Chapter

3

Networking Topologies, Connectors, and Wiring Standards

THE FOLLOWING COMPTIA NETWORK+ EXAM OBJECTIVES ARE COVERED IN THIS CHAPTER:

- ✓ **2.1 Categorize standard cable types and their properties**
    - ▪ Type:
    - ▪ CAT3, CAT5, CAT5e, CAT6
    - ▪ STP, UTP
    - ▪ Multimode fiber, single-mode fiber
    - ▪ Coaxial
        - ▪ RG-59
        - ▪ RG-6
    - ▪ Serial
    - ▪ Plenum vs. Non-plenum
    - ▪ Properties:
    - ▪ Transmission speeds
    - ▪ Distance
    - ▪ Duplex
    - ▪ Noise immunity (security, EMI)
    - ▪ Frequency
- ✓ **2.2 Identify common connector types**
    - ▪ RJ-11
    - ▪ RJ-45

- BNC
- SC
- ST
- LC
- RS-232

✓ **2.4 Given a scenario, differentiate and implement appropriate wiring standards**

- 568A
- 568B
- Straight vs. cross-over
- Rollover
- Loopback

✓ **2.8 Install components of wiring distribution**

- Vertical and horizontal cross connects
- Patch panels
- 66 block
- MDFs
- IDFs
- 25 pair
- 100 pair
- 110 block
- Demarc
- Demarc extension
- Smart jack
- Verify wiring installation
- Verify wiring termination

The idea of connecting a bunch of computers together hasn't changed a whole lot since the mid-1980s, but how we go about doing that certainly has. Like everything else, the technologies and devices we create our networks with have evolved dramatically and will continue to do so in order to keep up with the ever-quickening pace of life and the way we do business.

When you connect computers together to form a network, you want error-free, blazingly fast communication, right? Although "error-free" and reality don't exactly walk hand in hand, keeping lapses in communication to a minimum and making that communication happen really fast is definitely possible. But it isn't easy, and understanding the types of media and network topologies used in networking today will go far in equipping you to reach these goals. So will being really knowledgeable about and familiar with the array of components and devices used to control network traffic.

All of these networking ingredients are going to be the focus of this chapter. In it, I'll cover different types of networking media, discuss common topologies and devices, and compare the features that they all bring into designing a solid network that's as problem free and turbo charged as possible.

> **NOTE** To find up-to-the-minute updates for this chapter, please see `www.lammle.com` or `www.sybex.com/go/comptianetwork+`.

Physical Media

A lot of us rely on wireless networking methods that work using technologies like radio frequency and infrared, but even wireless depends on a physical media backbone in place somewhere. And the majority of installed LANs today communicate via some kind of cabling, so let's take a look at the three types of popular cables used in modern networking designs:

- Coaxial
- Twisted pair
- Fiber optic

Coaxial Cable

Coaxial cable, referred to as *coax*, contains a center conductor made of copper that's surrounded by a plastic jacket, with a braided shield over it. A plastic such as polyvinyl chloride (PVC) or fluoroethylenepropylene (FEP, commonly known as Teflon) covers this metal shield. The Teflon-type covering is frequently referred to as a *plenum-rated coating*, and it's definitely expensive but often mandated by local or municipal fire code when cable is hidden in walls and ceilings. Plenum rating applies to all types of cabling and is an approved replacement for all other compositions of cable sheathing and insulation like PVC-based assemblies.

The difference between plenum and non-plenum cable come down to how each is constructed and where you can use it. Many large multi-story buildings are designed to circulate air through the spaces between the ceiling of one story and the floor of the next; this space between floors is referred to as the *plenum*. And it just happens to be a perfect spot to run all the cables that connect the legions of computers that live in the building. Unless there's a fire—if that happens, the plenum cable becomes a serious hazard because its insulation gives off poisonous smoke that gets circulated throughout the whole building. Plus, plenum cables can actually become "wicks" for the fire, helping it quickly spread from room to room and floor to floor—yikes!

Because it's a great goal to prevent towering infernos, the National Fire Protection Association (NFPA) demands that cables run within the plenum have been tested and guaranteed as safe. They must be fire retardant and create little or no smoke and poisonous gas when burned. This means you absolutely can't use a non-plenum-type cable in the plenum, but it doesn't mean you can't use it in other places where it's safe. And because it's a lot cheaper, you definitely want to use it where you can.

Thin Ethernet, also referred to as *Thinnet* or 10Base-2, is a thin coaxial cable. It is basically the same as thick coaxial cable except it's only about ¼ in diameter. Thin Ethernet coaxial cable is Radio Grade 58 or just RG-58. Figure 3.1 shows an example of Thinnet.

Oh, by the way, if you use Thinnet cable, you've got to use *BNC* connectors to attach stations to the network, as shown in Figure 3.2.

> **NOTE** You don't have to know much about most coax cable types in networks anymore, especially the Thinnet and Thicknet types of coaxial cable. Thicknet was known as RG-58 A/U. Nowadays, we use 75ohm coax for cable TV; using coax in the Ethernet world is pretty much a thing of the past. RG-6 or CATV coax is used in our brave new broadband world.

Anyway, you can attach BNC connector with a crimper that looks like a weird pair of pliers and has a die to crimp the connector. A simple squeeze crimps the connector to the cable. You can also use a screw-on connector, but I avoid doing that because it's not very reliable.

Table 3.1 lists some specifications for the different types of coaxial cable, but understand that we only use RG-59 and RG-6 in today's world.

FIGURE 3.1 A stripped-back Thinnet

FIGURE 3.2 Male and female BNC connectors

Male

Female
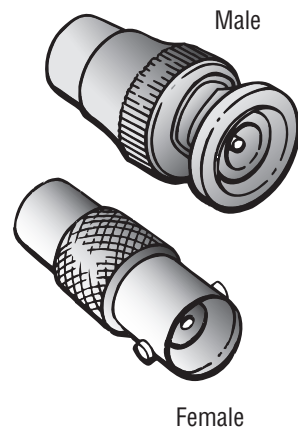
TABLE 3.1 Coaxial Cable Specifications

RG Rating	Popular Name	Ethernet Implementation	Type of Cable
RG-58 U	N/A	None	Solid copper
RG-58 A/U	Thinnet	10Base-2	Stranded copper

TABLE 3.1   Coaxial Cable Specifications *(continued)*

RG Rating	Popular Name	Ethernet Implementation	Type of Cable
RG-8	Thicknet	10Base-5	Solid copper
RG-59	Cable television Low cost, short distance	N/A	Solid copper
RG-6	Cable television, cable modems Longer distances than RG-59; some power implementations	N/A	Solid copper
RG-62	ARCnet (obsolete)	N/A	Solid/stranded

> **NOTE** An advantage of using coax cable is the braided shielding that provides resistance to electronic pollution like *electromagnetic interference (EMI)*, *radio frequency interference (RFI)*, and other types of stray electronic signals that can make their way onto a network cable and cause communications problems.

Twisted-Pair Cable

Twisted-pair cable consists of multiple individually insulated wires that are twisted together in pairs. Sometimes a metallic shield is placed around them; hence the name *shielded twisted-pair (STP)*. Cable without outer shielding is called *unshielded twisted-pair (UTP)*, and it's used in twisted-pair Ethernet (10Base-T, 100Base-TX, 1000Base-TX) networks.

Ethernet Cable Descriptions

Ethernet cable types are described using a code that follows this format: *N<Signaling>-X*. The *N* refers to the signaling rate in megabits per second, *<Signaling>* stands for the signaling type—either baseband or broadband—and the *X* is a unique identifier for a specific Ethernet cabling scheme.

