OSI Data Link Layer

Network Fundamentals – Chapter 7

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Objectives

Explain the role of Data Link layer protocols in data transmission.

Describe how the Data Link layer prepares data for transmission on network media.

Describe the different types of media access control methods.

Identify several common logical network topologies and describe how the logical topology determines the media access control method for that network.

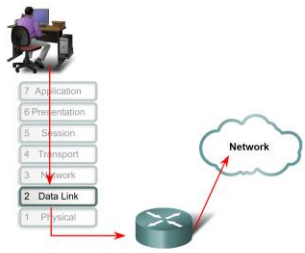
Explain the purpose of encapsulating packets into frames to facilitate media access.

Describe the Layer 2 frame structure and identify generic fields.

Explain the role of key frame header and trailer fields including addressing, QoS, type of protocol and Frame Check Sequence.

Data Link Layer – Accessing the Media

Describe the service the Data Link Layer provides as it prepares communication for transmission on specific media



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

Data Link Role

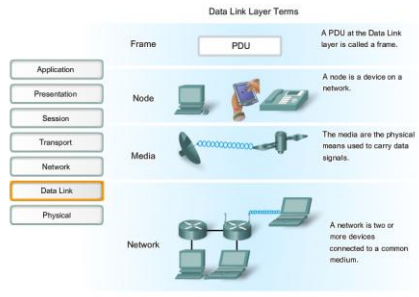
For Network layer packets to be transported from source host to destination host, they must traverse different physical networks.

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.

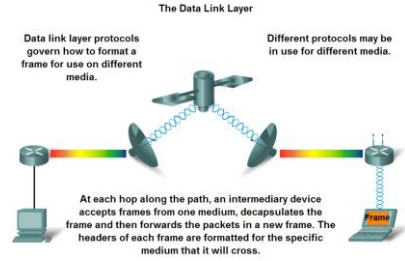
It is the role of the OSI Data Link layer to prepare Network layer packets for transmission and to control access to the physical media.

Data Link Terms



Data Link Layer – Accessing the Media

Describe why Data Link layer protocols are required to control media access



Different Media Requirements

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.

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.

Between the PC and the router may be an Ethernet link.

The routers are connected through a satellite link, and the laptop is connected through a wireless link to the last router.

In this example, as an IP packet travels from the PC to the laptop, it will be encapsulated into Ethernet frame, decapsulated, processed, and then encapsulated into a new data link frame to cross the satellite link.

For the final link, the packet will use a wireless data link frame from the router to the laptop.

Layered Approach to Networking

The Data Link layer effectively insulates the communication processes at the higher layers from the media transitions that may occur end-to-end.

A packet is received from and directed to an upper layer protocol, in this case IPv4 or IPv6, that does not need to be aware of which media the communication will use.

Without the Data Link layer, a Network layer protocol, such as IP, would have to make provisions for connecting to every type of media that could exist along a delivery path.

Moreover, IP would have to adapt every time a new network technology or medium was developed.

This process would hamper protocol and network media innovation and development. This is a key reason for using a layered approach to networking.

Data Link Services

The range of Data Link layer services has to include all of the currently used types of media and the methods for accessing them.

Because of the number of communication services provided by the Data Link layer, it is difficult to generalize their role and provide examples of a generic set of services.

For that reason, please note that any given protocol may or may not support all these Data Link layer services.

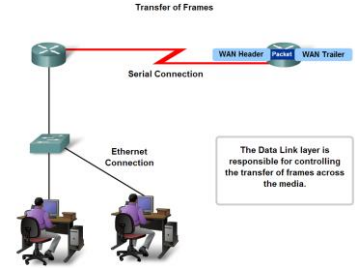
Extra Resources:

http://www.cisco.com/en/US/docs/internetworking/technology/handbook/Intro-to-Internet.html‘

http://www.tcpipguide.com/free/t_IPDatagramSizeMaximumTransmissionUnitMTUFragmentat.htm

Data Link Layer – Accessing the Media

Describe the role of framing in preparing a packet for transmission on a given media



Media Access Control

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.

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.

