

## CHAPTER10

# RELIABILITY ANALYSIS FOR THE BRIDGE NETWORK USING THE MOMENT GENERATING FUNTION

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**KEY WORDS:** MTFF, MTTR, MTBF, Bridge network, Moment Generating Function (MGF).

**ABSTRACT:** There are many measures that can be applied to assess the service quality of the bridge network such as the t-p connectivity, the tree connectivity, the TFF, MTTR, and the MTBF. The calculation of the MTFF & MTTR depends on the integration of the reliability function  $R(t)$ , and the availability function,  $A(t)$ , respectively. In this paper, new method is presented for the evaluation of the MTFF and the MTTR. The metho of attack is to use the MGF. Comparative analysis is presented between two networks and useful results are obtained.

### 1- INTRODUCTION:

The bridge network is a communication computer network which is widely used in the communication field, refer to fig. (1). It consists of 4-vertices:  $X_1, X_2, X_3$ , and  $X_4$ , and 5-edges:  $e_1, e_2, e_3, e_4$ , and  $e_5$ , as shown in Fig. (1a). In Fig. 1b another bridge network is illustrated but having only 4-edges and 4-vertices. In order to compare between the two graphs, we are going to calculate the MTFF, and MTBF for the two graphs.

In literature, the calculation o the MTFF dependos on the integration of the reliability function,  $R(t)$ , and the calculation of the MTTR depends on

## REFERENCES

1. P.S. Henry, "High - capacity lightwave local area networks", *IEEE Commun. Magazine*, Vol. 27, No. 10, Oct. 1989, pp. 20-26.
2. P.E. Green, "The future of fiber - optic computer networks", *IEEE Computers* Vol. 24, No. 9, Sept. 1991, pp. 78-87.
3. H.R. Van As, "Media access techniques: the evolution towards terabit / s LANS and MANs", *Computer Networks and ISDN Systems*, Vol. 26, (6-8), March 1994, pp. 603-656.
4. M.I. Karol and B. Glance, "A collision - avoidance WDM optical star network", *Computer Networks and ISDN Systems*, Vol. 26 (6-8), 1994, pp. 931-943.
5. L. Fratta, F. Borgonova, J. Bannister and M. Gerla, "Routing and admission control in the multihop wavelength-division optical network", *Computer Networks and ISDN Systems*, Vol. 26 (6-8), 1994, pp. 985-1005.
6. P. Poggiolini and Kazovsky, "STARNET": An integrated services broadband optical network with physical star topology, in: *Advanced Fiber communications technologies*", SPIE, Vol. 157, 1991, pp. 14-29.
7. C. Patridge, "Protocols for high-speed networks: some questions and a few answers", *Computer Networks and ISDN Systems*, 1993, pp. 1019-1028.
8. Distributed queue dual bus (DQDB) sub-network of a metropolitan area network (MAN), *IEEE Std. 802.6 / D15*, Dec., 1990.
9. FDDI Token Ring Media Access Control (MAC), *ANSIX3T9.5, Doc. X3.139/1987 (ISO 9312-2 / 1989)*.
10. Jack Brassil, Abhijit K. Choudhury, N. Cholas and F. Maxemehuk, "The Manhattan street network: a high performance, highly reliable metropolitan area network", *Computers Networks and ISDN Systems*, 1994, pp. 841-858.
11. Yoram Ofek, and Moti Yung, "Routing and flow control on the Meta Net: an overview", *Computers Networks and ISDN Systems*, 1994, pp. 859-872.
12. Anthony S. Acampora and Mark J. Karol, "An overview of lightwave packet networks", *IEEE Network*, Jan. 1989, pp. 29-40.

carries their aggregate transmission rate. Wavelength Division Multiplexing (WDM) is the most promising technique to achieve this goal. Examples of such experimental networks are presented including the passive star and the optical bus. Finally, it is expected that the photonic technology will mature in the near future and terabit networks would be a reality. However, it is now important to investigate higher-level network issues. One of the most important of these is the need to devise efficient medium - access techniques for packet communication.

## CONCLUSION

Today, Photonic technology has become the technology of choice for interoffice and long distance communications networks. This is reasonable since fiber optic transmission provides enormous usable bandwidth. A single mode fiber more than 20 THz for the low - loss wavelength windows at 1300 nm and 1500 nm alone.

Such tremendous capacity created great interest in developing new bandwidth - demanding applications in many diverse fields such as multimedia and the interconnection of mainframe computers. The present paper sheds light on the present and future high speed networks that use optic fiber transmission at the physical level. In principal they are calssified as second and third ion networks.

Second generation networks one limited by the electronic bottleneck where the electronic interfaces of the nodes put on upper limit of about 1 Gbps on the transmission speed. The fiber in such networks is used very inefficiently because the networks architectures and protocols stand short of making use of the available 20 THz bandwidth. However, such networks are still very fast compared to first generation ones that employ coaxial cables and / or microwave links. Examples of second generation networks are presented including bus, ring, and mesh topologies.

Third generation networks are still in its infancy being a subject of aggressive research. They tend to overcome the electronic bottleneck by developing new architectures and protocols that allow a single fiber to carry the full traffic of the entire network. (A single fiber today has the bandwidth to carry a traffic equivalent to all the telephone traffic in the entire U.S. during the busiest transmission time, which is about 1 Tbps). Thus, although each network node is limited to 1 Gbps by its electronic interface, yet several thousands of nodes can effectively communicate using a single fiber which

