided by a variety of computing facilities distributed throughout the organization.

As increasing numbers of desktop and portable computers and workstations are networked into computers distributed over wide geographic areas, the demand for the transmission of graphics, electronic mail, and voice mail, as well as access to a variety of databases, is increasing.

The net result of the above demands is high-performance networking. Higher performance requires high-speed links for computers and their peripherals.

Traditional Media Find It Hard to Cope

It often seems to take very little time for users to accept new technology and demand more from it, even though they may have resisted it initially. Thus, users tend to demand that everything be faster, multifunctional, reliable, and easy to use while at the same time relatively inexpensive.

User demands for increased speed, the ability to process large volumes of data, and high-quality graphics have been the prominent drivers influencing some of the most important recent innovations in networking technology. These demands have also influenced technologies now being introduced or currently under development.

Transmitting large volumes of complex data formats from one source to another over an intricate network with speed and accuracy has been a challenge for network designers and managers. The challenge is further complicated by the flexibility that users demand for transmitting data to and receiving data from the locations of their choice. All of this places a severe strain on the overall performance of the network.

Selecting the appropriate medium to meet the current and anticipated voice and data transmission requirements of the network is an issue that network managers must face eventually. It is obvious that traditional copper twisted-pair wire, which has worked well as the accepted medium for Ethernet and token-ring networks, cannot cope with the demands of high-performance networks.

Unshielded twisted-pair wiring, which has successfully accommodated transmission speeds up to 10 megabits per second (M bps) for Ethernet and 16M bps for token-ring networks, is insufficient for the multimedia domains of today's networks. However, switching to a transmission medium that accommodates higher bandwidth, such as fiber optic cable, requires careful planning and implementation. Having all that speed (10 times Ethernet and 6.25 times token-ring) is one thing, but managing it is quite another. Several nuts-and-bolts issues of a universally accepted fiber optic standard are yet to be ironed out.

Fiber Optics—The Promised Medium

Today, the issue that confronts network managers is not so much *whether* to switch to fiber optics—it is how soon, how much it will cost, and whether all or part of the network should be fiber optic.

Even before all these issues are carefully considered, many network managers worry about whether they should keep up with the rest of the industry and install fiber optics or chance being left behind in the technology race.

Some in the industry make it sound as though fiber optics is a panacea for all the ills that plague traditional media. However, a careful analysis of the investment-to-return ratio can yield some surprising results.

Fiber Optics—How Much Better?

Optical fiber uses light waves or pulses as the medium of transmission; thus, it transmits signals much faster than copper wire, which uses electrical current. However, accommodating high speed at the physical connections of a network is quite another matter.

In addition to speed, fiber optics offers other advantages. When fully developed it should eliminate the need for repeaters, amplifiers, and other intermediate equipment. Because it eliminates the problems of signal attenuation, it proves ideal for large backbone networks with unrepeated links. It is far more secure than copper twisted-pair wire, since it is much more difficult to tap into fiber optic connections. Fiber optics eliminates network noise as it is impenetrable to interference by electromagnetic and radio frequency (RF) waves. It also minimizes the effects of common problems in copper wires, such as broken cables and traffic overload.

While all this sounds very attractive, switching from twisted-pair wire to optical fiber or Fiber Distributed Data Interface (FDDI) can present several challenges. For instance, the network planner must decide whether to adopt the industry-accepted FDDI standard or one of the vendor-developed proprietary standards.

What Is FDDI?

Fiber Distributed Data Interface, or FDDI, is a fiber optic, transmission-based local area network (LAN) standard that has been under development at the American National Standards Institute (ANSI) since 1983. FDDI is an optical fiber-based version of the IEEE 802.5 standard. IEEE 802.5 defines the specifications for token-passing ring LANs, such as the IBM Token-Ring Network. However, FDDI deviates from 802.5 in several key application areas.

Besides using optical fiber as opposed to copper twisted-pair wire, FDDI employs two counter-rotating 100M bps independent rings, each providing a unique service in the transmission of data. The primary ring handles data, and the secondary ring provides backup and other services. FDDI allows the circulation of more than one packet of information, or token, through the ring at the same time, enabling it to achieve the higher data rates.

FDDI is equipped with two types of stations. The higher, or class A, station connects to both primary and secondary rings. The lower, or class B, station connects to either the primary or secondary ring; it cannot connect to both at the same time.

Standards are being finalized to specify the additional hardware, such as optic drivers, connectors, and station management systems, required at the Physical Media Dependent (PMD) standard level of FDDI. PMD specifies the characteristics of the hardware including connectors, the wavelength of the light transmitted through the medium, power requirements of the transmitters, and bypass through inactive network entities.

