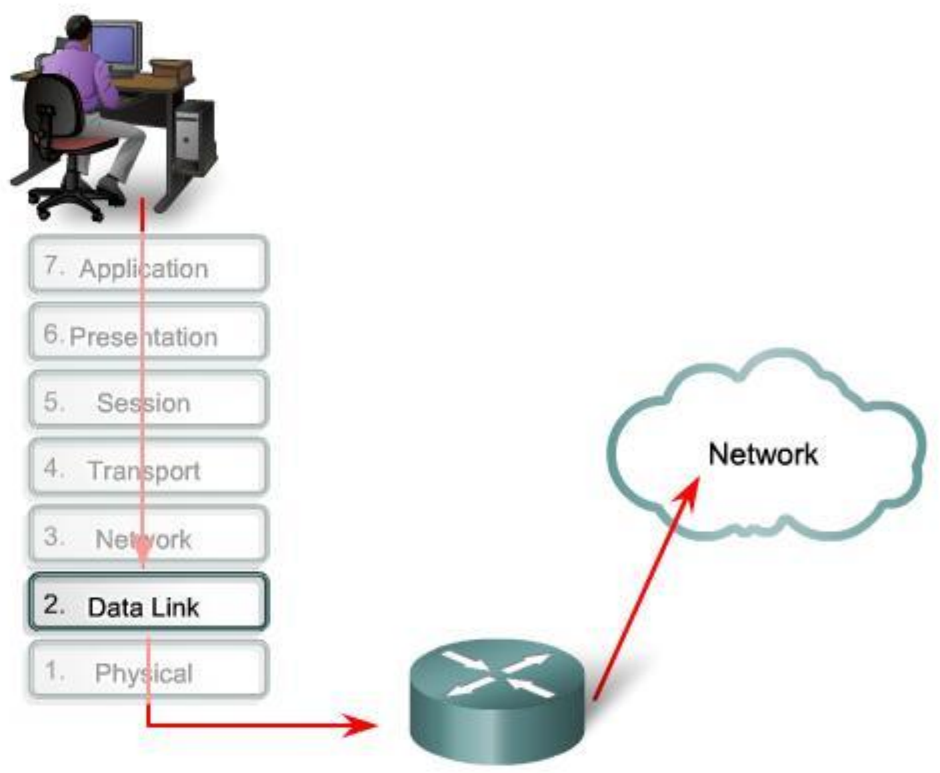
CCNA Exploration Network Fundamentals

Chapter 07

Data Link Layer

Updated: 24/06/2008

7.0.1 Introduction

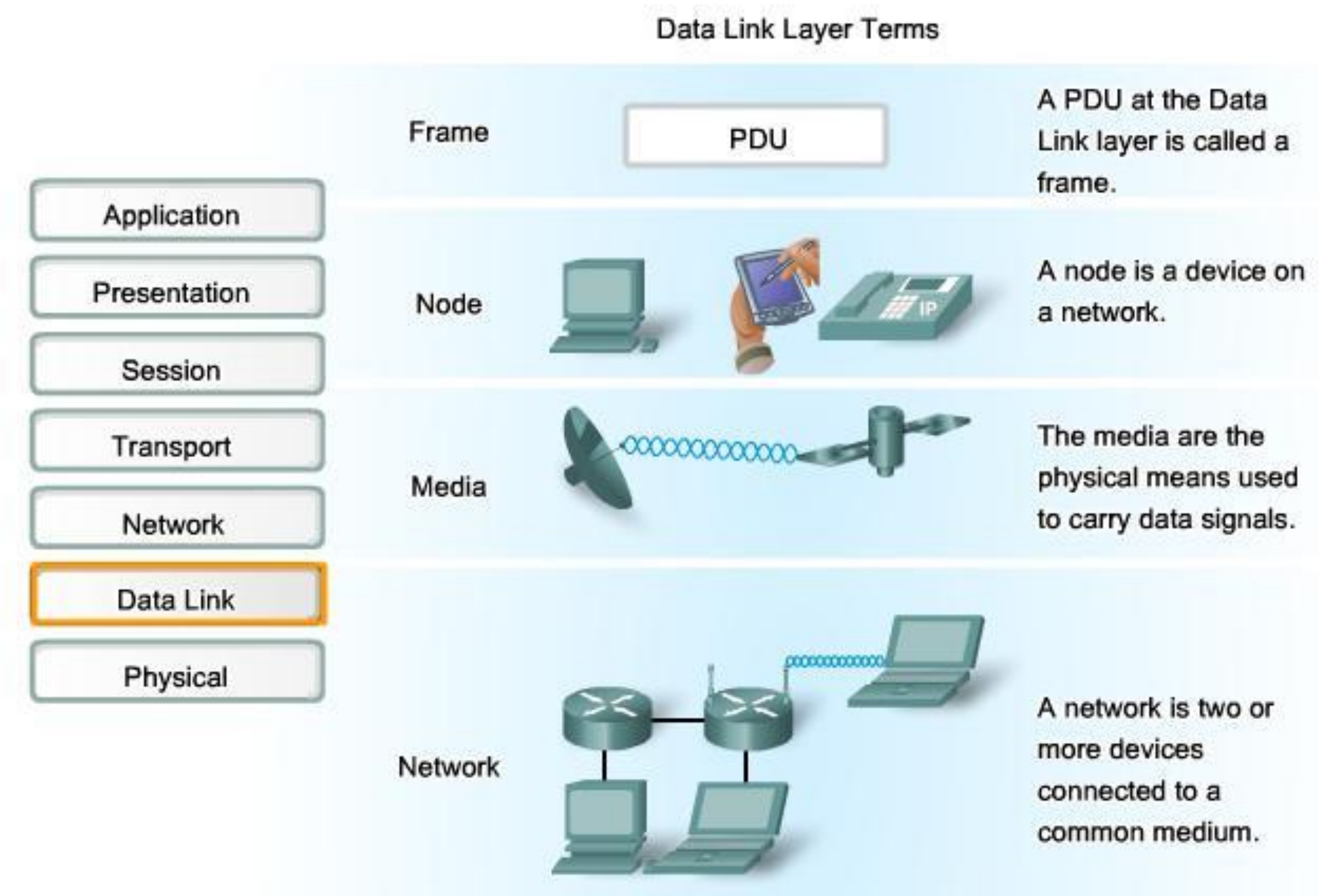


The Data Link layer prepares network data for the physical network.

7.0.1 Introduction

- For Network layer packets to be transported from source host to destination host, they must traverse different physical networks.
- These physical networks can consist of different types of physical media such as copper wires, microwaves, optical fibers, and satellite links.
- Network layer packets do not have a way to directly access these different media.
- It is the role of the OSI Data Link layer to prepare Network layer packets for transmission and to control access to the physical media.

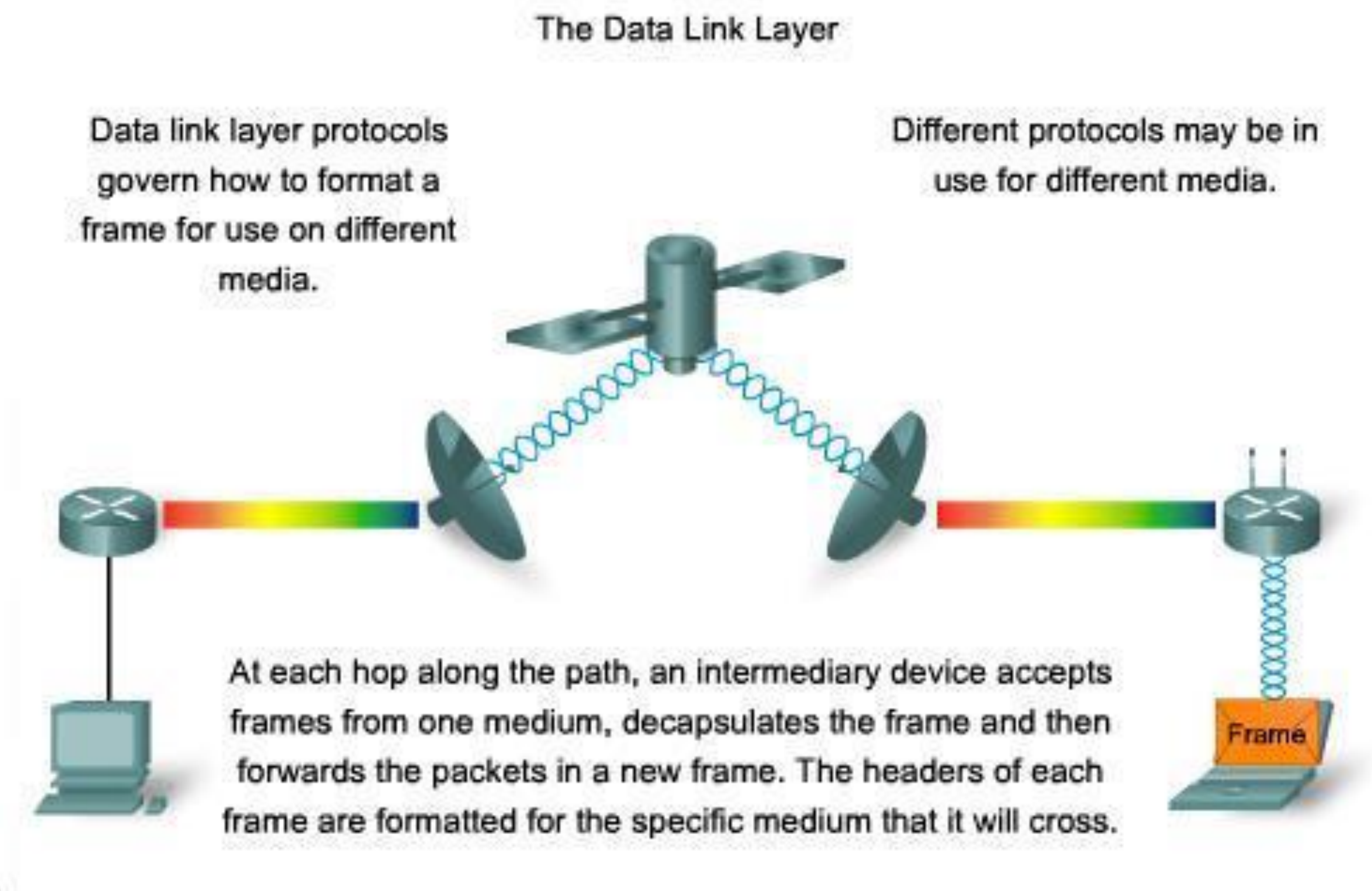
7.1 Data Link Layer – Accessing the Media
7.1.1 Data Link Layer – Supporting and Connecting to Upper Layer Services



7.1.1 Data Link Layer – Supporting and Connecting to Upper Layer Services

- The Data Link layer provides a means for exchanging data over a common local media.
- The Data Link layer performs two basic services:
  - Allows the upper layers to access the media using techniques such as framing
  - Controls how data is placed onto the media and is received from the media using techniques such as media access control and error detection
- A physical network is different from a logical network. Logical networks are defined at the Network layer by the arrangement of the hierarchical addressing scheme. Physical networks represent the interconnection of devices on a common media. Sometimes, a physical network is also referred to as a network segment.

