10GEA

10 GIGABIT ETHERNET ALLIANCE

10 Gigabit Ethernet Technology Overview White Paper

September, 2001

Technology Overview

Executive Summary

From its origin more than 25 years ago, Ethernet has evolved to meet the increasing demands of packet-switched networks. Due to its proven low implementation cost, its known reliability, and relative simplicity of installation and maintenance, its popularity has grown to the point that today nearly all traffic on the Internet originates or ends with an Ethernet connection. Further, as the demand for ever-faster network speeds has grown, Ethernet has been adapted to handle these higher speeds and the concomitant surges in volume demand that accompany them.

The One Gigabit Ethernet standard is already being deployed in large numbers in both corporate and public data networks, and has begun to move Ethernet from the realm of the local area network out to encompass the metro area network. Meanwhile, an even faster 10 Gigabit Ethernet standard is nearing completion. This latest standard is being driven not only by the increase in normal data traffic but also by the proliferation of new, bandwidth-intensive applications, including motion video.

The draft standard for 10 Gigabit Ethernet is significantly different in some respects from earlier Ethernet standards, primarily in that it will only function over optical fiber, and only operate in full-duplex mode, meaning that collision detection protocols are unnecessary. Because of these characteristics, Ethernet can now step up to 10 gigabits per second, however, it remains Ethernet, including the packet format, and the current capabilities are easily transferable to the new draft standard.

In addition, 10 Gigabit Ethernet does not obsolete current investments in network infra-structure. The task force heading the standards effort has taken pains to see that 10 Gigabit Ethernet is interoperable with other networking technologies such as SONET and has carefully added technology to the standard to enable Ethernet packets to travel across SONET links with very little inefficiency.

Ethernet's expansion for use in metro area networks can now be expanded yet again onto wide area networks, both in concert with SONET and also end-to-end Ethernet. With the current balance of network traffic today heavily favoring packet-switched data over voice, it is expected that the new 10 Gigabit Ethernet standard will help to create a convergence between networks designed primarily for voice, and the new data centric networks.

Introduction

This white paper is designed to provide a general discussion of the impending 10 Gigabit Ethernet standard to the technical reader. The draft 10 Gigabit standard is currently on track to be adopted in mid-2002.

This paper is sponsored by the 10 Gigabit Ethernet Alliance – a group of vendor companies interested in promoting the forthcoming standard. It begins with a brief history of the technology, and describes what the alliance is and its purposes. The paper then proceeds to present a description of the IEEE standards process, followed by the proposed standard itself, as it now stands, in a moderate level of technical detail. It concludes with a set of short discussions on how 10 Gigabit Ethernet may be used in various high-level applications scenarios.

A Brief History of Ethernet

In 1973, researchers at Xerox's Palo Alto Research Center, principally Robert Metcalfe and David Boggs, developed Ethernet as a technology for interconnecting the lab's Xerox Altos, early graphical personal computers also developed at PARC. Ethernet's clock was derived from the Alto's system clock, resulting in an initial data transmission rate of 2.94 Mbps. Metcalfe named the technology "Ethernet," choosing the word "ether" to describe the physical medium — a cable — that carries bits to all nodes in the network. Figure 1 shows a drawing by Metcalfe that illustrates the simplicity of the PARC researchers' design.

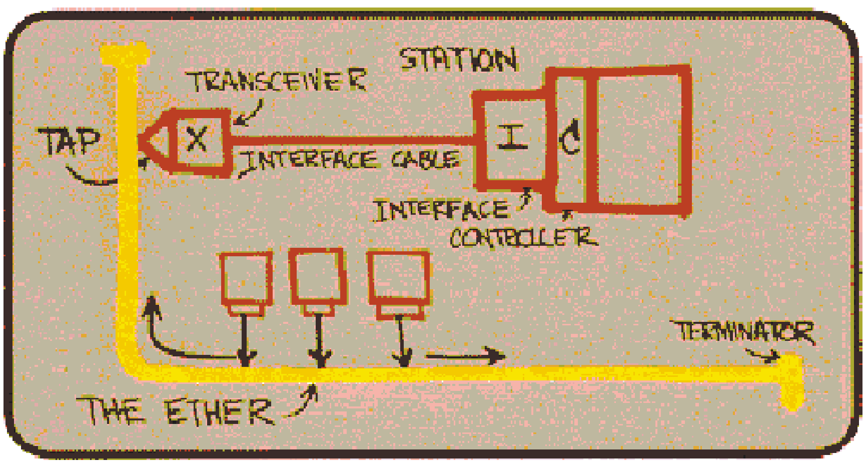


Figure 1. Robert Metcalfe's drawing of the first Ethernet design.

Metcalfe also posited a theorem about the growing importance of networks. Now known as "Metcalfe's Law," he predicted that the value of the network expands exponentially as the number of users increases. Not only was he correct about technological networks, his "law" has since also been successfully applied to the field of economics.

In some respects, Metcalfe's Law is similar to "Moore's Law." Coined from statements made by Intel co-founder Gordon Moore sometime in the 1970s, Moore's Law predicts that every 18 months the power of microprocessors will double while the price falls by half. Since Ethernet's introduction, both "laws" have proven themselves, with dramatic growth in large part due to the successful combination of Ethernet with the microprocessor.

As the speed of Ethernet has increased, first to 10 million bits per second (Mbps), then to 100 Mbps, and recently to 1 billion bits per second or 1 gigabit (Gbps), the price of Ethernet technology has also plummeted thanks to Moore's Law and manufacturing economies of scale. Likewise, networks became exponentially more valuable as the number of users swelled to hundreds of millions – thanks to Metcalfe's Law. Ethernet has become the dominant network technology in local area networks (LAN). And with the advent of Gigabit Ethernet, it has started to make substantial inroads into metro area networks (MAN).

Additionally, the volume of data communications traffic has grown to where, today, it outweighs circuit-switched voice traffic four to one. Eighty-percent of all network traffic is now data rather than voice.

