White paper

Nortel Networks

Optical Ethernet overview

What if all corporations could connect buildings thousands of miles apart as easily as if they were just connecting two floors of the same building? What if every access and metro network was as simple, fast, and reliable as a Local Area Network (LAN)? What if Metro Area Networks (MANs) and Wide Area Networks (WANs), with their multiple hand-offs and protocol translations, physical distance and hundreds to thousands of users were as simple to manage as a single LAN today? Can you imagine the possibilities? Wouldn't it be revolutionary? The revolution is spelled Optical Ethernet.

NORTEL NETWORKS™

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What is Optical Ethernet?

Fundamentally, Optical Ethernet represents the combination and extension of two existing technologies, Ethernet and optics. This marriage takes the best of both Ethernet and optics and magnifies their capabilities to create a new networking paradigm that fundamentally changes the way service providers and corporations plan, manage, and operate their networks. It is a technology that combines the ubiquity, flexibility and simplicity of Ethernet with the reliability and speed of optics. The resulting Optical Ethernet attributes—simplicity, speed, and reliability—remove the bandwidth bottleneck between the LAN and the WAN. Optical Ethernet also provides network versatility to meet a wide range of customer needs. Optical Ethernet can be implemented in either private or public networks; can be configured for point-to-point, mesh, or ring topologies; and can be utilized for LAN, MAN, and WAN applications. Whether offered as a managed service by a service provider or operated as a private network by the corporation, Optical Ethernet transforms the corporate network into a key competitive advantage.

Today's Ethernet

Today's Ethernet has come a long way since it was first implemented in the 1970s. Ethernet originally ran over thick coax and provided users with a shared 10 Mbps bandwidth connection. Ethernet soon progressed to running over unshielded twisted pair and offering dedicated 10 Mbps connections using switches. Today, switched Ethernet enables dedicated 100 Mbps to the desktop with 1 Gbps trunks and, within a few years, industry experts predict 1 Gpbs to the desktop and 10 Gbps trunks. In the thirty-some years it has been in existence, Ethernet has become ubiquitous; a widely standardized, plug and play technology that is used in over ninety percent of corporate LANs *(see Table A)*. Ethernet has reached this level of acceptance because it is simple to use, inexpensive, and has proven its worth.

Table A. Worldwide NIC shipments

Technology	Year 2000
Total Ethernet *(10 Mbps, Fast E, Gigabit E)*	91%
Wireless LAN	6%
Token ring	3%
ATM	< 1%

Source: IDC, July 2001

Today's optics

Similarly, optical technologies have come as far as Ethernet in arguably a shorter amount of time. Optical transmission speeds have grown from tens of megabits-per-second to 40 gigabits-per-second and vendors have recently demonstrated the ability to put 1.6 terabits-per-second on a single optical fiber, using Dense Wavelength Division Multiplexing (DWDM). Optics tremendous capacity as well as advances in all-optical, or photonic, networking that eliminates the need for electrical regeneration, have secured optics as the preeminent transport technology.