7.1.1 Data Link Layer – Supporting and Connecting to Upper Layer Services

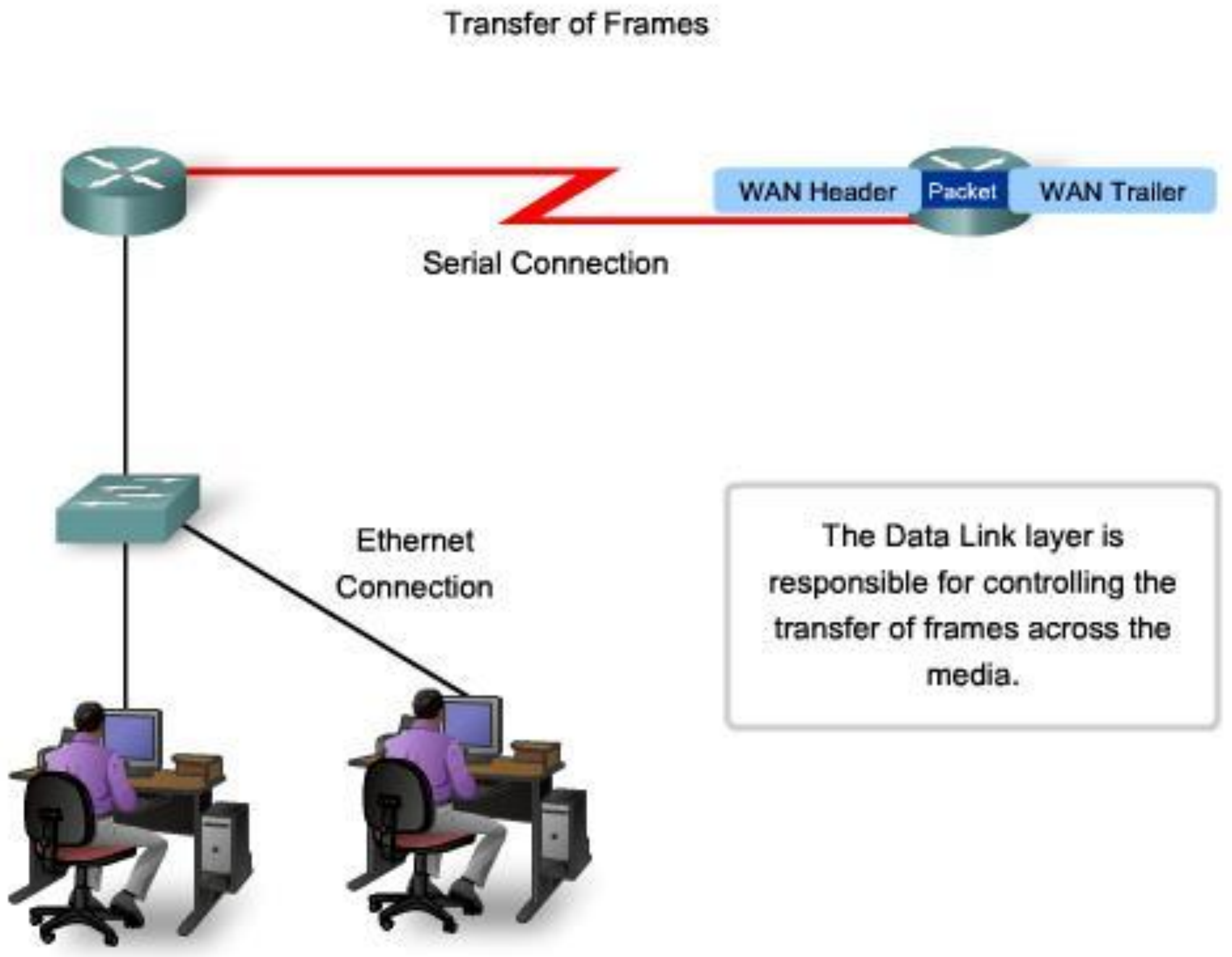


7.1.1 Data Link Layer – Supporting and Connecting to Upper Layer Services

Upper Layer Access to Media

- A network model allows each layer to function with minimal concern for the roles of the other layers.
- The Data Link layer relieves the upper layers from the responsibility of putting data on the network and receiving data from the network. This layer provides services to support the communication processes for each medium over which data is to be transmitted.
- In any given exchange of Network layer packets, there may be numerous Data Link layer and media transitions.
- At each hop along the path, an intermediary device - usually a router - accepts frames from a medium, decapsulates the frame, and then forwards the packet in a new frame appropriate to the medium of that segment of the physical network.

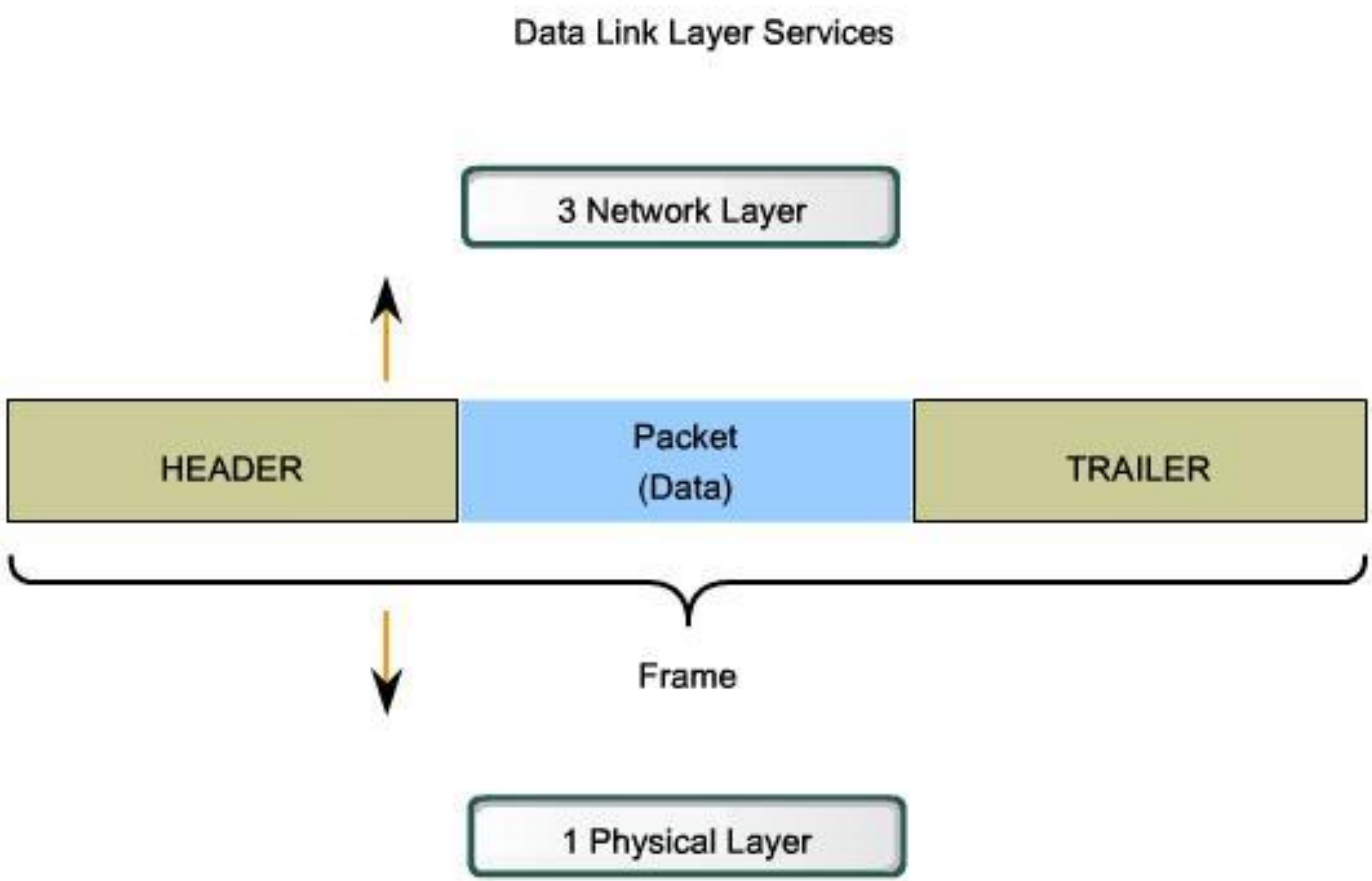
7.1.2 Data Link Layer – Controlling Transfer across Local Media



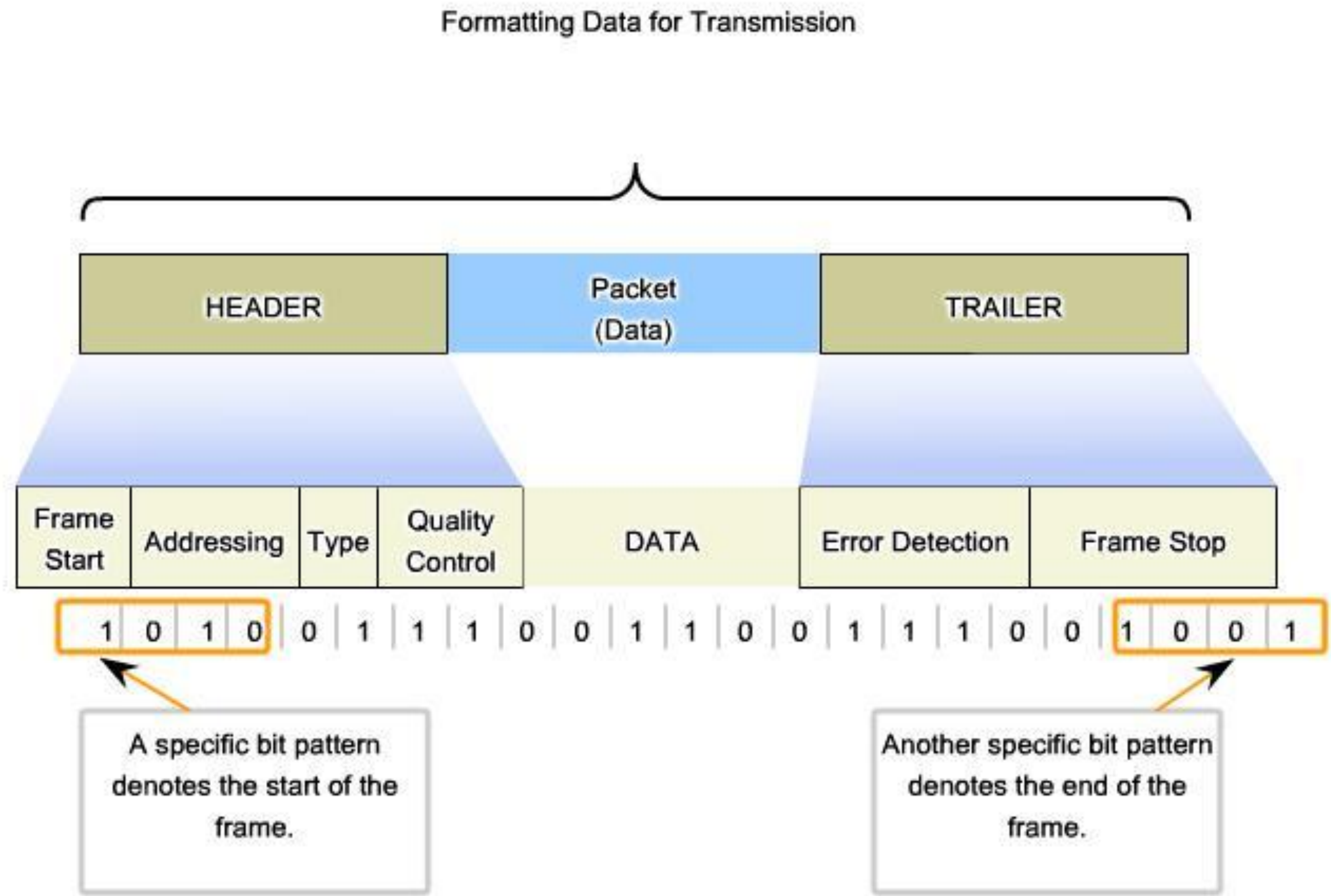
7.1.2 Data Link Layer – Controlling Transfer across Local Media

- Layer 2 protocols specify the encapsulation of a packet into a frame and the techniques for getting the encapsulated packet on and off each medium. The technique used for getting the frame on and off media is called the media access control method.
- For the data to be transferred across a number of different media, different media access control methods may be required during the course of a single communication.
- Each network environment that packets encounter as they travel from a local host to a remote host can have different characteristics. One network environment may consist of many hosts contending to access the network medium on an ad hoc basis. Another environment may consist of a direct connection between only two devices over which data flows sequentially as bits in an orderly way.
- The media access control methods described by the Data Link layer protocols define the processes by which network devices can access the network media and transmit frames in diverse network environments.

7.1.3 Data Link Layer – Creating a Frame



7.1.3 Data Link Layer – Creating a Frame



7.1.3 Data Link Layer – Creating a Frame

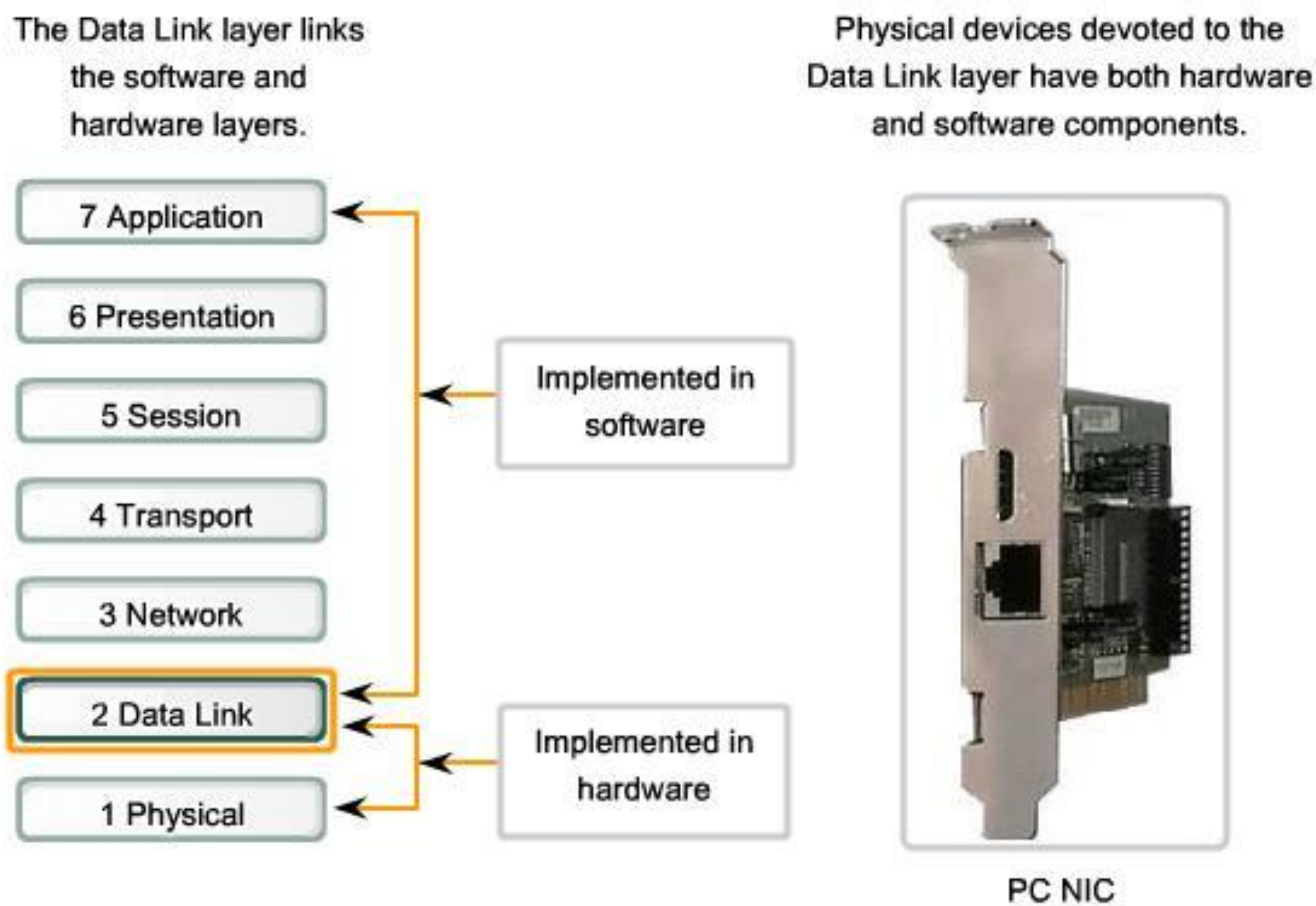
- Data Link layer protocols require control information to enable the protocols to function. Control information may tell:
  - Which nodes are in communication with each other
  - When communication between individual nodes begins and when it ends
  - Which errors occurred while the nodes communicated
  - Which nodes will communicate next

