WHITE PAPER

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FDDI Connectivity

For the last few years, Fiber Distributed Data Interface (FDDI) has enjoyed the distinction of being the only high-speed networking technology on which you could base an enterprise network. FDDI is standards based and has broad vendor and product support. In addition, switches and routers, which are needed to incorporate any new network technology into an existing network, are readily available from a number of vendors.

Today, FDDI is a mature network technology with defined standards. New emerging networking standards like Asynchronous Transfer Mode (ATM) and the various proposed Fast Ethernet standards will eventually give customers more options in choosing the "best" high-speed networking technology, but FDDI will continue to be important. It has technical features like fault tolerance and integrated network management which make it the preferred technology for any mission critical applications or services. This paper provides a brief overview of the basic features, benefits and methods for installing and using FDDI. Detailed information on how FDDI works is provided so readers will gain a greater comfort level with FDDI technology and an awareness of the issues which may arise when FDDI is actually implemented.

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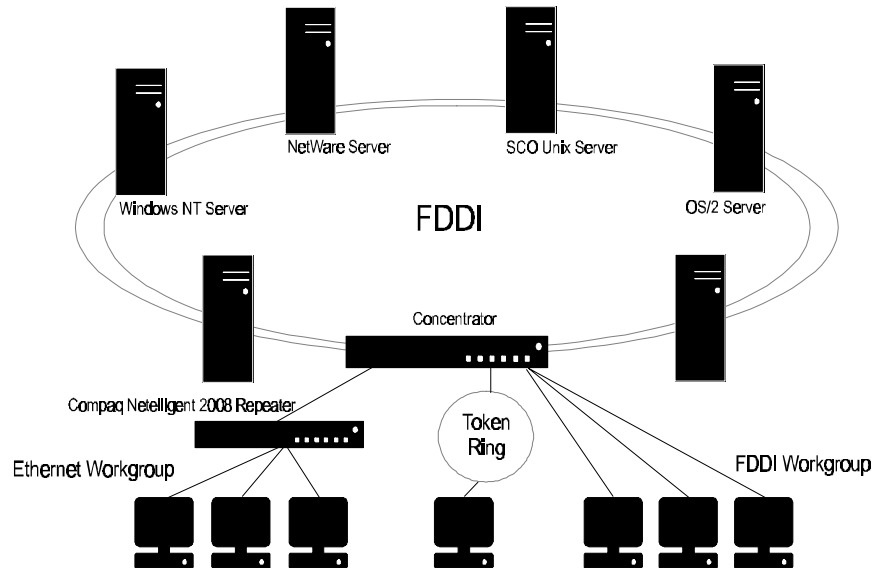
FDDI BACKGROUND

Figure 1

The Need for Higher Speed LANs

As networks have grown in size and the amount of mission critical data on the network has increased, the performance limitations of traditional network technologies like Ethernet and Token Ring have become obvious. Also, the migration of local area network (LAN) workgroup resources to centrally managed corporate backbones has accentuated the problem by increasing and concentrating the network traffic.

The two most common performance bottlenecks in Ethernet and Token Ring LANs are the network interface and the network itself.

In the case of the network interface, modern computers are capable of transferring data much faster than the 10 megabits per second (Mb/s) on Ethernet or the 16 Mb/s of Token Ring.

The network overall is a bottleneck because all of the devices, none of which are operating at peak throughput, have to share the limited bandwidth.

FDDI TECHNOLOGY

FDDI Basics

FDDI is an American National Standards Institute (ANSI) networking standard. Parts of the FDDI standard have also been adopted by the International Standards Organization (ISO) and are ISO standards as well. ANSI began work on the FDDI standardization in 1982. Although some parts of FDDI continue to evolve, most of the key elements of FDDI were defined in a first version in 1989 when products first started shipping.

Because FDDI is a mature, standards based networking technology, it is easy to mix FDDI products from different vendors. To ensure Interoperability, FDDI vendors test their products at

the Advanced Network Test Center (ANTC) or the University of New Hampshire Interoperability Lab which are independent organizations which perform multi-vendor Interoperability testing.

