Chapter 4: Network Access

Introduction to Networks

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Chapter 4: Objectives

Upon completion of this chapter, you will be able to:

- Identify device connectivity options.
- Describe the purpose and functions of the physical layer in the network.
- Describe basic principles of the physical layer standards.
- Identify the basic characteristics of copper cabling.
- Build a UTP cable used in Ethernet networks.
- Describe fiber-optic cabling and its main advantages over other media.
- Describe wireless media.
- Select the appropriate media for a given requirement and connect devices.

Chapter 4: Objectives (cont.)

Upon completion of this chapter, you will be able to:

- Describe the purpose and function of the data link layer in preparing communication for transmission on specific media.
- Describe the Layer 2 frame structure and identify generic fields.
- Identify several sources for the protocols and standards used by the data link layer.
- Compare the functions of logical topologies and physical topologies.
- Describe the basic characteristics of media control methods on WAN topologies.
- Describe the basic characteristics of media control methods on LAN topologies.
- Describe the characteristics and functions of the data link frame.

4.4 Media Access Control

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Chapter 4

4.1 Physical Layer Protocols

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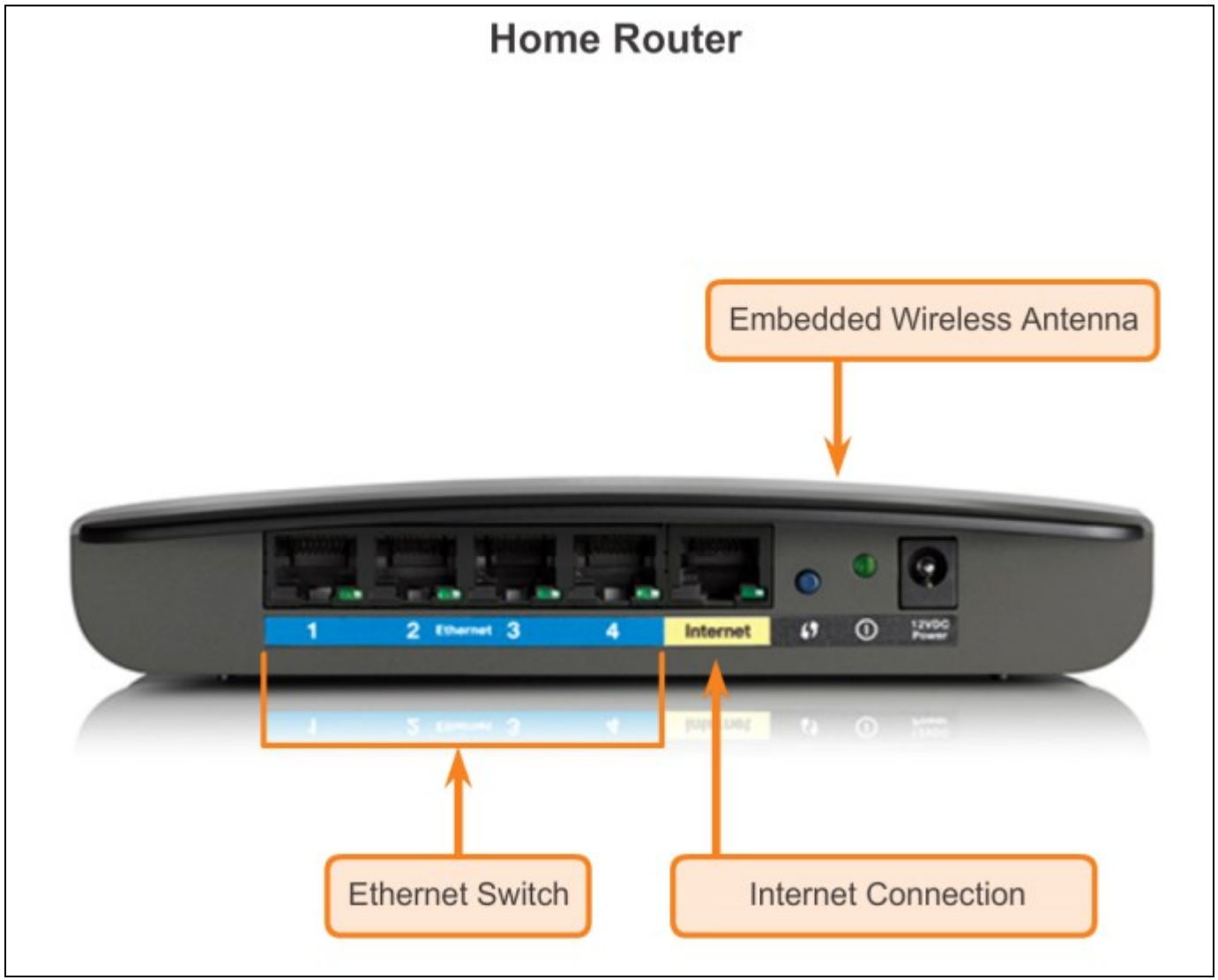
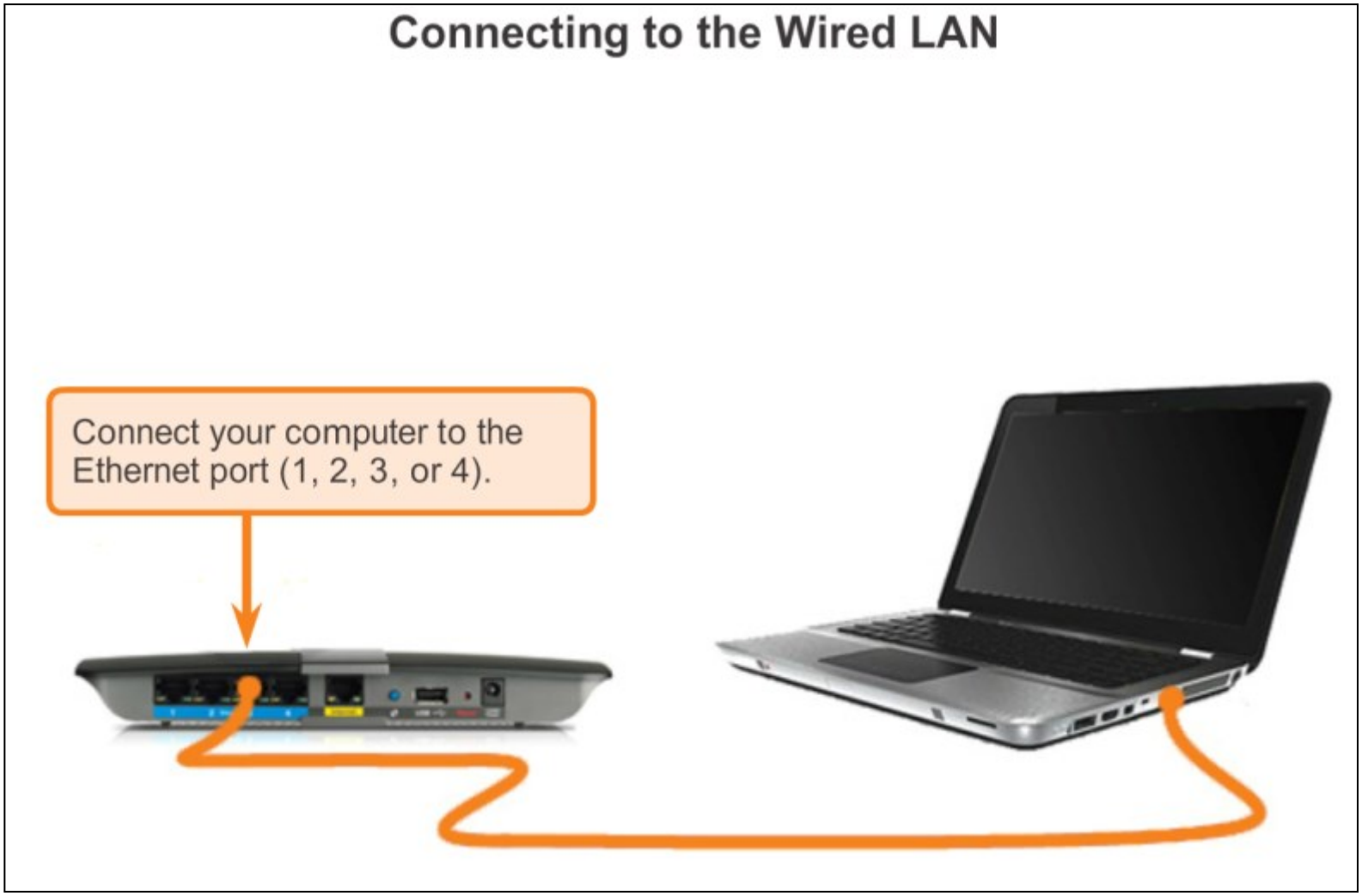
Connecting to the Network

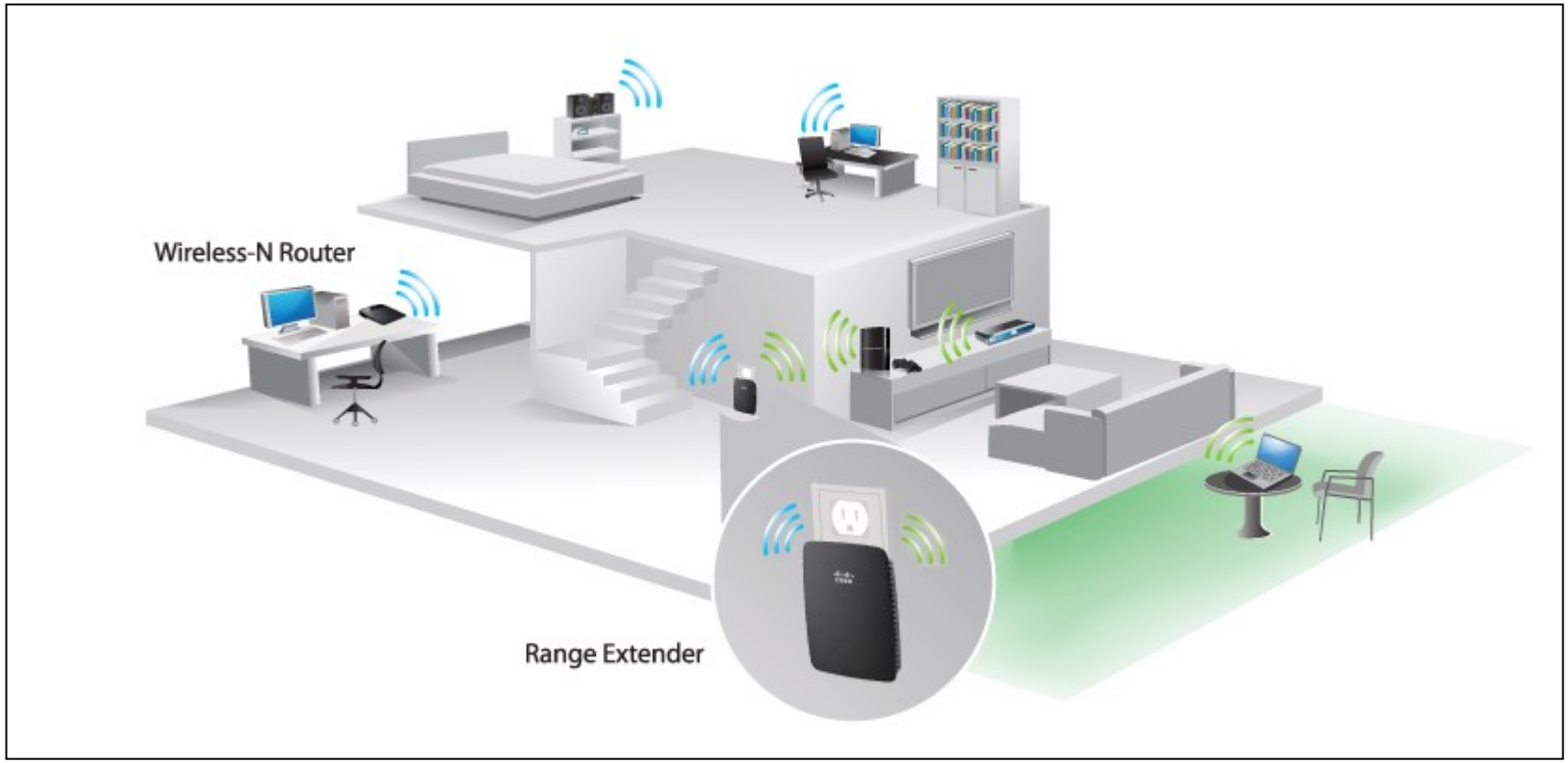


Connecting to the Network (cont.)



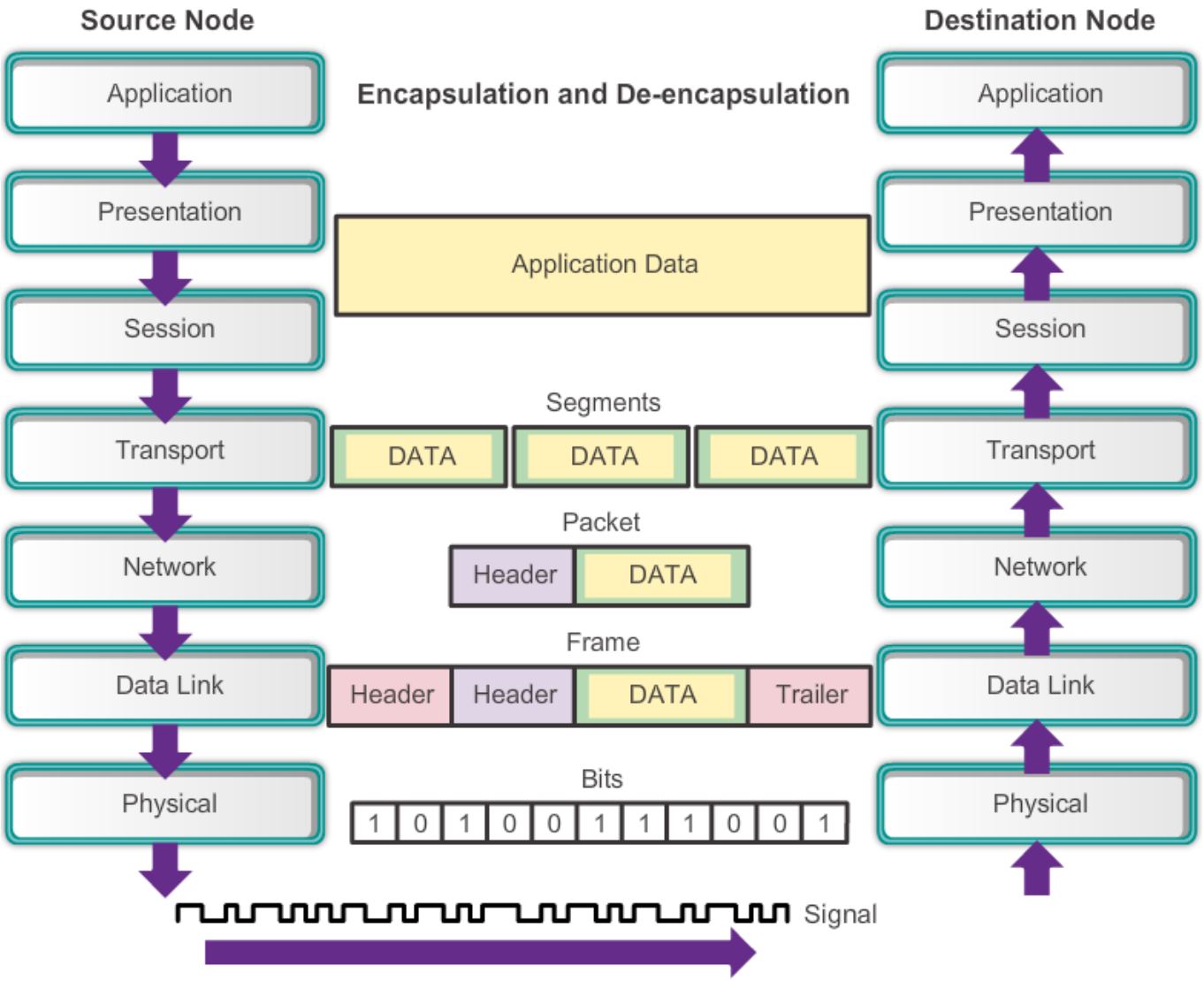
Network Interface Cards

Connecting to the Wireless LAN with a Range Extender



Purpose of the Physical Layer

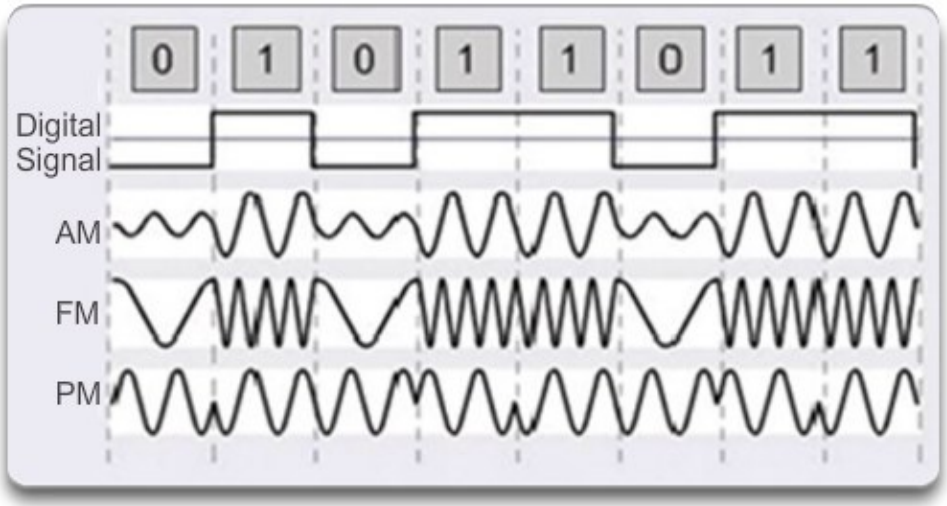
The Physical Layer



Physical Layer Media

Electrical Signals -
Copper cable

Light Pulse -
Fiber-optic cable



Microwave Signals -
Wireless

Physical Layer Standards

Standard Organization	Networking Standards
ISO	• ISO 8877: Officially adopted the RJ connectors (e.g., RJ-11, RJ-45) • ISO 11801: Network cabling standard similar to EIA/TIA 568.
EIA/TIA	• TIA-568-C: Telecommunications cabling standards, used by nearly all voice, video and data networks. • TIA-569-B: Commercial Building Standards for Telecommunications Pathways and Spaces • TIA-598-C: Fiber optic color coding • TIA-942: Telecommunications Infrastructure Standard for Data Centers
ANSI	• 568-C: RJ-45 pinouts. Co-developed with EIA/TIA
ITU-T	• G.992: ADSL
IEEE	• 802.3: Ethernet • 802.11: Wireless LAN (WLAN) & Mesh (Wi-Fi certification) • 802.15: Bluetooth

