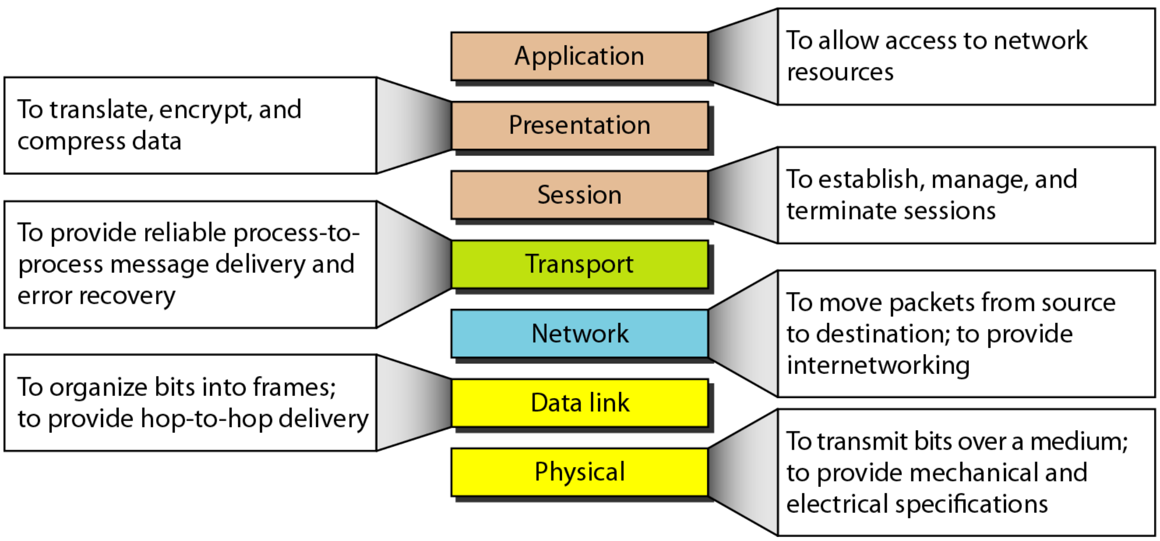
Network Cabling

Open Systems Interconnection (OSI) is a set of internationally recognized, non-proprietary standards for networking and for operating system involved in networking functions

7. Application Layer	All
6. Presentation Layer	People
5. Session Layer	Seem
4. Transport Layer	To
3. Network Layer	Need
2. Data Link Layer	Data
1. Physical Layer	Processing



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Lesson 1: Network Cabling

Building on our understanding of the different network topologies that connect computers, we focus next on the cables that connect them. In this lesson, we examine the construction, features, and operation of each type of cable, and the advantages and disadvantages of each.
After this lesson, you will be able to:

- Determine which type of cabling is best for any networking situation.
- Define terms related to cabling, such as shielding, crosstalk, attenuation, and plenum.
- Identify the primary types of network cabling.
- Distinguish between baseband and broadband transmissions and identify appropriate uses for each.

Estimated lesson time: 50 minutes

Primary Cable Types

The vast majority of networks today are connected by some sort of wiring or cabling that acts as a network transmission medium that carries signals between computers. Many cable types are available to meet the varying needs and sizes of networks, from small to large.

Cable types can be confusing. Belden, a leading cable manufacturer, publishes a catalog that lists more than 2200 types of cabling. Fortunately, only three major groups of cabling connect the majority of networks:

- Coaxial cable
- Twisted-pair (unshielded and shielded) cable
- Fiber-optic cable

The next part of this lesson describes the features and components of these three major cable types. Understanding their differences will help you determine which type of cabling is appropriate in a given context.

Coaxial Cable

At one time, coaxial cable was the most widely used network cabling. There were a couple of reasons for coaxial cable's wide usage: it was relatively inexpensive, and it was light, flexible, and easy to work with.

In its simplest form, *coaxial cable* consists of a core of copper wire surrounded by insulation, a braided metal shielding, and an outer cover. Figure 2.1 shows the various components that make up a coaxial cable.

The term *shielding* refers to the woven or stranded metal mesh (or other material) that surrounds some types of cabling. Shielding protects transmitted data by absorbing stray electronic signals, called *noise*, so that they do not get onto the cable and distort the data. Cable that contains one layer of foil insulation and one layer of braided metal shielding is referred to as *dual shielded*. For environments that are subject to higher interference, quad shielding is available. *Quad shielding* consists of two layers of foil insulation and two layers of braided metal shielding.

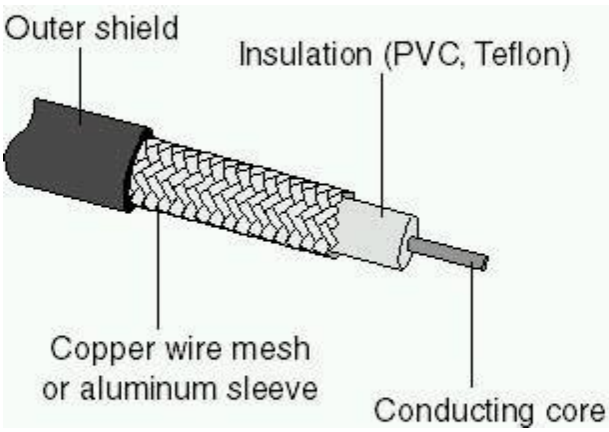


Figure 2.1 *Coaxial cable showing various layers*

The core of a coaxial cable carries the electronic signals that make up the data. This wire core can be either solid or stranded. If the core is solid, it is usually copper.

Surrounding the core is a dielectric insulating layer that separates it from the wire mesh. The braided wire mesh acts as a ground and protects the core from electrical noise and crosstalk. (*Crosstalk* is signal overflow from an adjacent wire. For a more detailed discussion of crosstalk, see the section Unshielded Twisted-Pair (UTP) Cable, later in this lesson.)