In terms of the role FDDI plays in a LAN, FDDI is comparable to other network topologies. In the familiar ISO Open Systems Interconnection (OSI) seven layer model, FDDI occupies the same layers as Ethernet and Token Ring. Because FDDI occupies the same OSI layers as Ethernet and Token Ring, the same applications and services that run on those topologies will also run on FDDI.

COMPARISON OF FDDI, ETHERNET AND TOKEN RING

Feature	FDDI	Ethernet	Token Ring
Raw data rate	100 Mb/s	10 Mb/s	4 and 16 Mb/s
Supported media	Fiber, Shielded Twisted Pair (STP), Category 5 Unshielded Twisted Pair (UTP)	Coax, UTP, STP, fiber	STP, UTP, fiber
Clocking	Distributed transmit and receive clocks	N/A	Centralized active ring monitor
Max. frame size	4500 bytes	1518 bytes	4500 bytes (4Mb/s) 17800 bytes (16Mb/s)
Priority levels	Synchronous 8 levels of async	No priority	8 levels between stations
Access protocol	Token passing – timed token rotation protocol	CSMA/CD	Token passing
Maximum of nodes	1000 connections (500 if all are dual attached)	1024	260
Topology	Logical dual-ring or dual-ring of trees	Bus	Logical single ring
Physical topology	Ring, hierarchical star, star	Star, bus, hierarchical star	Ring, star

Table 1

Although the logical role that FDDI plays in a network is comparable to Ethernet and Token Ring, there are significant technical differences between the technologies which are summarized in Table 1.

The main thing that distinguishes FDDI from traditional networks like Ethernet and Token Ring is network speed. While Ethernet is rated at 10 megabits per second (Mb/s) and Token Ring at 4 or 16 Mb/s, FDDI has a data rate of 100 Mb/s. FDDI uses a very efficient token passing protocol to control access to the network, so 100 Mb/s is very close to the real network throughput. For networks of any size, the effective throughput of 10 Mb/s Ethernet and 16 Mb/s Token Ring are 4 Mb/s and 12 Mb/s, respectively. In simple terms, FDDI can be viewed as a much larger network pipe which has much more usable capacity.

The two most common applications of FDDI are in high performance FDDI workgroups and on the network backbone. FDDI offers integrated network management and fault tolerance which translates into high network reliability and availability.

FDDI TECHNOLOGY - HOW DOES IT WORK?

FDDI Standards for Network Media

Although the 'F' in FDDI stands for 'Fiber,' FDDI runs on a wide variety of network media including copper media that can be mixed and matched within the same network.

Currently, the most common media used for FDDI is glass Multimode Fiber (MMF) with a 62.5 micron core and 125 micron cladding (referred to as 62.5/125 μm MMF) as shown in Figure 2. Fiber media has some basic advantages over copper media, for example:

Fiber cable information

Protective covering

Cladding diameter

Core

Standard multimode fiber sizes:
62.5/125 micron*
50/125 micron
100/140 micron
*recommended

Figure 2

1. Fiber media supports for greater node-to-node distances

2. It is immune to electromagnetic interference and

3. It does not generate any electromagnetic interference

The maximum node-to-node distance on multimode fiber is 2 km (1.2 miles). For even greater node-to-node distances up to 60 km (37 miles), FDDI can run on Single Mode Fiber (SMF). SMF devices are generally much more expensive than MMF devices.

The demand for FDDI over existing network cabling led to the development of FDDI over copper media. FDDI runs at the same speed regardless of the media used. When using copper media, the tradeoffs are:

1. Reduced node-to-node distances

2. Exposure to electromagnetic noise

3. Copper is not allowed in the main ring.

However, copper based FDDI products are less expensive than their fiber counterparts.

In December of 1993, the technical specification for running FDDI over Unshielded Twisted Pair (UTP) cabling was finalized by ANSI and called TP-PMD (Twisted Pair -Physical Media Dependent) v2.0. TP-PMD v2.2 is the latest version of the specification and is the result of editorial changes made in March 1995. The TP-PMD specification defines running FDDI on Category 5 UTP. TP-PMD is important because it allows FDDI to run over existing Ethernet cabling that implements all four pairs. The pinout is somewhat different since Ethernet uses pairs 1,2 and 3,6, while FDDI uses pairs 1,2 and 7,8. Existing Ethernet installs should be tested to ensure the FDDI pairs are functional. The encoding scheme used is called MLT-3, and so, TP-PMD and MLT-3 are often used interchangeably.

