Elk Technologies
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Module 6: Data Link Layer

Introduction to Networks

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Module Objectives

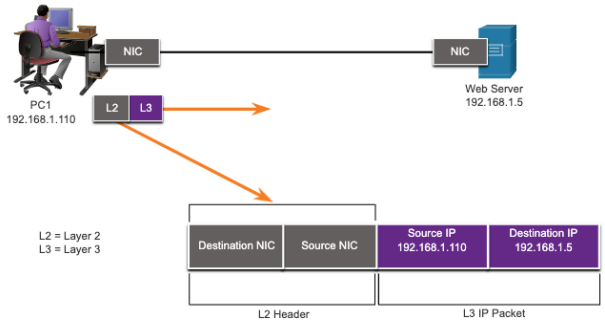
- Module Title: Data Link Layer
- Module Objective: Explain how media access control in the data link layer supports communication across networks.

Topic Title	Topic Objective
6.1 Purpose of the Data Link Layer	Describe the purpose and function of the data link layer in preparing communication for transmission on specific media.
6.2 Topologies	Compare the characteristics of media access control methods on WAN and LAN topologies.
6.3 Data Link Frame	Describe the characteristics and functions of the data link frame.

6.1 Purpose of the Data Link Layer

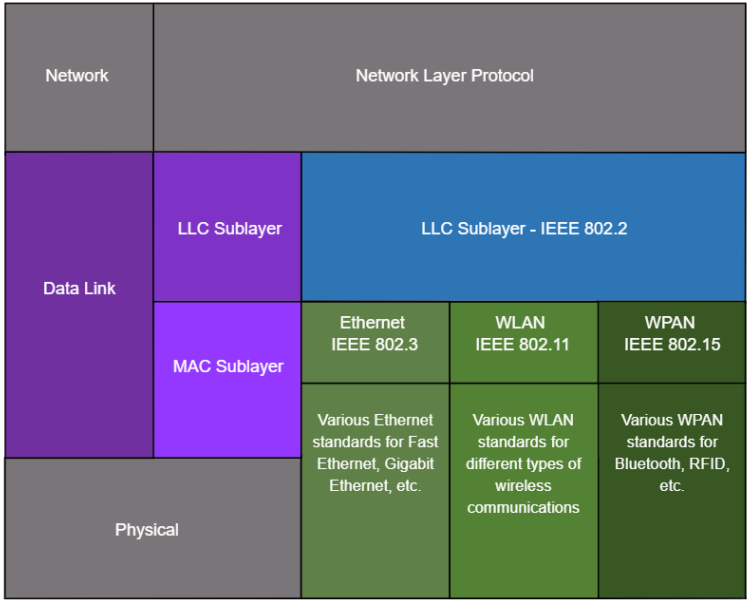
The Data Link Layer Services

- The Data Link layer is responsible
  - Communications between end-device network interface cards.
  - Managing the access of frames to the network media.
  - Specifying the encapsulation method used for specific types of media.
  - Encapsulating Layer 3 packets (IPv4 and IPv6) into Layer 2 Frames.
  - Packaging various Layer 3 PDUs into a frame format that is compatible with the network interface.
  - Performing error detection and rejects corrupts frames.
  - Shielding the upper layer protocols from being aware of the physical medium to be used in the communication.



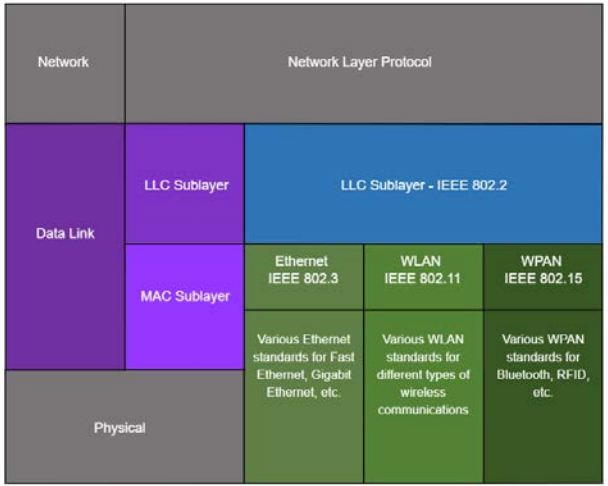
IEEE 802 LAN/MAN Data Link Sublayers

- IEEE 802 LAN/MAN standards are specific to the type of network (Ethernet, WLAN, WPAN, etc.).
- The Data Link Layer consists of two sublayers:
  1. **Logical Link Control (LLC)**
     - Communicates with the network layer
     - Identifies which network layer protocol is being used for the frame
     - Encapsulates packets into frames
     - Allows multiple Layer 3 protocols, such as IPv4 and IPv6, to utilize the same network interface and media
     - Add layer 2 control information to network protocol data



