A Transition Path to Gigabit Ethernet over WDM in Support of Emerging e-Business Applications

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Abstract: - This paper deals with a real-world Gigabit Ethernet over WDM migration at a corporate headquarter of a well known international organisation. A prominent communications provider had need to upgrade its enterprise network in order to ensure reliable infrastructure support to the emerging e-business applications.

Keywords: Gigabit Ethernet Technology, WDM, e-Business, Internet/Intranet

1 Introduction

The Internet Revolution is changing how we do business. Recent advances in mission-critical web applications (enterprise resource planning, e-commerce, Voice-over-IP, server co-location and private Intranets), together with the wide-spread use of the public Internet, are encouraging the development of new business and consumer relationships. A growing number of e-business applications are helping plan and manage resources, distribute information, provide customer services, and enable electronic commerce. Information is available from multiple sources, network traffic is unpredictable and performance demands are great. Change is rapid and constant. And the emergence of newer applications will keep the momentum of change moving.

Twenty-first century businesses require intelligent and economical networks to gather, publish, share and modify information. At the base of any successful e-business application is a highly sophisticated, high-performance network. Corporate network can become the most strategic asset and the most powerful competitive advantage in the marketplace. E-business packages generally assume a highly scalable and available Internet Protocol (IP) network infrastructure. To support them, traditional local area network (LAN) infrastructures must be upgraded to higher-performing switched topologies.

Traditional wide area networks (WAN) may also need to be upgraded to higher-speed services (xDSL, cable modems, ATM, Frame Relay, ISDN) to ensure robust application performance over WAN and remote access connections [1, 2, 3, 4, 5, 6]. What's more, Quality of Service (QoS) is a necessity when mission-critical e-business application traffic is moving across the network.

The long-term implication is that users will increasingly demand solutions for gigabit networking whose specific requirements include tens if not hundreds of gigabits per second of total network capacity, any-to-any communication, smooth migration of scalable performance that can be incrementally implemented anywhere in the network, and strong compatibility with the infrastructure of existing enterprise networks.

The New Internet Economy is profoundly transforming all private enterprises and public institutions. The question is no longer if or when it will impact an organization, but rather how to execute the transformation.

2 Gigabit Ethernet Technology Overview

Gigabit Ethernet provides 1Gb/s throughput (2Gb/s full-duplex) for campus networks with the simplicity of Ethernet at lower cost than other technologies of comparable speed. All three Ethernet speeds use the same IEEE 802.3 frame format, full-duplex operation and IEEE 802.3x flow control methods [7]. In half-duplex mode, Gigabit Ethernet employs the same fundamental Carrier Sense Multiple Access with Collision Detection (CSMA/CD) protocol to resolve contention for the shared media.

The emergence of Intranet applications portends a migration to new data types, including video, voice and 3-D visualizations of complex images. In the past it was thought that video might require a different networking technology designed specifically for multimedia. But today it is possible to mix data and video over Ethernet through a combination of the following:

- Increased bandwidth provided by Fast Ethernet and Gigabit Ethernet, enhanced by LAN switching,

- The emergence of new protocols, such as Resource Reservation Protocol (RSVP), that provide bandwidth reservation.
- The emergence of new standards such as 802.1Q and 802.1p which will provide virtual LAN (VLAN) and explicit priority information for packets in the network,
- The widespread use of advanced video compression such as MPEG-2.

These technologies and protocols combine to make Gigabit Ethernet an extremely attractive solution for the delivery of video and multimedia traffic, as illustrated in Figure 1.