The technology exists to take Ethernet to the next level. The time is ripe for establishing a standard that moves the goal posts for 10 Gbps further into metro area networks (MAN) and, ultimately, into wide area networks (WAN) as well. This move, we believe, will ultimately bring about a convergence in voice and data networks, while still retaining compatibility with existing Ethernet technologies – thus assuring the safety of investments that customers and service providers have already made.

The 10 Gigabit Ethernet Project

The purpose of the 10 Gigabit Ethernet proposed standard is to extend the 802.3 protocols to an operating speed of 10 Gbps and to expand the Ethernet application space to include WAN links. This will provide for a significant increase in bandwidth while maintaining maximum compatibility with the installed base of 802.3 interfaces, previous investment in research and development, and principles of network operation and management. In order to be adopted as a standard, the IEEE's 802.3ae Task Force has established five criteria that the new 10 Gigabit Ethernet P (proposed) standard must meet:

- It must have broad market potential, supporting a broad set of applications, with multiple vendors supporting it, and multiple classes of customers.
- It must be compatible with other existing 802.3 protocol standards, as well as with both Open Systems Interconnection (OSI) and Simple Network Management Protocol (SNMP) management specifications.
- It must be substantially different from other 802.3 standards, making it a unique solution for problem rather than an alternative solution.
- It must have demonstrated technical feasibility prior to final ratification.
- It must be economically feasible for customers to deploy, providing reasonable cost, including all installation and management costs, for the expected performance increase.

For a more complete discussion of the five criteria for 802.3ae, see: http://grouper.ieee.org/groups/802/3/ae/criteria.pdf

The 10 Gigabit Ethernet Alliance

The 10 Gigabit Ethernet Alliance (10GEA) was established in order to promote standards-based 10 Gigabit Ethernet technology and to encourage the use and implementation of 10 Gigabit Ethernet as a key networking technology for connecting various computing, data and telecommunications devices.

The charter of the 10 Gigabit Ethernet Alliance includes:

- Supporting the 10 Gigabit Ethernet standards effort conducted in the IEEE 802.3 working group
- Contributing resources to facilitate convergence and consensus on technical specifications
- Promoting industry awareness, acceptance, and advancement of the 10 Gigabit Ethernet standard
- Accelerating the adoption and usage of 10 Gigabit Ethernet products and services
- Providing resources to establish and demonstrate multi-vendor interoperability and generally encourage and promote interoperability and interoperability events
- Fostering communications between suppliers and users of 10 Gigabit Ethernet technology and products

Further information about the 10GEA can be found at: www.10gea.org..

10GEA Membership

The 10 Gigabit Ethernet Alliance was organized to facilitate and accelerate the introduction of 10 Gigabit Ethernet into the networking market. It was founded by networking industry leaders 3Com, Cisco Systems, Extreme Networks, Intel, Nortel Networks, Sun Microsystems, and World Wide Packets. In addition, the 10GEA supports the activities of the IEEE 802.3ae (10 Gigabit) Task Force, fosters the development of the 802.3ae (10 Gigabit Ethernet) standard, and promotes interoperability among 10 Gigabit Ethernet products. Currently, the 10GEA has a membership of over 100 companies, and a listing of those companies can be found at: http://www.10gea.org/about_companies.htm.

Standards Activities

The Institute of Electrical and Electronics Engineers (IEEE) was founded in order to foster the development of standards in all fields of science and technology within the organization's scope. A key principle throughout the standards process is consensus among the participants. The IEEE-SA (Standards Association) and its Standards Board oversee the process of standards formation through two committees. (See Figure 2.)

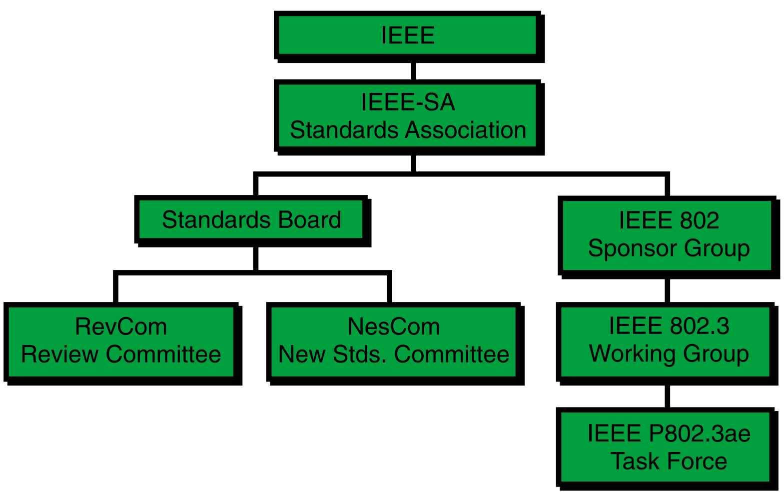


Figure 2. The IEEE groups involved in creating the 10 Gbps Ethernet standard.

The New Standards Committee (NesCom) ensures that proposed standards fall within the IEEE's scope, that they are assigned to the correct technical committees, and that the makeup of working groups, etc., fairly represents all interested parties. It also examines Project Authorization Requests (PAR) and recommends to the IEEE-SA Standards Board whether to approve them. The second committee, the Standards Review Committee (RevCom), examines proposed new and revised standards, ensures that such proposals represent a consensus of the members of the IEEE Sponsor balloting group, and makes recommendations to the Standards Board as to whether or not to approve a standard.

Standards Process Flow

A new standard begins with a "sponsor" – a technical society or committee within the IEEE that agrees to provide oversight during the standards development process. This begins with a "call for interest" and formation of a sponsor's "study group." The next step is to submit a Project Authorization Request to NesCom. Upon approval of the PAR by the committee, a "working group" comprised of interested parties is formed. Approval of the PAR also starts the clock ticking. The proposed standard must be completed within four years.

