CHAPTER 6

Modern Ethernet

The Network+ Certification exam expects you to know how to

- 1.2 Specify the main features of 802.2 (Logical Link Control) [and] 802.3 (Ethernet): speed, access method, topology, media
- 1.3 Specify the characteristics (for example: speed, length, topology, and cable type) of the following cable standards: 10BaseT and 10BaseFL; 100BaseTX and 100BaseFX; 1000BaseTX, 1000BaseCX, 1000BaseSX, and 1000BaseLX; 10GBaseSR, 10GBaseLR, and 10GBaseER
- 1.4 Recognize the following media connectors and describe their uses: RJ-11, RJ-45, F-type, ST, SC, IEEE 1394, LC, MTRJ
- 1.6 Identify the purposes, features, and functions of the following network components: hubs, switches
- 2.3 Identify the OSI layers at which the following network components operate: hubs, switches

To achieve these goals, you must be able to

- Define the characteristics, cabling, and connectors used in 10BaseT and 10BaseFL
- Explain how to connect multiple Ethernet segments
- Define the characteristics, cabling, and connectors used with 100Base and Gigabit Ethernet

Historical/Conceptual

The first generation of Ethernet network technologies enjoyed substantial adoption in the networking world, but their bus topology continued to be their Achilles' heel—a single break anywhere on the bus completely shut down an entire network. In the mid-1980s, IBM unveiled a competing network technology called Token Ring. You'll get the complete discussion of Token Ring in the next chapter, but it's enough for now to say that Token Ring used a physical star topology. With a star topology, any single break in the network affected only the one system using that cable to connect to the network—he rest of the network continued to operate normally. As a result, Token Ring began to take substantial market share away from Ethernet through the second half of the 1980s.

In response to this threat, Ethernet manufacturers scrambled to make a new form of Ethernet that would have three major new features. First, this new Ethernet would use a physical star to match the robustness of Token Ring. Second, this new Ethernet would dump the use of more expensive coax and adopt inexpensive UTP cabling. Third, this new Ethernet would still use the same frame types and speeds of the older Ethernets, allowing for easy interconnections of this new Ethernet with older Ethernet networks. In 1990, working in close concert with the IEEE, the Ethernet manufacturers unveiled a new Ethernet standard: the now famous 10BaseT. From the moment of its introduction, 10BaseT's ease of installation, reliability, and low price reestablished Ethernet as the networking technology of choice, reducing Token Ring from market dominance to minor player today.

In the years since 1990, a series of faster Ethernet versions have come onto the networking scene, gradually pushing 10BaseT into the background. Even though its time in the spotlight has now passed, 10BaseT defined nearly every aspect of the Ethernet we use today, from cabling to topology. A solid understanding of 10BaseT is therefore an important part of your network tech foundation, as it will help you understand all the current Ethernet technologies. Let's take an in-depth look at 10BaseT, from its topology to its technology, and see why 10BaseT and the newer Ethernet technologies based on it now dominate the networking world.

Test Specific

10BaseT

The most important thing to remember about *10BaseT* is that it is still Ethernet. Except for the type of cabling and the topology, 10BaseT is identical to 10Base2 or 10Base5. 10BaseT uses the same frames as the earlier Ethernets. 10BaseT operates at the same speed of 10 Mbps. Machines still identify other machines by their MAC addresses and use CSMA/CD. The key difference between 10BaseT and its physical bus topology predecessors is the location of the Ethernet segment. Let's take a closer look at each of these issues.

10BaseT Topology

10Base2 and 10Base5 each use a physical bus topology. With a physical bus, you have a cable winding around the network and every computer connects to this single cable. Some might take exception to this—10Base5 may truly use a single cable, but isn't 10Base2 actually a number of cables connected together via the T-connectors at each PC? Yes, that's true—but in the case of 10Base2, all those cables connected together form a single bus. The existence of those T-connectors all along the 10Base2 bus doesn't detract from the fact that the bus carries the same signals in the same way as the truly single 10Base5 cable. As far as the network is concerned, both 10Base5 and 10Base2 use a single cable.

In the previous chapter, one of the words used to define that single cable was a "segment." Let's take the definition of a segment one step further. A *segment* is a single physical connection, terminated on both ends, to which computers may connect to form a network. In 10Base5 and 10Base2, the segment winds its way around the network, with terminators sitting at either end.

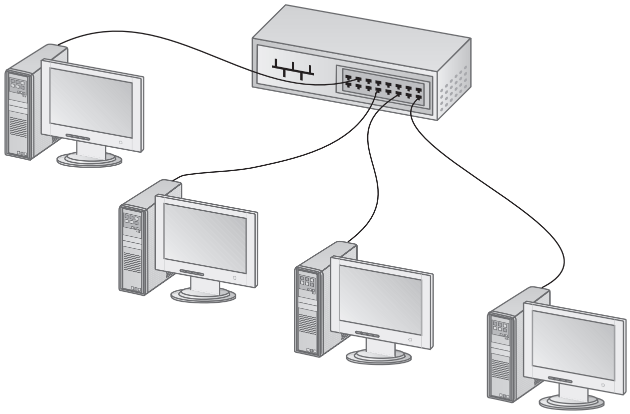


Figure 6-1
A 10BaseT network with each node connected to the hub

10BaseT also has a segment, but a 10BaseT segment doesn't wind all over the network. 10BaseT uses a physical star topology in which each node connects to a central hub (see Figure 6-1). The segment is still there—it's just shrunk into the hub (Figure 6-2).

TIP Depending on who's talking, you may hear 10BaseT called a star topology, a bus topology, or a *star bus topology*. Which term a particular tech uses to describe 10BaseT's topology often depends on her job description. For someone whose primary job is installing cable, 10BaseT is a star. Similarly, a software engineer writing a device driver for an Ethernet NIC could not care less where the cables go; she thinks of 10BaseT as a bus. The right answer is star bus!

Why shrink the segment into the hub? By using this hybrid star bus topology, 10BaseT enjoys the key benefit of a star topology: fault tolerance. The hub is nothing more than a multiport *repeater*, in that it repeats the signal coming in from one port to all the other

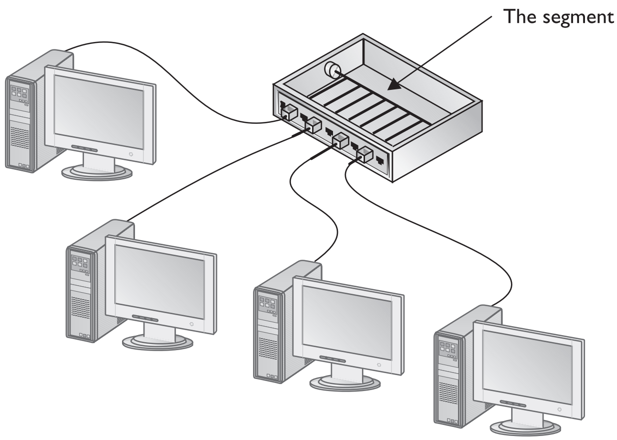


Figure 6-2
A 10BaseT hub contains the segment.

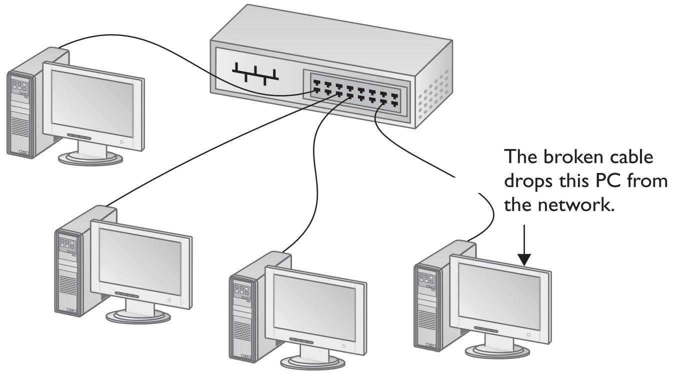


Figure 6-3 Because the Ethernet segment is protected inside the hub and remains unbroken, the break in the cable affects only one machine.

ports. The hub has no interest in MAC addresses and works completely at the OSI Physical layer, just like 10Base2 or 10Base5 repeaters. If a cable running to a specific node breaks, the break affects only that computer because the Ethernet segment itself is un broken (see Figure 6-3). If the segment itself breaks inside the hub, as shown in Figure 6-4, the entire network goes down.

10BaseT hubs come in a variety of shapes and sizes to support different sizes of networks. The biggest differentiator between hubs is the number of *ports*—connections—that a single hub provides. A small hub might have only four ports, while a hub for a large network might have 48 ports. As you might imagine, the more ports on a hub, the more expensive the hub. Figure 6-5 shows two hubs. On the top is a small, 8-port hub for small offices or the home. It rests on a 12-port rack-mount hub for larger networks.

NOTE Please don't crack open your Ethernet hubs looking for a piece of coaxial cable—it won't be there. The interior of an Ethernet hub contains a circuit board that serves the same function as the coaxial segments used in 10Base5 and 10Base2. When a hub fails, it's not because of a cable break; it's due to a failure in some part of the circuit board. The effect is the same, of course: if the hub fails, the entire segment fails.

