Deploying Gigabit Ethernet to the Desktop: Drivers and Applications

The Federal Reserve estimates that the greater use of information technology accounts for 60 percent of the gains in the non-farm business workplace productivity since 1995. One factor that has allowed this improvement is the drop in semiconductor costs and the associated drop in costs of PCs, which have enabled enterprises to enhance their use of information technology. Although the cost of software and communications equipment has not similarly declined, the price drop in high-speed computers has encouraged application development and improved the delivery of information to the desktop, which in turn has helped enterprises reduce the cost of travel and education.

Summary

Gigabit Ethernet has emerged as the technology of choice in LANs. Recently, use of 1000BASE-T, designed for use over unshielded twisted pair copper cable, has grown rapidly as users discover the performance benefits of Gigabit Ethernet to the desktop. Many factors are driving this industry trend:

- The price of Gigabit Ethernet over copper has dropped dramatically. Research from IDC shows that the average price for a fixed-configured Gigabit Ethernet switch port has dropped from about $800 per port when the technology was introduced in 1998 to less than $100 per connection in 2003. Likewise, Gigabit Ethernet Network Interface Cards (NICs) have decreased in price from an average of $500 in 1999 to less than $50.
- New, high-density switches allow users to deploy Gigabit Ethernet over their existing infrastructures of Category 5/5e cable, eliminating the need to rewire the LAN.
- The most important factor is that users implementing Gigabit Ethernet to the desktop are realizing significant, measurable, and immediate improvements in performance and productivity.

With the costs dropping more than 50 percent in the past six months, Gigabit Ethernet from the server to the desktop is now an affordable solution. End station manufacturers (including HP, Apple, Dell, Gateway, Sun, and IBM) are now shipping systems enabled for Gigabit Ethernet. Whether the connectivity is NIC-based or integrated in a LAN on the motherboard, the performance improvements are significant and will keep getting better. Therefore, Gigabit Ethernet to the desktop is no longer a question of if, but of when.

Gigabit Ethernet to the desktop will boost network performance in almost all cases. User response time will improve. Server performance will improve. Overall network capacity and responsiveness will increase. This white paper addresses the ways in which Gigabit Ethernet to the desktop can increase network performance and user productivity.

Introduction

Ethernet has been the most pervasive networking technology for the LAN since the 1970s. Initially, Ethernet ran at speeds of 10 Mbps over coaxial cable, then moved to fiber and unshielded twisted

pair (UTP) cable. In 1995, the IEEE approved the Fast Ethernet standard. Fast Ethernet, which runs at speeds of 100 Mbps, provides 10 times the bandwidth and additional features, such as auto-negotiation. Full-duplex capabilities were added with the 802.3x standard in 1997. Coupled with an attractive price, Ethernet has become a scalable and widely deployed technology.

After the IEEE developed and implemented the Fast Ethernet standard, an industry consortium called the Fast Ethernet Alliance pushed interoperability between vendors. Eleven companies formed a similar alliance, called the Gigabit Ethernet Alliance in May 1996. Soon after, the IEEE announced the formation of the 802.3z Gigabit Ethernet Standards project. The 802.3z standard was adopted in June 1998.

As manufacturing costs of Fast Ethernet technologies brought the cost-per-port of 10/100BASE-T near that of 10 Mbps the migration to 10/100-Mbps Ethernet began in earnest. As desktop computers improved their ability to process information at high speeds, businesses began to move from shared 10-Mbps to switched 10-Mbps to switched 10/100-Mbps at the desktop.

Gigabit Ethernet to the desktop is the next logical step in the movement toward higher bandwidth speeds. Gigabit Ethernet retains the Carrier Sense Multiple Access/Collision Detect (CSMA/CD) protocol, frame format, and support of full-duplex and half-duplex modes of operation of its 10-Mbps and 100-Mbps predecessors. Initially, the 802.3z standard defined support for single-mode fiber, multimode fiber, and shielded copper cable (short haul).

What is Driving the Technology?

There are a couple of critical drivers bringing Gigabit Ethernet to the desktop.

