CHAPTER 19

Exploring Cables and Connectivity

Chapter 18, "Introducing Networking Components," covers the basic hardware used in networks, such as network interface cards, switches, and routers. You connect this hardware together using cables. There are several different types of cables and connectors you can use depending on the characteristics of your network. Just as you can't put a square peg into a round hole, you can't put an RJ-45 connector into a fiber port, so it's important to know the differences, which you'll learn in this chapter.

Exam 220-801 objectives in this chapter:

- 1.7 Compare and contrast various connection interfaces and explain their purpose.
  - Physical connections
    - Other connector types: RJ-45, RJ-11
- 1.11 Identify connector types and associated cables.
  - Display Connector types
    - RJ-45
  - Display cable types
    - Coaxial
    - Ethernet
  - Device connectors and pin arrangements
    - RJ-45
  - Device cable types
    - Ethernet
    - Phone
- 2.1 Identify types of network cables and connectors.
  - Fiber
    - Connectors: SC, ST and LC

- Twisted Pair
  - Connectors: RJ-11, RJ-45
  - Wiring standards: T568A, T568B
- Coaxial
  - Connectors: BNC, F-connector

- 2.2 Categorize characteristics of connectors and cabling.
  - Fiber
    - Types (single-mode vs. multi-mode)
    - Speed and transmission limitations
  - Twisted pair
    - Types: STP, UTP, CAT3, CAT5, CAT5e, CAT6, plenum, PVC
    - Speed and transmission limitations
  - Coaxial
    - Types: RG-6, RG-59
    - Speed and transmission limitations
- 2.8 Identify various types of networks.
  - Topologies
    - Mesh
    - Ring
    - Bus
    - Star
    - Hybrid
- 2.10 Given a scenario, use appropriate networking tools.
  - Crimper
  - Punchdown tool
- 5.1 Given a scenario, use appropriate safety procedures.
  - Personal safety
    - Cable management

Exam 220-802 objectives in this chapter:

- 1.6 Setup and configure Windows networking on a client/desktop.
  - Network card properties
    - Half duplex/full duplex/auto

- 4.5 Given a scenario, troubleshoot wired and wireless networks with appropriate tools.
  - Tools
    - Punch down tools
    - Wire strippers
    - Crimper

REAL WORLD **CROSSOVER AND STRAIGHT-THROUGH CABLES**

Years ago, a technician was fired after throwing away several twisted-pair cables. His motives were valid, but his lack of knowledge ended up wasting the company's money and had him searching for another job.

He was trying to connect a computer to a switch by using a twisted-pair cable. He tried several of them, but most of them wouldn't work. Finally, he found one that would work. Thinking the others were worthless, he threw them away.

Later, his boss asked where the other cables were. The technician explained that none of them worked so he threw them away. His boss calmly said, "We need to talk."

I didn't hear the conversation behind closed doors, but I imagine his boss explained the wiring of a crossover cable and the difference between it and a straight-through cable. He probably explained that crossover cables are used to connect two networking devices together, but because key wires are purposely crossed over, they won't work when connecting a computer to a switch. In other words, the technician threw away good cables due to a gaping hole in his knowledge. Apparently, this knowledge gap was one too many, and it was the technician's last day on the job.

When you're finished with this chapter, you should know a lot more than just what a crossover cable is, but this does help emphasize the importance of having some basic knowledge of cables.

Introducing Ethernet

You can't write a letter to a friend and throw it into the street hoping it will magically be delivered. You have to put the letter in an envelope, properly address it, and then put it into a mailbox with proper postage. I'm betting this is nothing new to you.

Networks also have requirements for transferring data. Devices connected together must use compatible protocols, speeds, cables, and connection modes. Ethernet provides the standards used by these devices.

Ethernet is a group of specifications used for most wired networks. These standards identify the speed supported by different types of cables and how the cables connect through devices like hubs, switches, and routers. Cable types used in Ethernet networks include twisted-pair, coaxial, or fiber optic cables.

Data travels over these cables as data bits, and Ethernet standards define how these bits are packaged together as packets or frames. At this stage of your career, you don't need to know the details of how a packet or frame is created, but you do need to know specifics about cables.

NOTE **A+ AND NETWORK+**

After taking and passing the A+ certification exams, many people pursue the Network+ exam. You'll find that much of the material you learn in the A+ exam will help you with the Network+ exam. The primary difference is that the Network+ exam covers the networking topics in more depth.

Safety and Environmental Issues

When working with cables and connectivity, you need to be aware of some basic safety and environmental issues. Much of cable management is just common sense, but some of the environmental issues, such as plenum-safe cables and interference, might be new to you.

Cable Management and Trip Hazards

Cable management is the process of keeping cables neat. This often makes it easier to troubleshoot connectivity issues, and it can also reduce safety hazards.

For example, imagine a computer with multiple devices connected via USB cables and ports. If one of the devices stops working, you might want to move the cable to another port to see whether the problem is with the device or the USB port. If the cables are in a tangled mess, this simple troubleshooting step can be a challenge. On the other hand, if the cables are neat, it will be easy to identify the right cable and check it.

EXAM TIP

Cable management techniques reduce troubleshooting times. Technicians can easily identify connections for specific devices. Cable management can also reduce injuries from trip hazards.

Cables should not be run across a floor where someone can trip over them. Unfortunately, some people run power cables across a floor to a surge protector instead of just buying another surge protector. They might be saving a little on the expense side, but they are adding significant risk from the potential trip hazard.

If you must run a cable across a floor, you should cover it with heavy tape. For example, in some temporary lab environments, cables on the floor are covered with duct tape. This isn't ideal, but it significantly reduces the trip hazard.

PVC vs. Plenum-Safe Jackets

Cables have a protective covering around them known as a *jacket*. The jacket is typically made of *polyvinyl chloride (PVC)*, a type of flexible plastic. PVC is sufficient for most installations. However, when PVC burns, it can give off toxic fumes that can cause problems if the cable is run through certain areas, such as a plenum.

A *plenum* is an open space between walls, floors, or ceilings of a building where air is forced through for heating and cooling. Cables don't take much space and won't interfere with airflow, so it's common to run cables through these plenum spaces. However, if a fire spreads or ignites in a plenum and PVC cable is present, it's a huge problem. The air system will send the toxic fumes from the burning PVC to all the spaces receiving heated or cooled air. Additionally, the cable provides a path for the fire to spread to other areas.

To avoid this safety hazard, all cable running through a plenum must be rated as plenum-safe. Plenum-safe cable is fire-resistant and does not emit toxic fumes if it burns.

EXAM TIP

Plenum-safe cable is required for any cable going through a plenum, such as a raised floor, a dropped ceiling, or space inside walls.

Understanding Interference and Crosstalk

Many cables and connections are susceptible to interference that can disrupt or degrade the signals. Before digging into the cable types, it's important to understand the different types of interference.

The two primary types of interference are commonly known as *electromagnetic interference* (*EMI*) and *radio frequency interference* (*RFI*). Additionally, *crosstalk*, which occurs when data from one cable crosses over to another cable, can also cause problems.

NOTE **EMI AND RFI COMBINED PROTECTION**

EMI and RFI are sometimes combined into the same type of interference, categorized as EMI/RFI. There are technical differences, but technicians commonly protect against both EMI and RFI with shielded cables. If you can identify the source of the interference, you might be able to remove it.

