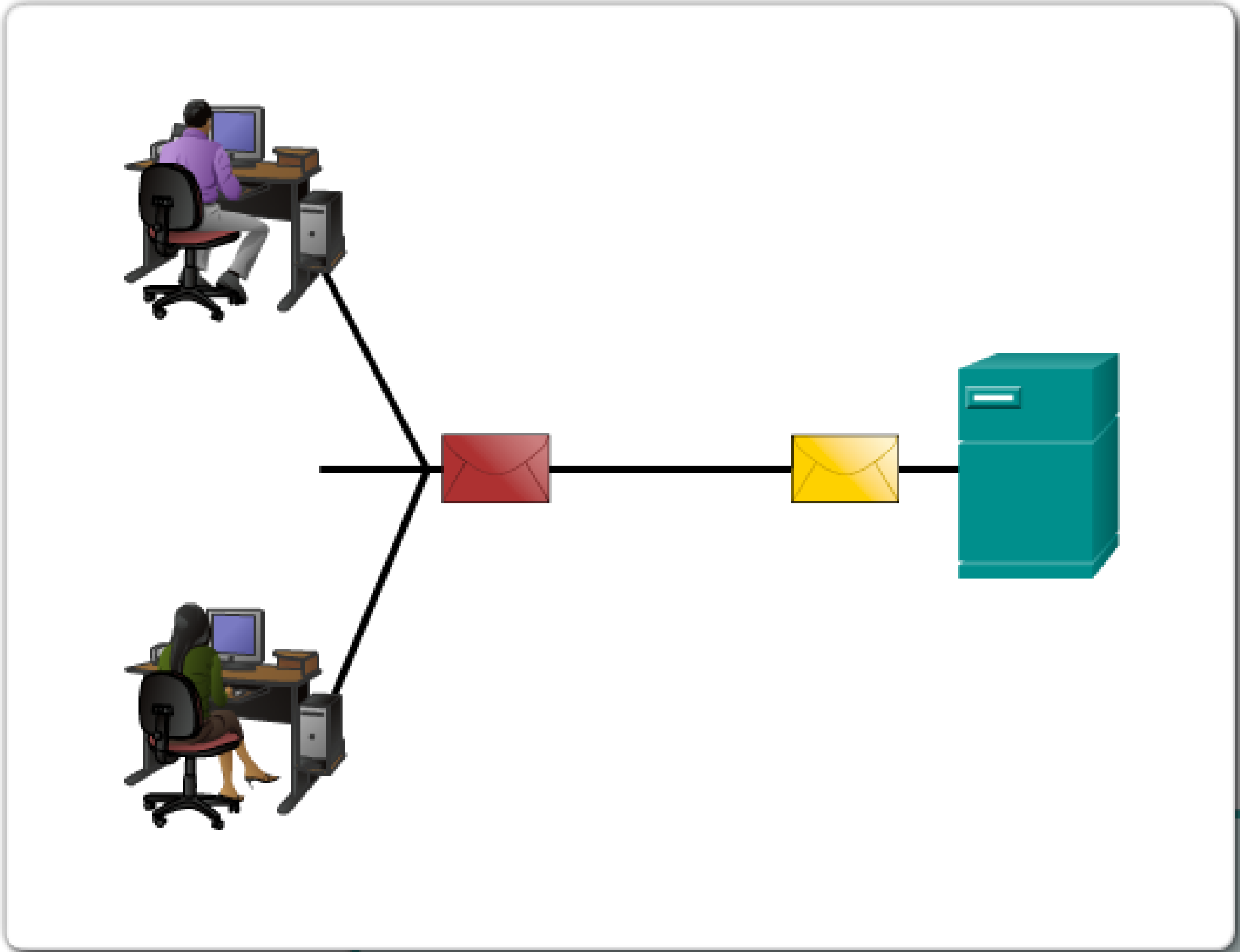
4.0.1.1 Chapter 4: Network Access

To support our communication, the OSI model divides the functions of a data network into layers. Each layer works with the layers above and below to transmit data.

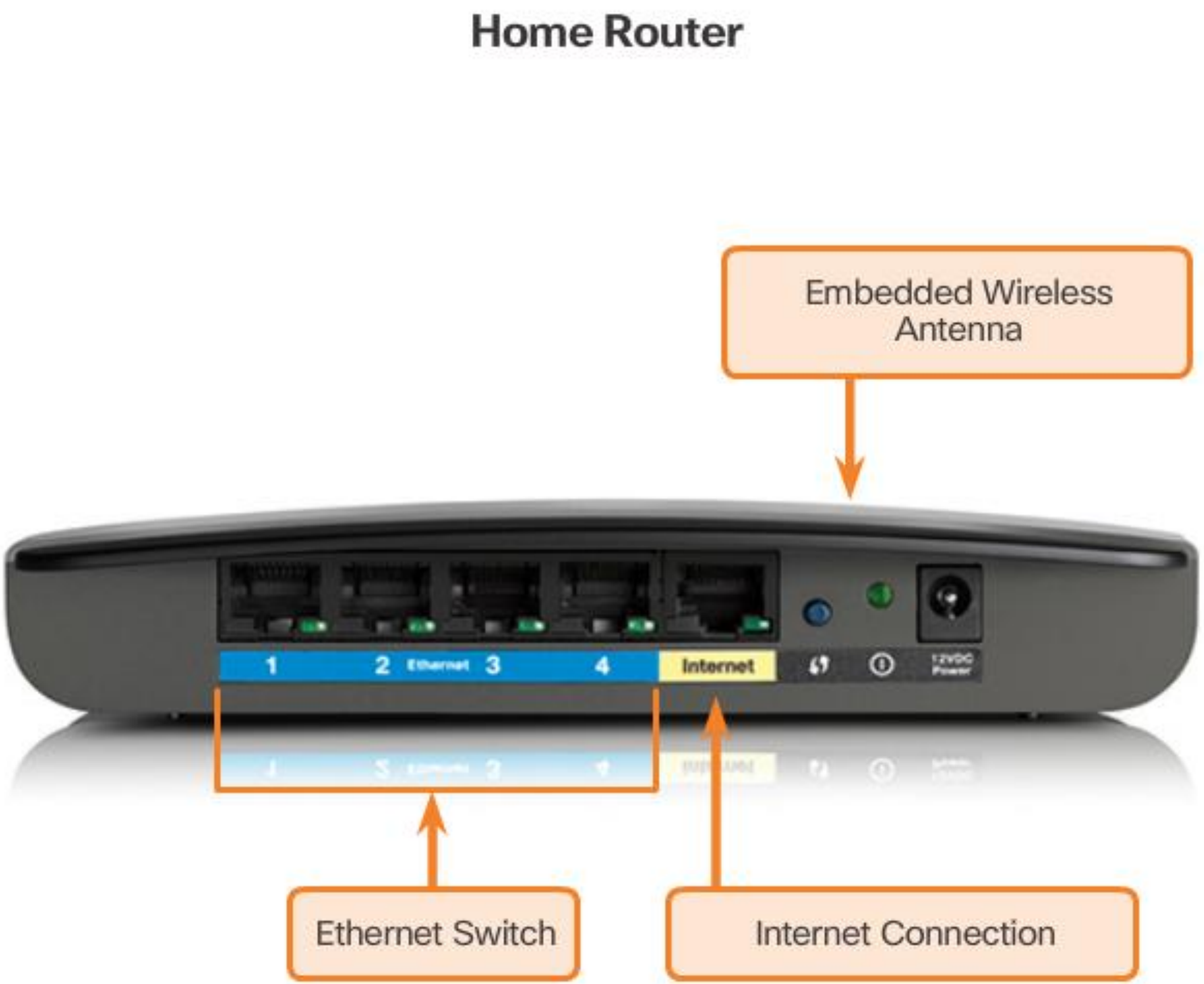
4.0.1.2 Class Activity – Managing the Medium



Class Activity – Managing the Medium

Data link protocols govern how to format a frame for use with different media.

4.1.1.1 Types of Connections



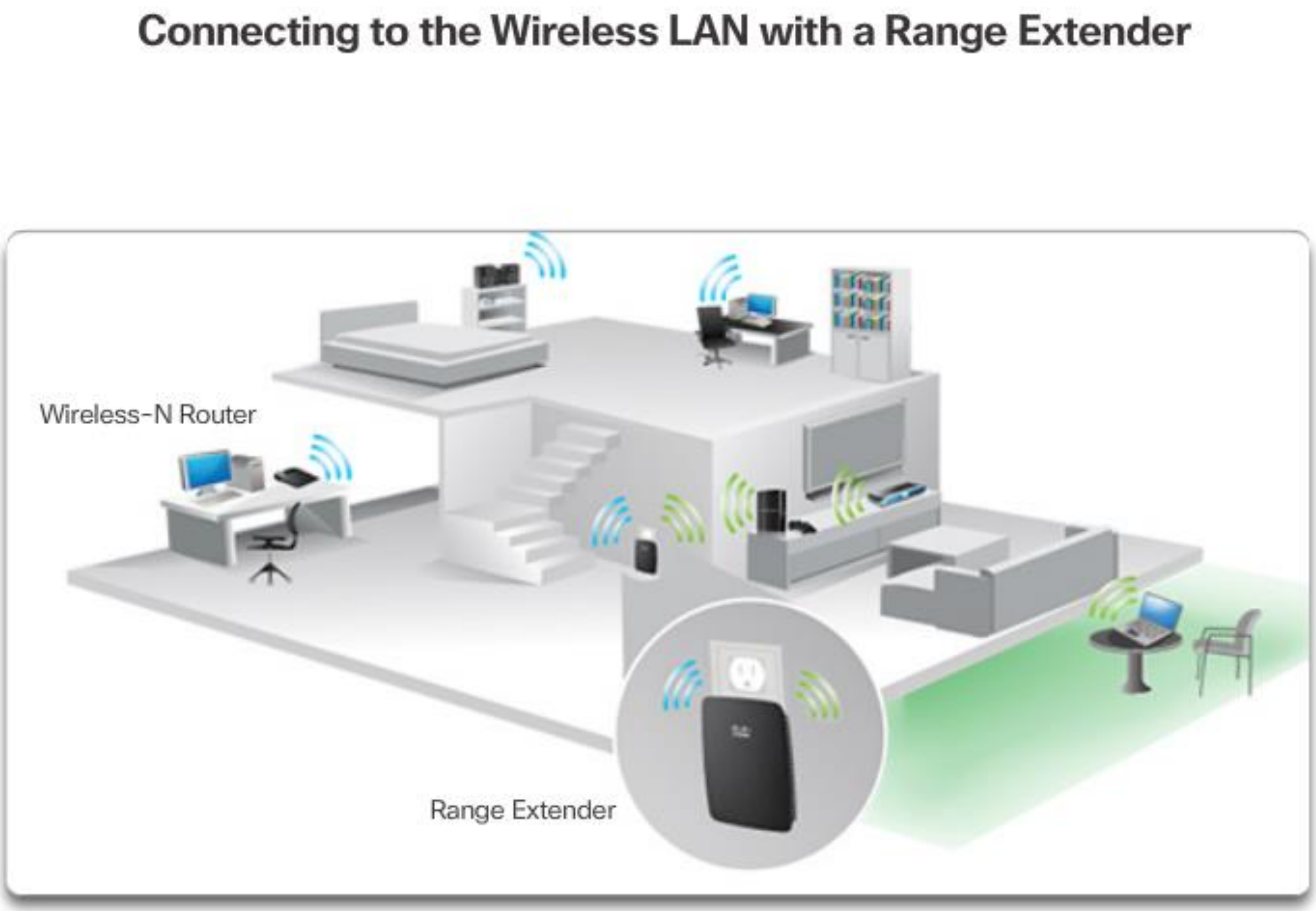
Whether connecting to a local printer in the home or a web site in another country, before any network communications can occur, a physical connection to a local network must be established. A physical connection can be a wired connection using a cable or a wireless connection using radio waves.

4.1.1.2 Network Interface Cards

Wired Connection using an Ethernet NIC

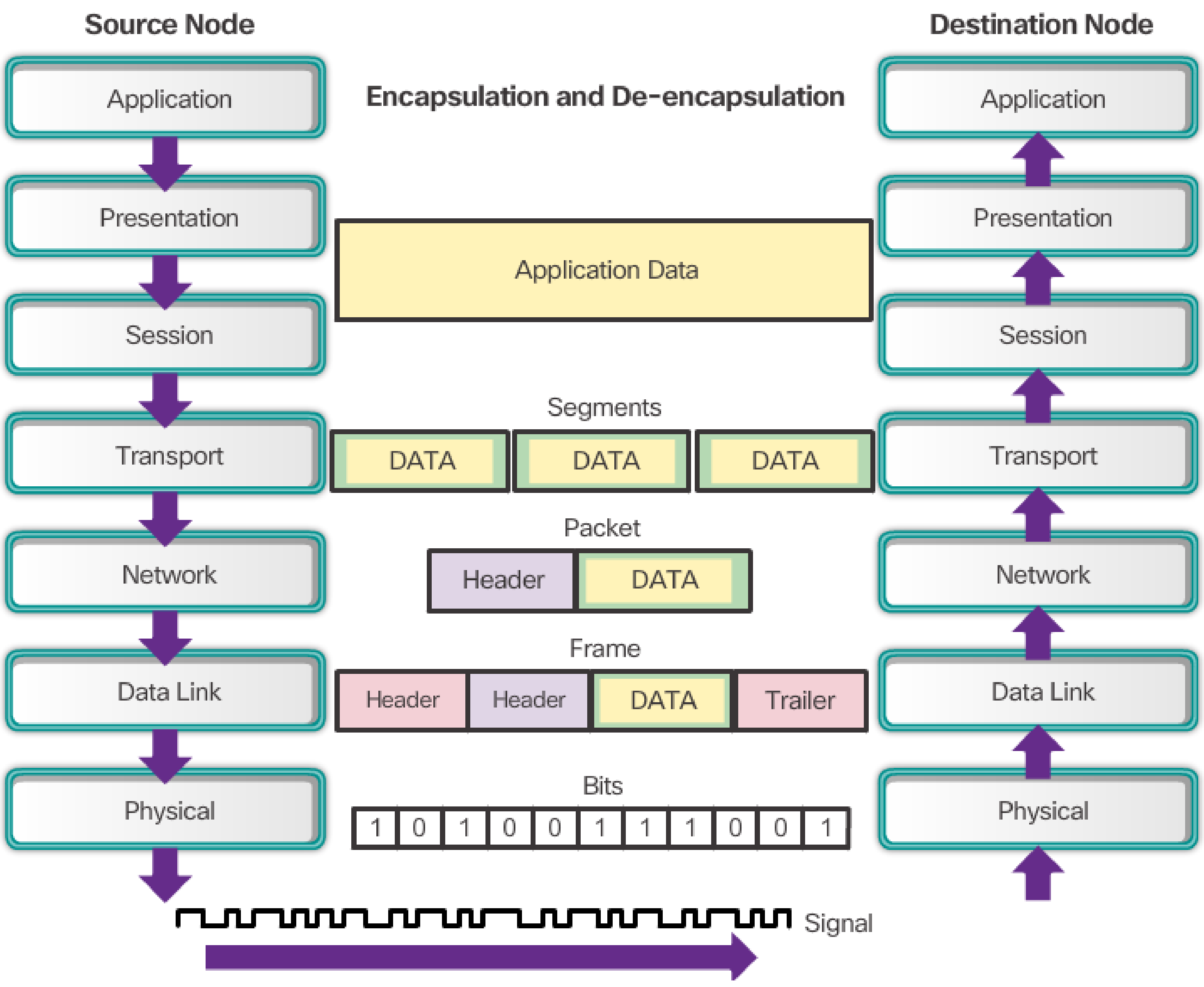
Network Interface Cards (NICs) connect a device to the network. Ethernet NICs are used for a wired connection, as shown in Figure 1, whereas WLAN (Wireless Local Area Network) NICs are used for wireless. An end-user device may include one or both types of NICs. A network printer, for example, may only have an Ethernet NIC, and therefore, must connect to the network using an Ethernet cable. Other devices, such as tablets and smartphones, might only contain a WLAN NIC and must use a wireless connection.

4.1.1.2 Network Interface Cards



All wireless devices must share access to the airwaves connecting to the wireless access point. This means slower network performance may occur as more wireless devices access the network simultaneously. A wired device does not need to share its access to the network with other devices. Each wired device has a separate communications channel over its Ethernet cable. This is important when considering some applications, such as online gaming, streaming video, and video conferencing, which require more dedicated bandwidth than other applications.

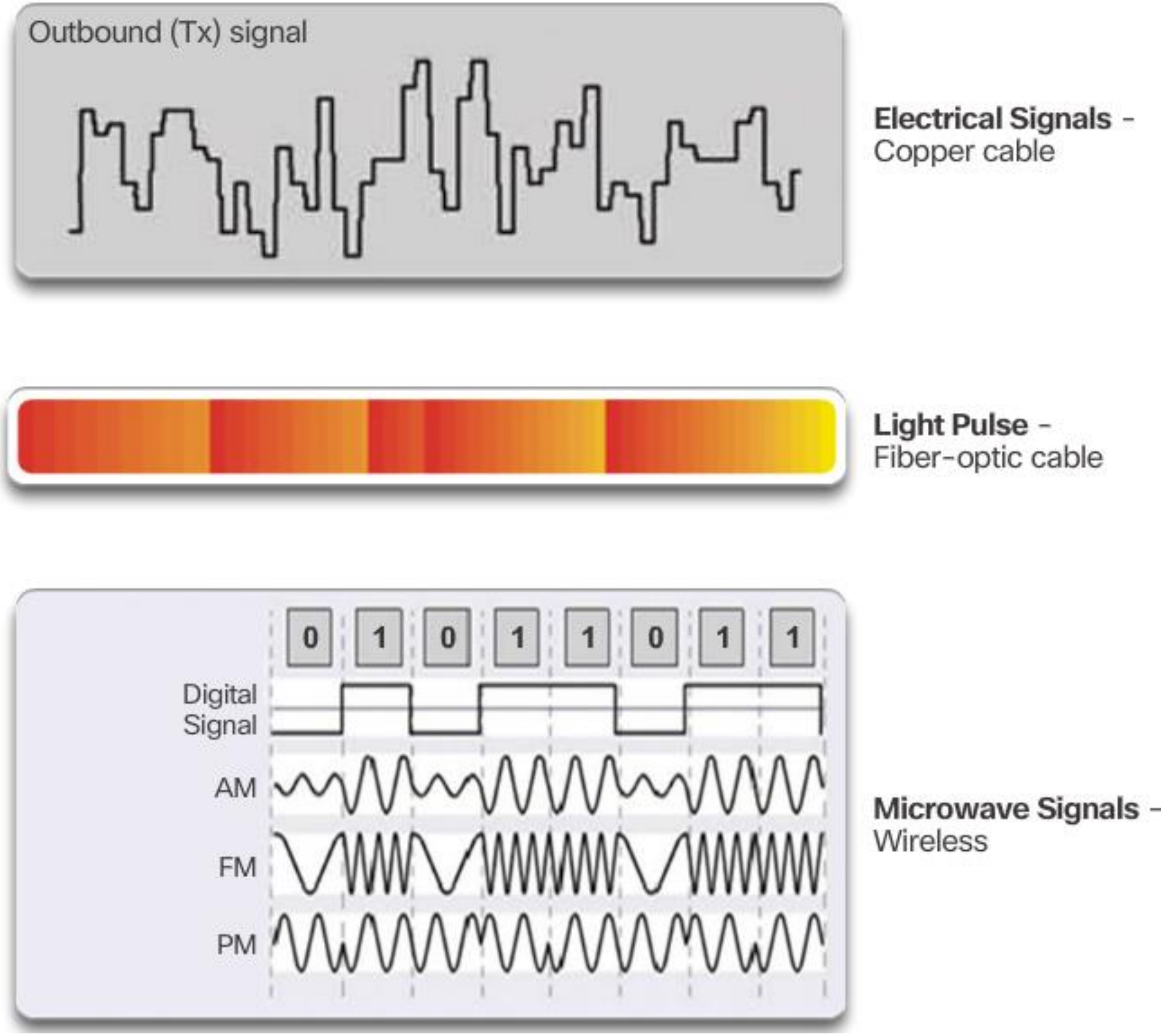
4.1.2.1 The Physical Layer



The process that data undergoes from a source node to a destination node is:

- The user data is segmented by the transport layer, placed into packets by the network layer, and further encapsulated into frames by the data link layer.
- The physical layer encodes the frames and creates the electrical, optical, or radio wave signals that represent the bits in each frame.
- These signals are then sent on the media, one at a time.
- The destination node physical layer retrieves these individual signals from the media, restores them to their bit representations, and passes the bits up to the data link layer as a complete frame.

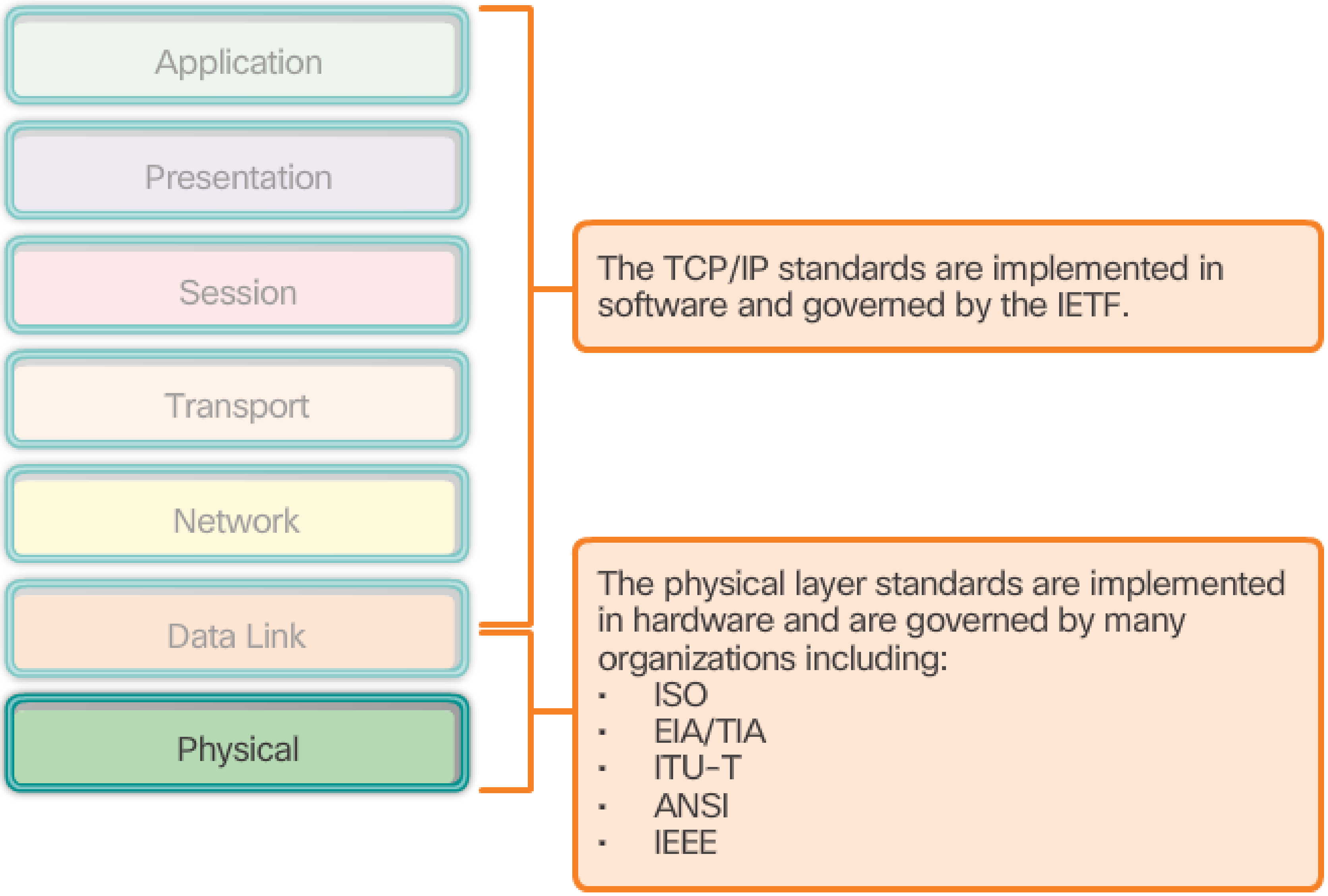
4.1.2.2 Physical Layer Media



There are three basic forms of network media. The physical layer produces the representation and groupings of bits for each type of media as:

- **Copper cable**: The signals are patterns of electrical pulses.
- **Fiber-optic cable**: The signals are patterns of light.
- **Wireless**: The signals are patterns of microwave transmissions.

