Upon completion of this chapter, you will be able to perform the following tasks:

- Describe the primary types of network cabling, including shielded and unshielded twisted-pair, coaxial, fiber optics (multimode and single-mode), and wireless communications
- Describe types and characteristics of cabling and connectors used in an Ethernet LAN
- Describe the necessary components for enabling WAN connectivity over serial or ISDN BRI, local loop using DSL, and a cable connection for a Cisco router

CHAPTER 4

Network Media (The Physical Layer)

This chapter examines several types of network media, including twisted-pair cable, coaxial cable, fiber-optic cable, and wireless. It highlights the concepts and procedures for assembling and cabling Cisco routers. This chapter also covers cabling and connectors used to interconnect switches and routers in a LAN or WAN. Finally, it presents factors that you should consider when selecting network devices.

Cabling and Infrastructure

Media is the actual physical environment through which data travels as it moves from one component to another, and it connects network devices. The most common types of network media are twisted-pair cable, coaxial cable, fiber-optic cable, and wireless. Each media type has specific capabilities and serves specific purposes.

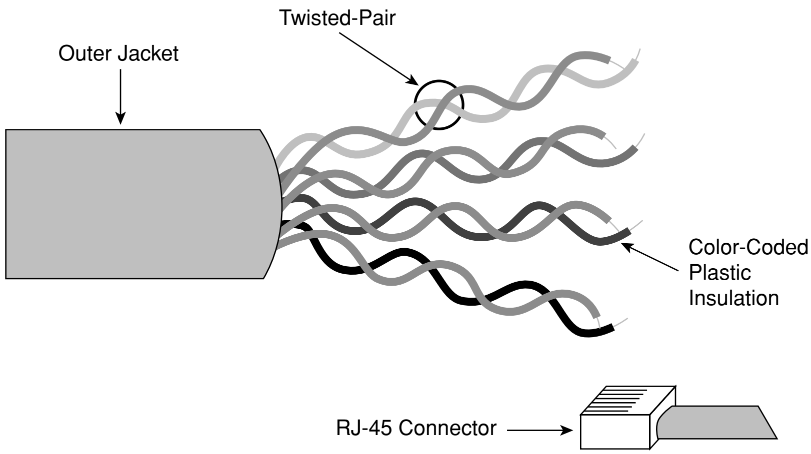
Understanding the types of connections that can be used within a network provides a better understanding of how networks function in transmitting data from one point to another.

Twisted-Pair Cable

Twisted-pair is a copper wire-based cable that can be either shielded or unshielded. Twisted-pair is the most common media for network connectivity.

Unshielded twisted-pair (UTP) cable, as shown in Figure 4-1, is a four-pair wire. Each of the eight individual copper wires in UTP cable is covered by an insulating material. In addition, the wires in each pair are twisted around each other. The advantage of UTP cable is its ability to cancel interference, because the twisted-wire pairs limit signal degradation from electromagnetic interference (EMI) and radio frequency interference (RFI). To further reduce crosstalk between the pairs in UTP cable, the number of twists in the wire pairs varies. UTP, as well as shielded twisted-pair (STP) cable, must follow precise specifications as to how many twists or braids are permitted per meter.

Figure 4-1 *Unshielded Twisted-Pair Cable*



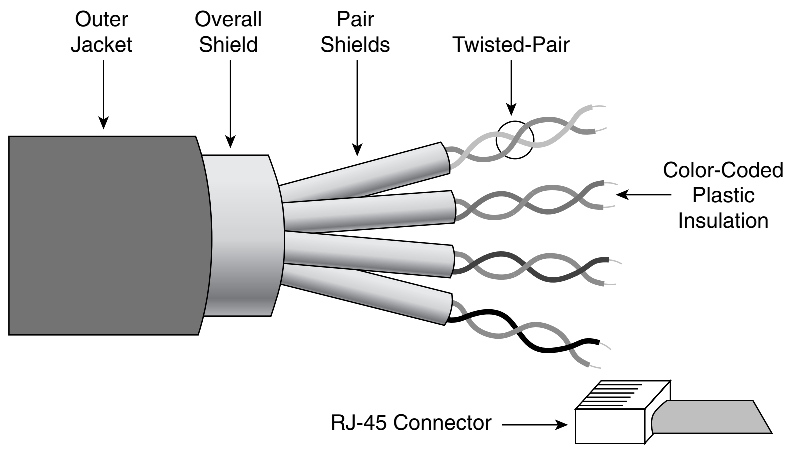
UTP cable is used in a variety of networks. When used as a networking medium, UTP cable has four pairs of either 22- or 24-gauge copper wire. UTP used as a networking medium has an impedance of 100 ohms, differentiating it from other types of twisted-pair wiring such as that used for telephone wiring. Because UTP cable has an external diameter of approximately 0.43 cm (0.17 inches), its small size can be advantageous during installation. Also, because UTP can be used with most of the major networking architectures, it continues to grow in popularity.

Several categories of UTP cable exist:

- **Category 1**—Used for telephone communications; not suitable for transmitting data
- **Category 2**—Capable of transmitting data at speeds of up to 4 Mbps
- **Category 3**—Used in 10BASE-T networks; can transmit data at speeds up to 10 Mbps
- **Category 4**—Used in Token Ring networks; can transmit data at speeds up to 16 Mbps
- **Category 5**—Capable of transmitting data at speeds up to 100 Mbps
- **Category 5e**—Used in networks running at speeds up to 1000 Mbps (1 Gbps)
- **Category 6**—Consists of four pairs of 24-gauge copper wires that can transmit data at speeds up to 1000 Mbps

Shielded twisted-pair (STP) cable, as shown in Figure 4-2, combines the techniques of shielding and the twisting of wires to further protect against signal degradation. Each pair of wires is wrapped in a metallic foil. The four pairs of wires are then wrapped in an overall metallic braid or foil, usually 150-ohm cable. Specified for use in Ethernet network installations, STP reduces electrical noise both within the cable (pair-to-pair coupling, or crosstalk) and from outside the cable (EMI and RFI). Token Ring network topology uses STP.

Figure 4-2 *Shielded Twisted-Pair Cable*



When you consider using UTP and STP for your network media, consider the following:

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

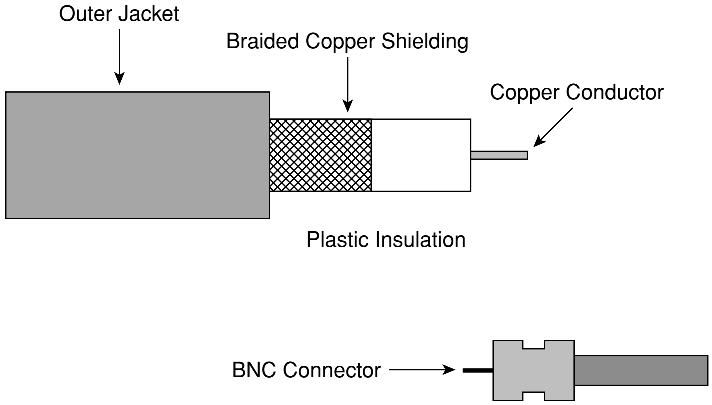
Twisted-pair cabling is the most common networking cabling in use today; however, some networks still use older technologies like coaxial cable, as discussed in the next section.

Coaxial Cable

Coaxial cable consists of a hollow outer cylindrical conductor that surrounds a single inner wire conducting element. This section describes the characteristics and uses of coaxial cable.

As shown in Figure 4-3, the single inner wire located in the center of a coaxial cable is a copper conductor, surrounded by a layer of flexible insulation. Over this insulating material is a woven copper braid or metallic foil that acts both as the second wire in the circuit and as a shield for the inner conductor. This second layer, or shield, can help reduce the amount of outside interference. An outer jacket covers this shield. The BNC connector shown looks much like a cable-television connector and connects to an older NIC with a BNC interface.

Figure 4-3 *Coaxial Cable*



Coaxial cable supports 10 to 100 Mbps and is relatively inexpensive, although more costly than UTP. Coaxial cable can be laid over longer distances than twisted-pair cable. For example, Ethernet can run approximately 100 meters using twisted-pair cable, but 500 meters using coaxial cable.

