CS553A-Introduction to Networking

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ATM vs. Gigabit Ethernet

For High Speed LANS

Student: Pei-Hsun Tsai
Professor: Dr. Vladimir V. Riabov

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1. *Glossary*

ATM: Asynchronous transfer mode, a comprehensive connection-oriented transmission protocol based on fixed-length cells, or "packets," of 53 bytes each spanning both LANs and WANs. Its developers designed ATM to integrate voice, video, and data into one network. ATM sets up end-to-end virtual connections before transferring data and negotiates quality of service (QoS) during the connection setup. The protocol is independent of transfer rates so it can seamlessly scale from a few megabits to multiple gigabits per second. The User Network Interface (UNI) and the Network to Network Interface (NNI) specify traffic routing and management for both public networks (telephone companies) and private networks.

CSMA/CD: Carrier sense multiple access/collision detection, in which all nodes attached to the network contend for access and listen for transmissions (carrier sense) in progress before starting to transmit (multiple access). If two or more nodes transmit at once, a collision occurs (collision detection) and nodes back off to retransmit at a randomly selected time. The collision domain limits cable distance because a node on one end must sense the smallest frame from a node on the farther end. The theoretical collision domain is 2500m for 10 Mbps, 250m for 100 Mbps, and 25m for 1000 Mbps Ethernet.

Edge device: Equipment at the edge of an ATM network that converts non-ATM traffic into ATM traffic. Functions for an edge device could include address translation, QoS translation, segmentation and reassembly of information frames into cells, concentration of traffic to high-speed pipes, and flow-control functions. Edge devices could forward packets at either layer 2 or 3 protocols.

Ethernet: The LAN standard that uses IEEE 802.3 CSMA/CD protocol and runs at a 10-Mbps transfer rate. It transfers data in variable-length packets of 64 to 1500 bytes. Ethernet has no inherent real-time traffic capability. IEEE 802.3 physical-layer standards include 10Base5, 10Base2, 10BaseT (10 Mbps, baseband, with a segment length of 500 or 185m or unshielded twisted pair).

Fast Ethernet: A network topology that incorporates changes to Ethernet at the physical layer only to provide 100-Mbps transfers. Fast Ethernet requires no changes to Ethernet software or media-access control (MAC), providing easy upgrades to higher speed transfers. IEEE 802.3u specifies Fast Ethernet.

Flow, or stream: A sequence of packets, each having the same QoS requirements.

Gigabit Ethernet (GE): The IEEE P802.3z proposed standard to increase Ethernet's data-transfer rate to 1000 Mbps. By following the example of Fast Ethernet, in which only the physical layer changed, GE will maintain full compatibility with existing Ethernet nodes and simultaneously increases the bandwidth to 1000 Mbps at the MAC to physical-layer interface. Other objectives include full- and half-duplex operating

modes; retaining the CSMA/CD method for half-duplex mode and IEEE P802.3x flow control for full-duplex mode; and distances of 500m on multimode fiber, 3 km on single-mode fiber-optic links, and 25m on copper. Another GE goal is to extend the copper link to 100m over Category 5 unshielded twisted-pair cable and meeting these goals for only two to three times what 100-Mbit Ethernet costs. Plans are to adopt the 1-Gbps Fibre Channel physical layer and speed it to 1.25 Gbps to account for the 8b/10b coding, so actual data throughput is 1 Gbps.

IEEE Project 802 LAN/MAN Standards Committee (LMSC): A committee that defines and proposes standards for LAN and metropolitan-area network (MAN) equipment, covering the physical and data-link layers. The standards under the LMSC umbrella include the 802.1 Network Management and Bridging, 802.2 Logical Link Control, 802.5 Token Ring, 802.10 Security, and 802.11 Wireless LAN.

IEEE P802.1p standards ("P" before the numbers stands for "proposed" in IEEE parlance): The Traffic Class Expediting and Dynamic Multicast Filtering working group is discussing how to add priority levels and expedite isochronous traffic. The group has not yet determined the number of priority levels. The group's goal is to improve support of time-critical and multicast-intensive applications, including multimedia interactive applications, across bridged LANs. A draft standard is as yet unavailable.

IEEE P802.1Q: A proposed standard that the Virtual Bridged LANs working group is developing to define an architecture and bridge protocols for the logical partitioning of bridged LANs to administratively defined groups of users, independent of physical location. The working group is discussing adding QoS capability to the standard. The group has not reached a consensus on how to accomplish this goal. A draft standard is unavailable.

IEEE 802.3: The committee that defines standards for Ethernet LANs, such as CSMA/CD, and physical layers, such as 10BaseT, 100BaseT, and 1000BaseT.

∫ The Full Duplex Operation working group, which is nearing completion of specifications for transmission and reception of IEEE 802.3 frames over media that supports simultaneous bidirectional signaling (twisted-pair and fiber). The group will also address flow-control mechanisms. Separate transmitting and receiving channels of twisted-pair and fiber technologies achieve this performance enhancement.

IEEE P802.3z: The Gigabit Ethernet task force, which is working on an extension to the familiar 802.3-specified Ethernet standard. The task force expects to release a first draft in the first quarter of this year and proceed with a working-group ballot in the third quarter. Even though the group does not expect full IEEE authorization until the first quarter of next year, devices typically start to claim compliance after

working-group ballot approval.

Internet Engineering Task Force (IETF): A forum for working groups to develop operational and technical standards within the Internet Protocol (IP) suite. A document begins the standards process as a working draft and progresses to a Requests for Comments (RFCs). RSVP and IP over ATM are working-draft documents in the IETF. Typically, the IETF waits until test-bed implementations have evaluated the technologies and then makes specifications.

Internet Protocol (IP): A protocol that provides a connectionless (datagram) service to the higher transport protocol. IP works across heterogeneous networks to discover and maintain topology information for routing and delivering packets.

Integrated Services (Intserv): An IETF working group extending the Internet service model to transition the Internet into a robust integrated-service communications infrastructure.

Integrated Services over Specific Link Layers (ISSLL): An IETF working group that coordinates adapting link-layer technology to provide RSVP and Intserv capability.

Layer: One of seven collections of network-processing functions in the Open Systems Interconnection (OSI) model that comprise rules and standards for successful data communication.

Layer 1: The physical layer in the OSI model, covering electrical-, optical-, and physical-media connections.

Layer 2: The data-link layer in the OSI model, covering bridge devices for data flow, addressing, and error detection.

Layer 3: The network layer in the OSI model, covering multiprotocol communications between network nodes, such as router devices.

Layer 4: The transport layer in the OSI model, covering end-to-end control of transmitted information.

Layer 5: The session layer in the OSI model, covering binding and unbinding logical links between users.

Layer 6: The presentation layer in the OSI model, covering control codes, special graphics, and character sets.

Layer 7: The application layer in the OSI model, covering file transfer, e-mail, and all other applications.

Multiprotocols over ATM (MPOA): An ATM Forum standard-basically, routing over ATM-that is now in final ballot and should become ratified by midyear. At the risk of increasing complexity, but for completeness, MPOA provides a means for all existing network protocol packets to traverse an ATM network. MPOA separates the switching from the routing and provides the connectivity of a fully routed environment

by unifying the approach to Layer 3 protocols.

Network-interface card (NIC): A card that connects a host computer to a network.

Remote monitoring (RMON): An IETF standard specifying nine levels of information gathering and reporting for network managers to proactively monitor and troubleshoot their networks.

Reservation Protocol (RSVP): The ReSerVation Protocol. An IETF working group is coordinating RSVP's development for supporting QoS classes in IP applications, such as videoconferencing and multimedia.

QoS: The appropriate allocation of bandwidth capacity and associated management processing to meet an application's requirements for time-sensitive delivery of information. Performance parameters that characterize QoS are transfer rates and allowed variations for peak, average, and minimum rates; transfer latency from source to destination; latency variations that are measured by differences in packet-to-packet delays; and packet error-and-loss ratios.

WinSock: An open-network application-programming-interface (API) standard that provides IP and Internet access under Windows. A group of vendors and individuals produced WinSock. The WinSock2 specification is both an API and an architecture. It handles multiple transport protocols and provides for QoS. WinSock2 is available for Windows NT 4.0 and 95. You can get more information at the Web site, www.winsock.com.

2. Abstract

The computing power needed by end hosts is continuously increasing and that power is growing geometrically. The advent of Internet is not making the life easier either and it is pushing the LAN/WAN to its limits. Also Most of the distributed applications are bandwidth hungry, consequently the campus networks demands high-speed connectivity between the servers and the workstations. Businesses are increasing their use of the Internet for all types of communications, from email and file transfer to web services and electronic commerce. All above factors are pushing the LANs to have high-speed connectivity between workstations as well as in the backbone. Network planners are looking for a technology that provides performance, reliability, high bandwidth, scalability, and QoS in some cases. However the biggest dilemma for them is: Which technology to choose? Both Gigabit Ethernet and ATM are forcing their way into LAN. Gigabit Ethernet is a 1000 Mbps extension of ubiquitous 10 Mbps and 100 Mbps Ethernet that users have worked with for years. There is enormous installed base of Ethernet adapters, switches, repeaters etc. On the other hand, ATM is relatively new and not many people are using ATM in LAN. However ATM has its own advantages? It integrates the different types of traffic well.