There are two types: Deterministic and Non-Deterministic

How devices handle access to the medium

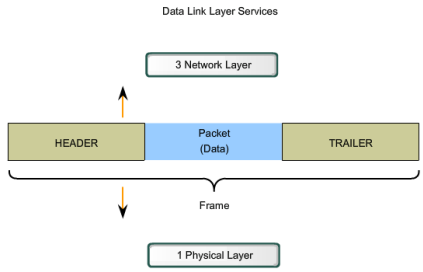
A node that is an end device uses an adapter to make the connection to the network e.g. NIC card

At intermediary devices such as a router, where the media type could change for each connected network, different physical interfaces on the router are used to encapsulate the packet into the appropriate frame, and a suitable media access control method is used to access each link.

The router in the figure has an Ethernet interface to connect to the LAN and a serial interface to connect to the WAN.

As the router processes frames, it will use Data Link layer services to receive the frame from one medium, decapsulate it to the Layer 3 PDU, re-encapsulate the PDU into a new frame, and place the frame on the medium of the next link of the network.

Data Link Layer Services



Header Information

The Data Link layer prepares a packet for transport across the local media by encapsulating it with a header and a trailer to create a frame.

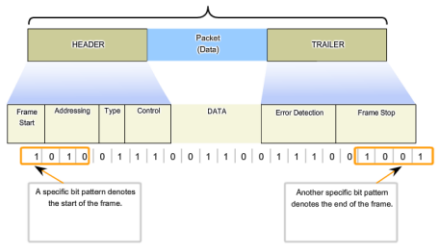
The Data Link layer frame includes:

1. **Data** - The packet from the Network layer
2. **Header** - Contains control information, such as addressing, and is located at the beginning of the PDU
3. **Trailer** - Contains control information added to the end of the PDU

NB: Control information may tell:

1. ***Which nodes are in communication with each other***
2. ***When communication between individual nodes begins and when it ends***
3. ***Which errors occurred while the nodes communicated***
4. ***Which nodes will communicate next***

Formatting Data For Transmission



Data Link Frame Fields

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.

Typical field types include:

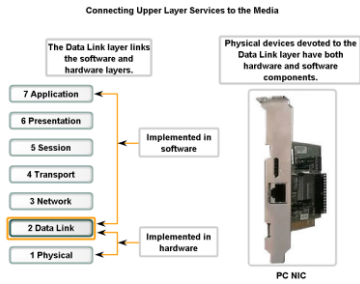
Start and stop indicator fields - The beginning and end limits of the frame

1. Naming or addressing fields
2. Type field - The type of PDU contained in the frame
3. Control - Flow control services
4. A data field -The frame payload (Network layer packet)

Fields at the end of the frame form the trailer. These fields are used for error detection and mark the end of the frame.

Data Link Layer – Accessing the Media

Describe the role the Data Link layer plays in linking the software and hardware layers



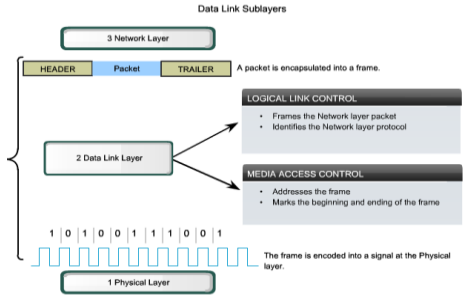
Data Link – Hardware and Software

The Data Link layer exists as a connecting layer between the software processes of the layers above it and the Physical layer below it.

As such, it prepares the Network layer packets for transmission across some form of media, be it copper, fiber, or the atmosphere.

The NIC is not solely a physical entity, however. Software associated with the NIC enables the NIC to perform its intermediary functions of preparing data for transmission and encoding the data as signals to be sent on the associated media.

Data Link Sublayers



Sublayers

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.

1. 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.
2. 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.

Data Link Layer – Accessing the Media

Identify several sources for the protocols and standards used by the Data Link layer

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)

Data Link Standards

The functional protocols and services at the Data Link layer are described by engineering organizations (such as IEEE, ANSI, and ITU) and communications companies.

Engineering organizations set public and open standards and protocols.

Data Link layer services and specifications are defined by multiple standards based on a variety of technologies and media to which the protocols are applied.

