10 Gigabit Ethernet – An Introduction

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Preface

This white paper has been created to provide information on the technologies used by the emerging standard for 10 Gigabit Ethernet. It anticipates an audience that is familiar with current local and wide area networking technologies. Additionally, this white paper is directed to those who need to understand the impact of 10 Gigabit Ethernet on existing local area network/metropolitan area network (LAN/MAN) and new metropolitan area network/wide area network (MAN/WAN) infrastructures as it applies to their enterprises or organizations. It describes the variety of anticipated physical interfaces that have become necessary to meet this new expanded role of Ethernet. The content of this document reflects current progress towards the standard at the time of writing this document. It will be updated as technical issues are refined through the standards process.

10 Gigabit Ethernet: The Strategic Alternative

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

- Easy, straightforward migration to higher performance levels without disruption
- Low cost of ownership – 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

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), synchronous optical network (SONET) or equivalent synchronous digital hierarchy (SDH) network, packet over SONET/SDH (POS), and spatial reuse protocol (SRP).

Additionally, networking topological design and operation has been transformed with the advent of intelligent Gigabit Ethernet multi-layer switches. In LANs, core network technology is rapidly shifting to 1 Gigabit Ethernet. One of the most exciting applications for this technology has been the growth of long-distance Gigabit Ethernet networks that can operate over metropolitan area network 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 where Gigabit Ethernet is being deployed over tens of kilometers in private networks, the Ethernet industry developed a way to not only increase the speed of Ethernet to 10 Gbps but also to extend its operating distances. Network managers will be able to use 10 Gbps Ethernet as a cornerstone for network architectures that encompass LANs, MANs and WANs using Ethernet as the end-to-end, Layer 2 transport method.

With the developing IEEE 802.3ae standard, Ethernet bandwidth can 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 physical infrastructures in the LAN, MAN, and WAN.

Since the creation of the IEEE 802.3ae task force in March 1999, hundreds of engineers from more than 100 companies have been working diligently to produce the first draft of the specification. This draft was reviewed at the September 2000 meeting and fully ratified standard is expected in the first half of 2002. Customers can expect to see fully functional, pre-standard products emerge early in 2001.

Easy Migration to Higher Performance

One of the most important questions network administrators face is how to increase bandwidth without disrupting the existing network. Designers of service provider and long distance networks have to build capacity today to provide for future growth. They are building out central offices and points of presence (POP) that need thousands of intra-building links between Gigabit or Terabit (1 trillion bits per second) switches and the SONET/SDH optical infrastructure. 10 Gigabit Ethernet follows the same form, fit, and function as its 10 Mbps, 100 Mbps, and 1 Gbps Ethernet precursors, enabling a straightforward incremental migration to higher-speed networking.

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 remained true to the Ethernet model, 10 Gigabit Ethernet continues the natural evolution of Ethernet in speed and distance.

While the IEEE standard for 1 Gigabit Ethernet, 802.3z, supported both full and half-duplex operation, customers selected products that provided only full duplex operation. For this reason, the IEEE 802.3ae task force unanimously decided that 10 Gigabit Ethernet will only support full-duplex operation. Because 10 Gigabit Ethernet supports only full duplex and does not support shared media, the Ethernet protocol becomes unlimited in reach. Only the physics of transmission and the physical media limit the distance of the link. 10 Gigabit Ethernet is Ethernet, except that it is faster and transmits in full duplex over greater distances.

Why 10 Gigabit Ethernet? Because it:

- Is the simplest way to scale enterprise and service provider (SP) networks,
- Leverages the installed base of more than 300 million Ethernet switch ports
- Supports all data services
- Supports local, metro, and wide area networks
- Is faster, cheaper, and simpler than alternatives
- Optionally matches MAN/WAN backbone speed of OC-192

Because the 10 Gigabit Ethernet Task Force has identified an optional interface that matches the data rate and protocol requirements of SONET OC-192/SDH STM-64, 10 Gigabit Ethernet will be compatible with SONET/SDH, thus enabling direct attachment of packet-based IP/Ethernet switches to the SONET/SDH and time division multiplexed (TDM) infrastructure. This feature is very important because it promises the ability for Ethernet to use SONET/SDH for Layer 1 transport across the WAN transport backbone.

