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FEATURES, ARCHITECTURE AND APPLICATIONS OF FDDI- AN OPTICAL FIBER BASED HIGH SPEED LAN

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Abstract- **Fiber Distributed Data Interface (FDDI) is an important step in the evolution of data communication networks, which have been progressing tremendously since the last two decades. FDDI is a packet transmission network. Synchronous packet transfer defines a guaranteed maximum bandwidth and a maximum access delay for the transmission in communication channel. The packet switching mode of operation is not suitable for handling circuit-switched applications that require isochronous service. Isochronous traffic requires, in addition to a guaranteed bandwidth, a fixed delay between successive transmission opportunities as well as a fixed transmission duration. To overcome these problems FDDI-II HRC project was initiated in 1985. FDDI-II can be defined as a network that combines synchronous and asynchronous packet transmission with isochronous channels. Some applications such as video and multimedia require the isochronous type service.**

The aim of this study is to provide an overview of FDDI and FDDI-II. First network configuration of FDDI and FDDI-II is introduced. Then FDDI protocols and transmission media are discussed. The paper concludes with a look at FDDI applications, internetworking methods and how FDDI can be used in various internetworking applications.

1. FDDI - OPTICAL DISTRIBUTED DATA INTERFACE

FDDI is a standard that provides data transmission with a rate of 100 Mbps. FDDI is the first applied network architecture whose standards were established at the beginning. It is based on dual ring architecture and optical fiber transmission medium. Although the first studies began in the early 1980s. FDDI is produced considering 1990s technology and fiber transmission medium.

The first studies about FDDI MAC and PHY layers were made in 1984 and FDDI MAC was approved by ANSI as a standard in 1986. PHY and PMD layers were also completed and approved at the end of 1986. To provide voice and video transmission. which are not possible in FDDI, as well as data transmission development of FDDI-II standard was also started during these studies. FDDI-II is capable of executing packet switched and circuit switched services synchronously.

1.1. Features and Network Configuration

The most important features of FDDI are as follows:

- Optical fiber based network with high transmission rate and flexibility
- A structure based on token passing protocols
- Fault tolerant dual ring architecture
- Ability to support up to 500 stations
- Ring length of more than 100km
- Possibility of 2 km distances between stations

There are equally authorized stations which do not need a central master station in FDDI networks. Its configuration is in the form of two token ring working in opposite directions. Primary ring transmits data. Secondary ring is not normally used in data transmission but is used for the reconfiguration of the system by attaching stations to one other when a failure occurs. Basic FDDI network is shown in Fig.1.

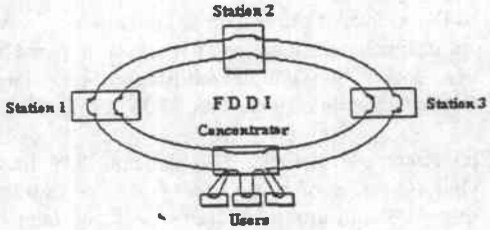

Figure 1. Basic FDDI Network

Similar to other local area networks data is transmitted in the form of frames or packets. FDDI uses Token Passing Protocols with ring topology. As well as higher transmission rates and increasing timing and control requests, the thought of creating a topology where a number of stations are distributed instead of a central environment provided the usage of an enhanced version of IEEE 802.5 Token Ring standards [1].

1.2. FDDI Station Types

There are two types of stations in FDDI: Type A and Type B. Type A stations are attached to both rings and have the ability of isolating the fault by connecting the rings to each other when a link failure occurs. These stations are called DAS- Dual Attachment Stations. Type B stations are attached only to primary ring. This attachment, which is called Single Attachment Station or shortly SAS, has a lower cost and less functionality. Attachment of both types to FDDI ring is shown in Fig.2. In addition, Ring Wiring Concentrator (RWC) connects Type B stations in a star topology.

The stations connected to the ring via RWC can attach to only one ring.

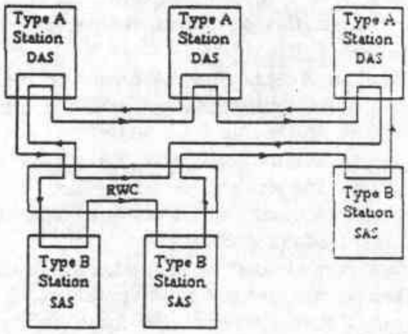

Figure 2. FDDI Ring Configuration

In the above example SAS stations can attach to the secondary ring. Since this property provides the usage of secondary ring for data communication, the amount of data transmission will increase. On the other hand, unless there is a bridge between primary and secondary rings, communication of a SAS station on the primary ring with any station on the secondary ring is impossible.