Also it provides guaranteed QoS service. This paper discusses in brief about the Gigabit Ethernet and ATM technology and then compares them based on performance, simplicity, practicality, affordability, QoS and whether these technologies fulfills the needs of high speed LANS. Also this paper discusses the basic modification that is needed in upper layer protocols so that to utilize the full capacity of these high-speed networks.

3.   Introduction to High Speed LANs

High demand of bandwidth due to bandwidth intensive applications has given birth to different high-speed technologies coming into LAN. Need of business is increasing and with companies opting for E-commerce, Multimedia etc, the 10 Mbps networks are no longer able to sustain the load. Consequently number of high-speed technologies has come up with commercial products for LAN. Two such high-speed technologies that are competing for a place in LAN are:

3.1 ATM

ATM in LAN is an attractive technology that eases the job of integration of WAN and LAN. With ATM already being there in WAN as backbone, the integration of ATM LAN   with ATM WAN becomes easier. Other than that ATM comes with excellent quality of service that is needed by multimedia applications in today's LAN.

3.2 Gigabit Ethernet

The extension of 100 Mbps fast Ethernet provides 1000 Mbps data rate. Deploying Gigabit Ethernet is obvious strategy since, it is compatible with existence Ethernet based LAN and it preserves the investment in existing systems.

3.3 Market Motivation to ATM and Gigabit Ethernet

A common rule of thumb for LAN backbones is that equipment will cost eight to ten times as much to own and operate as it does to buy. The price delta between these technologies becomes quite significant and plays directly into network operations, staffing, and budget growth.

Gigabit is at the start of a descending price curve while ATM has already been discounted generously over the last couple of years. Yet Gigabit Ethernet is still far less expensive. Looking ahead, Ethernet's greater volume will bring prices down at a faster rate than ATM, making Gigabit Ethernet more affordable more quickly than ATM.

4.   ATM Networks

Asynchronous Transfer Mode is considered as unifying technology that is designed to integrate voice, data, and video over high bandwidth circuits on both LAN

and WAN. Until the ATM was developed the networks were designed to support specific type of traffic. Earlier the public switched networks like telephone were used for transporting voice and packet switching networks like X.25 were used for transporting Data. Thus organization that needs support for more than one traffic type has to install more than one type of network. Operating multiple networks needs more maintenance, high degree of inefficiency and increased operational cost. Arrival of ATM provides a single network that can support all types of traffic mainly voice, data and video.

4.1 Origin of ATM

Asynchronous Transfer Mode originated because the previous Synchronous Transfer Mode was inefficient. In synchronous mode every station gets a time slot and it can only transmit in the time slot allotted to it. Time slot identifies uniquely the connection between two stations. So if the station has nothing to transmit, any other station cannot use its time slot. This is significant wastage of bandwidth and it also limits the number of connections that can be supported simultaneously. In ATM the station doesn't wait for its time slot to transmit, instead station can transmit asynchronously. In ATM the connection is identified by a connection identifier, which is carried along with the data. I.e. two stations are connected via a connection identifier known as VPI/VCI included in the transmitted packet instead of by a time slot as in STM networks. Connection identifier gives the flexibility to statistically multiplex several connections over the same link based on their traffic characteristics. For example if large number of connections are burst then they can be assigned to same link hoping that statistically they wont burst at the same time. And even if some of them burst at the same time, then there are enough buffers to hold them. This kind of multiplexing is also known as *Statistical Multiplexing.*

4.2 Overview

Asynchronous Transfer Mode also known as cell relay inherits the concept of Frame Relay. Like Frame Relay, ATM is connection oriented and relies on the reliability provided by the physical transmission media used. Modern digital techniques allow ATM to avoid error checking in the network and thus it can transport the data at faster rate. Like X.25 and Frame Relay, ATM allows multiple logical connections to be multiplexed over a single physical interface.

With in each logical connection the information flows as fixed sized packets called *cells.* The use of fixed length cells reduces the complexity in the software and enables low cost hardware to be developed to perform the cell switching.
ATM is based on switching of fixed size cells. The size of a cell is 53 bytes and is

always fixed. 53 bytes cell contains 48 byte of data and 5 bytes of header containing Virtual Circuit Identifier and Virtual Path Identifier.

Logical connections in ATM are analogous to virtual circuit in X.25 and DLCI in Frame Relay. In ATM the virtual connections are bundled in a Virtual Path Connection. So in ATM pair of Virtual Path Identifier and a Virtual Channel Identifier identifies a connection. VPI represents a bigger pipe and VCI represents number of small pipes with in a bigger pipe sharing the same path to destination. The VPI technique groups the connections sharing the same path through the network into a single unit. This leads to fast switching due to aggregation of individual connections and easy management as the actions are now based on groups of connections rather than individual connections.
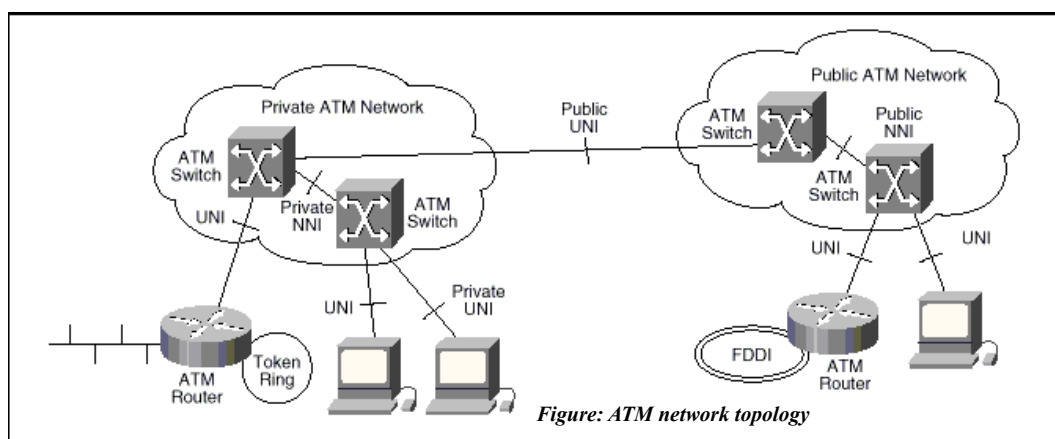

Figure: ATM network topology

Source: Alles, Anthony, Cisco Systems Inc, ATM Internetworking

4.3   ATM Functional Layers

ATM protocol architecture involved three layers. The physical layer describes the physical transmission of raw data over the network. The ATM layer relates with all services that provide packet transfer capabilities and AAL is service independent. ATM layer defines the use of fixed size cells whereas AAL maps higher layer information into ATM cells to be transported over ATM network and also assembles the incoming cells for delivery to higher layers.

4.3.1   Physical Layer

ATM doesn't define physical layer in its standard. Instead it uses the physical layer defined by other networking technologies.   The type of media that can be used as physical media in ATM includes, twisted pair (both shielded and non shielded), coaxial cable and fiber optic cable. The ATM physical layer provides transmission rate ranging from 1.544 Mbps to 622 Mbps. Higher rates could be achieved by using better physical media like STS-48. Thus ATM provides broad range of speeds.

4.3.2 ATM Layer

ATM layer act as an interface between physical layer and AAL. ATM relays the cells coming from AAL into physical layer and similarly ATM layer passes the cells to AAL layer coming from physical layer. ATM layer adds the 5-byte header to the cells coming from AAL and similarly extracts the 5-bytes header from the cells coming from physical layer. The functionality of ATM layer changes depending on whether it is in end station or in the switch. In switch the ATM layer is responsible for routing the incoming cells into correct outgoing interfaces. At end station the ATM layer passes the incoming cells from physical layer to AAL.

4.3.3 ATM Adaptation Layer

AAL layer provides an interface between higher layer protocols and ATM layer. The AAL layer only occurs at the end points. This is because AAL is needed for the different higher layer applications based on voice, data and video that want to access the ATM network. The primary function of AAL is to segment the data coming from applications into fixed sized cells. In the reverse direction AAL assembles the cells coming from ATM layer and passes it to application layer. AAL also takes care of transmission errors, lost cells, flow and timing control. Logically AAL is composed of two layers, Convergence sub layer and Segmentation and Reassembly. CS layer provides the functions needed to support specific applications. SAR does the segmentations and reassembly. To minimize the number of different AAL protocols that must be specified to meet variety of needs, ITU-T has defined four classes of service that covers most of the requirements of applications. The classification of applications is based on whether:

- Timing relationship is to be maintained between source and destination
- Application requires constant bit rate
- Transfer is connection oriented
- Transfer is connectionless

Based on the four application classes, AAL1 AAL2, AAL3/4 and AAL5 were defined. AAL1 was defined for constant bit rate applications like voice and video. AAL2 type is intended for variable-bit rate information. Type 2 doesn't require constant bit rate but still needs timing relations. AAL3/4 is designed for delay sensitive user data such as frame relay, X.25 and IP traffic. AAL5 was designed to provide a streamlined transport facility for the higher protocols that are connection-oriented.