The conducting core and the wire mesh must always be kept separate from each other. If they touch, the cable will experience a *short*, and noise or stray signals on the mesh will flow onto the copper wire. An electrical short occurs when any two conducting wires or a conducting wire and a ground come into contact with each other. This contact causes a direct flow of current (or data) in an unintended path. In the case of household electrical wiring, a short will cause sparking and the blowing of a fuse or circuit breaker. With electronic devices that use low voltages, the result is not as dramatic and is often undetectable. These low-voltage shorts generally cause the failure of a device; and the short, in turn, destroys the data.

A nonconducting outer shield—usually made of rubber, Teflon, or plastic—surrounds the entire cable.

Coaxial cable is more resistant to interference and attenuation than twisted-pair cabling. As shown in Figure 2.2, *attenuation* is the loss of signal strength that begins to occur as the signal travels farther along a copper cable.

Figure 2.2 *Attenuation causes signals to deteriorate*

The stranded, protective sleeve absorbs stray electronic signals so that they do not affect data being sent over the inner copper cable. For this reason, coaxial cabling is a good choice for longer distances and for reliably supporting higher data rates with less sophisticated equipment.

Types of Coaxial Cable

There are two types of coaxial cable:

- Thin (thinnet) cable
- Thick (thicknet) cable

Which type of coaxial cable you select depends on the needs of your particular network.

Thinnet Cable *Thinnet* cable is a flexible coaxial cable about 0.64 centimeters (0.25 inches) thick. Because this type of coaxial cable is flexible and easy to work with, it can be used in almost any type of network installation. Figure 2.3 shows thinnet cable connected directly to a computer's network interface card (NIC).

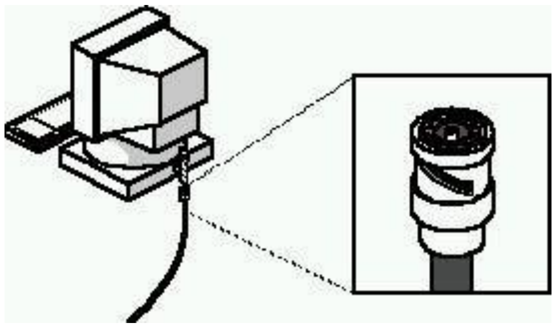


Figure 2.3 *Close-up view of thinnet cable showing where it connects to a computer*

Thinnet coaxial cable can carry a signal for a distance of up to approximately 185 meters (about 607 feet) before the signal starts to suffer from attenuation.

Cable manufacturers have agreed upon specific designations for different types of cable. (Table 2.1 lists cable types and descriptions.) Thinnet is included in a group referred to as the *RG-58* family and has 50ohm impedance. (*Impedance* is the resistance, measured in ohms, to the alternating current that flows in a wire.) The principal distinguishing feature of the RG-58 family is the center core of copper. Figure 2.4 shows two examples of RG-58 cable, one with a stranded wire core and one with a solid copper core.

Figure 2.4 *RG-58 coaxial cable showing stranded wire and solid copper cores*

Table 2.1 *Cable Types*

Cable	Description
RG-58/U	Solid copper core
RG-58 A/U	Stranded wire core
RG-58 C/U	Military specification of RG-58 A/U
RG-59	Broadband transmission, such as cable television

RG-6 Larger in diameter and rated for higher frequencies than RG-59, but also used for broadband transmissions

RG-62 ArcNet networks

Thicknet Cable *Thicknet* cable is a relatively rigid coaxial cable about 1.27 centimeters (0.5 inches) in diameter. Figure 2.5 shows the difference between thinnet and thicknet cable. Thicknet cable is sometimes referred to as Standard Ethernet because it was the first type of cable used with the popular network architecture Ethernet. Thicknet cable's copper core is thicker than a thinnet cable core.

Figure 2.5 *Thicknet cable has a thicker core than thinnet cable*

The thicker the copper core, the farther the cable can carry signals. This means that thicknet can carry signals farther than thinnet cable. Thicknet cable can carry a signal for 500 meters (about 1640 feet). Therefore, because of thicknet's ability to support data transfer over longer distances, it is sometimes used as a backbone to connect several smaller thinnet-based networks.

Figure 2.6 shows a device called a transceiver. A *transceiver* connects the thinnet coaxial cable to the larger thicknet coaxial cable. A transceiver designed for thicknet Ethernet includes a connector known as a *vampire tap*, or a piercing tap, to make the actual physical connection to the thicknet core. This connector is pierced through the insulating layer and makes direct contact with the conducting core. Connection from the transceiver to the NIC is made using a transceiver cable (drop cable) to connect to the *attachment unit interface* (AUI) port connector on the card. An AUI port connector for thicknet is also known as a *Digital Intel Xerox (DIX) connector* (named for the three companies that developed it and its related standards) or as a DB-15 connector.