4.1.2.3 Physical Layer Standards



Physical Layer Standards

The protocols and operations of the upper OSI layers are performed in software designed by software engineers and computer scientists. The services and protocols in the TCP/IP suite are defined by the Internet Engineering Task Force (IETF).

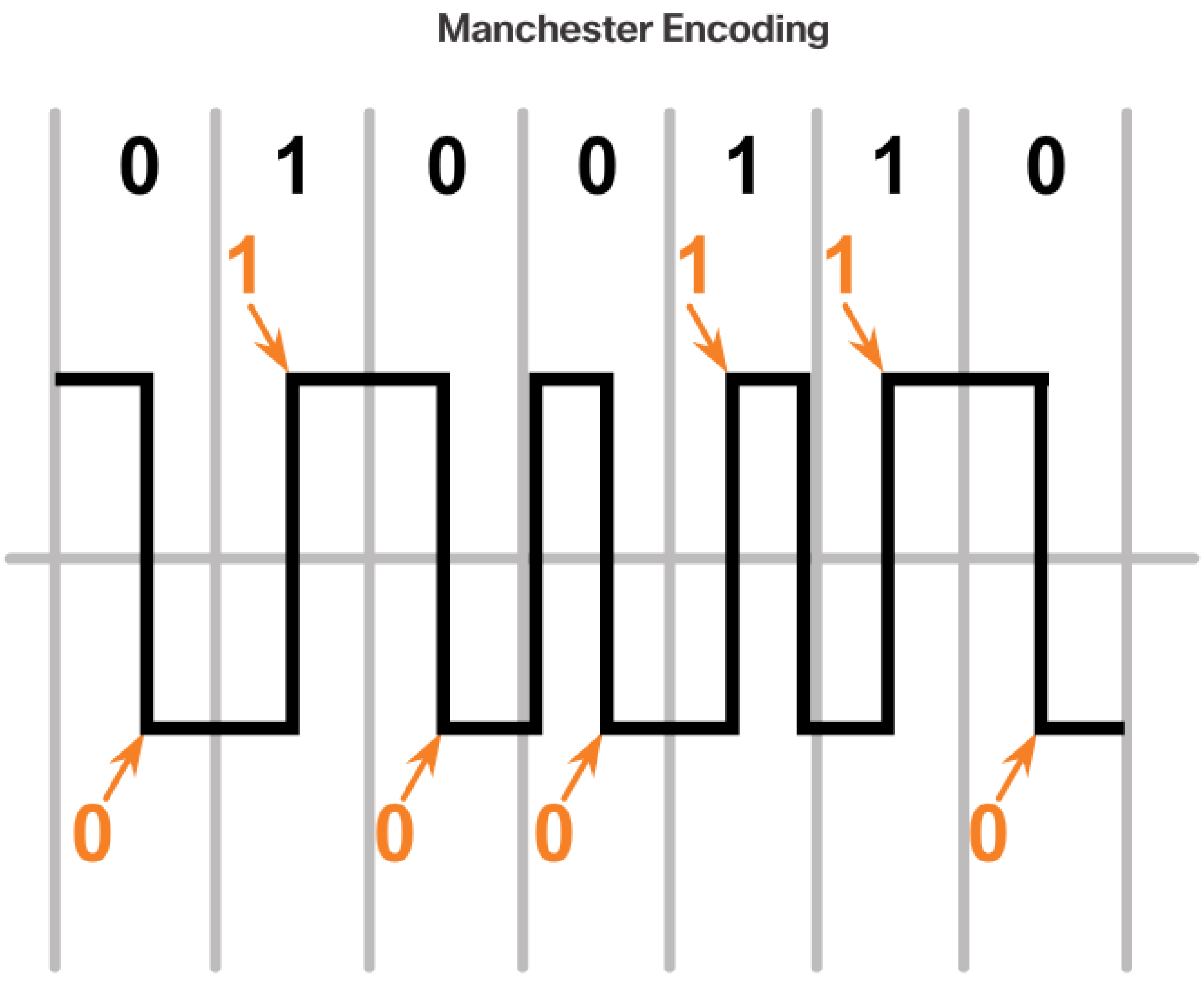
The physical layer consists of electronic circuitry, media, and connectors developed by engineers. Therefore, it is appropriate that the standards governing this hardware are defined by the relevant electrical and communications engineering organizations

4.1.2.4 Lab - Identifying Network Devices and Cabling

In this lab, you will complete the following objectives:

- Part 1: Identify Network Devices
- Part 2: Identify Network Media

4.1.3.1 Functions

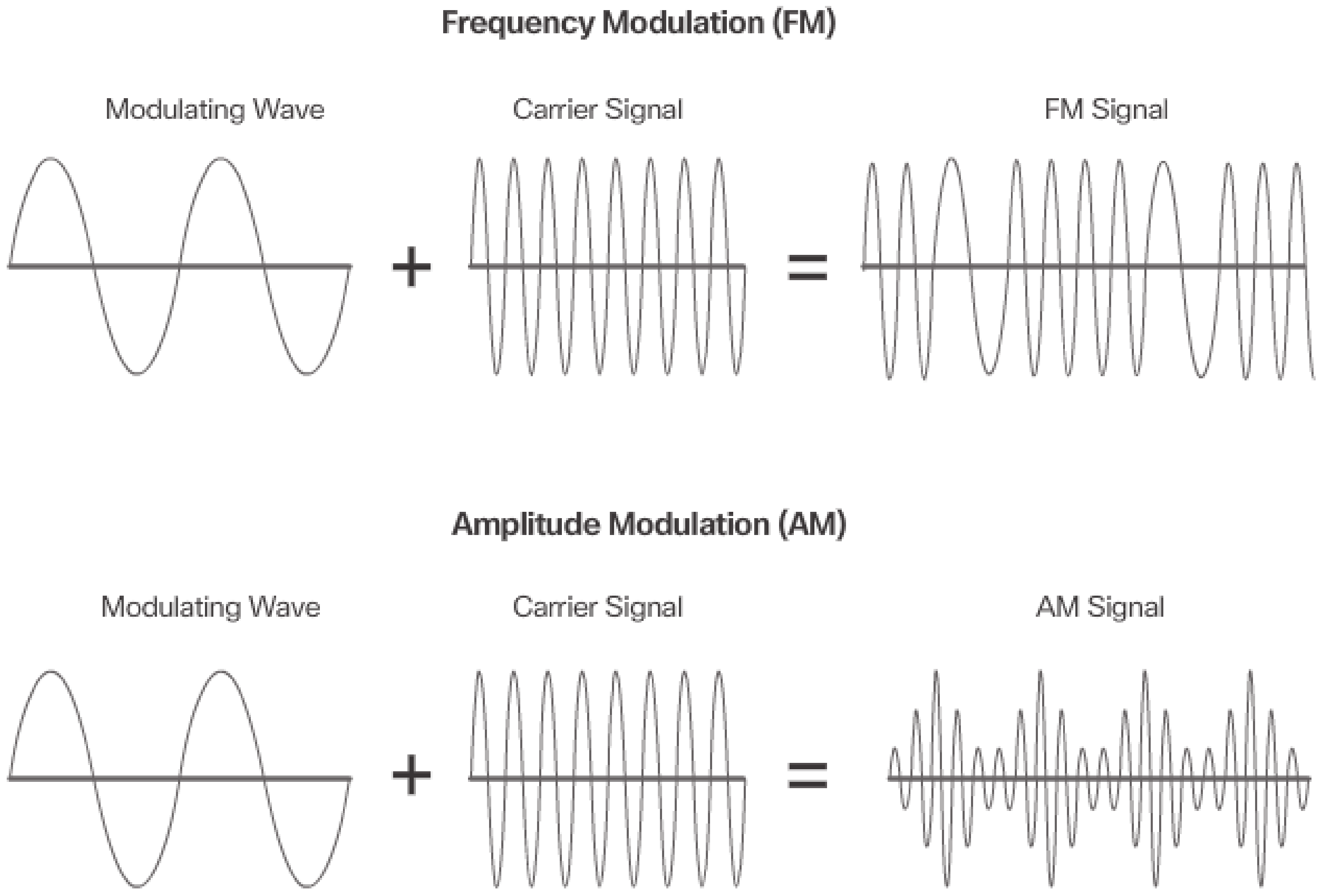


The transition occurs at the middle of each bit period.

Encoding

Encoding or line encoding is a method of converting a stream of data bits into a predefined "code”. Codes are groupings of bits used to provide a predictable pattern that can be recognized by both the sender and the receiver. In the case of networking, encoding is a pattern of voltage or current used to represent bits; the 0s and 1s.

4.1.3.1 Functions



There are many ways to transmit signals. A common method to send data is using modulation techniques. Modulation is the process by which the characteristic of one wave (the signal) modifies another wave (the carrier).

The nature of the actual signals representing the bits on the media will depend on the signaling method in use.

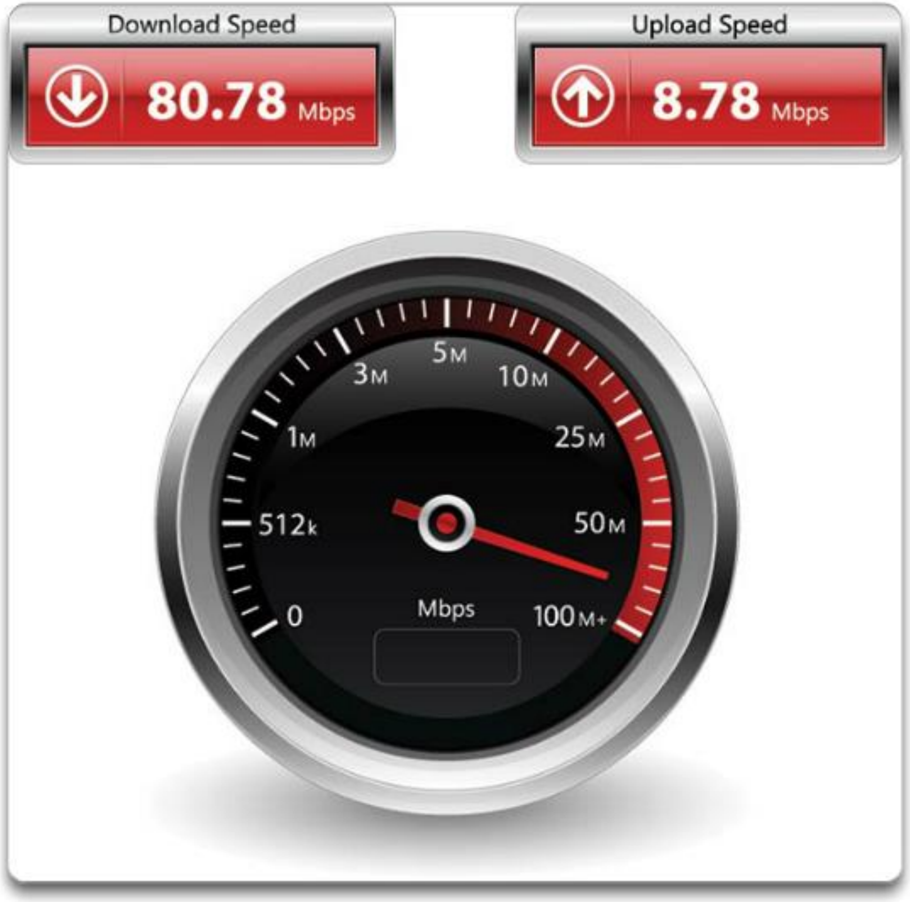
4.1.3.2 Bandwidth

Different physical media support the transfer of bits at different rates. Data transfer is usually discussed in terms of bandwidth and throughput.

Unit of Bandwidth	Abbreviation	Equivalence
Bits per second	b/s	1 b/s = fundamental unit of bandwidth
Kilobits per second	kb/s	1 kb/s = 1,000 bps = 10^3 bps
Megabits per second	Mb/s	1 Mb/s = 1,000,000 bps = 10^6 bps
Gigabits per second	Gb/s	1 Gb/s = 1,000,000,000 bps = 10^9 bps
Terabits per second	Tb/s	1 Tb/s = 1,000,000,000,000 bps = 10^12 bps

Bandwidth is the capacity of a medium to carry data. Digital bandwidth measures the amount of data that can flow from one place to another in a given amount of time. Bandwidth is typically measured in kilobits per second (kb/s), megabits per second (Mb/s), or gigabits per second (Gb/s). Bandwidth is sometimes thought of as the speed that bits travel, however this is not accurate. For example, in both 10Mb/s and 100Mb/s Ethernet, the bits are sent at the speed of electricity. The difference is the number of bits that are transmitted per second.

4.1.3.3 Throughput



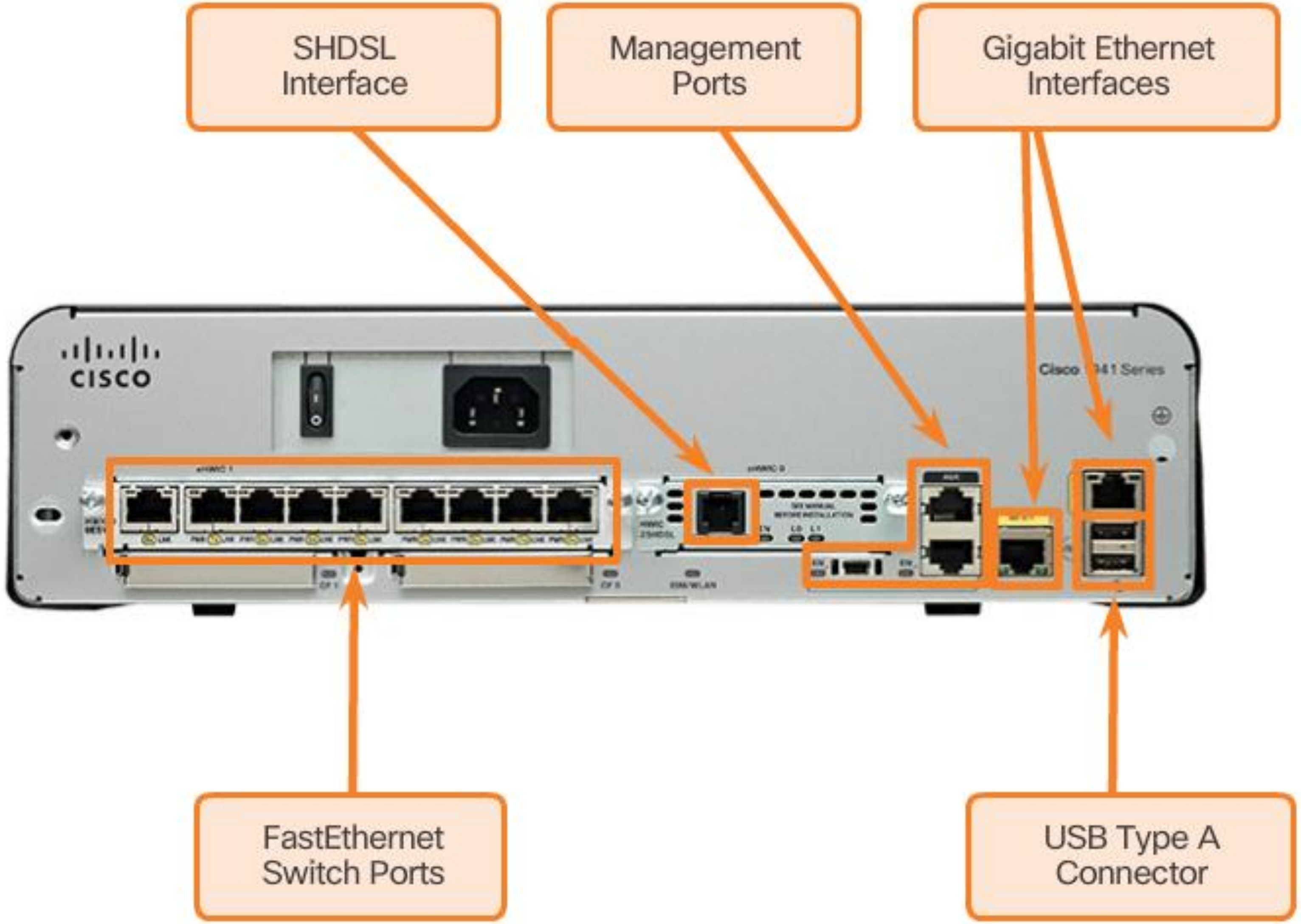
Throughput is the measure of the transfer of bits across the media over a given period of time.

Due to a number of factors, throughput usually does not match the specified bandwidth in physical layer implementations. Many factors influence throughput, including:

- The amount of traffic
- The type of traffic
- The latency created by the number of network devices encountered between source and destination

Latency refers to the amount of time, to include delays, for data to travel from one given point to another.

4.1.3.4 Types of Physical Media



The physical layer produces the representation and groupings of bits as voltages, radio frequencies, or light pulses. Various standards organizations have contributed to the definition of the physical, electrical, and mechanical properties of the media available for different data communications. These specifications guarantee that cables and connectors will function as anticipated with different data link layer implementations.

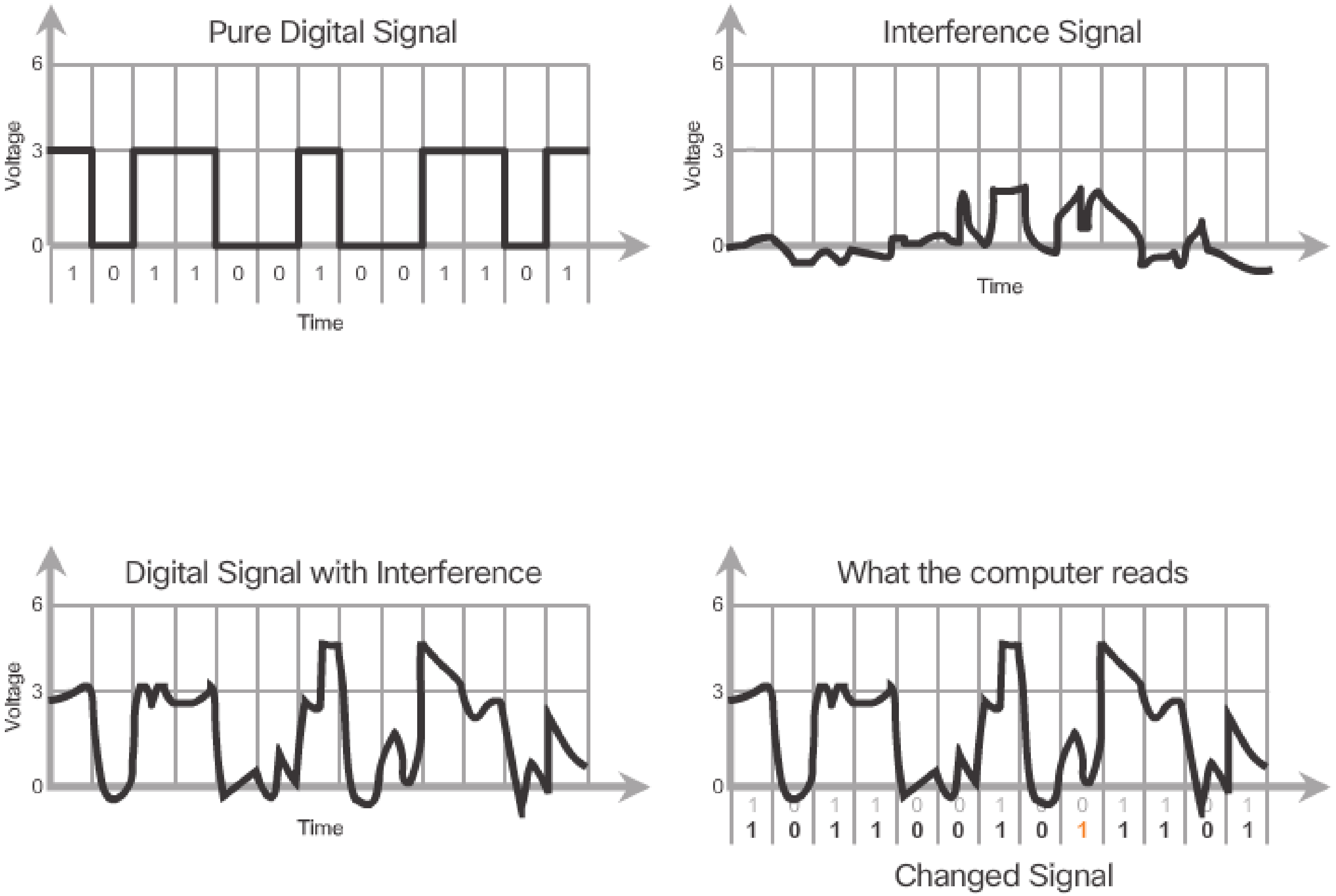
4.1.3.5 Activity - Physical Layer Terminology

Activity - Physical Layer Terminology

Descriptions of the physical layer are provided in the table. Drag each physical layer term to its description.

Term	Physical Layer Description
Physical components	Hardware devices, media, and connectors which transmit and carry bit signals
Signaling method	How 1s and 0s are represented on the media – varies, depending on encoding scheme
Synchronous	Evenly spaced time duration for signals
Frame encoding	A method for converting streams of data bits into groupings of bits – predefined
Asynchronous	Arbitrarily spaced time duration for signals

Check Reset

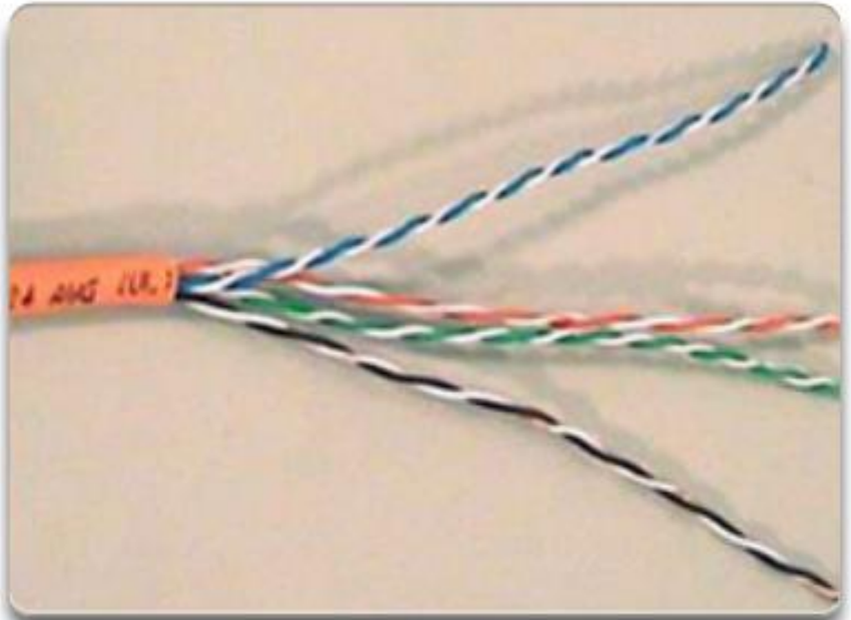


The timing and voltage values of the electrical pulses are also susceptible to interference from two sources:

- **Electromagnetic interference (EMI) or radio frequency interference (RFI) -** EMI and RFI signals can distort and corrupt the data signals being carried by copper media. Potential sources of EMI and RFI include radio waves and electromagnetic devices, such as fluorescent lights or electric motors as shown in the figure.