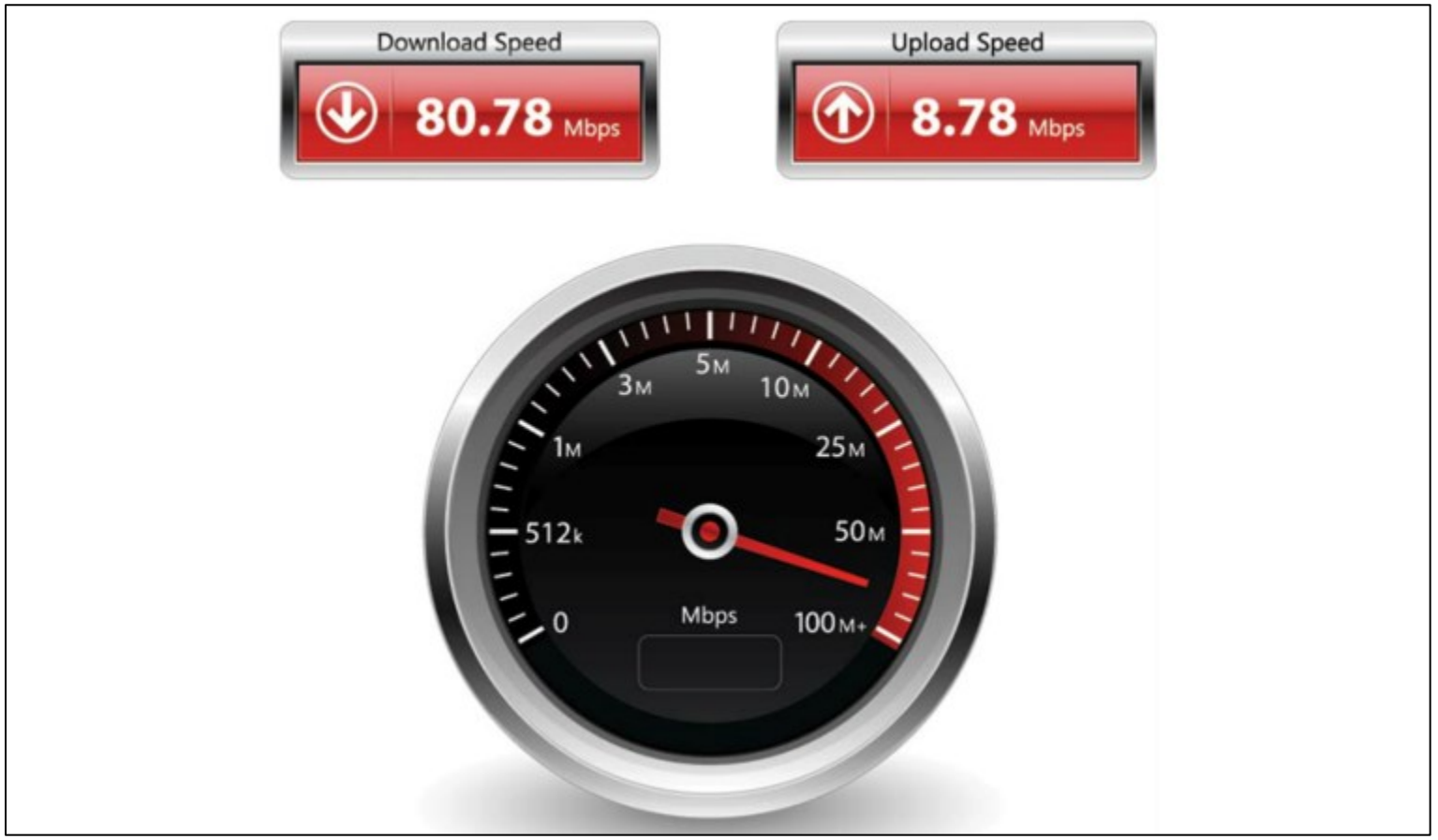
Physical Layer Fundamental Principles

Media	Physical Components	Frame Encoding Technique	Signalling Method
Copper Cable	• UTP • Coaxial • Connectors • NICs • Ports • Interfaces	• Manchester Encoding • Non-Return to Zero (NRZ) techniques • 4B/5B codes are used with Multi-Level Transition Level 3 (MLT-3) signaling • 8B/10B • PAM5	• Changes in the electromagnetic field • Intensity of the electromagnetic field • Phase of the electromagnetic wave
Fiber Optic Cable	• Single-mode Fiber • Multimode Fiber • Connectors • NICs • Interfaces • Lasers and LEDs • Photoreceptors	• Pulses of light • Wavelength multiplexing using different colors	• A pulse equals 1. • No pulse is 0.
Wireless Media	• Access Points • NICs • Radio • Antennae	• DSSS (direct-sequence spread-spectrum) • OFDM (orthogonal frequency division multiplexing)	• Radio waves

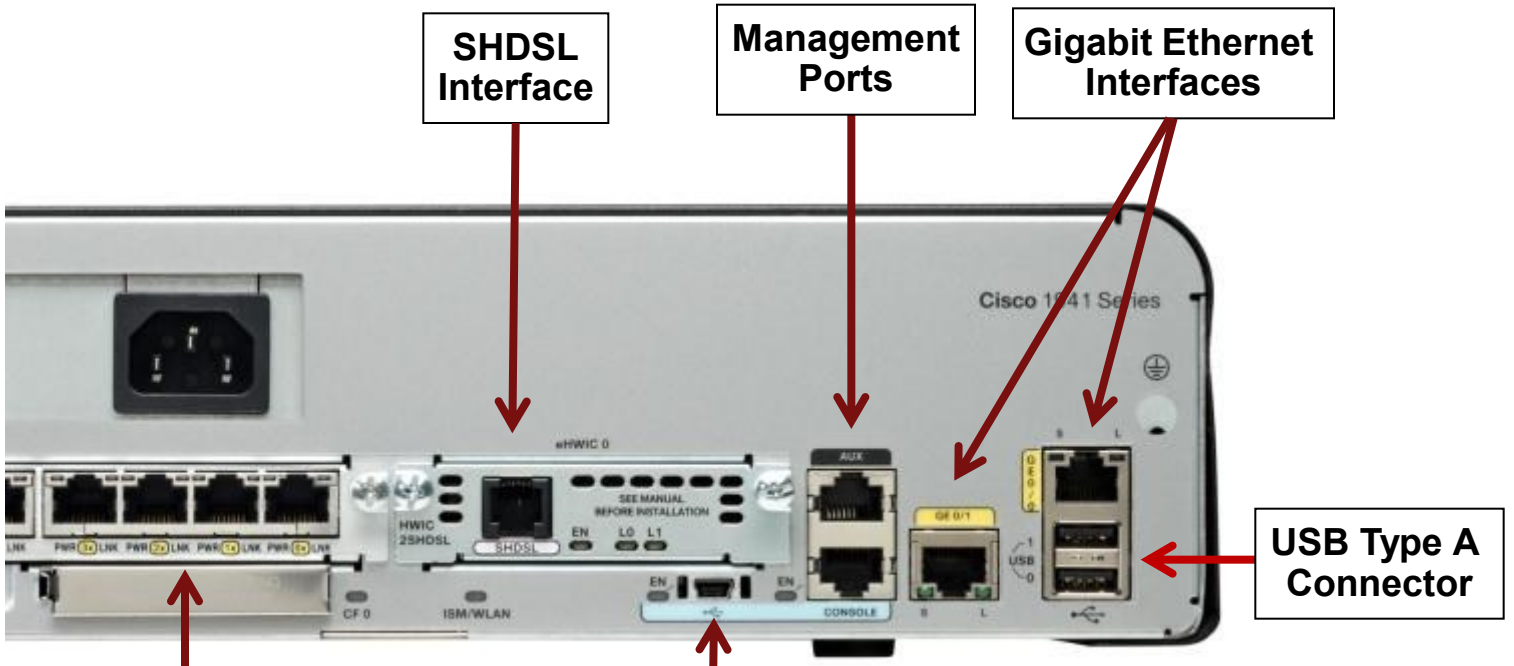
Bandwidth

Unit of Bandwidth	Abbreviation	Equivalence
Bits per second	bps	1 bps = fundamental unit of bandwidth
Kilobits per second	kbps	1 kbps = 1,000 bps = 10^3 bps
Megabits per second	Mbps	1 Mbps = 1,000,000 bps = 10^6 bps
Gigabits per second	Gbps	1 Gbps = 1,000,000,000 bps = 10^9 bps
Terabits per second	Tbps	1 Tbps = 1,000,000,000,000 bps = 10^12 bps

Throughput



Types of Physical Media



4.2 Network Media

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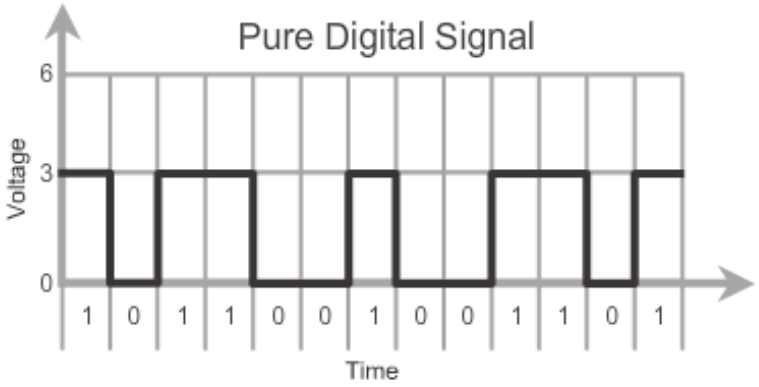
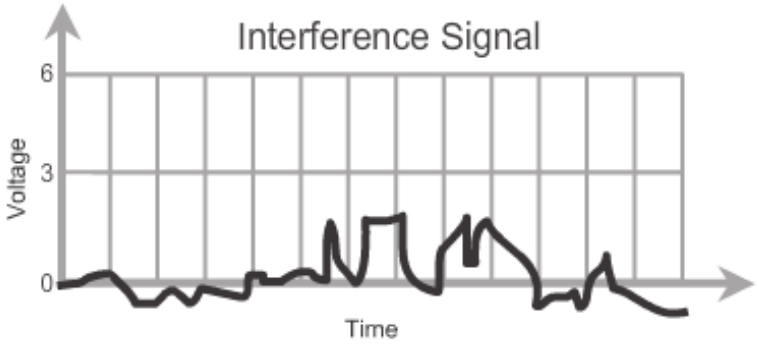
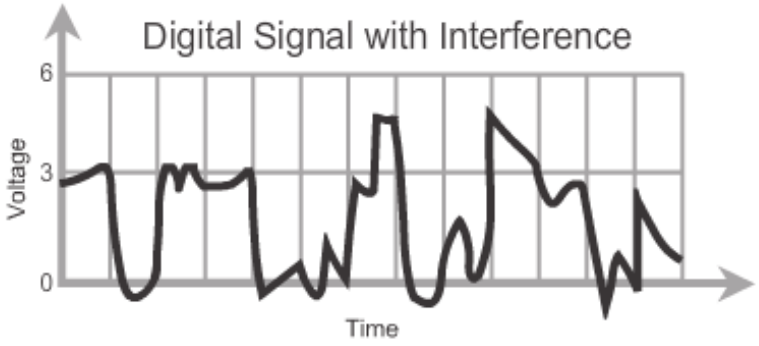
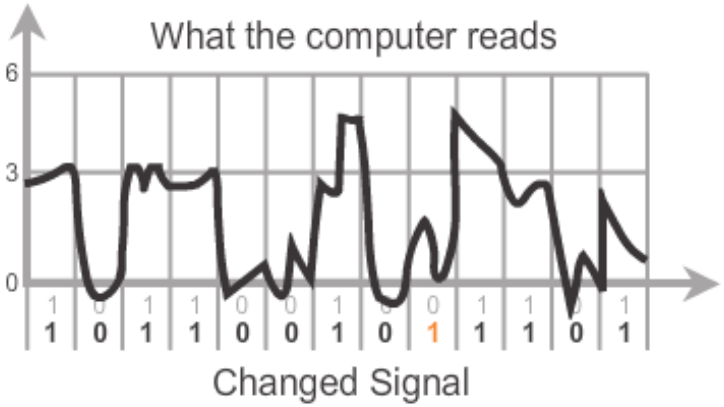
Characteristics of Copper Media