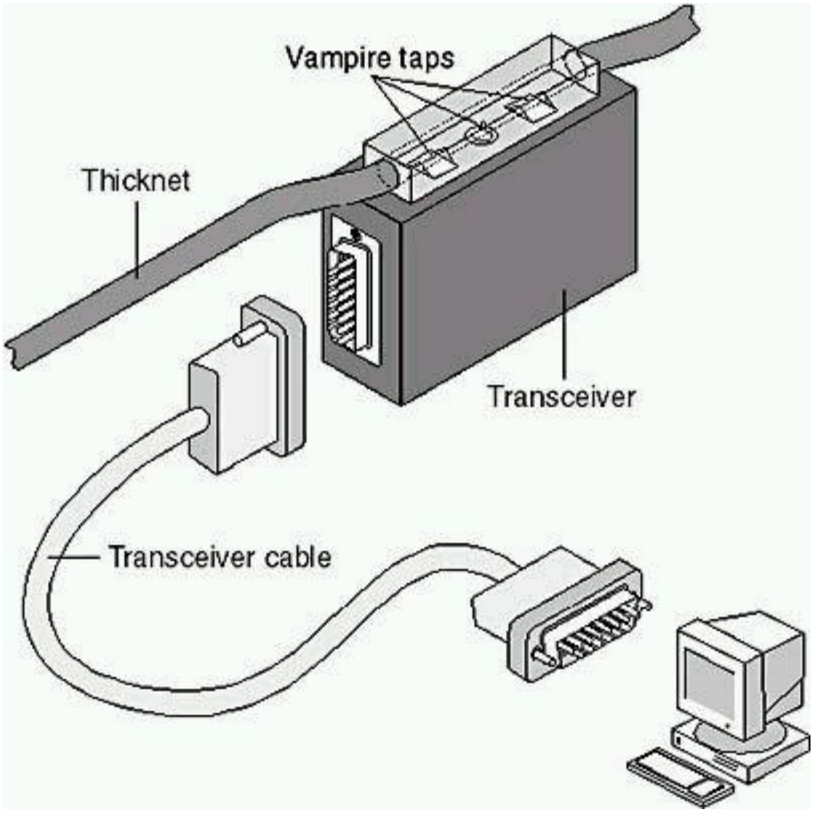


Figure 2.6 *Thicknet cable transceiver with detail of a vampire tap piercing the core*

Thinnet vs. Thicknet Cable As a general rule, the thicker the cable, the more difficult it is to work with. Thin cable is flexible, easy to install, and relatively inexpensive. Thick cable does not bend easily and is, therefore, harder to install. This is a consideration when an installation calls for pulling cable through tight spaces such as conduits and troughs. Thick cable is more expensive than thin cable, but will carry a signal farther.

Coaxial-Cable Connection Hardware

Both thinnet and thicknet cable use a connection component, known as a *BNC connector*, to make the connections between the cable and the computers. There are several important components in the BNC family, including the following:

- **The BNC cable connector** (Bayonet Neill–Concelman) Figure 2.7 shows a BNC cable connector. The BNC cable connector is either soldered or crimped to the end of a cable.

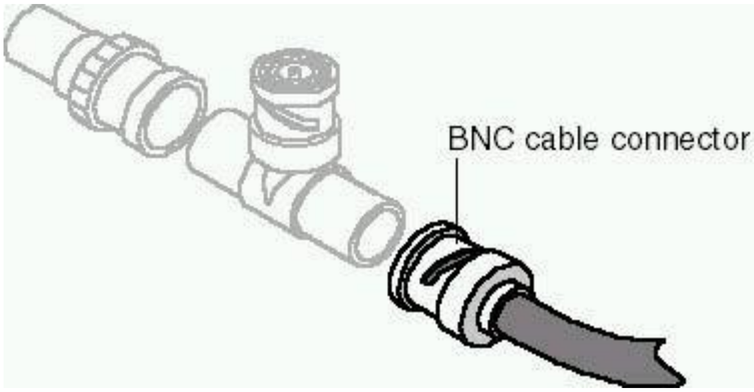


Figure 2.7 *BNC cable connector*

- **The BNC T connector** Figure 2.8 shows a BNC T connector. This connector joins the network interface card (NIC) in the computer to the network cable.

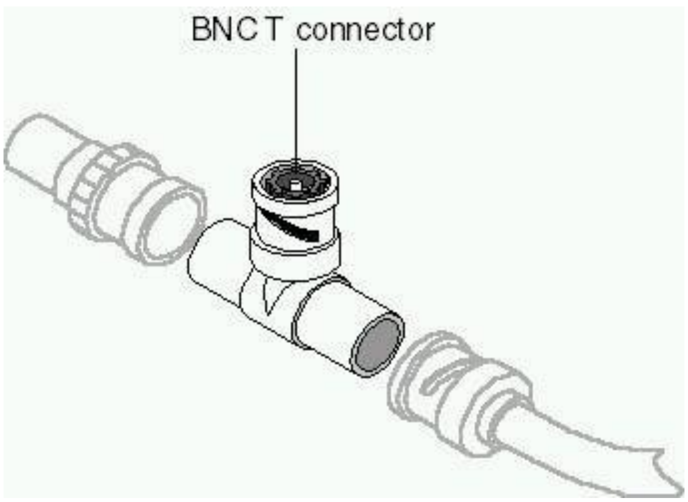


Figure 2.8 *BNC T connector*

- **The BNC barrel connector** Figure 2.9 shows a BNC barrel connector. This connector is used to join two lengths of thinnet cable to make one longer length.

Figure 2.9 *BNC barrel connector*

- **The BNC terminator** Figure 2.10 shows a BNC terminator. A BNC terminator closes each end of the bus cable to absorb stray signals. Otherwise, as we saw in Chapter 1, "Introduction to Networking," the signal will bounce and all network activity will stop.

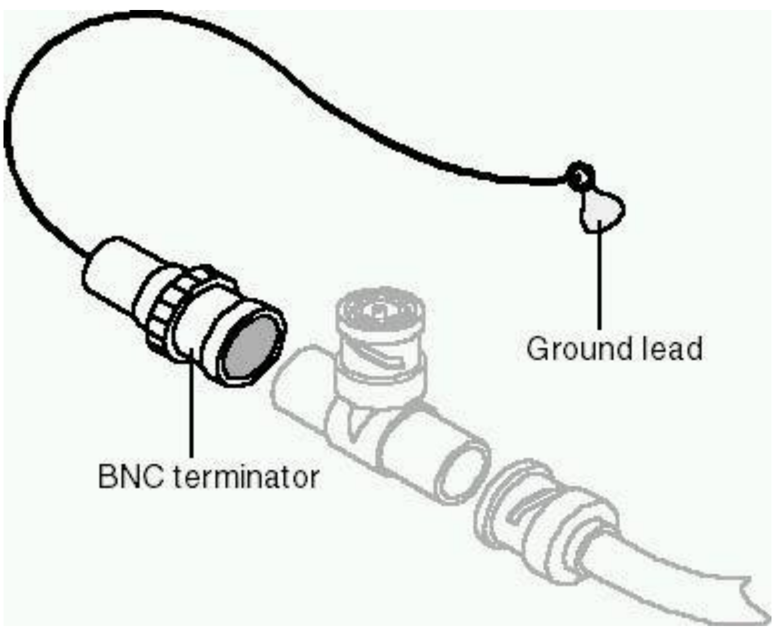


Figure 2.10 *BNC terminator*

NOTE

The origin of the acronym "BNC" is unclear, and there have been many names ascribed to these letters, from "British Naval Connector" to "Bayonet Neill-Councelman." Because there is no consensus on the proper name and because the technology industry universally refers to these simply as BNC-type connectors, in this book we will refer to this family of hardware simply as BNC.

