New passive optical network architectures for fiber-to-the-desk application

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We propose new network architectures that will compete with the existing copper based local area networks in overall cost and still offer a better performance: less downtime, lower maintenance cost, extended geometrical spans and larger headroom for future capacity increase. Presented passive fiber optic network topologies represent a novel approach in fiber-to-the-desk applications. In the proposed architectures the generally accepted standard for LAN, namely Fast Ethernet is used in order to provide cheaper implementation of the networks. Moreover, an architecture is presented based on ATM which is supposed to be the future protocol for LAN's.

Introduction

The demand for ever faster data transmission rates and high-bandwidth applications has attracted considerable interest in research and development of optical fiber local-area network and fiber-to-the-desk applications [1], [2]. Although some practical network proposals and realizations are available, copper interconnects still run to most desktops due to economical reasons [3]. Fiber based networks offer users increased reliability, fewer system outages and extended bandwidth. This is because optical fiber is essentially immune to many of the factors that adversely impact copper, such as electromagnetic interference, crosstalk and impedance mismatch [4].
In this paper the challenging demand for new network topology proposals is given which will compete the existing copper based networks in overall cost and still offer a better performance: less downtime, lower maintenance cost and larger headroom for future bandwidth increase. Presented network architectures are based on silica multimode fibers and multimode optical components. In order to bring medium speed local area optical networks beyond the level of point-to-point connections low-cost optical components, with a promise to cheap mass-production and usable in combination with cheap short wavelength lasers and multimode fibers must be used. Our proposed architectures lead to costs which are at least competitive with those of twisted pair networks which will be achieved by using short transmission wavelengths and multimode graded index silica fibers.
To facilitate a smooth transition from existing copper based networks to future optical LAN's the Fast Ethernet protocol [5], which is the most widely used standard nowadays, is chosen. Furthermore since Asynchronous Transport Mode (ATM) is believed to be the workhorse of future broadband transport services [6], not only in the higher network layers of the public networks but in the LAN's as well, we also gave a proposition of future ATM based fiber-optic LAN's. Two approaches require different network architectures, since the Fast Ethernet protocol is provided with facilities for collision detection and re-transmission, whereas ATM relies on digital switches.

Fast Ethernet Network Proposal

The use of generally accepted standards for accessing the networks assure low cost and widespread implementation of networks. This is the reason our first network proposal is based on Fast Ethernet IEEE 802.3 Base FX standard which uses a CSMA/CD protocol.

For efficiency reason the maximum transfer time between any two stations on one segment including repeaters is prescribed. In our proposal no repeaters are needed and therefore the transfer time equals the propagation time over the fiber. This allows us to connect nodes that are more apart than in wired LAN's. The maximum distance times bit-rate product for our proposed system equals 100 km·Mb/s. This exceeds by far the capacity of Fast Ethernets based on metal wiring. So, in the case that a bit-rate of 100 Mb/s is used the maximum distance between any two stations attached to the same LAN segment equals 1 km. The given figures are based on the limitation of the Fast Ethernet protocol. The fibers have a bandwidth-distance product of about 1 GHz·km, which means that for the given span the speed can be 10 times higher.

Since we would like the MAC service to remain unchanged all existing network layers can be used unaltered. Only the physical layer is changed. However, this architecture is doing more than only replacing copper by fiber; it reduces the cable length to be installed as well.

The solution presented in Fig. 1 implements segmentation of the LAN by means of wavelength division multiplexing (WDM). Since optical waves are used the configuration is a star, segmented in mini-stars.

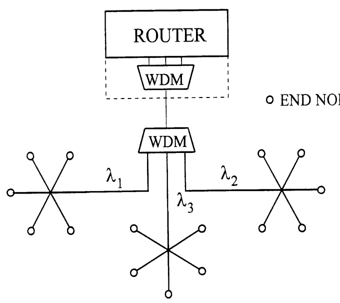

Figure 1. Network topology based on multiple single-wavelength optical stars using different wavelength for each star.

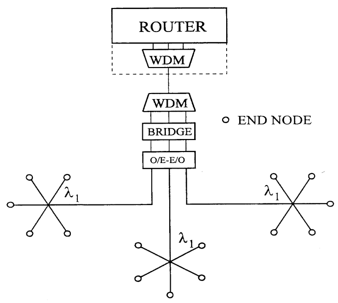

Figure 2. Network topology based on single-wavelength optical stars using the same wavelength for each star.

