White Paper

10 Gigabit Ethernet

Abstract

This paper describes the driving forces, major benefits, and key applications of 10-Gigabit Ethernet (10 GE).

The traditional view of Ethernet as only a wire-based LAN protocol is not only limited, it is no longer true. Now, in the midst of an Ethernet renaissance driven by sweeping transformations in global communications, commerce, and content delivery—and with new optical-based technologies and high-speed silicon—Ethernet is being taken into the wide area network (WAN).

The work of the Institute of Electrical and Electronics Engineers (IEEE) has historically generated incremental innovations in Ethernet technology, and the current 10 GE standard, 802.3ae, is undergoing development in order to make it local area network (LAN)- and WAN-compatible. Leveraging the skills and resources of previous versions of Ethernet provides an aggressive adoption schedule that ensures ratification in early 2002. Extending Ethernet to the WAN is logical and inevitable, and WAN-compatible 10 GE enables seamless integration of the LAN, metropolitan area network (MAN), and WAN—a catalyst to end-to-end optical Ethernet networking.

Market forces are auspiciously aligned to make 10 GE the unifying technology for a global network. Newer competitive local exchange carriers (service providers) and alternative operators, as well as incumbent service providers, are all seeking ways to extend their reach and provide new services, while avoiding the heavy investment of capital and resources.

The adoption of 10 GE promises to enable numerous applications, all revolving around the ability to interconnect networks seamlessly and cost-effectively at OC-192c rates over either time division multiplex (TDM) or dense wave division multiplexing (DWDM) optical networks. Initial market uptake of 10 GE will be huge, starting in the WAN and MAN by early 2001, and later in the LAN in 2003.

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Introduction

The explosion in Internet usage, for both consumer and business applications, is driving the seemingly insatiable demand for bandwidth to previously uncharted heights. Now, more than ever, it becomes obvious that the public and private worlds of telecommunications need to merge and provide a seamless end-to-end network (Figure 1). This unity must be accomplished by combining a well-accepted and recognized high-speed technology that is simple and economical, yet reliable and robust. 10 Gigabit Ethernet (10 GE) accomplishes all of these objectives by marrying two key technologies:

- Ethernet (the lowest cost Internet on-ramp)
- Optics (the lowest cost Internet core)

The ubiquity of the universal standard Ethernet, along with the robustness of carrier-grade optics, is a natural evolution in which Nortel Networks is playing a leading role.

End-to-End Optical Ethernet Connectivity

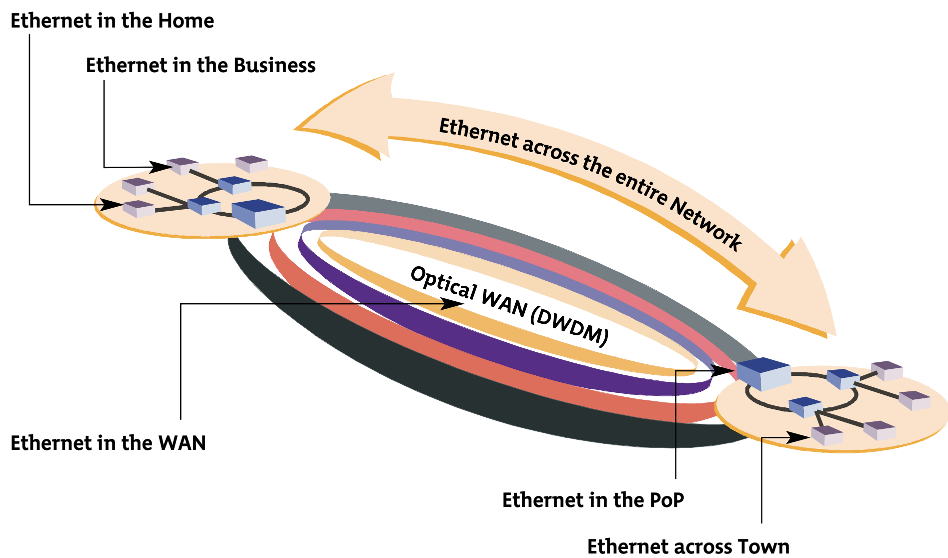

Figure 1. IEEE WAN-compatible 10 Gigabit Ethernet enables end-to-end seamless LAN-MAN-WAN integration across a DWDM optical network

Market adoption

What is 10 GE?

With full credit to the IEEE—which has piloted the evolution of the 802.3 Ethernet standard—Ethernet architectures have evolved from a shared 10-Mbps coaxial-based network, to a hubbed copper-based network, then to a switched network with dedicated 10-Mbps bandwidth to each node, and finally to a full-duplex optical fiber-based Gigabit Ethernet. At each stage, the IEEE displayed an ongoing commitment to the evolution of the 802.3 Ethernet standard by ensuring that Ethernet's scalability kept pace with the industry's technical and economic networking requirements over a wide variety of increasingly demanding applications. The latest in Ethernet technology, 10 GE, is a very high-speed Ethernet that ensures seamless compatibility with TDM and DWDM optical networks, establishing a common technology for end-to-end optical connectivity. The standard for this next generation of Ethernet is called IEEE 802.3ae (Figure 2).