The working group plans meetings and organizes the work that needs to be done to create the standard. When the task of defining a new standard is very large and/or complex, the working group will form a "task force" of people with more specialized skills to work on various aspects of the standard. Once a draft of the standard is complete, the working group will vote on it. (See Figure 3.) After the working group has passed the draft standard, the sponsoring group then circulates it for a vote – a process called "sponsor balloting."

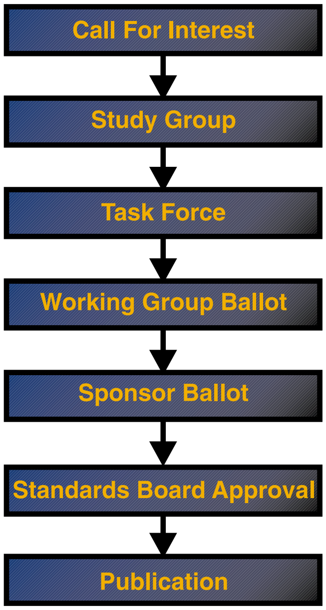


Figure 3. Flow chart showing the IEEE standards process.

The members of the sponsoring committee or group will then vote. In both ballots, 75% of the ballots sent out must be returned and, of those, 75% must be in favor of adopting the standard. Comments from voting members will also be incorporated into the final standards document. Finally, the IEEE-SA Standards Board must approve the final draft before its publication as a formal standard. For further information on the IEEE standards process, see:

IEEE

IEEE 802 LAN/MAN Standards Committee

IEEE 802.3 CSMA/CD (ETHERNET)

IEEE P802.3ae 10Gb/s Ethernet Task Force

http://standards.ieee.org/resources/glance.html

Timetable

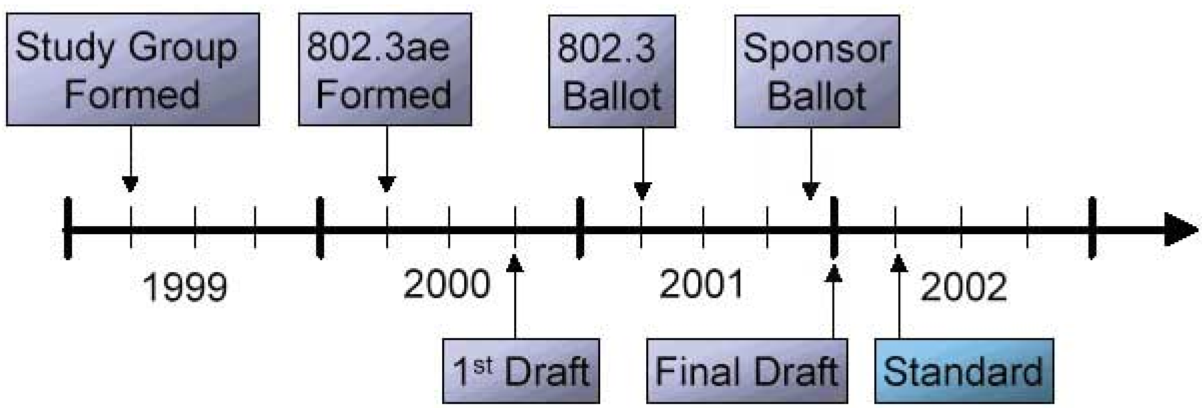


Figure 4 illustrates the current timetable for the 802.3ae standards process.

The 10 Gigabit Ethernet Standard

Under the International Standards Organization's Open Systems Interconnection (OSI) model, Ethernet is fundamentally a Layer 2 protocol. 10 Gigabit Ethernet uses the IEEE 802.3 Ethernet Media Access Control (MAC) protocol, the IEEE 802.3 Ethernet frame format, and the minimum and maximum IEEE 802.3 frame size.

Just as 1000BASE-X and 1000BASE-T (Gigabit Ethernet) remained true to the Ethernet model, 10 Gigabit Ethernet continues the natural evolution of Ethernet in speed and distance. Since it is a full-duplex only and fiber-only technology, it does not need the carrier-sensing multiple-access with collision detection (CSMA/CD) protocol that defines slower, half-duplex Ethernet technologies. In every other respect, 10 Gigabit Ethernet remains true to the original Ethernet model.

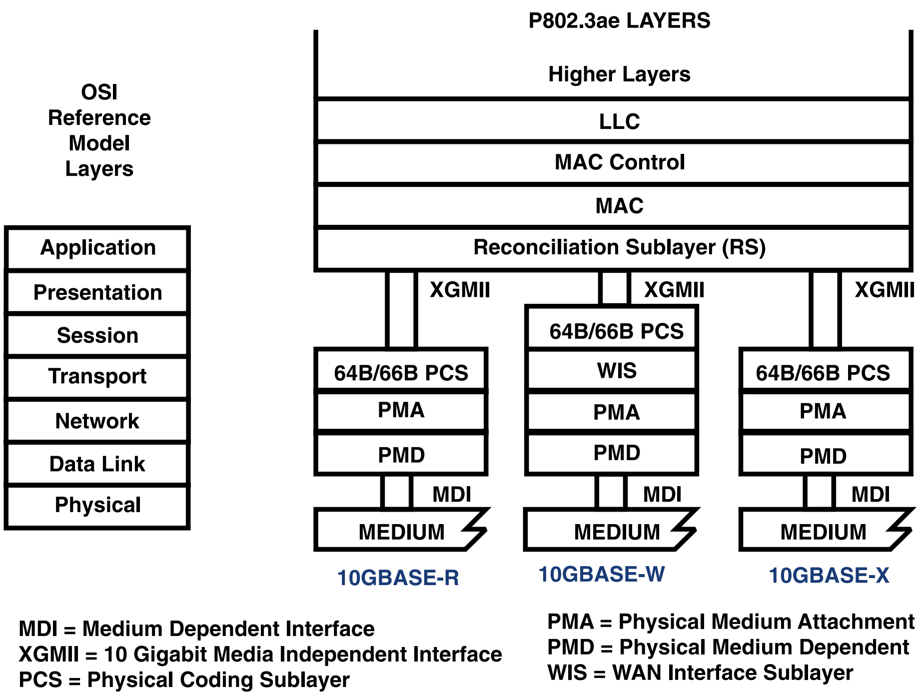


Figure 5. The architectural components of the LAN and WAN PHY

An Ethernet PHYsical layer device (PHY), which corresponds to Layer 1 of the OSI model, connects the media (optical or copper) to the MAC layer, which corresponds to OSI Layer 2. Ethernet architecture further divides the PHY (Layer 1) into a Physical Media Dependent (PMD) and a Physical Coding Sublayer (PCS). Optical transceivers, for example, are PMDs. The PCS is made up of coding (e.g., 64/66b) and a serializer or multiplexing functions.