Here's a common example: 100Base-*X*. The 100 tells us that the transmission speed is 100Mb, or 100 megabits. The *X* value can mean several different things, and the *T* is short for *twisted-pair*. This is the standard for running 100-Megabit Ethernet over two pairs (four wires) of Category 5, 5e, or 6 UTP.

So why are the wires in this cable type twisted? Because when electromagnetic signals are conducted on copper wires in close proximity—like inside a cable—it causes interference called *crosstalk*. Twisting two wires together as a pair minimizes interference and even

protects against interference from outside sources. This cable type is the most common today for the following reasons:

▪ It's cheaper than other types of cabling.

▪ It's easy to work with.

▪ It allows transmission rates that were impossible 10 years ago.

UTP cable is rated in these categories:

Category 1   Two twisted wire pairs (four wires). It's the oldest type and is only voice grade—it isn't rated for data communication. People refer to it as plain old telephone service (POTS). Before 1983, this was the standard cable used throughout the North American telephone system. POTS cable still exists in parts of the Public Switched Telephone Network (PSTN) and supports signals limited to the 1MHz frequency range.

> *Category* is often shortened to *Cat.* Today, any cable installed should be a minimum of Cat 5e because some cable is now certified to carry bandwidth signals of 350MHz or beyond. This allows unshielded twisted-pair cables to exceed speeds of 1Gbps—fast enough to carry broadcast-quality video over a network.

Category 2   Four twisted wire pairs (eight wires). It handles up to 4Mbps, with a frequency limitation of 10MHz, and is now obsolete.

Category 3   Four twisted wire pairs (eight wires) with three twists per foot. This type can handle transmissions up to 16MHz. It was popular in the mid-1980s for up to 10Mbps Ethernet, but it's now limited to telecommunication equipment and, again, is obsolete for networks.

Category 4   Four twisted wire pairs (eight wires), rated for 20MHz. Also obsolete.

Category 5   Four twisted wire pairs (eight wires), rated for 100MHz. But why use Cat 5 when you can use Cat 5e for the same price? I am not sure you can even buy plain Cat 5 anymore!

Category 5e (enhanced)   Four twisted wire pairs (eight wires), rated for 100MHz, but capable of handling the disturbance on each pair that's caused by transmitting on all four pairs at the same time—a feature that's needed for Gigabit Ethernet. Any category below 5e shouldn't be used in today's network environments.

Figure 3.3 shows a basic Cat 5e cable with the four wire pairs twisted to reduce cross-talk.

Category 6   Four twisted wire pairs (eight wires), rated for 250MHz. Cat 6 became a standard back in June 2002. You would usually use it as riser cable to connect floors together. If you're installing a new network in a new building, there's no reason to use anything but Category 6 UTP cabling as well as running fiber runs between floors.

FIGURE 3.3   Cat 5e UTP cable
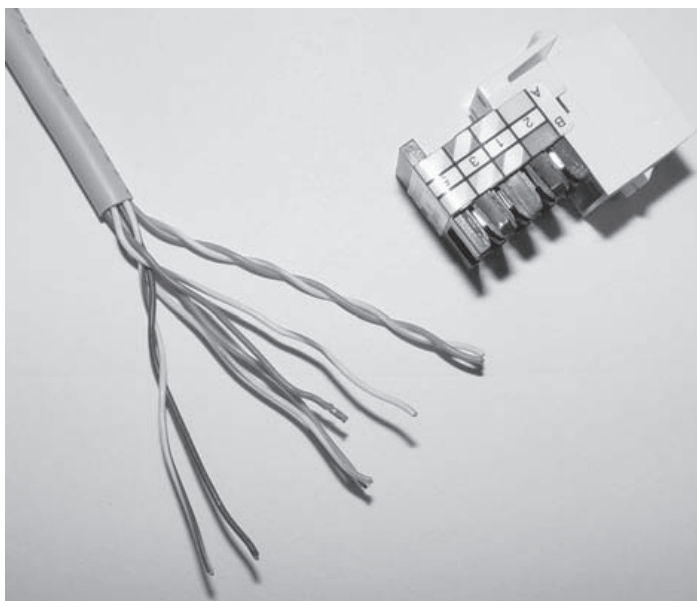
Connecting UTP

BNC connectors won't fit very well on UTP cable, so you need to use a *Registered Jack (RJ) connector*, which you're familiar with because most telephones connect with them. The connector used with UTP cable is called RJ-11 for phones that use four wires; RJ-45 has four pairs (eight wires), as shown in Figure 3.4.


🌐 Real World Scenario

Category 5e Cabling Tips

If you want data rates faster than 10Mbps over UTP, ensure that all components are rated to deliver this and be really careful when handling all components. If you yank on Cat 5e cable, it will stretch the number of twists inside the jacket, rendering the Cat 5e label on the outside of the cable invalid. Also, be certain to connect and test all four pairs of wire. Although today's wiring usually uses only two pairs (four wires), the standard for Gigabit Ethernet over UTP requires that all four pairs (eight wires) be in good condition.

Also be aware that a true Cat 5e cabling system uses rated components from end to end, patch cables from workstation to wall panel, cable from wall panel to patch panel, and patch cables from patch panel to hub. So if any components are missing, or if the lengths don't match the Category 5e specification, you just don't have a Category 5e cabling installation. And certify that the entire installation is Category 5e compliant. Be warned that doing this requires some pretty pricey test equipment to make the appropriate measurements.

FIGURE 3.4   RJ-11 and RJ-45 connectors
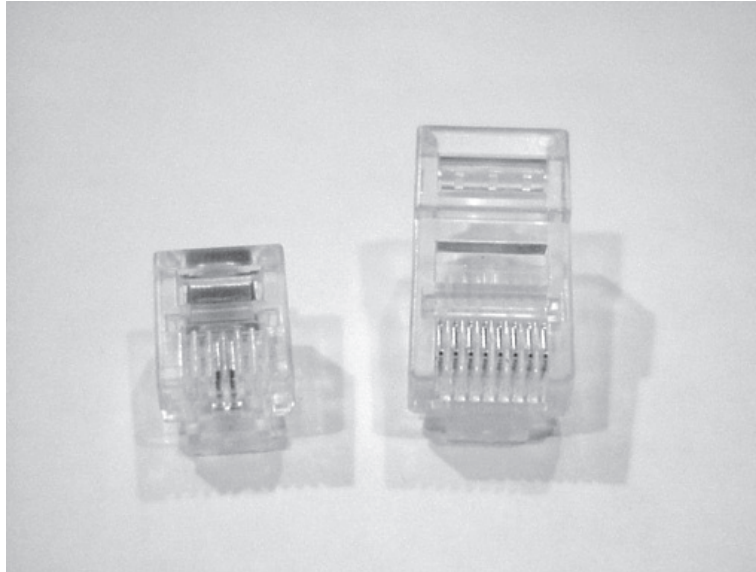
Most of the time, UTP uses RJ connectors; you use a crimper to attach them to a cable, just as you would with BNC connectors. The only difference is that the die that holds the connector is a different shape. Higher-quality crimping tools have interchangeable dies for both types of cables. We do not use RJ-11 for local area networks (LANs), but we do use them for our home Digital Subscriber Link (DSL) connections.

> **NOTE**   RJ-11 uses two wire pairs, and RJ-45 uses four wire pairs.

Fiber-Optic Cable

Because fiber-optic cable transmits digital signals using light impulses rather than electricity, it's immune to EMI and RFI.

Anyone who's seen a network's UTP cable run down an elevator shaft would definitely appreciate this fiber feature. Fiber cable allows light impulses to be carried on either a glass or a plastic core. Glass can carry the signal a greater distance, but plastic costs less. Whichever the type of core, it's surrounded by a glass or plastic cladding with a different refraction index that reflects the light back into the core. Around this is a layer of flexible plastic buffer that can be wrapped in an armor coating that's usually Kevlar, which is then sheathed in PVC or plenum.