The solution to these problems is often to use shielded cable or cable that is not susceptible to EMI/RFI problems, such as fiber optic cable. In some cases, you might be able to

identify the source of the problem and eliminate it. For example, you can avoid EMI from a power cable simply by not running a data cable next to a power cable.

EMI

Electromagnetic interference (EMI) comes from magnetic fields generated by a wide variety of sources. For example, power cables are carrying voltage, and as the power travels along the cable, it generates an EMI field around the cable.

You can't see the EMI field, but if you could, it would look similar to Figure 19-1. The power cable has three wires within it, and the EMI field extends outside of the cable. Many electricians have testers they place around power cables to measure the voltage. Think of putting your thumb and index finger around a cable and touching your fingertips. This tester is similar, but instead of fingers, it uses hinged metal arms to wrap around the cable. The metal arms measure the EMI field and can determine whether a cable is carrying a signal. This is certainly better than just cutting through a power cable to see if it's live.

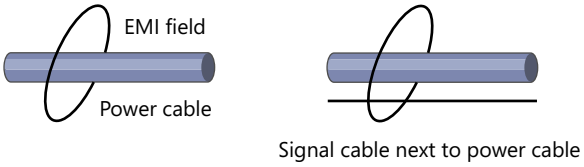


FIGURE 19-1 EMI field around a power cable.

On the right in Figure 19-1, you can see a signal cable next to a power cable. If you run a signal cable alongside a power cable, the EMI field can easily engulf the signal cable and disrupt the signal. Because of this, many organizations will not run power cables right next to signal cables, which is a simple but effective step to avoid EMI problems from power cables.

EXAM TIP

EMI can cause problems for signals if LAN cables and power cables are in close proximity to each other. You can avoid the problem by separating power cables and signal cables.

Other examples of potential sources of EMI include the following:

- **Magnets.** If they are too close, strong magnets can interfere with signals. This includes magnets from older CRT-based monitors and some uninterruptible power supplies (UPSs).
- **Motors.** This includes motors from electronic devices such as laser printers. If the motor is too close to other devices or cables, it can interfere with the signals.
- **Lights.** Many fluorescent lights emit EMI, which has caused problems in the past.

RFI

Radio frequency interference (RFI) is caused by *radio frequency (RF)* signal transmissions. As an example, an AM transmitter station in a field behind my home has sometimes boosted its power. These AM signals have leaked onto my phone lines and older TVs.

Some common examples in homes and offices are cordless phones and microwave ovens. They transmit frequencies in the 2.4-GHz range and can interfere with RF transmissions used on wireless networks. Chapter 23, "Exploring Wireless Networking," provides information about how you can use different channels to avoid problems from RFI.

Crosstalk

As mentioned earlier, crosstalk occurs when data from one cable crosses over to another cable. This can degrade the signals on each cable in some cases. At other times, it results in unauthorized users having access to data.

For example, Figure 19-2 shows how data can cross over from one cable to another. In this case, one cable is carrying secret data and the other is carrying unclassified data. If these two cables are right next to each other, secret data can cross over to the unclassified data cable.

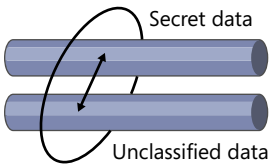


FIGURE 19-2 Crosstalk between two cables.

Quick Check

1. **What is the benefit of plenum-safe cables?**
2. **What type of interference can occur if you run data and power cables together?**

Quick Check Answers

1. **They are fire-resistant and don't emit toxic fumes.**
2. **Electromagnetic interference (EMI).**

Comparing Half-Duplex and Full-Duplex

Devices include a specification that identifies their capabilities for sending and receiving data at the same time. You should understand the following three terms:

- **Simplex.** *Simplex* allows traffic in only one direction, and one way only. That is, a connection can send data or receive data, but not both. This isn't common in a LAN today, but you might run across the term.
- **Half-duplex.** *Half-duplex* allows traffic in both directions, but in only one direction at a time. For example, walkie-talkies, push-to-talk radios, or press-to-talk cellular phones have this capability. You can listen or talk with the device, but while you're talking, you can't hear anyone else.
- **Full-duplex (also called duplex).** *Full-duplex* devices can send and receive at the same time. They include connections and cable support so that part of the cable is sending while part of the cable is receiving.

I've found that most people can easily grasp the meaning of these terms. Simplex is one-way only, half-duplex is two-way but only one direction at a time, and full-duplex is two-way simultaneous communications. However, connecting this concept to networking is sometimes challenging. Why is this important?

Imagine that I was using a walkie-talkie that allowed me to only talk or listen at any given time, and you were using a brand new cell phone that could also communicate on my walkie-talkie frequency. Your new phone allows you to talk and listen at the same time. However, if you start talking while I'm talking, I won't hear what you say. No matter how fancy your phone is, you still need to use it as a walkie-talkie when talking to me.

Similarly, to use full-duplex mode, all elements of a connection must support it. This includes both devices and the cable connecting them. For example, consider a brand new computer with a full-duplex network interface card (NIC) connecting to an older switch that uses only half-duplex. Because the switch can use only half-duplex, the computer must also use half-duplex.

Many older network devices use half-duplex. Because they can only send or receive at any given time, they are slower than full-duplex devices. Even if you connect a faster device using full-duplex, the faster device will use the slower half-duplex mode.

NOTE **LED COLOR SHOWS DUPLEX MODE**

Network devices often display an amber LED for the connection if they are using half-duplex. In contrast, the network device will have a green light if it is running in full-duplex mode. This is different for different devices, but the device documentation will describe the meaning of the different lights.

Many newer network devices use *auto-negotiation* or *autosense* to automatically detect the capabilities of connected devices. For example, if you purchase a 1,000-Mbps switch that works in full-duplex mode, it will also work at 10 Mbps in half-duplex mode.

When you plug a device into a port, the switch senses the speed and mode of the other device. It will automatically adjust the settings for the port to connect at the fastest possible speed and fastest mode. If you plug in a newer 1,000-Mbps full-duplex device into a different port, the switch will sense its capabilities and adjust the port for the faster full-duplex mode. This won't affect communication on other switch ports.

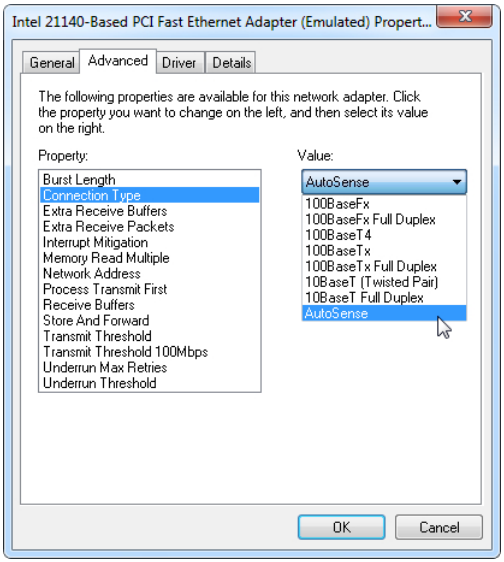
Unfortunately, some older devices don't have auto-negotiation. To ensure maximum compatibility, they default to slower speeds. If you want to use the faster speed or the faster mode, you have to manually configure the device.