The 802.3ae specification defines two PHY types: the LAN PHY and the WAN PHY (discussed below). The WAN PHY has an extended feature set added onto the functions of a LAN PHY. These PHYs are solely distinguished by the PCS. There will also be a number of PMD types. (See Figure 5.)

Chip Interface (XAUI)

Among the many technical innovations of the 10 Gigabit Ethernet Task Force is an interface called the XAUI (pronounced "Zowie"). The "AUI" portion is borrowed from the Ethernet Attachment Unit Interface. The "X" represents the Roman numeral for ten and implies ten gigabits per second. The XAUI is designed as an interface extender, and the interface, which it extends, is the XGMII, the 10 Gigabit Media Independent Interface. The XGMII is a 74 signal wide interface (32-bit data paths for each of transmit and receive) that may be used to attach the Ethernet MAC to its PHY. The XAUI may be used in place of, or to extend, the XGMII in chip-to-chip applications typical of most Ethernet MAC to PHY interconnects. (See Figure 6.)

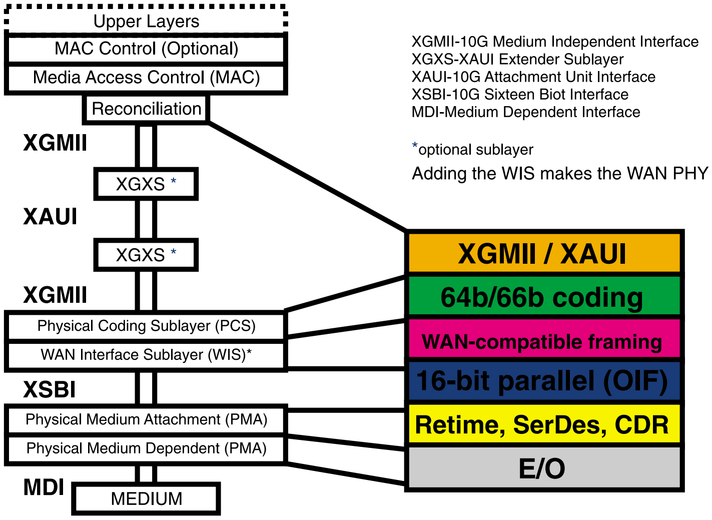


Figure 6. XAUI functions as an extender interface between the MAC and PCS

The XAUI is a low pin count, self-clocked serial bus that is directly evolved from the Gigabit Ethernet 1000BASE-X PHY. The XAUI interface speed is 2.5 times that of 1000BASE-X. By arranging four serial lanes, the 4-bit XAUI interface supports the ten-times data throughput required by 10 Gigabit Ethernet.

The XAUI employs the same robust 8B/10B transmission code of 1000BASE-X to provide a high level of signal integrity through the copper media typical of chip-to-chip printed circuit board traces. Additional benefits of XAUI technology include its inherently low EMI (Electro-Magnetic Interference) due to it's self-clocked nature, compensation for multi-bit bus skew — allowing significantly longer-distance chip-to-chip — error detection and fault isolation capabilities, low power consumption, and the ability to integrate the XAUI input/output within commonly available CMOS processes.

A multitude of component vendors are delivering or have announced XAUI interface availability on standalone chips, custom ASICs (application-specific integrated circuits), and even FPGAs (field-programmable gate arrays). The 10Gigabit Ethernet XAUI technology is identical or equivalent to the technology employed in other key industry standards such as InfiniBand(TM), 10 Gigabit Fibre Channel, and general purpose copper and optical backplane interconnects. This assures the lowest possible cost for 10 Gbps interconnects through healthy free market competition.

Specifically targeted XAUI applications include MAC to Physical layer chip and direct MAC-to-optical transceiver module interconnects. The XAUI is the interface for the proposed Ten Gigabit Pluggable optical module definition called the XGP. Integrated XAUI solutions together with the XGP will enable efficient low-cost 10 Gigabit Ethernet direct multi-port MAC to optical module interconnects with only PC board traces in between.

Physical Media Dependent (PMDs)

The IEEE 802.3ae Task Force has developed a draft standard that provides a physical layer that supports link distances for fiber optic media as shown in Table A.

PMD (Optical Transceiver)	Type of Fiber Supported	Target Distance (Meters)
850 nm serial	Multi Mode	65
1310 nm WWDM	Multi Mode	300
1310 nm WWDM	Single Mode	10,000
1310 nm Serial	Single Mode	10,000
1550 nm Serial	Single Mode	40,000

Table A. Listing of the PMDs that have been selected to meet the task force's distance objectives.

To meet these distance objectives, four PMDs were selected. The task force selected a 1310 nanometer serial PMD to meet its 2km and 10km single-mode fiber (SMF) objectives. It also selected a 1550 nm serial solution to meet (or exceed) its 40km SMF objective. Support of the 40km PMD is an acknowledgement that Gigabit Ethernet is already being successfully deployed in metropolitan and private, long distance applications. An 850 nanometer PMD was specified to achieve a 65-meter objective over multimode fiber using serial 850 nm transceivers.