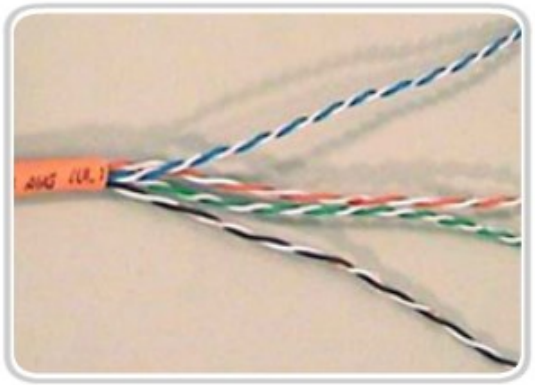




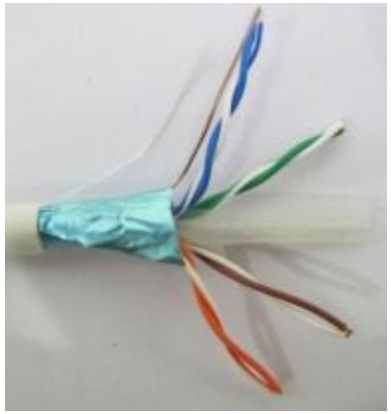




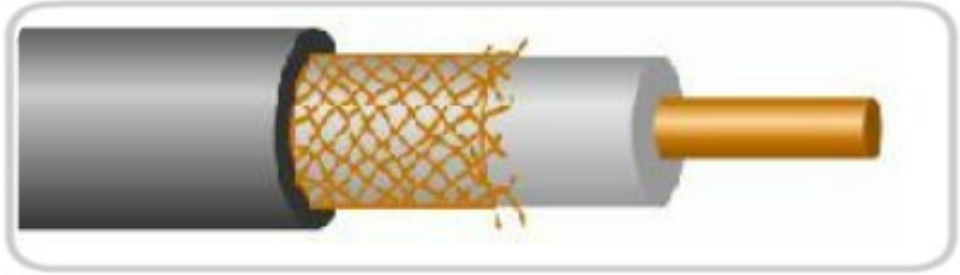
Copper Media



Unshielded Twisted Pair (UTP) Cable



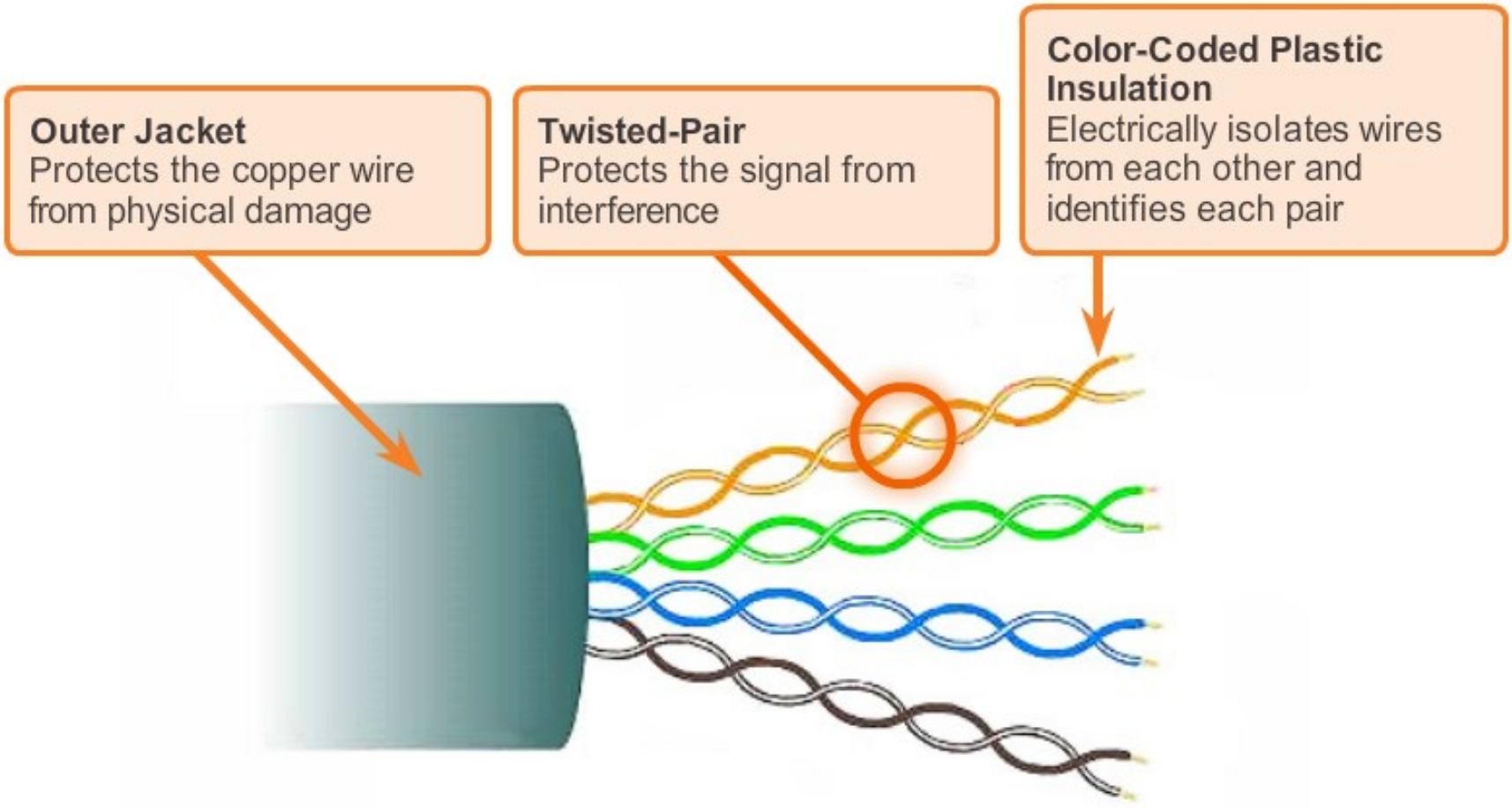
Shielded Twisted Pair (STP) Cable



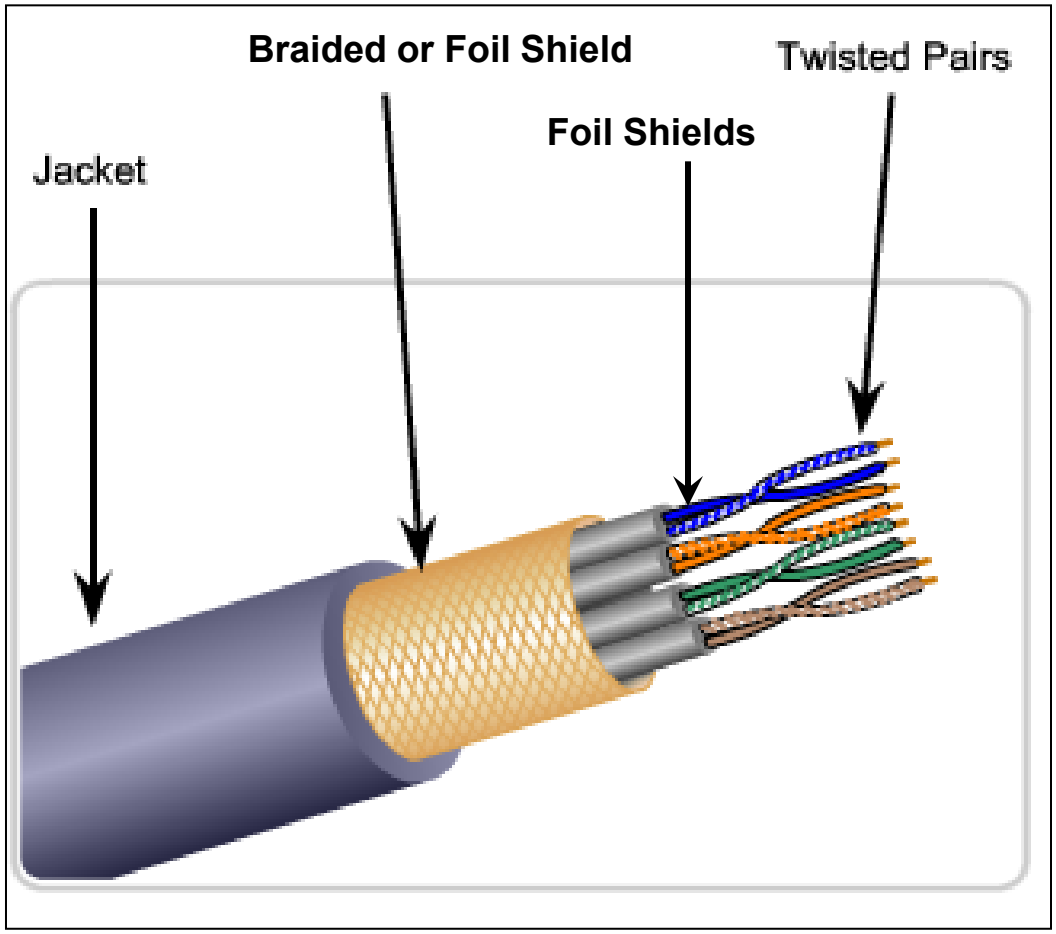
Coaxial Cable

Copper Cabling

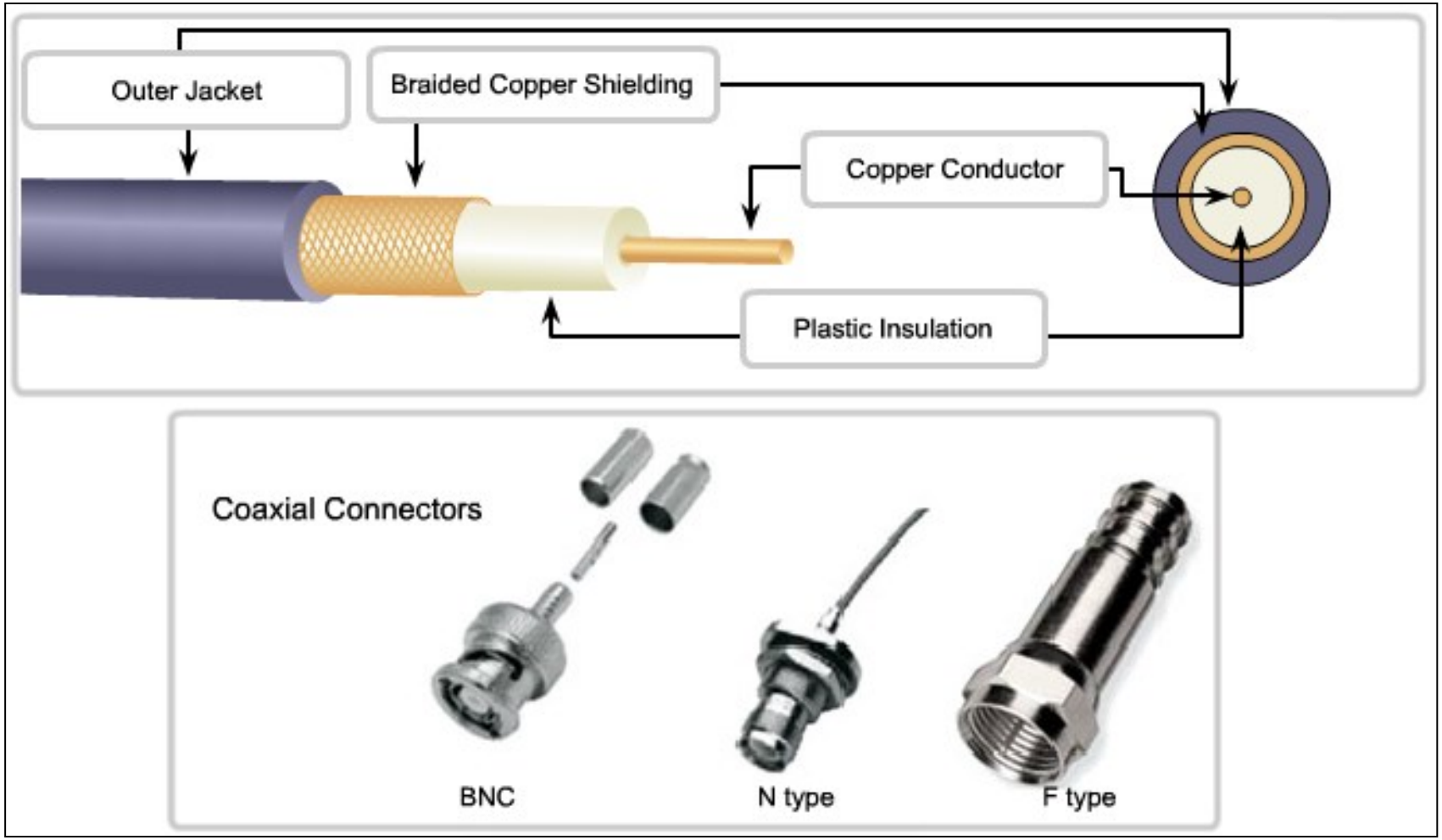
UTP Cable



STP Cable



Coaxial Cable



Cooper Media Safety

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

Cables must be connected correctly.

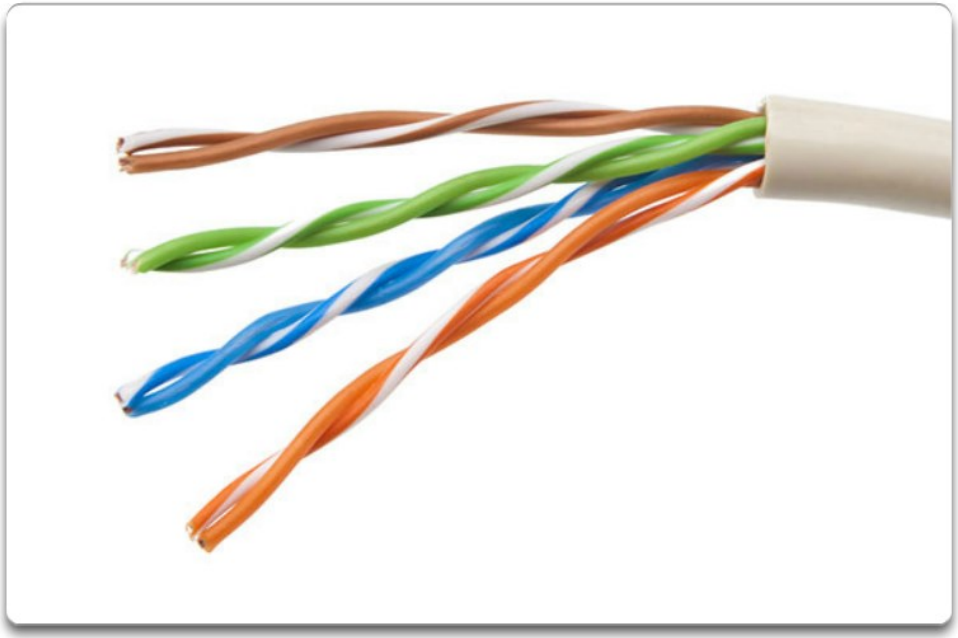
Installations must be inspected for damage.

Equipment must be grounded correctly.

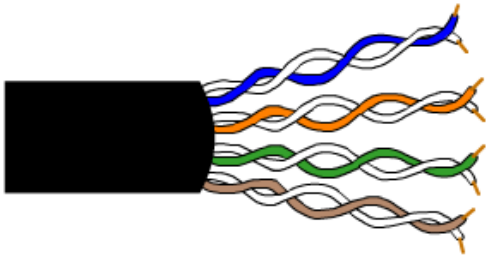
Properties of UTP Cabling

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:

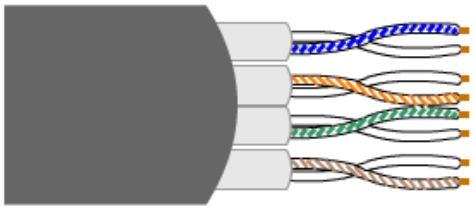
- Cancellation
- Varying the number of twists per wire pair



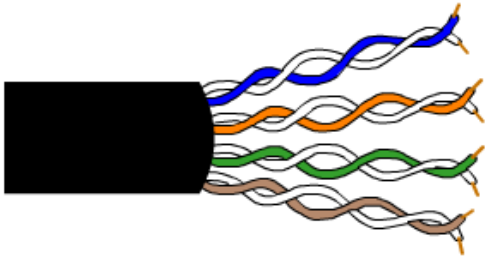
UTP Cabling Standards



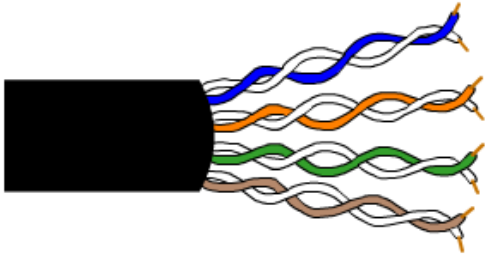
Category 3 Cable (UTP)



Category 7 Cable (ScTP)



Category 6 Cable (UTP)



Category 5 and 5e Cable (UTP)

Category 5 and 5e Cable (UTP)

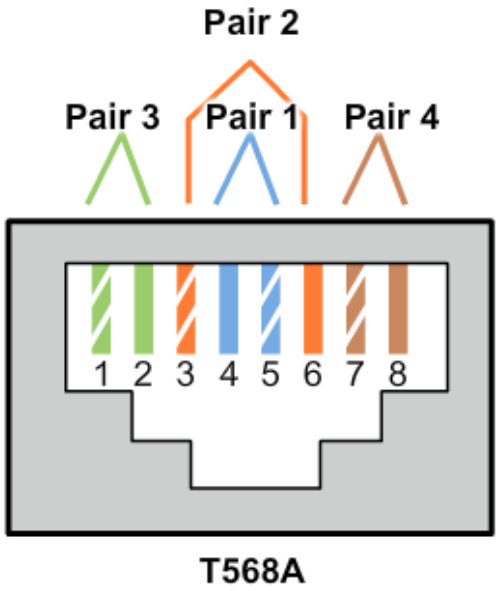
- Used for Data transmission
- Cat 5 supports 100 Mbps and can support 1000 Mbps but it is not recommended
- Cat 5e supports 1000 Mbps

UTP Connectors

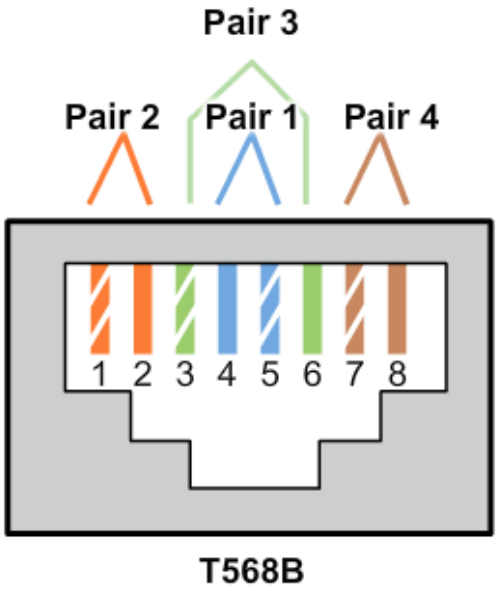
RJ-45 UTP Plugs

RJ-45 UTP Socket

Types of UTP Cable



T568A



T568B

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.

Testing UTP Cables

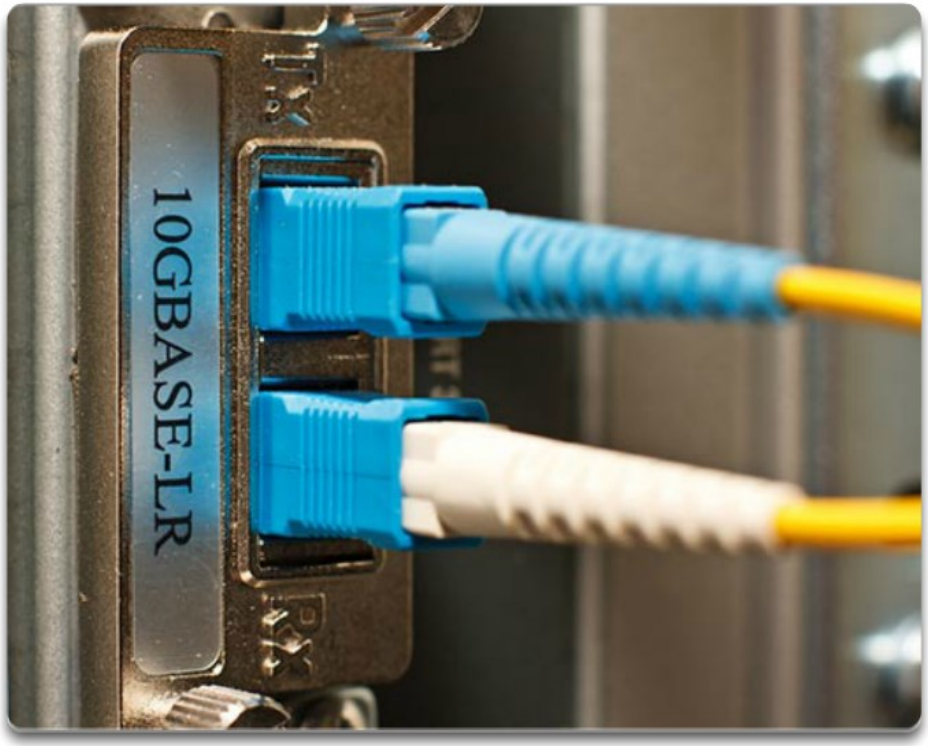
After installation, a UTP cable tester should be used to test for the following parameters:

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

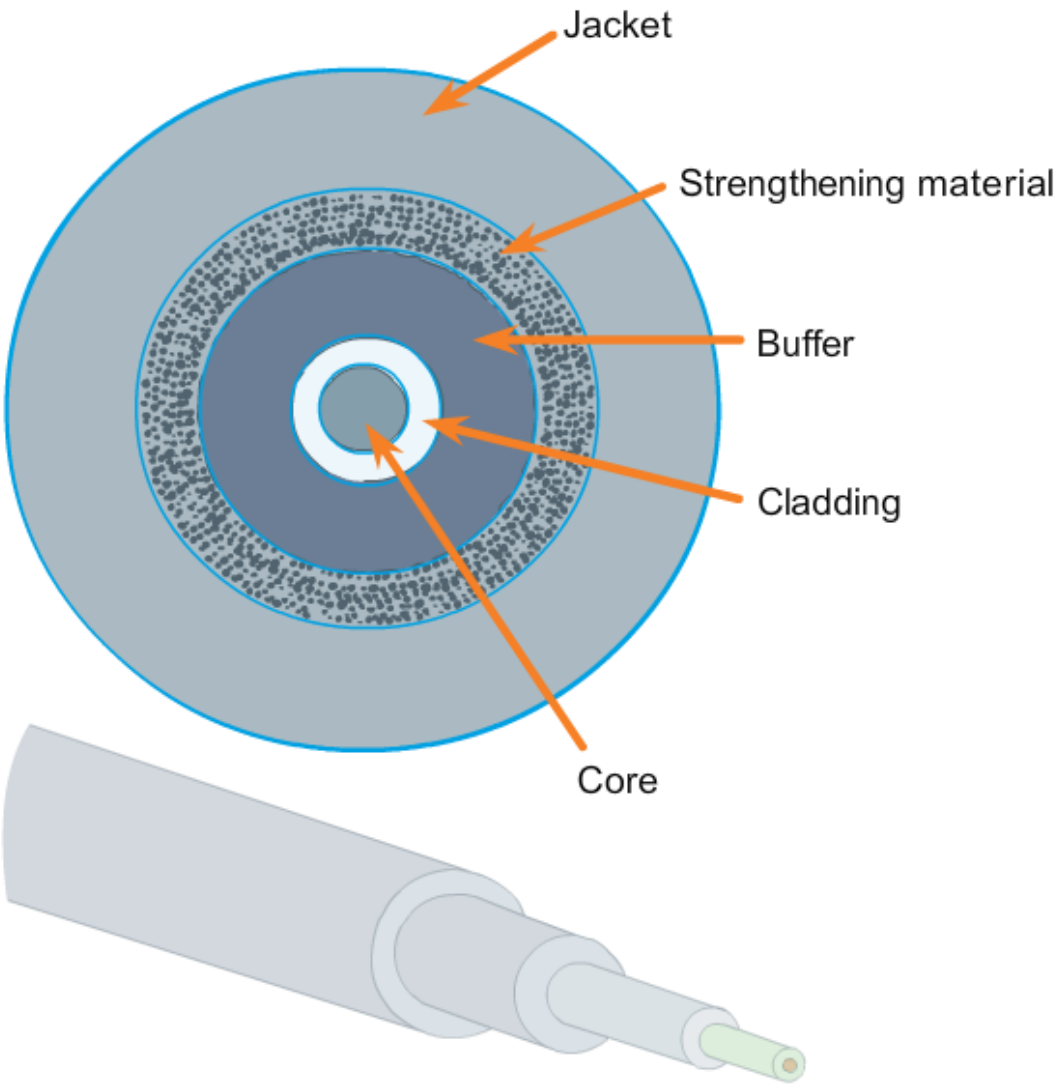
Properties of Fiber Optic Cabling

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

- Enterprise Networks
- Fiber-to-the-home (FTTH) and Access Networks
- Long-Haul Networks
- Submarine Networks