The SONET/SDH capability is especially important because it allows an immediate rollout of 10 Gbps Ethernet services by carriers. Just as the evolution of Ethernet was enhanced by common management tools and protocols (SNMP, RMON, etc.), SONET/SDH encapsulation allows carriers to provide end-to-end Ethernet capability while retaining their management structure.

It is also important to note that, advantageously, 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, as the receiving hub, switch, or router may retime and re-synchronize the data. In contrast, synchronous protocols, including SONET/SDH, require that each device share the same clock to avoid timing drift between transmission and reception equipment and subsequent increases in network errors.

Low Cost of Ownership

Experience with previous generations of Ethernet technology has shown that each new generation of Ethernet provides 10 times the bandwidth at only three to four times the cost of the previous generation, even in the earliest stages of adoption, with pricing eventually falling to commodity levels. Fundamental 10 Gigabit Ethernet technology decisions are being made within IEEE standards committees that will result in this same kind of cost performance improvement. Implementing 10 Gigabit Ethernet will lower the cost of building service provider POPs and central office networks. It will also significantly lower the cost of 10 Gbps intra-building links and will enable network designers to leverage the investment in installed OC-192 infrastructure.

Network managers of enterprise and service provider networks will be able to lower the costs of 10 Gbps links by implementing 10 Gigabit Ethernet in general, but the WAN PHYsical layer device (PHY) implementation will provide particular benefit. 10 Gbps WAN PHY links will cost less than 10 Gbps OC-192c links. Because the WAN PHY link is an asynchronous Ethernet link, it has no need to support the difficult, expensive-to-implement timing and jitter requirements of SONET/SDH synchronous optical networks where every device must share the same, precisely aligned stratum clock.

In more general cases, 10 Gigabit Ethernet will be a cost-effective means of building 10 Gbps links. First, there is the design philosophy of the Ethernet industry, which assumes high volumes and inherently low-cost design. Second, in contrast to 10 Gbps telecommunications lasers, the 10 Gigabit Ethernet short links—less than 40 km over single-mode (SM) fiber—will use low-cost, uncooled optics and in some cases vertical cavity surface emitting lasers (VCSEL), which are very low cost. Third, the Ethernet industry is supported by an aggressive merchant chip market that provides highly integrated silicon solutions. Fourth, the Ethernet market tends to spawn highly competitive start-ups with each new generation of technology. All this remains true for 10 Gigabit Ethernet.

When compatibility with SONET infrastructure is not a requirement, 10 Gigabit Ethernet LAN PHYs will be the most cost effective way to build 10 Gbps links for data networks. 10 Gigabit Ethernet interfaces will cost less than OC-192/STM-64 because there will be no need for expensive circuitry and methodologies to support synchronous timing. Short distance (less than 300 meter) 10 Gbps links built using WAN PHYs are expected to cost less than OC-192/STM-64 links. In addition, the WAN PHY enables both lower-cost 10 Gbps intra-building links and remains compatible with existing SONET infrastructure, it will decrease the cost of building networks that already have substantial amounts of installed SONET/SDH equipment.

Support for New Applications and Data Types

10 Gigabit Ethernet is Ethernet and, consequently, makes no changes to the Ethernet media access control (MAC) protocol or packet format. 10 Gigabit Ethernet supports all upper layer services, including all of the network services that operate at Layers 2 through 7 of the OSI seven-layered model, including high availability, QoS, voice over Internet protocol (VOIP) services, security and policy enforcement, server load balancing (SLB), Web caching, and domain name service (DNS) services. 10 Gigabit Ethernet will also support all standard Layer 2 functions: 802.1p, 802.1Q, VLANs, link aggregation, etc. Table A lists the affected complementary standards.