Hence, 10 GE is more than just the next higher speed Ethernet. WAN-compatible 10 GE is the technology capable of unifying both the private and public worlds of telecommunications. It expands the role of Ethernet to take full advantage of the established core network rates of OC-192. Links at 10-Gbps speeds are poised to become the next-generation multi-domain standard—uniting the LAN, MAN, and WAN. Consequently, adoption across these multiple domains will lead to large volume manufacturing and deployment, resulting in 10 GE providing greater bang for the buck, just like its predecessors: 10-, 100-, and 1000-Mbps Ethernet. Therefore, seamless integration of residential/campus networks and the optical backbone networks of carriers and service providers will fundamentally change the economics of IP-based networking through a 10 GE standard that has guaranteed worldwide multi-vendor interoperability. This promises to offer existing and emerging service providers the competitive advantage they are seeking to successfully establish themselves in the Internet economy.

When 10 GE?

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 speeds that couldn't keep pace with the first approved standard, 10-Mbps Ethernet. This placed the transmission bottleneck on the computer and not the network. Yet, once the IEEE agreed upon the necessity for 100 Mbps, the official standard required only 2.5 years of development. Then, the 1990s showed incredible growth in PC technology speed and, even with the advent of Fast Ethernet (100 Mbps), the transmission bottleneck moved away from the central processing unit (CPU) and onto the network. Consequently, Gigabit Ethernet was first mentioned in November 1995 and was a fully ratified standard less than three years later. Although this moved the transmission bottleneck back to the computer, it did not take long for the PC to catch up,

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	IEEE 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

Figure 2. The Evolution of Ethernet

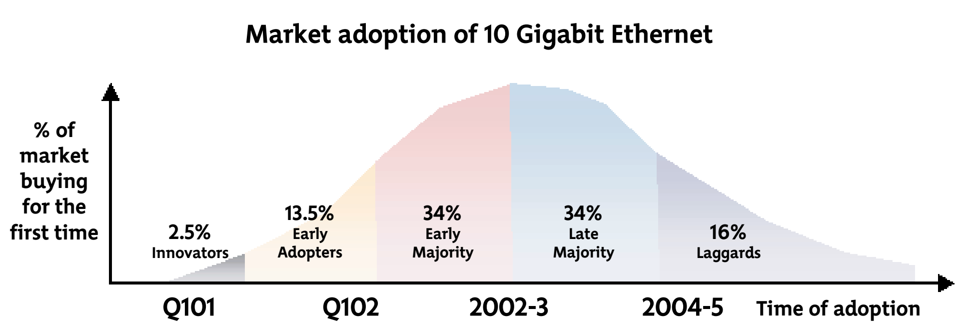

Figure 3. Innovators and early adopters will be primarily in the WAN market with the majority adopters occurring in the LAN, MAN, and WAN.

and once again the market saw the need for faster networks. These 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 3). In fact, in the second half of 2000, Nortel Networks was the first to offer WAN-compatible 10 GE capabilities in the long-haul optical arena by supporting 10 GE on its OPTera Long-Haul 1600 Optical Line System. This is just the beginning of the next Ethernet evolution, since industry analysts are already predicting that, starting in the WAN, the market potential of 10 GE will alter the business cases of other networking technologies. Therefore, this Ethernet revolution—with the adoption of 10 GE as the common link between the LAN and WAN—appears imminent because of the shared economic benefits it provides service providers, carriers, and their enterprise customers. Since many carriers are already experiencing a demand for 10 GE for storage applications or simple Ethernet connectivity for large enterprise customers, analysts' seemingly aggressive predictions are quite probable. Adoption of 10 GE as an industry standard with multi-billion-dollar revenues is backed by the ability of 10 GE to enable service providers and carriers to attack the business market with faster and more innovative services while addressing key economic needs.

Standards activities

802.3ae Task Force

In June of 1998, the IEEE 802.3z task force finalized and formally approved the Gigabit Ethernet standard. Less than a year later, in March of 1999, the Higher Speed Study Group (HSSG) held a "call for interest" for 10 GE with 140 participants, representing at least 55 companies, attending. The HSSG determined there was ample necessity for the next higher speed of Ethernet based upon a rapid growth of network and Internet traffic and a strong pull for 10 Gbps solutions such as GE aggregation, fiber channel, terabit routers, and next-generation input/output (I/O). Possibly the most compelling reason the HSSG recommended the adoption of a 10 GE standard to the IEEE was their desire to avoid the proliferation of custom, non-standard and therefore, probably non-interoperable solutions. Therefore, in January 2000, the IEEE Standards Board approved a Project Authorization Request for 10 GE, and the 802.3ae task force immediately began work with the following in mind:

PMD	LAN PHY (10.3125 Gbps)	WAN PHY (9.95328 Gbps=OC-192c rate)
850 nm Serial • 65m (existing MMF) • 300m (new MMF)	• **Adopters:** enterprises in campus environments for low-cost short-reach applications over existing and new multi-mode fiber.	• **Adopters:** not likely to be widely deployed
1300 WWDM • 300m (existing MMF) • 10-Km (SMF)	• 4 λ's each @ 3.125 Gbps • **Adopters:** enterprises in campus environments for switch-to-switch short-reach applications over existing MMF	• 4 λ's each @ 2.48832 Gbps • **Adopters:** enterprises wishing to connect in the near term to metro optical environments for switch-to-switch and possibly switch-to-transport short reach applications (few adopters)
1310 nm Serial • 10-Km (SMF)	• **Adopters:** new metro carriers with minimal existing infrastructure	• **Adopters:** carriers interconnecting to long-haul DWDM networks (plug-and-play)
1550 nm Serial • 40-Km (SMF)	• **Adopters:** carriers needing long-reach applications in the metro	• **Adopters:** carriers needing long-reach applications in both the metro and long haul

"The purpose of this project is to extend the 802.3 protocol to an operating speed of 10 Gbps and to expand the Ethernet application space to include WAN links in order to provide 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."