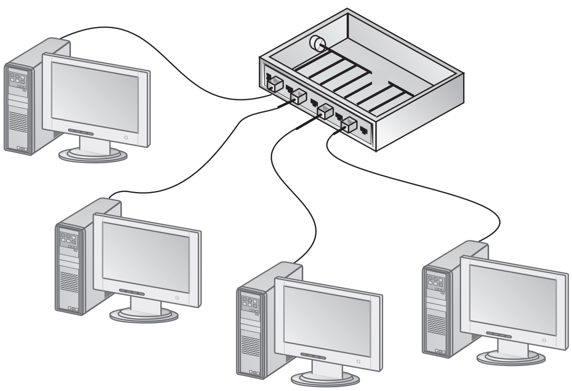


Figure 6-4 If the segment inside the hub breaks, then the entire segment fails.

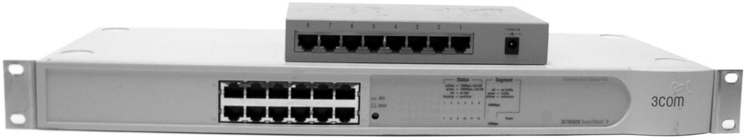


Figure 6-5 Two 10BaseT hubs

Regardless of size, all 10BaseT hubs need electrical power. Larger hubs will take power directly from a power outlet, while smaller hubs often come with an AC adapter. In either case, if the hub loses power, the entire segment will stop working.

TIP If you ever run into a situation on a 10BaseT or later network where none of the computers can get on the network, always first check the hub!

The name 10BaseT follows roughly the naming convention used for earlier Ethernet cabling systems. The number *10* refers to the speed: 10 Mbps. The word *Base* refers to the signaling type: baseband. The letter *T,* however, does not refer to a distance limitation like the *2* in 10Base2 or the *5* in 10Base5. Instead, it refers to the type of cable used: twisted-pair. 10BaseT uses unshielded twisted-pair (UTP) cabling.

UTP

Officially, 10BaseT requires the use of CAT 3 (or higher), two-pair, *unshielded twisted-pair (UTP)* cable. One pair of wires sends data to the hub while the other pair receives data from the hub. Although it is more sensitive to interference than coaxial cable, UTP cabling provides an inexpensive and flexible means to cable physical star networks. One minor difficulty with UTP stems from the fact that many other applications employ the same cabling. This can create some confusion when you're trying to determine if a piece of UTP in your ceiling is for your network or for your telephone system! Even though 10BaseT only requires two-pair cabling, for years, everyone has installed four-pair cabling to connect devices to the hub as insurance against the possible requirements of newer types of networking (see Figure 6-6). (Thank goodness they did! As you will see in the section "High-Speed Ethernet," newer forms of Ethernet need all four pairs.) Most UTP cables come with stranded Kevlar fibers to give the cable added strength, which in turn enables installers to pull on the cable without excessive risk of literally ripping it apart.

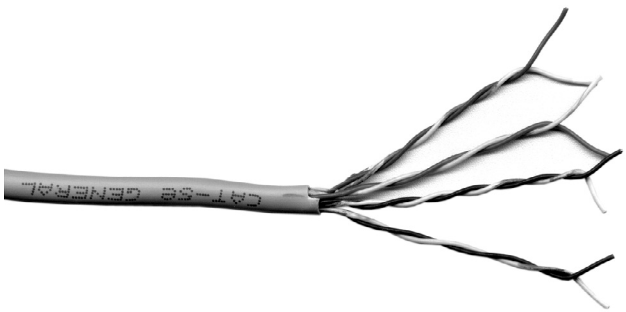


Figure 6-6 A typical four-pair CAT 5e unshielded twisted-pair cable

10BaseT also introduced the networking world to the *RJ-45 connector* (Figure 6-7). Each pin on the RJ-45 connects to a single wire inside the cable; this enables devices to put voltage on the individual wires within the cable. The pins on the RJ-45 are numbered from 1 to 8, as shown in Figure 6-8. The 10BaseT standard designates some of these numbered wires for specific purposes. As mentioned earlier, although the cable has four pairs, 10BaseT uses only two of the pairs. 10BaseT devices use pins 1 and 2 to send data, and pins 3 and 6 to receive data. Even though one pair of wires sends data and another receives data, a 10BaseT device cannot send and receive simultaneously. The rules of CSMA/CD still apply: only one device can use the segment contained in the hub without causing a collision. Later versions of Ethernet will change this rule.

An RJ-45 connector is usually called a *crimp*, and the act (some folks call it an art) of installing a crimp onto the end of a piece of UTP cable is called *crimping*. The tool we use to secure a crimp onto the end of a cable is a *crimper*. Each wire inside a UTP cable must connect exactly to the proper pin inside the crimp. Manufacturers color-code each wire

Figure 6-7
Two views of an RJ-45 connector

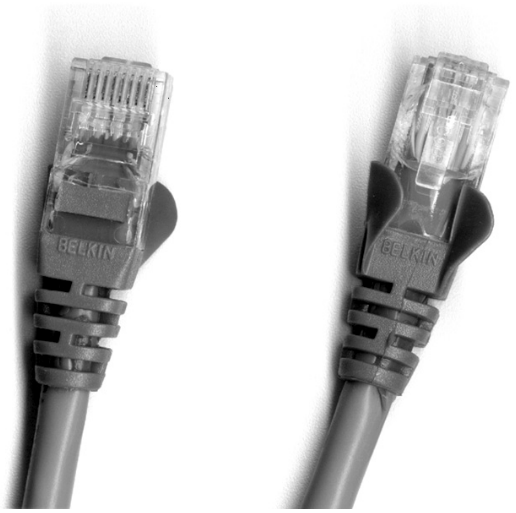
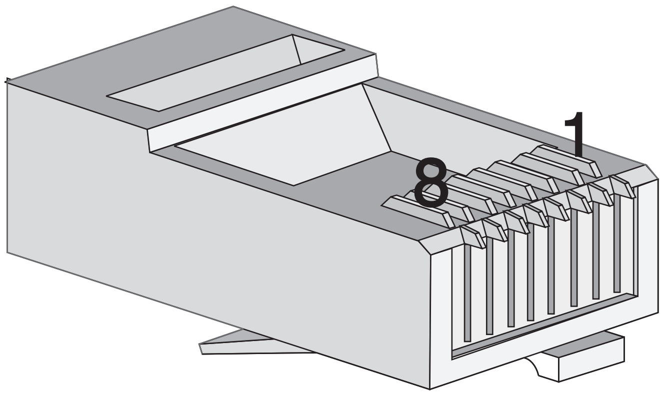


Figure 6-8
The pins on an RJ-45 connector are numbered 1 through 8.



within a piece of four-pair UTP to assist in properly matching the ends. Each pair of wires consists of a solid-colored wire and a striped wire: blue/blue-white, orange/orange-white, brown/brown-white, and green/green-white.

The Telecommunications Industry Association/Electronics Industries Alliance (TIA/EIA) defines the industry standard for correct crimping of four-pair UTP for 10BaseT networks. Two standards currently exist: the TIA/EIA 568A and the TIA/EIA 568B. Figure 6-9 shows the TIA/EIA 568A color code standard, and Figure 6-10 shows TIA/EIA 568B. Note that the wire pairs used by 10BaseT (1 & 2; 3 & 6) come from the same color pairs (green/green-white and orange/orange-white). Following an established color-code scheme, such as TIA/EIA 568A, ensures that the wires match up correctly at each end of the cable.

The ability to make your own Ethernet cables is a real plus for a busy network tech. With a reel of CAT 5e, a bag of RJ-45 connectors, a moderate investment in a crimping tool, and a little practice, you can kiss those mass-produced cables goodbye! You can make cables to your own length specifications, replace broken RJ-45 connectors that would otherwise mean tossing an entire cable—and in the bargain, save your company or clients time and money. If you make cables with any regularity, you'll probably find yourself mentally reciting the order of wire colors in the standard that you use. For example, I use the 568A standard for cables in my company's network, so when I sit down to crimp a cable end, I'm thinking, "green-white, green; orange-white, blue; blue-white, orange; brown-white, brown." I've even been known to say this out loud as I separate out the wires and put them in the correct order—it may sound like I'm chanting some weird incantation, but I rarely have to recrimp a faulty cable end!

TIP An easy trick to remembering the difference between 568A and 568B is the word "GO." The green and orange pairs are swapped between 568A and 568B, whereas the blue and brown pairs stay in the same place!

Figure 6-9
The TIA/EIA 568A standard

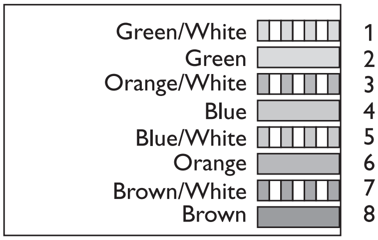
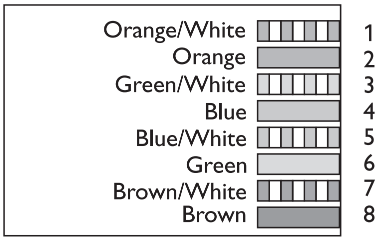


Figure 6-10
The TIA/EIA 568B standard



Why do the 568 standards say to split one of the pairs to the 3 & 6 position? Wouldn't it make more sense to wire them sequentially (1 & 2; 3 & 4; 5 & 6; 7 & 8)? The reason for this strange wiring scheme stems from the telephone world. A single telephone line uses two wires, and a typical RJ-11 connector has four connections. A single line is wired in the 2 & 3 positions; if the RJ-11 is designed to support a second phone line, the other pair is wired at 1 & 4. TIA/EIA kept the old telephone standard for backward compatibility. This standardization doesn't stop at the wiring scheme: you can plug an RJ-11 connector into an RJ-45 outlet.