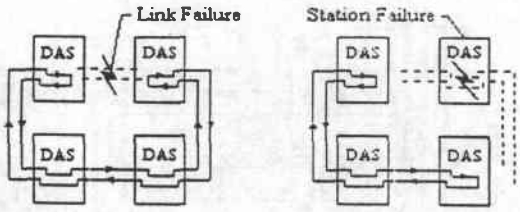

Figure 3. Reconfiguration of FDDI Ring in Link and Station Failures

Every station connected to FDDI network provides the signal continuity on the ring. In the case of a station failure other stations detect this and reconfiguring the ring, they provide a continuous communication. SAS stations cannot make this reconfiguration. Only the stations that are attached to both rings and that have appropriate MAC protocols can overcome this type of problem. Fig.3 shows how the ring reconfiguration is achieved in cases of link and station failures[1,2].

1.3. Ring Synchronization in FDDI Networks

FDDI uses three timers in every station to achieve synchronous traffic. The first one is Token Rotation Timer TRT. It shows the duration for the return of the token to the same station where it was released. Target Token Rotation Timer TTRT is given by specifications and determines the maximum waiting time of a station to receive the token again. TTRT has a value that varies from 4ms to 165ms. Recommended optimum value is 8ms. The third timer called Token Hold Timer THT determines the duration that a station can hold the token.

When a station receives the token, it compares TRT with TTRT. If TRT has a small value, it continues transmitting frames until duration reaches the value of TTRT. TTRT-TRT=THT for this process and the ring continues its normal function. A high value of TRT shows a very high load on the ring. Increase in TRT value up to twice of TTRT value is a fault signal and must be reported to LAN administrator. Being connected to the ring, a station reports its requested TTRT value to ring master. Ring master compares the values of all stations and provides the minimum requested TTRT value [2].

Finishing data transmission, station releases the token without waiting to receive new data. This is called 'early release'.

Briefly,

- There is always only one token on the ring.
- Station that receives the token has a right to transmit synchronous frame.
- When the token is received by a station if THT value is positive, data frames can be transmitted until the time is up.
- Every station releases the token after finishing the transmission.
- Due to the link delay more than one frame can exist on the ring at the same time, but there must be only one token.
- Stations are responsible from taking their own frames back from the ring after transmission.

2. ADVANCED OPTICAL DISTRIBUTED DATA INTERFACE: FDDI-II

In addition to packet switched services of basic FDDI standard FDDI-II was developed in 1985 to achieve circuit switched services as well. A circuit switched connection can be established between two stations with FDDI-II at a constant data transmission rate. Instead of transmitting addresses in frames a connection depending on pre-arrangement can be made.

Transmitting 125 μs cycles on the ring, FDDI-II provides circuit switched services. Establisment of a circuit switched connection requires regularly repeated time slots in the frame. FDDI-II is an advanced set of FDDI standard with differences being as follows:

- PHY physical layer standard was enhanced under the name of PHY-2
- Medium access control standard was enhanced as MAC-2
- A new HRC hybrid ring control standard and H-MUX hybrid multiplexer were developed for isochronous multiplexing.
- A special frame structure controlled by a specific station known as cycle master was developed.
- Cycles consist of a constant number of 8 bit time slots that are repeated in every 125μs. This feature provides ability of covering the units that are reserved for isochronous bandwidth on the ring which have channels with capacities varying from 8Kbps to 6Mbps.
- Since SMT station management services are not enough for the functionality of FDDI-II. SMT is enhanced as SMT-2 [3].

3. LAYERED ARCHITECTURE of FDDI and FDDI-II

The relation of FDDI layered network architecture developed by the Committee of ANSI X3T9.5 with the lowest two layers of OSI reference model is shown in Fig.4. FDDI station management protocol, which is not included in OSI model, is also indicated in the figure.