Formatting Data for Transmission

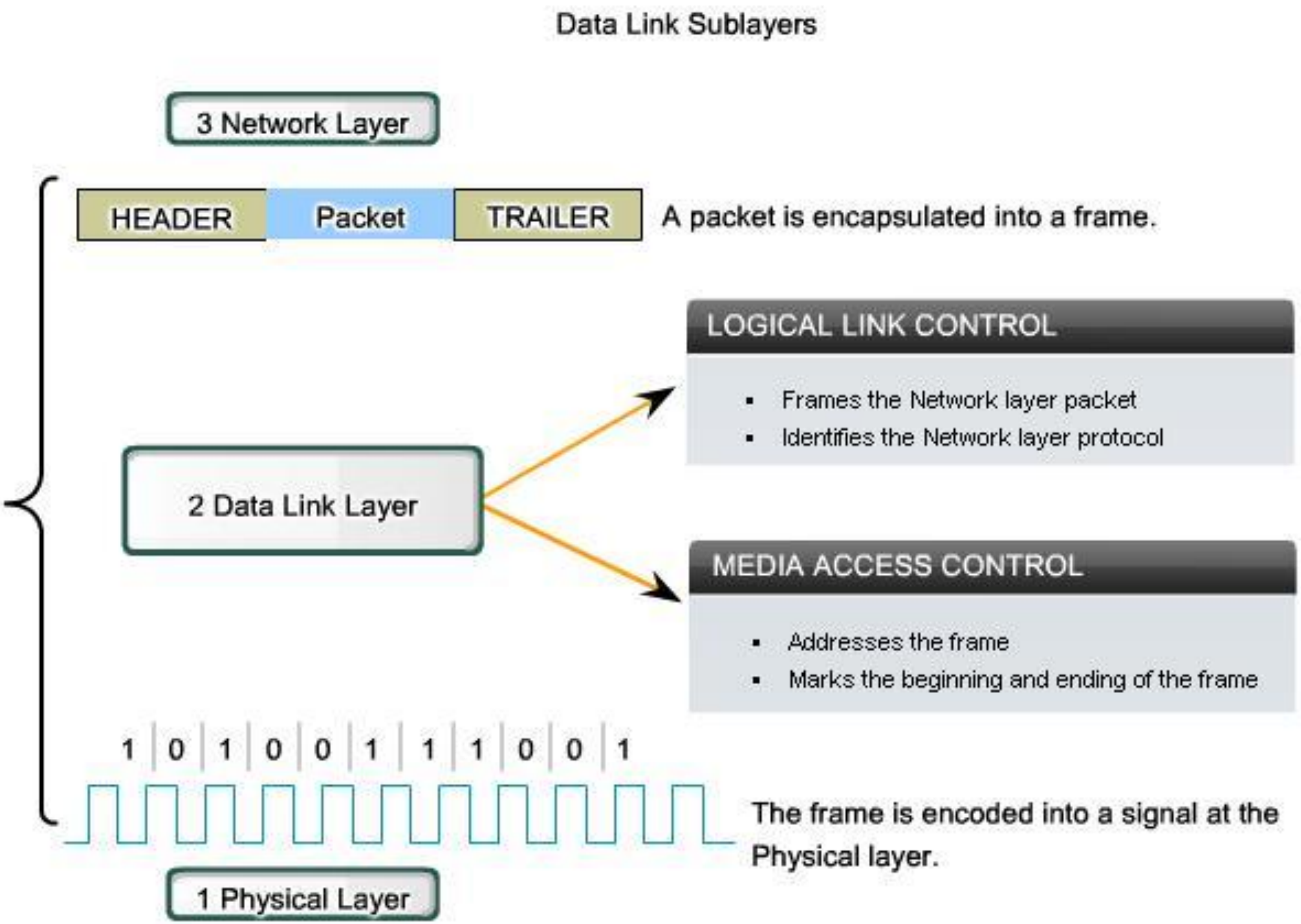
- When data travels on the media, it is converted into a stream of bits, or 1s and 0s.
- Framing breaks the stream into decipherable groupings, with control information inserted in the header and trailer as values in different fields. This format gives the physical signals a structure that can be received by nodes and decoded into packets at the destination.

7.1.4 Data Link Layer – Connecting Upper Layer Services to the Media

Connecting Upper Layer Services to the Media



7.1.4 Data Link Layer – Connecting Upper Layer Services to the Media



7.1.4 Data Link Layer – Connecting Upper Layer Services to the Media

Data Link Sublayers

- To support a wide variety of network functions, the Data Link layer is often divided into two sublayers: an upper sublayer and an lower sublayer.
- The upper sublayer defines the software processes that provide services to the Network layer protocols.
- The lower sublayer defines the media access processes performed by the hardware.
- Separating the Data Link layer into sublayers allows for one type of frame defined by the upper layer to access different types of media defined by the lower layer. Such is the case in many LAN technologies, including Ethernet.

7.1.4 Data Link Layer – Connecting Upper Layer Services to the Media

Logical Link Control

- Logical Link Control (LLC) 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 IP and IPX, to utilize the same network interface and media.

Media Access Control

- Media Access Control (MAC) provides Data Link layer addressing and delimiting of data according to the physical signaling requirements of the medium and the type of Data Link layer protocol in use.

7.1.5 Standards

Standards for the Data Link Layer

ISO:	HDLC (High Level Data Link Control)
IEEE:	802.2 (LLC), 802.3 (Ethernet) 802.5 (Token Ring) 802.11(Wireless LAN)
ITU:	Q.922 (Frame Relay Standard) Q.921 (ISDN Data Link Standard) HDLC (High Level Data Link Control)
ANSI:	3T9.5 ADCCP (Advanced Data Communications Control Protocol)

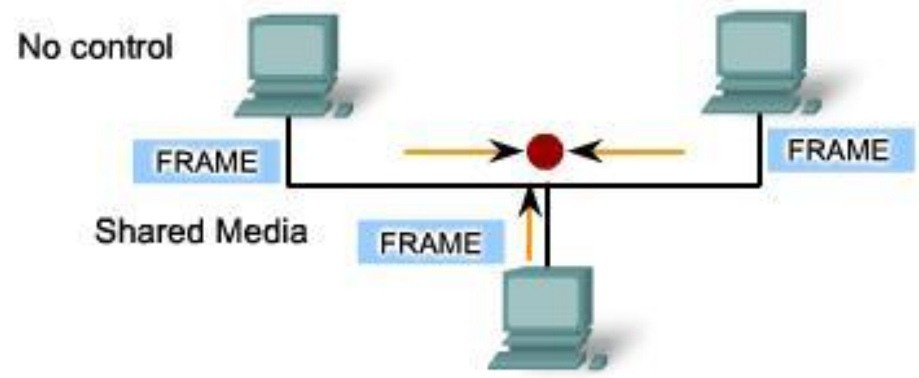
7.1.5 Standards

- Engineering organizations that define open standards and protocols that apply to the Data Link layer include:
  - International Organization for Standardization (ISO)
  - Institute of Electrical and Electronics Engineers (IEEE)
  - American National Standards Institute (ANSI)
  - International Telecommunication Union (ITU)
- Unlike the upper layer protocols, which are implemented mostly in software such as the host operating system or specific applications,
- Data Link layer processes occur both in software and hardware.
- The protocols at this layer are implemented within the electronics of the network adapters with which the device connects to the physical network.

7.2 Media Access Control Techniques
7.2.1 Placing Data on the Media

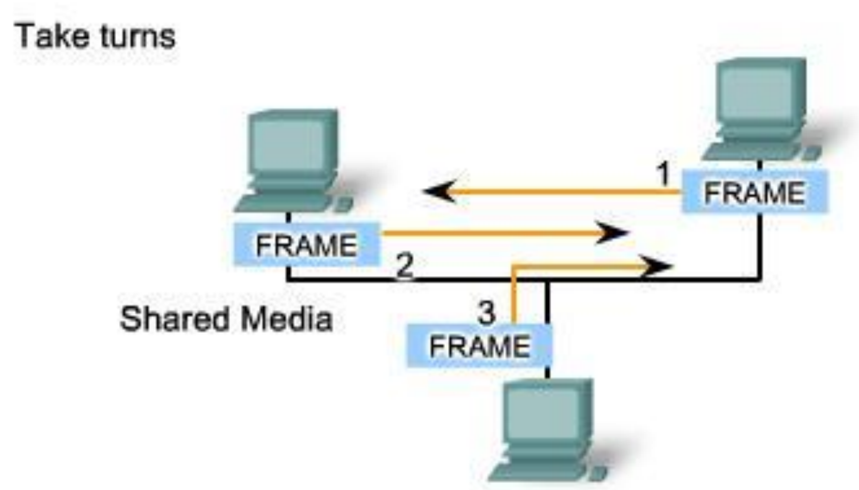
Media Access Control Methods

No control at all would result in many collisions.
Collisions cause corrupted frames that must be resent.



Methods that enforce a high degree of control prevent collisions, but the process has high overhead.

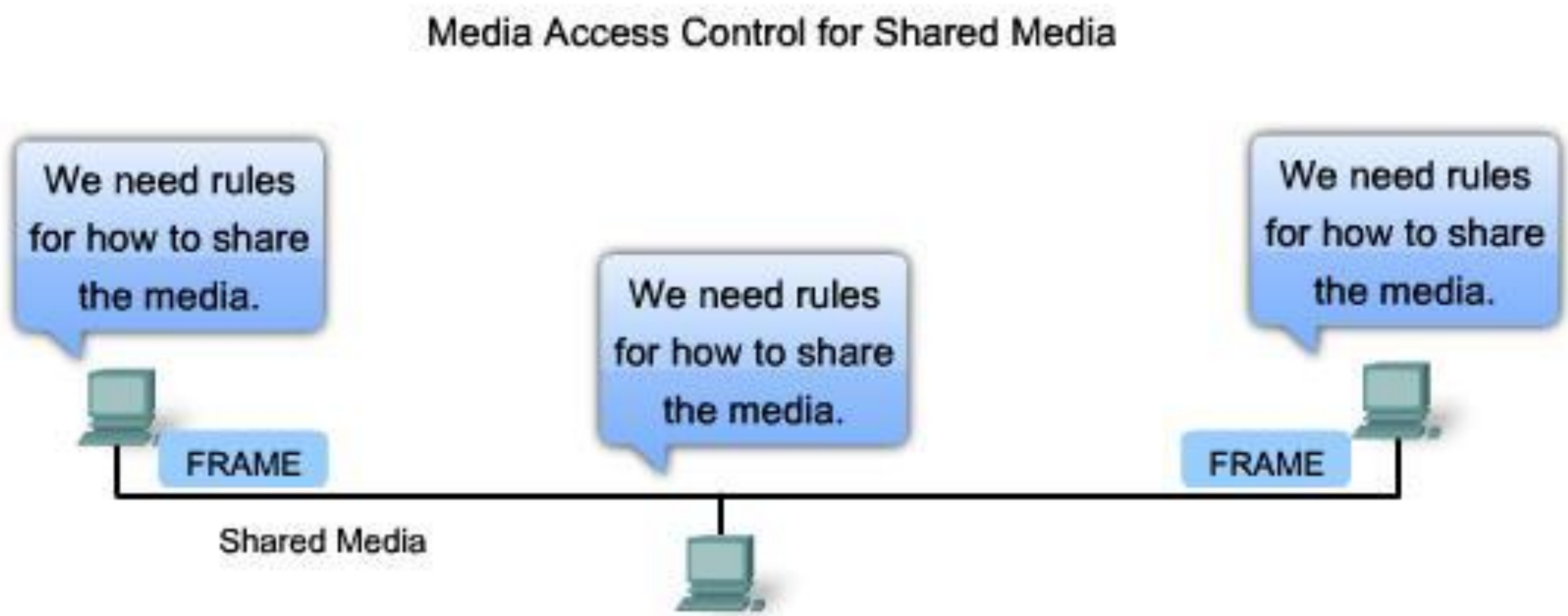
Methods that enforce a low degree of control have low overhead, but there are more frequent collisions.