Both the 568A and the 568B standards see a high quantity of use, but the 568A standard seems to be the most common in today's networks. Theoretically, as long as each end of each cable uses the same color code, many color codes could be used within the same building and everything would still work. 10BaseT devices do not care what color the wires are, they just need to have the pins on the RJ-45 connector match up at each end. Despite the fact that multiple color codes can work, the wise network tech will use a single color code throughout his or her entire organization. Consistency makes troubleshooting and repair easier by enabling network techs to assume the proper color code. If an end user trips over a cable and breaks the connector (of course, savvy network techs such as ourselves would never do such a thing), putting a new connector on the cable takes much less time if the tech knows with certainty which color code to use. If no standard color code exists, the poor network tech has to find the other end of the cable and figure out what color code was used on that particular cable. To save wear and tear on your techie tennis shoes, pick a standard color code and stick with it!

TIP For the Network+ exam, you won't be tested on the TIA/EIA 568A or B color codes. Just know that they are industry standard color codes for UTP cabling.

10BaseT Limits and Specifications

Like any other Ethernet cabling system, 10BaseT has limitations, both on cable distance and on the number of computers. The key distance limitation for 10BaseT is the distance between the hub and the computer. The twisted-pair cable connecting a computer to the hub may not exceed 100 meters in length. A 10BaseT hub can connect no more than 1024 computers, although that limitation rarely comes into play. It makes no sense for vendors to build hubs that large—or more to the point, that *expensive*—because excessive collisions can easily bog down Ethernet performance with far fewer than 1024 computers.

10BaseT Summary

- **Speed** 10 Mbps
- **Signal type** Baseband
- **Distance** 100 meters between the hub and the node
- No more than 1024 nodes per hub
- Star bus topology: physical star, logical bus
- Uses CAT 3 or better UTP cabling with RJ-45 connectors

PART II

10BaseFL

Just a few years after the introduction of 10BaseT, a fiber-optic version appeared, called *10BaseFL*. Fiber-optic cabling transmits data packets using pulses of light, rather than using electrical current. Using light instead of electricity addresses the three key weaknesses of copper cabling. First, optical signals can travel much farther. The maximum length for a 10BaseFL cable is up to two kilometers, depending how it is configured. Second, fiber-optic cable is immune to electrical interference, making it an ideal choice for high-interference environments. Third, the cable is much more difficult to tap into, making it a good choice for environments with security concerns. 10BaseFL uses a special type of fiber-optic cable called *multimode*, and employs one of two types of fiber-optic connectors: *SC connectors* or *ST connectors*. Figure 6-11 shows examples of these connector types.

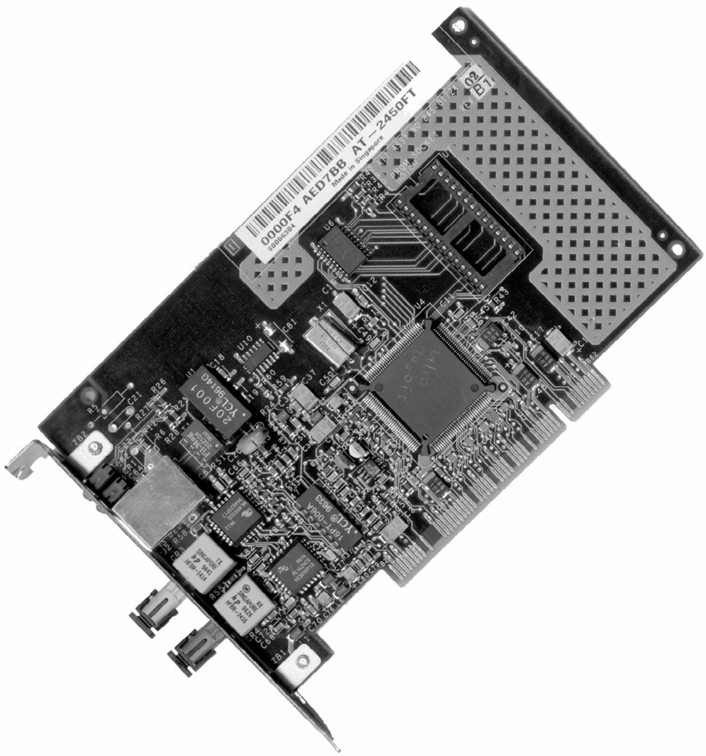
The presence of two connector standards has led to a bit of confusion in 10BaseFL, as well as later versions of networking that use fiber-optic cabling. As a result, most manufacturers of fiber products are moving toward the SC connector over the ST connector, although both types are still in common use. Figure 6-12 shows a typical 10BaseFL card. Note that it uses two fiber connectors—one to send, and one to receive. While 10BaseFL enjoyed some popularity for a number of years, most networks today are using the same fiber-optic cabling to run far faster network technologies.

10BaseFL Summary

- **Speed** 10 Mbps
- **Signal type** Baseband
- **Distance** 2000 meters between the hub and the node
- No more than 1024 nodes per hub
- Star bus topology: physical star, logical bus
- Uses multimode fiber-optic cabling with ST or SC connectors

Figure 6-11 ST (left) and SC (right) connectors for fiber-optic cable

Figure 6-12
Typical 10BaseFL card



Connecting Ethernet Segments

Sometimes, one hub is just not enough. Once an organization uses every port on its existing hub, adding additional nodes requires additional hubs. Even fault tolerance can motivate an organization to add more hubs. If every node on the network connects to the same hub, that hub becomes a single point of failure—if it fails, everybody drops off the network. The 10BaseT standard provides two methods for connecting multiple hubs: coaxial cable and crossover cables.

Coaxial cabling, either 10Base2 or 10Base5, can link together multiple 10BaseT hubs. By definition, a 10BaseT hub is a repeater. It brings in signals from one port and repeats them on all other ports. Some 10BaseT hubs come with a BNC or AUI connector, as shown in Figure 6-13. With the addition of an AUI or BNC port, a hub can repeat packets onto a coaxial segment just as easily as it can repeat them on UTP cabling. The coaxial segment can be used to connect two 10BaseT hubs, or it can have nodes directly attached to it, as shown in Figure 6-14.

NOTE A populated segment has one or more nodes directly attached to it.

Figure 6-13
10BaseT hub with BNC connector

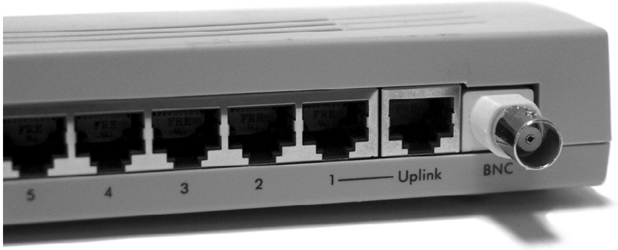
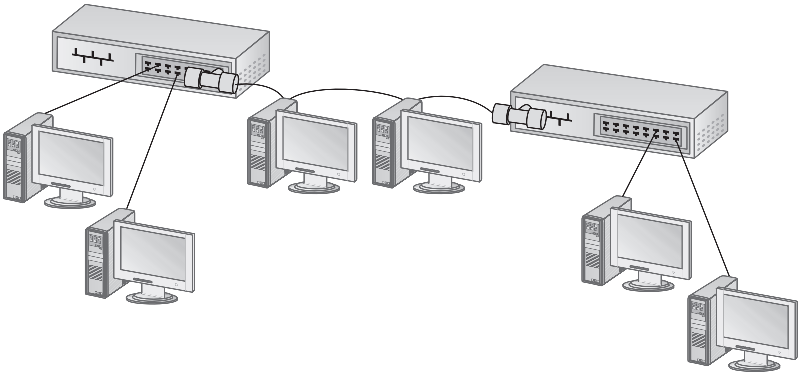


Figure 6-14
The segment connecting two hubs can be populated with machines.



Hubs can also connect to each other via special twisted-pair cables called crossover cables. A standard cable cannot be used to connect two hubs, because both hubs will attempt to send data on the second pair of wires (3 & 6) and will listen for data on the first pair (1 & 2). A *crossover cable* reverses the sending and receiving pairs on one end of the cable (see Figure 6-15). One end of the cable is wired according to the TIA/EIA 568A standard, while the other end is wired according to the TIA/EIA 568B standard. With the sending and receiving pairs reversed, the hubs can hear each other; hence the need for two standards for connecting RJ-45 jacks to UTP cables. To spare network techs the trouble of making special crossover cables, most older hubs have a special crossover port that crosses the wires inside the hub, as you can see in Figure 6-13, above. Unfortunately, when describing and labeling their crossover ports, hub manufacturers use a wide variety of terms, including crossover, uplink, in port, and out port. Most modern hubs have autosensing ports that turn themselves into crossover ports if necessary for communication (see Figure 6-16).

