Upon completing this chapter, you will be able to:

- Describe the primary types and uses of twisted-pair cables
- Describe the primary types and uses of coaxial cables
- Describe the primary types and uses of fiber-optic cables
- Describe the primary types and uses of wireless media
- Compare and contrast the primary types and uses of different media

CHAPTER 8

Network Media Types

Network media is the actual path over which an electrical signal travels as it moves from one component to another. This chapter describes the common types of network media, including twisted-pair cable, coaxial cable, fiber-optic cable, and wireless.

Twisted-Pair Cable

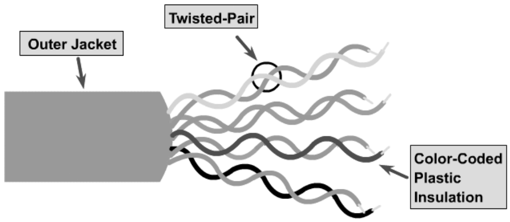
Twisted-pair cable is a type of cabling that is used for telephone communications and most modern Ethernet networks. A pair of wires forms a circuit that can transmit data. The pairs are twisted to provide protection against *crosstalk*, the noise generated by adjacent pairs. When electrical current flows through a wire, it creates a small, circular magnetic field around the wire. When two wires in an electrical circuit are placed close together, their magnetic fields are the exact opposite of each other. Thus, the two magnetic fields cancel each other out. They also cancel out any outside magnetic fields. Twisting the wires can enhance this *cancellation effect*. Using cancellation together with twisting the wires, cable designers can effectively provide self-shielding for wire pairs within the network media.

Two basic types of twisted-pair cable exist: unshielded twisted pair (UTP) and shielded twisted pair (STP). The following sections discuss UTP and STP cable in more detail.

UTP Cable

UTP cable is a medium that is composed of pairs of wires (see Figure 8-1). UTP cable is used in a variety of networks. Each of the eight individual copper wires in UTP cable ¥is covered by an insulating material. In addition, the wires in each pair are twisted around each other.

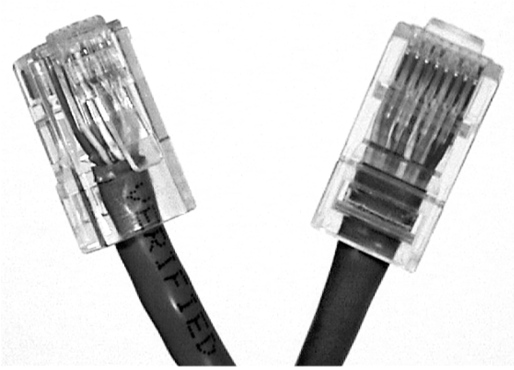
Figure 8-1 *Unshielded Twisted-Pair Cable*



UTP cable relies solely on the cancellation effect produced by the twisted wire pairs to limit signal degradation caused by electromagnetic interference (EMI) and radio frequency interference (RFI). To further reduce crosstalk between the pairs in UTP cable, the number of twists in the wire pairs varies. UTP cable must follow precise specifications governing how many twists or braids are permitted per meter (3.28 feet) of cable.

UTP cable often is installed using a Registered Jack 45 (RJ-45) connector (see Figure 8-2). The RJ-45 is an eight-wire connector used commonly to connect computers onto a local-area network (LAN), especially Ethernets.

Figure 8-2 *RJ-45 Connectors*



When used as a networking medium, UTP cable has four pairs of either 22- or 24-gauge copper wire. UTP used as a networking medium has an impedance of 100 ohms; this differentiates it from other types of twisted-pair wiring such as that used for telephone wiring, which has impedance of 600 ohms.

UTP cable offers many advantages. Because UTP has an external diameter of approximately 0.43 cm (0.17 inches), its small size can be advantageous during installation. Because it has such a small external diameter, UTP does not fill up wiring ducts as rapidly as other types of cable. This can be an extremely important factor to consider, particularly when installing a network in an older building. UTP cable is easy to install and is less expensive than other types of networking media. In fact, UTP costs less per meter than any other type of LAN cabling. And because UTP can be used with most of the major networking architectures, it continues to grow in popularity.

Disadvantages also are involved in using twisted-pair cabling, however. UTP cable is more prone to electrical noise and interference than other types of networking media, and the distance between signal boosts is shorter for UTP than it is for coaxial and fiber-optic cables.