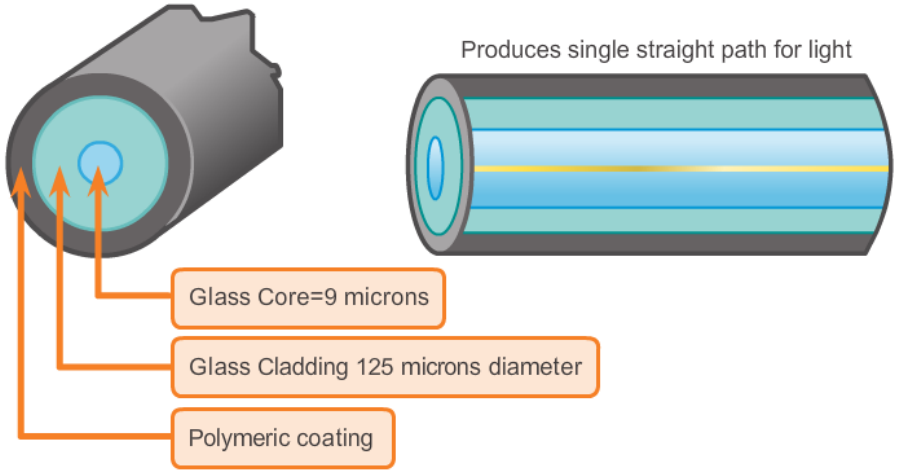


Fiber Media Cable Design



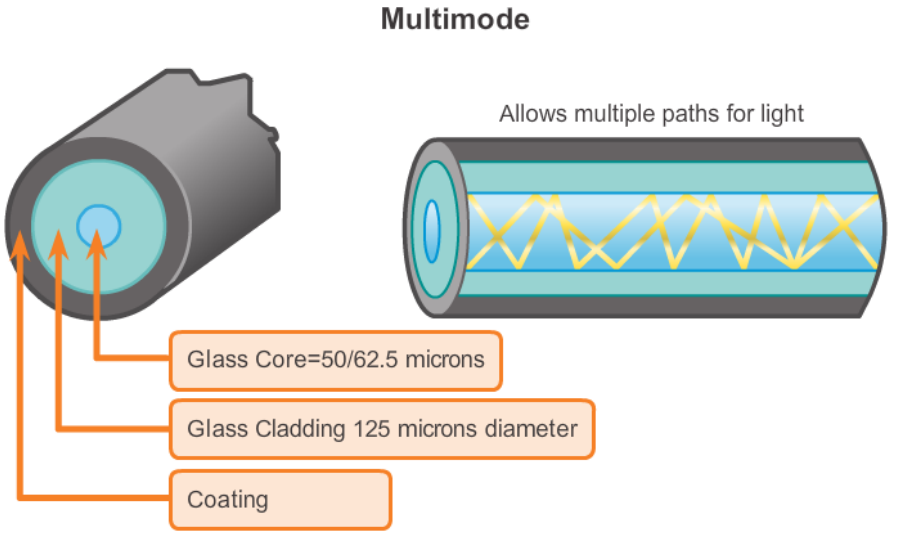
Types of Fiber Media

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

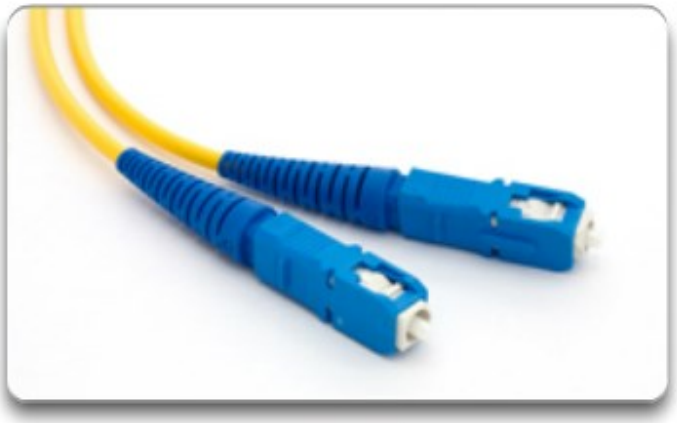
Multimode



- 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

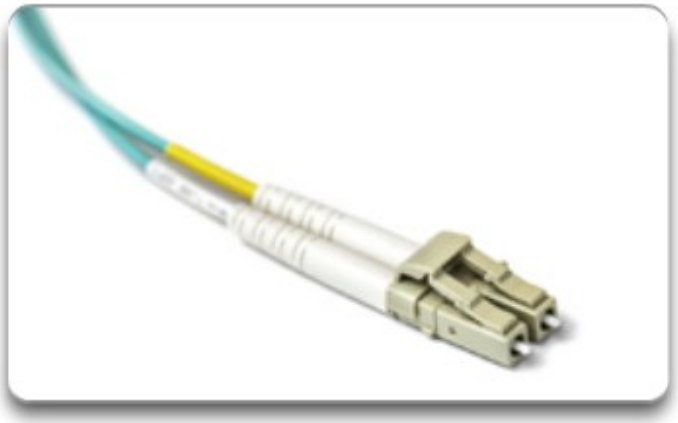
Network Fiber Connectors

ST Connectors



SC Connectors

LC Connector



Duplex Multimode LC Connectors

Testing Fiber Cables

Optical Time Domain Reflectometer (OTDR)

Fiber versus Copper

Implementation Issues	Copper Media	Fibre Optic
Bandwidth Supported	10 Mbps – 10 Gbps	10 Mbps – 100 Gbps
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

Properties of Wireless Media

Wireless does have some areas of concern including:

- Coverage area
- Interference
- Security

Types of Wireless Media

	• IEEE 802.11 standards
	• Commonly referred to as Wi-Fi.
	• Uses CSMA/CA
	• Variations include:
	  • 802.11a: 54 Mbps, 5 GHz
	  • 802.11b: 11 Mbps, 2.4 GHz
	  • 802.11g: 54 Mbps, 2.4 GHz
	  • 802.11n: 600 Mbps, 2.4 and 5 GHz
	  • 802.11ac: 1 Gbps, 5 GHz
	  • 802.11ad: 7 Gbps, 2.4 GHz, 5 GHz, and 60 GHz

	• IEEE 802.15 standard • Supports speeds up to 3 Mb/s • Provides device pairing over distances from 1 to 100 meters.
	• IEEE 802.16 standard • Provides speeds up to 1 Gbps • Uses a point-to-multipoint topology to provide wireless broadband access.

Wireless LAN

Cisco Linksys EA6500 802.11ac Wireless Router

802.11 Wi-Fi Standards

Standard	Maximum Speed	Frequency	Backwards Compatible
802.11a	54 Mbps	5 GHz	No
802.11b	11 Mbps	2.4 GHz	No
802.11g	54 Mbps	2.4 GHz	802.11b
802.11n	600 Mbps	2.4 GHz or 5 GHz	802.11b/g
802.11ac	1.3 Gbps (1300 Mbps)	2.4 GHz and 5.5 GHz	802.11b/g/n
802.11ad	7 Gbps (7000 Mbps)	2.4 GHz, 5 GHz and 60 GHz	802.11b/g/n/ac

4.3 Data Link Layer Protocols

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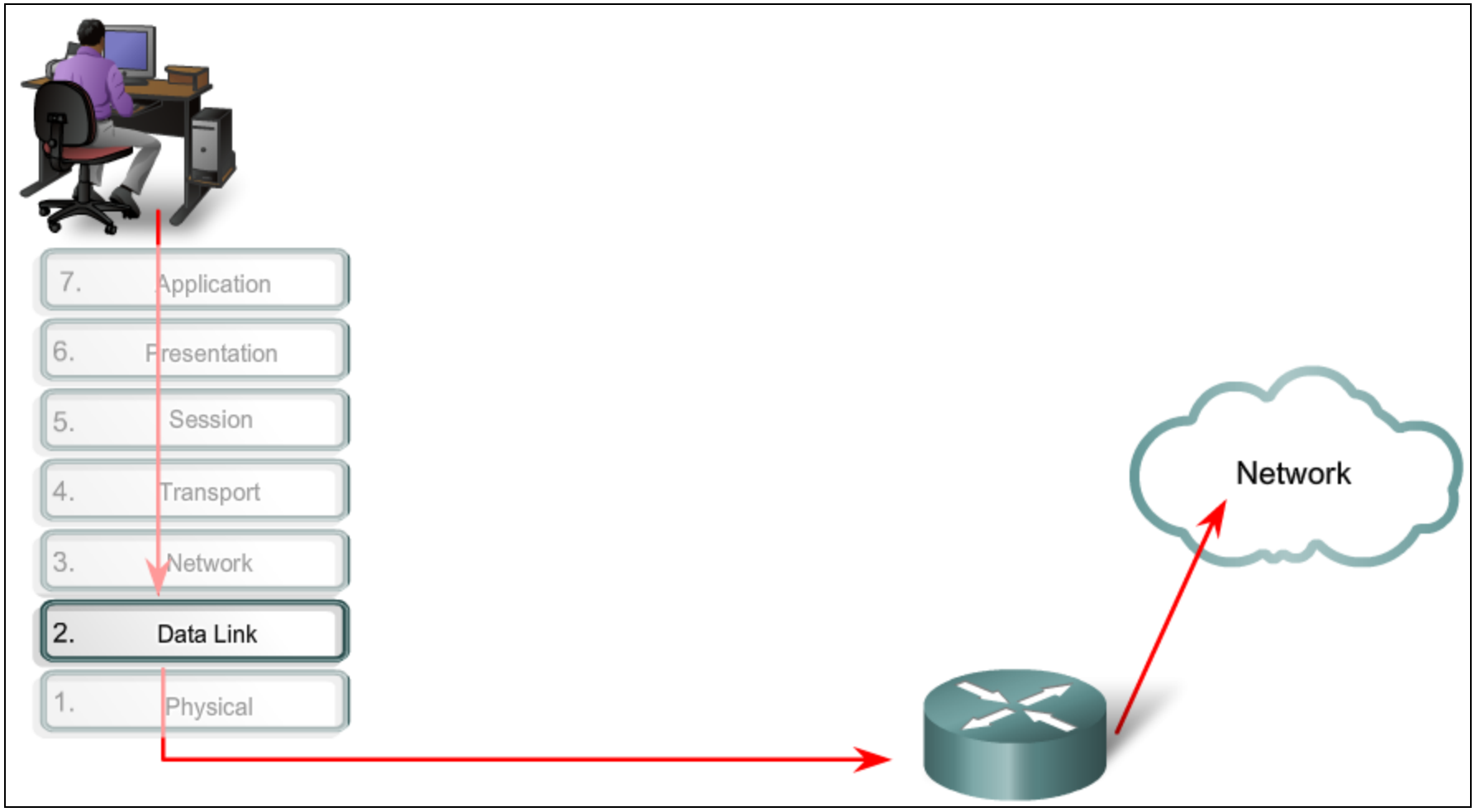
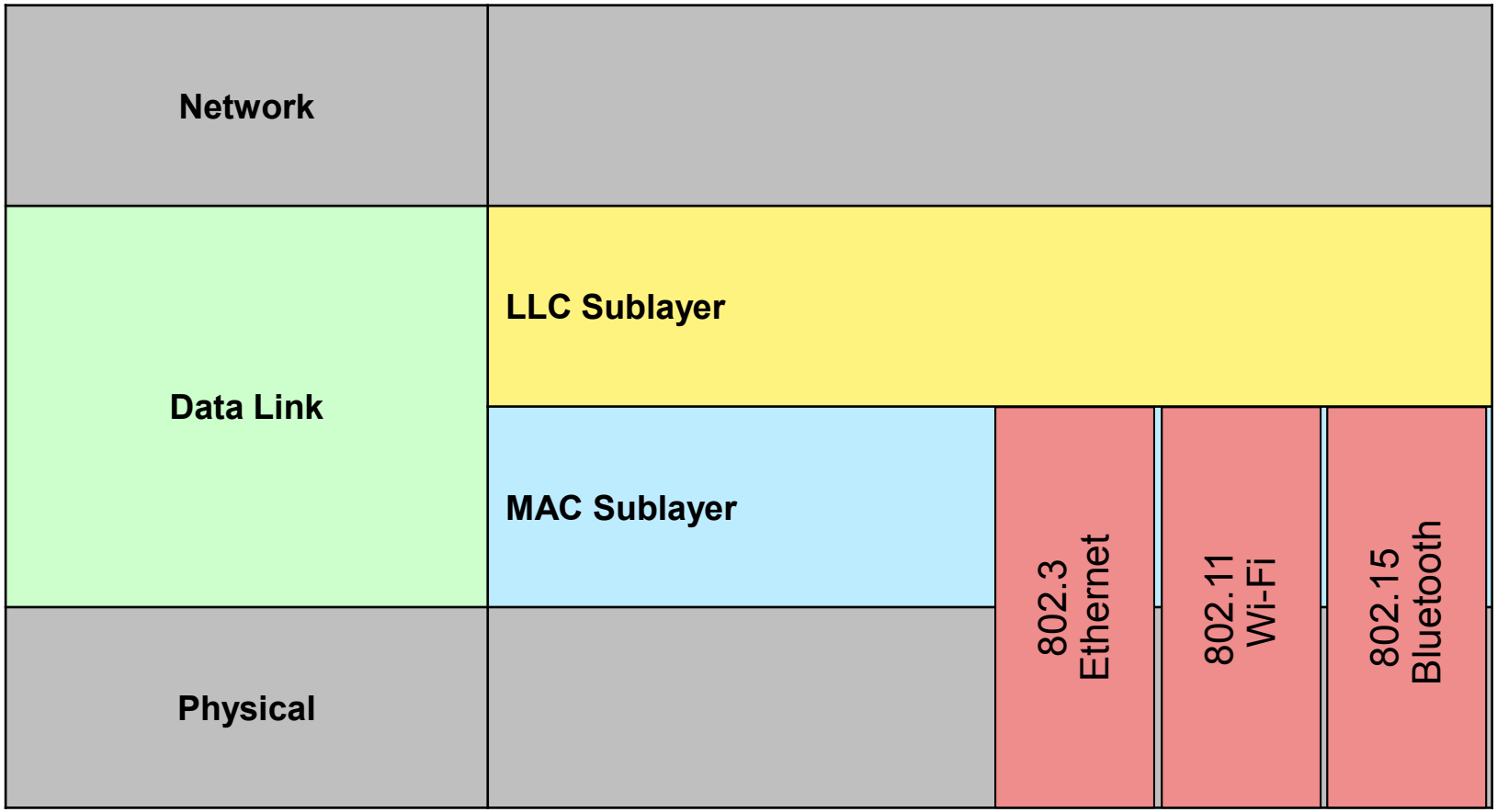
The Data Link Layer



Data Link Sublayers

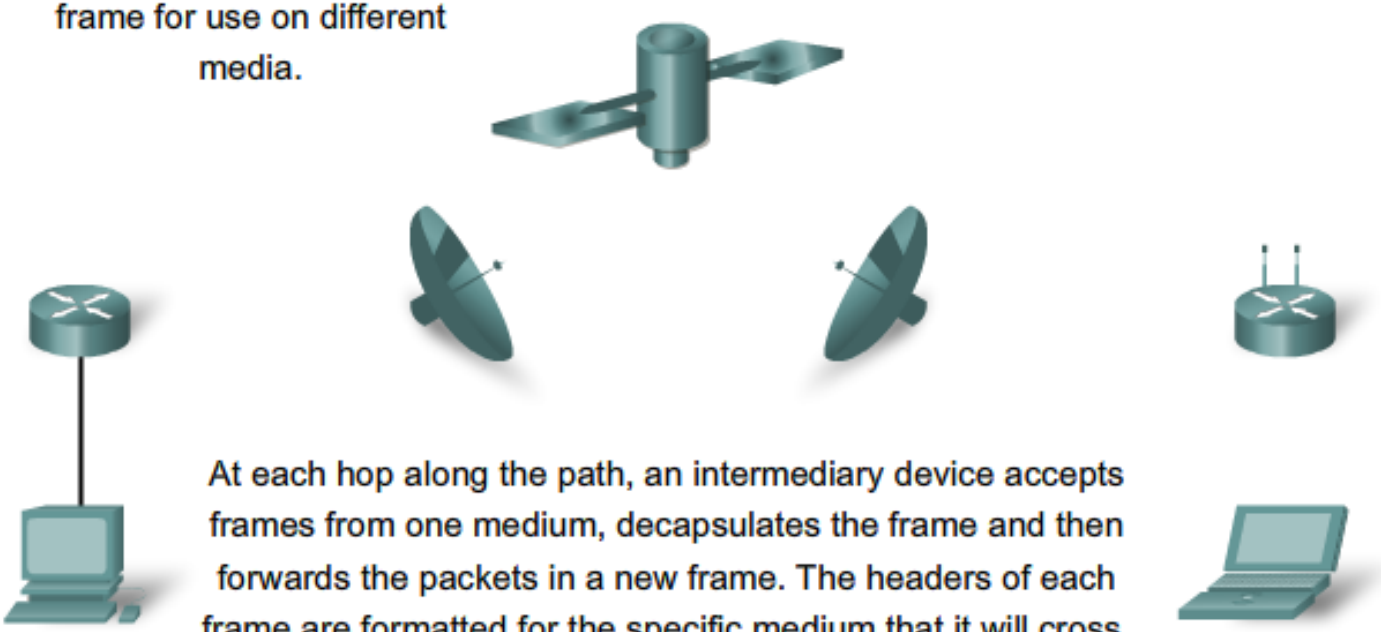


Media Access Control

The Data Link Layer

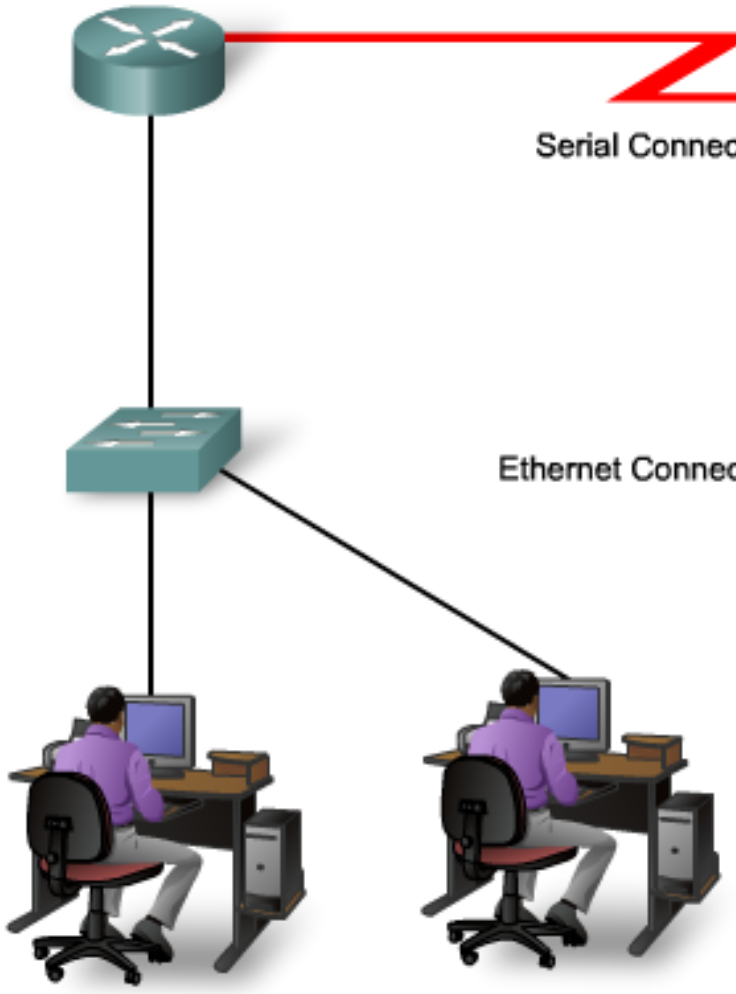
Data link layer protocols govern how to format a frame for use on different media.