For Token Ring cable plants, there are three different standards for running FDDI over Shielded Twisted Pair (STP): TP-PMD v2.2, SDDI and 'Green Book' STP. The TP-PMD specification for UTP mentioned above also defines a method for running FDDI over STP. Both SDDI and 'Green Book' STP are early ad hoc specifications. SDDI was developed by IBM, and 'Green Book' was developed by a number of different companies. Both SDDI and 'Green Book' enjoy fairly wide acceptance in the FDDI marketplace, but TP-PMD is the ANSI standard, and it will become the dominant FDDI over STP standard.
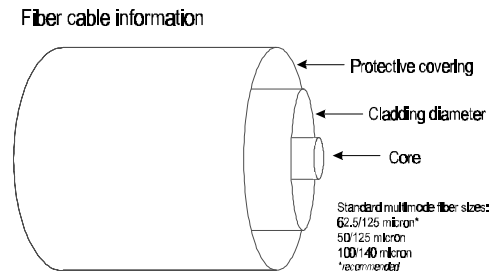
MEDIA SUPPORTED BY FDDI

Feature	Supported Media	Node-to-Node Distance
FDDI Multimode fiBer PMD	62.5/125 µm MMF, 100/140 µm MMF	2 km for 62.5/125 µm MMF
TP-PMD	IBM Type 1,2 and 6 STP, Category 5 UTP	100 m
IBM SDDI	IBM Type 1,2 and 6 STP	100 m
'Green Book'	IBM Type 1,2 and 6 STP	100 m

Table 2

FDDI's Dual Ring

The basic structure in an FDDI network is a dual ring as pictured in Figure 3. In the dual ring, one ring is the primary and the other ring is the secondary ring. When the primary ring is operational, the network traffic circulates on the primary ring and the secondary ring is inactive. In Figure 3, there are four stations on the dual ring. Note that there are two data paths into and out of each station. The importance of the redundant data path provided by the secondary ring will become clear when fault tolerance is discussed later.
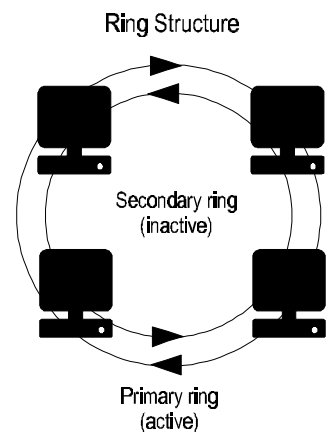
FDDI TOPOLOGY

FDDI Station Types

In an FDDI network, there are four basic station types: Dual Attach Station (DAS), Single Attach Station (SAS), Dual Attach Concentrator (DAC) and Single Attach Concentrator (SAC). Figure 4 shows the four basic station types in a network. "Stations" are typically computers, routers, bridges, etc. "Concentrators" in an FDDI network are similar in function to hubs in 10 Base-T networks. Concentrators act as central connection points onto the network.

