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OPTICAL NETWORKS AND LABORATORY SERVICES

Orlando CIAFFONI [1)], Maria Lorenza FERRER [1)], Giovanni MIRABELLI [2)] and Luciano TRASATTI [1)]

[1)] *INFN – Laboratori Nazionali di Frascati, P.O. Box 13, Frascati (RM) 00044, Italy*

[2)] *INFN – Sezione di Roma, Università degli Studi di Roma "La Sapienza", Piazzale Aldo Moro, Roma, Italy*

Possible technical solutions to the problem of high speed data links between laboratories are presented. Long distance networks (WAN), ranging from tens to hundreds of kilometers, offer a variety of possibilities, from standard 64 Kbit/s connections to optical fiber links and radio or satellite Mbit channels. Short range (up to 2–3 km) communications are offered by many existing LAN (local area network) standards (e.g. Ethernet [1]) up to 10 Mbit/s. The medium distance range (around 10 km) can be covered by high performance fiber optic links and the now emerging MAN (metropolitan area network) protocols. A possible area of application is between the Gran Sasso Tunnel Laboratory, the outside installations and other Italian and foreign laboratories.

1. Introduction

The importance of high speed data links between laboratories is steadily increasing, due to the higher and higher amount of data produced by modern experiments and to the growing demand for remote control and monitoring of complex apparata, located in critical environments. In this respect, the Gran Sasso Tunnel Laboratory offers an ideal experimental ground, for two different reasons:

(a) The need to control the experiments from the outside of the gallery (6–7 km distance). For some experiments the possibility is even considered to locate the counting room outside the tunnel.

(b) The wish to monitor the experiments from remote laboratories, even in the United States.

2. Wide area networks

Standard analog data links are limited to 19.2 Kbit/s. The Italian telephone company is experimenting different techniques of digital data links. Experimental 64 Kbit/s PCM (pulse code modulation) connections are operative, and a project for a 2 Mbit/s optical fiber link along the Autosole has been presented.

Radio links offer higher data rates and are essentially cheaper to install, but they require the communicating stations to be optically visible for each other. A good area of application of this technique could be in the connection between relatively close INFN Sections and Laboratories.

Satellite links offer channels with speeds up to 2 Mbit/s in 34 Kbit/s steps. Two satellites are available at this moment in Europe for commercial users: TELECOM 1 and ECS. An Italien satellite, ITALSAT, will be available in 1988. However, several problems are becoming apparent: the price, although lower than ground connections, is still high, and the delay associated with the long flight path tends to create response problems for high level network protocols which use heavily handshake techniques. An interesting problem connected with the satellite service is that the geostationary orbit, necessary to reduce antenna costs and network management, is already practically full. Almost 80 satellites are flying on this orbit, and their number cannot increase too much in the future.

In contrast, a new submarine cable using optical fibers is being laid down between the USA, France and England, showing that the fiber optic technology is rapidly expanding.

3. Local area networks (LAN)

Local area networks, in contrast, offer high bit rates, good software support, and a good grade of standardization. Unfortunately, serious limitations in their capabilities are their very short range (in the case of Ethernet, 2.8 km with fiber optic repeaters) and the difficulty to interconnect different LANs, either similar or different. Several instruments to overcome this limitation are being proposed: gateways, routers, bridges and repeaters.

The most powerful, which is also the most cumbersome, is the gateway. A gateway, working from level 4 of the ISO/OSI (open systems interconnect) standard upwards, converts protocols from a network architecture to another. Its capabilities are high because, since it understands the structure of the data it handles, it can communicate between different networks, for instance implementing a file transfer between two different machines. For the same reason, their throughput is low, because the software overhead they require is high.

Routers work at a lower level (up to OSI level 3). They are not concerned with data structures, and therefore can only interconnect networks of the same architecture. However, they understand message handling and, for instance. can choose the best way to transmit a message through a complicated network. Moreover, they are aware of the packet structure of the interconnected networks, and can translate from one to another. An example is the DEC Ethernet/DDCMP router.

Bridges are even more simple and, therefore, more efficient. They work at levels 1–2 of the OSI, and transmit packets between different sections of the same network, choosing which messages belong to any section. A typical bridge example is a way to interconnect two Ethernet sections beyond the 2.8 km limit. Two bridges are installed, one as a node of every section. Every bridge monitors the traffic on its section, and only transmits to the other bridge the packets which have addresses belonging to the other section. This method is very simple and very powerful. Since a bridge only handles packets, and not messages, it does not influence the higher level message and data structures, to which it is transparent. For instance, a bridge between two Ethernet sections is completely unaware of the upper protocol layers, which could be DECNET or TCP/IP or any other standard. On the other hand it can heavily reduce traffic on a CSMA/CD network (e.g. Ethernet), since not all packets must travel to all stations. Every section sees only the packets of the other section (or sections) which are addressed to itself, and is not burdened with the internal traffic of the others. Because of its inherent simplicity, a bridge is capable of maintaining the high bit rates of the original network.

Bridges between Ethernets using fiber optic links are becoming available from various vendors, including DEC. Unfortunately the DEC product, because of the fiber technology used, is limited to a distance of 2.8 km between the two Ethernet sections it connects. This distance is too short to be useful for the Gran Sasso Laboratory, where 6 km must be covered to carry data outside the tunnel, and where one (or more) Ethernet networks inside the tunnel would have to be connnected with one (or more) Ethernet sections in the outside installation.

