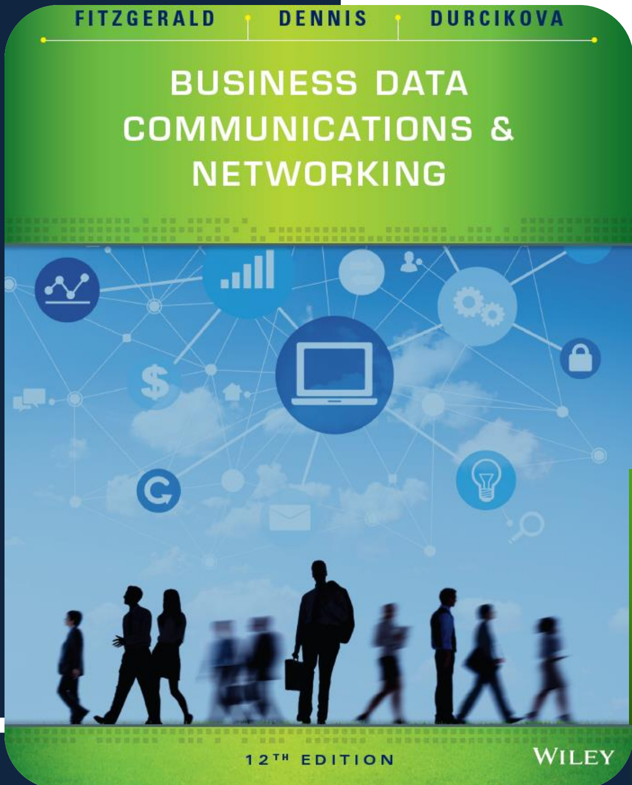

Business Data Communications & Networking

Chapter 4

Data Link Layer

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Outline

- Data Link Layer
  - Media Access Control
    - Controlled Access
    - Contention Access
  - Error Control
    - Prevention
    - Detection
    - Correction
  - Protocols
    - Async
    - SDLC
    - Ethernet
    - PPP
    - Transmission Efficiency and Throughput
- Implications for Management

Data Link Layer

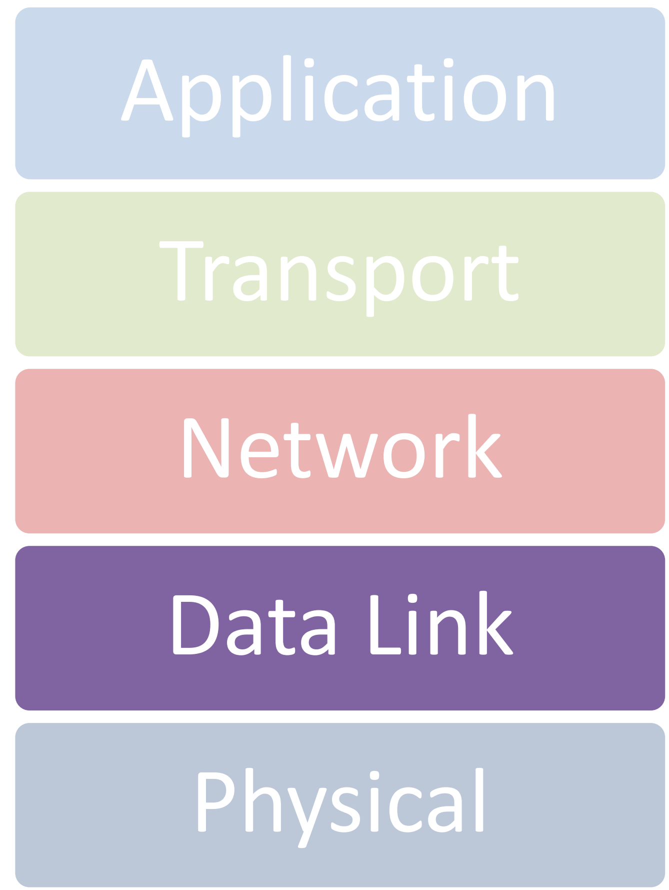
- Layer 2 in the Internet model
- Responsible for moving messages from one device to another

- Controls the way messages are sent on media

- Organizes physical layer bit streams into coherent messages for the network layer