Coaxial-Cable Grades and Fire Codes

The type of cable grade that you should use depends on where the cables will be laid in your office. Coaxial cables come in two grades:

- Polyvinyl chloride (PVC) grade
- Plenum grade

Polyvinyl chloride (PVC) is a type of plastic used to construct the insulation and cable jacket for most types of coaxial cable. PVC coaxial cable is flexible and can be easily routed through the exposed areas of an office. However, when it burns, it gives off poisonous gases.

A *plenum* is the shallow space in many buildings between the false ceiling and the floor above; it is used to circulate warm and cold air through the building. Figure 2.11 shows a typical office and where to use—or not use—PVC and plenum-grade cables. Fire codes give very specific instructions about the type of wiring that can be routed through this area, because any smoke or gas in the plenum will eventually blend with the air breathed by everyone in the building.

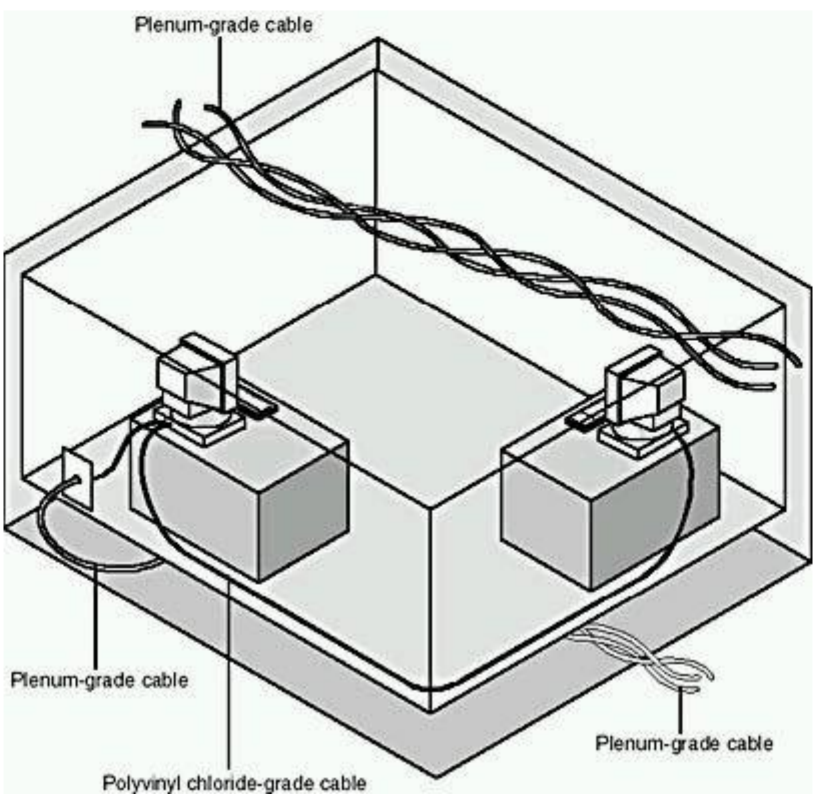


Figure 2.11 *Plenum-grade cabling is required in the plenum by fire codes*

Plenum-grade cabling contains special materials in its insulation and cable jacket. These materials are certified to be fire resistant and produce a minimum amount of smoke; this reduces poisonous chemical fumes. Plenum cable can be used in the plenum area and in vertical runs (for example, in a wall) without conduit. However, plenum cabling is more expensive and less flexible than PVC cable.

NOTE

You should consult your local fire and electrical codes for specific regulations and requirements for running networking cable in your office.

Coaxial-Cabling Considerations

Consider the following coaxial capabilities when making a decision about which type of cabling to use.

Use coaxial cable if you need a medium that can:

- Transmit voice, video, and data.
- Transmit data for greater distances than is possible with less expensive cabling.
- Offer a familiar technology with reasonable data security.

Twisted-Pair Cable

In its simplest form, *twisted-pair cable* consists of two insulated strands of copper wire twisted around each other. Figure 2.12 shows the two types of twisted-pair cable: *unshielded twisted-pair (UTP)* and *shielded twisted-pair (STP)* cable.

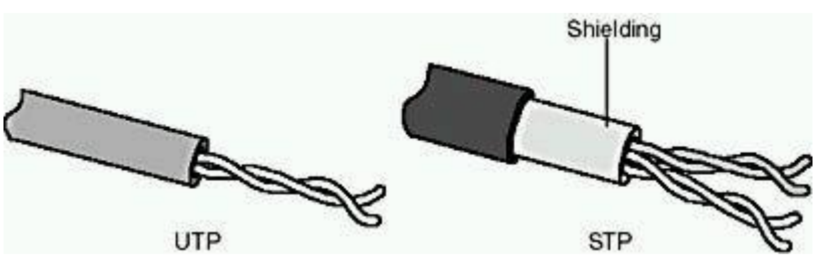


Figure 2.12 *Unshielded twisted-pair and shielded twisted-pair cables*

A number of twisted-pair wires are often grouped together and enclosed in a protective sheath to form a cable. The total number of pairs in a cable varies. The twisting cancels out electrical noise from adjacent pairs and from other sources such as motors, relays, and transformers.

Unshielded Twisted-Pair (UTP) Cable

UTP, using the 10BaseT specification, is the most popular type of twisted-pair cable and is fast becoming the most popular LAN cabling. The maximum cable length segment is 100 meters, about 328 feet.