On the FDDI dual ring, you can only have dual attachment devices (DASs or DACs). Also, these DAS and DAC devices must be connected with fiber. Single attach devices (SASs and SACs) connect to an FDDI concentrator as pictured
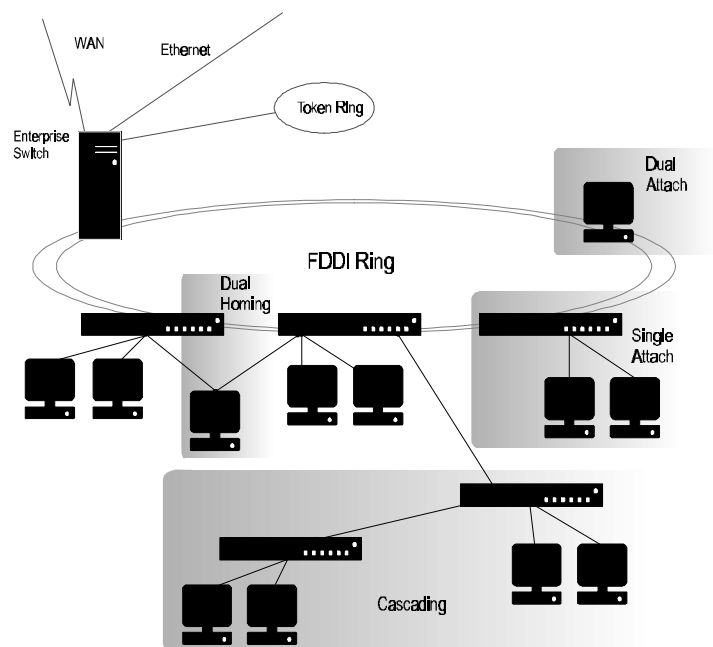

Figure 3

Figure 4

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in Figure 4. These devices can be connected with copper or fiber. Off of the dual ring, concentrators can be cascaded to create hierarchical star networks.

An alternative connection type for dual attachment devices is called 'dual homing' and is pictured in Figure 4. When a DAS (or DAC) is dual homed, it is connected to two different concentrators. Connecting to two different concentrators allows for redundant data paths into the dual homed device providing fault tolerance. In a dual homed connection, one concentrator connection is active and the other is used as a backup. If there is a problem with the active connection, the device will automatically switch to the connection on the backup concentrator without disrupting network service. Dual homed devices can be connected with either copper or fiber.

FDDI ADVANCED FEATURES

An overview of FDDI Features

In addition to FDDI's high throughput, FDDI has a number of advanced features which make it an ideal networking technology for high reliability, mission critical LANs. Two of the advanced features are FDDI's integrated network management and fault tolerance.

Integrated Network Management

As many network managers are discovering, network management systems are valuable tools for monitoring and troubleshooting the network. On most LAN topologies, network management is something that is added onto the network in the form of SNMP (Simple Network Management Protocol). On the other hand, FDDI has sophisticated network management and monitoring capabilities designed into the network specification. Because management is integrated into FDDI, the facilities are designed specifically to manage an FDDI network.

Every node on an FDDI network has Station Management (SMT). SMT can be implemented in software or firmware. The SMT in each station monitors the FDDI network at the link, node and network level. Table 3 summarizes the monitoring and management functions of SMT.

In Table 3, note that the network level functions include remote management protocols. The SMT remote management services are similar to SNMP services in that you can get and set various networking parameters, but unlike SNMP, you do not need an upper layer network protocol like TCP/IP because the services are part of FDDI.

One way to use FDDI's network management facilities is through an SMT network management console. SMT network managers are available from a number of different vendors and are similar to SNMP management consoles except they use SMT rather

SMT MANAGEMENT FUNCTIONS

Link level functions	
	Connection management
	Fault isolation and recover
	Statistics gathering
	Noise and error monitoring
Node level functions	
	Station insertion/removal
	Station initialization
	Configuration management
	Fault isolation and recovery
	Statistics gathering
Network level functions	
	Remote management protocols
	Fault isolation and recovery
	Duplication detection and resolution
	Statistics gathering

Table 3

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than SNMP services.

If you are already using an SNMP management console, you can manage all FDDI stations which implement SNMP, but you can also manage FDDI stations that do not implement SNMP through the use of an SMT proxy agent. The SMT proxy agent translates the console's SNMP requests to equivalent SMT requests. Proxy agents are relatively new, so they are just coming onto the market.

Fault Tolerance Fault tolerance is one of the features which is possible because SMT is constantly monitoring the network status.