7.2 Media Access Control Techniques
7.2.1 Placing Data on the Media

- Regulating the placement of data frames onto the media is known as media access control.
- The method of media access control used depends on:
  - Media sharing - If and how the nodes share the media
  - Topology - How the connection between the nodes appears to the Data Link layer

7.2.2 Media Access Control for Shared Media



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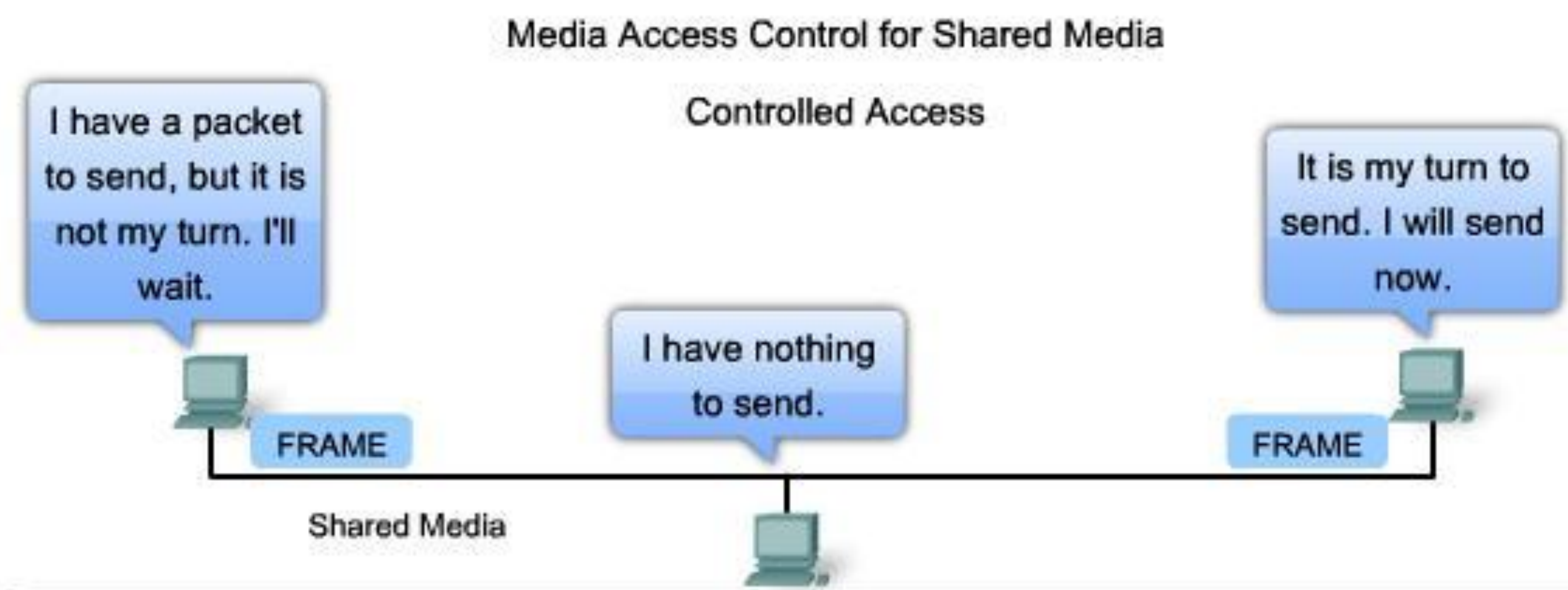
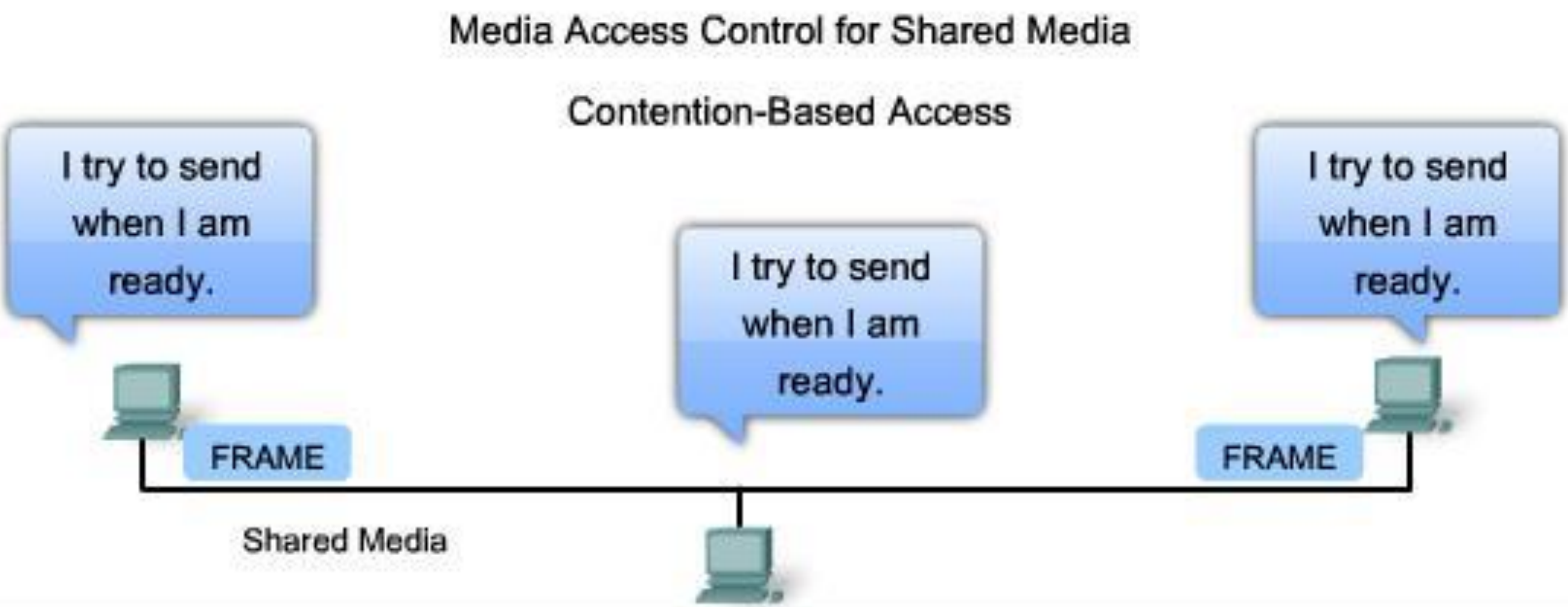


Method	Characteristics	Example
Controlled Access	• Only one station transmits at a time • Devices wishing to transmit must wait their turn • No collisions • Some deterministic networks use token passing	• Token Ring • FDDI

7.2.2 Media Access Control for Shared Media



Method	Characteristics	Example

Contention Based Access	• Stations can transmit at any time
	• Collisions exist
	• Mechanisms exist to resolve contention:
	  • CSMA/CD for Ethernet networks
	  • CSMA/CA for 802.11 wireless networks
		• Ethernet
		• Wireless

7.2.2 Media Access Control for Shared Media

- There are two basic media access control methods for shared media:
  - Controlled - Each node has its own time to use the medium
  - Contention-based - All nodes compete for the use of the medium

Controlled Access for Shared Media

- When using the controlled access method, network devices take turns, in sequence, to access the medium.
- This method is also known as scheduled access or deterministic.
- If a device does not need to access the medium, the opportunity to use the medium passes to the next device in line.
- When one device places a frame on the media, no other device can do so until the frame has arrived at the destination and has been processed by the destination.
- Although controlled access is well-ordered and provides predictable throughput, deterministic methods can be inefficient because a device has to wait for its turn before it can use the medium.

7.2.2 Media Access Control for Shared Media

Contention-based Access for Shared Media

- Also referred to as non-deterministic, contention-based methods allow any device to try to access the medium whenever it has data to send.
- To prevent complete chaos on the media, these methods use a Carrier Sense Multiple Access (CSMA) process to first detect if the media is carrying a signal.
- If a carrier signal on the media from another node is detected, it means that another device is transmitting.
- When the device attempting to transmit sees that the media is busy, it will wait and try again after a short time period. If no carrier signal is detected, the device transmits its data. Ethernet and wireless networks use contention-based media access control.
- It is possible that the CSMA process will fail and two devices will transmit at the same time. This is called a data collision. If this occurs, the data sent by both devices will be corrupted and will need to be resent.

7.2.2 Media Access Control for Shared Media

- Contention-based media access control methods do not have the overhead of controlled access methods.
- A mechanism for tracking whose turn it is to access the media is not required.
- However, the contention-based systems do not scale well under heavy media use.
- As use and the number of nodes increases, the probability of successful media access without a collision decreases.
- Additionally, The recovery mechanisms required to correct errors due to these collisions further diminishes the throughput.
- CSMA is usually implemented in conjunction with a method for resolving the media contention.
- The two commonly used methods are:
  - CSMA/Collision Detection
  - CSMA/Collision Avoidance

7.2.2 Media Access Control for Shared Media

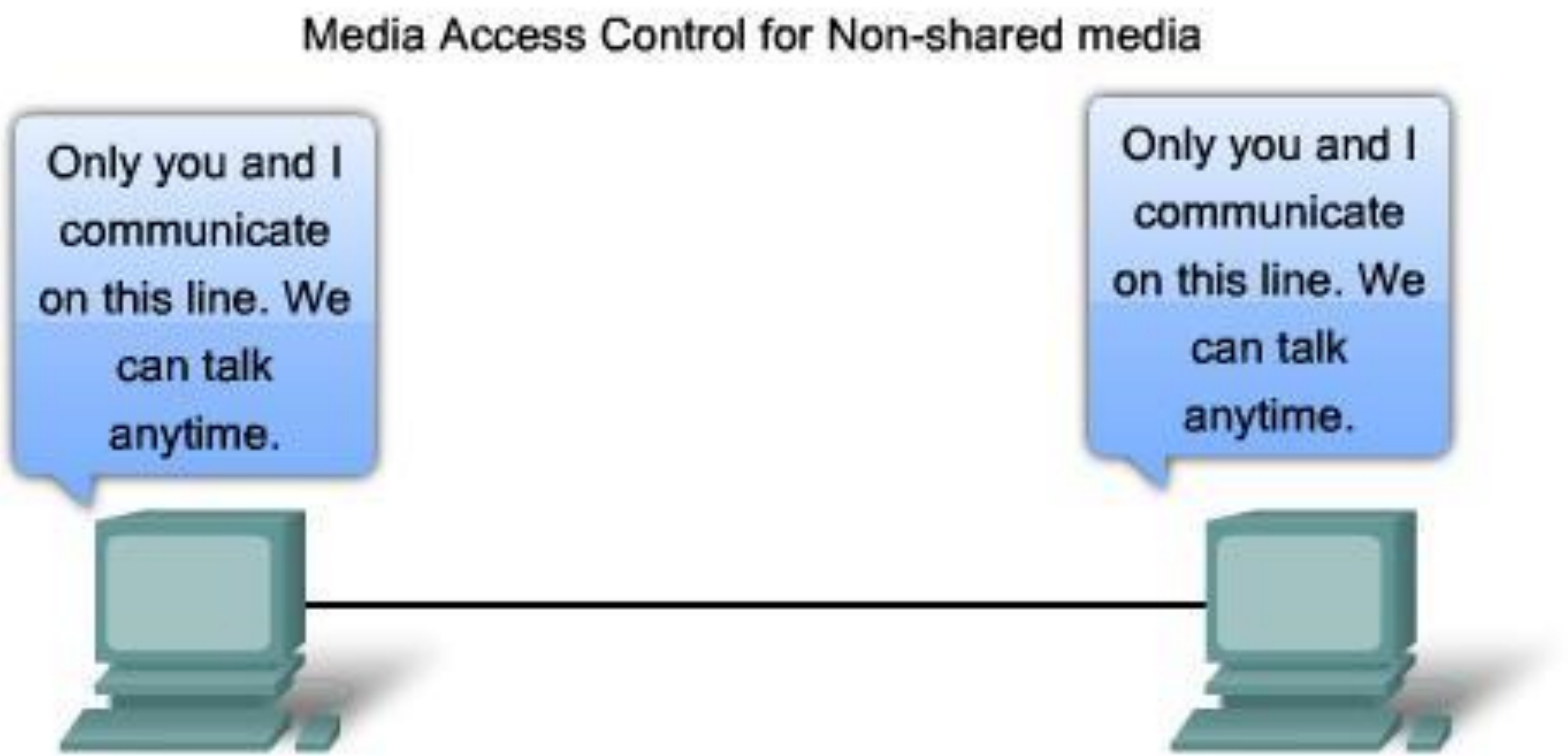
CSMA/Collision Detection

- In CSMA/Collision Detection (CSMA/CD), the device monitors the media for the presence of a data signal.
- If a data signal is absent, indicating that the media is free, the device transmits the data.
- If signals are then detected that show another device was transmitting at the same time, all devices stop sending and try again later.
- Traditional forms of Ethernet use this method.