Different protocols may be in use for different media.



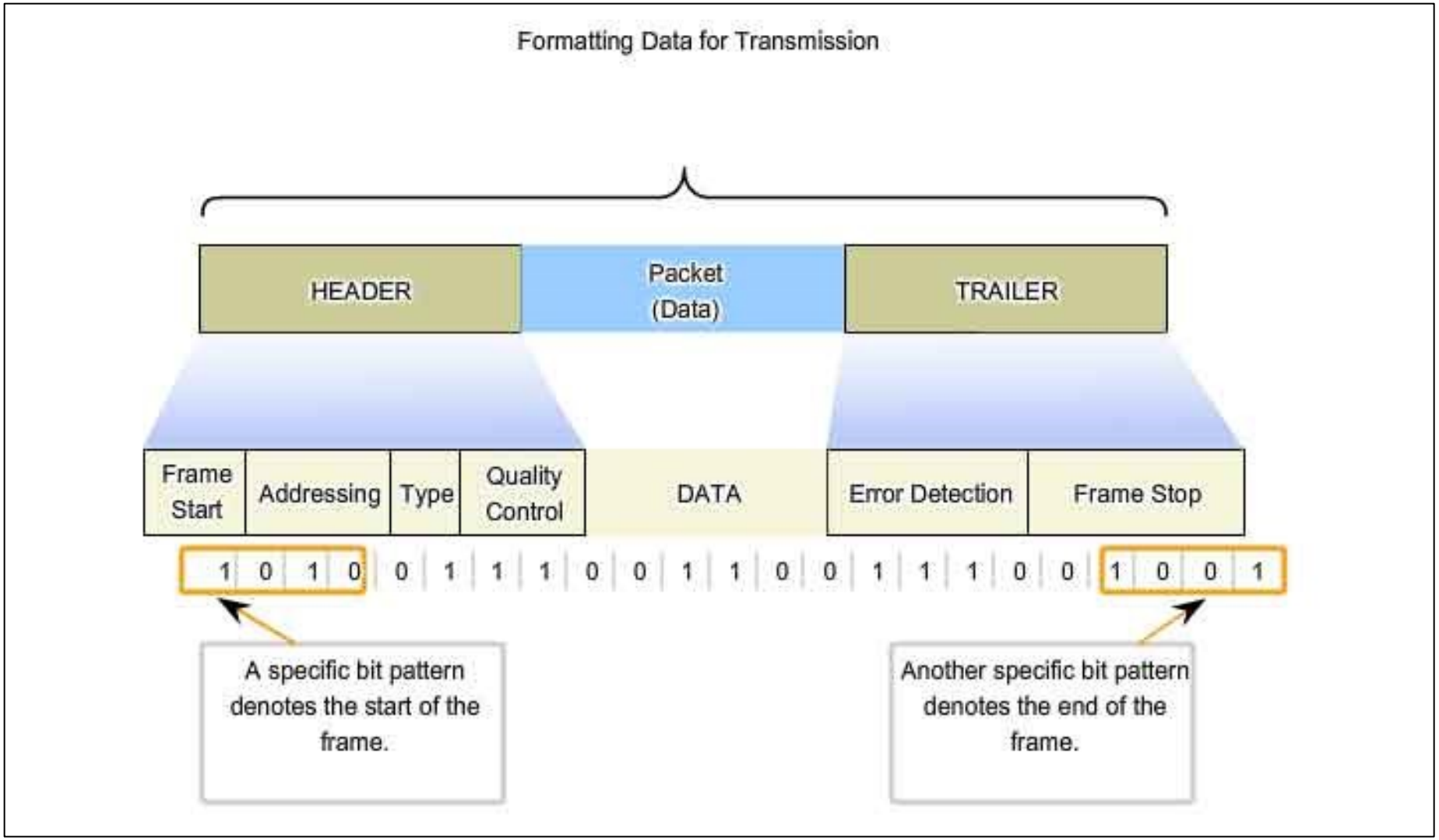
At each hop along the path, an intermediary device accepts frames from one medium, decapsulates the frame and then forwards the packets in a new frame. The headers of each frame are formatted for the specific medium that it will cross.

Providing Access to Media

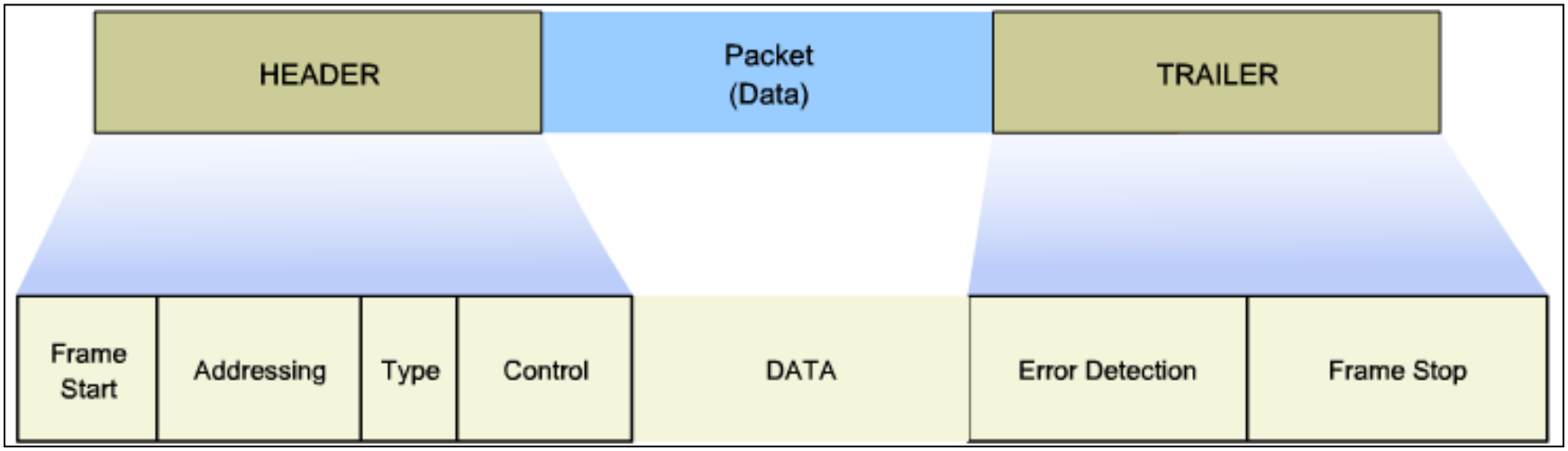


The Data Link layer is responsible for controlling the transfer of frames across the media.

Formatting Data for Transmission



Creating a Frame

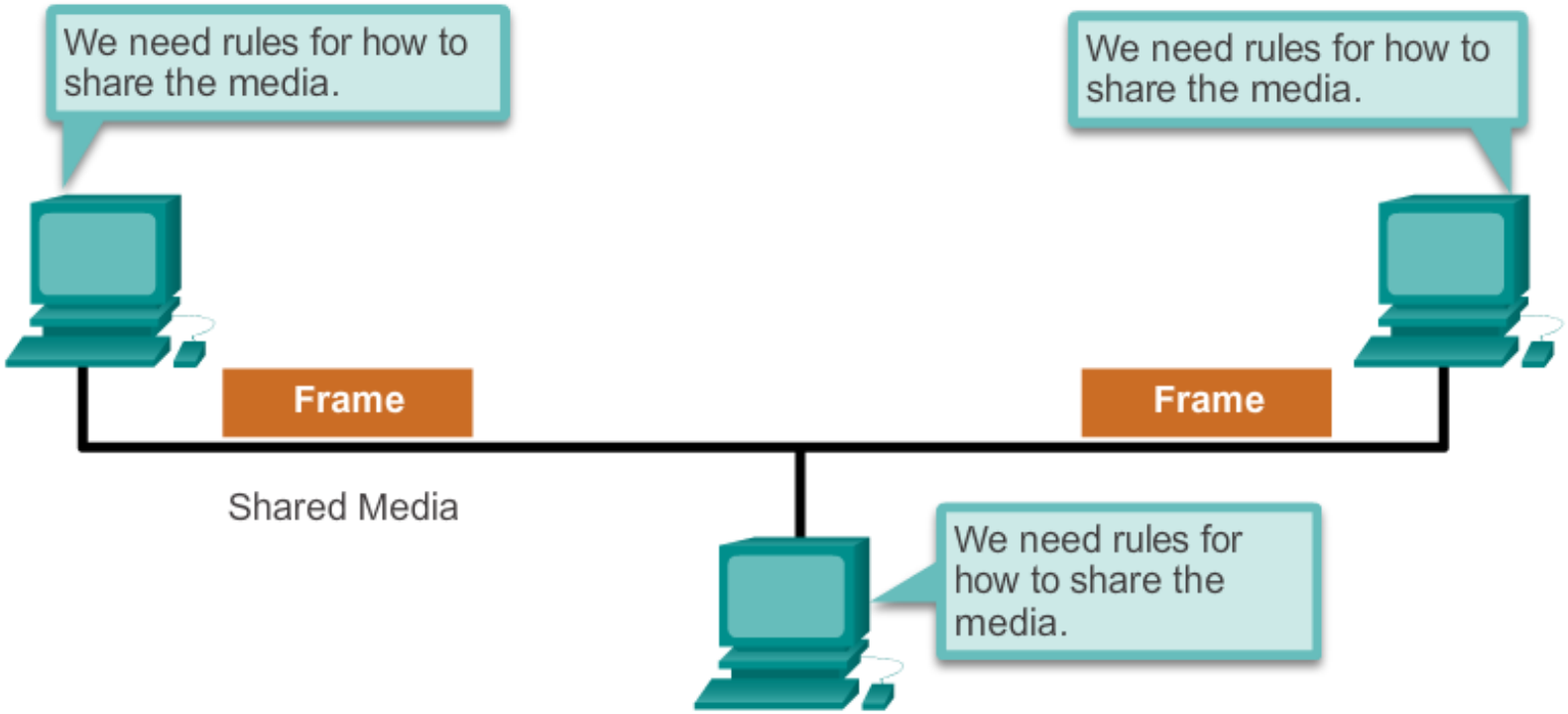


Data Link Layer Standards

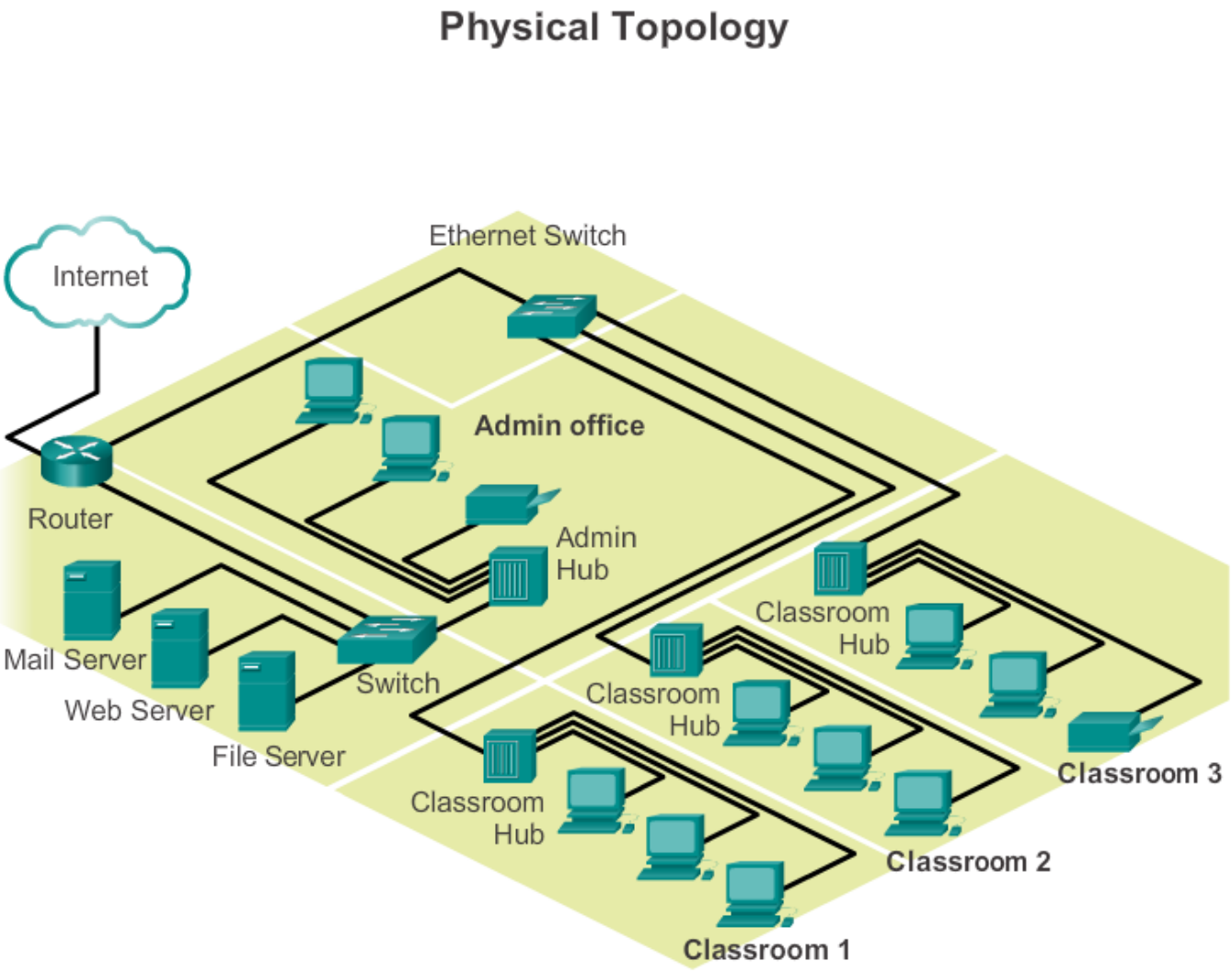
Standard organization	Networking Standards
IEEE	• 802.2: Logical Link Control (LLC) • 802.3: Ethernet • 802.4: Token bus • 802.5: Token passing • 802.11: Wireless LAN (WLAN) & Mesh (Wi-Fi certification) • 802.15: Bluetooth • 802.16: WiMax
ITU-T	• G.992: ADSL • G.8100 - G.8199: MPLS over Transport aspects • Q.921: ISDN • Q.922: Frame Relay
ISO	• HDLC (High Level Data Link Control) • ISO 9314: FDDI Media Access Control (MAC)
ANSI	• X3T9.5 and X3T12: Fiber Distributed Data Interface (FDDI)