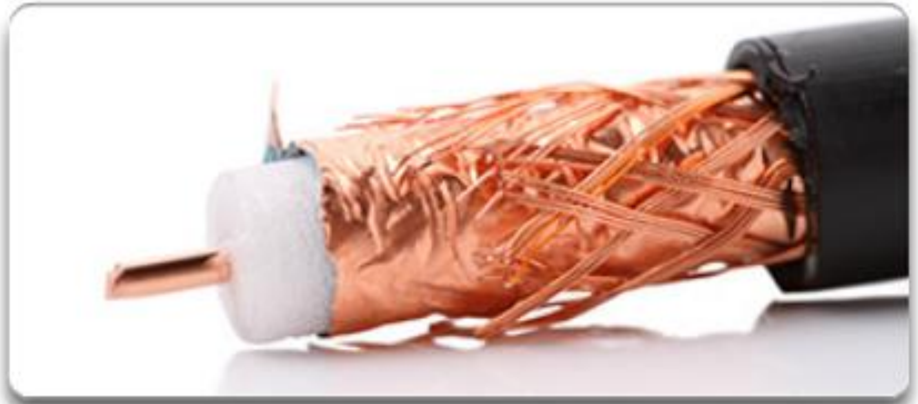
- **Crosstalk** - Crosstalk is a disturbance caused by the electric or magnetic fields of a signal on one wire to the signal in an adjacent wire. In telephone circuits, crosstalk can result in hearing part of another voice conversation from an adjacent circuit. Specifically, when an electrical current flows through a wire, it creates a small, circular magnetic field around the wire, which can be picked up by an adjacent wire.

4.2.1.2 Copper Media



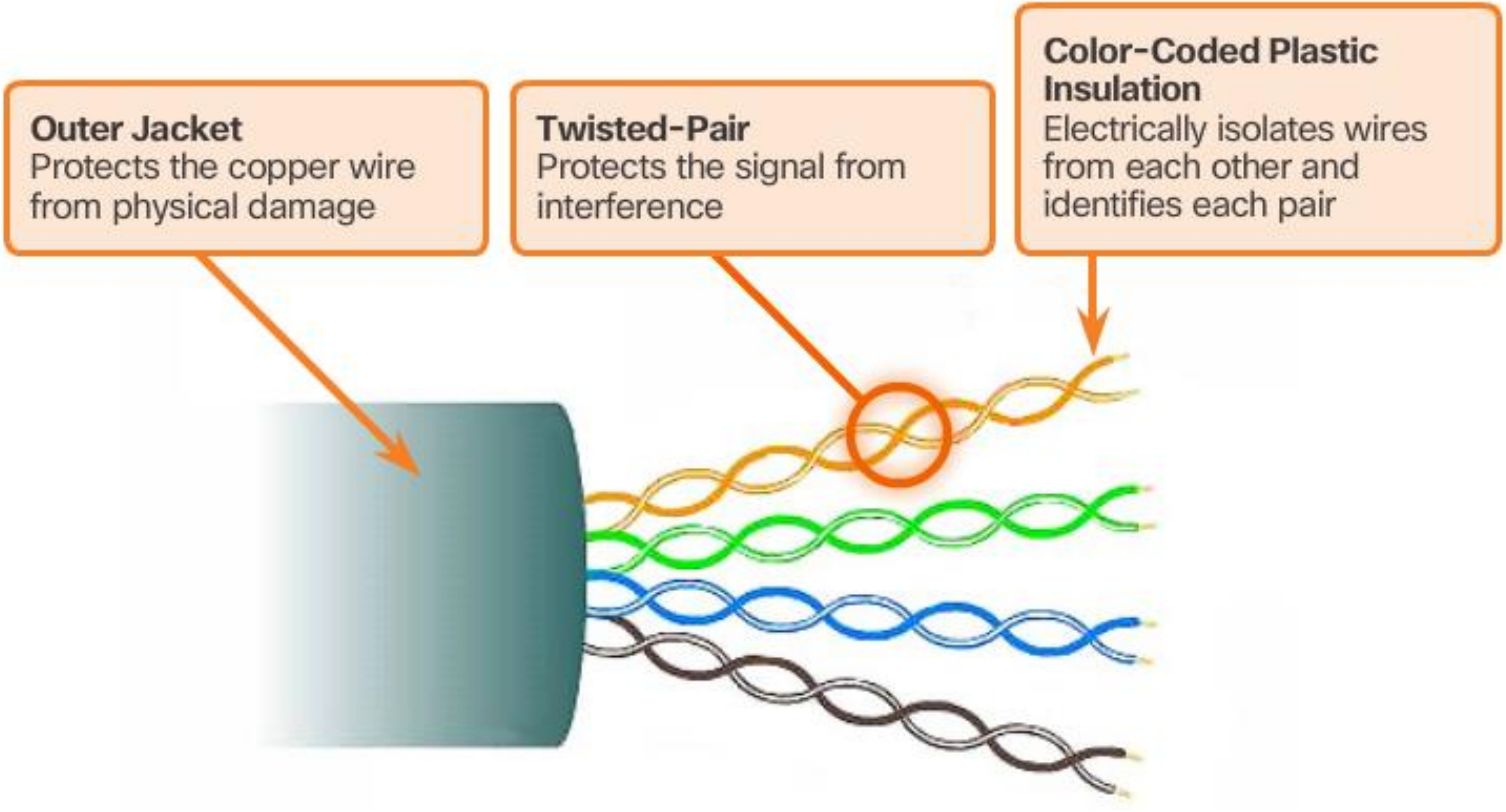
Unshielded Twisted-Pair (UTP) cable

Shielded Twisted-Pair (STP) cable

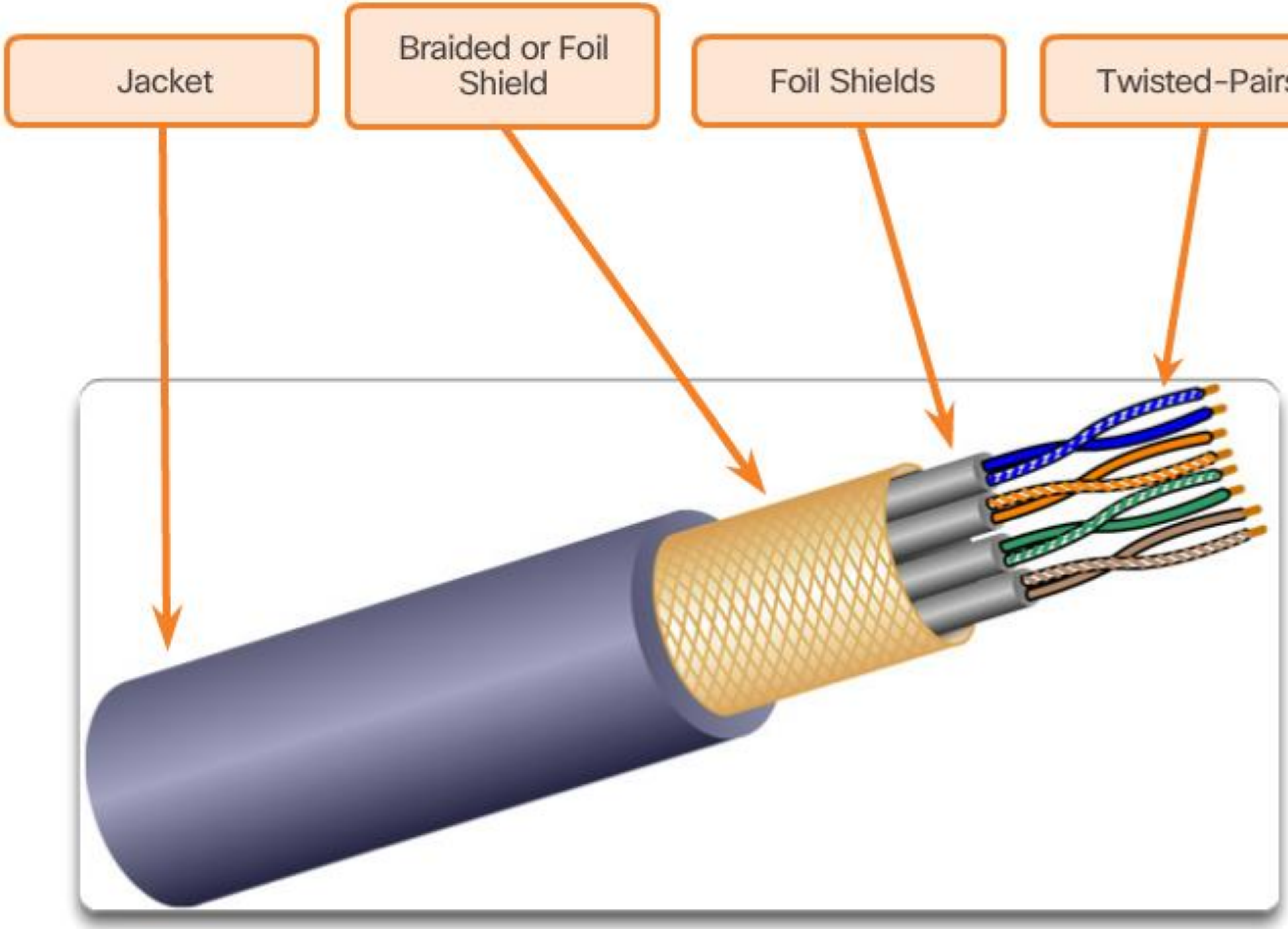


Coaxial cable

4.2.1.3Unshielded Twisted-Pair Cable

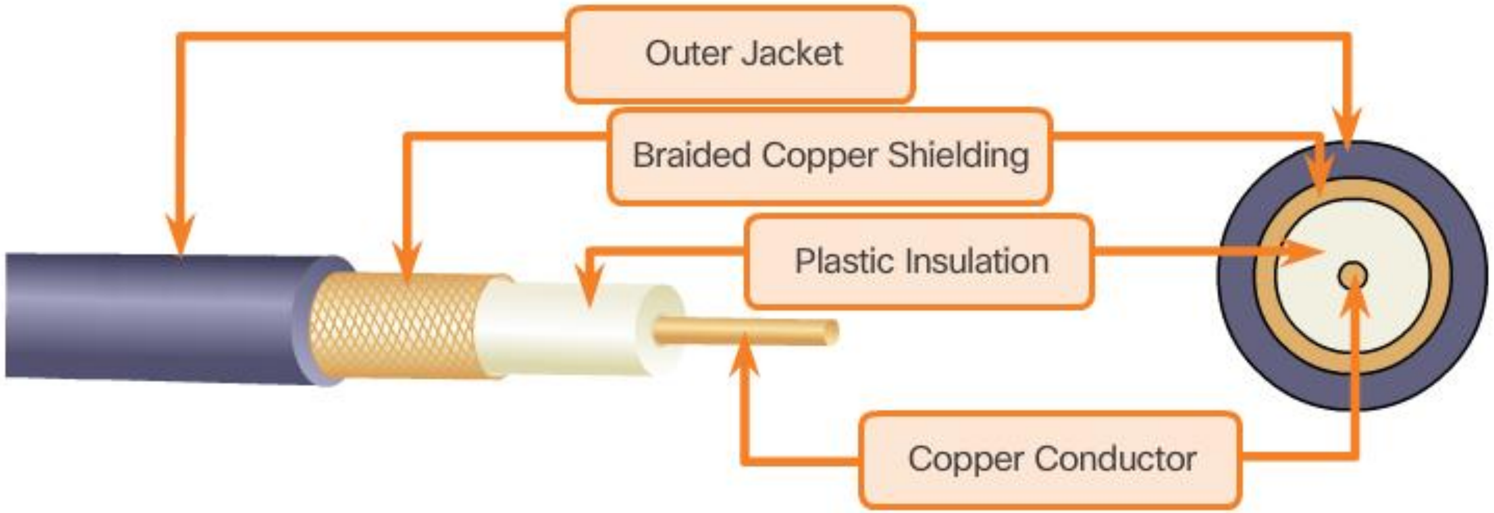


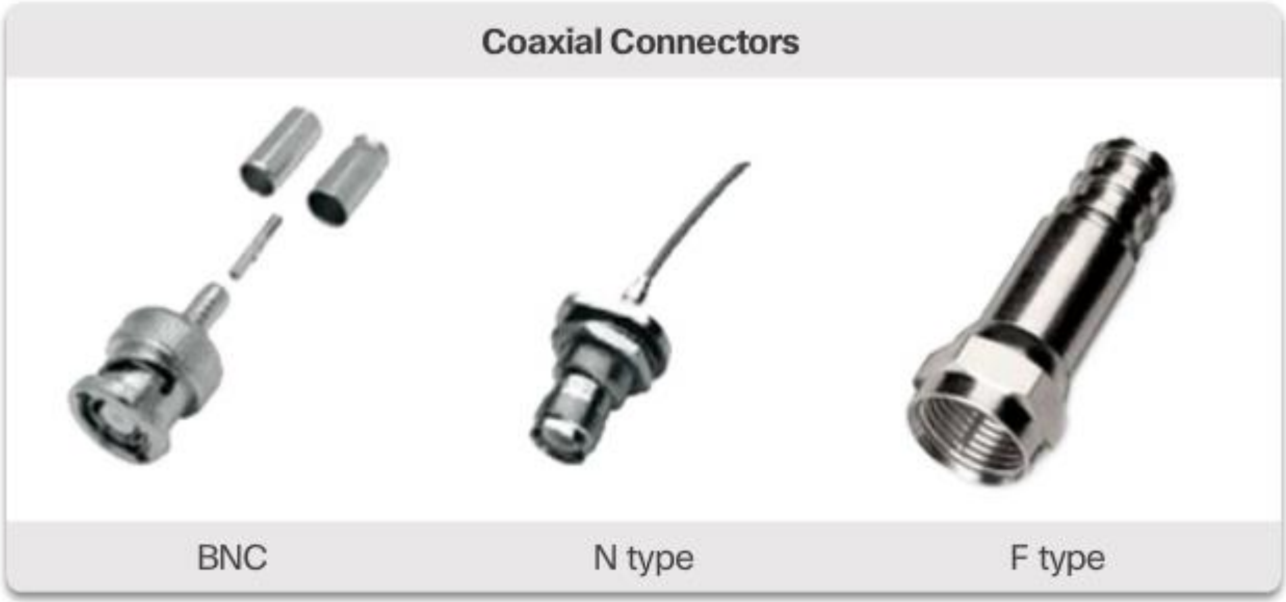
4.2.1.4 Shielded Twisted-Pair Cable



Shielded twisted-pair (STP) provides better noise protection than UTP cabling. However, compared to UTP cable, STP cable is significantly more expensive and difficult to install. Like UTP cable, STP uses an RJ-45 connector.

4.2.1.5 Coaxial Cable





Although UTP cable has essentially replaced coaxial cable in modern Ethernet installations, the coaxial cable design is used in:

- Wireless installations: Coaxial cables attach antennas to wireless devices. The coaxial cable carries radio frequency (RF) energy between the antennas and the radio equipment.
- Cable Internet installations: Cable service providers provide Internet connectivity to their customers by replacing portions of the coaxial cable and supporting amplification elements with fiber-optic cable. However, the wiring inside the customer's premises is still coax cable.

4.2.1.6 Copper Media Safety

The separation of data and electrical power cabling must comply with safety codes.

Cables must be connected correctly.

Installations must be inspected for damage.

Equipment must be grounded correctly.

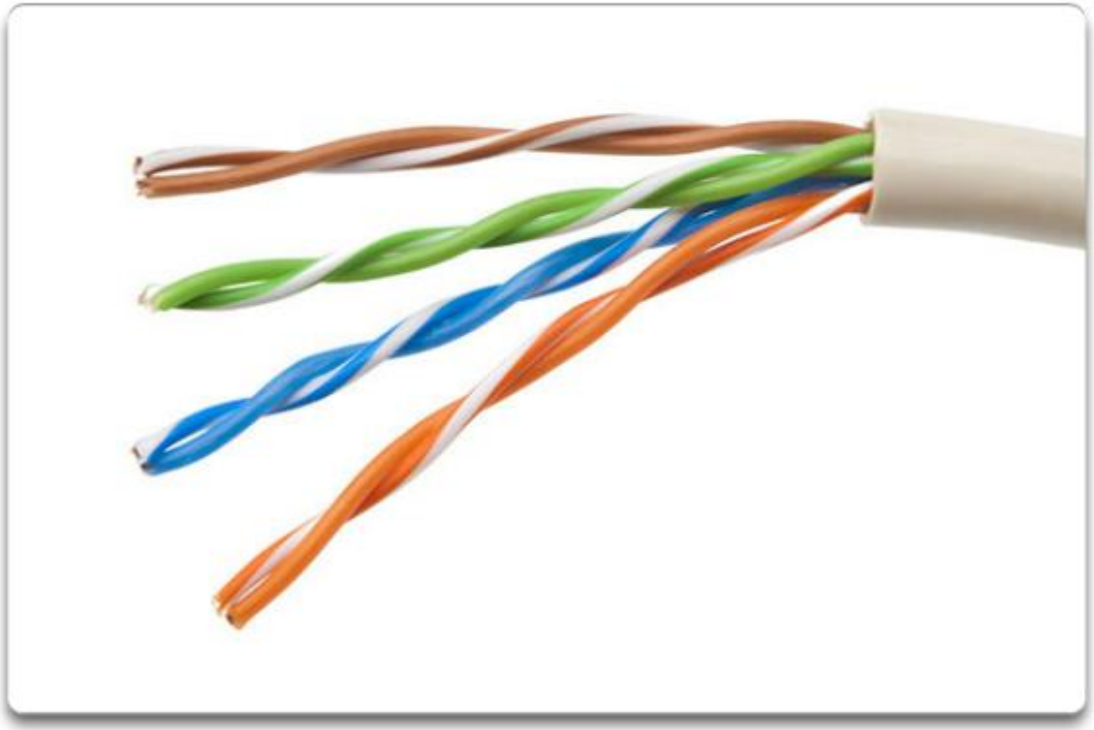
4.2.1.7 Activity - Copper Media Characteristics

Activity - Copper Media Characteristics

UTP, STP, and coaxial copper media characteristics are provided in the table. Click the appropriate field to match the characteristic to the media type.

	UTP	STP	Coaxial
1. The new Ethernet 10GB standard uses this form of copper media		✓	
2. Attaches antennas to wireless devices – can be bundled with fiber-optic cabling for two-way data transmission			✓
3. Counters EMI and RFI by using shielding techniques and special connectors		✓	
4. Most common network media	✓		
5. Terminates with BNC, N type and F type connectors			✓

4.2.2.1 Properties of UTP Cabling



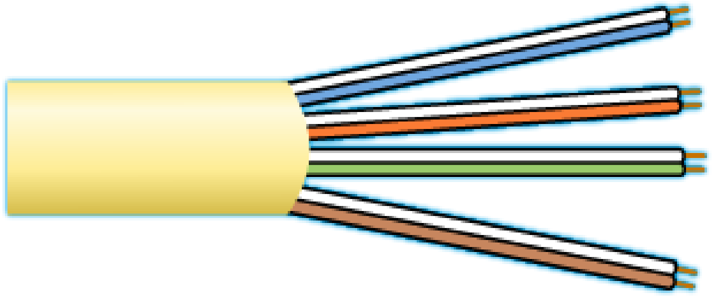
UTP cable does not use shielding to counter the effects of EMI and RFI. Instead, cable designers have discovered that they can limit the negative effect of crosstalk by:

- **Cancellation**: Designers now pair wires in a circuit. When two wires in an electrical circuit are placed close together, their magnetic fields are the exact opposite of each other. Therefore, the two magnetic fields cancel each other and also cancel out any outside EMI and RFI signals.
- **Varying the number of twists per wire pair**: To further enhance the cancellation effect of paired circuit wires, designers vary the number of twists of each wire pair in a cable. UTP cable must follow precise specifications governing how many twists or braids are permitted per meter (3.28 feet) of cable. Notice in the figure that the orange/orange white pair is twisted less than the blue/blue white pair. Each colored pair is twisted a different number of times.

4.2.2.2 UTP Cabling Standards

Category 3 Cable (UTP)

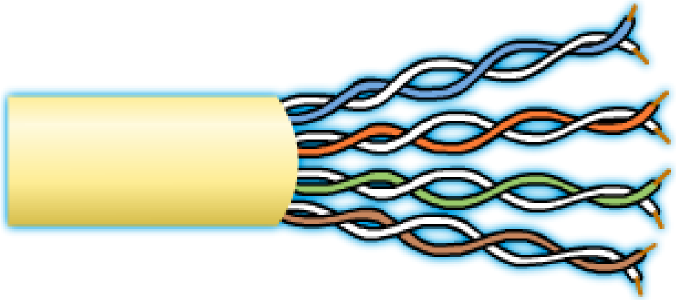
- Used for voice communication
- Most often used for phone lines



Category 3 Cable (UTP)

Category 5 and 5e Cable (UTP)

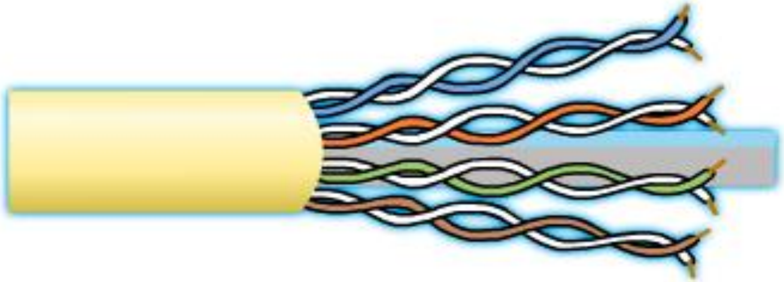
- Used for data transmission
- Cat5 supports 100 Mb/s and can support 1000 Mb/s, but it is not recommended
- Cat5e supports 1000 Mb/s



Category 5 and 5e Cable (UTP)

Category 6 Cable (UTP)

- Used for data transmission
- An added separator is between each pair of wires allowing it to function at higher speeds
- Supports 1000 Mb/s – 10 Gb/s, though 10 Gb/s is not recommended



Category 6 Cable (UTP)

