Cables, connectors, and ports

This chapter covers

- The specifications and standards that allow computers to communicate
- The fundamentals of traffic over a network
- Types of wired connections and cabling standards
- The uses of unshielded twisted pair and fiber-optic connections in networks

In chapter 2, we looked at a few diagrams showing network nodes connected with cables. In this chapter, we will look at the specific kinds of cables, connectors, and ports used to make those connections. These topics are part of section 1.0, Network Fundamentals, of the CCNA exam. Specifically, we will cover aspects of exam topic 1.3, which is as follows:

- **1.3 Compare physical interface and cabling types**
    - 1.3.a Single-mode fiber, multimode fiber, copper
    - 1.3.b Connections (Ethernet shared media and point-to-point)

In the past, there have been many different ways to connect devices, and there still are. However, in modern networks, *Ethernet* reigns supreme and is by far the most common connection type. Perhaps you have heard of Ethernet before in reference to *Ethernet cables*. Ethernet is not one single thing but rather a collection of standards for physical wired connections as well as rules for communicating over those connections. In this chapter, we will look at two different kinds of physical connections between devices: those using copper cables and those using fiber-optic cables.

3.1 Network standards

In modern networks, the use of standards is crucial for the successful communication between devices. The Institute of Electrical and Electronics Engineers (IEEE) plays a significant role in establishing these standards. For instance, in 1983, the IEEE first defined the IEEE 802.3 standard, which is known as Ethernet (refer to Figure 3.1 for an overview of Ethernet standards).

Note:

The IEEE also defines the IEEE 802.11 standard, commonly recognized as Wi-Fi. The IEEE 802.11 series enables wireless communication in various environments (see Figure 3.2 for a comparison between Ethernet and Wi-Fi).

Ethernet has become a universal standard for network connections and is built on a family of standards that define how messages are formatted and transmitted over a network. Understanding these standards is essential for ensuring efficient communication and connectivity in modern networks.

3.2 Binary: Bits and bytes

You will learn about bit, byte, megabit, megabyte, and kilobyte. With the exponential growth in data, knowing how to interpret these terms is essential for understanding networking. The primary concern in networks today is the speed of data transfer, especially as more and more people subscribe to gigabit internet connections that can download files that are gigabytes in size. Comparing the speed of modern connections, you might recall the old dial-up internet connection.

To understand how these terms relate, we need to define what a bit is. A bit is simply a binary digit. It represents the smallest unit of data in computing. Each bit can either be a 0 or a 1. A byte, on the other hand, is made up of 8 bits. For instance, a byte can represent a single character.

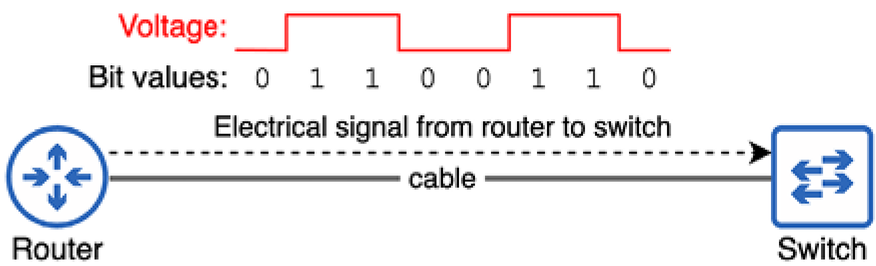
Binary is the language of computers. All data and instructions processed by computers are represented in binary. When you perform computations in binary, the computer reads the data as a series of 0s and 1s. Each of these bits corresponds to a binary state that indicates whether a circuit is on or off. You might encounter different types of data, such as images, sound, video, and text, represented in binary code, which is essential for a computer to understand.

In networking, the transmission of data occurs through various means, including fiber optics and copper wiring. In binary systems, data is transmitted as electrical pulses. A binary "0" represents a low voltage state, while a binary "1" represents a high voltage state. Figure 3.1 illustrates the relationship between bits and bytes; it shows how binary data is transmitted through networks, changing voltage levels that indicate either a 0 or a 1.