Figure 6-15
A crossover cable reverses the sending and receiving pairs.

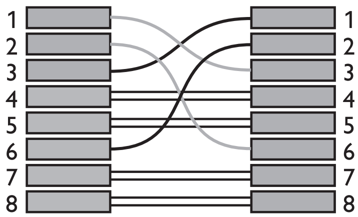


Figure 6-16 Hub with autosensing crossover ports

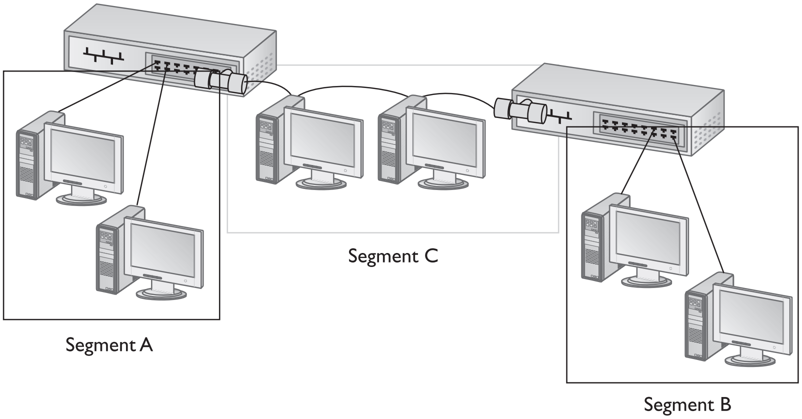
In a pinch, you can use a crossover cable to connect two computers together using 10BaseT NICs with no hub between them at all. This is handy for the quickie connection needed for a nice little home network or when you absolutely, positively must chase down a friend in a computer game!

Be careful about confusing crossover cables with crossover ports. First, never connect two hubs by their crossover ports. Take a regular cable; connect one end to the crossover port on one hub and the other end to any regular port on the other hub. Second, if you use a crossover cable, just plug each end into any handy regular port on each hub.

If you mess up your crossover connections, you won't cause any damage, but the connection will not work. Think about it. If you take a straight cable (that is, not a crossover cable) and try to connect two PCs directly, it won't work. Both PCs will try to use the same send wires and same receive wires. When you plug the two PCs into a hub, the hub electronically crosses the data wires, so one NIC sends and the other can receive. If you plug a second hub to the first hub using regular ports, you essentially cross the cross and create a straight connection again between the two PCs! That won't work. Luckily, nothing gets hurt (except your reputation if one of your colleagues notes your mistake!).

Multiple segments in a network provide greater fault tolerance than a single segment. Each segment functions or fails on its own. Figure 6-17 shows three segments: *A*, *B*, and *C*. Segments *A* and *B* are 10BaseT hubs; segment *C* is a 10Base2 segment. A failure of one segment does not cause other segments to fail. The failure affects only transmissions that rely on the failed segment. For example, if Cindy's pet rat Gidget escapes and chews through segment *C*, computers on segment *A* cannot communicate with computers on segment *B*, but computers on segment *A* can continue to communicate with each other, and computers on segment *B* can also continue to communicate with each other (see Figure 6-18). Of course, the poor computers on segment *C* must sit idle and twiddle their thumbs until some kind network tech repairs the damage wrought by the evil Gidget.

Figure 6-17 Two hubs connected by a 10Base2 segment



How Big Can an Ethernet Network Be? The 5-4-3 Rule

When multiple Ethernet segments connect to each other with hubs and repeaters, they remain part of the same collision domain (see Figure 6-19). As discussed in Chapter 5, "Ethernet Basics," a collision domain is a set of Ethernet segments that receive all traffic generated by any node within those segments. A set of restrictions known as the *5-4-3 rule* limits the size of an Ethernet collision domain.

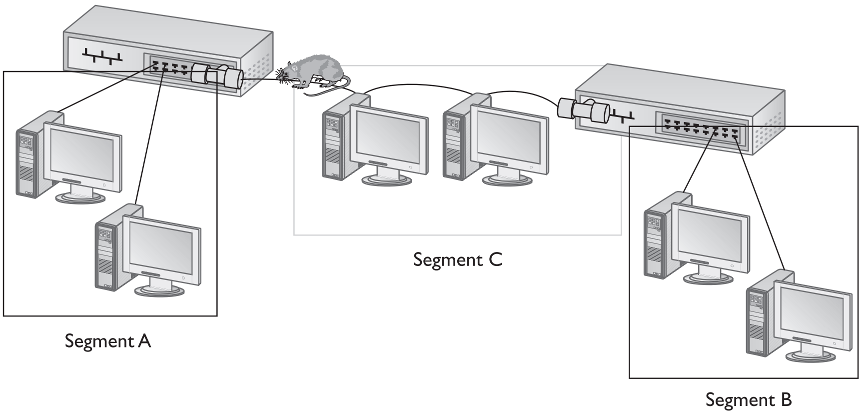


Figure 6-18 Segment C's failure prevents communication between segments A and B, but does not affect communication within segments A and B.

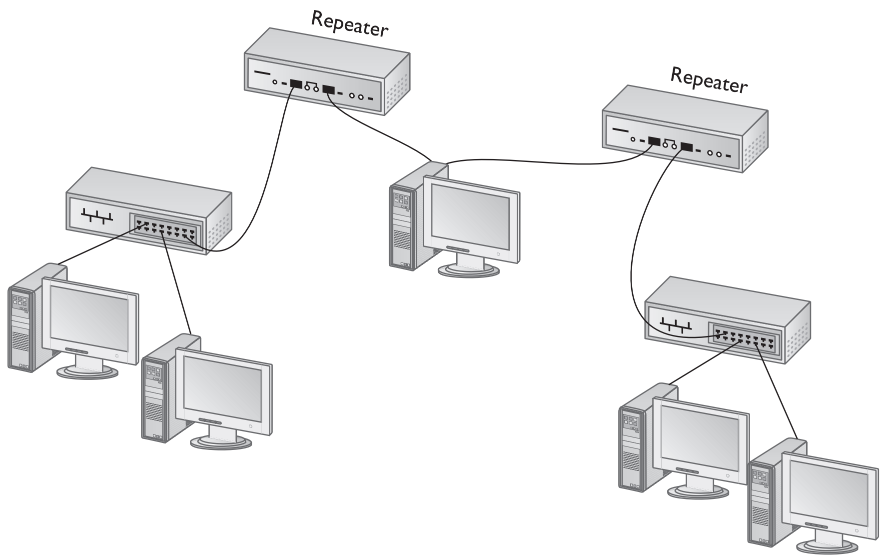


Figure 6-19 An Ethernet collision domain

A Useful Approximation

For Ethernet networks to function properly, each node must detect when its own transmissions collide with those of another node. When a node detects a collision, it waits a random period of time and then re-sends the packet. (Refer back to Chapter 5 for a more detailed discussion of CSMA/CD.) If the sending node fails to detect a collision, it won't know to resend the packet, and the packet will be lost. Ethernet nodes stop checking for collisions once they send the last byte of each data packet. If the network is large enough that the last byte leaves the sending node before the first byte reaches every other node on the network, an undetected collision can occur. In the event of a collision between two machines on the extreme edges of the network, neither node retransmits its data packet, causing the data packets to be lost. Clearly, a collision domain that's too big can be a serious problem!

The question, then, is: "How big is too big?" A precise answer would require a series of arcane calculations that determine variables with thrilling names like *round-trip signal propagation delay* and *interpacket gap*. Fortunately, the average network tech doesn't need to do these difficult calculations. The networking industry has developed a general rule—the so-called 5-4-3 rule—that enables technicians to build networks within safe size limits without needing to earn advanced math degrees.

The 5-4-3 rule is pretty easy to remember: it states that in a collision domain, no two nodes may be separated by more than *5* segments, *4* repeaters, and *3* populated segments.

To calculate a network's compliance with the 5-4-3 rule, trace the worst-case path between two machines—in other words, the path between two machines that will yield the highest number of segments, repeaters, and populated segments. We consider a segment populated if any systems are connected to that segment. This might then beg the question: "Why would anyone want to have a segment that isn't populated? That's easy—sometimes we use a separate segment as a way to connect other segments.

Figure 6-20 shows a network with 5 segments, 4 repeaters, and 3 populated segments. The path between machines *A* and *C* represents the worst-case path because the packets must pass through all of the segments and repeaters on the network. The paths between *A* and *B*, or *B* and *C*, are irrelevant for calculating compliance with the 5-4-3 rule because a longer path exists between two other machines. The path between machine *A* and machine *C* uses all five segments, all four repeaters, and all three populated segments.

NOTE When calculating the 5-4-3 rule, a hub counts as both a repeater and a segment.