EXAM TIP

Full-duplex provides the fastest performance. If you suspect network devices are running slower than they should, check the mode and speed of the device. You might need to manually configure the device to use full-duplex mode and the fastest speed.

You can use the following steps to verify the duplex settings of a NIC on a Windows 7–based computer.

1. Click Start, and select Control Panel.
2. Type **network** in the Search Control Panel text box.
3. Select View Network Connections.
4. The NIC is commonly labeled Local Area Connection, but it might have been renamed. Right-click the connection and select Properties. Click Configure.
5. Click the Advanced tab. You'll see several of the NIC properties and assigned values. Different vendors use different property names, and when you select a property, it will show the current value of the property.
6. Select the property used for the connection speed and duplex settings. In the following graphic, this setting is named Connection Type, but you might see it named Speed & Duplex or something similar. To show the other available choices, click the arrow for the Value settings.



7. Identify the setting used for autosense or auto-negotiation. In the graphic, it's named AutoSense, but you might see it listed as Auto Negotiation or something similar.

NOTE **MAC ADDRESS**

This graphic also shows how someone can change the media access control (MAC) address of a NIC. You can select Network Address and enter a new MAC address.

Quick Check

1. **What mode supports simultaneous communication?**
2. **What allows switches to automatically use the fastest speed and mode?**

Quick Check Answers

1. **Full-duplex mode.**
2. **Autosense or auto-negotiation.**

Comparing Bits per Second and Bytes per Second

Many speeds are listed as bits per second (bps), but you might also see speeds listed as bytes per second (Bps). Bits per second has a lowercase *b*, as in *bps*. Bytes per second has an uppercase *B*, as in *Bps*.

These two speeds are very different. Eight bits make up a byte, so 100 MBps indicates eight times more data than 100 Mbps. It's a subtle difference between *b* and *B*, but there is a huge difference in the meaning. It's important to be able to recognize the difference between the two.

Network connectivity is almost always listed in bits per second (bps). This includes the speed of a NIC, a switch, a router, and a connection to an Internet Service Provider (ISP). Unfortunately, some ISPs have listed download speeds with Bps, which confuses things.

Disk transfer speeds are sometimes listed in bytes per second, such as 150 MBps. You might also see disk transfer speeds listed in bits per second (bps), such as 3 Gbps. However, an uppercase *B* still means bytes, and a lowercase *b* still means bits.

Memory is always listed in bytes. For example, a 2-GB memory stick has two gigabytes (about 2 billion bytes) of memory storage capacity. It's incorrect to list this memory stick as 2 Gb, with a lowercase *b*.

Common Network Cables and Connectors

The most common type of cable you'll see in most networks today is twisted-pair. However, there are different types of twisted-pair cables and cables other than twisted-pair. In this section, you'll learn about the differences.

Ethernet Twisted-Pair

Twisted-pair cable used with Ethernet connections includes four twisted pairs of wires. Each pair has a specific number of twists per meter, with different pairs having a different number of twists. Even though the pairs are right next to each other in the same cable, these twists prevent signals from crossing over to each other. Additionally, the number of twists per meter determines the frequency capabilities of the cable. Higher frequencies allow the cable to transmit more data.

RJ-45 vs. RJ-11

Ethernet twisted-pair uses registered jack (*RJ-45*) connectors on both ends. These connectors are technically called 8P8C (eight pins eight contacts), but technicians call them RJ-45 connectors. However, 8P8C helps emphasize that the cable has eight wires as four pairs.

For example, one end can plug into the RJ-45 port of a computer's network interface card (NIC), and the other end can plug into a switch. Figure 19-3 shows the RJ-45 connector on the back of a computer.

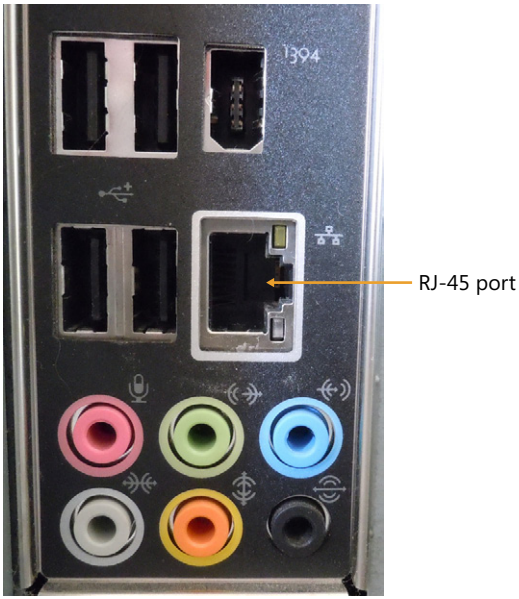


FIGURE 19-3 RJ-45 connector on back of computer.

> ***NOTE*** **TWO LEDS**
>
> **Figure 19-3 also shows two LEDs on the RJ-45 port. They aren't labeled, but the LED on the top right is the Link light used to show connectivity. The LED on the bottom right is the activity light, and it blinks when it detects activity on the port.**

The RJ-45 connector is similar to the *RJ-11* connector used for phones. However, RJ-11 connectors are smaller than RJ-45 connectors. Also, phone cables using RJ-11 connections have only two pairs of wires, while Ethernet twisted-pair cables using RJ-45 connectors have four pairs of wires.

IMPORTANT **PHONE CABLES CARRY VOLTAGE THAT CAN DAMAGE ETHERNET EQUIPMENT**

You should be careful never to plug an RJ-11 connector into a RJ-45 port. The RJ-45 port is bigger than the RJ-11 connector, so it won't fit snugly, but you might still connect some pins and cause damage.

Also, some newer phone systems use RJ-45 connectors. Always make sure you are connecting to the right port.

Figure 19-4 shows an example of a twisted-pair cable commonly used in Ethernet networks. One end of the cable is cut so that you can see the four pairs of twisted wires. The other end shows the RJ-45 connector common in Ethernet networks. In the figure, pin 8 is on the left and pin 1 is on the right. For comparison, an RJ-11 phone connector is shown next to the RJ-45 connector.

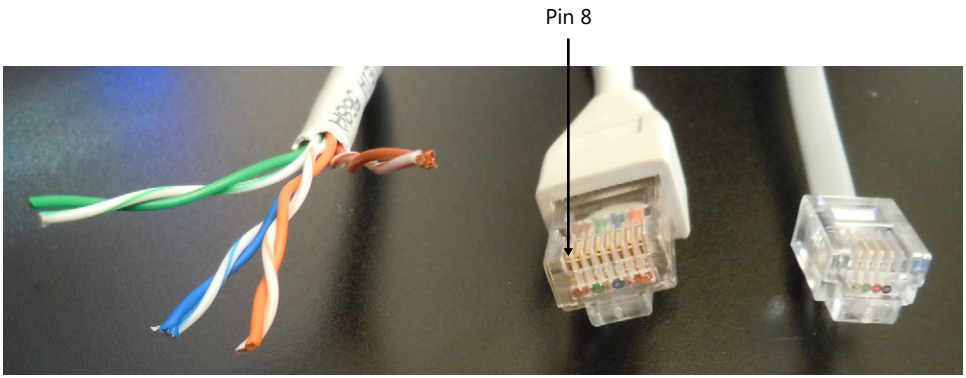


FIGURE 19-4 Twisted-pair cable with RJ-45 and RJ-11 connectors.