Traditional UTP cable, as shown in Figure 2.13, consists of two insulated copper wires. UTP specifications govern how many twists are permitted per foot of cable; the number of twists allowed depends on the purpose to which the cable will be put. In North America, UTP cable is the most commonly used cable for existing telephone systems and is already installed in many office buildings.

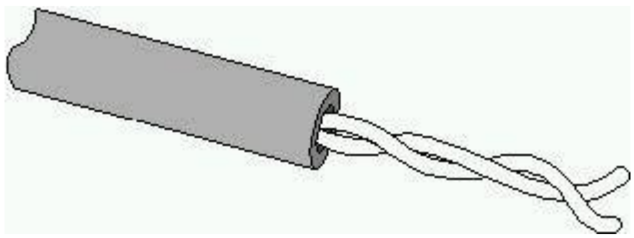


Figure 2.13 *UTP cable*

The 568A Commercial Building Wiring Standard of the Electronic Industries Association and the Telecommunications Industries Association (EIA/TIA) specifies the type of UTP cable that is to be used in a variety of building and wiring situations. The objective is to ensure consistency of products for customers. These standards include five categories of UTP:

- **Category 1** This refers to traditional UTP telephone cable that can carry voice but not data transmissions. Most telephone cable prior to 1983 was Category 1 cable.
- **Category 2** This category certifies UTP cable for data transmissions up to 4 megabits per second (Mbps). It consists of four twisted pairs of copper wire.
- **Category 3** This category certifies UTP cable for data transmissions up to 16 Mbps. It consists of four twisted pairs of copper wire with three twists per foot.
- **Category 4** This category certifies UTP cable for data transmissions up to 20 Mbps. It consists of four twisted pairs of copper wire.
- **Category 5** This category certifies UTP cable for data transmissions up to 100 Mbps. It consists of four twisted pairs of copper wire.

Most telephone systems use a type of UTP. In fact, one reason why UTP is so popular is because many buildings are prewired for twisted-pair telephone systems. As part of the prewiring process, extra UTP is often installed to meet future cabling needs. If preinstalled twisted-pair cable is of sufficient grade to support data transmission, it can be used in a computer network. Caution is required, however, because common telephone wire might not have the twisting and other electrical characteristics required for clean, secure, computer data transmission.

One potential problem with all types of cabling is crosstalk. Figure 2.14 shows crosstalk between two UTP cables. (As discussed earlier in this lesson, crosstalk is defined as signals from one line interfering with signals from another line.) UTP is particularly susceptible to crosstalk, but the greater the number of twists per foot of cable, the more effective the protection against crosstalk.

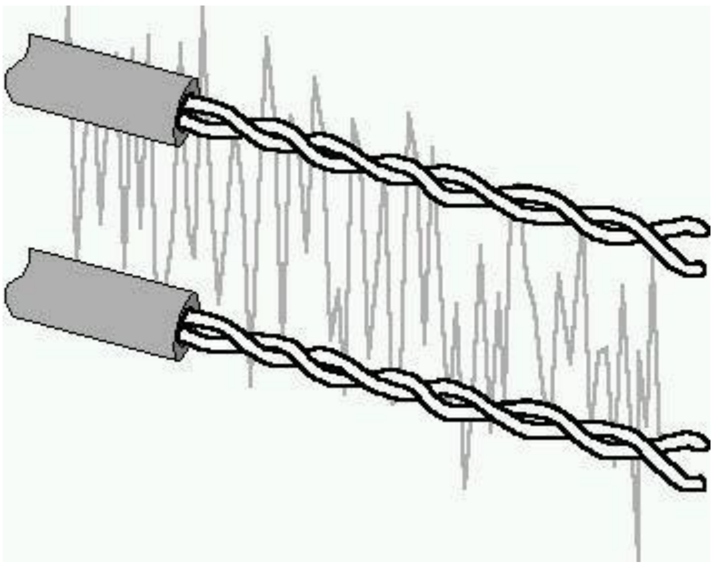


Figure 2.14 *Crosstalk occurs when signals from one line bleed into another line*

Shielded Twisted-Pair (STP) Cable

STP cable uses a woven copper-braid jacket that is more protective and of a higher quality than the jacket used by UTP. Figure 2.15 shows a two-twisted-pair STP cable. STP also uses a foil wrap around each of the wire pairs. This gives STP excellent shielding to protect the transmitted data from outside interference, which in turn allows it to support higher transmission rates over longer distances than UTP.

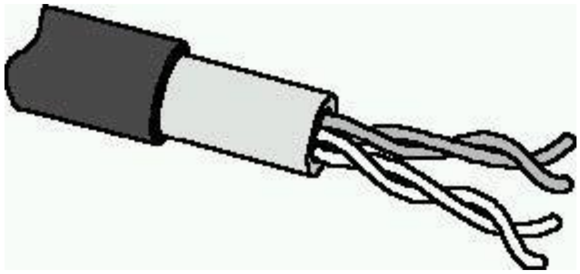


Figure 2.15 *STP cable*

Twisted-Pair Cabling Components

While we have defined twisted-pair cabling by the number of twists and its ability to transmit data, additional components are necessary to complete an installation. As it is with telephone cabling, a twisted-pair cable network requires connectors and other hardware to ensure proper installation.

Connection hardware Twisted-pair cabling uses RJ-45 telephone connectors to connect to a computer. These are similar to RJ-11 telephone connectors. An RJ-45 connector is shown in Figure 2.16. Although RJ-11 and RJ-45 connectors look alike at first glance, there are crucial differences between them.

The RJ-45 connector is slightly larger and will not fit into the RJ-11 telephone jack. The RJ-45 connector houses eight cable connections, while the RJ-11 houses only four.