Exam Tip

Understanding the binary number system is crucial for the CCNA exam. In future sections, we will cover how to convert between binary and other number systems, including decimal, which is commonly used in everyday life.

Figure 3.1 A router sends 1 byte of data to a switch. Changes in the voltage of the electric signal indicate values of 0 or 1.



In modern networking, speed is a crucial factor for network connections that can transmit data at remarkable rates. However, many factors can influence the speed across different networks, including the type of cables used and the technology deployed. When discussing these speeds, it’s common to encounter terms like kilobits, megabits, and gigabits. Here’s a breakdown of the common units:

1. Kilobit (kb) = 1,000 (thousand) bits
2. Megabit (Mb) = 1,000,000 (million) bits (1,000 kilobits)
3. Gigabit (Gb) = 1,000,000,000 (billion) bits (1,000 megabits)
4. Terabit (Tb) = 1,000,000,000,000 (trillion) bits (1,000 gigabits)

Network speeds are typically measured in bits per second (bps). For example:

- 56 kbps (kilobits per second)
- 100 Mbps (megabits per second)
- 10 Gbps (gigabits per second)
- 1 Tbps (terabits per second)

1,000 or 1,024 Bits?

It's essential to clarify the difference between 1,000 and 1,024 when discussing data measurement. For instance:

- 1 kilobit can be seen as 1,000 bits in decimal terms but is often represented as 1,024 bits (2^10) in binary terms.
- Similarly, 1 megabit is 1,000,000 bits in decimal, but 1,024 kilobits (2^20) in binary.

This distinction arises from the binary numbering system, where values are based on powers of two. Here's a quick reference for binary multiples:

- 1 kibibit (KiB) = 1,024 bits
- 1 mebibit (MiB) = 1,024 kibibits
- 1 gibibit (GiB) = 1,024 mebibits
- 1 tebibit (TiB) = 1,024 gibibits

3.3 Copper UTP Connections

Copper cables are essential for wired network connections. Using copper cabling, particularly twisted-pair cables (UTP), is common in Ethernet networks.

- Ethernet Cables: These cables are used for connecting devices in a local area network (LAN). The Ethernet standard ensures that devices can communicate effectively over these copper cables.
- 8P8C Connectors: The standard connector for these Ethernet cables is the 8P8C (eight positions, eight contacts) connector, commonly known as an RJ45 connector.

In Figure 3.2, you might see two 8P8C ports on a Cisco switch (left) and an 8P8C connector on a copper UTP network cable (right). This figure illustrates how devices in a network are interconnected using Ethernet cables, allowing for the transmission of data at high speeds.

Figure 3.2 shows an 8-position, 8-contact (8P8C) connector used in Ethernet cables for network connections. This standard allows for the connectivity of devices over a network using copper cables. Each cable is equipped with specific wiring standards that ensure efficient data transmission.

Connectors and Cables

- RJ45 Connector: This is the standard connector for Ethernet cables, also known as Registered Jack. It plays a crucial role in connecting devices within a network. The RJ45 connector has specific pin arrangements that adhere to Ethernet standards.
- Copper Cables: The cables used in Ethernet connections are typically unshielded twisted pair (UTP) cables. These cables consist of pairs of wires twisted together to reduce electromagnetic interference (EMI).

Shielded Twisted Pair (STP) cables are also used in some applications where EMI is a concern. STP cables contain additional shielding that helps protect against interference from external sources.

Types of Twisted Pair Cables

1. Unshielded Twisted Pair (UTP): These cables are widely used for networking because they are cost-effective and sufficient for most applications. UTP cables are less protected against external interference.
2. Shielded Twisted Pair (STP): These cables include a shielding layer that helps reduce EMI, making them suitable for environments with high interference.

3.3.1 IEEE 802.3 Standards (Copper)

The IEEE 802.3 standards define the Ethernet connections and set specifications for various aspects, including cable types and maximum transmission speeds. Here are some key points regarding these standards:

- Transmission Speeds: The standards dictate the maximum speed at which data can be transmitted over Ethernet connections.
- Task Groups: Various IEEE task groups work on developing these standards. For instance, IEEE 802.3 includes a range of specifications that determine the parameters for Ethernet networks.