Capabilities	Gigabit Ethernet	Fast Ethernet	ATM	FDDI
IP Compatibility	Yes	Yes	Requires RFC 1557 or IP over LANE today; I-PNNI and/or MPOA in the future	Yes
Ethernet Packets	Yes	Yes	Requires LANE	Yes, though 802.1h translation bridging
Handle Multimedia	Yes	Yes	Yes, but application needs substantial changes	Yes
Quality of Service	Yes, with RSVP and/or 802.1p	Yes with RSVP and/or 802.1p	Yes with SVCs or RSVP with complex mapping from IETF (work in progress)	Yes, with RSVP and/or 802.1p
VLANs with 802.1Q/p	Yes	Yes	Requires mapping LANE and/or SVCs to 802.1Q	Yes

Figure 1. High-Speed Network Capabilities

Gigabit Ethernet, like all Ethernet specifications, specifies the data link (layer 2) of the OSI protocol model [8]. Gigabit Ethernet provides high-speed connectivity, but does not by itself provide a full set of services such as Quality of Service (QoS), automatic redundant fail-over or higher-level routing services; these are added via other open standards.

802.1p and 802.1Q (Layer 2 functions) facilitate quality of service over Ethernet by providing a means for "tagging" packets with an indication of the priority or class of service desired for the packet. These tags allow applications to communicate the priority of packets to internetworking devices.

RSVP support can be achieved by mapping RSVP sessions into 802.1p service classes. The Resource Reservation Protocol (RSVP) is a network-control protocol that enables Internet applications to obtain special qualities of service (QoSs) for their data flows. RSVP is not a routing protocol; instead, it works in conjunction with routing protocols and installs the equivalent of dynamic access lists along the routes that routing protocols calculate. RSVP occupies the place of a transport protocol in the OSI model seven-layer protocol stack [9]. RSVP has gained industry acceptance as a preferred way to request and provide quality of network connections.

The Layer 3 functions can be scaled in multiple ways that provide implementation options: one option is on a system basis; the second is by distributing Layer 3 functionality around the network. Putting Layer 3 switching in the distribution layer and backbone of the campus segments the campus into smaller, more manageable pieces [10]. Layer 3 switching is hardware-based routing. Traditional software-based routers forward in the 500,000 packets per second range. Layer 3 switches forward up to 8 million packets per second [11]. Although they both route packets,the integration of forwarding using high-speed ASIC (Application-Specific Integrated Circuit) technology differentiates Layer 3 switches from traditional software-based routers. Like intelligent, high-performance Layer 2 switches, Layer 3 switches support flexible deployment options such as port aggregation and virtual LANs. They also deliver advanced levels of network management with extensive built-in Layer 2 Remote Monitoring (RMON) capabilities, as well as higher-level RMON2 monitoring capabilities [12]. In addition, Layer 3 switches can use their packet-by-packet filtering capability to support Class of Service (CoS) and Quality of Service (QoS) based on the IEEE 802.1p and the 802.1Q standards as well as RSVP bandwidth reservation scheme.

Link or port aggregation or trunking often comes up in discussions of Gigabit Ethernet migration. 802.3ad link aggregation is a technology that allows multiple physical links to be treated as a single aggregate logical link [13]. Gigabit Ethernet links can be aggregated with link aggregation technology. The advantages of link aggregation are higher bandwidth, redundant links, and load sharing.

Wavelength division multiplexing (WDM) is a layer 1 transparent transmission technology that puts data from different sources together on an optical fiber, with each signal carried on its own channel (a channel is a separate light wavelength within a combined, multiplexed light stream).

Various implementations of Gigabit Ethernet may include one or more of these standards in order to provide a more robust or functional networking connection, but the overall success of Gigabit Ethernet is not tied to any one of them. The advantage of modular standards is that any one piece may evolve and be adopted at a pace determined by market need and product quality.

The IEEE 802.3z Gigabit Ethernet standard specified three transceivers to cover three media:

- 1000Base-LX — Full-duplex operation with long-wavelength (1300nm) devices over multimode or single-mode optical fiber. 1000BASE-LX is targeted at longer multimode building fiber backbones and single-mode campus backbone.
- 1000BASE-SX — Full-duplex operation with short-wavelength (850nm) devices over multimode optical fiber. 1000BASE-SX is targeted at lowest cost multimode fiber runs in horizontal building cabling and shorter backbone applications.
- 1000BASE-CX — Full-duplex operation over copper cable that could be used for interconnection of clusters in equipment rooms [14].

