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FUTURE OF ASYNCHRONOUS TRANSFER MODE NETWORKING

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A Thesis

Presented to the

Faculty of

California State University,

San Bernardino

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In Partial Fulfillment

of the Requirements for the Degree

Master of Business Administration

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by

Fakhreddine Mohamed Hachfi

June 2004

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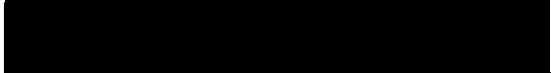
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June 2004

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ABSTRACT

The growth of Asynchronous Transfer Mode ATM was considered to be the ideal carrier of the high bandwidth applications like video on demand and multimedia e-learning. ATM emerged commercially in the beginning of the 1990's. It was designed to provide a different quality of service at a speed up to 10 Gbps for both real time and non real time application. ATM aims at providing both guaranteed bandwidth to support real-communication and dynamic bandwidth sharing to accommodate data traffic. The turn of the 90s saw a variety of technologies being developed. Terabit Routers, Network processor and optical switches in a new era in the broadband communication technology.

This project analyzes these technologies, compares it to the Asynchronous Transfer Mode and assesses the future of the ATM.

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LIST OF ACRONYMS

802.3   : IEEE CSMA/CD.

10GMII   : 10-Gigabit Media Independent Interface.

ABR   : Aavailable bit rate.

ADM   : Add/Drop Multiplexer.

ALL   : ATM Adaptation Layer.

ANSI   : American National Standards Institute.

ATM   : Asynchronous Transfer Mode.

B-ISDN   : Broadband Integrated Services Digital Network.

CBR   : Constant Bit Rate.

CCITT   : Consulting Committee International of Telephone
            and Telegraph.

CLP   : Cell Loss Priority.

CNET   : France's national telecommunications R&D center.

CRC   : Cyclic redundancy check.

CSMA/CD   : Carrier Sense Multiple Access with Collision
            Detection.

DA   : Destination address.

DWDM   : Dense Wavelength Division Multiplexing.

ECSA   : Exchange Carriers Standards Association.

FCS   : Frame check sequence.

FDDI   : Fiber Distributed Data Interface.

Gbps   : Gigabyte per second.

GFC   : Generic follow control.

HEC   : Header Error Check.

IEEE	:	Institute of Electrical and Electronics Engineers.
IOF	:	Interoffice.
IP	:	Internet Protocol.
ISDN	:	Integrated Services Digital Network.
ISP	:	Internet service provider.
ITU-T	:	International Telecommunication Union Telecommunication Standardization Sector.
LAN	:	Local Area Network.
LTE	:	Line-Terminating Equipment.
MAC	:	Media Access Control.
MAN	:	Metropolitan Area Network.
Mbps	:	Megabyte per second.
MCR	:	Minimum Cell Rate.
MDI	:	Medium Dependent Interface.
MPLS	:	Multi Protocols Label Switching.
Nrt-VBR	:	non-real-time variable bit rate.
OSI	:	Open System Interconnection.
PCS	:	Physical Coding Sublayer.
PMA	:	Physical Medium Attachment.
PMD	:	Physical Medium Dependent.
PRE	:	Preamble.
PT	:	Payload Type.
PTE	:	Path-Terminating Equipment.
QoS	:	Quality of Service.

Rt-VBR   : Real-time variable bit rate.

SA   : Source addresses.

SDH   : Synchronous Digital Hierarchy.

SNMP   : Simple Network Management Protocol.

SOF   : Start-of-frame delimiter.

SOHOs   : Small Office and Home Office.

SONET   : Synchronous Optical Network.

STE   : Section Terminating Equipment.

STM   : Synchronous Transport Module.

STS   : Synchronous Transport Signal.

SVC   : Switched Virtual Channel.

TCP   : Transmission Control Protocol.

TDM   : Time Division Multiplexed.

UBR   : Unspecified Bit Rate.

UDP   : User Data Protocol.

UNI   : User Network Interface.

VBR   : Variable Bit Rate.

VCCs   : Various Information Streams.

VCI   : Virtual Channel identifier.

VLSI   : Very Large Scale Integration.

VPI   : Virtual Path Identifier.

WAN   : Wide Area Network.

WDM   : Wavelength Division Multiplexing.

CHAPTER ONE

THE ASYNCHRONOUS TRANSFER MODE

Introduction

The telephone network has grown from the days of
Alexander Graham Bell to insure a reliable and a high
quality of service of voice. The voice networks required a
constant bandwidth per user connection. These networks
were not really designed for the transport of large
amounts of data. The Integrated Services Digital Network
(ISDN) evolves from Circuit Switched Telephone Networks
and could handle both digitized voice and data. However,
the apparition of ISDN didn't help much because of the
limitation of its bandwidth that carries a maximum of 2
Megabyte per second (Mbps). Although an ISDN connection
offers a very good Quality of Service (QoS), the bandwidth
was not sufficient for applications like Real time Video
and Audio Conferencing. Many others technologies were
developed for data application such as X25 and Frame
Relay. Frame Relay can operate up to 44 Mbps but it could
not deliver the required QOS for Real Time Applications.
Therefore, there was a need for Broadband Integrated
Services Digital Network (B-ISDN) and with the growth of
Asynchronous Transfer Mode (ATM) this was deemed to be the

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ideal carrier of the high bandwidth applications like video on demand and multimedia e-learning, which BISDN promised.

The ATM was introduced by Telecom History as follow: "ATM was adopted by Consulting Committee International of Telephone and Telegraph (CCITT) in 1989 to become the international standard for Broadband ISDN. The work on ATM was conducted in parallel by a group of switching researchers from France's national telecommunications R&D center (CNET) and another group of researchers from what was then Bellcore's Applied Research. Although the BISDN vision of integrated voice, data and video to the desktop using ATM has not materialized, because of the phenomenal growth of Internet, the technology has nevertheless emerged as a leader in providing transport for carriers' backbone networks" (Telecom History, 2003).

This chapter covers the technology of ATM, ATM traffic classification, quality service in ATM network, and ATM was ahead of its time.

ATM Technology

ATM stands for Asynchronous Transfer Mode, an evolution of today's frame relay, called fast packet. Emily Ta described the fast packet switching as an

emerging architecture that defines a packet format for
high-sped digital transmission of voice, data, and video
over a single backbone and provides the true medium
integration (Emily, 2001).

ATM is the transfer mode chosen for B-ISDN network.
ATM defines the way in which information from users is
matched onto the physical network. The information
transmitted from user in ATM use packets of fixed sizes,
called ATM cell.

ATM Cell

The ATM frame is called Cell. Each cell is 53 octets
long with an information field of 48 octets and a header
of 5 octets. The information field, or the cell payload,
contains the information sent from users. The header holds
network information such as routing. The switching of ATM
cells is executed by using labels in the header of cell
that contains routing information.

Information field (48octet) *Header*

Octet 53   *Octet1 (8 bits)*
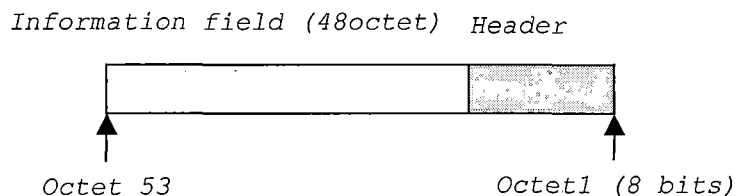
Figure 1. Format of ATM Cell

Structure of ATM Cell's Header. The cell header is used to route cell between switches. A closer look at the cell header shows its different functional parts.

GFC		VPI	
VPI		VCI	
VCI			
VCI		PI	CLP
HEC			

8   1 Bits

5 octets

Figure 2. Structure of an ATM Cell's Header

- The Generic follow control (GFC) field is reserved to indicate congestion.

- The Virtual Path Identifier (VPI) gives a high level of routing for ATM cell.

- The Virtual Channel identifier (VCI) gives a low level of routing.

- The Payload Type (PT) identifies the type of data contained in ATM cell.

- The Header Error Check (HEC) field is to execute of checksum over the cell header for bit error detection/correction in the header.

- The Cell Loss Priority (CLP) bit can be used to tell the network that a cell is or is not considered less

important. Therefore if there is any loss of cell,

the 'less important' one are lost.

As claimed by Paula Fronseca the cell headers

structure shown in the figure 2 is used only at the User

Network Interface (UNI), the point at which users have

access to the network, at the network node interface,

between nodes, there is no GFC field and therefore the

size of the VPI field is the same. (Fonseca, 1996).

ATM network Operation. In an ATM network based

network, the information is transferred in an Asynchronous

way with its arrival at the system input. Paula describes

the process of the transfer of information in the ATM

network in this way: "When information arrives, it is put

into buffers until there is enough data to fill an ATM

cell, after which it is transported through the network.

When there is no information to be transmitted, an

unassigned cell will be transmitted (Fonseca, 1996).

As the figure 3 shows, the ATM network can have

switches arranged in mesh, in which there are many

connections between switches. A mesh creates the potential

for multiple alternative paths between the sender and the

receiver (Panko, 2003).

Each station in an ATM network has a unique 20-octet

ATM address. These addresses are used by switches to

establish a path between the sender and the receiver. This path is called critical path and all the traffic between the 2 stations follow over this path.

ATM switch 1   ATM switch 2

Virtual Circuit

Client PC

ATM switch 4

ATM switch 3

Virtual Circuit

ATM switch 5
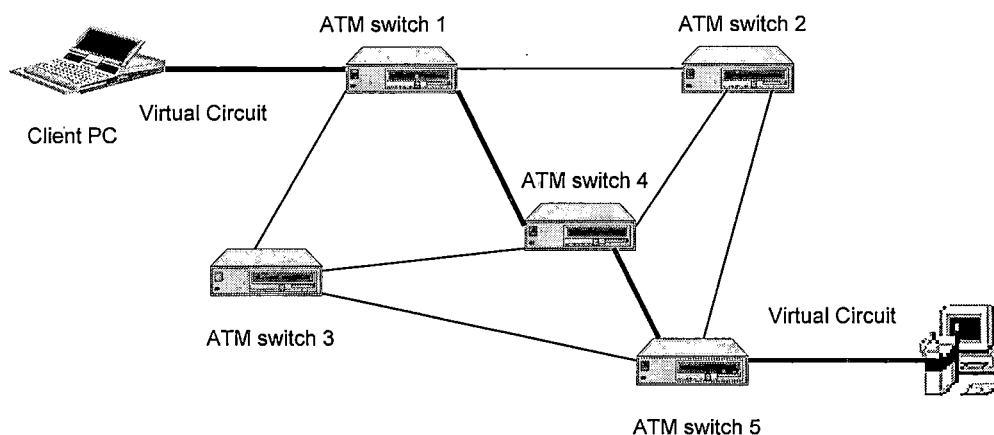
(Panko, 2003)
Figure 3. ATM Network with Virtual Circuit

If switch or trunk line along the virtual circuit fails, communication can longer take place using this virtual circuit. However the switches can use alternative paths to create a new virtual circuit and send subsequent cell along that virtual circuit (Panko, 2003).