Although UTP was once considered to be slower at transmitting data than other types of cable, this is no longer true. In fact, UTP is considered the fastest copper-based medium today. The following summarizes the features of UTP cable:

- **Speed and throughput**—10 to 1000 Mbps
- **Average cost per node**—Least expensive
- **Media and connector size**—Small
- **Maximum cable length**—100 m (short)

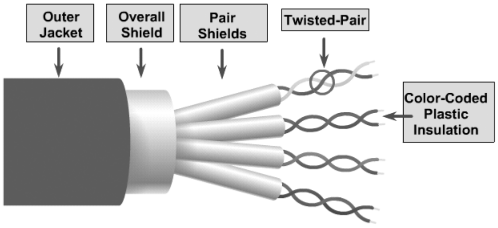
Commonly used types of UTP cabling are as follows:

- **Category 1**—Used for telephone communications. Not suitable for transmitting data.
- **Category 2**—Capable of transmitting data at speeds up to 4 megabits per second (Mbps).
- **Category 3**—Used in 10BASE-T networks. Can transmit data at speeds up to 10 Mbps.
- **Category 4**—Used in Token Ring networks. Can transmit data at speeds up to 16 Mbps.
- **Category 5**—Can transmit data at speeds up to 100 Mbps.
- **Category 5e** —Used in networks running at speeds up to 1000 Mbps (1 gigabit per second [Gbps]).
- **Category 6**—Typically, Category 6 cable consists of four pairs of 24 American Wire Gauge (AWG) copper wires. Category 6 cable is currently the fastest standard for UTP.

Shielded Twisted-Pair Cable

Shielded twisted-pair (STP) cable combines the techniques of shielding, cancellation, and wire twisting. Each pair of wires is wrapped in a metallic foil (see Figure 8-3). The four pairs of wires then are wrapped in an overall metallic braid or foil, usually 150-ohm cable. As specified for use in Ethernet network installations, STP reduces electrical noise both within the cable (pair-to-pair coupling, or crosstalk) and from outside the cable (EMI and RFI). STP usually is installed with STP data connector, which is created especially for the STP cable. However, STP cabling also can use the same RJ connectors that UTP uses.

Figure 8-3 *Shielded Twisted-Pair Cable*



Although STP prevents interference better than UTP, it is more expensive and difficult to install. In addition, the metallic shielding must be grounded at both ends. If it is improperly grounded, the shield acts like an antenna and picks up unwanted signals. Because of its cost and difficulty with termination, STP is rarely used in Ethernet networks. STP is primarily used in Europe.

The following summarizes the features of STP cable:

- **Speed and throughput**—10 to 100 Mbps
- **Average cost per node**—Moderately expensive
- **Media and connector size**—Medium to large
- **Maximum cable length**—100 m (short)

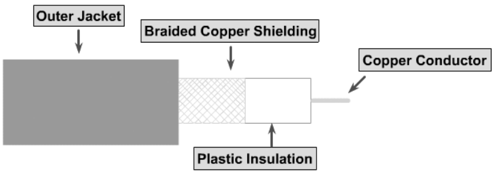
When comparing UTP and STP, keep the following points in mind:

- The speed of both types of cable is usually satisfactory for local-area distances.
- These are the least-expensive media for data communication. UTP is less expensive than STP.
- Because most buildings are already wired with UTP, many transmission standards are adapted to use it, to avoid costly rewiring with an alternative cable type.

Coaxial Cable

Coaxial cable consists of a hollow outer cylindrical conductor that surrounds a single inner wire made of two conducting elements. One of these elements, located in the center of the cable, is a copper conductor. Surrounding the copper conductor is a layer of flexible insulation. Over this insulating material is a woven copper braid or metallic foil that acts both as the second wire in the circuit and as a shield for the inner conductor. This second layer, or shield, can help reduce the amount of outside interference. Covering this shield is the cable jacket. (See Figure 8-4.)

Figure 8-4 *Coaxial Cable*



Coaxial cable supports 10 to 100 Mbps and is relatively inexpensive, although it is more costly than UTP on a per-unit length. However, coaxial cable can be cheaper for a physical bus topology because less cable will be needed. Coaxial cable can be cabled over longer distances than twisted-pair cable. For example, Ethernet can run approximately 100 meters (328 feet) using twisted-pair cabling. Using coaxial cable increases this distance to 500m (1640.4 feet).