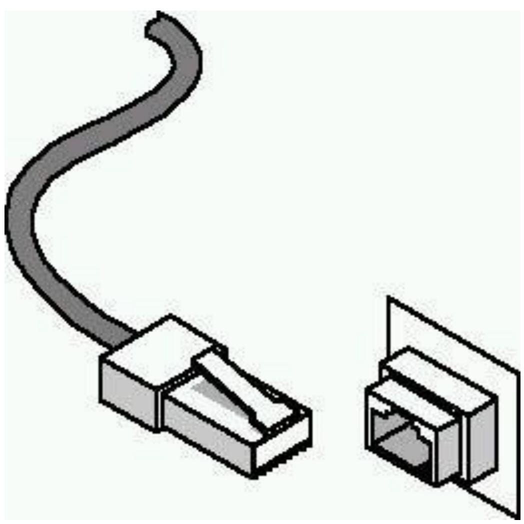


Figure 2.16 *RJ-45 connector and jack*

Several components are available to help organize large UTP installations and make them easier to work with. Figure 2.17 shows various twisted-pair cabling components.

Distribution racks and rack shelves Distribution racks and rack shelves can create more room for cables where there isn't much floor space. Using them is a good way to organize a network that has a lot of connections.

Expandable patch panels These come in various versions that support up to 96 ports and transmission speeds of up to 100 Mbps.

Jack couplers These single or double RJ-45 jacks snap into patch panels and wall plates and support data rates of up to 100 Mbps.

Wall plates These support two or more couplers.

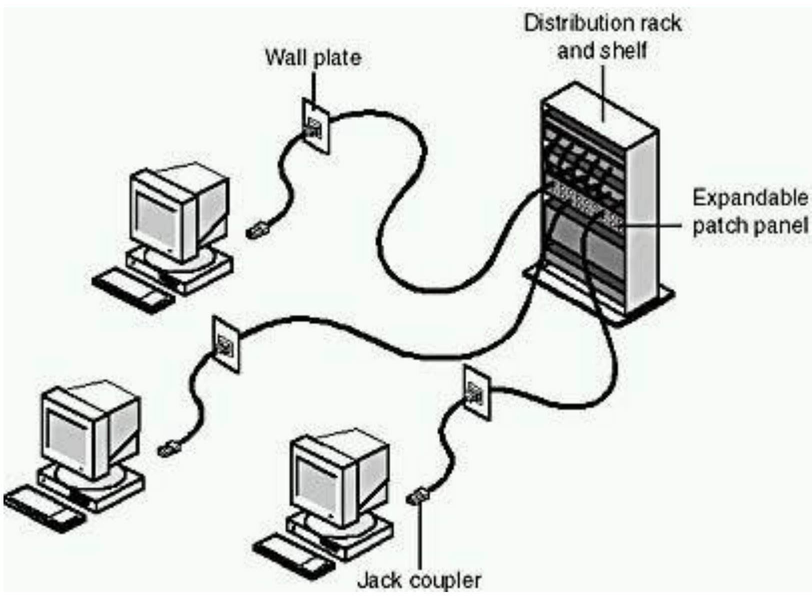


Figure 2.17 *Various twisted-pair cabling components*

Twisted-Pair Cabling Considerations

Use twisted-pair cable if:

- Your LAN is under budget constraints.
- You want a relatively easy installation in which computer connections are simple.

Do not use twisted-pair cable if:

- Your LAN requires a high level of security and you must be absolutely sure of data integrity.
- You must transmit data over long distances at high speeds.

Fiber-Optic Cable

In *fiber-optic cable*, optical fibers carry digital data signals in the form of modulated pulses of light. This is a relatively safe way to send data because, unlike copper-based cables that carry data in the form of electronic signals, no electrical impulses are carried over the fiber-optic cable. This means that fiberoptic cable cannot be tapped, and its data cannot be stolen.

Fiber-optic cable is good for very high-speed, high-capacity data transmission because of the purity of the signal and lack of signal attenuation.

Fiber-Optic Cable Composition

An optical fiber consists of an extremely thin cylinder of glass, called the *core*, surrounded by a concentric layer of glass, known as the *cladding*. The fibers are sometimes made of plastic. Plastic is easier to install, but cannot carry the light pulses for as long a distance as glass.

Because each glass strand passes signals in only one direction, a cable includes two strands in separate jackets. One strand transmits and one receives. A reinforcing layer of plastic surrounds each glass strand, and Kevlar fibers provide strength. See Figure 2.18 for an illustration of fiber-optic cable. The Kevlar fibers in the fiber-optic connector are placed between the two cables. Just as their counterparts (twisted-pair and coaxial) are, fiber-optic cables are encased in a plastic coating for protection.

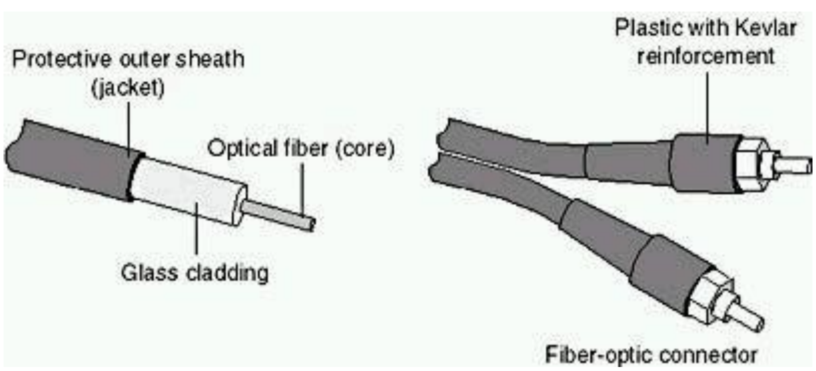


Figure 2.18 *Fiber-optic cable*

Fiber-optic cable transmissions are not subject to electrical interference and are extremely fast, currently transmitting about 100 Mbps with demonstrated rates of up to 1 gigabit per second (Gbps). They can carry a signal—the light pulse—for many miles.

Fiber-Optic Cabling Considerations

Use fiber-optic cable if you:

- Need to transmit data at very high speeds over long distances in very secure media.