IEEE 802 LAN/MAN Data Link Sublayers

- The Data Link Layer consists of two sublayers:
  2. **Media Access Control (MAC)**
     - The MAC sublayer is responsible for data encapsulation
     - Defines the media access processes performed by the hardware
     - Provides data link layer addressing and access to various network technologies
     - Provides a mechanism to allow multiple devices to communicate over a shared medium
     - Controls the NIC responsible for sending and receiving data on the physical medium
     - Provides synchronization between nodes
     - Communicates with Ethernet to send and receive frames over copper or fiber-optic cable
     - Communicates with wireless technologies such as Wi-Fi and Bluetooth
     - Implements a trailer to performs error detection
     - Provides placement of data frames onto the media



Providing Access to Media

- Physical networks can consist of different types of physical media such as copper wires, optical fibers, and wireless consisting of electromagnetic signals, radio and microwave frequencies, and satellite links .
- Packets exchanged between nodes may experience numerous data link layers and media transitions.
- Data Link layer protocols govern how to format a frame for use on different media.
- The headers of each frame are formatted for the specific medium that it will cross.
- At each hop along the path, a router performs four basic Layer 2 functions:
  - Accepts a frame from the network medium.
  - De-encapsulates the frame to expose the encapsulated packet.
  - Re-encapsulates the packet into a new frame.
  - Forwards the new frame on the medium of the next network segment.

Data Link Layer Standards

- Data link layer protocols are defined by engineering organizations:
  - Institute for Electrical and Electronic Engineers (IEEE).
  - International Telecommunications Union (ITU).
  - International Organizations for Standardization (ISO).
  - American National Standards Institute (ANSI).

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	• 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)

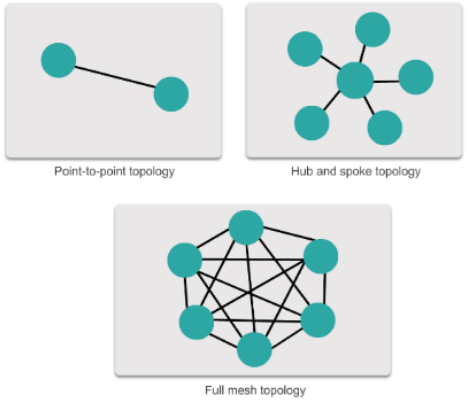
6.2 Topologies

Physical and Logical Topologies

- The topology of a network is the arrangement and relationship of the network devices and the interconnections between them.
- There are two types of topologies used when describing networks:
  - **Physical topology** – shows physical connections and how devices are interconnected.
    - 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 determine the path that will be taken
  - **Logical topology** – identifies the virtual connections between devices using device interfaces and IP addressing schemes.
    - Refers to the way a network transfers frames from one node to the next
    - These logical signal paths are defined by data link layer protocols
    - Determine the media access control method used

WAN Topologies

- There are three common physical WAN topologies:
  - **Point-to-point** – The simplest and most common WAN topology. Consists of a permanent link between two endpoints.
  - **Hub and spoke** – Similar to a star topology where a central site interconnects branch sites through point-to-point links.
  - **Mesh** – Provides high availability but requires every end system to be connected to every other end system.
    - Administrative and physical costs can be significant
    - **Partial Mesh** – Connects some but not all remote sites
  - **Hybrid** – Variation or combination of all three.