Additionally, the task force selected two versions of the wide wave division multiplexing (WWDM) PMD, a 1310 nanometer version over single-mode fiber to travel a distance of 10km and a 1310 nanometer PMD to meet its 300-meter-over-installed-multimode-fiber objective.

Physical Layer (PHYs)

The LAN PHY and the WAN PHY will operate over common PMDs and, therefore, will support the same distances. These PHYs are distinguished solely by the Physical Encoding Sublayer (PCS). (See Figure 7.) The 10 Gigabit LAN PHY is intended to support existing Gigabit Ethernet applications at ten times the bandwidth with the most cost-effective solution. Over time, it is expected that the LAN PHY may be used in pure optical switching environments extending over all WAN distances. However, for compatibility with the existing WAN network, the 10 Gigabit Ethernet WAN PHY supports connections to existing and future installations of SONET/SDH (Synchronous Optical Network/Synchronous Digital Hierarchy) circuit-switched telephony access equipment.

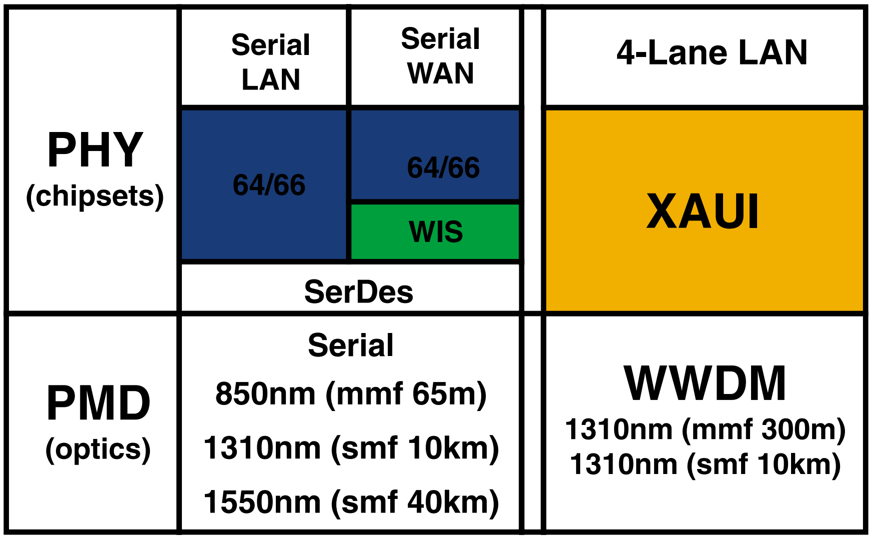
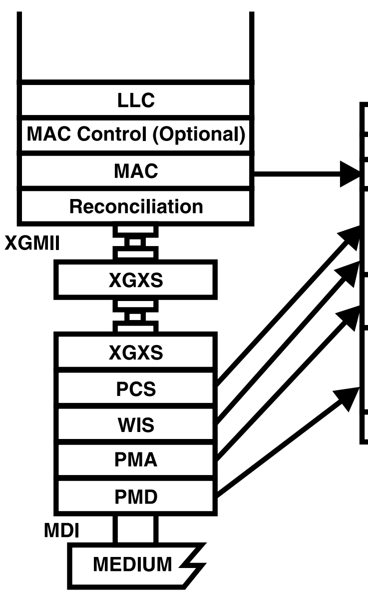


Figure 7. Conceptual Diagram of the PHYs and PMDs.

The WAN PHY differs from the LAN PHY by including a simplified SONET/SDH framer in the WAN Interface Sublayer (WIS). Because the line rate of SONET OC-192/SDH STM-64 is within a few percent of 10 Gbps, it is relatively simple to implement a MAC that can operate with a LAN PHY at 10 Gbps or with a WAN PHY payload rate of approx-imately 9.29 Gbps. (See Figure 8.)



Stack	10 GE LAN PHY		10 GE LAN PHY
	Serial	WWDM	Serial
MAC	10.0 Gbits/s	10.0 Gbits/s	10.0 Gbits/s
PCS	64B66B	8B10B	64B66B SONET framing $X^7 + X^6 + 1$
PMA Interface	XSBI	XAUI	XSBI
PMD	1550nm DFB 1310nm FP 850 nm vcsel	1310 WWDM	1550nm DFB 1310nm FP 850 nm vcsel
Line Rate	10.3 Gbit/s	4x3.125 Gbit/s	9.953 Gbit/s

Figure 8. Detailed Illustration of the LAN and WAN PHYs and associated PMDs.

In order to enable low-cost WAN PHY implementations, the task force specifically rejected conformance to SONET/SDH jitter, stratum clock, and certain SONET/SDH optical specifications. The WAN PHY is basically a cost effective link that uses common Ethernet PMDs to provide access to the SONET infrastructure, thus enabling attachment of packet-based IP/Ethernet switches to the SONET/SDH and time division multiplexed (TDM) infrastructure. This feature enables Ethernet to use SONET/SDH for Layer 1 transport across the WAN transport backbone.

It is also important to note that Ethernet remains an asynchronous link protocol. As in every Ethernet network, 10 Gigabit Ethernet's timing and synchronization must be maintained within each character in the bit stream of data, but the receiving hub, switch, or router may re-time and re-synchronize the data. In contrast, synchronous protocols, including SONET/SDH, require that each device share the same system clock to avoid timing drift between transmission and reception equipment and subsequent increases in network errors where timed delivery is critical.

The WAN PHY attaches data equipment such as switches or routers to a SONET/SDH or optical network. This allows simple extension of Ethernet links over those networks. Therefore, two routers will behave as though they are directly attached to each other over a single Ethernet link. Since no bridges or store-and-forward buffer devices are required between them, all the IP traffic management systems for differentiated service operate over the extended 10 Gigabit Ethernet link connecting the two routers.