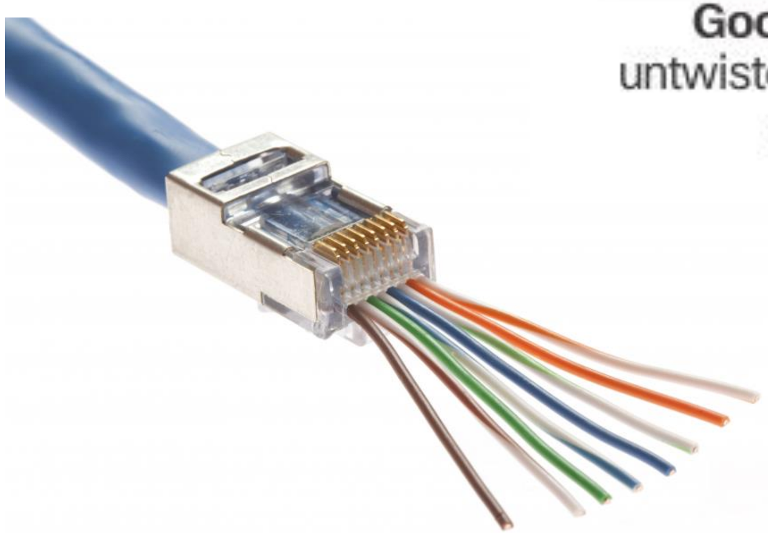
4.2.2.3 UTP Connectors

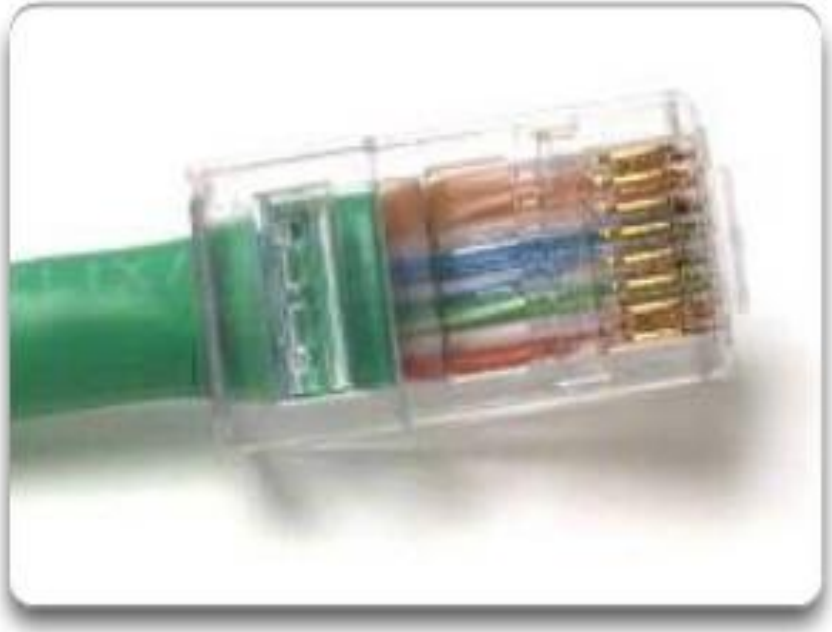
RJ-45 UTP Plugs

RJ-45 UTP Socket

4.2.2.3 UTP Connectors

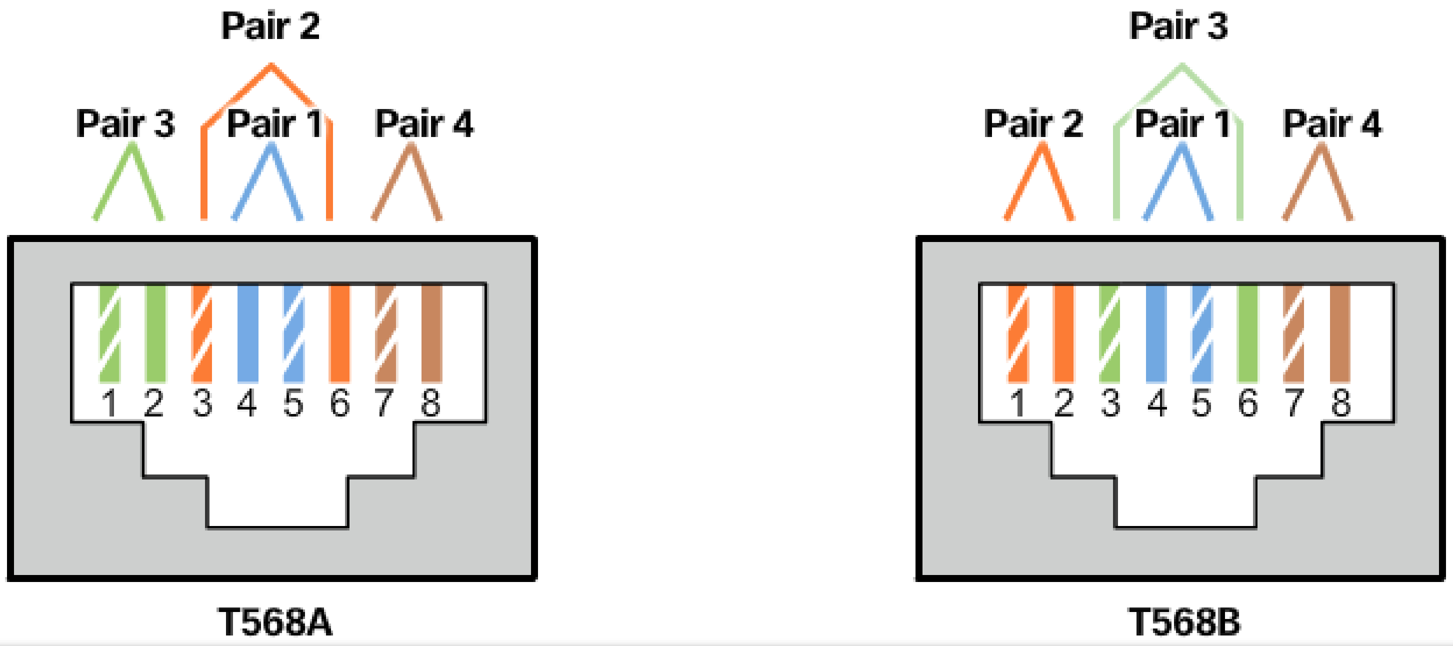
Bad connector - Wires are exposed, untwisted, and not entirely covered by the sheath.





Good connector - Wires are untwisted to the extent necessary to attach the connector.

4.2.2.4 Types of UTP Cable



Cable Type	Standard	Application
Ethernet Straight-through	Both ends T568A or both ends T568B	Connects a network host to a network device such as a switch or hub.
Ethernet Crossover	One end T568A, other end T568B	• Connects two network hosts • Connects two network intermediary devices (switch to switch, or router to router)
Rollover	Cisco proprietary	Connects a workstation serial port to a router console port, using an adapter.

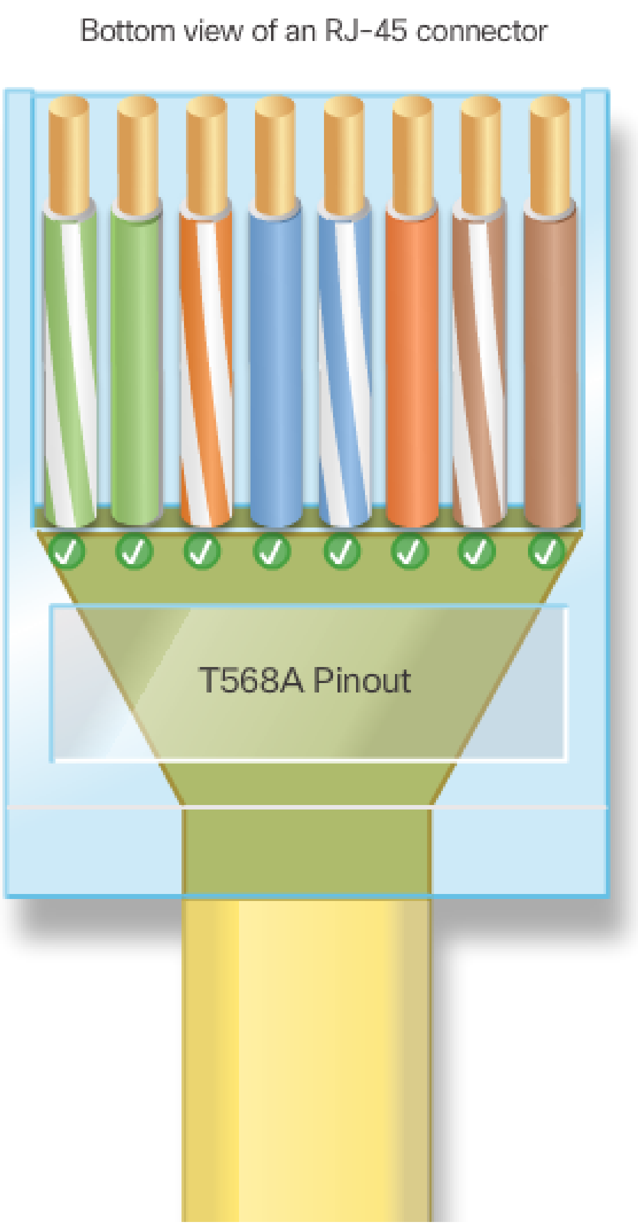
- **Ethernet Straight-through**: The most common type of networking cable. It is commonly used to interconnect a host to a switch and a switch to a router.
- **Ethernet Crossover**: A cable used to interconnect similar devices. For example to connect a switch to a switch, a host to a host, or a router to a router.
- **Rollover**: A Cisco proprietary cable used to connect a workstation to a router or switch console port.

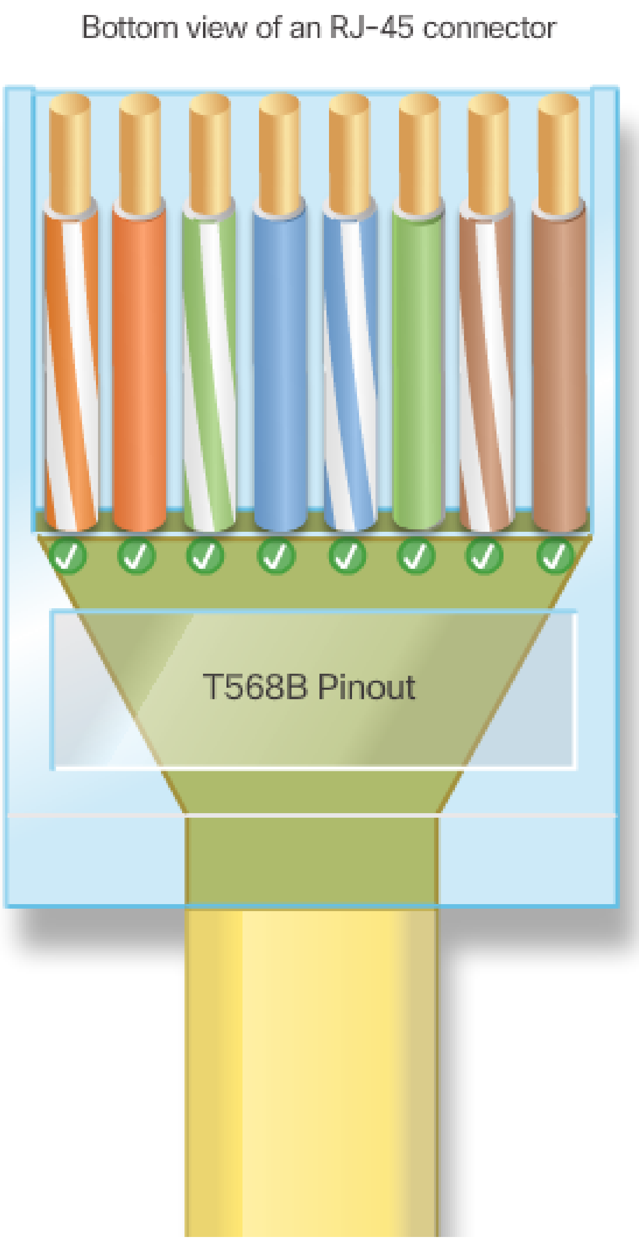
4.2.2.5 Testing UTP Cables

After installation, a UTP cable tester, like the one shown in the figure, should be used to test for the following parameters:

- Wire map
- Cable length
- Signal loss due to attenuation
- Crosstalk

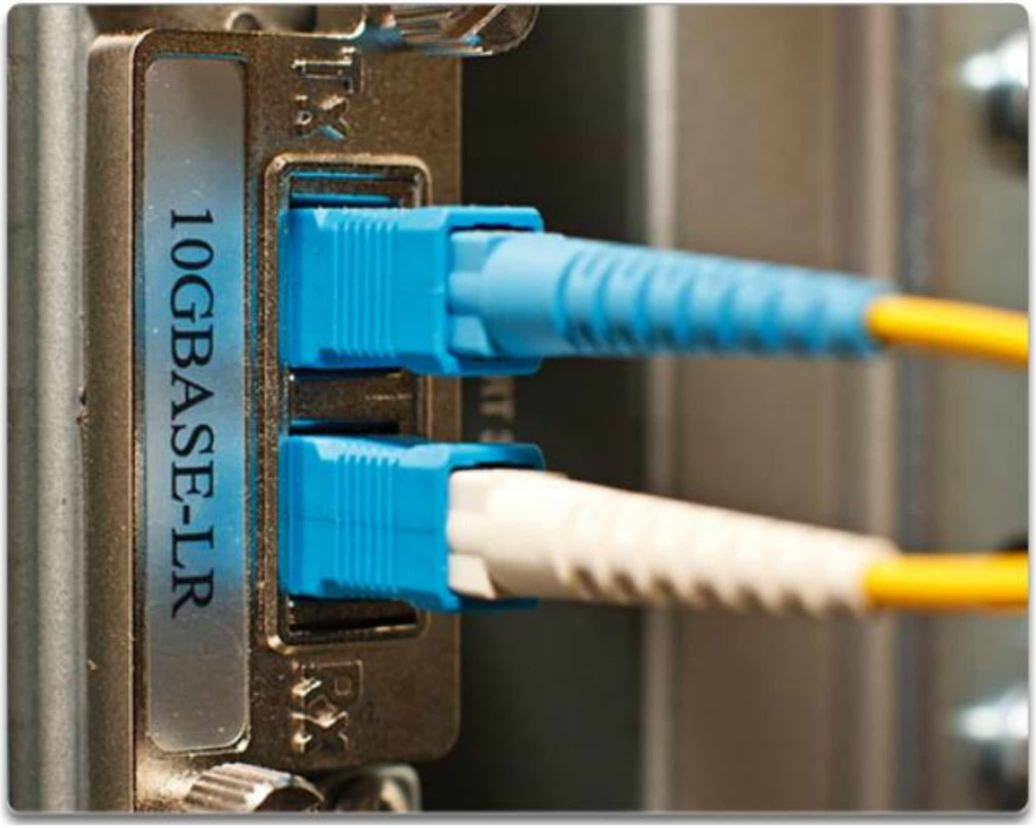
4.2.2.6 Cable Pinouts





4.2.2.7 Lab - Building an Ethernet Crossover Cable

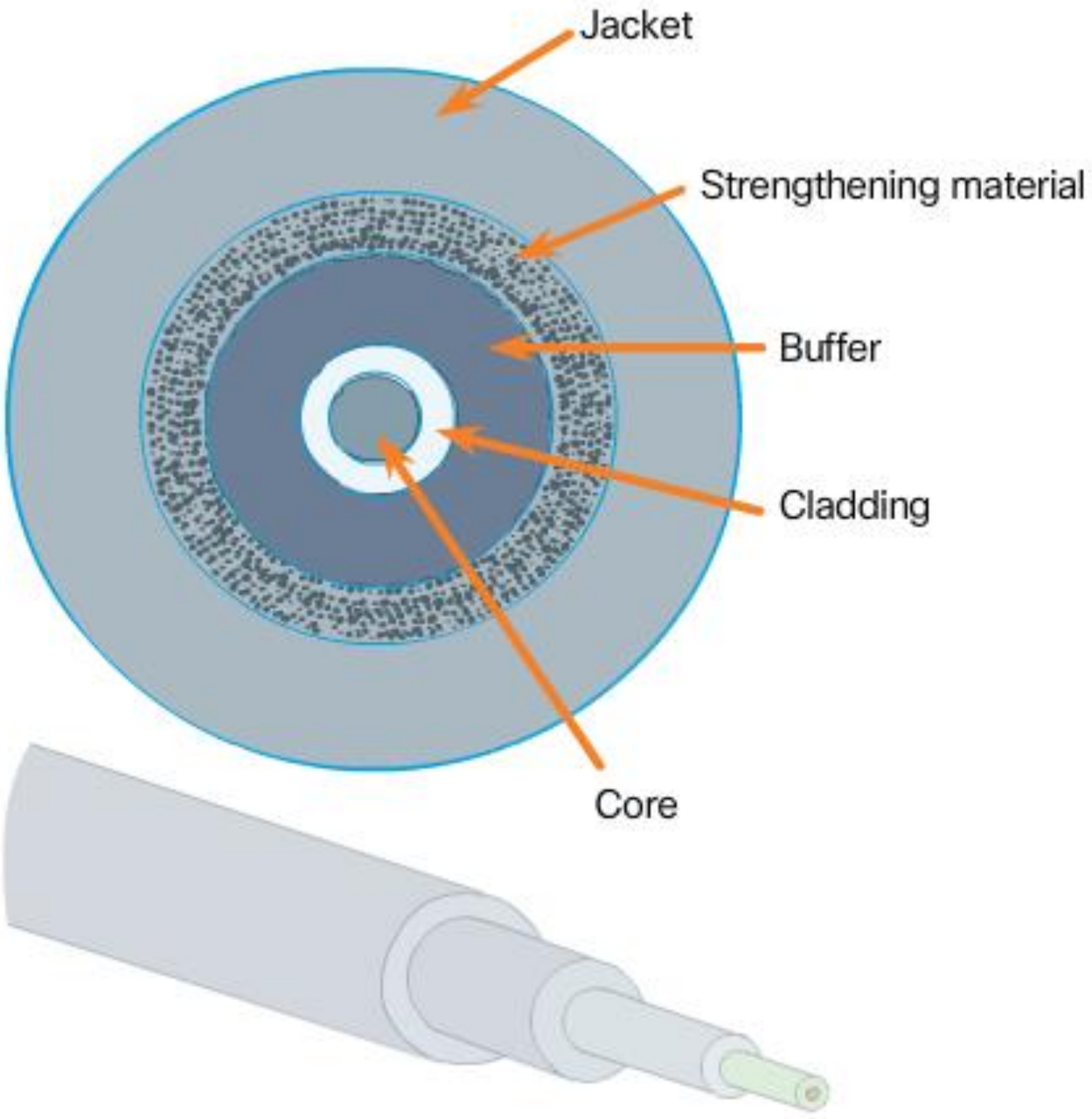
4.2.3.1 Properties of Fiber-Optic Cabling



Fiber-optic cabling is now being used in four types of industry:

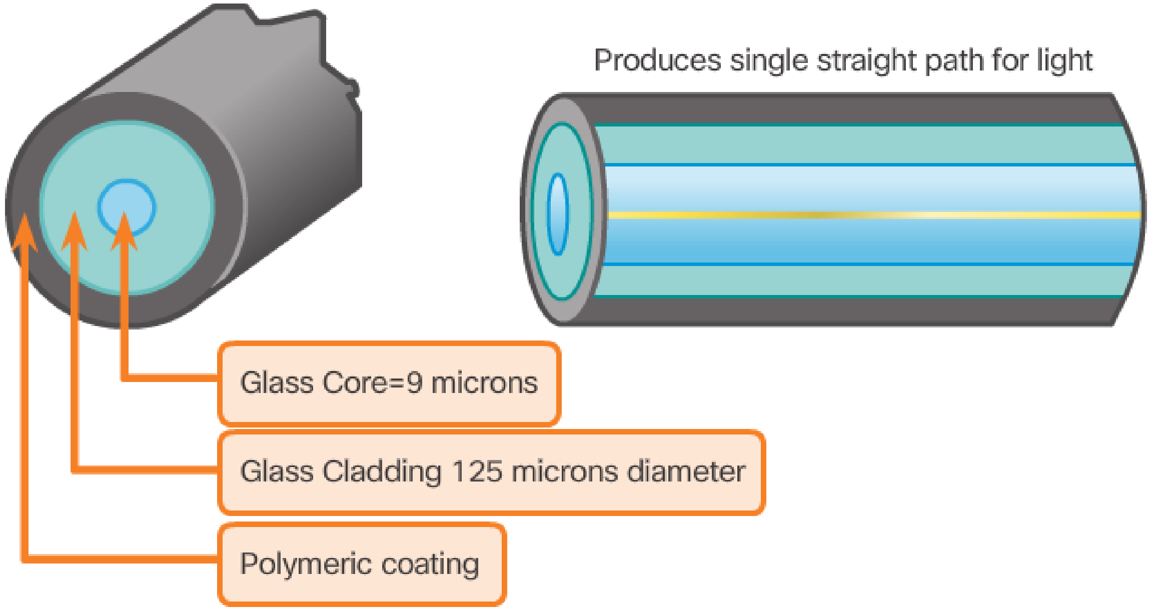
- **Enterprise Networks**: Used for backbone cabling applications and interconnecting infrastructure devices.
- **Fiber-to-the-Home (FTTH)**: Used to provide always-on broadband services to homes and small businesses.
- **Long-Haul Networks**: Used by service providers to connect countries and cities.
- **Submarine Networks**: Used to provide reliable high-speed, high-capacity solutions capable of surviving in harsh undersea environments up to transoceanic distances. Click here to view a telegeography map that depicts the location of submarine cables.

4.2.3.2 Fiber Media Cable Design



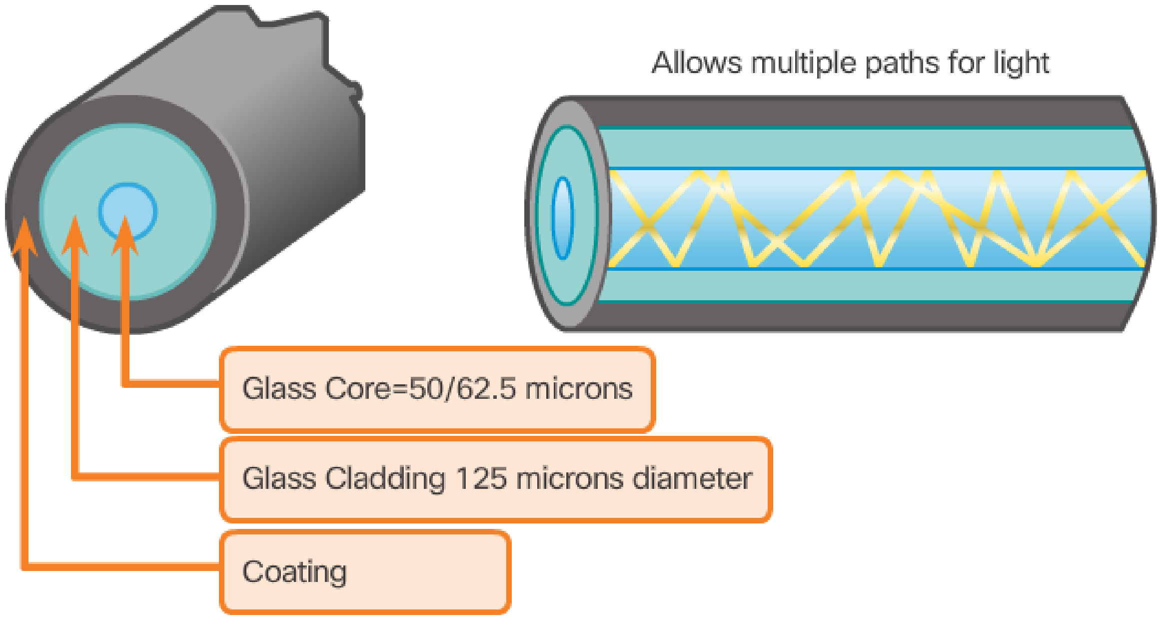
4.2.3.3 Types of Fiber Media

Single Mode



- Small core
- Less dispersion
- Suited for long distance applications
- Uses lasers as the light source
- Commonly used with campus backbones for distances of several thousand meters

Multimode



- Larger core than single mode cable
- Allows greater dispersion and therefore, loss of signal
- Suited for long distance applications, but shorter than single mode
- Uses LEDs as the light source
- Commonly used with LANs or distances of a couple hundred meters within a campus network

4.2.3.4 Fiber-Optic Connectors

ST Connectors

Straight-Tip (ST) Connectors

One of the first connector types used. The connector locks securely with a " twist-on/twist-off" bayonet style mechanism.

SC Connectors

Subscriber Connector (SC) Connectors

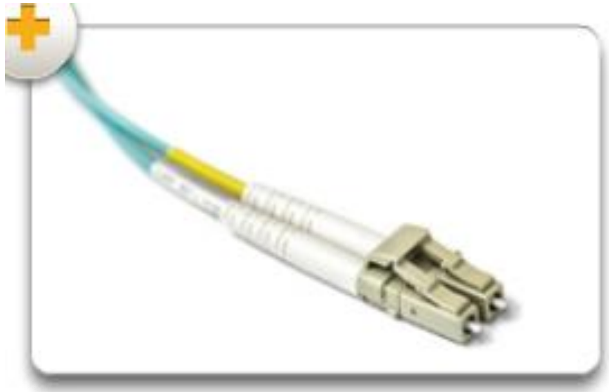
Sometimes referred to as square connector or standard connector. It is a widely adopted LAN and WAN connector that uses a push-pull mechanism to ensure positive insertion. This connector type is used with multimode and single-mode fiber.

4.2.3.4 Fiber-Optic Connectors

LC Connector

Lucent Connector (LC) Simplex Connectors

A smaller version of the fiber-optic SC connector. It is sometimes called a little or local connector and is quickly growing in popularity due to its smaller size.



Duplex Multimode LC Connectors

Duplex Multimode LC Connectors

Similar to a LC simplex connector, but using a duplex connector.