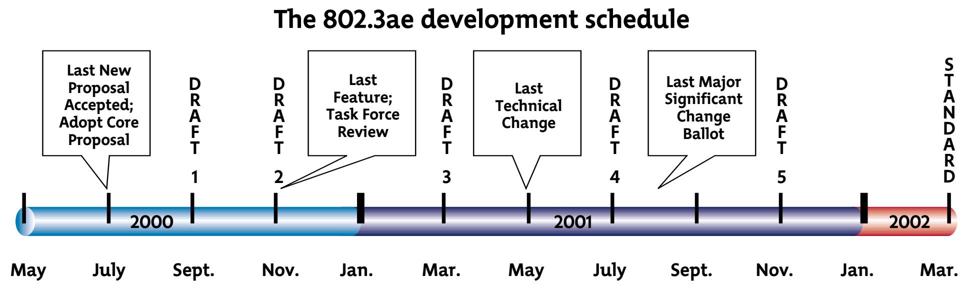

Figure 4. Leveraging the skills and resources of previous versions of Ethernet provides an aggressive adoption schedule that ensures ratification in early 2002.

1310 and 1550 Serial WAN-PHY

Without trivializing the complexities of optical networking, 1310/1550 serial communications are mature and relatively simple. This is due to the fact that they are based upon widely accepted technologies that comply with the International Telecommunications Union (ITU) channel plan. These communications utilize a technology, Dense Wavelength Division Multiplexing (DWDM) that was originally designed to relieve fiber congestion. DWDM is capable of offering 160 channels on a single ring using a composite optical signal carrying multiple information streams, each signal transmitted on a separate optical wavelength. Each optical signal can carry any protocol, such as SONET or Ethernet, with a bit rate ranging up to 10 Gbps and provides maximum flexibility to a carrier's migration and provisioning strategy by allowing a carrier to provide an OC-12 link to one customer and an OC-48 link to another customer, all on the same ring. Although the primary value of DWDM is cost-effective transport of high aggregate bit rates over a long distance on as few fibers as possible, alleviating fiber exhaust, it also provides local carriers competitive advantages such as greater connectivity, enhanced service delivery, high reliability, and network flexibility at a time when service and market mix are extremely difficult to manage and predict. While serial optical interfaces operating at 1310 and 1550 nm are true carrier-grade solutions, other technologies such as Wide Wavelength Division Multiplexing (WWDM) exist that are more suited to campus environments and are poised to take advantage of the legacy multimode fiber. WWDM is an interface based on parallel optics that places multiple optical signals on a single fiber. However, since the wavelengths are spread far apart, only four separate wavelengths can be used. For this reason, parallel optics requires an increased number of components (lasers, drivers, detectors, cross connects, amplifiers and also necessitates filters and alignments that aren't even necessary in serial implementations) that potentially add risk and complexity in a time when carriers are already facing increased competition and a shortage of skilled technical personnel. In addition, DWDM allows a composite throughput of 1.6 terabits per second (160 wavelengths at 10Gb/s), whereas WWDM allows only 10 gigabits per second (4 wavelengths at 2.5Gb/s). Finally, DWDM utilizes a management architecture based upon the ITU's Telecommunications Management Network (TMN) standard. TMN aids carriers in delivering 99.999% uptime solutions and ensuring Quality of Service (QoS) to customers in an era where service and reliability are the cornerstones of their business.

Commitment toward this new development has consistently increased, and now more than 225 engineers, representing at least 100 companies, are involved in this technical effort. In fact, incredible progress has already been made with the initial draft of the standard being released on September 18, 2000 and Draft 2.0 released on December 1, 2000. These first drafts represent a significant milestone in the development process since the most heavily debated issues, the physical (PHY) layer and its physical media dependent (PMD) interfaces, have been agreed upon and defined.

The 802.3ae development process is right on track to reach its goal of a ratified standard in March of 2002 (Figure 4). For more information, the standards development is publicly accessible at: *http://grouper.ieee.org/groups/802/3/ae/index.html*

10 Gigabit Ethernet Alliance

In support of the worldwide adoption of the IEEE 802.3ae standard is the 10 GE Alliance (10GEA). The 10GEA is a multi-vendor computing and telecommunications industry consortium that follows the pattern of success set by the Fast and Gigabit Ethernet Alliances. Nortel Networks is a key founding member of the 10GEA, along with a host of companies including Extreme Networks, Sun Microsystems, Intel, 3Com, World Wide Packets, and Cisco Systems. Both the IEEE and the 10GEA recognize that the true value of 10 GE lies in open, standards-based interoperability. As such, the 10 Gigabit Ethernet Alliance promotes 10 GE technology and its real-world applications, provides technical contributions to the IEEE 802.3ae task force, and encourages interoperability testing of its members' products. The 10GEA represents a unique collaboration of major internetworking companies and component suppliers that ensures worldwide multivendor product interoperability, including the WAN.

The 10 GE strategy of Nortel Networks

Technology commercialization

Nortel Networks has made a multimillion-dollar strategic investment in the 10 GE program to create a new high-speed (OC-192c rate) optical Ethernet for service providers and carriers. Nortel Networks is a founding member and continues to play an active role in the 10GEA to promote interoperability. Nortel Networks also plays a leading role in the 802.3ae task force in defining the 10 GE standard and enabling WAN compatibility. Of significant importance, Nortel Networks engages customers to validate the market potential and timing of 10 GE against their economic and technical requirements. This creates a complete 10 GE program that is comprised of a portfolio of optical Internet products that span DWDM optical networking, and also includes carrier-class switching and routing, optical server/storage connectivity solutions, and professional services.