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

When you work with cable, consider its size. As the thickness, or diameter, of the cable increases, so does the difficulty in working with it. Cable must often be pulled through existing conduits and troughs that are limited in size. Coaxial cable comes in a variety of sizes. The largest diameter, frequently referred to as *Thicknet*, was specified for use as Ethernet backbone cable because historically it had greater transmission length and noise rejection characteristics. However, Thicknet cable can be too rigid to install easily in some environments because of its thickness. Generally, the more difficult the network media is to install, the more expensive it is to install. Coaxial cable is more expensive to install than twisted-pair cable, and Thicknet cable is almost never used except for special-purpose installations, where shielding from EMI or distance requires the use of such cables.

In the past, coaxial cable with an outside diameter of only 0.35 cm, sometimes referred to as *Thinnet*, was used in Ethernet networks. It was especially useful for cable installations that required the cable to make many twists and turns. Because Thinnet was easier to install, it was also cheaper to install. Thus, it was also referred to as *Cheapernet*. However, because the outer copper or metallic braid in coaxial cable comprised half the electrical circuit, special care needed to be taken to ground it properly, by ensuring that a solid electrical connection existed at both ends of the cable. Installers frequently failed to make a good connection. Connection problems resulted in electrical noise, which interfered with signal transmission. For this reason, despite its small diameter, Thinnet is no longer commonly used in Ethernet networks.

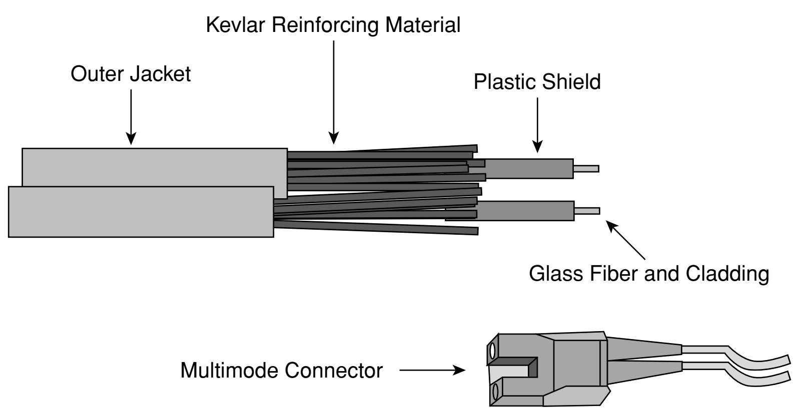
Although coaxial cable offers some distance advantages over twisted-pair, the disadvantages far outweigh the benefits. If a communications signal needs to travel a greater distance at high rates of speed, it is more common to use fiber-optic cable.

Fiber-Optic Cable

Fiber-optic cable is a networking medium capable of conducting modulated light transmission. This section describes the types, characteristics, and uses of fiber-optic cable.

Fiber-optic cable used for networking consists of two fibers encased in separate sheaths. Viewing it in cross section in Figure 4-4, you can see that each optical fiber is surrounded by layers of protective buffer material: usually a plastic shield, then a plastic such as Kevlar, and finally, an outer jacket that provides protection for the entire cable. The plastic conforms to appropriate fire and building codes. The purpose of the Kevlar is to furnish additional cushioning and protection for the fragile, hair-thin glass fibers. Where buried fiber-optic cables are required by codes, a stainless steel wire is sometimes included for added strength. Several connectors can connect fiber to the networking device; the most common is a SC connector, which has two optics, one connecting to transmit and the other connecting to receive.

Figure 4-4 *Fiber-Optic Cable*



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

Fiber-optic cable does not carry electrical impulses as copper wire does. Instead, signals that represent bits are converted into pulses of light. Two types of fiber-optic cable exist:

- **Single-mode**—Single-mode fiber-optic cable allows only one mode (or wavelength) of light to propagate through the fiber. This type of cable is capable of higher bandwidth and greater distances than multimode and is often used for campus backbones. Single-mode cable uses lasers as the light-generating method and is more expensive than multimode cable. The maximum cable length of single-mode cable is 60+ km (37+ miles).
- **Multimode**—Multimode fiber-optic cable allows multiple modes of light to propagate through the fiber. Multimode cable is often used for workgroup applications, using light emitting diodes (LEDs) as light-generating devices. The maximum length of multimode cable is 2 km (1.2 miles).

The characteristics of the different media have a significant impact on the speed of data transfer. Although fiber-optic cable is more expensive, it is not susceptible to EMI and is capable of higher data rates than any of the other types of networking media discussed here. Fiber-optic cable is also more secure because it does not emit electrical signals that could be received by external devices.

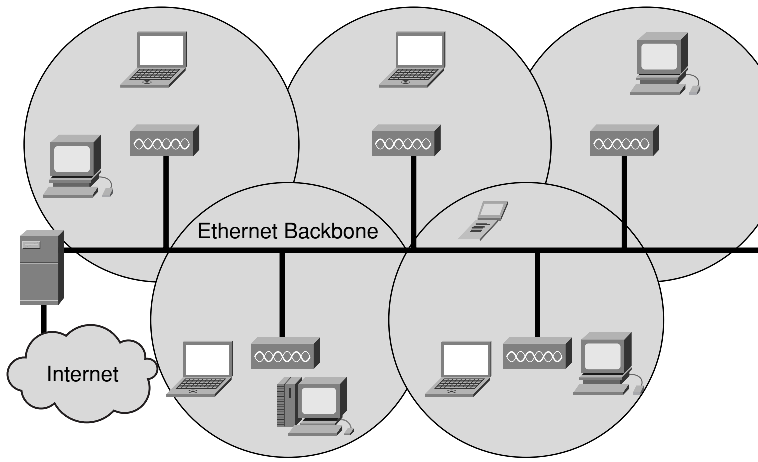
NOTE Even though light is an electromagnetic wave, light in fibers is not considered wireless because the electromagnetic waves are guided in the optical fiber. The term *wireless* is reserved for radiated, or unguided, electromagnetic waves.

In some instances, it might not be possible to run any type of cable for network communications. This situation might be the case in a rented facility or in a location where you do not have the ability to install the appropriate infrastructure. In these cases, it might be useful to install a wireless network, as discussed in the next section.

Wireless Communications

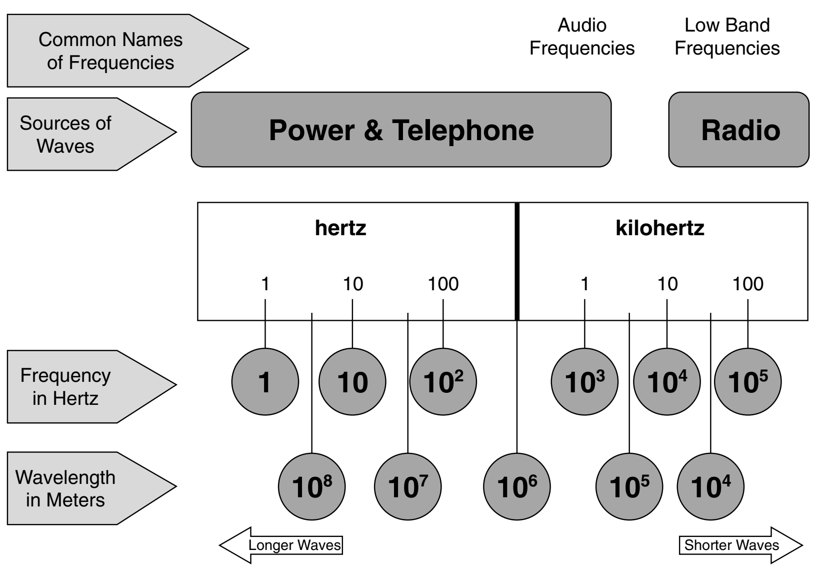
Wireless networks are becoming increasingly popular, and they utilize a different type of technology. Wireless communication uses radio frequencies (RFs) or infrared waves to transmit data between devices on a LAN. For wireless LANs, a key component is the wireless hub, or access point, used for signal distribution. To receive the signals from the access point, a PC or laptop needs to install a wireless adapter card, or wireless network interface card (NIC). Figure 4-5 shows a number of wireless access points connected to an Ethernet backbone to provide access to the Internet.

Figure 4-5 *Wireless Access Points*



Wireless signals are electromagnetic waves that can travel through the vacuum of outer space and through a medium such as air. No physical medium is necessary for wireless signals, making them a versatile way to build a network. They use portions of the RF spectrum to transmit voice, video, and data. Wireless frequencies range from 3 kHz to 300 GHz. The data-transmission rates range from 9 kbps to 54 Mbps. Figure 4-6 shows the electromagnetic spectrum chart.