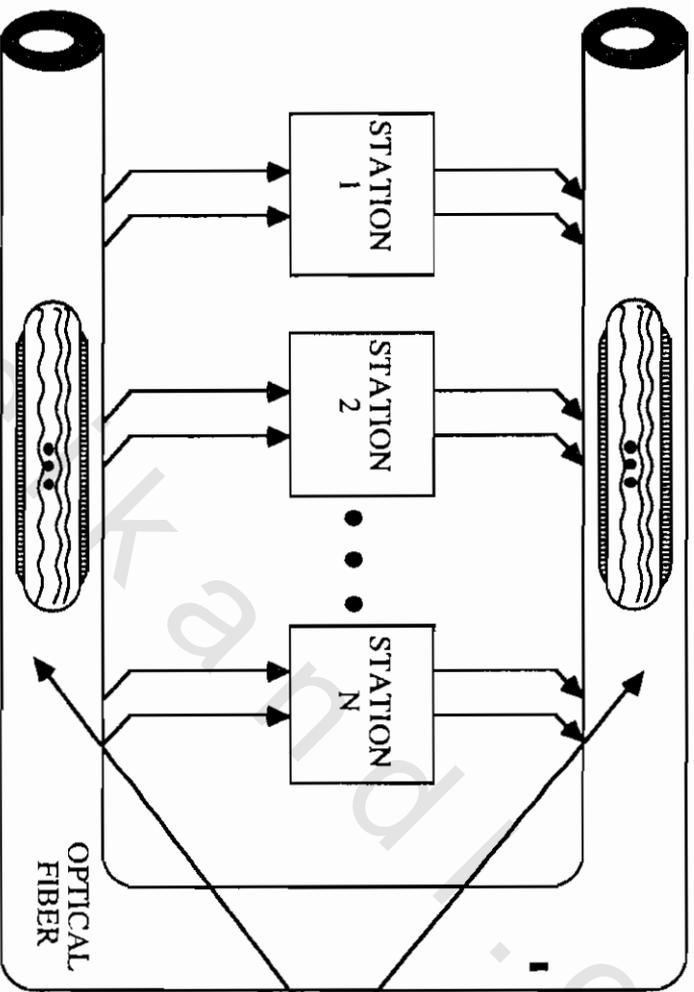
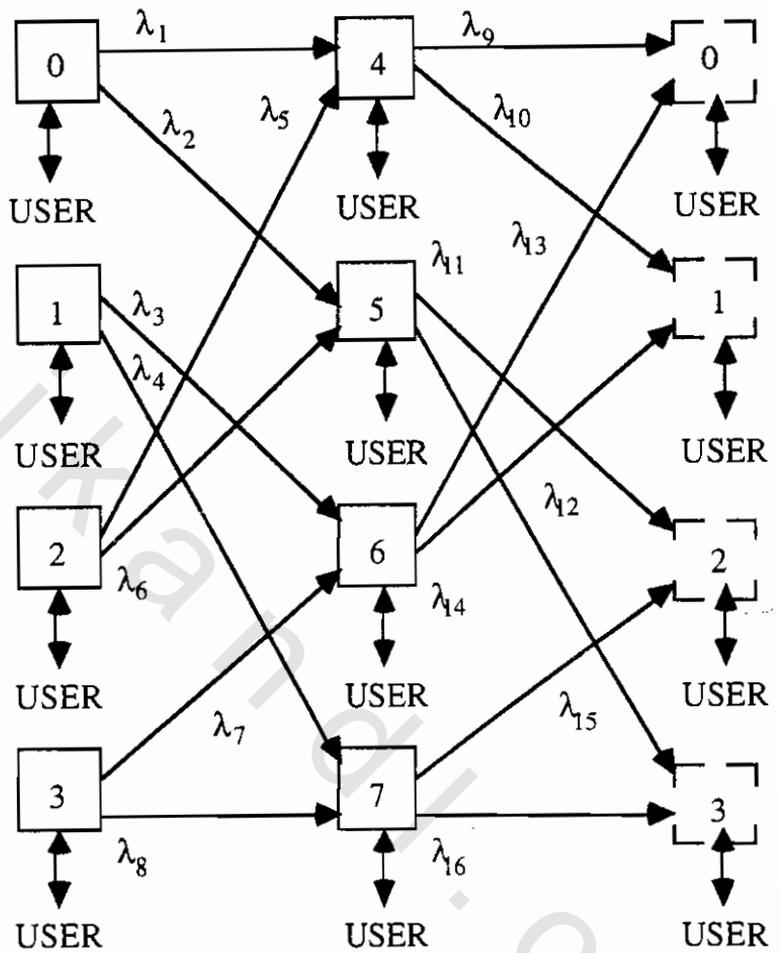


Fig. 12 A N - station WDM realized on an optical bus with 2N WDM channels



$P$  = number of  $\lambda$  s for Tr. & Rcv.

$K$  = max. number of hops to reach the dest.

Fig. 11 b - 8- NIU ( $p = 2, K = 2$ ) ShuffleNet connectivity graph

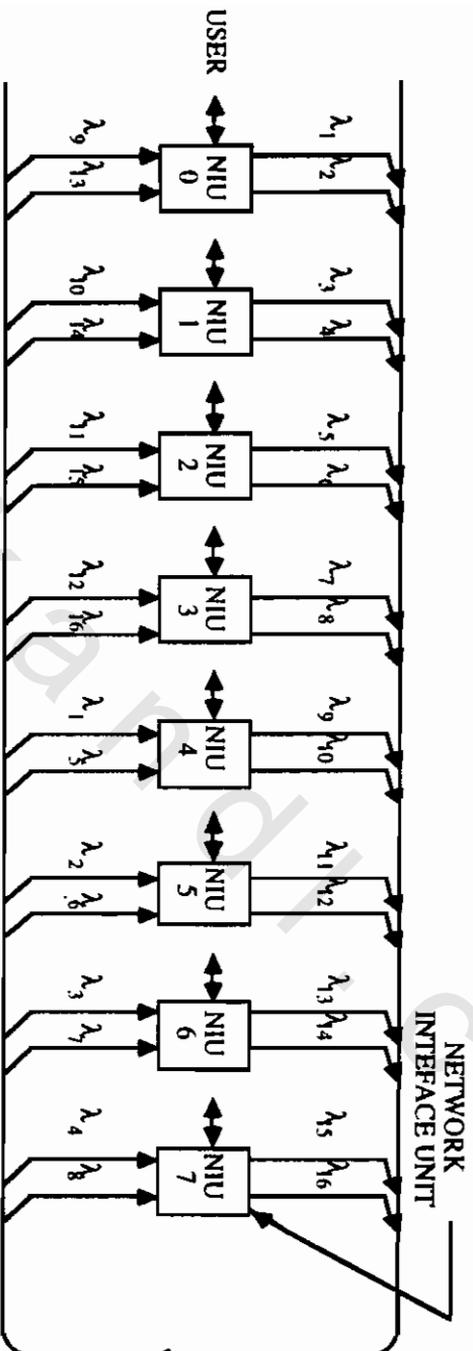


Fig. 11 a - A Multihop lightwave network for a bus topology

Most of the protocols coordinate the transmissions via a control channel on a common wavelength. A typical example is the "Protection Against Collision" (PAC) network<sup>(12)</sup>. In this network collisions are avoided by allowing a node access to a channel only if the channel is available. Also, packets simultaneously accessing the same channel are denied access. The concept is similar to that in collision avoidance stars, except that it is now extended to a multi-channel environment.