4.2.3.4 Fiber-Optic Connectors

Common Fiber Patch Cords

SC-SC Multimode Patch Cord

LC-LC Single-mode Patch Cord

ST-LC Multimode Patch Cord

SC-ST Single-mode Patch Cord

4.2.3.5 Testing Fiber Cables

Optical Time Domain Reflectometer (OTDR)

Three common types of fiber-optic termination and splicing errors are:

- **Misalignment**: The fiber-optic media are not precisely aligned to one another when joined.
- **End gap**: The media does not completely touch at the splice or connection.
- **End finish**: The media ends are not well polished, or dirt is present at the termination.

4.2.3.6 Fiber versus Copper

Implementation Issues	UTP Cabling	Fiber-optic Cabling
Bandwidth supported	10 Mb/s - 10 Gb/s	10 Mb/s - 100 Gb/s
Distance	Relatively short (1 - 100 meters)	Relatively high (1 - 100,000 meters)
Immunity to EMI and RFI	Low	High (Completely immune)
Immunity to electrical hazards	Low	High (Completely immune)
Media and connector costs	Lowest	Highest
Installation skills required	Lowest	Highest
Safety precautions	Lowest	Highest

4.2.3.7 Activity - Fiber Optics Terminology

	Multimode	Single-mode
1. Can help data travel approximately 1.24 miles or 2 km/2000 m	✓	
2. Uses light emitting diodes (LEDs) as a data light source transmitter	✓	
3. Uses lasers in a single stream as a data light source transmitter		✓
4. Used to connect long-distance telephony and cable TV applications		✓
5. Can travel approximately 62.5 miles or 100 km/100000 m		✓
6. Used within a campus network	✓	

4.2.4.1 Properties of Wireless Media

Wireless does have some areas of concern, including:

- **Coverage area**: Wireless data technologies work well in open environments. However, certain construction materials used in buildings and structures, and the local terrain, will limit the effective coverage.
- **Interference:** Wireless is susceptible to interference and can be disrupted by such common devices as household cordless phones, some types of fluorescent lights, microwave ovens, and other wireless communications.
- **Security: D**evices and users, not authorized for access to the network, can gain access to the transmission. Network security is a major component of wireless network administration.
- **Shared medium:** WLANs operate in half-duplex, which means only one device can send or receive at a time. The wireless medium is shared amongst all wireless users. The more users needing to access the WLAN simultaneously, results in less bandwidth for each user. Half-duplex is discussed later in this chapter.

4.2.4.2 Types of Wireless Media

Wi-Fi: Standard IEEE 802.11

Standard IEEE 802.16: WiMAX:

Standard IEEE 802.15: Bluetooth:

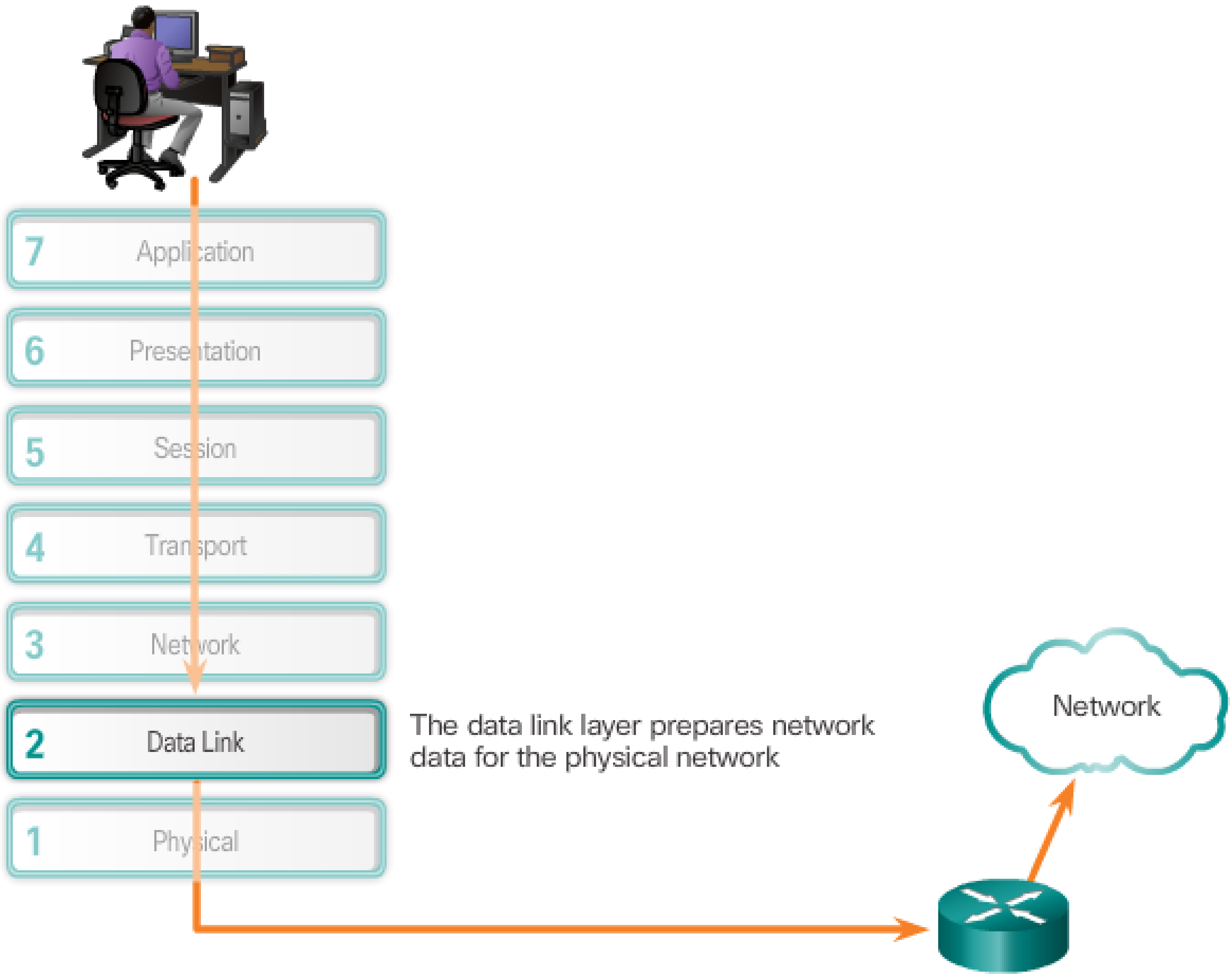
4.2.4.3 Wireless LAN

Cisco WRP500 Wireless Broadband Router

4.2.4.4 Packet Tracer – Connecting a Wired and Wireless LAN

4.2.4.5 Lab - Viewing Wired and Wireless NIC Information

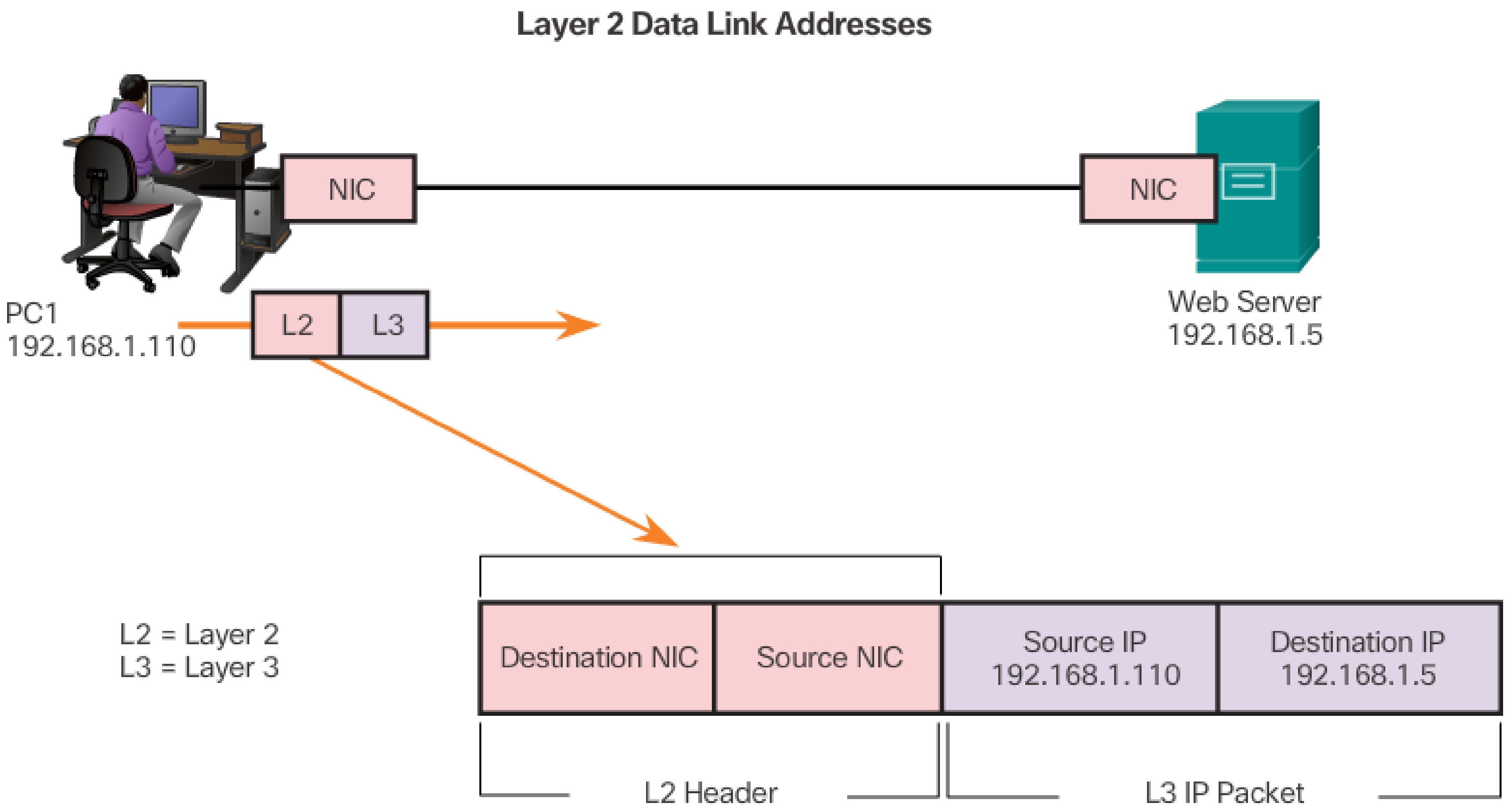
4.3.1.1 The Data Link Layer



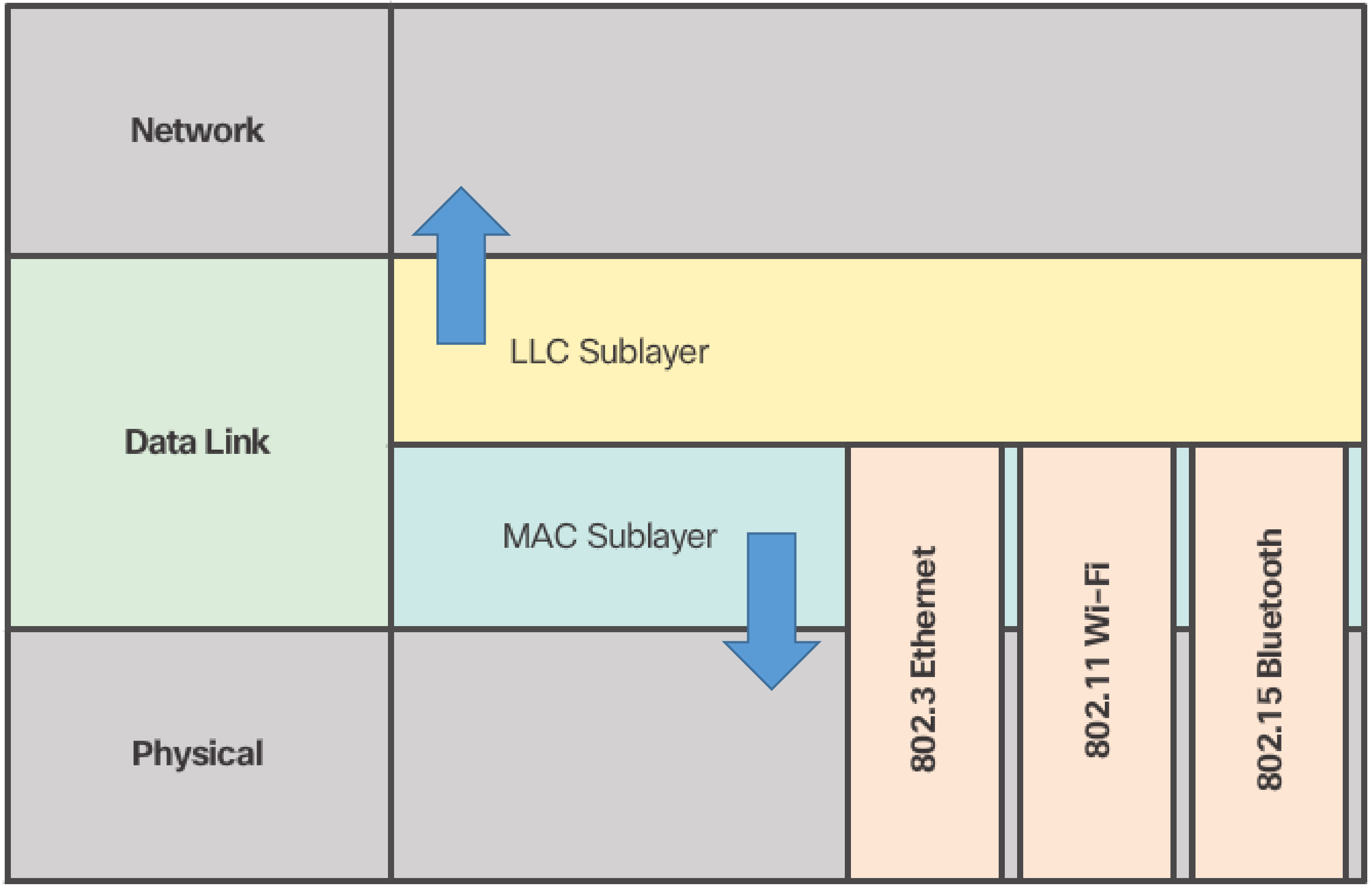
The data link layer of the OSI model (Layer 2), as shown in Figure 1, is responsible for:

- Allowing the upper layers to access the media
- Accepting Layer 3 packets and packaging them into frames
- Preparing network data for the physical network
- Controlling how data is placed and received on the media
- Exchanging frames between nodes over a physical network media, such as UTP or fiber-optic
- Receiving and directing packets to an upper layer protocol
- Performing error detection

4.3.1.1 The Data Link Layer



4.3.1.2 Data Link Sublayers



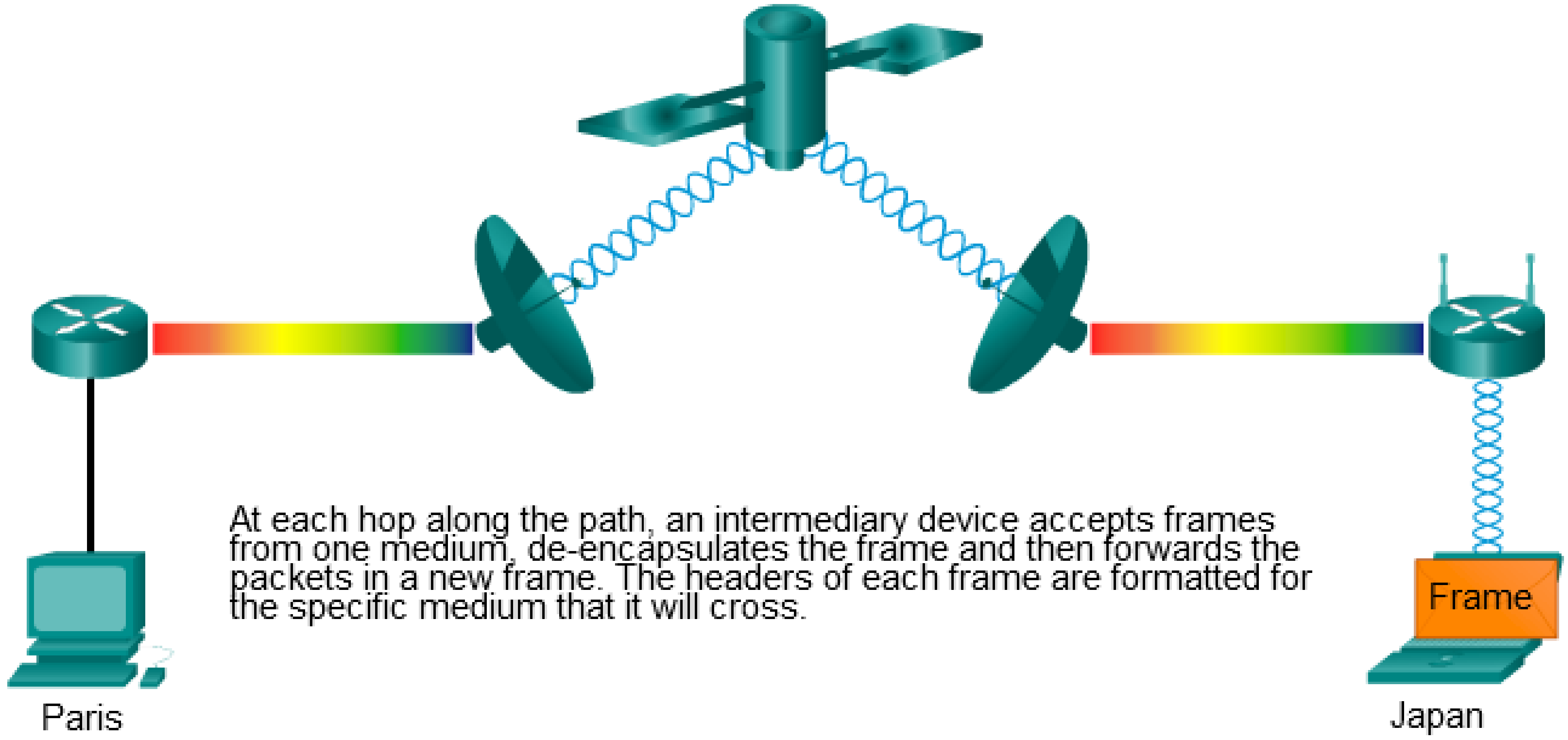
The data link layer is divided into two sublayers:

- **Logical Link Control (LLC)** - This upper sublayer communicates with the network layer. It places information in the frame that identifies which network layer protocol is being used for the frame. This information allows multiple Layer 3 protocols, such as IPv4 and IPv6, to utilize the same network interface and media.
- **Media Access Control (MAC)** - This lower sublayer defines the media access processes performed by the hardware. It provides data link layer addressing and access to various network technologies.

4.3.1.3 Media Access Control

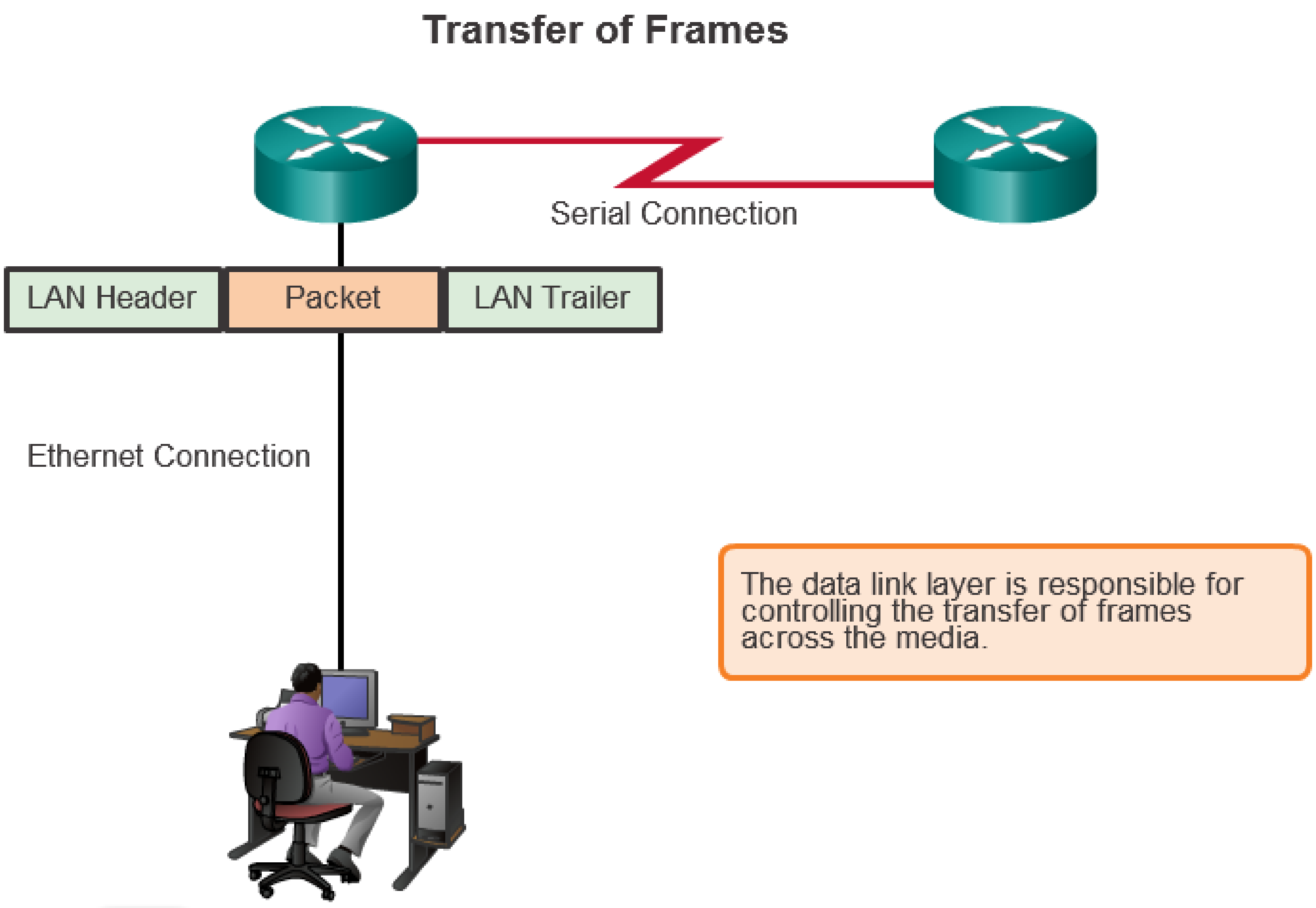
Data link layer protocols govern how to format a frame for use on different media.

Different protocols may be in use for different media.



At each hop along the path, an intermediary device accepts frames from one medium, de-encapsulates the frame and then forwards the packets in a new frame. The headers of each frame are formatted for the specific medium that it will cross.