Leveraging installed WAN infrastructure

An important aspect of the Nortel Networks 10 GE strategy is the recognition that, although 10 GE is the first Ethernet technology to unify the LAN, MAN and WAN, adoption and implementation of 10 GE will begin in the WAN. To fully and immediately extend Ethernet to the WAN, the IEEE 802.3ae task force defined an Ethernet draft standard specification in such a way that ensures seamless compatibility with the massive installed base of TDM and DWDM optical networking gear, since currently the majority is synchronous optical network (SONET)-based. North American spending in 2000 in the optical transport market reached $20.6 billion and will grow to over $45 billion in 2004 (RHK, October 2000). As a result, WAN-compatible 10 GE is addressing the need for seamless compatibility with this massive installed base of TDM and DWDM optical networks.

The current market

The Internet has become much more than a research project. It is evolving into the central nervous system of a global eCommerce universe, where time and distance barriers have yielded to the ability to communicate and transact business “anytime, anywhere.” In addition, the Internet promises to generate significant revenues for all types of players, both large and small, since it drastically alters the traditional barriers to entry and/or exit.

The following worldwide forecasts for Internet related business and traffic indicate that the growth will continue at an explosive pace:

- eCommerce—$269 billion in 2000 to $2.6 trillion in 2004 (IDC, August 2000)
- Internet protocol virtual private network (IP VPN)—$2 billion in 2000 to $17.6 billion in 2004 (IDC, October 2000)
- Hosting services—$4 billion in 2000 to $18 billion in 2005 (Probe, February 2000)
- Voice over packet (VoP)—$864 million in 2000 to $10.7 B in 2005 (Probe, March-August 2000)

Market potential

Beginning in the WAN where demand for Ethernet at OC-192c rates is already well established, 10 GE is forecasted to have a huge market impact (Figure 5). Over 90,000 OC-192c TDM and DWDM ports will be lit in the year 2000, with a substantial number of these ports carrying Ethernet traffic (Dell’Oro, February 2000). This conclusion is based upon a recent IEEE study of WAN traffic patterns, which determined that more than 99 percent of all packets were less than 1500 bytes, the Ethernet

WAN-compatible 10 GE represents a significant step forward towards the integration of packet-based technologies and optical networking that underpin *"the high performance Internet."*

802.3ae defines two OSI Layer 1 (Physical) specifications: a LAN PHY and a WAN PHY. The LAN PHY was primarily adopted to support legacy and dark fiber, whereas the WAN PHY was adopted to support the installed SONET/SDH infrastructure. Both were adopted to unify the LAN, MAN and WAN. While embracing a WAN-compatible 10 GE that operates at OC-192c rates, the task force did reject conformance to SONET jitter, stratum clock, and other SONET optical specifications. The inclusion of a SONET framing sublayer onto the WAN PHY allows 10 GE switches and routers to attach to SONET access equipment and use the SONET infrastructure for Layer 1 transport. These links remain asynchronous Ethernet links, presenting Layer 2 Ethernet packets to the SONET infrastructure with just enough SONET management information that the link may be managed as a SONET link. However, the similarity between SONET and 10 GE WAN PHY stops there since SONET 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 segment to the next. On the other hand, WAN-compatible 10 Gigabit Ethernet remains an asynchronous protocol and operates like any other asynchronous network interface. Therefore, there is no need to support the expensive timing, clocking and jitter requirements of the synchronous optical network where every device shares the same precisely aligned stratum clock. In addition, the 10 GE WAN PHY provides advanced network manageability that goes beyond what the traditional Ethernet LAN PHY offers. This includes, but is not limited to, integration into existing SONET Operational Support Systems, Performance Management, Fault Sectionalization and Path Trace. As a result, WAN-compatible 10 GE provides the industry a robust Ethernet solution that maintains the simplicity of Ethernet, yet leverages the considerable installed infrastructure, offers superior network management and provides a logical path forward for future networks.