Figure 4-6 *Electromagnetic Spectrum*



You can differentiate electromagnetic waves by their frequency. Low-frequency electromagnetic waves have a long wavelength (the distance from one peak to the next on the sine wave), while high-frequency electromagnetic waves have a short wavelength.

Some common applications of wireless data communication include the following:

- Accessing the Internet using a cellular phone
- Home or business Internet connection over satellite
- Beaming data between two handheld computing devices
- Wireless keyboard and mouse for the PC

Another common application of wireless data communication is the wireless LAN (WLAN), which is built in accordance with Institute of Electrical and Electronic Engineers (IEEE) 802.11 standards. WLANs typically use radio waves (for example, 902 MHz), microwaves (for example, 2.4 GHz), and infrared (IR) waves (for example, 820 nm) for communication. Wireless technologies are a crucial part of the future of networking.

Comparing Media Types

The choice of media type affects the type of network interface cards installed, the speed of the network, and the ability of the network to meet future needs. Table 4-1 compares the features of the common network media, including UTP, STP, coaxial cable, fiber-optic, and wireless connections.

Table 4-1 *Comparing Media Types*

Media Type	Maximum Segment Length	Speed	Comparative Cost	Advantages	Disadvantages
UTP	100 meters	10 Mbps 100 Mbps	Least expensive	Easy to install, widely available, widely used	Susceptible to interference; can cover only a limited distance
STP	100 meters	10–100 Mbps	More expensive than UTP	Reduced crosstalk, less susceptible to EMI than UTP or Thinnet	Difficult to work with; can cover only a limited distance
Coaxial	500 meters (Thicknet) 185 meters (Thinnet)	10–100 Mbps	Relatively inexpensive, but more costly than UTP	Less susceptible to EMI than other types of copper media	Difficult to work with (Thicknet); limited bandwidth; limited application (Thinnet); damage to cable can bring down entire network

Table 4-1 *Comparing Media Types (Continued)*

Media Type	Maximum Segment Length	Speed	Comparative Cost	Advantages	Disadvantages
Coaxial	500 meters (Thicknet) 185 meters (Thinnet)	10–100 Mbps	Relatively inexpensive, but more costly than UTP	Less susceptible to EMI than other types of copper media	Difficult to work with (Thicknet); limited bandwidth; limited application (Thinnet); damage to cable can bring down entire network
Fiber-optic	3 km and further (single-mode) 2 km and further (multimode)	10–1000 Mbps (single-mode) 100 Mbps–9.92 Gbps (multimode)	Expensive	Cannot be tapped easily, so security is better; can be used over great distances; not susceptible to EMI; higher data rate than coaxial and twisted-pair	Difficult to terminate
Wireless	50 km—global	1–54 Mbps	Expensive	Does not require installation of media	Susceptible to atmospheric conditions

The media you choose has an important impact on the network's capabilities. You should consider all the factors before making your final selection.

Cabling and Infrastructure Section Quiz

Use these practice questions to review what you learned in this section.

1 What is the maximum cable length for STP?

A 100 ft

B 150 ft

C 100 m

D 1000 m

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

A It is capable of achieving 10 to 100 Mbps.

B It is inexpensive.

C It can run for a longer distance unboosted.

D All of the above.

3 A ________ fiber-optic cable transmits multiple streams of LED-generated light.

A Multimode

B Multichannel

C Multiphase

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

A Radio frequencies

B LED-generated light

C Fiber optics

D None of the above

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

A It is inexpensive.

B It is easy to install.

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

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

Choosing LAN Cabling Options

Several types of cables and connectors can be used in LANs, depending on the requirements for the network and the type of Ethernet to be implemented. These connectors also vary depending on the type of media that you have installed.

Learning about the different types of cables and connectors in an Ethernet LAN and their various functions can help you understand more about how a LAN works.

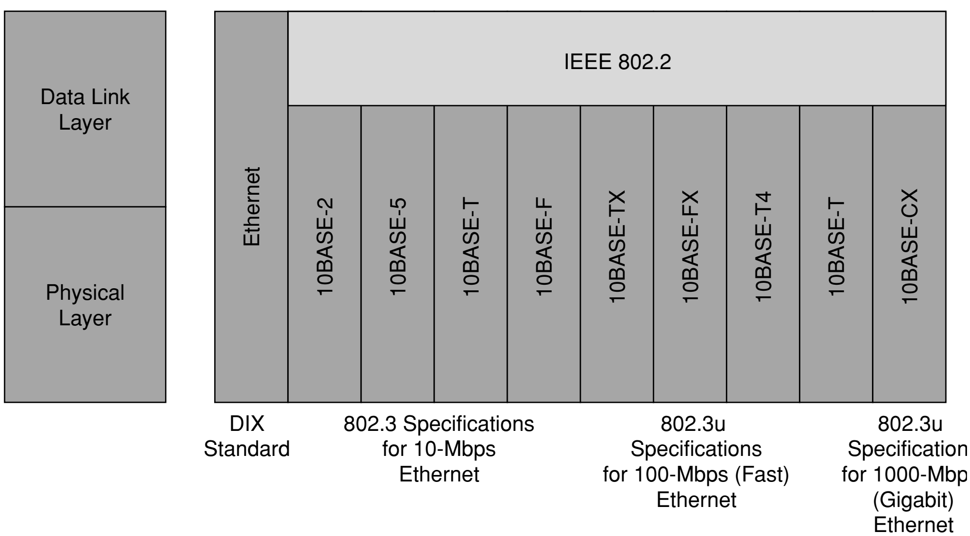
LAN Physical Layer

Ethernet is the most widely used LAN technology. Since its initial implementation, Ethernet has been extended to four new types:

- 802.3u (Fast Ethernet)
- 802.3z (Gigabit Ethernet over Fiber)
- 802.3ab (Gigabit Ethernet over UTP)
- 802.3ae (10 Gigabit Ethernet)

The cabling aspects of the LAN exist at Layer 1 of the Open System Interconnection (OSI) reference model. Figure 4-7 shows a subset of physical layer implementations that can be deployed to support Ethernet.

Figure 4-7 *Ethernet at the Physical Layer*



Ethernet in the Campus

Before implementing a network, you need to determine the requirements for the network. You can remember a few common recommendations on how various Ethernet technologies can be used in a campus network environment.

In many modern installations, infrastructure costs for cabling and adapters can be high. Using the appropriate Ethernet connectivity provides the necessary speed for the parts of the network that require it while controlling costs.

In general, you can use Ethernet technologies in a campus network in several different ways:

- An Ethernet speed of 10 Mbps can be used at the access layer to provide adequate performance for most users. In addition, 100-Mbps Fast Ethernet can be used for high-bandwidth-consuming clients or servers.
- Gigabit Ethernet is typically used as the link between the access layer and network devices, supporting the aggregate traffic from each Ethernet segment on the access link.
- To enhance client-server performance across the campus network and avoid bottlenecks at the server, Fast Ethernet or Gigabit Ethernet links can be used to connect enterprise servers. Gigabit Ethernet, in combination with switched Fast Ethernet, creates an effective solution for avoiding slow networks.
- Gigabit Ethernet links can provide the connection between the distribution layer and the core. Because the campus network model supports dual links between each distribution layer router and core switch, you can load balance the aggregate traffic from multiple-access switches across the links.
- Gigabit Ethernet (or 10 Gigabit Ethernet) should be used between switches and the backbone. The fastest affordable media should be implemented between backbone switches.

Table 4-2 outlines the recommendations for Ethernet deployment.

Table 4-2 *Ethernet Connectivity Recommendations*

Network Hierarchy Layer	Ethernet 10 Mbps	Fast Ethernet 100 Mbps	Gigabit Ethernet 1000 Mbps	10 Gigabit Ethernet 10000 Mbps
Access layer	Connects users with low to moderate bandwidth requirements	Connects users with high-speed requirements or servers with low to moderate usage	Connects servers with high usage	Not currently recommended at this layer
Distribution layer	Not recommended at this layer	Connects routers and switches with moderate usage	Interconnects access switches with Fast Ethernet users and used to connect distribution switches to core layer	Not currently recommended at this layer
Core layer	Not recommended at this layer	Not recommended at this layer	Interconnects core switches in networks with moderate use	Interconnects core switches with high usage

NOTE Currently, some organizations are considering providing Gigabit Ethernet to the end user; however, not many applications can take full advantage of this infrastructure, and providing Gigabit Ethernet to the end user can potentially create a bottleneck between network devices. You should consider this carefully before installing gigabit technology to the end users.