Working Groups and Task Groups

The IEEE has designated working groups that develop specific standards for networking technologies. For example:

- 802.3: This group is responsible for the Ethernet standard, which governs wired networks.
- 802.11: This group covers wireless networking standards, commonly known as Wi-Fi.

Each task group within the IEEE focuses on different aspects of networking, such as speed, security, and compatibility. For instance, task groups may address updates to existing standards or propose new standards altogether.

Examples of Ethernet Standards

Table 3.1 provides examples of Ethernet standards and their specifications related to copper cabling. Some common Ethernet standards include:

- 10BASE-T: Supports speeds up to 10 Mbps.
- 100BASE-TX: Supports speeds up to 100 Mbps.
- 1000BASE-T: Supports speeds up to 1 Gbps.

These standards outline the technical requirements necessary for the effective implementation of Ethernet networking.

Table 3.1 A handful of Ethernet standards [(view table figure)]

Speed	Speed-derived name	IEEE task group	Informal name	Maximum cable length
10 Mbps	Ethernet	IEEE 802.3i	10BASE-T	100 m
100 Mbps	Fast Ethernet	IEEE 802.3u	100BASE-T	100 m
1 Gbps	Gigabit Ethernet	IEEE 802.3ab	1000BASE-T	100 m
10 Gbps	10 Gig Ethernet	IEEE 802.3an	10GBASE-T	100 m

Exam Tip

Make sure to remember that, as a general rule, there are three main categories of Ethernet standards relating to maximum cable length, speed-derived names, and informal names. This knowledge can be useful when addressing questions about these standards.

The Ethernet standards for ports have a maximum cable length that typically does not exceed 100 meters. The performance of the GBV cables should always comply with the maximum specified lengths, particularly when installing in large networks. This includes Ethernet cabling technology and is vital for optimal performance.

Note

The cables used in your Ethernet standards must be classified according to specific categories defined by the Telecommunications Industry Association (TIA) and the Electronic Industries

Alliance (EIA). Although the term "Ethernet cable" may not directly refer to cables defined by the IEEE 802.3 standard, it is still widely used.

For example, the standards define cables categorized as Category 5 (Cat 5), which are suitable for various Ethernet installations. Table 3.2 lists some common UTP cable standards that are relevant for Ethernet data transmission.

Table 3.2 Common UTP cable standards [(view table figure)]

Speed	Ethernet informal name	Cable name
10 Mbps	10BASE-T	Cat 3
100 Mbps	100BASE-T	Cat 5
1 Gbps	1000BASE-T	Cat 5e
10 Gbps	10GBASE-T	Cat 6a

3.3.2 Straight-through and Crossover Cables

Both types of cables are essential for network communications, and their use depends on the specific Ethernet standards that dictate their application:

- 10BASE-T cables are typically used for 10 Mbps connections.
- 100BASE-TX cables are commonly used for 100 Mbps connections.
- 1000BASE-T cables support 1 Gbps connections.
- 10GBASE-T cables are used for 10 Gbps connections.

In general, the type of cable used for a particular connection depends on the equipment being connected. The most common cable types for Ethernet connections are straight-through and crossover cables. The difference lies in how the wires are arranged within the cable and the type of devices being connected.

Straight-through Cables

Straight-through cables are the most common type used in networking. They connect devices of different types, such as:

- A switch to a computer.
- A router to a switch.