For LANs, coaxial cable offers several advantages. It can be run with fewer boosts from repeaters for longer distances between network nodes than either STP or UTP cable. Repeaters regenerate the signals in a network so that they can cover greater distances. Coaxial cable is less expensive than fiber-optic cable, and the technology is well known; it has been used for many years for all types of data communication.

When working with cable, you need to consider its size. As the thickness, or diameter, of the cable increases, so does the difficulty in working with it. Many times cable must be pulled through existing conduits and troughs that are limited in size. Coaxial cable comes in a variety of sizes. The largest diameter (1 centimeter [cm]) was specified for use as Ethernet backbone cable because historically it had greater transmission length and noise-rejection characteristics. This type of coaxial cable is frequently referred to as *Thicknet*. As its nickname suggests, Thicknet cable can be too rigid to install easily in some situations because of its thickness. The general rule is that the more difficult the network medium is to install, the more expensive it is to install. Coaxial cable is more expensive to install than twisted-pair cable. Thicknet cable is almost never used except for special-purpose installations.

A connection device known as a *vampire tap* was used to connect network devices to Thicknet. The vampire tap then was connected to the computers via a more flexible cable called the attachment unit interface (AUI). Although this 15-pin cable was still thick and tricky to terminate, it was much easier to work with than Thicknet.

In the past, coaxial cable with an outside diameter of only 0.35 cm (sometimes referred to as *Thinnet*) was used in Ethernet networks. Thinnet was especially useful for cable installations that required the cable to make many twists and turns. Because it was easier to install, it was also cheaper to install. Thus, it was sometimes referred to as *Cheapernet*. However, because the outer copper or metallic braid in coaxial cable comprises half the electrical circuit, special care had to be taken to ensure that it was properly grounded. Grounding was done by ensuring that a solid electrical connection existed at both ends of the cable. Frequently, however, installers failed to properly ground the cable. As a result, poor shield connection was one of the biggest sources of connection problems in the installation of coaxial cable. Connection problems resulted in electrical noise, which interfered with signal transmittal on the networking medium. For this reason, despite its small diameter, Thinnet no longer is commonly used in Ethernet networks.

The most common connectors used with Thinnet are BNC, short for British Naval Connector or Bayonet Neill Concelman, connectors (see Figure 8-5). The basic BNC connector is a male type mounted at each end of a cable. This connector has a center pin connected to the center cable conductor and a metal tube connected to the outer cable shield. A rotating ring outside the tube locks the cable to any female connector. BNC T-connectors are female devices for connecting two cables to a network interface card (NIC). A BNC barrel connector facilitates connecting two cables together.

Figure 8-5 *Thinnet and BNC Connector*

The following summarizes the features of coaxial cables:

- **Speed and throughput**—10 to 100 Mbps
- **Average cost per node**—Inexpensive
- **Media and connector size**—Medium
- **Maximum cable length**—500 m (medium)

Plenum Cable

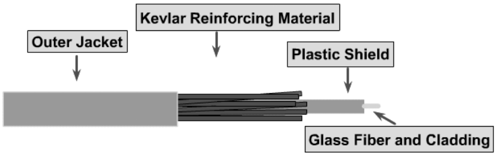
Plenum cable is the cable that runs in plenum spaces of a building. In building construction, a plenum (pronounced PLEH-nuhm, from Latin meaning "full") is a separate space provided for air circulation for heating, ventilation, and air-conditioning (sometimes referred to as HVAC), typically in the space between the structural ceiling and a drop-down ceiling. In buildings with computer installations, the plenum space often is used to house connecting communication cables. Because ordinary cable introduces a toxic hazard in the event of fire, special plenum cabling is required in plenum areas.

In the United States, typical plenum cable sizes are AWG sizes 22 and 24. Plenum cabling often is made of Teflon and is more expensive than ordinary cabling. Its outer material is more resistant to flames and, when burning, produces less smoke than ordinary cabling. Both twisted-pair and coaxial cable are made in plenum cable versions.