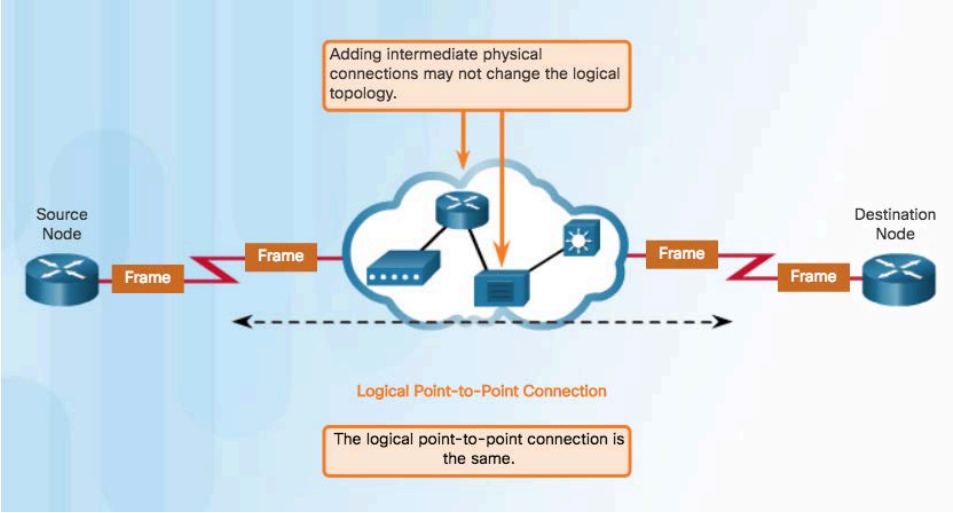


Point-to-Point WAN Topology

- Physical point-to-point topologies directly connect two nodes.
- The nodes may not share the media with other hosts.
- Because all frames on the media can only travel to or from the two nodes, Point-to-Point WAN protocols can be very simple.

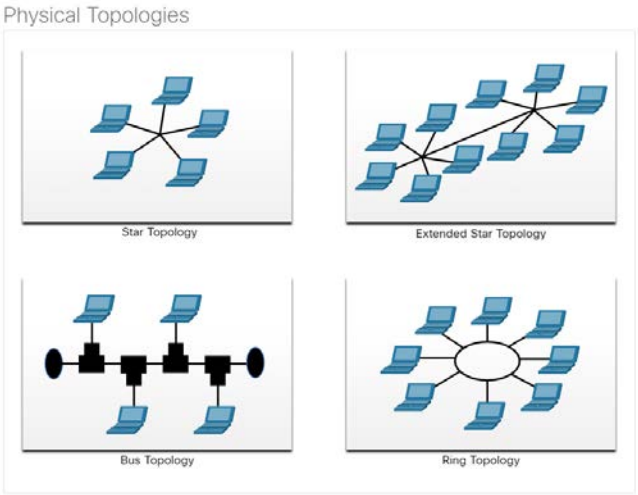
Logical WAN Point-to-Point Topology

- End nodes communicating in a point-to-point network can be physically connected via several different intermediate devices.
- However, the use of physical devices in the network does not affect the logical topology.
- The logical connection between nodes forms what is called a virtual circuit.



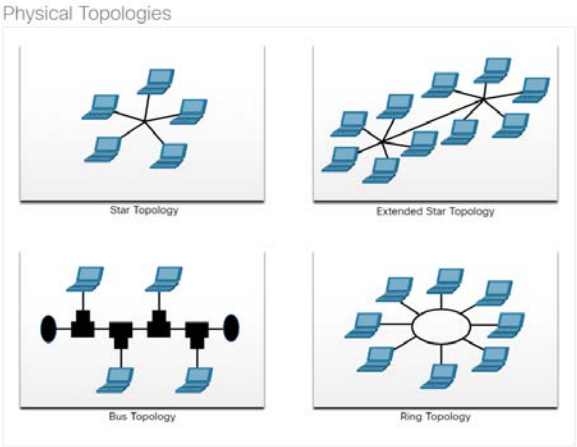
LAN Topologies

- End devices on LANs are typically interconnected using:
  - **Star** – End devices connect to a central intermediate device and use Ethernet switches
  - **Extended Star** – End devices connect to a central intermediate device (switch), which in turn connects to other central intermediate devices (switches)
- Star and extended star topologies are easy to install, very scalable and easy to troubleshoot.



