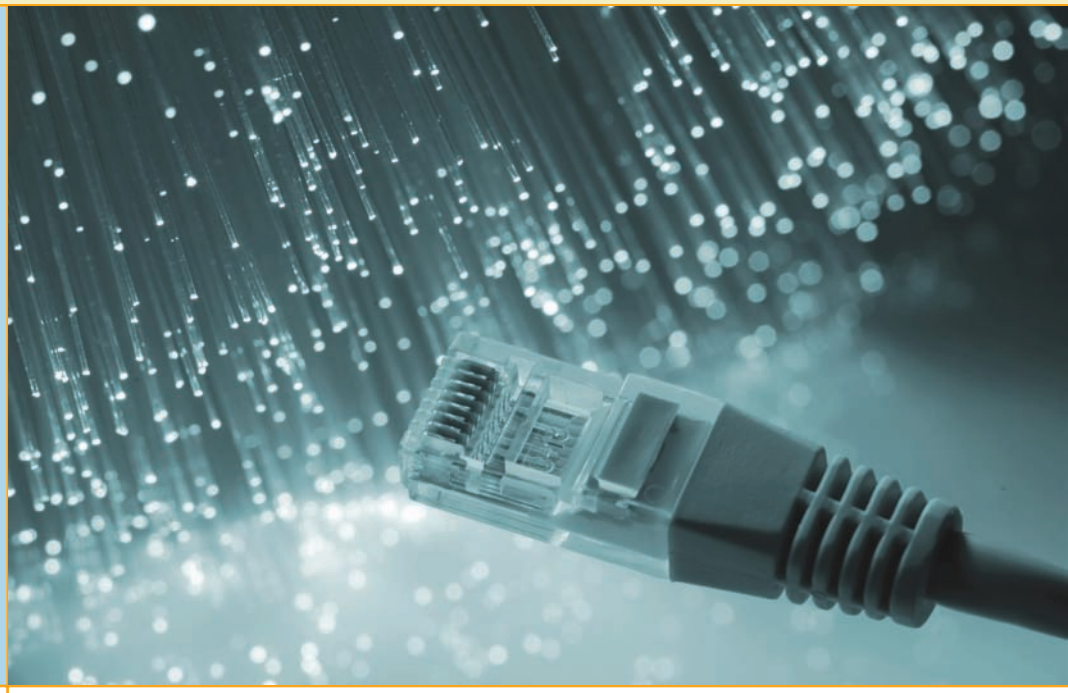
chapter 5

Modern Ethernet

"To expect the unexpected shows a thoroughly modern intellect."
—Oscar Wilde



In this chapter, you will learn how to

- **Describe the varieties of 100-megabit Ethernet**
- **Discuss copper- and fiber-based Gigabit Ethernet**
- **Compare the competing varieties of 10-Gigabit Ethernet**

Within a few years of introduction, 10BaseT proved inadequate to meet the growing networking demand for speed. As with all things in the computing world, bandwidth is the key. Even with switching, the 10-Mbps speed of 10BaseT, seemingly so fast when first developed, quickly found a market clamoring for even faster speeds. This chapter looks at the improvements in Ethernet since 10BaseT. You'll read about 100-megabit standards and the several standards in Gigabit Ethernet. The chapter wraps up with the newest speed standards, 10-Gigabit Ethernet.

Test Specific

Before diving into the newer standards, let's get a few facts about Ethernet out of the way:

- There are only four Ethernet speeds: 10 megabit, 100 megabit, 1 gigabit, and 10 gigabit.
- Every version of Ethernet uses either unshielded twisted pair (UTP) or fiber. (There were a few exceptions to this rule, but they were rare and weird.)
- Every version of Ethernet uses a hub or a switch, although hubs are incredibly rare today.
- Only 10- and 100-megabit Ethernet may use a hub. Gigabit and 10-Gigabit Ethernet networks must use a switch.
- Every version of Ethernet has a limit of 1024 nodes.
- Every UTP version of Ethernet has a maximum distance from the switch or hub to the node of 100 meters.

100-Megabit Ethernet

The quest to break 10-Mbps network speeds in the Ethernet world started in the early 1990s. By then 10BaseT Ethernet had established itself as the most popular networking technology (although other standards, such as IBM's Token Ring, still had some market share). The goal was to create a new speed standard that made no changes to the actual Ethernet frames themselves. By doing this, the 802.3 committee ensured that different speeds of Ethernet could interconnect, assuming you had something that could handle the speed differences and a media converter if the connections were different.

Cross Check

Interconnecting Ethernet Networks

You learned about the devices used to connect different types of Ethernet networks—hubs and switches—in Chapter 3, "Cabling and Topology." Check your memory now. What's the difference between the two devices? Which would you prefer for connections and why?

100BaseT

If you want to make a lot of money in the technology world, create a standard and then get everyone else to buy into it. For that matter, you can even give the standard away and still make tons of cash if you have the inside line on making the hardware that supports the standard.

