Network Technologies: Some Options

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Abstract:
Over the past 18 months, computer and telecommunications vendors have done an excellent job of promoting their leading-edge technologies at network shows across the globe. Unfortunately, this information doesn't necessarily help the manager faced with immediate strategic choices. On the contrary, the decision-making process grows more difficult as the number of options increases. Advances in transmission technologies, such as high-speed transmission over Unshielded Twisted Pair (UTP) media, and switching technologies, such as Asynchronous Transfer Mode (ATM) and Ethernet switching, have given rise to new competing approaches. To add to the confusion, technologies initially designed for one application are now proposed in contexts extending far beyond their initial scope, such as Frame Relay to support telephony and ATM to construct a LAN. This article describes how various LAN and WAN technologies compare and which one is best suited for what environment.

(*) Published in Windows NT Magazine, January 1996

The Limits of Conventional Hubs

Let's examine LANs first. The rationale behind setting up shared-medium LANs — Ethernet, Token Ring, and Fiber Distributed Data Interface (FDDI) — where all systems exchange information over the same cabling system — stems from the fact that cables were expensive, as were installation and switching. Not surprisingly, the idea of using common cabling to connect the offices on a floor and the floors in a building without intermediary switching was certainly attractive. It turned out, however, that hooking up the connections was more complicated than it sounded.

First, deploying a simple linear cable created numerous operational difficulties for introducing new stations, locating faulty equipment, making physical interventions, or isolating part of the network. Because of these limitations, the physical bus topology was replaced by the physical star topology. Under the star topology, all LANs become physically organized around cascaded wiring hubs where administrators can perform technical intervention much more efficiently. In addition, for the LANs to take full advantage of the central position of the hub, developers decided to add increasingly powerful management functions.

If the topology remains a bus, LAN frames entering through a single port in a hub exit through all the ports in the hub. More precisely, the frame exits from one port, visits the stations cabled to that port, and returns to the hub so it can exit through the next port. Both Ethernet and token-passing networks (FDDI and Token Ring) use probabilistic techniques to share access to the common medium, but FDDI and Token Ring employ a more deterministic scheme (i.e., token passing) where each station is guaranteed access to the medium. Ethernet provides no such guarantee. Therefore, under a heavy load from many stations, the performance of a Token Ring or an FDDI
network will degrade far less than that of an Ethernet network.

Clearly, the conventional Ethernet hub approach has reached its limits. The propagation of frames sent to multiple recipients, called "multicast frames," over the LAN poses increasing difficulties, especially with the emergence of multimedia applications that depend on multicasting techniques. Also, sharing 10 megabits per second (Mbps) bandwidth between many stations cannot address the bit-rate requirements of a number of applications. What are the available options for providing higher-speed connections?

Segmentation Doesn't Scale

The simplest way to provide higher-speed connections is to reduce the number of stations per segment, increase the number of individual segments, and interconnect the segments using conventional store-and-forward boxes (i.e. bridges or routers). This technique is called segmentation. Although it may be a stop-gap solution, segmentation doesn't scale well enough to turn it into a strategy.

A single bridge or router wouldn't be economical or sufficient in a medium-size organization. Several bridges or routers would be needed, and they would need to be inter interconnected by some form of high-speed point-to-point connections or by a backbone system. Unfortunately, those bridges or routers, which would have to completely store the frames before retransmitting them after some form of processing and control, would become bottlenecks. They would also introduce additional delays in the end-to-end transit time. A simple extrapolation of the segmenting approach would be to dedicate 10Mbps Ethernet segments to individual stations. This is a simple, practical way to connect certain demanding systems with special requirements, such as packet-based teleconferencing systems or multimedia servers, but like segmentation, it doesn't scale well.

FDDI on the Desktop: Too Little, Too Late

Another option would be to replace Ethernet or Token Ring networks with FDDI networks. FDDI uses a shared-medium technique similar to that of Token Ring but operates at 100Mbps instead of 16Mbps. A full-scale FDDI implementation is constructed of two physically separate rings that are dual-connected to all the FDDI adapters on the network. The backbone of an FDDI network is normally made up of optical-fiber cable. You can achieve connectivity to the desktop with either optical fiber or copper twisted-pair.

FDDI has mainly been used for two purposes: to serve as a backbone interconnecting lower-speed LANs (e.g., 10Mbps Ethernet and 16Mbps Token Ring LANs), and to provide direct, high-speed attachments for hosts and routers.

Unfortunately, FDDI seems to be "too little, too late" for three reasons. First, FDDI in its current version doesn't support full isochronism, which is the ability to transport real-time data such as voice on a guaranteed basis. Thus, when it is heavily loaded, the quality of service FDDI provides may be limited. Second, FDDI remains a shared-medium technology unless you devote one ring per station. When the average traffic of each station is increased by an order of magnitude — driven by multimedia applications and the increasing power of individual stations — the limitations you've experienced with your current 16Mbps Token Ring LANs will disappear. As a result, each station will have access only to bandwidth equal to 100Mbps divided by the number of stations. Third, the cost of FDDI remains high, even though interfaces for twisted-pair cables are less expensive than those for their fiber counterparts.