Optical Ethernet—more than the sum of its parts

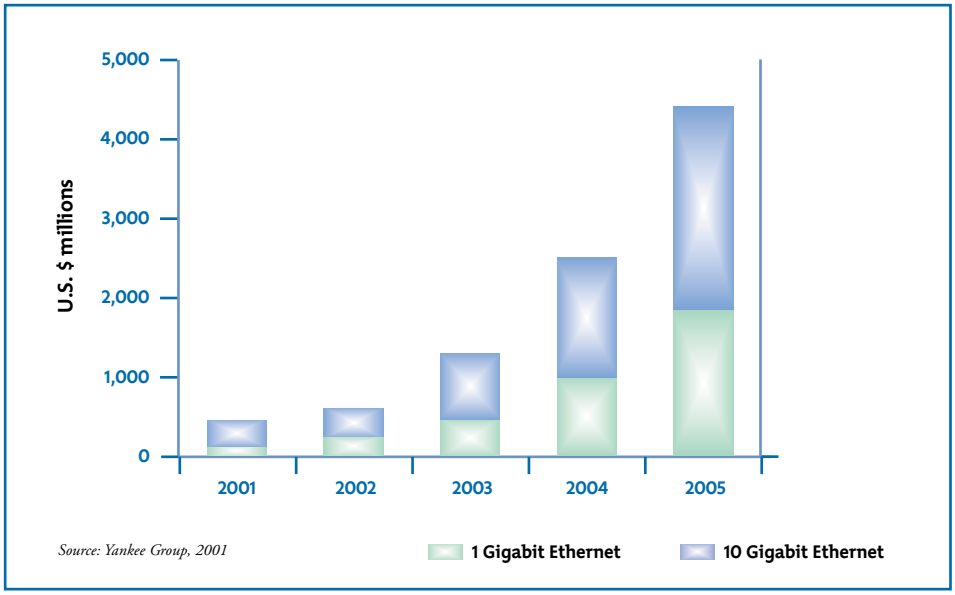
Optical Ethernet, however, is more than just Ethernet plus Optics. Industry standards bodies as well as vendors have been developing specific Optical Ethernet solutions that are more than merely running Ethernet over Optics. As a result, Optical Ethernet redefines the performance and economics of both service provider and corporate networks in several ways.

First, Optical Ethernet simplifies the network. As a Layer 2 connectionless technology, Optical Ethernet removes

Key network attribute	Today's networks	Optical Ethernet
Complexity	Higher • Multiple protocols from LAN to WAN	Lower • Ethernet from LAN to WAN
Access bandwidth	• Fractional T1s, T1s, T3s • Weeks to months to provision	• Up to 10 Gbps, 1 Mbps at a time • Hours to provision
Performance	• Higher latency • Higher jitter	• LAN performance end-to-end
Staffing	• Network specialists for each protocol	• Network generalists

Table B. Optical Ethernet simplifies the network

Figure 1. North American hardware revenue



the addressing network complexities and other network complexity issues seen with Frame Relay (FR) and Asynchronous Transfer Mode (ATM) based networks *(see Table B)*. As well, Optical Ethernet removes the need for multiple protocol conversions that create significant management headaches for network operators—because it is Ethernet end-to-end. Multiple protocol conversions also impede network performance by introducing latency and jitter into the network. Latency and jitter are two important attributes that describe the predictability and delay in a network and determine what services and applications can be effectively offered.

Optical Ethernet's network simplicity extends into the provisioning and reconfiguring of the network as well. No longer will businesses have to wait weeks or months for an additional T1 or spend time reconfiguring the network every time a change is made. Optical Ethernet's bandwidth can be increased or decreased without a service call and allows for network changes without reconfiguring each network element.

In addition to simplicity, speed is a key attribute of Optical Ethernet. With the deployment of Optical Ethernet, the bandwidth bottleneck is broken. Optical Ethernet connectivity allows for access speeds of 10 gigabits-per-second—orders of magnitude faster than today's T3s. Bandwidth is also available in more granular slices. No longer are Information Technology (IT) staffs forced to jump from a T1 to a T3 (1.5 Mbps to 45 Mbps) when all they really need is another megabit of bandwidth. Optical Ethernet access links can be increased in 1 Mbps increments to deliver bandwidth from 1 Mbps to 10 Gpbs or anywhere in between.

Moreover, Optical Ethernet topologies enable greater reliability than today's access networks can provide. For example, one type of Optical Ethernet solution—Ethernet over Resilient Packet Ring—provides for recovery in less than 50 milliseconds in the event of a catastrophic failure, such as a line cut. This high availability guarantees up time in networks that deliver mission critical applications.