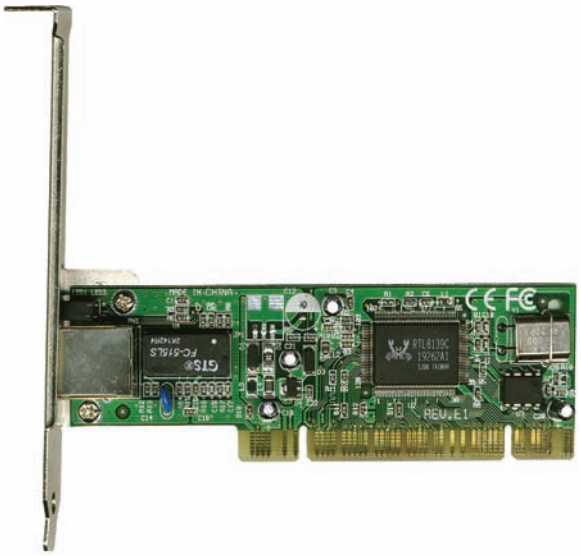
When it came time to come up with a new standard to replace 10BaseT, network hardware makers forwarded a large number of potential standards, all focused on the prize of leading the new Ethernet standard. As a result, two UTP Ethernet standards appeared, **100BaseT4** and **100BaseTX**. 100BaseT4 used CAT 3 cable while 100BaseTX used CAT 5. By the late 1990s, 100BaseTX became the dominant 100-megabit Ethernet standard. 100BaseT4 disappeared from the market and today it's forgotten. As a result, we almost never say 100BaseTX today, simply choosing to use the term **100BaseT**.

100BaseT was at one time called **Fast Ethernet**. The term still sticks to the 100-Mbps standards—including 100BaseFX, which you'll read about in an upcoming section—even though there are now much faster versions of Ethernet.

100BaseTX (100BaseT) Summary

- **Speed** 100 Mbps
- **Signal type** Baseband
- **Distance** 100 meters between the hub and the node
- **Node limit** No more than 1024 nodes per hub
- **Topology** Star-bus topology: physical star, logical bus
- **Cable type** Uses CAT 5(e) or better UTP cabling with RJ-45 connectors

Upgrading a 10BaseT network to 100BaseT is not a small process. First you need to make sure you have CAT 5 cable or better. This isn't a big deal, because almost all network cables installed in the past decade are at least CAT 5. Second, you must replace all the old 10BaseT NICs with 100BaseT NICs. Third, you need to replace the 10BaseT hub or switch with a 100BaseT hub/switch. Making this upgrade cost a lot in the early days of 100BaseT, so people clamored for a way to make the upgrade a little easier. This was done via multispeed, auto-sensing NICs and hubs/switches.



• **Figure 5.1** Typical 100BaseT NIC

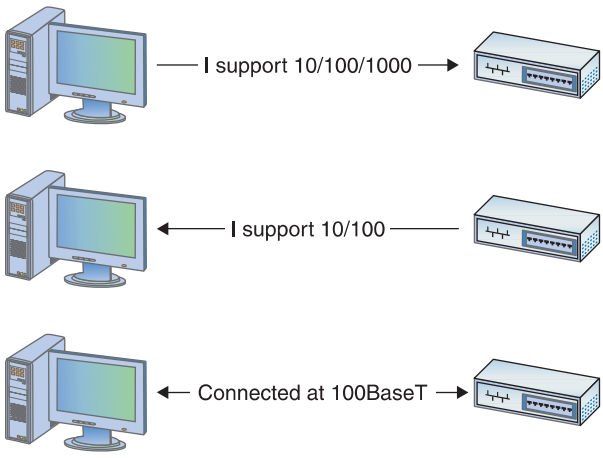
Figure 5.1 shows a typical multispeed, auto-sensing 100BaseT NIC from the late 1990s. When this NIC first connects to a network it starts to negotiate automatically with the hub or switch to determine the other device's highest speed. If they both do 100BaseT, then you get 100BaseT. If the hub/switch only does 10BaseT, then the NIC does 10BaseT. All of this happens automatically (Figure 5.2).

It is impossible to tell a 10BaseT NIC from a 100BaseT NIC without close inspection. Look for something on the card to tell you the card's speed. Some NICs may have extra link lights to show the speed (see Chapter 6, "Installing a Physical Network," for the scoop on link lights). Of course, you can always

Tech Tip

Lingo

If you want to sound like a proper tech, you need to use the right words. Techs don't actually say, "multispeed, auto-sensing," but rather "10/100." As in, "Hey, is that a 10/100 NIC you got there?" Now you're talking the talk!



• **Figure 5.2** Auto-negotiation in action

just install the card as shown in Figure 5.3 and see what the operating system says it sees!

It's very difficult to find a true 10BaseT NIC any longer because 100BaseT NICs have been around long enough to have pretty much replaced 10BaseT. All modern NICs are multispeed and auto-sensing. That applies to 100BaseT NICs and faster NICs as well.

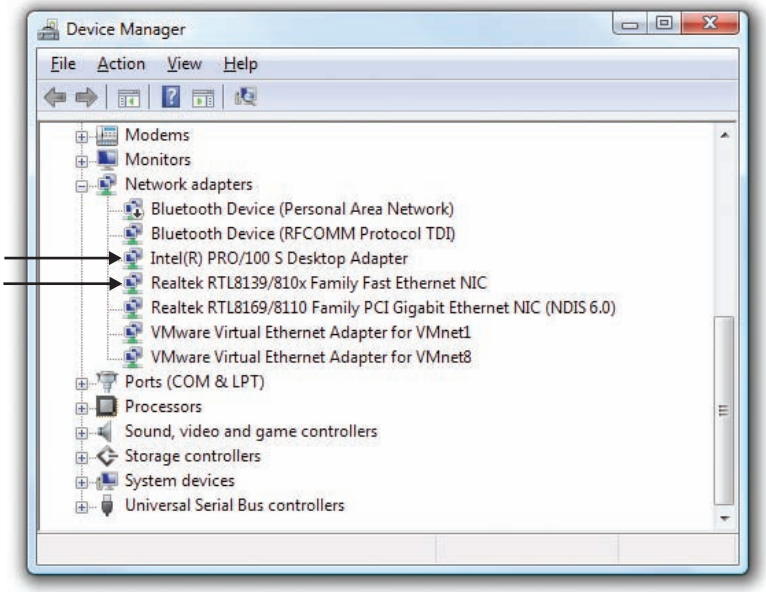


Figure 5.3 Typical 100BaseT NIC in Vista

100BaseFX

Most Ethernet networks use UTP cabling, but quite a few use fiber-based networks instead. In some networks, using fiber simply makes more sense.