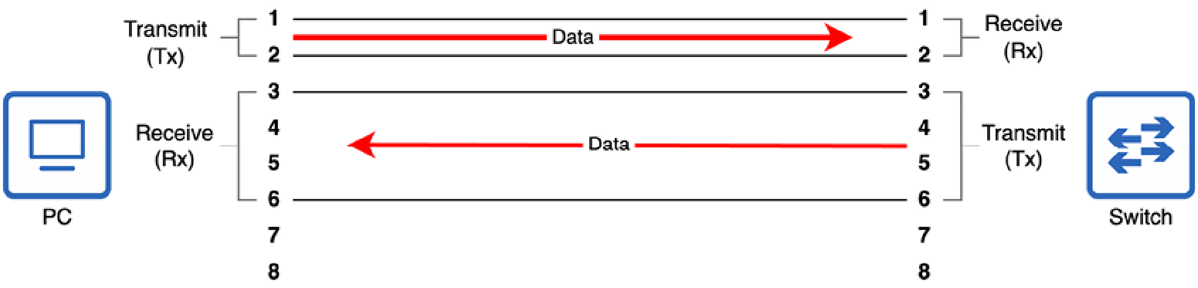
In terms of wiring, the straight-through cable configuration typically follows this standard:

1. Pins 1 and 2 are connected on both ends to the same color-coded wires.
2. Pins 3 and 6 are similarly connected.

To elaborate, if you refer to Figure 3.3, you will see how a straight-through cable is wired. For example, in a switch-to-computer connection, you will connect pin 1 of the switch to pin

1 of the cable and pin 2 of the switch to pin 2 of the cable. Similarly, pin 3 of the switch connects to pin 3 of the computer and pin 6 to pin 6.

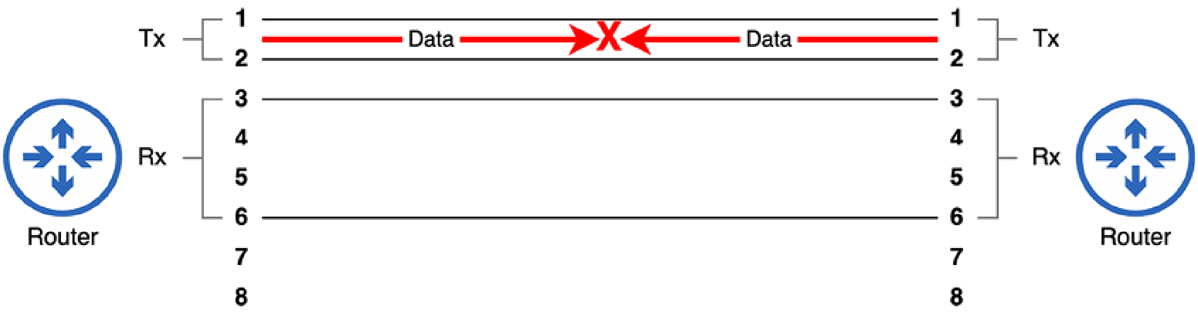
Figure 3.3 A PC and a switch connected via a straight-through cable



Using a straight-through cable allows a PC to connect with a switch, enabling seamless data transmission. This works because the Ethernet connection standards define how data should be transmitted between devices. In Figure 3.3, a straight-through cable connects pins 1 and 2 on the PC to the corresponding pins on the switch (represented in the wiring diagram). The switch connects its pins 3 and 6 to transmit data to the PC.

However, what would happen if two switches were connected with a straight-through cable? Or routers? In such a case, using a straight-through cable could lead to problems, as illustrated in Figure 3.4.

Figure 3.4 Two routers connected via a straight-through cable. Because both routers transmit data using the same pin pair, communication fails.



When two routers are connected using a straight-through cable, the communication fails because both routers transmit data using the same pin pair.

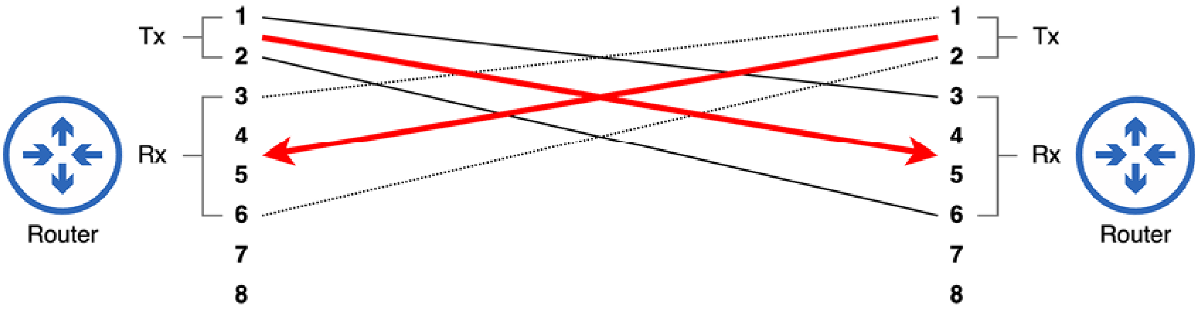
In general, using a straight-through cable for similar devices can cause a communication failure. The cable's configuration does not allow for the proper exchange of data. This is where crossover cables come into play.