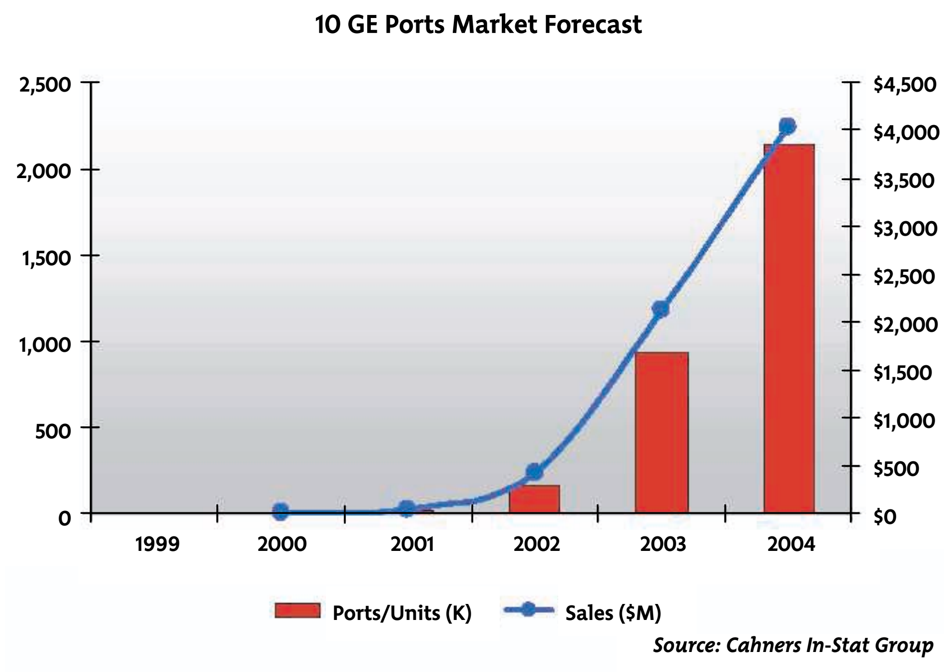

Figure 5. Over 2,000,000 10 Gigabit Ethernet ports expected in 2004

packet size limit. In addition, the demand for OC-192c ports is expected to extend to the MAN, when enterprise applications (e.g., IP, VPN, and transparent LAN services) drive up the demand for traffic aggregation. Correspondingly, revenue from WAN-compatible 10 GE sales in the WAN/MAN in 2001 will grow by 2500 percent, up to U.S. $1.8 billion in 2003. Networking economics and demands for multi-gigabit capacity will draw 10 GE into the more traditional LAN backbone environments by late 2003. As 10 GE begins to penetrate the LAN, the combined LAN/MAN/WAN market for 10 GE is expected to more than double, increasing to almost U.S. $4 billion in 2004. By 2004, over 2,000,000 ports of 10 GE will exist (Cahners In-Stat Group, September 2000), most of which are will likely be in the WAN and MAN.

Competitive advantage in the Internet economy

Service providers and alternative service providers want to attack business markets by changing the traditional bandwidth-pricing paradigm. WAN-compatible 10 GE solutions provide the following low cost connectivity advantages:

- **Reduced infrastructure costs.** There is no additional equipment required for protocol conversion and rate mismatch with WAN-compatible 10 GE.
- **Simplified connection management.** There are fewer ports required with Ethernet switched point-of-presence (PoP) architectures than with traditional point-to-point.
- **Reduced network operating complexity.** Ethernet is a simple, well known, and easy-to-operate interface.
- **Lower operating costs.** The declining cost curve of Ethernet-based networking is a well-known factor in its universal market acceptance. While in operation, Ethernet offers the lowest cost/Mbps of all competing data transport technologies. In addition, the relative cost of adopting Ethernet technology—considering its maturity and installed base—is low.
- **Lower training and support costs.** Eighty percent of traditional network installation costs comprise management, training, and support costs. Leveraging the massive human capital associated with accumulated training and deployment of Ethernet technology can cut these costs dramatically.

Speed and flexibility to deliver new high-bandwidth IP services

10 GE operates at OC-192c rates, the common denominator in today's high-speed terabit networking domain. As

demand for offerings grow, Ethernet switched PoPs will enable connectivity of additional core or edge routers without the need to provision a link to every other router in the PoP. This will greatly enhance service deployment velocity. 10 GE also provides flexibility to provision services customized to specific customer needs. Ethernet is highly scalable, maintaining compatibility with existing network infrastructure, and allowing services to be provisioned at any permutation of 10Mb/100Mb/1Gb/10Gb Ethernet speeds.

Guaranteed worldwide multi-vendor interoperability

IEEE 802.3 Ethernet is the most widely adopted, highest quality, IP-optimized industry standard prevalent in LANs today. The IEEE 802.3 level of specification is unsurpassed. This ensures open, standards-based compatibility between endpoints of any network, including those based on multi-vendor solutions. In addition, the 10GEA is diligently working to promote vendor interoperability.

End-to-end seamless integration

IEEE 802.3ae WAN-compatible 10 GE ensures seamless compatibility with TDM and DWDM optical networks, establishing a common technology for end-to-end optical connectivity of the LAN, MAN and WAN. As part of this, the 10 GE data rate matches OC-192c for compatibility with the existing installed base of optical infrastructure and most major Greenfield players.

Optimized packet transport

Carriers and service providers can protect their investment in existing infrastructure while adding additional capability at a low implementation cost. Moving data seamlessly at a billion bits per second between data and optical networks, 10 GE is a plug-and-play solution that transparently integrates with existing carrier and service provider optical networks.

Applications

With the prospect of the Internet providing so many revenue-generating opportunities, service providers, incumbent carriers, and service providers are racing to implement a wide variety of IP-based eCommerce and Internet services. These services are targeted to improve the competitiveness of enterprises, meet consumer demand for high-speed Internet access, and generate revenues from both new and existing customers.

Newer service providers and alternative operators, in particular, want to enter existing markets with cost-effective network architectures that support their innovative business models. Incumbent carriers, in turn, need to keep pace with customer demand and maintain their customer base. They are paying close attention to technologies that can provide them with a significant competitive advantage through the ability to provision faster and more innovative services at lower prices than what currently exist. Industry watchers and consultants view 10 Gigabit Ethernet as a disruptive technology and it is now being considered by innovative network planners as they prepare their future networks.

10 GE in the enterprise

Storage area networking (SAN) represents the future of enterprise storage and creates new business opportunities for service providers. When strategically implemented, interconnected SANs provide an unprecedented ability to share, consolidate, manage and protect IT computing resources timely and reliably. Storage networking services are designed to be high-speed subnetworks connecting servers and storage, where the storage resources are accessible by any number of servers directly using high-speed interconnect technology such as 10 GE. SANs enable storage to be externalized from the server, and in doing so, enable storage to be shared among multiple servers without affecting system performance, data integrity, or the primary network. SANs are not a new concept and are actually prevalent today, with more than 25 percent of data center network storage attributable to some form of SAN, with enterprise systems connection (ESCON) as the standard interface. However, this type of architecture is now moving out of the data center and into the rest of the organization. This move mandates a technology that is simple and well known—10 GE. Using robust storage solutions enables new revenue opportunities for service providers by delivering traditional data center and storage networking to the enterprise. This will allow providers to offer enterprises such services as remote mirroring, disaster recovery, centralized disk on demand, business continuity, and centralized tape backup.