The ATM Protocol Reference Model

When the protocol Reference Model for B-ISDN is combined with the ATM concept, another protocol is obtained that emphasize the ATM role in broadband networks.

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Paula Fonseca stated that the transport cells between

two ATM entities is a function of the physical layer,

while the multiplexing, cell demultiplexing and routing

functions using the VCI and VPI fields of the cell header

are performed by the ATM layer, which is common to all

type of services (Fonseca, 1996).

	Management Plan			
High layer protocol and functions	Signaling and control	Connection--less data	Connection--oriented data	Video Voice
Adaptation layer	Convergence			VBR CBR
	Segmentation and reassembly			
Transfer mode	ATM			
	Physical layer			
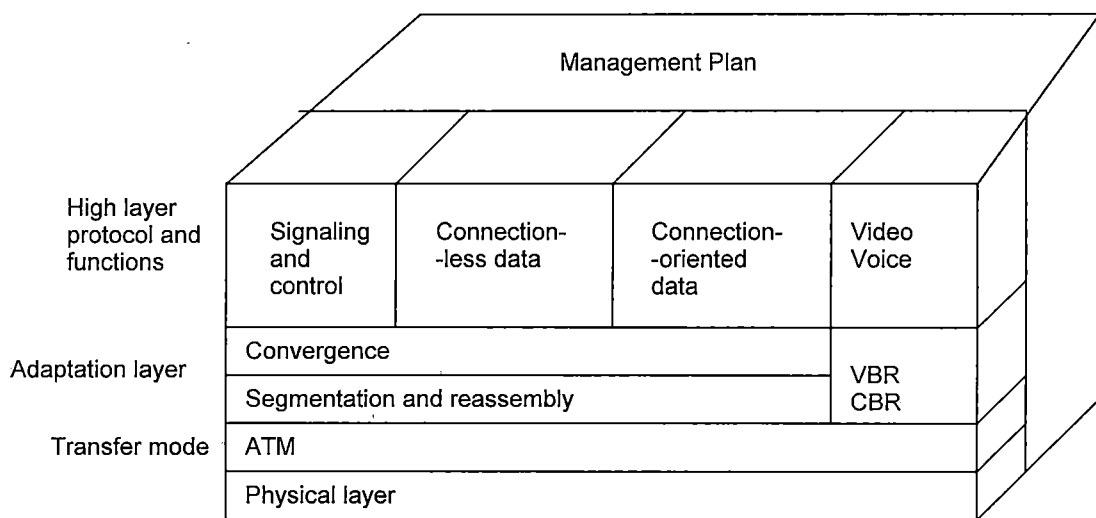
(Fonseca, 1996)
Figure 4. The Protocol Transfer Mode for ATM

Layering in ATM. ATM follows the Open System

Interconnection (OSI) model in layering. The ATM standard

is limited to the physical and data link layers.

Table 1. ATM Layering

OSI	ATM		
Data Link	ALL(ATM Adaptation Layer) (Application-Dependent)	Convergence Service (CS)	
		Segmentation and Reassembly (SAR)	
	ATM (Application-Independent)		
Physical	Physical		

(Panko, 2003)

The physical layer guarantees the transport of ATM cells between two ATM entities. The ATM layer is common to all type of services. It assures cell multiplexing, cell demultiplexing and routing function using the VCI and VPI field of the cell header. The ATM adaptation layer provides the functionalities, through specific protocols (AAL1, AAL2, AAL3/4, and AAL5), required for each service class to reach its desired QoS. The AAL receive information from higher layers and segmented into ATM cells; a reverse process is maintained if information comes from lower layer.

ALL Types. Table 2 shows which protocol is used for each type of service.

Table 2. Adaptation Layer Protocols and Services Classes

Service Class	Characteristics	Protocol used
Circuit emulation, CBR video (e.g. telephony)	CBR; connection- oriented required timing relationship between source and destination	AAL1
VBR video and audio (e.g. compressed video)	VBR; connection- oriented required timing relationship between source and destination	ALL2
Connection-oriented data transfer (e.g. frame relay)	VBR; connectionless; timing relationship between source and destination not required	AAL3/4
Connection data transfer (e.g. Ethernet LANs)	VBR; connectionless; timing relationship between source and destination not required	AAL5

(Fonseca, 1996)

ATM Traffic Classification

The types of traffic supported by an ATM network can be classified according to three characteristics: bandwidth, latency, and cell-delay variation. Mark Juliano defined bandwidth, latency and cell-delay variation as follow: "Bandwidth is the amount of network capacity required to support a connection. Latency is the amount of delay associated with a connection. Cell-delay variation is the range of the delays experienced by each group of associated cells" (Juliano, 1994).

ATM networks carry four types of traffic: constant bit rate (CBR), variable bit rate (VBR), available bit rate (ABR), and unspecified bit rate (UBR).

CBR Traffic

CBR traffic includes voice and video. To handle this traffic, the ATM network provides a sustained amount of bandwidth, low latency, and low cell-delay variation.

VBR Traffic

VBR traffic is handled similarly to CBR except that the bandwidth requirement varies. An ATM network supporting a videoconferencing application guarantees that a certain amount of bandwidth will always be available during a conference, but the actual bandwidth used can vary. There are two types of VBR, Real-time variable bit rate (rt-VBR) and non-real-time variable bit rate (nrt-VBR).

ABR Traffic

ABR traffic requires no specific bandwidth or delay parameters and is acceptable for many data applications. ABR connections support Local Area Network (LAN) traffic such as email and file transfers. Transmission Control Protocol/ Internet Protocol (TCP/IP) and NetWare will also use ABR connections. Paula Fonseca described the ABR traffic as follow: "A traffic source is classified as ABR

when it has no possibility of describing its traffic

characteristic in a very precise manner giving however

some minimum traffic requirement such as the minimum cell

rate, which means that it will be sensitive to loss."(

Fonseca, 1996).

UBR Traffic

The UBR service (e.g., a talk session in a computer

that uses the User Data Protocol (UDP)) as defined by

Paula Fonseca in her thesis does not provide any

descriptive traffic characteristics; consequently, this

type of service does not get any QoS guarantee from the

network. (Fonseca, 1996).

ATM Traffic Control

The design of an appropriate ATM traffic control is

the most important challenge for the success of an ATM

based B-ISDN. The primary role of traffic control

procedure is to protect the network so it can achieve the

required network performance objective, e.g. in term of

cell loss probability or cell transfer delay. The ATM

traffic control can be defined as the actions taken by

network to void congestion.

The ATM layer traffic control has many objectives,

such as simplicity, flexibility, and robustness. The

simplicity can appear in the requirement of designing a

simple ATM layer traffic control mechanism that minimizes

network equipment complexity at the same time as

maximizing network utilization. The traffic control

process should be flexible to set up an ATM layer QoS

classes sufficient for all existing and foreseeable

service. The requirement of robustness is very important

in any traffic control process in order to achieve high

resource efficiency under any traffic circumstance while

maintaining simple control function.

QoS in ATM

The QoS is the collective effect of service

performances that determine the degree of satisfaction of

a user of the specific service.

Table 3 shows the QoS requirement of some

applications.

Table 3. ATM Application and Their QoS Requirement

Application	Traffic Characteristics	QoS Requirements
Real-time video (using MPEG)	4 Mbit/s to 6 Mbit/s, CBR traffic	Low average delay and delay variation; very low cell loss.
Electronic mail	Each message size ranging from less than 1000 bytes up to several Mbytes, with very long message interarrival times.	Maximum delay should be in the order of a few minutes.
Software download	Five sizes up to several Mbytes.	Maximum delay in the order of a few seconds.

(IEEE Communications Magazine, 1994)

The ATM Forum has defined four ATM Layer service classes, each with scalable QoS levels:

Class A

Class A, or CBR, traffic is characterized by a continuous stream of bits at a steady rate. Class A traffic is low-bandwidth traffic that is highly sensitive to delay and intolerant to cell loss.

Class B and C

Class B and C traffic, defined as VBR, can be characterized by voice or video applications that use compression. Class B traffic is RT-VBR, where end-to-end delay is critical, such as interactive video conferencing. Class C is Nrt-VBR traffic, where delay is not so critical, such as video playback, training tapes and video mail messages.

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Class D

Class D traffic is split into two classes: ABR and UBR. UBR is a "best effort" service that does not specify bit rate or traffic parameters and has no quality of service guarantees. Originally devised as a way to make use of excess bandwidth, UBR is subject to increased cell loss and the discard of whole packets. ABR, like UBR, is also a best effort service, but differs in that it is a managed service, based on minimum cell rate (MCR) and with a low cell loss. No delay variation guarantee is currently envisioned for either UBR or ABR service classes. (Telecom history, 2003)

ATM Was Ahead of its Time

The Asynchronous Transfer Mode provided a great solution for converged Networking where Real Time and non Real Time Voice, Video and Data could all be transported perhaps even over one ATM connection over wide distances with assured delay, delay variation and cell loss. ATM was ahead of its time; it assured the best quality among all networking and offered the best solutions. The cost per Mbps over the WAN using ATM was extremely high. This was due to the fact that ATM switches and ATM cards were extremely expensive. Therefore ATM could be deployed only

by organizations like AT&T who could afford the price. Many researchers talked about the opportunity of ATM in to desktop technology. Jayasurya Venugopalan said: "ATM was envisaged to be a desktop technology also. However, the high price tags and the exponential decrease in prices of Intel processors as well as those of Intel's contemporaries coupled with the availability of Ethernet plug and play technology at lower costs restricted ATM to make it to the desktop. With a competitive pricing, ATM would have made sufficient inroads into desktop technology." (Venugopalan, 2002).

Conclusion

ATM emerged commercially in the early 1990s. It was a revolution in the networking area. ATM was designed to provide a differentiated QOS at speeds up to 10 Gigabyte per second (Gbps) for both Real Time and non Real Time Applications. The key of innovation in the ATM was the word asynchronous, non-periodic. The Asynchronous Transfer Mode follows the OSI model in layering and its standard is limited to the physical and data link layers. ATM networks carry four types of traffic: CBR, VBR, ABR, and UBR. ATM cells are all fixed 53 bytes long. ATM end systems and switches were available commercially only in the mid 90s.

