A Survey on FDDI in Networking

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Abstract**—**The fiber distributed data interface (FDDI) standard supports synchronous and asynchronous data transmissions. It allows each station to have multiple classes of asynchronous data, and meets the requirements of different classes by means of a timer-based priority scheme. The performance of a FDDI network carrying multiple classes of traffic is considered. An analytical model is presented to evaluate the throughput of synchronous traffic and asynchronous traffic. The model can be used to evaluate the throughput of individual priority classes and the mean token-cycle time of the network, when the network offered load varies from very low values to high values. The governing equations for the throughput characteristics and mean token-cycle time are strictly functions of network parameters. In this paper we have covered various aspects of FDDI in networking. We tried to cover all the advantages and disadvantages of FDDI with different network modes.

Keywords**—***FDDI; TTRT; Throughput; Delay.*

I. INTRODUCTION

Over three years ago, the American National Standards Institute (ANSI) began work in committee X3T9.5 to specify a standard token ring computer network based on optical fibers. The Fiber Distributed Data Interface - hereafter referred to as FDDI - is the emerging standard which sets out the results of their work. As the product of a group effort by many commercial vendors, the FDDI document can be expected to standardize all commercially developed, fiber-based computer networks (much as Ethernet has done for traditional cable networks). R531 has followed the work of the ANSI committee and has begun efforts to see the FDDI realized as a product. There are many potential uses for such a network. What follows is a brief outline of how the FDDI functions, possible applications of the FDDI to high-speed networks, the status of its development, and a summary of future directions in FDDI development.Several years ago, Digital recognized this growth trend and began to plan and develop a second-generation LAN that would follow Ethernet and provide an evolutionary path to higher performance.

FDDI is a token passing ring based on fiber-optic technology. The operation of the network is similar to that of the IEEE 802.5 token ring standard, with some important differences. First, FDDI is based on light fiber. It is a ring network which consists of a circular set of point-to-point fiber connections between nodes. Un1ike the 802.5 ting, FDDI is counter-rotating. That means that the network actually contains two rings which pass information in opposite directions. A node may be connected to one or both rings. A node which is connected to both rings is known as a Class A (or double duplex connection) node. A node which is connected to only one ring is known as a Class B (or single duplex connection) node. Class B nodes connect to the ring via a Class A station known as a Wiring Concentrator. Class B nodes are cheaper and simpler to wire, but are less robust and reliable. As many as one thousand nodes can be connected to the network at once. Stations can be separated by up to two kilometers as long as the total ring length is less than two hundred kilometers.

Each ring consists of a single light fiber. Since each fiber can carry one hundred megabits of data per second, the effective bandwidth of the network is two hundred megabits per second. It should also be realized that each fiber carries one hundred megabits of data per second. The fibers actually run at 125 megabits per second with 80 percent efficiency (the rest of the bandwidth is taken up by clocking signals). The coding scheme used to achieve 80 percent efficiency also makes it possible to use LED diodes instead otlaser diodes to drive the fiber. This helps to keep costs low without sacrificing reliability. FDDI even has a special "wrap" mode, which automatically causes it to reconfigure and continue running if a link in the ring breaks. FDDI is being designed as a versatile, high performance networking standard[1].

The most important aspect of the FOOi design is that the network does not have a central management or "watchdog" facility. Instead, each node in an FDDI network maintains its own network status model. Since control is decentralized, it is easiest to explain how the network functions by examining it during normal operation and then contrasting that with what happens when a link breaks. Other general aspects of the network which also need to be examined include the structure of the protocol layers, transmissions synchronization, bandwidth allocation, and transmission coding. Finally, the use of the second ring needs to be clarified.

The selection of FDDI as the second-generation LAN was made with great deliberation. This paper explores the criteria for that choice and the history of the FDDI system to the present. The theory of FDDI operation, the development of the FDDI technology’s role in Digital’s networks, and the resulting products are also presented and discussed.

Fiber Distributed Data Interface (FDDI) is a standard for data transmission in a local area network. It uses optical fiber as its standard underlying physical medium, although it was also later specified to use copper cable, in which case it may be called CDDI (Copper Distributed Data Interface), standardized as TP-PMD (Twisted-Pair Physical Medium-Dependent), also referred to as TP-DDI (Twisted-Pair Distributed Data Interface).