Ethernet Media and Connector Requirements

In addition to considering the requirements for the Ethernet LAN, the media and connector requirements for each implementation must be considered. This topic outlines the cable and connector specifications used to support Ethernet implementations.

The cable and connector specifications used to support Ethernet implementations are derived from the Electronic Industries Alliance and (newer) Telecommunications Industry Alliance (EIA/TIA) standards body. The categories of cabling defined for Ethernet are derived from the EIA/TIA-568 (SP-2840) Commercial Building Telecommunications Wiring Standards. EIA/TIA specifies an RJ-45 connector for UTP cable. The letters *RJ* stand for *registered jack*, and the number *45* refers to a specific physical connector that has eight conductors.

Table 4-3 compares the cable and connector specifications for the most popular Ethernet implementations.

The important difference to note is the media used for 10-Mbps Ethernet versus 100-Mbps Ethernet. In today's networks, in which you see a mix of 10- and 100-Mbps requirements, you must be aware of the need to change over to UTP Category 5 to support Fast Ethernet.

Connection Media

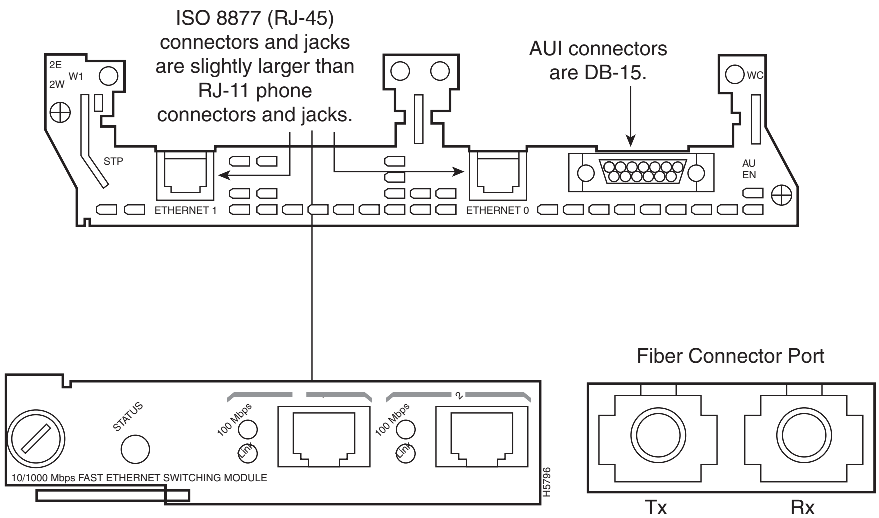
Several connection media can be used in an Ethernet LAN implementation. Figure 4-8 illustrates different connection types—attachment unit interface (AUI), RJ-45, and gigabit—used by each physical layer implementation. The RJ-45 connector and jack are the most prevalent. RJ-45 connectors are discussed in more detail later in this chapter.

In some cases, the type of connector on a NIC does not match the type of media that it needs to connect to. As shown in Figure 4-8, an interface exists for the AUI connector on many Cisco devices. The AUI is the 15-pin physical connector interface between a computer's NIC and coaxial Ethernet cable.

Table 4-3 *TCable and Connector Specifications*

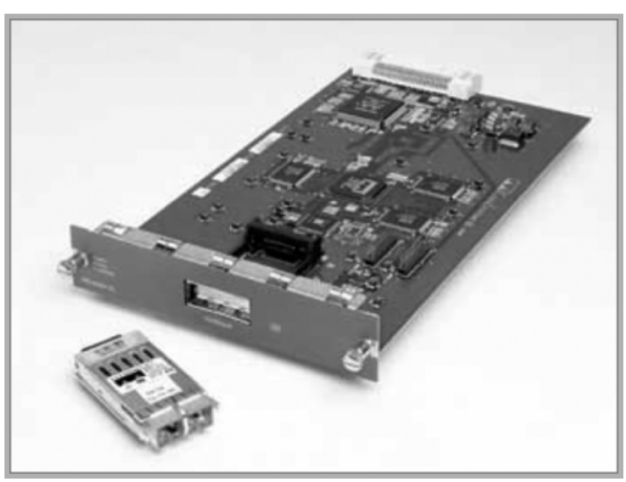
	10BASE-2	10BASE-5	10BASE-T	100BASE-TX	100BASE-FX	1000 BASE-CX	1000 BASE-T	1000 BASE-SX	1000 BASE-LX
Media	50-ohm coaxial (Thinnet) RG-58 coaxial cable	50-ohm coaxial (Thicknet) RG-50 coaxial cable	EIA/TIA Category 3, 4, 5 UTP 2 pair	EIA/TIA Category 5 UTP 2 pair	62.5/125 micro multimode fiber	STP	EIA/TIA Category 5 UTP 4 pair	62.5/50 micro multimode fiber	9 micro single-mode fiber
Maximum Segment Length	185 m (606.94 ft)	500 m (1640.4 ft)	100 m (328 ft)	100 m (328 ft)	400 m (1312.3 ft)	25 m (82 ft)	100 m (328 ft)	260 m (853 ft)	3-10 km (1.86–6.2 miles)
Topology	Bus	Bus	Star	Star	Point-to-point	Star or point-to-point	Star or point-to-point	Point-to-point	Point-to-point
Connector	AUI or BNC connector	AUI	ISO 8877 (RJ-45)	ISO 8877 (RJ-45)	MT-RJ or SC connector	ISO 8877 (RJ-45)	ISO 8877 (RJ-45)	SC	SC

Figure 4-8 *Ethernet Connection Types*



A Gigabit Interface Converter (GBIC), like the one shown in Figure 4-9, is a hot-swappable input/output device that plugs into a Gigabit Ethernet port. A key benefit of using a GBIC is that GBICs are interchangeable. This allows users the flexibility to deploy other 1000BASE-X technology without needing to change the physical interface/model on the router or switch. GBICs support UTP (copper) and fiber-optic media for Gigabit Ethernet transmission.

Figure 4-9 *GBIC*



Typically, GBICs are used in the LAN for aggregation and in the backbone. You also see GBICs in SANs and MANs.

The fiber-optic GBIC is a transceiver that converts serial electric currents to optical signals and optical signals to digital electric currents. Some of the optical GBICs include the following:

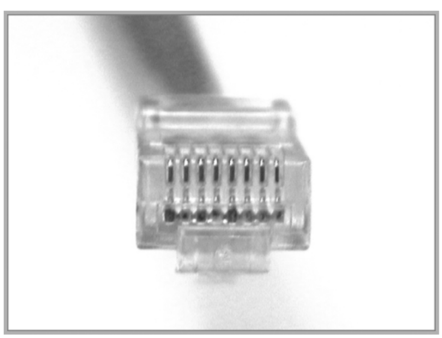
- Short wavelength (1000BASE-SX)
- Long wavelength/long haul (1000BASE-LX/LH)
- Extended distance (1000BASE-ZX)

UTP Implementation

In a UTP implementation, you must determine the EIA/TIA type of cable and whether to use a straight-through or crossover cable. This section describes the types of connectors used in a UTP implementation and the characteristics and uses of straight-through and crossover cables.

If you look at an RJ-45 transparent end connector, like the one in Figure 4-10, you can see eight colored wires, twisted into four pairs. Four of the wires (two pairs) carry the positive or true voltage and are considered *tip* (T1 through T4); the other four wires carry the inverse of false voltage grounded and are called *ring* (R1 through R4). Tip and ring are terms that originated in the early days of the telephone. Today, these terms refer to the positive and the negative wires in a pair. The wires in the first pair in a cable or a connector are designated as T1 and R1, the second pair is T2 and R2, and so on.