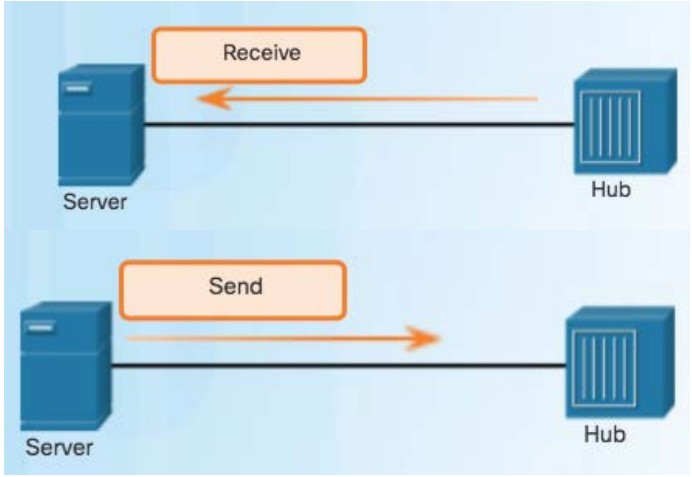
LAN Topologies

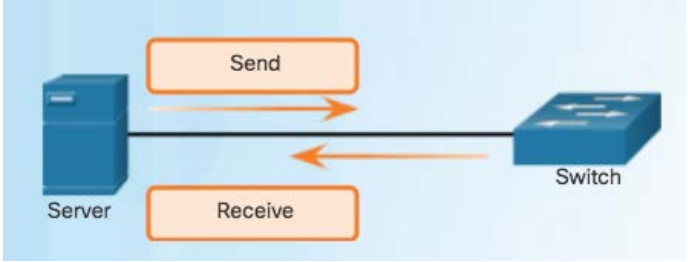
- Early Ethernet and Legacy Token Ring technologies provide two additional topologies:
  - **Bus** – All end systems chained together and terminated on each end.
    - Used in legacy networks
    - All end systems are chained to each other and terminated in some form on each end
    - Switches are not 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
  - **Ring** – Each end system is connected to its respective neighbors to form a ring.
    - Unlike the bus topology, the ring does not need to be terminated
    - Were used in legacy Fiber Distributed Data Interface (FDDI) and Token Ring networks



Half and Full Duplex Communication

- **Half-duplex communication**
  - Only allows one device to send or receive at a time on a shared medium.
  - Used on WLANs and legacy bus topologies with Ethernet hubs.
- **Full-duplex communication**
  - Allows both devices to simultaneously transmit and receive on a shared medium.
  - Data link layer assumes that the media is available for transmission for both nodes at any time.
  - Does not require media arbitration in the data link layer.
  - 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.





Access Control Methods

- **Contention-based access**
  - All nodes operating in half-duplex, competing for use of the medium. Examples are:
    - Carrier sense multiple access with collision detection (CSMA/CD) as used on legacy bus-topology Ethernet.
    - Carrier sense multiple access with collision avoidance (CSMA/CA) as used on Wireless LANs.
- **Controlled access**
  - Deterministic access where each node has its own time on the medium.
  - Used on legacy networks such as Token Ring and ARCNET.

Contention-Based Access – CSMA/CD

- **CSMA/CD**
  - Used by legacy Ethernet LANs.
  - Operates in half-duplex mode where only one device sends or receives at a time.
  - Uses a collision detection process to govern when a device can send and what happens if multiple devices send at the same time.
  - All network devise must listen before transmitting.
  - **CSMA/CD collision detection process**:
    - Devices transmitting simultaneously will result in a signal collision on the shared media.
    - Devices detect the collision.
    - Devices wait a random period of time and retransmit data.

Contention-Based Access – CSMA/CA

- **CSMA/CA**
  - Used by IEEE 802.11 WLANs.
  - Operates in half-duplex mode where only one device sends or receives at a time.
  - Uses a collision avoidance process to govern when a device can send and what happens if multiple devices send at the same time.
- **CSMA/CA collision avoidance process**:
  - When transmitting, devices also include the time duration needed for the transmission.
  - Other devices on the shared medium receive the time duration information and know how long the medium will be unavailable.