How Does FDDI Work?

As stated earlier, the FDDI standard is based on connecting a LAN with an optical fiber medium. It can connect LAN stations at a distance of up to 100 kilometers; the point-to-point links of each station cannot be more than 2 kilometers from each other.

FDDI follows the same methodology as IEEE 802.5 in stipulating the access method to the LAN. The data should be formatted in packets before it

Figure 1.
The Token

PA	SD	FC	ED

The "token" is a sequenced signal that grants a network station access to the LAN. It consists of four parts: Preamble (PA), Starting Delimiter (SD), Frame Control (FC), and Ending Delimiter (ED).

is transported over the LAN via tokens. A token is a uniquely sequenced signal that constantly circulates on the LAN. A station that wishes to transmit data captures the token by removing it from the ring.

The token consists of four parts.[1]

PA (Preamble): 16 or more "idle" symbols provide a pattern to establish and maintain clock synchronization among stations on the ring.

SD (Starting Delimiter): a specific pattern or explicit sequence that indicates the start of the frame or token.

FC (Frame Control): indicates that the sequence is a token.

ED (Ending Delimiter): Consists of two consecutive T symbols to indicate the end of the token frame.

When a station wants to transmit data, it captures the token and converts it into a frame. The frame consists of all the parts of the token along with source and destination addresses, an information field, and a frame status field.

DA (Destination Address): a 48-bit field that identifies the station(s) for which the frame is intended.

SA (Source Address): identifies the address of the station that originates the frame.

INFO (Information): contains the data packet.

FS (Frame status): consists of three control indicators used for error detection, address recognition, and frame copy indicator.

The station that has the token can send as many frames as it has prepared until it completes the transmission or its token-holding timer expires.

The frames are passed along to all downstream stations. Each station receives the frame and decides whether the destination address matches its ID. If it does, it copies the frame into its memory, sets the frames copied bit in the frame status indicator to C, and forwards the frame to the next station. The frame passes through all stations until it reaches the originating station.

It is the responsibility of the originating station to remove the frame from circulation and pass the token, devoid of data and additional information, along the ring.

The token-based transmission protocol is dependent on the unique characteristics of optical fiber as a transmission medium. It is best suited for point-to-point signal transmission in a ring configuration.

How Do FDDI and Token-Ring Differ?

Since both FDDI and token-ring standards use token-passing and ring wiring configurations, they work primarily the same way. However, beyond the medium and data transmission method, they differ considerably in several ways.

Multiple-Token Transmission

In FDDI, the transmitting station must free the token as soon as all frames have been transmitted or the token-holding time expires, whichever is sooner. This allows the transmission of multiple frames at the same time along the LAN. By contrast, in token-ring, only one frame can be in circulation at a given time.

Restricted Token Feature

This feature enables defined stations to shut out others to enable the system to process high-priority work. High-priority data packets can be transmitted to select stations quickly by disabling some nonpriority stations. This can be done for very brief periods, and the disabled stations can be reactivated as soon as required.

Timed Token Protocol

Low-priority messages can be removed from the network to give priority to select messages. This can be done without disabling any stations.

Two Rings

As stated earlier, FDDI is equipped with two rings, with the secondary ring acting as a backup facility.

This ring can be reprogrammed in the event of the failure of the primary ring, and data transmission can be continued without interruption.

Characteristics of Optical Fiber

Optical fiber uses light waves or pulses to transmit data; copper twisted-pair wire uses electrical signals. The use of light waves provides features that are unique to the operation of an FDDI LAN.

All attached equipment—printers, computers, terminals, bridges—should have the capability to translate to and from electrical and optical signals. This is logical since that equipment operates on electrical power and needs to originate and receive data over electrical media.

Optical fiber has three main components:

- Core—contains the optical fiber strands through which light pulses travel.
- Cladding—covers the core and consists of a dielectric material.
- Jacket—outer cover that protects the core and cladding.

Fiber optic cables are currently available in two types: single and multimode. Multimode cables have a much larger core size than the single-mode variety. However, the main difference between the two types lies in the number of light modes they can transmit at a time. A light mode is a unique optical wave that propagates in the optical fiber. The single-mode cable can accommodate one mode at a time, while the multimode cable can hold several light modes at once. While the single-mode cable uses laser as the light source, multimode cables use light-emitting diodes (LEDs).

The Role of LEDs

As stated earlier, in order to enable optical fibers to transmit data, electrical signals must be converted to light pulses at the source and reconverted to electrical signals at the destination. Currently available data originating and receiving devices are powered by electricity and as such can handle only the data that is electrically coded.