The Asynchronous Transfer Mode provided a great solution
for converged Networking and was ahead of its time.

CHAPTER TWO

ETHERNET AND 10 GIGABIT ETHERNET

Introduction

Ethernet is the world's most pervasive networking technology, since the 1970's. It is considered as one of the real competitor of ATM network. In his research, The Gigabit Ethernet, Vijay Moorthy said: "it is estimated that in 1996, 82% of all networking equipment shipped was Ethernet. In 1995, the Fast Ethernet Standard was approved by the Institute of Electrical and Electronics Engineers (IEEE). Fast Ethernet provided 10 times higher bandwidth, and other new features such as full-duplex operation, and auto-negotiation. This established Ethernet as a scalable technology. Now, with the emerging Gigabit Ethernet standard, it is expected to scale even further" (Moorthy, 1997).

The Fast Ethernet standard is a developed form of Ethernet. It was pushed by an industry consortium called the Fast Ethernet Alliance. Vijay Moorthy continues his talk about the invention of the new technologies; he defined the introduction of Gigabit Ethernet to the market as follow: "A similar alliance, called the Gigabit Ethernet Alliance was formed by 11 companies in May 1996,

soon after IEEE announced the formation of the IEEE

Carrier Sense Multiple Access with Collision Detection

(802.3z) Gigabit Ethernet Standards project. At last

count, there were over 95 companies in the alliance from

the networking, computer and integrated circuit

industries." (Moorthy, 1997). The Gigabit Ethernet

standard was deployed in large numbers in both corporate

and public data networks.

As the demand for high-speed networks continues to

grow, the need for a faster Ethernet technology is

apparent. In March 1999, The 10 Gigabit Ethernet was

developed. The 10-Gigabit Ethernet is basically a

faster-speed version of Ethernet. It will support the data

rate of 10 gigabits per second.

This chapter covers these technologies and gives a

general idea about the market of Ethernet, Gigabit

Ethernet and 10-Gigabit Ethernet.

Ethernet and /Gigabit Ethernet

Ethernet was created at the Xerox Palo Alto Research

Center in the 1970. The original Ethernet was a 2.94 Mbps

Carrier Sense Multiple Access with Collision Detection

(CSMA/CD) system and was used to connect over 100 personal

workstations on a 1 Km cable. Moorthy explained the

CSMA/CD as follow: "CSMA/CD refers to the protocol used by stations sharing the medium, to arbitrate use of the medium." (Moorthy, 1997). In the beginning of the 1980's the Ethernet standardization was passed to the IEEE's 802 LAN/MAN Standard Committee. The original 802.3 standard was published in 1985. The IEEE 802.3 standard was based on the 10 Mbps Ethernet. In 1995, IEEE adopted the 802.3u Fast Ethernet standard. Fast Ethernet is a 100 Mbps Ethernet standard. With Fast Ethernet came full-duplex Ethernet. The next step in the evolution of Ethernet is Gigabit Ethernet. The IEEE 802.3z committee developed the standard.

The IEEE 802.3 committee approved the 802.3z Gigabit Ethernet Standardization project in March, 1996. According to Moorthy, 54 companies expressed there intent to participate in the standardization project of the Gigabit Ethernet. The Gigabit Ethernet Alliance was formed in May 1996 by 11 companies: 3Com Corp., Bay Networks Inc., Cisco Systems Inc., Compaq Computer Corp., Granite Systems Inc., Intel Corporation, LSI Logic, Packet Engines Inc., Sun Microsystems Computer Company, UB Networks and VLSI Technology (Moorthy, 1997). The 802.3z has been working on fiber optic and a shielded jumper cable assembly ("short-haul copper") solutions for Gigabit Ethernet. A

new task force was formed in the spring of 1997 to work on a "long-haul copper" solution based on four pairs of Category 5 cabling wiring. The 802.3ab task force is working to standardize a Gigabit Ethernet link of 100 meters maximum length on four pairs of Category 5 UTP cabling. As said by the Gigabyte Ethernet Alliance, The Gigabit Ethernet standards define an interface (called the GMII) to the Ethernet Media Access Control (MAC) layer, management, repeater operations, topology rules, and four physical layer signaling systems: 1000BASE-SX (short wavelength fiber), 1000BASE-LX (long wavelength fiber), 1000BASE-CX (short run copper) and 1000BASE-T (100-meter, four-pair Category 5 UTP)" (Gigabyte Ethernet Alliance, 1997). Figure 5 shows the relationship of the various members of the Gigabit Ethernet technology family.

Media Access Control (MAC)
Full duplex/ Half duplex

Gigabit Media Independent Interface (GMII)

MAC

PHY

1000 BASE-X 8b/10b Encoder/Decoder

1000 BASE-T Encoder/Decoder

1000 BASE-CX Transceiver

1000 BASE-LX Transceiver

1000 BASE-SX Transceiver

1000 BASE-T Transceiver

802.3z   802.3ab
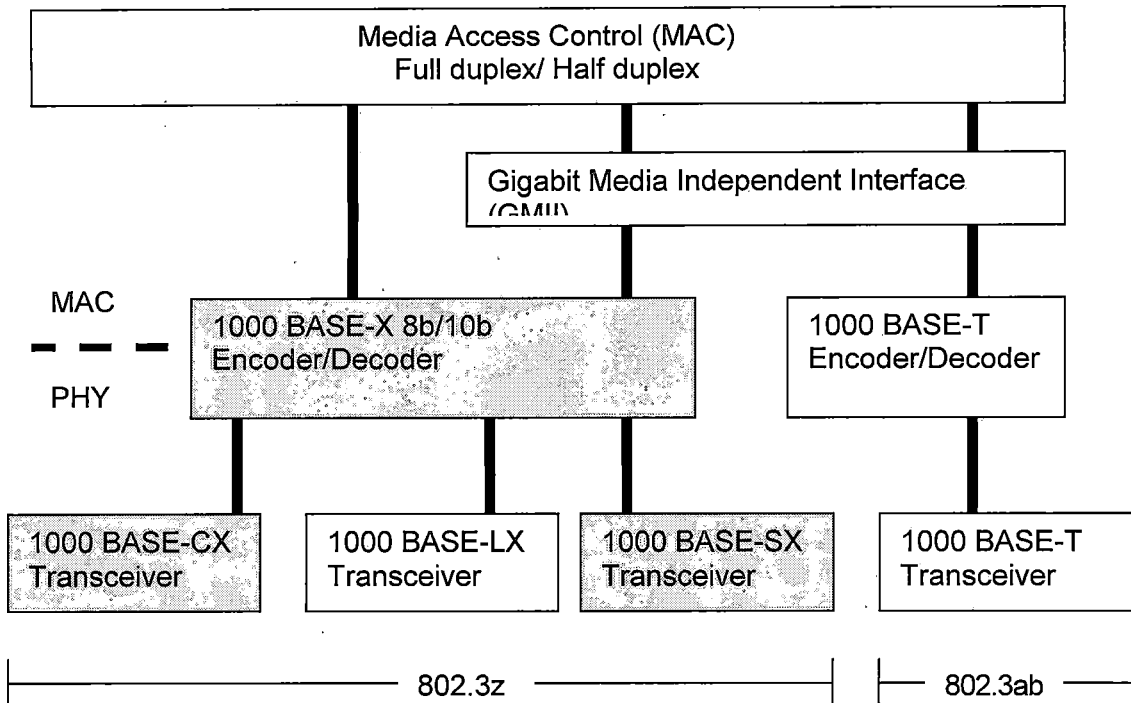
Fiber Channel Based Technology

(Gigabyte Ethernet Alliance, 1997)
Figure 5. The Gigabit Ethernet Technology Family

The Evolution of Ethernet

The evolution of Ethernet from the Xerox Palo Alto Research Center to 10 Mbps and then to 100 Mbps took over 20 years to complete. This relaxed progression was partly due to the slower computing. The 1990s showed incredible growth in PC technology speed and, even with the advent of Fast Ethernet (100 Mbps). The Gigabit Ethernet was first mentioned in November 1995 and was a fully ratified standard less than three years later. The rapid development and adoption paces for networking and

computing technologies have paved the way for pre-standard

10 GE products to ship long before the standard is fully

ratified in early 2002.

Figure 6 shows the evolution of Ethernet during the

last 30 years.

Year	Event
1970	Corning develops first low-loss single mode fiber
1972	Bob Metcalfe et. al develop first experimental 2.94 Mbps Ethernet at Xerox Parc calling it at the time, the ALTO ALOHA NETWORK.
1980	DEC-INTEL-XEROX present formal specifications for 10 Mbps Ethernet (Ethernet Blue Book)
1980	First Transatlantic single mode fiber optic cable, TAT-8
1983	IEEE approves standard for 10 Mbps Ethernet over coax cable
1986	Start-up SynOptics ships Ethernet hub supporting transmission over twisted pair telephone lines.
1989	International Organization for Standards (ISO) approves Ethernet standard (ISO88023)
1990	Start-up Kalpana ships first full-duplex Ethernet switch, the Etherswitch
1993	EEE approves standard 10 Mbps Ethernet over fiber
1995	IEEE approves standard 100 Mbps Fast Ethernet over twisted pair and fiber
1996	82% of all networking equipment shipped was Ethernet
1997	IEEE approves standard for full duplex Ethernet
1998	IEEE approves standard 1000 Mbps (Gigabit Ethernet) over fiber and coax
1998	25 Year anniversary of Ethernet
1999	50,000,000 PCs worldwide are networked over Ethernet
1999	53,000,000 parts of 10/100 Layer 2 ports shipped
2000	Data traffic surpassed voice traffic on public networks worldwide
2000	Nortel Networks announces first WAN-compatible 10 Gigabit Ethernet interfaces
2001	IEEE to release final draft of 10 Gigabit Ethernet standard.
2002	IEEE to ratify 10 Gigabit Ethernet standard
2004	Over 2,000,000 10 Gigabit Ethernet ports expected to ship.

(Siwamogsatham, 1999)
Figure 6. The Evolution of Ethernet

The IEEE 802.3 Logical Relationship
to the ISO Reference Model

The ISO data link layer is divided into two IEEE 802
sub layers, the MAC sub layer and the MAC-client sub
layer. The IEEE 802.3 physical layer corresponds to the
ISO physical layer. Figure 7 shows the IEEE 802.3 logical
layers and their relationship to the OSI reference model.