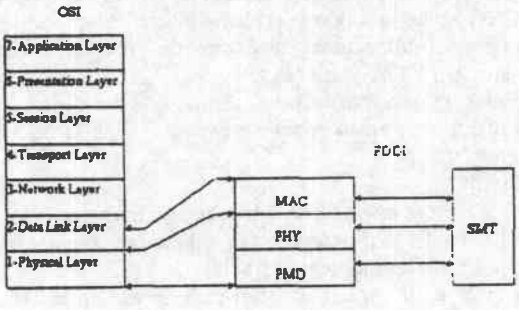

Figure 4. FDDI and OSI Reference Model

PMD- Physical Medium Dependent Layer is the layer where optical features of FDDI are defined. PMD defines the wavelength needed for optical communication, the physical medium, connectors, optical connection and receiver function. It also defines optional optical by-pass switch. This switch, which can be located in or out of the station, provides link connection when station failure takes place or power goes off. Selecting the right medium among different choices is also PMD's responsibility.

- Multi Mode Fiber MMF-PMD
- Single Mode Fiber SMF-PMD
- Low Cost Fiber LCF-PMD
- Shielded Twisted Pair STF-PMD
- Unshielded Twisted Pair UTP-PMD
- Synchronous Optical Network SONET

Today the above six PMD alternatives have been defined. While the first three of these are actively in use now, the others are under development [1,2].

PHY- Physical Layer provides medium independent functions depending on OSI physical layers. It achieves transportation of data strings from one station to another and access of each station to the ring. It creates system clock and synchronization of data traffic on the ring, performs 4B5B encoding of data that comes from the above layer so data is converted to the appropriate form that PMD can transmit and converts the data that comes from the ring to the appropriate form for the above layer by decoding.

PHY gives services to SMT about the operation and management of FDDI ring. It informs the above layer at the beginning and end of each data block and keeps the ring working even if there is no data transmission. SMT layer controls the ring operation with the help of information that comes from PHY.

FDDI physical layer uses a two-stage encoding scheme. First, 4-bit binary symbols are converted to 5-bit codes with 4B5B coding scheme. nBmB block codes are used with NRZ codes and their bandwidths are m/n times higher than NRZ codes. Since each 4-bit data transmission requires the transmission of 5 bits on the optical fiber in 4B5B codes, 125Mbps channel is used to achieve a 100Mbps effective data rate. In the second stage, this bit stream is converted to a NRZI bit stream [1,2].

MAC- Medium Access Control Layer defines the access method for transmitting and receiving data on the ring and is responsible from addressing. Also in addition to data frames control characters needed for FDDI control frames are created. This specific medium access method of FDDI networks is based on timed token rotation protocol.

Ring access is controlled by a special frame called token. There is only one token on the ring at a given time. When a station receives the token, it has the right to transmit data. Finishing the transmission, it must release the token.

FDDI-II defines Physical Layer and lower half of Data Link Layer of OSI reference model. FDDI-II is similar to FDDI with differences in HRC, which is composed of H-MUX and I-MAC, P-MAC, PHY-2 and SMT-2 modules. These differences provide not only flexibility but also FDDI compatible operation to the designed network. FDDI-II terminal architecture is shown in Fig.5.

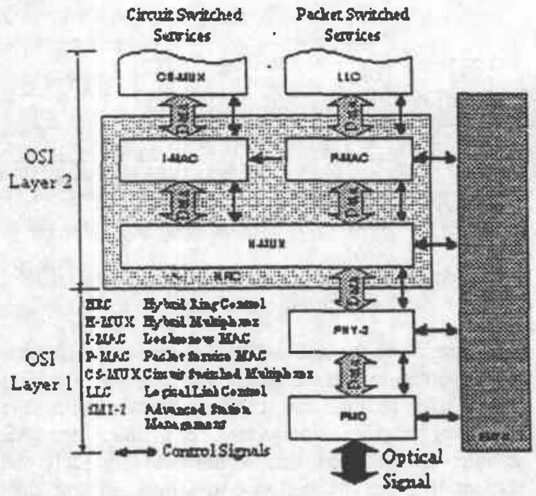

Figure 5. FDDI Terminal Structure

An FDDI-II node is a composition of FDDI and HRC units. HRC consists of two protocols: Hybrid Multiplexer H-MUX and Isochronous Medium Access Control I-MAC.

Hybrid ring control (HRC) protocol defines two modes called basic and hybrid modes. Operations in basic mode are FDDI operations. Hybrid mode operations are based on a special frame structure called a cycle. In addition to synchronous and asynchronous services, isochronous services are provided by circulating 125µs cycles on the ring. Both packet switched and isochronous data can be transmitted within this cyclic frame structure.