Name	Standards Body	Description
802.3ad	IEEE 802.3	Link aggregation for load balancing, resiliency, and bandwidth
802.1p	IEEE 802.1 Spec. part of 802.1D	Multicast pruning
802.1Q	IEEE 802.1	Enables VLAN support and allows assignment of priority bits for class of service (CoS)
MPLS	IETF	Multi-protocol label switching; A Layer 3 service
SNMP	IETF	Most popular form of Ethernet management
RMON	IETF	Remote Monitoring for Ethernet

Table A. Affected Complementary Standards

Ethernet supports all the services listed above. As TCP/IP becomes more robust and incorporates enhanced services and features, such as packetized voice and video, Ethernet can also carry these services without modification.

The Emerging 10 Gigabit Ethernet standard: IEEE 802.3ae

The 10 Gigabit Ethernet Task Force is working to define a standard that meets the design objectives listed below.

- Preserve the 802.3 Ethernet frame format at the MAC client service interface
- Meet 802 functional requirements with the possible exception of hamming distance
- Preserve the minimum and maximum frame size of the current 802.3 standard
- Support full duplex only
- Support star-wired LANs using point-to-point links and structured cabling topologies
- Specify an optional media independent interface (MII)
- Support P802.3ad link aggregation
- Support a speed of 10 Gbps at the MAC/PLS service interface
- Define two families of PHYs – LAN and WAN
- Define a mechanism to adapt the MAC/PLS data rate to the data rate of the WAN PHY (Physical Layer device)
- Provide Physical Layer specifications that support a specific set of multimode and single mode optical fiber link distances (defined in Table B below)
- Support fiber media selected from the second edition of ISO/IEC 11801

An Ethernet PHY (Layer 1 of the OSI model) connects the media (optical or copper) to the Media Access Control (MAC), 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., 8b/10b) and serializer or multiplexing functions.

The 802.3ae specification defines two PHY types: the LAN PHY and the WAN PHY (discussed below). The WAN PHY is simply an optional extended operating feature added to a LAN PHY. There will also be a number of PMD types. Both LAN and WAN PHY types will support every PMD type, and therefore support the same distances. These PHYs are solely distinguished by the PCS.

The IEEE 802.3ae Task Force is working to ensure that the 10 Gigabit Ethernet standard provides a physical layer that supports link distances for fiber optic media as shown in Table B.

At least 65 meters over multimode fiber (MMF)
At least 300 meters over installed MMF
At least 2 kilometers over single-mode fiber (SMF)
At least 10 kilometers over SMF
At least 40 kilometers over SMF

Table B. Distance Objectives for IEEE 802.3ae

To meet these distance objectives, four PMDs were selected (see Table C) from over 20 different PMD proposals supporting various distances and media types. At the July, 2000 meeting, the IEEE 802.3ae task force selected a 1310 nanometer serial PMD to meet its 2 km and 10 km single-mode fiber (SMF) objectives. It also selected a 1550 nm serial solution to meet (or exceed) its 40 km SMF objective. Support of the 40 km PMD is an acknowledgement that Gigabit Ethernet is already being successfully deployed in metropolitan and private, long distance applications.

At the September 2000 meeting, the task force refined its objectives to those shown in Table B above[1] and selected an 850 nanometer serial PMD to meet the 65 meter objective and the 1310 nanometer wide wave division multiplexing (WWDM), PMD to meet the 300 meter over installed multimode fiber objective. This WWDM PMD also supports single mode fiber up to 10,000 meters. These are listed in Table C below.