Figure 5
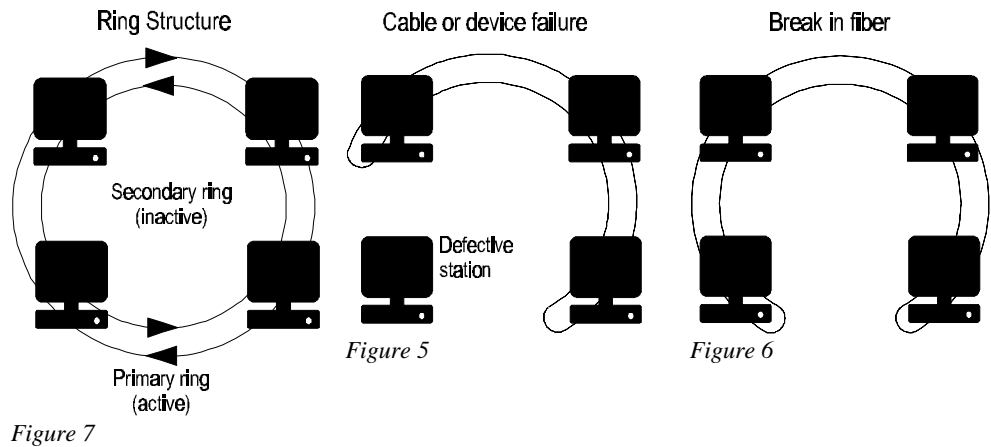
Figure 6

Figure 7

For dual attachment devices on the dual ring, fault tolerance is a standard feature. In the simple network in Figure 7, the four DAS nodes have redundant data paths: each station can send and receive data on the primary and secondary ring

If a station on the network is turned off or malfunctions, the adjacent stations will detect the error and automatically reconfigure the network around the fault without disrupting normal network service as shown in Figure 5. In Figure 5, the network configuration is called a "ring wrap". Whenever there is a network fault, SMT management consoles will be notified with an appropriate SMT frame.
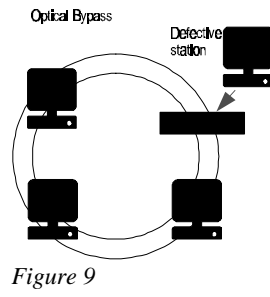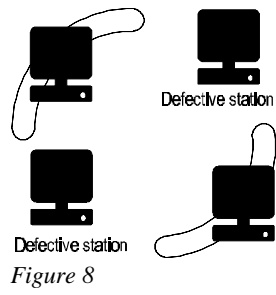
If a cable fault occurs in the ring, the adjacent stations will again detect the fault and automatically wrap the network around the fault as shown in Figure 6. In this case as well, the fault recovery will be automatic and any management stations will be notified.

If there are multiple faults on the dual ring, the stations will "wrap" around the faults as before, but with multiple faults, there is potential for ring segmentation. In Figure 8, there are two station faults. Although all the other machines are still functioning, the network has been divided into two separate rings. To prevent ring segmentation on fiber based networks, optical bypass switches can be used to bypass a faulty station as in Figure 9. Note that an optical bypass is of limited use if there are multiple cable faults on the network.

FDDI CONNECTIVITY *(cont.)*

Figure 8   *Figure 9*

As described earlier, a dual homing device provides a fault tolerant connection to the network. In a dual homed configuration, concentrators perform fault tolerance and fault isolation functions. In a dual homed connection, the primary concentrator can fail completely, and the network will continue to operate properly (see Figure 10).

The most practical fault tolerant network designs mix dual attachment and dual homing. In addition, fiber and copper media can be mixed to provide a balance of cost effectiveness and security.

Figure 10

HOW TO BUILD FDDI LANS

Incorporating FDDI into Existing Networks

Today the most common application of FDDI is on the network backbone although more FDDI is being deployed to the desktop. Adding an FDDI backbone to an existing network has a number of benefits:

- FDDI's fault tolerance and integrated network management promotes greater network reliability and manageability.

- FDDI's greater throughput will alleviate or eliminate any network bottlenecks or network congestion problems.

- File and database servers on the backbone will have greater throughput and will be able to service more users reducing the overall number of servers.

- FDDI's greater throughput allows backups over the network at local backup device speeds reducing the number of required backup devices and allowing centralized backup services.