Thus, in order for the fiber optic network to function, it is necessary that the optical links be provided with an optical transmitter at the source and an optical receiver at the destination, both connected by optical fiber. The transmitter receives the electrical data signal, converts it into optical pulses, and transmits it on the optical fiber. The receiver receives the optical signal, converts it into electrical format, and passes it on to the memory of the receiving device.

A light source is required at the source for the optical transmitter to send the optical signals along the fiber. Currently available transmitters employ two types of light sources: LEDs or laser diodes. The FDDI standard recommends LEDs based on several considerations, including bandwidth, reliability, cost, and effective transmission distance.

Selecting a Suitable Fiber Optic Cable

The choice of suitable fiber optic cable is dependent upon the specific requirements of the LAN. Several factors, including the number of stations in the LAN, distance between the stations, overall length of the LAN, type of data that is transmitted, frequency of use, LAN configuration, and the match between the transmitter and optical fiber characteristics, should be considered when selecting the appropriate fiber optic cable.

The FDDI standard permits a peak data transmission of 100M bps across links. However, this is still considered a theoretical rate, and the actual rate is generally much lower.

The industry specifies sizes in defining the categories of fiber optic cables. The size is measured in microns, where a micron or micrometer is one millionth of a meter. The ratio between the size of the core diameter and the cladding diameter, expressed in microns, defines the type of fiber optic cable. The FDDI standard recognizes the following cable sizes:

- 50/125 microns
- 62.5/125 microns
- 85/125 microns
- 100/140 microns

The primary recommendation is to use 62.5/125-micron cables.

Other important features that influence cable selection include number of fibers, wavelength capacity, bandwidth, weight, maximum recommended load, maximum bend radius, type of outer jacket, and aperture number. These features are application specific and should be carefully considered depending on the design, configuration, and usage of the LAN. The selection of the appropriate cable based on one or more of the above-mentioned features can only be made by experienced and qualified experts.

FDDI and OSI

Like Ethernet, Arcnet, and token-ring, FDDI primarily specifies standards at the physical layer of the seven-layer Open Systems Interconnection (OSI) protocols. At the physical layer, the protocol specifies the minimum requirements that products designed to meet the standard must conform to in order to receive and transmit data packets that are structured by the standard. The standard does not stipulate any restrictions on how this conformity is to be achieved. Vendors can design products according to proprietary specifications as long as the products can handle standard data packets.

Vendors often employ innovative approaches in designing products according to the FDDI standard, differing considerably in how they meet the requirements.

FDDI specifies standards on how the ring should operate, maximum speed, and bandwidth. Even the methodology used to translate optical pulses to and from electrical signals can be unique to vendor-designed specifications as long as they can perform error-free translation.

Thus, if the product meets the physical interface requirements and can be plugged into the ring and perform minimum translation, transmission, and reception as per the FDDI standard, it is usually certified as conforming to the standard.

In theory, all equipment, irrespective of vendor, should be capable of interoperating successfully on a standard ring. In practice, however, this is not always possible. While equipment might coexist, that is, acknowledge each other's presence and even receive and transmit data packages (as long as they are formatted according to standards), it can still experience difficulty in meeting all aspects of the standard. This is especially true when it comes to handling a variety of source data, such as high-quality graphics and multimedia data packets.

Currently, nearly 400 vendors offer products that conform to the FDDI standard. These products include network interface cards, servers, network management stations, bridges, routers, media access units, transceivers, and optical bypass switches. Prices vary considerably from vendor to vendor. Additionally, many vendors offer extensive on-site monitoring and maintenance, licensing agreements, and warranties.

A number of considerations, including installation, warranty, backup services, training, product design and ease of use, cost, and compatibility with existing systems, should be addressed before selecting a vendor.

FDDI on Twisted Pair

While FDDI stipulates optical fiber as the accepted transmission medium, some vendors have managed to provide near-FDDI performance on twisted-pair wire. These products provide FDDI-stipulated data packet transmission in speeds up to 100M bps over twisted-pair-based LAN configurations that are designed according to FDDI specifications.

These LAN configurations and products can provide most of the features of FDDI over twisted-pair wire, with the obvious exception of the inherent advantages of optical fiber such as immunity to EMI/RF and data security.

The products are designed to meet the interface standards at the physical layer of OSI and are packed with the capabilities to meet the performance requirements of FDDI, without the need to translate from light pulses to electrical signals and vice versa. However, they require appropriate interface devices, such as interface cards, in each node/station attached to the LAN that conform to the proprietary design of the system.