FDDI and FDDI-II nodes can operate on the same network only in basic mode, which only supports packet switched services. Operations supported in basic and hybrid modes are shown in Table 1.[1,2]

Table 1. FDDI II Traffic Types

Traffic Type	Example	Basic Mode	Hybrid Mode
Asynchronous	Interactive Traffic	Yes	Yes
Synchronous	Real-Time Control	Yes	Yes
Isochronous	Voice/Video	No	Yes

4. CABLES USED IN FDDI APPLICATIONS

While FDDI backbone uses 62.5/125μm graded index optical fiber as transmission medium in general, some parts of the network consider other medium choices. FDDI bacbone was designed to operate with distances more than 2km and a transmission rate of 100Mbps. Cable segments that provide connection with horizontal work stations can transmit 100MHz bandwidth to distances up to 100m. In general, most of the horizontal connection applications are limited with distances up to 50m. Operating costs of 62.5/125μm optical fiber are more than conventional copper cables. Two different media alternatives have been developed to restrict the increasing cost. The first one is the copper twisted pair and the other is 200/230μm step index optical fiber. Twisted pair has some advantages. Costs of cable, connection components and location process are low. Since there is no need to a special equipment, it is easy to locate connection components. Costs of transmitters are relatively low compared to the required amount for optical fiber. Also unshielded twisted pairs have wide location possibilities. But beside these advantages there are also some disadvantages. Bandwidth capacity and attenuation restrict the transmission of 100MHz only to a distance of 100m. A high level noise can occur on these cables. Shielded twisted pair decreases the noise to a lower level but cable dimensions and costs increase.

Step index 200/230μm optical fibers have a low cost. Bandwidth and loss characteristics provide the usage of lengths of nearly 125m. Termination of 200/230μm optical fiber is easier than 62.5/125μm fiber. 200/230μm optical fibers have better mechanical parameters and also they are less sensitive to microbending losses than 62.5/125μm optical fibers. But for distances of more than 2km, system performance can be provided only by 62.5/125μm optical fiber

Twisted pair is the cheapest choice. Since copper cable implementation is an old technology, a decrease in cost will not be seen in the future but it is estimated that cost of optical fiber systems will decrease by 30%. [3].

5. FDDI APPLICATIONS

Emphasizing only its bandwidth capacity leads to neglecting all other important points of FDDI such as its high performance, geographic deployment and support to new kinds of applications.

Some FDDI applications on the market are as follows:

- Playing a backbone role, it connects different user groups in campus sites that have networks previously formed by different types of LANs.
- Deploying vertically in buildings, FDDI backbone network connects horizontal LANs of floors and apartments.
- Connection of devices that have low transmission rates with FDDI network and bridging functions between LANs of different vendors.
- Direct connection of high performance devices with the help of its transmission rate and performance support to the backbone network.
- Support to new bandwidth applications such as medical imaging and graphics in engineering.

5.1. Interconnecting FDDI with 100Base-X and 100Base-T2

The first and most apparent FDDI application is the connection of different LANs to FDDI backbone using FDDI based bridges.There are several bridging methods: encapsulation, translation and transparent method. These methods differ in the way frames are analyzed in the bridge and introduced to the FDDI network. In this section, interconnection of FDDI with 100Base-X and 100Base-T2 LANs will be discussed. First a short description of 100Base-X and 100Base-T2 will be given and then bridging methods will be explained.

100Base-X: The approach in the 100Base-X family was to take the existing physical-layer standard from FDDI and adapt it to Ethernet. 100Base-X family includes 100Base-FX, which runs over 62.5/125μm multimode optical fiber, and 100Base-TX, which runs over Category 5 UTP cable. The basic features of 100Base-X are inherited from the FDDI standard including the use of 4B5B block coding and full-duplex signalling [4].

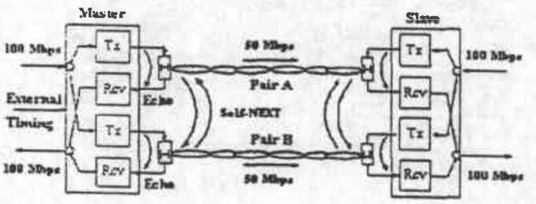

Figure 6. Full-Duplex Transmission Over Two Wire Pairs

100Base-T2: For 100Base-T2 a full-duplex baseband transmission concept was adopted. Bidirectional 100Mbps transmission over two pairs is accomplished by full-duplex transmission of 50Mbps streams over each of two wire pairs as shown in Fig.6. Full-duplex transmission requires two transmitters and two receivers at each end of a link as well as separation of the simultaneously transmitted and received signals on each pair.