PMD (Optical Transceiver)	Fiber Supported	Diameter (microns)	Bandwidth (MHz•km)	Minimum Distance (meters)
850 nm serial	Multimode	50.0	400	65
1310 nm WWDM	Multimode	62.5	160	300
1310 nm WWDM	Single Mode	9.0	N.A.	10,000
1310 nm serial	Single Mode	9.0	N.A.	10,000
1550 nm serial	Single Mode	9.0	N.A.	40,000

Notes: N.A. Not applicable
The Task Force is still investigating the merits of supporting high bandwidth 50 micron multimode fiber

Table C. Optical Transceivers for 10 Gigabit Ethernet

The LAN PHY and the WAN PHY will operate over common PMDs and therefore support the same distances. These PHYs are distinguished solely by the encoding sublayer. The 10 Gigabit LAN PHY is intended to support existing Gigabit Ethernet

[1] This change to the Task Force objectives will be put before the IEEE 802.3 Working Group for ratification at the November 2000 plenary meeting.

applications at ten times the bandwidth with the most cost-effective solution. Over time, it is expected that the LAN PHY will be used in pure optical switching environments extending over all WAN distances. In the mean time, 10 Gigabit Ethernet will be able to operate over WAN distances by using the WAN PHY to connect to the SONET/SDH infrastructure.

The WAN PHY differs from the LAN PHY by the inclusion of a simplified SONET/SDH framer, discussed below. Since the line rate of SONET OC-192/SDH STM-64 is within a few percent of 10 Gbps, it is simple to implement a MAC able to operate with a LAN PHY at 10 Gbps or a WAN PHY at the SONET/SDH payload rate. 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 simply a low cost link using common Ethernet PMDs that provides access to the SONET infrastructure. Many vendors expect this to become the strategic alternative for building links between SONET/SDH equipment and routers.

10 Gigabit Ethernet in the LAN

As in Figure 1 below, 10 Gigabit Ethernet will be used in service provider and enterprise data centers and LANs. Initially, network managers will use 10 Gigabit Ethernet to provide high-speed interconnection between large-capacity switches inside the data center or computer room or between buildings. As the need increases, 10 Gigabit Ethernet will be deployed throughout the entire network, and will include switch to server and MAN and WAN access applications.