Fiber-Optic Cable

Fiber-optic cable used for networking consists of two fibers encased in separate sheaths. If you were viewing it in a cross-section, you would see that each optical fiber is surrounded by layers of protective buffer material, usually a plastic shield, then a plastic such as Kevlar, and finally an outer jacket. The outer jacket provides protection for the entire cable, while the plastic conforms to appropriate fire and building codes. The Kevlar furnishes additional cushioning and protection for the fragile, hair-thin glass fibers (see Figure 8-6). Wherever buried fiber-optic cables are required by codes, a stainless-steel wire sometimes is included for added strength.

Figure 8-6 *Fiber-Optic Cable*



The light-guiding parts of an optical fiber are called the *core* and the *cladding*. The core is usually very pure glass with a high index of refraction. When a cladding layer of glass or plastic with a low index of refraction surrounds the core glass, light can be trapped in the fiber core. This process is called *total internal reflection*. It allows the optical fiber to act like a light pipe, guiding light for tremendous distances, even around bends. Fiber-optic cable is the most expensive of the four media discussed in this chapter, but it supports line speeds of more than 1 Gbps.

Two types of fiber-optic cable exist:

- **Single-mode**—Single-mode fiber cable allows only one mode (or wavelength) of light to propagate through the fiber. It is capable of higher bandwidth and greater distances than multimode, and it is often used for campus backbones. This type of fiber uses lasers as the light-generating method. Single-mode cable is much more expensive than multimode cable. Its maximum cable length is more than 10 km (32808.4 feet).
- **Multimode**—Multimode fiber cable allows multiple modes of light to propagate through the fiber. It is often used for workgroup applications and intrabuilding applications such as risers. It uses light-emitting diodes (LEDs) as a light-generating device. The maximum cable length is 2 km (6561.7 feet).

The characteristics of the different transport media have a significant impact on the speed of data transfer. Fiber-optic cable is a networking medium capable of conducting modulated light transmissions. Compared to other networking media, it is more expensive. However, it is not susceptible to EMI, and it is capable of higher data rates than any of the other types of networking media discussed in this chapter. Fiber-optic cable does not carry electrical impulses as other forms of networking media that use copper wire do. Instead, signals that represent bits are converted into beams of light.

NOTE Even though light is an electromagnetic wave, light in fibers is not considered wireless because the electromagnetic waves are guided in the optical fiber. The term *wireless* is reserved for radiated, or unguided, electromagnetic waves.

Fiber-optic connectors come in single-mode and multimode varieties. The greatest difference between single-mode connectors and multimode connectors is the precision in the manufacturing process. The hole in the single-mode connector is slightly smaller than in the multimode connector. This ensures tighter tolerances in the assembly of the connector. The tighter tolerances make field assembly slightly more difficult.

A number of different types of fiber-optic connectors are used in the communications industry. The following list briefly describes two of the commonly used connectors:

- **SC**—SC type connectors feature a push-pull connect and disconnect method. To make a connection, the connector is simply pushed into the receptacle. To disconnect, the connector is simply pulled out.
- **ST**—ST fiber-optic connector is a bayonet type of connector. The connector is fully inserted into the receptacle and is then twisted in a clockwise direction to lock it into place (see Figure 8-7).

Figure 8-7 *ST Fiber-Optic Connector*

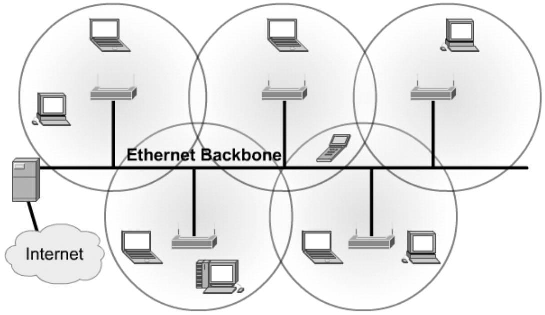
The following summarizes the features of fiber-optic cables:

- **Speed and throughput**—More than 1 Gbps
- **Average cost per node**—Expensive
- **Media and connector size**—Small
- **Maximum cable length**—More than 10 km for single mode; up to 2 km for multimode

Wireless Communication

Wireless communication uses radio frequencies (RF) or infrared (IR) waves to transmit data between devices on a LAN. For wireless LANs, a key component is the wireless hub, or access point, used for signal distribution (see Figure 8-8).