The above benefits are fairly obvious, but the point about backups deserves more explanation. When backing up data on one machine to a backup device on another machine over Ethernet, the remote machine will typically be backed up at a rate of 7 to 15 MBytes per minute (MB/m) regardless of the speed of the backup device. Assuming that Ethernet's throughput is about 40% of its bandwidth or 4 Mb/s, a backup rate of 15 MB/ m (2 Mb/s) uses about 50% of Ethernet's usable bandwidth. High end tape drives like 8mm and Digital Linear Tape (DLT) drives can backup at rates in the range of 35 to 70 MB/m. When backing up over FDDI, those devices can still backup at those rates. Assuming a single tape device has a backup rate of 50 MB/m (6.7 Mb/s) over FDDI, it will be utilizing less than 7% of FDDI's effective bandwidth, so there is still plenty of band-width available on the network.

When building an FDDI backbone, all the corporate file servers, database servers, communication servers and other corporate devices should be moved to the backbone. Moving departmental servers or any local resources to the backbone is optional.

Once the question of what devices will be moved to FDDI has been answered, the next question is how to get from the existing LAN to the FDDI backbone. There are two answers:

1. Bridge the existing LAN to FDDI or
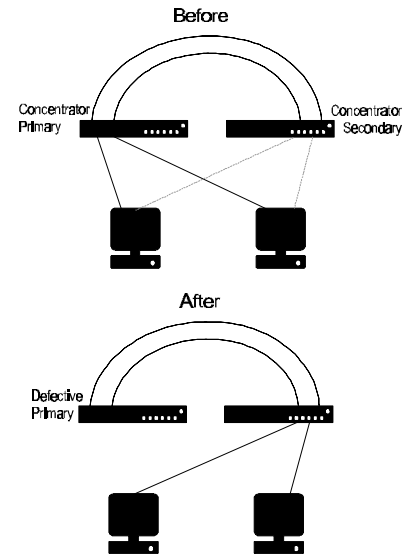
2. Route the existing LAN to FDDI

Whether bridging or routing is the best solution depends on the specific details of the network. From a product standpoint, there are products for all different needs and applications from reasonably priced low end products to high performance, high end products. Connecting an existing network to FDDI is very easy. In fact, most hub vendors have some sort of FDDI connectivity solution for their hubs, so connecting to FDDI may be as simple as adding a new hub card.

When installed, the resulting network will probably look something like Figure 11 where there is a server farm and the backbone runs up the building.

For a network that spans multiple buildings, all the buildings can share the same backbone or multiple building backbones can feed a central campus backbone (see Figure 12).

NETWORKING AND FDDI

Building an FDDI Server Farm

An effective FDDI backbone relies on the concept of consolidating the various corporate servers into server farms. When building a server farm, the two main factors that need to be weighed are level of fault tolerance and cost . Usually, a mixture of the three basic connection types is the most cost effective.

1. **Dual homing to two concentrators** – Dual homing offers the greatest level of fault tolerance, but it is also the most expensive to implement because there is the cost of the dual attachment interfaces and the cost of the dual concentrator ports. Typically, mission critical servers and devices like bridges and routers are dual homed or dual attached.
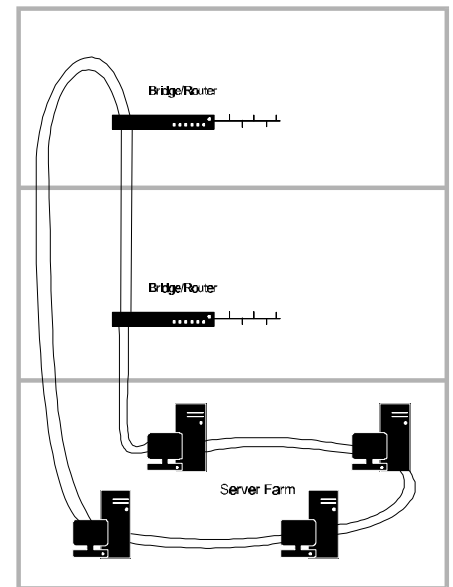