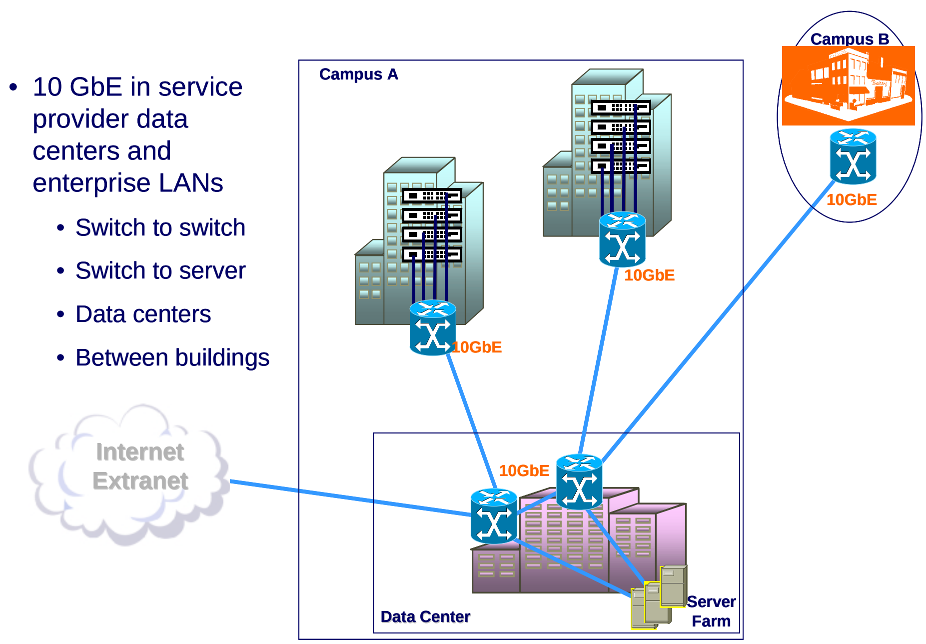

Figure 1. 10 Gigabit Ethernet in the LAN

10 Gigabit Ethernet in the MAN over Dark Fiber

Figure 2 shows 10 Gigabit Ethernet used as the backbone technology of a metropolitan area network. Gigabit Ethernet is already being deployed as a backbone technology for dark fiber metropolitan networks. With appropriate 10 Gigabit Ethernet optical transceivers and single mode fiber, service providers will be able to build links reaching 40 km or more.

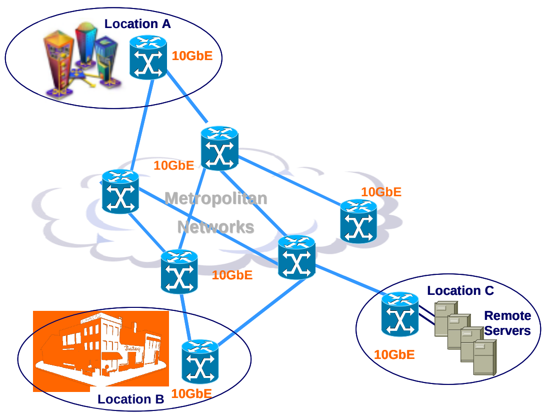

Figure 2. 10 Gigabit Ethernet in the MAN

10 Gigabit Ethernet in the MAN over DWDM

As shown in Figure 3, 10 Gigabit Ethernet will be a natural fit with dense wave division multiplexing (DWDM) equipment as more of the later is deployed in metropolitan applications. For enterprises, access to 10 Gigabit Ethernet services over DWDM will enable serverless buildings, remote backup and disaster recovery. For service providers, 10 Gigabit Ethernet in the MAN will enable the provisioning of dark wavelength gigabit services at costs less than T3 or OC-3/STM-1 services.

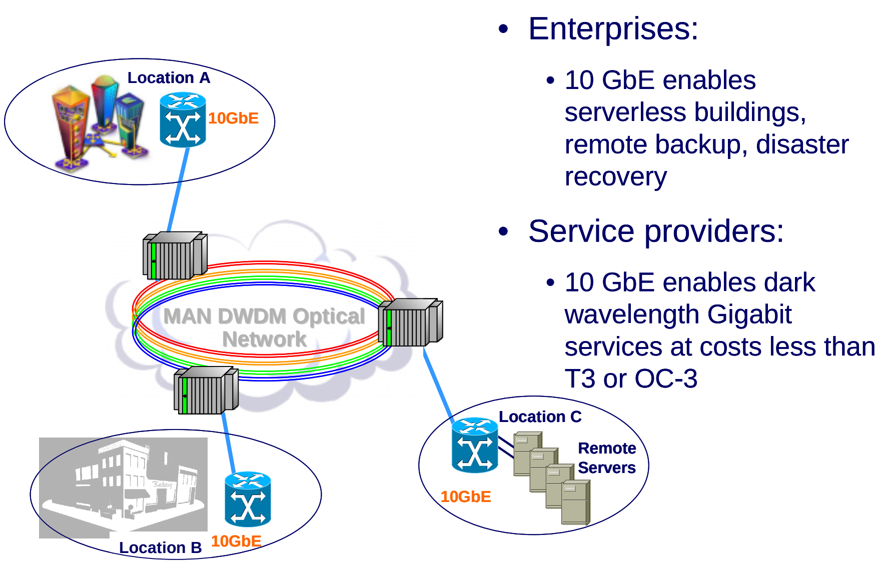

Figure 3. 10 Gigabit Ethernet over DWDM

10 Gigabit Ethernet in the WAN

10 Gigabit Ethernet will enable Internet service providers (ISPs) 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 will allow the construction of wide area networks that connect geographically dispersed LANs between campuses or POPs over the SONET/SDH/TDM network. Figure 4 shows that the 10 Gigabit Ethernet link between the service provider's switch and the DWDM device or LTE might in fact be very short, less than 300 meters.