- First, the price is compelling. Considering the tenfold increase in performance for a relatively small incremental cost, the move to Gigabit Ethernet to the desktop is financially attractive. With the 802.3ab specification, existing Category 5/5E cable can be used for all hosts connected by Ethernet, Fast Ethernet, and Gigabit Ethernet. The 10/100/1000-Mbps Ethernet ports available on high-density LAN switches today allow the network manager to migrate as business and budget dictate higher-speed end stations.
- Second, the increase in speed at the end station enables employees to be vastly more productive. Based on the volume of network-based applications used in business today, corporations are spending countless dollars while employees wait for information to make decisions critical to business operations. Reducing that wait time saves money for the company. So not only does a faster network transfer data faster, but it also improves the efficiency of the end user.

Decreasing Cost

At first, implementing Gigabit Ethernet required an infrastructure with fiber-optic cable, which meant that network managers were often forced to rewire portions of their buildings, particularly in the risers or between wiring closets. This issue was resolved in 1999, when the IEEE adopted an industry standard for Gigabit Ethernet over standard Category 5 copper cabling (802.3ab), commonly called 1000BASE-T. This made widespread deployment of Gigabit Ethernet over the existing copper infrastructure affordable. Because the vast majority of desktop connections are made over UTP, this industry standard has made the deployment of Gigabit Ethernet to the desktop possible.

Another trend leading to the widespread adoption of Gigabit Ethernet to the desktop is the inclusion of Gigabit Ethernet adapters on the PC motherboards. According to the data from the

Dell\QOro group, Gigabit Ethernet NICs and LAN-on-the-motherboard connection sales increased 421 percent between the first and third quarters of 2002, from 691,000 to 3.6 million units. LAN-on-the-motherboard (Gigabit Ethernet copper) interface sales over the same period saw growth of 659 percent, from 435,000 to 3.3 million units.

Improving Performance and Productivity

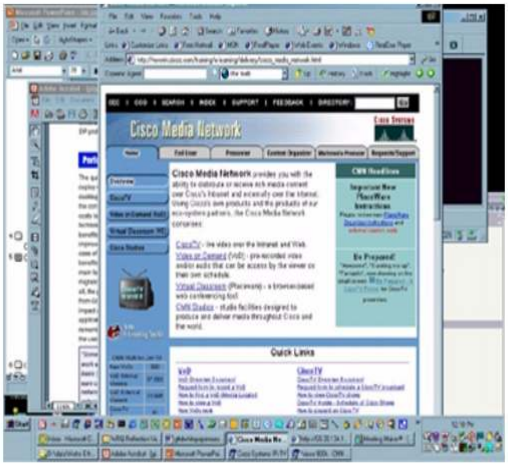
The simultaneous use of multiple applications by users in today's enterprise can benefit significantly by deploying Gigabit Ethernet to the desktop. Certain applications (such as online backup and recoveries and large file transfers from data center servers and storage plants) benefit at a far greater level than others. These types of applications have an effect on the traffic associated with all other applications that are using network resources during the same time period.

As desktop PCs and applications become more advanced through improvements in architecture and capabilities, they make employees much more productive through the automation of processes that historically were done manually. Information used in the decision-making process that affects profits is made available at significantly faster rates as data is extracted, delivered, and analyzed at significantly faster rates. However, as these applications become more advanced, they also become more bandwidth-intensive. As more traffic is generated, network performance decreases, and so does employee productivity.

Today, users may have one application in the foreground and several applications active in the background. Each user has a unique "compute profile," which is the mix of applications requiring computer processor power and network bandwidth. Although each application has its own traffic pattern, within the bigger picture of the compute profile, the aggregate of the application traffic patterns should be applied to the available bandwidth. This reflects the true bandwidth and network use of the users and their applications.

Multicast or on-demand video, e-mail with large attachments, file transfers, on-demand backups and recovery, customer relationship management, and enterprise resource planning, as well as Web and Java-based tools, are among the list of applications that users run every day, perhaps without realizing it (Figure 1). Each one has unique traffic patterns and bandwidth requirements. Now, aggregate the traffic of all the applications and multiply that by the number of users in the workgroup, the department, the floor, and the wiring closet. How long will a user wait at 10 Mbps or 100 Mbps to get the information needed for each application that is running?