Finally, Optical Ethernet is significantly less expensive than today's networks. The cost savings can be seen in both operational and capital cost savings. Merrill Lynch, in fact, estimates a 4:1 cost savings for gigabit Ethernet versus ATM or SONET (Synchronous Optical Network)[1]. A simple example of the infrastructure savings comes from the fact that Ethernet interface cards cost a fraction of what ATM or Packet over SONET interface cards cost. Nortel Networks is converting its own internal network to Optical Ethernet—a network that spans six continents. Estimates predict the cost savings will be between 30 and 40 percent.

Why now?

The convergence of multiple factors has caused the market discontinuity that Optical Ethernet is now fulfilling. First, as mentioned above, corporations are continuing to choke on the increasing complexity of their IT demands. IT network traffic is continuing to rise at dizzying rates, making network maintenance and provisioning a formidable challenge. To compound the situation, more traffic is going out of the corporate network into MAN and WAN networks, translating into more sophisticated and expensive equipment and operations. These factors drive the complexity of networks operations

[1] "Ethernet Everywhere", Merrill Lynch, March 13, 2001

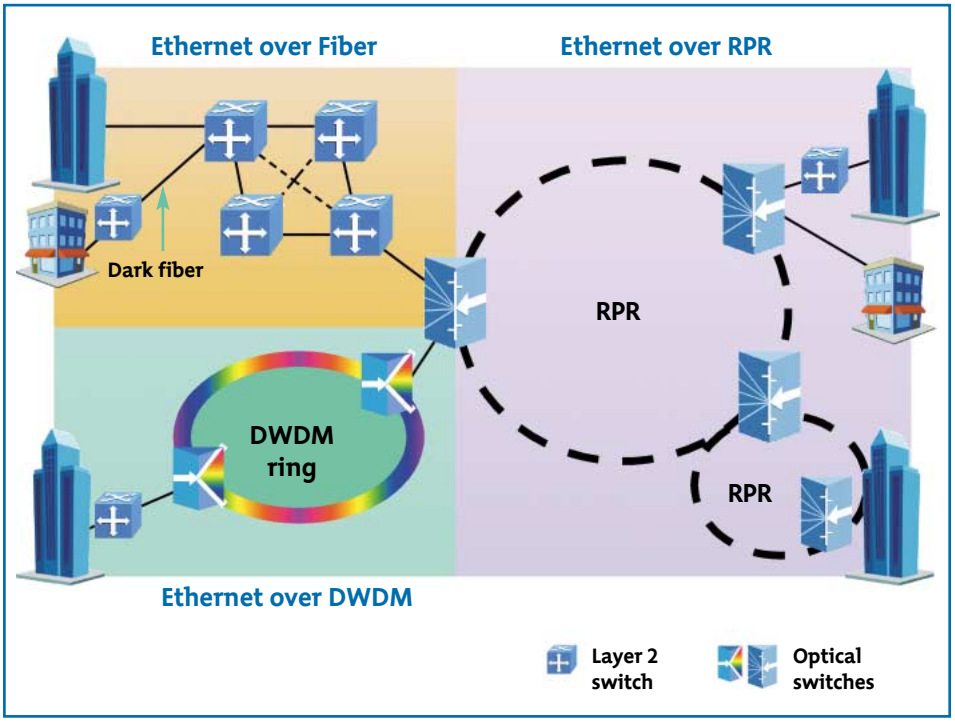
and staffing to the point that it becomes a distraction to the corporation's core business.

Second, bandwidth prices from service providers have been declining while IT labor costs have become more expensive. For service providers, this puts increasing pressure on them to find ways to move up the value chain away from undifferentiated products and services towards more profitable, value-added services. For corporations, this pushes them to look for ways to outsource or consolidate their IT networks.

Finally, technology advances have also occurred. Optical Ethernet needs fiber and the increasing availability of fiber to businesses has opened the door. Communications Industry Research has estimated that nearly one hundred thousand businesses in the U.S. have fiber access[2] and 35 to 45 percent of unconnected commercial buildings are within three-quarters of a mile of fiber[3]. Additionally, Ethernet has continually become faster, now reaching 10 Gbps, and Ethernet platforms have become more resilient and robust. Both improve Ethernet's fit in the MAN and WAN. For its part, optics has seen advances in the adoption of optical interfaces in networking equipment for corporations and service providers and optics has continued to extend the length over which it can travel.