Controlling Access to the Media

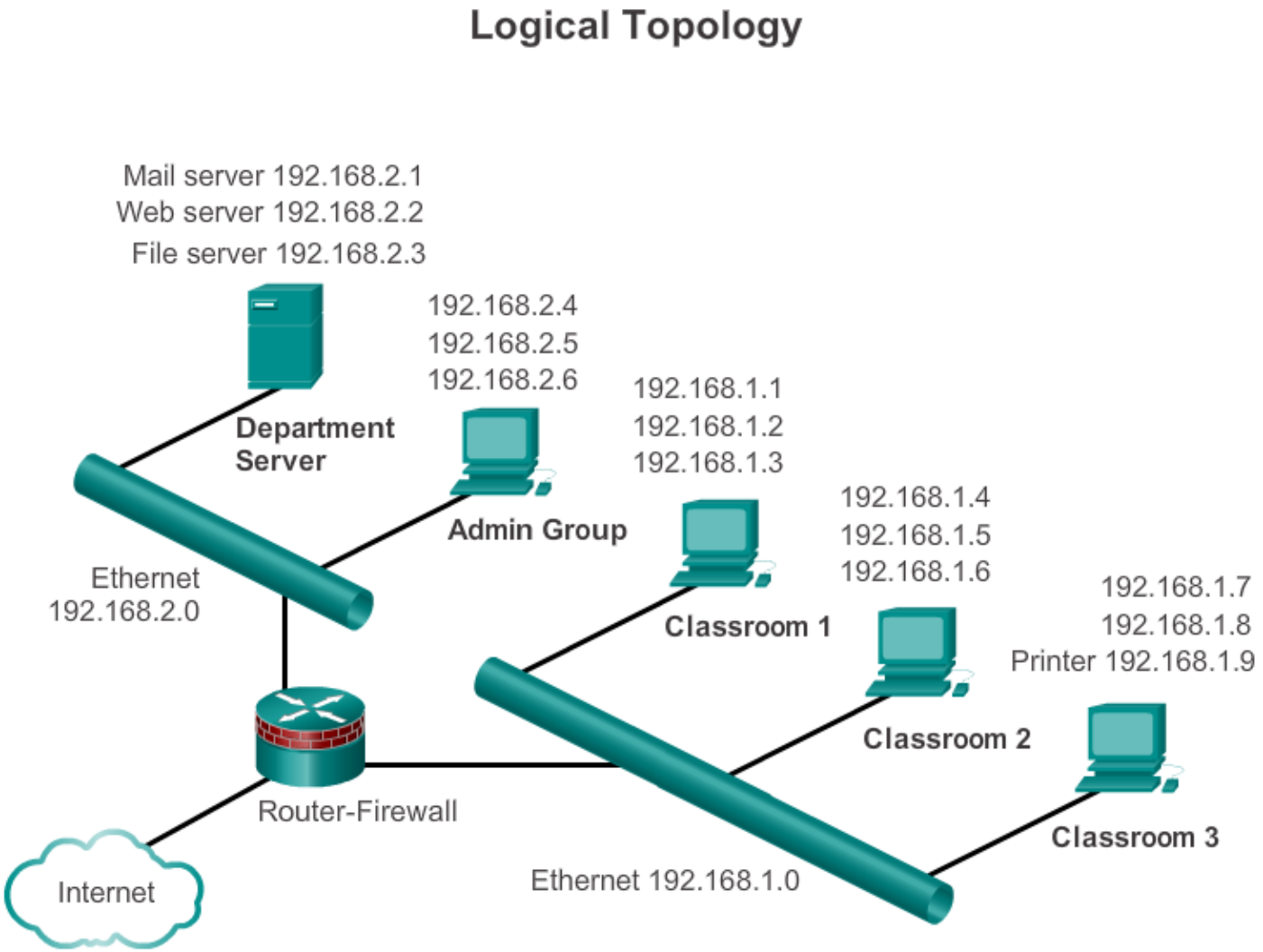
Sharing the Media



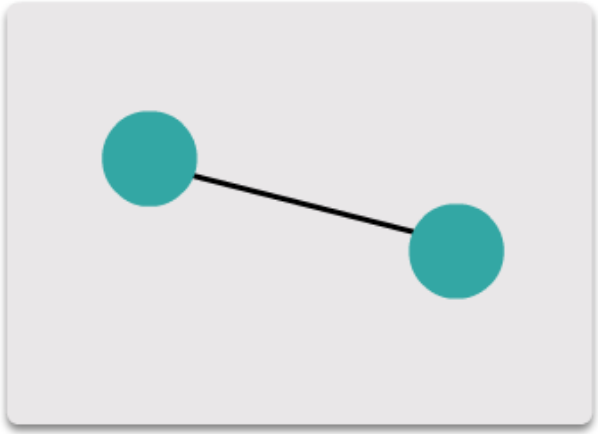
Physical and Logical Topologies



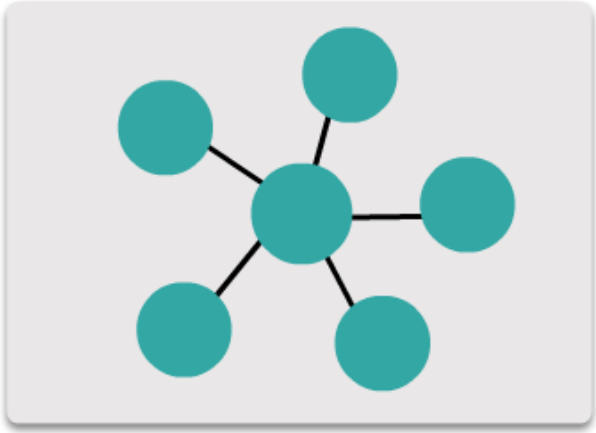
Physical and Logical Topologies (cont.)