FDDI was effectively made obsolete in local networks by Fast Ethernet which offered the same 100 Mbit/s speeds, but at a much lower cost and, since 1998, by Gigabit Ethernet due to its speed, and even lower cost, and ubiquity.

FDDI provides a 100 Mbit/s optical standard for data transmission in local area network that can extend in range up to 200 kilometers (120 mi). Although FDDI logical topology is a ring-based token network, it did not use the IEEE 802.5 token ring protocol as its basis; instead, its protocol was derived from the IEEE 802.4 token bus timed token protocol. In addition to covering large geographical areas, FDDI local area networks can support thousands of users. FDDI offers both a Dual-Attached Station (DAS), counter-rotating token ring topology and a Single-Attached Station (SAS), token bus passing ring topology.[2]

FDDI, as a product of American National Standards Institute X3T9.5 (now X3T12), conforms to the Open Systems Interconnection (OSI) model of functional layering using other protocols. The standards process started in the mid 1980s.[3] FDDI-II, a version of FDDI described in 1989, added circuit-switched service capability to the network so that it could also handle voice and video signals.[4] Work started to connect FDDI networks to synchronous optical networking (SONET) technology.

A FDDI network contains two rings, one as a secondary backup in case the primary ring fails. The primary ring offers up to 100 Mbit/s capacity. When a network has no requirement for the secondary ring to do backup, it can also carry data, extending capacity to 200 Mbit/s. The single ring can extend the maximum distance; a dual ring can extend 100 km (62 mi). FDDI had a larger maximum-frame size (4,352 bytes) than the standard Ethernet family, which only supports a maximum-frame size of 1,500 bytes,[a] allowing better effective data rates in some cases.

Designers normally constructed FDDI rings in a network topology such as a "dual ring of trees". A small number of devices, typically infrastructure devices such as routers and concentrators rather than host computers, were "dual-attached" to both rings. Host computers then connect as single-attached devices to the routers or concentrators. The dual ring in its most degenerate form simply collapses into a single device. Typically, a computer-room contained the whole dual ring, although some implementations deployed FDDI as a metropolitan area network.[5]

FDDI requires this network topology because the dual ring actually passes through each connected device and requires each such device to remain continuously operational. The standard actually allows for optical bypasses, but network engineers consider these unreliable and error-prone. Devices such as workstations and minicomputers that might not come under the control of the network managers are not suitable for connection to the dual ring.

As an alternative to using a dual-attached connection, a workstation can obtain the same degree of resilience through a dual-homed connection made simultaneously to two separate devices in the same FDDI ring. One of the connections becomes active while the other one is automatically blocked. If the first connection fails, the backup link takes over with no perceptible delay.

The most important aspect of the FOOi design is that the network does not have a central management or "watchdog" facility. Instead, each node in an FDDI network maintains its own network status model. Since control is decentralized, it is easiest to explain how the network functions by examining it during normal operation and then contrasting that with what happens when a link breaks. Other general aspects of the network which also need to be examined include the structure of the protocol layers, transmissions synchronization, bandwidth allocation, and transmission coding. Finally, the use of the second ring needs to be clarified.

A fully functioning FDDI ring network will consist of the two counter-rotating fiber rings, Class A stations, Wiring Concentrators, and optional Class B stations. (See fig. 1.) The Class A stations use two duplex interfaces: one interface contains the receiver for the first ring and the transmitter for the second, the other interface contains the transmitter for the first ring and the receiver for the second. The connector cable which plugs into an interface holds two fibers, one strand each for both rings. The Class A station is known as "double duplex" because it connects to two such cables. Since a Class B station connects to only one ring, it requires only one pair of fibers. One cable is sufficient to carry two fibers, so Class B stations are called "single duplex." Both classes of stations contain optical bypass relays which passively connect the fibers entering and leaving the node in the event that the node is not operating. Notice, however, that a Class B station requires the two strands in its cable be from the same ring. This is why Class B stations must connect to the FDDI via a Wiring Concentrator, which manages the interfaces for the Class B station. The Wiring Concentrator is also able to drop any of the Class B nodes connected to it if their link breaks, thus saving the FDDI network from having to reconfigure (a Class B node connected via a single link which has broken would be disconnected frorn the FDDI network despite any reconfiguration). The Wiring Concentrator is also designed to cut costs by allowing connections by Class B stations through other (slower) media, such as coaxial cable.