The 5-4-3 rule's limitations apply not to the entire network, but rather to the paths within the network. Figure 6-21 shows a network that complies with the 5-4-3 rule, but has 6 segments, 6 repeaters, and 5 populated segments within the entire network. Hub 1 counts as both a segment and a repeater, but not as a populated segment because no computers attach directly to it. Segments that link other segments together, but have no computers directly attached to them, are called *link segments*. This network follows the 5-4-3 rule because no path between two machines ever traverses more than 5 segments,

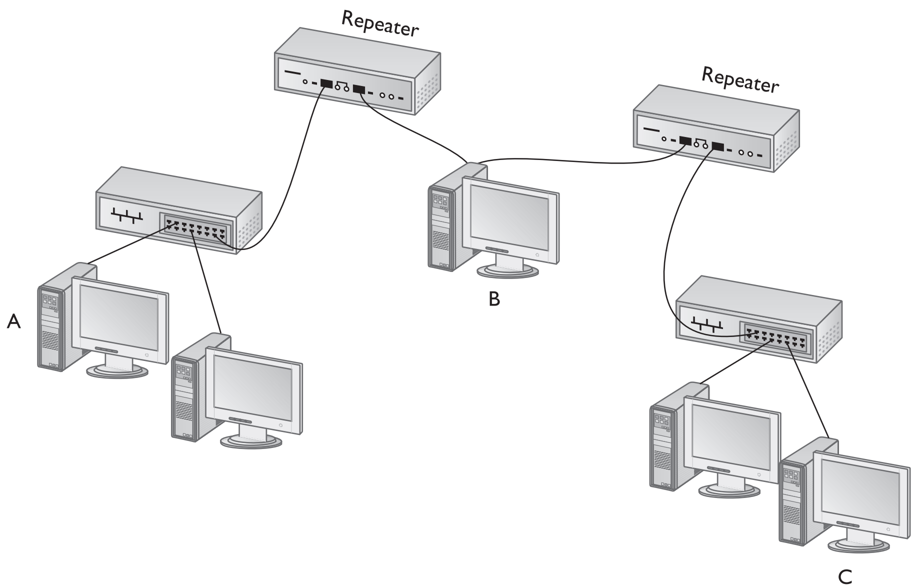


Figure 6-20 A network with 5 segments, 4 repeaters, and 3 populated segments

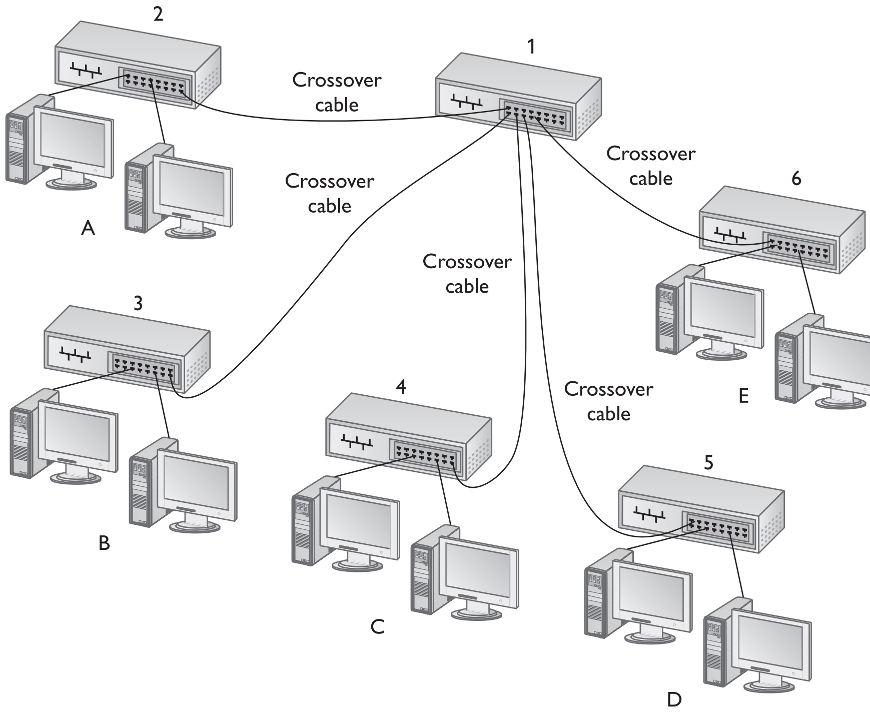


Figure 6-21 A network with 6 segments that complies with the 5-4-3 rule

4 repeaters, or 3 populated segments. For example, the path between computers *A* and *C* runs through 3 segments (hubs 2, 1, and 4), 3 repeaters (hubs 2, 1, and 4), and 2 populated segments (hubs 2 and 4).

The 5-4-3 rule imposes limits on the size of an individual Ethernet collision domain, but the limits are generous. The network shown in Figure 6-21 can contain thousands of individual machines. Remember that each hub can support up to 1024 PCs; because of the demands of modern operating systems and applications, however, 10-Mbps Ethernet networks with far fewer than 1024 machines can become too busy and congested to function well. Manufacturers have overcome congestion and size limitations using a number of fascinating improvements to the original 10BaseT standard that I'll call high-speed Ethernet.

NOTE Rather than make 1024-port hubs that would have a limited market and be expensive to replace in the event of failure, manufacturers make stackable hubs. Stackable hubs are hubs with a special proprietary connection that enables them to function in groups, called *stacks*, as a single device. For the purposes of the 5-4-3 rule, all the hubs in a stack are considered a single segment, repeater, and populated segment.

High-Speed Ethernet

As any fighter pilot will tell you, sometimes you just feel the need—the need for speed. While plain-vanilla Ethernet performs well enough for basic file and print sharing, today's more demanding network applications, such as Lotus Notes, SAP, and Microsoft Exchange, as well as other vital office applications like Half-Life and Unreal Tournament, can quickly saturate a network running at 10 Mbps. Fortunately, those crazy kids over at the IEEE keep expanding the standard, providing the network tech in the trenches with new tools that provide additional bandwidth. These cool new tools include Fast Ethernet, full-duplex Ethernet, Gigabit Ethernet, and switched Ethernet.

100Base Ethernet

Fast Ethernet is not a single technology. The term *Fast Ethernet* refers to any of several Ethernet flavors that operate at 100 Mbps. Rather than limiting Ethernet to a single high-speed solution, the IEEE endorsed multiple standards for Fast Ethernet and allowed the marketplace to choose from among them. The major variations include 100BaseT and 100BaseFX.

100BaseT

The IEEE supports two variations of *100BaseT*: 100BaseTX and 100BaseT4. Both flavors physically resemble 10BaseT, using a star bus topology and connecting to hubs with UTP cabling. The 100 in their names reflects the fact that the cable connecting a device to a hub can send data at speeds up to 100 Mbps. The difference between 100BaseTX and 100BaseT4 lies in the quality of the cable required. 100BaseTX requires CAT 5 or better cabling to achieve a speed of 100 Mbps using only two pairs of wires. Like 10BaseT, 100BaseTX ignores the remaining two pairs. 100BaseT4 uses all four pairs to achieve 100 Mbps performance using lower quality CAT 3 or better cabling. Think of the cable as a highway: 100BaseTX increases capacity by raising the speed limit, while 100BaseT4 increases capacity by adding additional lanes.

NOTE 100BaseVG, also known as 100BaseVGAnyLAN, is not a flavor of Ethernet. Designed to run over Category 3 (voice grade) cabling, it does not use CSMA/CD to determine access to the cable. The IEEE 802.12 committee controls the standards for 100BaseVG. As the popularity of 100BaseTX has grown, the importance of competitors like 100BaseVG has diminished dramatically.

Both 100BaseTX and 100BaseT4 allow organizations to take advantage of their existing UTP cabling. If the existing UTP wiring was properly installed, you can upgrade a network from 10BaseT simply by replacing hubs and network cards, with no recabling required.

100BaseTX and 100BaseT4 are not interchangeable. If you have 100BaseTX hubs, then you must also have 100BaseTX NICs. Equally, if your hub is 100BaseT4, then you must have 100BaseT4 NICs. Over the past few years, 100BaseTX has pushed 100BaseT4 out of the market so completely that devices labeled as 100BaseTX are now practically impossible to find. When you purchase 100BaseTX equipment now, it usually just says 100BaseT.

UTP cabling cannot meet the needs of every organization, however, for three key reasons. First, the 100-meter distance limitation of UTP-based networks is inadequate for networks covering large buildings or campuses. Second, UTP's lack of electrical shielding makes it a poor choice for networks functioning in locations with high levels of electrical interference. Finally, the Maxwell Smarts and James Bonds of the world find UTP cabling (and copper cabling in general) easy to tap, making it an inappropriate choice for high-security environments. To address these issues, the IEEE 802.3 standard provides for a flavor of 100-megabit Ethernet using fiber-optic cable, called 100BaseFX.

NOTE Even though shielded twisted-pair cabling is available, its use is rare. Most installations will use fiber-optic cable in situations where UTP is not adequate.

100BaseFX

The *100BaseFX* standard saw quite a bit of interest for years, as it combined the high speed of 100Base Ethernet with the reliability of fiber optics. Outwardly, 100BaseFX looks exactly like 10BaseFL: both use the same multimode fiber-optic cabling, and both use SC or ST connectors. 100BaseFX is an improvement over 10BaseFL, however, supporting a maximum cable length of 400 meters.