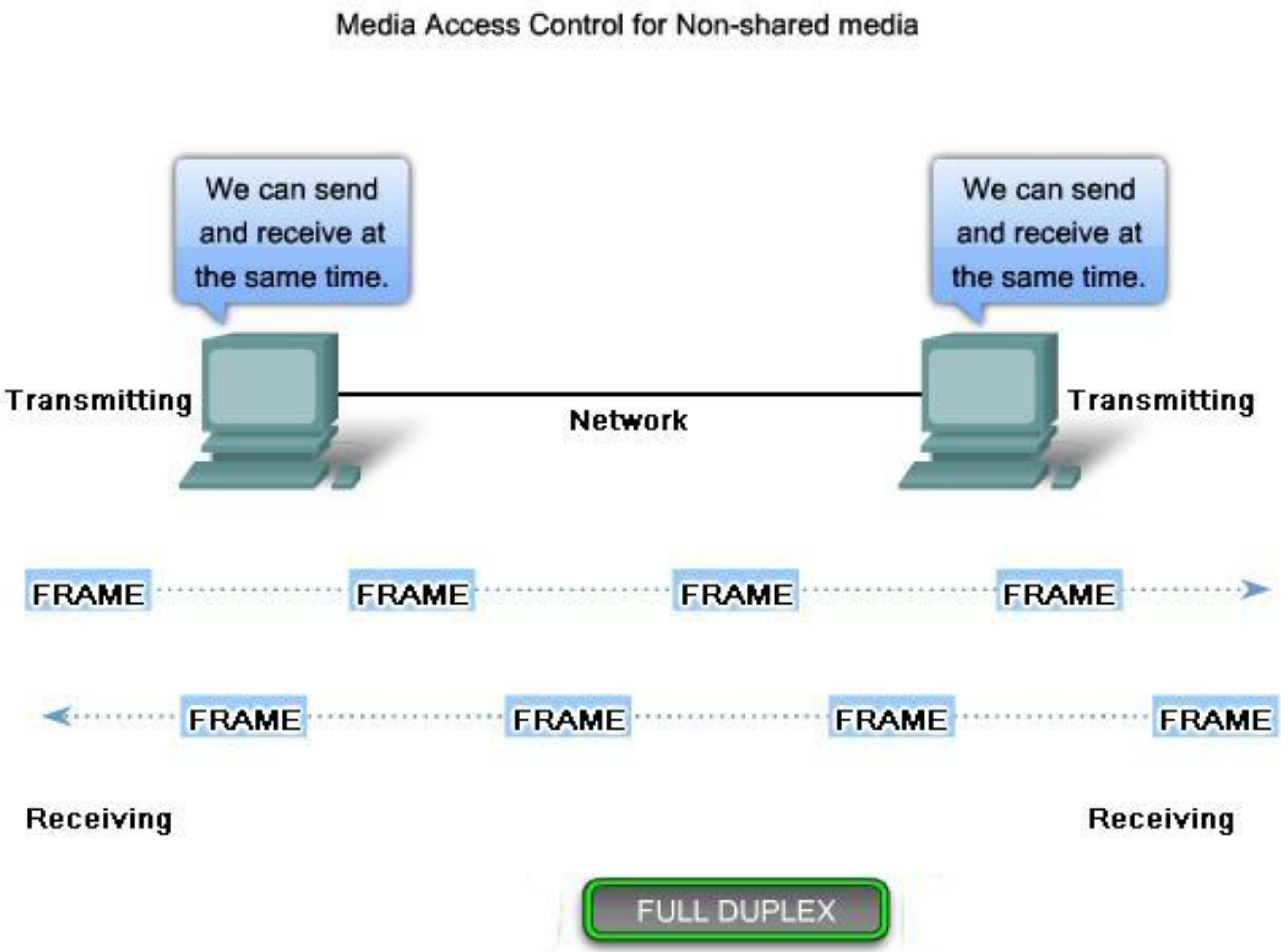
CSMA/Collision Avoidance

- In CSMA/Collision Avoidance (CSMA/CA), the device examines the media for the presence of a data signal.
- If the media is free, the device sends a notification across the media of its intent to use it.
- The device then sends the data.
- This method is used by 802.11 wireless networking technologies.

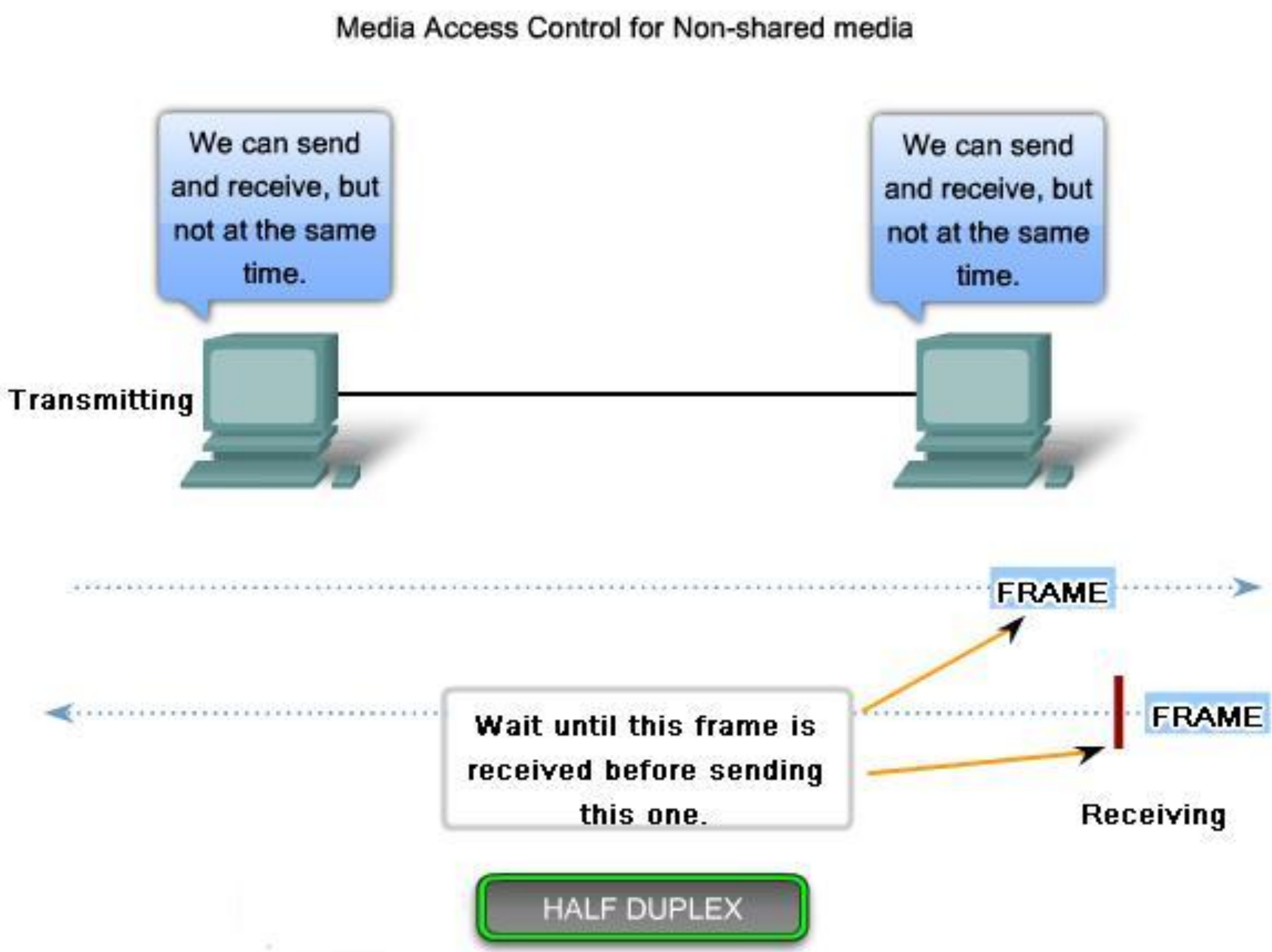
7.2.3 Media Access Control for Non-Shared Media



7.2.3 Media Access Control for Non-Shared Media



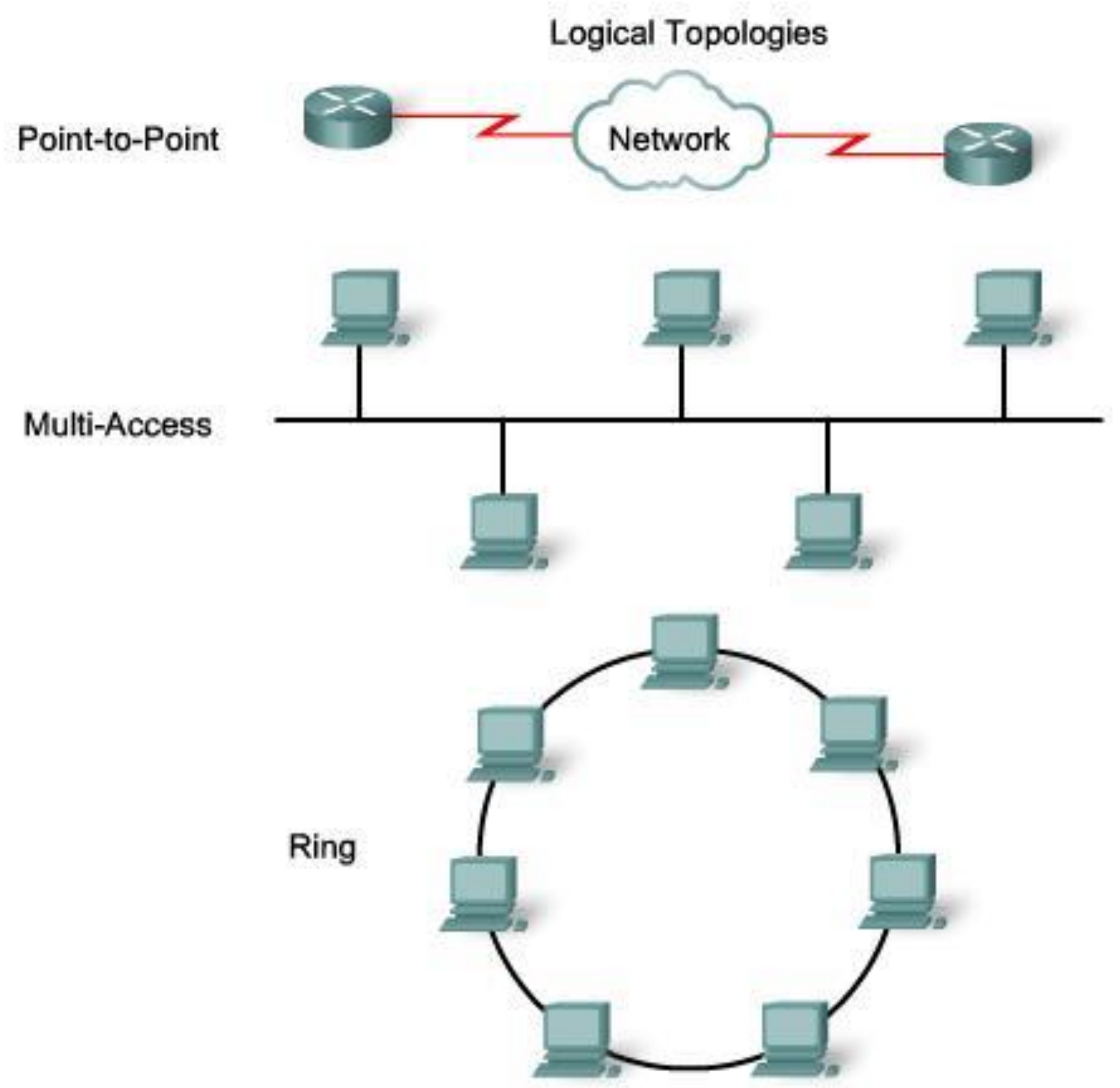
7.2.3 Media Access Control for Non-Shared Media



7.2.3 Media Access Control for Non-Shared Media

- Media access control protocols for non-shared media require little or no control before placing frames onto the media. These protocols have simpler rules and procedures for media access control. Such is the case for point-to-point topologies.
- In point-to-point connections, the Data Link layer has to consider whether the communication is half-duplex or full-duplex.
- Half-duplex communication means that the devices can both transmit and receive on the media but cannot do so simultaneously. Ethernet has established arbitration rules for resolving conflicts arising from instances when more than one station attempts to transmit at the same time.
- In 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. Therefore, there is no media arbitration necessary in the Data Link layer.