4.4 ATM Services

ATM network is designed to carry different types of traffic at the same time. Traffic could be voice, video or IP traffic. Internally all different traffic is carried as 53

bytes cells. However handling of traffic depends on the characteristics and requirements of the traffic. ATM provides different service categories that are used by end system to identify the type of service needed.

Following types of services are defined by ATM forum:

- **Constant Bit Rate**

This service is needed by application which continuously needs constant bit rate. Example applications are Videoconferencing, Interactive Audio.

- **Real Time Variable Bit Rate**

Real time VBR service is needed by applications that need constant delay. RT-VBR service is needed by time sensitive applications in which required data rate varies over a time. RT-VBR allows network to do statistical multiplexing.

- **Non-Real time Variable Bit Rate**

Non rt-VBR services are designed for applications having bursty traffic but are not sensitive to delay variation i.e. variable delay is tolerated. Expected traffic characteristics are identified in advance and resources are allocated accordingly. The application species the peak cell rate, average cell rate and sustainable rate and measure of how bursty the cells may be. Examples are airline reservation, bank transactions etc. Non rt-VBR applications allows network to be more flexible as the network can now perform statistical multiplexing more efficiently.

- **Available Bit Rate**

Bursty applications that use TCP or other end-to-end protocols use ABR services. In ABR every application specifies a Peak Cell Rate and Minimum Cell Rate. Network allocates the resources so that at least MCR is available to every application. Unused capacity is then allocated fairly among all ABR sources. Explicit feedback is provided to ABR sources by the network so that to allocate resources in fair manner. Of course the unused capacity is used by UBR services discussed next.

- **Unspecified Bit Rate**

Applications belonging to this category are those, which can tolerate delays and cell loss. In UBR service the cells are forwarded on first come first basis using the capacity, which is not used by CBR, VBR or ABR services. No resource allocation is done for applications in this category. This service is known as ***best-effort*** service like IP.
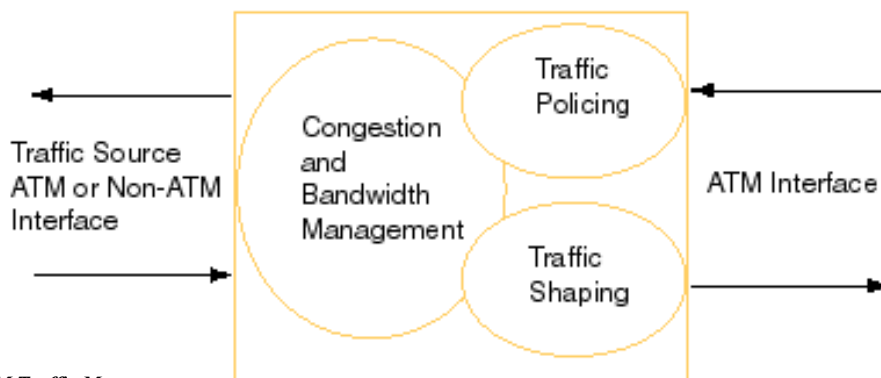
4.5 Traffic Management and QoS

Figure: ATM Traffic Management

Source: Alles, Anthony, Cisco Systems Inc, ATM Internetworking

A key advantage of ATM is that it can carry traffic of different type like voice, video, data etc. Different type of traffic necessitates a mechanism that can fairly manage the traffic coming on different virtual connections of different type. Traffic management in ATM does this by appropriately providing Quality of Service for different types of traffic. By doing so traffic management also achieves efficient bandwidth utilization of the network.

ATM traffic management has following components:

4.5.1   *Negotiations of a contract between end system and the network*

To make the QoS job easier for the network, ATM Forum define 5 different QoS classes. Five different classes are Class 0, Class 1, Class 2, Class 3, Class 4, which corresponds to best effort applications, CBR circuit emulation applications, VBR video and audio applications, connection-oriented data, and connectionless data respectively. For each specified QoS class, the network specifies an objective value for each QoS parameters.

Each of the QoS classes has a conformance definition to which traffic carried with that class must conform. The conformance definition consists of series of QoS parameter negotiated between the end station and the ATM network. This negotiation forms a contract that an end station must comply. On having a contract network should provide the necessary QoS support to the application as requested by it in the contract.

4.5.2   *Connection Admission Control*

ATM network uses Connection Admission Control to reserve the bandwidth for each virtual connection in ATM network. Every time a new connection is made, the network checks to see if it can fulfill the QoS requirements and the traffic characteristics of the incoming connection. The traffic characteristics are defined by set of traffic descriptors, which are provided by source to the network when they request a connection. The ATM network, depending on the type of incoming

connection needs following traffic descriptors:

O **Peak Cell Rate (PCR)**

Defines an upper bound on the traffic that can be submitted by the source into the ATM network. PCR is defined in terms of T, where T is the minimum intercell spacing in seconds. This is needed for CBR traffic.

O **Sustainable Cell Rate (SCR)**

It is the upper bound on the average rate that could be sent over a period on an ATM connection. SCR is basically measure of bursty traffic. SCR is needed for VBR services as it enables the network to allocate resources efficiently.

O **Maximum Burst Size (MBS)**

MBS is the maximum burst size that can be sent continuously at PCR. If the cells are presented to the network at MBS interspersed by idle time period, then at no time overall rate should exceed the SCR. MBS is also specified for VBR sources.

O **Minimum Cell Rate (MCR)**

MCR specifies the minimum rate that should be allocated to an ABR source by the network. MCR makes sure that ABR sources never have to transmit at rate lower than MCR.

4.5.3   Traffic Policing

The incoming traffic on a virtual connection is measured by traffic policing component and it discards the traffic that exceeds the negotiated parameters specified in the contract. Traffic policing is usually performed at the entry point of the network so that to make sure that incoming traffic conforms to the contract. Traffic policing employs Generic Cell Rate Algorithm (GCRA), which is also commonly known as *Leaky Bucket Algorithm*. Leaky bucket algorithm checks the rate at which traffic arrives on a virtual connection. And if the arrival rate doesn't conform to the contract then it either marks them as potential candidates for discard during congestion or if arrival rate too high, it immediately drops them. Cells could be marked as potential candidate for discard my setting the CLP bit in the cell. CLP = 1 makes them likely candidates to be dropped in case of congestion. Policing is usually used for VBR traffic where source is allowed to send burst of traffic over a period of time.

4.5.4   Traffic Shaping

Traffic shaping shapes the traffic coming on an ATM interface that doesn't conform to the traffic contract and then it ensures by adjusting the incoming rate that traffic reaches the destination without getting discarded. Traffic shaping does this by buffering the traffic and sending it into the network at some later time. Traffic shaping enhances the QoS for each connection. Provided the incoming traffic behaves

according to the contract, traffic shaping could handle bursts of traffic from source very well. At the ATM interface large cell buffers are used that can buffer the bursty traffic from the source. ATM network then sends the traffic at proper rate. This smoothes the transmission and also reduces the probability of lost cells and retransmissions. If traffic shaping is not done to incoming burst, it may be possible that the incoming traffic may not conform to the contract and the cell has to be dropped in that case. Traffic shaping does introduces some delays, but it's always better to have delay rather than losing the cell and wait for its retransmission.

4.5.5   *Congestion Control*

Congestion occurs in a network when all the resources are being used and more connections demands resources. In this scenario network would start dropping the packet and won't be able to provide proper service. Consequently congestion has to be avoided/controlled in order to provide proper QoS according to the contract. Congestion usually occurs with permanent virtual connections, since switched virtual connections could be denied connection or the requirements for them could be negotiated in case of congestion. Two different discard techniques are used to avoid/control the congestion. The discarding policy targets entire packets rather than targeting individual cells.

O   **Early and Partial Packet Discard**

Early packet discard policy is based on discarding packets before the buffers overflow. In partial discard, cells belonging to a packet are partially discarded. For example if a packet consists of 100 cells and 50th cell has to be dropped, then in such case all the cells after 50th cell will be dropped. This will be useful since anyway those cells won't be of any use when they are passed to the upper layers.

O   **Early Packet Discard**

In EPD, whole packet is dropped. That is if the network decides to drop one cell in packet then all the cells belonging to that packet would get dropped.