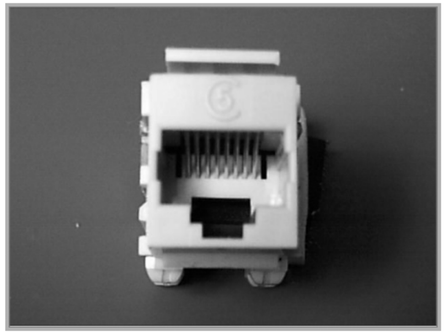
Figure 4-10 *RJ-45 Connector*



The RJ-45 plug is the male component, crimped at the end of the cable. As you look at the male connector from the front (the side with the metal pins exposed), the pin locations are numbered from 8 on the left to 1 on the right.

The RJ-45 jack, shown in Figure 4-11, is the female component in a network device, wall, cubicle partition outlet, or patch panel.

Figure 4-11 *RJ-45 Jack*

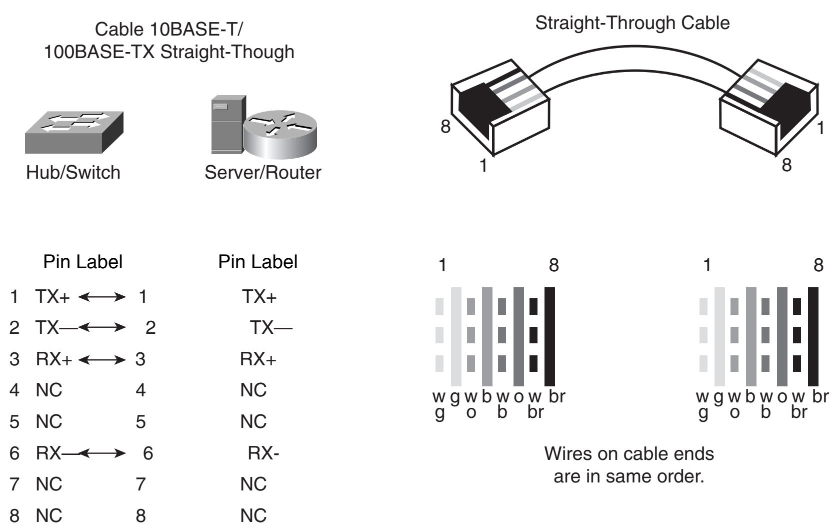


In addition to identifying the correct EIA/TIA category of cable to use for a connecting device (depending on what standard is being used by the jack on the network device), you need to determine which of the following to use:

- A straight-through cable
- A crossover cable

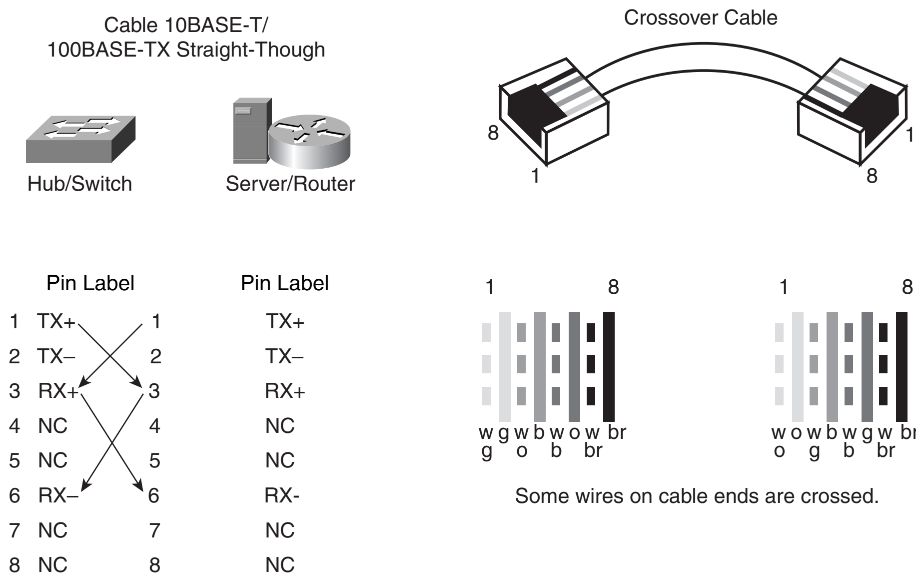
The RJ-45 connectors on both ends show all the wires in the same order. If the two RJ-45 ends of a cable are held side by side in the same orientation, the colored wires (or strips or pins) are seen at each connector end. If the order of the colored wires is the same at each end, the cable is straight-through. Figure 4-12 shows the wiring for a straight-through cable.

Figure 4-12 *Straight-Through Cable Wiring*



With crossover, the RJ-45 connectors on both ends show that some of the wires on one side of the cable are crossed to a different pin on the other side of the cable. Specifically, for Ethernet, pin 1 at one RJ-45 end should be connected to pin 3 at the other end. Pin 2 at one end should be connected to pin 6 at the other end, as shown in Figure 4-13.

Figure 4-13 *Crossover Cable Wiring*



Each device using RJ-45 connectors transmits or receives on particular pins depending on the device type. A PC or router typically transmits on pins 1 and 2 while a switch or hub receives on pins 1 and 2. You must follow certain guidelines when connecting these devices.

Use straight-through cables for the following cabling:

- Switch to router
- Switch to PC or server
- Hub to PC or server

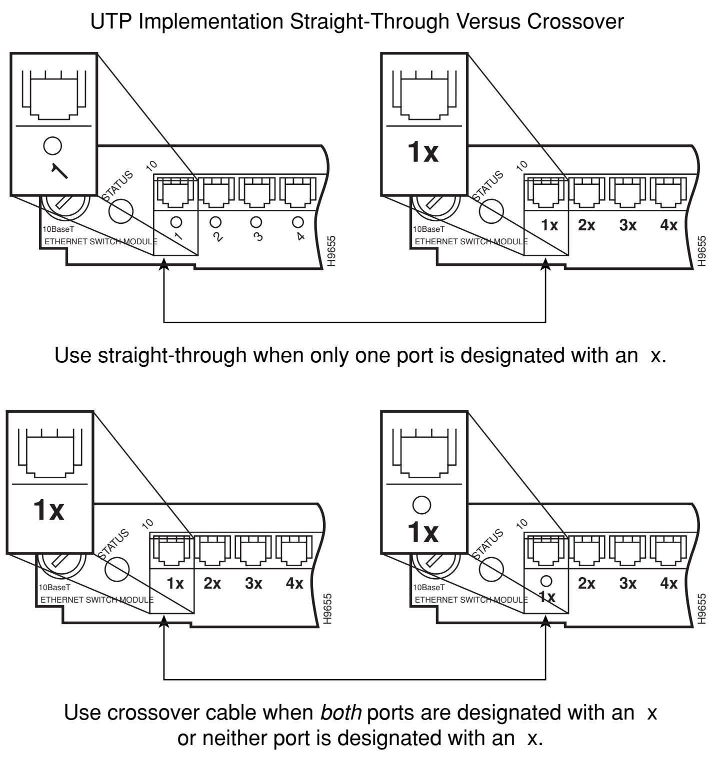
Use crossover cables for the following cabling:

- Switch to switch
- Switch to hub
- Hub to hub
- Router to router
- PC to PC
- Router to PC

Occasionally, ports on network devices are marked with an X, like those in Figure 4-14. This marking means that these devices receive on pins 1 and 2, or that they are crossed. When connecting devices in a network, you might be required to use a variety of cable types.

NOTE Most hubs and some switches have a port that can be changed from X to not-X by moving a switch or pressing a button. This feature enables you to use straight-through cables where crossovers would ordinarily be required.

Figure 4-14 *RJ-45 Port Designations*



Being aware of the different cabling media types, specifications, and connectors is an important step to interconnecting network devices.

LAN Cabling Options Section Quiz

Use these practice questions to review what you learned in this section.

1 Which of the following is an 802.3u specification?

- **A** 10BASE-F
- **B** 10BASE-T
- **C** 100BASE-TX
- **D** 1000BASE-CX

2 Which of the following is a more appropriate choice for Ethernet connectivity?

- **A** 10-Mbps Ethernet as a connection between server and LAN
- **B** Gigabit Ethernet as the link at the access layer to provide good performance
- **C** Fast Ethernet as a link between the access layer and distribution layer devices to support the aggregate traffic from each Ethernet segment on the access link
- **D** 100-Mbps between core switches to provide greater bandwidth.