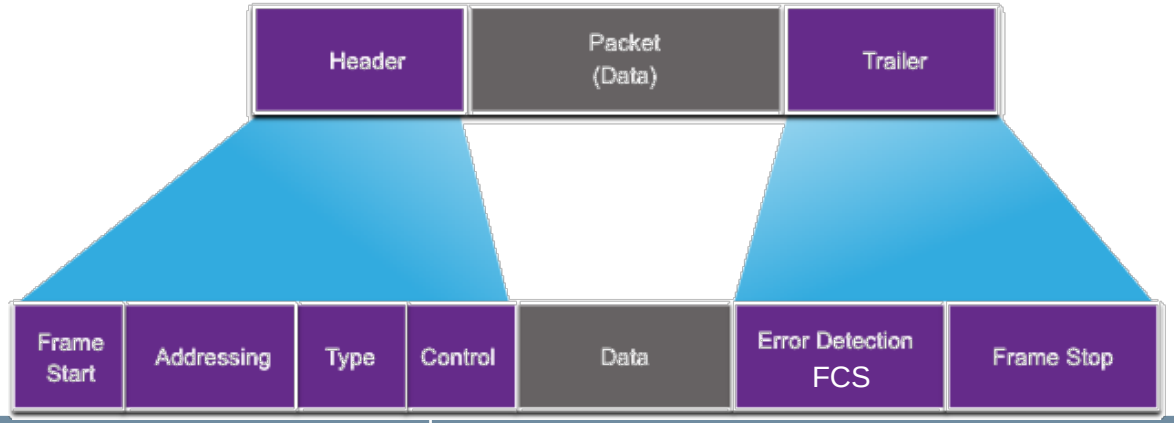
6.3 Data Link Frame

The Frame

- Data is encapsulated by the data link layer with a header and a trailer to form a frame.
- All data link frames has three parts in common:
  - Header
  - Data
  - Trailer
- The fields of the header and trailer vary according to data link layer protocol.
- The amount of control information carried with in the frame varies according to access control information and logical topology.

Frame Fields

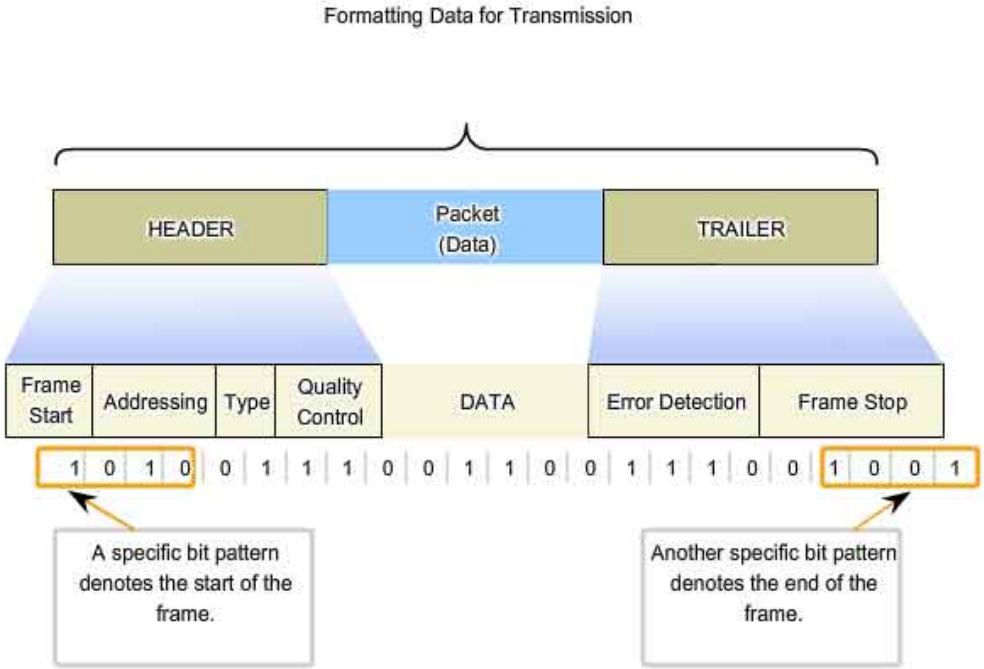
- Structure of the frame and the fields contained in the header and trailer depend on Layer 3 protocols.



Field	Description
Frame Start and Stop	Identifies beginning and end of frame
Addressing	Indicates source and destination nodes
Type	Identifies encapsulated Layer 3 protocol
Control	Identifies flow control services
Data	Contains the frame payload
Error Detection	Used for determine transmission errors
The function of the **Cyclic Redundancy Check (CRC)**, found in the **Frame Check Sum (FCS)** field, is to verify the integrity of the received frame	