#### Optical bus networks:

A shuffle network can be realized using a common optical bus which can simultaneously carry several packets transmitted using different wavelengths. A typical example is shown in Fig. 11-a, in which each node can transmit and / or receive packets using two different wavelengths. Fig. 11-b shows the connectivity graph of this example. It indicates that at most two hops are needed to transfer a packets from any source to any destination. Fig. 12 shows the Wavelength division Optical Network (WON)<sup>(13)</sup> which is based on the shuffle network using a single optical fiber.

### THIRD GENERATION NETWORKS

In the second generation networks, the used network architecture and protocols imply that most or all of the transmitted data all over the entire network should pass through the electronic sections of the nodes. The nodes' electronic interfaces can typically operate at dedicated to a fixed wavelength channel. Fig. 10 shows a passive star WDM network with tunable optical transmitters. However, conflict situations may occur in such star networks. A packet collision at the star occurs if two or more nodes simultaneously transmit on the same wavelength. Conflicts can also take place if the network uses fixed transmitters and tunable receivers. It may occur that more than one transmitter has selected the same destination. In that case, one of the packets gets lost because the receiver can tune to only one of the wavelength channels at a time. In addition, the receiver must be instructed to which wavelength to tune. In either case, access protocols have to prevent collisions and contentions, or resolve them when they occur.

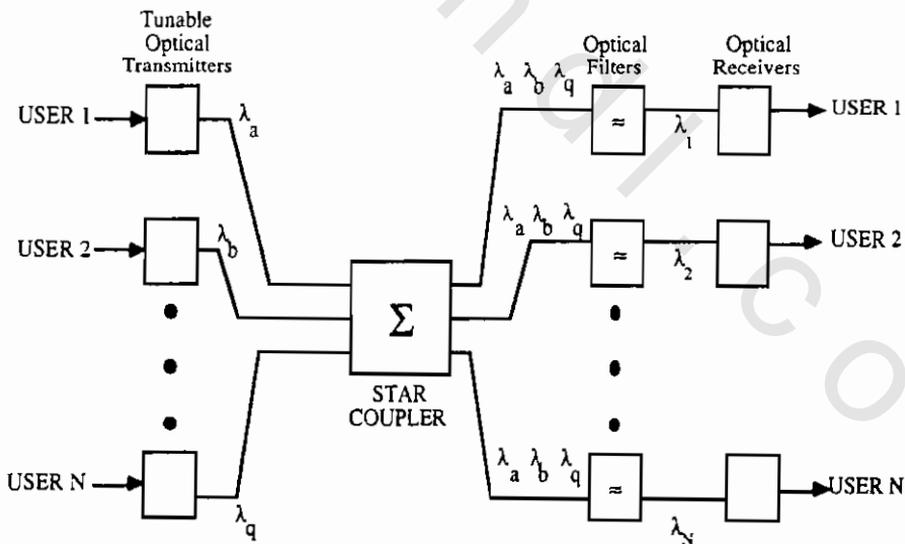
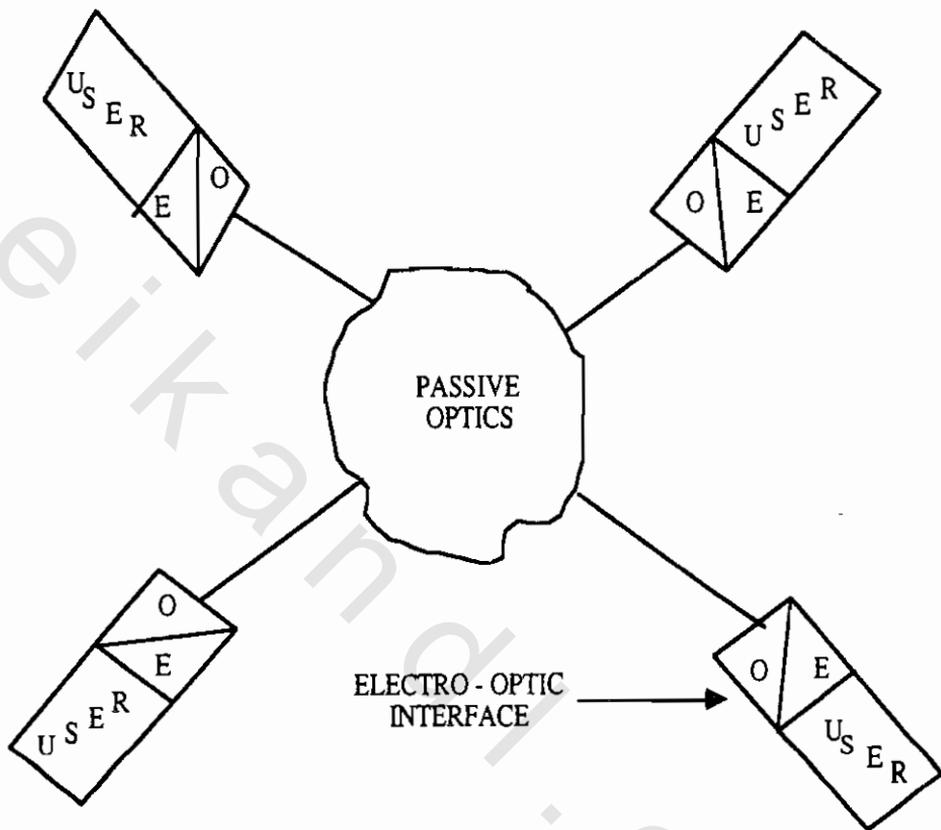
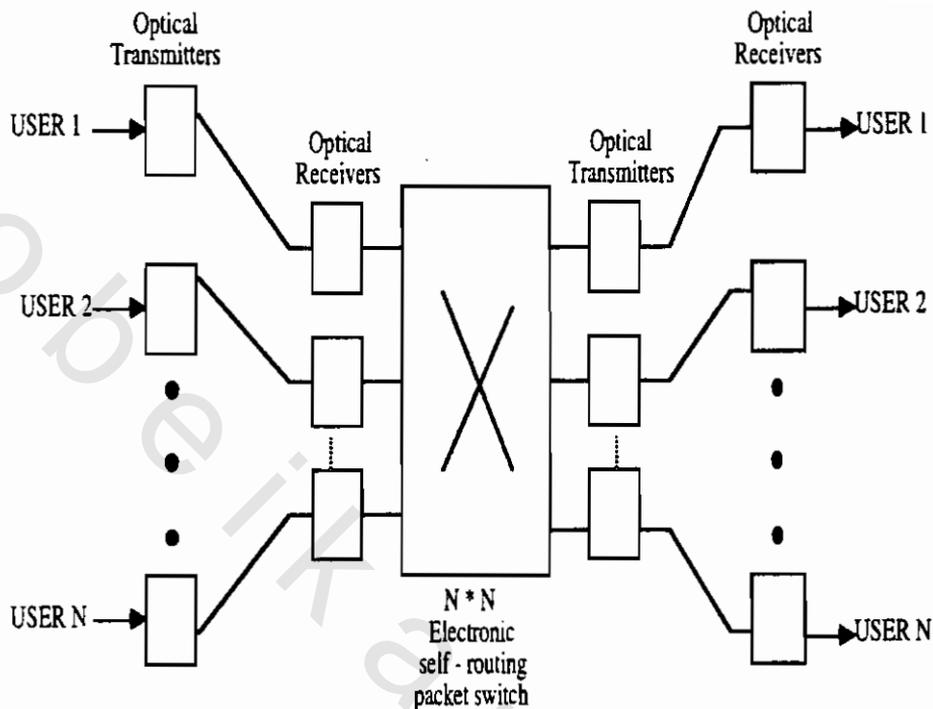