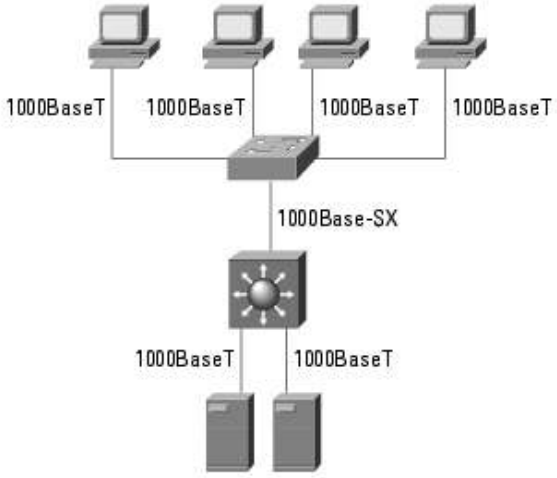
Figure 1. Example of a User's Desktop



There is an effect on the Gigabit Ethernet-connected servers that have to wait while the clients connected at 10 Mbps or 100 Mbps slowly take information off the wire (Figure 2). As more applications are run at the 10/100-Mbps-connected desktops requesting data from servers, the effect on the servers increases.

When a client requests data from a server, the server sends out the requested data in a burst of packets at rates as close to Gigabit Ethernet speeds as possible. When the packets are sent to the switch supporting the user, they are buffered and then delivered to the client at 10 or 100 Mbps. The server then waits for an acknowledgement from the user before forwarding the next segment of data. All this time the session remains open for multiple users and multiple applications, using server resources. The network at this point is "server-bound." Because network performance has decreased from an application standpoint, each user now has a longer wait and the user's productivity level drops as well.

Figure 2. Gigabit-Ethernet-Connected Servers to 100-Mbps-Connected Desktops



By changing the desktop connection to Gigabit Ethernet, the far-end bottleneck is eliminated because the desktop will remove the data from the wire at rates more in line with the rates at which the server sends the data. The faster that data and acknowledgements can be sent, the more efficiently the network will perform. The value of Gigabit Ethernet to the desktop is how quickly the data is put on and taken off the wire, thereby allowing a larger number of files to move between various hosts, servers, and applications.

Note: Not all PCs can support full Gigabit Ethernet speeds because of limitations of the internal peripheral component interconnect (PCI) bus. Many older systems were not designed with Gigabit Ethernet speed in mind. Systems with processor speeds below 500 MHz will see only 1.5 to 2 times the performance improvement. However, those with speeds greater than 800 MHz will see performance increases from 4 to 6 times that of 100 Mbps. The newer multigigahertz-based processor systems can now drive close to Gigabit Ethernet speeds, and further improvements from Intel will allow systems to move data at full-duplex Gigabit Ethernet speeds.

Moving to a Gigabit Ethernet solution from server to client not only provides increases in productivity, but it also provides a platform to ensure effective delivery of the next generation of applications and to ensure that productivity and network performance are preserved even with the addition of future demands and applications. The investment pays off now and adds further benefits in the long term.

Cisco and Gigabit Ethernet to the Desktop

To support the move toward gigabit speeds to the desktop and network servers, Cisco Systems® provides 10/100/100-Mbps ports in multiple platforms ranging from the chassis-based solutions of the Cisco® Catalyst® 6500 Series (16-48 ports, 10/100/1000 Mbps), the Cisco Catalyst 4500 Series (12 ports, 1000BASE-T; or 24-48 ports, 10/100/1000 Mbps). Gigabit Ethernet stackable solutions are available with the Cisco Catalyst 3550 Series (12 ports, 10/100/1000 Mbps) and the new Cisco Catalyst 3750 Series (24 or 48 ports, 10/100/1000 Mbps).

Cisco tests of Gigabit Ethernet to the desktop reflected significant improvements in multiple types of applications. The true value is in the reduction in the amount of time the data spent in transit on the network. When compared with 10 Mbps, Gigabit-Ethernet-connected hosts spent 88 percent less time waiting while the data was in transit. Compared with 100 Mbps, Gigabit Ethernet wait times were 47 percent lower.

Test Methodology

To test the arguments of increased throughput and less network wait times using Gigabit Ethernet from end to end, Cisco set up a test environment with tools to model real user traffic. Traffic models for an 8-hour workday were developed based upon analyzing actual network traffic and real applications used day-to-day.

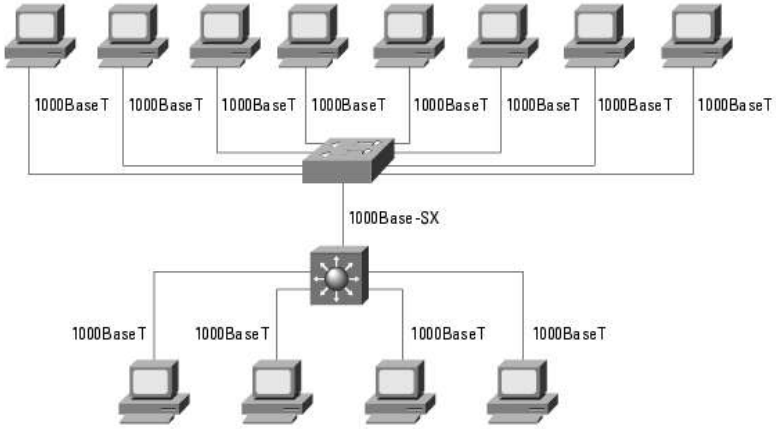
Traffic and application types modeled include:

- Cisco IP/TV®, Real Media, and Windows Media for audio and video streaming
- Ariba, a Web ordering and purchasing tool
- Saba/EMS, a Web e-learning tool
- Connected TLM, a backup and recovery application
- Reflection X, an X and Telnet services application
- Microsoft Outlook, e-mail
- Microsoft Office applications (Word, Excel, Visio, and PowerPoint)
- Clarify, a Java-based application for customer service
- Internet Explorer, Netscape, and Opera browsers

The test environment (Figure 3) consisted of both Linux and Windows 2000 hosts to represent both the client and server platforms. The topology represents a single wiring closet with a

connection down to a core or data center switch. NetIQ's Chariot was used for scripting and traffic generation. NetIQ's Chariot test tool simulates applications and uses the full TCP protocol stack of the client.

Figure 3. Ethernet Technology Lab Test Bed



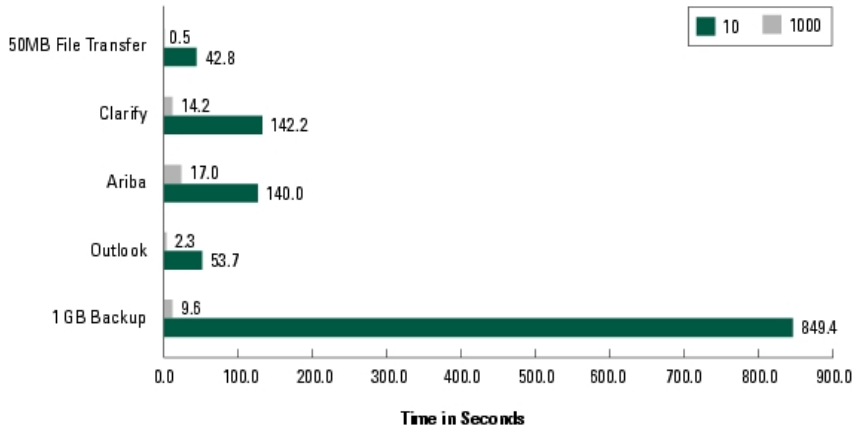
Note: In this testing, end hosts will not keep a given Gigabit Ethernet interface continuously filled, as you would see with network load testers. Application traffic is bursty by nature, with on and off periods of transmission. Many applications are TCP-based, meaning that a set, or window, of data is sent and must be acknowledged before the next window of data is sent.

Test Results

Baseline tests were performed at 10, 100, and 1000 Mbps on each application to understand best performance of the single application. To effectively test real-world scenarios, the user-modeled traffic was again sent over 10-, 100-, and 1000-Mbps connections. The user-modeled traffic simulates multiple applications in use simultaneously with both foreground and background traffic flows.

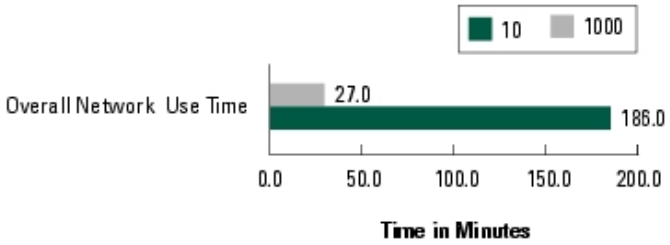
The results reflect a significant reduction in the amount of network time used to move the data between the clients and the servers. When compared with 10 Mbps, 1000 Mbps shows a substantial improvement per application (Figure 4). The most significant improvements were for those applications in which large amounts of data were transferred from both the client and server. The file-backup process, for example, reflects the backup of 1 GB of data. With hosts connected at 10 Mbps, it took 14 minutes and 9 seconds, compared with 9.8 seconds for hosts connected at 1000 Mbps, a 98.8-percent reduction in network use time.

Figure 4. Comparison of Test Results for 10 Mbps and 1000 Mbps



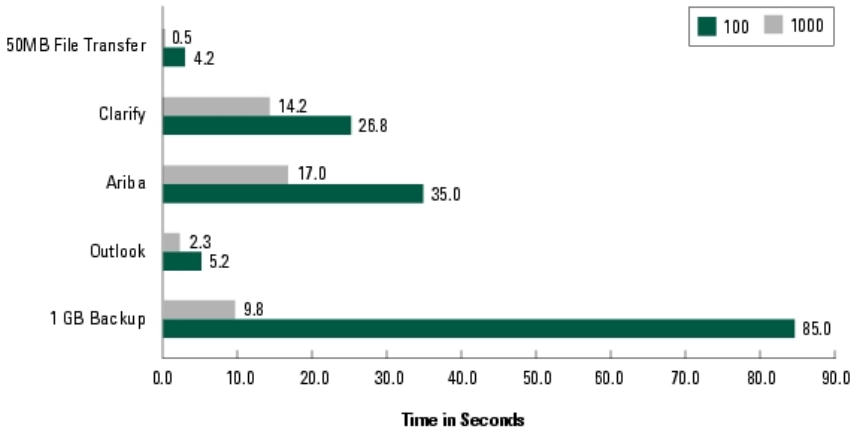
Although this represents only a single application, the overall effect of all the applications running over an 8-hour period reflected a reduction from 3.1 hours of network use time to only 27 minutes of network use time (Figure 5). This is a 689-percent performance improvement and 85-percent reduction of resource use and wait time.

Figure 5. Overall Improvement of 1000 Mbps over 10 Mbps



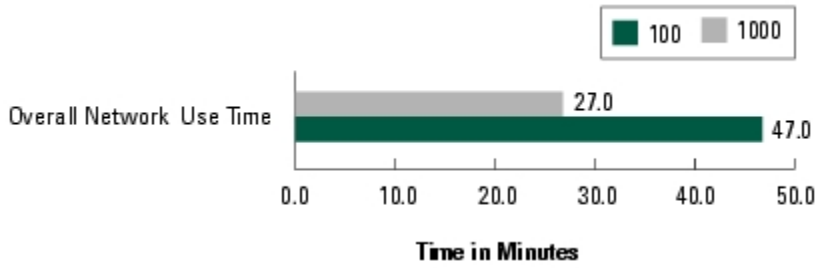
Even when compared to 100 Mbps, 1000 Mbps still resulted in a dramatic reduction in the amount of network time used to move the data between the clients and the servers (Figure 6). As before, the most significant improvements were for those applications where large amounts of data were transferred from both client and server. The file-backup process, for example, reflects the backup of 1 GB of data. With hosts connected at 100 Mbps, it took 85 seconds, compared with 9.8 seconds for hosts connected at 1000 Mbps, an 867-percent performance increase and an 88-percent reduction in network use time.

Figure 6. Comparison of Test Results for 100 Mbps and 1000 Mbps



Although this represents a single application, the overall effect of all the applications running over an 8-hour period reflects a reduction from 47 minutes of network use time to only 27 minutes of network use time (Figure 7). This is a 174-percent performance improvement and a 44-percent reduction of resource use and wait time.

Figure 7. Overall Improvement of 1000 Mbps over 100 Mbps



Deployment of Gigabit Ethernet

Gigabit Ethernet runs over most existing Category 5 copper and all installed fiber cabling. It works with other Ethernet components without the issues of other networking technologies. This makes the transition to Gigabit Ethernet as easy as swapping or adding a new module to your chassis or adding a fixed-configuration switch in a closet, distribution point, core, or data center.

Because the backbone (or core) aggregates all traffic on the network and servers receive the most traffic of all systems on the network, the way to gain the greatest improvement with the least investment in many networks is to start by implementing Gigabit Ethernet in the backbone and servers. High-density Gigabit Ethernet switches with both fiber- and copper-based Gigabit Ethernet ports, such as the Cisco Catalyst 6500 Series, should be placed on the backbone. Gigabit Ethernet server adapters should be installed in the servers.

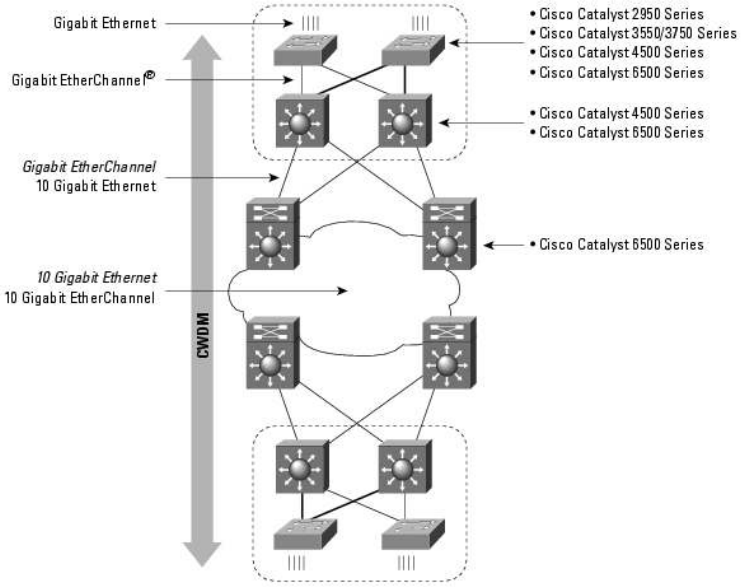
The next step is to add Gigabit Ethernet to the distribution switches. Cisco Catalyst 6500 and 4500 series switches can easily be equipped with Gigabit Ethernet connections.

The final step is to add Gigabit Ethernet to the wiring closet (or access) switches by adding Gigabit Ethernet uplinks and the necessary ports for power users. High-density 10/100/1000-Mbps port blades are available for Cisco Catalyst 6500 and 4500 series switches and can easily be deployed. For customers who purchase stackable switch solutions, Cisco has both low- and high-density Gigabit Ethernet switches with the Cisco Catalyst 3550 and 3750 series switches, respectively.

The stackable switches provide the ability to connect to the fiber uplinks through Gigabit Ethernet uplink modules.

With the core, distribution, and access layers equipped for Gigabit Ethernet, all new desktops with Gigabit Ethernet connections will take full advantage of Gigabit Ethernet speed (Figure 8).

Figure 8. Gigabit Ethernet Campus Network Design



Conclusion

The evolution of Gigabit Ethernet is introducing new levels of performance throughout networks, from the backbone to the desktop. Deployment of high-bandwidth applications and more powerful servers and desktops will continue for the foreseeable future and will require faster network connections. Deploying new desktops with 10/100/1000-Mbps copper connections is the most economical way to prepare for these rapid increases in bandwidth requirements.

The expansion of Gigabit Ethernet to the edge of the network will provide measurable improvements in performance for most applications and users. The cost of Gigabit Ethernet has fallen so dramatically that it is no longer the single most significant factor in a deployment decision. Gigabit Ethernet equipment will probably be more affordable to deploy than its 10/100-Mbps predecessors with far greater benefits to your network and your company. The time is rapidly approaching where virtually every worker will need to use Gigabit Ethernet bandwidth to access complicated, bandwidth-intensive applications.

For network managers, success is defined by their ability to implement a networked infrastructure with capacity that can consistently remain ahead of user demands at any time. Can you afford not to move forward and make the investment in an evolutionary change in one of the most important utilities of your business?

Cisco believes that business and technology needs are rapidly driving the industry toward a Gigabit Ethernet networking model. Cisco takes a much broader approach than its competition in its combination of end-to-end Gigabit Ethernet multilayer switching solutions, which use proven Cisco technology to achieve the best performance, function, service application, migration, and manageability.

As always, Cisco continues to provide customers with intelligent, high-performance systems that deliver value-added end-to-end services. Cisco will continue leading the industry by offering a smooth, comprehensive migration to next-generation networks. The implication is clear: When considering how to implement a Gigabit Ethernet networking solution for your business, go to the leader that defines the complete solution rather than just a part of it.

References

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Catalyst 4500 Series switches: http://www.cisco.com/go/catalyst4500

Catalyst 3550 Series switches http://www.cisco.com/go/catalyst3550

Catalyst 3750 Series switches: http://www.cisco.com/go/catalyst3750

Gigabit Ethernet Solutions from Cisco and Intel: http://www.ciscointelalliance.com

Gigabit Technology Papers

Gigabit Ethernet (802.1z): 1000BASE-T Delivering Gigabit Intelligence on a Copper Infrastructure: http://www.cisco.com/en/US/tech/tk389/tk214/tech_digest09186a0080091a86.html.

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