7.2.4 Logical Topology vs Physical Topology



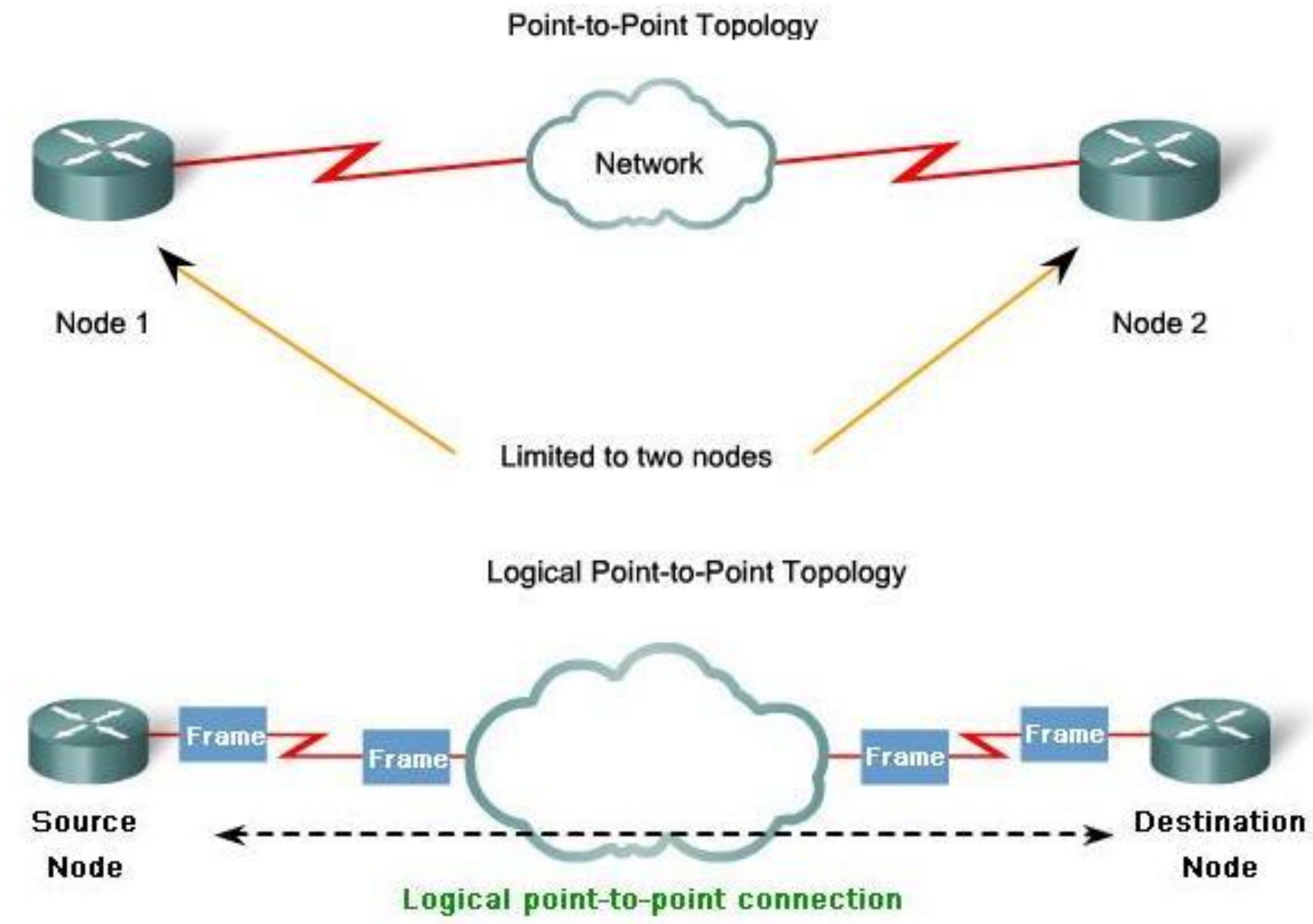
7.2.4 Logical Topology vs Physical Topology

- The topology of a network is the arrangement or relationship of the network devices and the interconnections between them.
- Network topologies can be viewed at the physical level and the logical level.
- The physical topology is an arrangement of the nodes and the physical connections between them. The representation of how the media is used to interconnect the devices is the physical topology. These will be covered in later chapters of this course.
- A logical topology is the way a network transfers frames from one node to the next. This arrangement consists of virtual connections between the nodes of a network independent of their physical layout. These logical signal paths are defined by Data Link layer protocols. The Data Link layer "sees" the logical topology of a network when controlling data access to the media. It is the logical topology that influences the type of network framing and media access control used.

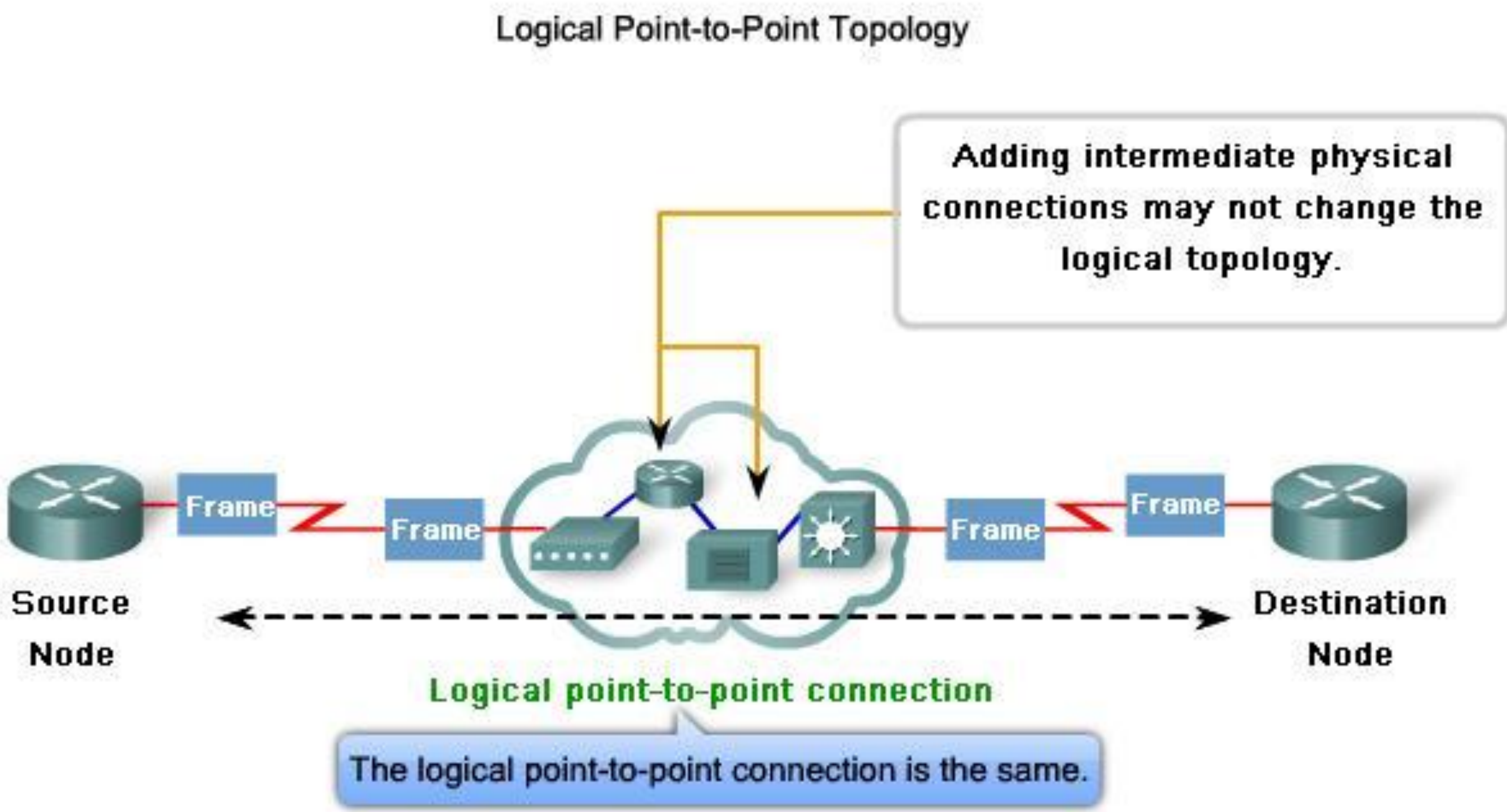
7.2.4 Logical Topology vs Physical Topology

- The physical or cabled topology of a network will most likely not be the same as the logical topology.
- Logical topology of a network is closely related to the mechanism used to manage network access. Access methods provide the procedures to manage network access so that all stations have access. When several entities share the same media, some mechanism must be in place to control access.
- Logical and physical topologies typically used in networks are:
  - Point-to-Point
  - Multi-Access
  - Ring