UTP cabling cannot meet the needs of every organization 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.

The **100BaseFX** standard saw quite a bit of interest for years, as it combined the high speed of 100-megabit 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 offers improved data speeds over 10BaseFL and equally long cable runs, supporting a maximum cable length of two kilometers.

Tech Tip

Shielded Twisted Pair

Installing networks in areas of high electrical interference used to require the use of shielded twisted-pair (STP) cabling rather than UTP. Even though you can still get STP cabling today, its use is rare. Most installations will use fiber-optic cable in situations where UTP won't cut it.

Try This!

Hub Search

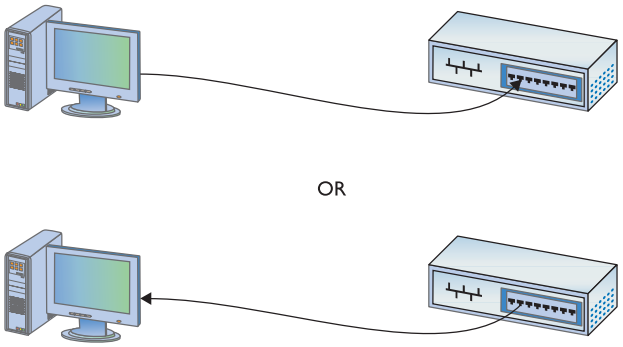
At this point, you've seen different implementations of Ethernet, from 10BaseT (which you read about in Chapter 4) to 100BaseTX and 100BaseFX. If you planned a network today, what kind of equipment could you buy? Don't look at me for the answer—instead, try this!

Go to your local computer store with pen and paper ready, and jot down the variations you find. Does the store carry 10BaseT hubs? What about 10/100 hubs for easy migration? What about a hub that supports both fiber and UTP, so you can connect 100BaseFX and 100BaseTX networks? Finally, how much do these things cost?

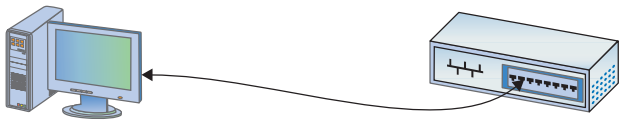
Just as the old 10BaseFL was often called 10BaseF, 100BaseFX is sometimes called simply 100BaseF.

100BaseFX Summary

- **Speed** 100 Mbps
- **Signal type** Baseband
- **Distance** Two kilometers between the hub and the node
- **Node limit** No more than 1024 nodes per hub
- **Topology** Star-bus topology: physical star, logical bus
- **Cable type** Uses multimode fiber cabling with ST or SC connectors



• **Figure 5.4** Half-duplex; sending at the top, receiving at the bottom

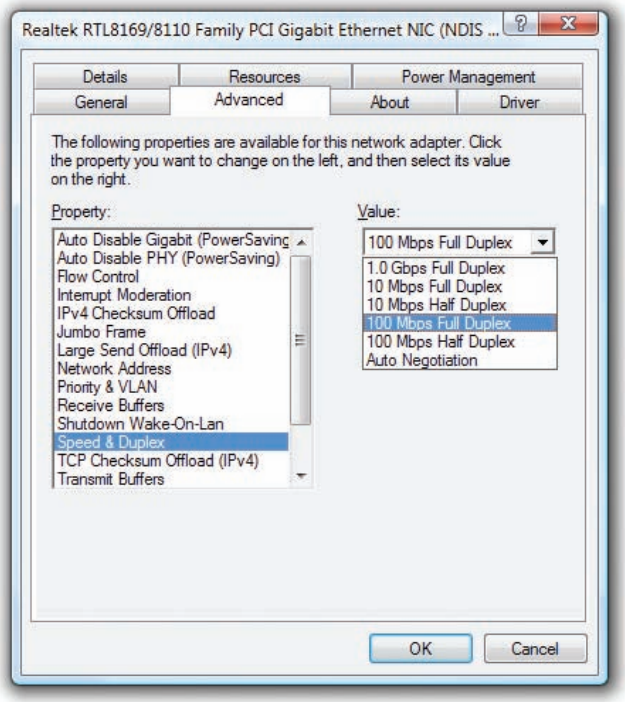


• **Figure 5.5** Full-duplex

Full-Duplex Ethernet

Early 100BaseT NICs, just like 10BaseT NICs, could send and receive data, but not at the same time—a feature called **half-duplex** (Figure 5.4). The IEEE addressed this characteristic shortly after adopting 100BaseT as a standard. By the late 1990s, most 100BaseT cards could auto-negotiate for full-duplex. With **full-duplex** a NIC can send and receive at the same time, as shown in Figure 5.5.

Almost all NICs today can go full-duplex. The NIC and the attached hub/switch determine full- or half-duplex during the auto-negotiation process. The vast majority of the time you simply let the NIC do its negotiation. Every operating system has some method to force the NIC to a certain speed/duplex, as shown in Figure 5.6.