Optical Ethernet is fulfilling the market discontinuity created by these factors. Optical Ethernet serves as the enabling infrastructure that allows corporations to outsource and consolidate all or part of their IT networks and allows service providers to efficiently and profitably offer IT network managed services. Together, these factors are driving significant demand for Optical Ethernet. The Yankee Group recently forecasted a cumulative $5 billion market and compound annual growth rate of ninety percent for Optical Ethernet equipment between 2001 and 2005 *(see Figure 1)*.

Figure 2. Optical Ethernet building blocks



Optical Ethernet building blocks

There are three basic building blocks that can be used to construct an Optical Ethernet network, whether private (corporate) or public (service provider). Each of these building blocks delivers its own advantages. Specific Optical Ethernet network topologies will vary depending upon the needs of the network operator and in many cases may include a hybrid approach that leverages multiple building blocks *(see Figure 2)*.

Ethernet over Fiber (EoF)
The first building block is Ethernet over Fiber. This implementation is simple electrical to optical translation over dark fiber. It can deliver functionality over point-to-point and mesh network topologies. EoF is a very cost-effective, high-performance (up to 10 Gbps) solution and can span distances as great 70 kilometers.

Ethernet over Resilient Packet Ring (EoRPR)
A second Optical Ethernet building block is Ethernet over Resilient Packet Ring. EoRPR is deployed in a ring topology and can take advantage of existing SONET infrastructure. One benefit of this type of implementation is that it solves the traditional problem of SONET bandwidth "waste" because in Ethernet over RPR, the SONET

[2] "Optical Access in the Public Network", Communications Industry Researchers, October, 2000
[3] "An Investor's Guide to Metropolitan Optical Services", Dain Rauscher Wessels, March 22, 2001

ring's bandwidth is utilized in both directions instead of only one. Additionally, Ethernet over RPR takes advantage of SONET's link-layer protection and provides less than 50 milliseconds fail-over. The RPR ring can span thousands of kilometers and provides a flexible, multi-service Optical Ethernet implementation.

Ethernet over DWDM (EoDWDM)
Ethernet over DWDM utilizes DWDM as its core transport. It delivers massive bandwidth for point-to-point, mesh, or ring implementations. EoDWDM is particularly effective in high-bandwidth, extreme-performance scenarios, such as information storage solutions or data center interconnection. EoDWDM is bite rate and protocol independent that allows it to work in almost any network scenario.

Hybrid
The above building blocks can also be merged together in hybrid implementations. Topologies can be combined as well, blending point-to-point, ring and/or mesh topologies, to deliver unique functionality Every corporation or service provider has unique requirements and objectives for their networks and Optical Ethernet is flexible and adaptable enough to fit almost any circumstance.

Corporate challenges and Optical Ethernet benefits

According to a recent survey by Forrester Research[4], 68 percent of Global 2500 corporations are looking for their IT networks to provide competitive advantage. IT networks can provide corporations with competitive advantages in a variety of ways. This would include faster delivery of information, better access to customers and suppliers, support for next-generation applications, enhanced employee collaboration and productivity, and improved resource utilization.

Corporations, however, face a variety of networking challenges when pursuing these objectives. Network complexity is increasing daily with the addition of new users, new nodes, and new network links. As traffic traverses the network from source to destination, it often undergoes a series of protocol translations, each of which adds complexity to the network. Network complexity represents the number one networking problem faced by the Global 2500[5].