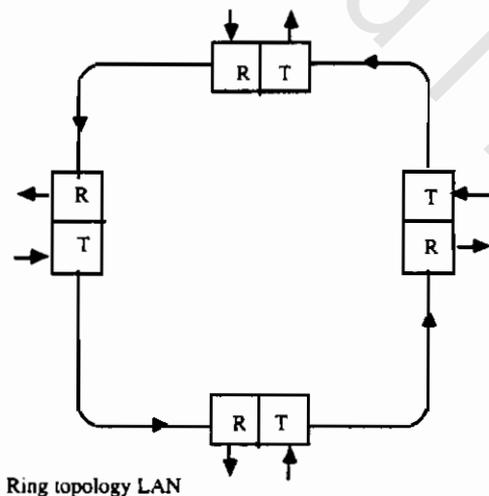
Fig. 10 Concurrency via wavelength division multiplexing



**Fig. 9 A fully distributed lightwave network**



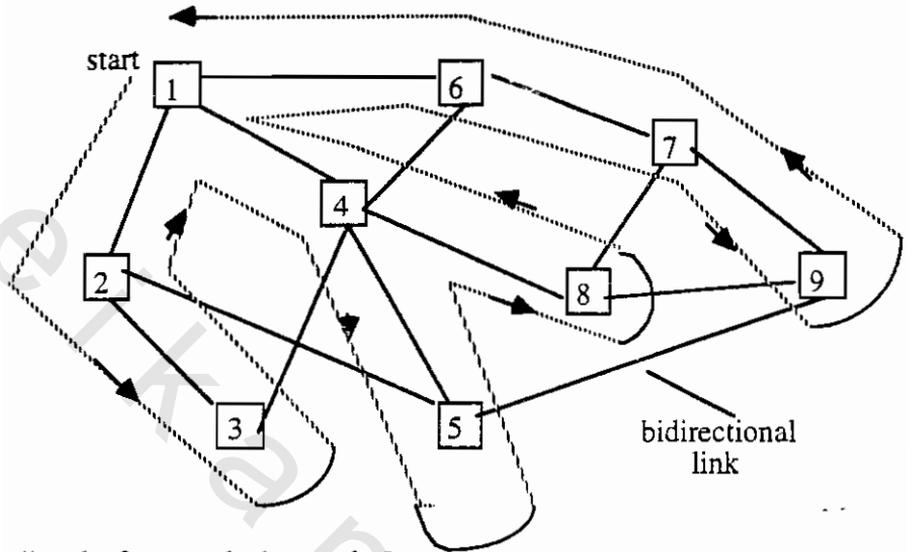
**Fig. 8 a - Electronic bottleneck in an active star topology**



**Fig. 8 b - Electronic bottleneck in a ring topology LAN**

virtual embedded ring:

1-2-3-2-1-4-5-4-8-4-1-6-7-9-7-6-1



all paths from node 1 to node 8:

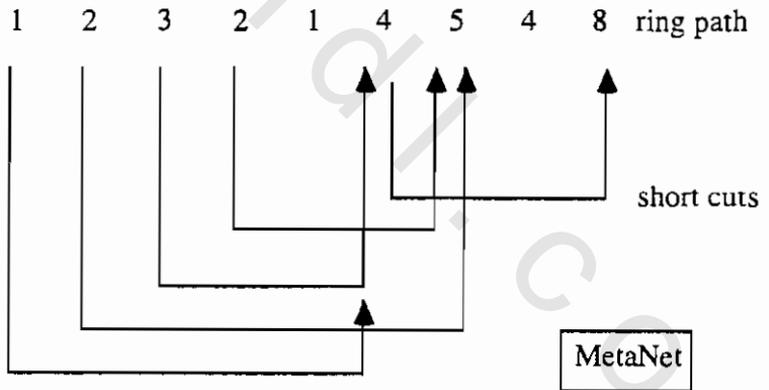
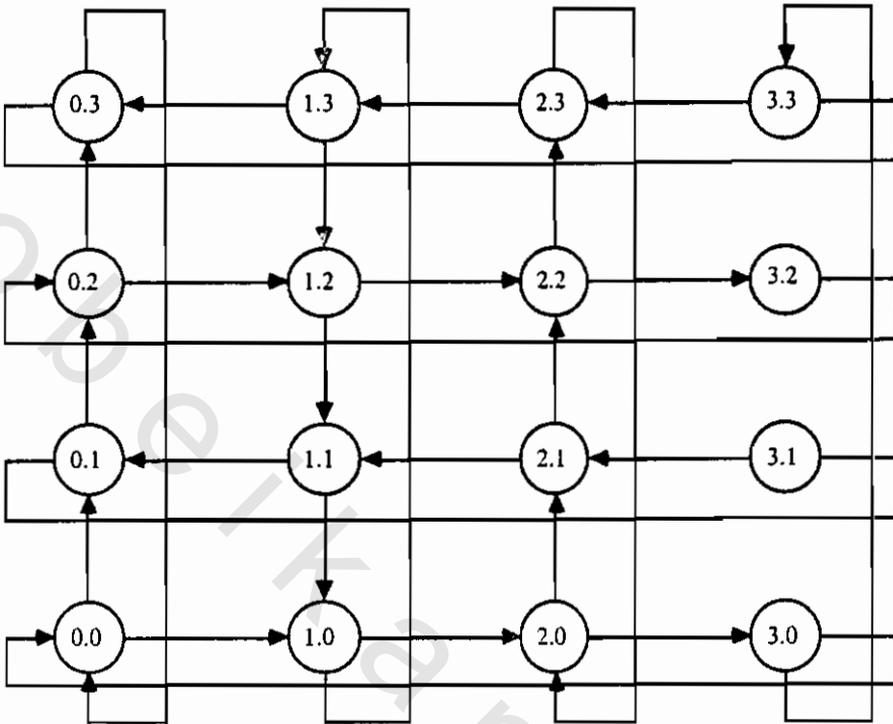
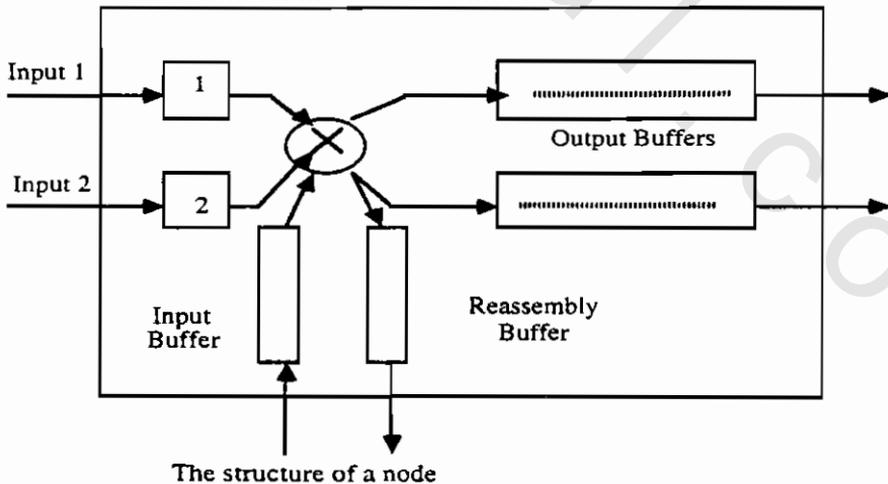