Migrating to Fast Ethernet

Upgrading an entire network to 100BaseTX can be a daunting task. 100BaseTX requires new hubs, new NICs, and often upgrades to the existing cabling. For organizations with more than a few machines, upgrading every node can take months or even years. Fortunately, the conversion can be done slowly. In fact, organizations that want to do so can purchase 10/100BaseT devices. A 10/100BaseT device automatically functions as a 100BaseT device when plugged into another 10/100BaseT or 100BaseT device, but functions as a 10BaseT device when plugged into another 10BaseT device. The existence of these hybrid devices enables organizations to roll out 100BaseT in batches, providing high-speed access to the machines that need it.

Gigabit Ethernet

For the true speed junkie, an even more powerful version of Ethernet exists: *Gigabit Ethernet*. The IEEE has approved two different versions of Gigabit Ethernet. The first version, published under the 802.3z standard and known as 1000BaseX, is divided into a series of standards, with names such as 1000BaseCX, 1000BaseSX, and 1000BaseLX. The 802.3ab standard defines a single UTP solution called 1000BaseT. Of all these Gigabit standards, 1000BaseT has come out as the dominant Gigabit Ethernet standard.

1000BaseT uses four-pair UTP cabling to achieve gigabit performance. Like 10BaseT and 100BaseT, 1000BaseT has a maximum cable length of 100 meters. 1000BaseT connections and ports look exactly like the ones on a 10BaseT or 100BaseT network.

NOTE The term *Gigabit Ethernet* is more commonly used than *1000BaseT*.

The 802.3z standards require a bit more discussion. Let's look at each of these solutions in detail to see how they work.

1000BaseCX 1000BaseCX uses a unique shielded cable known as twinaxial cable (Figure 6-22). Twinaxial cables are special shielded 150-Ohm cables with a length limit of only 25 meters. 1000BaseCX has made little progress in the Gigabit Ethernet market. 1000BaseCX falls under the IEEE 802.3z standard.

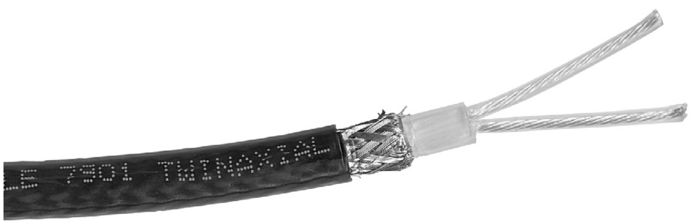
1000BaseSX Many networks upgrading to Gigabit Ethernet use the 1000BaseSX standard. 1000BaseSX uses multimode fiber-optic cabling to connect systems, with a generous maximum cable length of over 500 meters; the exact length is left up to the various manufacturers. 1000BaseSX uses an 850-nm (nanometer) wavelength LED to transmit light on the fiber optic cable. Like 1000BaseCX, 1000BaseSX comes under the 802.3z standard. 1000BaseSX devices look exactly like the 100BaseFX products you read about earlier in this chapter, but they rely exclusively on the SC type of connector.

1000BaseLX 1000BaseLX is the long-distance carrier for Gigabit Ethernet. 1000BaseLX uses single-mode (laser) cables to shoot data at distances up to five kilometers—and some manufacturers use special repeaters to increase that to distances as great as 70 kilometers! The Ethernet folks are trying to position this as the Ethernet backbone of the future, and already some large carriers are beginning to adopt 1000BaseLX. You may live your whole life and never see a 1000BaseLX device, but odds are good that you will encounter connections that use such devices in the near future. 1000BaseLX looks like 1000BaseSX, and is also part of the 802.3z standard.

New Fiber Connectors

Around the time that Gigabit Ethernet first stated to appear, two problems began to surface with ST and SC connectors. First, ST connectors are relatively large, twist-on connectors, requiring the installer to twist the cable when inserting or removing a cable. Twisting is not a popular action with fiber-optic cables, as the delicate fibers may fracture. Also, big-fingered techs have a problem with ST connectors if the connectors are

Figure 6-22
Twinaxial cable



too closely packed: they can't get their fingers around them. SC connectors snap in and out, making them much more popular than STs. However, SC connectors are also large, and the folks who make fiber networking equipment wanted to pack more connectors onto their boxes. This brought about two new types of fiber connectors, known generically as SFF (Small Form Factor) connectors. The first SFF connector—the MTRJ, or Mechanically Transferable Registered Jack, shown in Figure 6-23—gained popularity with important companies like Cisco and is still quite common.

The second type of popular SFF connector is the LC, or Local Connecter, shown in Figure 6-24. LC-type connectors are very popular, particularly in the United States, and many fiber experts consider the LC connector to be the predominant fiber connector.

LC and MTRJ are the most popular types of SFF fiber connections, but many others exist. The fiber industry has no standard beyond ST and SC connectors, which means that different makers of fiber equipment may have different connections.

10-Gigabit Ethernet

The ongoing demand for bandwidth on the Internet means that the networking industry is continually reaching for faster LAN speeds. Not only must speeds increase, but they must increase while keeping strong backward compatibility—or no one will buy the technology! The progression of Ethernet from 10 Mbps up to 1 Gbps is a testament to that attitude. The other factor that comes into the minds of network hardware manufacturers is the degree of speed increase. Let's look at the different speeds of Ethernet over the years: 10 Mbps, 100 Mbps, and 1 Gbps. Note that every jump is a factor of ten—but why is that? There's no law of physics that says each generation must be ten times faster than the last. The amount of speed increase in each generation is the result of marketing, plain and simple. Most manufacturers of Ethernet hardware feel that customers aren't motivated to buy into any new Ethernet generation with less than a tenfold speed increase, and perhaps they're right—but it makes for increasingly tough increases in speed.

Figure 6-23
MTRJ connector

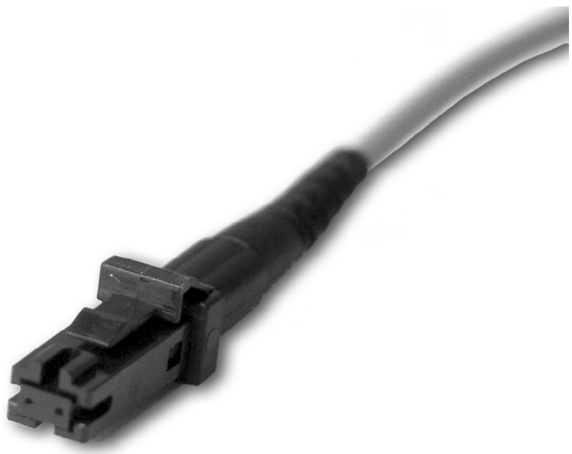
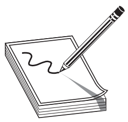


Figure 6-24
LC connector

This leads me to the newest and fastest Ethernet to date: 10 Gbps. Initially standardized in 2002 under the IEEE 802.3ae committee, 10-Gigabit Ethernet—commonly abbreviated as 10GbE—is only now showing up in very high-level LANs and WANs. Did I say *WANs*? Yes, I did; one of the goals of the 10GbE standard was that it would work as both an Ethernet LAN and WAN solution. Certain versions of the 802.3ae standard provide for segment lengths of up to 40 kilometers, so it's clear that the 802.3ae folks have taken a long-distance view for 10GbE.

10GbE is true Ethernet, although it is exclusively full-duplex and must run on fiber. There are 802 groups working to create 10GbE solutions that run on twinaxial and even UTP, but it will probably be quite some time before those technologies appear on store shelves. In order to wrap your mind around 10GbE, you need to remember that it was designed from the ground up as a fiber solution. When you use fiber, you're using light, not electricity, to send signals down the line. Light, unlike electricity, has multiple wavelengths. Different wavelengths of light exhibit different qualities. Longer wavelength light tends to travel longer distances, but usually requires more complex circuitry or more power. Lower-bandwidth fiber optics tend to use LEDs as their light sources, as LEDs are inexpensive and easy to use. Higher-bandwidth fiber optics usually use lasers as their light source. Laser light travels much farther than regular light, but the hardware that produces it is considerably more difficult to manufacture.

The creators of 10GbE recognized the many different types of fiber optics in use, and wanted 10GbE to work on as many different types as possible. They achieved this goal by defining seven different media types to work with different types of fiber.



NOTE Before reading about these different media types, be sure you understand that these are Physical layer issues. Each of these types transmits exactly the same type of Ethernet frames!

The 10GBaseSR and 10GBaseSW media types are designed for use over short wavelength (850 nm) multimode fiber. The maximum fiber length is 300 meters, although this will vary depending on the type of multimode fiber used. The 10GBaseSR media type is designed for typical Ethernet LAN connections. The 10GBaseSW media type is designed to connect to SONET equipment. 10GBaseSR has seen usage in co-location facilities to interconnect large networks that traditionally relied on ATM-type connections.

The 10GBaseLR and 10GBaseLW media types are designed for use over long wavelength (1310 nm) single-mode fiber. The maximum fiber length is 10 kilometers, although this will vary depending on the type of single-mode fiber used. The 10GBaseLR media type is designed for typical Ethernet LAN connections. The 10GBaseLW media type is designed to connect to SONET equipment. 10GBaseLR is the most popular 10GbE media type.