Crossover cables

A crossover cable connects specific pins in a way that allows for effective communication between similar devices. For instance, pins 1 and 2 are connected to pins 3 and 6 of the other device. This configuration allows routers to communicate effectively when connected to one another.

In Figure 3.5, the devices are connected using a crossover cable, where the Tx pin pair of one router connects to the Rx pin pair of the other router.

Figure 3.5 Two routers connected via a crossover cable. The Tx pin pair of one router connects to the Rx pin pair of the other router.



As shown, using crossover cables facilitates communication between two routers by ensuring that the transmit pins connect to the receive pins.

Table 3.3 Common device types and their Tx/Rx pin pairs (view table figure)

In networking, different devices have specific pin configurations for transmitting and receiving data. Table 3.3 summarizes common device types and their corresponding Tx/Rx pin pairs:

Device type	Transmit (Tx) pins	Receive (Rx) pins
Router	1 and 2	3 and 6
Firewall	1 and 2	3 and 6
PC/Server	1 and 2	3 and 6
Switch	3 and 6	1 and 2

Note

Using a straight-through cable when connecting devices like switches or routers can lead to ineffective communication. It's essential to match the cable type with the devices being connected to ensure proper data transfer.

Auto MDI-X

Figure 3.7 demonstrates this concept. The two routers are connected via a straight-through cable. Routers typically transmit data on the 1-2 pair and receive data on the 3-6 pair, but thanks to Auto MDI-X the router on the right reverses that; it transmits data on the 3-6 pair and receives data on the 1-2 pair.

Figure 3.7 Two routers connected via a straight-through cable. The router on the right uses Auto MDI-X to adjust which pins it uses to transmit and receive data.

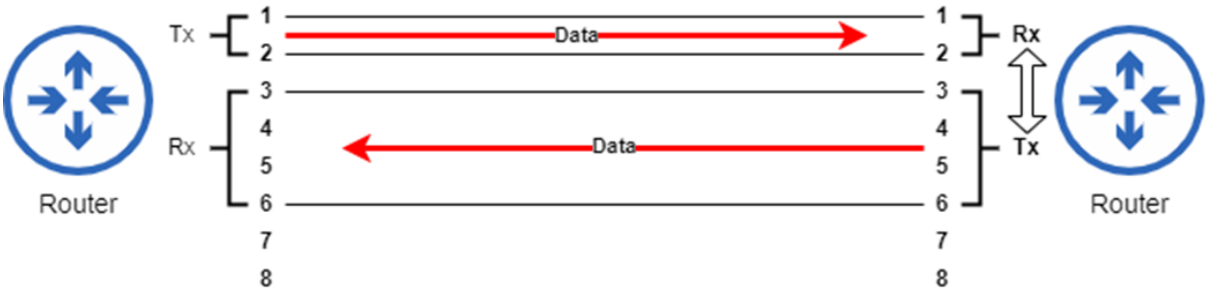
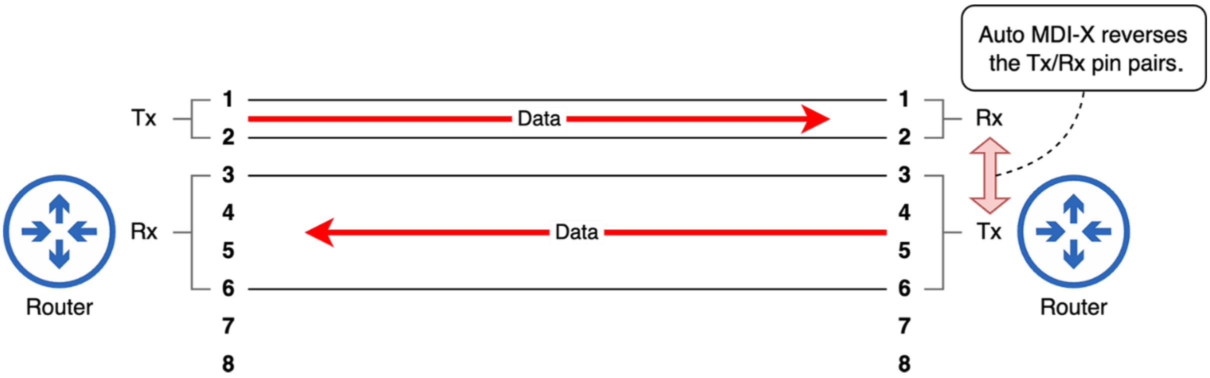


