CHAPTER

3

CABLES AND THE CABLING INFRASTRUCTURE

After reading this chapter and completing the exercises, you will be able to:

- Identify the various types of cable and their characteristics
- Compare cable types and characteristics
- Identify and differentiate between the various network topologies
- Create an effective network design
- Identify which network elements you must include in your documentation

Every network needs a solid foundation, regardless of its size. The cables are the framework of that foundation; without the necessary cables in place, no network can exist. Designing the cable layout and selecting the appropriate types of cable for use are crucial to a network's success.

This chapter describes the popular cable types you need to know, as well as their specifications and network topologies. When you are designing a network for an organization, this information helps you to assess the organization's current needs and plans for future growth. Creating a network design that is both sound and flexible provides the solid foundation you need.

CABLE TYPES AND CHARACTERISTICS

When selecting cable for your telecommunications system, you must match your needs with the characteristics of the cable. The three basic types of cable are coaxial, twisted-pair, and fiber-optic. As an alternative to using cable in your system, you might consider **wireless** technologies, which transmit signals through the atmosphere. The five basic characteristics you must consider when choosing cable are its throughput and bandwidth, cost, size and scalability, connectors, and noise immunity. The following sections describe each cable type and its characteristics.

Cable Characteristics

The five characteristics described in this section pertain to all means of **data transmission**, in which signals are generated by voltage and then sent over a designated path. These signals can be either analog or digital. **Analog** signals are variable voltages that create continuous waves of sound, resulting in inexact transmissions. **Digital** signals are precise voltages that create pulses with specific values called bits, resulting in more precise transmissions. You must consider the following characteristics when selecting data transfer **media** for transmitting signals:

- **Throughput and bandwidth** — **Throughput** is the amount of data that a cable can transmit during a given period. This time is usually measured in **megabits** (1,000,000 bits) per second, or Mbps. Throughput potential is determined by the physical nature of the cable. If you try to send more data through a copper wire than it is designed to handle, the result will be lost data and data errors. Noise and other devices connected to transmission media can also limit throughput. **Bandwidth** is the measure of the difference between the highest and lowest frequencies that media can transmit. The range of these frequencies is expressed in **hertz (Hz)**, and is directly related to throughput. The higher the bandwidth, the higher the throughput, because higher frequencies can transmit more data in a given period than lower frequencies.

- **Cost** — Because the cost for different types of cable varies and depends on the available hardware, several factors can influence the final cost of choosing one type of cable over another. You should consider the costs of installation, the transmission rate as it affects productivity, and the obsolescence potential of the media. You should also consider whether a new infrastructure is needed or the existing one is sufficient; the maintenance and support costs for new and existing systems play a part in this decision.

- **Size and scalability** — Three specifications determine a cable's size and **scalability** (growth ability and potential): maximum nodes per segment, maximum length per segment, and maximum network length. Each of these specifications is based on a physical characteristic of the wire. **Attenuation**, the amount of signal loss over a given distance, limits the maximum number of nodes and the maximum length of a segment. Maximum network length is determined by **latency**, the delay between entering commands on your computer and their acceptance by the server.

- **Connectors** — **Connectors** are the hardware that connects the cable to the network device. Each type of cable requires a specific connector. The connectors you choose affect the cost of installation and maintenance.
- **Noise immunity** — Noise can distort data signals. Two types of noise that can affect data transmission are **electromagnetic interference (EMI)** and **radio frequency interference (RFI)**. Both EMI and RFI are waves that emanate from cables carrying electricity or electrical devices, including motors, power lines, televisions, copiers, and fluorescent lights. RFI can also be caused by a strong broadcast signal from a radio or television station.

Cable Types

Now that you understand the characteristics of cables, you need to learn more about each type of popular cable and how it works.

Coaxial Cable

Coaxial cable, also called "coax" for short, was the foundation for Ethernet networks in the 1980s and remained a popular medium for many years. Coaxial cable consists of a central copper core surrounded by an insulator, a braided metal shielding called braiding, and an outer plastic cover called a sheath or jacket. Figure 3-1 depicts a typical coaxial cable. The copper core carries the electromagnetic signal, and the braiding acts as both a shield against noise and a ground for the signal. The insulator layer usually consists of a ceramic or plastic material such as polyvinyl chloride (PVC) or Teflon®. The insulator protects the copper core from the metal shielding to prevent a short circuit in case the two touch. The jacket protects the cable from physical damage and is usually manufactured from a flexible, fire-resistant plastic.

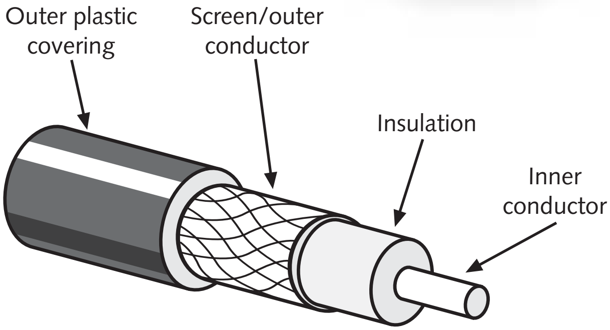

Figure 3-1 Coaxial cable

Coaxial cable has a high resistance to interference from noise due to its insulation and protective braiding. Coax can also carry signals farther than twisted-pair cabling before signal amplification is necessary, although not as far as fiber-optic cabling. Coax is more expensive than twisted-pair cable and generally supports lower throughput. Coax requires each end of its segments to be terminated with a 50-ohm resistor to control **signal bounce** (sometimes called signal reflection), a phenomenon in which data signals travel endlessly between the two ends of the network. Coax also requires each cable to be grounded on one end.

Coaxial cable comes in a variety of types with different specifications; however, only two or three types of coax are used today. In telecommunications, the most important specification for coaxial cable is its **impedance**, the measurement of a conductor's opposition, or resistance, to the flow of alternating current. Each unit of this resistance is expressed as an **ohm**.

To better understand the concept of resistance, visualize an open window. Wind easily blows through it, but if a mesh screen is placed over the window, it creates opposition to the wind. Each time another, more tightly woven mesh screen is placed over the window, resistance to the wind increases. Placing a piece of glass over the window provides total opposition to the wind.

Each type of coaxial cable is defined by its own specifications, as shown in Table 3-1.

Table 3-1 Types of coaxial cable

Designation	Type	Impedance	Description
RG-58 /U	Thinwire	50 ohms	Solid copper core
RG-58 A/U	Thinwire	50 ohms	Stranded copper core
RG-58 C/U	Thinwire	50 ohms	Military version of RG-58 A/U
RG-59	CATV	75 ohms	Broadband cable, used for cable TV
RG-8	Thickwire	50 ohms	Solid core; approximately 0.4-inch diameter
RG-11	Thickwire	50 ohms	Stranded core; approximately 0.4-inch diameter
RG-62	Baseband	90 ohms	Used for ARCnet and IBM 3270 terminals

Twisted-Pair Cable

Twisted-pair cable is the most common form of cabling used on LANs today. It is relatively inexpensive, flexible, and easy to install. It does not span as great a distance as coax, but it can span significant distances before requiring the use of a **repeater** to regenerate and amplify signals. Twisted-pair cable can easily accommodate a variety of network layouts, or **topologies**, and can handle faster networking transmission rates than coaxial cable. Because of its flexibility, twisted-pair is more prone to physical damage than coaxial cable. The benefits of twisted-pair, however, outweigh this drawback.