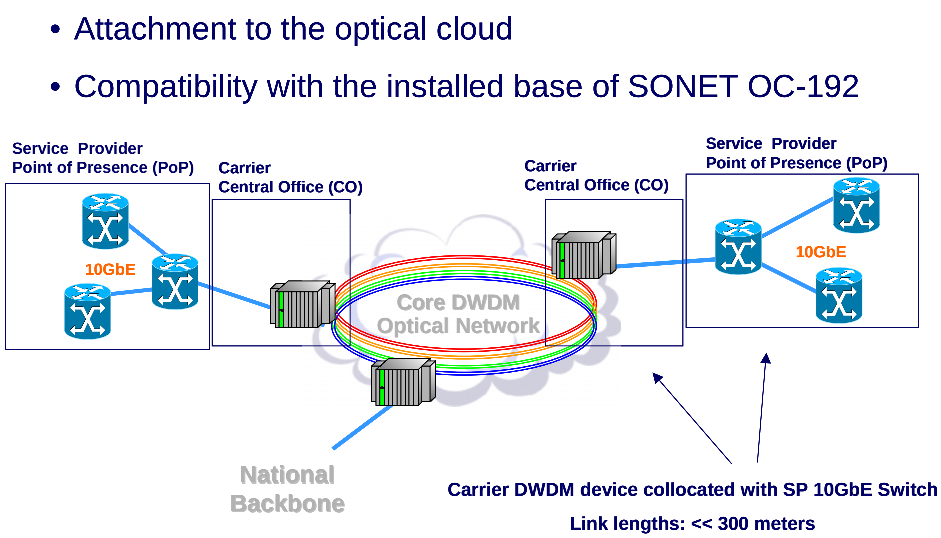

Figure 4. 10 Gigabit Ethernet for High-Speed Co-location

Summary

10 Gigabit Ethernet is the most important new networking technology. It unifies the LAN, MAN, and WAN, enables dark fiber/wavelength metropolitan area networks, supports distances of 10 km to 40 km or more over dark fiber, and will optionally operate across OC-192 SONET/STM-64 SDH infrastructure.

10 Gigabit Ethernet defines a LAN PHY that, with simple encoding will transmit Ethernet packets on dark fiber and dark wavelengths. 10 Gigabit Ethernet also defines a SONET/SDH-friendly WAN PHY to enable transmission of Ethernet through the SONET/SDH transport infrastructure without passing through a protocol gateway or other conversions. 10 Gigabit Ethernet will support distances of 65 to 300 meters on multimode fiber and 10 to over 40 km on single mode fiber. Long-distance reach on single mode fiber enables simple, low-cost metropolitan sized networks with Layer 3 switches or routers and 10 Gigabit Ethernet backbones.

Appendix A: How the WAN PHY Works

The WAN PHY attaches data equipment such as switches or routers to a SONET/SDH or optical network. This allows the extension of Ethernet links over a SONET/SDH or optical network. Figure 5 below shows that a typical installation would have two routers each with a 10 Gigabit Ethernet WAN PHY attached to a similar interface on a SONET/SDH line termination equipment (LTE).