Figure 3.6 Two routers connected via a straight-through cable. The router on the right uses Auto MDI-X to adjust which pins it uses to transmit and receive data.



1000BASE-T and 10GBASE-T

Figure 3.8 Pin and wire pairs used on 1000BASE-T and 10GBASE-T connections. All eight wires of the cable are used.

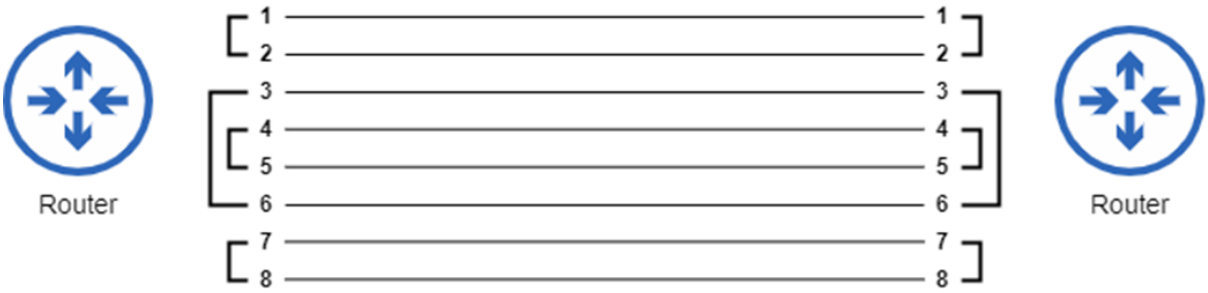


Figure 3.7 Pin and wire pairs used on 1000BASE-T and 10GBASE-T connections. All eight wires of the cable are used.

If a crossover cable is used, the 1-2 and 3-6 pairs are crossed over as in 10BASE-T and 100BASE-T, and the new 4-5 and 7-8 are crossed over as well. However, thanks to Auto MDI-X we no longer have to worry about selecting the proper cable type, and it's probably not something you'll be tested on.

3.4 Fiber-optic connections

Fiber-optic cables, instead of transmitting electrical signals along a copper wire, transmit light signals along a glass fiber. The glass fiber used is more flexible than you might think of when you imagine glass, but still fiber-optic cables must be handled with care; a sharp bend in the cable can damage the glass fiber, rendering the cable unusable. Even if the glass fiber doesn't snap, bending the cable can cause light to leak out of the cable, resulting in a weakening of the signal.

3.4.1 The anatomy of a fiber-optic cable

Figure 3.9 shows a Cisco switch with a couple of SFP transceivers: one inserted into an SFP port and one on top of the switch. Notice that two cables connect to the SFP transceiver, not one. When connecting two devices together with fiber-optic cables, it's important to connect the cables correctly: one device's transmitter must connect to the other device's receiver, otherwise communication is not going to happen (similar to correctly selecting straight-through/crossover cables when connecting devices that don't support Auto MDI-X).

Figure 3.9 A Cisco switch with an SFP transceiver inserted into one of its SFP ports. An additional SFP is placed on top of the switch.