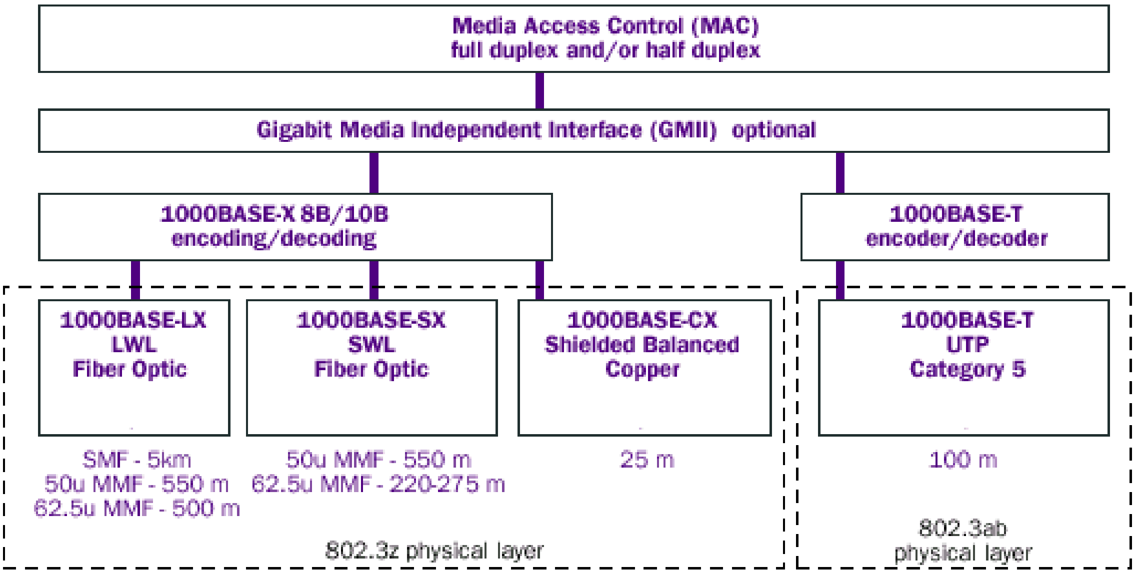

Figure 2. Gigabit Ethernet Media Options and Standards

Another task force, IEEE 802.3ab, has defined the physical layer to run Gigabit Ethernet over the installed base of Category 5 cabling at distances of up to 100 meters. Figure 2 summarises the various Gigabit Ethernet options and the standards that define them.

Any Category-5 UTP wiring that is able to support 100Base-T transmission should successfully support Gigabit Ethernet over Copper as well. If necessary, the relating corrective actions are defined in a simple field procedure detailed in the ANSI/TIA/EIA-TSB-95. The Gigabit Ethernet Alliance recommends that all new cable installations designed for 1000BASE-T deployment should be specified as Category 5e (enhanced Cat 5).

3 Objective

Growing number of users on the network, more current applications, faster desktop computers, and faster network servers have created a demand for higher-performance LAN segment capacity and faster response times. Bandwidth enhancement beyond Fast Ethernet is needed to provide smooth network operation in the face of emerging bandwidth requirements.

Migration toward gigabit bandwidth on the LAN backbone should provide the International communications industry leader with appropriate infrastructure to meet the needs of evolving enterprise network. Preservation of installed user applications, network operating systems, network equipment, and network management are highly desirable, as network bandwidth migrates to gigabits per second. However, the increase in bandwidth and network layer performance must be available in incremental, manageable steps, thus providing a migration to gigabit networking, which is cost effective and practical to implement.

The key challenge is to deploy scalable, flexible network that will accommodate growing demands for bandwidth, stability, and manageability, while minimizing the financial impact on existing network infrastructure.

4 Requirements

To successfully scale a campus network, several key requirements have been addressed:

- Existing and emerging applications will require higher bandwidth and lower latency.