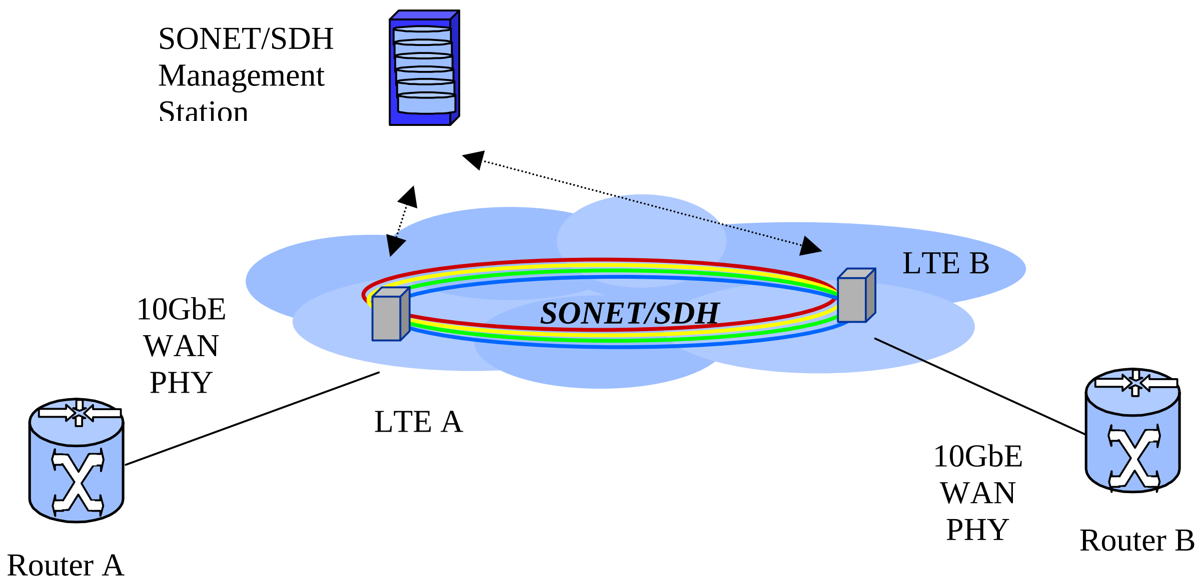

Figure5. How the WAN PHY Works

The WAN PHY allows the two routers to 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 the two routers, all the IP traffic management systems for differentiated service operate over the extended 10 Gigabit Ethernet link connecting routers A and B.

To simplify management of extended 10 Gigabit Ethernet links, the WAN PHY provides some 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 PHY, 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 PCS and PMD layers common to the LAN PHY.

Byte stuffing originated from bit stuffing (also known as justification). In multi-lane transmission with byte length coding, it will be difficult to do bit stuffing. It is primarily used to retime and realign frames in the presence of jitter and frequency variance. Figure 6 below illustrates how byte stuffing is accomplished within the SONET/SDH payload.

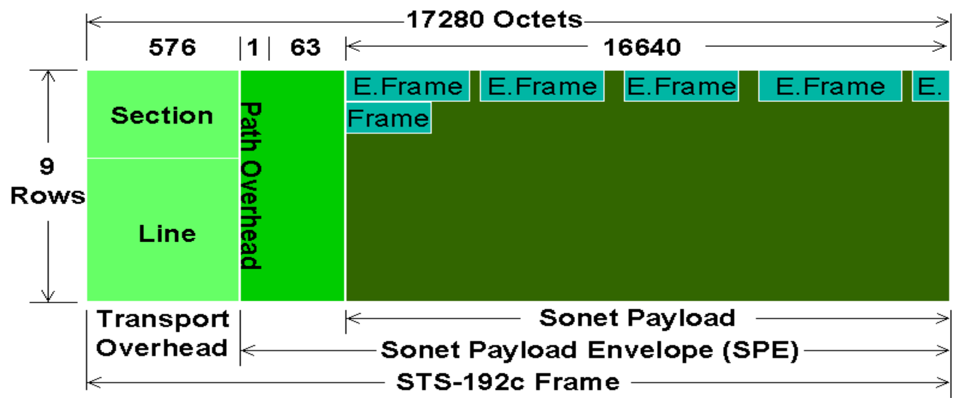

Figure 6. Byte Stuffing within the SONET/SDH payload

A packet passing through router A, in Figure 5, begins at the IP layer. From the IP layer, the packet is passed to the 10 Gigabit Ethernet MAC where it is formatted into an Ethernet frame. The MAC passes the frame to the 64b/66b encoder. The 64b/66b encoder creates 66 bit words each carrying 64 bits of data. These 66 bit words pass to the WIS as a logically continuous bit stream. Data leaves the WIS as 16 bit words to the optic transceiver module, which in turn transmits bits into the fiber. The transceiver module may be any of the 10 Gigabit Ethernet PMD types.