The length of twisted-pair cables is limited to 100 meters (about 328 feet). Therefore, the distance between a computer and a switch or between a switch and a router can't be more than 100 meters. If the distance between the devices is longer than 100 meters, you need to use a repeater. A repeater simply amplifies the signal so that it can go up to another 100 meters. Other cable types can also use repeaters, but their maximum distance is different from that of twisted-pair cables.

UTP vs. STP

Most Ethernet cable is *unshielded twisted-pair (UTP),* similar to that shown in Figure 19-4. However, in some situations, EMI, RFI, or crosstalk can cause problems with unshielded cable. You can use *shielded twisted-pair (STP)* to prevent these problems.

Figure 19-5 shows a comparison of the different types of shielding. All types of twisted-pair have a covering, or jacket, over the pairs to protect them. STP cables also have a metallic shielding around the pairs to prevent interference and crosstalk. In simple STP, it has shielding only around all four pairs. In S/UTP, it has shielding around each of the pairs. In S/STP, it has

shielding around each of the pairs and then again around all four pairs. Additional shielding provides additional protection.

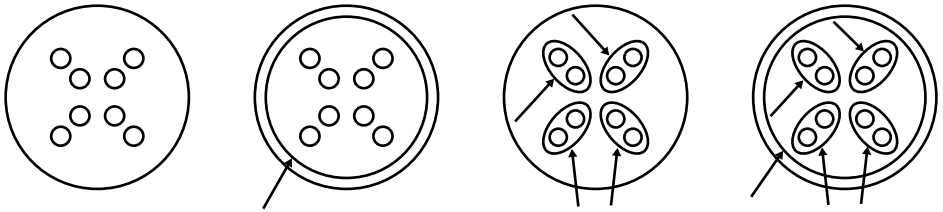


FIGURE 19-5 Four pairs in unshielded and shielded twisted-pair.

EXAM TIP

STP provides protection against EMI, RFI, and problems related to crosstalk. STP is more expensive than UTP, so UTP is more common. However, if the environment has problems with EMI or RFI, or if data must be protected from crosstalk, it is worth the expense.

Comparing Categories

Twisted-pair is identified using different categories. Each category includes different specifications, and higher numbers indicate newer cables that can support faster speeds.

Each of these categories is commonly shortened to *CAT* and the number, as shown in Table 19-1. The table lists the maximum speeds of each, along with some comments. Each cable includes four pairs of wires and has a maximum length of 100 meters.

TABLE 19-1 Categories of Twisted-pair Cable

Category	Maximum Speed	Frequency	Comments
CAT 3	10 Mbps	16 MHz	Rarely used today
CAT 5	100 Mbps	100 MHz	Recommended maximum speed of 100 Mbps
CAT 5e	1,000 Mbps	100 MHz	Enhanced version of CAT 5
CAT 6	10 Gbps	250 MHz	Used with 10GBase-T

Notice that CAT 5 has a recommended maximum of 100 Mbps. The original specification for 1000BaseT indicated that you could use CAT 5 for 1,000 Mbps. However, in practice it often had problems with signal loss at 1,000 Mbps. CAT 5e is an enhanced version of CAT 5 and supports 1,000 Mbps without any problems.

EXAM TIP

You should know the category of cable required for different speeds. For example, if you are installing a Gigabit network, you must use at least CAT 5e cables.

T568A vs. T568B

A twisted-pair cable includes four pairs of wires, and each pair is twisted around each of the others as shown in Figure 19-4. It's not apparent from the black-and-white photo, but these pairs have matching colors. The colors of the four pairs are:

- Green, and white with a green stripe
- Blue, and white with a blue stripe
- Orange, and white with an orange stripe
- Brown, and white with a brown stripe

When building a twisted-pair cable, specific colored wires should go to specific pins in the RJ-45 connector. There are two standards in use: *T568A* and *T568B*. It doesn't matter which standard is used in a cable as long the same standard is used on both ends.

Table 19-2 shows the pinout for each of the standards. You can see that the differences are with the green pair and the orange pair. T568A has the green pair on pins 1 and 2 and the orange pair on pins 3 and 6. T568B has the green pair on pins 3 and 6 and the orange pair on pins 1 and 2.

TABLE 19-2 T568A and T568B Color Codes

T568A Color	RJ-45 Pin	T568B Color
White, green stripe	1	White, orange stripe
Green	2	Orange
White, orange stripe	3	White, green stripe
Blue	4	Blue
White, blue stripe	5	White, blue stripe
Orange	6	Green
White, brown stripe	7	White, brown stripe
Brown	8	Brown

Crossover Cable

Most twisted-pair cable is created as a *straight-through cable* using either the T568A or T568B standard. Pin 1 on one connector goes to Pin 1 on the other connector. This is required when connecting computers to network devices such as switches.

However, sometimes you need to connect similar network devices together, such as a computer with a computer, a switch with a switch, or even a router with a switch. In this case, specific pins of the cables need to be crossed over. Interestingly, if you wire one connector using T568A and the other connector using T568B, you've created a *crossover cable*.

> ***NOTE*** **CAT 6 USES AUTOSENSE**
>
> **CAT 6 devices sense when a crossover cable is needed and automatically adjust the connection internally. Because of this, you don't need CAT 6 crossover cables.**

The crossover cable allows one device to receive data transmitted by the other device. With a standard straight-through cable, the pins are wired so that similar devices would be transmitting on the same pins, effectively blocking the traffic.

Figure 19-6 shows an example. When connecting a computer to a switch, you'd use a regular straight-through cable. However, when connecting the switch to a router, you'd use a crossover cable.

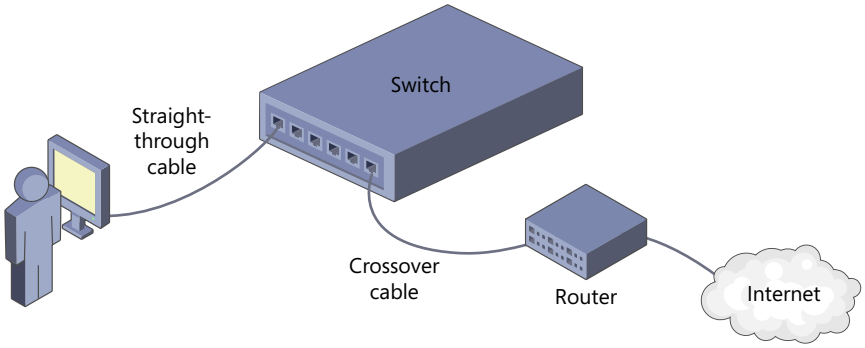


FIGURE 19-6 Crossover cable used to connect a switch and a router.

> ***NOTE*** **LABELING CABLES**
>
> **Technicians commonly mark crossover cables with *X* to indicate that they are crossover cables. Additionally, you can place both of the clear plastic RJ-45 connectors side by side and look at the cables. If the colors of the wires are in the same order on both (such as orange, blue, and green), it is a straight-through cable. If the colors are in a different order on one of the connectors (such as green, orange, and blue), it is a crossover cable. There are more wires and more colors, but the solid orange, blue, and green wires stand out.**

You can also connect two computers together with a crossover cable. It isn't common, but it does allow you to create a miniature network of two computers without a hub or a switch.