The scarcity and expense of access bandwidth in today's networks represents an additional challenge for corporations *(see Figure 3)*. Today, corporate LANs run at hundreds of megabits per second. Similarly, WANs, built on optical systems capable of terabit speeds, are blazingly fast. Unfortunately, connections between the LAN and the WAN are extremely limited and have created an access bandwidth bottleneck. The average corporate site today uses a fractional T1 (multiple 64 Kbps channels), a full rate T1 (1.5 Mbps) or at best a T3 (45 Mbps) to connect their LAN to the WAN. While 45 Mbps may sound like a lot a first, consider the case of a corporate network with 100 desktops. Assuming 80 of the 100 desktops use a full-duplex 100 Mbps Ethernet network interface card, and that 75 percent of the traffic generated by those 80 desktops is destined for the WAN, 12 Gbps can converge on the business' access link at the same time. While this represents an extreme example, even 10 percent of the traffic, 1.2 Gbps, represents far more than a T3

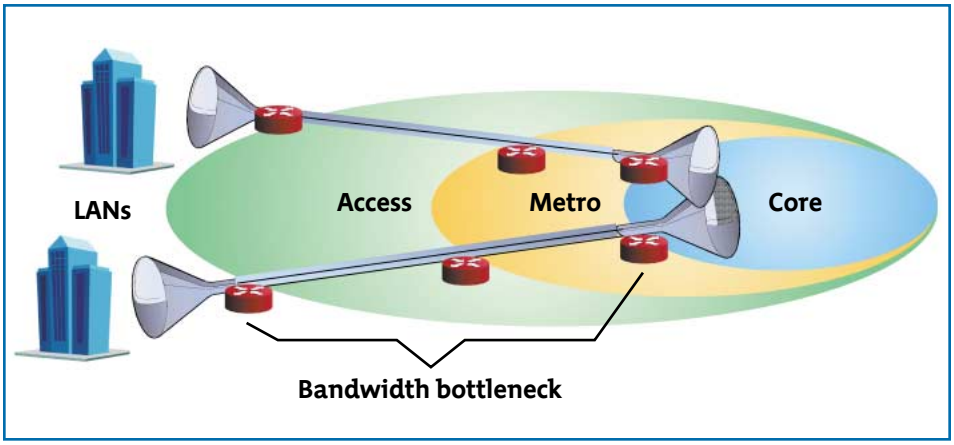


Figure 3. Bandwidth

[4] Forrester Research, "The New Enterprise Network", January, 2001

[5] Ibid 4

can provide. Compounding the problem of the access bandwidth bottleneck are the long provisioning times required for turning up new links—typically measured in weeks or months, and the inflexible nature of the service—corporations are unable to scale their bandwidth linearly and instead must scale their bandwidth in increments of T1s or T3s.

Network complexity and the access bandwidth bottleneck lead to a third challenge, poor network performance. Every time a packet undergoes a protocol conversion or requires a Layer 3 lookup, latency, jitter, and unpredictability are introduced into the network. Similarly, the access bandwidth bottleneck creates the need to throttle back the number of packets-per-second and to establish queues that add additional latency and jitter and degrade network performance. For existing applications and current networking paradigms, this level of performance may be acceptable. For CIOs implementing new applications or trying to consolidate network resources in the WAN, today's network performance represents a critical obstacle.

A fourth challenge confronting corporations is the issue of IT staffing. As networks have become increasingly complex, the skills required to run the network have become more and more specialized. In the past, network generalists could perform the majority of network jobs. Today corporations must recruit, hire, train, and retain network specialists with detailed knowledge of specific network functions, such as security or the operations and maintenance of each specific networking technology (e.g., IP, FR, ATM) used in the network.

Corporations that integrate Optical Ethernet in their own network or purchase Optical Ethernet as a managed service will see several benefits. First, Optical Ethernet removes the bandwidth bottleneck. Optical Ethernet delivers seamless bandwidth availability from the LAN to the WAN in speeds ranging from 1 Mbps to 10 Gbps, in 1 Mbps increments. Corporations can increase or decrease their bandwidth according to their own network plans, possibly speeding a new application deployment and increasing network utilization. According to a Nortel Networks business case, a corporation implementing an Ethernet over Fiber network can expect a 22X increase in available bandwidth and 34 percent savings in total cost of ownership when compared to a T3 access solution.