The cable itself comes in either single-mode fiber (SMF) or multimode fiber (MMF); the difference between them is in the number of light rays (the number of signals) they can carry. Multimode fiber is most often used for shorter-distance applications and single-mode fiber for spanning longer distances.

Although fiber-optic cable may sound like the solution to many problems, it has pros and cons just like the other cable types.

Here are the pros:

- Is completely immune to EMI and RFI
- Can transmit up to 40 kilometers (about 25 miles)

And here are the cons:

- Is difficult to install
- Is more expensive than twisted-pair
- Troubleshooting equipment is more expensive than twisted-pair test equipment
- Is harder to troubleshoot

Single-Mode Fiber

Single-mode fiber-optic cable (SMF) is a very high-speed, long-distance media that consists of a single strand—sometimes two strands—of fiber glass that carries the signals. Light-emitting diodes (LEDs) and laser are the light sources used with SMF. The light source is transmitted from end to end and pulsed to create communication. This is the type of fiber cable employed to span really long distances because it can transmit data 50 times further than multimode fiber at a faster rate.

Clearly, because the transmission media is glass, the installation of SMF can be a bit tricky. Yes, there are outer layers protecting the glass core, but the cable still shouldn't be crimped or pinched around any tight corners.

Multimode Fiber

Multimode fiber-optic cable (MMF) also uses light to communicate a signal; but with it, the light is dispersed on numerous paths as it travels through the core and is reflected back. A special material called *cladding* is used to line the core and focus the light back onto it. MMF provides high bandwidth at high speeds over medium distances (up to about 3,000 feet), but beyond that it can be really inconsistent. This is why MMF is most often used within a smaller area of one building; SMF can be used between buildings.

MMF is available in glass or in a plastic version that makes installation a lot easier and increases the installation's flexibility.

Fiber-Optic Connectors

A whole bunch of different types of connectors are available to use with fiber-optic cables, but the two most popular are the *straight tip (ST)* and *subscriber (*or *square*) *connector (SC).* The ST fiber-optic connector (developed by AT&T) is one of the most widely used fiber-optic connectors; it uses a BNC attachment mechanism similar to Thinnet's that makes connections and disconnections fairly frustration free. In fact, this is the feature that makes this connector so popular. Figure 3.5 shows an example of an ST connector. Notice the BNC attachment mechanism.

The SC connector is another type of fiber-optic connector. As you can see in Figure 3.6, SC connectors are *latched*—a mechanism holds the connector in securely and prevents it from falling out.

SC connectors work with either single-mode or multimode optical fibers and will last for around 1,000 matings. They're being used more now but still aren't nearly as popular as ST connectors for LAN connections.
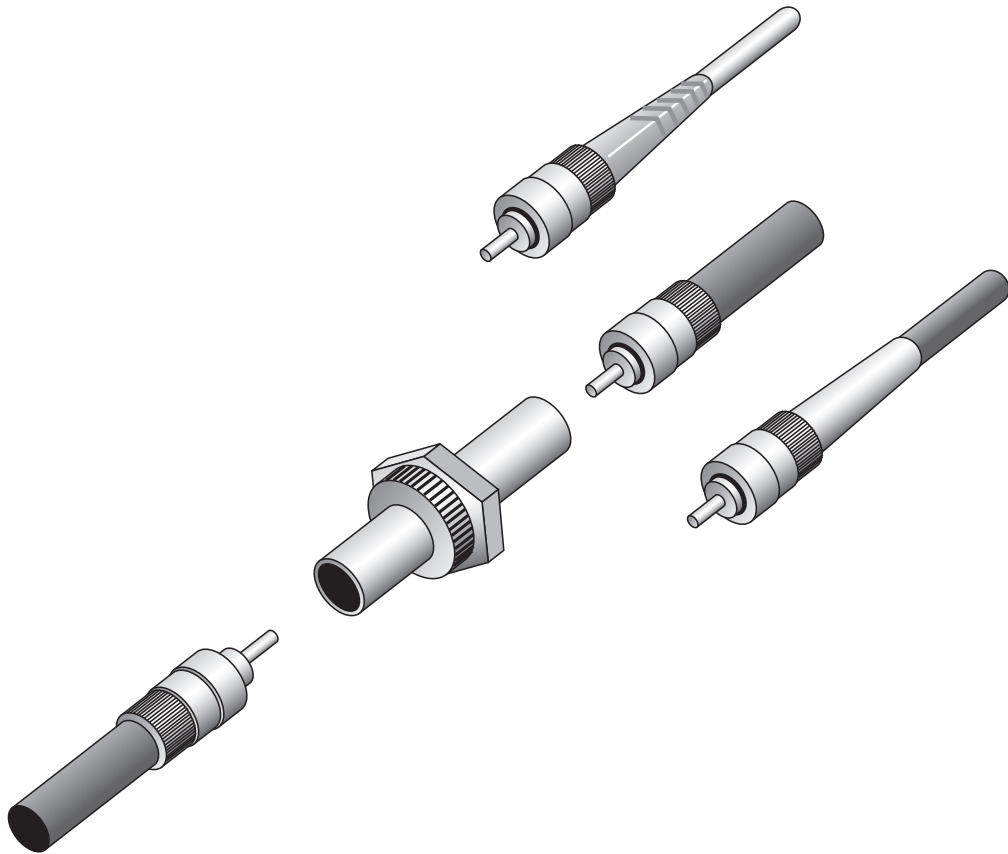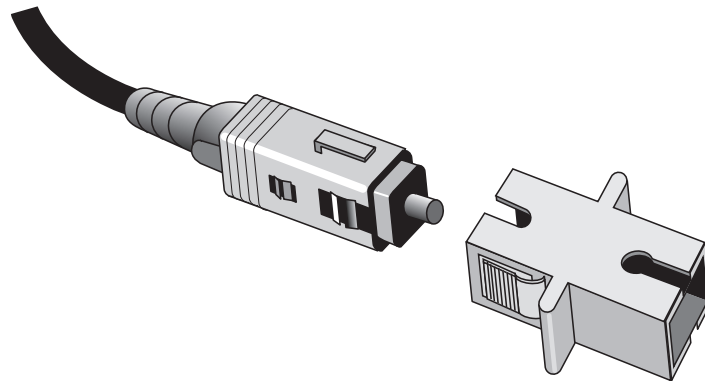
FIGURE 3.5   An example of an ST connector

FIGURE 3.6   A sample SC connector

🌐 **Real World Scenario**

Should I Use Copper or Fiber?

If your data runs are measured in miles, fiber optic is your cable of choice because copper just can't give you more than about 1,500 feet without electronics regenerating the signal. The standards limit UTP to a pathetic 228 feet.

Another good reason to opt for fiber is if you require high security, because it doesn't create a readable magnetic field. Although fiber-optic technology was initially super expensive and nasty to work with, it's now commonly used for Gigabit or 10GB Internet backbones.

Ethernet running at 10Mbps over fiber-optic cable to the desktop is designated 10Base-FL; the 100Mbps version of this implementation is 100Base-FX. The *L* in the 10Mbps version stands for *link.* Other designations are *B* for *backbone* and *P* for *passive.*

Small Form Factor Fiber-Optic Connectors

Another cool fiber-optic connector is the *small form factor (SFF)* connector, which allows more fiber-optic terminations in the same amount of space than its standard-sized counterparts. The two most popular versions are the *mechanical transfer registered jack (MT-RJ or MTRJ)*, designed by AMP, and the *Local Connector (LC)*, designed by Lucent.