- Compatibility with installed servers, desktops and network equipment.
- Protocol compatibility is important to leverage existing applications and to smooth migration.
- Gigabit Ethernet leverages other technologies such as Class of Service (CoS) traffic prioritisation and Quality of Service (QoS) data delivery to limit jitter and latency.
- Integration of data, video, and voice services can be a key objective for cost reduction. Here, consolidation of WAN services, the campus backbone, and management simplify and lower cost.
- The availability of networking products, embedded management agents and management application is a key factor and must be consistent with the planned deployment for scaling campus network performance.

5 Migration Scenario

The following scenario details a practical solution for network migration to Gigabit Ethernet technology. International communications provider has also planned to extend its Milan based headquarter to another building. Figure 3 shows the original enterprise network architecture. In this scenario:

- Core router fails to solve the problem of scalability because software-based routers have limited capacity and port density.
- Users on the switched segments are experiencing bottlenecks from their 10 Mbps links.
- Users on the shared segments are experiencing slow response times.
- Cabling system is based on Cat 5 copper wiring.

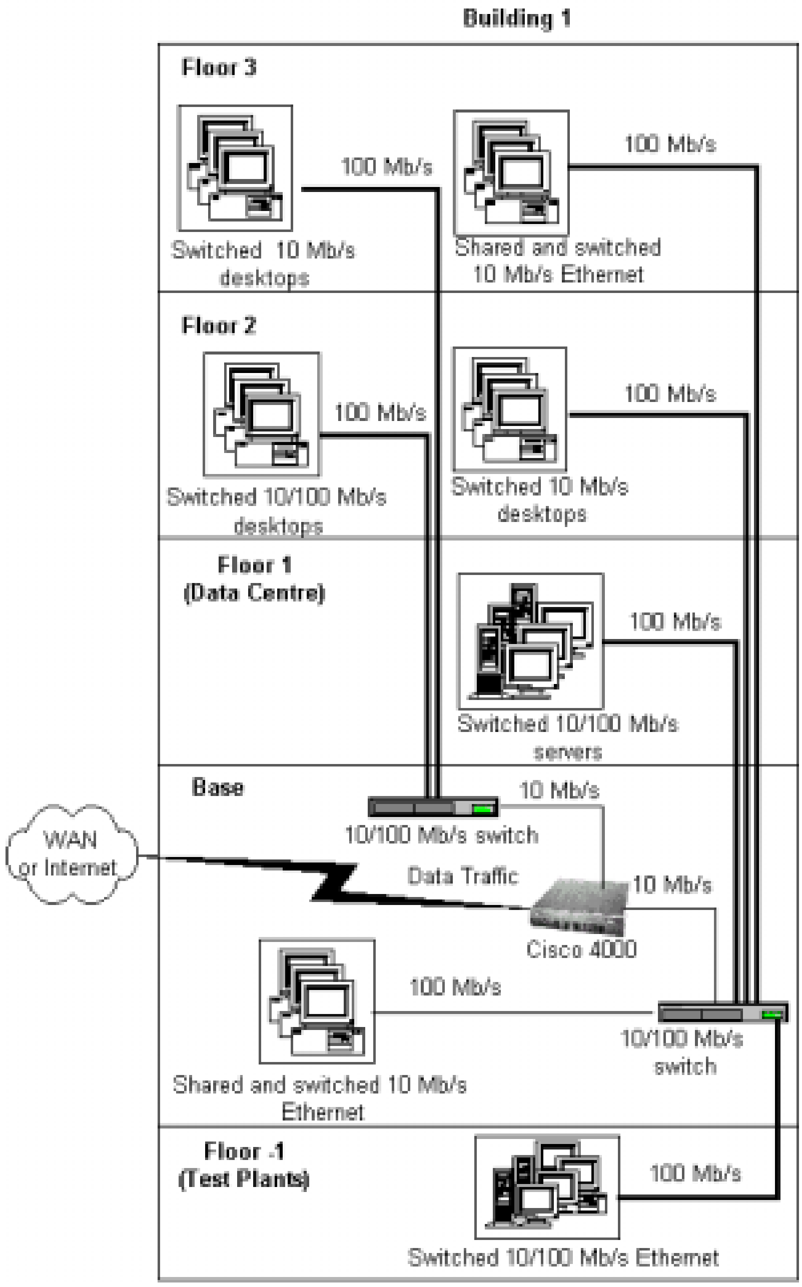

Figure 3. Original Enterprise Network

Migration to Gigabit Ethernet has been implemented by employing the following Extreme Networks Layer3 switches having a non-blocking internal architecture:

- The Alpine 3808 is designed for high-density, high-reliability core applications [15]. With up to 32 Gigabit Ethernet or 256 10/100BASE-T ports (internal capacity of 64 Gb/s), it acts as a collapsed backbone that aggregates multiple segments and risers into a central star.
- The Summit4 has 16 10/100 Mb/s (Megabit per second) Ethernet ports, six Gigabit Ethernet ports and an internal capacity of 17.5 Gb/s (Gigabit per second). The Summit4 is designed to meet integrated server switching requirements [16].
- The Summit48 has 48 10/100 Mbps Ethernet ports, two Gigabit Ethernet ports and an internal capacity of 17.5 Gb/s [17]. The Summit48 was deployed for distribution switching and, in cascade to Summit4, for segment and end stations switching.
- The Summit24 has 24 10/100 Mbps Ethernet ports, one Gigabit Ethernet port and an internal capacity of 8.5 Gb/s. The Summit24 was deployed, where needed, in cascade to Summit48 or Summit4 for segment and end stations switching.

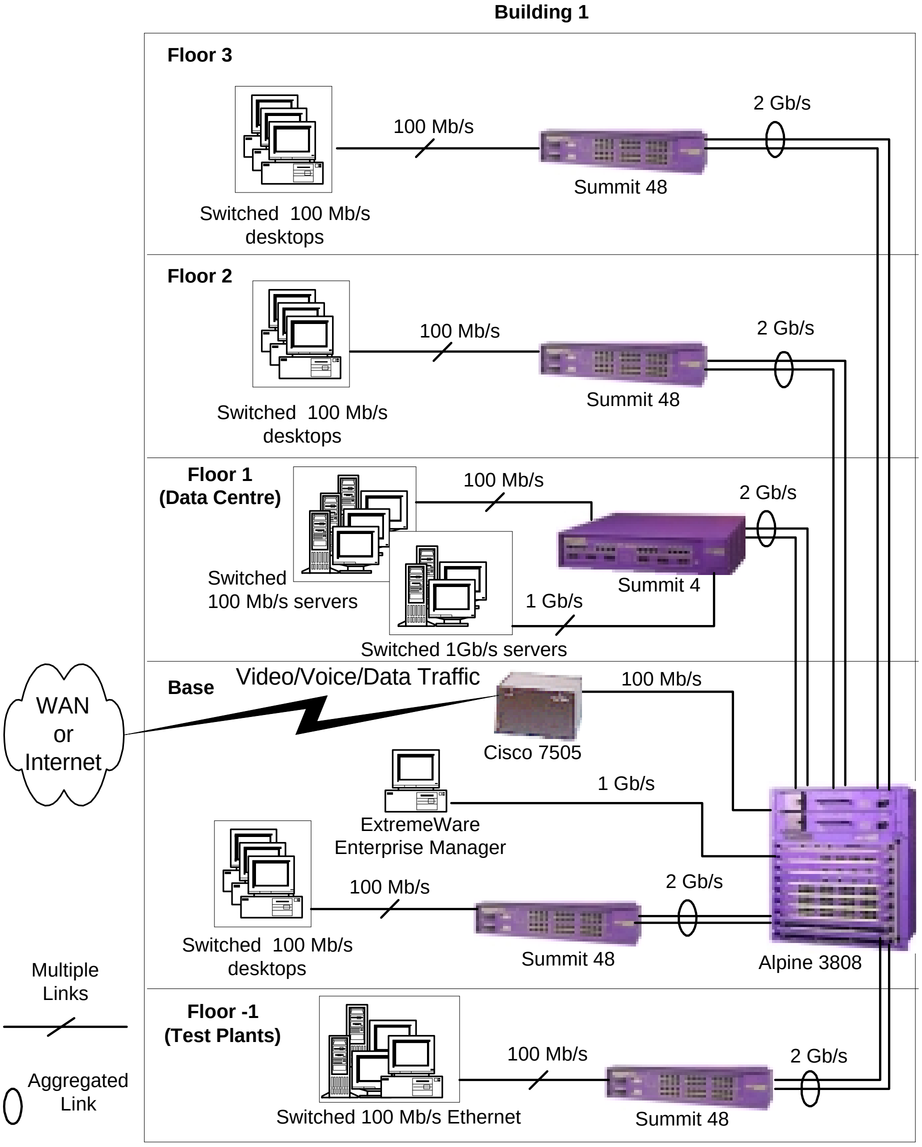

Figure 4. Enterprise Network Upgrading (Phase 1)

Figure 4 illustrates the first upgrading phase, implemented in four areas:

- Upgrading the building 1 backbone to fiber optic (multimode fiber connecting to Summit48 and Summit4 access switches) while leveraging horizontal copper wiring (Cat 5).
- Upgrading the building 1 backbone to 2 Gb/s aggregated link.
- High-performance servers can be connected directly to the backbone with Gigabit Ethernet NICs increasing throughput to the servers.
- Upgrading to 100 Mb/s Fast Ethernet connections between the end stations and relative access switches to deliver increased performance to the desktop cost-effectively.

The ExtremeWare Enterprise Manager platform was employed to ensure an efficient network management. WAN connection was upgraded to Cisco 7505 to deliver solution for the evolving enterprise-wide multiservice network.