4.6   *Key Advantages of ATM*

The key advantage of ATM is that it provides different services over a common network infrastructure. Due to its connection oriented nature ATM provides simplified routing of cells. ATM provides constant or rather predictable delay to traffic. Also it provides dynamic bandwidth allocation. By using statistical multiplexing ATM provides high bandwidth utilization. If ATM is used in both LAN and WAN it reduces the complexity of protocol conversion while going from LAN to WAN and vice-versa. ATM wins lot of point in flexibility and scalability as ATM is designed to cope up with demands of future applications. ATM provides the integration of different technologies

like ISDN, X.25 and Frame Relay. And most importantly ATM provides guaranteed Quality of Service.

5. *Gigabit Ethernet*

Eighty percent of the LAN is Ethernet based and there is no reason why shouldn't it increase in coming years. Ethernet is ubiquitous and its simplicity, low maintenance accounts for its success. Gigabit Ethernet represents an evolution rather than revolution in LAN technologies. Ethernet has come up long way from 10Base5 to 1000BaseT to support demands of bandwidth hungry applications.

Modern organizations depend on their LAN to provide connectivity for a growing number of complex mission critical desktop computing applications. However the conventional 10 Mbps LANs are unable to provide necessary response time and bandwidth needed by bandwidth intensive desktop applications. The 100 Mbps fast Ethernet has become the technology of choice providing non-disruptive evolution to 100 Mbps Ethernet from 10 Mbps Ethernet. Gigabit Ethernet took a step ahead in Ethernet series and came up with 1000 Mbps Ethernet. Gigabit Ethernet provides 1000 Mbps of bandwidth for campus area networks with a cost much lower than other competing technologies. The gigabit Ethernet because of its lower cost and its easy fit with existing Ethernet will be adopted quicker than previous high speed technologies such as FDDI and ATM.

5.1 Overview

Gigabit Ethernet like all its predecessors provides an unacknowledged connectionless service. Frame may be send to unicast address or to multicast addresses. Gigabit Ethernet uses the legacy CDMA/CD protocol for shared media arbitration and for collision detection. For most of the network users, gigabit Ethernet could be deployed without providing extra training to support staff and users. The applications remains the same only the data rate has increased to 1000 Mbps.
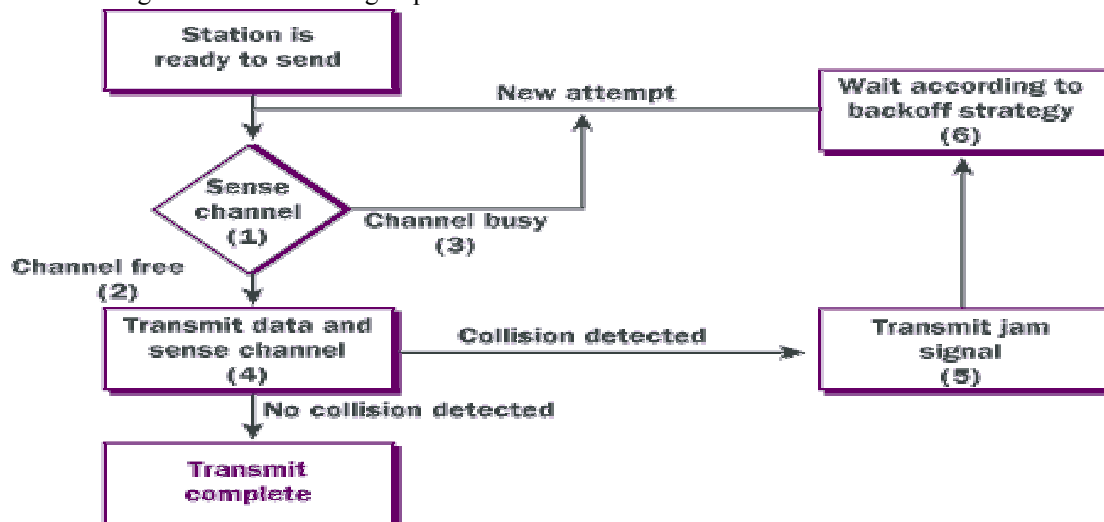
Figure: The Gigabit Ethernet technology family

Source: Basic information about Gigabit Ethernet is provided in The Gigabit Ethernet Alliance White Paper
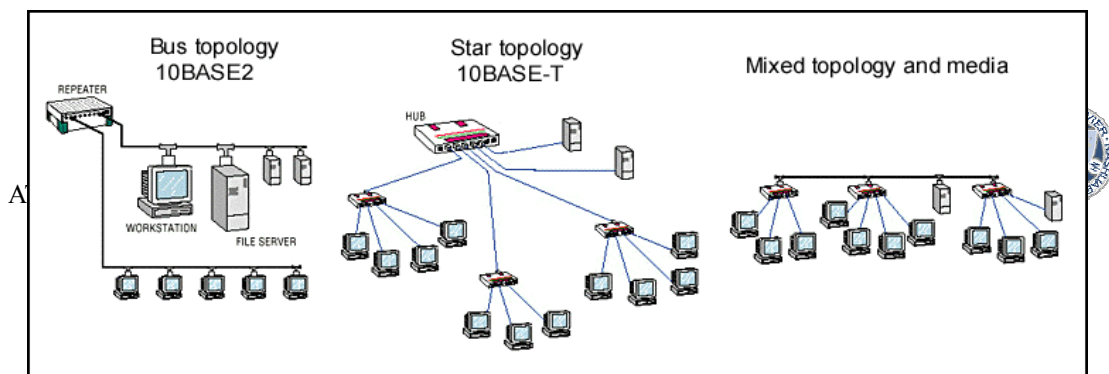
5.2 *Physical Layer*

Gigabit Ethernet borrows the fiber channel specification for its physical layer. Gigabit Ethernet also uses original Ethernet technologies for link control.

5.3 *Topology*

Like 10Base-T and 100Base-T, Gigabit Ethernet also supports both shared and switched LAN configurations. However Gigabit Ethernet is may not be very useful for shared configurations. Existing networks are UTP based and Gigabit Ethernet doesn't provide a reliable solution over UTP. Other than that very few technologies can take advantage of gigabit capacity available. The disk access and CPU become bottleneck. In fact fast Ethernet switches works better, as it runs over UTP. Also the propagation delay in Gigabit Ethernet restricts the available topologies. In fact we can only have two different kinds of topologies in shared configurations.

- A point-to-point link with exactly two stations
- A set of stations connected to a single hub/repeater with either copper or optical-fiber connections.

Switched LAN offers better bandwidth and the Gigabit switch could be used for campus backbone. There is no restriction because of the less propagation delay since there is no CDMA/CD. The only restriction comes from the maximum lengths supported by the physical media.

Bus topology 10BASE2   Star topology 10BASE-T   Mixed topology and media
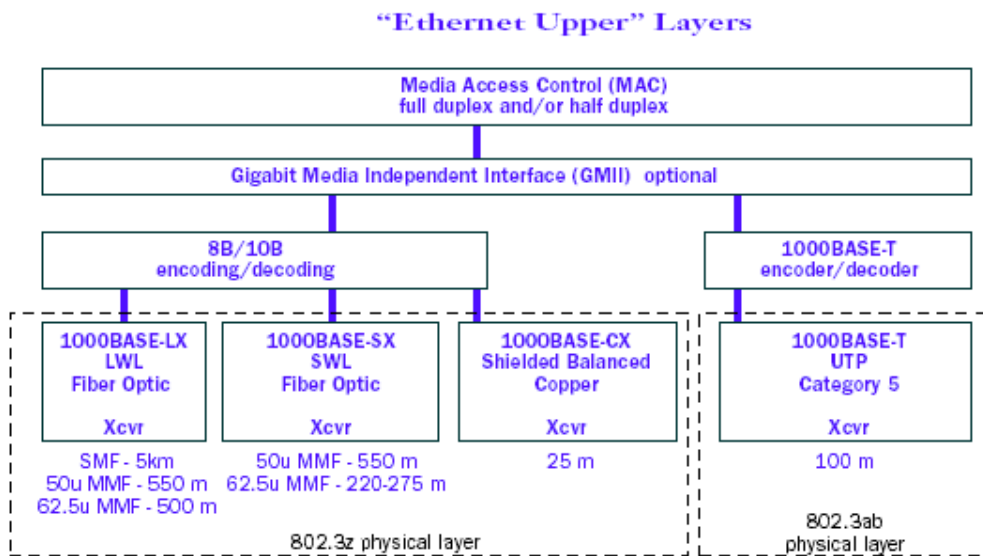
5.4 MAC Layer

Figure: The Gigabit Ethernet technology family

Source: Basic information about Gigabit Ethernet is provided in The Gigabit Ethernet Alliance White

Paper. This document focuses specifically on 1000BASE-T

In 1996 IEEE 802.3 group created the 802.3z task force. The objective of the task force was develop a Gigabit Ethernet standard that allows half and full duplex operations at 1000 Mbps, uses CDMA/CD protocol for channel arbitration, uses the 802.3 Ethernet frame format and is backward compatible with 10Base-T and 100Base-T.

Gigabit Ethernet uses the same CDMA/CD protocol for its MAC layer. Gigabit Ethernet like 10Base-T or 100Base-T can operate in either half-duplex or full-duplex mode.