Fig. 7 Meta Net: embedded virtual ring



**Fig. 6a - A 4 4 Manhattan Street network. Nodes are identified by row and column number**



**Fig. 6b - The structure of a node in the MSN network**

### 3.1. The Manhattan street network (MSN):<sup>(10)</sup>

As shown in Fig. 6, the MSN network consists of a regular structure with an even number of rows and columns. Nodes in the same row or column are connected by unidirectional rings, with directions alternating in adjacent rows and columns. Each node has two incoming and two outgoing links.

The connection grid of nodes forms a toroidal surface. Access to the network is based either on a slotted ring mechanism or an insertion buffer mechanism. In the bi-directional MSN (BMSN), each ring is replaced by a bi-directional ring, i.e., a dual ring. In this configuration, the number of rows and columns does not have to be an even number. Routing is done by deflection. If two packets destined to the same output link arrive simultaneously one of them must take another route. It should be noted that each node is supposed to handle a heavy load that is almost equal to the overall packet rate generated by all nodes in the network. Since each packet is converted into an electronic signal during the switching process, then the total network load would be limited by the electronic bottleneck.

### 3.2. The Meta Net:<sup>(11)</sup>

This is an arbitrary mesh network which may be viewed as a natural generalization of the regular mesh. The Meta Net architecture provides fair access and bounded delays on an arbitrary meshed topology. The routing scheme, called convergence routing, attempts to direct packets over the shortest path to their destinations while routing deflections are restricted by a virtual embedded ring that determines the longest path between a source and its destination. Fig. 7 shows an 9-node network with an embedded virtual ring. It also indicates all the paths a packet may take from node 1 to node 8. Larger networks may contain more than one virtual ring. The Meta Net is also limited by the electronic bottleneck.

An extension-called FDDI-II adds the capability for circuit-switched service (isochronous service) to the existing packet data service. As an upward-compatible enhancement of the basic FDDI, it uses nearly the same physical layer standards and the packet-switched traffic is handled without any protocol changes. The FDDI-II protocol integrates isochronous and packet data on the same FDDI medium by dividing the transmission capacity of the ring dynamically between both service classes. The isochronous BW is again subdivided in several channels allocated for continuous connections between dedicated stations.

### 3. Mesh Networks:

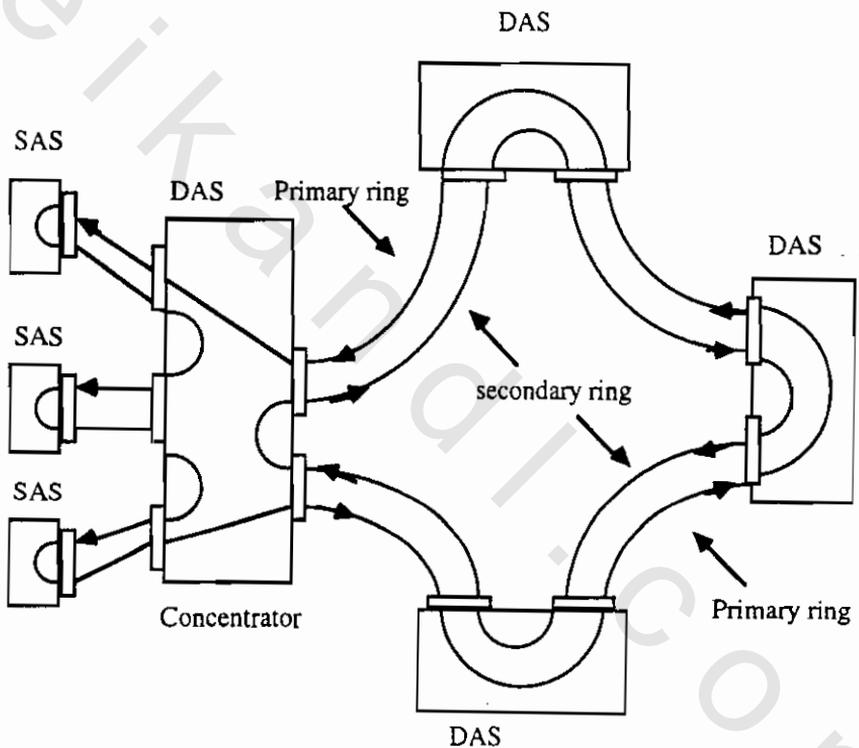
Both DQDB and FDDI have achieved successes in standard bodies, are built with modest existing technology and are likely to be widely deployed.