• **Figure 5.6** Forcing speed and duplex in Windows Vista

Full-duplex doesn't increase the speed of the network, but it doubles the bandwidth. Image a one-lane road expanded to two lanes while keeping the speed limit the same.

Gigabit Ethernet

By the end of the 1990s, the true speed junkie needed an even more powerful version of Ethernet. In response, IEEE created **Gigabit Ethernet**, today the most common type of Ethernet found on new NICs.

The IEEE approved two different versions of Gigabit Ethernet. The most widely implemented solution, published under the IEEE **802.3ab** standard, is called **1000BaseT**. The other 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.

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

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

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

1000BaseCX

1000BaseCX uses a unique cable known as twinaxial cable (Figure 5.7). 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.

• **Figure 5.7** Twinaxial cable

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 220 to 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. 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.

Cross Check

SC and ST

You saw the common fiber-optic cable SC and ST connectors way back in Chapter 3, so cross-check your knowledge here. What distinguishes the two? Can 100BaseFX NICs use either one? Which do you need to twist, like a bayonet?

1000BaseLX

1000BaseLX is the long-distance carrier for Gigabit Ethernet. 1000BaseLX uses single-mode (laser) cables to shoot data at distances up to 5 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 connectors look like 1000BaseSX connectors.

Figure 5.8 MT-RJ connector

New Fiber Connectors

Around the time that Gigabit Ethernet first started 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 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 **Small Form Factor (SFF)** connectors. The first SFF connector—the **Mechanical Transfer Registered Jack (MT-RJ)**, shown in Figure 5.8—gained popularity with important companies like Cisco and is still quite common.

The second type of popular SFF connector is the **Local Connecter (LC)**, shown in Figure 5.9. LC-type connectors are very popular, particularly in the United States, and many fiber experts consider the LC-type connector to be the predominant fiber connector.

Figure 5.9 LC-type connector

Tech Tip

Implementing Multiple Types of Gigabit Ethernet

Because Ethernet packets don't vary among the many flavors of Ethernet, network hardware manufacturers have long built devices capable of supporting more than one flavor right out of the box. Ancient hubs supported 10Base2 and 10BaseT at the same time, for example.

The Gigabit Ethernet folks created a standard for modular ports called a gigabit interface converter (GBIC). With many Gigabit Ethernet switches and other hardware, you can simply pull out a GBIC module that supports one flavor of Gigabit Ethernet and plug in another. You can replace an RJ-45 port GBIC, for example, with an SC GBIC, and it'll work just fine. Electronically, the switch or other Gigabit device is just that—Gigabit Ethernet—so the physical connections don't matter. Ingenious!

LC and MT-RJ are the most popular types of SFF fiber connections, but many others exist, as outlined in Table 5.1. The fiber industry has no standard beyond ST and SC connectors, which means that different makers of fiber equipment may have different connections.

Table 5.1 Gigabit Ethernet Summary

Standard	Cabling	Cable Details	Connectors	Length
1000BaseCX	Copper	Twinax	Twinax	25 m
1000BaseSX	Multimode fiber	850 nm	Variable—LC is common	220–500 m
1000BaseLX	Single-mode fiber	1300 nm	Variable—LC, SC are common	5 km
1000BaseT	CAT 5e/6 UTP	Four-pair/full-duplex	RJ-45	100 m

10-Gigabit Ethernet

The ongoing demand for bandwidth on the Internet means that the networking industry is continually reaching for faster LAN speeds. **10-Gigabit Ethernet (10 GbE)** is showing up in high-level LANs, with the anticipation of trickle-down to the desktops in the near future.

Because 10 GbE is still a new technology, there are a large number of standards in existence. Over time many of these standards will certainly grow in popularity and some will disappear. For now, though, the landscape is in flux. 10 GbE has a number of fiber standards and two copper standards. 10 GbE was first and foremost designed with fiber optics in mind. As a result, it has only been since 2008 that 10-GbE copper products have actually (and very expensively) began to appear for sale.

Fiber-based 10 GbE

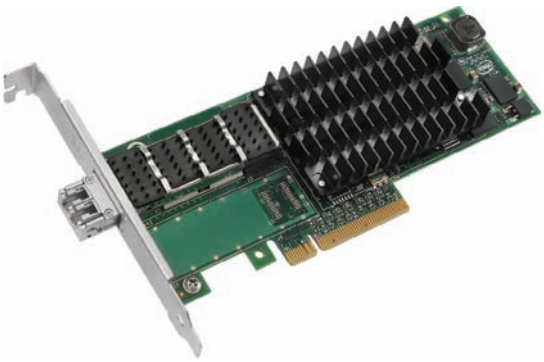
When the IEEE members sat down to formalize specifications on Ethernet running at 10 Gbps, they faced an interesting task in several ways. First, they had to maintain the integrity of the Ethernet frame. Data is king, after all, and the goal was to create a network that could interoperate with any other Ethernet network. Second, they had to figure out how to transfer those frames at such blazing speeds. This second challenge had some interesting ramifications because of two factors. They could use the traditional Physical layer mechanisms defined by the Ethernet standard. But, there was already in place a perfectly usable ~10-Gbps fiber network, called **SONET**, used for wide area networking (WAN) transmissions. What to do?

The IEEE created a whole set of 10-GbE standards that could use traditional LAN Physical layer mechanisms, plus a set of standards that could take advantage of the SONET infrastructure and run over the WAN fiber. To make the 10-Gbps jump as easy as possible, the IEEE also recognized the need for different networking situations. Some implementations need data transfers that can run long distances over single-mode fiber, for example, whereas others can make do with short-distance transfers over multimode fiber. This led to a lot of standards for 10 GbE.