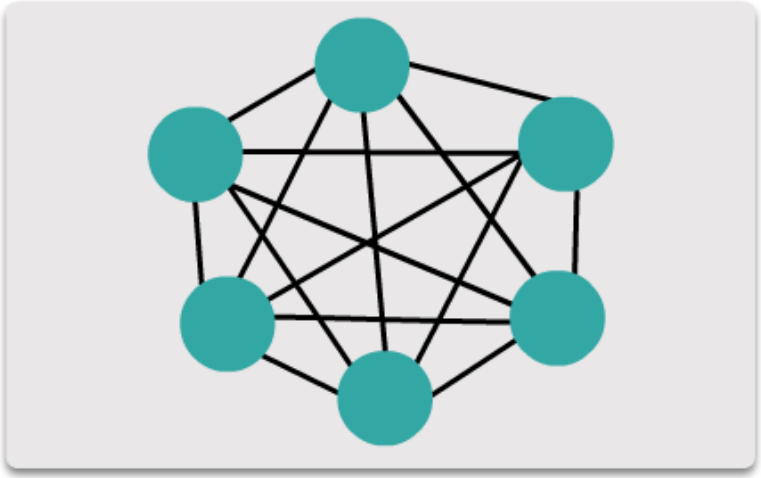
Common Physical WAN Topologies



Point-to-point topology

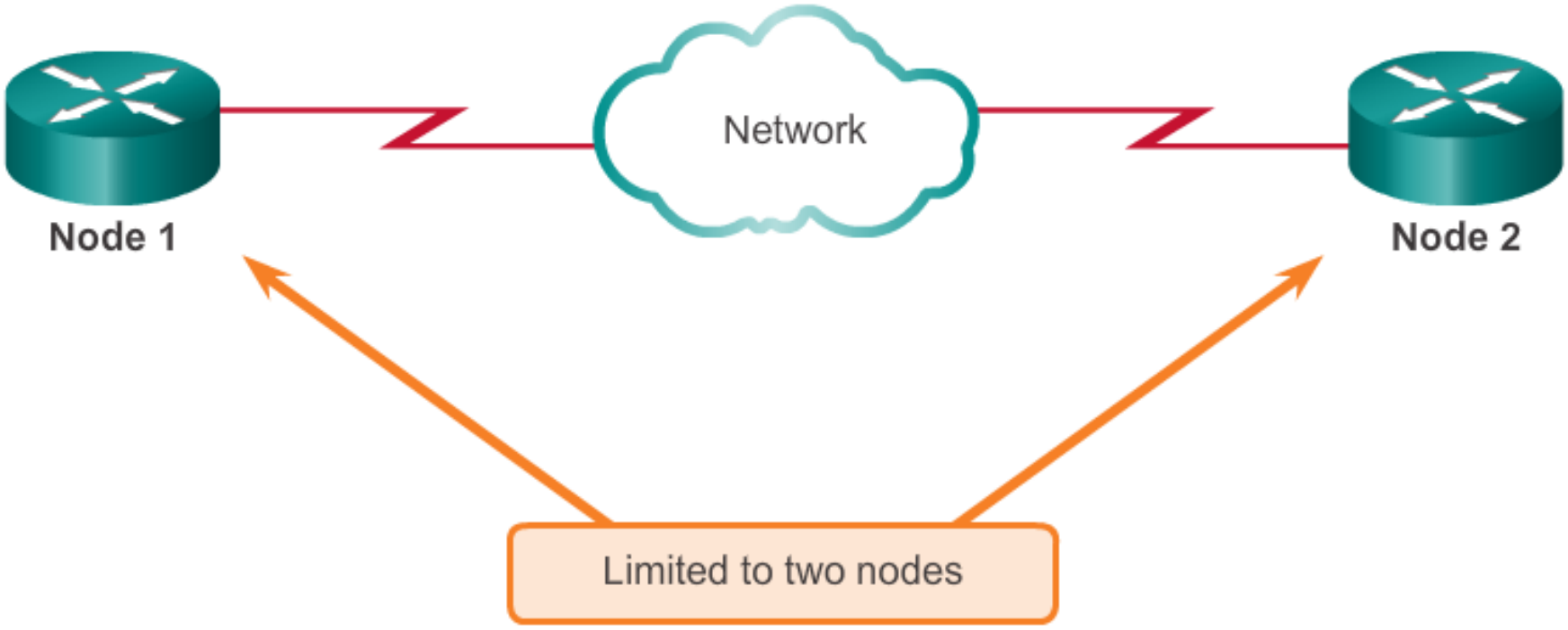


Hub and spoke topology

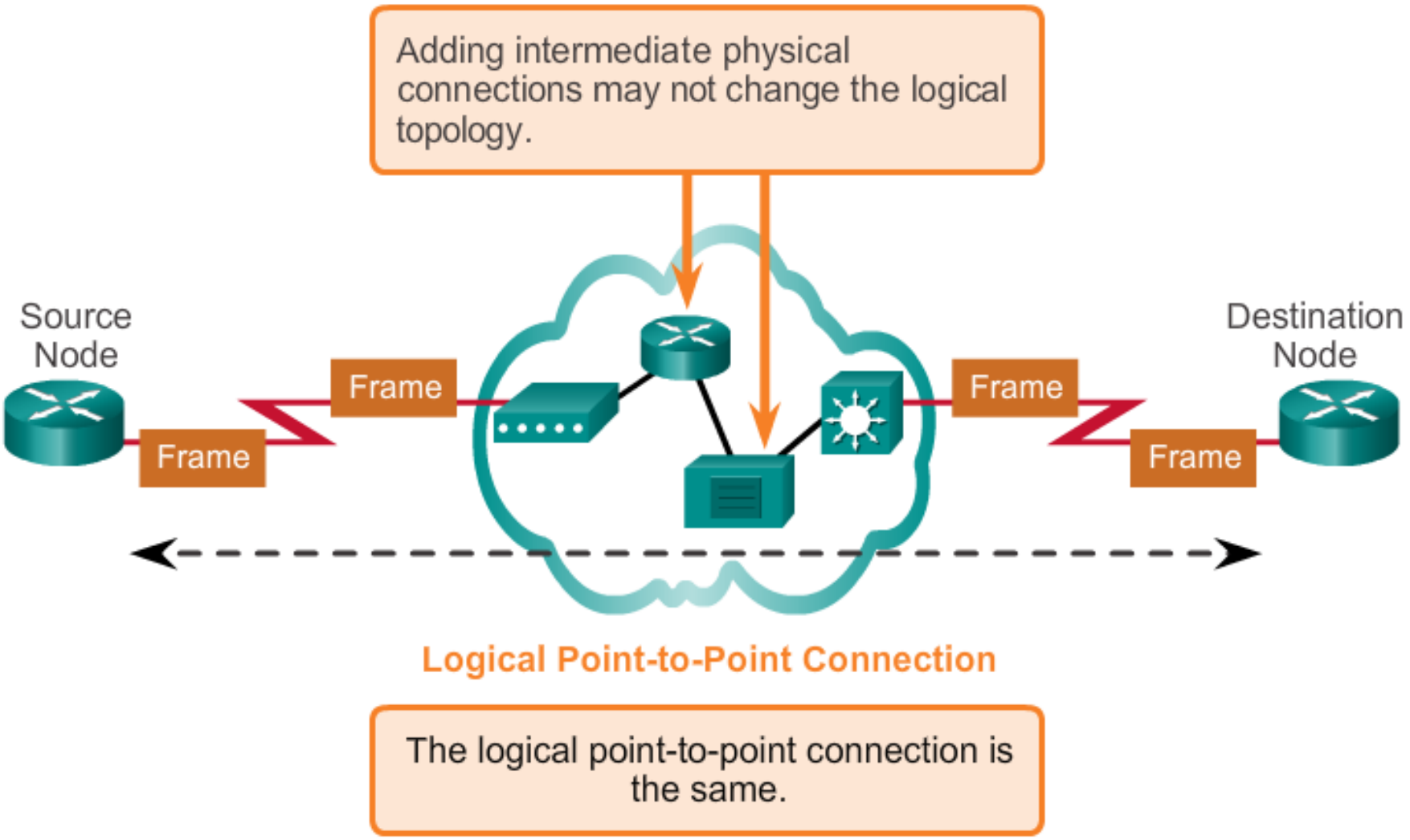


Full mesh topology

Physical Point-to-Point Topology

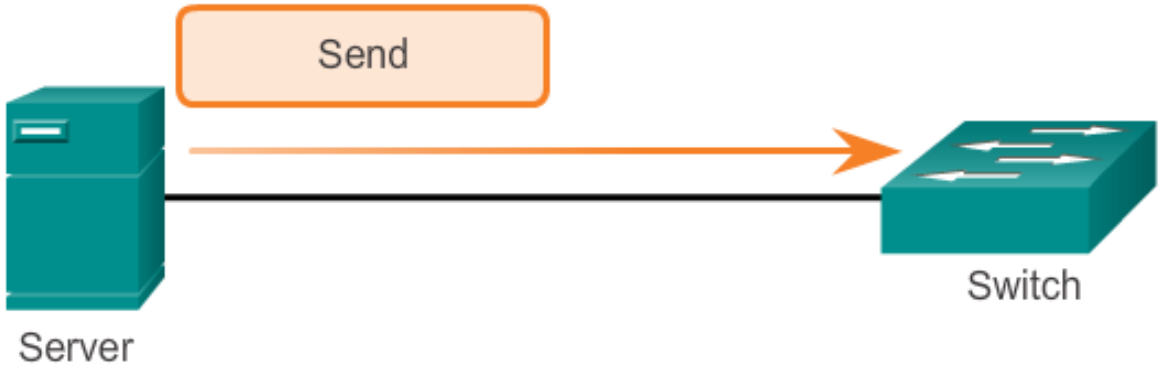


Logical Point-to-Point Topology

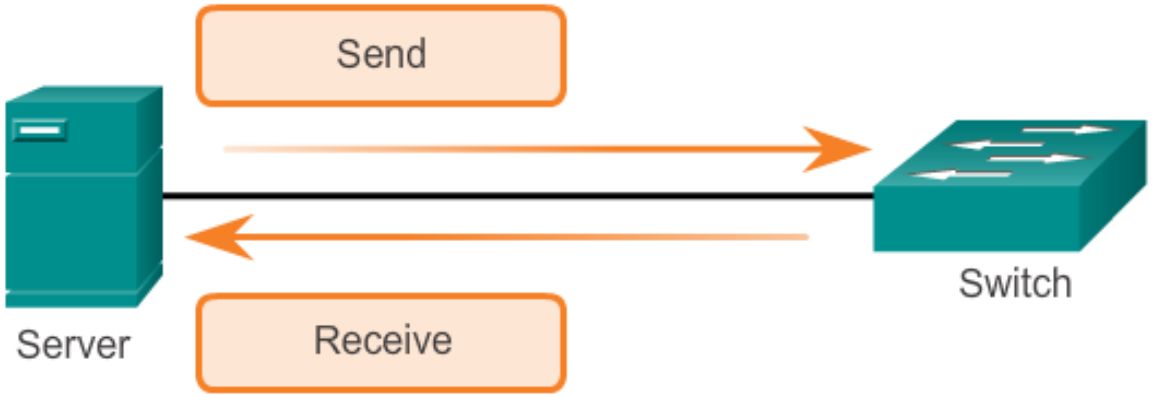


Half- and Full-Duplex

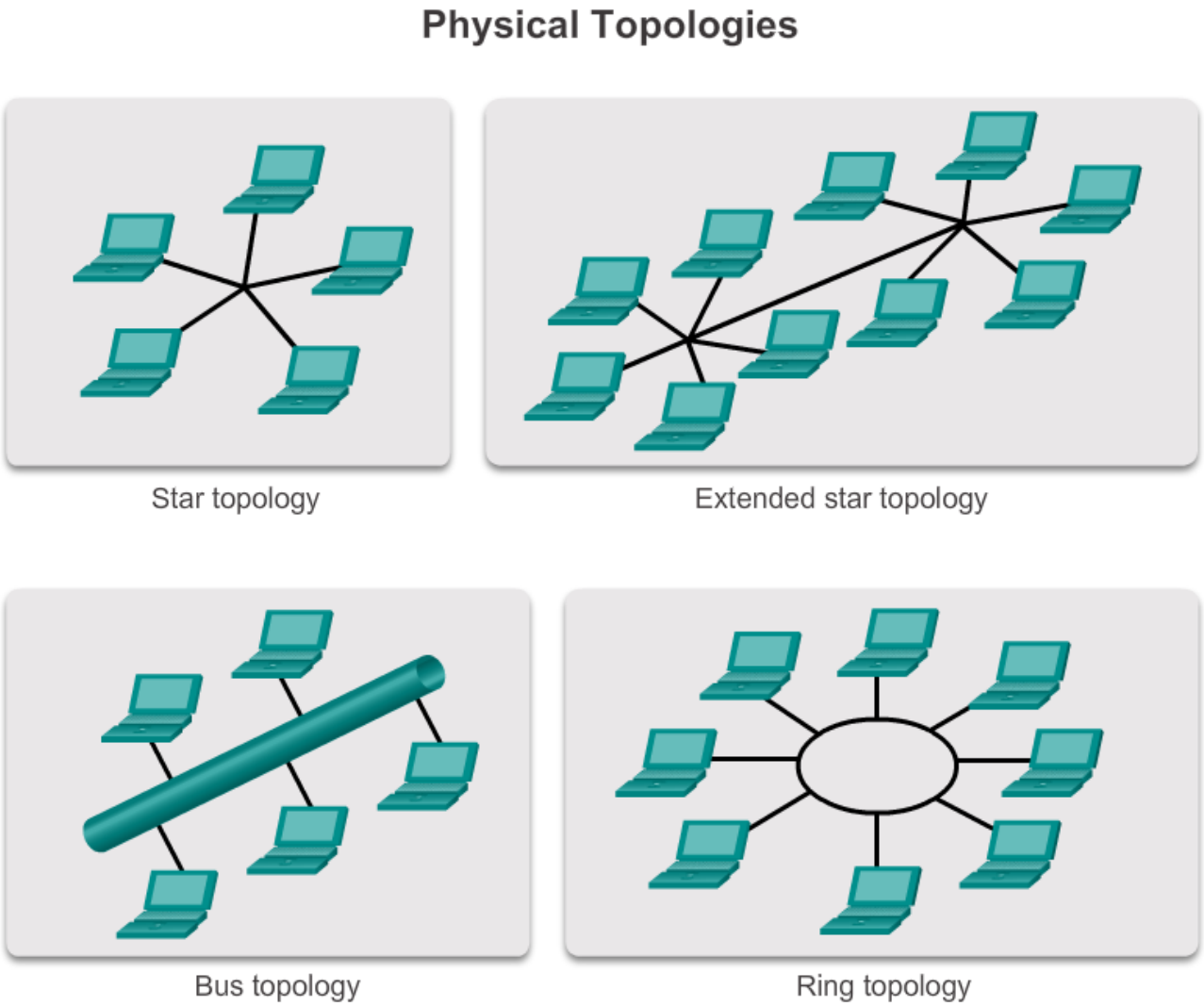
Half-Duplex



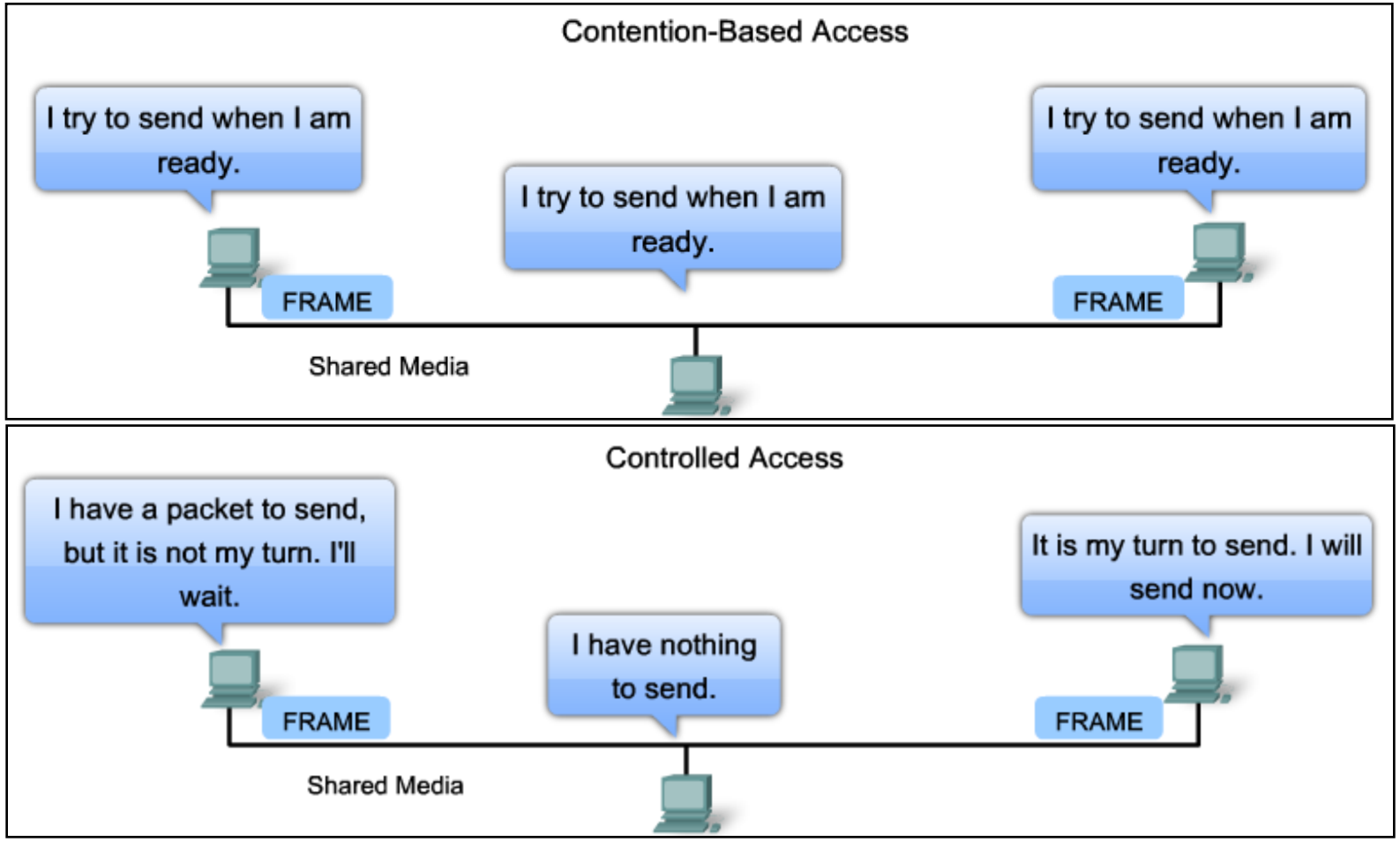
Full-Duplex



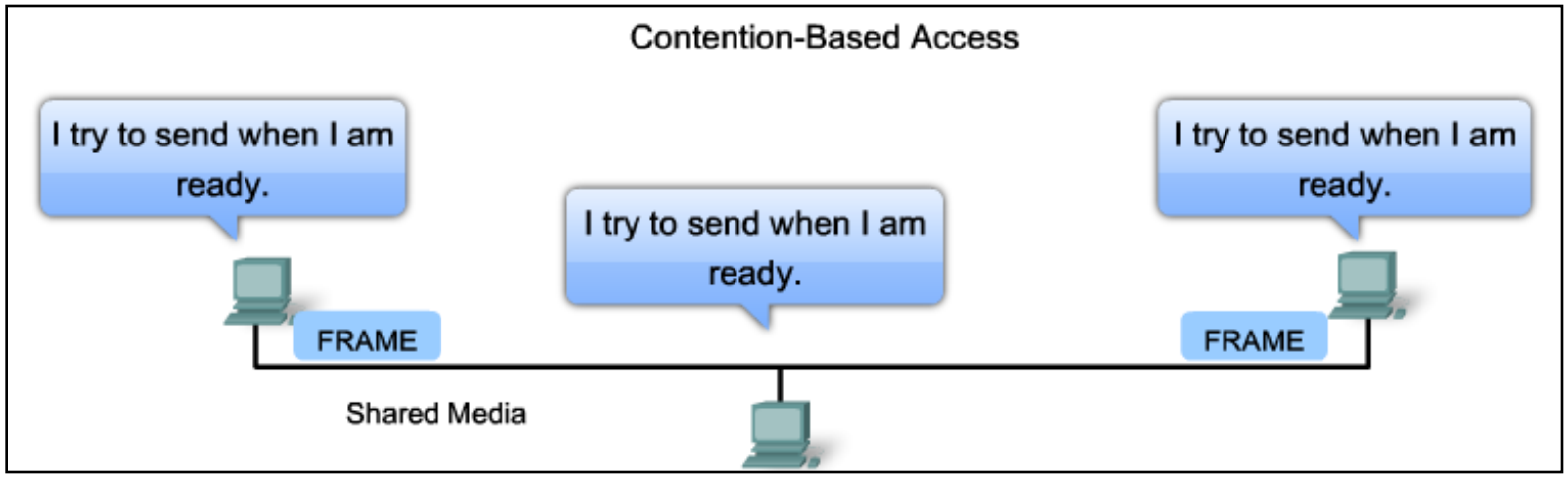
Physical LAN Topologies



Logical Topology for Shared Media



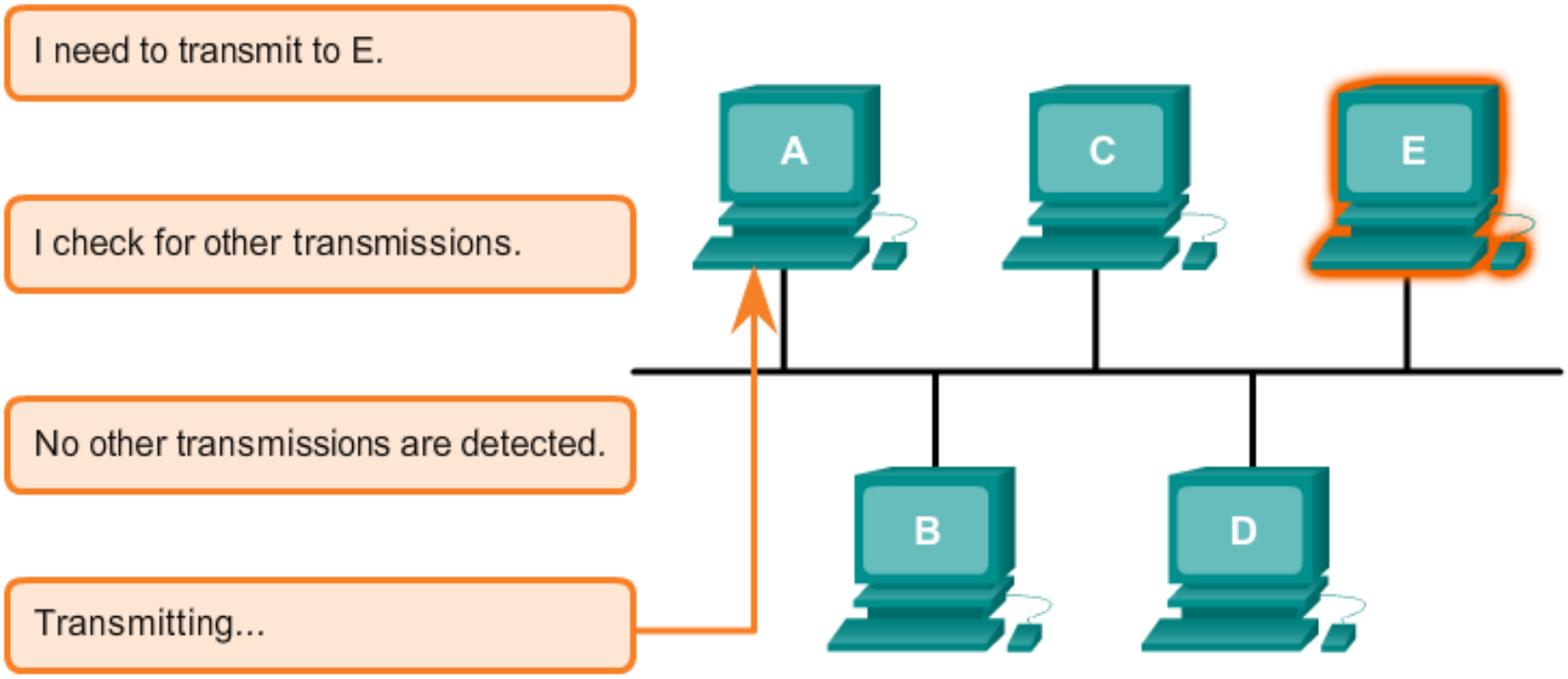
Contention-Based Access



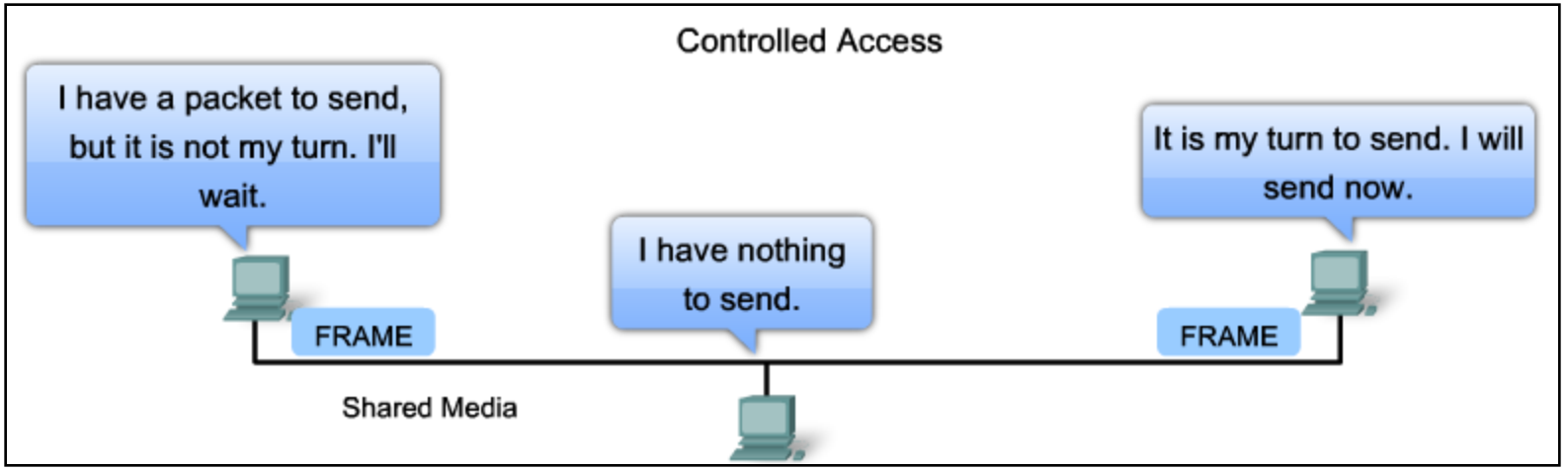
Characteristics	Contention-Based Technologies
• Stations can transmit at any time • Collision exist • There are mechanisms to resolve contention for the media	• CSMA/CD for 802.3 Ethernet networks • CSMA/CA for 802.11 wireless networks

Multi-Access Topology

Logical Multi-Access Topology

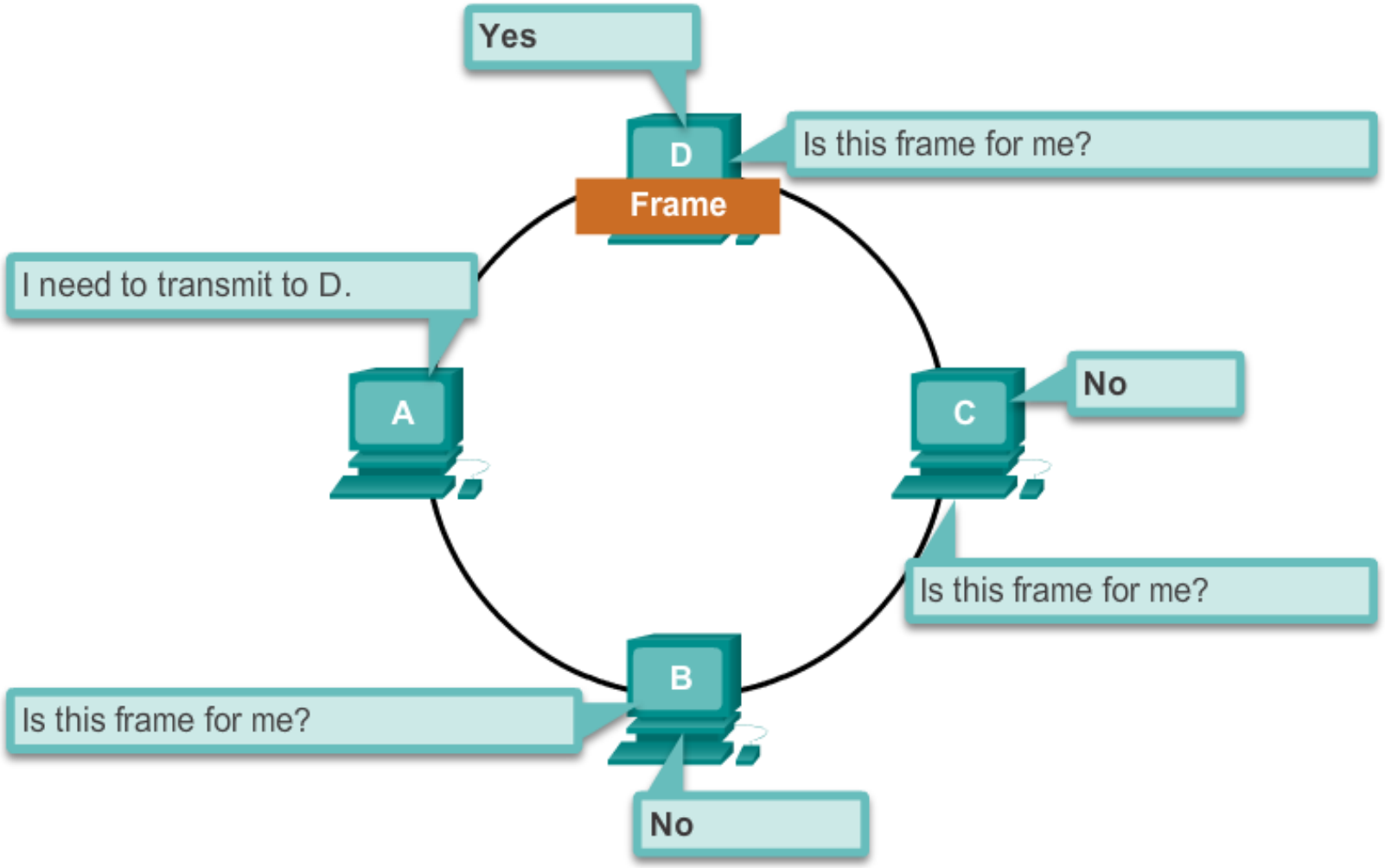


Controlled Access



Characteristics	Controlled Access Technologies
• Only one station can transmit at a time • Devices wanting to transmit must wait their turn • No collisions • May use a token passing method	• Token Ring (IEEE 802.5) • FDDI

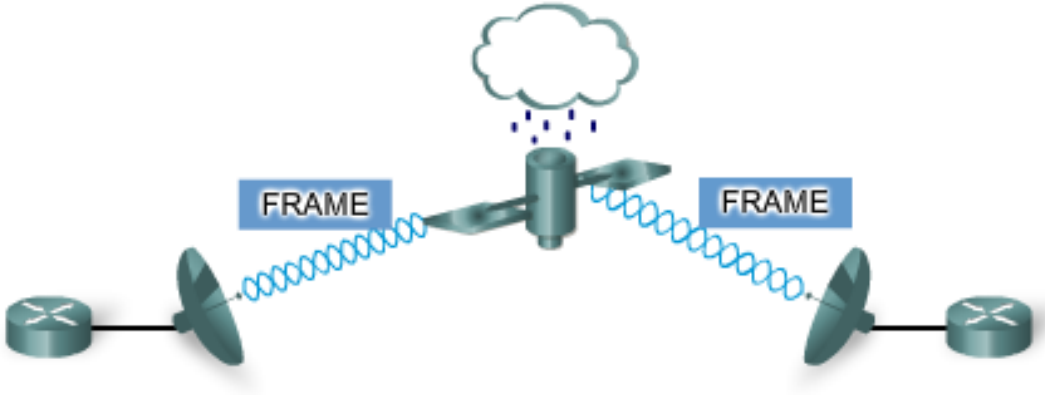
Ring Topology



The Frame

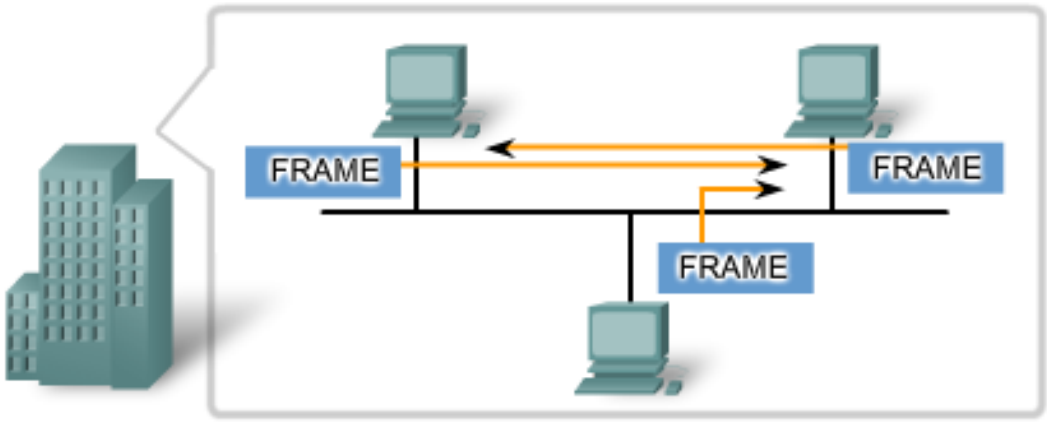
In a fragile environment, more controls are needed to ensure delivery. The header and trailer fields are larger as more control information is needed.