Twisted-pair cable is the type of cable used to wire telephones. Different applications may call for different grades of twisted-pair cable; however, no matter what the grade or application, all twisted-pair cable consists of insulated copper wires, each with a diameter of 0.4 to 0.8 mm, twisted in pairs around each other and encased in a plastic coating (Figure 3-2). The telephone industry refers to these pairs as the tip and ring. One of the wires in the pair, the **tip**, is connected to the positive side of a battery, which is the telephone industry's equivalent of a ground in a standard electrical circuit. The other wire, the **ring**, is the DC negative wire (–48 volts) that carries the signal.

The twists in the pairs, also referred to as **balanced-pair**, help to reduce the effects of **crosstalk**, the infringement of the signal from one wire pair on another wire pair's signal. Crosstalk is quantified in **decibels (dB)**, a measurement unit of signal strength or of a sound's intensity. Silence measures 0 dB, a sound that is 10 times more powerful measures 10 dB, and a sound that is 100 times more powerful is 20 dB (not 100 dB). **Alien crosstalk**, which occurs when signals from one cable interfere with an adjacent cable's transmission, is another form of crosstalk. It is often caused by bundling too many cables in a conduit that is too small.

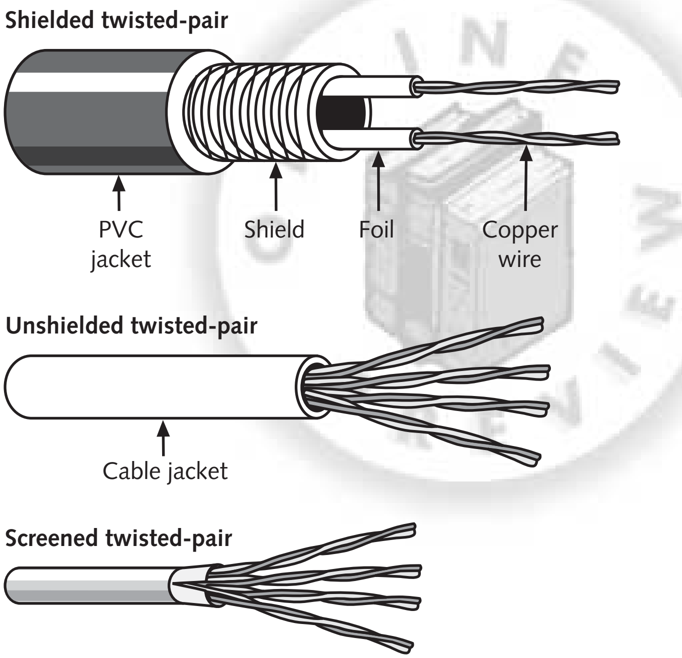

Figure 3-2 Shielded, unshielded, and screened twisted-pair cable

The number of twists per inch in a pair of wires determines how resistant the pair will be to noise. Better, more expensive twisted-pair cable has more twists per foot, an amount known as the **twist ratio**. One drawback of a high twist ratio is the possibility of greater attenuation.

Twisted-pair cable falls into three categories: shielded twisted-pair, unshielded twisted-pair, and screened twisted-pair.

- **Shielded twisted-pair (STP)** — STP consists of twisted pairs that are individually insulated and surrounded by a shielding made of a metallic substance, such as foil or braided metal, that must be properly grounded. The shielding acts as an antenna by converting the noise into a current that induces an equal, yet opposite, current on the twisted pairs it surrounds. The noise on the shielding mirrors the noise on the twisted pairs, allowing the two to cancel each other out. The effectiveness of the shield depends on the environmental noise to which the STP is subjected; the grounding mechanism; and the material, thickness, symmetry, and consistency of the shielding.
- **Unshielded twisted-pair (UTP)** — UTP consists of one or more insulated pairs of wires encased in a plastic sheath. Because it does not contain additional shielding, it is less expensive and less resistant to noise than STP and screened twisted-pair (ScTP). UTP protects against EMI and RFI by providing an electrical balance between the two conductors in a pair and a uniform twist, also referred to as balanced-pair.
- **Screened twisted-pair (ScTP)** — ScTP consists of one or more insulated pairs of wires contained in a full foil laminate shield, with at least one tinned, copper drain wire encased in a plastic sheath. Because of its construction, ScTP offers superior immunity to radio frequency fields and reduced crosstalk. ScTP protects against EMI and RFI by providing an electrical balance between the two conductors in a pair and a uniform twist. The drain wire and screen must always maintain continuity and a single point of ground.

In 1991 the American National Standards Institute (ANSI), Electronic Industries Alliance (EIA), and Telecommunications Industry Association (TIA) released their joint standard, called the ANSI/EIA/TIA-568 Commercial Building Wiring Standard. Also known as structured cabling, this standard was designed for uniform, enterprise-wide, multivendor cabling systems. The standard accomplishes two objectives: It divides twisted-pair wiring into several categories, as shown in Table 3-2, and suggests how networking media can be best installed to maximize performance and minimize maintenance.

Table 3-2 Twisted-pair categories, data rates, and applications

Category	Maximum Data Rate	Usual Application and Information
CAT1	20 Kbps	Voice communications, doorbell wiring
CAT2	4 Mbps	Not usually found on modern networks, but still used on IBM cabling systems and Token Ring networks
CAT3	Usually 10 Mbps, but 16 Mbps is possible	Voice and data on 10-Mbps Ethernet networks and 4-Mbps Token Ring networks
CAT4	16 Mbps to 20 Mbps	16-Mbps Token Ring (not used much); guaranteed up to 20-MHz (megahertz) signal
CAT5	100 Mbps	100-Mbps Ethernet and ATM (Asynchronous Transfer Mode); guaranteed up to 100-MHz signal

Table 3-2 Twisted-pair categories, data rates, and applications (continued)

Category	Maximum Data Rate	Usual Application and Information
Enhanced CAT5	1000 Mbps or 1 Gbps (gigabits per second)	Fast Ethernet and other fast technologies; signal rates as high as 200 MHz, with advanced methods for reducing crosstalk
CAT6	1000 Mbps	Fast Ethernet and other fast technologies. Same as Enhanced CAT5, but better performance. Guaranteed signal rates of 250 MHz.
CAT7	Unknown at this time	Same as CAT6, with signal rates of 600 MHz. The CAT7 standard was still in testing at press time.

Fiber-Optic Cable

Fiber-optic cable, also called fiber, contains one or more glass fibers in its core. Data is transmitted by converting electrical signals at the sending end into optical signals, which are then transmitted through the central fibers via a pulsing light sent from a laser or light-emitting diode (LED), and reconverted into electrical signals at the receiving end. Around the fibers is a layer of glass, called **cladding**; it has a lower refractive index than the core. The **refractive index**, which measures the ability to bend light, enables the cladding to act like a mirror, reflecting light back to the core in patterns that vary depending on the transmission mode. This behavior is known as total internal reflection; it allows the fiber to bend around corners without diminishing the integrity of the signal. Over the cladding is a layer of plastic and a braiding of Kevlar® (an advanced polymeric fiber), also known as the buffer, that protect the inner core. A plastic jacket covers the braiding. Figure 3-3 shows the different layers of a typical fiber-optic cable.