Figure 11

1. **Dual Attachment to the dual ring** – This configuration offers fault tolerance, but it will not recover from multiple failures. In som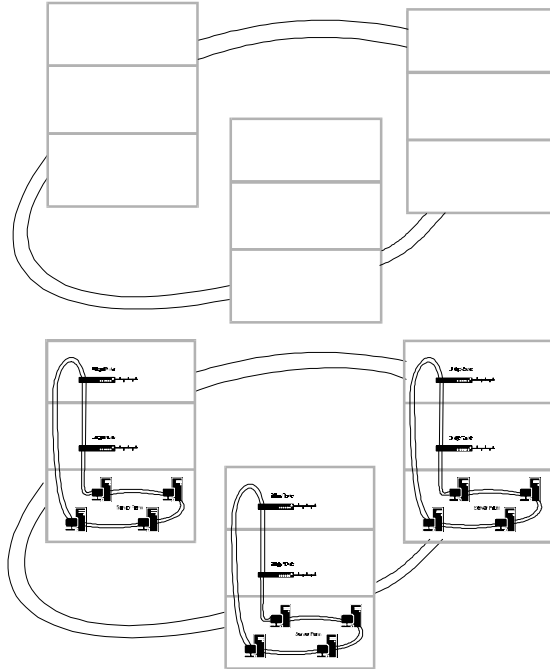e situations, the fault tolerance of the dual ring is sufficient because the backbone is in a controlled, stable environment. Unless optical bypasses are employed, it is generally a good idea to minimize the number of devices directly on the dual ring to reduce the risk of ring segmentation. For very small backbones, dual attachment is often the most cost effective configuration because there is no need for a concentrator. Again, mission critical servers and devices like bridges and routers should be dual attached or dual homed.

Figure 12

2. **Single Attachment to a single concentrator** – Single attachment offers FDDI's speed advantage and fault isolation properties, but it does not offer fault tolerance or fault recovery like dual homing or dual attachment. In situations where the backbone is in a controlled environment and faults are unlikely, single attachment is the most cost effective strategy since single attachment interfaces are less expensive than their dual attachment counter-parts. Devices which are likely to be down some of the time but require FDDI's speed like user workstations should be single attached.

INTERNETWORKING AND FDDI

Network Protocols on FDDI

NETWORK PROTOCOL FRAME TYPES

Protocol	FDDI Frame Type
TCP/IP	SNAP
OSI	802.2 LLC
DECNET	SNAP
Apple Talk (FDDI Talk	SNAP
NetBEUI	802.2 LLC
IPX	SNAP, 802.2 LLC, and 'RAW'

Table 4

To this point, we have concentrated on the features of FDDI exclusive of any exchange of real data. For any LAN technology to be useful, machines on the LAN have to be able to exchange data which means using a network protocol like Novell's IPX or TCP/IP.

For network data, FDDI has two basic frame types: frames with an 802.2 LLC header and frames with SNAP headers. For all network protocols except IPX, there is a standard which defines the FDDI frame type used for that protocol. On FDDI, IPX can run on several frame types as it does on Ethernet. Table 4 lists popular protocols and the defined FDDI frame type.

Internetworking FDDI and Ethernet

You can Internetwork an FDDI LAN to an Ethernet LAN with either a bridge or router. Both bridging and routing FDDI is generally Plug and Play, but there are a few issues worth noting.

Since Novell's IPX protocol runs on four different Ethernet frame types, the IPX Ethernet frame type is important because the frame types are bridged differently. Table 5 summarizes the Ethernet IPX frame types and the bridged FDDI equivalents.In March 1993, Novell announced that it is phasing out "raw" frame types. In NetWare v4.x, the FDDI_RAW frame type is no

FDDI AND ETHERNET FRAME TRANSLATIONS FOR BRIDGED IPX

Ethernet IPX Frame	FDDI IPX Frame	Notes
ETHERNET_802.2	FDDI_802.2	
ETHERNET_II	FDDI_SNAP	
ETHERNET_802.2	FDDI_RAW	Novell is eliminating "raw" frame types and FDDI_RAW will no longer be supported
ETHERNET_SNAP	FDDI_SNAP	Bridge may need special configuration

Table 5

longer supported. The implication for sites running ETHERNET_802.3 IPX is the frame type for IPX Ethernet nodes need to be changed before IPX can be bridged to NetWare v4.x servers on FDDI. Note that routing of ETHERNET_802.3 will still be possible.