FDDI currently has less than 1% penetration in the LAN interface market, but it may remain a backbone technology of choice for a couple of years, especially for large campuses.

100BaseT's Popularity

A more recent option for high-speed communications is 100Mbps Ethernet. Two Versions exist: 100BaseT and 100VG-AnyLAN. Although both versions run on UTP, they are drastically different. 100BaseT was developed by a group of companies called the Fast Ethernet Alliance. The idea behind Fast Ethernet is to keep the sharing mechanism used by conventional Ethernet, the Carrier Sense Multiple Access with Collision Detection (CSMA-CD), but to adapt the physical characteristics to enable it to operate 10 times faster (100Mbps). Stations connect to 100BaseT hubs in the same way that they connect to 10BaseT hubs.
One consequence of this approach is that the same collision problems you experience over conventional Ethernet affect the functioning of 100BaseT networks — each packet entering a 100BaseT hub visits all the stations sharing the 100Mbps bandwidth. (There are two modes of Fast Ethernet: 100BaseT4 and 100BaseTX, which run over different types of UTP cable.) In 1995, the penetration of 100BaseT technology was still modest, but analysts have predicted that the number of installed ports will have reached 1,000,000 by the spring 1996.

The 100VG-AnyLAN technology has been proposed by another group of companies under the leadership of Hewlett-Packard and IBM. In fact, this technology has little to do with Ethernet. In contrast to the 100BaseT technology, 100VG-AnyLAN retains the Ethernet frame format but uses a deterministic protocol called the Demand Priority Access Method (DPAM) instead of CSMA-CD. DPAM provides guaranteed access to the media using an access method that is conceptually similar to token passing; in reality, however, it offers greater flexibility than CSMA-CD and can better handle prioritized traffic. Under 100VG-AnyLAN, stations are connected to a switching hub. These, in turn, may be connected to other switching hubs. 100VG-AnyLAN requires four unshielded twisted pairs in a Category 3 UTP cable. Though about 200,000 ports had been installed at the time of this writing, the future of 100VG-AnyLAN seems cloudy.

**Switching: A Turn On!**

The next two technologies are significantly different from 100BaseT and 100VG-AnyLAN Ethernet because they don't suffer from the limitation of getting only a slice of the 100Mbps bandwidth. Indeed, they rely on the principle of LAN switching. There are two types of LAN switching: Frame switching, which is used in Ethernet switching solutions, and cell switching, which is used by ATM solutions.

A LAN switch is a device which receives traffic from copper or fiber cable segments, identifies blocks of data originating from them, and redirects the data blocks to other cable segments. The essential difference between a LAN switch and the wiring hubs used for 10BaseT or 100BaseT Ethernet LANs is that each packet entering the LAN switch visits only one output connection instead of all the stations — note that functionally, a LAN switch is close to a multiport bridge. Therefore, if a single station is attached to a LAN switch through a 10Mbps link, the entire 10Mbps of bandwidth is dedicated to it.

Switched Ethernet uses the LAN frame-switching technique and can handle data blocks of variable length. An Ethernet switch interconnects a number of segments, each of which is attached to one or more stations. The most popular use of Ethernet switching is for 10Mbps Ethernet networks. Its advantage in this environment is that introducing a 10Mbps Ethernet switch doesn't require any extra wiring or any new LAN adapters. Most Ethernet switches support only UTP cabling (i.e., 10BaseT), but there are about 70 million 10BaseT Ethernet adapters installed worldwide.

High-end Ethernet switches are available for 100BaseT networks. Furthermore, hybrid 10Mbps/100Mbps switching products are available to service both types of Ethernet networks concurrently. These devices constitute an attractive and flexible solution. Even more attractive are the double-hybrid devices that merge switched Ethernet with regular Ethernet hub functions. These devices function as dual switches/hubs and can mix 10Mbps and 100Mbps access bit rates. End-user stations with normal requirements can simply connect to shared 10Mbps segments. On the other hand, end-user stations that have high bandwidth requirements, such as access to remote video servers or high-quality video conferencing, can connect to dedicated switch ports. Similarly, mainframes or data/multimedia servers may connect to shared 100Mbps segments or attach directly to dedicated 100Mbps switched ports.