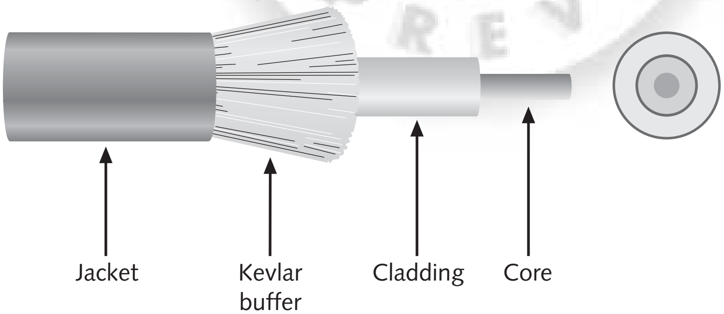

Figure 3-3 Basic optical fiber

Fiber comes in a number of different types, but all of its variations fall into two categories: single-mode and multimode. **Single-mode fiber** carries a single mode of light to transmit data from one end of the cable to another. Data can travel faster and farther on single-mode fiber, but the cost is extremely high. **Multimode fiber** carries up to hundreds of thousands of modes of light simultaneously, and is the type of fiber-optic system used by most data networks.

COMPARING CABLES AND THEIR CHARACTERISTICS

Now that you are familiar with the various cable types and the characteristics that pertain to all media, you can compare these cables. This comparison helps you make the best decisions when selecting cable for your applications. The terms that define the types of media used by a network include 10Base5, 10Base2, 10BaseT, and 100 (or 1000)BaseT. The "10" (or "100," or "1000") refers to the data speed or throughput in Mbps. The "Base" refers to baseband, which means that the cable uses all of its bandwidth for each transmission. The "5" is short for 500 m and the "2" is short for 185 m, both of which refer to the maximum cable segment lengths. Finally, the "T" refers to twisted-pair. Understanding these terms helps you identify cable immediately.

ThickNet (10Base5)

ThickNet (10Base5) cabling is also known as ThickWire Ethernet, Yellow Ethernet, and Yellow garden hose, due to its yellow sheath. The following list describes ThickNet's characteristics:

- ThickNet has a maximum transmission rate of 10 Mbps and uses **baseband** transmission, in which digital signals are sent through direct-current pulses applied to the wire. The signal requires exclusive use of the wire's capacity, which means that only one signal can be transmitted at a time.
- Although ThickNet is less expensive than fiber-optic cable, it is significantly more expensive than ThinNet or twisted-pair cable.
- ThickNet requires the use of a **vampire tap** (a connector that pierces a hole in the wire) to connect to a transceiver, and a drop cable to connect the telecommunications devices. A vampire tap is shown in Figure 3-4.
- Because of its wide diameter and shielding, ThickNet has the highest resistance to noise of any commonly used cabling option.
- ThickNet's high noise resistance allows data to travel for greater distances than most other types of cabling. The maximum segment length is 500 m. ThickNet can accommodate a maximum of 100 nodes per segment. Its total maximum network length is 1500 m. To minimize interference between stations, devices must be separated by at least 2.5 m.

ThinNet (10Base2)

ThinNet cabling (10Base2) is also known as thin Ethernet or black Ethernet for its black sheath. It was the most popular medium for Ethernet LANs in the 1980s. The following list describes ThinNet's characteristics:

- ThinNet can transmit data at a maximum rate of 10 Mbps, and uses baseband transmission.

- ThinNet is less expensive than ThickNet and fiber-optic cable, but more expensive than twisted-pair cable. Prefabricated cables are available for the low cost of approximately $1 per foot, which is why ThinNet is sometimes referred to as "cheapnet."
- ThinNet uses **BNC (British Naval Connector)** and **BNC/T** connectors to connect the wires to devices (Figure 3-5). The BNC is the connector that goes on the cable, and the BNC/T is a T-shaped adapter that connects on one end to the station's network interface card. The bus connects to the other two ends.

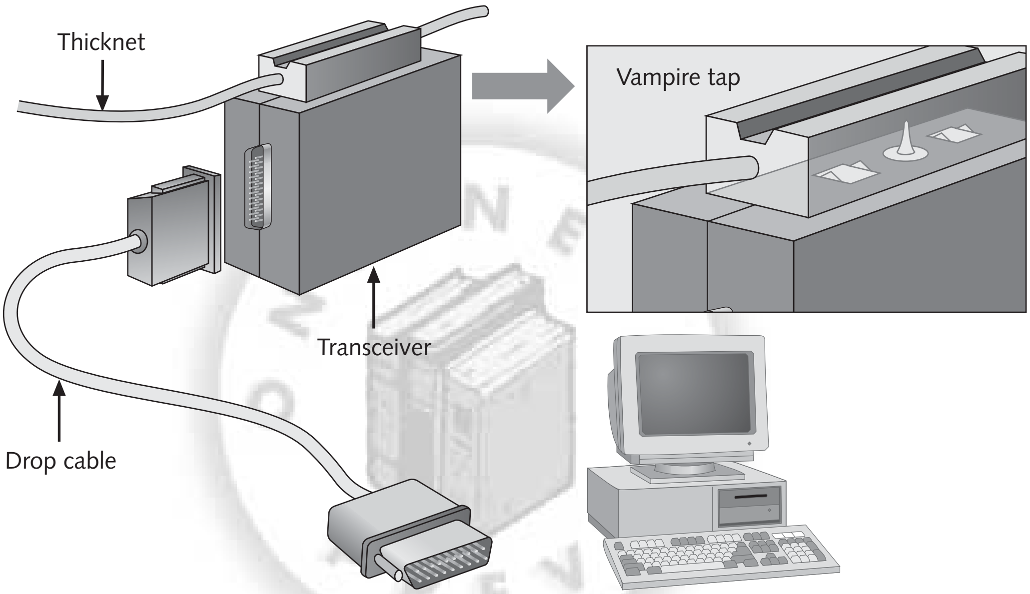

Figure 3-4 Vampire tap

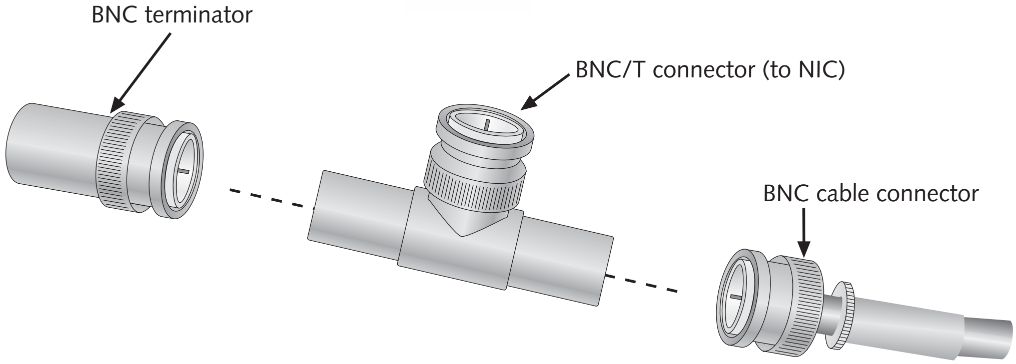

Figure 3-5 BNC and BNC/T connectors

- Because of its insulation and shielding, ThinNet is more resistant to noise than twisted-pair cable, but not as resistant as ThickNet.
- ThinNet has a maximum segment length of 185 m and can accommodate 30 nodes per segment. The total maximum network length for ThinNet is slightly more than 550 m. To minimize interference between stations, devices must be separated by at least 0.5 m.