- Major functions of a data link layer protocol
  - Media Access Control
  - Error Control
  - Message Delineation

Internet Model



Outline

- Media Access Control
  - Controlled Access
  - Contention Access
- Error Control
  - Prevent
  - Detect
  - Correct
- Protocols
  - Message Delineation
  - Ethernet
  - PPP
  - Transmission Efficiency

Media Access Control

- Controls which device transmits and when
- Important on
  - Multipoint (shared) circuits
  - Half-duplex point-to-point circuits
- Two approaches to control
  1. Contention access
  2. Controlled access

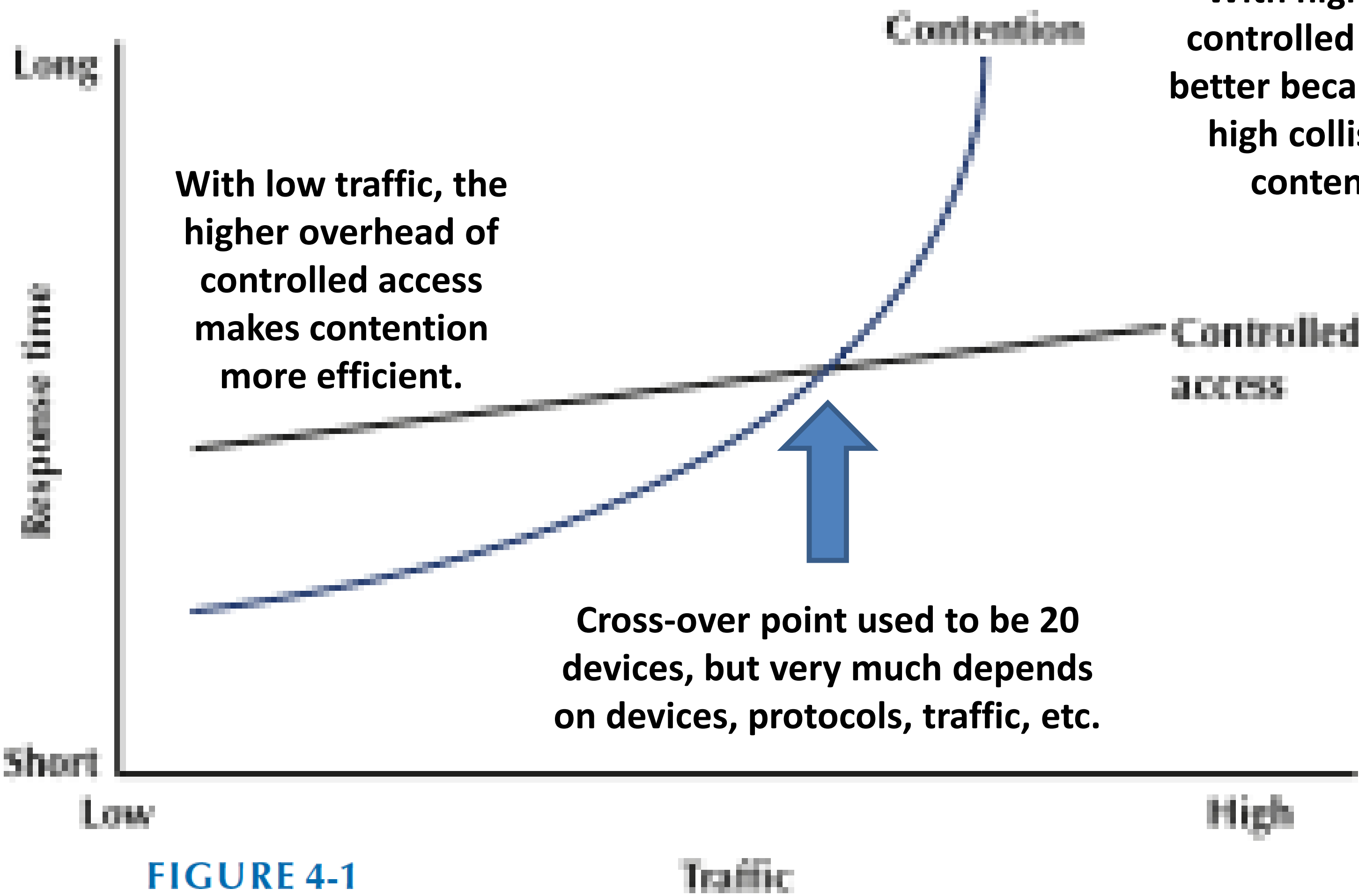
Media Access Control

- Contention
  - Transmit whenever circuit is available with no centralized control
  - Common in Ethernet LANs
  - When devices transmit at the same time, a **collision** occurs
  - Devices must be "polite" and follow these steps:
    1. "Listen" for traffic
    2. If another device is transmitting, wait to transmit
    3. Otherwise, transmit (and keep listening)
    4. If another device begins to transmit, stop and wait

Media Access Control

- Controlled access
  - Common in wireless LANs
  - **Access Request**
    - Each device must get "permission" to transmit, similar to raising a hand
  - **Polling**
    - **Roll-call polling**
      - Central device (controller) determines which devices can transmit
      - Each client is checked periodically to see if it needs to transmit
    - **Hub Polling (token passing)**