Some of these standards integrate both Layer 2 and Layer 1 services.

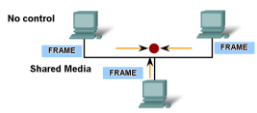
For example, a device implementing the Data Link layer on a computer would be the network interface card (NIC). For a laptop, a wireless PCMCIA adapter is commonly used. Each of these adapters is the hardware that complies with the Layer 2 standards and protocols.

Media Access Control Techniques

Explain the necessity for controlling access to the media

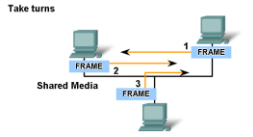
Media Access Control Methods

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.



Media Access

In the same way, there are different ways to regulate the placing of frames onto the media.

The protocols at the Data Link layer define the rules for access to different media.

Some media access control methods use highly-controlled processes to ensure that frames are safely placed on the media.

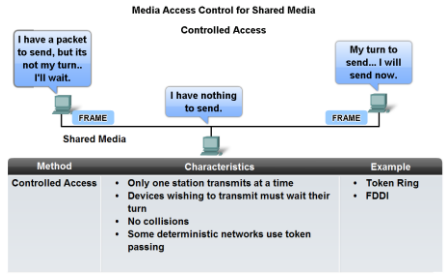
These methods are defined by sophisticated protocols, which require mechanisms that introduce overhead onto the network.

The method of media access control used depends on:

1. Media sharing - If and how the nodes share the media
2. Topology - How the connection between the nodes appears to the Data Link layer

Media Access Control Techniques

Identify two media access control methods for shared media and the basic characteristics of each



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

CSMA/CD and CSMA/CA

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

Controlled Access

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.

Contention Based

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.

CSMA/CD and CSMA/CA

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.

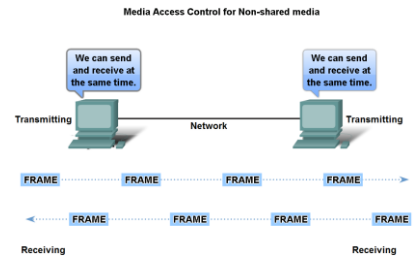
If signals are then detected that show another device was transmitting at the same time, all devices stop sending and try again later. Traditional forms of Ethernet use this method.

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.

Media Access Control Techniques

Define Full Duplex and Half Duplex as it relates to Media Access Control for non-shared media



Half Duplex and 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.

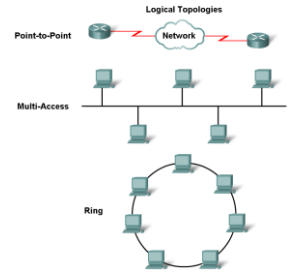
In full-duplex communication, both devices can transmit and receive on the media at the same time.

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.

Media Access Control Techniques

Describe the purpose of a logical topology and identify several common logical topologies



Logical Topology

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.

The physical or cabled topology of a network will most likely not be the same as the logical topology.

Physical Topology

The physical topology is an arrangement of the nodes and the physical connections between them.

Logical topology of a network is closely related to the mechanism used to manage network access.

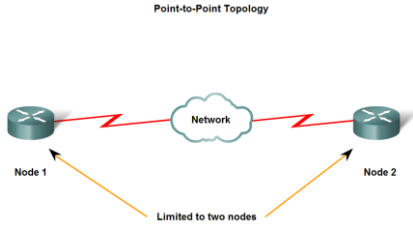
Access methods provide the procedures to manage network access so that all stations have access. When several entities share the same media, some mechanism must be in place to control access. Access methods are applied to networks to regulate this media access. Access methods will be discussed in more detail later.

Logical and physical topologies typically used in networks are:

1. Point-to-Point
2. Multi-Access
3. Ring

Media Access Control Techniques

Identify the characteristics of point-to-point topology and describe the implications for media access when using this topology



Point-to-Point

A point-to-point topology connects two nodes directly together, as shown in the figure. In data networks with point-to-point topologies, the media access control protocol can be very simple.