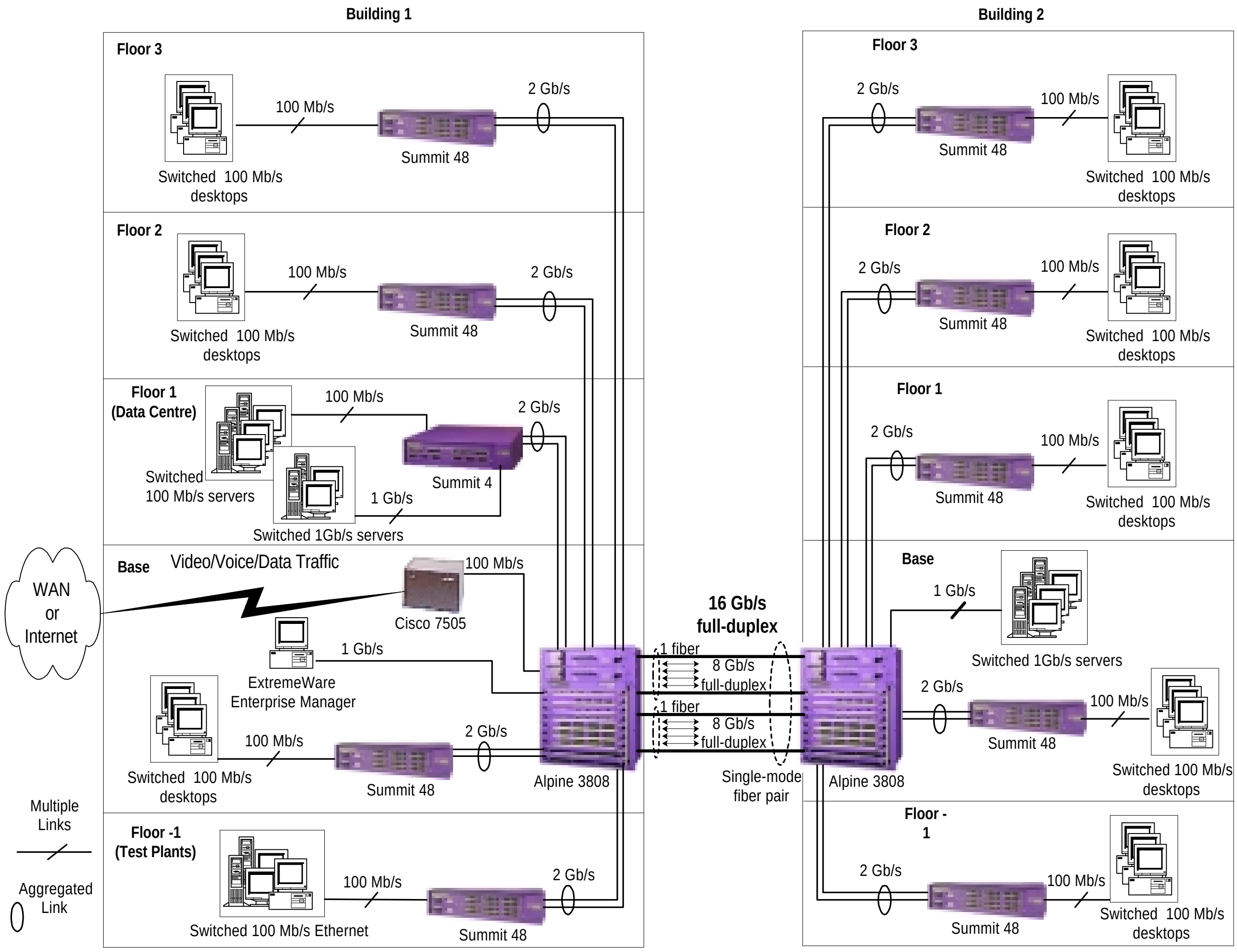

Figure 5. Upgraded Enterprise Network (Phase 2)

Figure 5 shows the upgraded enterprise network after the Phase 2 completion. Building 2 cabling is based on fiber optic (multimode fiber connecting to Summit48 and Summit4 access switches) and Cat5e (horizontal copper runs).

Gigabit Ethernet was deployed over WDM infrastructure at the corporate backbone, connecting two Alpine 3808 switches. The Alpine3808 switches integrate state-of-the-art WDM technology to optically multiplex eight full-duplex Gigabit Ethernet channels (eight discrete light wavelengths between 1500 and 1550 nanometers) onto one single-mode fiber pair, providing a throughput of 16 Gb/s full-duplex in the corporate backbone [18]. Furthermore, the eight channels are multiplexed so that four full-duplex channels go to one single-mode fiber and four full-duplex channels go to the other. In this way, a bidirectional traffic in each single-mode fiber makes up the pair. In addition to supporting alternate-path routing over single-mode optical fiber, this approach adds far more resiliency and fault tolerance to existing optical network infrastructure. In the Figure 5, if one fiber in the single-mode fiber pair fails, the other fiber will continue to handle full-duplex traffic between Alpine3808 switches at gigabit speed and avoid disrupting network services and e-business transactions.

6 Conclusion

The upgraded enterprise network now supports a greater number of segments, more bandwidth per segment and multiservice provisioning. Elaborated practical solution for a corporate network migration to Gigabit Ethernet demonstrates the flexibility and strength of Ethernet to power applications and to dispel the belief that customers require expensive ATM connections at the desktop to run rich, enterprise-wide e-business and multimedia applications. Ethernet is a multimedia-ready technology, capable of supporting Gigabit-size bandwidths, traffic prioritisation and multicasting at roughly one-third the cost of ATM to the desktop.

Ethernet is very much alive because it is the most widely deployed LAN networking protocol [19]; because alternative technologies that might have displaced it were and remain more complex, more costly, and require forklift upgrades; and because technologists have extended the capabilities of the original version 1.0 Ethernet so manifestly that it still meets the communication needs of current LAN users. The network that Metcalfe and Boggs invented will be sending packets efficiently into the new century.

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