II. Related Work

In this paper we evaluate the performance of a homogeneous FDDI token ring network in the presence of synchronous and asynchronous traffic. Every node has one synchronous class and multiple asynchronous classes of traffic. Analytical expressions are given to evaluate the throughput characteristics of different classes. Simulation results for an FDDI network are presented to validate the model. The throughput characteristics are analysed for different threshold values of the asynchronous classes.

In an FDDI token ring network [l, 21, the stations are serially connected by the transmission medium to form a closed loop, and a token controls the right to access the physical medium. Any station may capture the token by removing it from the ring. After the removal of the token, the station may begin to transmit information frame(s). When the information transmission is completed, the station immediately issues a new token. All active stations regenerate and repeat each symbol that circulates in the ring. Only the addressed destination station copies the information bits as they are regenerated and repeated. The station that transmitted the information is responsible for the removal of a frame from the ring. FDDI standard supports two types of traffic:

(i) Synchronous traffic: a class of data transmission service whereby each requester is preallocated a maximum bandwidth and guaranteed a response time not to exceed a specific delay.

(ii) Asynchronous traffic : a class of data transmission service whereby all requests for service contend for a pool of dynamically allocated ring bandwidth and response time.

A set of timers and several parameters are used to limit the length of time a station may transmit messages before passing the token to the next station. Further, the same timers and parameters are also used to control the duration of information transmission of each class within a station. Each station maintains two timers, namely the Token-Rotation-Timer (TRT) and the Token-HoldinLTimer (THT). TRT at node j is used to time the interval taken by the token to circulate around the ring starting from node j. When node j recaptures the token, TRT is reset and restarted immediately. Before resetting TRT, its current value is assigned to THT. TRT becomes active during message transmission at node j. THT becomes active only during asynchronous message transmission. When the token is passed to the next station, THT is reset and becomes inactive while TRT continues to run until the token arrives at node j again. During ring initialisation, all stations negotiate the value of the parameter called the Target-TokenRotation-Time (TTRT). This negotiated value is related to the fastest response time required by network traffic. FDDI standard specifies the lower and upper bounds for TTRT. At the end of the negotiation period, the smallest TTRT requested becomes the operative TTRT for the network. The variable T-Opr in each station is set to the smallest value of TTRT. If a station captures the token before its TRT reaches the value of TTRT, it is an 'early' token. If it captures the token after TRT has exceeded the value of TTRT, then it is a 'late' token. An early token may be used to transmit both synchronous and asynchronous traffic. A late token may only be used to transmit synchronous traffic. When a token is captured, the station is allowed to transmit synchronous traffic first. The duration of transmission will be decided by the station management (SMT) during ring initialisation, depending on the individual synchronous traffic requirement of the station [2]. The duration for which synchronous traffic is transmitted can be expressed as a percentage of TTRT, i.e. a station would require 100% allocation to transmit synchronous traffic for a duration of TTRT. To make the explanation simple, designate the duration for which a station is allowed to initiate the transmission of the synchronous messages by T,, the High-Priority-Token-Time.