While the idea of FDDI capabilities on twisted pair might sound attractive (particularly in terms of the savings gained from not having to rewire the premises with fiber optic cables), long-term issues such as upgradability and coexistence with other media (including fiber optics) have to be addressed.

Switching to FDDI

Network managers that plan to switch to fiber optic LANs or backbone networks must consider several issues before they take the leap. First, switching to FDDI involves reconfiguring the current network facilities and equipping them with FDDI-based equipment such as FDDI PC interfaces, transceivers, routers, servers, and host interfaces.

Since the migration to FDDI has been slow, the FDDI network must coexist with traditional copper wire-based networks. Additionally, most existing networks are equipped with cabling that is tailored to existing facilities, and rewiring for fiber is expensive.

Planning the Switch

Before switching to FDDI, network managers should determine whether optical fiber will serve the current and future needs of the organization and justify the investment required.

As stated earlier, it is absolutely essential to plan ahead before embracing FDDI. Plans to switch to a new technology should be preceded by a thorough analysis of the existing facility and its performance. It is not unusual to find that despite the availability of network management systems and their report generation capabilities, some network managers do not produce reports on the performance of their networks. As a first step to analyze the performance characteristics of the current network facilities, prepare the following.

Map of the Enterprise and the Location of the Network Entities. The map should identify the location of all important network entities. Identification should be followed by:

- Enterprise-specified ID number of the entity
- Manufacturer's ID number
- Brand name, year of manufacture, and other significant details
- Performance/other limitations or specifications suggested by vendor (This can be noted separately.)

General Inventory of All Network Equipment. The inventory should list all items. Note the following:

- Name of the item
- ID number. Enterprise/vendor
- Number of units installed
- Number of units available as backup

Entity/Node Performance Analysis Report. Generate a report that analyzes the performance of the various nodes of the network in the last three years. The report should include:

- How often node broke down
- How soon fault was rectified
- Reason for failure

Traffic Analysis Report. Analyze the traffic in the network as per:

- Volume of data
- Volume of voice
- Duration of high traffic during given time of day
- Volume of data/voice traffic, such as essential file transfer or special voice signal flow, during dedicated hours

Problem Analysis Report. This report enables you to gauge how well the network is performing.

- Determine various alarms, their root cause, and remedial measures
- Determine duration of network unavailability due to alarms
- Detailed trouble ticket analysis

With this documentation, a network manager can gain a thorough understanding of the reliability of the various network nodes, vendor-provided services, and usage analysis by department/type of service. Meaningful statistics generated from the reports enables the network manager to establish current trends in network use, predict future trends to a considerable degree of accuracy, plan assignments of current resources, and acquire new resources such as fiber optics.

Fiber Optic Backbone Systems

Considering that most organizations which plan to install fiber optic-based LAN systems already have considerable twisted-pair and coaxial cable-based equipment, some experts recommend a gradual migration to FDDI rather than a complete switchover.

While equipment can be installed without much difficulty, rewiring the premises for fiber optics can involve considerable effort and expense. In several cases, pulling a new wiring system can be more expensive than the cost of new materials. Thus, plans to install new wiring systems should be approached carefully.

Currently, most fiber optic LANs are installed as backbone systems that provide connection to twisted-pair and coaxial cable-based desktop systems. Fiber optic LANs are expensive and in many cases are not required at all levels of the organization. They might be more suited to specific workgroups that use applications involving high-quality graphics, full-motion video and other types of image processing, and high-priority data transfer. Fiber optic LANs are also ideal as the interface between workgroup LANs and mainframe systems.

Determining Future Growth and Network Goals

Determining the future growth of the network is as much art as science. It is subject to such unpredictable factors as business growth, the general state of the economy, natural disasters and disasters of human origin, and the performance of Wall Street. The need for additional network facilities is dependent on the growth of voice and data traffic. This in turn is determined by the growth of the organization. The network manager can determine the need for network services by the information that management can provide on future growth plans for the organization, additional data processing services likely to be added, types of business services likely to be introduced, and the number of additional phones and computing facilities to be installed.

However, it is not so difficult to determine an overall goal for the network. The goal should include:

- Eliminating existing shortcomings/problems
- Providing additional facilities
- Providing flexibility and greater access
- Eliminating additional "middle" facilities and providing direct access to users
- Automating user facilities
- Making the network easier to use
- Ensuring maximum availability and minimum downtime

Checklist to Determine Need

Whether fiber optics is required can be determined by the kinds of complaints that users voice over current facilities. They generally include:

- Slow response time
- Periodic unavailability of network services
- Overlapping user needs
- Data corruption in transmission
- Increasing system crashes due to overuse
- Too many trouble tickets
- False alarms
- Too many service calls

These signs indicate that the network is increasingly incapable of handling current traffic and may require fiber optic capabilities.