The 10GBaseER and 10GBaseEW media types are designed for use over extra long wavelength (1550 nm) single-mode fiber. The maximum fiber length is 40 kilometers, although this will vary depending on the type of single-mode fiber used. The 10GBaseER media type is designed for typical Ethernet LAN connections, while the 10GBaseEW media type is designed to connect to SONET equipment. 10GBaseER is expensive and has only seen substantial use in long-distance interconnects to replace a leased line.

10GBaseLX4 is the odd duck. The previous six media types all use a single wavelength of light, sending a serial signal. This media type uses wave division multiplexing technology, using four or more wavelengths of light over a single pair of either single-mode or multimode fiber-optic cable. 10GBaseLX4 has had little industry support.

10GBaseSW, 10GBaseLW, and 10GBaseEW only exist to allow 10GbE connections over existing SONET lines; see Chapter 16, “Remote Connectivity,” for details on SONET. Many network experts see these 10GbE-over-SONET solutions as little more than short-term solutions until 10GbE lines replace the SONET lines. Replacing SONET lines with 10GbE provides two benefits: first, you no longer need equipment on each end to convert Ethernet to SONET and back again. Second, because SONET is no longer needed, anyone willing to make a large enough up-front investment can own their own native Ethernet fiber cables, in WAN and MAN situations where typically they would be at the mercy of the local SONET carriers’ lease rates.

This hodgepodge of 10GbE Ethernet types might have been the ultimate disaster for hardware manufacturers. All types of 10GbE send and receive the exact same signal; only the physical medium is different. Imagine a single router that had to come out in seven different versions to match all these types! Instead, the 10GbE industry devised a very clever, very simple concept called *multisource agreements*, or *MSAs*. An MSA is a modular transceiver that you plug into your 10GbE equipment, enabling you to convert from one media type to another by inserting the right transceiver. Unfortunately, there have been as many as four different MSA types competing in the last few years. Figure 6-25 shows a typical MSA called XENPAK.

Figure 6-25
XENPAK MSA

NOTE Not all 10GbE manufacturers use MSAs in their equipment.

For now, 10GbE equipment is the exclusive domain of extremely high-bandwidth LANs and WANs, including parts of the "big pipe" Internet connections.

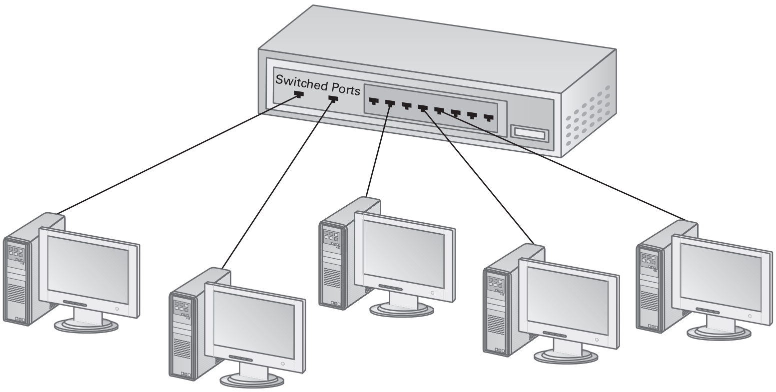
Switched Ethernet

Don't feel like upgrading all your NICs and hubs to get more speed? How would you like to dramatically improve performance just by replacing your hub? *Switched Ethernet* may be the solution for you! An *Ethernet switch* is a special hub that can place some devices into their own collision domains. In essence, an Ethernet switch is a hub with a bridge built in. *Switches*, like bridges, work at the OSI Data Link layer, or Layer 2—in fact, they're often referred to as Layer 2 switches. Physically, an Ethernet switch looks much like any other Ethernet hub, except for the addition of one or more switched ports (see Figure 6-26). Logically, an Ethernet switch puts each device plugged into one of its switched ports into its own collision domain. As one system begins to send data to another system, a switch looks at the incoming MAC addresses and creates a single collision domain (see Figure 6-27).

Using an Ethernet switch provides two benefits. First, if both the sender and the receiver are on their own switched ports, the full bandwidth of that connection (10, 100, or 1000 megabits) is available to them—no other machine can cause a collision. Second, the switch can act as a buffer, enabling devices running at different speeds to communicate. Without this buffering capability, a Gigabit Ethernet card would overload a slow NIC.

Ethernet switches can also connect segments to a backbone. A *backbone* is a segment that connects other segments. Most backbones are lightly populated or unpopulated. In most cases, a backbone runs at a higher speed than the segments it connects. Figure 6-28 shows a network that supplies 10BaseT to networked desktops, and connects the hubs to a 100BaseT backbone segment. In some cases, heavily accessed machines, such as file servers, plug directly into the backbone, as shown in Figure 6-29.

Figure 6-26 An eight-port switch with two switched ports



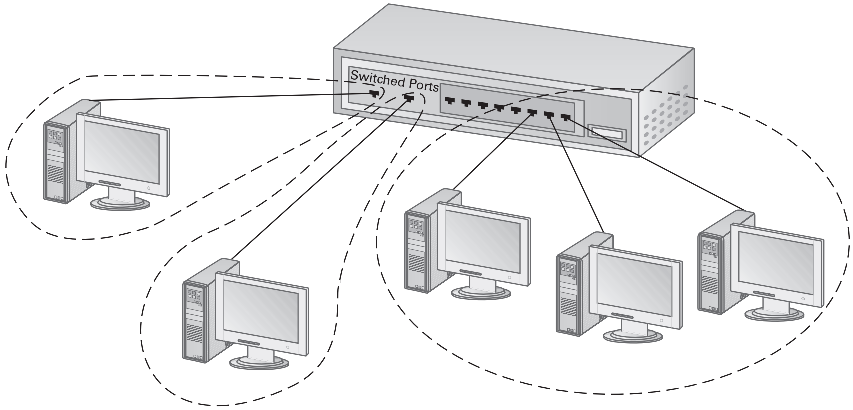


Figure 6-27 Devices plugged into switched ports are isolated on their own collision domains.

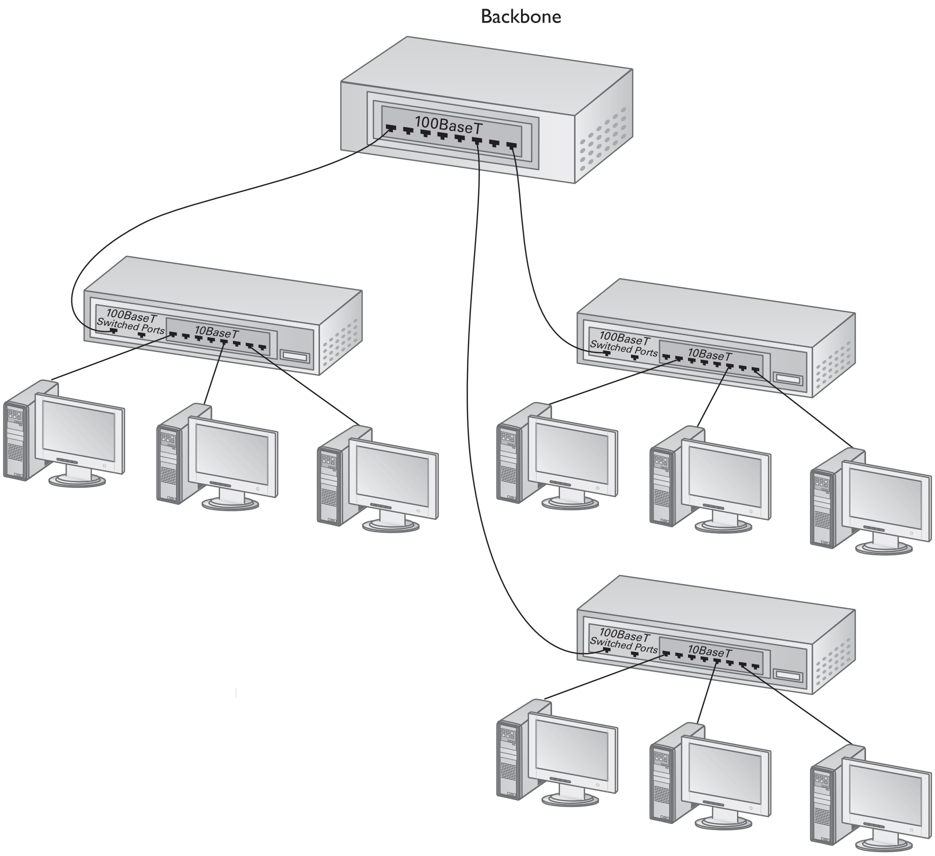


Figure 6-28 Desktop machines run at 10 Mbps, but the backbone runs at 100 Mbps.