Twisted-Pair: Shielded, Unshielded, and Screened (10BaseT)

Whether shielded, screened, or unshielded, all twisted-pair cables share many of the same characteristics. The following list describes the characteristics of STP, ScTP, and UTP cable, and highlights their similarities and differences:

- Both STP and UTP can transmit data at 10 Mbps. CAT5 UTP can transmit data at 100 Mbps, and enhanced CAT5 and CAT6 can transmit data at 1000 Mbps (1 Gbps).
- The costs of STP, ScTP, and UTP vary and depend on the grade of copper used, the category rating, and any enhancements. However, STP and ScTP are usually more expensive than UTP, enhanced CAT5 usually costs about 20 percent more than regular CAT5, and CAT6 is even more expensive than enhanced CAT5.
- All twisted-pair cables use 8-pin **RJ-45 connectors** and jacks, which look very much like standard telephone connectors and jacks, as shown in Figure 3-6.
- Because of their shielding or screening, STP and ScTP are more resistant to noise than UTP. UTP is the least noise-resistant of the major cable types. UTP may use filtering and balancing techniques to offset the effects of noise.
- The maximum segment length for STP and UTP is 100 m; for ScTP, it is 98 m. These are shorter spans than those for coaxial cable, because twisted-pair is more susceptible to noise. Twisted-pair can accommodate a maximum of 1024 nodes per segment. The maximum overall network length depends on the transmission method used.

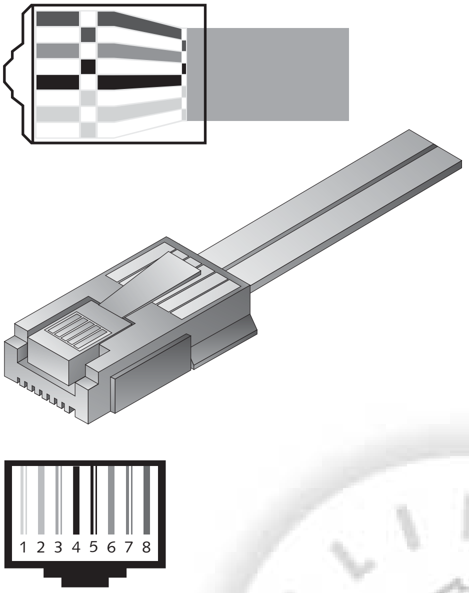

Figure 3-6 RJ-45 connector

Fiber-Optic Cable

Fiber-optic cable is also known as fiber. Until recently, fiber was used primarily as a **backbone cable**. This is the cabling that connects one telecommunications room (TR) to another, as well as connecting TRs to equipment rooms and one building's equipment room to another's. The following list describes the characteristics of fiber-optic cable:

- Fiber has always been able to reliably transmit data at rates as high as 1 Gbps. With the use of **dense wave division multiplexing (DWDM)**, which combines and transmits multiple signals simultaneously at different wavelengths on the same fiber, data has been transmitted at guaranteed rates in excess of 40 Gbps. Such high throughput is partly due to the physics of light traveling over glass. Light encounters virtually no resistance, so it can travel at a faster rate.
- Fiber is one of the most expensive types of cable. The cost of running it to a desktop was once prohibitive, and is only now becoming affordable. Not only is the cable more expensive, but network communication devices used with fiber, such as **network interface cards (NICs)** and **hubs**, can cost up to five times more than similar devices designed for twisted-pair networks.
- Fiber is more difficult to install and modify than most other cabling. Installing and splicing fiber is extremely difficult and precise work, and requires hiring a certified fiber cable installer, which costs more than hiring a twisted-pair cable installer. Many manufacturers of fiber-optic cable and accessories have begun to develop products that make fiber-optic installations easier.

- Fiber cabling uses several different types of connectors. The industry standards are the **ST** and **SC connectors**, as shown in Figure 3-7, and the MT-RJ small form factor connectors.

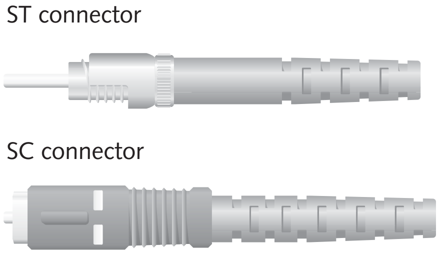

Figure 3-7 ST and SC fiber-optic connectors

- Fiber is immune to both EMI and RFI, and therefore has the best noise immunity of any cabling. This high noise resistance is one reason that fiber can span such long distances before requiring repeaters to regenerate the signal.
- Fiber can transmit signals over much greater distances and carry information at significantly greater speeds than coax or twisted-pair cable. The maximum network segment length for fiber is 100 m. The maximum overall network length varies depending on the type of fiber-optic cable used. With multimode fiber, the maximum network length is 2 km; with single-mode fiber the limit is 3 km. However, single-mode fiber is used primarily in long-distance network infrastructure and almost never for local networking, except as a trunk.

Wireless Technologies

Wireless networking refers to computers that communicate using standard network rules or protocols, but without the use of cabling to connect the computers. Instead, the computers send and receive information by means of wireless signals produced by infrared or radio waves. Infrared waves require the sending and receiving equipment to be in a direct line of sight, but radio waves do not.

A wireless network can be installed as the sole network in an organization, or it can extend a wired network to areas where wiring would be too difficult or expensive to implement. Wireless networks can be configured to provide the same network functionality as any wired network.

Wireless networks require NICs to be installed in the network device, just like any wired network, but the wireless NIC contains a built-in antenna. Wireless networks use **access points**, which work like the hubs used in a wired network. The access point broadcasts and receives signals to and from surrounding computers via the NIC. Access points also provide the interconnection point between a wireless and wired network.

Wireless networks currently transmit data at a rate of approximately 11 Mbps. This rate depends primarily on the number of network users and the size of the files being transferred. The rate also depends on the computer's distance from the access point, and on the material of any structures that may be in the line of sight. In addition, because the network's range may extend beyond the walls of a building, additional security measures may be necessary to ensure that data is protected.

NETWORK TOPOLOGIES

There are two types of network topologies. The first type, **physical topology**, is the physical layout of the network, including the configuration of the cables and devices. The second type, **logical topology**, refers to the method used to communicate between devices. You must understand physical topologies before you design a network, because they can affect the logical topology you choose (for example, Ethernet or Token Ring), how your building is cabled, and what kind of media you use. Understanding a network's physical topology is also necessary for troubleshooting its problems or making changes in its infrastructure.

Physical topologies are classified according to three geometric shapes: bus, ring, and star. These shapes can also be mixed to create hybrid topologies. A fourth type of topology, referred to as fault-tolerant mesh, is often required for high-availability networks.

Bus Topology

A **bus topology** consists of a single cable that connects all the nodes on a network without intervening connectivity devices. A bus topology requires the use of a 50-ohm resistor, called a **terminator**, at each end. Most bus topologies use Ethernet as their communication method. Figure 3-8 shows a typical bus topology.

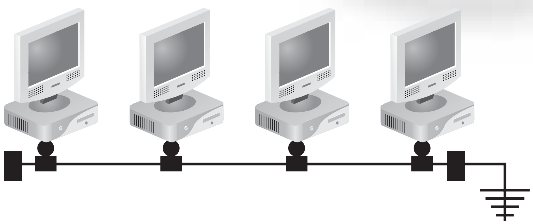

Figure 3-8 Bus topology

The single cable is called the bus, and it can support only one channel. As a result, every node shares the total capacity of the bus. A bus topology can be considered a **peer-to-peer** topology, because every device on the network shares the responsibility for getting data from one point to another. Also, every node is alerted about every transmission, and every transmission passes through each node, although only the intended recipient of the transmission reads and processes it.