Quinary pulse-amplitude baseband modulation at the rate of 25 Mbaud is employed for each wire pair [5].

Encapsulation Method: In the encapsulation method, a 100Base-X or 100Base-T2 frame is packed into the information field of an FDDI envelope. By this way, the content of the 100Base-X or 100Base-T2 (or any other LAN) remains unchanged.

Encapsulation method has the ability to designate closed users groups that prevent unauthorized access to secure sections [6].

Transparent Method: Transparent method copies the frame from one port to another. One-to-one mapping of frames exists for both ports.

Original Ethernet frames cannot be mapped onto the FDDI with transparent method for two reasons: FDDI requires LLC fields but original Ethernet frames do not use LLC. There is also no room for the type field of Ethernet frames in FDDI frame format.

Another problem of transparent method is the difficulty in stripping frames from the network. [6]

Translation Method: The translation method maps 100Base-X or 100Base-T2 frames to the FDDI frame in the same way as a transparent bridge does. It maps the information contained in the original Ethernet type field into the LLC field of the FDDI packet and it also provides a stripping method to overcome the problem of random address transmission[6].

5.2. Local Area Networks Expanded with FDDI

Selected backbone type must be fault tolerant, have a high transmission rate and have a structure that is not affected by the on/off functions or faults in terminals. In the below application, being forced by the high traffic load of servers and terminals, the network has been expanded with an effective backbone structure.

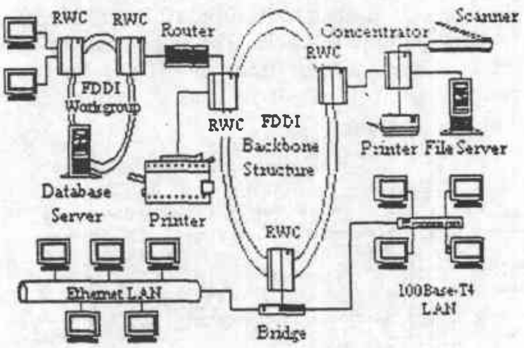

Figure 7. Expanded Campus Network

100Mbps transmission rate, high fault tolerance, insensitivity to electromagnetic interferance and optical fiber transmission medium are some of the features that make FDDI standard an attractive choice.

Stations, concentrators, routers and bridges are used on a network expanded with FDDI. To implement an effective backbone structure, DAS stations are preferred with the aim of providing continuous communication in cases of link or station failures.

Because of the high traffic load a 100 Base-T4 and a standard Ethernet LAN have been expanded with an FDDI backbone in the example application. Then another FDDI network has been connected to this structure. The two FDDI networks are connected to each other via RWCs and a router.

FDDI workgroup consists of a database server and terminals which are attached to the ring via RWC. Another RWC connects the group of printers, scanner and file server to FDDI backbone. 100Base-T4 and 802.3 Ethernet LAN are interconnected to FDDI backbone with a bridge and a RWC. Brouters (bridge/routers) can also be connected to this configuration for WAN interconnections.

CONCLUSION

With its dual ring architecture FDDI has a high fault tolerance. Depending on frame transmission, its protocol supports 100Mbps transmission rate. Because of optical fiber transmission medium it has a structure that cannot be affected by electromagnetic interferance. Though it has a high cost, it is a good choice for implementation of a backbone structure because it can operate under heavy data traffic load without any performance degradation.

FDDI-II version has been developed for applications such as voice and video that are very sensitive to variable delays. Although this network, which has a high transmission rate and flexibility, has been designed to have optical fiber based structure, shielded and unshielded twisted pairs are also used in applications. The reason is the low cost of copper twisted pair. But it is expected that 200/230μm optical fiber will take the place of twisted pair in the near future. Since costs of optical fiber communication systems will rapidly decrease in near future, these systems will become more attractive.

Presently, works about FFOL (FDDI follow-on LAN) are going on. Initially FFOL will operate at a data rate less than 1.2Gbps but in time this rate will be increased to more than 2.4 Gbps. This network will also support both packet switched and circuit switched services.

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