As we move from a server-centric to a storage-centric world, SANs using 10 GE provide many potential benefits to the enterprise:

- Eliminating bottlenecks via increased bandwidth
- Extending storage capabilities over greater distances while eliminating router hops
- Enhancing scalability through access to multiple infrastructure devices
- Making control plane available on day one, with migration to full automatically switched optical network (ASON) solution

10 GE in the points of presence

Convergence on a data-centric telecommunications world has resulted in service providers' PoPs starting to look more and more like large campus backbones, with Ethernet switched architectures

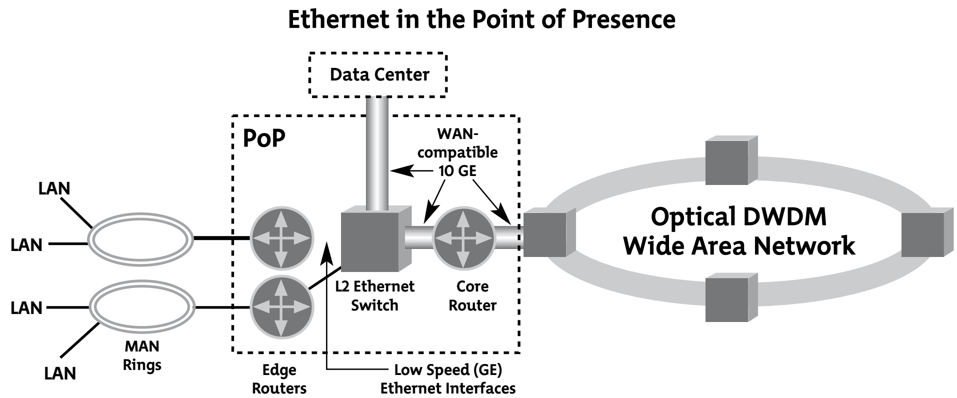

Figure 6. WAN-Compatible 10 GE provides an economical way to link the access and backbone segments of a PoP and provide a seamless Ethernet on-ramp to high-capacity TDM or DWDM optical networks.

(Figure 6). Today, a large PoP is typically a complex subnetwork composed of multiple access routers and multiple backbone routers connected by Ethernet switches. Layer 2 Ethernet switches with 10 GE interfaces will address higher-capacity requirements and provide low-cost connectivity, scalability, and simplified connection management. 10 GE interfaces on L2 Ethernet switches will enable aggregation of lower-capacity access link traffic (from edge routers) onto higher-capacity (10 GE) links to core routers based on a common OC-192 rate from the Ethernet switch to the core router. This will enable flexibility in service provisioning (i.e., lower-capacity access services) yet efficient and cost-effective use of more expensive (relative to L2 Ethernet switches) core router interfaces. Ports on a L2 Ethernet switch are an order of magnitude cheaper than those on a core router. As service providers' businesses grow and PoP capacities scale, L2 Ethernet switched PoPs will enable connectivity of additional core or edge routers without the need to provision a link to every other router in the PoP. This reduction in the number of links required for intra-PoP connectivity will simplify connection management and reduce infrastructure and operational costs associated with multiple ports (and management) required for each link. It will also offload local traffic (access-access, access-server, access-peering router) from core routers where it is not required. This is a more economical use of network investments and more cost-effective than typical point-to-point architectures.

PoPs using WAN-compatible 10 GE permits end-to-end seamless integration of the LAN/MAN/WAN and provides many potential benefits to the service provider:

- Optimized packet transport that meets capacity and architectural scalability needs for delivery of next-generation IP services
- Simplified connection management
- Reduced infrastructure and operational costs
- Guaranteed multi-vendor interoperability

10 GE in the MAN

Large corporate campuses can have many thousands of users per site, with extremely heavy traffic between campuses (Figure 7). In addition, inter-LAN traffic often reaches the multi-gigabit range today and will continue to grow. Interconnecting campus LANs on a single, shared, high-capacity metropolitan ring can seamlessly link all sites on a VPN under a common Ethernet protocol, with no translations required between sites. The need for 10 GE ring interconnection will be accelerated by general Internet access traffic, which is often hubbed to one or two PoPs in a carrier MAN, creating very high traffic concentrations at these ring nodes. WAN-compatible 10 GE is ideally suited for this task.

WAN-compatible 10 GE provides the opportunity to implement dependable IP VPN services that ensure applications are secure, reliable and scalable.