A bus topology offers the following advantages:

- It is easy to install and add devices.
- It requires less cable than other topologies.
- It is less expensive to install than other topologies.

Unfortunately, a bus topology also has its disadvantages:

- The bus requires 50-ohm resistors, called terminators, at each end.
- The entire network shuts down if the cable breaks.
- It is difficult to troubleshoot problems if the network shuts down.
- A bus topology is not designed for large applications. The limit is about 10 connections.

Ring Topology

In a **ring topology**, each node is connected to the two nearest nodes so that the entire network forms a circle (Figure 3-9). Data is transmitted in one direction around the ring. Each node receives every transmission; when passing on a transmission, the node acts as a repeater, a device that regenerates signals. A ring network has no ends, and data stops at its prescribed destination, so it does not require terminators. The ring topology generally uses token passing as its communication method, which prevents network collisions.

The token-passing method controls a node's ability to transmit data. Before a node can transmit data, it must first possess the token. While a node has the token, no other node can transmit data until the active node is finished. The data packet is attached to the token and passed around the ring until it reaches the target node. The target node receives the data and sends the token back around the ring until the original transmitting station picks it up, checks the token to determine that the data has been received, and then releases the token back to the ring for another node to use.

The ring topology is used primarily by Token Ring and FDDI networks. A **Fiber Distributed Data Interface (FDDI)** contains two rings: a primary ring and a secondary ring. The secondary ring provides fault tolerance (redundancy) and backup if the primary ring fails (Figure 3-9). This redundancy is crucial to modern implementations and avoids the point-of-failure problem of single-ring topologies.

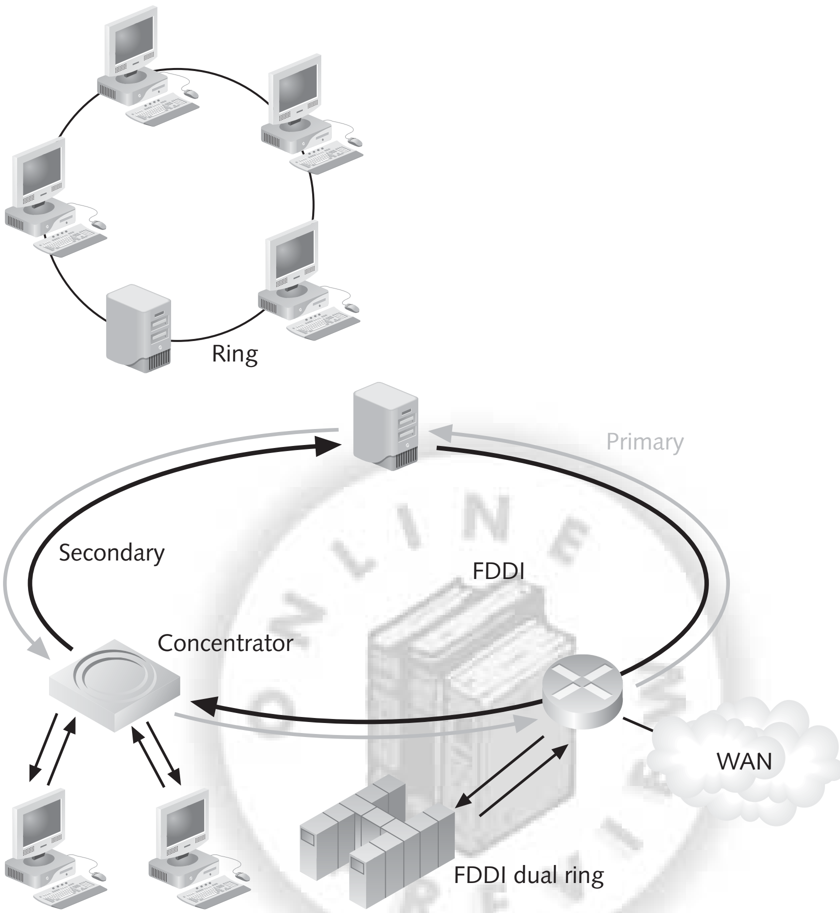

Figure 3-9 Ring topology and FDDI dual ring

A ring topology includes the following advantages:

- No network collisions occur, due to the data transmission method it uses.
- Each node functions as a repeater, so the need for additional network hardware is limited.
- Less cable is required than with other topologies.

The ring topology also has the following disadvantages:

- A single malfunctioning workstation can disable the entire network.
- It is not very flexible or scalable, because response time slows with each additional node.
- Before making additions or changes or performing maintenance, you must shut down the network, because all nodes are wired together.

Star Topology

In a **star topology**, every node is connected through a central device, such as a hub. Figure 3-10 shows a typical star topology. Any physical cable in a star topology connects to only two devices, so a cabling problem will affect only two nodes at most. All nodes transmit data to the hub, which then retransmits the data to the segment that contains the destination node.

Star topologies require more cable and configuration than other topologies, but a single malfunctioning cable or workstation will not disable the entire network. A hub failure can disable an entire segment, but usually will not shut down the entire network.

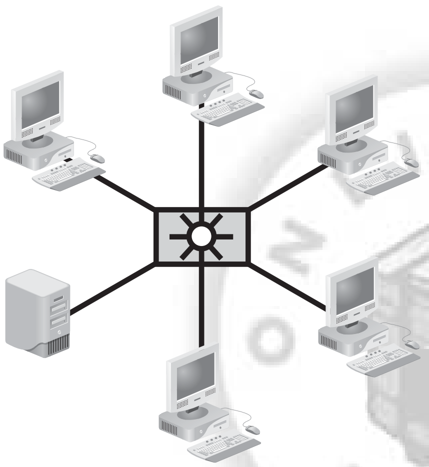

Figure 3-10 Star topology

Because of the way star topologies are wired, they are easy to move, isolate, or interconnect with other networks. Adding nodes, performing maintenance, or making other changes will not affect or disable the network. Because star topologies offer more flexibility and scalability than other topologies, most modern Ethernet networks use them.

Star topologies offer the following advantages:

- A break in one cable does not affect all other stations, because there is only one station per segment.
- The star topology is more reliable because there is only one station per segment.
- Troubleshooting a star topology is easier because symptoms usually point to one station or segment.
- No terminators are necessary because media are terminated at the station and the hub.
- The star topology is more flexible and scalable than other topologies.

Although a star topology offers many advantages, it has a few disadvantages as well:

- Star topologies use more cable than most other topologies.
- Hubs are usually more expensive than terminators.
- A hub failure can take down an entire LAN segment.

Mesh Topology

In a **mesh topology**, all devices share many redundant interconnections with each node, as shown in Figure 3-11. There are two types of mesh topologies: full mesh and partial mesh.

In a full-mesh topology, every node is interconnected with every other node in the network, providing multiple routes for data to travel from origin to destination with the greatest amount of redundancy. If one route has a problem or fails, data can be directed to any one of the other routes. Full mesh is generally reserved for use in network backbones.

In a partial-mesh topology, some nodes are connected using the full-mesh scheme, while others are connected to only one or two other nodes. This approach still provides redundancy, but to a lesser degree than the full mesh. Partial-mesh topologies are commonly found in LANs that are connected to a full-mesh backbone.

Mesh topologies offer the following advantages:

- If one connection fails, data can be redirected to multiple alternate paths.
- Mesh topology provides a high level of security, because each device has its own connection to every other device.
- There are few problems with troubleshooting a mesh topology.
- The mesh offers greater stability and reliability.

Even though mesh topology offers many advantages, it still has a few disadvantages:

- It uses much more cable than any other topology.
- It is more expensive to install than other topologies.
- It can be difficult to install and configure on very large networks.