The MT-RJ fiber-optic connector was the first small form factor fiber-optic connector to be widely used, and it's only one-third the size of the SC and ST connectors it most often replaces. It offers these benefits:

- Small size
- TX and RX strands in one connector
- Keyed for single polarity
- Pre-terminated ends that require no polishing or epoxy
- Easy to use

Figure 3.7 shows an example of an MT-RJ fiber-optic connector.

LC is a newer style of SFF fiber-optic connector that's pulling ahead of the MT-RJ. It is especially popular for use with Fibre-Channel adapters (FCs) and is a standard used for fast storage area networks and Gigabit Ethernet adapters. Figure 3.8 depicts an example of the LC connector.

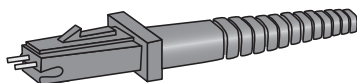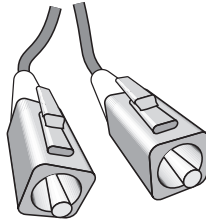**FIGURE 3.7**   A sample MT-RJ fiber-optic connector

F I G U R E 3 . 8   A sample LC fiber-optic connector

It has similar advantages to MT-RJ and other SFF-type connectors but is easier to termi-nate. It uses a ceramic insert just as standard-sized fiber-optic connectors do.

Serial Cables

Except for multi-mode fiber, all the cable flavors I've talked about so far are considered serial cable types. In network communications, *serial* means that one bit after another is sent out onto the wire or fiber and interpreted by a network card or other type of interface on the other end.

Each 1 or 0 is read separately and then combined with others to form data. This is very different from parallel communication where bits are sent in groups and have to be read together to make sense of the message they represent. A good example of a parallel cable is an old printer cable—which has been replaced by USB, as I'll get to in a minute.

RS-232

Recommended Standard 232 (RS-232) was a cable standard commonly used for serial data signals connecting data-terminal equipment and data-communications equipment, as when you connect a computer's serial port to an external modem.

Figure 3.9 shows an example of one of the many types of RS-232 cables.

Because most laptops don't even come with these types of connectors anymore, they've pretty much been replaced by things like USB and FireWire.

Universal Serial Bus (USB)

Universal Serial Bus (USB) is now the built-in serial bus du jour of most motherboards. You usually get a maximum of 4 external USB interfaces, but add-on adapters can take that up to as many as 16 serial interfaces. USB can actually connect a maximum of 127 external devices, and it's a much more flexible peripheral bus than either serial or parallel.

We use USB to connect printers, scanners, and a host of other input devices like keyboards, joysticks, and mice. When connecting USB peripherals, you've got to connect them either directly to one of the USB ports (as shown in Figure 3.10) on the PC or to a USB hub that is connected to one of those USB ports.

FIGURE 3.9 An RS-232 cable end

FIGURE 3.10 A USB port
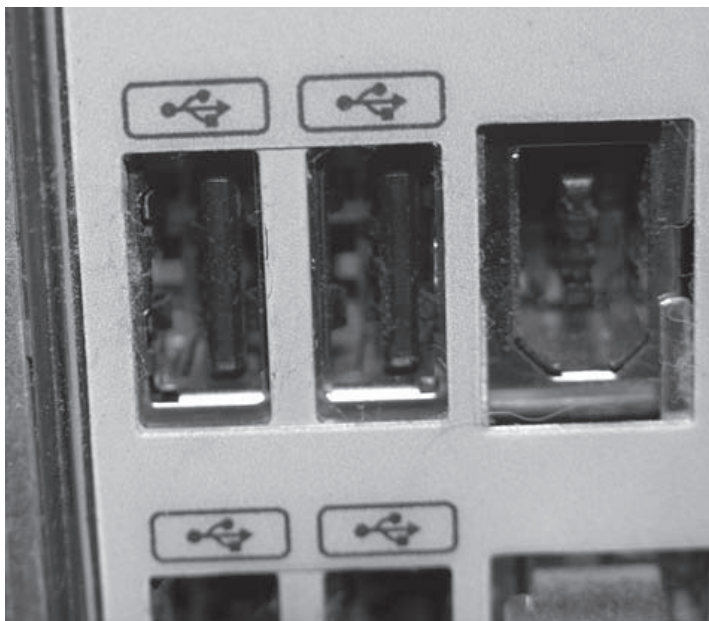
Hubs can be chained together to provide multiple USB connections; but even though you can connect up to 127 devices, it's really not practical to go there. Each device has a USB plug, as shown in Figure 3.11.

FIGURE 3.11   A USB plug
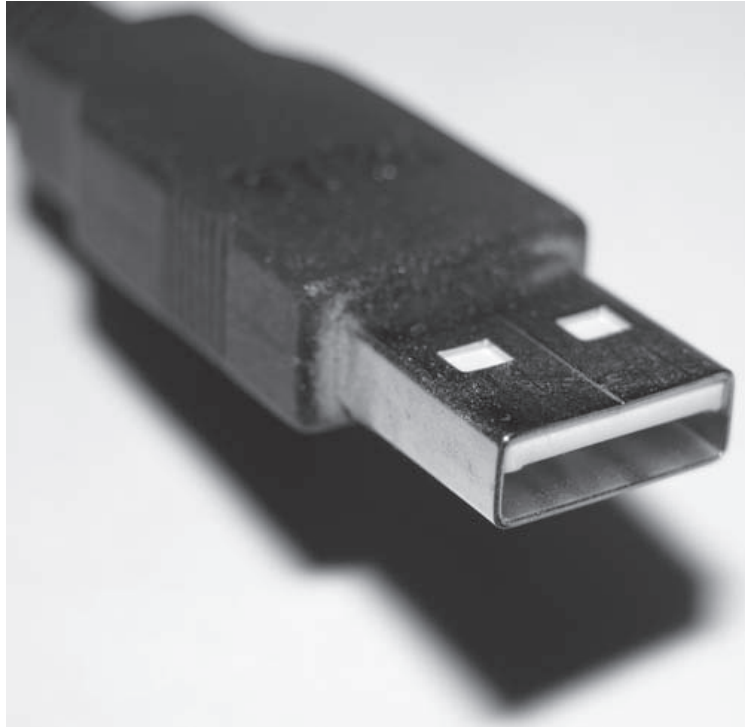
Properties of Cables

The reason we use so many different types of cables in a network is that each type has its own set of properties that specifically make it the best to use for a particular area or purpose. Different types vary in transmission speeds, distance, duplex, noise immunity, and frequency, and I'll cover each of these next.

Transmission Speeds

Based on the type of cable or fiber you choose and the network that it's installed in, network administrators can control the speed of a network to meet the network's traffic demands. Admins usually permit, or would like to have, transmission speeds of up to 10Gbps or higher on the core areas of their networks that connect various network segments. In the distribution and access areas, where users connect to switches, it's typically 100Mbps per connection; but transmission speeds are creeping up because the traffic demand is getting higher.

Distance

A deciding factor used in choosing what cable type to use is often the topology of a network and the distance between its components. Some network technologies can run much further than others without communication errors, but all network communications technologies are prone to *attenuation*—the degradation of signal due to the medium itself and the distance signals have to travel. Some cable types suffer from attenuation more than in others. For instance, any network using twisted-pair cable should have a maximum segment length of only 328 feet (100 meters).

Duplex

All communications are either half-duplex or full-duplex. The difference is whether the communicating devices can "talk" and "listen" at the same time.

During half-duplex communication, a device can either send communication or receive communication, but not both at the same time. Think walkie-talkie—when you press the button on the walkie-talkie, it turns the speaker off, and you can't hear anything the other side is saying.