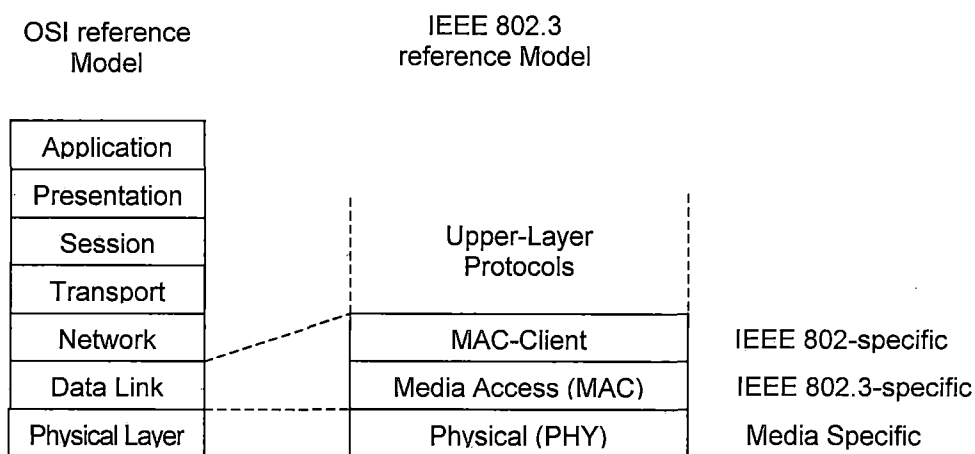| OSI reference Model	IEEE 802.3 reference Model	
Application		
Presentation	Upper-Layer Protocols	
Session		
Transport		
Network	MAC-Client	IEEE 802-specific
Data Link	Media Access (MAC)	IEEE 802.3-specific
Physical Layer	Physical (PHY)	Media Specific

Figure 7. Ethernet Logical Relationship to the ISO

The MAC-client sub layer may be Logical Link Control
(LLC) or Bridge entity. The Logical Link Control provides
the interface between the Ethernet MAC and the upper
layers in the protocol stack of the end station. The LLC
sub layer is defined by IEEE 802.2 standards. The Bridge
entities provide LAN-to-LAN interfaces between LANs that
use the same protocol (for example, Ethernet to Ethernet)
and also between different protocols (for example,

Ethernet to Token Ring). Bridge entities are defined by IEEE 802.1 standards.

The MAC sublayer has two primary responsibilities:

- Data encapsulation, including frame assembly before transmission, and frame parsing/error detection during and after reception

- Media access control, including initiation of frame transmission and recovery from transmission failure.

The Basic Ethernet Frame Format

The IEEE 802.3 standard defines a basic data frame format that is required for all MAC implementations, plus several additional optional formats that are used to extend the protocol's basic capability. The basic data frame format contains the seven fields shown in Figure 8.

Field	Description
Preamble (7 octets) 10101010...	Begins synchronization
Start of frame Delimiter (1 octet)	End synchronization signals start of content frame
Destination Address (6 octets)	48 bits Expressed for humans in Hexadecimal
Source Address (6 octets)	48 bits Expressed for humans in Hexadecimal
Length (2 octets)	Length of data field in octets 1,500(decimal) maximum
Data field (variable)	LLC frame
PAD	(Needed it data Field is less than 46 octet Minimum; Data Field plus PAD will be 46 octets)
Frame check Sequence (4 octet)	Error detection Field

(Panko, 2003)
Figure 8. Ethernet Frame

- The Preamble (PRE) consists of 7 bytes. The PRE is an alternating pattern of ones and zeros that tells receiving stations that a frame is coming, and that provides a means to synchronize the frame-reception portions of receiving physical layers with the incoming bit stream.

- The Start-of-frame delimiter (SOF) consists of 1 byte. The SOF is an alternating pattern of ones and zeros, ending with two consecutive 1-bits indicating that the next bit is the left-most

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bit in the left-most byte of the destination
address.

- Destination address (DA) consists of 6 bytes.
  The DA field identifies which station(s) should
  receive the frame.

- Source addresses (SA) consists of 6 bytes. The
  SA field identifies the sending station.

- Length/Type—consists of 4 bytes. This field
  indicates either the number of MAC-client data
  bytes that are contained in the data field of
  the frame, or the frame type ID if the frame is
  assembled using an optional format.

- Data—is a sequence of n bytes of any value,
  where n is less than or equal to 1500. If the
  length of the Data field is less than 46, the
  Data field must be extended by adding a filler
  (a pad) sufficient to bring the Data field
  length to 46 bytes.

- The Frame check sequence (FCS) consists of 4
  bytes. This sequence contains a 32-bit cyclic
  redundancy check (CRC) value, which is created
  by the sending MAC and is recalculated by the
  receiving MAC to check for damaged frames.

10-Gigabit Ethernet

10-Gigabit Ethernet is the faster-speed version of Ethernet. It supports the data rate of 10 Gbps. It offers similar benefits to those of the preceding Ethernet standard. Many groups of users demand 10-Gigabit Ethernet such as enterprise users, universities, telecommunication carriers, and Internet service providers.

Benefits of 10 Gigabit Ethernet

According to Siwaruk Siwamogsatham, One of the main benefits of 10-Gigabit standard is that it offers a low-cost solution to solve the demands for bandwidth. Not only the cost of installation is low, but the cost of network maintenance and management is minimal as well. Management and maintenance for 10-Gigabit Ethernet may be done by local network administrators (Siwamogsatham, 1999).

10 Gigabyte Ethernet has many others benefits. It allows faster switching and uses the same Ethernet format. 10-Gigabit Ethernet allows seamless integration of LAN, MAN, and WAN.

Market Requirement

There is a broad demand of the 10Gigabyte Ethernet in the LAN, MAN, and the WAN markets. Each market has its own requirement.

In the local area Network market, Siwaruk said "applications typically include in-building computer servers, building-to-building clusters, and date centers. In this case, the distance requirement is relaxed, usually between 100 and 300 meters. But, the cost requirement is stringent" (Siwamogsatham, 1999).

In the metropolitan area network, the distance requirement is moderate, usually between 2 kms and 20 kms. In this market, applications usually include campus backbones, enterprise backbones, and storage area networks.

The WAN markets include Internet service providers and Internet backbone facilities.

Table 4 summarizes typical span requirements for different applications.

Table 4. Distance Requirement

Applications	Typical Distance
Local Storage Area Networks	100 m
Remote Storage Area Networks	300m/2km/40km
Disaster Recovery Facilities	300m/2km/40km
Enterprise networks	100m
Enterprise Aggregation Facilities	500m
Campus Backbone	10km
Enterprise Backbone	300m/2km/40km
Internet Service Providers	100m
Internet Aggregation Facilities	300m/2km/40km
Internet Backbone Facilities	300m/2km

(Bynum, 1999)

10-Gigabit Ethernet Technology

The Ethernet protocol basically implements the physical and the data link layer of the OSI model. Figure 9 depict shows the typical Ethernet protocol stack and the relationship to the OSI model.
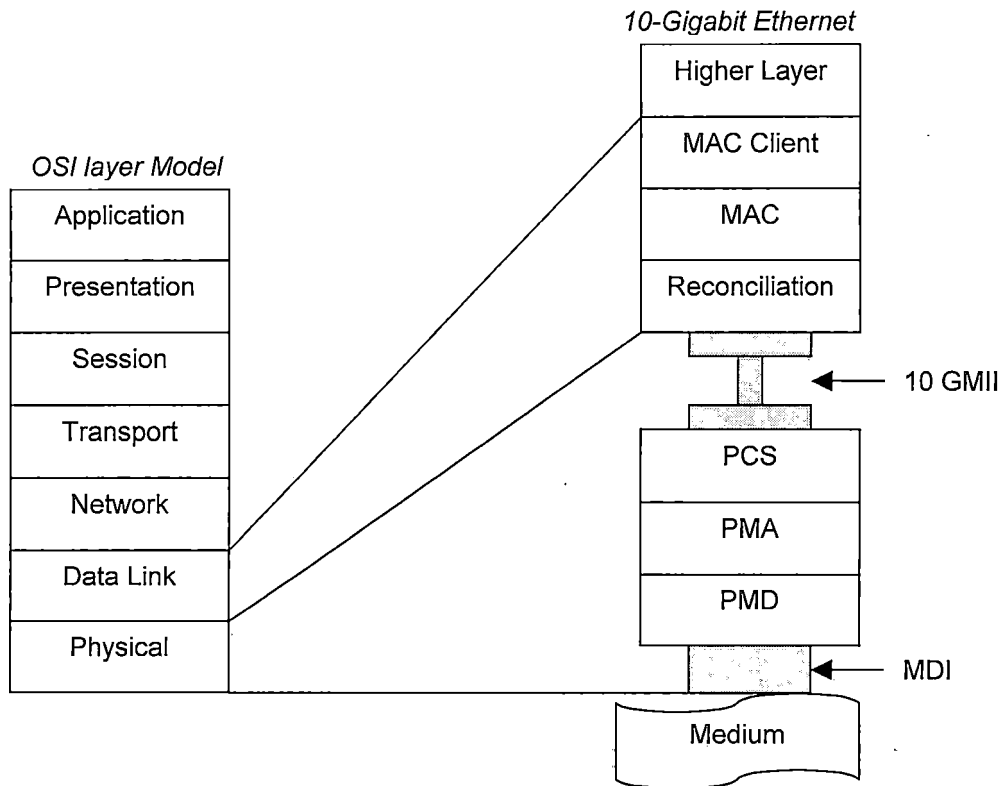
(Siwamogsatham, 1999)
Figure 9. Ethernet Protocol Layer

Medium Dependent Interface (MDI)

MDI is referred a connector. It defines different connector types for different physical media and PMD device.

Physical Medium Dependent (PMD)

The PMD sublayer is responsible for signal transmission. The typical PMD functionality includes amplifier, modulation, and wave shaping. Different PMD devices may support different media.

Physical Medium Attachment (PMA)

The PMA sublayer is responsible for serialize code groups into bit stream suitable for serial bit-oriented physical devices and vice versa. Synchronization is also done for proper data decoding in this sublayer.

Physical Coding Sublayer (PCS)

The PCS sublayer is responsible for coding and encoding data stream to and from the MAC layer. The default coding technique has not been defined.

10-Gigabit Media Independent Interface (10GMII)

10GMII provides a standard interface between the MAC layer and the physical layer. It isolates the MAC layer and the physical layer, enabling the MAC layer to be used with various implementations of the physical layer.

Reconciliation Sublayer

The reconciliation sublayer acts as a command translator. It maps the terminology and commands used in the MAC layer into electrical formats appropriate for the physical layer entities.

MAC

The media access control sublayer provides a logical connection between the MAC clients of itself and its peer station. It main responsibility is to initialize, control, and manage the connection with the peer station.