7.2.5 Point-to-Point Topology



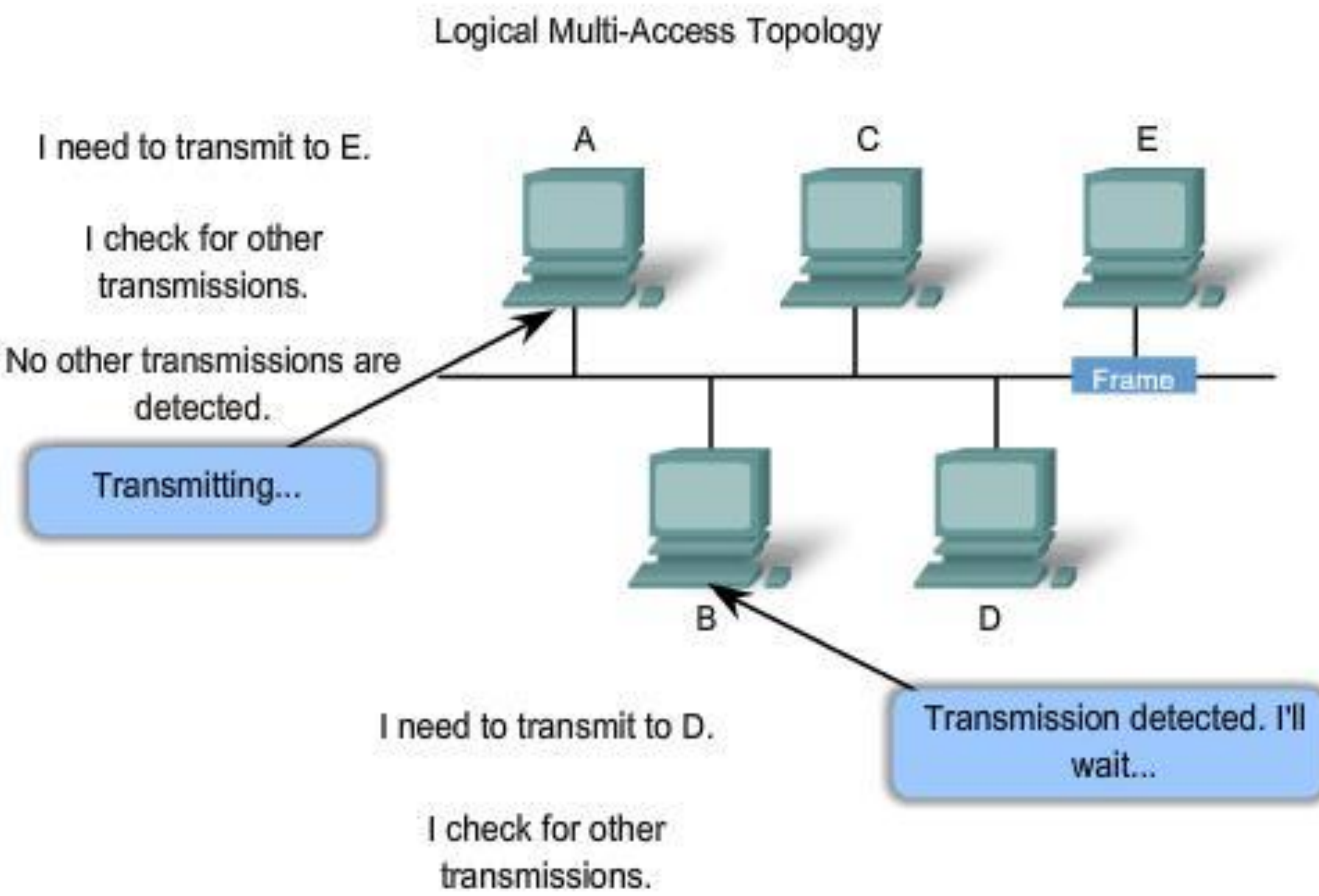
7.2.5 Point-to-Point Topology



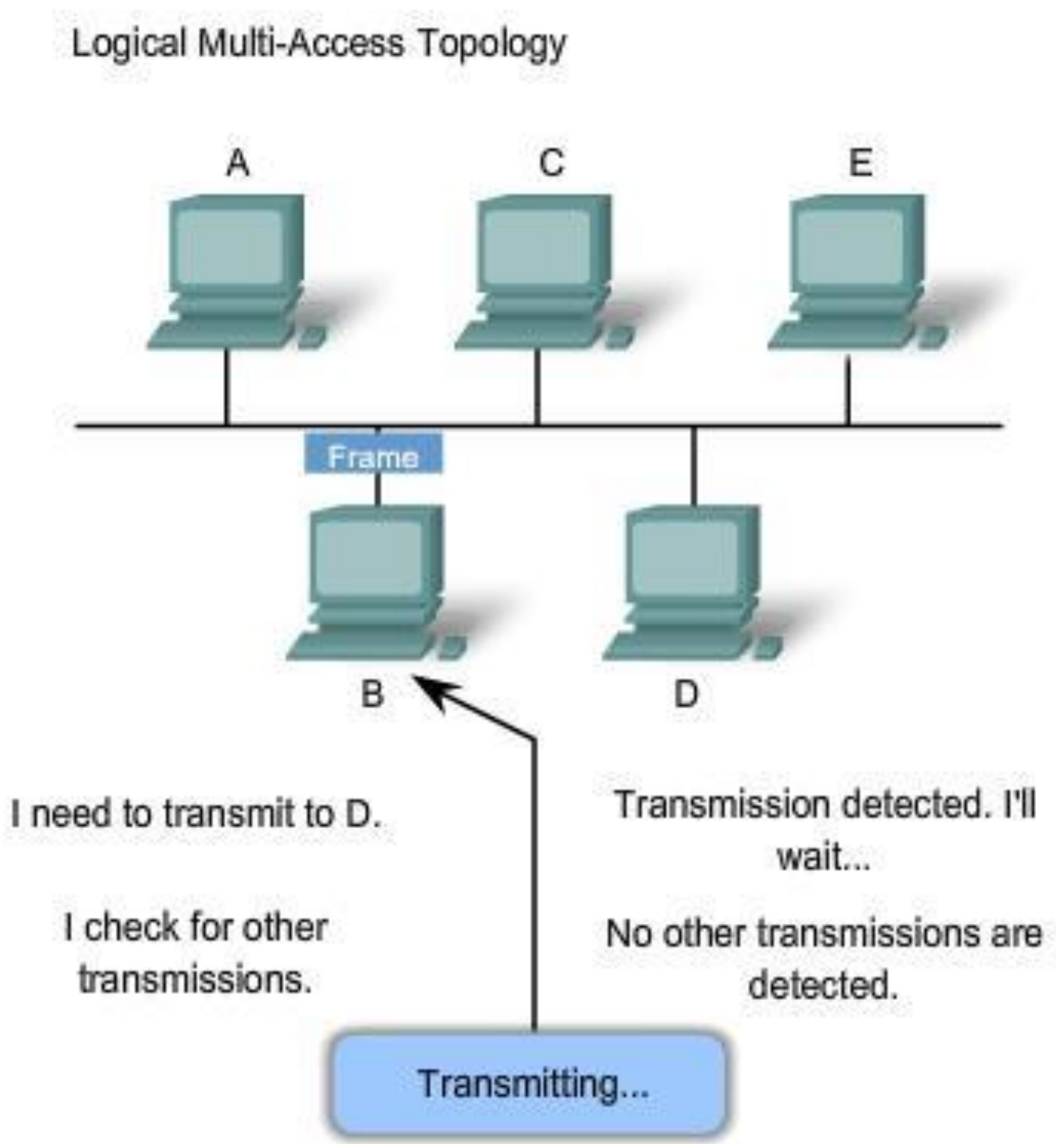
7.2.5 Point-to-Point Topology

- A point-to-point topology connects two nodes directly together.
- In data networks with point-to-point topologies, the media access control protocol can be very simple.
- All frames on the media can only travel to or from the two nodes.
- The frames are placed on the media by the node at one end and taken off the media by the node at the other end of the point-to-point circuit.
- In point-to-point networks, if data can only flow in one direction at a time, it is operating as a half-duplex link.
- If data can successfully flow across the link from each node simultaneously, it is a full-duplex link.

7.2.6 Multi-Access Topology



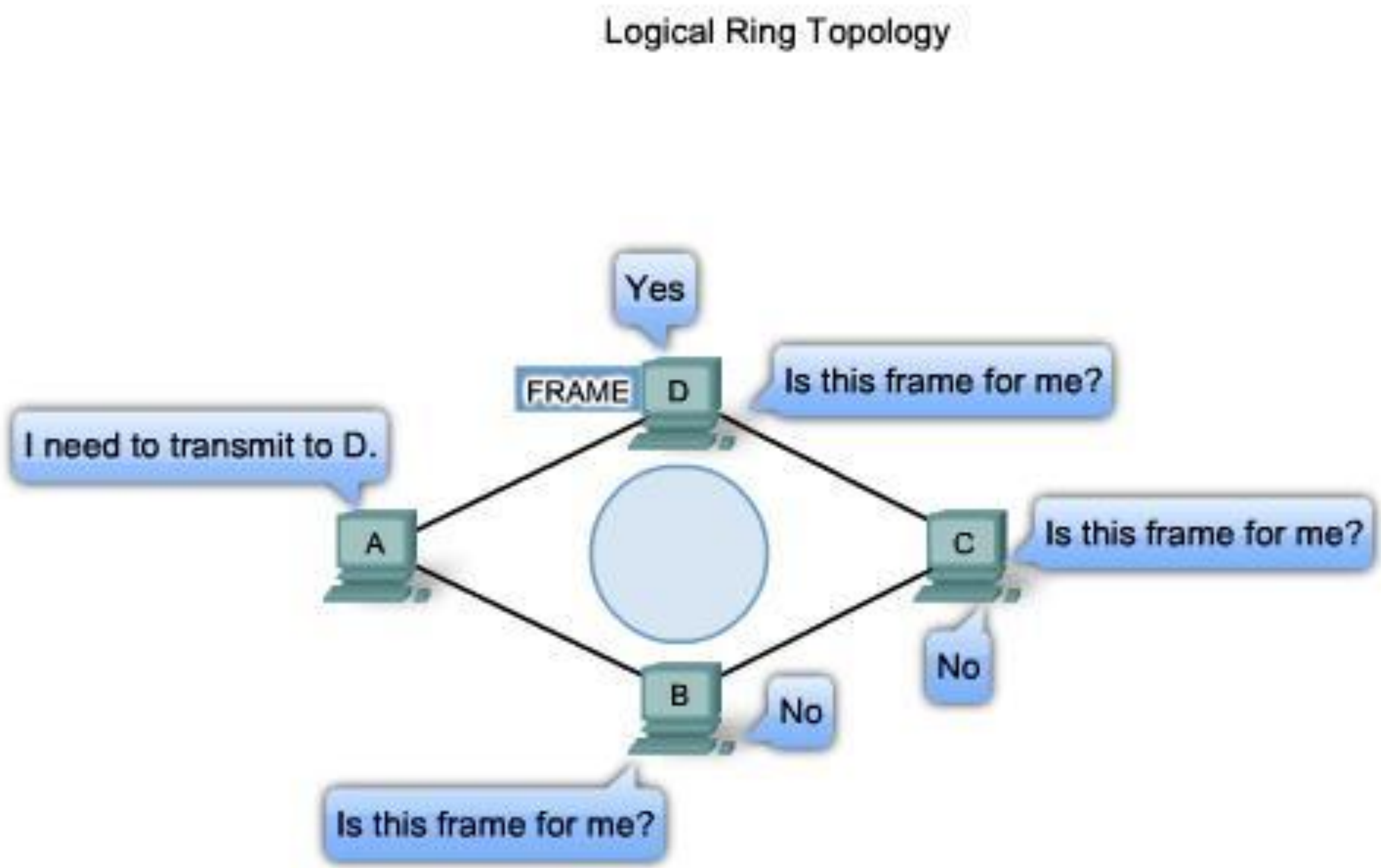
7.2.6 Multi-Access Topology



7.2.6 Multi-Access Topology

- A logical multi-access topology enables a number of nodes to communicate by using the same shared media. Data from only one node can be placed on the medium at any one time. Every node sees all the frames that are on the medium, but only the node to which the frame is addressed processes the contents of the frame.
- Having many nodes share access to the medium requires a Data Link media access control method to regulate the transmission of data and thereby reduce collisions between different signals.
- The media access control methods used by logical multi-access topologies are typically CSMA/CD or CSMA/CA. However, token passing methods can also be used.
- The Data Link layer protocol specifies the media access control method that will provide the appropriate balance between frame control, frame protection, and network overhead.

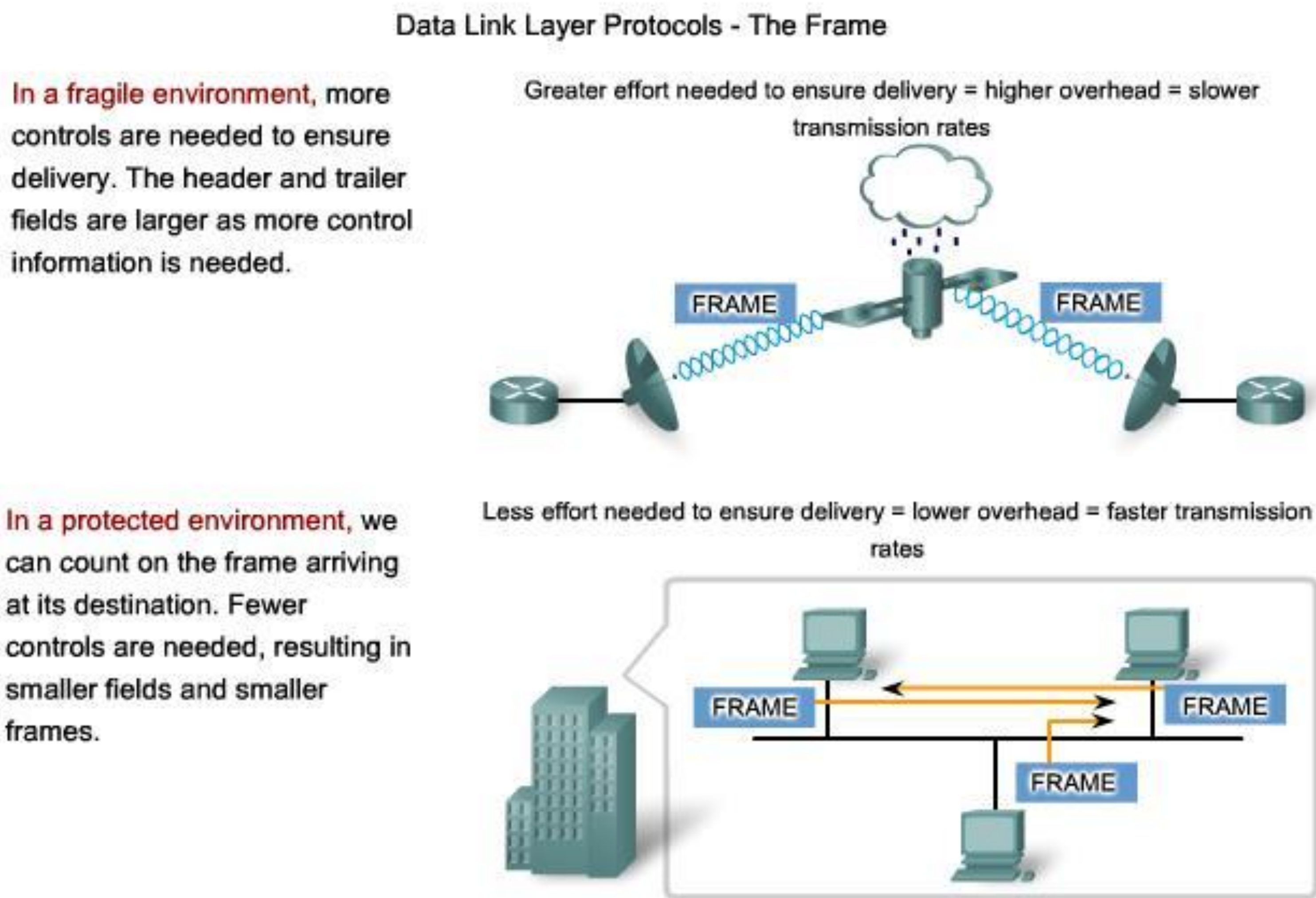
7.2.7 Ring Topology



7.2.7 Ring Topology

- In a logical ring topology, each node in turn receives a frame. If the frame is not addressed to the node, the node passes the frame to the next node. This allows a ring to use a controlled media access control technique called token passing.
- Nodes in a logical ring topology remove the frame from the ring, examine the address, and send it on if it is not addressed for that node. In a ring, all nodes around the ring- between the source and destination node examine the frame.
- There are multiple media access control techniques that could be used with a logical ring, depending on the level of control required. Only one frame at a time is usually carried by the media. If there is no data being transmitted, a signal (known as a token) may be placed on the media and a node can only place a data frame on the media when it has the token.
- The Data Link layer "sees" a logical ring topology. The actual physical cabling topology could be another topology.