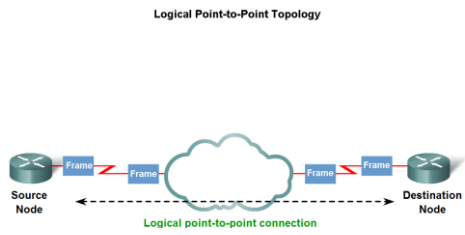
All frames on the media can only travel to or from the two nodes.

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.

Media Access Control Techniques

Contrast logical and physical topologies



Logical Connections

The end nodes communicating in a point-to-point network can be physically connected via a number of intermediate devices.

However the use of physical devices in the network does not affect the logical topology.

As shown in the figure, the source and destination node may be indirectly connected to each other over some geographical distance.

In some cases, the logical connection between nodes forms what is called a virtual circuit.

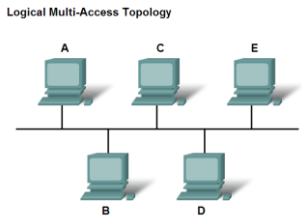
A virtual circuit is a logical connection created within a network between two network devices.

The two nodes on either end of the virtual circuit exchange the frames with each other. This occurs even if the frames are directed through intermediary devices.

Virtual circuits are important logical communication constructs used by some Layer 2 technologies.

Media Access Control Techniques

Identify the characteristics of multi-access topology and describe the implications for media access when using this topology



Logical Multiple Access

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.

The media access control methods used by logical multi-access topologies are typically CSMA/CD or CSMA/CA.

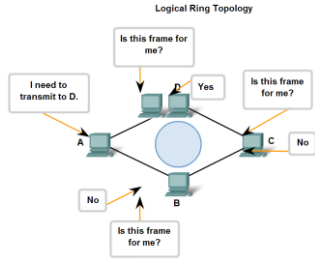
However, token passing methods can also be used.

A number of media access control techniques are available for this type of logical topology.

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.

Media Access Control Techniques

Identify the characteristics of ring topology and describe the implications for media access when using this topology



Logical 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.

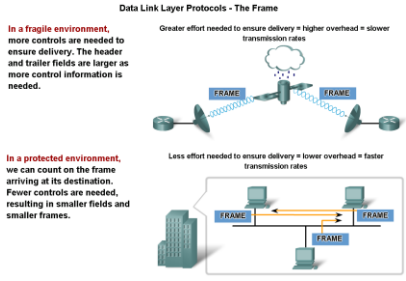
Nodes in a logical ring topology remove the frame from the ring, examine the address, and send it on if it is not addressed for that node.

In a ring, all nodes around the ring- between the source and destination node examine the frame.

Remember that the Data Link layer "sees" a logical ring topology. The actual physical cabling topology could be another topology.

Media Access Control Addressing and Framing Data

Describe the purpose of encapsulating packets into frames to facilitate the entry and exit of data on media



Data Layer Framing

The Data Link layer protocol describes the features required for the transport of packets across different media.

These features of the protocol are integrated into the encapsulation of the frame.

When the frame arrives at its destination and the Data Link protocol takes the frame off the media, the framing information is read and discarded.

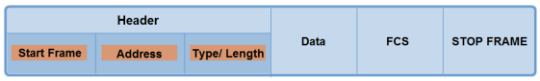
There is no one frame structure that meets the needs of all data transportation across all types of media.

As shown in the figure, 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.

Media access control addressing and framing data

Describe the role of the frame header in the Data Link layer and identify the fields commonly found in protocols specifying the header structure

The Role of the Header

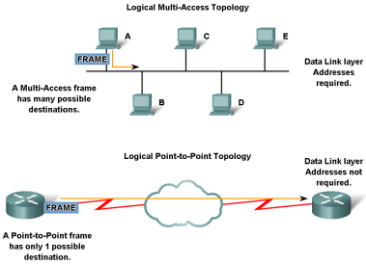


Frame Header Fields

1. **Start Frame field** - Indicates the beginning of the frame
2. **Source and Destination address fields** - Indicates the source and destination nodes on the media
3. **Priority/Quality of Service field** - Indicates a particular type of communication service for processing
4. **Type field** - Indicates the upper layer service contained in the frame
5. **Logical connection control field** - Used to establish a logical connection between nodes
6. **Physical link control field** - Used to establish the media link
7. **Flow control field** - Used to start and stop traffic over the media
8. **Congestion control field** - Indicates congestion in the media

Media access control addressing and framing data

Describe the role of addressing in the Data Link layer and identify cases where addresses are needed and cases where addresses are not needed



Layer 2 Addressing

Because the frame is only used to transport data between nodes across the local media, the Data Link layer address is only used for local delivery.