Many devices can dynamically modify the wiring within the port. These devices have a button labeled MDI/MDIX, short for medium dependent interface (MDI)/medium dependent interface crossover (MDIX). If you set it to MDIX, you can use a straight-through cable, but it wires the port as if a crossover cable were connected. Newer devices include an auto-MDIX capability. They don't have the MDI/MDIX button but can automatically sense the correct connection and select the correct mode.

Wire Strippers and Wire Crimper

You can purchase ready-made cables in many different lengths. However, if you're wiring several computers together, it's often cheaper to make your own cables, and it's relatively easy with the right tools. The two primary tools you need are the following:

- **Wire strippers.** The *wire strippers* are used to strip off the jacket and then to strip off the insulation on each wire.
- **Crimper.** A wire *crimper* squeezes the RJ-45 connector around the cable to hold it in place. You can buy basic crimpers for less than $10.

You strip off about 2 inches of the jacket and about 1/2 to 3/4 inch of the individual wires. Next, place the wires into the RJ-45 connector, matching them up to the correct pin. Be careful to untwist only what is absolutely needed to strip the wire and place it in the correct pin. If you untwist too much, it can reduce the frequency capabilities of the cable and result in errors when transmitting data at the highest speed. With everything in place, you use the crimper to squeeze the connector onto the wire.

NOTE **MAKE YOUR OWN CABLES**

If you want to solidify some of this knowledge, here's a valuable project: buy some twisted-pair cable, some RJ-45 (8P8C) connectors, and a combo wire stripper/wire crimper tool. You can get it all for less than $30, and after making a few cables, you'll have a much deeper understanding of the wiring. And you'll be a step ahead for the Network+ exam.

Punchdown Tool

Cables sent through the walls to other rooms rarely have connectors. Instead, they are attached to jacks and punchdown blocks by using a *punchdown tool*.

Figure 19-7 shows the typical path of a cable in most organizations. Twisted-pair cable with RJ-45 connectors will run from the computers to RJ-45 jacks in the wall. Cables are attached to the other side of the jack inside the wall and then run to a punchdown block in a wiring room. Last, a short twisted-pair cable with two RJ-45 connectors is run from the other side of the punchdown block to a network device, such as a switch.

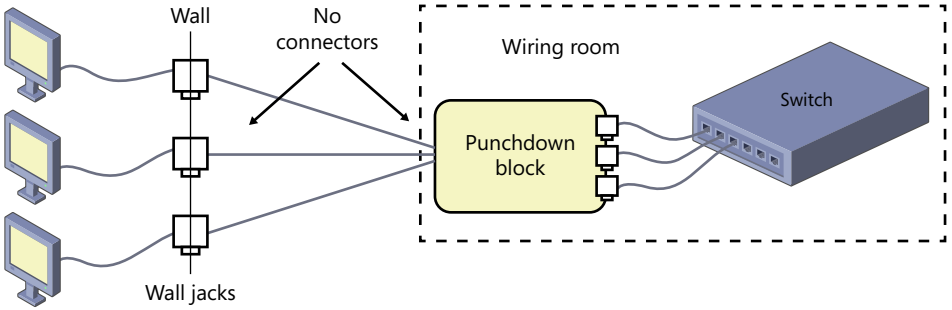


FIGURE 19-7 Cable path from computer to switch.

You use wire strippers and crimpers to create cables with the RJ-45 connectors. You use a punchdown tool to connect the cables to the back of the RJ-45 jacks and to the punchdown block.

A punchdown tool is a small handheld spring-loaded tool. A technician places a wire over the jack or in a slot in the punchdown block and then pushes the wire in with the punchdown tool. With a little pressure, the spring-loaded mechanism releases, stripping the wire and securing it in place.

Fiber Optic Cable

Fiber optic cable is made of a flexible glass material, and signals travel over fiber as light pulses. The many different types of connectors used for fiber include the following:

- **SC.** *SC* is short for *square connector*, and as you'd expect, it's shaped like a square.
- **LC.** *LC* is short for *Lucent Connector* because it was developed by Lucent Technologies. This is a miniaturized version of the SC connector and is becoming very popular in new installations.
- **ST.** *ST* is short for *straight tip,* and the connectors are round.

Fiber is more expensive and more difficult to work with than twisted-pair cables. It's rare to see it in small offices/home offices (SOHOs), but many larger organizations are using it more and more. Fiber has three important benefits over twisted-pair cable:

- **Signals can travel much farther.** Some types of fiber optic cable can carry signals as far as 10 kilometers (km), or over 6 miles, without a repeater. Compare this to the 100-meter limitation of twisted-pair cable.
- **It can carry more data.** Fiber cables have a larger bandwidth, allowing them to send and receive more data.
- **It's immune to EMI and RFI problems.** Because signals travel as light pulses, EMI and RFI interference doesn't affect the signal. Additionally, the light pulses can't cross over to other cables, so it's immune to crosstalk problems.

EXAM TIP

Fiber optic cable is superior to other cable types. Signals can travel farther without a repeater, and fiber has more bandwidth. You should also remember that fiber commonly uses SC, LC, and ST connectors.

Fiber comes in two forms: *multi-mode fiber (MMF)* and *single-mode fiber (SMF)*. MMF allows multiple signals to travel in the same cable. SMF is used for only one signal, and data can travel farther on an SMF cable than it can on an MMF cable. Table 19-3 lists some MMF and SMF characteristics.

TABLE 19-3 MMF and SMF Characteristics

Characteristic	MMF	SMF
Size	Larger core	Smaller core
Max Distance	Up to 2 km	Up to 40 km
Max Speed	Up to 10 Gbps	Up to 10 Gbps
Core	Plastic core	Glass core

While the table shows the maximum distance and maximum speeds, MMF fiber cannot send data the maximum distance using the maximum speed. For example, it can transmit data at a rate of 100 Mbps up to 2 km or transmit data at a rate of 10 Gbps up to 300 meters, but it cannot transmit data at the maximum of 10 Gbps the maximum distance of 2 km.

Coaxial Cable

Coaxial cable is similar to the cable that you use to connect a TV to a VCR or DVD player, or even a TV to a cable TV connection. It includes a copper core, insulation, and shielding covered by a cable jacket. Many older networks used coaxial cable, but it has been replaced with twisted-pair or fiber cable, and it's rare to use coaxial cable in a local area network. However, it is commonly used for TV and cable TV connections and, in some cases, to network TV devices.

The two primary types of coaxial cables used with TV connections are *RG-59* and *RG-6*:

- **RG-59.** This was originally used with cable TV connections and is efficient when transmitting analog signals. It can be used to transmit data between video systems, such as between a DVD player and a TV. It was used in some early networks but can transmit only a limited amount of data. RG-59 uses a *BNC* connector, which uses a push and turn connection.
- **RG-6.** This cable has a larger center conductor than RG-59 does, and it has additional shielding. It has become the standard used with cable TV and satellite TV systems because it is more efficient when transmitting any digital signals, including High Definition (HD) signals. Networks using coaxial cable today will use RG-6. It uses an *F-type screw-on connector*.