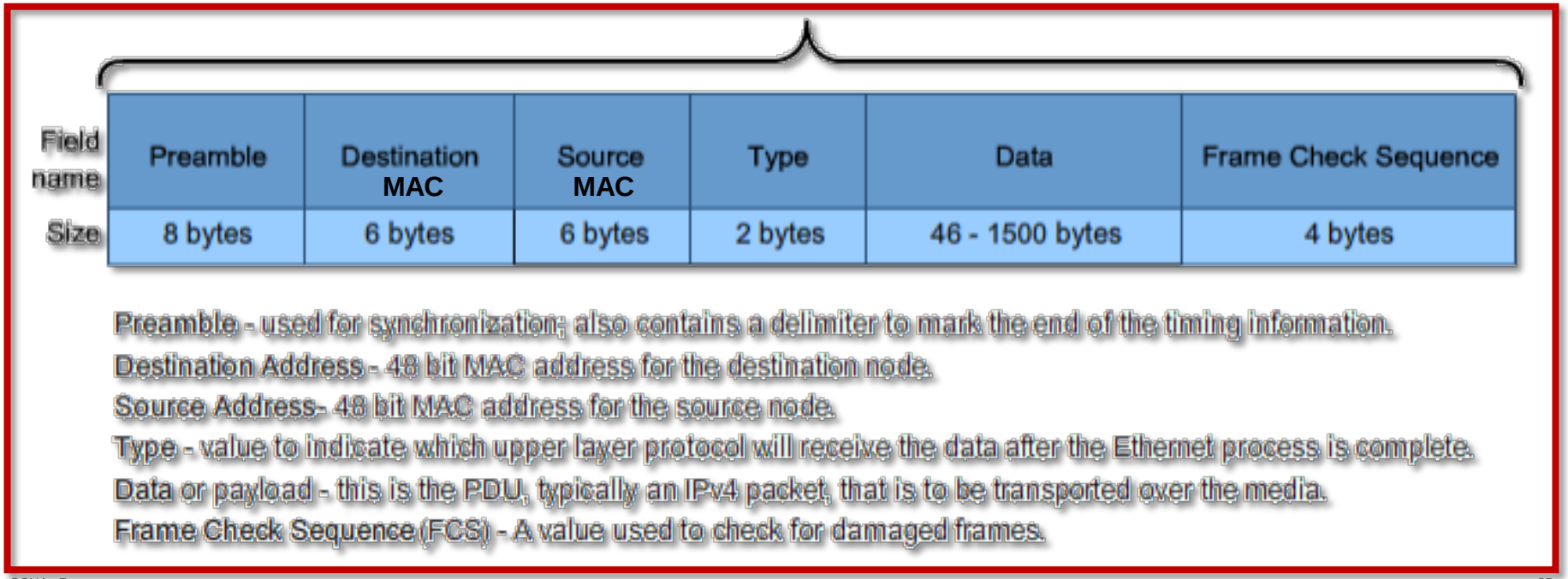
Frame Fields

- The transmitting node inserts start and stop bits into the frame to identify the beginning and end of a frame.



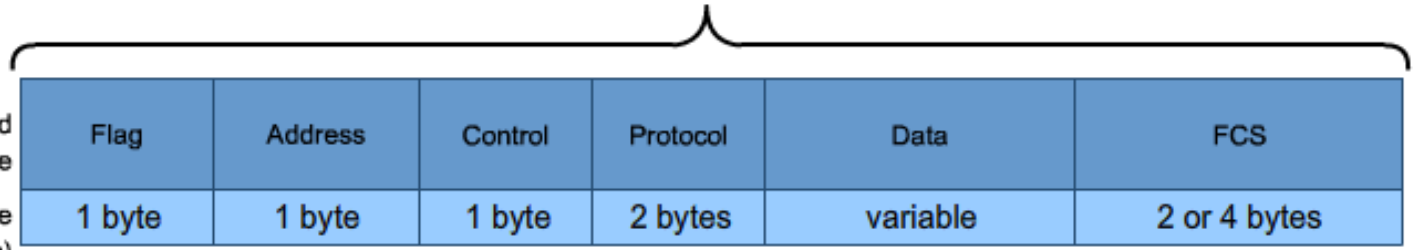
Ethernet Frame

- Ethernet examines the **Frame Check Sum** (FCS) and **minimum frame size** to determine if errors occurred in the transmission and reception before its passed to the data link layer or discarded by the NIC.



Point-to-Point Protocol Frame

A Common Data Link Protocol for WANs



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.