4.3.1.4 Providing Access to Media



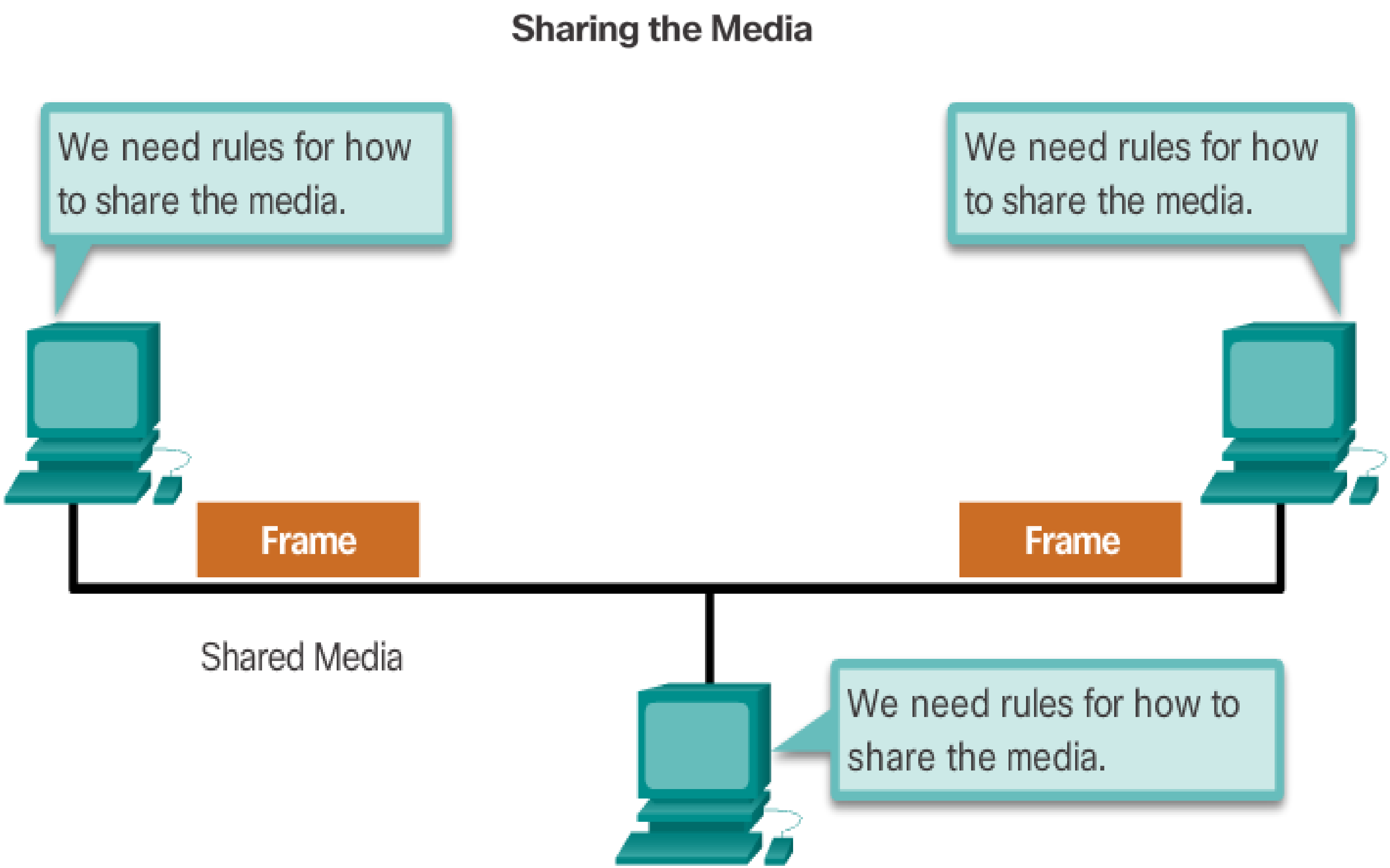
At each hop along the path, a router:

- Accepts a frame from a medium
- De-encapsulates the frame
- Re-encapsulates the packet into a new frame
- Forwards the new frame appropriate to the medium of that segment of the physical network

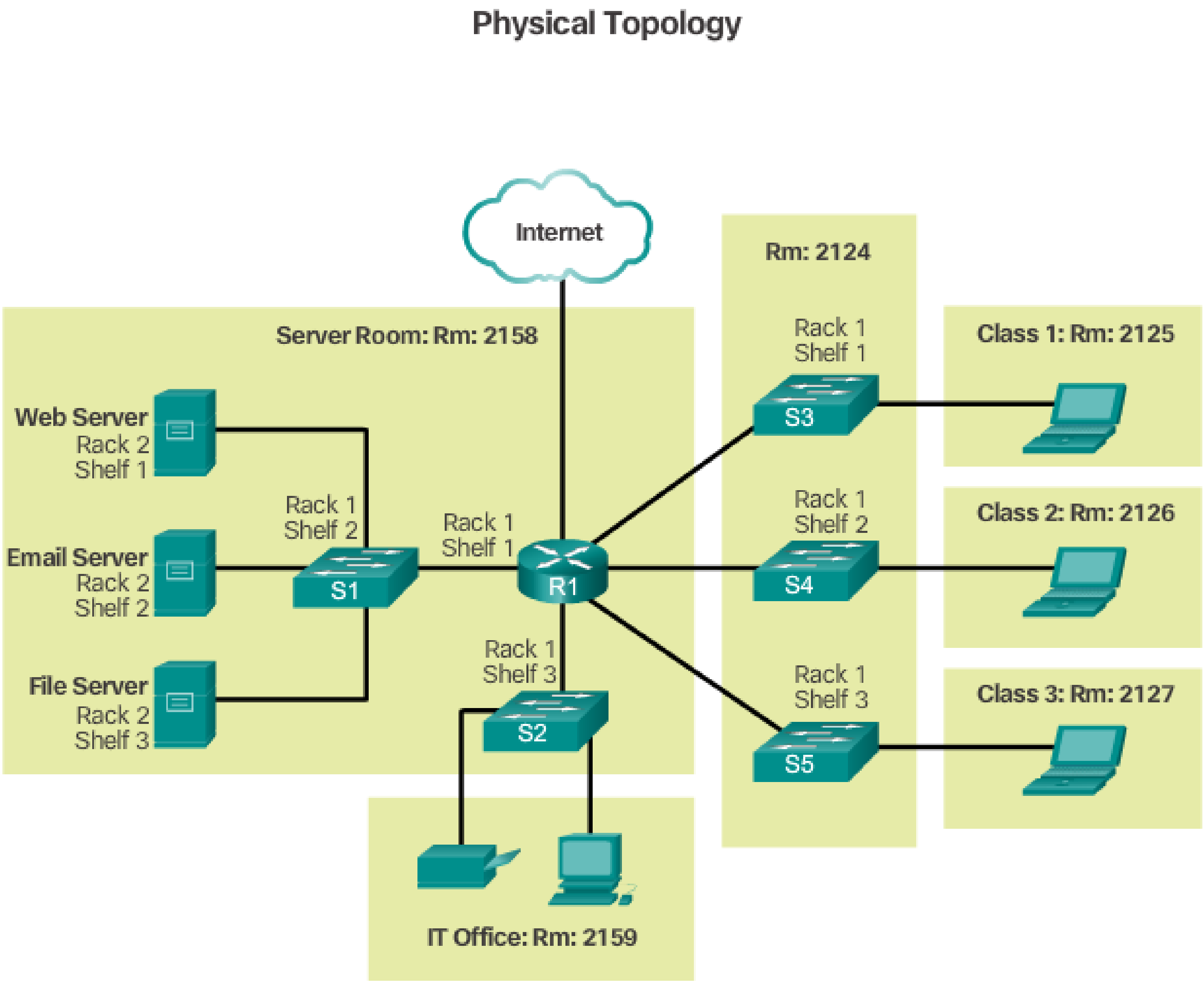
4.3.1.5 Data Link Layer Standards

- Institute of Electrical and Electronics Engineers (IEEE)
- International Telecommunication Union (ITU)
- International Organization for Standardization (ISO)
- American National Standards Institute (ANSI)

4.4.1.1 Controlling Access to the Media

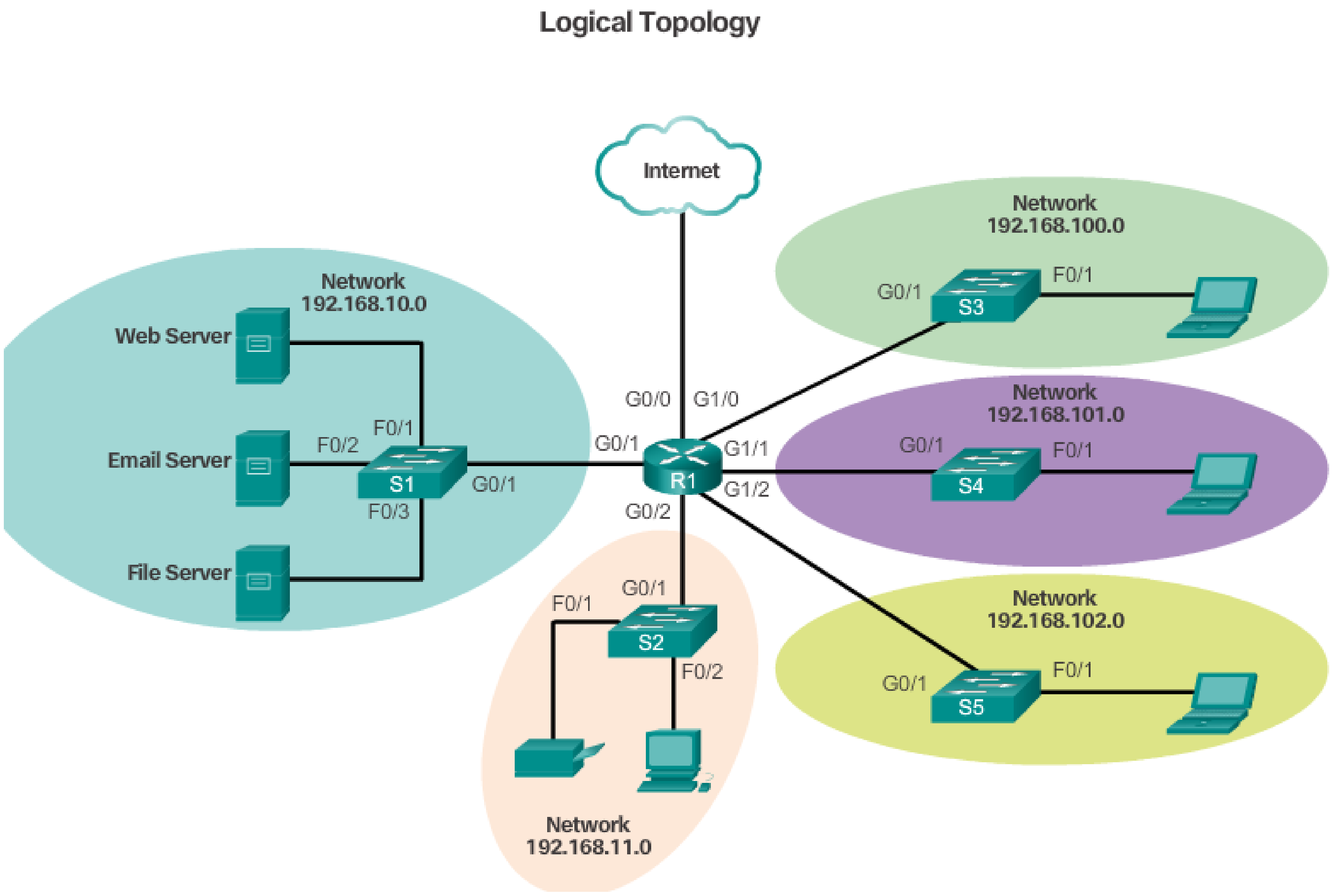


4.4.1.2 Physical and Logical Topologies



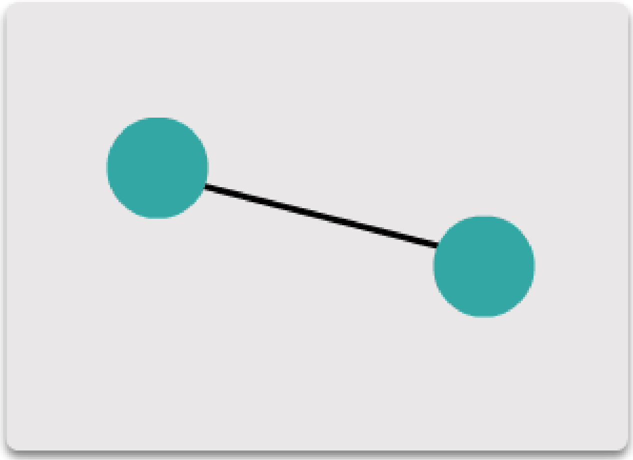
- **Physical topology** - Refers to the physical connections and identifies how end devices and infrastructure devices such as routers, switches, and wireless access points are interconnected. Physical topologies are usually point-to-point or star.

4.4.1.2 Physical and Logical Topologies

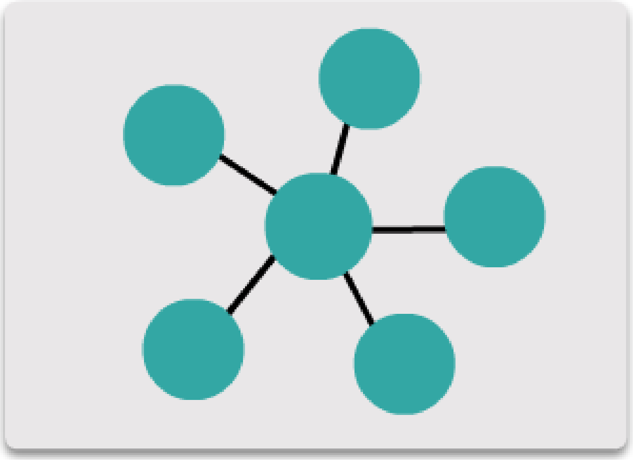


Logical topology - Refers to the way a network transfers frames from one node to the next. This arrangement consists of virtual connections between the nodes of a network. These logical signal paths are defined by data link layer protocols. The logical topology of point-to-point links is relatively simple while shared media offers different access control methods.

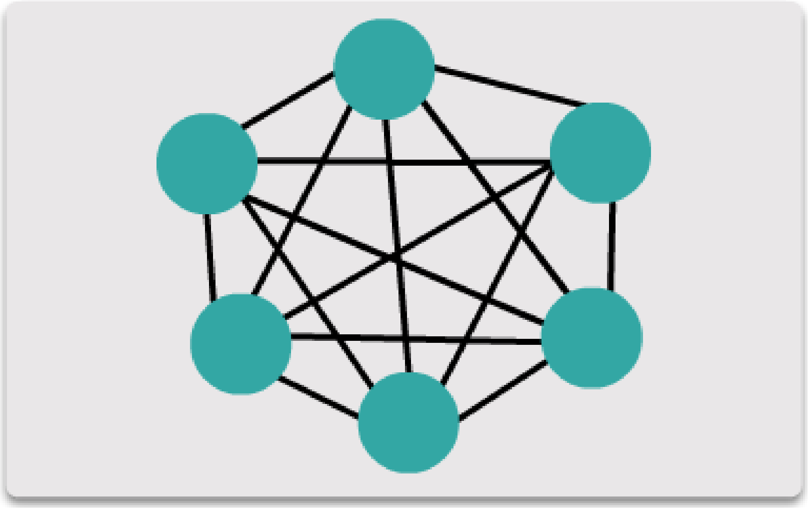
4.4.2.1 Common Physical WAN Topologies



Point-to-point topology



Hub and spoke topology

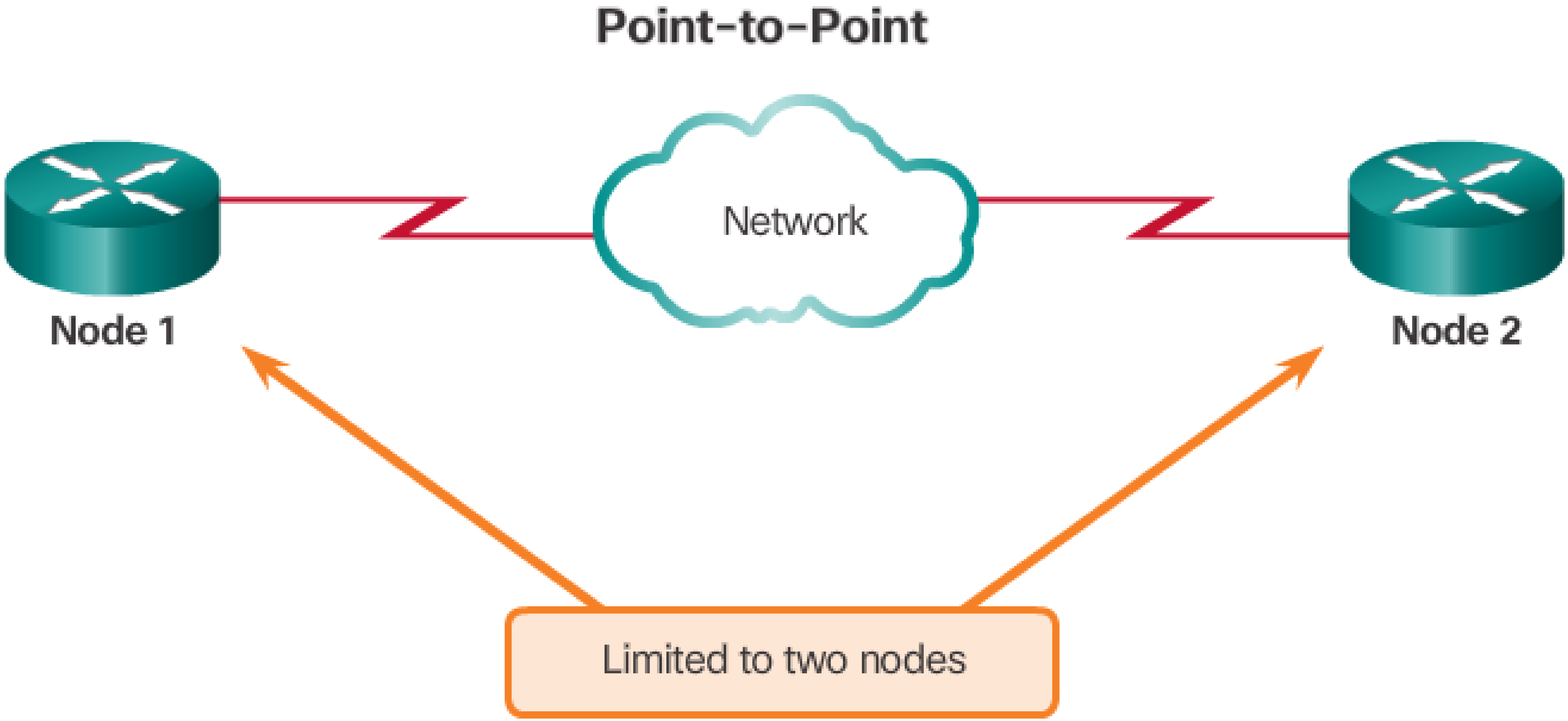


Full mesh topology

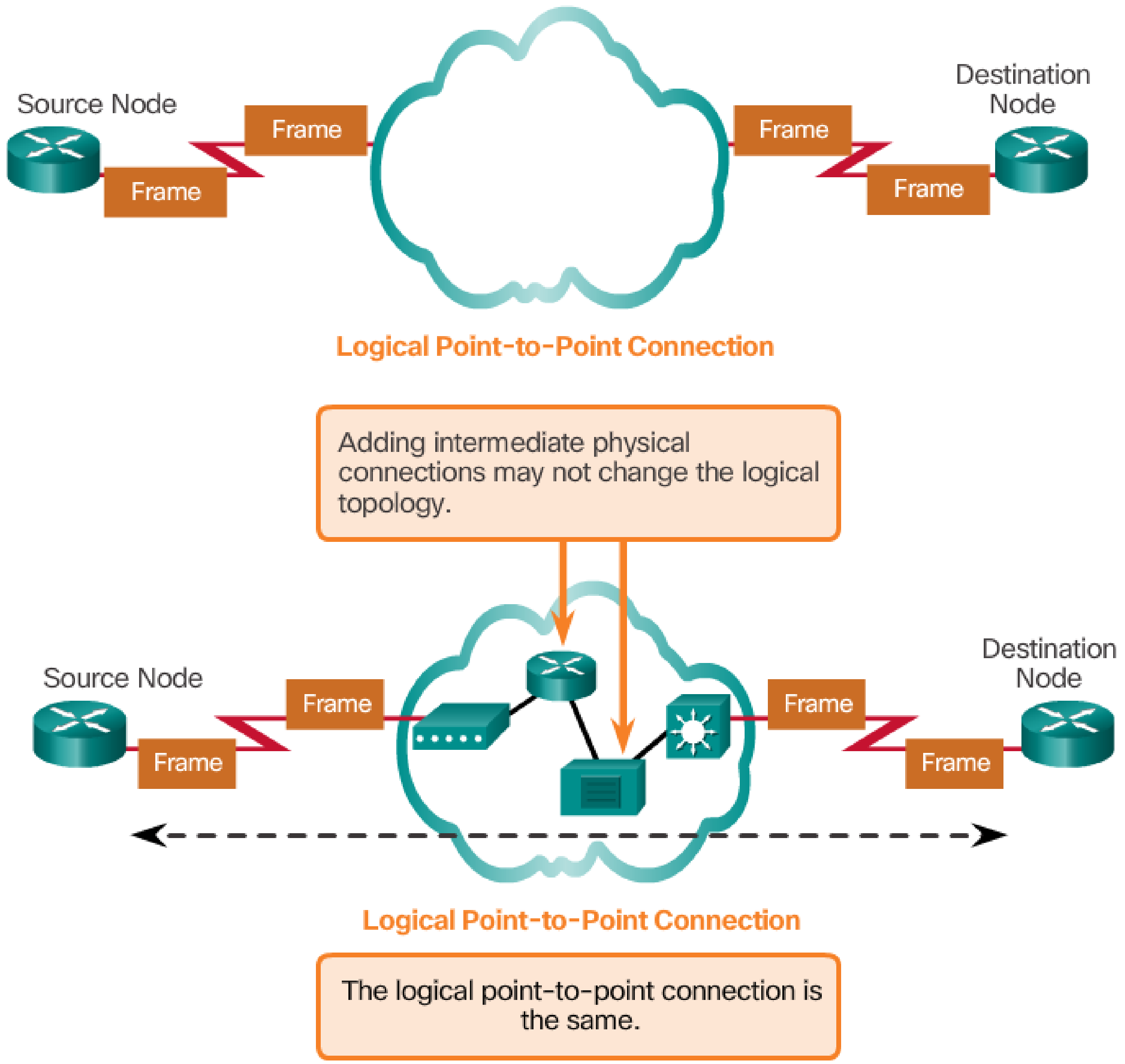
WANs are commonly interconnected using the following physical topologies:

- **Point-to-Point -** This is the simplest topology that consists of a permanent link between two endpoints. For this reason, this is a very popular WAN topology.
- **Hub and Spoke** - A WAN version of the star topology in which a central site interconnects branch sites using point-to-point links.
- **Mesh** - This topology provides high availability, but requires that every end system be interconnected to every other system. Therefore the administrative and physical costs can be significant. Each link is essentially a point-to-point link to the other node. Variations of this topology include a partial mesh where some but not all of end devices are interconnected.