The Cost of Fiber Optics

In order to determine the financial and performance viability of installing fiber optics, network managers should focus on the following critical components of the network.

Cost of Technology

Determining the exact short- and long-term costs of technology has eluded even the most accomplished managers. While it is tempting to concentrate on the initial costs of the technology (i.e., acquiring new hardware/software and services), the long-term operating costs and various hidden or subsequent overheads are hard to determine. The cost analysis should determine the following.

Hardware: Determine the cost of all hardware/nodes to be acquired. Prepare an analysis of cost versus capacity for each component. In many cases, it is wiser to spend a little more money and acquire higher capacity, even though it may not be required immediately. Determine whether the vendors offer special upgrade deals.

Service: All vendor-supplied service costs should be thoroughly analyzed for the type of facilities provided. This should be further matched with the performance guarantees provided and the penalties the vendors are prepared to bear for failure to perform to contract obligations.

Personnel: Determine whether the new facilities can be managed by existing personnel or if new personnel must be recruited. Determine:

- Number of new personnel required
- Salaries and other compensations
- Cost of training existing personnel

Monthly Line/Operating Costs: Match the current line/operating costs with projected costs in terms of:

- Tariff/routing ratio and least-cost routing analysis
- Analysis of operating costs for design options available

Wiring/Installation Costs

While the installation cost of fiber is coming down, the cable itself is still very expensive. The network manager has the option to install full or partial fiber cables depending upon network needs. He or she can further decide to install fiber optic sheaths throughout the facility and selectively install fiber, leaving the rest of the sheaths for later fiber installation.

Layout Remodeling

Depending upon the existing physical layout, it may be necessary to remodel to accommodate fiber optic cables. This expenditure is layout specific and can be substantial depending upon the requirements.

Current FDDI Costs

While they are coming down rapidly, current costs of FDDI are quite high. FDDI requires several components, such as FDDI PC interfaces, routers, servers, and hosts with FDDI interfaces, that are several times more expensive than comparable equipment compatible with Ethernet and token-ring standards.

PCs are still much slower than the transmission speeds available for Ethernet and token-ring LANs. Thus, the user should not expect dramatic increases in the transmission speed of data originating from PCs configured with FDDI interfaces. However, substantial speed increases can be achieved in workstations.

The most important advantage of FDDI lies in its capability to provide access to more users on a single network than either Ethernet or token-ring can provide. Generally, Ethernet and token-ring networks require bridges and routers to connect more than 190 users per network. It is estimated that the average cost of bridges and/or routers ranges from $5,000 to $6,500 per 10 to 50 users on Ethernet and token-ring networks. Eliminating this cost can result in substantial savings.

The cost of FDDI interface cards currently ranges from $2,500 to $3,500. Since not every PC on the network may need these, FDDI can be attractive even to first-time users.

It may be viable for some users to selectively install FDDI in some segments of the facility and provide interfaces to Ethernet and token-ring routing over FDDI for the rest. This requires routers with FDDI interfaces, which are currently quite expensive; the estimated cost for these devices is over $30,000 per router. Whether such costs can be justified depends entirely on the projected need for the extra facility.

Is FDDI Really for You?

The answer to this question depends on the need for high bandwidth and the future growth plans for the network. It is generally agreed that if LANs currently service fewer than 100 PCs or workstations, and the number is unlikely to rise in the near future, FDDI may not prove cost effective. However, if the applied load across the network (number of packets/tokens per second) increases dramatically, then FDDI can be an attractive proposition even if the number of PCs/workstations remains the same.

However, if both the work load and the number of connections increase dramatically, network managers can plan for a hybrid network consisting of existing Ethernet or token-ring networks and FDDI.

Unfortunately, a clear answer to the question eludes simplification. A thorough analysis of existing and projected network needs, based on the guidelines stated previously and relating to the overall goals of the network, can provide some clues as to whether FDDI is really for you.

Despite the rapid acceptance of FDDI and a considerable decrease in the cost of fiber optic cables and components, it is unlikely that coaxial cable and twisted-pair wire will become obsolete anytime soon. It appears that for the foreseeable future, all three media types will coexist as users wrestle with the decision to migrate to FDDI.

References

[1]FDDI Overview for the Non-Technical Manager. (IN-Net Corp. San Diego. CA 92128-3495) ■