5.4.1   Half Duplex

However the half duplex mode poses problems that result in reducing the distances between stations or change the MAC layer for gigabit Ethernet. This is because use of CDMA/CD protocol implies a relation between minimum length of the frame and the maximum round trip propagation delay. 10Base-T and 100Base-T standards used to have a minimum frame length of 64 bytes. The reason of having minimum frame is to prevent a station from completing the transmission of a frame before the first bit has reached the far end of the cable, where it may collide with

another frame. Consequently a minimum frame size of 64 bytes is kept so that if there is collision (even at far end of the cable) the transmitter should stop and wait for random period before re-transmitting the frame. In 10Base-T the 512 bits or 64 bytes could be transmitted in 51.2 microseconds. Depending on the cable and repeaters used the 10 Mbps Ethernet could be or order 2.5 KM. The conclusion is for a given minimum length frame, the extent of the network scales inversely with the data rate. So as the bit rate increases, the sender transmits the frame faster. As a result in case of higher data rates if the same minimum frame size and maximum cable lengths are maintained, then a host may transmit the frame too fast before it can know about the collision at far end. Two things could be done to avoid this problem:

- Keep the minimum frame length same, but decrease the maximum cable length
- Keep the maximum cable length same, but decrease the increase the minimum frame length.

In 100Base-T Ethernet extent of the network was reduced to the order of 200 meter. This is done because if you increase the minimum frame size, the corresponding changes have to be made in higher layer protocol. Also this would have resulted in incompatibility between 10 Mbps and 100 Mbps.

However if the similar approach were to be used for Gigabit Ethernet, then the resulting network would be of order 20 meter, which is completely inadequate for practical purposes. In Gigabit Ethernet, extent of the network was kept as 200 meter; also the minimum frame size was kept as 64 bytes only at the software layer. However the MAC algorithm is modified to increase the frame as seen on the wire so that the shorter frame appears longer by using an approach called carrier extension. Whenever the frame is shorter than 512 bytes, it is padded with extension symbols.

5.4.1.1   *Carrier Extension*

As mentioned above, to keep the minimum frame length to 64 bytes extension symbols were added to make it 512 bytes before the frame is sent on wire. Hence such a solution will need a modification in CSMA/CD protocol also. Now the actual minimum frame of 64 bytes is no longer transmitted in 512 bit times. In fact for any frame less than 512 bytes is transmitted in 4096 bit times so that to increase the propagation delay. The frames that are shorter than 512 bytes contain extra extension symbols. So the MAC transmits the frame, including the extension symbols while looking for the collision. If a collision occurs the station sends a jamming signal and will back off even if it has successfully transmitted the data portion of the frame. Similarly the receiver will discard the frame if it is less than 512 bytes, even if it has successfully received the data portion of the frame.

5.4.1.2 *Frame Bursting*

Carrier extension is simple but is costly and degrades the performance. In worst case (512 – 64) extra bytes could be transmitted. Another proposed solution is to send frames in burst. Maximum burst size is limited to 1500 bytes. When a transmitter has number of packets to transmit, the first frame is padded with extension symbols if required and rest of the frames are transmitted back to back without padding them with extension symbols even if they are less than 512 bytes.

5.4.2 *Full Duplex*

In full duplex mode each user gets dedicated bandwidth and there is no need of contention-based protocols. The complexity of half-duplex due to CDMA/CD, carrier extension, frame bursting and back off ranges is all gone. All this is needed if stations are contending for a shared channel. There is no need to sense the channel; station can transmit/receive at will. Also there is no need of carrier extension, since it was needed to ensure that long transmissions lasted long enough for CDMA/CD to work properly.

5.5 *QOS in Gigabit Ethernet*

Gigabit Ethernet defines link layer specifications, so Gigabit Ethernet in itself doesn't provides Quality of Service. Gigabit Ethernet depends on network layer protocol RSVP for Quality of Service. RSVP was designed to provide applications consistent bandwidth, latency and jitter from the network connections.

Resource Reservation Protocol (RSVP) allows host applications to communicate their Quality of Service needs to the network. RSVP is a signaling protocol used by the receiver to request QoS and bandwidth from the sender. User can specify QoS and bandwidth per application flow. The source sends a message containing its Quality of Service requirements towards destination. While the message propagates toward the receiver, the network allocates the resources for the application. RSVP capable routers also implements traffic shaping and policing functions to control the bandwidth in order to ensure fairness among all application flows seeking QoS. RSVP is designed as best effort QOS. That is the request for a particular will be acknowledged but the network may or may not deliver it. True end-to-end QOS requires guarantees for transfer rates with specified peak rate, average rate and minimum rates. Also the time sensitive traffic must deliver the data within time constraints. To overcome the RSVP inabilities, the IETF integrated services group is developing adaptation protocols for Ethernet to provide priorities, scheduling and flow control for time sensitive traffic. Also some of the Gigabit Ethernet switches are designed with policy-based bandwidth management and multiple priority classes to guarantee minimum and maximum bandwidth. 802.1p and 802.1Q standards are proposed for providing Quality of

Service over Ethernet.

5.6 Application Areas

Gigabit Ethernet is useful in the environment where 10/100 Ethernet switching is prominent and 100 Mbps, FDDI or OC-3 backbones are not sufficient to provide needed support. Another application is to provide high-speed connectivity for servers, where each server has dedicated 100 Mbps Ethernet, FDDI or ATM connections and backbone access to servers is operating at near capacity.

5.7 Key Advantages of Gigabit Ethernet

Gigabit Ethernet uses the same old frame formats; there is no need of slow emulations and translations. Cost is not much in comparison with fast Ethernet and 10 Mbps Ethernet. It uses already established management protocols of 10/100 Mbps Ethernet. Gigabit Ethernet design, installation and configuration are all same as 10/100 Mbps Ethernet, so there is no need to provide training to network administrators.

6 ATM Vs Gigabit Ethernet

It is known that both ATM and Gigabit Ethernet are competing for a place in high-speed Local Area Networks. This section discusses the advantages and disadvantages of having ATM or Gigabit Ethernet in the LAN based on facts mentioned in above sections. LAN like WAN is not driven by high bandwidth only. However other factors come into the picture like cost of equipment, maintainable, scalability. Also the LAN usually has to connect to some wide area network. So LAN/WAN internetworking is an important factor in selecting a technology. Also few LAN applications demand quality of service from the network.

6.1 Simplicity

Gigabit Ethernet certainly has edge over ATM as far as simplicity is concerned. Gigabit Ethernet is identical with its lower-speed cousins but has scaled up in speed. It still uses the same old 802.3 formats. This means you don't have to provide training to the users of Gigabit Ethernet. Since Gigabit Ethernet switches are compatible with 10/100 Mbps Ethernet switches, the deployment of Gigabit switches would be an easier job in comparison with ATM switches. On the other hand ATM technology is quite complex when it comes to implementation of LANE or MPOA in order to support LAN. LANE introduces the additional complexity of having designated servers so that to provide LAN services. Extra configuration has to be done by the network administrators.

6.2 Affordability

Technology	Equipment Type	1996 Equipment Price/Port	1999 Equipment Price/Port	Change %
Shared Fast Ethernet	Hub	$137	$85	-39%
Switched Fast Ethernet	Switch	$785	$390	-50%
Shared FDDI	Concentrator	$835	$650	-22%
Switched FDDI	Switch	$4000	$1860	-54%
ATM 622 Mbps Estimate (multimode fiber)	Switch	$6600	$4800	-27%
Shared Gigabit Ethernet IEEE goal (multimode fiber)	Hub	N.A.	$470 to $700 ** (2x to 3x Fast Ethernet MM)	
Switched Gigabit Ethernet IEEE goal (multimode fiber)	Switch	N.A.	$1070 to $1610 ** (2x to 3x Fast Ethernet MM)	

Source: Dell'Oro Group

** Estimates based on Dell'Oro Group info and IEEE goals

Study says that 80 percent of existing LANs are Ethernet based. Upgrading a LAN into ATM will need installation of costly hardware. ATM interface cards are much more expansive than corresponding Ethernet cards. Also the software has to be upgraded that includes device drivers, applications and operating systems. On the other hand Gigabit Ethernet hardware wont be much costly than traditional 10/100 Mbps Ethernet. Also Gigabit Ethernet would use same applications and operating system will need few modifications.

6.3 LAN and WAN internetworking

ATM has advantage when it comes have internetworking with WAN. Perhaps ATM provides best LAN to WAN migration. Unlike Gigabit Ethernet that pushes the bottleneck to WAN, ATM provides wide range of data rates and adapts to different access rates of WAN. ATM Forum has designed 25 Mbps full duplex mode by using category-3 UTP. Also ATM provides 155 Mbps, 622 Mbps and 2.5 Gbps. Thus servers can choose any data rate as low as 1.55 Mbps and as high as 2.5 Gbps. However Gigabit speeds scales well in LAN, but there is definitely mismatch when you WAN access links of order 1.5 Mbps, 155 Mbps OC-3.