The 10-GbE standards are defined by several factors: the type of fiber used, the wavelength of the laser or lasers, and the Physical layer signaling type. These factors also define the maximum signal distance.

There are proposed Ethernet standards that go way beyond 10-Gbps speeds, including a 100-GbE proposal, but nothing is fully standardized as of this writing. 10 GbE is the reigning king of network speeds.

Chapter 14, "Remote Connection Basics," covers SONET in great detail. For now just think of it as a data transmission standard that's different from the LAN Ethernet standard.



• **Figure 5.10** A 10GBaseSR NIC (photo courtesy of Intel Corporation)

The IEEE uses specific letter codes with the standards to help sort out the differences so that you know what you're implementing or supporting. All the standards have names in the following format: "10GBase" followed by two other characters, what I'll call *xy*. The *x* stands for the type of fiber (usually, though not officially) and the wavelength of the laser signal; the *y* stands for the Physical layer signaling standard. The *y* code is always either *R* for LAN-based signaling or *W* for SONET/WAN-based signaling. The *x* differs a little more, so let's take a look.

10GBaseS*y* uses a short-wavelength (850 nm) signal over multimode fiber. The maximum fiber length is 300 meters, although this will vary depending on the type of multimode fiber used. **10GBaseSR** (Figure 5.10) is used for Ethernet LANs and **10GBaseSW** is used to connect to SONET devices.

Standard	Fiber Type	Wavelength	Physical Layer Signaling	Maximum Signal Length
10GBaseSR	Multimode	850 nm	LAN	26–300 m
10GBaseSW	Multimode	850 nm	SONET/WAN	26–300 m

10GBaseL*y* uses a long-wavelength (1310 nm) signal over single-mode fiber. The maximum fiber length is 10 kilometers, although this will vary depending on the type of single-mode fiber used. **10GBaseLR** is used for Ethernet LANs and **10GBaseLW** is used to connect to SONET equipment. 10GBaseLR is the most popular and cheapest 10-GbE media type.

Standard	Fiber Type	Wavelength	Physical Layer Signaling	Maximum Signal Length
10GBaseLR	Single-mode	1310 nm	LAN	10 km
10GBaseLW	Single-mode	1310 nm	SONET/WAN	10 km

10GBaseE*y* uses an extra-long-wavelength (1550 nm) signal over single-mode fiber. The maximum fiber length is 40 kilometers, although this will vary depending on the type of single-mode fiber used. **10GBaseER** is used for Ethernet LANs and **10GBaseEW** is used to connect to SONET equipment.

Standard	Fiber Type	Wavelength	Physical Layer Signaling	Maximum Signal Length
10GBaseER	Single-mode	1550 nm	LAN	40 km
10GBaseEW	Single-mode	1550 nm	SONET/WAN	40 km

The 10-GbE fiber standards do not define the type of connector to use and instead leave that to manufacturers (see the upcoming section "10-GbE Physical Connections").

Copper-based 10 GbE

It took until 2006 for IEEE to come up with a standard for 10 GbE running UTP—called, predictably, 10GBaseT. **10GBaseT** looks and works exactly like the slower versions of UTP Ethernet. The only downside is that 10GBaseT running on CAT 6 has a maximum cable length of only 55 meters.

Table 5.2 10-GbE Summary

Standard	Cabling	Wavelength/ Cable Details	Connectors	Length
10GBaseSR /SW	Multimode fiber	850 nm	Not defined	26–300 m
10GBaseLR /LW	Single-mode fiber	1310 nm	Variable—LC is common	10 km
10GBaseER /EW	Single-mode fiber	1550 nm	Variable—LC, SC are common	40 km
10GBaseT	CAT 6/6a UTP	Four-pair/ full-duplex	RJ-45	55/100 m

The updated CAT 6a standard enables 10GBaseT to run at the standard distance of 100 meters. Table 5.2 summarizes the 10-GbE standards.

10-GbE Physical Connections

This hodgepodge of 10-GbE types might have been the ultimate disaster for hardware manufacturers. All types of 10 GbE 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 10-GbE industry simply chose not to define the connector types and devised a very clever, very simple concept called **multisource agreements (MSAs)**. An MSA is a modular transceiver that you plug into your 10-GbE 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 past few years. Figure 5.11 shows a typical MSA called XENPAK.

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

Backbones

The beauty and the challenge of the vast selection of Ethernet flavors is deciding which one to use in your network. The goal is to give your users as fast a network response time as possible, combined with keeping costs at a

• Figure 5.11 XENPAK MSA

Tech Tip

The Other 10-Gigabit Ethernet Fiber Standards

Manufacturers have shown in the early days of 10-GbE implementation a lot of creativity and innovation to take advantage of both existing fiber and the most cost-effective equipment. This has led to a variety of standards that are not covered by the CompTIA Network+ competencies, but that you should know about nevertheless. The top three as of this writing are 10GBaseL4, 10GBaseLRM, and 10GBaseZR.

The 10GBaseL4 standard uses four lasers at 1300-nanometer wavelength over legacy fiber. On FDDI-grade multimode cable, 10GBaseL4 can support up to 300-meter transmissions. The range increases to 10 kilometers over single-mode fiber.

The 10GBaseLRM standard uses the long wavelength signal of 10GBaseLR, but over legacy multimode fiber. The standard can achieve a range of up to 220 meters, depending on the grade of fiber cable.