3 Which standard body created the cables and connector specification used to support Ethernet implementation?

- **A** ISO
- **B** NSI
- **C** EIA/TIA
- **D** IETF

4 Which of the following statements does *not* correctly describe a media connector?

- **A** RJ-45 connectors are 8-pin connectors that resemble telephone jacks.
- **B** An AUI is a 15-pin connector used between an NIC and an Ethernet cable.
- **C** The GBIC is a transceiver that converts serial electric currents to optical signals and vice versa.
- **D** None of the above is correct.

5 For which of the following would you *not* need to provide a crossover cable?

A Connecting uplinks between switches

B Connecting routers to switches

C Connecting hubs to switches

D Connecting to a console port

Understanding WAN Cabling

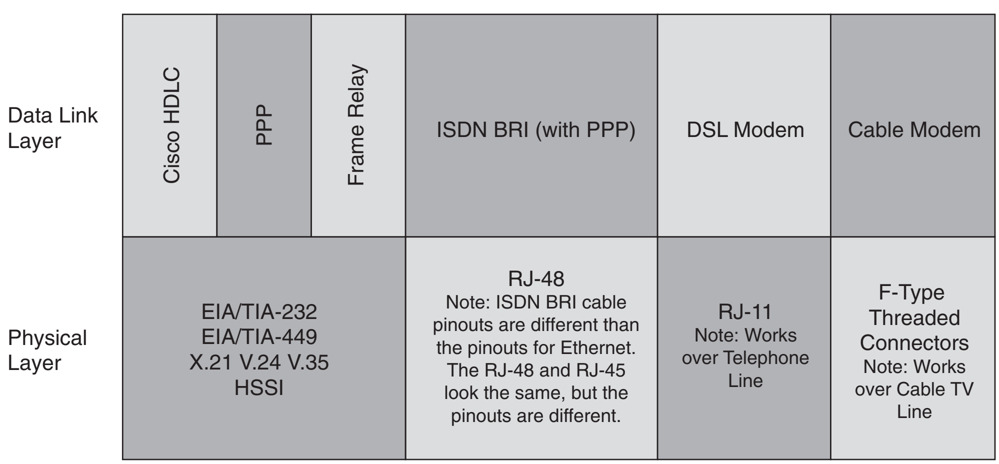
Just as several types of physical layer implementations for LANs exist, various kinds of serial and router connections can also be used in a WAN environment, depending on the network requirements.

Learning about the different types of WAN serial and router connections and their functions can help you understand more about how a WAN works.

WAN Physical Layer

Many physical implementations carry traffic across the WAN. Needs vary, depending on the distance of the equipment from the services, the speed, and the actual service itself. Figure 4-15 shows a subset of physical implementations that support some of the more prominent WAN solutions today.

Figure 4-15 *WAN at the Physical Layer*



Serial connections support WAN services such as dedicated leased lines that run the Point-to-Point Protocol (PPP) or Frame Relay. The speed of these connections ranges up to E1 (2.048 Mbps).

Other WAN services, such as ISDN, offer dial-on-demand connections or dial backup services. An ISDN BRI is composed of two 64-kbps bearer channels (B channels) for data, and one 16-kbps data channel (D channel) for signaling and other link-management tasks. PPP is typically used to carry data over the B channels.

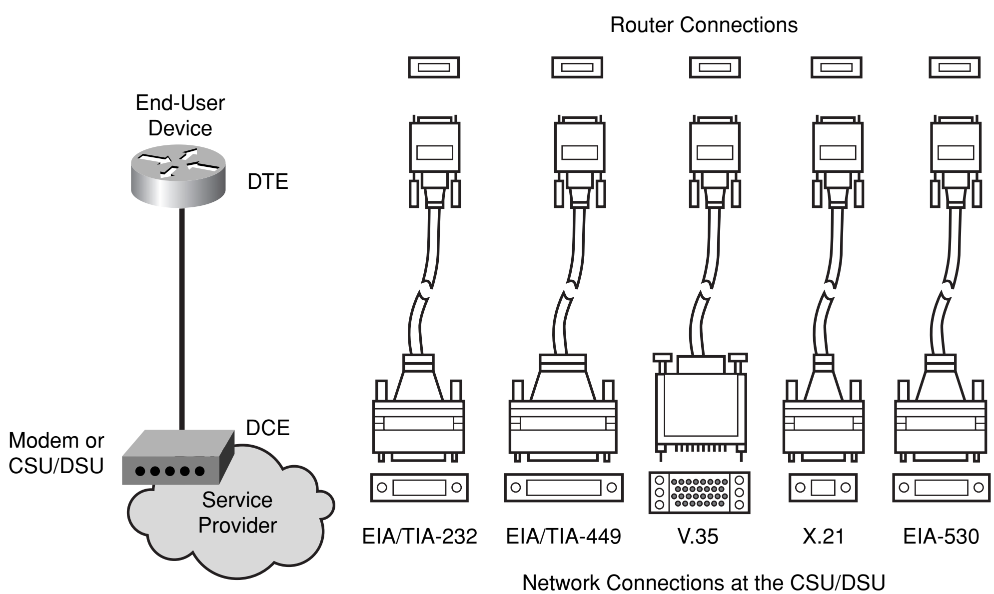
With the increasing demand for residential broadband high-speed services, DSL and cable modem connections are beginning to dominate. For example, typical residential DSL service can offer a speed of up to 1.5 Mbps over the existing telephone line. Cable services, which work over the existing coaxial cable TV line, also offer high-speed connectivity matching or surpassing that of DSL.

WAN Serial Connections

For long-distance communication, WANs use serial transmission. Serial transmission is a method of data transmission in which bits of data are transmitted sequentially over a single channel. This one-at-a-time transmission contrasts with parallel data transmission, which transmits several bits at a time. To carry the bits, serial channels use a specific electromagnetic or optical frequency range.

Figure 4-16 shows all the different serial connector options available for Cisco routers.

Figure 4-16 *Serial Connectors*



Serial ports on Cisco routers use a proprietary 60-pin connector or smaller "smart serial" connector. The type of connector on the other end of the cable is dependent on the service provider or end-device requirements.

Frequencies, described in terms of their cycles per second (Hz), function as a band or spectrum for communication. For example, the signals transmitted over voice-grade telephone lines use up to 3 kHz. The size of this frequency range is called the *bandwidth*. Another way to express bandwidth is to specify the amount of data in bits per second that can be carried using two of the physical layer implementations (EIA/TIA-232 and EIA/TIA-449). Table 4-4 compares physical standards for these two WAN serial connection options.

Table 4-3 *Comparison of Physical Serial Standards*

Data Rates in bps	EIA/TIA-232 Distance in Meters	EIA/TIA-449 Distance in Meters
2400	60	1250
4800	30	625
9600	15	312
19,200	15	156
38,400	15	78
115,200	3.7	N/A
1,544,000 (T1)	N/A	15

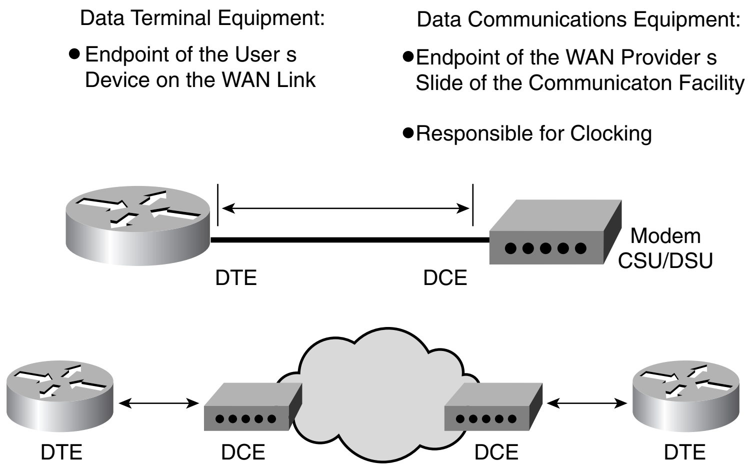
Several types of physical connections allow you to connect to serial WAN services. Depending on the physical implementation that you choose or the physical implementation that your service provider imposes, you need to select the correct serial cable type to use with the router.

Serial Connections

In addition to determining the cable type, you need to determine whether you need data terminal equipment (DTE) or data circuit-terminating equipment (DCE) connectors for your WAN equipment. The DTE is the endpoint of the user's device on the WAN link. The DCE is typically the point where responsibility for delivering data passes into the hands of the service provider.