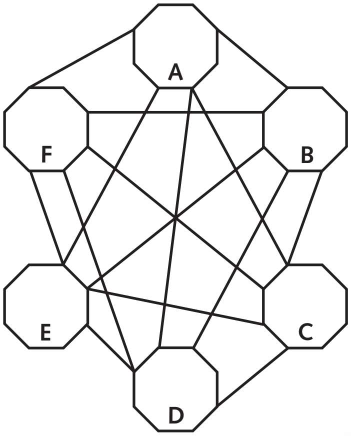

Figure 3-11 Mesh topology

CREATING AN EFFECTIVE NETWORK DESIGN

Before you begin designing a network, you must know its relative scale and what your customer expects the network to accomplish. The prerequisites of network design include assessing functional requirements, sizing the network, and defining connectivity needs. Once you complete the preliminary assessment, you can begin your design work.

This section discusses the steps for ensuring that your design is flexible and solid, and that it meets your customer's expectations. The following list helps you make these determinations:

- **Assessing functional requirements** — Make a list of the tasks that should be automated or made more efficient. Determine which business applications need support, and determine whether the network will simply provide shared access to word-processing files or support multiuser databases. Also, identify other needs such as electronic mail, Web servers, point-of-sale operations, and Internet access.
- **Sizing the network** — Determine the network's expected size by establishing the number of users and their intensity of use. Plan for future growth by building in extra capacity from the beginning. Calculate the possible network capacity in two or three years by estimating the number of potential new users; also, account for possibly dramatic increases in the average user's data storage needs, based on your customer's business strategy. Plan your design to accommodate easy growth with incremental additions of existing technology.
- **Connectivity** — Define which types of external connections you need. Determine the need for Internet access and whether the network requires a dial-up connection or a full-time, dedicated link. Also, determine the amount of required bandwidth and the need to connect with any private (external) networks.

Once you complete the prerequisites, you can begin the design work. Network design involves several layers, and you need to make decisions about each of them:

- **Network type** — The options include Ethernet, ATM, and Token Ring. The relative bandwidth that the network must support is a significant factor in choosing a network type.
- **Physical network** — This includes the cabling, faceplates, and other components of the basic infrastructure. The kind of cabling you install depends on the network type your customer selects.
- **Network communications equipment** — The network requires devices such as hubs and routers before it can operate.
- **Network operating system** — Microsoft Windows NT Server, Windows 2000 Advanced Server, Windows XP, and Novell NetWare are currently the dominant systems. However, they are not the only available systems. Be aware that your customer may already have made this decision.
- **Client workstations** — Consider which hardware the customer needs. These decisions depend on which network operating system and workstation operating system the customer selects.
- **Network server hardware**
- **Data backup hardware and software**

NETWORK ELEMENTS YOU NEED TO DOCUMENT

Before you begin your documentation project or define your documentation policies, you must first decide what you need to document. Every network is unique and has its own documentation needs. In this section, you will learn which network elements you most likely need to document.

The first section of your documentation manual should describe the network. This description should give any reader a basic understanding of how the network works and what it includes. This section should include information about the network topology, the network architectures used, the installed operating systems, and the number of devices and users served. This section should also provide contact information for people who are responsible for various aspects of the network, and for key vendors. Use this section as an overview of your network; you can describe the finer details in later sections.

The next section, which documents your cable plant, is among the most critical documentation tasks. This is the most frequently used section; it defines the physical layout of your network cabling, the terminations used, and the conventions for labeling your cable and connectivity equipment. You must also include the results of any tests completed on the cable plant. Every time the network requires additions, moves, or changes, this documentation will probably be consulted and modified. Therefore, the documentation must be kept current—incorrect or outdated information can be worse than no documentation at all. For example, outdated documentation can result in a critical piece of equipment being disconnected, instead of the workstation that was just removed from service.

Proper documentation of the items in each equipment room, including their location, is crucial to a customer's ability to troubleshoot problems quickly and effectively. The equipment rooms house internetworking devices, servers, and telephone equipment, and are the junction points for horizontal and backbone cabling.

Your efficiency in modifying and troubleshooting networks is greatly enhanced when you document the internetworking devices. When describing these devices, you must first list the devices themselves, then document which devices are connected to other devices, and list each device's capabilities and limitations. Also, list the available network management features on each device, as well as the device's port usage, physical and logical addresses, model numbers, serial numbers, and hardware and software revision numbers.

Any computers that provide shared resources or network services are referred to as servers, and require detailed documentation. Include the hardware configuration, operating system and application version numbers, NIC information, and the system model and serial numbers in your server documentation.

Documentation of workstations is often the most difficult to maintain, for several reasons. For example, workstations and their users usually create most support and troubleshooting tasks. By documenting each workstation's hardware and software configurations, along with its physical and logical addresses, you can save considerable time and effort when resolving a problem. In addition, your network policies should limit the changes that users can make to their workstations. If you enforce these policies, maintaining current records will be much easier.

Chapter Summary

- Cabling is the basic framework of a solid network foundation. To successfully design a network cable layout, you need a thorough knowledge of cable types, their specifications, and network topologies. This information helps you to assess the organization's current needs and plans for future growth.
- All cabling media have five basic characteristics you must consider when selecting cable for your telecommunications systems: throughput and bandwidth, cost, size and scalability, connectors, and noise immunity.
- The three basic types of cable are coaxial, twisted-pair, and fiber-optic. Coaxial cable has a high resistance to interference, can carry signals for a greater distance than twisted-pair cable before requiring repeaters, and must be terminated with a 50-ohm resistor at each end of a segment. Twisted-pair cable is the same as the cable used to wire telephones, and is the most common form of cabling used on LANs

today. Twisted-pair is relatively inexpensive, flexible, and easy to install. It can be shielded, unshielded, or screened. Fiber is among the most expensive media, but has the highest throughput and bandwidth. It transmits optical signals in the form of light over glass fibers.

- There are two categories of fiber: multimode and single-mode. Single-mode fiber transmits in a single mode of light, which allows data to travel more rapidly and for greater distances. Multimode fiber transmits up to hundreds of thousands of modes of light simultaneously, which allows more data to be transmitted at one time. However, data cannot travel as fast or as far on multimode fiber.
- The coaxial cables used for networks are ThickNet (10Base5) and ThinNet (10Base2). Both were used extensively in the early years of Ethernet.
- Wireless networking refers to computers that communicate using standard network rules or protocols, but without the use of cabling to connect the computers. A wireless network can be installed as the sole network in an organization, or it can extend a wired network to areas where wiring would be too difficult or expensive to implement. Wireless networks can be configured to provide the same network functionality as any wired network.
- Network topologies come in three basic geometric shapes: bus, ring, and star. A fourth type of topology, referred to as fault-tolerant mesh, is often required for high-availability networks. The bus topology is the least expensive and the most difficult to troubleshoot. The ring topology is difficult to troubleshoot for the same reasons, but is not subject to network collisions because of its communication method. The star topology is the most commonly used, and offers the most advantages. It is more expensive because it uses more cable than other topologies, but it is more reliable because of its wiring. If one station goes down in a star topology, the rest of the network is not affected.
- Before you begin designing a network, you must know its relative scale and what your customer expects the network to accomplish. The prerequisites of network design include assessing functional requirements, sizing the network, and defining connectivity needs. Once you complete the preliminary assessment, you can begin your design work.
- Before you begin your documentation project or define your documentation policies, you must first decide what you need to document. Every network has its own documentation needs.