Finally, some manufacturers have adopted the 10GBaseZR "standard," which isn't part of the IEEE standards at all (unlike 10GBaseL4 and 10GBaseLRM). Instead, the manufacturers have created their own set of specifications. 10GBaseZR networks use a 1550-nanometer wavelength over single-mode fiber to achieve a range of a whopping 80 kilometers. The standard can work with both Ethernet LAN and SONET/WAN infrastructure.

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

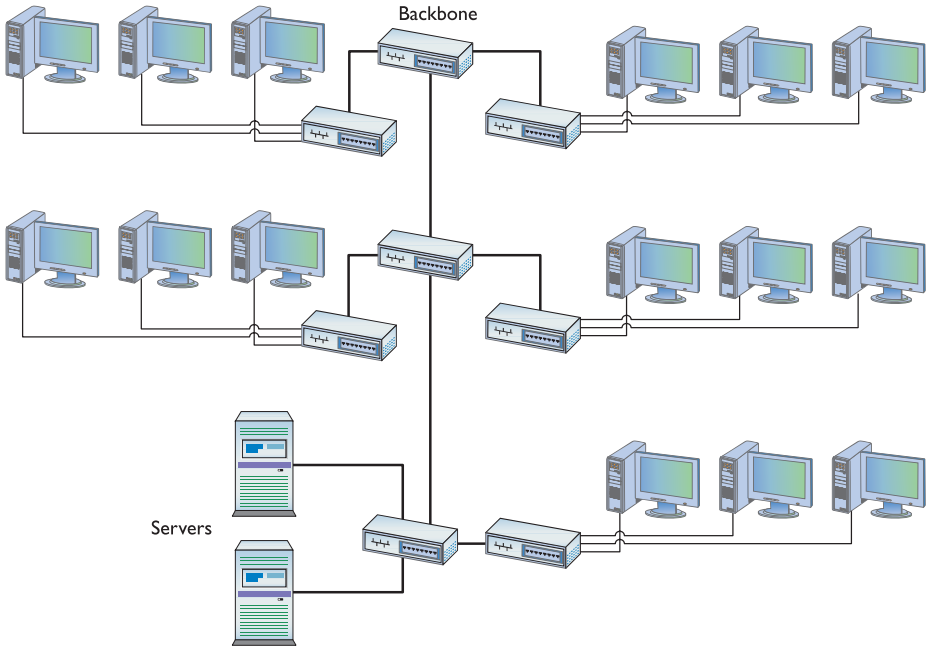


Figure 5.12 Typical network configuration showing backbone

reasonable level. To combine these two issues, most network administrators find that a multispeed Ethernet network works best. In a multispeed network, a series of high-speed (relative to the rest of the network) switches maintain a backbone network. No computers, other than possibly servers, attach directly to this backbone. Figure 5.12 shows a typical backbone network. Each floor has its own switch that connects to every node on the floor. In turn, each of these switches also has a separate high-speed connection to a main switch that resides in the computer room of the office.

In order to make this work, you need switches with separate, dedicated, high-speed ports like the ones shown in Figure 5.13. The add-on ports on the switches run straight to the high-speed backbone switch.

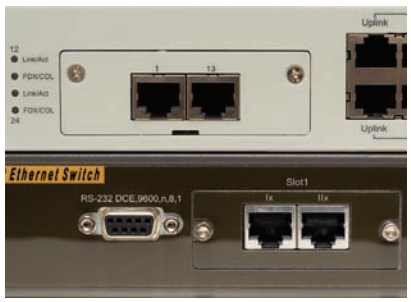


Figure 5.13 Switches with dedicated, high-speed add-on ports

Know Your Ethernets!

This single chapter is little more than a breakdown of the evolution of UTP Ethernet since the old 10BaseT standard. Make sure you know the details of these Ethernet versions and take advantage of the summaries and tables to recognize the important points of each type.

Additionally, keep in mind that you've only just begun to delve into the world of switching. The book has covered thus far only the functions of a basic switch. There is a lot more to see in terms of the capabilities of these powerful devices, but you first need to understand networking a bit deeper.

Try This!

Shopping for Switches

Cisco, one of the industry leaders for Ethernet switches, has a great Web site for its products. Imagine that you are setting up a network for your school or business (keep it simple and pick a single building if you're in a large organization). Decide what type of switches you'd like to use, including both the backbone and local switches. If you're really motivated, decide where to physically locate the switches. Don't be afraid to try a fiber backbone—almost every Cisco switch comes with special ports to enable you to pick the type of Ethernet you want to use for your backbone.

Chapter 5 Review

Chapter Summary

After reading this chapter and completing the exercises, you should understand the following about Ethernet.

Describe 100-Megabit Ethernet

- Fast Ethernet includes two UTP variations, both arranged in a physical star, but operating in a logical bus—100BaseTX and 100BaseT4.
- In 100BaseTX Ethernet cabling systems, speeds are 100 Mbps, wires are twisted copper pairs, signals are baseband, and distance is limited to 100 meters from the node to the hub, with a limit of 1024 ports per hub. The cabling used must be CAT 5e UTP crimped with RJ-45 connectors.
- In 100BaseT4 Ethernet cabling systems, speeds are 100 Mbps, wires are twisted copper pairs, signals are baseband, and distance is limited to 100 meters from the node to the hub, with a limit of 1024 ports per hub. The cabling used is CAT 3 UTP with RJ-45 connectors. The main difference from 100BaseTX is that all four pairs of wires are used in data transmission.
- Limitations of Fast Ethernet over UTP include distance (only 100 meters), inadequate shielding for some installations, and relative ease of intruder break-ins on the physical cable.
- The fiber-optic variation of Fast Ethernet, 100BaseFX, overcomes these limitations, offering immunity to electrical interference and a range of up to two kilometers from node to hub.
- A half-duplex NIC can only send or receive at any one time. Full-duplex NICs can send and receive at the same time, thereby doubling the bandwidth (but not the speed).