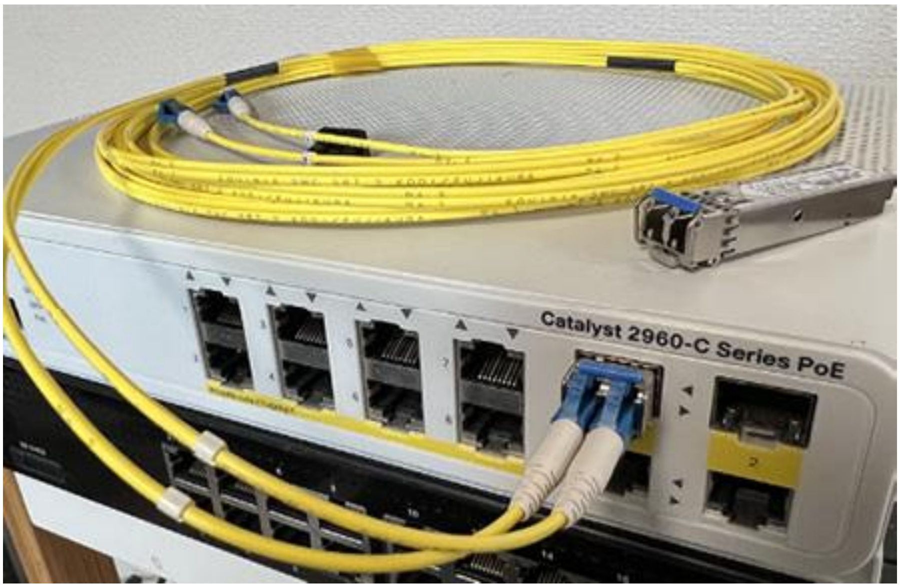


Figure 3.8 A Cisco switch with an SFP transceiver inserted into one of its SFP ports. An additional SFP is placed on top of the switch.

Figure 3.9 The typical structure of a fiber-optic cable. An outer jacket (4) and buffer (3) serve to protect and contain the inner components. A layer of reflective cladding (2) helps carry the light signal along the glass core (1).

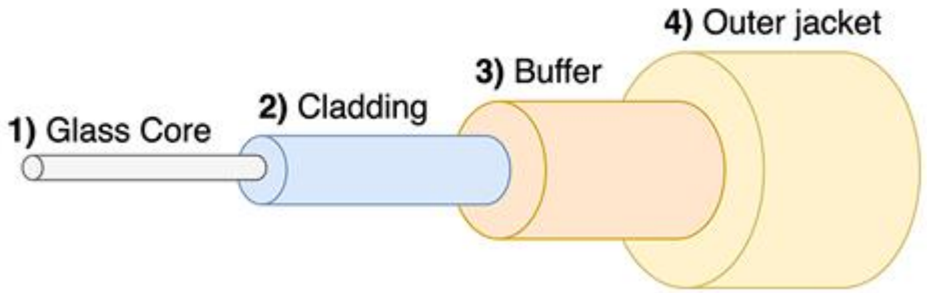
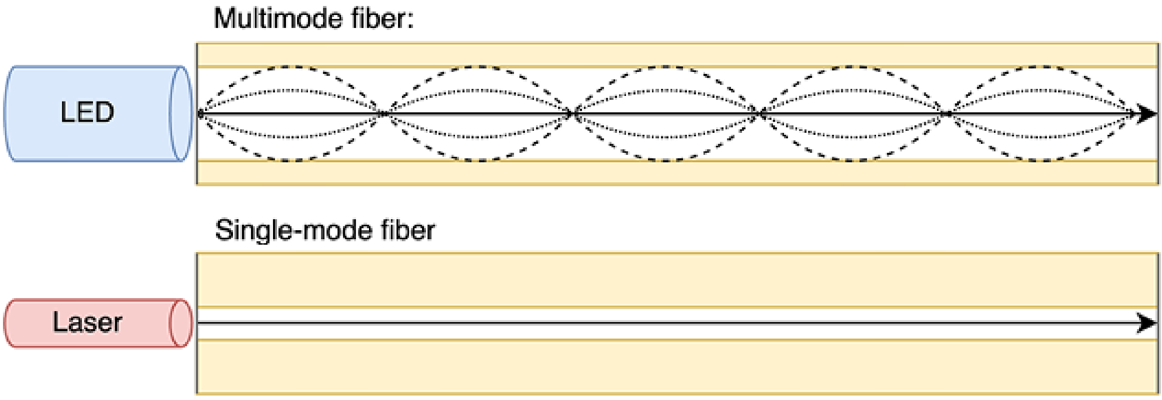