Each segment of LAN uses its own specific wavelength. A common signal transfer path to the router is created by inserting a WDM multiplexer. In this way cabling length is reduced and the maximum allowable length of the signal can be implemented. The mini–stars are supposed to comprise end nodes that show an extensive mutual exchange of information, for example the workstations of a team working on the same CAD or CAM project. The geographical spread of the nodes will be small, so that a long common transmission line to the router is allowed. The stars are assumed to have passive optical star couplers. Therefore, electronic equipment is only

met in the router, which facilitates simple maintenance and allows for an increase geographical spread since there is no additional electronic delay. A disadvantage of the presented scheme is found in the fact that the different network interfaces in the end nodes require light sources emitting different wavelengths.
The impact of the proposed new passive optical LAN set-up is tenfold increase in bandwidth-distance product (to 100 Mb/s·km) over UTP category 5 cabling at equal or comparable cost. This means that at equal maximum link span of 100 m the bandwidth can increase tenfold (up to 1 Gb/s) or that the allowable linkspan can increase to 1 km at 100 Mb/s bandwidth. Further increase in bandwidth distance product is limited primarily by the Fast Ethernet protocol itself rather than by the limitations of multimode fiber.
The second architecture based on Fast Ethernet protocol is shown in Fig. 2. Here an electronic bridge is introduced quite near to the end nodes. This enables higher speed, but means electronic equipment (including power supply) to be installed outside the router cabinet. The main advantage of this solution is that network cards can be identical for the end nodes all over the LAN involved. Similar to the first solution cabling length is limited, which contributes to cost savings in both cases.

ATM Based Network proposal

Since ATM represents the workhorse of future broadband transport services in LAN applications, we present two different network proposals based on this technique. Combination of ATM and optical fibers asks for specific network architectures. It is the greatest scientific challenge to develop those architectures.
Since ATM is a central switched transmission technology no common transmission path can be applied, but each end node should have its own transmission path to the switch. In order to save cabling, different multiplex techniques are presented.

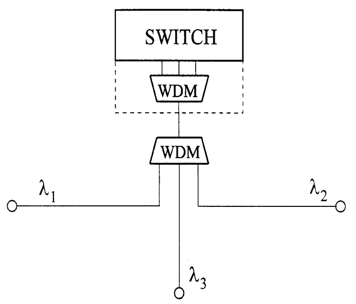

Figure 3. ATM Network topology based on multi-wavelength transmission.

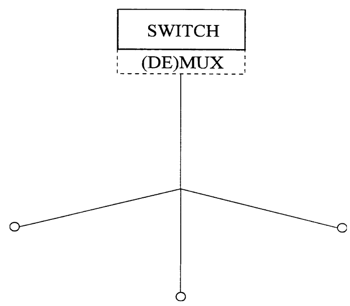

Figure 4. Network topology based on single wavelength transmission in combination with TDM or CDMA.

Fig. 3 shows a solution by using wavelength multiplexing. Each end node has been allocated a specific wavelength which is known in the switch. To save cabling various user links are applied to a wavelength division multiplexer (WDM). From that point to the switch a single fiber carries the multiplexed wavelength that are

demultiplexed before entering the switch. The stability requirements for WDM devices as long as we stick to multi-mode systems are less stringent, since in these systems the wavelengths are not so densely packed as in single mode systems, but the disadvantage of using the different wavelength remains.
A second network architecture for ATM transmission is presented in Fig. 4. In this scheme different multiplexed techniques are candidates. The first one being Time Division Multiplexing (TDM). Since the end nodes will be situated at different distances from the switch, carefully and flexible timing of the data packets is required together with an advanced protocol, in order to prevent the collision of packets. A second multiplex technique used in this architecture can be Coding Division Multiple Access (CDMA). The application of this multiplexed scheme in optical network is quite new; moreover, optical networks offer new alternatives for this kind of demultiplexing [7].

Conclusion

In this paper new network architectures for fiber optic LAN's were presented. This network architectures are based on the widespread multiple access technique Fast Ethernet and the ATM protocol, which provoke to be the future protocol of the LAN's. In the Fast Ethernet network proposal a star network is segmented in mini-stars using passive optical star couplers. Electronic equipment is only met in the router which facilitates simple maintenance and allows for an increase in geographical spread. In order to reduce cabling WDM is used in the common line to the router. In order to avoid the use of different wavelengths another network proposal is suggested in which electronic bridges are introduced so that all node network interfaces can use the same wavelength. The reliance on different multiple access techniques in ATM networks provides advantage in reducing cabling distance from the switch to each node. In multi wavelength transmission this is achieved by connecting all nodes to a WDM multiplexer. Other widespread techniques like TDM with flexible timing of the data packets can be used, as well as new technique for optical network applications like CDMA.

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