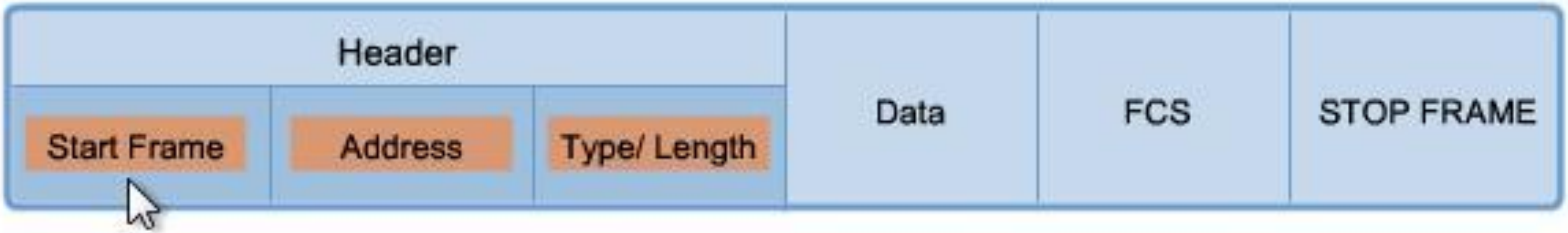
7.3 Media Access Control Addressing and Framing Data
7.3.1 Data Link Layer Protocols – The Frame



7.3.1 Data Link Layer Protocols – The Frame

- 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
- 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.
- There is no one frame structure that meets the needs of all data transportation across all types of media. Depending on the environment, the amount of control information needed in the frame varies to match the media access control requirements of the media and logical topology.

7.3.2 Framing – Role of the Header



The **Start Frame** field tells other devices on the network that a frame is coming along the medium.

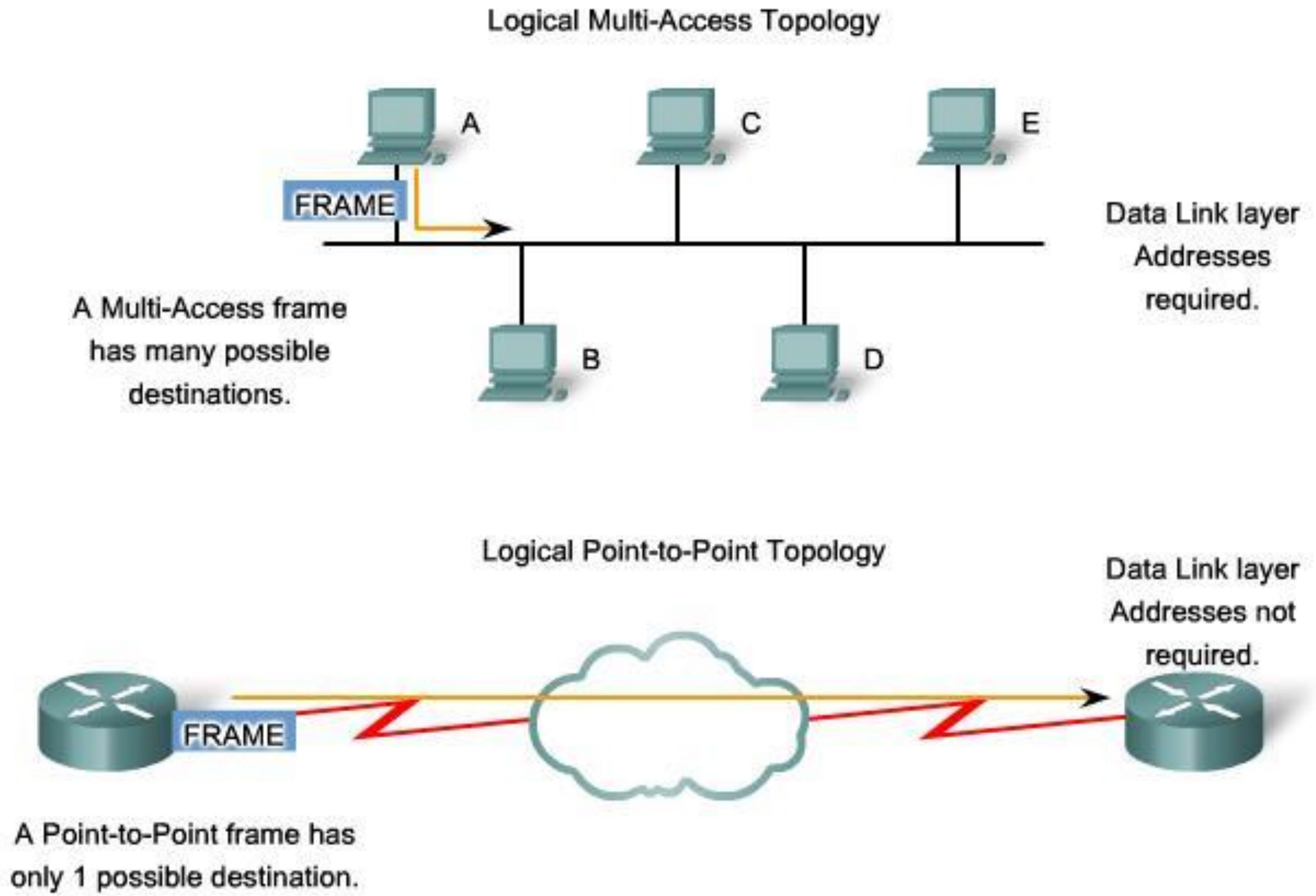
The **Address** field stores the source and destination Data Link addresses.

The **Type/Length** field is an optional field used by some protocols to state either what type of data is coming or possibly the length of the frame.

7.3.2 Framing – Role of the Header

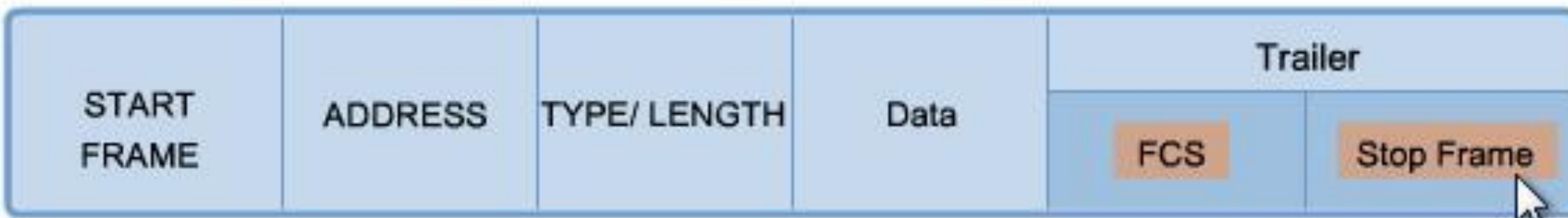
- The frame header contains the control information specified by the Data Link layer protocol for the specific logical topology and media used.
- Typical frame header fields include:
  - Start Frame field - Indicates the beginning of the frame
  - Source and Destination address fields - Indicates the source and destination nodes on the media
  - Priority/Quality of Service field - Indicates a particular type of communication service for processing
  - Type field - Indicates the upper layer service contained in the frame
  - Logical connection control field - Used to establish a logical connection between nodes
  - Physical link control field - Used to establish the media link
  - Flow control field - Used to start and stop traffic over the media
  - Congestion control field - Indicates congestion in the media

7.3.3 Framing – Where the Frame Goes



7.3.4 Framing – Role of the Trailer

The Frame Check Sequence 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.

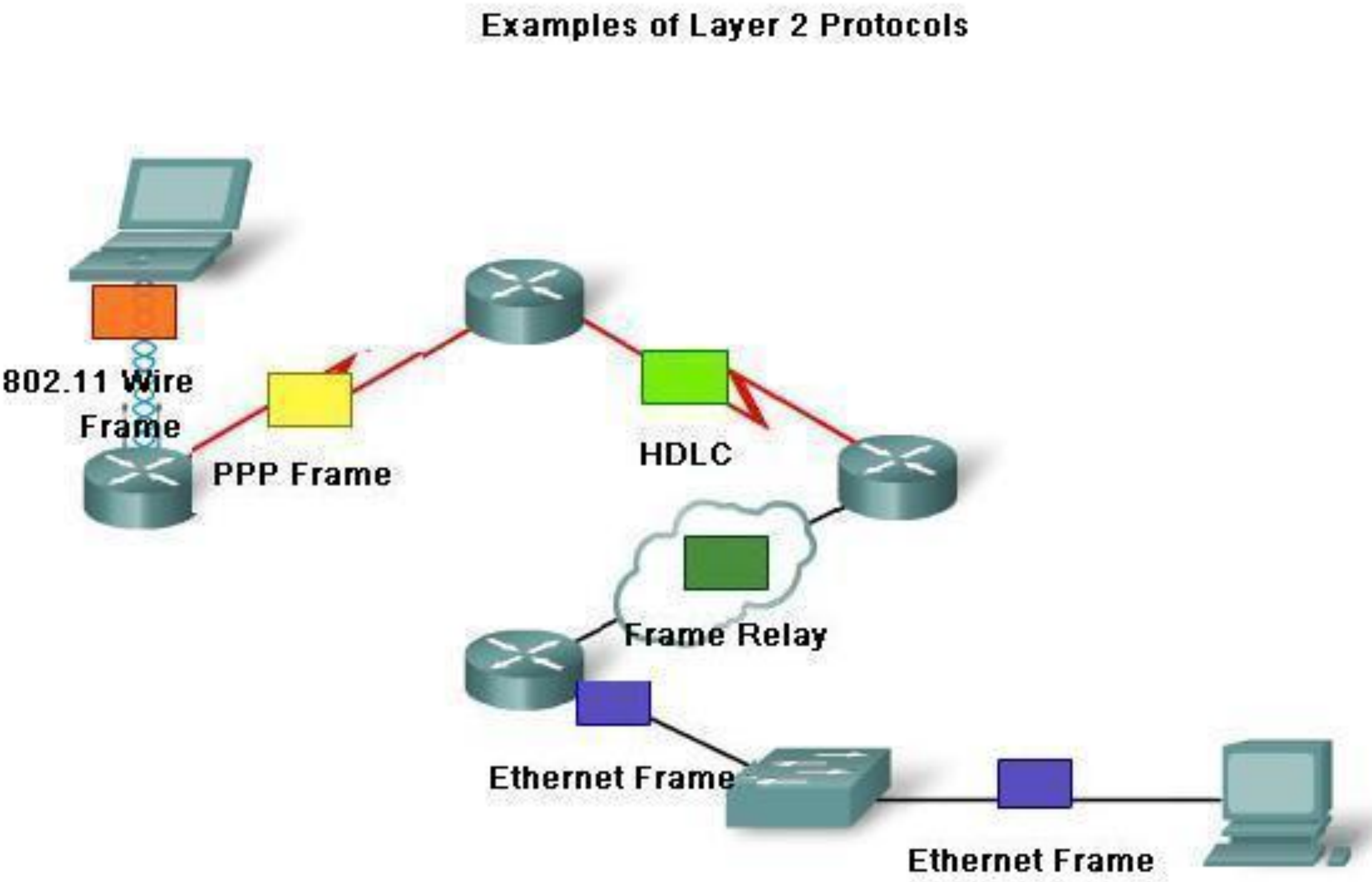


The **Stop Frame** field, also called the Frame Trailer, is an optional field that is used when the length of the frame is not specified in the Type/Length field. It indicates the end of the frame when transmitted.

7.3.4 Framing – Role of the Trailer

- Data Link layer protocols add a trailer to the end of each frame. The trailer is used to determine if the frame arrived without error.
- This process is called error detection. Error detection is different from error correction. Error detection is accomplished by placing a logical or mathematical summary of the bits that comprise the frame in the trailer.
- The cyclic redundancy check (CRC) value is placed in the Frame Check Sequence (FCS) field of the frame to represent the contents of the frame.
- When the frame arrives at the destination node, the receiving node calculates its own logical summary, or CRC, of the frame. The receiving node compares the two CRC values. If the two values are the same, the frame is considered to have arrived as transmitted. If the CRC value in the FCS differs from the CRC calculated at the receiving node, the frame is discarded.
- There is always the small possibility that a frame with a good CRC result is actually corrupt. Errors in bits may cancel each other out when the CRC is calculated. Upper layer protocols would then be required to detect and correct this data loss.

7.3.5 Data Link Layer Protocols – The Frame



7.3.5 Data Link Layer Protocols – The 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.

7.3.5 Data Link Layer Protocols – The Frame

- The Layer 2 protocol used for a particular network topology is determined by the technology used to implement that topology. The technology is, in turn, determined by the size of the network - in terms of the number of hosts and the geographic scope - and the services to be provided over the network.
- LAN Technology - A Local Area Network typically uses a high bandwidth technology that is capable of supporting large numbers of hosts. A LAN's relatively small geographic area (a single building or a multi-building campus) and its high density of users make this technology cost effective.
- WAN Technology -However, using a high bandwidth technology is usually not cost-effective for Wide Area Networks that cover large geographic areas (cities or multiple cities, for example). The cost of the long distance physical links and the technology used to carry the signals over those distances typically results in lower bandwidth capacity.
- Difference in bandwidth normally results in the use of different protocols for LANs and WANs.

7.4 Putting It All Together
7.4.1 Follow Data Through an Internetwork