To simplify management of extended 10 Gigabit Ethernet links, the WAN PHY provides most of the SONET/SDH management information, allowing the network manager to view the Ethernet WAN PHY links as though they are SONET/SDH links. It is then possible to do performance monitoring and fault isolation on the entire network, including the 10 Gigabit Ethernet WAN link, from the SONET/SDH management station. The SONET/SDH management information is provided by the WAN Interface Sublayer (WIS), which also includes the SONET/SDH framer. The WIS operates between the 64B/66B PCS and serial PMD layers common to the LAN PHY.

10 Gigabit Ethernet in the Marketplace

The accelerating growth of worldwide network traffic is forcing service providers, enterprise network managers and architects to look to ever higher-speed network technologies in order to solve the bandwidth demand crunch. Today, these administrators typically use Ethernet as their backbone technology. Although networks face many different issues, 10 Gigabit Ethernet meets several key criteria for efficient and effective high-speed networks:

- Easy, straightforward migration to higher performance levels without disruption,
- Lower cost of ownership vs. current alternative technologies – including both acquisition and support costs
- Familiar management tools and common skills base
- Ability to support new applications and data types
- Flexibility in network design
- Multiple vendor sourcing and proven interoperability

Managers of enterprise and service provider networks have to make many choices when they design networks. They have multiple media, technologies, and interfaces to choose from to build campus and metro connections: Ethernet (100, 1000, and 10,000 Mbps), OC-12 (622 Mbps) and OC-48 (2.488 Gbps), SONET or equivalent SDH network, packet over SONET/SDH (POS), and the newly authorized IEEE 802 Task Force (802.17) titled Resilient Packet Ring.

Network topological design and operation has been transformed by the advent of intelligent Gigabit Ethernet multi-layer switches. In LANs, core network technology is rapidly shifting to Gigabit Ethernet and there is a growing trend towards Gigabit Ethernet networks that can operate over metropolitan area distances.

The next step for enterprise and service provider networks is the combination of multi-gigabit bandwidth with intelligent services, leading to scaled, intelligent, multi-gigabit networks with backbone and server connections ranging up to 10 Gbps.

In response to market trends, Gigabit Ethernet is currently being deployed over tens of kilometers in private networks. With 10 Gigabit Ethernet, the industry has developed a way to not only increase the speed of Ethernet to 10 Gbps but also to extend its operating distance and interconnectivity. In the future, network managers will be able to use 10 Gigabit Ethernet as a cornerstone for network architectures that encompass LANs, MANs and WANs using Ethernet as the end-to-end, Layer 2 transport method.

Ethernet bandwidth can then be scaled from 10 Mbps to 10 Gbps – a ratio of 1 to 1000 — without compromising intelligent network services such as Layer 3 routing and layer 4 to layer 7 intelligence, including quality of service (QoS), class of service (CoS), caching, server load balancing, security, and policy based networking capabilities. Because of the uniform nature of Ethernet across all environments when IEEE 802.3ae is deployed, these services can be delivered at line rates over the network and supported over all network physica infrastructures in the LAN, MAN, and WAN. At that point, convergence of voice and data networks, both running over Ethernet, becomes a very real option. And, as TCP/IP incorporates enhanced services and features, such as packetized voice and video, the underlying Ethernet can also carry these services without modification.

As we have seen with previous versions of Ethernet, the cost for 10 Gbps communications has the potential to drop significantly with the development of new technologies. In contrast to 10 Gbps telecommunications lasers, the 10 Gigabit Ethernet short links — less than 40km over single-mode (SM) fiber — will be capable of using lower cost, uncooled optics and, in some cases, vertical cavity surface emitting lasers (VCSEL), which have the potential to lower PMD costs. In addition, the industry is supported by an aggressive merchant chip market that provides highly integrated silicon solutions. Finally, the Ethernet market tends to spawn highly competitive start-ups with each new generation of technology to compete with established Ethernet vendors.

Applications for 10 Gigabit Ethernet

10 Gigabit Ethernet in Local Area Networks

Ethernet technology is already the most deployed technology for high performance LAN environments. With the extension of 10 Gigabit Ethernet into the family of Ethernet technologies, the LAN now can reach farther and support up coming bandwidth hungry applications.

Similar to Gigabit Ethernet technology, the 10 Gigabit proposed standard supports both single-mode and multi-mode fiber mediums. However in 10 Gigabit Ethernet, the distance for single-mode fiber has expanded from the 5km that Gigabit Ethernet supports to 40km in 10 Gigabit Ethernet.

The advantage for the support of longer distances is that it gives companies who manage their own LAN environments the option of extending their data centers to more cost-effective locations up to 40km away from their campuses. This also allows them to support multiple campus locations within that 40km range. Within data centers, switch-to-switch applications, as well as switch to server applications, can also be deployed over a more cost effective multi-mode fiber medium to create 10 Gigabit Ethernet backbones that support the continuous growth of bandwidth hungry applications. (See Figure 9.)

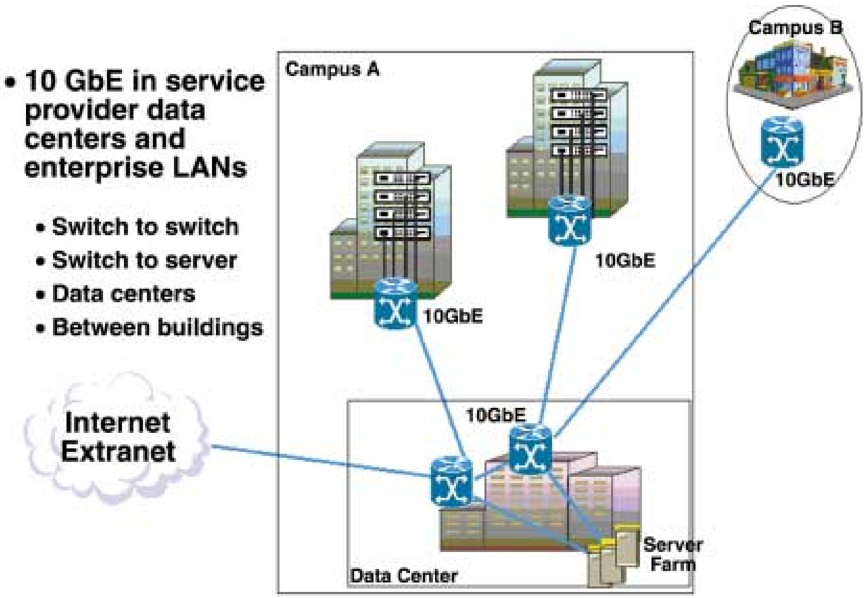


Figure 9. Illustration of 10 Gigabit Ethernet use in expanded LAN environments.