The initial success of such linear topology networks (MAN) is due in part to their relative implementation simplicity. Media access is straightforward in linear networks, and routing is almost trivial. Though these networks are relatively easy to construct, it remains unclear whether they can satisfy anticipated network requirements in terms of reliability, throughput and security.

These demands anticipated force us to consider alternative solutions in MAN design. The mesh networks are candidates to overcome these anticipated demands. Such networks provide a high aggregate throughput because they exploit space diversity and traffic locality. In these regularly structured networks, the combination of packet routing and access control plays a major role. Routing is done either by deflection or in a store-and-forward manner.

With deflection routing, a packet is routed another path when more than one packet complete for the same output link. Two examples for regular and arbitrary mesh networks are given below.

A station gains the right to transmit when it detects the passing token. First it transmits the frames of the highest priority synchronous access class. The remaining transmission time can be used sending asynchronous frames. The amount of time a station is allowed to transmit asynchronous frames depends on the time of the successive token arrival at this station in order to satisfy the maximum token rotation time. Since the protocol allows multiple frame transmissions per token arrival and a station has to pass on the token immediately after the end of frame transmission, it provides efficient use of the high transmission capacity.



**SAS = Single Attachment Station.**

**DAS = Dual Attachment Station.**

**Fig. 5 Example for the FDDI network**

DQDB and its variations exploit access concurrency and therefore achieve the full network throughput. On the other hand, individual node throughputs tend to become unfair if propagation delays are dominant.

## 2. Fiber Distributed Data Interface (FDDI):<sup>(9)</sup>

FDDI is an international network standard that is considered to be the optical substitute of the Ethernet which dominated the first generation of local area networks. It has a double ring topology as shown in Fig. 5.

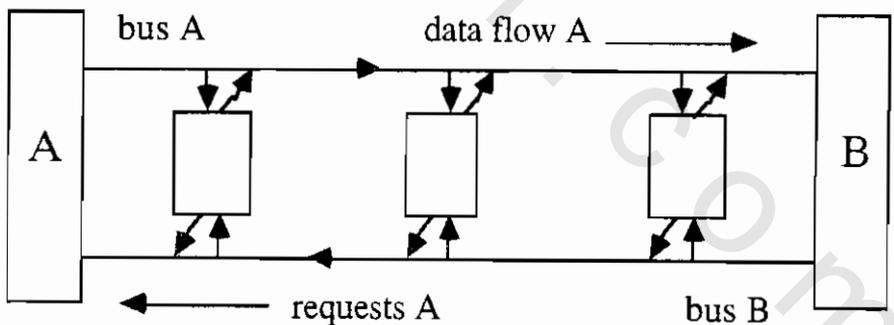
Based on a fiber optical medium the FDDI protocol defines a general purpose inter connection for all kinds of computers and peripherals with a transmission capacity of 100 Mb/s based on two counter-rotating rings. An FDDI network provides an interconnection for information exchanges among up to 500 stations over of up to 100 Km. Its transmission capacity of 100 Mbit/s enables high performance interconnections in both the front-end and the back-end computer environment. If installed as a backbone it may interconnect lower speed sub-networks or concentrators. Based on packet switching the basic FDDI protocol makes accessible the high transmission capacity of users applications implementing a "bandwidth on demand" concept with a guaranteed bandwidth and response time for real traffic. In FDDI networks data is transmitted in packets called frames, which are passed sequentially between active stations. The shared medium is de-centrally controlled according to a timed token protocol, which has been optimized for high-speed transmission and significantly enhanced to accommodate both synchronous (guatanteed BW and response time for applications with predictable BW and response time requirements), and asynchronous (dynamic BW sharing for applications with bursty or potentially unlimited (BW requirements) services. Each station has an allocated synchronous BW, and asynchronous service instantaneously allocates BW that is unallocated or unused.

generated by the head - end node of each bus. Every node receives and transmits on both buses, so bus selection is based on the destination. The DQDB protocols reserves a slot on bus A via a request bit in a slot on bus B. Access to the bus is controlled by a request and countdown counter.

The first version of the DQDB protocol showed unfair behavior by giving preference to some nodes depending on their relative position on the transmission bus. Several protocol modifications are suggested to overcome this disadvantage. A typical enhancement is given below.

Generalized - DQDB.

In this scheme behavior is reduced by allowing more than one transmission to be scheduled. This results in a better approximation of the order of packets that become ready across the network. For its realization, several countdown counters and a request counter are necessary. The speed of the reservation flow is also increased because multiple request bits can be set as they are not already in use.



**Fig. 4 Distributed Queue Dual Bus (DQDB)**

e-Virtual reality: aims to stimulate an environment so realistically that the user believes that he is in the new environment This needs accurate mixing of: sound, visual images, and sensations (such as touch and temperature). Examples for such applications include remote surgery and flight simulation.

The first generation networks can not provide the high speed required for the above-mentioned applications. New architectures and protocols are considered to provide efficient networks at such high speeds. Architectures and protocols of the second and third generation Networks are considered in the next sections. Media access protocols coordinate the access to a communication network among geographically distributed nodes. The challenge is:

- to ensure fair sharing of transmission capacity,
- to obtain high throughput and network utilization together with low and bounded delays,
- to support priorities and different traffic classes,
- to strive for simplicity, robustness and easy implementability, all at the same time.

## **SECOND GENERATION NETWORKS**

Within this technology generation a variety of network configurations and access mechanisms can be identified.

### 1. Distributed queueing:

The purpose of distributed queueing is to obtain or at least to approximate, a single view of FIFO queue for each pending transmission in all active nodes across the network. Fig.4 shows the IEEE 802.6 standard Distributed-Queue Dual-Bus. It employs (DQDB)<sup>(8)</sup> a dual bus consisting of unidirectional slotted buses A and B operating in opposite directions. The slots are