Do not use fiber-optic cable if you:

- Are under a tight budget.
- Do not have the expertise available to properly install it and connect devices to it.

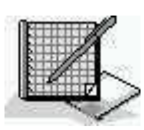
Table 2.3 *Cable Comparison Summary*

Characteristics	Thinnet coaxial (10Base2) Cable	Thicknet coaxial (10Base5) Cable	Twisted-pair (10BaseT) Cable[1]	Fiber-optic Cable
Cable cost	More than UTP	More than thinnet	UTP: Least expensive STP: More than thinnet	More than thinnet, but less than thicknet
Usable cable length[2]	185 meters (about 607 feet)	500 meters (about 1640 feet)	UTP and STP: 100 meters (about 328 feet)	2 kilometers (6562 feet)
Transmission rates	4-100 Mbps	4-100 Mbps	UTP: 4-100 Mbps STP: 16-500 Mbps	100 Mbps or more (> 1Gbps)
Flexibility	Fairly flexible	Less flexible than thinnet	UTP: Most flexible STP: Less flexible than	Less flexible than thicknet

			UTP	
Ease of installation	Easy to install	Moderately easy to install	UTP: Very easy; often preinstalled STP: Moderately easy	Difficult to install
Susceptibility to interference	Good resistance to interference	Good resistance to interference	UTP: Very susceptible STP: Good resistance	Not susceptible to interference
Special features	Electronic support components are less expensive than twisted-pair cable	Electronic support components are less expensive than twisted-pair cable	UTP: Same as telephone wire; often preinstalled in buildings STP: Supports higher transmission rates than UTP	Supports voice, data, and video
Preferred uses	Medium to large sites with high security needs	Linking thinnet networks	UTP: smaller sites on budget. STP: Token Ring in any size	Any size installation requiring speed and high data security and integrity

[1] This column provides information for both unshielded twisted-pair (UTP) and twisted-pair (STP) cable.

[2] Usable cable length can vary with specific network installations. As technology improves, usable cable length also increases.

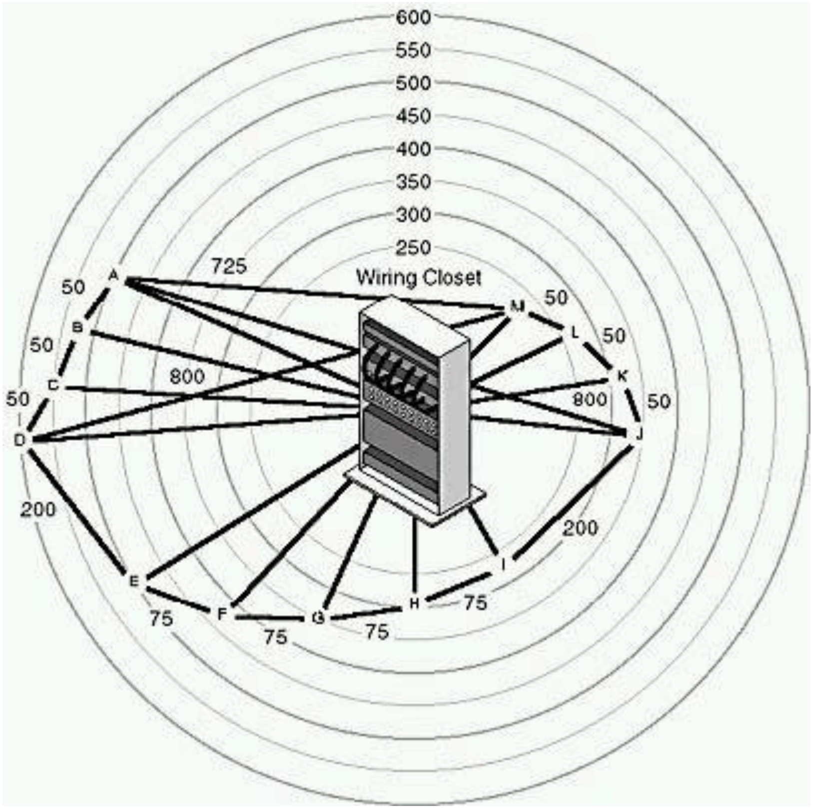


Exercise 2.1: Case Study Problem

You have been asked to review the proposals submitted by a consulting firm to design the cabling scheme for your company's new office building. Table 2.4 and the following diagram illustrate your company's cabling needs.

Table 2.4 *Your Company's Cabling Needs*

Location	Distance	Location	Distance
A to B	15 meters (50 feet)	Hub to A	152 meters (500 feet)
B to C	15 meters (50 feet)	Hub to B	160 meters (525 feet)
C to D	15 meters (50 feet)	Hub to C	168 meters (550 feet)
D to E	61 meters (200 feet)	Hub to D	184 meters (600 feet)
E to F	23 meters (75 feet)	Hub to E	152 meters (500 feet)
F to G	23 meters (75 feet)	Hub to F	130 meters (425 feet)
G to H	23 meters (75 feet)	Hub to G	107 meters (351feet)
H to I	23 meters (75 feet)	Hub to H	91 meters (300 feet)
I to J	61 meters (200 feet)	Hub to I	84 meters (275 feet)
J to K	15 meters (50 feet)	Hub to J	107 meters (351 feet)
K to L	15 meters (50 feet)	Hub to K	99 meters (325 feet)
L to M	15 meters (50 feet)	Hub to L	84 meters (275 feet)
A to M	221 meters (725 feet)	Hub to M	69 meters (226 feet)
D to M	244 meters (800 feet)	A to J	244 meters (800 feet)



The consulting firm has recommended that you implement 10BaseT Category 5 UTP wire for your company's network. Based on this information, answer the following questions:

1. Where does this recommendation violate the UTP and 10BaseT specifications?
2. What type of cabling might you recommend instead?