Key Terms

access points — The wireless equivalent of the hubs used in a wired network. Access points broadcast and receive wireless signals to and from surrounding computers via a NIC. Access points also provide the interconnection point between a wireless and wired network.

alien crosstalk — The interference of signals from one cable with an adjacent cable's transmission.

analog — Analog signals are variable voltages that create continuous waves of sound, resulting in inexact transmissions.

attenuation — The amount of signal loss over a given distance.

backbone cable — The cabling that connects one telecommunications room (TR) to another, TRs to equipment rooms, or one building's equipment room to another's.

balanced-pair — The twists in cable pairs that help to reduce the effects of crosstalk.

bandwidth — The measure of the difference between the highest and lowest frequencies that media can transmit.

baseband — The transmission of digital signals through direct-current pulses applied to the wire. Baseband requires exclusive use of the wire's capacity, which means that only one signal can be transmitted at a time.

BNC (British Naval Connector) and **BNC/T** — The type of connector used on ThinNet (10Base2) cable. The BNC is the connector that goes on the cable. The BNC/T is a T-shaped adapter that connects on one end to the station's network interface card. The bus connects to the other two ends.

bus topology — A single cable that connects all the nodes on a network without intervening connectivity devices.

cladding — In fiber-optic cable, a layer of glass around the fibers that acts like a mirror and reflects light back to the core.

coaxial cable — Cable that consists of a central copper core surrounded by an insulator, a braided metal shielding called braiding, and an outer cover called a sheath or jacket.

connector — A piece of hardware that connects the cable to the network device.

crosstalk — The infringement of the signal from one wire pair on another wire pair's signal.

data transmission — The sending of signals generated by voltage over a designated path.

decibel (dB) — A measurement unit of signal strength or of a sound's intensity.

dense wave division multiplexing (DWDM) — The combination and transmission of multiple signals simultaneously at different wavelengths on the same fiber.

digital — Digital signals are precise voltages that create pulses with specific values called bits, resulting in more precise transmissions.

electromagnetic interference (EMI) — Waves that emanate from electrical devices or cables carrying electricity.

Fiber Distributed Data Interface (FDDI) — In a ring topology, this interface contains two rings: a primary ring and a secondary ring. The secondary ring provides fault tolerance (redundancy) and backup if the primary ring fails.

fiber-optic cable — Cable that contains one or more glass fibers in its core. Data is transmitted by converting electrical signals at the sending end into optical signals, which are then transmitted through the central fibers via a pulsing light sent from a laser or light-emitting diode (LED), and reconverted into electrical signals at the receiving end.

hertz (Hz) — The unit for measuring a range of frequencies.

hub — A multiport repeater containing one port that connects to a network's backbone and multiple ports that connect to a group of workstations. Hubs regenerate digital signals.

impedance — The measurement of a conductor's opposition, or resistance, to the flow of alternating current.

latency — The delay between entering commands on your computer and their acceptance by the server.

logical topology — The method used to communicate between devices.

medium — A means of transmitting signals, usually via cable. The plural form of the word is *media*.

megabit — One million bits of data.

mesh topology — A system in which all nodes and devices share many redundant interconnections.

multimode fiber — Fiber that carries up to hundreds of thousands of modes of light simultaneously.

network interface card (NIC) — The device that enables a workstation to connect to the network and communicate with other computers.

ohm — A measurement of resistance.

peer-to-peer — A means of networking computers using a single cable.

physical topology — The physical layout of the network, including the configuration of the cables and devices.

radio frequency interference (RFI) — Waves that emanate from electrical devices or cables carrying electricity. RFI can also be caused by a strong broadcast signal from a radio or television station.

refractive index — The measure of a material's ability to bend light.

repeater — A connectivity device that regenerates and amplifies an analog or digital signal.

ring — One of the wires in a pair, in twisted-pair cabling. The ring is connected to the DC negative wire (–48 volts) that carries the signal.

ring topology — In this system, each node is connected to the two nearest nodes so that the entire network forms a circle. Data is transmitted in one direction around the ring. Each node receives every transmission; when passing on a transmission, the node acts as a repeater, a device that regenerates signals.

RJ-45 connectors — The 8-pin connectors used with twisted-pair cable.

SC connector — One of the most popular connectors made for fiber-optic cable.

scalability — Growth ability and potential.

signal bounce — A phenomenon in which data signals travel endlessly between the two ends of the network.

single-mode fiber — Fiber that carries a single mode of light to transmit data from one end of a cable to another.

ST connector — One of the most popular connectors made for fiber-optic cable.

star topology — In this system, every node is connected through a central device, such as a hub. Any physical cable on a star topology connects to only two devices, so a cabling problem will affect only two nodes at most. All nodes transmit data to the hub, which then retransmits the data to the segment that contains the destination node.

terminator — A resistor at the end of a bus network that stops signals after they reach their destination.

throughput — The amount of data that a cable can transmit during a given period of time.

tip — One of the wires in a pair, in twisted-pair cabling. The tip is connected to the positive side of a battery, which is the telephone industry's equivalent of a ground in a standard electrical circuit.

topology — The physical layout of network components.

twist ratio — The number of twists per meter or foot in twisted-pair cable.

twisted-pair cable — Cable that consists of insulated copper wires, each with a diameter of 0.4 to 0.8 mm, twisted around each other and encased in a plastic coating.

vampire tap — A connector that pierces a hole in a ThickNet cable.

wireless — Technology that transmits signals through the atmosphere.

REVIEW QUESTIONS

1. What type of network design helps provide a solid foundation?
   a. one that has the right workstations
   b. one that is sound and flexible
   c. one that has the right network operating system
   d. one that has the proper cable installed
2. What is the physical layout of the networking components called?
   a. cabling
   b. floor plan
   c. physical components and cable plan
   d. topology (physical)
3. What are the three most common topologies?
   a. bus, circle, and star
   b. bus, ring, and star
   c. circle, star, and torus
   d. ring, arc, and star

4. What is one advantage of a bus topology?
   a. All workstations run to a central device.
   b. It is the easiest topology for troubleshooting problems.
   c. It is inexpensive.
   d. It is difficult to design and implement.
5. What is one advantage of a ring topology?
   a. It prevents network collisions due to the media access method or architecture required.
   b. All workstations are wired to one another with termination points.
   c. Each station functions as a repeater, but the topology still requires additional network hardware, such as hubs.
   d. Because all stations work together, it is easy to add a station.
6. What are two of the primary differences between a star topology and the other topologies?
   a. A data signal from one station is transmitted to all other stations on the network.
   b. All computers are wired directly to a central location.
   c. A data signal from any station goes to a central device, which transmits the signal according to the established access method for the type of network.
   d. The star topology uses the least amount of cable.
7. What are two of the biggest advantages of a star topology?
   a. Problems are easier to locate because symptoms often point to one station.
   b. A break in one cable does not affect all other stations, because there is only one station per segment.
   c. It is the least expensive topology to install.
   d. It is the best topology to use when you have very few users.
8. Which type of cable is most often used on the backbone of a network?
   a. twisted-pair
   b. hybrid
   c. thick coaxial
   d. fiber-optic
9. Coaxial cable has a very large bandwidth, which means it can handle large volumes of data at high speed and is better protected from electromagnetic interference than other types of cable, so it can carry signals over much greater distances before the signal degrades. True or False?