On the other end of the 10 Gigabit Ethernet WAN PHY link between router A and the LTE is a corresponding interface in a SONET/SDH line termination equipment. The PMD of this interface recovers the optical signal, transforming it back into an electrical bit stream. Bits received at the line termination equipment are buffered in a jitter elimination buffer. The LTE retimes the data bits, moving them from the asynchronous 10 Gigabit Ethernet WAN PHY to the synchronous SONET/SDH network. Time adjustments necessary in the SONET/SDH network are accommodated by moving the pointers within the SONET/SDH management information. The LTE manipulates the management information and then delivers the bit stream onto the SONET/SDH network.

At the other end of the SONET/SDH network, the receiving line termination equipment reverses the process. (See link between router B and the LTE.) First, the management information is inspected and modified. Since the stratum-clocked SONET/SDH network is more accurate than the asynchronous 10 Gigabit Ethernet, the LTE does not need to retime the bit stream before forwarding it to the 10 Gigabit Ethernet optics module for transmission over the 10 Gigabit Ethernet WAN PHY link.

At the receiving router B, the PMD converts the optic signal to a 16 bit wide electrical signal. This signal is delivered to the WIS to remove the SONET/SDH framing, recording useful information in its management registers. The remaining 64b/66b PCS bit stream is delivered to the receiving decoder where 64 bits of data are extracted from the 66 bit code words. This data is delivered to the MAC that then parses the Ethernet frames, checking the CRC (cyclic redundancy code) and removing header fields. The WIS features described will typically be implemented in digital CMOS (complimentary metal oxide semiconductor) logic, which adds very little cost to the WAN PHY interfaces.

The similarity between SONET/SDH and a 10 Gigabit Ethernet WAN PHY stops at the insertion of the SONET/SDH management information. SONET/SDH systems use synchronized high accuracy stratum clocks to form a synchronous clock hierarchy. These high accuracy clocks support regenerators that recreate the signals moving from one SONET/SDH segment to the next. The 10 Gigabit Ethernet WAN PHY operates like any other asynchronous network interface. Each link is separated from the clock domain of the next link by a store and forward buffer device like a router, bridge, or repeater.

Even though the 10 Gigabit Ethernet WAN PHY provides SONET/SDH management information, it provides only a subset requiring no complex software as used in the SONET/SDH networks. The 10 Gigabit Ethernet WAN PHY does not support complex features of SONET/SDH networks, like protection switching. Instead, the 10 Gigabit Ethernet WAN PHY supports standard 802.3 link aggregation for sharing bandwidth on a second link.

Appendix B: About the 10 GEA

The 10 Gigabit Ethernet Alliance was formed 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. Additionally, the Alliance will support the activities of IEEE 802.3 Ethernet committee, foster the development of the 802.3ae (10 Gigabit Ethernet) standard, and promote interoperability among 10 Gigabit Ethernet products.

The charter of the 10 Gigabit Ethernet Alliance includes:

- Supporting the 10 Gigabit Ethernet standards effort conducted in the IEEE 802.3 working committee
- 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 inter-operability and interoperability events
- Fostering communications between suppliers and users of 10 Gigabit Ethernet technology and products

Appendix C: Glossary

Acronyms

802.3ae – The proposed IEEE standard for 10 Gigabit Ethernet

802.3z – The IEEE standard for Gigabit Ethernet

CoS – Class of Service

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 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. 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 sublayer 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 sublayer).

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

WDM -- 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).