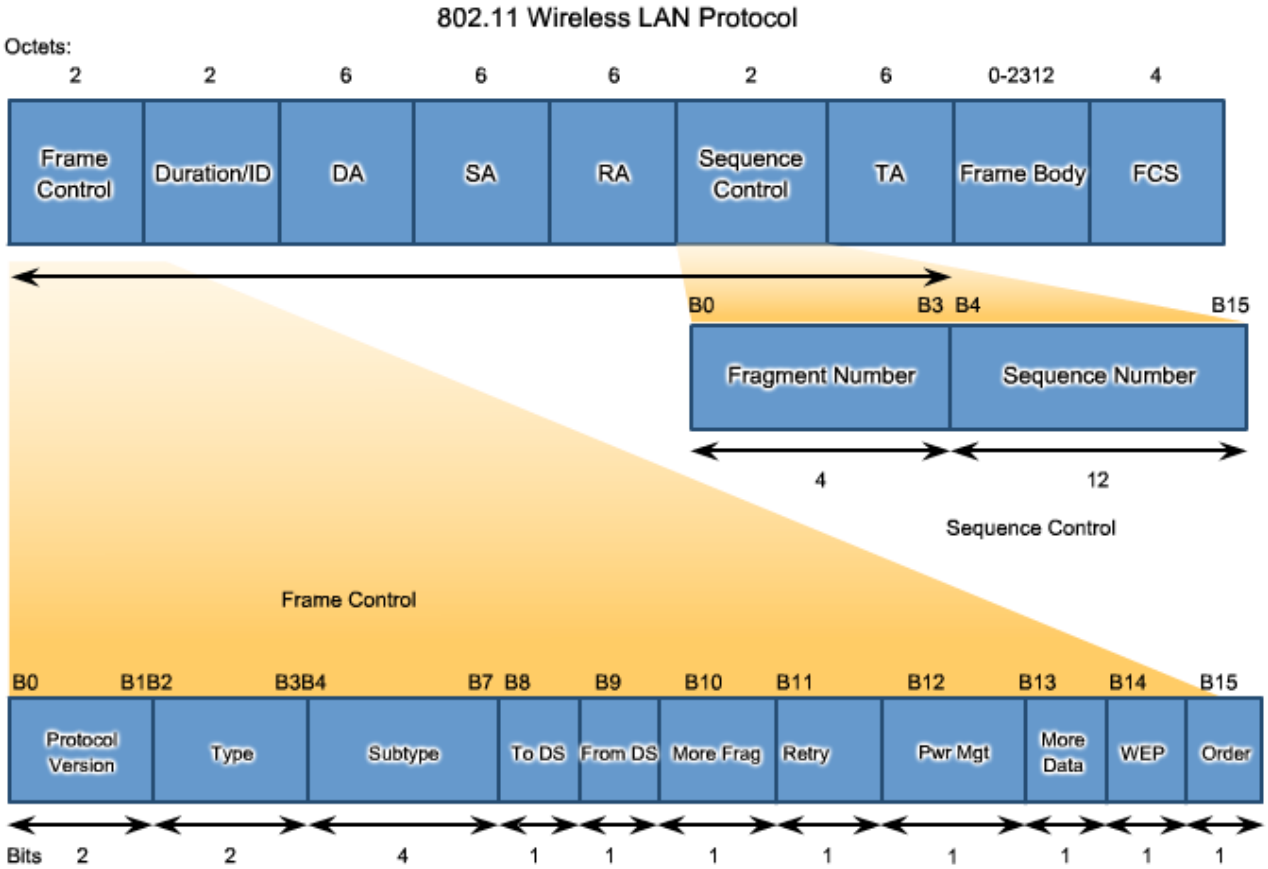
Control- A single byte that contains the binary sequence 00000011, which calls for transmission of user data in an unsequenced frame.

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.

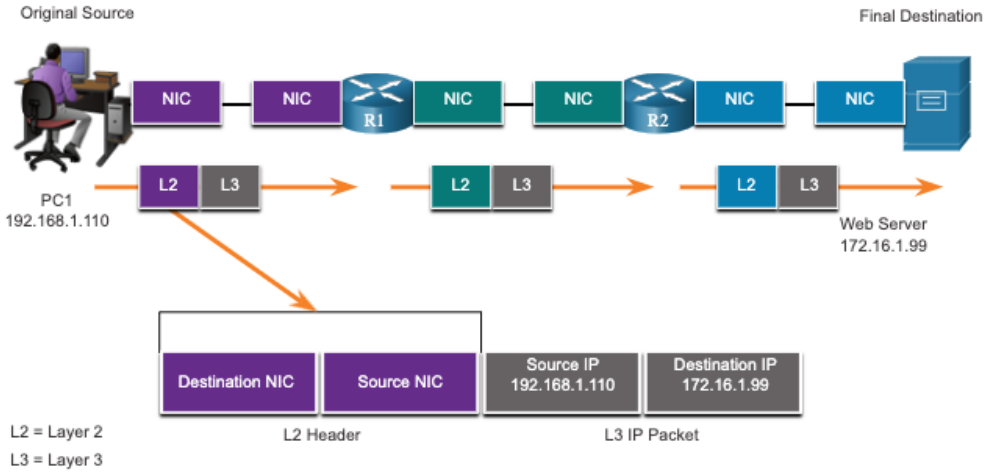
Frame Check Sequence (FCS) - Normally 16 bits (2 bytes). By prior agreement, consenting PPP implementations can use a 32-bit (4-byte) FCS for improved error detection.