Figure 3.10 Light travels down an MMF cable at multiple angles (*modes*), whereas light travels down SMF cables at a single angle.



Single-mode fiber cables use a very narrow core in combination with laser transmitters that send light down the cable at a single angle. These laser transmitters are typically more expensive than the LED transmitters used by multimode fiber cables. However, single-mode fiber cables also support much greater maximum distances: up to tens of kilometers.

3.4.2 UTP vs. fiber

On the other hand, fiber-optic connections are more common for connections between network infrastructure, for example connecting switches and routers that are located in separate floors or separate buildings.

However, fiber cabling has a couple more advantages over copper UTP: one is that copper UTP cables are vulnerable to *electromagnetic interference* (EMI). This is generally not a concern, but in environments with lots of electrical equipment, EMI can negatively affect the signals traveling along a UTP cable. A second disadvantage is that copper UTP cables can emit (*leak*) their signal outside of the cable. This leaked signal is quite weak, but it’s possible that it can be detected and read, posing a security risk.

The most common considerations for whether to use copper UTP or fiber cabling are maximum distance, cost, and which connection type is supported by the devices to be connected. Most client devices (such as PCs) do not have SFP ports which can be used for fiber-optic connections, so a UTP connection is the only choice.

Summary

- Standards provide agreed-upon sets of rules for communication over networks.

- Ethernet is a family of standards defined by the Institute of Electrical and Electronics Engineers (IEEE) 802.3 working group. It defines standards for communication over physical wired connections.
- Computers compute and communicate using binary: 0s and 1s. Each binary digit is called a *bit*, and a group of 8 bits is called a *byte*.
- Network speeds are measured in bits per second using units like kilobit (1,000 bits), megabit (1,000 kilobits), gigabit (1,000 megabits), and terabit (1,000 gigabits).
- The most common connection type in Ethernet LANs uses copper unshielded twisted pair (UTP) cables. Unshielded means the wires in the cable do not have a metallic shield around them to protect against electromagnetic interference (EMI). Twisted pair means the eight wires in the cable are twisted together to form four pairs of two wires. The twisting of the wires reduces EMI between the wires of each pair.
- UTP cables use 8 position 8 contact (8P8C) connectors, also known as *Registered Jack-45* (RJ45).
- 10BASE-T and 100BASE-T connections use two of the four wire/pin pairs in a UTP cable, and 1000BASE-T and 10GBASE-T connections use all four pairs. All connection types support a maximum cable length of 100 meters.
- In 10BASE-T and 100BASE-T connections, different device types send and receive data using different pins of the connector; however, Auto MDI-X allows devices to automatically adjust which pins to use for which purpose.
- Fiber-optic cables send light signals down a glass fiber core and support much greater maximum distances than UTP cables.
- Single-mode fiber (SMF) cables support greater maximum distances (tens of kilometers) than multimode fiber (MMF) cables (hundreds of meters), but the laser-based small form factor pluggable (SFP) transceivers used by SMF connections are more expensive than the LED-based transceivers used by MMF connections.
- Fiber-optic connections are more expensive than copper UTP connections, largely due to the cost of the SFP transceivers.
- UTP connections are more common between end hosts and switches because of their lower cost and because the 100-meter maximum cable length is usually sufficient. Additionally, most client devices (such as PCs) only support UTP connections.
- Fiber-optic connections are more common between network infrastructure devices because of the increased maximum cable length. Network devices often connect to other network devices on different floors and in different buildings.