

# Gigabit Ethernet

## **Introduction to Gigabit Ethernet**

The Ethernet protocol is the most widely used local area networks (LANs) in organizations today. Since its introduction in the early 1970s, the demand for higher bandwidth and speed in keeping pace with the increased volume of network traffic has spearheaded the Ethernet from 10BASE-T (10 Mbps), Fast Ethernet (100 Mbps), to Gigabit Ethernet (1 Gbps).

## **Evolution of Ethernet**

The Ethernet is a network transport protocol invented by Dr Robert Metcalf and developed by Digital, Intel, and Xerox for local area networks (LANs). Operating at Layer 1 (Physical) and Layer 2 (Data Link) of the 7-layer Open Systems Interconnection (OSI) networking model, the Ethernet is a reliable protocol that transports data packets to devices connected to the network.

Many organizations depend upon LAN to provide connectivity for the increasing number of complex and mission critical computing applications. As the network traffic volume increases, the 10 Mbps Ethernet (10BASE-T) becomes inadequate to maintain acceptable performance for the increased number of desktops and servers environment, so higher speed networks such as Fast Ethernet has been introduced.

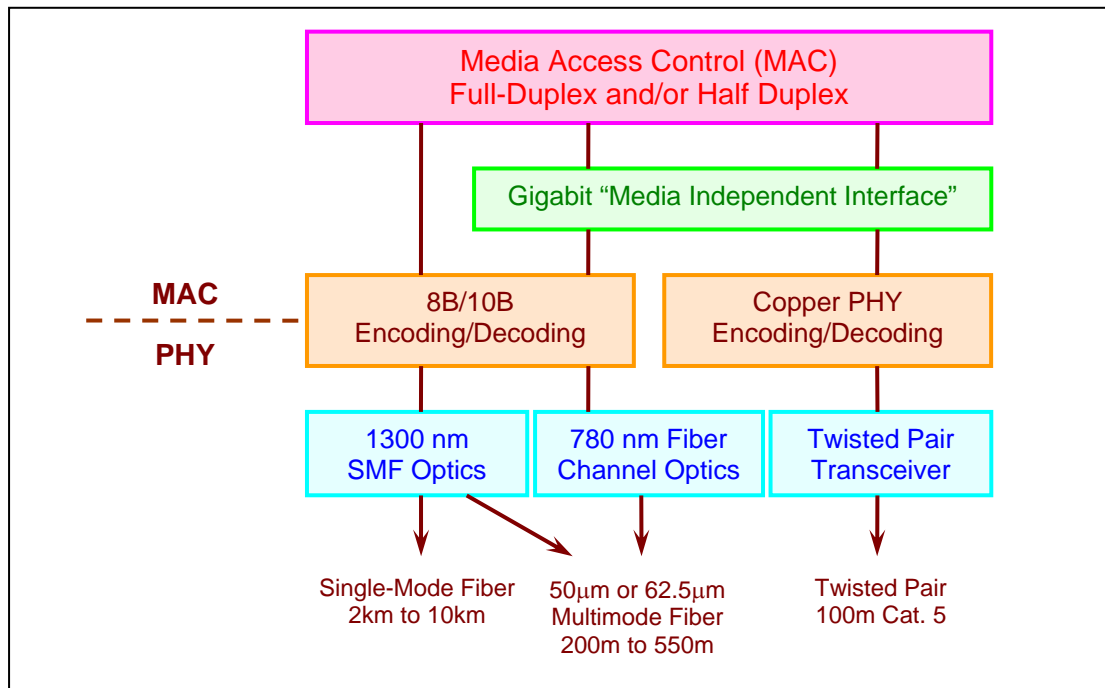
Fast Ethernet (100BASE-T) provides LAN with high-speed, smooth, and non-disruptive performance at 100 Mbps. As more powered applications are being developed and demand for speed increases over time, there is a need for even higher-speed network technology to cater for backbones and servers for LAN, hence the introduction of Gigabit Ethernet.

## **What is Gigabit Ethernet?**

Gigabit Ethernet is an extension of the successful and commonly used 10 Mbps Ethernet and 100 Mbps Fast Ethernet standards for network connectivity. Gigabit Ethernet is tenfold faster than Fast Ethernet and provides a bandwidth of 1 Gbps. It offers an upgrade path for current Ethernet 10 Mbps or Fast Ethernet 100 Mbps

installations to Ethernet 1000Mbps speed and is backward compatible with existing workstations, thus reducing the need for re-training, new management tools, and additional investment on protocol stacks or middleware.

Gigabit Ethernet uses full- or half-duplex Carrier Sense Multiple Access Collision Detection (CSMA/CD) to prevent network collisions and maintains the same frame format and size as Ethernet and Fast Ethernet as defined by IEEE 802.3 standard.



**Figure 1.** Functional Elements of Gigabit Ethernet Technology

With the support for half and full duplex operation, Gigabit Ethernet is an ideal backbone for interconnection technology for use with 10Mbps and 100 Mbps switches. The easy upgrade path to Gigabit Ethernet is also ideal for connection to high-performance server and future high-end desktop computers demanding more bandwidth.

### **Benefits of Gigabit Ethernet**

Gigabit Ethernet is one hundred times faster than the regular 10 Mbps Ethernet and ten times faster than 100 Mbps Fast Ethernet. This increase in data rates offers greater support for video conferencing, complex imaging, and other data-intensive applications.

Apart from being backward compatible with earlier Ethernet network architecture, the Gigabit Ethernet also provides the following advantages:

**a. Extension of current Ethernet**

Gigabit Ethernet uses the same transmission schemes and frame format as Ethernet and Fast Ethernet. There is no need to acquire additional protocol stacks and middleware.

**b. Availability of Management and Troubleshooting tools**

Established Ethernet and Fast Ethernet management and troubleshooting systems can be used on Gigabit Ethernet. Simple Network Management Protocol (SNMP) can also be adopted. With network management applications, the administrator can view the status of all devices in the network from a central station. Ethernet troubleshooting tools are also available and with many people already familiar with the Ethernet, current administrators, support staff, and users will not face any difficulty in installation processes, maintenance, and troubleshooting.

**c. Affordable Hardware and Low Cost**

With the rapid decrease in price per port for the Ethernet and Fast Ethernet, the cost of Gigabit Ethernet per port is also expected to follow similar decreases.

**d. Network Reliability**

The success of an enterprise depends on the reliability of the network. The structured Ethernet wired system has been proven reliable for many years.

**e. Minimal Training**

The design, installation, and configuration are the same as Ethernet and Fast Ethernet, therefore the installation and support is relatively simple to understand and administer.

**f. Familiar Technology**

The products, methodologies, and support protocols follow specifications according to IEEE standards and are certified compatible with Ethernet and Fast Ethernet, therefore there is minimum impact on network administrators or staff.

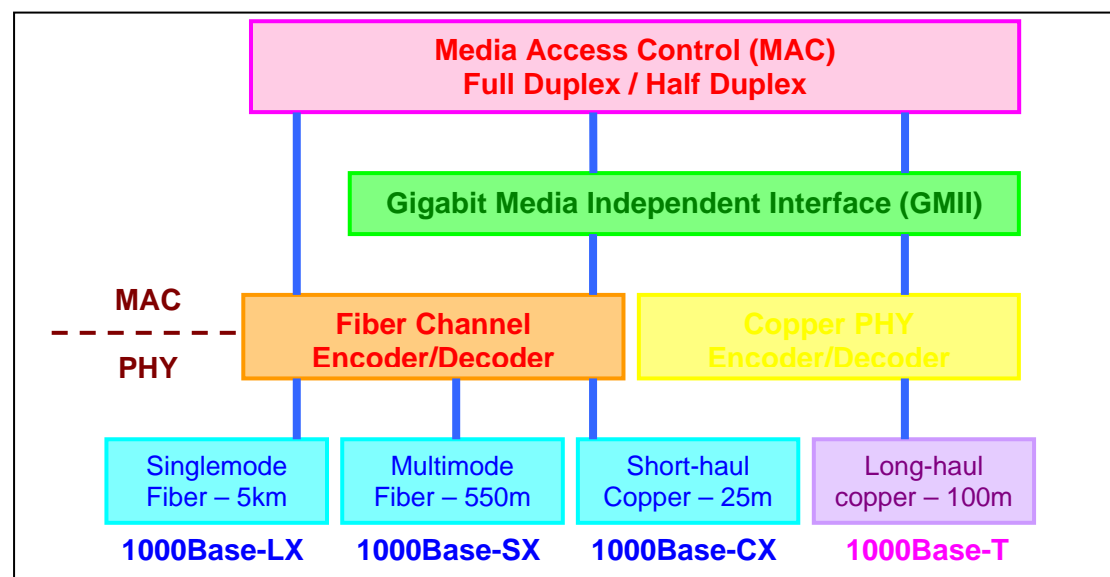
## Standard Evolution

The main reason for the success of Ethernet is because of its progressive standards in meeting networking requirements according to IEEE specifications. Synonymous to the IEEE 802.3 standard, the Gigabit Ethernet is essentially an extension evolving from its predecessors, the 10 Mbps Ethernet and the 100 Mbps Fast Ethernet.

When the 10 Mbps Ethernet was first introduced, the cables used for networking consist of two types of coaxial cables, Thick Ethernet and Thin Ethernet. Later, the unshielded twisted pair (UTP) copper cable is used and becomes the main type of cable.

As the demand for more bandwidth in network increases, Fast Ethernet following the IEEE 802.3u specification was formed in 1995. Promoted by the Fast Ethernet Alliance, Fast Ethernet has ten times greater bandwidth than the former Ethernet, and runs at data rates of 100 Mbps. Fast Ethernet also support features such as full duplex and auto-negotiation and is backward compatible with IEEE 802.3 Ethernet.

The Gigabit Ethernet is designed as a switched technology that uses fiber for uplinks and connections between buildings. In 1998, IEEE adopted the 802.3z as the standard for Gigabit Ethernet over fiber optic cables. Since then, Gigabit Ethernet is used extensively in servers with Gigabit Ethernet network interface cards and implemented in network backbones to remove traffic bottlenecks. A year later, in 1999, IEEE standardized IEEE 802.3ab Gigabit Ethernet over copper, allowing Gigabit speeds to transmit over Cat-5 cables.



**Figure 2.** Gigabit Ethernet Standards

Gigabit Ethernet is fully compatible with Ethernet and Fast Ethernet. It employs the same specifications of CSMA/CD, Ethernet frame, full duplex, flow control, among other things. Gigabit Ethernet also support traffic management techniques that deliver Quality of Service (QoS) such as IEEE 802.1p layer 2 prioritization, ToS coding bits for layer 3 prioritization, differentiated services, and resource reservation protocol (RSVP). Gigabit Ethernet also supports 802.1q VLAN, layer 4 filter and layer 3 switching at Gigabit speeds. With IEEE 802.3ad, or link aggregation, Gigabit Ethernet can achieve 16 Gbps by trunking.

<b>Standard</b>	<b>Speed</b>	<b>Distance</b>	<b>Media</b>
10Base-T	10 Mbps	100 m	Copper
100Base-TX	100 Mbps	100 m	Copper
100Base-FX	100 Mbps	2 km	Multimode Fiber
1000Base-LX	1000 Mbps	5 km	Singlemode Fiber
	1000 Mbps	550 m	Multimode Fiber
1000Base-SX	1000 Mbps	550 m	Multimode Fiber (50 $\mu$ )
	1000 Mbps	275 m	Multimode Fiber (62.5 $\mu$ )
1000Base-CX	1000 Mbps	25 m	Copper
1000Base-T	1000 Mbps	100 m	Copper

### **IEEE 802.3z Standard**

The key objective of the 802.3z Gigabit Ethernet standards is to develop a Gigabit Ethernet standard that does the following:

- Allow half- and full-duplex operation at the speed of 1000 Mbps
- Uses the same 802.3 Ethernet frame format
- Uses the same CSMA/CD access method with one repeater per collision domain
- Backward compatible with Ethernet and Fast Ethernet technologies

The 802.3z Ethernet standard also identifies the following three objectives for link distances:

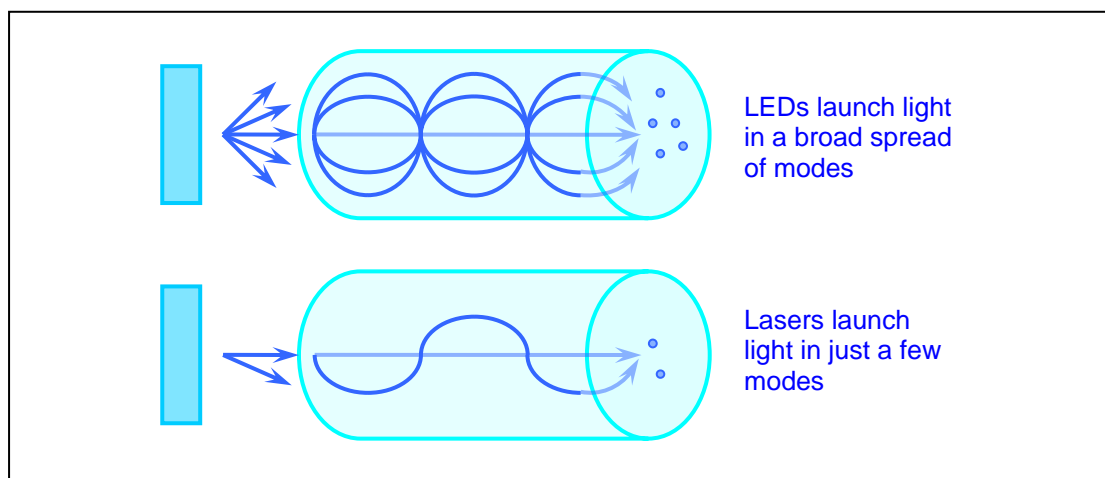
- a multimode fiber optic link with maximum length of 550 meters
- a singlemode fiber optic link with maximum length of 3 km (later extended to 5 km)
- a copper based link with maximum length of at least 25 meters.

The 802.3z standard includes a specification for optional Gigabit Media Independent Interface (GMII).

Two PHYs or OSI physical layer devices provide Gigabit transmission over fiber-optic cabling. 1000Base-SX is targeted at low cost multimode fiber that runs in the shorter backbone applications, while 1000Base-LX is targeted at longer multimode fiber backbones and singlemode fiber backbones. For multimode fiber, the standards define Gigabit transmission of over maximum distance ranging from 220 to 550 meters. For singlemode fiber, it is covered by the long wavelength standard, defines transmission of 5 kilometers.

*==Reference Only==*

Challenges associated with using lasers on multimode fiber become more apparent as the operating speed increases, introducing a problem known as differential mode delay (DMD). DMD affects multimode fiber that uses SX lasers. When one mode of light experience jitters or line distortion, it causes the single mode to be divided in two or more modes of light. This can cause data loss. Multimode fiber is designed for short-distance light emitting diodes (LEDs) and not lasers.



**Figure 3. Light in Multimode Fiber Optic Cable**

The fix is known as “conditional launch”. If the light travels through the center of the core in a straight line, it is directed at a slight angle just off the center of the core and the modal delay is corrected.

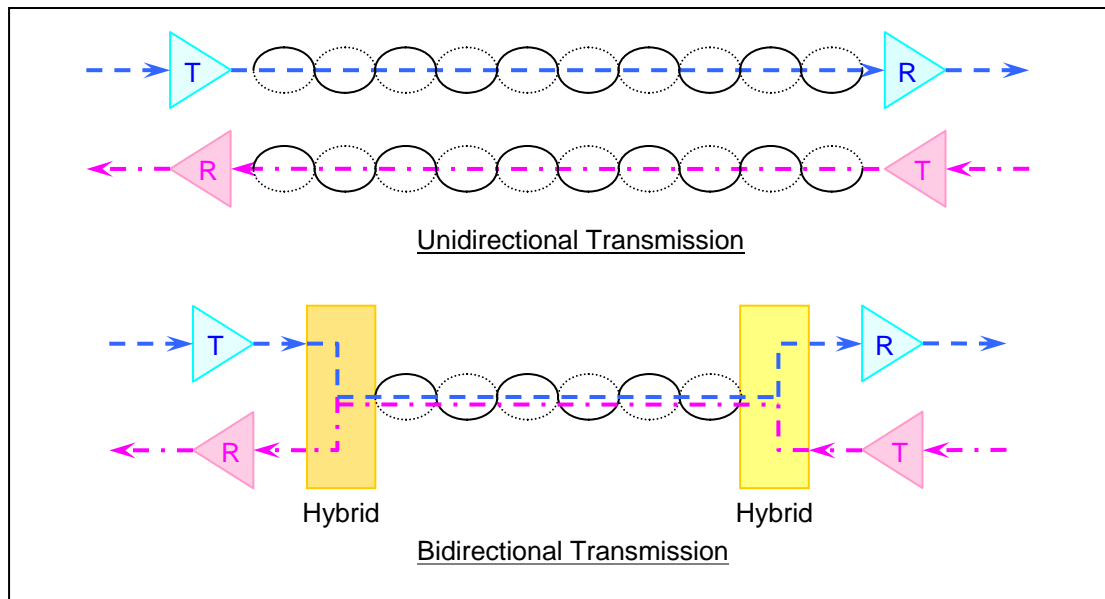
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There are also two standards for Gigabit Ethernet transmission over copper cabling. The first copper link standard is defined by the 802.3z task force and is called 1000Base-CX. It supports interconnection of equipment where the physical interface is short-haul copper. It is a short jumper interconnection for 25 meters. This standard uses the fiber channel-based 8B/10B coding at the serial line rate of 1.25 Gbps and runs over 150-ohm balanced, shielded cables.

### **IEEE 802.3ab Standard**

The second copper link standard is defined by the 802.3ab task force and is called 1000Base-T. Category 5 (Cat-5) cabling is currently the most commonly used data grade cabling. 1000Base-T is intended to provide a Gigabit Ethernet solution for these networks and it requires operation on four pairs, 100-ohm Cat-5 balanced copper cabling.

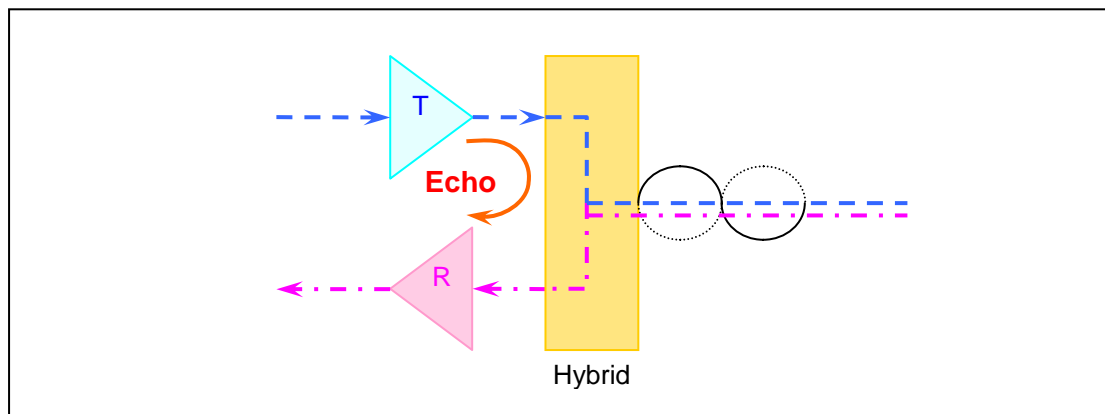
Signals transmitted by 10Base-T and 100Base-TX are unidirectional, which means transmission is in one direction on a single wire pair. Signals transmitted by Gigabit Ethernet on the other hand are bidirectional, which means transmission is simultaneous in both directions on the same wire pair. Both transmit and receive signals occupy the same wire pair. 1000Base-T uses bidirectional signaling on all four pairs. The bidirectional data transmission on a single pair is enabled by devices called hybrids. The hybrids will stop the local transmitted signal from being mixed with the local received signals.



**Figure 4.** Unidirectional and Bidirectional Transmission

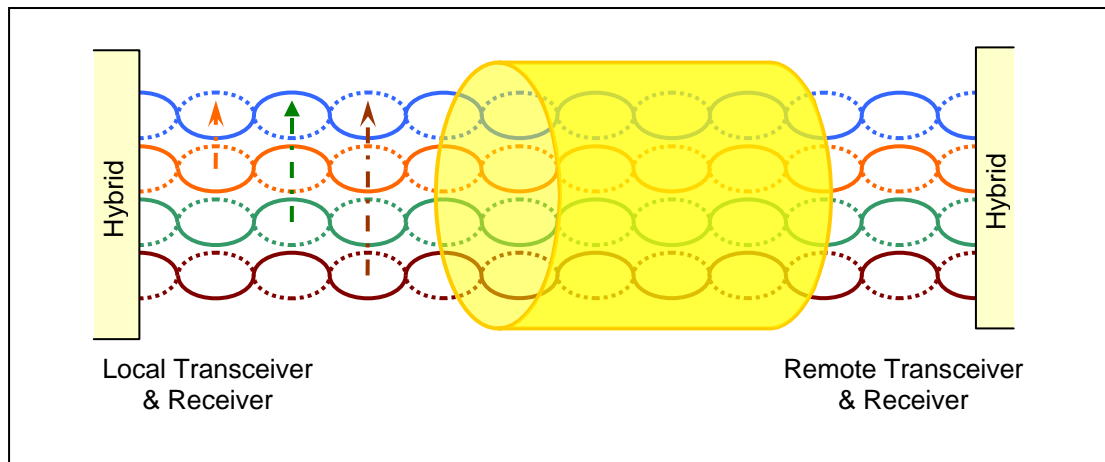
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Bidirectional transmission on the same wire will result in echo. It is caused by the effect of cabling return loss and the hybrid function. Return loss is a measure of the reflected energy caused by impedance mismatches in the cabling system. Echo is then countered by echo cancellation.



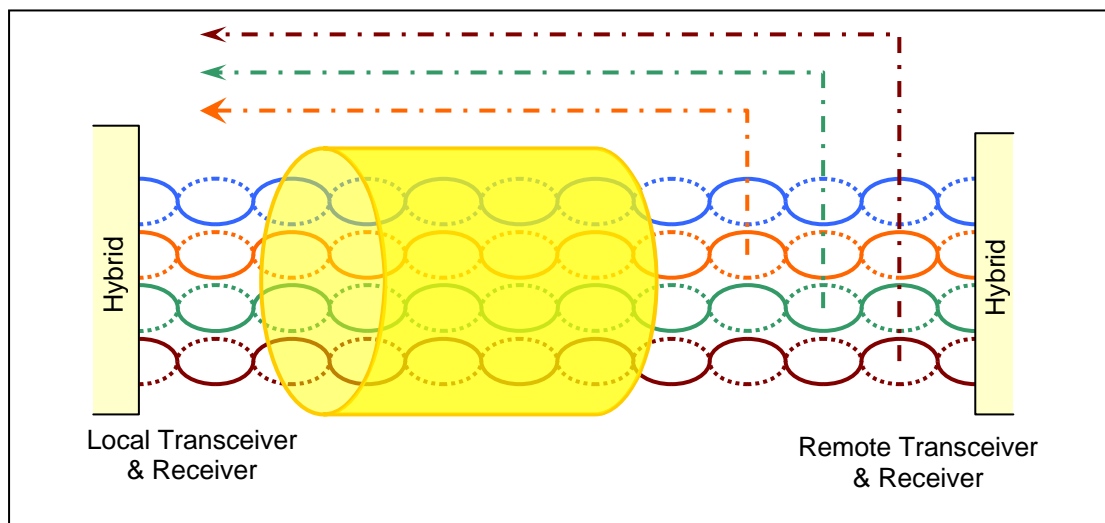
**Figure 5.** Echo

Since 1000Base-T uses all four pairs of wire, each pair is affected by crosstalk from the other three pairs. Crosstalk is unwanted signals coupled between adjacent wire pairs. Crosstalk is characterized in reference to the transmitter. Near-end crosstalk (NEXT) is crosstalk that appears at the output of a wire pair at the transmitter end of the cable. NEXT increases the noise at the receiver and degrades the signal-to-noise (SNR).



**Figure 6.** Next-End Crosstalk

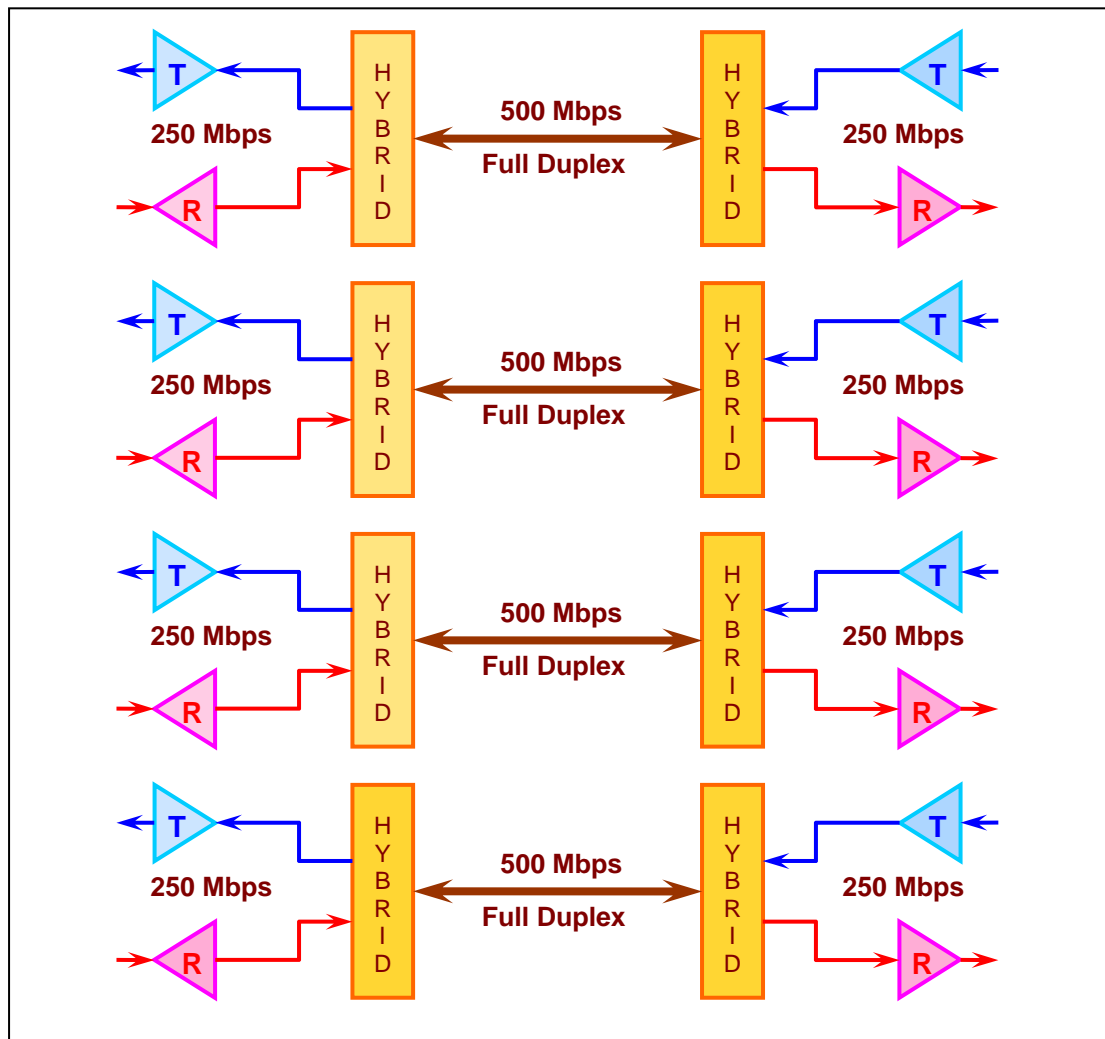
Far-end crosstalk (FEXT) is crosstalk that appears at the output of a wire pair at the far end of the cable from the transmitter. Equal level far-end crosstalk (ELFEXT) is defined as the measure of the unwanted signal coupling from a transmitter at the near end into a neighboring pair measured at the far end relative to the received signal level measured on the same pair.



**Figure 7.** Far-end Crosstalk

Full-duplex transmission consists of transmitting and receiving data simultaneously in both directions on each of the four wire pairs. Hybrid circuits are used to enable bi-directional transmission over single wire pairs by filtering out the transmit signal at the receiver. Although hybrid networks with good trans-hybrid loss minimize the amount of transmitter signal that is coupled into the receiver, it still cannot remove all the transmit signal. This transmit signal from the hybrid and the return loss of the cable require cancellers that are added to each wire pair to remove the transmit echo signal.

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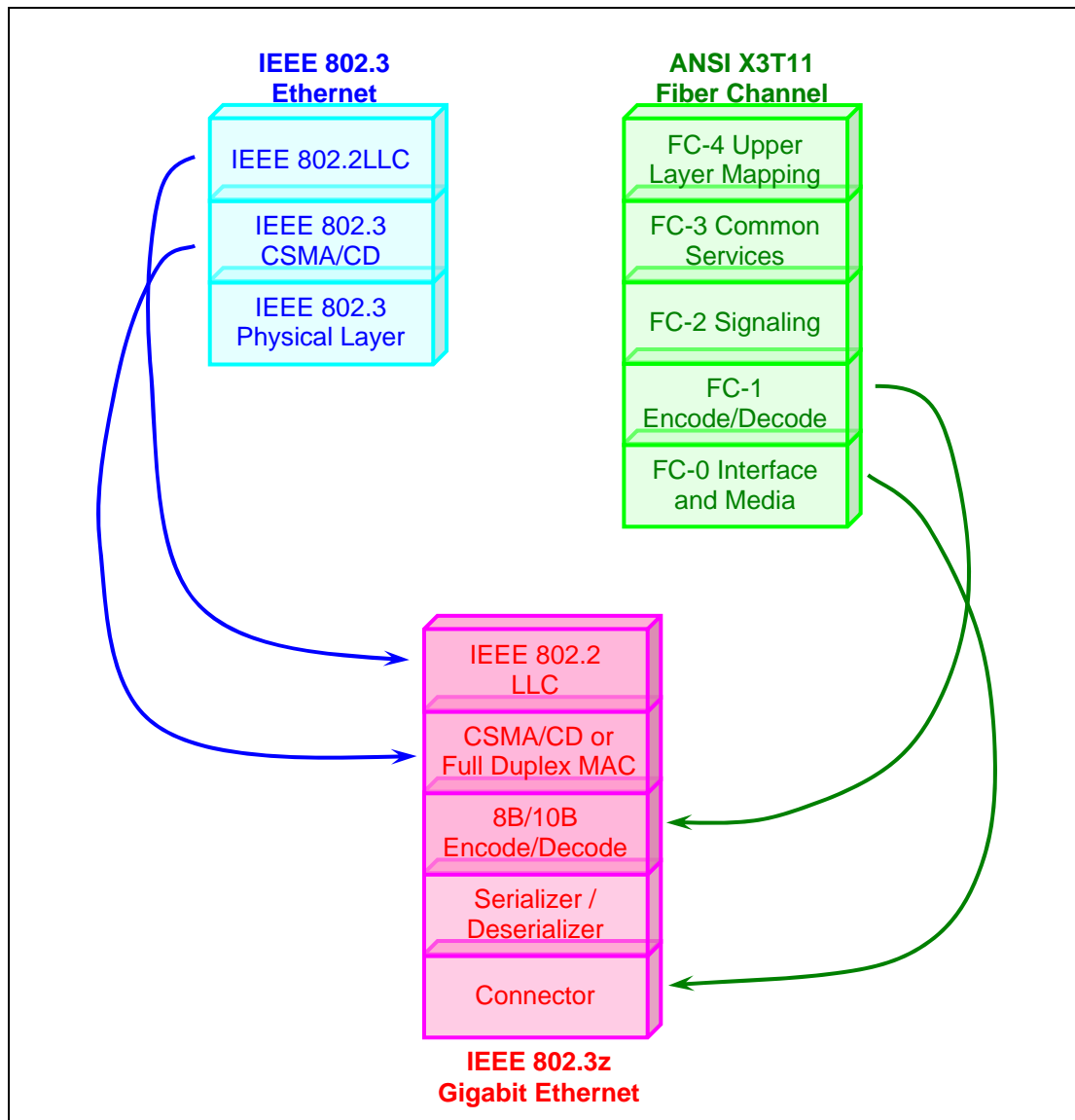


**Figure 8.** Full Duplex Transmission using Hybrids

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### **Gigabit Ethernet Protocol Architecture**

To increase the speed from 100 Mbps Fast Ethernet to 1 Gbps Gigabit Ethernet, there are several changes that need to be made to the physical interface. IEEE has decided that Gigabit Ethernet will look like Ethernet from the data link layer upwards. To accelerate to 1 Gbps, it will involve merging two technologies, IEEE 802.2 Ethernet and ANSI X3T11 Fiber Channel. The figure below shows the key components from each technology that has been leveraged to form Gigabit Ethernet.



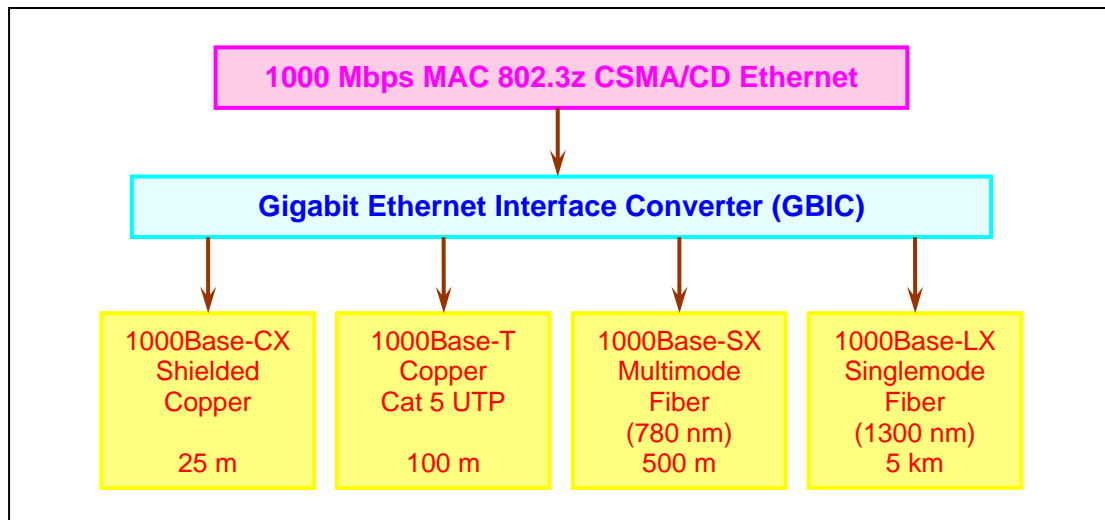
**Figure 9.** Gigabit Ethernet Protocol Stack

The Gigabit Ethernet standard takes advantage of the existing high-speed physical interface technology from the Fiber Channel and maintains the IEEE 802.3 Ethernet frame format.

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### **Gigabit Ethernet Interface Converter (GBIC)**

The Gigabit interface converter (GBIC) allows the network managers to configure each Gigabit port for short wavelength (SX), long wavelength (LX) and long-haul interfaces on port-by-port basis. The long-haul GBICs extend the single-mode fiber distance from the standard 5 km to 10 km. This long-haul GBIC is not part of the 802.z standard but it allows the switch vendors to build a single physical switch or switch module according to the customer's fiber requirement.



**Figure 10.** Function of GBIC Interface

The two laser standards that are supported over fiber are 1000Base-SX (short wavelength laser) and 1000Base-LX (long wavelength laser). The differences between the use of short and long wavelength laser technologies are cost and distance. At difference wavelengths, dips in attenuation are found over the cable. Short wavelength lasers are readily available because variations of these lasers are used in compact disc technology. Long wavelength lasers take advantage of attenuation dips at longer wavelengths in the cable. Although short wavelength lasers are cheaper, they can transverse a shorter distance. Long wavelength lasers which are more expensive can transverse longer distance. Both laser standards support over multimode fiber.

The two types of multimode fiber supported by Gigabit Ethernet are 62.5 and 50 micron-diameter fibers. The 62.5-micron fiber is typically seen in Ethernet, Fast Ethernet and FDDI backbone. It has a lower modal bandwidth, especially with short wavelength lasers. This means short wavelength lasers over 62.5-micron fiber will transverse shorter distances compared to long wavelength lasers. Comparing with 62.5-micron fiber, the 50-micron fiber has better modal bandwidth characteristics and will be able to transverse longer distances with short wavelength lasers.

Singlemode fiber uses a 9-micron core and 1300-nanometer laser. It can achieve the longest distance. The small core and lower-energy laser elongate the wavelength of the laser and allow it to transverse greater distances. It can reach the greatest distances of all media with the least reduction in noise. There is however no support for short wavelength lasers over singlemode fiber.

The table below shows the Gigabit Ethernet distance specifications for fiber optic media. For 62.5 micron diameter 160 MHz\*km multimode (MM) fiber, the distance is specified at 220 meters. As the bandwidth of the fiber increase, the minimum range for multimode fiber increases up to 550 meters. For long wavelength transceiver (1000Base-LX), it can reach 550 meters for all media types. For single mode fiber with 1000Base-LX, the distance is specified up to 5 km.

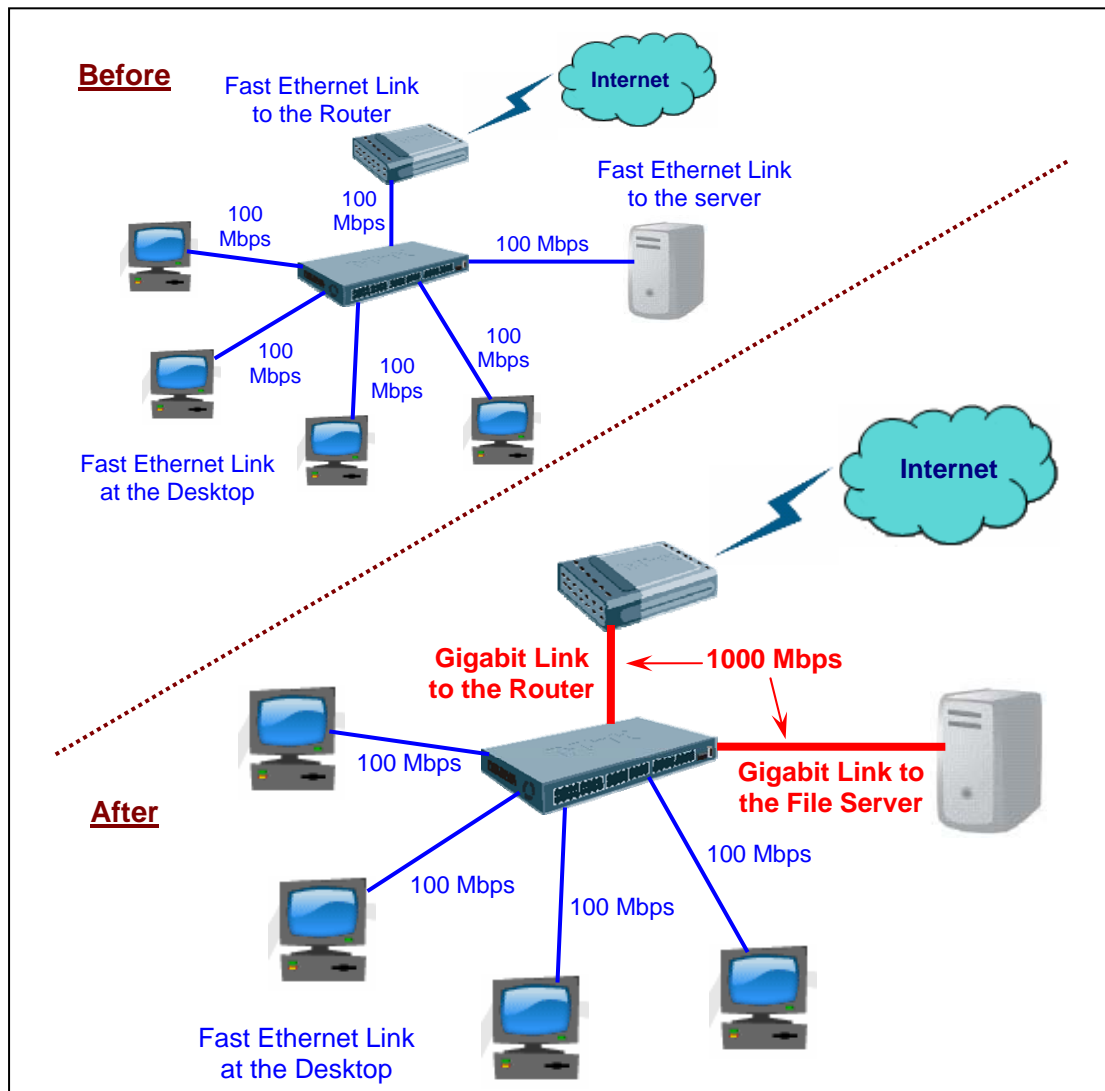
Standard	Fiber Type	Diameter (microns)	Modal Bandwidth (MHz*km)	Minimum Range (meters)
1000Base-SX	Multimode	62.5	160	2 to 220 *
	Multimode	62.5	200	2 to 275 **
	Multimode	50	400	2 to 500
	Multimode	50	500	2 to 550 ***
1000Base-LX	Multimode	62.5	500	2 to 550
	Multimode	50	400	2 to 550
	Multimode	50	500	2 to 550
	Singlemode	9	N/A	2 to 5000

- \* The TIA 568 building wiring standard specifies 160/500 MHz\*km multimode fiber
- \*\* The international ISO/IEC 11801 building wiring standard specifies 200/500 MHz\*km multimode fiber
- \*\*\* The ANSI Fiber Channel specification specifies 500/500 MHz\*km 50-micron multimode fiber and 500/500 fiber has been proposed for inclusion in ISO/IEC 11801

### **Gigabit Ethernet Migration and Deployment**

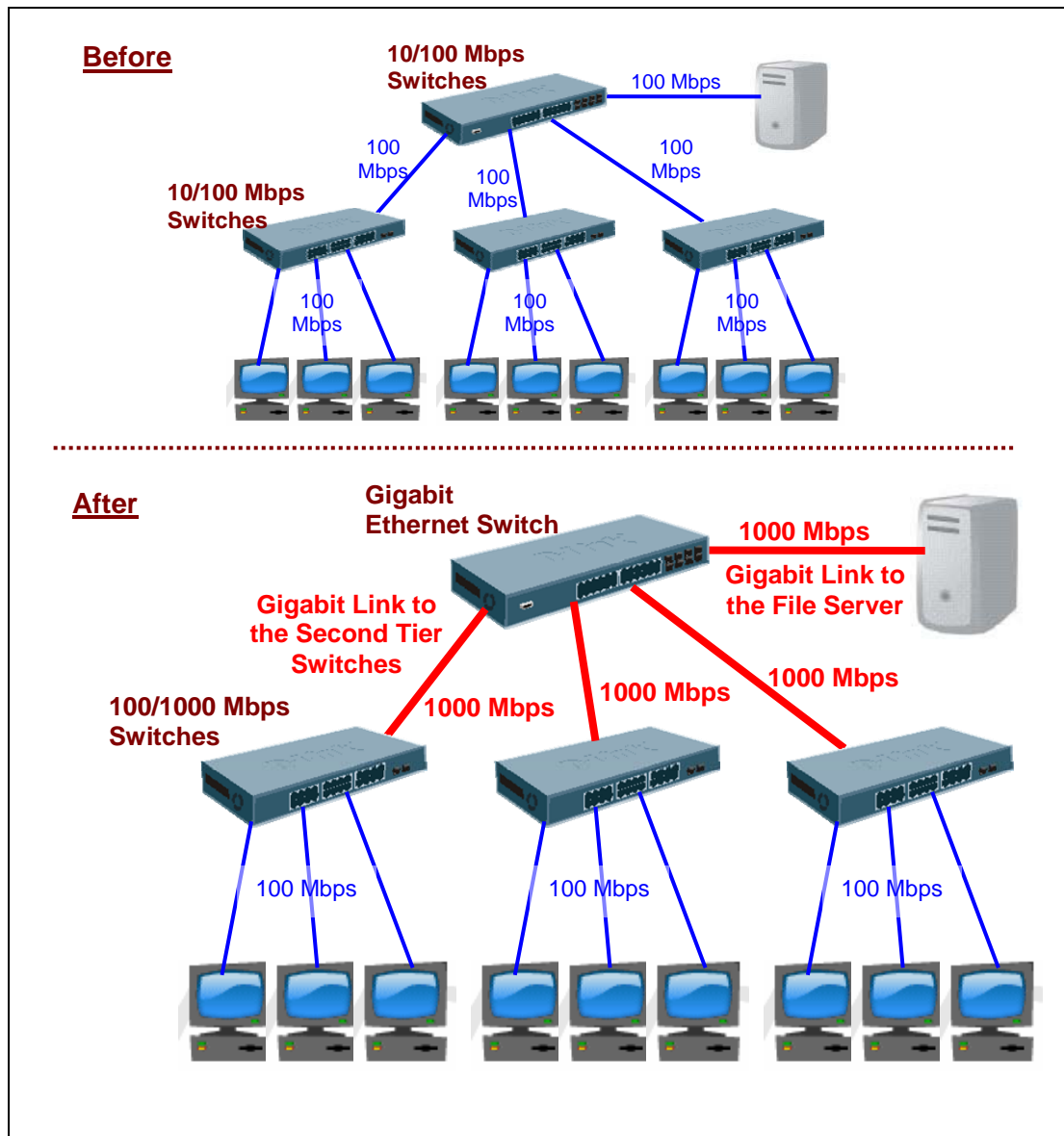
If many computers need to access a server through the same speed, the backbone must be large enough to support it. With the rapid growth of Internet technologies and applications, more network traffic begins to travel across the IP subnets. It becomes necessary to aggregate this traffic at switch stacks and backbone levels before moving it across subnets or out to the WAN. Gigabit Ethernet provides a “large pipe” to alleviate congestion at these aggregation points. Switch-to-server deployments can be implemented to boost access to the server resources and one of

the ideal ways to share such resources is to install Gigabit Ethernet network interface cards to the servers.



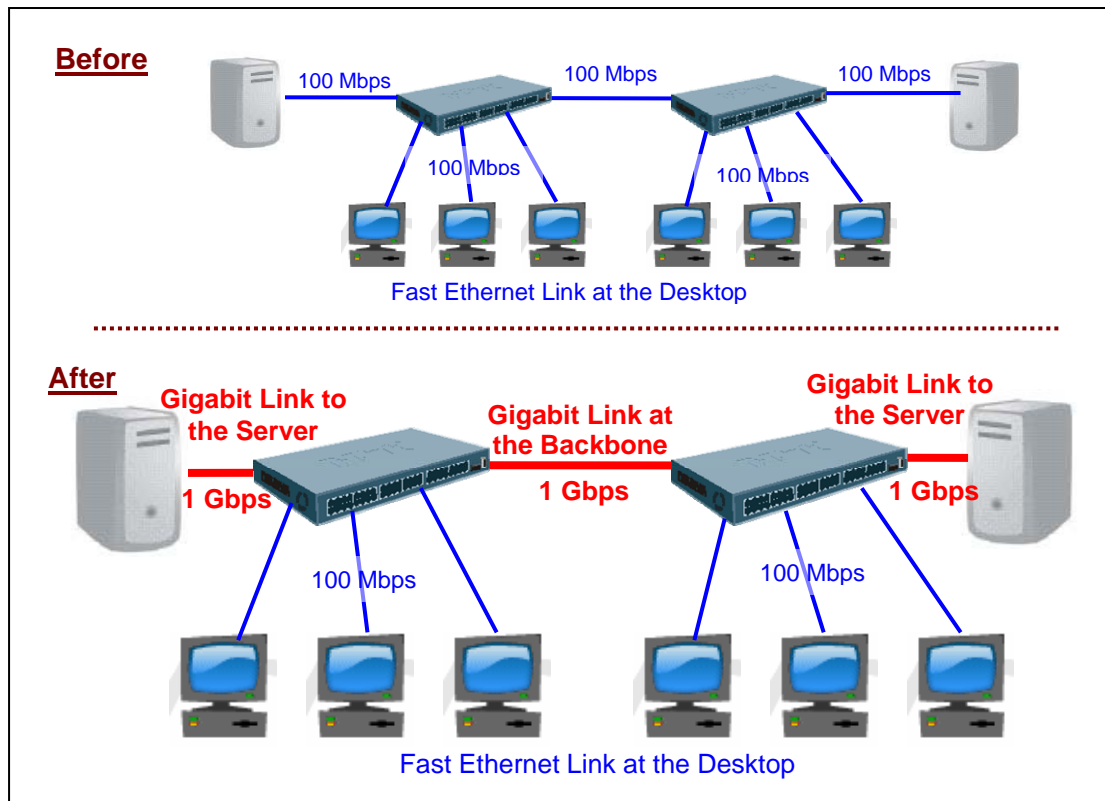
**Figure 11.** Gigabit Deployment to the WAN and Servers

Most desktop computers today are installed with Fast Ethernet network interface cards. Over time however there will be pressure to increase the backbone bandwidth in order to maintain speed performance with increased number of users connected to the network. In such cases, the Gigabit Ethernet switches can be deployed at the backbone using 100 or 1000 Mbps switches. With this configuration, the network will then be able to support greater number of segments with each segment having more bandwidth and greater number of nodes.



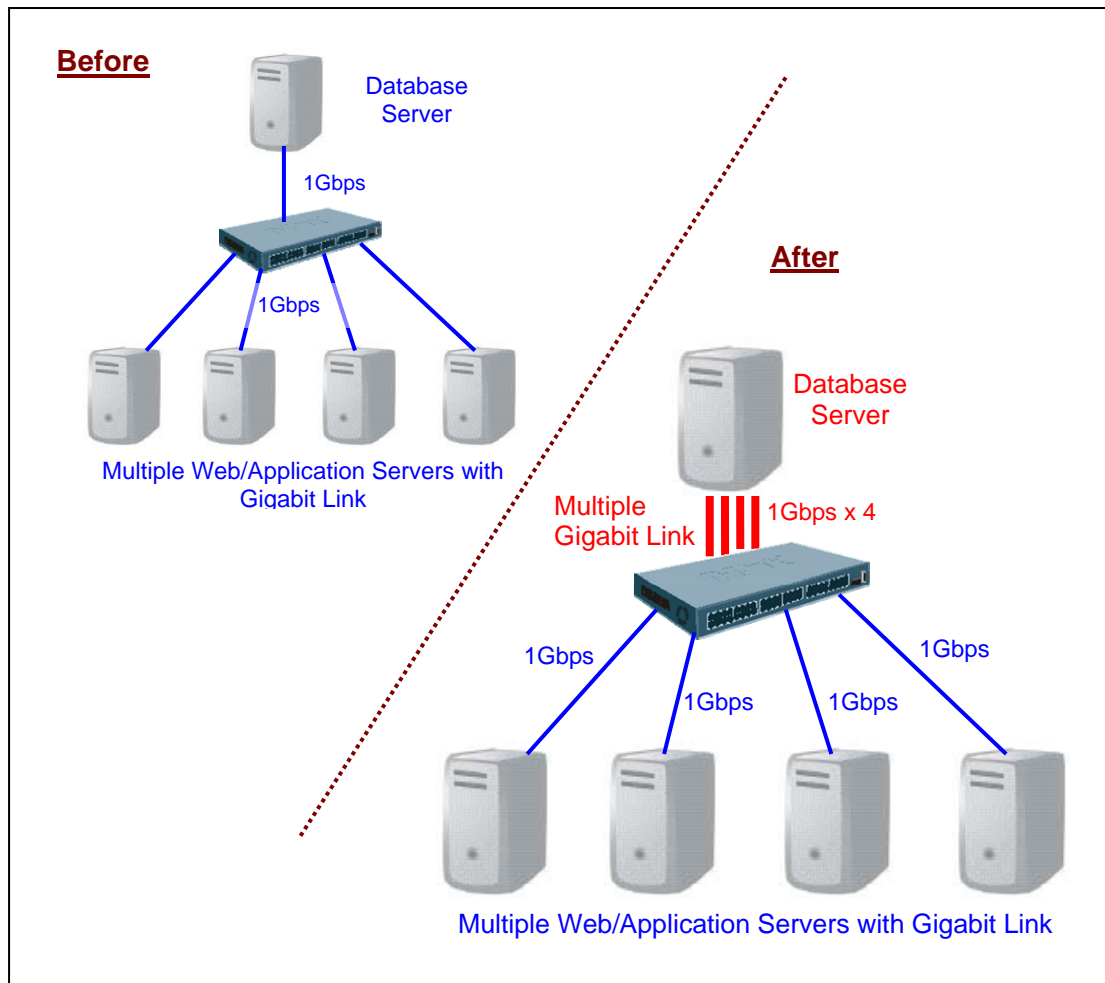
**Figure 12.** Gigabit Deployment at the backbone

A common scenario of a Gigabit deployment is the implementation of switch-to-switch links. To upgrade 100 Mbps links of the original Fast Ethernet switches to 1000 Mbps, a high-bandwidth switch-to-switch link may be used to enable the Gigabit switches to support greater number of computers and switched segments.



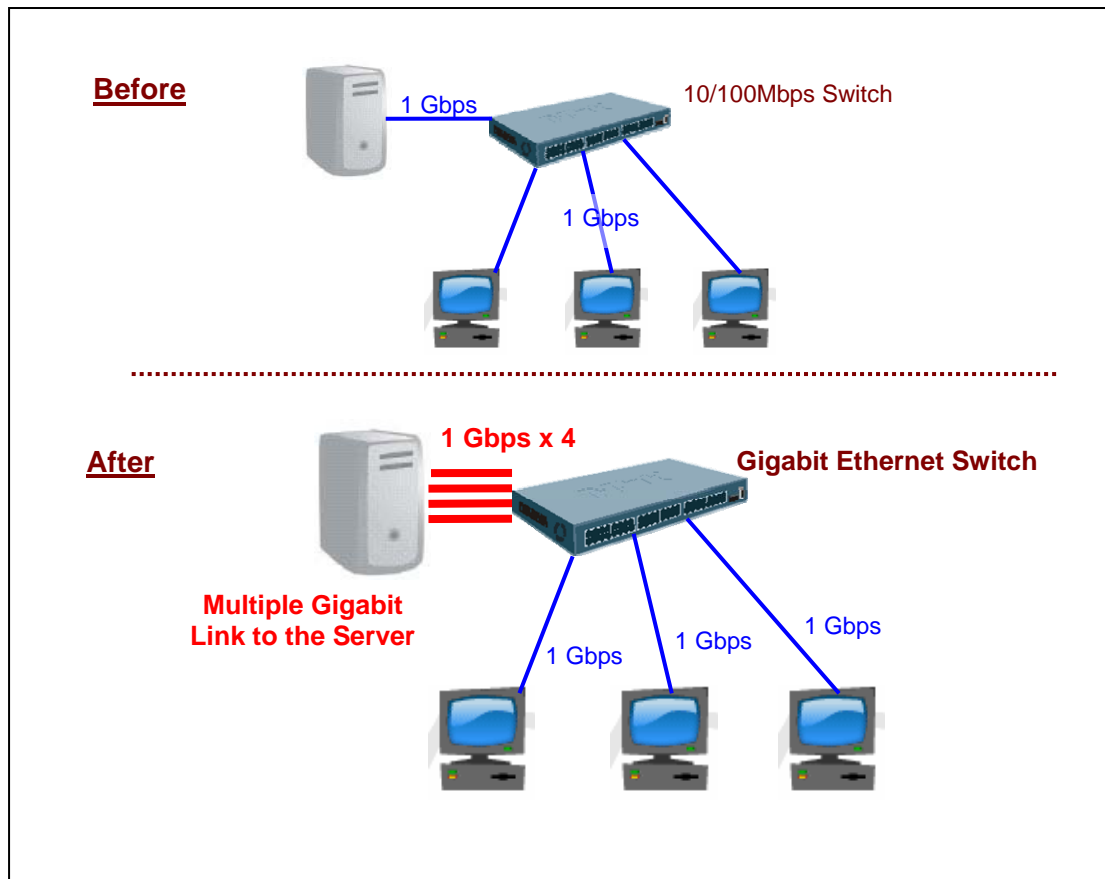
**Figure 13.** Gigabit Deployment for Switch-Switch Links

The demand for increased number of new servers to the network and support for applications such as data warehousing and database query calls for servers to be able to process larger files and transfer data at faster speed. This demand requires networks that connect the servers to also support the same performance. This is one of the reasons why many computers are migrating to Fast Ethernet. In an ideal network environment, every server should have a Gigabit Ethernet connection. Higher-demand servers such as database servers will require multiple Gigabit connections to serve several web servers. Using this method, network bottlenecks can be eliminated.



**Figure 14.** Multiple Gigabit Link

The demand for better performance and greater speed in networks will continue to grow. Workstations installed with 10 or 100 Mbps Ethernet connections will soon be replaced and servers will be scaled to multi-Gigabit speeds. Switches that use 10 or 100 Mbps will become obsolete and be replaced as technology enters into a new era of network standards.



**Figure 15.** Gigabit Deployment to the Desktop

### **Summary for Gigabit Ethernet**

Local Area Networks (LANs) that use Ethernet today can now scale its speed from 10 to 100 or 1000 Mbps Ethernet. The deployment of bandwidth hungry applications and the pressure of more powerful processors and operating systems demand faster network connection which has now become a necessity. In an ideal environment, all network backbones and servers should utilize Gigabit Ethernet. Gigabit Ethernet is an ideal choice for organizations as it offers progressive upgrade from earlier Ethernet configurations following IEEE standards. Gigabit Ethernet is also cost-effective because network managers, administrators, and support staff who are familiar with Ethernet need not be re-trained to be able to support Gigabit Ethernet.