As previously discussed, Optical Ethernet is a technology that is simpler in terms of network management, hardware and software requirements, and IT staffing levels. Simplicity translates into cost savings as more common and less expensive networking equipment is needed with fewer and less specialized IT staff managing the network. Server and router consolidation savings are easily seen through data center and Internet access consolidation. Finally, Optical Ethernet helps deliver competitive advantages to corporations by enabling mission critical and productivity-increasing applications to be easily and securely deployed in the network. Network Area Storage (NAS) and video conferencing are only two examples of applications that can take advantage of the bandwidth availability and low latency and jitter that Optical Ethernet delivers.

Service provider challenges and Optical Ethernet benefits

Service providers, today, also face networking and business challenges. Key challenges for service providers include: increasing revenue generation, reducing costs, managing product life cycles, and addressing access bandwidth bottlenecks.

Revenue generation is always a major concern for service providers as they continually seek to enhance the value of the products they sell. This is a key challenge for service providers as pricing pressures are a constant battle. For example, at the end of 1998, service providers' wholesale bandwidth prices were falling by 50 percent every 18 months. Since the middle of 2000, prices have been dropping by 50 percent every six months[6]. Service providers are continually looking for ways to add value and competitive differentiation to the products that they sell.

In close relation, service providers must closely manage their costs. As their core networks become more and more complex, the related costs of maintaining and managing those networks increases as well. The human resource costs alone have risen dramatically as network specialists are needed to manage different portions of the network.

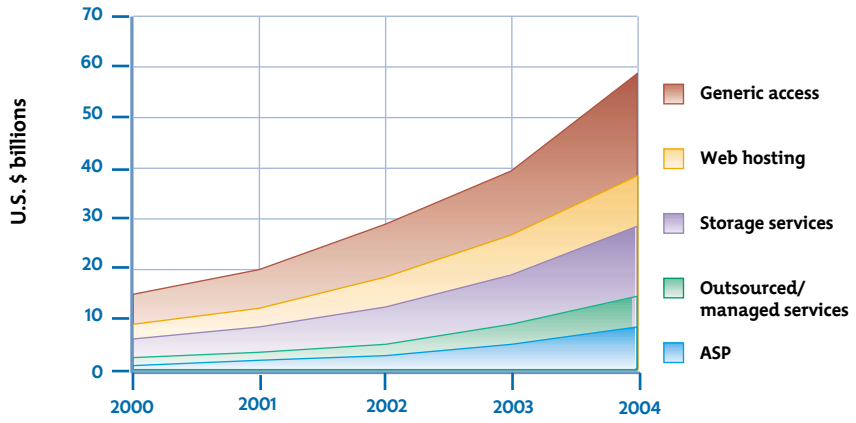
[6] Red Herring, January 16, 2001

Service providers also have to regard the products and services that they sell to their end-customers as a portfolio. Product portfolios need active management to ensure new products and services are in the pipeline to compensate for more mature or declining products and services. This aspect of their business naturally impacts both revenue generation and overall cost reductions.

Finally, as with corporations, service providers battle the access network bottleneck. As their core networks reach out to their end-customers in urban and rural areas, service providers are faced with managing different types of access facilities (copper, fiber, wireless, etc.) with corresponding bandwidth variations and, often times, different network technologies (ATM, IP, FR, etc.). These access network constrictions impact the quantity and quality of the services and products that they can sell into a given market.