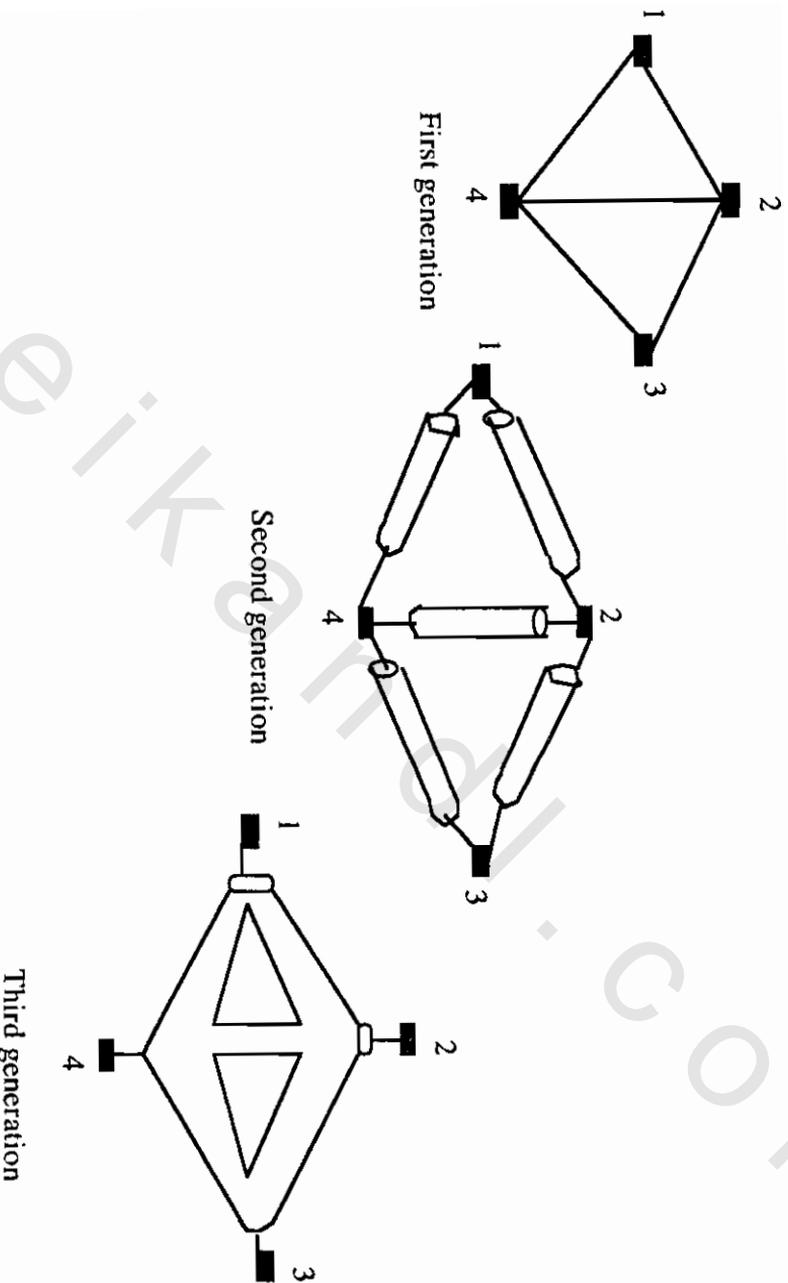
The purpose of this article is to shed light on some typical second and third generation high speed networks. We point to the new architectures and protocols employed by such networks and their suitability to the requirements of the emerging new set of bandwidth demanding applications.

The article is structured as follows. Section entitled: high speed applications, points to some applications that appear certain to consume very large bandwidth, probably up to 1 Gbit/s per node. The following two sections give examples to networks from the second and third technology generations, respectively. Concluding remarks are given in the last section.

## **HIGH SPEED APPLICATIONS**

The gigabit applications are appearing first in LAN and MAN environments. Examples of such applications include<sup>(7)</sup>:

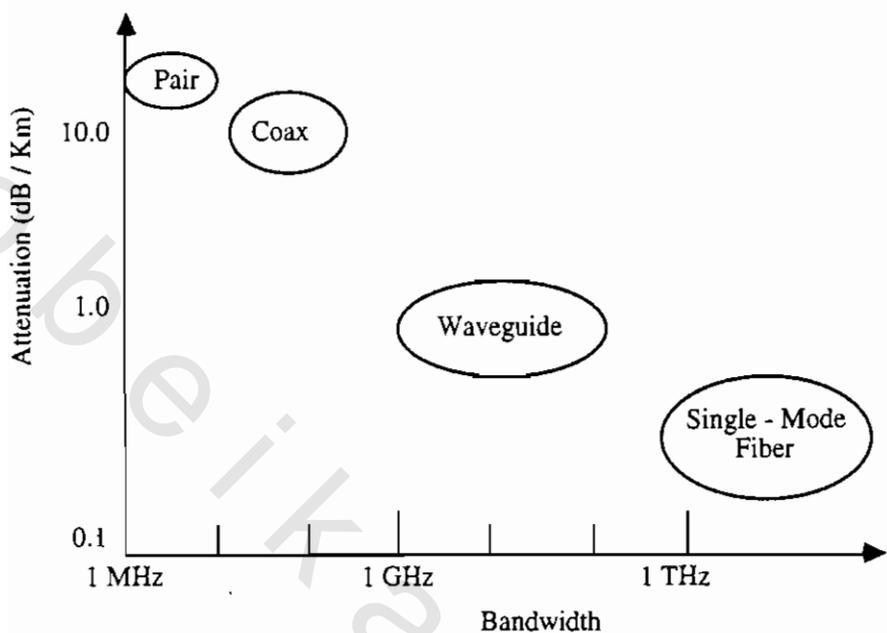
- a- Networks to provide supercomputer support for hundreds or thousands of high-performance workstations with live-motion color graphics. This application is on already urgent requirement in university and other research environments.
- b- Multimedia applications require the transmission of documents that combine several data types such as audio, video, text, graphics and images. Another area is the multimedia tele-conferencing with full audio and video capabilities.
- c- The interconnection of computer mainframes to each other and to their storage peripherals within one center via a LAN or MAN. This is called "the glass house". Also, the interconnection of glass houses.
- d- Medical imaging with very high quality requirements. In particular, uncompressed imaged are used to preserve all details, and it is estimated that the scanning of 1 or 2 uncompressed imaged per second can generate about 1 Gbps.



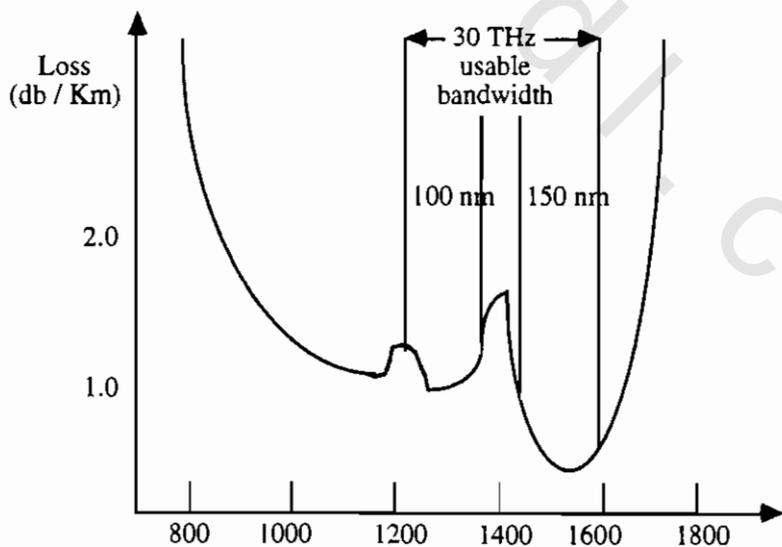
**Fig. 3 Schematic representation of three generations for a toy network consisting of four nodes**

Upon examining the physical-level technology, three generations can be identified<sup>(2)</sup> as shown in Fig.3.