Addresses at this layer have no meaning beyond the local network.

Compare this to Layer 3, where addresses in the packet header are carried from source host to destination host regardless of the number of network hops along the route.

If the packet in the frame must pass onto another network segment, the intermediate device - a router - will decapsulate the original frame, create a new frame for the packet, and send it onto the new segment.

The new frame will use source and destination addressing as necessary to transport the packet across the new media.

Addressing Requirements

The need for Data Link layer addressing at this layer depends on the logical topology.

Point-to-point topologies, with just two interconnected nodes, do not require addressing.

Once on the medium, the frame has only one place it can go.

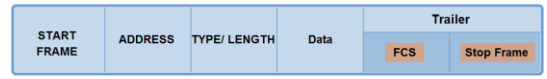
Because ring and multi-access topologies can connect many nodes on a common medium, addressing is required for these typologies.

When a frame reaches each node in the topology, the node examines the destination address in the header to determine if it is the destination of the frame.

Media access control addressing and framing data

Describe the importance of the trailer in the Data Link layer and its implications for use on Ethernet, a "non-reliable" media

The Role of the Trailer



Frame Check Sequence

The Frame Check Sequence (FCS) field is used to determine if errors occurred in the transmission and reception of the frame.

Error detection is added at the Data Link layer because this is where data is transferred across the media.

The media is a potentially unsafe environment for data.

The signals on the media could be subject to interference, distortion, or loss that would substantially change the bit values that those signals represent.

The error detection mechanism provided by the use of the FCS field discovers most errors caused on the media.

Cyclic Redundancy Check

To ensure that the content of the received frame at the destination matches that of the frame that left the source node, a transmitting node creates a logical summary of the contents of the frame.

This is known as the cyclic redundancy check (CRC) value. This value is placed in the Frame Check Sequence (FCS) field of the frame to represent the contents of the frame.

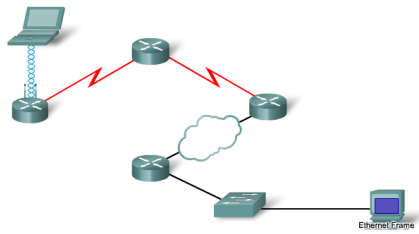
When the frame arrives at the destination node, the receiving node calculates its own logical summary, or CRC, of the frame.

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.

Data Link Layer Protocols

Examples of Layer 2 Protocols



Data Layer Protocols

Protocols that will be covered in CCNA courses include:

1. Ethernet
2. Point-to-Point Protocol (PPP)
3. High-Level Data Link Control (HDLC)
4. Frame Relay
5. Asynchronous Transfer Mode (ATM)

Each protocol performs media access control for specified Layer 2 logical topologies.

This means that a number of different network devices can act as nodes that operate at the Data Link layer when implementing these protocols.

These devices include the network adapter or network interface cards (NICs) on computers as well as the interfaces on routers and Layer 2 switches.

Ethernet

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

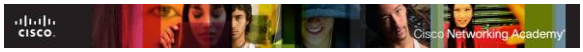
Point-to-Point Protocol

A Common Data Link Protocol for WANs

Frame

Field name	Flag	Address	Control	Protocol	Data	FCS
Size (bytes)	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.



Summary

In this chapter, you learned to:

- Explain the role of Data Link layer protocols in data transmission.
- Describe how the Data Link layer prepares data for transmission on network media.
- Describe the different types of media access control methods.
- Identify several common logical network topologies and describe how the logical topology determines the media access control method for that network.
- Explain the purpose of encapsulating packets into frames to facilitate media access.
- Describe the Layer 2 frame structure and identify generic fields.
- Explain the role of key frame header and trailer fields, including addressing, QoS, type of protocol, and Frame Check Sequence.