Explain Gigabit Ethernet

- There are two Gigabit Ethernet standards approved by the IEEE: 802.z (1000BaseX) and 802.3ab (1000BaseT).
- 1000BaseT uses four-pair UTP cabling and has a maximum length of 100 meters.
- 1000BaseX is divided into a number of standards: 1000BaseCX, 1000BaseSX, and 1000BaseLX.
- 1000BaseCX uses twinaxial cable with a maximum length of 25 meters.
- 1000BaseSX uses multimode fiber-optic cable with a maximum length between 220 and 500 meters, depending on the manufacturer.
- 1000BaseLX uses single-mode fiber-optic cable with a maximum length of 5 kilometers. Some manufacturers use repeaters to extend the maximum length to 70 kilometers.
- The Small Form Factor (SFF) fiber connector includes the Mechanical Transfer Registered Jack (MT-RJ) and the Local Connector (LC), both of which were created to overcome problems with the ST and SC connectors.

Describe 10-Gigabit Ethernet

- 10-Gigabit Ethernet (10 GbE) has several fiber standards and two copper standards. Copper products have only recently become available.
- SONET is the networking standard for long-distance optical connections that serve as the main backbone for the Internet.
- 10 GbE is organized into six different standards: 10GBaseSR, 10GBaseSW, 10GBaseLR, 10GBaseLW, 10GBaseER, and 10GBaseEW.
- 10GBaseS*y* uses multimode fiber with a maximum length of 300 meters. 10GBaseLR is used for Ethernet LANs while 10GBaseSW is used to connect to SONET devices.
- 10GBaseL*y* uses single-mode fiber with a maximum length of 10 kilometers. 10GBaseLR is for Ethernet LANs while 10GBaseLW is used to connect to SONET devices. 10GBaseLR is the most popular and cheapest 10-GbE media type.
- 10GBaseE*y* uses single-mode fiber with a maximum length of 40 kilometers. 10GBaseER is used for Ethernet LANs while 10GBaseEW is used to connect to SONET devices.
- 10GBaseT defines 10-Gigabit Ethernet over UTP cable. It is capable of a maximum distance of 55 meters with CAT 6, while using CAT 6a can achieve 100 meters.

- All types of 10 GbE send and receive the exact same signal. Network devices, such as routers, that need to support different 10-GbE cable types use multisource agreements to enable different cable types to connect.

Key Terms

10GBaseER *(88)*
10GBaseEW *(88)*
10GBaseLR *(88)*
10GBaseLW *(88)*
10GBaseSR *(88)*
10GBaseSW *(88)*
10GBaseT *(88)*
10-Gigabit Ethernet (10 GbE) *(87)*
100BaseFX *(83)*
100BaseT *(81)*
100BaseT4 *(81)*
100BaseTX *(81)*
1000BaseCX *(85)*
1000BaseLX *(85)*
1000BaseSX *(85)*
1000BaseT *(85)*
1000BaseX *(85)*
802.3ab *(85)*
802.3z *(85)*
Fast Ethernet *(81)*
full-duplex *(84)*
Gigabit Ethernet *(85)*
half-duplex *(84)*
Local Connector (LC) *(86)*
Mechanical Transfer Registered Jack (MT-RJ) *(86)*
multisource agreements (MSAs) *(89)*
Small Form Factor (SFF) *(86)*
SONET *(87)*

Key Term Quiz

Use the Key Terms list to complete the sentences that follow. Not all terms will be used.

1. When a network device can both send and receive data at the same time, it is said to be _____.
2. _____ has a maximum cable length of two kilometers and uses multimode fiber with ST or SC connectors.
3. 100BaseT is also known as _____.
4. _____ can use CAT 3 but _____ must use CAT 5 or better.
5. 802.3z and 802.3ab are both _____ standards.
6. _____ supports the longest maximum distance for Gigabit Ethernet.
7. The _____ and _____ IEEE standards support the longest maximum distance for 10-Gigabit Ethernet.
8. Many fiber experts consider the _____ connector to be the predominant fiber connector.
9. _____ is the cheapest and most popular 10-GbE media type.
10. Routers with _____ can accept a variety of 10-GbE media types.

Multiple-Choice Quiz

1. Which of the following are 100BaseT cable types? (Select three)
   - **A.** CAT 3
   - **B.** CAT 5
   - **C.** CAT 5e
   - **D.** 10BaseFL
2. What is the physical limit for the number of ports on an Ethernet hub?
   - **A.** 24
   - **B.** 256
   - **C.** 512
   - **D.** 1024