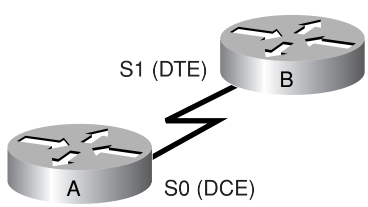
As shown in Figure 4-17, if you are connecting directly to a service provider, or to a device (like a channel/data service unit [CSU/DSU]) that performs signal clocking, the router is a DTE and needs a DTE serial cable. This situation is typically the case for routers.

Figure 4-17 *DTE and DCE Connections*



In some cases, the router needs to be the DCE. For example, if you are performing a back-to-back router scenario in a test environment, one of the routers is a DTE, and the other is a DCE. Figure 4-18 shows a back-to-back router configuration. To implement this, you need a DTE cable for one router, and a DCE cable for another router. You might also be able to buy a special back-to-back cable, which is wired with a DTE side and DCE side.

Figure 4-18 *Back-to-Back Router Connections*



When you are cabling routers for serial connectivity, the routers have either fixed or modular ports. The type of port being used affects the syntax that you use later to configure each interface.

Figure 4-19 shows an example of a router with fixed serial ports (interfaces). Each port is given a label of port type and port number, for example, Serial 0. To configure a fixed interface, specify the interface using this convention.

Figure 4-19 *Fixed Serial Ports*

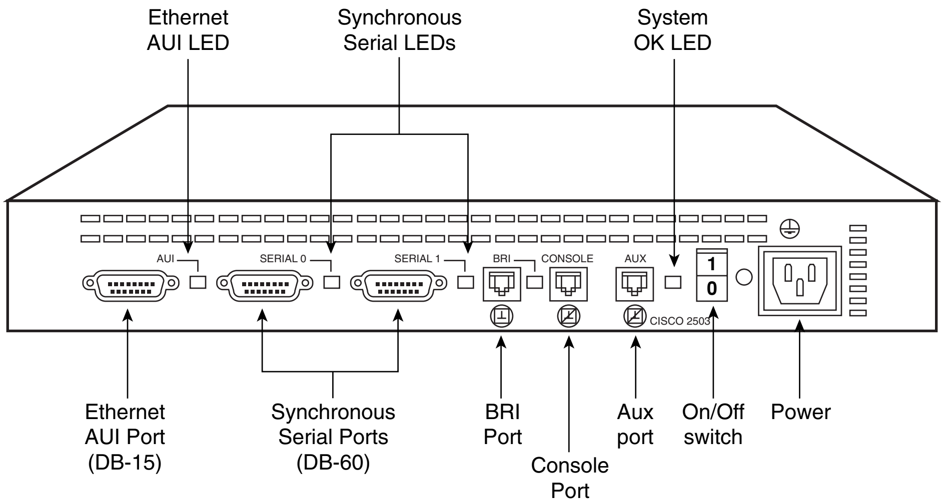
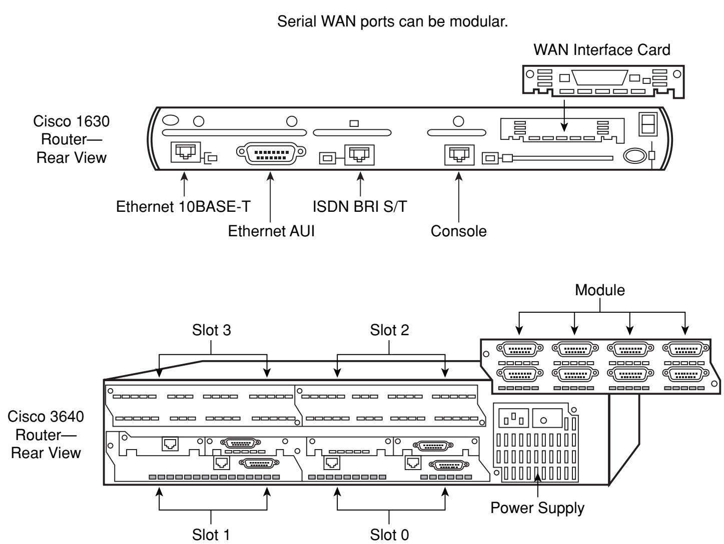


Figure 4-20 shows examples of routers with modular serial ports. Usually, each port is given a label of port type, slot (the location of the module), and port number. To configure a port on a modular card, it is necessary to specify the interface using the convention "port type slot number/port number." For example, given serial 1/0, the type of interface is a serial interface, the slot number where the interface module is installed is slot 1, and the port referenced on that serial interface module is port 0.

Figure 4-20 *Modular Serial Portsts*



ISDN BRI Connections

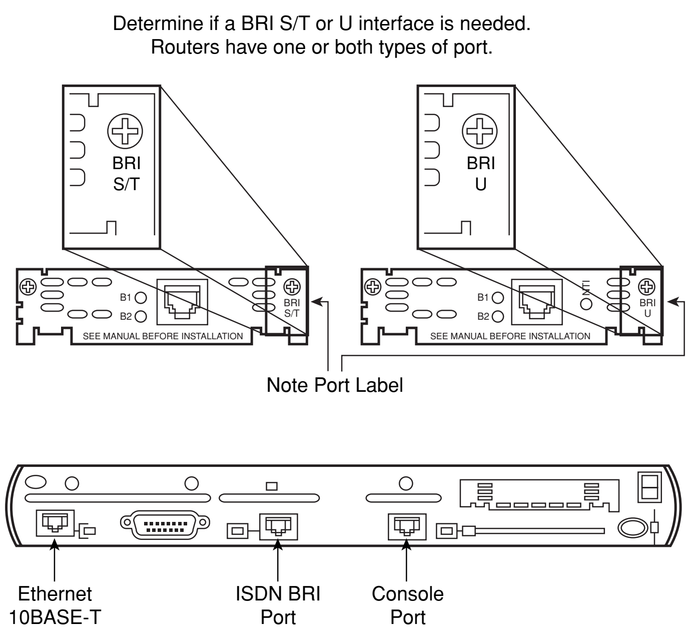
With ISDN BRI, you can use two types of interfaces: BRI S/T and BRI U, which are reference points for user connectivity. To determine the appropriate interface, you need to verify whether you or the service provider provides a Network Termination 1 (NT1) device.

An *NT1 device* is an intermediate device between the router and the service provider ISDN switch (cloud) that connects four-wire subscriber wiring to the conventional two-wire local loop. In North America, the customer typically provides the NT1, while in the rest of the world, the service provider provides the NT1 device.

You might find it necessary to provide an external NT1 if an NT1 is not integrated into the router. Looking at the labeling on the router interface is the easiest way to determine if the router has an integrated NT1. A BRI interface with an integrated NT1 is labeled *BRI U*, and a BRI interface without an integrated NT1 is labeled *BRI S/T*. Because routers can have multiple ISDN interface types, you must determine the interface needed when the router is purchased. You can determine the type of ISDN connector that the router has by looking at the port label.

Figure 4-21 shows the different port types for the ISDN interface. To interconnect the ISDN BRI port to the service-provider device, use a UTP Category 5 straight-through cable.

Figure 4-21 *ISDN Interface Types*



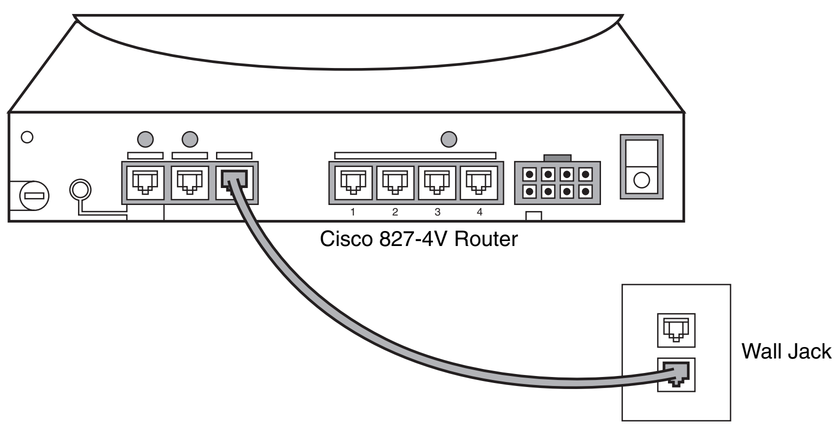
WARNING It is important to insert a cable running from an ISDN BRI port only to an ISDN jack or an ISDN switch. ISDN BRI uses voltages that can seriously damage non-ISDN devices.