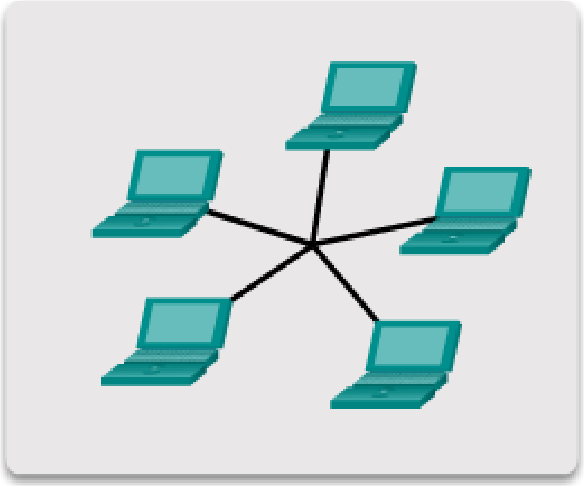
4.4.2.2 Physical Point-to-Point Topology



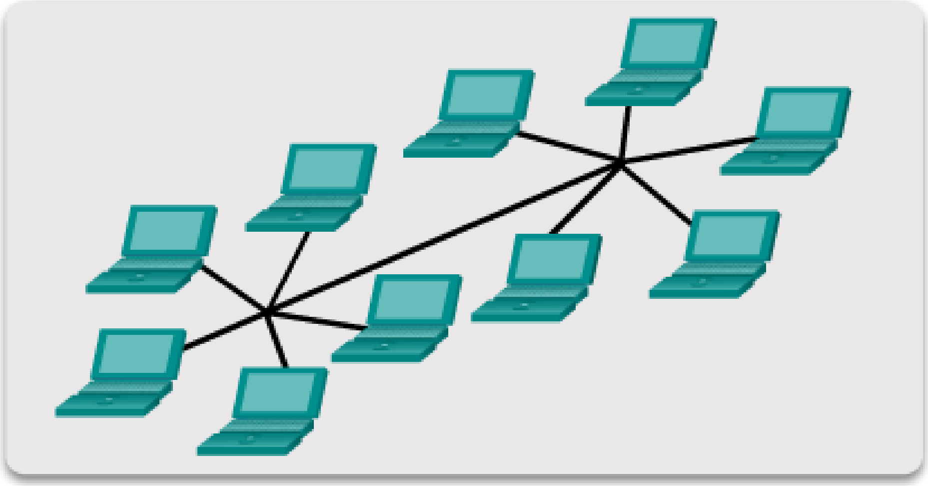
4.4.2.3 Logical Point-to-Point Topology



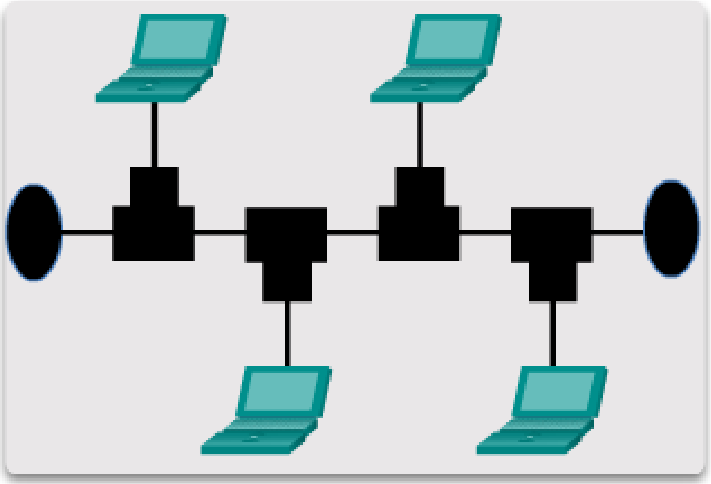
4.4.3.1 Physical LAN Topologies Topologies



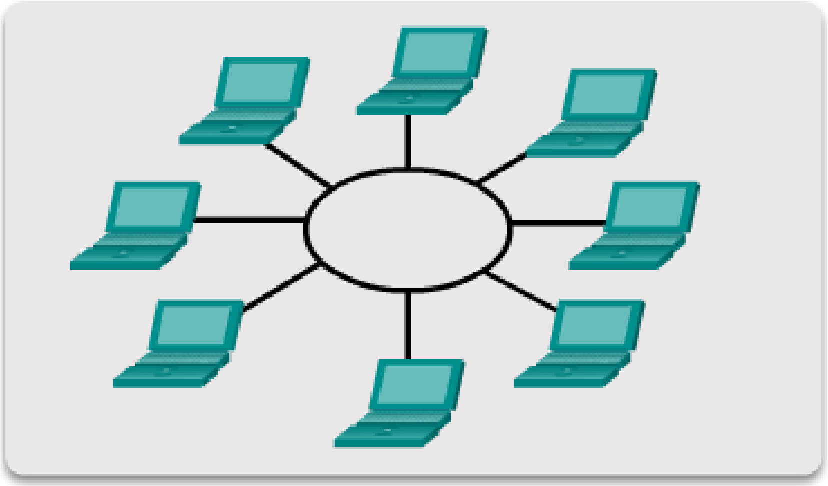
Star topology



Extended star topology



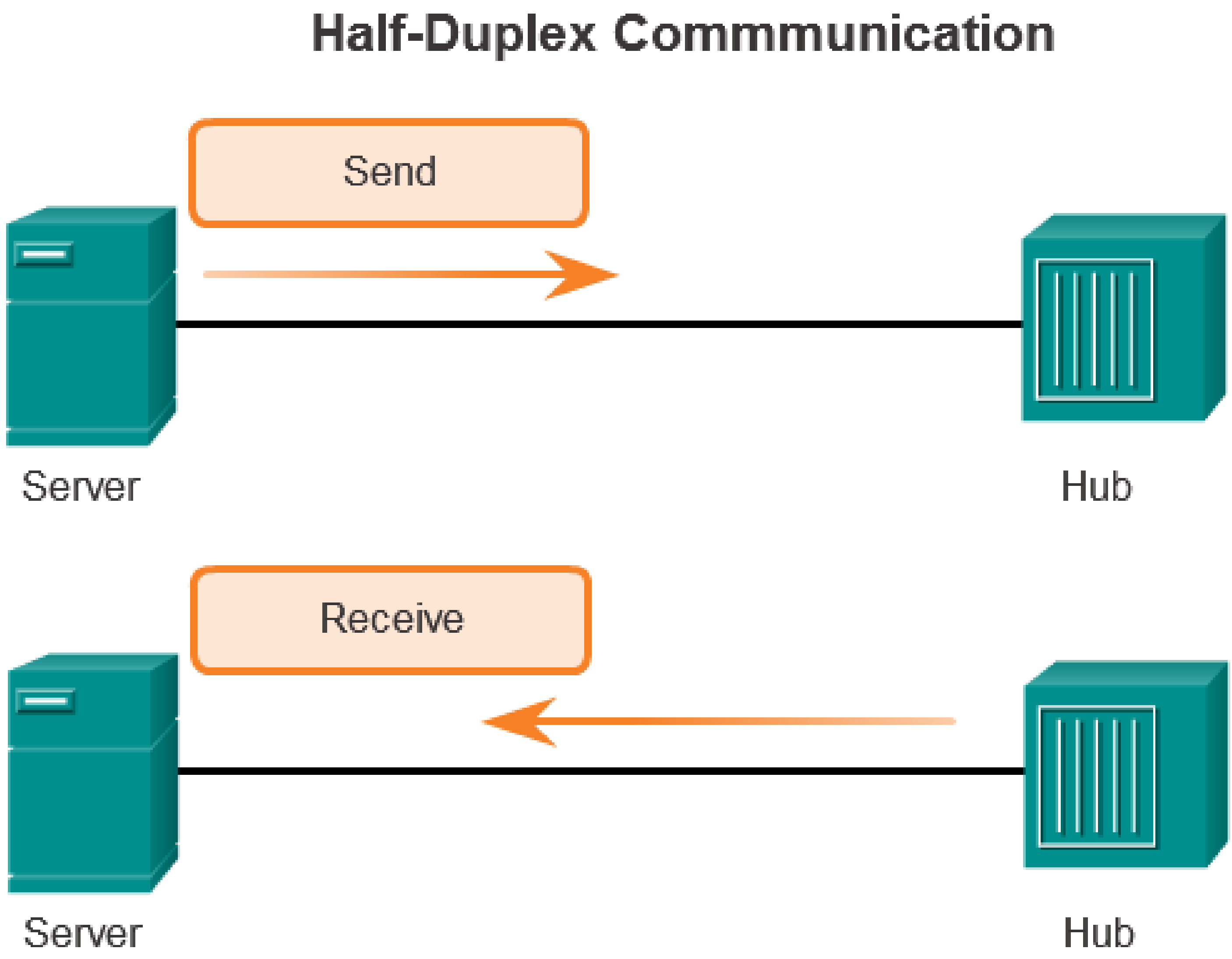
Bus topology



Ring topology

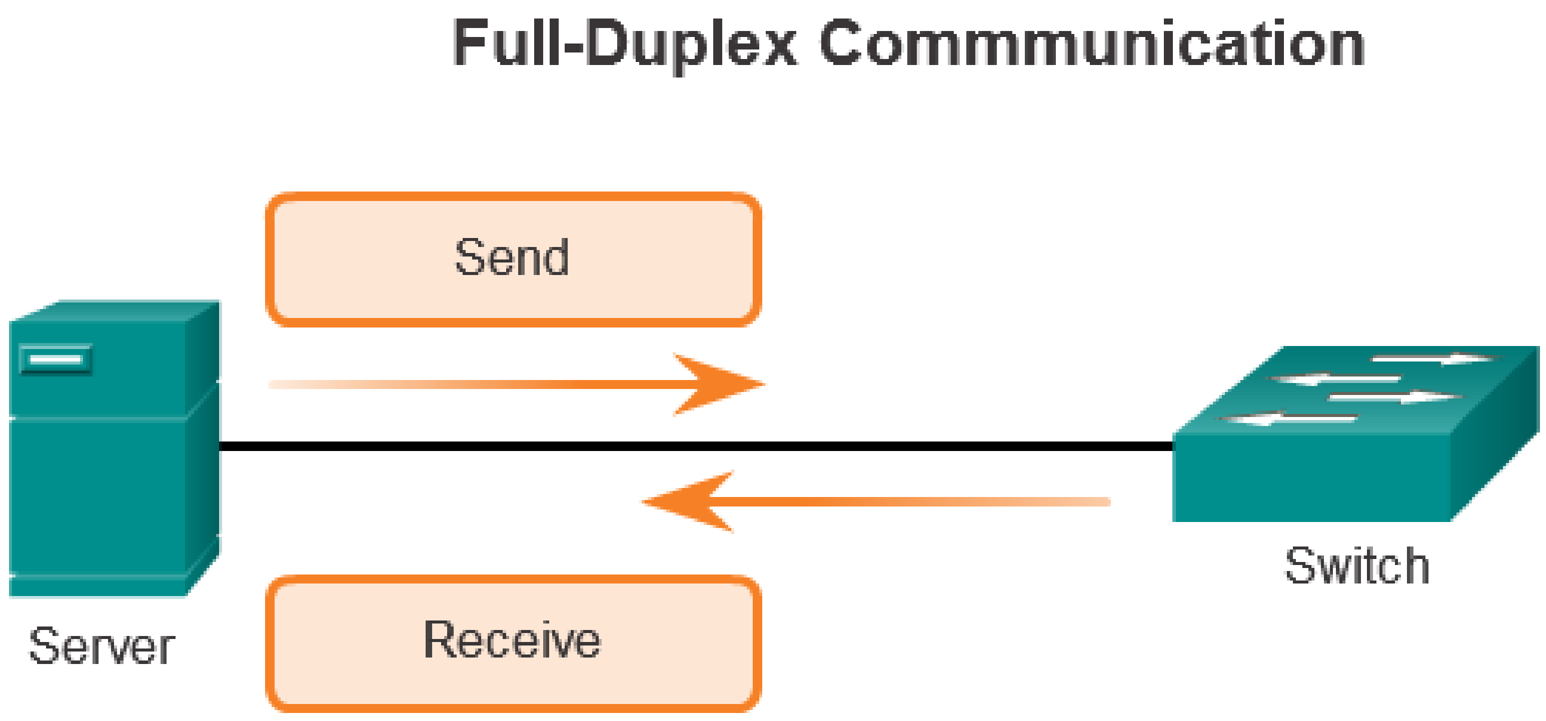
- **Star** - End devices are connected to a central intermediate device. The star topology is easy to install, very scalable (easy to add and remove end devices), and easy to troubleshoot.
- **Extended Star** - In an extended star topology, additional Ethernet switches interconnect other star topologies.
- **Bus** - Infrastructure devices such as switches are not required to interconnect the end devices. Bus topologies using coax cables were used in legacy Ethernet networks because it was inexpensive and easy to set up.

4.4.3.2 Half and Full Duplex



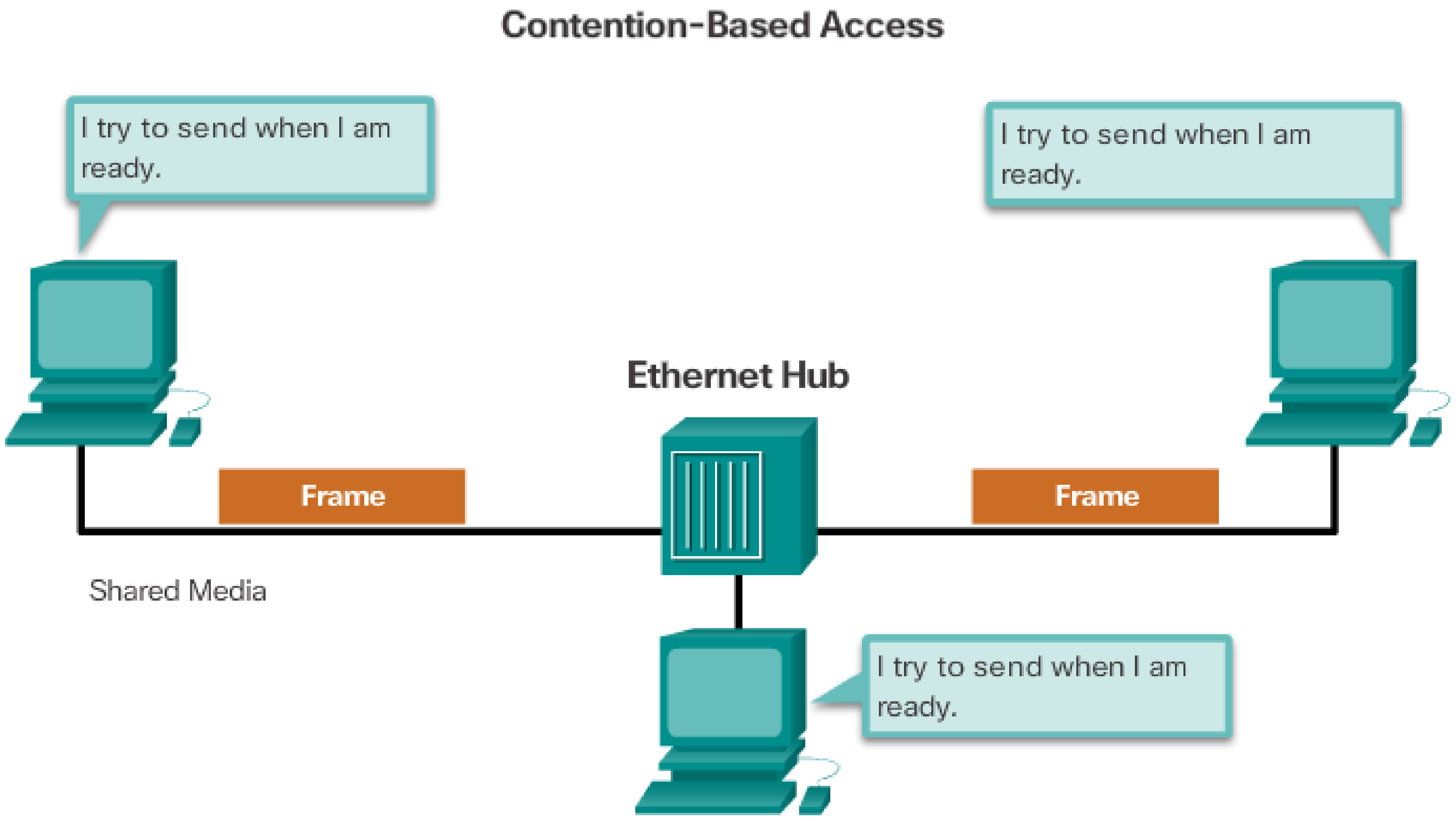
- **Half-duplex communication** - Both devices can transmit and receive on the media but cannot do so simultaneously. The half-duplex mode is used in legacy bus topologies and with Ethernet hubs. WLANs also operate in half-duplex. Half-duplex allows only one device to send or receive at a time on the shared medium and is used with contention-based access methods. Figure 1 shows half-duplex communication.

4.4.3.2 Half and Full Duplex



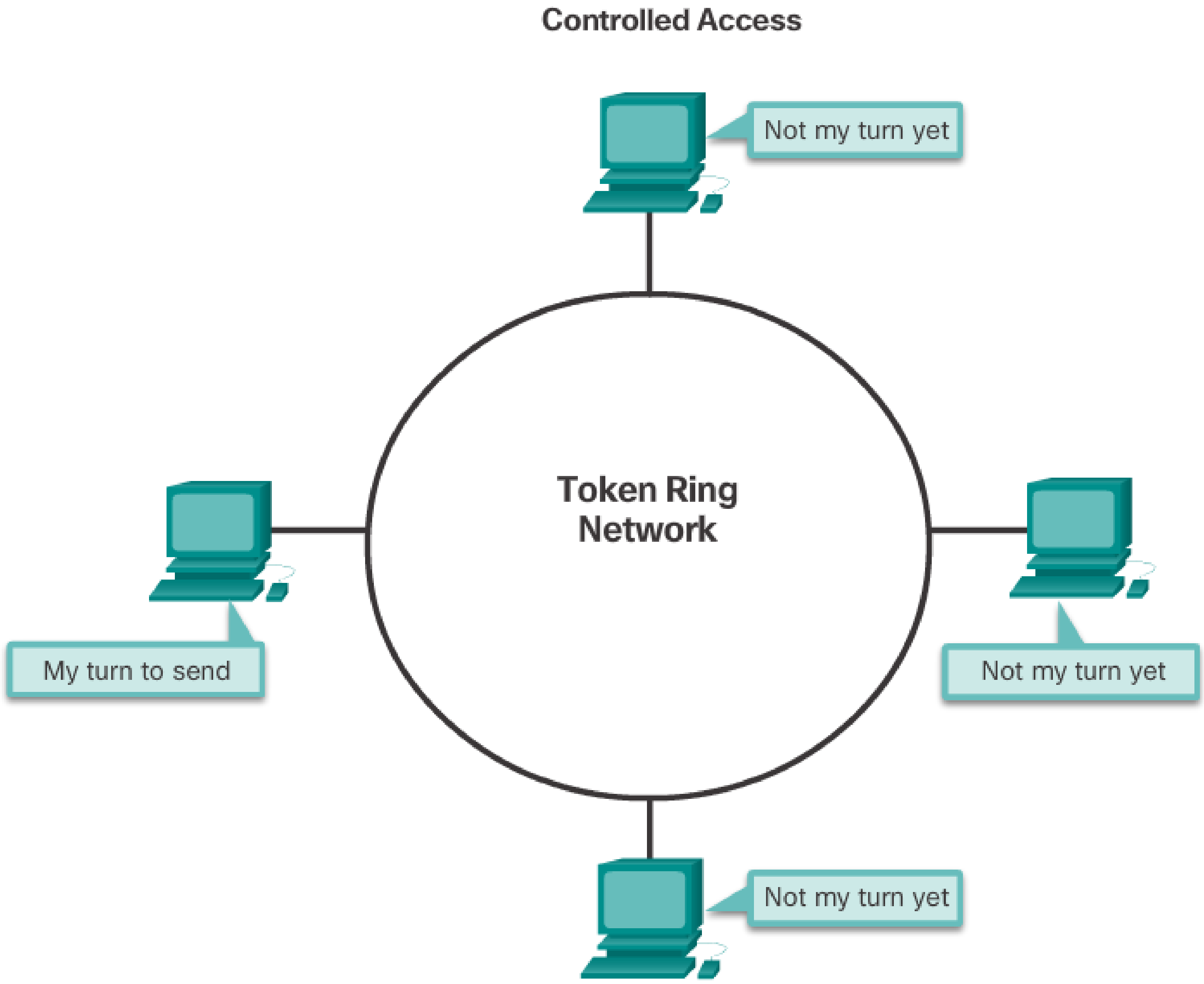
- **Full-duplex communication** - Both devices can transmit and receive on the media at the same time. The data link layer assumes that the media is available for transmission for both nodes at any time. Ethernet switches operate in full-duplex mode by default, but can operate in half-duplex if connecting to a device such as an Ethernet hub. Figure 2 shows full-duplex communication.

4.4.3.3 Media Access Control Methods



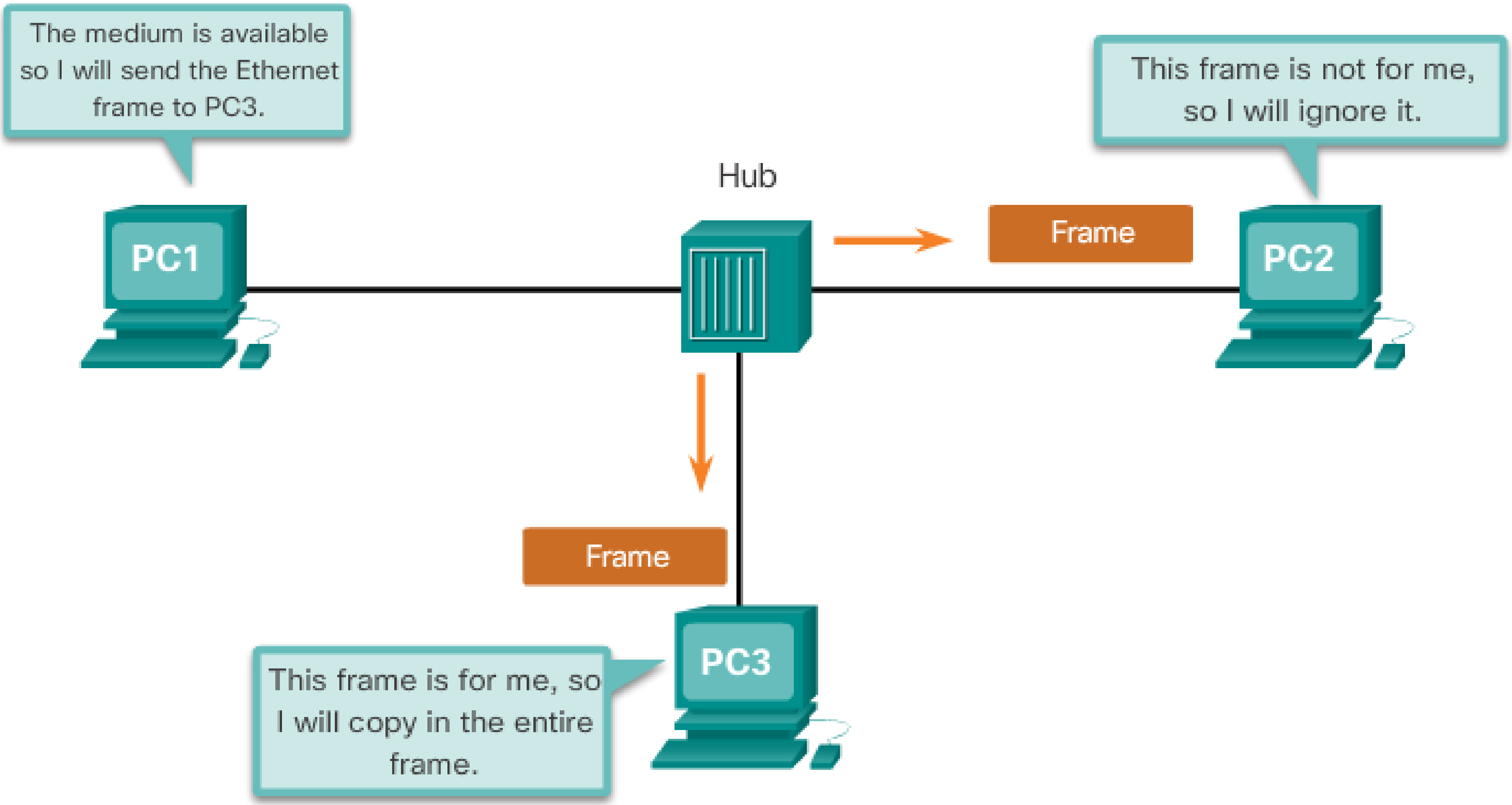
Contention-based access - All nodes operating in half-duplex compete for the use of the medium, but only one device can send at a time. However, there is a process if more than one device transmits at the same time. Ethernet LANs using hubs and WLANs are examples of this type of access control. Figure 1 shows contention-based access.