6.4 Ethernet and ATM in Bandwidth

ATM offered massive bandwidth at the time it was introduced. Speeds of 155 Mbps and awesome 622 Mbps attracted people to ATM. It was seen that once the need for greater bandwidths arises, Ethernet LANs get replaced with ATM networks. The speed of 25 Mbps was proposed as the bandwidth to the desktop, but in practice is was not worth going from 10 Mbps Ethernet to 25 Mbps ATM, mostly for economical reasons.

After two upgrades, Ethernet fights back. ATM can no longer compete in pure speed. The routing and switching technology has improved and ATM alone can't take advantage of simple and fast hardware switching. The new gigabit speeds put burden on the back-end servers, and the server processing speed is becoming the bottleneck rather than the network.

An important point to make is that the actual bandwidth for the payload is always smaller than the full transmission speed of the medium. This is because the protocols and their headers eat up some of the total bandwidth, and there usually exists a couple layers of protocols.

6.5 Ethernet and ATM in LAN Backbone

Real fight between Ethernet and ATM is in the LAN backbone. Again the simplicity, price, installed base, requirement for multimedia are the key factors in choosing the LAN backbone. Availability of the Gigabit Ethernet equipments and its low prices are driving it ahead of ATM. Moreover industry study forecasts that Ethernet is going to dominate for next several years. ATM is a neat technology and by providing QoS techniques and efficient traffic management it looks that ATM should be the choice for the LAN backbone. However there are not enough applications in LAN that need the QoS capabilities. Some of the applications that need QoS and constant bandwidth will still opt for full duplex Gigabit Ethernet since deploying ATM is costly affair. These applications then rely on 802.1p standards to provide quality of service. At this time it seems that Gigabit Ethernet is ahead of ATM in the battle of backbones. However Gigabit Ethernet has to come up with features like prioritization, full QoS to stay ahead in the race. ATM has lot of features and that makes it more flexible and complex and hence more costly. But ATM prices are coming down and installed base is increasing. If you think about future, ATM is the technology for the LAN backbone.

6.6 Quality of Service Support

QoS is the area where ATM is far ahead than its competing technology. As discussed above, ATM has built in QoS capability whereas Gigabit Ethernet depends on RSVP to provide quality of service. RSVP is also termed as *soft state* as the request of QoS has to be communicated to all the routers between source and destination. Each router has to maintain extra piece of information. The RSVP provides best effort quality of service that means a router may acknowledge the request of QoS but may fail to deliver it. On the other hand ATM provides guaranteed QoS. ATM reserves bandwidth and deny connections if it founds that accepting those connections would degrade the quality of service to existing connections. So if the user is running video

intensive multimedia applications or user want to integrate the voice with data, ATM seems to better choice. ATM provides better QoS by having different QoS classes for applications needing different type of QoS. Also in RSVP packets transmitted may take different paths making life difficult for RSVP whereas ATM avoids this since each node in end-to-end path verifies whether the QoS requirements will be met or not.

Capabilities	Gigabit Ethernet	Fast Ethernet	ATM	FDDI
IP Compatibility	Yes	Yes	Requires RFC 1557 or IP over LANE today; I-PNNI and/or MPOA in the future	Yes
Ethernet Packets	Yes	Yes	Requires LANE	Yes, though 802.1h translation bridging
Handle Multimedia	Yes	Yes	Yes, but application needs substantial changes	Yes
Quality of Service	Yes, with RSVP and/or 802.1p	Yes with RSVP and/or 802.1p	Yes with SVCs or RSVP with complex mapping from IETF (work in progress)	Yes, with RSVP and/or 802.1p
VLANs with 802.1Q/p	Yes	Yes	Requires mapping LANE and/or SVCs to 802.1Q	Yes

Table: High-Speed Network Capabilities

6.7 Gigabit Ethernet Bottlenecks

Generally whenever a frame is received on the NIC of desktop, the host CPU is interrupted and the interrupt handler, which is part of the device driver, receives the data from NIC buffers into its host buffers. However when the data is coming at the rate equal to hundreds of Mbps, the number of interrupts to CPU increases and CPU is not able to process so many interrupts and becomes a bottleneck. Even on fast Ethernet if the NIC is continuously receiving data at 100 Mbps, there is nothing much a desktop can do other than just processing the interrupts. Also the conventional frame size of 1500 bytes is of no help either. MTU size of 1500 causes the NIC to interrupt the host often. Situation gets worse with Gigabit NIC and demands fine-tuning of software running on the host as well as the fine-tuning of firmware on the NIC. It is being found that a desktop can only achieve 30% of the throughput while using Gigabit Ethernet NIC. Software on the host has to fine tuned so that to avoid extra copy overhead that is involved as the data is moved up to the applications. Recently Alteon has come up with Acenic Gigabit Ethernet card that is specifically designed to reduce the overheads by having an intelligent firmware running on NIC. Following are some of the special features that improves throughput:

● **Interrupt Coalescing**

Interrupt coalescing technique wait for certain number of frame to be received or a time period whichever is earlier before interrupting the host CPU. This reduces the

number of interrupt that is to be processed by the Host CPU and thus improves the performance. However this does introduces latency but that the tradeoff with the bandwidth.

- **Jumbo Frames**

    Alteon implemented the idea of having frame size greater than 1500. Jumbo frames of 9000 bytes could be used for transmitting and receiving. Having greater MTU size also reduces the number of interrupts and increases the performance. However Jumbo frames are optional and is turned on when the user changes MTU size to be greater than 1500 on a particular NIC.

- **TCP/UDP/IP Checksums**

    TCP/UDP/IP checksums are costly operations when done in host. However the same could be done in the firmware with very little overhead on firmware. Acenic card provides the facility of calculating TCP/UDP/IP checksums in NIC memory and thus relieves the host from calculating checksums.

6.8 ATM Bottlenecks

The conventional LAN uses TCP/IP based network. However the TCP was not designed for high-speed backbones. Some of the backs off strategies used by TCP in case of congestion are very conservative. This approach may be good for normal backbones, but with ATM as backbone this approach is considered too conservative.
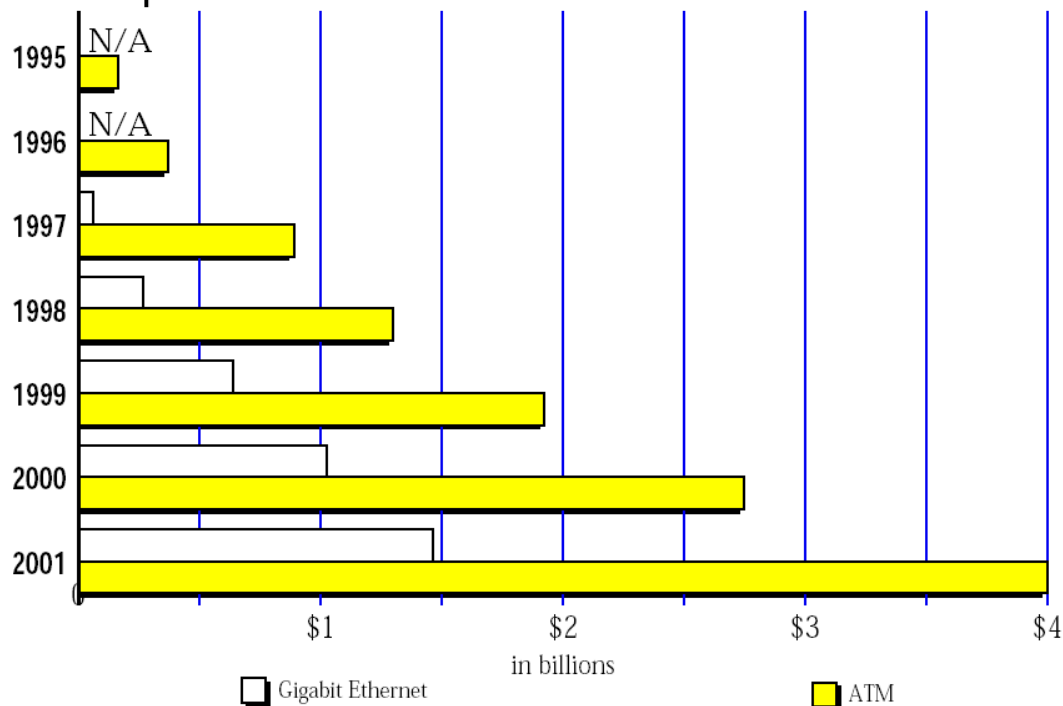
6.9 Market Motivation