In full-duplex communication, both devices can send and receive communication at the same time. This means that the effective throughput is doubled and communication is much more efficient. Full-duplex is typical in most of today's switched networks. I'll discuss both full and half duplex in more detail in Chapter 4, "The Current Ethernet Specifications."

Noise Immunity (Security, EMI)

Any time electrons are pushed through two wires next to each other, it creates a magnetic current. And we can create a current in the wires. This is good because without *magnetic flux*, we wouldn't be using computers—the power that surges through them is a result of it. The bad news is that it also creates two communications issues.

First, because the wire is creating a current based on the 1s and 0s coursing through it, with the right tools in hand, people can read the message in the wire without cutting it or even removing the insulation. You've heard of this—it's called *tapping* the wire, and it's clearly a valid security concern. In ancient history, high-security installations like the Pentagon actually encased communication wires in lead shielding to prevent them from being tapped. STP wires make tapping a little harder, but not hard enough.

The best way to solve the magnetic-flux problem caused by electricity is to not use these wires at all. As I said, fiber-optic cables carry the signal as light on a glass or really pure plastic strand, and light is not susceptible to magnetic flux, making fiber optics a whole lot harder to tap. It's still not impossible—you can do it at the equipment level, but you have to actually cut and then repair the cable to do that, which isn't likely to go unnoticed.

The second magnetic-flux issue comes from the outside in instead of from the inside out. Because wires can take on additional current if they're near any source of magnetism, you've got to be really careful where you run your cables. You can avoid EMI by keeping copper cables away from all powerful magnetic sources like electric motors, speakers,

amplifiers, fluorescent light ballasts, and so on. Just keep them away from anything that can generate a magnetic field!

Frequency

Each cable type has a specified maximum frequency that gives you the transmission bandwidth it can handle. Cat 5e cable is tested to 100MHz maximum frequency and can run 1Gbps signals for relatively short distances. That's maxing it out, but it's still good for connecting desktop hosts at high speeds. On the other hand, Cat 6 is a 250MHz cable that can handle 1Gbps data flow all day long with ease. Cat 6 has a lot more twists and thicker cables, so it is best used when connecting floors of a building.

> **NOTE** Although signal is measured as bandwidth, the capacity to carry the signal in a cable is measured as frequency.

Wiring Standards

Ethernet cabling is an important thing to understand, especially if you're planning to work on any type of LAN network. There are different types of wiring standards available:

- Straight-through cable (586A)
- Crossover cable (586B)
- Rolled cable (rollover)
- Hardware loopback

We will look into each one of these, and then I'll end this section with some examples for you.

568A vs. 568B

If you look inside a network cable, you will find four pairs of wires twisted together to prevent crosstalk; they're also twisted like this to help prevent EMI and tapping. The same pins have to be used on the same colors throughout a network to receive and transmit; but how do you decide which color wire goes with which pin? The good news is that you don't have to decide—at least not completely. Two wiring standards have surfaced that have been agreed on by over 60 vendors including AT&T, 3Com, and Cisco (although there isn't 100 percent agreement). In other words, over the years, some network jacks have been pinned with the 568A standard and some have used the 568B standard, which can cause a bit of confusion if you don't know what you're looking at in your network.

If you're thinking, "What's the difference, and why does it matter?" the answer is the position of four wires on one side of the cable—that's it! There are eight wires in each UTP cable; pins 4, 5, 7, and 8 aren't used in either standard.

> **NOTE**   If you're installing new cabling to each cubicle and/or office, you need to make sure to connect all eight pins—and use Cat 5e or Cat 6. Voice over IP (VoIP) uses all eight pins, and it's really common to have voice and data on the same wire at the same time in today's networks.

This only leaves the wire pairs to connect to pins 1, 2, 3, and 6. If we connect the green-white, green, orange-white, and orange wires to pins 1, 2, 3, and 6, respectively, on both sides of the cable, we're using the 568A standard and creating the kind of straight-through cable that's regularly implemented as a regular *patch cable* for most networks. On the other hand, if we switch from pin 1 to pin 3 and from pin 2 to pin 6 on one side only, we've created a *crossover cable* for most networks.

Straight-Through Cable

The straight-through cable is used to connect a host to a switch or hub, or a router to a switch or hub.

> **NOTE**   No worries—I'll tell you all about devices like switches, hubs, and routers in detail in Chapter 5, "Networking Devices."

Four wires are used in straight-through cable to connect Ethernet devices. It's really pretty simple to do this; Figure 3.12 depicts the four wires used in a straight-through Ethernet cable.

Notice that only pins 1, 2, 3, and 6 are used. Connect 1 to 1, 2 to 2, 3 to 3, and 6 to 6, and you'll be up and networking in no time. Just remember that this would be a 10/100 Ethernet-only cable, and it wouldn't work with 1000Mbps Ethernet, voice, Token Ring, ISDN, and so on.

FIGURE 3.12   Straight-through Ethernet cable

| Hub/Switch		Host
1	⟷	1
2	⟷	2
3	⟷	3
6	⟷	6
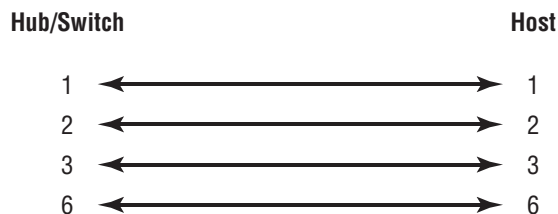
Crossover Cable

The same four wires are used in this cable; and just as with the straight-through cable, you just connect the different pins together. Crossover cables can be used to connect these devices:

▪ Switch to switch

▪ Hub to hub

▪ Host to host

- Hub to switch
- Router direct to host

Check out Figure 3.13, which demonstrates how each of the four wires are used in a crossover Ethernet cable.

FIGURE 3.13   Crossover Ethernet cable

Hub/Switch		Hub/Switch
1		1
2		2
3		3
6		6
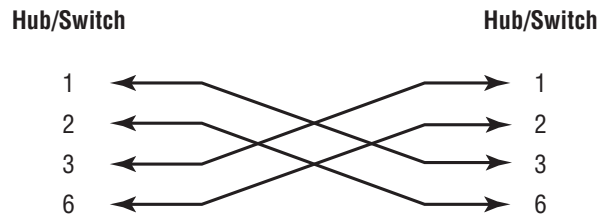
Okay—did you notice that instead of connecting 1 to 1, 2 to 2, and so on, we connected pins 1 to 3, and 2 to 6, on each side of the cable? A crossover cable is typically used to connect two switches together, but it can also be used to test communications between two workstations directly, bypassing the switch.

A crossover cable is used only in Ethernet UTP installations. You can connect two workstation NICs or a workstation and a server NIC directly with it.

> **TIP**   You're going to find out a lot more about how important it is to label basically everything. But for now, make sure to label a crossover cable as what it is so that no one tries to use it as a workstation patch cable. If they do that, the workstation won't be able to communicate with the hub and the rest of the network!

It's really cool that you can carry a crossover cable with you in your tool bag along with your laptop—then, if you want to ensure that a server's NIC is functioning correctly, you can just connect your laptop directly to the server's NIC using your handy crossover cable. You should be able to log in to the server if both NICs are configured correctly.

Use a cable tester to make sure that what you're dealing with is in fact a crossover cable. The tester can also tell you if there's a problem with the cable. Figure 3.14 shows an inexpensive cable tester for UTP.

This cost-effective little tool will tell you beyond a shadow of a doubt if you have a straight-through or crossover cable—or even if there's a problem with the cable.

Rollover Cable

Although rollover cable isn't used for hooking Ethernet connections together, you can use it to connect a host to a router console serial communication (com) port.