Conclusion

Ethernet is the most used network topology in industry today and it is for this reason that Ethernet has the most integrated software and hardware there is in networking today. Fast Ethernet has not changed the standard of Ethernet it has only made it faster. The hopes for this new, faster Ethernet are that it will revolutionize current Ethernet so it can continue to be the network topology of choice. 100BaseT brings to the desktop what is desired the most, more speed. Fast Ethernet becomes one of the real competitors of ATM in the broadband market. Chapter 4 will compare the fast Ethernet and the ATM technologies.

CHAPTER THREE

THE OPTICAL NETWORKING AND SONET

Introduction

In the early 1980s, a revolution in
telecommunications networks began spawned by the use of a
relatively unassuming technology: fiber optic cable. Since
then, the great cost savings and increased network quality
has led to many advances in the technologies required for
optical networks. The recent developments have turned the
optical networking business into one of the most dynamic
areas of the telecommunications industry. The need for
optical standards led to the creation of the synchronous
optical network (SONET). SONET was formulated by the
Exchange Carriers Standards Association (ECSA) and the
American National Standards Institute (ANSI), which sets
industry standards in the United States for
telecommunications and other industries. The increased
configuration flexibility and bandwidth availability of
SONET provides significant advantages over the older
telecommunications system. Since the 1990, SONET becomes
one of the major competitors of ATM network. This chapter
covers the optical network drivers and market. It

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underlines the synchronous optical network, the SONET
transport hierarchy and the SONET framing.

The Optical Networking

Definition

Optical networks are high-capacity telecommunications
networks based on optical technologies and component that
provide routing, grooming, and restoration at the
wavelength level as well as wavelength-based services. The
origin of optical networks is linked to Wavelength
Division Multiplexing (WDM) which arose to provide
additional capacity on existing fibers. Before the
introduction of optical networks, the reduced availability
of fibers became a big problem for the network providers.
Muralikrishna Gandluru said: "the development of optical
networks and the use of DWDM (Dense Wavelength Division
Multiplexing) technology, a new and probably, a very
crucial milestone is being reached in network evolution"
(Gandluru, 1999). DWDM is a fiber-optic transmission
technique. It involves the process of multiplexing many
different wavelength signals onto a single fiber.

Optical Network Drivers

Many factors are driving the need for optical networks.
A few of the most important reasons for migrating to the

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optical layer are Fiber Capacity, restoration capability, reduced cost and wavelength service.

Fiber Capacity. The first implementation of what has emerged as the optical network began on routes that were fiber-limited. Providers needed more capacity between two sites, but higher bit rates or fibers were not available. The only options in these situations were either to install more fiber, which is an expensive and labor-intensive chore, or place more time division multiplexed (TDM) signals on the same fiber. WDM provided many "virtual" fibers on a single physical fiber. By transmitting each signal at a different frequency, network providers could send many signals on one fiber just as though they were each traveling on their own fiber.

Restoration Capability. As network planners use more network elements to increase fiber capacity, a fiber cut can have massive implications. In current electrical architectures, each network element performs its own restoration. For a WDM system with many channels on a single fiber, a fiber cut would initiate multiple failures, causing many independent systems to fail. By performing restoration in the optical layer rather than the electrical layer, optical networks can perform protection switching faster and more economically.

Additionally, the optical layer can provide restoration in networks that currently do not have a protection scheme. By implementing optical networks, providers can add restoration capabilities to embedded asynchronous systems without first upgrading to an electrical protection scheme.

Reduced Cost. In systems using only WDM, each location that demultiplexes signals will need an electrical network element for each channel, even if no traffic is dropping at that site. By implementing an optical network, only those wavelengths that add or drop traffic at a site need corresponding electrical nodes. Other channels can simply pass through optically, which provides tremendous cost savings in equipment and network management. In addition, performing space and wavelength routing of traffic avoids the high cost of electronic cross-connects, and network management is simplified.

Wavelength Services. One of the great revenue-producing aspects of optical networks is the ability to resell bandwidth rather than fiber. By maximizing capacity available on a fiber, service providers can improve revenue by selling wavelengths, regardless of the data rate required. To customers, this service provides the same bandwidth as a dedicated fiber.

Optical Network Technology

We can classify the optical network technologies into early and current technologies.

Early Technologies. When fiber optics came into use, network providers soon found that some improvements in technology could greatly increase capacity and reduce cost in existing networks. These early technologies eventually led to the optical network as it is today.

a- Broadband WDM

The first incarnation of WDM was broadband WDM. In 1994, by using fused biconic tapered couplers, two signals could be combined on the same fiber. The performance did not compare to today's technologies, the couplers provided twice the bandwidth out of the same fiber, which was a large cost savings compared to installing new fiber.

b- Optical Amplifiers

The second basic technology and perhaps the most fundamental to today's optical networks as well, was the erbium-doped optical amplifier. The amplifier provided enormous cost savings over electrical regenerators, especially in long-haul networks.

Current Technologies. Systems deployed today use devices that perform similar functions as earlier devices, but are much more efficient and precise.

a- DWDM

Dense wavelength division multiplexing combines multiple signals on the same fiber, ranging up to 40 or 80 channels. By implementing DWDM systems and optical amplifiers, networks can provide a variety of bit rates and a multitude of channels over a single fiber.

b- Optical Amplifiers

The performance of optical amplifiers has improved significantly—with current amplifiers providing significantly lower noise and flatter gain. The total power of amplifiers has also steadily increased.

c- Narrowband Lasers

The advanced lasers with narrow bandwidths provide the narrow wavelength source that is the individual "channel" in optical networks. These laser sources emit a highly coherent signal that has an extremely narrow bandwidth. Depending on the system used, the laser may be part of the DWDM system or embedded in the SONET network element. When the precision laser is embedded in the SONET network element, the system

is called an embedded system. When the precision

laser is part of the WDM equipment in a module called

a transponder, it is considered an open system

because any low-cost laser transmitter on the SONET

network element can be used as input

d- Fiber Bragg Gratings

Commercially available fiber Bragg gratings have been

important components for enabling WDM and optical

networks. A fiber Bragg grating is a small section of

fiber that has been modified to create periodic

changes in the index of refraction. The wavelength

specific properties of the grating make fiber Bragg

gratings useful in implementing optical add/drop

multiplexers. Bragg gratings are also being developed

to aid in dispersion compensation and signal

filtering as well.

e- Thin Film Substrates

Another essential technology for optical networks is

the thin film substrate. The substrate can be made by

coating a thin glass or polymer substrate with a thin

interference film of dielectric material to pass

through only a specific wavelength and reflect all

others.

Markets for Optical Networks

The evolution to the optical layer in telecommunications networks will occur in stages in different markets because the traffic types and capacity demands for each are different. Figure 10 shows the optical network market between 1997 and 2001 in million of dollars.
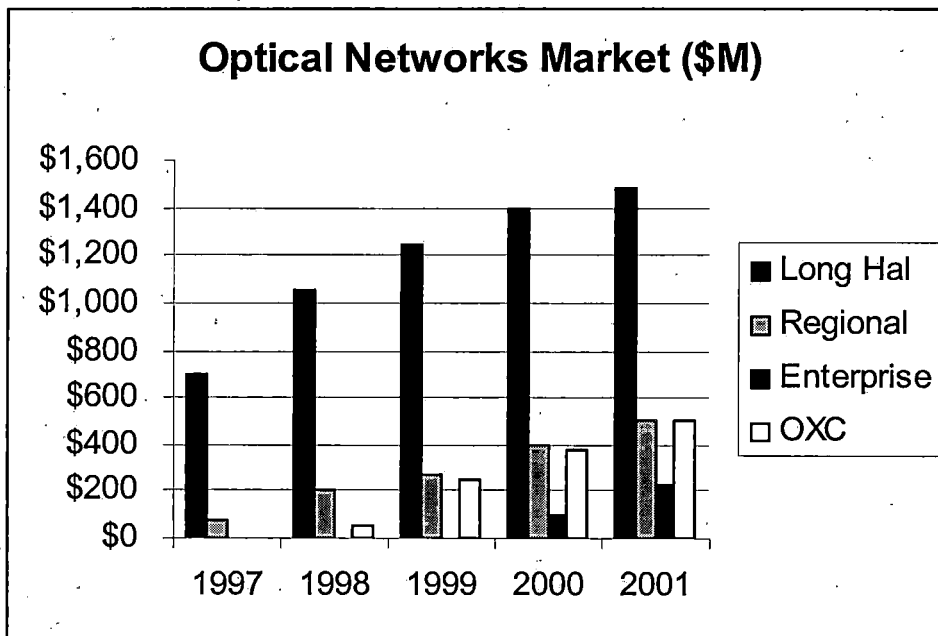

Figure 10. Optical Networks Market ($M)

Long-Haul Networks. The long-haul networks were the first to have large-scale deployment of optical amplifiers and wideband WDM systems mainly because of cost reductions. Optical amplifiers are a cheaper alternative to a large number of electrical regenerators in a span.

Metro Interoffice (IOF) Networks. Networks in the metro interoffice (IOF) market have different needs for optical technologies. IOF networks are typically more interconnected and geographically localized. Because of the traffic patterns and distances between offices, optical rings and optical cross-connects will be required much earlier. IOF networks not only need to distribute traffic throughout a region, they must also connect to the long-haul network. As the optical network evolves, wavelengths add/drop and interconnections will add the flexibility and value that IOF networks require.

Business Access Networks. The application of optical networks is not so clear with these networks. Many more complexities arise in these networks, including variable bit-rate interfaces, different cost structures, and different capacity needs. Optical networks designed for the business access environment will need to incorporate lower-cost systems to be cost-effective and enable true wavelength services. The challenge will be proving when and where DWDM is effective in access networks.

The SONET

Definition

SONET is a standard for optical telecommunications transport formulated by the Exchange Carriers Standards Association for the American National Standard Institute. The comprehensive SONET standard is expected to provide the transport infrastructure for worldwide telecommunications for the next decade.

A similar standard, Synchronous Digital Hierarchy (SDH), has also been established in Europe by the International Telecommunication Union Telecommunication Standardization Sector (ITU-T). SONET equipment is generally used in North America, and SDH equipment is generally used everywhere else in the world. Both SONET and SDH are based on a structure that has a basic frame format and speed. The frame format used by SONET is the Synchronous Transport Signal (STS). On the other hand the frame format used by SDH is the Synchronous Transport Module (STM).