Figure 8-8 *Wireless Network*



To receive the signals from the access point, a PC or laptop must install a wireless adapter card (wireless NIC). *Wireless signals* are electromagnetic waves that can travel through the vacuum of outer space and through a medium such as air. Therefore, no physical medium is necessary for wireless signals, making them a very versatile way to build a network. Wireless signals use portions of the RF spectrum to transmit voice, video, and data. Wireless frequencies range from 3 kilohertz (kHz) to 300 gigahertz (GHz). The data-transmission rates range from 9 kilobits per second (kbps) to as high as 54 Mbps.

The primary difference between electromagnetic waves is their frequency. Low-frequency electromagnetic waves have a long wavelength (the distance from one peak to the next on the sine wave), while high-frequency electromagnetic waves have a short wavelength.

Some common applications of wireless data communication include the following:

- Accessing the Internet using a cellular phone
- Establishing a home or business Internet connection over satellite
- Beaming data between two hand-held computing devices
- Using a wireless keyboard and mouse for the PC

Another common application of wireless data communication is the wireless LAN (WLAN), which is built in accordance with Institute of Electrical and Electronics Engineers (IEEE) 802.11 standards. WLANs typically use radio waves (for example, 902 megahertz [MHz]), microwaves (for example, 2.4 GHz), and IR waves (for example, 820 nanometers [nm]) for communication. Wireless technologies are a crucial part of the today's networking. See Chapter 28, "Wireless LANs," for a more detailed discuss on wireless networking.

Comparing Media Types

Presented in Table 8-1 are comparisons of the features of the common network media. This chart provides an overview of various media that you can use as a reference. The medium is possibly the single most important long-term investment made in a network. The choice of media type will affect the type of NICs installed, the speed of the network, and the capability of the network to meet future needs.

Table 8-1 *Media Type Comparison*

Media Type	Maximum Segment Length	Speed	Cost	Advantages	Disadvantages
UTP	100 m	10 Mbps to 1000 Mbps	Least expensive	Easy to install; widely available and widely used	Susceptible to interference; can cover only a limited distance
STP	100 m	10 Mbps to 100 Mbps	More expensive than UTP	Reduced crosstalk; more resistant to EMI than Thinnet or UTP	Difficult to work with; can cover only a limited distance
Coaxial	500 m (Thicknet) 185 m (Thinnet)	10 Mbps to 100 Mbps	Relatively inexpensive, but more costly than UTP	Less susceptible to EMI interference than other types of copper media	Difficult to work with (Thicknet); limited bandwidth; limited application (Thinnet); damage to cable can bring down entire network
Fiber-Optic	10 km and farther (single-mode) 2 km and farther (multimode)	100 Mbps to 100 Gbps (single mode) 100 Mbps to 9.92 Gbps (multimode)	Expensive	Cannot be tapped, so security is better; can be used over great distances; is not susceptible to EMI; has a higher data rate than coaxial and twisted-pair cable	Difficult to terminate

Summary

In this chapter, you learned the following key points:

- Coaxial cable consists of a hollow outer cylindrical conductor that surrounds a single inner wire conductor.
- UTP cable is a four-pair wire medium used in a variety of networks.
- STP cable combines the techniques of shielding, cancellation, and wire twisting.
- Fiber-optic cable is a networking medium capable of conducting modulated light transmission.
- Wireless signals are electromagnetic waves that can travel through the vacuum of outer space and through a medium such as air.

Review Exercises

1 What is the maximum cable length for STP?

a. 100 feet

b. 150 feet

c. 100 meters

d. 1000 meters

2 Which connector does UTP use?

a. STP

b. BNC

c. RJ-45

d. RJ-69

3 What is an advantage that coaxial cable has over STP or UTP?

a. It is capable of achieving 10 Mbps to 100 Mbps.

b. It is inexpensive.

c. It can run for a longer distance unboosted.

d. None of the above.

4 A _______ fiber-optic cable transmits multiple streams of LED-generated light.

a. multimode

b. multichannel

c. multiphase

d. None of the above

5 Wireless communication uses which of the following to transmit data between devices on a LAN?

a. Radio frequencies

b. LED-generated light

c. Fiber optics

d. None of the above

6 What is one advantage of using fiber-optic cable in networks?

a. It is inexpensive.

b. It is easy to install.

c. It is an industry standard and is available at any electronics store.

d. It is capable of higher data rates than either coaxial or twisted-pair cable.