And if you have a router or switch, you use this cable to connect your PC running HyperTerminal or some other terminal-emulation program to the hardware. Eight wires are used in this cable to connect serial devices, although not all eight are used to send information (just as in Ethernet networking). Figure 3.15 shows the eight wires used in a rolled cable.

FIGURE 3.14   An inexpensive cable tester

FIGURE 3.15   Rolled Ethernet cable
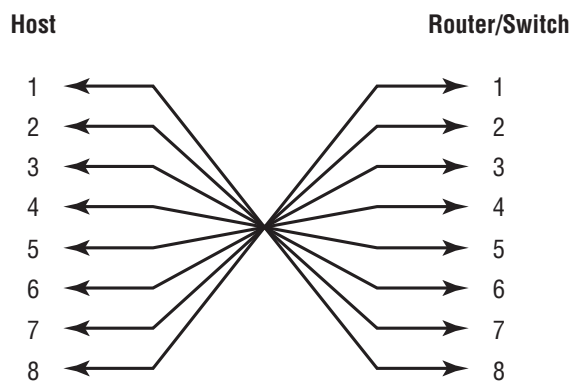
These are probably the easiest cables to make because you just cut the end off on one side of a straight-through cable, turn it over, and put the connector back on—using a new connector, of course.

Hardware Loopback

In any talk about wiring, loopback isn't so much a wiring standard as it is a way to redirect data flow. Sometimes you may need a computer to think it has a live connection to a network when it doesn't, because it's a good testing strategy and because you need a live

network to install. In these cases, you will need to trick the PC into seeing its own output as input; and you do this with a loopback plug. It works a lot like a crossover cable except that it connects the transmit pins directly to the receive pins, as shown in Figure 3.16. It's used by the NIC's software diagnostics to test transmission and reception capabilities, and you just can't completely test an NIC without one of these cool devices.

**FIGURE 3.16** A hardware loopback and its connections

Pin#
1
2
3
4
5
6
7
8
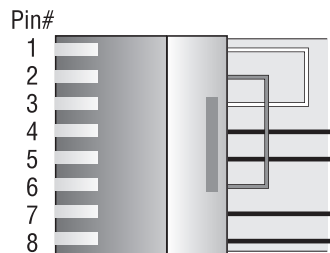
In a loopback, pins 1 & 3 and
pins 2 & 6 are connected

Usually, the hardware loopback is no bigger than a single RJ-45 connector with a few small wires on the back. If a NIC has hardware diagnostics that can use the loopback, the hardware loopback plug will be included with the NIC. To use it, simply plug the loopback into the RJ-45 connector on the back of the NIC, and start the diagnostic software. Select the option in your NIC's diagnostic software that requires the loopback, and start your diagnostic routine. These diagnostics will tell you if the NIC can send and receive data.

Test Your Cable Understanding

You've taken a look at the various RJ-45 UTP cables. With that in mind, what cable is used between the switches in the following?

Switch

?

Switch

A

B
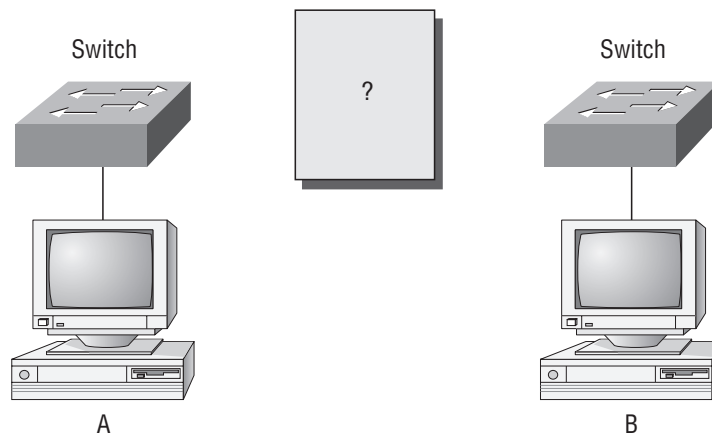
In order for host A to ping host B, you need a crossover cable to connect the two switches together. But what types of cables are used in the network shown in the following?

In the second example, there are a variety of cables in use. For the connection between the switches, we'd clearly use a crossover cable like the one you saw in the earlier example. The trouble is, here we have a console connection that uses a rolled cable. Plus, the connection from the router to the switch is a straight-through cable, which is also what's running between the hosts to the switches.

Installing Wiring Distributions

By now, you're probably getting the idea that there are a lot more components in the average computer networks than meets the eye, right? If this isn't exactly a news bulletin to you, then you either already are, or have been, involved in the initial installation of the network. If the latter describes you, you probably will be, or already are, involved in the purchase and installation of the components that will connect the computers throughout your organization's building. And it may also be up to you to verify that all of the network components have been installed properly and tested. So, let's go over each of these components and the process of verifying their proper installation.

Vertical and Horizontal Cross-Connects

A *cross-connect* is a location within a cabling system that facilitates the termination of cable elements, plus the reconnection of those elements with jumpers, termination blocks, and/or cables to a patch panel and so on. In other words, it's where all the wires come together. Cables that run from communications closets to wall outlets are known as *horizontal cables*, because they are generally used on the same floor of a building.

Backbone cables that connect equipment rooms, telecommunications rooms, and other physical termination points are referred to as *vertical cables*, because they often go

from floor to floor in a building. All of these cables will eventually connect to each other and finish off the network cabling for the building. The exact pieces involved depend on the size of the installation, the needs of the organization, and the structure in which they're installed.

> **NOTE** The maximum length of a Cat-3 horizontal cross-connect (meaning from wall outlet to closet) is 100 meters (328 feet).

Patch Panels

A *patch panel* is usually a rack or wall-mounted structure that houses cable connections. A patch cable generally plugs into the front side, while the back holds the punched-down connection of a longer, more permanent cable. The purpose of the patch panel is to give the administrator a non-grief-ridden way to change the path of a signal quickly when needed. Figure 3.17 depicts a modern patch panel.

FIGURE 3.17   A patch panel
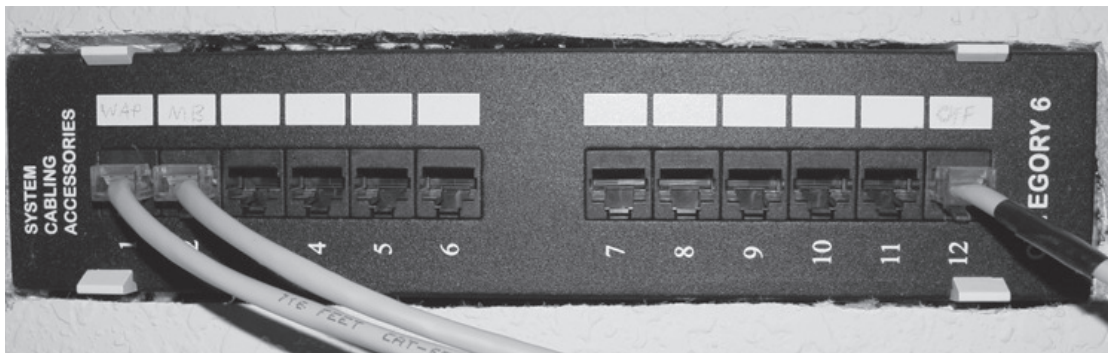
These come in really handy if a cable inside a wall becomes damaged or fails because a network administrator can "patch around" the dead cable by simply changing the connection on two patch panels.

66 Block

In the past, one of the most common types of patch panels was known as a *66 block*. Even though these are now considered legacy equipment, they're still listed as an objective on the exam. Figure 3.18 shows a 66 block.

We don't use them much anymore because they're very large in comparison to newer wire-terminating devices, and they have a relatively small (25-pair) capacity. The final nail in their coffin is that they are unsuited for any network communications faster than 10Mbps. But once in a while, you still see these used in some telephone installations.