If the token is late, the station will issue a new token immediately after transmitting synchronous traffic for a duration of T,. For an early token, the station is allowed to transmit asynchronous traffic provided the current value of THT is less than the value of TTRT. The difference between the current value of THT and TTRT determines the asynchronous bandwidth available to this station. However, a station cannot hold the token longer than TTRT to initiate message transmission. It has been stated that the protocol guarantees an average response time for synchronous traffic not greater than TTRT, and a maximum response time not greater than twice TTRT The stations in an FDDI network monitors the network performance using several counters and timers located at each station. The Late Counter Late-Ct is one such counter. The Late-Ct is set to zero during ring initialisation. If TRT reaches T-Opr before the token is received at that station (a late token condition), TRT is reset and Late-Ct is incremented by one. In this case however, when the station receives the token, neither the TRT nor the Late-Ct will be reset. Instead, TRT is allowed to continue counting to accumulate the lateness of the current cycle into the next cycle. If TRT reaches T-Opr for the second time, Late-Ct will be incremented to 2. This is a faulty situation which, if allowed, will violate the upper bound for the average token-rotation time. This condition will cause error recovery procedures to be carried out in the ring [20]. If the station receives the token on or before TRT reaches T-Opr, then TRT and Late-Ct are reset. Therefore a Late-Ct less than or equal to 1 indicates that the average token-cycle time for the network is not greater than T-Opr, and the network is functioning properly. FDDI standard also supports a priority scheme for asynchronous traffic. Each priority class at a station has a threshold value T-Pri(i) (i = 1, ..., n). Class 1 is assumed to have the highest priority, and class n the lowest priority among asynchronous classes of traffic. Transmission of messages of an asynchronous class begins with class 1 and continues with the lower priority classes sequentially. The asynchronous traffic of class i may only be transmitted if the current value of THT is less than the class threshold value T-Pri(i). Since, the difference between the current value of THT and TTRT reflects the asynchronous bandwidth, the maximum value that can be assigned to T-Pri(i) of class i is restricted to TTRT. If there are no messages in class i, or if the THT has exceeded the T-Pri(i), then the next lower class is served. A new token is issued when there are no more messages, or the lowest priority class has been served according to the above scheme.

At present, FDDI only exists as an incomplete ANSI standard. Everything except the Station Management protocol has been finished. The finished protocols are now in various stages of review in preparation for acceptance as international standards. It could be as long as a year, though, before the Station Management protocols are completed. The reasons for this are that many controversial issues were deferred for inclusion in the Station Management document. Many vendors are willing to begin hardware development work now but can not get the support because the protocols are not finished. However, many of them refuse to agree on the protocols because they want to skew the protocols to favor their own development. Also, they often cooperate less than they should for fear of their competitors. The idea of establishing an exclusive de facto standard by finishing development first may be one of the few motivations of committee members. There is, therefore, a good possibility that FDDI products will come to market before the standard is complete and accepted by the International Standards Organization (ISO). These first products will most likely be based on a chip set being worked on by Advanced Micro Devices (despite some skepticism about slipping AMD production schedules). The serious flaw of these early products will be that they incorporate an incomplete or extrapolated Station Management protocol. The vendors will disagree about just what constitutes a minimal operating set of Station Management controls. For this reason, the early FDDI products will most likely not be able to interconnect with the FDDI products of other vendors. They will also be limited as to how many stations they can support and the configurations that will be allowed. The special issues of Station Management in Wiring Concentrators will probably push back their availability to some later date after the initial FDDI product is brought to market. The early products will quickly converge to a common Station Management specification, and this, most likely, will be what emerges as the standard Station Management. Interest in FDDI will increase among third-party hardware vendors, and as the technology reaches greater acceptance, an increasing number of lower-cost products will become available. This scenario is taken from the way Ethernet reached maturity. In the future, we will also see the emergence of FDDI-11, on which work has already begun. FDDI-11 embodies all of normal FPDI services, with the added ability to support circuit switching for time-sensitive data (such as voice or video). FDDI-11 dynamically partitions the available bandwidth between packet and circuit switched services, for optimal bandwidth utilization. National Semiconductor seems to be leading development of FDDI-11, but no implementations are expected for several years.

III. CONCLUSION

FDDI is still in the future, but it may be available on a developmental basis within a year. That is, for organizations which are willing to pay for development costs, most vendors will claim that a working prototype could be delivered within a year. Commercial availability is still about two years in the future. For the Agency, this means that a very high bandwidth network will be commercially available to interconnect almost all computers within two years. R531 is beginning investigations with the hope of making the technology available before it becomes commercial. FDDI holds great promise for solving the Agency's long term computer networking and tommunications needs. In addition, it offers the chance to migrate from traditionah proprietary networking solutions which are still in use (such as Network Systems Corporation's HYPERchannel) to less expensive and more reliable means of communication and interconnection.

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