802.11 Wireless Frame



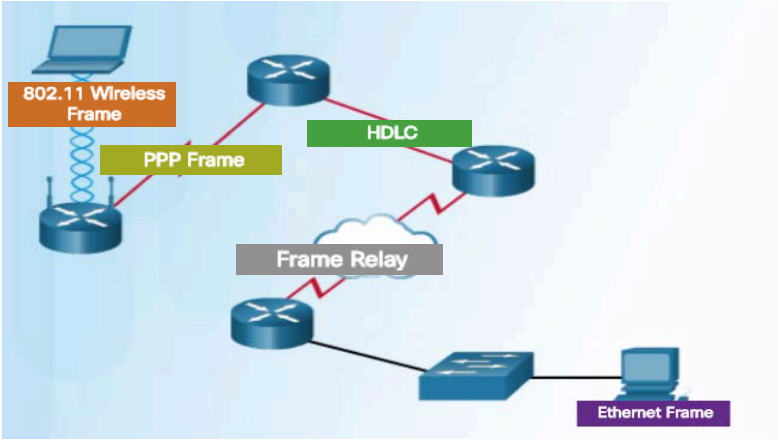
Layer 2 Addresses

- Each data link frame contains the source data link address (Source MAC) of the NIC card sending the frame, and the destination data link address (Destination MAC) of the NIC card receiving the frame.
- Also referred to as a physical address.
- Contained in the frame header.
- Used only for local delivery of a frame on the link.
- Updated by each device that forwards the frame.



LAN and WAN Frames

- The logical topology and physical media determine the data link protocol used:
  - Ethernet
  - 802.11 Wireless
  - Point-to-Point Protocol (PPP)
  - High-Level Data Link Control (HDLC)
  - Frame-Relay
- Each protocol performs media access control for specified logical topologies.



OSI Layers		LAN Specification						
Data Link Layer	LLC Sublayer	Ethernet	IEEE 802.2					
	MAC Sublayer		IEEE 802.3 (Ethernet)	IEEE 802.3u (FastEthernet)	IEEE 802.3z (GigabitEthernet)	IEEE 802.3ab (GigabitEthernet over Copper)	Token Ring/IEEE 802.6	FDDI
Physical Layer	Physical Layer							

6.4 Module Practice and Quiz

What did I learn in this module?

- The data link layer of the OSI model (Layer 2) prepares network data for the physical network.
- The data link layer is responsible for network interface card (NIC) to network interface card communications.
- The IEEE 802 LAN/MAN data link layer consists of the following two sublayers: LLC and MAC.
- The two types of topologies used in LAN and WAN networks are physical and logical.
- Three common types of physical WAN topologies are: point-to-point, hub and spoke, and mesh.

What did I learn in this module?

- Half-duplex communications exchange data in one direction at a time. Full-duplex sends and receives data simultaneously.
- In contention-based multi-access networks, all nodes are operating in half-duplex.
- Examples of contention-based access methods include: CSMA/CD for bus-topology Ethernet LANs and CSMA/CA for WLANs.
- The data link frame has three basic parts: header, data, and trailer.
- Frame fields include: frame start and stop indicator flags, addressing, type, control, data, and error detection.
- Data link addresses are also known as physical addresses.
- Data link addresses are only used for link local delivery of frames.

New Terms and Commands

- Logical Link Control (LLC)
- Medial Access Control (MAC)
- Institute of Electrical and Electronic Engineers (IEEE)
- International Telecommunications Union (ITU)
- International Organization for Standardization (ISO)
- American National Standards Institute (ANSI)
- Physical Topology
- Logical Topology
- Half-duplex
- Full-duplex
- CSMA/CD
- CSMA/CA
- Cyclic Redundancy Check (CRC)
- Contention-based access
- Controlled access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