FIGURE 3.18 A 66 block
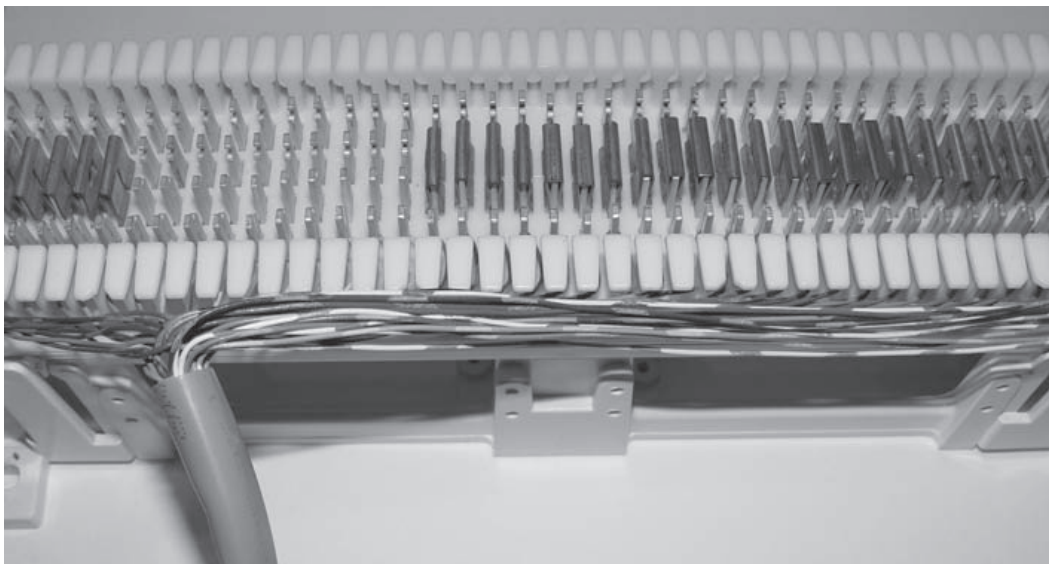
MDF/IDF

The *main distribution frame (MDF)* is a wiring point that's generally used as a reference point for telephone lines. It's installed in the building as part of the pre-wiring, and the internal lines are connected to it. After that, all that's left is to connect the external (telephone company) lines to the other side to complete the circuit. Often, another wire frame called an *intermediate distribution frame (IDF)* is located in an equipment or telecommunications room. It is connected to the MDF and is used to provide greater flexibility for the distribution of all the communications lines to the building. It is typically (and better be) a sturdy metal rack designed to hold the bulk of cables coming from all over the building!

25 Pair

A *25-pair cable* consists of 25 individual pairs of wires all inside one common insulating jacket. It's not generally used for data cabling, just for telephone cabling, and especially for backbone and cross-connect cables because it reduces the cable clutter significantly. This type of cable is often referred to as a *feeder cable* because it supplies signal to many connected pairs. In the picture of the 66 block, Figure 3.18, a 25-pair wire is connected to the 66 block to provide connectivity to the IDF.

100 Pair

100-pair feeder cables can be used for really huge telephone company installations. They combine 100 pairs of wires into one large, insulated cable. These large cables are also used in aerial installations and sometimes in buried and duct-type installations that run up and down a building. To keep the pairs unique, you've got to use colors other than the traditional networking ones.

110 Block

A newer type of wiring distribution point called a *110 block* has replaced most telephone wire installations and is also used for computer networking. On one side, wires are punched down; the other side has RJ-11 (for phone) or RJ-45 (for network) connections.

110 blocks come in sizes from 25 to more than 500 wire pairs, and some are capable of carrying 1Gpbs connections when used with Category 6 cables. The hitch is that using Cat 6 with the 110 block is really difficult because of the size of the Cat 6 wiring.

Demarc/Demarc Extension

The *demarc* (short for demarcation) is the last point of responsibility of the service provider. It's often at the MDF in your building connection (if your building is large), but it's usually just an RJ-45 jack that your channel service unit/data service unit (CSU/DSU) connects into from your router to wide area network (WAN) connections (CSU/DSU's are explained in detail in Chapter 5).

When troubleshooting, network admins often test for connectivity on both sides of the demarc to determine if the problem is internal or external. The length of copper or fiber that begins after the demarc but still doesn't reach all the way up to your office is referred to as a *demarc extension.*

Smart Jack

A *smart jack*, also called a network interface device (NID) or network interface unit, is owned by the PSTN and is a special network interface that's often used between the service provider's network and the internal network. You can't physically test to an actual demarc because it is just an RJ-45 jack, but the service provider may install a NID that has power and can be looped for testing purposes.

The smart-jack device may also provide for code and protocol conversion, making the signal from the service provider usable by the devices on the internal network like the CSU/DSU.

🌐 Real World Scenario

Above and Beyond the Network+!

If you have a Cisco router that is having a problem—such as a serial WAN connection issue—and you're using a serial port on your router to connect to a port on a CSU/DSU, type this at the enabled Cisco router console or telnet port:

```
config t
int s0/0
loopback
```

At this point, your interface will come up and look like it is working. That is, of course, if your connection from the router to the CSU/DSU is working properly. If not, you have a local problem.

Verifying Correct Wiring Installation

Because most of us aren't insecure enough to constantly go around thinking that we've made a whole bunch of mistakes, it's common for installers to assume that they haven't made any at all. Yes, they may test a cable or two for good measure, but they really do leave most cables totally untested and worse—they either keep incomplete, sketchy records or no records at all. A truly professional installer will verify each cable's connectivity and keep detailed records of when it was tested and when it passed the connectivity test.

Oh… and let me count the ways things can go wrong when pulling a network cable. Copper cables can be placed a little too close to a magnetic source and can be affected by EMI. Cable jackets can be ripped off completely when pulling the cable through a tight space or around a corner. Cables can be cut wrong and extended beyond the maximum length for their type. Fiber-optic cables are really fragile and can be easily and expensively damaged if they're handled roughly or poorly installed.

The best cable-installer companies assume that some of these things will go wrong, and therefore they will test, test, and test again. So if you're handling your own installation, you should do the same things. Consider yourself your own customer—you want to keep yourself happy, don't you? Seriously, the old carpenter's rule of "measure twice, cut once" applies to cable installations as well, both literally and figuratively.

The moral of this story is that you should test frequently during installation and again when you're done. And definitely make sure you keep complete and detailed records to refer to, just in case something nasty happens later.

Verifying Proper Wiring Termination

By the way, the number of things that can go wrong when terminating copper wires totally dwarfs the number that can happen when pulling cables. With a minimal amount of training and a little patience, almost anyone can pull a network cable without damaging it—at least, most of the time. Proper termination of copper cables to a punch-down block is much trickier and requires practice to get right, so save yourself that pain by always inspecting the installation and verifying that all wires are terminated properly in the right order.

Fiber-optic termination requires extra-special (read, expensive) equipment and training. Unless your installers spend hours cutting, stripping, polishing, and terminating the fiber-optic cable and look for any mistakes or damage as thoroughly as a CSI looks for clues at a crime scene, they probably won't get it done right the first time. You should always test a new connection with the appropriate tool. We will discuss the tools used to test connections in Chapter 18, "Software and Hardware Tools."

> **NOTE** The tools to test the installation and termination of both UTP and fiber are covered in Chapter 18.

Summary

I know getting through this chapter probably wasn't the most fun you've had recently. But understanding all those types of wires and cabling, along with their unique capacities, their associated standards, and the right connectors to use with them plus where to place them is integral to having a solid, foundational understanding of the things that make a great network run quickly and reliably.