ATM Versus Gigabit Ethernet

Revenue Comparison

Sales Comparison

in billions
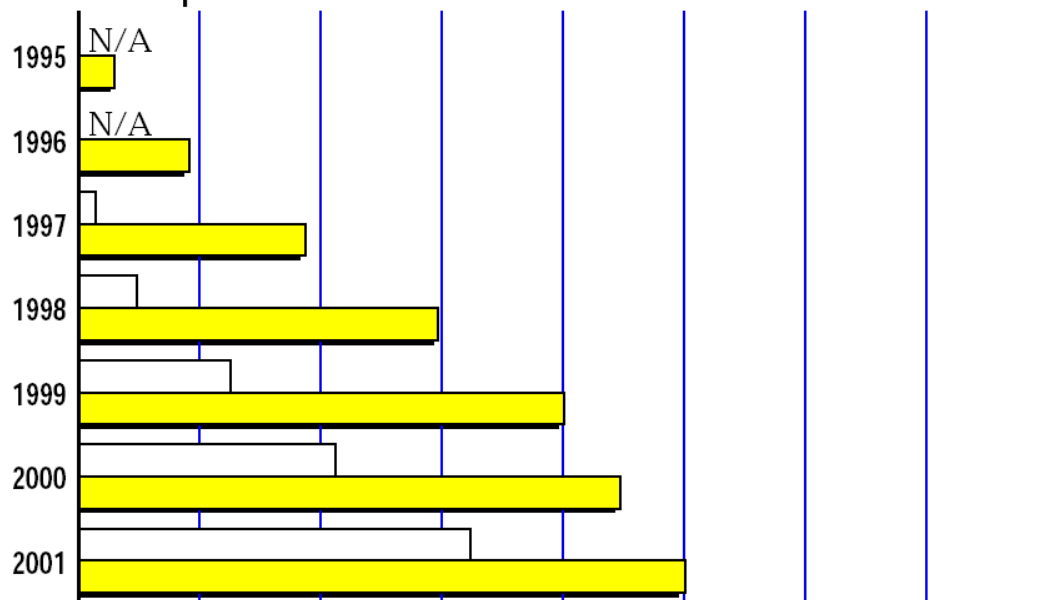
☐ Gigabit Ethernet   ☐ ATM

Note: Figures for 1997-2001 are projected.   Source: In-Stat

6.9.1   Major Vendors

While Gigabit Ethernet is not quite standardized yet, many networking companies have already made the technology available. Buying Gigabit Ethernet components

made before the standard is approved is somewhat risky; because there is a chance they will not be interoperable with post-standard components. Consolidation of voice, video and data services over a single network is a dream come true for most large corporations. ATM vendors have touted this selling point for years, and many large corporations bought into ATM early. But is ATM still a wise investment for the LAN in light of the commodity frame-switching market. Here is a list of companies that are currently developing Gigabit Ethernet and ATM products.

Alteon Networks San Jose, CA (408) 574-5500 www.alteon.com	**AMCC** San Diego, CA (800) 755-2622	**Brooktree** San Diego, CA (619) 452-7580	**Fore Systems** Warrendale, PA (412) 772-6600 www.fore.com
Fujitsu Microelectronics San Jose, CA (408) 922-9000	**I-Cube** Campbell, CA (408) 341-1888 www.icube.com	**IDT** Santa Clara, CA (800) 345-7015	**IgT** Gaithersburg, MD (301) 990-9890
Integrated Circuit Systems San Jose, CA (408) 297-1201	**Ipsilon Networks** Palo Alto, CA (888) 477-4566 www.ipsilon.com	**LSI Logic** Milpitas, CA (408) 433-8000	**MMC Networks** Santa Clara, CA (408) 653-1810
Motorola Phoenix, AZ (800) 441-2447	**National Semiconductor** Sunnyvale, CA (800) 272-9959 www.national.com	**NEC Electronics** Mountain View, CA (800) 366-9782	**Packet Engines** Spokane, WA (509) 922-9190 www.packetengines.com
PMC-Sierra Burnaby, BC, Canada (604) 688-7300	**Siemens Components** Cupertino, CA (408) 777-4500	**S-MOS Systems** San Jose, CA (408) 922-0200	**Texas Instruments** Dallas, TX (800) 477-8924, ext 4500
Toshiba San Jose, CA (800) 879-4963	**TranSwitch** Shelton, CT (203) 929-8810	**Triquint Semiconductor** Beaverton, OR (503) 644-3535	**Vitesse Semiconductor** Camarillo, CA (805) 388-3700
VLSI Technology San Jose, CA (408) 434-3000	**WideBand** Independence, MO (816) 220-3000		
ATM Forum Mountain View, CA www.atmforum.com	**Gigabit Ethernet Alliance** Cupertino, CA	**Internet Engineering Task Force** Reston, VA	

www.gigabit-ethernet.org   www.ietf.cnri.reston.va.us

6.9.2   *Business Applications*

● **Gigabit Ethernet**

Gigabit Ethernet supports all of these applications and at a very fast rate. Many of these applications require the transmission of large files over the network. Scientific applications demand ultra-high bandwidth networks to communicate 3D visualizations of complex objects ranging from molecules to aircraft. Magazines, brochures and other complex, full-color publications prepared on desktop computers are transmitted directly to digital-input printing facilities. Many medical facilities are transmitting complex images over LAN and WAN links, enabling the sharing of expensive equipment and specialized medical expertise. Engineers are using electronic and mechanical design automation tools to work interactively in distributed development teams, sharing files in the hundreds of gigabytes.

Many companies are now employing Internet technologies to build private intranets, enabling users in an organization to go beyond electronic mail and access critical data through familiar Web browsers, opening the door to a new generation of multimedia client/server applications. While intranet traffic is currently composed primarily of text, graphics and images, this is expected to expand in the near future to include more bandwidth-intensive audio, video and voice.

Data warehousing has become popular as a way of making enterprise data available to decision makers for reporting and analysis without sacrificing the performance, security or integrity of production systems. These warehouses may comprise gigabyte or terabytes of data distributed over hundreds of platforms and accessed by thousands of users, and must be updated regularly to provide users near-real-time data for critical business reports and analyses.

Network backup of servers and storage systems is common in many industries, which require enterprise information to be archived. Such backups usually occur during off-hours and require large amounts of bandwidth during a fixed amount of time (4 to 8 hours). The backup involves gigabytes or terabytes of data distributed over hundreds of servers and storage systems throughout an enterprise.

A recent survey of video applications conducted by a leading industry analyst shows interest in video increasing rapidly as computers offer native MPEG decoding capability and as low-cost encoding chip sets become more widely available. The survey looked at a number of video-based applications, including video conferencing, education and human resources from several companies.

● **ATM**

The telecommunications companies are investigating fiber optic cross country

and cross oceanic links with Gigabit/sec speeds, and would like to carry in an integrated way, both real time traffic such as voice and hi-res video which can tolerate some loss but not delay, as well as non real time traffic such as computer data and file transfer which may tolerate some delay but not loss. The problem with carrying these different characteristics of traffic on the same medium in an integrated fashion is that the peak bandwidth requirement of these traffic sources may be quite high as in high-res full motion video, but the duration for which the data is actually transmitted may be quite small. In other words, the data comes in bursts and must be transmitted at the peak rate of the burst, but the average arrival time between bursts may be quite large and randomly distributed. For such bursty connections, it would be a considerable waste of bandwidth to reserve them a bucket at their peak bandwidth rate for all times, when on the average only 1 in 10 bucket may actually carry the data. It would be nice if that bucket could be reused for another pending connection. And thus using STM mode of transfer becomes inefficient as the peak bandwidth of the link, peak transfer rate of the traffic, and overall burstiness of the traffic expressed as a ratio of peak/average, all go up. In the judgement of the industry pundits, this is definitely the indicated trend for multimedia integrated telecommunications and data communications demands of global economies in the late 90's and early 21st century.

6.9.3   Future Trends

- ### Gigabit Ethernet
- A New Era for Ethernet

Since the early days of workgroup LANs, Ethernet's adaptability has enabled thetechnology to keep pace with the continuously expanding needs of worldwide users. Now, with a new Gigabit Ethernet standard on the horizon, Ethernet will continue to play a leading role in meeting organizations' business-critical networking needs. Comparable to the way 10 Mbps and 100 Mbps Ethernet shaped the networking market in the 1980s and 90s, 1 Gbps Ethernet is poised to do the same well into the 21st century. Similarly, just as 3Com pioneered Ethernet and Fast Ethernet solutions, the company is also taking the lead in defining Gigabit Ethernet through its participation in the IEEE 802.3 standards committees and its prominent role in the Gigabit Ethernet Alliance.

The Alliance predicts that the IEEE 802.3z working group will complete the Gigabit Ethernet standard for fiber and short-haul copper in early 1998, with the first working group ballot in mid-1997. Soon after this initial ballot, 3Com plans to begin delivering interoperable, cost-effective Gigabit Ethernet solutions that set new benchmarks in price/performance. 1000BASE-T products supporting Gigabit Ethernet over long-haul copper (UTP) will follow the working group ballot of the 802.3ab

working group, which should occur in mid-1998. Just as with Ethernet and Fast Ethernet products, 3Com will provide users with the industry's most comprehensive array of Gigabit Ethernet products, including Gigabit Ethernet switches, Fast Ethernet switches with gigabit uplinks, buffered distributors, and Gigabit Ethernet NICs for servers.