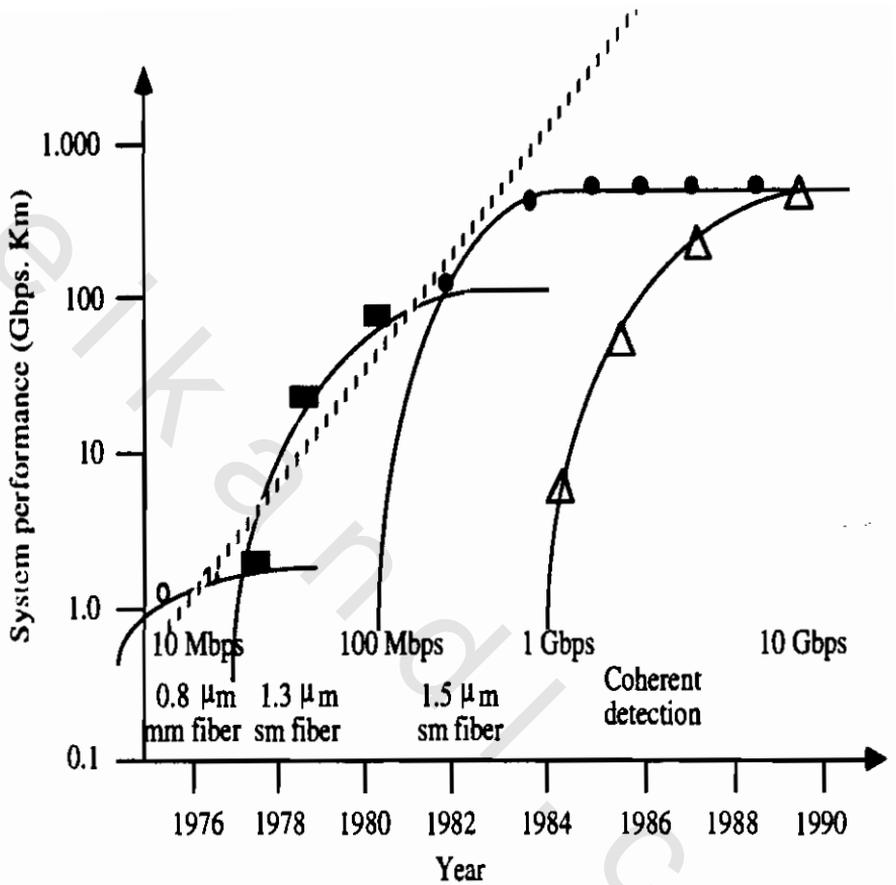
- (i) The first generation: Up to the early 1980s, fibers were not used in computer networks and coaxial cables were the natural available choice for high speed data transmission, which is limited to some 10 Mbps. Examples of LANs and MANs that developed in that period include the 802.3 Ethernet and the 802.5 token ring as well as CATV connections. First generation WANs include ARPANet, SNA/DNA, and TCP/IP, all of which are based on communication channels similar to that used by the telephone industry.
- (ii) The second generation: Fibers have been substituted for copper in traditional network architectures. Examples of LANs and MANs based on this idea include the FDDI ring and the 802.6 DQDB bus networks. However the electronic front end of each node in such networks must still be fast enough to handle the bits from all (or most) of the nodes in the entire network, as had been the case with first generation networks. This drastically limits the total network throughput to the electronic processing capability of a single node which is about 1 Gbps. This situation is the electronic bottleneck, where a fiber capable of tens of terabit per second (Tbps) is throttled by an electronic interface limited to far less.
- (iii) The third generation: This is the subject of aggressive research activities to employ the non-classical unique properties of fibers. In particular, wavelength division multiplexing (WDM) provides optical transparency that is allowing many electronic channels to be transmitted and multiplexed on the same fibre while preserving all the characteristics of every electronic channel such as speed, coding, and timing structure<sup>(3)</sup>. Examples of such experimental networks include PAC<sup>(4)</sup>, WON<sup>(5)</sup>, and StarNet<sup>(6)</sup>.



**Fig 2a - Loss and bandwidth of transmission media**



**Fig 2b - The low-loss region of an optical fiber**



**Fig. 1 Progress in fiber-optic links, as measured by product of bit-rate times required inter-repeater distance**

## INTRODUCTION

In the early days of computer networking, the emphasis was to allow users to exchange programs and low-volume data across a network. A typical example of that to log-on at a remote site to query a database and get some results, or to send electronic mail. Such applications require only very little bandwidth for individual users, and transmission speeds of up to few Mbps were satisfactory for that purposes.

The maturing of the fiber-optic technology in the early 1980s allowed to exploit the ultra high speed optical communication in computer networks. Figure 1 shows steady increase in the performance of fiber-optic links which is measured by the product of bit-rate times the required inter-repeater distance. As shown in Fig. 2 a single mode fiber has a high bandwidth measured in tens of tera hertz ( 1 THz = 1000 GHz) in addition to a very low attenuation of less than 1 db / Km.<sup>(1)</sup> Such revolutionary technology inspired the emergence of an entire new set of applications that appears to consume very large bandwidth, up to the maximum possible throughput that can be achieved by the digital electronic components at the nodes of a lightwave network. Using state-of-the-art electronics, this allows probably up to 1 Gbps per node.

The natural reaction to the optical communication impact was to substitute fiber for copper within the framework of some existing computer network architecture. However, although this method improves the network performance, yet there would be inherent limitations that deny the full use of the available optical bandwidth. Indeed, to exploit the available tens of THZ bandwidth, computer networks need to be redesigned. The physical-level topologies, the layer structure, the protocols within the layers, and the network control functions, all of which should be replaced with an eye on the available ultra high speed, low attenuation, and very low bit-error rate (about  $10^{-15}$ ) of the fiber-optic technology.