4.4.3.3 Media Access Control Methods



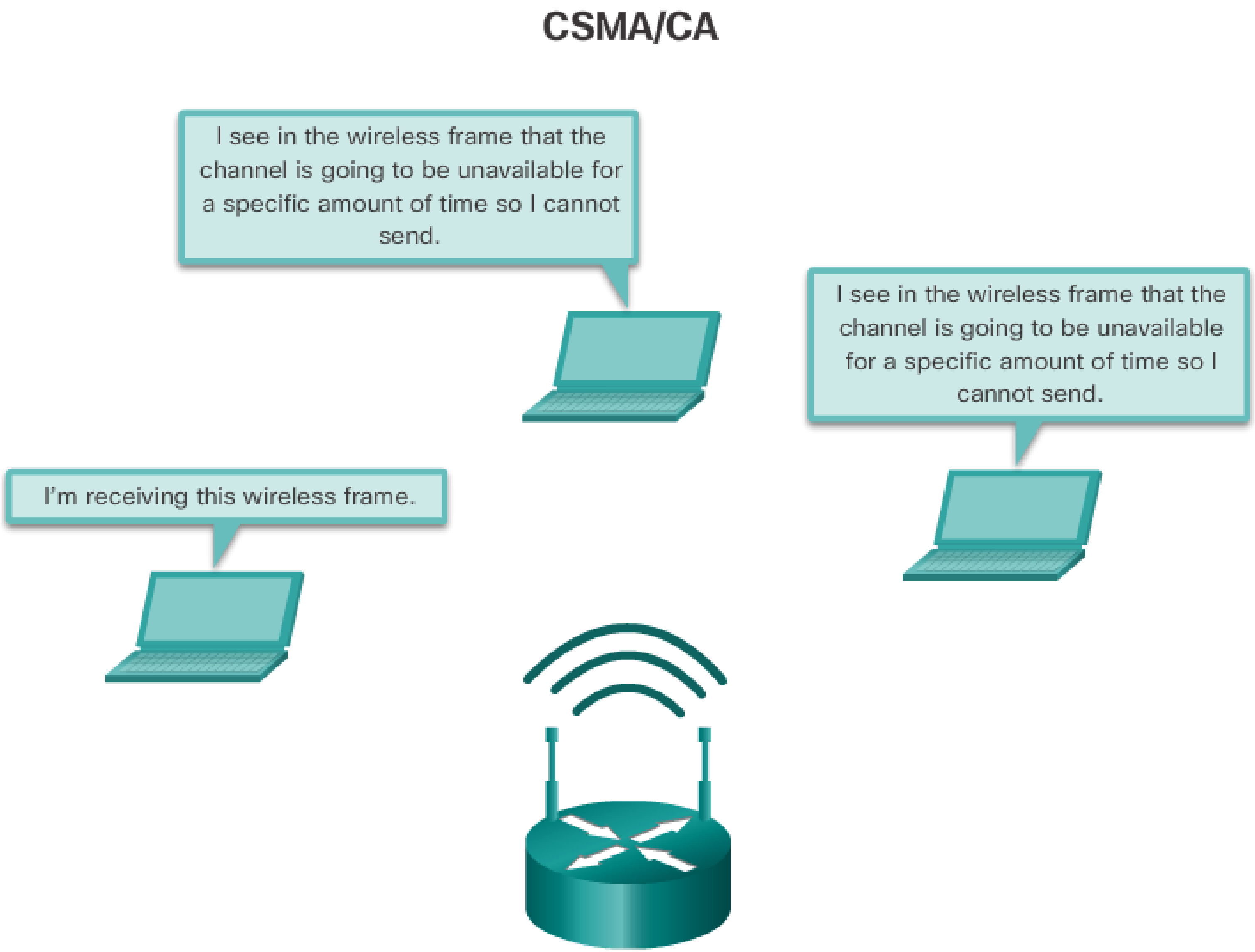
Controlled access - Each node has its own time to use the medium. These deterministic types of networks are inefficient because a device must wait its turn to access the medium. Legacy Token Ring LANs are an example of this type of access control. Figure 2 shows controlled access. Refer to the Chapter Appendix to learn more about controlled access.

4.4.3.4 Contention-Based Access – CSMA/CD



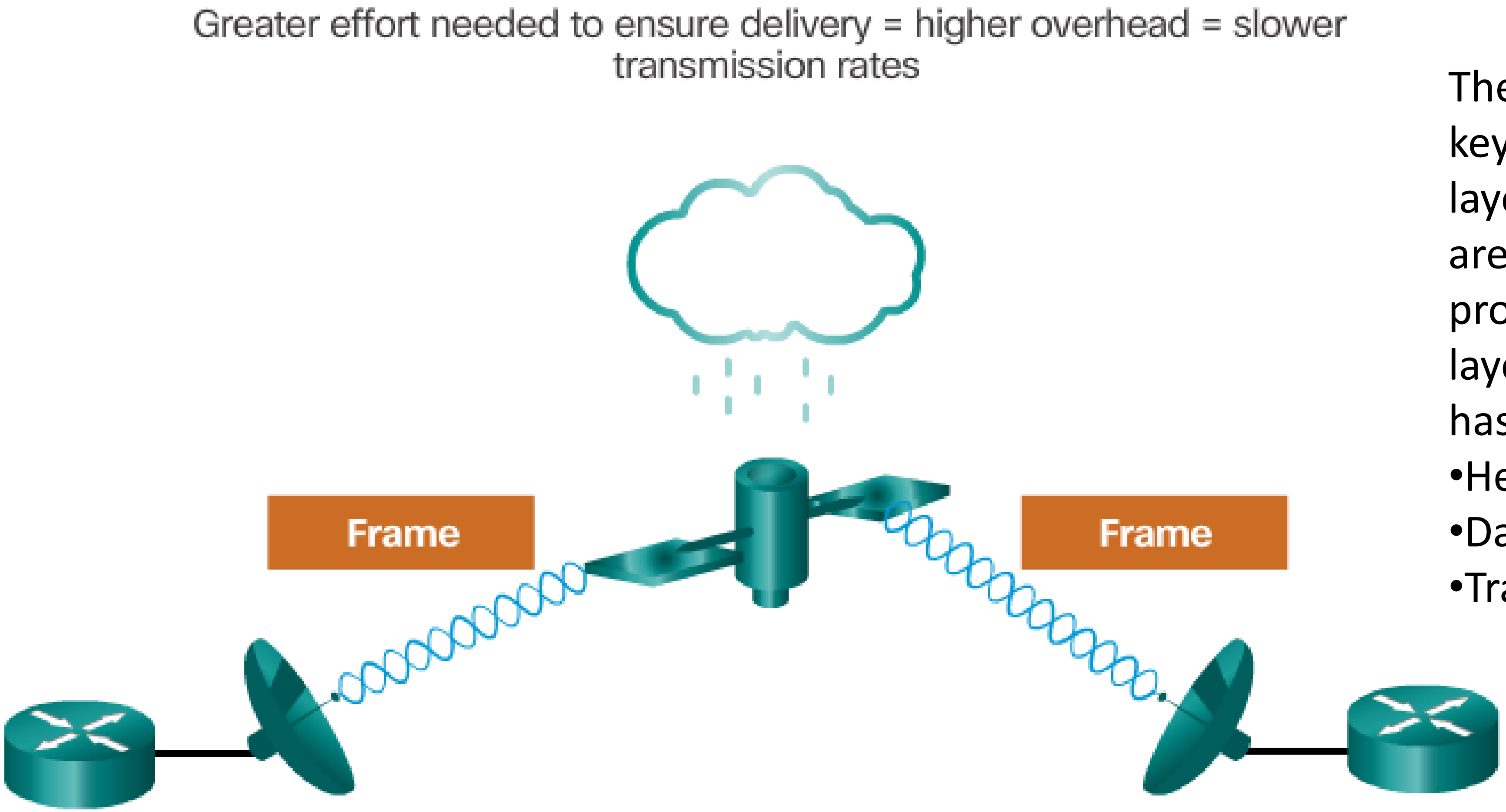
4.4.3.5 Contention-Based Access – CSMA/CA

Multiple Access/Collision Avoidance



Another form of CSMA that is used by IEEE 802.11 WLANs is Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA). CMSA/CA uses a method similar to CSMA/CD to detect if the media is clear. CMSA/CA also uses additional techniques. CMSA/CA does not detect collisions but attempts to avoid them by waiting before transmitting

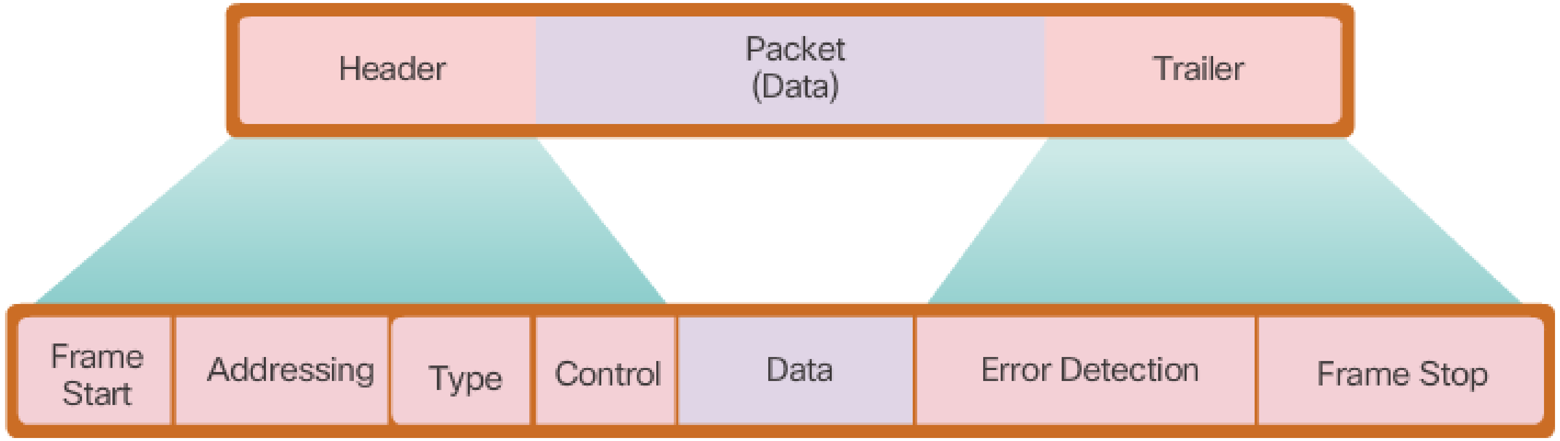
4.4.4.1 The Frame



The description of a frame is a key element of each data link layer protocol. Although there are many different data link layer protocols that describe data link layer frames, each frame type has three basic parts:

- Header
- Data
- Trailer

4.4.4.2 Frame Fields



Frame start and stop indicator flags - Used to identify the beginning and end limits of the frame.

Addressing - Indicates the source and destination nodes on the media.

Type - Identifies the Layer 3 protocol in the data field.

Control - Identifies special flow control services such as quality of service (QoS). QoS is used to give forwarding priority to certain types of messages.

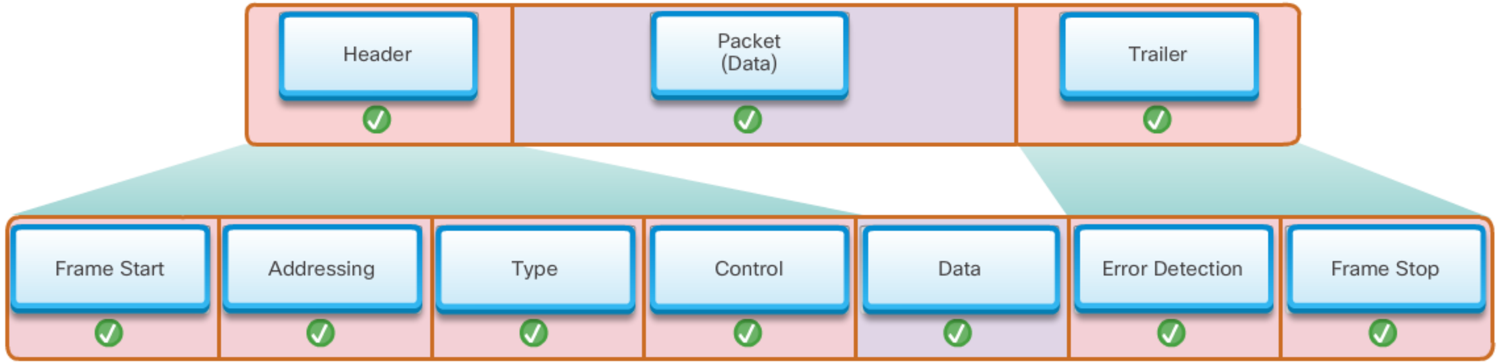
Data - Contains the frame payload (i.e., packet header, segment header, and the data).

Error Detection - These frame fields are used for error detection and are included after the data to form the trailer.

4.4.4.3 Activity – Generic Frame Fields

Activity - Part 1: Generic Frame Fields

Drag the generic frame field to its correct location on the diagram.

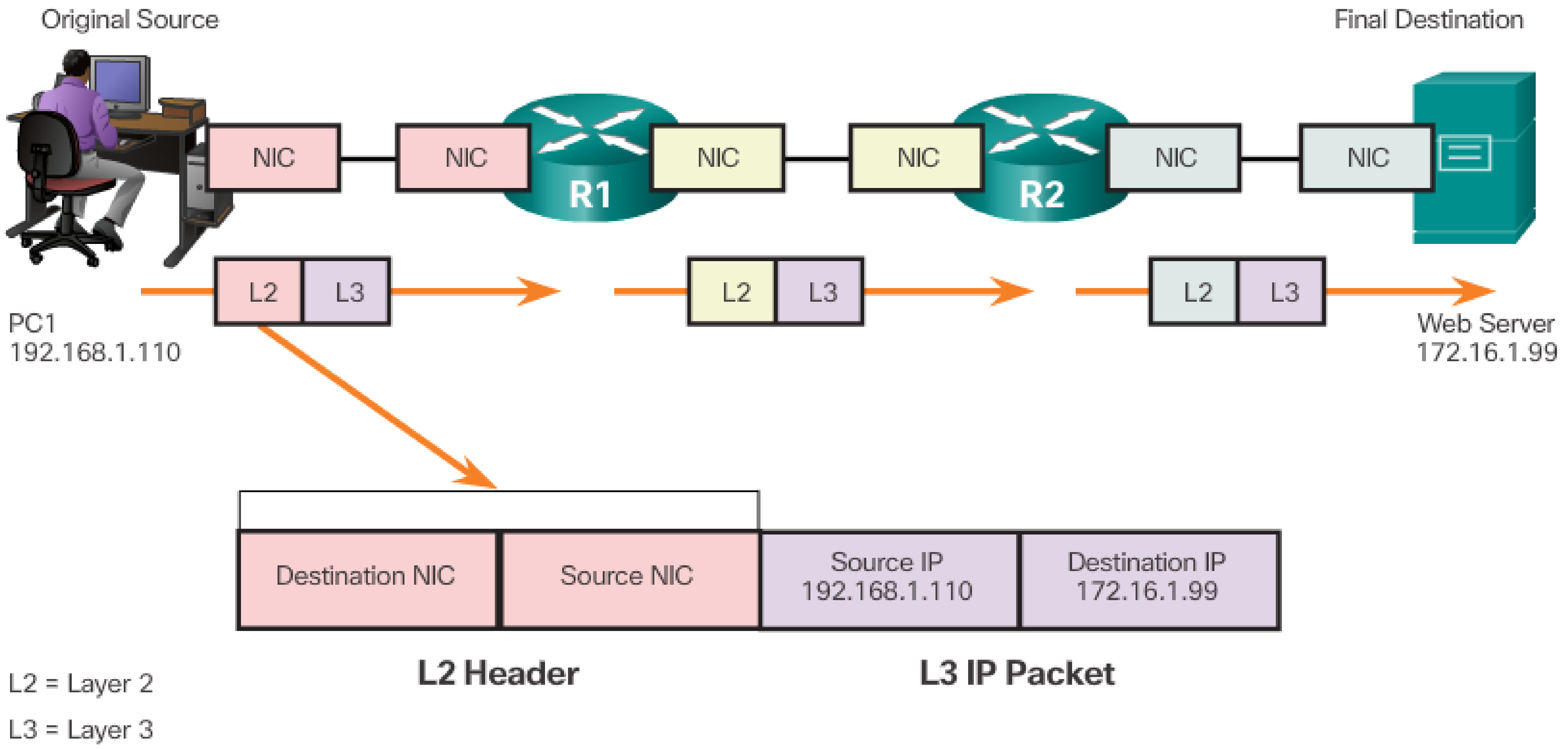


Activity - Part 2: Generic Frame Fields

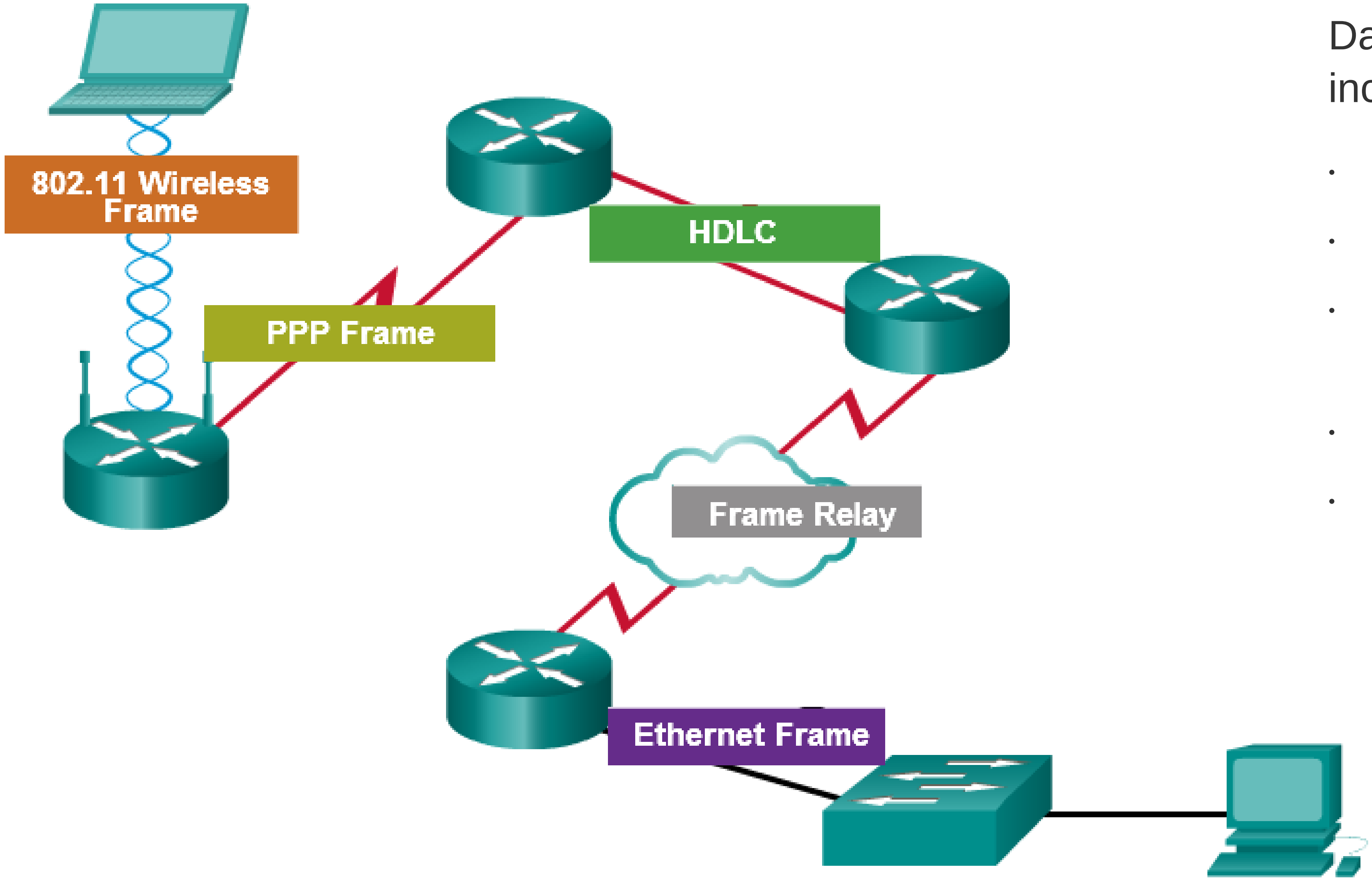
Drag and drop the generic frame field to its description.

Data	Contains the IP header, transport layer PDU, and data
Type	Identifies the Layer 3 protocol used by the LLC
Frame stop indicator flag	Marks the end of the frame
Addressing	Identifies source and destination hosts by MAC address
Control	Specifies special flow control services

4.4.4.4 Layer 2 Address



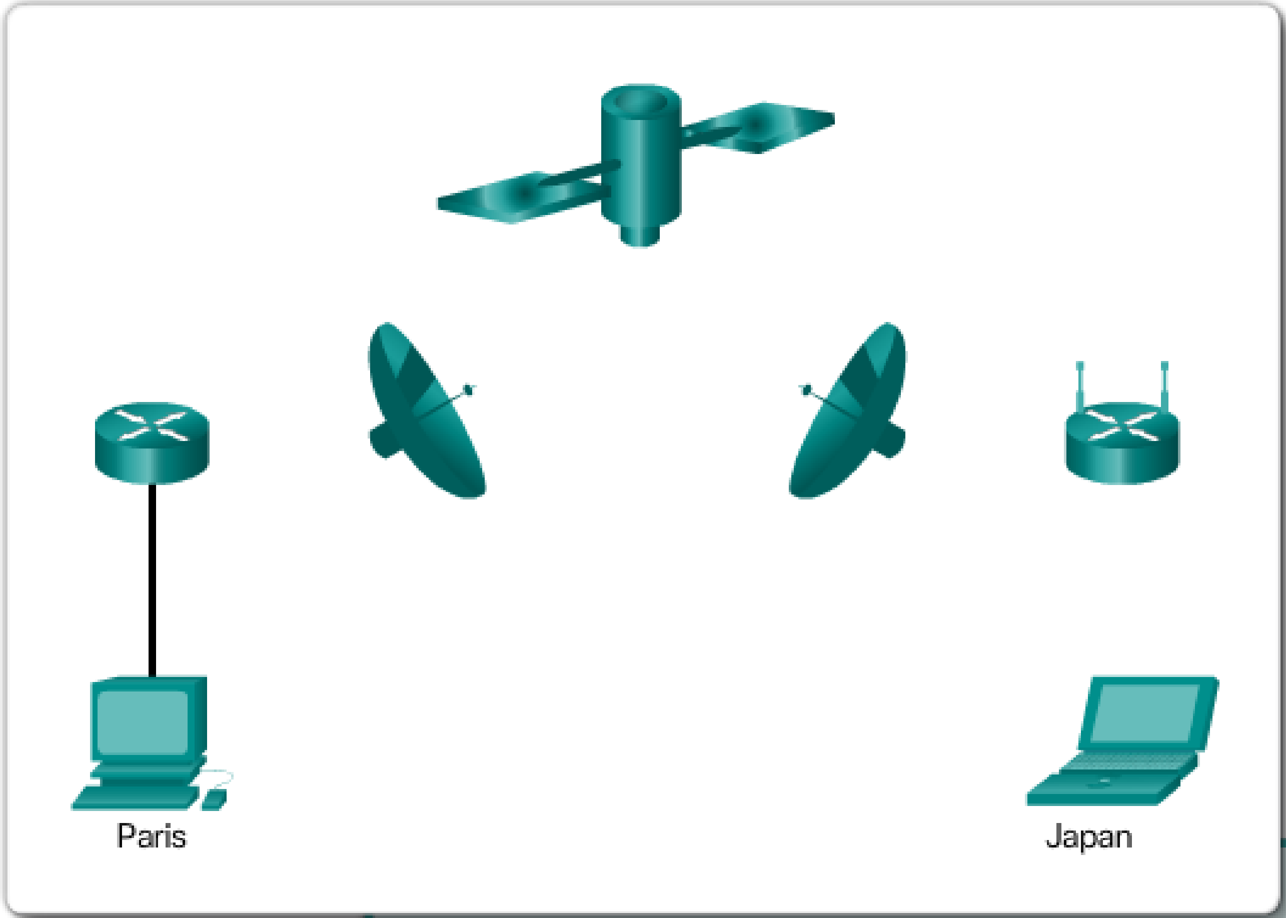
4.4.4.5 LAN and WAN Frames



Data link layer protocols include:

- **Ethernet**
- **802.11 Wireless**
- **Point-to-Point Protocol (PPP)**
- **HDLC**
- **Frame Relay**

4.5.1.1 Class Activity – Linked In!



The Network Access Layer combines the type of data link and signaling method to deliver data packets securely and seamlessly.

4.5.1.2 Chapter 4: Network Access