The SONET Transport Hierarchy

There are three levels of hierarchy: section, line and path. Each level terminates its corresponding fields in the SONET payload. Figure 11 shows the 3 levels of hierarchy:
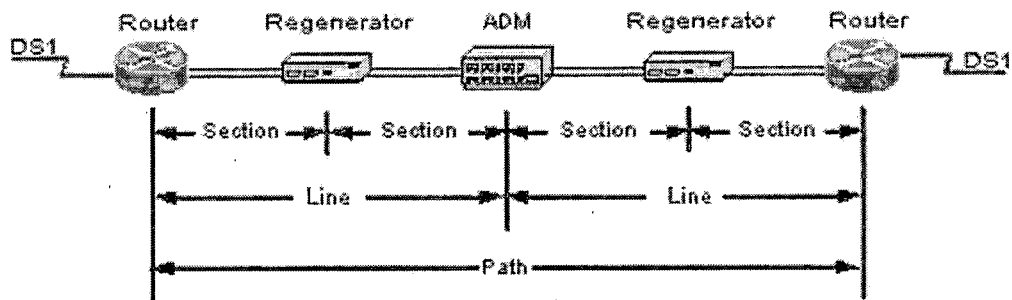
Figure 11. Three Levels of Hierarchy

Section. A section is a single fiber run that can be terminated by a network element (Line or Path) or an optical regenerator. The main function of the section layer is to properly format the SONET frames, and to convert the electrical signals to optical signals. Section Terminating Equipment (STE) can originate access, modify, or terminate the section header overhead.

Line. Line-Terminating Equipment (LTE) originates or terminates one or more sections of a line signal. The LTE does the synchronization and multiplexing of information on SONET frames. Multiple lower-level SONET signals can be mixed together to form higher-level SONET signals. An Add/Drop Multiplexer (ADM) is an example of LTE.

Path. Path-Terminating Equipment (PTE) interfaces non-SONET equipment to the SONET network. At this layer the payload is mapped into the SONET frame.

SONET Framing

A standard STS-1 frame is 9 rows by 90 bytes. The first 3 bytes of each row represent the Section and Line overhead. These overhead bits comprise framing bits, and pointers to different parts of the SONET frame. For STS-1, a single SONET frame is transmitted in 125 microseconds, or 8000 frames per second. An STS-3 is very similar to STS-3c. The frame is 9 rows by 270 bytes. The first nine columns contain the transport overhead section, and the rest is SPE. For both STS-3 and STS-3c, the transport overhead (Line and Section) is the same. For an STS-3 frame, the SPE contains three separate payloads and three separate path overhead fields. In essence, it is the SPE of three separate STS-1s packed together one after another.

SONET Technology for Transport

SONET technology was developed in the mid 1980s to create a next-generation physical layer transport. SONET defines the transmission speed, line encoding, and signal multiplexing mechanism to transport a heterogeneous mix of traffic. The SONET overhead mechanism facilitates transport of legacy private-line traffic in addition to newer mappings for Layer 2 protocols such as ATM, fiber distributed data interface (FDDI). SONET is designed to be

a transport mechanism that maps existing asynchronous circuit-based traffic into a synchronous payload envelope, hence greatly simplifying the process of demultiplexing traffic at the other end of the connection. Legacy multiplexing equipment that switched asynchronous traffic would require bit stuffing to accommodate jitter as well as extraction of payload at each switching point in the network.

Prevalent Technologies for SONET Access

The solutions available for SONET access can be categorized into four types of services. Each of these services is offered over a SONET ring, albeit with different tariffs and equipment requirements.

- T1 leased-line services

- Frame Relay

- ATM

- Packet over SONET

Table 5 shows the benefits and limitations of prevalent access technologies.

Table 5. Technologies for SONET Access

Access Technology	Benefits	Limitations
Leased Lines	Widespread availability due to large installed base	Declining tariffs as technology and associated equipment mature
		Fixed bandwidth connection to the CE (upgrade from T1 to T3 would require changing CTE and CE equipment)
		Uses aging copper plant, requiring line conditioning and signal regenerators to operate at rated speeds
Frame Relay	Ability to share the transmission medium for point to multipoint connections	Data rates above T1 not commonly available
	Saves costs by statistical multiplexing of user payload accommodates occasional burstiness of traffic while guaranteeing a minimum throughput over time	No built-in support for applications such asmultimedia transport that require QoS guarantees
		Requires extensive provisioning because DLCIs need to be set up for all end nodes
ATM	ATM provides an integrated network for all traffic types - voice, data, and video	Because IP dominates in the desktop market, transporting LAN traffic on the WAN requires additional overhead to map IP protocols to run over ATM
	ATM provides support for quality of service (QoS), enabling a network operator to offer support for delay-sensitive applications	Overlay network required to provide end-to-end services
Packet over SONET	Low overhead point-to-point transport of IP data - fixed 6-byte header for all packets from 64 to 1,518 bytes	IP protocols to achieve QoS are still being deployed across the WAN
	Simplicity of PPP allows lower complexity and hence lower-cost edge devices to encapsulate IP data	Voice transport over IP would require infrastructure upgrades throughout the network to achieve results comparable to today's TDM network

(Cisco System, 1999)

Wideband Packet over SONET (WPOS)

IP over SONET has already been deployed in Internet Service Provider (ISP) inter point-of-presense (POP) connections because of its improved efficiency and reduction in complexity. Cisco Systems extends this technology to the access fiber. The notable difference between the WPOS and IP over SONET is the use of channelized SONET payloads. Using the channelized SONET payloads, IP traffic on the premises now has a dedicated point-to-point pipe between CTE and the data termination point through a public SONET network rather than a shared statistically multiplexed pipe with its performance. In the case of TLAN interconnect applications, WPOS allows point-to-network connections instead of the point-to-point connections possible with solutions available today, implying that it would be possible to create a LAN-to-LAN private network mesh connecting more than two locations together using WPOS technology without requiring identical equipment on both ends. Chapter 4 emphasizes this topic and compares the IP over SONET to the IP over ATM.

Conclusion

Because of the cost benefits and the utility of the optical technology, SONET becomes one of the real

competitors of ATM in the broadband market. Many studies

conclude that SONET will earn many markets in the

near-term. The next chapter will compare the optical

technology to the ATM and it will cover the market of each

technology

CHAPTER FOUR

ATM VERSUS ETHERNET AND SONET

Introduction

In today's world, with demand for high speed access
to data, voice, and video ever-growing, companies all over
the world are looking for the most cost-effective way to
upgrade their network infrastructure to support new and
existing applications requiring higher bandwidth and
latency performance needs. In the past, the only choice
was to upgrade network backbones and WAN links to ATM. But
this is not the case today. Today there are others choices
such as Gigabit Ethernet and the SONET. This chapter
covers the advantage and disadvantage of each technology
and compares the fast Ethernet and SONET to the ATM.

ATM Versus Fast Ethernet

ATM and Gigabit Ethernet are ones of the famous
technologies that compete for the first place in
high-speed networks. This section discusses the advantages
and disadvantages of having ATM or Gigabit Ethernet in the
LAN, WAN and other networks based on some definitions and
information mentioned in chapter 1 and 2 of this research.

Simplicity

Gigabit Ethernet is simpler than ATM in many issues. Gigabit Ethernet still uses the same 802.3 formats. This means managers do not have to provide training to the users of Gigabit Ethernet. Pei-Hsun said in his research: "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" (Tsai, 2001). On the other hand ATM technology is quite complex when it comes to implementation of LANE or MPOA in order to support LAN.

Quality of Service

Until these days, QoS was a key differentiator between ATM and Gigabit Ethernet. ATM was the only technology that promised QoS for voice, video, and data traffic. In the research Gigabit Ethernet and ATM a technology perspective, the authors said: "The difference between ATM and Gigabit Ethernet in the delivery of QoS is that ATM is connection- oriented, whereas Ethernet is connectionless" (Nortel, 2003).

The table of high speed capability compares the quality of service and the compatibility of the ATM and fast Ethernet.

Table 6. High-Speed Network Capabilities

Capability	Gigabit Ethernet	Fast Ethernet	ATM
IP compatibility	Yes	Yes	Requires RFC 1557or IP over Lane
Ethernet Packets	Yes	Yes	Requires Lane
Handle Multimedia	Yes	Yes	Yes but application needs substantial changes
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
VLANs with 802.1Q/p	Yes	Yes	Requires mapping LANE and/or SVCs to 802.1Q

(Tsai, 2001)

Multimedia Performance Comparison

Data. Ethernet is perfectly acceptable for data networks. On a fully utilized 100BaseT network, data traffic can be buffered during transmission without the destination node experiencing unacceptable delays. Since data traffic does not require the constant flow of packets, as does video and voice, this buffering does not sacrifice quality.

Voice. The structure of ATM lends itself well to the implementation of voice traffic over the network. ATM use The ALL1 protocol to set up a Switched Virtual Channel (SVC) throughout the network at the initiation of a

session and eliminate this SVC at the end of the session. The SVC is very similar to the physical switching done by the telephone network and is therefore very adept to carry good quality voice traffic.

Fast Ethernet has made huge progress over 10BaseT Ethernet in delivering these voice packets to the destination quickly. This improvement is due primarily to the increased bandwidth of the lines. Because of the continuous bit rate associated with voice communication, the Fast Ethernet packet would be large in comparison with an ATM cell. In the case of lost or damaged packets/cells, a loss for delayed Fast Ethernet will have a significant impact on voice communication performance compared to a small ATM cell. For this reason, Fast Ethernet is not a good solution for good communication on a congested network.

Video. A constant stream is needed to provide good quality pictures from source to destination. Therefore video traffic is very similar to voice traffic. The link from sender to receiver is not guaranteed in the Ethernet and that perform the same problem. As in voice, the structure of ATM lends itself well to the implementation of video traffic over the network. The SVC that is set up

by the network will assure a constant stream that is
necessary for good quality.

LAN and WAN Internetworking

ATM has advantage when it comes have internetworking
with WAN. Perhaps ATM provides best LAN to WAN migration.
Pei-Hsun Tsai said: "unlike Gigabit Ethernet that pushes
the bottleneck to WAN, ATM provides wide range of data
rates and adapts to different access rates of WAN" (Tsai,
2001). The 25 Mbps full duplex mode was designed by ATM
forum 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.

Ethernet and ATM in Bandwidth

ATM offered considerable bandwidth at the time it was
introduced. Speeds of 155 Mbps and awesome 622 Mbps
attracted people to Tsai said: "ATM. Therefore Ethernet
LANs get replaced with ATM networks" (Tsai, 2001). The
speed of 25 Mbps was proposed as the bandwidth to the
desktop. In practice it was not worth to go from 10 Mbps
Ethernet to 25 Mbps ATM, mostly for economical reasons.

Ethernet comes back after two upgrades. ATM can no
longer compete in pure speed. The routing and switching
technology has improved and ATM alone can't take advantage

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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.