**ATM: As a Backbone First**

The second LAN switching technology is ATM. It was developed to address the transmission requirements for concurrent voice, video, and data transmission over wide-area fiber-optic links. ATM's strength is that it can transport multiple data streams on separate virtual circuits operating at different data rates. As the use of optical-fiber cabling became more prevalent in the LAN environment, ATM switches were developed to bring the advantages of ATM to LANs.
In contrast to switched Ethernet, which handles variable-length frames, ATM switches handle fixed-length data blocks, called cells. But this is not the only difference — ATM also offers a wide scope of access speeds, ranging from a few Mbps to 155Mbps or 622Mbps. Because ATM is a connection-oriented technology, no station can communicate with another station without establishing an end-to-end logical connection. This is currently a major complication because logical connections must be defined in advance by the network manager. In the future, stations will be able to establish their own connections dynamically. The main advantage of a connection-oriented technology is that it guarantees the quality of service parameters, such as transit delays and average throughput.

Because ATM is connection-oriented, it is difficult — but certainly not — to run connectionless protocols like Internet Protocol (IP) or Internet Packet xChange (IPx) on an ATM network. Also, the cost of implementing ATM remains high, even when compared to implementing 100Mbps Ethernet or FDDI solutions. For these reasons, ATM will initially be used in a LAN environment to build the LAN backbone — a role played by FDDI today. Multimedia servers can also directly attach to an ATM backbone to reap the performance benefits, but deployment at the desktop will come slowly.

Who Needs 100Mbps?

Before turning to wide-area networking, let’s look at the actual requirement for high-speed connections to the desktop. Who needs 100Mbps on the desktop? Videoconferencing only requires between 100Kbps and 1000Kbps. Compressed CD-quality sound needs only 200Kbps. Broadcast-quality video works well at 4Mbps. Even High-Definition Television (HDTV) will require only from 25Mbps to 30Mbps. For most multimedia applications, 100Mbps is overkill.

Amazingly enough, perhaps the only type of application which justifies such a high bit rate is interactive access to high-resolution images stored on remote servers, such as in medical environments where doctors and technicians need to access X-rays and other types of scans. In that environment, the critical element is the time required to download an image — it should not exceed a few seconds — and simple arithmetic indicates that bit rates of 50Mbps to 80Mbps may be necessary.

WAN Technologies

On the WAN front, the situation is slightly more simple, although several competing options are available. Two of these options are Frame Relay and ATM. Both come from the International Telecommunications Union (ITU) standardization process, and both can be used either to build corporate networks over leased circuits or to access a service provided by a network operator.

The protocol used as the interface between the user’s local network and a wide-area Frame Relay network is defined in a standard. Frame Relay was designed to interconnect LANs through a WAN. The initial objectives of Frame Relay were to service conventional computer-based data applications, such as the transfer of email or computer files; developers did not envision support for telephone connections and video-conferencing sessions, but it became necessary anyway.

Telephony over Frame Relay

Frame Relay can be defined as a service that multiplexes various flows of information asynchronously. Thus, Frame Relay is often presented as an alternative to synchronous time-division multiplexing where the overall bandwidth of a wide-area link (e.g., leased line) is split into several fully independent channels, each with an assigned fixed bit rate.

In Frame Relay, the various data flows are carried by logical channels at committed rates. These rates are guaranteed. But the key advantage of Frame Relay is that it can exceed the committed rate when other channels are idle, so a single link can achieve much higher speeds than the committed rate. This technique is particularly well-suited for interconnecting sites with leased lines (e.g., T1 or T3 lines) supporting multiple services in parallel, including audio-video streams (which can be intelligently multiplexed to take advantage of all available bandwidth).

The multiplexing idea behind Frame Relay is similar to that of ATM and X.25. Like them, Frame Relay requires a connection has been set up before packets can be transmitted. But unlike ATM, Frame Relay has no sophisticated mechanisms to specify grades of service. In practice, however, several manufacturers are proposing Frame Relay networks with
performance guarantees. Virtual connections may then seemingly emulate the behavior of physical circuits, as in the case of ATM. Mechanisms that are already present in Frame Relay, such as priority frames and discard-eligibility marks, support assigning priorities to data streams. This capability is used by vendors to assign higher priority to audio streams in the support of audio-video real-time transmission.

The Role of ATM in WANs

ATM was designed to transport multiple data streams over wide-area fiber-optical links. In particular, ATM is an important component in the Broadband Integrated Services Digital Network (B-ISDN), the fiber-based follow-up to the current copper-based ISDN technology. The full-scale deployment of B-ISDN, however, is definitely in the future. In the meantime, several private and public networking vendors have started offering end-to-end ATM links to the market. These offerings allow you to leverage ATM's advantages in a private WAN environment.

Unlike Frame Relay — basically a plug-and-play service — deploying ATM in a private network requires that you do the bulk of the integration work. You must determine how to partition the different data streams and data rates supported by the link as well as how to interface your equipment to the link. In other words, installing a wide-area ATM link is a lot like installing a T3 link for combined voice, video, and data services. You do the integration yourself.

About The Author

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