Once implemented, Gigabit Ethernet solutions will give organizations an attractive solution to relieve networking pressures created by the increasing number of data-intensive applications and expanding user demands discussed in this paper. Because Gigabit Ethernet is able to deliver bandwidth as organizations need it and to leverage existing technologies in Ethernet-based networks, it will be a valuable asset to enterprise networks around the world.

- ***ATM***

Regardless of the presence or absence of these incentives, the demand for ATM is believed to grow into the year 2010 with the market for ATM access equipment escalating from $205 million in 1997 to $1.28 billion in the year 2001. With the following benefits of Asynchronous Transfer Mode, it is not hard to appreciate the demands and implications for the future:

> "Incremental Migration-Efforts within the standards organizations and the ATM Forum continue to assure that embedded networks will be able to gain the benefits of ATM incrementally-upgrading portions of the network based on new application requirements and business needs.

> Simplified Network Management-ATM is evolving into a standard technology for local, campus/backbone and public and private wide area services. This uniformity is intended to simplify network management by using the same technology for all levels of the network.

> Long Architectural Lifetime-The information systems and telecommunications industries are focusing and standardizing on ATM. ATM has been designed from the onset to be scalable and flexible in:

>> Geographic distance
>> Number of users
>> Access and trunk bandwidths (As of today, the speeds range from
>> Megabits to Gigabits)

> ATM enables applications-Due to its high speed and the integration of traffic types, ATM will enable the creation and expansion of new applications such as multimedia to the desktop.

> This flexibility and scalability assures that ATM will be around for a long time."

6.9.4 Business Examples

● **Gigabit Ethernet**

Although the gigabit Ethernet standard hasn't yet been finalized, several vendors have already announced that they are working on products. One example is Texas Instruments.

Lots of people are talking about where and when to deploy Gigabit Ethernet, but chief information officer at the U.S. Army Aberdeen Test Center in Aberdeen Proving Ground, Md., is building a Gigabit Ethernet LAN backbone to collect and distribute military equipment test data, such as battle tank acceleration and weaponry accuracy tests, around the country.

● **ATM**

Pre-Configuration: Configure ATMs to customer specifications and deliver them directly to the installation location. This eliminates unnecessary freight charges and minimizes the time for installation. This means that your ATM can be up and running within minutes not hours.

Complete Packaging: By shipping each ATM as a complete package. It comes with topper sign, credit card logo, receipt paper, and operator manual. Everything you need to get started is right there in the box.

E-Business Processes: By using the internet we have made our business process faster and more efficient. Some examples are:

Web Order Management System: Our Authorized Distributors can access our web site and place an order at any time. You do not have to call and you do not have send a fax.

E-Mail Confirmation: Once an order is confirmed, send you back an e-mail confirmation.

Order Tracking: Each order has a tracking number and you can view the status or your order via the web.

Electronic Invoice: Once an order is shipped, an electronic invoice is sent automatically via e-mail in addition to postal mail. E-mail payment confirmation, and many more.

7.   Conclusion

Application	Data Types/Size	Network Traffic Implication	Network Need
Scientific Modeling, Engineering	• Data files • 100's of megabytes to gigabytes	• Large files increase bandwidth required	• Higher bandwidth for desktops, servers and backbone
Publications, Medical Data Transfer	• Data files • 100's of megabytes to gigabytes	• Large files increase bandwidth required	• Higher bandwidth for desktops, servers and backbone
Internet/Intranet	• Data files now • Audio now • Video is emerging • High transaction rate • Large files, 1 MB to 100 MB	• Large files increase bandwidth required • Low transmission latency • High volume of data streams	• Higher bandwidth for servers and backbone • Low latency
Data Warehousing, Network Backup	• Data files • Gigabytes to terabytes	• Large files increase bandwidth required • Transmitted during fixed time period	• Higher bandwidth for servers and backbone • Low latency
Desktop Video Conferencing, Interactive Whiteboarding	• Constant data stream • 1.5 to 3.5 Mbps at the desktop	• Class of service reservation • High volume of data streams	• Higher bandwidth for servers and backbones • Low latency • Predictable latency

Table: Summary of Applications Driving Network Growth

The above discussion shows that Gigabit Ethernet has edge over ATM due to its simplicity, cost effectiveness, and affordability. By simply providing enough bandwidth at the backbone, Gigabit Ethernet will satisfy every network requirements that a user expects from ATM. Gigabit is existing, proven and installed technology. It has low cost of ownership, no retraining is required and no new protocols are needed except few modifications. In nutshell, most of the networks already use Ethernet so it would be beneficial to keep using the same technology on desktop and scale the same technology across the network backbone. ATM does have its advantages, but its need is for specific applications needing high Quality of Service, mostly multimedia-based applications. Also to efficiently utilize the capabilities of such high-speed technologies in LAN environment the NIC device drivers and application software has to be fine-tuned.

8.   References and Links

1. **Gigabit Ethernet Accelerating the standard for speed**,
    http://www.gigabit-ethernet.org

2. **IEEE 802.3z** ftp site, *http://grouper.ieee.org/groups/802/3/z/index.html*

3. Rich Seifert, "*Gigabit Ethernet: Technology and Applications for High-Speed LANs*," Addison-Wesley, 1998

4. Jayant Kadambi, et al, "*Gigabit Ethernet: Migrating to High-Bandwidth LANs*," Prentice Hall, 1998

5. David McDysan and Darren Spohn, "*ATM Theory and Applications*", McGraw-Hill Series, 1999

6. William Stallings, "*High Speed Networks: TCP/IP and ATM Design Principles*", Prentice Hall, 1998

7. **Gigabit Ethernet Technology**,
    http://www.compaq.com/products/networking/docs/wp.html

8. **Gigabit Ethernet Accelerating the standard for speed**,
    http://www.gigabit-ethernet.org

9. **Gigabit Ethernet and ATM A Technology Perspective**,
    http://www.nortelnetworks.com

10. David E. McDysan, Darren L. Spohn, "**ATM Theory and Application (McGraw-Hill Series on Computer Communications)**," McGraw-Hill, 1998

11. M. R. Karim, "**ATM Networks Application, Systems and Design**," Prentice Hall, 2000

12. Sean Riley, Robert A. Breyer, "**Switched, Fast, and Gigabit Ethernet (Mtp Network Engineering Series)**", New Riders, 1999

13. ATM Forum, Technical Specifications, February 1999
    <http://www.atmforum.com/atmforum/specs/approved.html>

14. Chowdhry, Pankaj, Cell Taxes: A Necessary Evil?, PC Week, December 15, 1997
    <http://www.speed-demon.com/sonet.html>

15. Cisco Systems Inc, Ethernet/IEEE 802.3, April 13, 1999
    <http://www.cisco.com/univercd/cc/td/doc/cisintwk/ito_doc/55771.htm>

16. Cisco Systems Inc, Packet over SONET/SDH, March 1, 1999
    <http://www.cisco.com/warp/public/733/12000/gspos_an.htm>

17. COOK Report, Optical IP Backbone Revolution Emerges, Canarie Runs IP Over DM Eliminating SONET and ATM, July 1998
    <http://cookreport.com/07.04.shtml>

18. Data Communications magazine, Euro-ATM: Get ready for the Rollouts, February 1997

19. Data Communications magazine, ISP Backbones, September 21, 1997

20. Fiber Optics magazine, SONET/SDH in the 21st Century, March 1999
    <http://www.prgguide.com/reports/fiber/r17-44w.html>

21. Gigabit Ethernet Alliance, Ethernet: Dominant Network Technology, no date
    <http://www.gigabit-ethernet.org/technology/whitepapers/gige/dominant.html>

22. Jain, Raj, ATM Networks: An Overview, no date
    <ftp://ftp.netlab.ohio-state.edu/pub/jain/courses/bnr/b_atm/index.htm>

23. Lantronix inc, Ethernet Tutorial, no date
<http://www.lantronix.com/htmfiles/mrktg/catalog/etntba.htm>

24. Symborski, Carl, ATM FAQ: How come an ATM cell is 53 bytes anyway?, June 18, 1997
    <http://cell-relay.indiana.edu/cell-relay/FAQ/ATM-FAQ/d/d7.htm#D7>

25. Battle of the Backbones: ATM vs. Gigabit Ethernet
    <http://www.data.com/tutorials/backbones.html>

26. Can Gigabit Ethernet and RSVP beat ATM?
    <http://www.zdnet.com/pcweek/reviews/0908/08rsvp.html>

27. Cells vs. Frames: Which Wins on the Backbone?
    <http://www.data.com/tutorials/wins.html>

28. Comparison of IP-over-SONET and IP-over-ATM Technologies
    http://www.trillium.com/whats-new/wp_ip.html