Although it will be possible to connect up to 7 DEC bridges in series allowing a total distance of 21 km, this solution is not feasible for the Gran Sasso installation because of the need to install powered apparatus in the middle of the gallery.

Bridges between Ethernets have been implemented using satellite links (TRANSLAN/Vitalink). However, these bridges are not capable of maintaining the bit rates of an Ethernet network.

4. Fiber optics

Fiber optic links have undergone a high development in the last few years. The technology now offers not only multimode (graded refraction index) fibers, which are limited to a speed of a few tens of Mbit/s for a range of a few km, but also monomode fibers, whose characteristic bandwidth is approximately 50 Gbit/(s km) when working in the so-called second window (1285–1330 nm). With these new fibers, links of up to 40 km at a speed of 140 Mbit/s are becoming standard, while the interface electronics are striving to match the fiber possibilities. Many 140 Mbit/s fiber links are installed, and some of these will be upgraded to 565 Mbit/s without changing the fibers installed when the interface apparata will be available (middle of 1987).

The interface to the external world is in itself standardized by the CCITT recommendation G 703, which specifies the time slot multiplexing technique with a chain of standard intermediate speeds between the 140 Mbit/s of the media and the single telephone channel. The multiplexing scheme is as follows:

(1) The 140 Mbit/s media channel is divided into 4×34.368 Mbit/s channels.

(2) A 34.368 Mbit/s channel is divided into 4×8.448 Mbit/s channels.

(3) A 8.448 Mbit/s channel is divided into 4×2.048 Mbit/s channels.

(4) A 2.048 Mbit/s channel is divided into 32×64 Kbit/s channels.

All possible mixtures of the above possibilities are allowed: for instance, within a 140 Mbit/s fiber link, a modern Delta encoded TV channel at 68 Mbit/s could use two of the four 34 Mbit/s channels leaving the other two for data, 64 Kbit links and phone channels. TV channels using only 34 Mbit/s will be available commercially in a few years. The bit error rate of such a system is guaranteed to be better than 10^{-9}.

However, much remains to be done in the area of multiple access to very high speed data channels. Fiber optics seem to have made feasible the idea of metropolitan area networks, but the access mechanisms to this kind of medium are still in the development stage.

5. Metropolitan area networks

MAN is a new achronim recently appeared in communication literature. Generally, a MAN is a network capable of providing high speed switched connectivity across distances typical of those found within a metropolitan area. Furthermore it should be capable of carrying different kinds of traffic (e.g., voice, video, data) simultaneously.

If one puts together the concept of MAN and the fiber optic bandwidth, it becomes immediately obvious that the standard (and not standard) LAN protocol techniques are no more feasible.

When the data flow runs at these frequencies, a great part of the access protocol must be moved down to the hardware level, which means that the protocols themselves must be heavily changed (and simplified).

We have contacted the leading Italien industries active in the field. The results are that the know-how is available, and they have shown a high interest in collaborating with INFN on experimental implementations to study the big possibilities offered by this rapidly expanding field.

We have conducted a study of new topologies, protocols and optoelectronic elements to try to apply these new techniques to the physics laboratory, with an eye to possible experiments which could be of interest also to the telecommunication community.

One of the most promising fiber optic topologies seems to be the STAR connection, which uses optical stars to connect the various users and involves the flooding technique. An optical star is a passive optical device capable of collecting information by several input fibers (of the order of 10–20), and of sending it out to a similar amount of output fibers. This way, the information leaving a port reaches all the other ports of the network (flooding). Every station receives and bufferizes packets from the whole network, and only passes them to the upper levels if the address is correct.

The mechanism of access to the network for transmission is the most delicate part of the problem. Several possibilities are being proposed: token, virtual token, CSMA, and even less standard protocols which use a separate bus (either a copper wire or a low-speed fiber) to implement a prereservation mechanism.

There are examples in the literature of star configurations up to 100 Mbit/s [2] connecting 16 terminals separated by up to 2 km.

It would be extremely interesting to try to extend this kind of protocol to configurations involving more than one star, taking advantage of the continuously emerging new devices (high power laser diodes, low-loss star couplers, etc.) using, if necessary, optical repeaters to extend the system.

In view of the now emerging interest in MANs (metropolitan area networks), we have imagined a configuration with several stars interconnected by some 10 km optic fiber, using [3–5]:

- Better than 0.5 Gbit/s monomode fiber;
- Passive star couplers 10×10, $20 \times 20, \cdots$ and repeaters or bridges between stars;
- Flooding technique: All messages are simultaneously sent to all stations.

It will be necessary to have two different kinds of protocols: one inside every star and one to interconnect the stars. The protocol inside a star will be implemented using a centralized arbitration mechanism. One station will play the role of master controller and will be connected with an additional point-to-point bus to each of the other stations, allowing arbitration and resource assignment during a transmission cycle on the fast bus. Compared to a system without control bus, this scheme will provide higher throughput and shorter waiting time at the cost of more complicated hardware installation.

The additional bus could be implemented using low speed fiber optic systems, since the amount of data to be exchanged on it will be very low.

As far as the protocol between different stars is concerned, we are considering either of a token mechanism (real or virtual) or an extension of the separate bus with the reservation mechanism. The final solution will be chosen depending on the implementation difficulty and on the gain to be achieved with the different schemes.

6. Conclusions

A wide range of possibilities is becoming available in the high speed telecommunication field, both for long distance connections and in particular for the extension of short dedicated networks to longer distances. A new installation like the Gran Sasso Tunnel Laboratory seems to be an ideal testing ground for the application of these new possibilities.

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