Service providers can derive the same types of benefits that corporations see as they offer Optical Ethernet as a managed/outsourced service to corporations. By bundling applications such as storage solutions, Voice over IP, or eCommerce applications with connectivity services, service providers can provide higher value-added product bundles to their portfolios and capture their share of the growing value-added services market *(see Figure 4)*. Bundled services are harder to duplicate by competitors and prevent price and margin erosion. Nortel Networks tests revealed that Optical Ethernet reduces latency by over thirty percent and reduces jitter by over ninety percent when compared to traditional routed networks. This provides the high performance needed by these more sophisticated applications and will allow service providers to deliver value-added services and applications. Finally, Optical Ethernet gives service providers a future-looking network from which new products and services can continue to evolve, ensuring continued profitability of their product portfolios.

Figure 4. U.S. market—value-added services



Source: IDC & Probe Research Reports, 2000 and 2001

Summary

Optical Ethernet delivers today what could only be imagined before. It fundamentally changes the way networks are being designed, built, and operated by creating a new networking solution that extends the boundaries of the LAN environment to encompass the MAN and WAN. By providing a seamless evolution path, Optical Ethernet allows service providers to increase their revenue and decrease costs while continuing to support legacy services. It allows corporations to gain competitive advantage from their networks by reducing IT costs, delivering information faster, increasing employee productivity and improving resource utilization. The coming Optical Ethernet revolution will only be limited by our imaginations, delivering in one solution, a fast, simple, and reliable network.

Appendix I

Nortel Networks Optical Ethernet solutions

The Nortel Networks Optical Ethernet solutions are one of the most diverse and highest performing in the industry. They constitute point-to-point, ring and mesh network topologies and leverage Nortel Networks industry leading Ethernet and Optical portfolios. Nortel Networks Optical Ethernet portfolio is composed of several leading edge products, all available today, including: the Passport 8600 Routing Switch, the OPTera Packet Edge System, the OPTera

Metro product portfolio (OPTera Metro 3000 and 5000 series), Business Policy Switch 2000 and the Preside network management system. More information on Nortel Networks Optical Ethernet portfolio can be found at www.nortelnetworks.com/oe.

Nortel Networks Optical Ethernet solutions can be implemented in several ways including:

- Ethernet over Fiber using the Passport 8600 Routing Switch and Business Policy Switch 2000
- Optical Ethernet over Resilient Packet Ring using the OPTera Packet Edge Systems on the OPTera Metro 3000 series
- Ethernet over DWDM using the OPTera Metro 5000 series
- Hybrid Optical Ethernet solutions that combine the above

Nortel Networks is committed to leading the industry in Optical Ethernet solutions. Some of our leadership areas include:

- First vendor to demonstrate WAN-compatible 10 gigabit Ethernet
- A leader in both the Metro Optical and Ethernet Switching markets
- Standards leadership—such as co-authoring the IEEE's 10 Gigabit Ethernet and Resilient Packet Rings Standards groups and continued activity in related working groups of the IETF, ANSI, and ITU
- Founding member of the 10 Gigabit Ethernet Alliance, Resilient Packet Ring Alliance, and Metro Ethernet Forum

Appendix II

Nortel Networks Optical Ethernet applications

Nortel Networks Optical Ethernet solutions deliver and enable an extraordinary number of services and applications. These services generally fall into two categories—connectivity-type services and enabled services *(see Figure 5)*. Connectivity-type services include basic services such as private line and access services, aggregation and backhaul, and LAN extension.

Additionally, Optical Ethernet delivers a second category of services and applications generally called "enabled" services. Examples of these applications and services include managed services (applications hosting, disaster/recovery and storage solutions) and industry specific applications (supply chain management, customer relationship management, and transaction based, e-commerce applications). These "enabled" services can include any application or service that requires a high level of network performance. For example, voice over IP is an application ideally suited for Optical Ethernet in that it requires low levels of network latency and jitter. Network storage and disaster/ recovery services are another example of services requiring Optical Ethernet network performance. These services both require "real-time" end-to-end network performance, plentiful bandwidth availability, and the highest levels of reliability and security.