Greater effort needed to ensure delivery = higher overhead = slower transmission rates



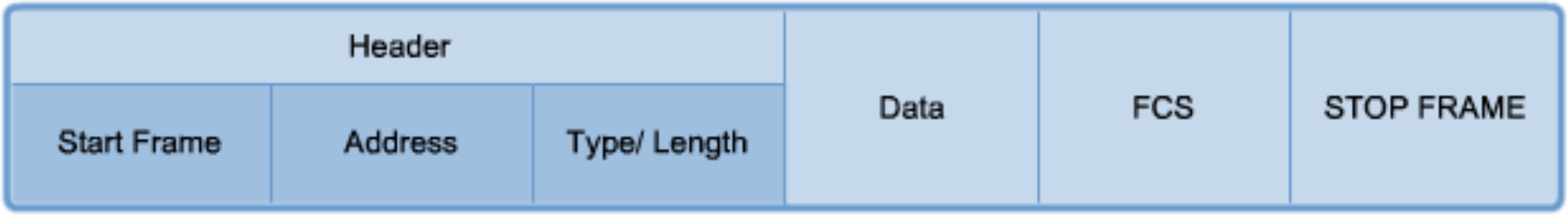
In a protected environment, we can count on the frame arriving at its destination. Fewer controls are needed, resulting in smaller fields and smaller frames.

Less effort needed to ensure delivery = lower overhead = faster transmission rates

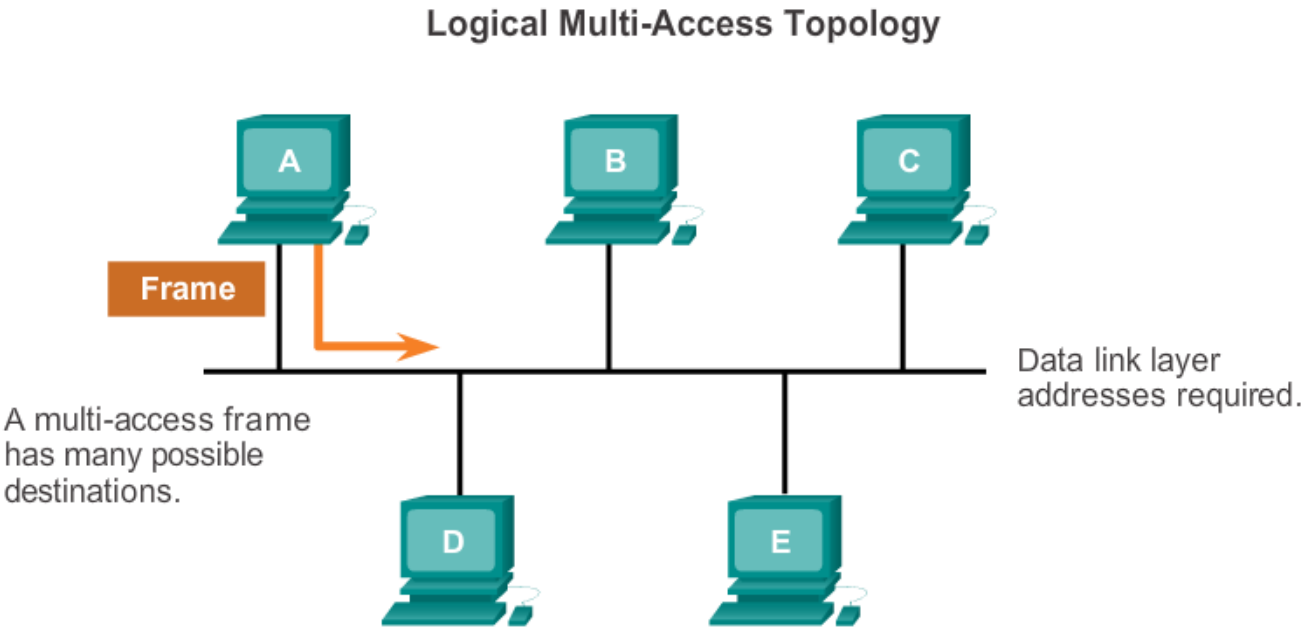


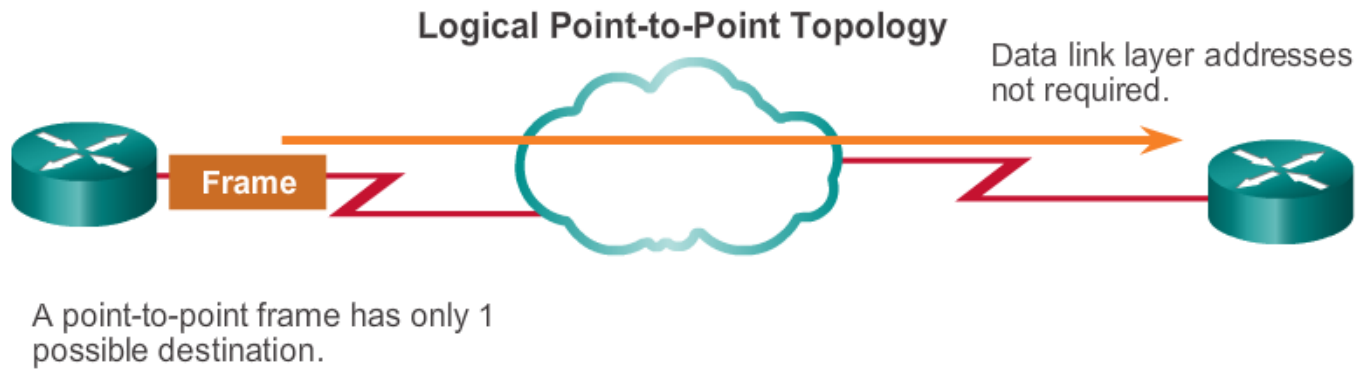
Data Link Frame

The Header



Layer 2 Address





Data Link Frame

The Trailer

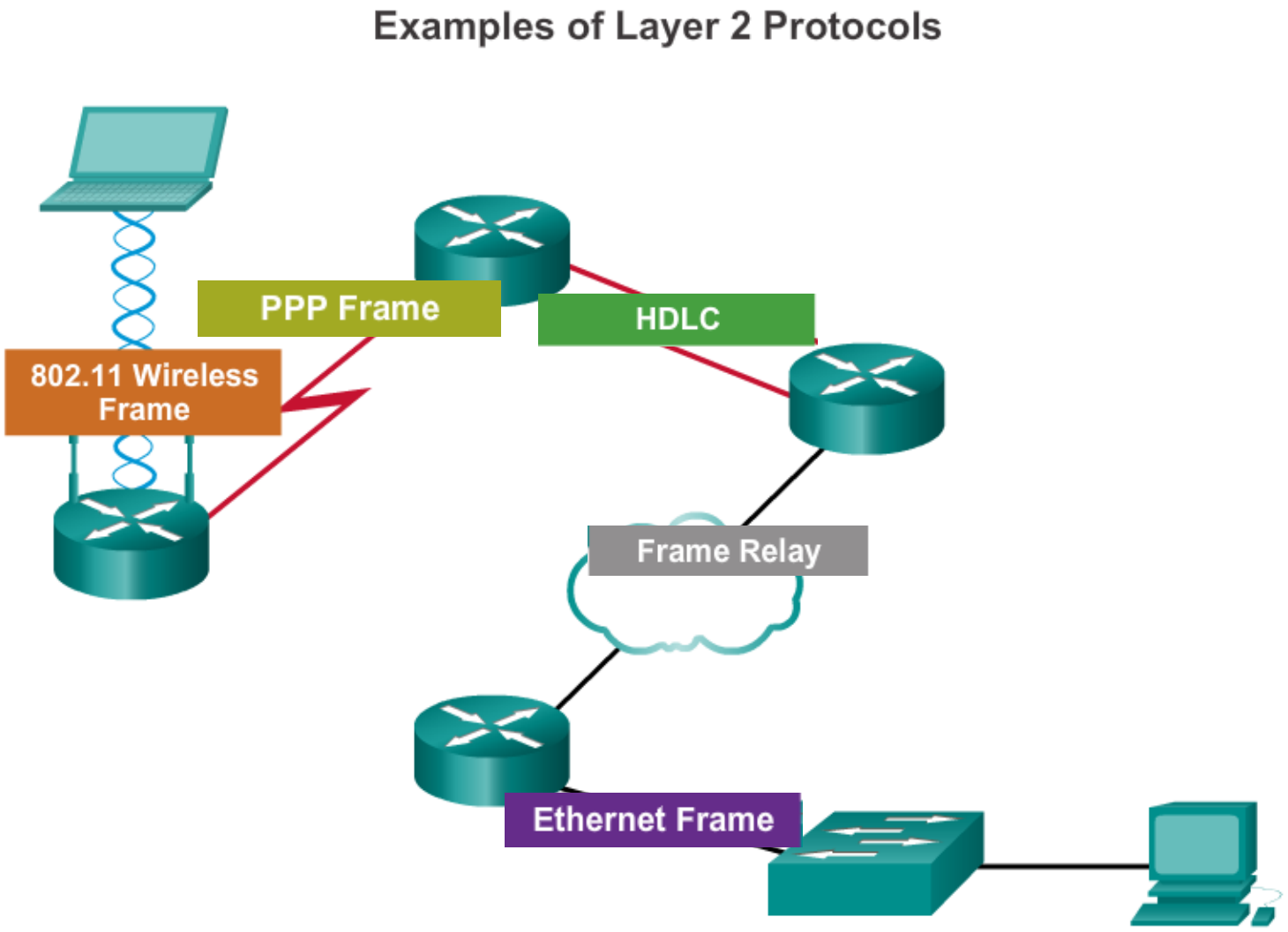
Frame Check Sequence

This field is used for error checking. The source calculates a number based on the frame's data and places that number in the FCS field. The destination then recalculates the data to see if the FCS matches. If they don't match, the destination deletes the frame.

Stop Frame

This field, also called the Frame Trailer, is an optional field that is used when the length of the frame is not specified in the Type/Length field. It indicates the end of the frame when transmitted.

LAN and WAN Frames



Ethernet Frame

Ethernet Protocol

A Common Data Link Layer Protocol for LANs

	Frame					
Field name	Preamble	Destination	Source	Type	Data	Frame Check Sequence
Size	8 bytes	6 bytes	6 bytes	2 bytes	46 - 1500 bytes	4 bytes

Preamble - Used for synchronization; also contains a delimiter to mark the end of the timing information
Destination Address - 48-bit MAC address for the destination node
Source Address - 48-bit MAC address for the source node
Type - Value to indicate which upper layer protocol will receive the data after the Ethernet process is complete
Data or payload - This is the PDU, typically an IPv4 packet, that is to be transported over the media.
Frame Check Sequence (FCS) - A value used to check for damaged frames

Point-to-Point Protocol Frame

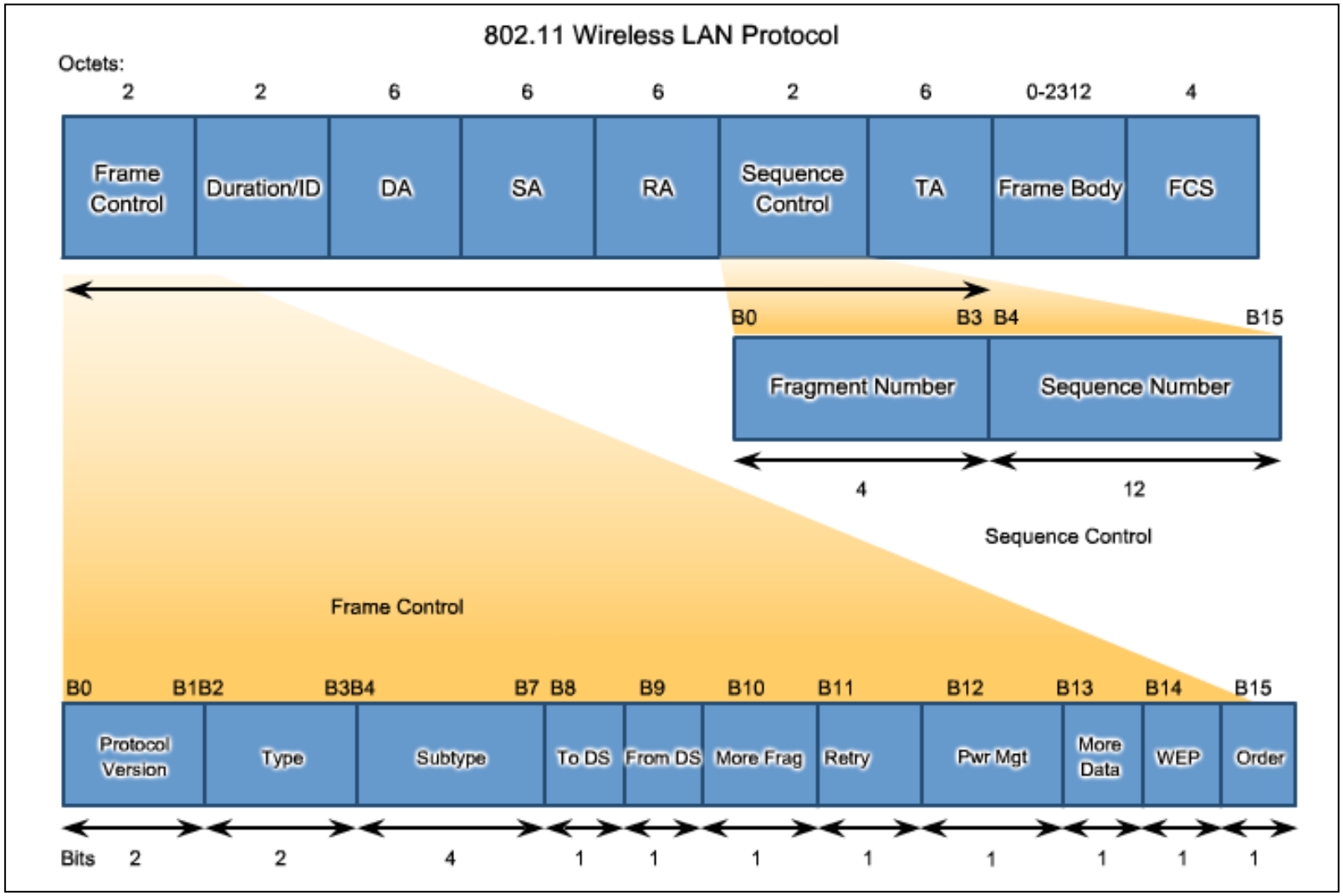
Point-to-Point Protocol

A Common Data Link Protocol for WANs

	Frame					
Field name	Flag	Address	Control	Protocol	Data	FCS
Size	1 byte	1 byte	1 byte	2 bytes	variable	2 or 4 bytes

Flag - A single byte that indicates the beginning or end of a frame. The flag field consists of the binary sequence 01111110.
Address - A single byte that contains the standard PPP broadcast address. PPP does not assign individual station addresses.
Control - A single byte that contains the binary sequence 00000011, which calls for transmission of user data in an unsequenced frame.
Protocol - Two bytes that identify the protocol encapsulated in the data field of the frame. The most up-to-date values of the protocol field are specified in the most recent Assigned Numbers Request For Comments (RFC).
Data - Zero or more bytes that contain the datagram for the protocol specified in the protocol field.
Frame Check Sequence (**FCS**) - Normally 16 bits (2 bytes). By prior agreement, consenting PPP implementations can use a 32-bit (4-byte) FCS for improved error detection.

802.11 Wireless Frame



Summary

- The TCP/IP network access layer is the equivalent of the OSI data link layer (Layer 2) and the physical layer (Layer 1).
- The OSI physical layer provides the means to transport the bits that make up a data link layer frame across the network media.
- The physical layer standards address three functional areas: physical components, frame encoding technique, and signaling method.
- Using the proper media is an important part of network communications. Without the proper physical connection, either wired or wireless, communications between any two devices will not occur.
- Wired communication consists of copper media and fiber cable.
- There are three main types of copper media used in networking: unshielded-twisted pair (UTP), shielded-twisted pair (STP), and coaxial cable. UTP cabling is the most common copper networking media.

Summary (cont.)

- Optical fiber cable has become very popular for interconnecting infrastructure network devices. It permits the transmission of data over longer distances and at higher bandwidths (data rates) than any other networking media.
- Wireless media carry electromagnetic signals that represent the binary digits of data communications using radio or microwave frequencies.
- The data link layer is responsible for the exchange of frames between nodes over a physical network media. It allows the upper layers to access the media and controls how data is placed and received on the media.
- Among the different implementations of the data link layer protocols, there are different methods of controlling access to the media. These media access control techniques define if and how the nodes share the media.
- The actual media access control method used depends on the topology and media sharing. LAN and WAN topologies can be physical or logical.

Summary (cont.)

- WANs are commonly interconnected using the point-to-point, hub and spoke, or mesh physical topologies.
- In shared media LANs, end devices can be interconnected using the star, bus, ring, or extended star (hybrid) physical topologies.
- All data link layer protocols encapsulate the Layer 3 PDU within the data field of the frame. However, the structure of the frame and the fields contained in the header and trailer vary according to the protocol.