      - One device begins the poll and then passes it to another device until it reaches them all

Media Access Control



With low traffic, the higher overhead of controlled access makes contention more efficient.

With high traffic, controlled access is better because of the high collisions of contention.

Cross-over point used to be 20 devices, but very much depends on devices, protocols, traffic, etc.

FIGURE 4-1
Relative response times

Error Control

- Network errors
  - Types
    - Corrupted data
    - Lost data
  - Caused by problems in transmission (not humans)
- Networks should be designed with:
  - Error prevention
  - Error detection
  - Error correction

Sources of Network Errors

- Line noise and distortion
  - Major reason for errors and caused by several sources
  - More likely on electrical media
  - Undesirable electrical signal
  - Degrades performance of a circuit
  - Manifestation
    - Extra bits
    - “Flipped” bits
    - Missing bits

Error Prevention

Source of Error	What Causes It	How to Prevent or Fix
White Noise	Movement of electrons	Increase signal strength
Impulse Noise	Sudden increases in electricity (e.g., lightning)	Shield or move the wires
Cross-talk	Multiplexer guardbands too small or wires too close together	Increase the guardbands or move or shield the wires
Echo	Poor (misaligned) connections	Fix the connections or tune equipment
Attenuation	Gradual decrease in signal over distance	Use repeaters
Intermodulation noise	Signals from several circuits combine	Move or shield the wires