NOTE **BNC**

BNC is an acronym for Bayonet Neill-Concelmen, but it's rare that anyone spells it out. In other words, this is one acronym that you don't need to remember what it stands for.

Some cable companies have begun using coaxial cables between multiple boxes to create in-home networks. For example, DirecTV sells a Whole Home DVR that allows you to record television shows on a DVR room in one room and then play the shows from any DirecTV box in the house. It uses RG-6 cable with *F*-type connectors but will not work with the older RG-59 cable.

Older networks used RG-58 or RG-8 cable. For example, 10Base2 used RG-58 with BNC connectors and could transmit data at a rate of 10 Mbps up to 185 meters. 10Base5 used RG-8 with screw-on *N* connectors and could transmit data at a rate of 10 Mbps up to 500 meters.

Quick Check

1. **Name the two wiring standards used for twisted-pair cabling.**
2. **Name three common connectors used with fiber.**

Quick Check Answers

1. **T568A and T568B.**
2. **SC, LC, and ST.**

Speeds and Specifications

Ethernet uses a specific naming convention. If you learn this format, you can usually identify the speed and what type of cable it is using. If you know the cable, you'll have an idea of the connector it needs.

The basic specification is *n*BASE-*x*, where *n* indicates the speed and *x* is an identifier for the cable. Table 19-4 shows some examples.

TABLE 19-4 Specification Examples

Specification	Speed	Cable and connector
10BASE2	10 Mbps	Coaxial cable using a BNC connector
100BASE-T	100 Mbps	Twisted-pair (notice the T) using an RJ-45 connector
1000BASE-LX	1,000 Mbps	Fiber cable using an ST or SC connector
10GBase-T	10 Gbps	Twisted-pair using an RJ-45 connector

You can see that if the first number is 10, it indicates the speed is 10 Mbps. If it's 100, it indicates a speed of 100 Mbps, and 1,000 indicates 1,000 Mbps (or 1 Gbps). The last item in the table uses 10G to indicate 10 Gbps.

EXAM TIP

There are many more identifier letters, and if you follow your studies into the Network+ exam, you'll dig deeper. However, if you can identify the speed and the cable type, you'll be prepped for the A+ exams. The speed is easy because it's just the first number. Identifying the cable is a little more challenging, but the identifier gives the clue. If it's 2, 5, or *C*, it's coaxial. If it starts with a *T*, it's twisted-pair. The rest are fiber.

Ethernet Speeds

Traditional Ethernet operates at 10 Mbps. That was certainly fast when it first came out, but it is relatively slow today. Most network devices can operate at speeds faster than 10 Mbps, with 1 Gbps common in most networks. Table 19-5 shows some common specifications used with traditional Ethernet.

TABLE 19-5 Some Common Ethernet Specifications

Cable type	Name	Comments
Coaxial	10Base2	Maximum distance 185 meters. Also called Thinnet.
Coaxial	10Base5	Maximum distance 500 meters. Also called Thicknet.
Twisted-pair	10BaseT	CAT 5 cable using two pair of a four-pair cable. Maximum distance 100 meters.
Fiber	10Base-FL	Can reach distances up to 550 meters (about 1,800 feet).

Fast Ethernet

Fast Ethernet improved the speed from 10 Mbps to 100 Mbps. Most Fast Ethernet cables are either twisted-pair or fiber, as shown in Table 19-6.

TABLE 19-6 Fast Ethernet Specifications

Cable type	Name	Comments
Twisted-pair	100Base-T	CAT 5 cable using two pairs in a four-pair cable.
Twisted-pair	100Base-Tx	Most common form of 100Base-T. Supports full-duplex mode.
Fiber	100Base-FX	Not compatible with 10Base-FL used in Ethernet.
Fiber	100Base-SX	Uses two strands of fiber: one for receiving and one for transmitting.

Gigabit Ethernet

Gigabit Ethernet is becoming much more common. Data can travel at 1 gigabit per second (1 Gbps), and it's commonly labeled as either 1,000 Mbps or 1 Gbps. Gigabit Ethernet requires all devices to use auto-negotiation and full-duplex mode.

A gigabit network can easily transfer broadcast quality video over a network. For example, home users can use one computer to store movies and TV and broadcast them to any TV in the home. Table 19-7 shows some common Gigabit Ethernet specifications.

TABLE 19-7 Gigabit Ethernet Specifications

Cable type	Name	Comments
Twisted-pair	1000Base-T	CAT-5E 6 cable using all four pairs of a four-pair cable. Max distance 100 m.
Single-mode Fiber	1000Base-LX	Max distance 5 km.
Single-mode Fiber	1000Base-ZX	Max distance 70 km.
Multi-mode Fiber	1000Base-SX	Max distance 550 m.
Multi-mode Fiber	1000Base-LX	Max distance 550 m.

The tables in these sections do not include all the possible specifications, but they do give you an idea of some common cables used with Ethernet. More specifically, they cover the specifications you can expect to see on an A+ exam.

10-Gigabit Ethernet

It isn't as common today, but 10-Gigabit Ethernet is being used in some networks. Just as the name implies, it can reach speeds of 10 Gbps. Twisted-pair using 10 Gigabit is identified as 10GBase-T, and it requires CAT 6 cable. Table 19-8 shows some of the 10-Gigabit standards.

TABLE 19-8 10-Gigabit Ethernet Specifications

Cable type	Name	Comments
Twisted-pair	10GBase-T	CAT-6 or enhanced CAT-6A cable. Max distance 100 m.
Single-mode Fiber	10GBASE-LR	LR indicates long range. Max distance 10 km.
Single-mode Fiber	10GBASE-ER	ER indicates extended range. Max distance 40 km.
Multi-mode Fiber	10GBASE-SR	SR indicates short range. Max distance 400 m.

Quick Check

1. What type of connector is used with 100Base-T?
2. What is the speed of 1000BaseT?

Quick Check Answers

1. RJ-45.
2. 1,000 Mbps or 1 Gbps.

Topologies

Computers can be organized within a network by using different network topologies. The *topology* refers to how the devices are logically connected, and the most common topology is the star topology. The following sections describe the different topologies in more detail.

EXAM TIP

Know the basics about the five basic topologies when preparing for the exam. These were not tested in previous versions of A+, but because they were added in this version, you can fully expect to see some questions related to them.

Star

A *star topology* has multiple devices connected to a central device such as a switch or hub. For example, Figure 19-8 shows a star topology. If you substitute the central device with a star, you can see how it got its name.

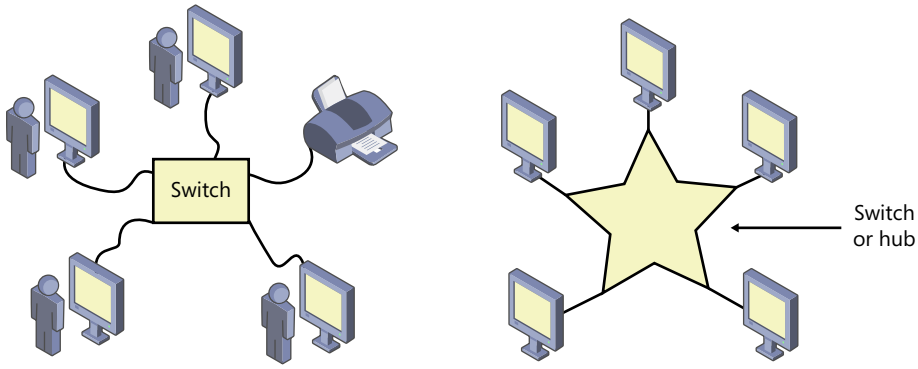


FIGURE 19-8 Star topology.