10. Coaxial cable requires a termination at each end of each segment with a ________________.
    a. vampire tap
    b. 55-ohm resistor
    c. 50-Mhz connector
    d. 50-ohm resistor
11. Why is twisted-pair cable the most common form of cabling used in LANs today?
    a. It is less expensive to install than other forms of cabling.
    b. It is flexible.
    c. It is easy to install.
    d. all of the above
12. What is throughput?
    a. the amount of time it takes to transmit data
    b. the amount of data a cable can transmit during a given time period
    c. the frequency at which data is transmitted
    d. the range of frequencies that data uses for transmission
13. In fiber optics, signals are converted from electrical into modulated optical signals, transmitted through a thin glass fiber, then reconverted into electrical signals. True or False?
14. What is bandwidth?
    a. a range of frequencies
    b. the amount of data that can be transmitted at one time
    c. the amplification of a data signal
    d. the measure of the difference between the highest and lowest frequencies that media can transmit
15. What are the two categories of optical fiber?
    a. multistrand and single-strand
    b. multicore and single-core
    c. multiple and single
    d. multimode and single-mode
16. Multimode fiber is more expensive than single-mode because it can carry multiple paths as it travels from the transmitter to the receiver. True or False?

17. What is latency?
    a. the time it takes data to travel from one network to another network
    b. the transmission speed of your data
    c. the transmission distance of your data
    d. the delay between entering commands on your computer and their acceptance by the server
18. EMI is electronic magnetic interruption. True or False?
19. Crosstalk occurs when a signal traveling on a nearby wire pair infringes on another wire pair's signal. True or False?
20. Fiber-optic cable offers very high bandwidth and can operate at distances in excess of ________________.
    a. 1000 meters
    b. 500 meters
    c. 100 meters
    d. 2000 meters
21. Baseband transmission is ________________.
    a. several signals transmitting at the same time
    b. only one signal transmitting at a time
    c. several signals transmitting over the same cable, but taking turns
    d. There is no such thing as baseband transmission.
22. Which type of cable has the best noise immunity and thus has the longest maximum network lengths?
    a. fiber-optic
    b. twisted-pair
    c. coaxial
    d. none of the above
23. What is attenuation?
    a. the loss of signal power between points
    b. information-carrying capacity
    c. total opposition of a circuit to the flow of current
    d. the bending of a signal

24. What is cladding?
    a. the radius of curvature that a cable can bend without hurting performance
    b. the layer of glass (or other transparent material) surrounding the light-carrying core of an optical fiber
    c. a device that cuts an optical fiber in a flat, smooth, and perpendicular manner
    d. a device mounted on the end of an optical fiber and used for joining it to another fiber end, light source, or detector
25. Coaxial cable consists of a central copper core surrounded by an insulator, a braided metal shielding called braiding, and an outer plastic cover called a sheath. True or False?

Hands-on Projects

Project 3-1

When choosing transmission media for your network, you need to consider the five basic characteristics of cable. For this project, you will create a chart of the three major cable types and then list the various subtypes under each major cable type. Complete the chart by identifying each of the five basic characteristics for each type.

> **NOTE:** Most of the information you need is in the first three chapters of your text. You can also search the Internet. If you use information from any Web sites, note them as references on your chart before turning it in.

Project 3-2

Survey organizations and businesses in your area to determine which cabling types, transmission speeds, and transport models are used on their LANs. From this information, you should be able to determine the most popular networking design approaches, which approaches may grow in popularity, and which ones may become obsolete.

1. Identify at least five businesses, civic organizations, or schools in your area that use networking technology. For example, you can identify insurance agencies, school districts or particular local schools, retail store chains, utility companies, and architectural firms.
2. For each of your choices, find the contact information for the Information Technology (IT) department manager.
3. Call the IT department manager and ask the following questions:
   - What is the transmission speed of your network?
   - What type of cabling is used for your network backbone?

- What type of wiring does your network use? Do you use the same type of wiring for the backbone as you use for connecting workstations?
- Which topology does your network use?
- How many nodes are on your network?
- Are all your network devices in one building? If not, where are the others, and how are they connected?
- If you had an unlimited budget, what types of upgrades would you make to your network?
- If you only had enough money in your budget for one upgrade, which one would you make?

4. Compile the answers from all the managers. Which network transmission speed is most popular? Which type of backbone? Which topology? Which type of interbuilding connection? Which network upgrade?
5. From the list you compiled, which items should grow in popularity, and why? Which items may become obsolete, and why?

Project 3-3

HANDS-ON PROJECTS

Knowing what type(s) of cable to use, and when, is only part of your training as a telecommunications professional. Understanding network design is another important tool. In this exercise, you will go to an Internet site and read four good articles about designing networks.

1. Using a workstation in your class that has Internet access, go to the following Web site:

   www.networkcomputing.com/netdesign/soho1.html

2. Read the first article. You can then keep clicking the Next Page button to read the remaining articles, or you can change the address in your browser. The address should remain the same except for the */soho1.html*. For each additional article, change *soho1* to *soho2*, *soho3*, and *soho4*.
3. After reading all four articles, write a summary of each. Include the most important points to remember for your future work in this field.
4. At the end of each summary, list what you learned from each article.

Project 3-4

HANDS-ON PROJECTS

Answer the following questions about fiber-optic cable and write a summary of your findings.

1. What is fiber-optic cable?
2. Define each physical component of fiber-optic cable.

3. What is the most ideal use for “basic” optical fiber?
4. For which other applications is fiber available?

NOTE

In addition to using your text, you can find information at *www.commspecial.com/fiberguide.htm*.

HANDS-ON PROJECTS

Project 3-5

List the procedures to follow when designing an effective network, and explain why each step is important. Use your text and any appropriate source material, and identify the source(s) in your report.

HANDS-ON PROJECTS

Project 3-6

Define the following networking and telecommunications terms:

- Host (to a dumb terminal)
- Carrier Sense Multiple Access with Collision Detection (CSMA/CD)
- Hub (active and passive)
- Cable terminator (coaxial)
- Token Ring
- Ethernet
- Network collision
- Repeater
- Network access method
- Transceiver
- Broadband
- Baseband
- Network interface card (NIC)
- Vampire tap

The following Web sites will help you find these definitions:

- *www.whatis.com*
- *www.about.com*. Type **glossary** in the **Search** box, then click the links that appear.
- *www.techfest.com/networking/cabling/cableglos.htm*

CASE PROJECTS

Case Project 1

Create a proposal for prewiring a new building. The building has one floor with 15 private offices, one work area with 15 employees, and one telecommunications closet. The equipment room is the entrance facility for the building, and is next to the telecommunications closet. The distance from the telecommunications closet to the most distant workstation is 70 meters. Good speed and bandwidth are desirable in your proposal, but size and scalability are more important. Cost is not a major factor, but it is a consideration. Your proposal should include the type(s) of cable you would use (workstation, horizontal, backbone), the approximate cost of the cable, and explanations for your selection(s).

NOTE

Use the Internet to obtain cable pricing. Some useful Web sites for cable and equipment pricing are:

- *www.sfcable.com*
- *www.cablemaster.com*
- *www.directron.com*

Case Project 2

Describe an optical fiber system. Identify and explain its three basic components. Include the various types of each component and their characteristics.

Case Project 3

Identify and thoroughly explain each of the factors that most commonly affect the performance of an optical fiber system.

Case Project 4

Research information about the construction of fiber-optic cable, and then report your findings. In your report, discuss the two types of buffering in use today; the three basic, tight-buffered fiber cable types; when and how each one is used; and the three categories of optical fiber cable designated for building use. For this project, use sources from the library and the Internet.