Both ETHERNET_II and ETHERNET_SNAP IPX frames are translated to FDDI_SNAP frames. When bridging from FDDI back to Ethernet, bridges normally bridge FDDI_SNAP frames to ETHERNET_II. Most bridges can be configured to bridge IPX on FDDI_SNAP to ETHERNET_SNAP.

Most network protocols negotiate a common frame size. One exception to this is TCP/IP's User Datagram Protocol (UDP). FDDI's maximum frame size is 4500 bytes and, Ethernet's is 1514 bytes, so there is a significant difference in the allowable maximum packet size. In networks where TCP/IP traffic will be bridged, IP fragmentation is an important bridge feature because oversized FDDI TCP/IP frames are split into smaller frames appropriate for Ethernet. If a bridge does not support IP fragmentation, bridging FDDI and Ethernet is still possible, but the maximum frame size on FDDI should be reduced to the Ethernet maximum constraining FDDI.

Because routers operate at the network protocol layer, the only real consideration when routing Ethernet and FDDI is whether the router supports the desired network protocol. Some routers only support a limited number of frame types for IPX which is also a consideration. IP routers perform IP fragmentation, so the difference in FDDI's and Ethernet's frame sizes is not an issue. Some network protocols like NetBEUI are not routable, so bridging is the only option.

Internetworking FDDI and Token Ring

Bridging Token Ring to FDDI (and Ethernet) can be problematic because the address representations in the protocol headers are different. Bridges do not change protocol headers when translating frames. For protocols like IPX, you can select which representation to use in the protocol headers, but for TCP/IP's Address Resolution Protocol (ARP), this is usually not possible.

Because of the difficulties in bridging Token Ring, Token Ring is usually routed to FDDI. As is the case for Ethernet, the only real issues are whether the required protocol is supported and if the required IPX frame type is supported.

DIRECTIONS OF FDDI

Emerging FDDI Technologies

Although FDDI is a mature technology, new features are being added to support multimedia applications.

FDDI supports two types of network traffic: asynchronous and synchronous. Both asynchronous and synchronous traffic can coexist on the same network. Today, all FDDI traffic is asynchronous and is fine for most networking applications. Synchronous or asynchronous FDDI is a different mode of transmission onto the network in which stations have guaranteed bandwidth and guaranteed latency which is critical for multimedia applications like real-time voice or video. The synchronous mode of transmission has always been a part of the FDDI standard, but it was not complete in all the implementation details. The FDDI Synchronous Forum, a multi-vendor industry workgroup which studies issues relating to synchronous network traffic, has published the FDDI Synchronous Forum "Implementer's Agreement" (IA) which fills in the missing details. In the IA, an application called a Synchronous Bandwidth Allocator (SBA) is defined which is responsible for overall synchronous traffic management. The IA also defines a set of services called End Station Support (ESS) that are required to make use of the SBA and synchronous traffic.

If the hardware can support synchronous transmission, the SBA and ESS are simply driver updates. If the hardware cannot support synchronous traffic, it will be limited to only sending asynchronous traffic

FUTURE DIRECTIONS AND FDDI

The future of FDDI: as has been the case since FDDI products first appeared in 1989, the cost of implementing FDDI continues to decrease. Higher design integration and increasing production volume will lower manufacturing costs.

Even after new network technologies are standardized, FDDI will continue to be important because its advanced technical features make it ideal and cost effective for a variety of applications.

Additional FDDI Reading

The ANSI X3T9.5 Documents which define FDDI. (Many of the ANSI documents are available in text and in Postscript form via anonymous FTP from NIS.NSF.NET at 35.1.1.48 under / working. groups/fddi.)

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Shah, Amit and G. Ramakrishnan, FDDI:- A High-speed Network, PTR Prentice-Hall, Inc., Englewood Cliffs, NJ, 1994.

RFC 1512 - Defines SNMP MIB Objects for SMT v7.3 MIB.