DSL Connections

Routers can also be connected to an asymmetric digital subscriber line (ADSL). The Cisco 827 ADSL router has one ADSL interface. To connect an ADSL to the ADSL port on a router, one end of the phone cable is connected to the ADSL port on the router. The other end of the phone cable is connected to the external wall phone jack.

To connect a router for DSL service, you need a phone cable with RJ-11 connectors. The RJ-11 connector is the same one used on a traditional telephone connection and is slightly smaller than a RJ-45 connector. Figure 4-22 shows a connection to a phone jack with DSL services. DSL works over standard telephone lines. It uses only two pins on the RJ-11 connector.

Figure 4-22 *DSL Connection*



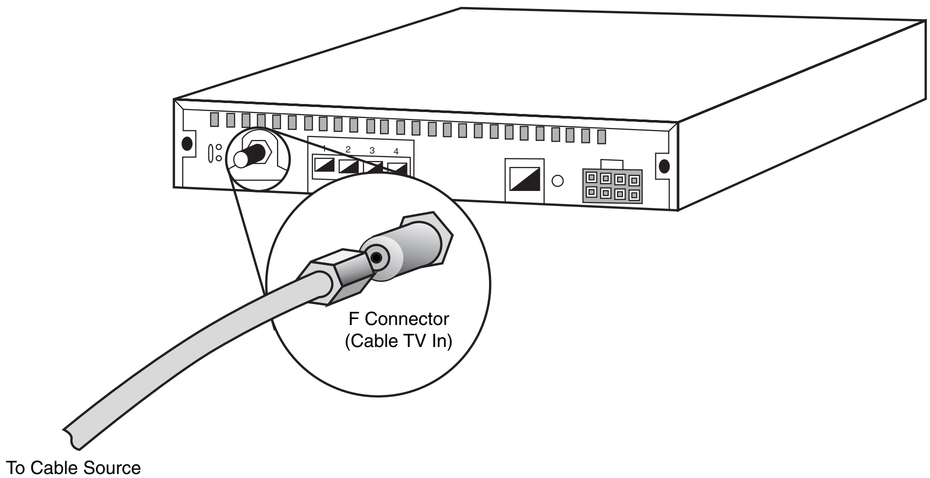
Cable Connections

The Cisco uBR905 cable access router provides high-speed network access on the cable television system to residential and small office/home office (SOHO) subscribers. The uBR905 router has an F-connector coaxial cable interface that can be connected to a cable system.

To connect the Cisco uBR905 cable access router to the cable system, a cable splitter/directional coupler can be installed, if needed, to separate signals for TV and computer use. If necessary, you can also install a high-pass filter to prevent interference between TV and computer signals.

The coaxial cable is connected to the F connector of the router, as shown in Figure 4-23.

Figure 4-23 *Cable Connection*



Asynchronous Router Connections

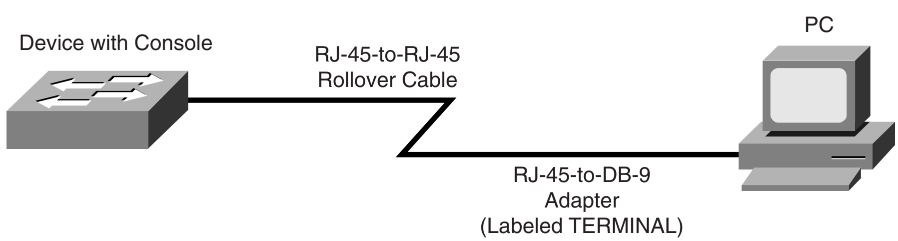
All Cisco devices also have at least one asynchronous connection that is used for management purposes. In some cases, these devices might also have an auxiliary asynchronous device that can be used for management or dialup network connections. When configuring and managing Cisco devices, you must be aware of how to connect to these ports.

Console Port Connections

To initially configure the Cisco device, you must provide a management connection, also known as a *console connection*, directly to the device. For Cisco equipment, this management attachment is called a *console port*. The console port allows monitoring and configuring of a Cisco hub, switch, or router.

The cable used between a terminal and a console port is a rollover cable, with RJ-45 connectors as illustrated in Figure 4-24.

Figure 4-24 *Connecting a Device with a Console Cable*



The rollover cable, also known as a console cable, has a different pinout than the straight-through or crossover RJ-45 cables used with Ethernet or the ISDN BRI. The pinout for a rollover cable is as follows:

1–8
2–7
3–6
4–5
5–4
6–3
7–2
8–1

To set up the connection between your terminal and the Cisco console port, you must perform the following:

Step 1 Cable the device to the PC using a rollover cable. You might need an RJ-45-to-DB-9 or and RJ-45-to-DB25 adapter for your PC or terminal.

Step 2 Configure terminal emulation software for the PC with the following COM port settings: 9600 bps, 8 data bits, no parity, 1 stop bit, and no flow control.

This connection to the console port provides you with access to the device's executive process command-line interface (CLI). From there, you can configure the device.

NOTE Many PCs and laptops are no longer manufactured with a 25- or 9-pin (legacy) serial connector. Instead, most devices now ship with USB connectors. If you are working with a USB connector, you need to obtain a USB-to-DB-9 converter cable to connect to the console.

Auxiliary Connections

The auxiliary (AUX) port is another asynchronous connection that can provide out-of-band management—management not using the network bandwidth—through a modem. To provide out-of-band management, you can connect a modem directly to the AUX port. When you dial the modem, you are connected to the AUX port and the executive process CLI. The AUX port must be configured using the console port before it can be used in this manner.

The AUX port can also be used as a dial-on-demand WAN port for passing user traffic.

Understanding WAN Cabling Section Review

Use these practice questions to review what you learned in this section.

1. Which of the following is *not* a physical WAN implementation?

   A. DSL

   B. ISDN

   C. Frame Relay

   D. Gigabit Ethernet

2. What type of data transmission method is used by a WAN?

   A. Parallel

   B. Serial

   C. Single

   D. Multimode

3. Which of the following media interconnects the ISDN BRI port to the service provider device?

   A. UTP straight-through

   B. UTP crossover

   C. Coaxial

   D. Fiber-optic

4. What type of connector is used for DSL connection?

   A. RJ-45

   B. RJ-11

   C. BNC

   D. DB-9

5 What type of connector connects a router and cable system?

A RJ-45

B RJ-11

C F-Type

D AUI

6 What type of cable connects a terminal and a console port?

A Straight-through

B Rollover

C Crossover

D Coaxial

Chapter Summary

As you begin to build an internetwork, the first thing you have to consider is the physical implementation of the LAN and WAN connections. These considerations include speed of services, infrastructure, and physical interfaces. This chapter discussed how Ethernet physical layer standards correlate to the infrastructure that you have to install to use the services. This chapter also reviewed the connection differences for WAN connections and how to connect to a console or AUX port for management of the device.

Chapter Review Questions

Use these review questions to test your knowledge of the concepts discussed in this chapter.

1 What is the maximum cable length for Thinnet coaxial cable?

A 100 meters

B 185 meters

C 500 meters

D 1600 meters

2 What are the transmission rates of wireless communication?

A 9–11 Mbps

B 9 kbps–54 Mbps

C 1–9 Mbps

D 1 kbps–9 Mbps

3 At which layer of the OSI model do the cabling aspects of a LAN exist?

A Transport

B Network

C Data link

D Physical

4 Which of the following are *not* optical GBICs?

A Short wavelength (1000BASE-SX)

B High-frequency wavelength (1000BASE-FX/HX)

C Long wavelength/long haul (1000BASE-LX/LH)

D Extended distance (1000BASE-ZX)

5 How is serial transmission different from parallel transmission? (Select two.)

A Serial transmission is faster than parallel transmission.

B They use different connectors.

C Serial transmission sends data 1 bit at a time, and parallel transmission sends several bits at one time.

D Parallel transmission is used over WAN links.

6 Typically, a router is ________.

A A DTE device

B A DCE device

C Both a DTE and a DCE device

D Neither a DTE nor a DCE device

7 If you are using an ISDN device that has an interface marked *BRI S/T*, what does this imply?

A The BRI interface is capable of supertransmission.

B The device has an NT1 built in.

C The device does not have an NT1 built in.

D The ISDN send/transmit interface.