Ethernet and ATM in LAN Backbone

The simplicity, price, installed base, requirement for multimedia are the key factors in choosing the LAN backbone. The 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. There are not enough applications in LAN that need the QoS capabilities. ATM has also lot of features and that makes it more flexible and complex and hence more costly. For these reasons ATM does not look as an efficient technique for the LAN. Many researchers said that Gigabit Ethernet is ahead of ATM in the battle of backbones. On the other hand, many others said that ATM prices are coming down and installed base is increasing for that reason ATM will be the technology for the LAN backbone in the future.

Revenue Comparaison
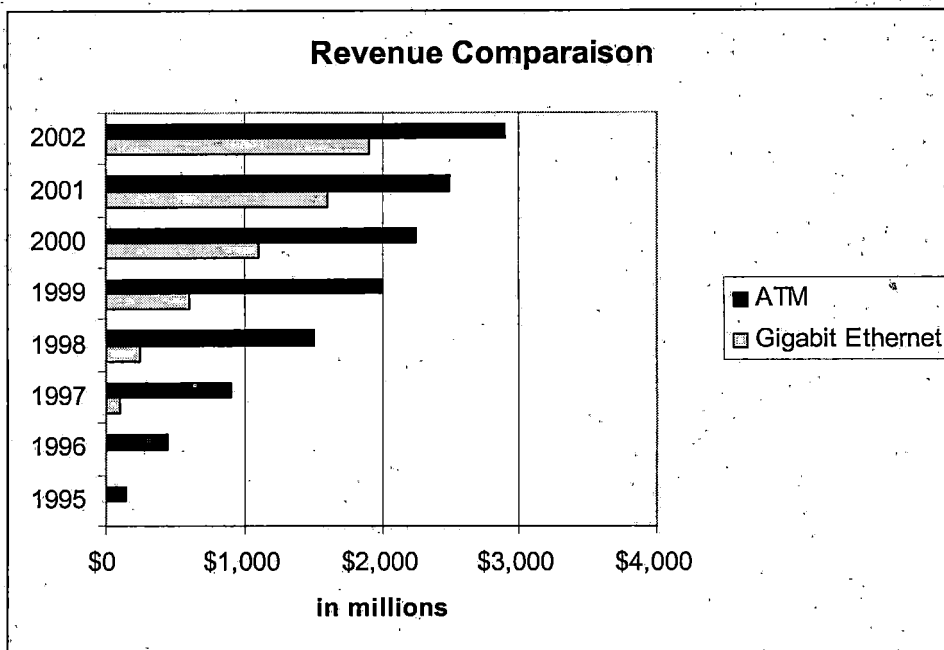
(Tsai, 2001)
Figure 12. Revenue Comparison

Sales Comparaison
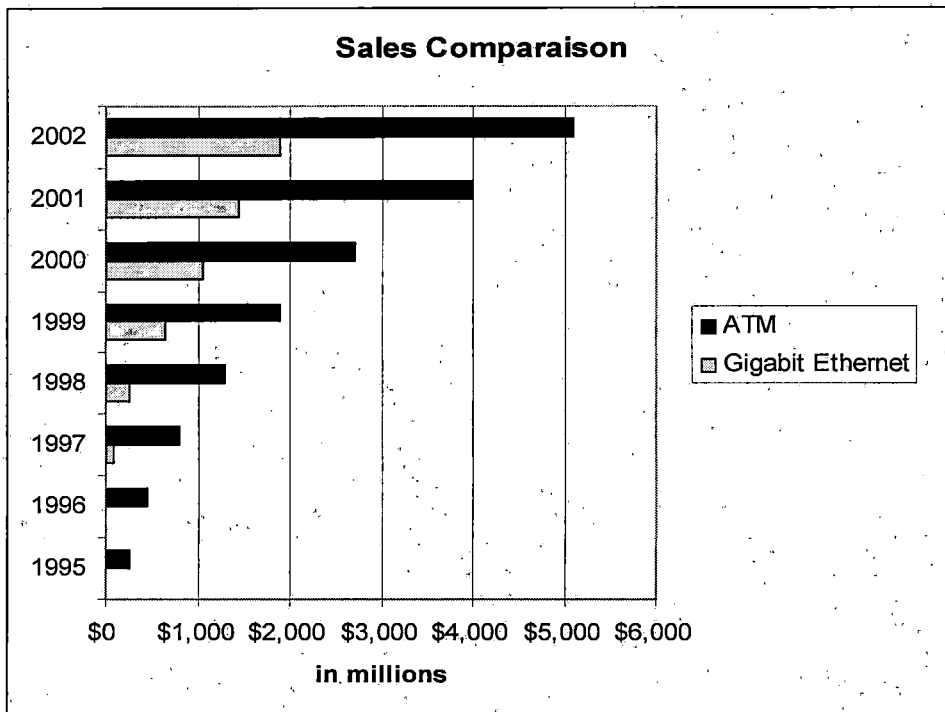
(Tsai, 2001)

Figure 13. Sale Comparison

ATM Versus SONET

ATM and SONET are competing in many areas in high-speed networks. This section discusses the difference between ATM and SONET and the comparison of IP over SONET and IP over ATM.

Bandwidth Capacity

ATM goes considerably further than the 10 Mbps and 16 Mbps offered by legacy Ethernet and token ring LANs. There are ATM standards for transmission at 52 Mbps, 100 Mbps, 155 Mbps and 622 Mbps. In contrast SONET capacity starts with 51.84 Mbps and reaches to 2488.32 Mbps. This

difference in the bandwidth capacity results from

different multiplexing hierarchies.

Transmission Delay

There is very little delay in transmission because

ATM uses very short fixed-length packets that can be

switched in hardware (instead of software). Low delay

makes ATM useful for interactive and multimedia

applications as well as voice and video, which cannot

tolerate delay. On the other hand, every hop of SONET

introduces a 125.10^{-6} second delay regardless of speed.

Network Availability and Scalability

The network is always available to run applications

on demand because of the ATM's increased bandwidth and low

delay. Control mechanisms at various levels in the network

ensure that congestion does not become a problem. ATM is

also easily scalable, meaning that the amount of bandwidth

can be tailored to the needs of expanding application

complexity and faster host processors without adversely

impacting the performance of other applications and hosts

on the network.

IP over SONET and IP over ATM

Bandwidth Management. IP OVER ATM allows multiple

information streams to share the same link at the same

time, while guaranteeing a certain amount of bandwidth for

each stream. IP OVER ATM provides a full suite of
capabilities for managing the bandwidth allocation to the
Various Information Streams (VCCs) flowing over a link. It
assigns flexible bandwidth to these VCCs based on the
required quality of service. On the other hand, IP over
SONET does not have any provision for bandwidth
management. All bandwidth is available by all customers
and all applications at all times. There are no end-to-end
traffic guarantees that allow the user to be sure that the
data will arrive in a timely fashion. If a node or a link
becomes congested, packets are often dropped in a random
fashion (depending on the features employed on the
router). There can be problems over slow links, in which
the transmission of a large packet belonging to a low
priority flow can block the transmission of other high
priority packets. For example, a large packet in a
low-priority file transfer flow can delay a much smaller
but more time-sensitive voice packet. This variability in
delay can negate the benefits of the bandwidth efficiency
provided by IP-over-SONET, for delay sensitive real-time
applications, over bandwidth-constrained links.

Management Control. ATM can be managed by Simple
Network Management Protocol (SNMP). On the other hand
SONET is managed by a protocol which is TL-1. It is

supposed that this protocol will give its operation to another protocol that is CMIP. This is an advantage for ATM because SNMP is designed to be simple. This management protocol can not configure SONET equipment/ bandwidth from IP platform.

Quality of Service. ATM provides a rich set of QoS parameters that can be negotiated for each VCC. Intelligent queuing and scheduling mechanisms in the switches ensure that the negotiated QoS is provided. ATM provides various service classes that can fit different application requirements. For example, applications with very specific QoS requirements can use a CBR or VBR service. On the other hand, applications with elastic requirements can use ABR or UBR service. On the other hand PPP operates over a single point-to-point link and does not provide any QoS capabilities. IP layer has to manage its packet transmissions intelligently to ensure proper QoS for the information flows.

Multiservices Networks. SONET routers were designed to handle IP traffic only. Service providers who operate these networks must also run separate networks for frame relay, leased line, cell relay, and SMDS traffic. In many cases, these other networks are being consolidated onto ATM backbones to provide many advantages. On the other

hand, ATM was designed to work as a multiservices-network fabric. It accommodates various types of transport services including frame relay, cell relay, circuit emulation, and switched multimegabit data service (SMDS), as well as various types of user traffic, including data, voice, and video.

Why not ATM?

Compared to Ethernet, ATM networks have proven themselves to be more efficient, faster, and more reliable when it comes to video and voice applications. The ATM has demonstrated also to be better when it is compared to SONET and it comes to bandwidth. It has proven to be more efficient and scalable when it comes to capacity, transmission delay, bandwidth management, quality of service, multiservices network and management control. So why isn't ATM becoming the network of choice? The biggest reason is the high cost of the Asynchronous Transfer Mode. The network of choice for many years has been Ethernet and SONET now becomes one of the respected choices in many fields. The slow move from Ethernet to Fast Ethernet made companies purchase the needed NICs and run them at 10BaseT until they can afford to purchase the other needed equipment to upgrade to 100BaseT. This ease of migration

is not in place for the move to ATM networks. ATM equipment is not too much more expensive, except for the adapters, but the cost in implementing this equipment is very high. The current network basically has to be thrown out to make room for an entire ATM network. In view of the hardship involved in changing to an ATM network most developers of ATM equipment have come out with Ethernet switches that will allow an Ethernet network to be changed into an ATM network; an Ethernet- to-ATM switch . It is obligatory to deal with the same buyer of ATM equipment. It is difficult to integrate ATM equipment with equipment from another company. It is a very risky move, and there are too many considerations to be taken into account for such a move which is why ATM will not become the first choice. Chapter 5 will cover the future of ATM in the broadband networking.

Conclusion

ATM has proven to be more efficient and reliable then many other technologies. The ATM still face many challenges in the broadband networking market. Chapter five will underline the place of ATM in the broadband networking and discuss the future of ATM.

CHAPTER FIVE

ATM'S FUTURE

Introduction

As it was discussed in the previous chapters, ATM faced several challenges the last decades. Many new technologies compete with the ATM in the broadband networking. This project emphasized two majors' competitors: Fast Ethernet and SONET/SDH.

Chapter 5 discusses the future of ATM and assesses with the help of some market surveys the future of ATM and where it will fit in the broadband networking.

ATM Environments

ATM passed by different environments, such as the prevailing environment, ATM: the top of technologies and the new environment.