WAN-compatible 10 GE in the Metropolitan Area Network

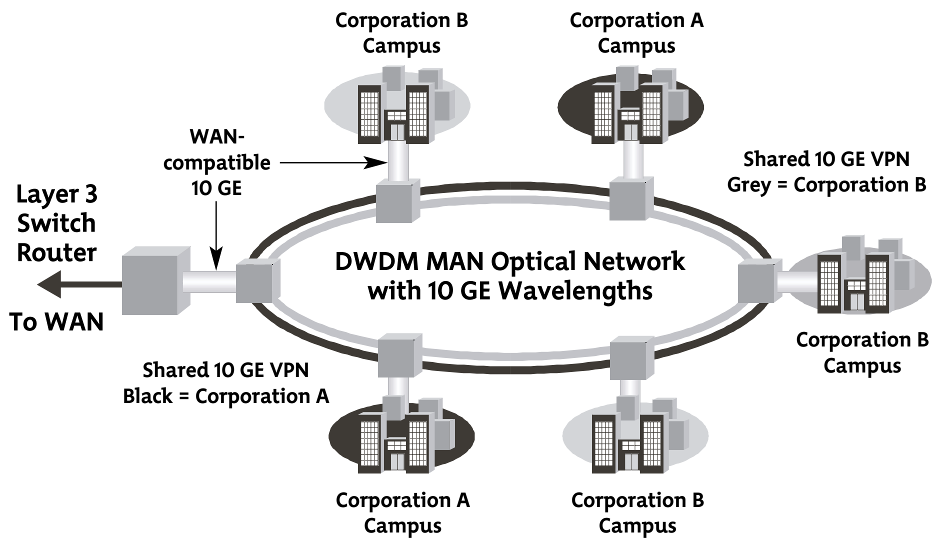

Figure 7. WAN-compatible 10 GE can seamlessly link all sites on a VPN under a common Ethernet protocol, with no translations required between sites.

Additional benefits include:

- Implementation of a single management infrastructure that can be scaled to meet the anticipated size of the customer base
- Facilitating customer control of effective security policies and applications
- Reduced latency with guaranteed service-level agreements (SLAs)
- Reliable and less-expensive alternative to private line communication networks

10 GE in the WAN

Wholesale services segments are witnessing new business models and new carriers competing in the marketplace, all with varying degrees of success. These new threats indicate that a provider must have the ability to wholesale more than just one type of service (i.e. dial, VPN, or VoP). One of the most important new features of the wholesale market segment is the vast increase in the supply of fiber-optic cable in the United States. Numerous carriers are emerging as they string fiber across the country, and they have the potential to become new backbone carriers. Some carriers are very focused on wholesale-only services for their new fiber, some are selling to other Internet service providers (ISPs) and to enterprises, and some are looking at entirely new target customers, such as content providers. Although they are very different from each other, these companies share a common bond—new fiber deployments and increased competition. This proliferation of new fiber is in recognition of the need for higher-speed bandwidth for an array of applications and services.

Service providers that wholesale service and applications can differentiate themselves using WAN-compatible 10 GE to sell or rent the same ports and lambdas to different customers, at different times of the day, and for different applications.

WAN-compatible 10 GE provides competitive advantage by:

- Leveraging economies of scale, including
  - Operational efficiencies through higher density access switches and universal port capability
  - Lower rates for equipment and telecom services through volume
- Enabling incremental revenues from multiple sources
- Allowing the flexibility to offer new services as new Internet applications become profitable business models

Summary

As the boundaries of LANs, MANs, and WANs continue to blur, network unification requires segments connecting to each other more easily, at lower cost, and with fewer network operational and management requirements. In this environment, the preeminent solution—providing high performance, high efficiency, and low cost at all scales—is Ethernet. The development of WAN-compatible 10 GE represents the type of incremental innovation that is changing the very economics of networking. Ethernet is the most widely adopted (over 95 percent global market share), highest quality, and data-optimized standard prevalent in LANs today. 10 GE represents the logical evolution of the ubiquitous Ethernet married with the reliability of optical networks. 10 GE addresses the challenges facing carriers and service providers today: unprecedented bandwidth growth, profitable service differentiation, and building reliable "future-proofed" networks. The Nortel Networks implementation of the IEEE 802.3ae WAN-compatible standard will maintain compatibility with all previous versions of Ethernet (e.g. 10-Mbps, 100-Mbps, 1-Gbps) and continue the Ethernet tradition of providing the most cost-effective networking technology. The Nortel Networks adoption of the IEEE 802.3ae WAN-compatible 10 GE provides seamless connectivity for data and optical networks without incurring any additional networking delays or infrastructure costs, all based on a non-proprietary solution. Finally, WAN-compatible 10 GE provides the industry a robust Ethernet solution that maintains the simplicity of Ethernet, yet leverages the considerable installed infrastructure, offers superior network management, and provides a logical path forward for future networks.

10 Gigabit Ethernet: a catalyst for end-to-end optical Ethernet connectivity—it's transforming the technology landscape, while empowering service providers to deliver next-generation IP services faster and cheaper than ever before.

Glossary/Acronym Lookup

10 GE—10 Gigabit Ethernet. Ethernet operating at 10 billion bits per second as defined by the IEEE 802.3ae standard.

10GEA—10 Gigabit Ethernet Alliance. The specific purpose of the Corporation is to promote standards based 10 Gigabit Ethernet technology and to encourage the utilization and implementation of 10 Gigabit Ethernet as a key networking technology for connectivity of various computing, data and telecommunications devices

ASON—Automatically Switched Optical Networks. Mechanism to add intelligence to the optical layer by utilizing a set of signaling and routing protocols. This next generation capability will enhance existing optical service velocity and operation.

CPU—Central Processing Unit. The computing part of a computer. The "brain" of the computer. It manipulates data and processes instructions coming from software or a human operator.

DWDM—Dense Wavelength Division Multiplexing. The higher-capacity version of WDM, which is a means of increasing the capacity of fiber-optic data transmission systems through the multiplexing of multiple wavelengths of light.

eCommerce—Electronic Commerce. Buying and selling over the public Internet, the public Web and corporate intranets.

ESCON—Enterprise Systems Connectivity. A high-speed fiber optic channel for linking IBM ES/9000 mainframe processors to disk drives and other mainframes.

Gbps—Gigabits per second. The transmission of exactly one billion bits per second.