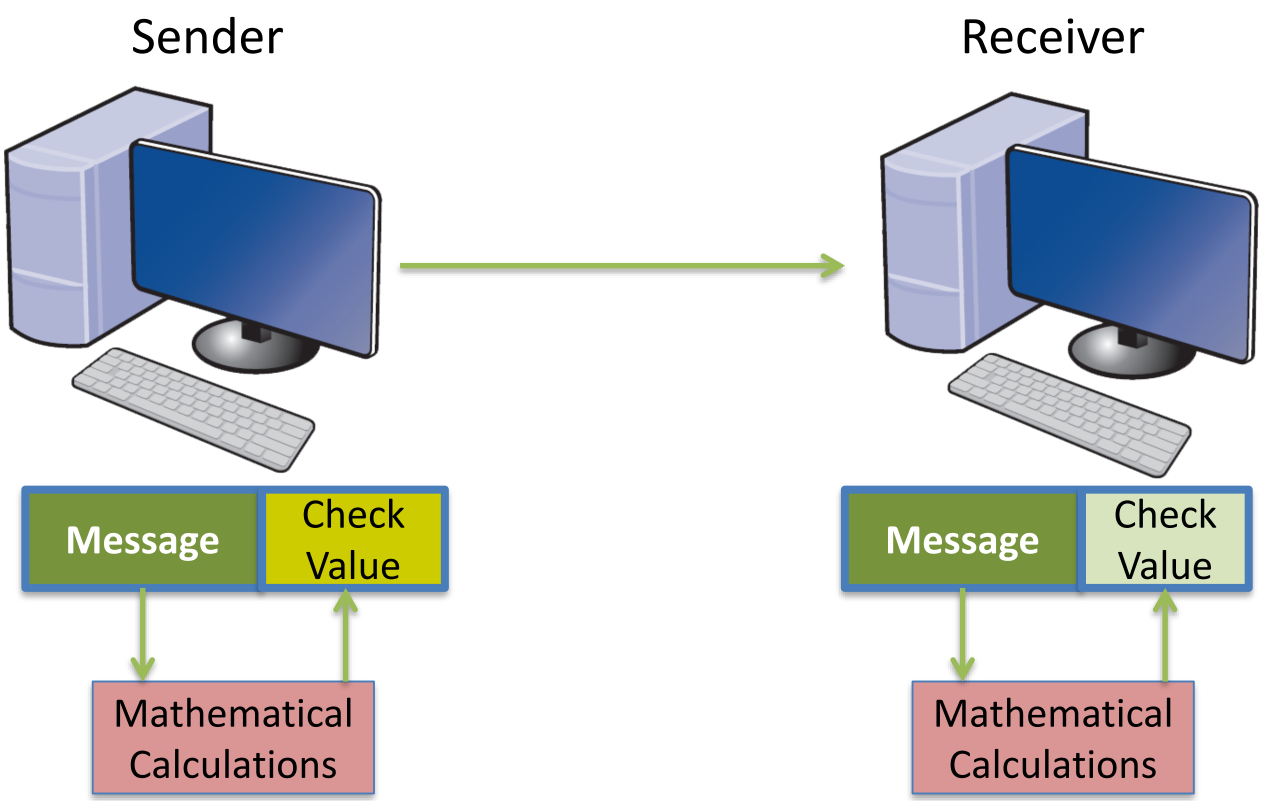
Error Detection

- Receivers need to know when the data transmitted is not correct
- Add "check value" (error detection value) to message

- Check value produced by mathematical formula

Error Detection

- Both sender and receiver calculate check value
- Sender tests whether the check values match



Error Detection

- Parity check
  - 1-bit check value
  - Based on the number of 1's in the message
    - Even parity: number of 1's remains even
    - Odd parity: number of 1's remains odd
  - Simple, but only detects 50% of errors

<u>Example (Even Parity)</u>

Character: 'A'
Binary: 01000001
Parity Bit: 0

Character: 'C'
Binary: 01000011
Parity Bit: 1

Error Detection

- Checksum
  - 1-byte (typically) check value
  - Checksum algorithms vary in the creation of check values
  - Detects 95% of errors

Error Detection

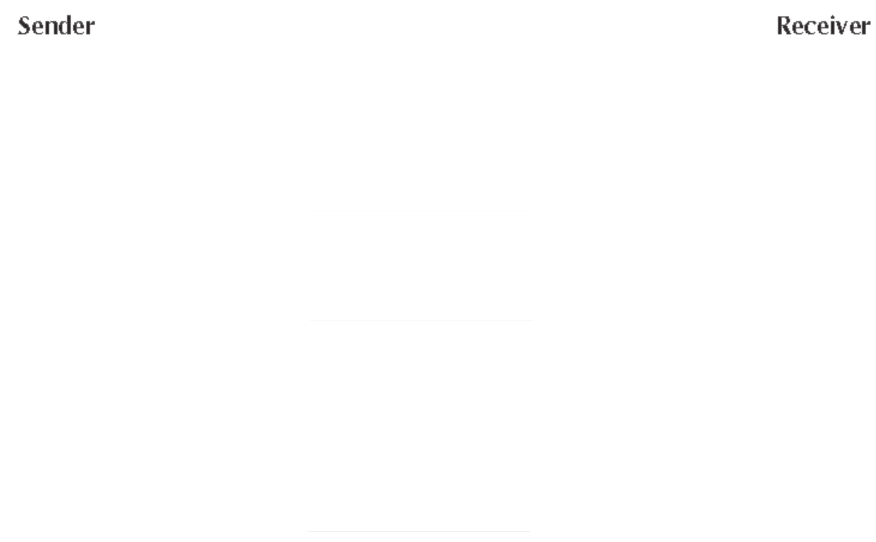
- Cyclic redundancy check (CRC)
  - Treats message as a single binary number
  - Divides by a preset number
  - