Lesson 2:Gigabit Ethernet

At a Glance

Ethernet is the most popular network technology today. The majority of all installed network connections are using Ethernet technology. When considering ways to improve the efficiency and speed of a network, it is appropriate to think in terms of changing an existing technology that is already in place across the world. By improving on the technology operating over an infrastructure already in place, added costs are reduced since much, if not all, of the current wiring could continue to be used.

It was with this goal in mind that the Institute Electrical and Electronics Engineers (IEEE) formed the Gigabit Ethernet standards task force to create specifications for Gigabit Ethernet, which would increase transmission rates to 1000 Mbps, using existing legacy infrastructures.

What You Will Learn

After completing this lesson, you will be able to do the following:

- Identify physical specifications for Ethernet, Fast Ethernet, and Gigabit Ethernet
- Compare the basic network functions of Ethernet, Fast Ethernet, and Gigabit Ethernet
- Understand the role of carrier extensions, frame bursting, and the 802.3ab standard in extending the diameter and efficiency of Gigabit Ethernet
- Understand the relationship of Gigabit Ethernet to legacy networks and ATM
- Understand key network design terminology

Student Notes:

Tech Talk

- **Carrier Extension**—Non-data carrying bit added to a frame.
- **Dual-Duplex Mode**—Both transmit and receive signals occupy the same wire pair simultaneously.
- **Extension Bits**—Extra bits added to the Ethernet frame that prevents the detection of idle space between the transmitting frames.
- **ISO**—The International Organization for Standardization. An organization that works to create global standards for communication and information exchange.
- **Legacy Networks**—Older networks already installed which often need updating over time.
- **Nanometer**—Measurement represented by nm, which is one billionth of a meter.
- **Network Diagram**—A highly detailed graphical representation of the network.
- **Slot-time**—The unit of time the Ethernet MAC layer takes to handle collisions.

Ethernet Basics

In the early 1970's, Robert Metcalfe, an employee of the Xerox Palo Alto Research Center in California, developed a new system for interconnecting networks called Ethernet. By 1980, Ethernet became an open standard (i.e., a standard anyone could use) through the joint efforts of Digital Equipment Corporation, Intel, and Xerox. In 1985, the IEEE released the 802.3 CSMA/CD Ethernet standard that was later adopted by ISO.

IEEE 802.3 CSMA/CD Standard

Ethernet uses the Carrier Sense Multiple Access/Collision Detection (CSMA/CD) protocol when transmitting data. Carrier Sense allows a computer device to "sense" whether or not another transmission is being "carried" over the network. Before a device sends data, it listens for a carrier (jam) signal. If a carrier signal is detected, it waits until that transmission is completed. Collision Detection means that a sending device can "detect" simultaneous transmission attempts. When two or more devices try to send data at the same time, the signals collide. Detecting the collision, all devices stop transmitting and wait a random amount of time before attempting to retransmit data. The random time provision prevents simultaneous retransmissions.

Multiple Access means that all devices have equal access to the network. No device has priority over others, nor can it lock out any other device connected to the network. Information can be transmitted at any time by any device. All devices on the network receive the transmission and check the framed packet's destination address. If the destination address matches the device's address, the device accepts the data; if the address does not match, the device simply ignores the transmission.

IEEE 802.3 Physical Layer Specifications

The IEEE 802.3 standards set the specifications for cable types, lengths, and signaling devices for 10BaseT and 100BaseT Ethernet networks.

The majority of 10BaseT Ethernet networks use Category 5 unshielded twisted pair (UTP) cabling with a star topology and a maximum cable segment distance between repeaters of 100 meters (328 feet). Each segment may have up to 2 repeaters. The maximum diameter of the LAN may not exceed 2000 meters. Each LAN supports up to 1,024 devices. The transmission rate of a 10BaseT Ethernet network is 10 Mbps. In many networks, 10BaseT is used for both the backbone and the individual segments of a LAN.

In 1995, the IEEE added a supplement to the Ethernet standard (802.3u), which formally standardized the Fast Ethernet system (100BaseTX) using Category 5 UTP cable. Fast Ethernet is 10 times faster than 10BaseT Ethernet, yet it has the same frame format, segment lengths, and twisted pair cabling. It differs from 10 Mbps Ethernet in the type of signal encoding used. Fast Ethernet uses, with some minor modifications, the same specifications of FDDI. Using the FDDI signal encoding system allows Fast Ethernet to operate at transmission rates of 100 Mbps. At this speed, however, the diameter of the LAN must be reduced to approximately 200 meters. This reduction in the diameter of the LAN is due to Fast Ethernet using the same collision-detection system as 10BaseT. Since the transmitting speeds are 10 times faster, the distance for detection must be reduced by a factor of 10. For this reason, 100BaseTX is most frequently used only for the backbone of a LAN.

Physical Specifications for 10 Mbps and 100 Mbps Ethernet

Ethernet Type	Speed	Cable Type	Segment Length	Network Diameter	Network Function
10BaseT	10 Mbps	Cat 3,4 or 5 UTP (STP)	100 Meters	2000 Meters	Backbone and Segments
100BaseTX	100 Mbps	2-pair Cat 5 UTP or STP	100 Meters	200 Meters	Primarily Backbone

Check Your Understanding

- Describe how 10BaseT Ethernet and Fast Ethernet might be used in a network.

Gigabit Ethernet

Gigabit Ethernet is an extension of the 10 Mbps and 100 Mbps Ethernet standards. It offers data bandwidths of 1000 Mbps, while remaining compatible with the majority of previously installed (legacy) network cabling. Since it uses the same Ethernet 802.3 Carrier Sense Multiple Access with Collision Detection (CSMA/CD) protocol, frame format, and frame size as the current Ethernet installations, it reduces the cost of upgrading by allowing existing wiring to transmit at gigabit speeds.

The key objectives of the IEEE task force were to develop a Gigabit Ethernet standard that:

- Allowed half- and full-duplex operation at speeds of 1000 Mbps
- Used the 802.3 Ethernet frame format
- Used the CSMA/CD access method in half-duplex mode with support for one repeater per network segment
- Allowed compatibility with 10BaseT and 100BaseT technologies, which permits users to keep their existing, Category 5 cabling

Network equipment, e.g., routers and switches, can be easily replaced, but the horizontal cabling located within walls and ceilings is very difficult and costly to replace. The goals above are important because they allow Ethernet to remain the leader in network technology and still move to greater bandwidth without major changes in existing network cabling. Although some equipment will need to be replaced, every effort is being made to keep those replacements to a minimum.

What is 802.3z?

This standard defines three cable specifications. It specifies two standards for fiber optic media: 1000BaseS and 1000BaseL. The “S” indicates that the cable is used for short wavelengths of 770 to 860 nanometers (nm), which supports segment lengths up to 550 meters for shorter backbones. The “L” indicates that the cable is used for long wavelengths of 1270 to 1355nm, which supports segment lengths up to 5000 meters for longer backbones and campus backbones connecting multiple buildings.

The third cable specification, 1000BaseCX, defines the use of 150-ohm STP copper cabling for distances up to 25 meters. It is primarily intended for use in a switching closet.

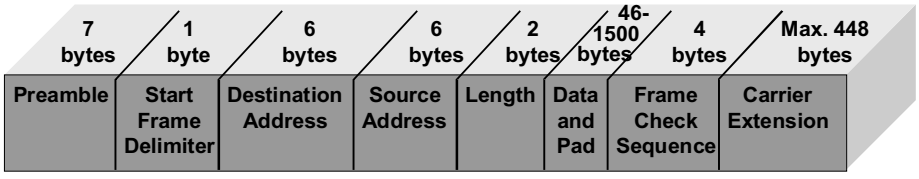
Extending the Diameter of Gigabit Ethernet Networks

Just as Fast Ethernet operates at 10 times the speed of 10BaseT, Gigabit Ethernet operates 10 times faster than Fast Ethernet. Remember that the network diameter for Fast Ethernet is only 1/10th (200 meters) of the diameter of 10BaseT (2000 meters) due to the increase in speed and the use of the same CSMA/CD protocol. The 802.3z Ethernet standard currently defines specifications that support a Gigabit Ethernet LAN with a maximum cable distance of 25 meters (~1/10th of Fast Ethernet). Such a short distance allows Gigabit Ethernet to be used only within a small room since the typical required distance between a hub and a workstation is 100 meters.

In order to maintain a 200-meter network diameter at Gigabit speeds operating in half-duplex mode, the minimum CSMA/CD carrier time, the amount of time to transmit a frame, has to be extended. The Ethernet slot-time must be extended as well. Slot-time is the unit of time the Ethernet MAC layer takes to handle collisions. The task force desired to make these changes without modifying the frame. Gigabit Ethernet extends the carrier time by adding a carrier extension. A carrier extension consists of non-data carrying bits added to a frame.

The carrier extension feature fixes the timing problems in CSMA/CD without changing the minimum packet size of 64 bytes recognized by the MAC layer. With a carrier extension the frame signal remains on the system for a minimum slot-time of 512 bytes, which is 8 times the original Ethernet slot-time. Any frame already 512 bytes or more in length does not require extensions.

Gigabit Ethernet Frame

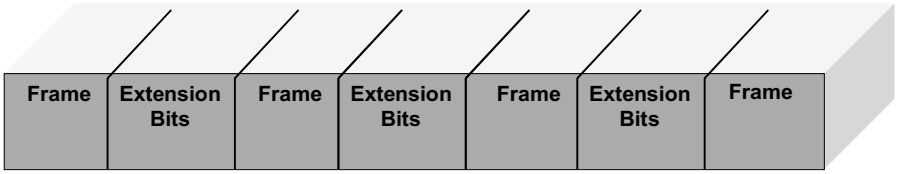


In full-duplex mode, the CSMA/CD protocol is not used as a media access control mechanism, so slot time is not a problem. Gigabit Ethernet operating in full-duplex mode does not need carrier extensions.

Frame Bursting

As an additional means to improve the performance of shorter frames, the Gigabit Ethernet standard incorporated into the CSMA/CD algorithm an optional feature, originally found on Novell NetWare networks, called frame bursting. Frame bursting allows servers, switches, and other devices to send a stream or series of bursts of small frames without waiting for acknowledgement. Other devices on the same wire defer to the stream of transmissions as long as there is no idle time detected. In order to prevent idle time between bursts, the transmitting device places extension bits into the frames following the first frame. The extension bits prevent the detection of idle space between the transmitting frames.

Frame Bursting Using Extension Bits



The primary danger in using frame bursting is that verification does not occur until several packets have been sent ahead, and errors will cause the re-transmission of those frames.

Check Your Understanding

- What is a carrier extension and how does it increase the network diameter of Gigabit Ethernet?

What is 802.3ab?

Current Ethernet installations use two of the four pairs in Category 5 wire for Ethernet. Many have left the other two pairs idle for future growth. A task force was formed to create a standard, 802.3ab, for Gigabit Ethernet using all four pairs of Category 5 cable. Referred to as 1000BaseT, this solution uses all four pairs of wires in UTP in dual-duplex mode, sending and receiving simultaneously on each pair.

If you can imagine data traveling on a highway, then in the current world it is traveling in a single car on a single lane, with all of the data arriving in that one car at 100 Megabits per second. With the 802.3ab standard, the data is traveling in eight cars at 125 Megabits per second on an eight-lane highway; thus, the full data packet has arrived 10 times (8 * 125 = 1000) faster than at 100 Mbps.

When the 802.3ab Ethernet standard is completed, gigabit speeds will be possible over existing UTP cable runs from the wiring closet directly to the workstation.

Physical Specifications for 1000 Mbps Ethernet

Ethernet Type	Speed	Cable Type	Segment Length	Network Diameter	Network Function
1000BaseS	1000 Mbps	Shortwave Fiber-Optic	550 meters	1100 meters	Building Backbone
1000BaseL	1000 Mbps	Longwave Fiber-Optic	5000 meters	10,000 meters	Campus Backbone
1000BaseCX	1000 Mbps	150-Ohm STP	25 Meters	Not Applicable	Switching Closet - Backbone
1000BaseT	1000 Mbps	4-pair Cat 5 UTP	100 Meters	200 Meters	Backbone or cable runs

Updating Legacy Ethernet Networks

Upgrading from Fast Ethernet to Gigabit Ethernet will not require changes in cabling, for the most part. However, it will require new switches, hubs, and network interface cards. These devices are being developed to use the Gigabit Ethernet standards and provide the greater bandwidth and speed needed for today's and tomorrow's networks.

It is expected that Gigabit Ethernet will first be used in backbone and switch-to-switch connections. Upgrading to Gigabit Ethernet may include:

- Upgrading switch-to-switch connections to increase speed between segments
- Upgrading switch-to-server connections to increase access to applications and data
- Upgrading a switched Fast Ethernet backbone by replacing these with Gigabit Ethernet switches and/or repeaters
- Upgrading a shared FDDI backbone by installing new FDDI switches/routers
- Upgrading high-performance workgroups by installing Gigabit Ethernet Network Interface Cards

While certainly not requirements, these steps show the most likely order in which the components of an Ethernet network could be converted to Gigabit Ethernet. By replacing switches and other backbone connections first, a network would be able to begin using Gigabit Ethernet immediately.

Buffered Distributors

A new network device called a buffered distributor or full-duplex repeater is under development by various vendors. A buffered distributor is a full-duplex, multi-port, hub-like device that connects two or more Gigabit Ethernet segments. As with repeaters, a buffered distributor forwards all incoming frames without examining the address information. However, a buffered distributor may buffer, or store, one or more incoming frames before forwarding them. It uses flow control to manage the frames, which makes it capable of receiving and transmitting frames simultaneously. This allows multiple ports on the distributor to share one gigabit of bandwidth.

Gigabit Ethernet Versus ATM

Some network managers have questioned whether Gigabit Ethernet will replace ATM. Although Gigabit Ethernet and ATM at first may appear to be competing technologies, in reality they are complementary technologies. Gigabit Ethernet adds a new dimension to the scalability of Ethernet in LANs. It will allow for high-speed connections as backbones to existing LANs and eventually as the connection wire between the workstation and the wiring closet. With ATM transmission rates of 2.4 Gbps expected in the near future, it is still recommended to use ATM for WAN connections where there is a strong need for high quality, integrated services such as voice, video, and data.

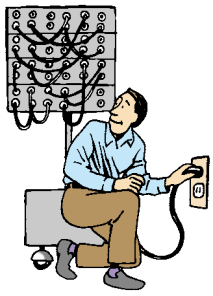
Check Your Understanding

- Describe how the different gigabit Ethernet types will be used in a network infrastructure once Gigabit Ethernet is implemented fully.

Try It Out: Key Network Design Terminology

Materials Needed:

- Windows 95 PC
- Any Word Processor (e.g., MS Word) or Spreadsheet (e.g., MS Excel)
- Pen/Pencil and Paper



There are seven key network design terms that are important to understand when creating a network design proposal.

- **Network Architecture**—This is the overall high-level, long-term view of the network. It is the basis for the network design. Think of it as the "grand plan" of the network, showing the overall direction of the network infrastructure. It contains general diagrams and information that represents an outline of a network that would satisfy the needs of the client.
- **Network Design**—This is the exact details of the network with very specific information about the network's products, technologies, installation, and configuration requirements. It is the end product that the network designer will propose to the client. It contains detailed diagrams and a complete description of the design with justifications for the design.
- **Network Diagram**—A network diagram may be generalized or very specific. Generalized diagrams are often included in the network architecture document. The detailed diagrams are included in the network design. For example, the network architecture diagram may show a wiring closet, but the network design diagram will show the entire wiring closet layout.
- **Network Requirements**—This is the list of the client's business requirements that influence the choices of technologies used in creating the network design. In assessing the network requirement, it is important to consider not only the current needs, but also the future needs of the client. The network requirements are used to create the network architecture and design.
- **Basic Rules**—These are design guidelines and recommendations that should be observed when designing a network. Some guidelines are generic, meaning they apply to any network. Other guidelines are only specific to the client's needs. For example, the Ethernet standards are generic guidelines that are very specific about the type of cables that are to be used in any Ethernet network.
- **Routing Architecture**—This is a list of the routing protocols and where they will be used within the network. This architecture includes whether the network will use Layer 2 or Layer 3 switching. This architecture uses information from the network architecture to determine what routing protocols would be used.

- **Addressing Plan**—This is a plan to allocate network addresses according to several possible addressing approaches, including using IPv4, IPv6, and classless interdomain routing (CIDR). Subnet masks assignments would also be proposed in this plan. The plan is dependent on the information from the network architecture and the routing architecture.

  1. Work with a partner on this assignment.
  2. Using the definitions of the network design terminology, design an organizational chart that represents the relationship of the different terms.
  3. With the knowledge you have gained about Ethernet technologies, list the issues that are associated with 10BaseT, Fast Ethernet, and Gigabit Ethernet under the Basic Rules section of your chart.
  4. Are there other sections where you could list questions or issues that relate to Ethernet technology? Try to categorize at least three other questions and issues in the appropriate sections of the chart.

Rubric: Suggested evaluation criteria and weightings:

Criteria	%	Your Score
Logical organizational chart	50	
Thorough list of basic Ethernet rules	30	
Three questions or issues categorized appropriately	20	
TOTAL	**100**	

Stretch Yourself: The Home Network Analysis and Design

Materials Needed:

- Windows 95 PC
- Any Word Processor (e.g., MS Word) or Spreadsheet (e.g., MS Excel)
- Pen/Pencil and Paper
- Color Pencils or Color Markers for color illustration
- Student Portfolio

The network diagram is a graphical representation of the network. It contains a high level of detail. An accurate network diagram is helpful so that valuable time is not lost when the network manager is troubleshooting.

The diagram should include as much detail as possible. For example, it will not only show where a wiring closet should be placed, but it will also show the complete layout of the wiring closet.

In the Network Wizards activity in Unit One, Lesson One of this course, you worked with a team to research home networking kits and gather information necessary to do a preliminary proposal for creating a network in a selected home.

In this activity, you will analyze the information you gathered thoroughly and then develop the network design.

1. Gather together your original design team and review the information you gathered about the specific home and networking kits.

2. Conduct a thorough analysis of the information you have gathered. If you need more information, gather it before you complete your diagram.

3. Using your analysis, create a detailed diagram of the home network you would propose for your homeowner. Your diagram must be accurate. You must, as much as possible, have the diagram proportional to the actual house. Wiring plans, electrical outlets, connection drops, locations of computers and peripherals, etc., must be included in your diagram. Use multiple colors or line symbols to indicate different components of your diagram and include a legend.

4. To accompany your diagram, write a description of the diagram with specifications as to what kit you would use, what wiring is needed, and what equipment (i.e., routers, hubs, switches, NICs) is required. Include your justifications for this design.

5. Place the diagram and description in your portfolio.

Rubric: Suggested evaluation criteria and weightings:

Criteria	%	Your Score
Enthusiastic and responsible participation as a network design team member	25	
Accurate and complete diagram suitable for reproduction	50	
Description representing thorough synthesis of information	25	
TOTAL	**100**	

Network Wizards: Network Design Portfolio Case Study

Materials Needed:

- Windows 95 PC
- Any Word Processor (e.g., MS Word) or Spreadsheet (e.g., MS Excel)
- Pen/Pencil and Paper
- Student Network Design Proposal Working Draft

Part One: Gathering Information Overview

The second phase, information gathering, begins once you and your client have agreed on the statement of work. During this process, you will gather as much information as possible about the client's business and the network.

This week, your assignment is to conduct the pre-site data gathering by creating a questionnaire for your client to complete and return to you.

The information desired from the pre-site questionnaire includes:

- Primary and secondary technical contacts at the company
- Network design goals perceived by the client
- Key business objectives of the company (e.g., Will the company participate in e-commerce or web-based educational activities?)
- Applications that are critical to the operation of the company (e.g., e-mail or a specific database that needs to be accessible 24 hours per day)
- Design constraints (e.g., all workstations must be connected using Ethernet)
- Network protocols in use now or in the future (e.g., AppleTalk or Novell NetWare)
- Current network topology
- Plans for changes to the topology
- Current network addressing structure
- Current desktop operating systems
- Current routing protocols
- Plans for company growth
- Voice requirements
- Current problems with the existing network

Part Two: Creating the Questionnaire

1. There should be at least one question for each of these issues. Upgrading to Gigabit Ethernet may be a viable solution for your case study. Be sure to include questions that prompt the client to consider this option.

2. After you have written your questionnaire, submit it to your teacher for review and comments.

3. Make any revisions before giving the questionnaire to your client.

4. Assure the client that he or she is free to leave any part of the questionnaire blank. Your client may not be comfortable disclosing some of the information to a student. You can complete your portfolio case study with the information the client shares.

5. Make sure you are always courteous and remember to thank the client for his or her time.

Rubric: Suggested evaluation criteria and weightings:

Criteria	%	Your Score
Clear and concise questions that address all network issues	50	
Professional quality questionnaire suitable for reuse for other network design proposals	50	
TOTAL	**100**	

Summary

Gigabit Ethernet

In this lesson, you learned the following:

- The physical specifications for Ethernet, Fast Ethernet, and Gigabit Ethernet
- The basic network functions of Ethernet, Fast Ethernet, and Gigabit Ethernet
- The roles of carrier extensions, frame bursting, and the 802.3ab standard in extending the diameter and efficiency of Gigabit Ethernet
- The relationship of Gigabit Ethernet to legacy networks and ATM
- The key network design terminology

Review Questions

Gigabit Ethernet

Part A:

1. A network diameter up to 1100 meters is supported by:
   a. 1000BaseCX Ethernet
   b. Fast Ethernet
   c. 10BaseT Ethernet
   d. 1000BaseT Ethernet
   e. 1000BaseS
2. Longwave fiber-optic cable is used to support:
   a. 1000BaseCX Ethernet
   b. 100BaseTX Ethernet
   c. 1000BaseL Ethernet
   d. 1000BaseS Ethernet
   e. All of the above
3. Untwisted pair cable is used to support:
   a. 1000BaseS only
   b. 1000BaseT, 100BaseTX, and 10BaseT
   c. 1000BaseCX and 1000BaseL
   d. 1000BaseL only
   e. 1000BaseL, 1000BaseS, and 1000BaseCX

4. The network diameter of 10BaseT Ethernet is
   a. 1100 meters
   b. 10,000 meters
   c. 200 meters
   d. 25 meters
   e. 2000 meters
5. The network diameter of 10,000 meters is support by:
   a. 1000BaseCX
   b. 100BaseTX
   c. 10BaseT
   d. 1000BaseL
   e. 1000BaseS

Part B:

1. Building backbones are mostly likely to be built using:
   a. 1000BaseT Ethernet
   b. 100BaseTX Ethernet
   c. 1000BaseS Ethernet
   d. 10BaseT Ethernet
   e. All of the above.
2. In a Gigabit Ethernet environment, which physical specification is most likely to be used to build the switching closet backbone?
   a. 1000BaseCX
   b. 1000BaseS
   c. 1000BaseS and 1000BaseL
   d. 1000BaseT
   e. 1000BaseS and 1000BaseT
3. 1000BaseL Ethernet is most likely to used to build:
   a. The backbone in a switching closet
   b. The segment or cable runs of a network
   c. A campus backbone
   d. A building backbone
   e. The backbone of a small LAN

4. Which Ethernet physical specification would be most likely used for either the backbone or the segment runs of a network?

   a. 100BaseTX and 1000BaseS Ethernet

   b. 100BaseTX and 1000BaseCX Ethernet

   c. 1000BaseL and 100BaseTX Ethernet

   d. 1000BaseS and 1000BaseL Ethernet

   e. 10BaseT and 1000BaseT

Part C:

1. Describe what a carrier extension is and how it is used in Gigabit Ethernet.

2. Describe frame bursting in Gigabit Ethernet.

3. What is the 802.3ab standard?

Part D:

1. List five possible activities that may be necessary to upgrade legacy networks to Gigabit Ethernet.

2. Some network managers have questioned whether Gigabit Ethernet will replace ATM. Explain what the current thoughts are on the relationship of Gigabit Ethernet and ATM will be in the future.

Scoring

Criteria	%	Your Score
Part A: Identify physical specifications for Ethernet, Fast Ethernet, and Gigabit Ethernet.	25	
Part B: Compare the basic network functions of Ethernet, Fast Ethernet, and Gigabit Ethernet.	20	
Part C: Understand the role of carrier extensions, frame bursting, and the 802.3ab standard in extending the diameter and efficiency of Gigabit Ethernet.	30	
Part D: Understand the relationship of Gigabit Ethernet to legacy networks and ATM.	25	
TOTAL	**100**	
Try It Out: Understand the key network design terminology.	**100**	
Stretch Yourself:	**100**	
Network Wizards:	**100**	
FINAL TOTAL	**400**	

Resources:

Gigabit Ethernet Alliance. (1999). Gigabit Ethernet Technology. Available On-line: http://www.gigabit-ethernet.org/technology/whitepapers/gige_0698/technology.html#technology

Gigabit Ethernet Alliance. (1999). Gigabit Ethernet Migration. Available On-line: http://www.gigabit-ethernet.org/technology/whitepapers/gige_0698/migration.html.

Optimized Engineering Corporation. (1999). Network Interconnect Devices: Repeaters, Bridges, Switches, Routers. Available On-line: http://www.optimized.com/COMPENDI/L1-Inter.html#MakeConn.

Spurgeon, C. E. (1997). Practical Networking With Ethernet, Boston: International Thomson Computer Press.