The Prevailing Environment

ATM end systems and switches were available commercially only in the mid 90s when the Very Large Scale Integration (VLSI) technology had matured to give low micron technology affording high transistor density at fairly low operative powers. At this time switching could not be done in the optical domain. This was because the cell header had to be processed in each switching element.

Therefore all switching had to be done electrically. ATM used fiber optic media to give throughputs per port per direction of up to 2.5 to 10 Gbps. With its small fixed 53-byte cell and 5-byte header, ATM was the most optimal and fastest way of switching to leverage on the bandwidth availability of the optical media. There may have been differences as to what exactly the cell payload size must be: 24 or 32 or 64, but there can be no questioning to the fact that the smallness of the cell size was indeed quite optimal.

ATM: The Top of Technologies

The typical bandwidths available from 155 Mbps to 10 Gbps in the mid 90s could not really be used as most organizations found it difficult to use such high bandwidth. More significantly, the cost per Mbps over the WAN using ATM was extremely high. This was due to the fact that ATM switches and ATM cards were extremely expensive. Since there was no significant increase in the volume of switches purchased, ATM continued to be very expensive and could be deployed only by organizations like AT&T who could afford the price. At this time there were not sufficient applications to utilize the high bandwidth and QOS that an ATM card and an ATM switching network would give in a LAN environment. For that reason and with the

availability of Ethernet plug and play technology at lower costs ATM didn't target the desktop technologies. ATM really provided a great solution for converged Networking where Real Time and non Real Time Voice, Video and Data could all be transported perhaps even over 1 ATM connection over wide distances with assured delay, delay variation and cell loss.

One of the most important reasons that led ATM to be ahead and in the top of the market in the mid 90s is that Converged Networking did not really exist at this time.

New Environment

The end 90s and the early 2000s saw the development and fair degree of maturity of major technologies such as Gigabit and 10 Gigabit Ethernet, Terabit Routing, and optical networking. Jayasurya Venugopalan said that the apparition of these technologies contradicted the assumption of ATM that fast switching at 10 Gbps per interface was possible only by chopping up into small cells and switching in the electrical domain.(Venugopalan, 2002).

Gigabit Ethernet, basically on optical fiber, enhanced the bandwidth availability in local Area and Intra-Office Corporate Networks. 10 Gigabit Ethernet which is basically a point to-point technology was deployed for

Wide Area connectivity also. The Optical Technology has been there from the 60s but the turn of the century saw amazing advances and maturity in optical technology.

ATM Today

Jayasurya said: "bandwidth was aplenty but there were no takers! No one could afford the bandwidth. Supply was greater than demand, so something had to give..." (Venugopalan, 2002).

In early 2001 Terabit Routers and Optical Switches could practically find no market at all due to the change in the climate and environment. No one was prepared to invest in these costly devices and since there was no volume, prices obviously never came down.

It was then that ATM got a new lease of life. It seemed before the slowdown that ATM would be crunched between the Fast Ethernet cum Gigabit in corporate LANs and the DSL, cable, wireless and fiber access from homes and Small Office and Home Office (SOHOs) on one side, and the optical core on the other. However, 2001 with all the economic turmoil gave the opportunity to ATM for consolidation and giants like AT&T and Sprint used their ATM infrastructure for delivering Wide Area connectivity by using ATM and Frame Relay. These solutions proved to be

cost effective. Denise Pappalardo in his article AT&T expanding reach of networks at the end of 2003: "AT&T's frame relay and ATM networks will reach 50 countries by year-end, whereas today they span 30. The company says it originally planned to have frame relay and ATM in 40 countries by year-end" (Pappalardo, 2003).

Moreover, since ATM used SONET for high Gbps transmission it was able to effectively use the sophisticated management of the optical links which SONET automatically provided by including its fast restoration times for failed optical links.

Jayasurya Venugopalan said: "Even now, we do not see any considerable demand for optical switching in the core." So ATM with its undoubted QOS assurance abilities continues to be a major player in the core (Venugopalan, 2002).

The following two charts show two results from studies conducted in Europe. The two results demonstrate how ATM got a new lease of life between 2001 and 2002, and how it dominated with its undoubted QOS assurance abilities.
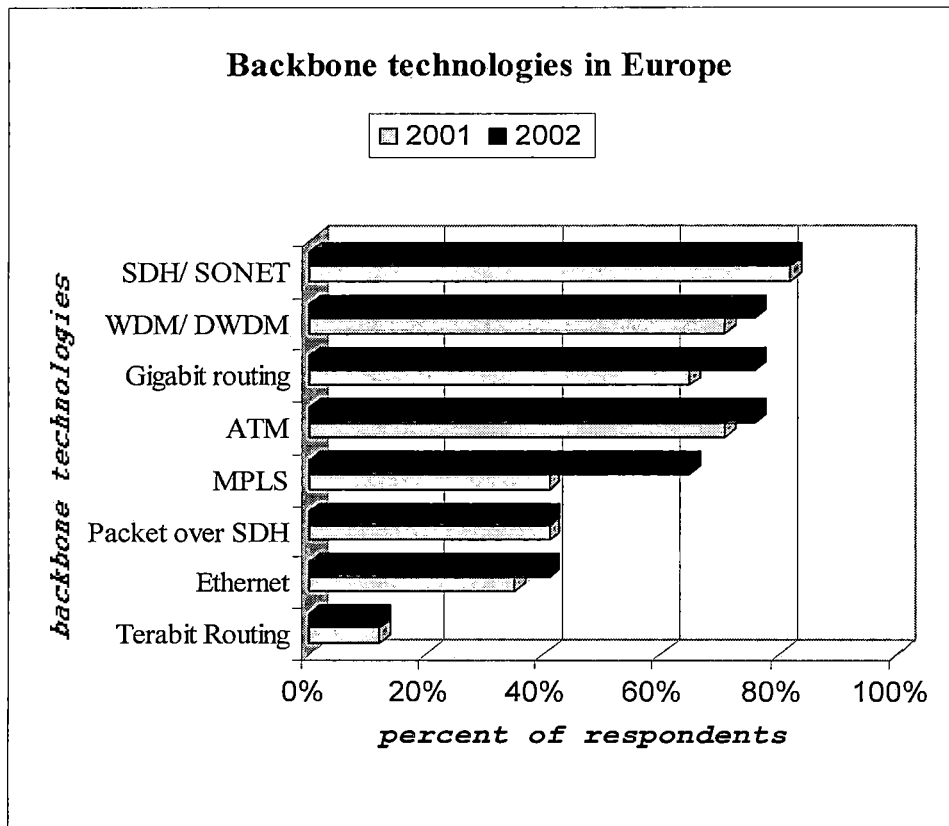
Figure 14. Backbone Technologies in Europe

QOS technologies in Europe

QoS Technologies (y-axis): ATM, MPLS, IPv6, Diff Serv, Cisco Tag Switching, RSVP

x-axis: 0% 20% 40% 60% 80%

percent of respondents
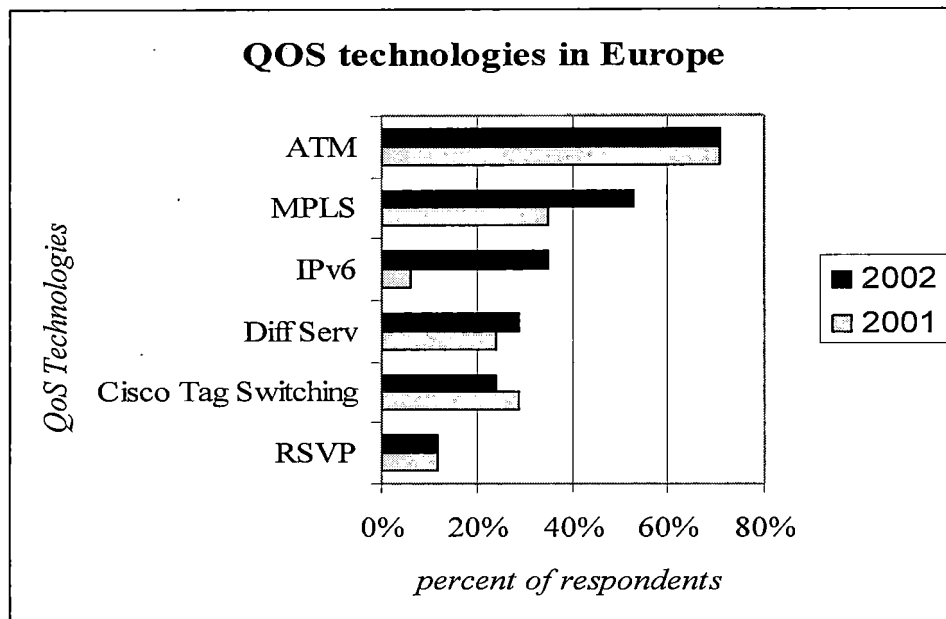
Legend: ■ 2002 □ 2001

Figure 15. QOS Technologies in Europe

Future of ATM

ATM has the tools to make it the obvious choice for

multimedia. ATM's price will eventually come down and

should be able to compete with Fast Ethernet in the LAN

market. With WANs, ATM is very useful simply because of

its speed and utilization. The faster the network traffic

can arrive the better the network and ATM provides the

speed needed for these networks. ATM will continue to

exist at the edge between the user access like DSL or

cable or fiber or low bandwidth ATM and the optical core.

ATM was designed with Service Level Agreements in mind

with assured QOS. Network Management Systems have yet to

evolve and are mature to give a guaranteed QOS over an IP

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network even if it is Multi Protocols Label Switching (MPLS) enabled. 10 Gigabit Technology is yet to be deployed on a large scale over large distances. So there is no doubt that the next decade will definitely see ATM having its own slice of the networking market. Many researchers are trying to forecast the future of ATM in long term. With the current melting point of such a really large number of communication technologies scholars cannot assess the future of ATM and most of researchers said that Time alone will tell.

Conclusion

After more than a decade of development and deployment, asynchronous transfer mode (ATM) has reached middle age—matures enough to be dependable, experienced enough to be useful. ATM networks have proven themselves to be more efficient, faster, and more reliable than many others technologies. ATM switches have evolved into today's multiservice WAN switches, and now provide a reliable, cost-effective foundation for frame relay, DSL, IP, ISDN, private line, wireless and, of course, native ATM services.

Because it is entrenched in public data networks and making inroads into telephony and wireless, ATM isn't

about to yield to IP, MPLS or any other upstart
technology. Instead, vendors and service providers
continue to find new ways to depend on ATM. Customers
believe in ATM, demand is increasing and new markets are
opening. The asynchronous transfer mode may have its own
slice of the networking market for the next decade. After
that what is going to be the future of ATM? With the
current melting point of such a really large number of
communication technologies one can only say: "Time alone
will tell."

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