With 10 Gigabit backbones installed, companies will have the capability to begin providing Gigabit Ethernet service to workstations and, eventually, to the desktop in order to support applications such as streaming video, medical imaging, centralized applications, and high-end graphics. 10 Gigabit Ethernet will also provide lower network latency due to the speed of the link and over-provisioning bandwidth to compensate for the bursty nature of data in enterprise applications. Additionally, the LAN environment must continue to change to keep up with the growth of the Internet.

10 Gigabit Ethernet in Metropolitan and Storage Area Networks

Vendors and users generally agree that Ethernet is inexpensive, well understood, widely deployed and backwards compatible from Gigabit switched down to 10 Megabit shared. Today a packet can leave a server on a short-haul optic Gigabit Ethernet port, move cross-country via a DWDM (dense wave division multiplexing) network, and find its way down to a PC attached to a "thin coax" BNC (Bayonet Neill Concelman) connector, all without any re-framing or protocol conversion. Ethernet is literally everywhere, and 10 Gigabit Ethernet maintains this seamless migration in functionality.

Gigabit Ethernet is already being deployed as a backbone technology for dark fiber metropolitan networks. With appropriate 10 Gigabit Ethernet interfaces, optical transceivers and single mode fiber, service providers will be able to build links reaching 40km or more. (See Figure 10.)

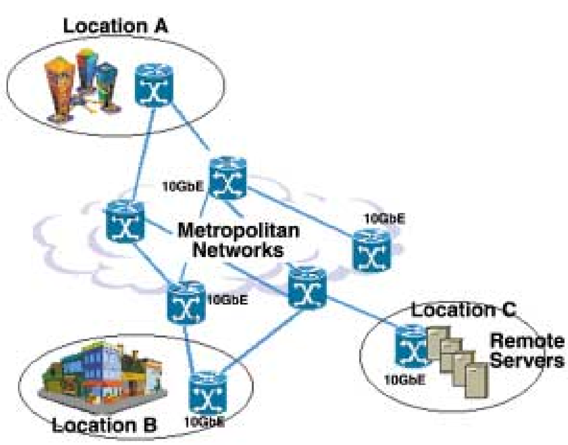


Figure 10. An Example of 10 Gigabit Ethernet use in a MAN.

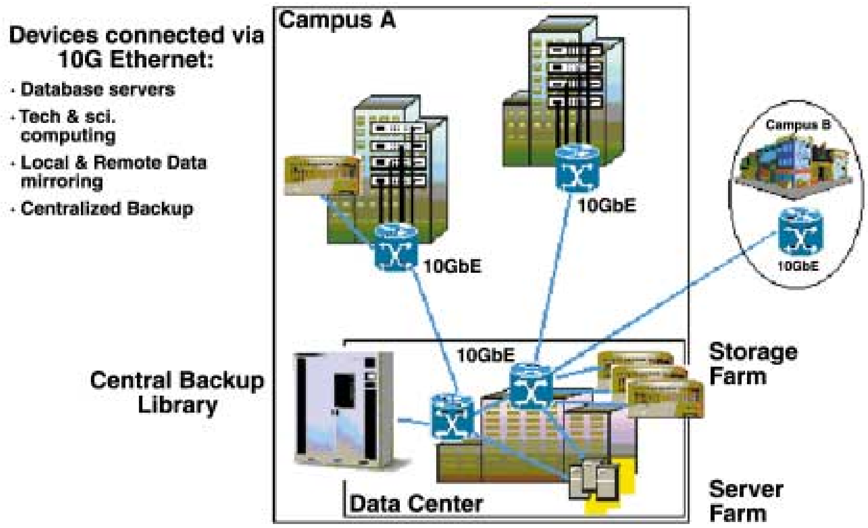


Figure 11. Use of 10 Gigabit Ethernet in Storage Area Networks.

Additionally, 10 Gigabit Ethernet will provide infrastructure for both network-attached storage (NAS) and storage area networks (SAN). Prior to the introduction of 10 Gigabit Ethernet, some industry observers maintained that Ethernet lacked sufficient horsepower to get the job done. Ethernet, they said, just doesn't have what it takes to move "dump truck loads worth of data." 10 Gigabit Ethernet, can now offer equivalent or superior data carrying capacity at similar latencies to many other storage networking technologies including 1 or 2 Gigabit Fiber Channel, Ultra160 or 320 SCSI, ATM OC-3, OC-12 & OC-192, and HIPPI (High Performance Parallel Interface). While Gigabit Ethernet storage servers, tape libraries and compute servers are already available; users should look for early availability of 10 Gigabit Ethernet end-point devices in the second half of 2001.

There are numerous applications for Gigabit Ethernet in storage networks today, which will seamlessly extend to 10 Gigabit Ethernet as it becomes available. (See Figure 11.) These include:

•Business continuance/disaster recovery

•Remote backup

•Storage on demand

•Streaming media

10 Gigabit Ethernet in Wide Area Networks

10 Gigabit Ethernet will enable Internet service providers (ISP) and network service providers (NSPs) to create very high-speed links at a very low cost, between co-located, carrier-class switches and routers and optical equipment that is directly attached to the SONET/SDH cloud. 10 Gigabit Ethernet with the WAN PHY will also allow the construction of WANs that connect geographically dispersed LANs between campuses or POPs (points of presence) over existing SONET/SDH/TDM networks. 10 Gigabit Ethernet links between a service provider's switch and a DWDM (dense wave division multiplexing) device or LTE (line termination equipment) might in fact be very short — less than 300 meters. (See Figure 12.)