3. When a network device can only send data or receive data, but not both at the same time, it is operating in what mode?
   - **A.** Duplex
   - **B.** Full-duplex
   - **C.** Half-duplex
   - **D.** Halfplex
4. What important backbone technology is also known as Gigabit Ethernet?
   - **A.** 100BaseT
   - **B.** 100BaseFL
   - **C.** 100BaseFX
   - **D.** 1000BaseT
5. What are the two major UTP variations of Fast Ethernet?
   - **A.** 100BaseTL
   - **B.** 100BaseTX
   - **C.** 100BaseFL
   - **D.** 100BaseT4
6. What are three limitations of Fast Ethernet over UTP?
   - **A.** Distance is restricted to 100 meters from node to hub.
   - **B.** Shielding may be inadequate for some installations.
   - **C.** Intrusion from outsiders may be possible without detection.
   - **D.** The obsolete technology is insufficient for most networks.
7. Which standard defines Fast Ethernet using fiber cabling?
   - **A.** 10BaseFL
   - **B.** 100BaseFX
   - **C.** 100BaseT4
   - **D.** 100BaseTX
8. Which of the following are fiber connector types? (Select three)
   - **A.** LC
   - **B.** LS
   - **C.** MT-RJ
   - **D.** ST
9. What do you need to connect varying 10-GbE cable types to the same router?
   - **A.** SFF connectors on all cables
   - **B.** SC connectors on all cables
   - **C.** Multisource agreements on the router
   - **D.** This is not possible.
10. Which standard defines Gigabit Ethernet over UTP copper wire?
    - **A.** 802.3ab
    - **B.** 802.3e
    - **C.** 802.3GbUTP
    - **D.** 802.3z
11. You've lost the manual to your router. How can you tell the difference between a 1000BaseT port and a 100BaseT port on a router just by looking?
    - **A.** The 1000BaseT ports are noticeably larger.
    - **B.** The 100BaseT ports are green while the 1000BaseT ports are gray.
    - **C.** 1000BaseT ports are reversed with the clip on the top.
    - **D.** You can't tell the difference by looking. They look exactly the same.
12. Which statement about Ethernet is correct?
    - **A.** Only 10- and 100-megabit Ethernet may use a hub. Gigabit Ethernet must use a switch.
    - **B.** 10- and 100-megabit Ethernet has a limit of 1024 nodes. Gigabit Ethernet has no limit.
    - **C.** Gigabit Ethernet that uses UTP cabling has a maximum distance between the node and switch of 250–400 meters, depending on the manufacturer.
    - **D.** All versions of 10-Gigabit Ethernet use the same cabling.
13. What will happen if you connect a 10BaseT NIC to an auto-sensing switch?
    - **A.** The switch will operate in hub mode.
    - **B.** The entire switch will operate at 10 megabits, even if there are 100-megabit devices attached.
    - **C.** The 10BaseT NIC will operate at 10 megabits while connected 100-megabit devices will operate at their full speed of 100 megabits.
    - **D.** The 10BaseT NIC will overclock to run at 100 megabits.

14. What benefit does full-duplex offer?
    - **A.** It allows all NICs on a hub to send signals at the same time without collisions.
    - **B.** It doubles the bandwidth of the network.
    - **C.** It doubles the speed of the network.
    - **D.** It doubles both the bandwidth and the speed of the network.
15. What is the difference between the *R* and *W* designations in 10GBase standards? For example, 10GBaseLR and 10GBaseLW, or 10GBaseER and 10GBaseEW?
    - **A.** The *R* indicates "regular," or half-duplex. The *W* indicates "wide mode," the 10-Gigabit Ethernet version of full-duplex.
    - **B.** The *R* indicates "read," or the ability to receive signals, while the *W* indicates "write," or the ability to send signals.
    - **C.** The *R* and *W* indicate differences in the circuitry, with the *W* versions used to connect to SONET equipment.
    - **D.** The *R* indicates the use of UTP while the *W* indicates the use of fiber optics.

Essay Quiz

1. Which types of computer network cable connections are you familiar with already? Write a short paragraph describing your experience.
2. Your manager has just informed you that several departments at your company will be switching over to fiber-optic NICs. How many and what type of connectors will be needed for each node on the new segment? Document your recommendations.
3. Compose a letter to the network administrator of a nearby telecommunications company or ISP (Internet service provider). Introduce yourself in the top part of the letter as a networking student. Then ask if the company ever gives tours or holds open houses for the public. Close the letter by thanking the person reading it for their time. Spell-check and have others proofread your letter. Consider mailing the letter if you are serious about your visit and your instructor approves your final copy.
4. Prepare a list of questions you would ask a large organization's network administrator regarding cabling, connections, hubs, switches, and even routers. Use the situation described in Essay 3 to help you create your list of questions.
5. Prepare a thank-you note in advance for having been allowed to participate in a tour, as described in Essay 3. Mention some of the items you observed during the visit. If you would be interested in seeking employment at their facility, consider mentioning that and asking about the steps you would need to take to prepare for such a position. Sometimes a simple thank-you note can help land a job!

Lab Projects

• Lab Project 5.1

Find a hub or switch at your school or company. Examine the wiring closely to determine what cable connections it uses. Try to determine whether the cabling was placed neatly and in an organized manner, whether the ports are clearly labeled, and whether all the ends were crimped well. Be prepared to discuss your findings with the rest of the class.

• Lab Project 5.2

Use the Internet to research prices to order 100 each of the connectors from the following list. Don't forget to include basic shipping and handling to your organization's location, as these would be a price factor in real life.

- RJ-45 connectors
- SC connectors
- ST connectors
- MT-RJ connectors
- LC connectors

From your research, which connectors would be the least costly?

• Lab Project 5.3

All these standards! How can you remember them?

Make a chart that compares the features (cabling, connectors, data throughput, and so on) of the following Ethernet technologies:

- 10BaseT
- 10BaseFL
- 100BaseTX
- 100BaseFX
- 1000BaseT
- 1000BaseCX
- 1000BaseLX
- 1000BaseSX
- 10GBaseSR/10GBaseSW
- 10GBaseLR/10GBaseLW
- 10GBaseER/10GBaseEW