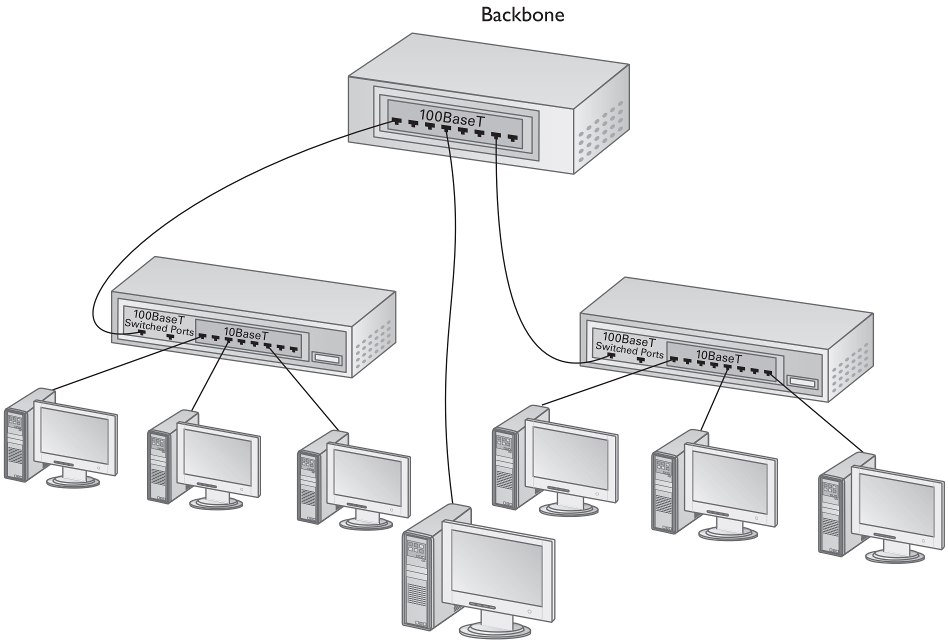


Figure 6-29 Heavily accessed machines can be plugged directly into the backbone.

Full-Duplex Ethernet

Ethernet switching opens up another avenue for improving the performance of the network: full-duplex Ethernet. *Full-duplex* means that a device can send and receive data simultaneously. Normally, Ethernet transmissions are *half-duplex*—in other words, at any given moment, a machine can either send or receive data, but not both. If a machine sends and receives simultaneously in half-duplex mode, a collision occurs. In the event of a collision, the CSMA/CD rules kick in, causing the machine to stop sending and wait a random period of time before trying again. CSMA/CD allows many machines to share the same segment, but requires all communication to be half-duplex.

A switched Ethernet connection running over UTP, however, not only creates a two-machine-only segment, it also uses separate pairs of wires for sending and receiving. Each pair of wires acts as a separate channel, enabling the devices at each end to communicate with one another in full-duplex mode. If the Ethernet NICs on each end of a switched connection support full-duplex mode, turn it on and enjoy the benefits! Note that not all Ethernet NICs support full-duplex operation; however, those that do will have a full-duplex option that you can turn on using their setup programs (see Figure 6-30).

Full-duplex Ethernet offers impressive performance gains. A 10BaseT full-duplex connection has a theoretical bandwidth of 20 Mbps (2×10 Mbps), while a 100BaseT full-duplex connection has a theoretical bandwidth of 200 Mbps (2×100 Mbps). Because there should never be collisions on a full-duplex connection, the real-world speeds of

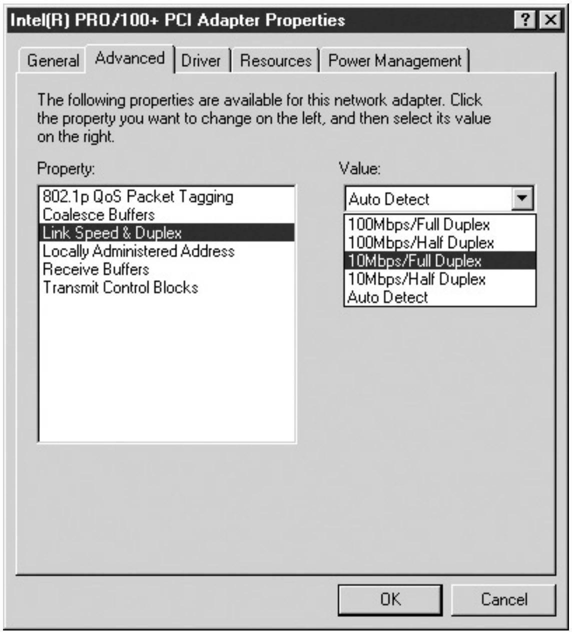


Figure 6-30 If a card supports full-duplex mode, its setup program will have an option to switch between half- and full-duplex.

full-duplex Ethernet approach these theoretical maximums. Unfortunately, many older 10BaseT devices do not support full-duplex operation; however, most 100Base and 1000Base Ethernet standards require full-duplex operation, making it an assumed function on those devices.

TIP For the exam, know that in half-duplex communication, a device cannot send when it is receiving and vice versa. In full-duplex communication, however, a device can send and receive at the same time.

Here's a thought: if a switched network creates separate collision domains for all the nodes, does the 5-4-3 rule still apply? Good question! If you answered "No," that's even better! Once you start using switches, the entire concept of 5-4-3 goes out the window; there are no limitations due to collisions, except within individual collision domains.

The wonderful benefits of switches make them extremely common today. By replacing a hub with a switch, your network can take advantage of collision-free, full-duplex communication to achieve much higher speeds.

Conclusion

While 10Base2 and 10Base5 soldier on in some networks, the use of the star bus hybrid topology for UTP- and fiber-optic-based Ethernet networks enables techs to build more robust and flexible networks. The capability to use high-speed segments, full-duplex operation, bridging, routing, and switching gives the network architect a full toolkit with which to build fast, stable networks. For all these reasons, UTP and fiber dominate the networking industry today, leaving coaxial to dwindle away.

Chapter Review

Questions

1. Star bus networks use a ______________ star and a ___________ bus.
   A. Physical, logical
   B. Logical, physical
   C. Hub, Ethernet
   D. Ethernet, hub
2. The *T* in 10BaseT refers to
   A. Topology
   B. Ten-Mbps speed
   C. Twisted-pair cable
   D. Transport technology
3. Fault tolerance is the key advantage of what topology?
   A. Bus
   B. Ring
   C. Star bus
   D. Bus ring
4. The maximum distance that can separate a 10BaseT node from its hub is
   A. 50 meters
   B. 100 meters
   C. 185 meters
   D. 200 meters
5. When used for Ethernet, unshielded twisted pair uses what type of connector?
   A. RG-58
   B. RJ-45
   C. RJ-11
   D. RS-232
6. What is the maximum number of nodes that can be connected to a 10BaseT hub?
   A. 1024
   B. 500
   C. 100
   D. 185

7. Which of the following is not true of crossover cables?
   A. They are a type of twisted-pair cabling.
   B. They reverse the sending and receiving wire pairs.
   C. They are used to connect hubs.
   D. The ends of a crossover cable are wired according to the TIA/EIA 568B standard.
8. Which of the following connectors are used by 10BaseFL cable? (Select two.)
   A. SC
   B. RJ-45
   C. RJ-11
   D. ST
9. Which of the following cable types does not use CAT 3 cabling?
   A. 100BaseTX
   B. 10BaseT
   C. 100BaseT4
   D. 100BaseVG
10. Within an Ethernet collision domain, the 5-4-3 rule limits 10-megabit Ethernet networks to ________________ between any two machines.
   A. 5 populated segments, 4 repeaters, and 3 hubs
   B. 5 segments, 4 repeaters, and 3 populated segments
   C. 5 tokens, 4 packets, and 3 broadcasts
   D. 5 segments, 4 repeaters, and 3 hubs

Answers

1. **A.** Star bus networks use a physical star, which provides improved stability, and a logical bus that maintains compatibility with existing Ethernet standards.
2. **C.** The *T* in 10BaseT refers to its use of twisted-pair cabling. This differs from 10Base2 and 10Base5, where the 2 and 5 refer to the maximum segment lengths. The *10* in 10BaseT refers to its 10-Mbps speed.
3. **C.** Fault tolerance is the key advantage of the star bus topology. Fault tolerance refers to a system's capability to continue operating when part of it is not working. In this case, a break in a network cable affects only the machine connected to that cable; the others can continue to communicate.
4. **B.** The maximum distance between a 10BaseT node and its hub is 100 meters.

5. **B.** UTP cable uses an RJ-45 connector when used for Ethernet. RG-58 is the type of coaxial cable used with 10Base2. RJ-11 is the standard four-wire connector used for regular phone lines. RS-232 is a standard for serial connectors.
6. **A.** A 10BaseT hub can connect no more than 1024 nodes (computers).
7. **D.** One end of a crossover cable is wired according to the TIA/EIA 568B standard; the other is wired according to the TIA/EIA 586A standard. This is what crosses the wire pairs and enables two hubs to communicate without colliding.
8. **A, D.** 10BaseFL uses two types of fiber-optic connectors called SC and ST connectors.
9. **A.** 100BaseTX requires CAT 5 or better cabling. 10BaseT, 100BaseT4, and 100BaseVG can all use CAT 3 cabling.
10. **B.** Within a collision domain, the 5-4-3 rule limits 10-megabit Ethernet networks to 5 segments, 4 repeaters, and 3 populated segments between any two machines.