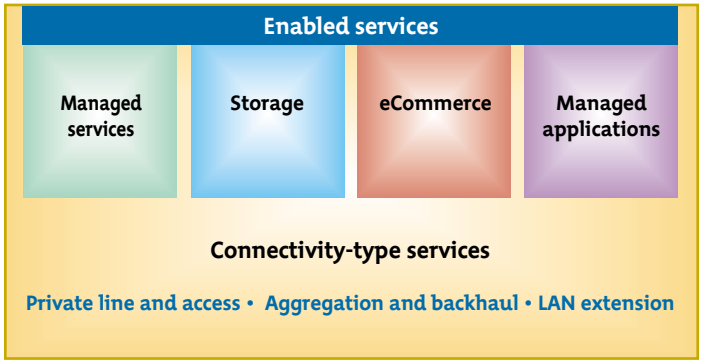
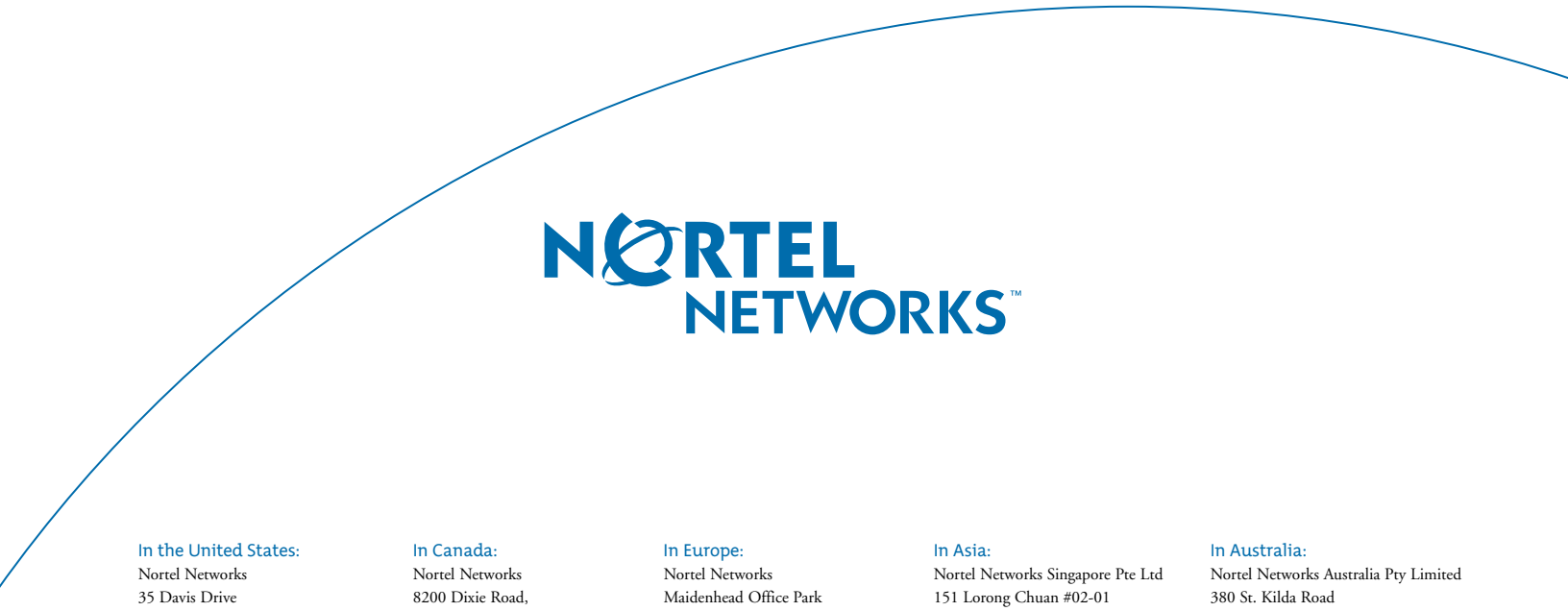


Figure 5. Enabled and connectivity-type services



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