While this looks like a star when drawn, it does not indicate the physical layout. For example, imagine an Ethernet classroom with 20 computers. The computers would connect to RJ-45 jacks in the classroom walls. Cables run from the jacks to a punchdown block in a wiring room, and short cables run from the block to a switch, as shown in Figure 19-7.

A benefit is that each device has a direct line to the switch or hub, and if you use a switch, devices don't compete with each other to send traffic along the line. Also, if a connected device fails, it is the only device affected; it doesn't prevent other devices from working.

Bus

A *bus topology* has multiple devices connected to each other in a logical line. A unique characteristic of bus topologies is that both ends of the line must be terminated. When a signal travels along a cable, it will be reflected back without this terminator. This reflected signal results in data collisions and prevents any usable data transmissions.

Figure 19-9 shows a bus topology commonly used in older 10Base2 networks. Each device had a T connector, and devices were connected in a line with coaxial cable and BNC connectors. The devices on each end connected to a terminator instead of to another device.

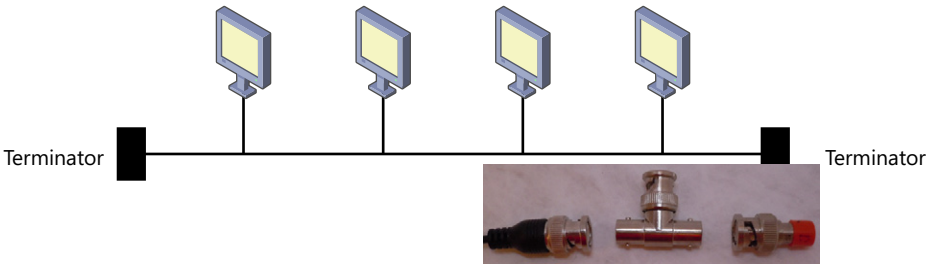


FIGURE 19-9 Bus topology.

A bus topology is very simple to configure and uses less cable than a star topology. However, it is very problematic with 10Base2 networks. If a terminator is removed or if a cable anywhere on the bus is disconnected or faulty, all devices on the bus stop communicating. Not only that, but it's not a simple matter to identify the break. In contrast, when a single computer in a star network fails, it is the only one affected and the problem is with its cabling.

Ring

A *ring topology* has all computers logically configured in a single circle or a ring. Data travels around the ring to different devices. Most ring topologies use a logical token and are called *token ring networks*.

The token is a specially formatted set of bytes passed to devices in the ring. Devices can transmit data only when they have the token, and after they transmit their data, they pass the token on to the next computer.

A token ring network does not scale well. In other words, performance is seriously degraded as the number of devices increases. You can think of this as a single piece of paper passed around by a group of people, and each person can talk only when holding the piece of paper. This might work with 10 people in a room, but imagine if there were 100 or 1,000 people. Each person would have fewer opportunities to communicate. Similarly, ring topologies are effective only with a small number of devices.

Figure 19-10 shows different configurations of a ring topology. One of the problems discovered early with ring topologies is that if any single computer failed, it broke the ring and all traffic stopped. Many rings added a *multistation access unit* (*MAU*). The computers were still in a logical ring, but all devices sent and received data through the MAU. If a device failed, the MAU sensed the failure and didn't pass the token to the failed device.

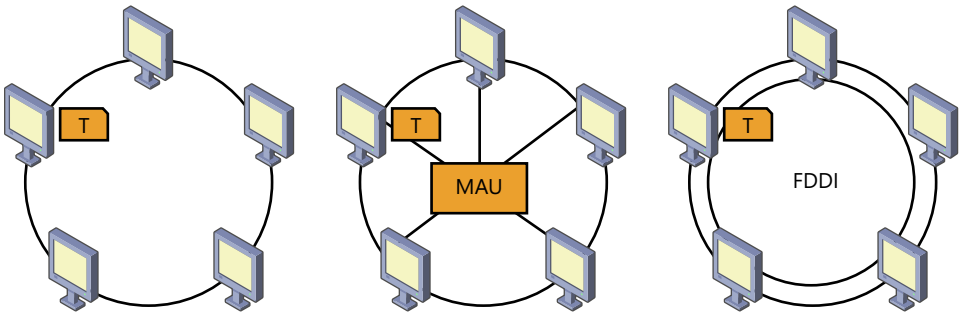


FIGURE 19-10 Ring topology.

NOTE **HYBRID**

A ring topology using an MAU is actually a hybrid of a ring and a star.

Fiber Distributed Data Interface (FDDI) is a type of token ring topology that uses fiber optic cable and two rings. The second ring provides a redundant path that can be used if the first path fails.

Mesh

A *mesh topology* is one where each device has a connection with all other computers in the network. It provides a high degree of redundancy, allowing devices to continue to communicate even if multiple connections fail. However, it is rarely used due to the expense.

Figure 19-11 shows an example of a mesh topology with five computers. Each computer needs four connections, and the network requires a total of 10 connections. If you had 10 computers, each computer would need nine connections, and the network would require a total of 45 connections.

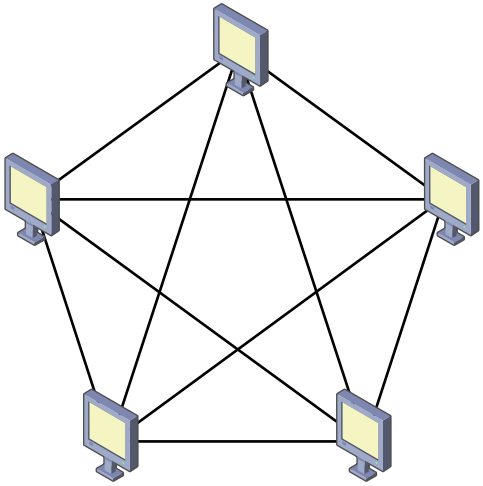


FIGURE 19-11 Mesh topology.

NOTE **CALCULATING CONNECTIONS IN A MESH TOPOLOGY**

You can calculate the number of connections in a mesh with the following formula: *n* x (*n*-1) / 2 where *n* is the number of devices. For example, with five devices, the formula is: 5 × (5-1) / 2 or 5 x 4 (20) divided by 2 (10).

Hybrid

A *hybrid topology* is a combination of any two or more of the other topologies, and many networks use a hybrid topology. For example, end user computers are commonly configured in a star topology. The same network can connect to servers using a high-speed FDDI topology.