It's critical for you to grasp the basics of networking. Having the facts about how a good network is designed and implemented and what goes into that process will make you an effective and efficient technician—and maybe, some day, a highly paid system administrator.

Exam Essentials

Understand the various types of cables used in today's networks.   Coaxial (other than for cable modems) is rarely used, but twisted-pair and fiber optics are very common in today's networks.

Understand the various types of ends that are used on each type of cable.   Coax uses BNC; twisted-pair uses RJ-11 for voice and RJ-45 for data; and fiber uses various ends, depending on its use.

Understand what a 586A cable is.   A 586A cable is also known as an Ethernet straight-through cable and is used to connect hosts to switches, for example.

Understand what a 586B cable is.   A 586B cable is also known as an Ethernet cross-over cable and is used to connect switches to switches, for example.

Written Lab

1. Which UTP wiring uses four twisted wire pairs (eight wires) and is rated for 250MHz?

2. The point at which the operational control or ownership changes from your company to a service provider is referred to as_____.

3. Which type of cable will you use to connect switches?

4. Which RG rating of coax is used for cable modems?

5. Which UTP uses four twisted wire pairs (eight wires), is rated for 100MHz, and is capable of handling the disturbance on each pair caused by transmitting on all four pairs at the same time?

6. You want to connect a host to a switch port. What type of Ethernet cable will you use?

7. What type of hardware do you need to make a computer think it has a live connection to a network even when it doesn't?

8. 586A uses which pins to make a connection?

9. 586B uses which pins to make a connection?

10. What are two advantages of fiber-optic cabling?

(The answers to the Written Lab can be found following the answers to the Review Questions for this chapter.)

Review Questions

1. Why would a network administrator use plenum-rated cable during an installation? (Choose 2)

    A. Low combustion temperature

    B. High combustion temperature

    C. Reduces toxic gas released during a fire

    D. Is not susceptible to any interference

2. Which of the following Ethernet unshielded twisted-pair (UTP) cables types is most commonly used?

    A. 10Base-T

    B. 100Base-TX

    C. 1000Base-TX

    D. All of the above

3. UTP cable is rated in the following categories except:

    A. Category 2

    B. Category 3

    C. Category 5e

    D. Category 8

4. What type of connector does UTP cable typically use?

    A. BNC

    B. ST

    C. RJ-45

    D. SC

5. Which of the following provides the longest cable run distance?

    A. Single-mode fiber

    B. multi-mode fiber

    C. category 3 UTP

    D. Coax

6. You need to crimp on a connector using an RJ-45 connector. Which pin-out configuration would you use to connect a host into a switch?

    A. UTP

    B. 586A

    C. 586B

    D. Rolled

7. Fiber-optic cable is immune to electromagnetic interference (EMI) and radio frequency interference (RFI) because it:

    A. Transmits analog signals using electricity

    B. Transmits analog signals using light impulses

    C. Transmits digital signals using light impulses

    D. Transmits digital signals using electricity

8. What type of cable transmits lights from end-to-end?

    A. Coax

    B. Fiber-optic

    C. UTP

    D. Category 2

9. What is the main difference between single-mode fiber (SMF) and multimode fiber (MMF)?

    A. Electrical signals

    B. Number of light rays

    C. Number of digital signals

    D. Signal mode can be run a shorter distance

10. What type of cable should be used if you need to make a cable run longer than 100 meters?

    A. Category 5e

    B. Category 6

    C. Fiber-optic

    D. Wireless link

11. Which of the following are fiber-optic connectors? (Select three.)

    A. BNC

    B. ST

    C. RJ-11

    D. SC

    E. LC

    F. RJ-45

12. You need to connect two devices on a vertical connect and they need to send voice traffic. Which of the following cable will you use?

    A. Cat-3

    B. Cat -5

    C. Crossover

    D. Rolled

13. How many hosts on a half-duplex segment can talk at one time?

   A. 0

   B. 1

   C. 2

   D. Unlimited

14. Which type of cable does EMI have the least effect on?

   A. Coax

   B. Fiber-optic

   C. UTP

   D. STP

15. How many devices can be connected to a full-duplex segment?

   A. 0

   B. 1

   C. 2

   D. 4

16. How many wires are used in UTP during transmission?

   A. 2

   B. 4

   C. 6

   D. 8

17. A cross-over cable is used to connect all of the following except:

   A. Switch to switch

   B. Host to host

   C. Hub to switch

   D. Host to switch

18. Which type of cable should be used to connect to the console port on a router?

   A. Console cable

   B. Cross-over cable

   C. Straight-through cable

   D. USB

19. The purpose of the demarcation point is to separate the customer from whom?

   A. The branch office

   B. Headquarters

   C. The data center

   D. The service provider

20. You need to make a 586B cable. How many pairs will you use?

   A. 1

   B. 2

   C. 3

   D. 4

Answers to Review Questions

1. B, C. Plenum-rated cable means that the coating doesn't begin burning until a much higher temperature of heat; doesn't release as many toxic fumes as PVC when it does burn; and is rated for use in air plenums that carry breathable air, usually as non-enclosed fresh-air return pathways that share space with cabling.

2. D. UTP is commonly used in twisted-pair Ethernet like 10Base-T, 100Base-TX, 1000Base-TX, and so on.

3. D. Unshielded twisted-pair has standards from Category 2–6 for use on Ethernet networks. There is no Category 8 defined.

4. C. UTP usually connects with RJ-45. You use a crimper to attach an RJ connector to a cable.

5. A. Single mode fiber allows for the maximum cable run distances.

6. B. You would use a straight-through cable to connect a host to a switch, and that pin-out is called 586A.

7. C. Fiber-optic cable transmits digital signals using light impulses rather than electricity; therefore it is immune to EMI and RFI.

8. B. Remember that fiber-optic cable transmits a digital signal using light impulses. Light is carried on either a glass or a plastic core.

9. B. The difference between single-mode fibers and multimode fibers is in the number of light rays (and thus the number of signals) they can carry. Generally speaking, multimode fiber is used for shorter-distance applications and single-mode fiber for longer distances.

10. C. Standards limit UTP to a mere 100 meters. Different fiber-optic types have different maximum lengths, but fiber-optic is the only cable type that can extend well beyond 100 meters.

11. B, D, E. There are many different types of fiber-optic connectors. SC, ST, LC, and MT-RJ are some of the more typical connectors in use today.

12. B. To connect two devices for voice on a vertical connect, the minimum cable you can use is category 5.

13. B. In half-duplex communication, a device can either send communication or receive communication, but it cannot do both at the same time.

14. B. Fiber-optic cable only transmits light (not electricity like UTP), so EMI has zero effect on it.

15. C. Full-duplex communication requires a point-to-point configuration because the collision-avoidance circuit is disabled.

16. B. Both wiring standards for UTP (568A and 568B) utilize only pins 1, 2, 3, and 6.

17. D. All devices that are pinned the same for transmit and receive require a cross-over cable to communicate directly.

18. A. A rolled cable or console cable would be used to connect a host to a router console serial communication (com) port.

19. D. The demarcation point or demarc is the point at which the operational control or ownership changes from your company to a service provider. This is often at the MDF in relation to telephone connections and the CSU/DSU in regard to WAN connections.

20. B. A 586B is a crossover cable and this cable uses two pairs of wires.

Answers to Written Lab

1. Category 6

2. Demarcation point or demarc

3. Crossover or 586B

4. RG-6

5. Category 5e

6. Straight-through or 586A

7. A hardware loopback

8. 1, 2, 3, and 6

9. 1 to 3 and 2 to 6

10. It is completely immune to EMI and RFI and can transmit up to 40 kilometers (about 25 miles).