Answers

Lesson Summary

The following points summarize the main elements of this lesson:

- Three primary types of cables are used with networks: coaxial, twisted-pair, and fiber-optic.
- Coaxial cable comes in two varieties: thinnet and thicknet.
- Thinnet cable is about 0.64 centimeters thick (0.25 inches) and can carry a signal for a distance of up to 185 meters (607 feet).
- Thicknet cable is about 1.27 centimeters (0.5 inches) in diameter and can carry a signal for a distance of up to 500 meters (1640 feet).
- The BNC connector is used with both thinnet and thicknet cables.

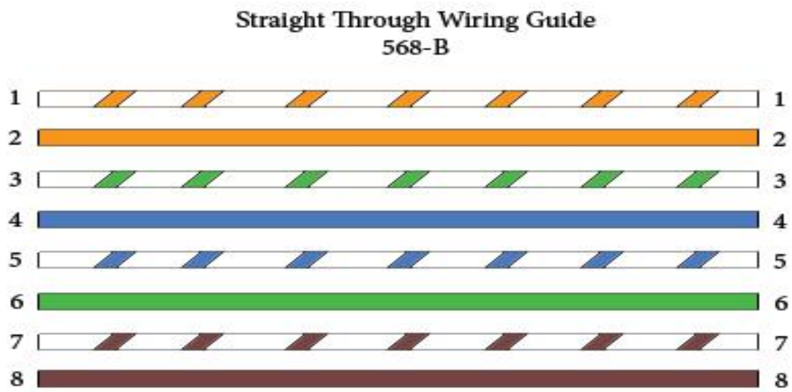
- Coaxial cables come in two grades, classified according to how they will be used: PVC-grade cable is used in exposed areas; plenum-grade cable has a fire-safety rating and is used in enclosed areas such as ceilings and walls.
- Twisted-pair cable can be either shielded (STP) or unshielded (UTP).
- The number of twists per unit of length and the protective shielding provide protection from interference.
- Twisted-pair cables conform to five standards, called categories. Each category provides specifications for increasing the speed of data transmission and resistance to interference.
- Twisted-pair cables use RJ-45 telephone connectors to connect to computers and hubs.
- Fiber-optic cables use light to carry digital signals.
- Fiber-optic cables provide the greatest protection from noise and intrusion.
- Data signals can be either baseband or broadband.
- Baseband transmission uses digital signals over a single frequency.
- Broadband transmission uses analog signals over a range of frequencies.
- IBM uses its own system of cabling and standards, but follows the same basic technology as other cables.

Straight-Through Wired Cables

Straight-Through refers to cables that have the pin assignments on each end of the cable. In other words Pin 1 connector A goes to Pin 1 on connector B, Pin 2 to Pin 2 ect. Straight-Through wired cables are most commonly used to connect a host to client. When we talk about cat5e patch cables, the Straight-Through wired cat5e patch cable is used to connect computers, printers and other network client devices to the router switch or hub (the host device in this instance).

- **Connector A**
  - Pin 1
  - Pin 2
  - Pin 3
  - Pin 4
  - Pin 5
  - Pin 6
  - Pin 7
  - Pin 8

- **Connector B**
    - Pin 1
    - Pin 2
    - Pin 3
    - Pin 4
    - Pin 5
    - Pin 6
    - Pin 7
    - Pin 8

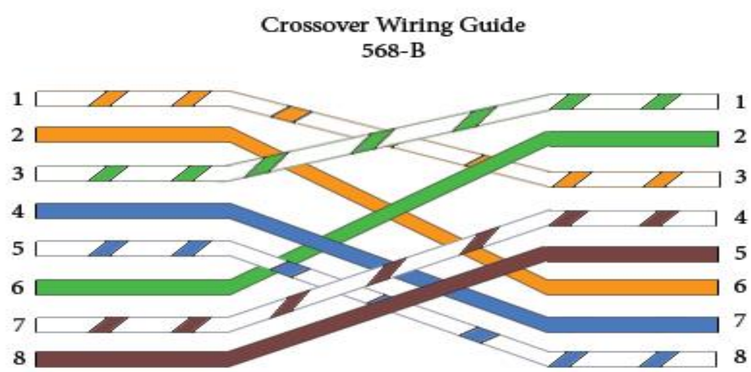


Crossover Wired Cables

Crossover wired cables (commonly called crossover cables) are very much like Straight-Through cables with the exception that TX and RX lines are crossed (they are at oposite positions on either end of the cable. Using the 568-B standard as an example below you will see that Pin 1 on connector A goes to Pin 3 on connector B. Pin 2 on connector A goes to Pin 6 on connector B ect. Crossover cables are most commonly used to connect two hosts directly. Examples would be connecting a computer directly to another computer, connecting a switch directly to another switch, or connecting a router to a router.*Note: While in the past when connecting two host devices directly a crossover cable was required. Now days most devices have auto sensing technology that detects the cable and device and crosses pairs when needed.*

- **Connector A**
    - Pin 1
    - Pin 2
    - Pin 3
    - Pin 4
    - Pin 5
    - Pin 6
    - Pin 7
    - Pin 8

- **Connector B**
    - Pin 3
    - Pin 6
    - Pin 1
    - Pin 7
    - Pin 8
    - Pin 2
    - Pin 4
    - Pin 5



Rollover Wired Cables

Rollover wired cables most commonly called rollover cables, have opposite Pin assignments on each end of the cable or in other words it is "rolled over". Pin 1 of connector A would be connected to Pin 8 of connector B. Pin 2 of connector A would be connected to Pin 7 of connector B and so on. Rollover cables, sometimes referred to as Yost cables are most commonly used to connect to a devices console port to make programming changes to the device. Unlike crossover and straight-wired cables, rollover cables are not intended to carry data but instead create an interface with the device.

- **Connector A**
    - Pin 1
    - Pin 2
    - Pin 3
    - Pin 4
    - Pin 5
    - Pin 6
    - Pin 7
    - Pin 8

- **Connector B**
    - Pin 8
    - Pin 7
    - Pin 6
    - Pin 5
    - Pin 4
    - Pin 3
    - Pin 2
    - Pin 1