Hosting Services—Services related to the development, management, and maintenance of an Internet presence. The components of hosting services include the physical infrastructure, network connectivity, hardware and software management, network management and performance-related services, and professional services.

HSSG—Higher Speed Study Group. IEEE study group formed to decide if when there was a need for 10 Gigabit Ethernet.

IEEE—Institute of Electrical and Electronic Engineers. World's largest technical professional society, founded in 1884 and consisting of over 320,000 members in 147 countries. The IEEE's technical objectives "focus on advancing the theory and practice of electrical, electronics and computer engineering and computer science."

IP—Internet Protocol. The most important of the protocols on which the Internet is based. The IP protocol is a standard describing software that keeps track of the Internet's addresses for different nodes, routes outgoing messages, and recognizes incoming messages.

ISO—International Organization for Standardization. The ISO or IOS (it's known as both) is responsible for defining international standards covering all fields other than electrical and electronic engineering.

ISP—Internet Service Provider. A vendor who provides access for customers (companies and private individuals) to the Internet and the World Wide Web.

ITU—International Telecommunication Union. Based in Geneva, Switzerland, the most important telecom standards-setting body in the world.

IXC—Inter-eXchange Carrier. Long-haul long distance carriers. Also known as an IEC.

LAN—Local Area Network. A fancy name for a communications network connecting personal computers, workstations, printers, file servers and other devices inside a building or a campus.

MAN—Metropolitan Area Network. A high-speed data intra-city network that links multiple locations within a campus or city.

Layer 1 (L1)—Physical Layer. The Physical Layer deals with the physical means of sending data over lines (i.e. the electrical, mechanical and functional control of data circuits).

Layer 2 (L2)—Data Link Layer. The Data Link Layer is concerned with procedures and protocols for operating the communications lines. It also has a way of detecting and correcting error messages.

Layer 3 (L3)—Network Layer. The Network Layer determines how data is transferred between computers. It also addresses routing within and between individual networks.

Layer 4 (L4)—Transport Layer. The Transport Layer defines the rules for information exchange and manages end-to-end delivery of information within and between networks, including error recovery and flow control.

Layer 5 (L5)—Session Layer. The Session Layer is concerned with dialog management. It controls the use of the basic communications facility provided by the Transport layer.

Layer 6 (L6)—Presentation Layer. The Presentation Layer provides transparent communications services by masking the differences of varying data formats between dissimilar systems.

Layer 7 (L7)—Applications Layer. The Applications Layer contains functions for particular applications services, such as file transfer, remote file access and virtual terminals.

Mbps—Megabits per second. The transmission of exactly one million bits per second.

OC-12—Optical Carrier Level-12. SONET channel of 622.08 million bits per second.

OC-48—Optical Carrier Level-48. SONET channel of 2.488 thousand million bits per second (Gbps).

OC-192c—Optical Carrier Level-192. SONET channel of 9.95328 thousand million bits per second (Gbps).

OSI—Open Systems Interconnection. The only internationally accepted framework of standards for communication between different systems made by different vendors. ISO's goal is to create an open systems networking environment where any vendor's computer system, connected to any network, can freely share data with any other computer system on that network or a linked network. OSI was developed by the ISO.

PC—Personal Computer. A computer for one person's use.

PCS—Physical Coding Sublayer. Coding and serializer or muxing functions. The PCS is responsible for distinguishing between the two PHYs.

PHY—PHYsical. The physical layer, which is comprised of a PMD and a PCS.

PMD—Physical Media Dependent. This sublayer defines the parameters as the lowest level. An optical transceiver is an example of a PMD.

PoP—Point of Presence. The IXC equivalent of a local phone company's central office or the point at which an ISP exchanges traffic and routes at Layer 2.

QoS—Quality of Service. Quality of Service is a measure of the telephone service quality provided to a subscriber.

SAN—Storage Area Network. A network which links host computers to storage servers and systems.

SLA—Service Level Agreement. An agreement between a user and a service provider, defining the nature of the service provided and establishing a set of metric to be used to measure the level of service provided against the agreed level of service.

SONET—Synchronous Optical NETwork. A family of fiber optic transmission rates created to provide the flexibility needed to transport many digital signals with different capacities, and to provide a design standard for manufacturers.

SP—Service Provider. A telecommunications service provider or an organization that provides connections to a part of the Internet.

TDM—Time Division Multiplexing. A technique for transmitting a number of separate data, voice and/or video signals simultaneously over one communications medium by quickly interleaving a piece of each signal one after another.

TMN—Telecommunications Management Network. A network management model defined in ITU-1 recommendation M.30 and related recommendations, and intended to form a standard basis for management of advanced networks.

TLS—Transparent LAN Service. TLS provides native LAN speed interconnection of corporate sites within a local metropolitan area.

VLAN—Virtual LAN. A logical grouping of users regardless of their physical locations on the network.

VPN—Virtual Private Network. A private communications network that uses another communications network as its backbone.

VoP—Voice over Packet. The technology used to transmit voice conversations over packet-based networks. (The traditional telephone network is circuit-based).

WAN—Wide Area Network. A computer and voice network bigger than a city or metropolitan area which is treated differently than a LAN or MAN due to speed of light timing considerations.

WDM—Wavelength Division Multiplexing. A means of increasing the data-carrying capacity of an optical fiber by simultaneously operating at more than one wavelength.

WWDM—Wide Wavelength Division Multiplexing. A means of transmitting data on optical fiber by using parallel optics and spreading the wavelengths wider to eliminate the need for thermally controlled lasers.

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