Quick Check

1. **What topology connects multiple devices using a central device such as a switch?**
2. **What topology restricts communication until a device has a token?**

Quick Check Answers

1. **Star.**
2. **Ring, or token ring.**

Chapter Summary

- Ethernet is a group of specifications for networks. The standards identify speeds, cable types, and connections. Cables defined in Ethernet standards include twisted-pair, coaxial, and fiber optic cables.
- Cable management ensures that cables don't present a trip hazard and also results in easier troubleshooting.
- Plenum-safe cable is fire-resistant and does not emit toxic fumes when it burns.
- EMI comes from magnetic fields, including fields generated by power cables, magnets, lights, and motors.
- RFI comes from radio transmissions, including those from cordless phones and microwave ovens.
- Simplex transmissions go only one way on a cable. Half-duplex transmissions can be sent and received, but only one way at a time. Full-duplex transmissions can send and receive at the same time.
- Simplex is rarely used in networks anymore. Gigabit Ethernet devices all use full-duplex mode.
- LED lights on devices often indicate a device's speed and mode (such as full-duplex or half-duplex). Most devices automatically configure the fastest speed and mode, but older devices might need to be manually configured.
- Twisted-pair network cables include four pair of twisted wires. Each end of the cable has an RJ-45 connector, and they can plug into RJ-45 ports on devices.
- RJ-11 cables are smaller and carry voltages that can damage components if plugged into an RJ-45 port.
- Shielded twisted-pair (STP) provides protection against EMI and RFI.
- CAT 3 supports 10 Mbps but is rarely used today. CAT 5 supports 100 Mbps, CAT 5e supports 1 Gbps, and CAT 6 supports 10 Gbps. All are limited to 100 meters.
- Two standards used for wiring cables are T568A and T568B. The same standard must be used on both ends of the cable to create a straight-through cable.
- Crossover cables are used to connect network devices together, such as a switch and a router, or even two computers as a mini-network. Some devices include auto-MDIX capabilities to dynamically wire a port as if a crossover cable were connected.
- Wire crimpers clamp a prepared twisted-pair cable onto an RJ-45 jack. Punchdown tools connect twisted-pair wires to jacks or punchdown blocks.
- Fiber optic cable can carry signals farther than twisted-pair or coaxial cable without a repeater. It can also carry more data in smaller cables. Fiber is immune to EMI and RFI problems. Fiber cables commonly use SC, LC, or ST connectors.

- Coaxial cable is similar to cables used with TVs and DVD players. RG-59 cable uses BNC twist-on connectors. RG-8 cable uses a screw-on F-type connector.
- Ethernet cable specifications are commonly listed as *n*Base-*x*, where *n* is the speed, and *x* indicates the cable type.
- Original Ethernet used a speed of 10 Mbps. Fast Ethernet has speeds of 100 Mbps, and Gigabit Ethernet reaches speeds of 1,000 Mbps (or 1 Gbps).
- Topologies identify how devices are logically configured in a network. A star topology includes a central device such as a switch, a bus configures devices in a line, and a ring configures devices in a circle. A hybrid is a combination of any two or more topologies.

Chapter Review

Use the following questions to test your knowledge of the information in this chapter. The answers to these questions, and the explanations of why each answer choice is correct or incorrect, are located in the "Answers" section at the end of this chapter.

1. Of the following choices, what can a technician employ to easily identify connections for devices?
   - **A.** Shielding
   - **B.** Cable management
   - **C.** Fiber optic cable
   - **D.** Plenum-safe cable
2. What type of cable should you use in spaces used for air conditioning?
   - **A.** Twisted-pair
   - **B.** Fiber
   - **C.** Coaxial
   - **D.** Plenum-safe
3. What mode allows data to travel in both directions at the same time?
   - **A.** Simplex
   - **B.** Half-duplex
   - **C.** Full-duplex
   - **D.** MDIX

4. What type of connector will you find on a twisted-pair cable connected to a switch?

   A. RJ-11

   B. RJ-45

   C. BNC

   D. LC

5. Which category cable is the minimum recommended to support speeds of 1,000 Mbps?

   A. CAT 3

   B. CAT 5

   C. CAT 5e

   D. CAT 6

6. What type of cable would you use to connect two computers together that have RJ-45 ports?

   A. Twisted-pair crossover cable

   B. Twisted-pair straight-through cable

   C. Fiber crossover cable

   D. Fiber straight-through cable

7. What type of connector will you find on a fiber optic cable?

   A. RJ-11

   B. RJ-45

   C. BNC

   D. LC

Answers

1. **Correct Answer:** B
   - **A. Incorrect:** Shielding can reduce problems from interference but won't help identify connections.
   - **B. Correct:** Cable management ensures that cables are relatively neat and easy to trace. Cable management also reduces trip hazards.
   - **C. Incorrect:** Fiber provides higher speeds and longer lengths without a repeater, but cables still need to be kept neat.
   - **D. Incorrect:** Plenum-safe cable is fire-resistant and doesn't emit toxic fumes, but cables still need to be kept neat.
2. **Correct Answer:** D
   - **A. Incorrect:** Twisted-pair can be used as long as it has a plenum-safe jacket.
   - **B. Incorrect:** Fiber can be used as long as it has a plenum-safe jacket.
   - **C. Incorrect:** Coaxial can be used as long as it has a plenum-safe jacket.
   - **D. Correct:** Plenum-safe cable should be used in air-handling spaces because it is fire-resistant and doesn't emit toxic fumes.
3. **Correct Answer:** C
   - **A. Incorrect:** Data can be only sent or only received when using a simplex connection.
   - **B. Incorrect:** Half-duplex allows data to be sent or received on the same cable, but not at the same time.
   - **C. Correct:** Data travels in both directions at the same time with full-duplex mode.
   - **D. Incorrect:** Medium dependent interface crossover (MDIX) is a mode that allows a port to change connections as though it were connected with a crossover cable.
4. **Correct Answer:** B
   - **A. Incorrect:** RJ-11 connectors are used for phone connections.
   - **B. Correct:** RJ-45 connectors are used for twisted-pair cables connecting network devices, such as a switch.
   - **C. Incorrect:** BNC connectors are used for coaxial cables.
   - **D. Incorrect:** LC connectors are used for fiber cables.

5. **Correct Answer:** C

   A. **Incorrect:** CAT 3 is used for speeds up to 10 Mbps.

   B. **Incorrect:** CAT 5 is used for speeds up to 100 Mbps. It has errors when used at 1,000 Mbps, so CAT 5e is recommended instead.

   C. **Correct:** CAT 5e is an enhanced version of CAT 5, and it supports speeds up to 1,000 Mbps.

   D. **Incorrect:** CAT 6 is used for speeds up to 10 Gbps.

6. **Correct Answer:** A

   A. **Correct:** A twisted-pair crossover cable is used to connect two computers together directly through their RJ-45 ports.

   B. **Incorrect:** A straight-through cable is used to connect a computer to a switch but not to another computer.

   C. **Incorrect:** Fiber optic does not use crossover cables.

   D. **Incorrect:** Fiber optic does not use RJ-45 connectors but instead uses SC, LC, and ST connectors.

7. **Correct Answer:** D

   A. **Incorrect:** RJ-11 connectors are used for phone connections.

   B. **Incorrect:** RJ-45 connectors are used for twisted-pair cables.

   C. **Incorrect:** BNC connectors are used for coaxial cables.

   D. **Correct:** LC connectors are one type of connector used for fiber cables. Other common connectors are SC and ST.