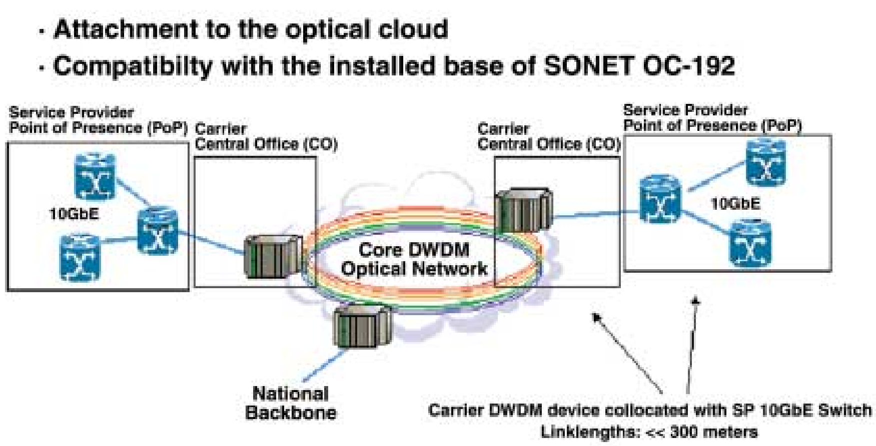


Figure 12. Example of 10 Gigabit Ethernet in WAN applications.

Conclusion

As the Internet transforms longstanding business models and global economies, Ethernet has withstood the test of time to become the most widely adopted networking technology in the world. Much of the world's data transfer begins and ends with an Ethernet connection. Today, we are in the midst of an Ethernet renaissance spurred on by surging E-Business and the demand for low cost IP services that have opened the door to questioning traditional networking dogma. Service providers are looking for higher capacity solutions that simplify and reduce the total cost of network connectivity, thus permitting profitable service differentiation, while maintaining very high levels of reliability.

Enter 10 Gigabit Ethernet. Ethernet is no longer designed only for the LAN. 10 Gigabit Ethernet is the natural evolution of the well-established IEEE 802.3 standard in speed and distance. It extends Ethernet's proven value set and economics to metropolitan and wide area networks by providing:

- Potentially lowest total cost of ownership (infrastructure/operational/human capital)
- Straightforward migration to higher performance levels
- Proven multi-vendor and installed base interoperability (Plug and Play)
- Familiar network management feature set

An Ethernet-optimized infrastructure build out is taking place. The metro area is currently the focus of intense network development to deliver optical Ethernet services. 10 Gigabit Ethernet is on the roadmaps of most switch, router and metro optical system vendors to enable:

- Cost effective Gigabit-level connections between customer access gear and service provider POPs (points of presence) in native Ethernet format
- Simple, very high speed, low-cost access to the metro optical infrastructure
- Metro-based campus interconnection over dark fiber targeting distances of 10/40km and greater
- End to end optical networks with common management systems

Glossary

Acronyms

802.3ae – The proposed IEEE standard for 10 Gigabit Ethernet
802.3z – The IEEE standard for Gigabit Ethernet
CoS – Class of Service
CWDM – Coarse Wave Division Multiplexing
DWDM – Dense Wave Division Multiplexing
Gbps – Gigabits per second or billion bits per second
IEEE – Institute of Electrical and Electronics Engineers
IP – Internet Protocol
ISO – International Standards Organization
LAN – Local Area Network
MAC – Media Access Control layer
MAN – Metropolitan Area Network
Mbps – Megabits per second or million bits per second
MMF – Multi Mode Fiber
OC–X – Optical Carrier Level
PCS – Physical Coding Sublayer
PHY – Physical layer device
PMD – Physical Media Dependent
POP – Points of Presence
RMON – Remote Monitoring
QoS – Quality of Service
SMF – Single Mode Fiber
SNMP – Simple Network Management Protocol
SDH – Synchronous Digital Hierarchy
SONET – Synchronous Optical Network
Tbps – Terabits per second or trillion bits per second
TCP/IP – Transmission Control Protocol/Internet Protocol
TDM – Time Division Multiplexing
WAN – Wide Area Network
WDM – Wave Division Multiplexing
WIS – WAN Interface Sublayer
WWDM – Wide Wave Division Multiplexing

Terms

Dense Wave Division Multiplexing — Wavelengths are closely spaced, allowing more channels to be sent through one fiber. Currently, systems using 100Ghz spacing are deployed in the WAN environment. Overall wavelength range is typically between 1530nm to 1560nm. The minimum and maximum wavelengths are restricted by the wavelength dependent gain profile of optical amplifiers.

Media Access Control — The media access control sub layer 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. The MAC layer of the 10 Gigabit protocol uses the same Ethernet address and frame formats as other speeds, and will operate in full-duplex mode. It will support a data rate of 10 Gbps using a pacing mechanism for rate adaptation when connected to a WAN-friendly PHY.

OC-192 — A speed of SONET interconnect with a payload rate of 9.584640 Gbps, primarily used in WAN environments.

Physical Coding Sublayer — Part of the PHY, the PCS sub layer is responsible for encoding the data stream from the MAC layer for transmission by the PHY layer and decoding the data stream received from the PHY layer for the MAC layer.

PHY – The physical layer device, a circuit block that includes a PMD (physical media dependent), a PMA (physical media attachment), and a PCS (physical coding sub layer).

PMD — Part of the PHY, the physical media dependent sub layer is responsible for signal transmission. The typical PMD functionality includes amplifier, modulation, and wave shaping. Different PMD devices may support different media.

WDWM — A technique used to effectively transmit several wavelengths (i.e. — colors of light) from several laser sources through one fiber. Each laser source would be calibrated to send a unique optical wavelength (which are separated at the receiving end of the fiber).

10 GIGABIT ETHERNET ALLIANCE

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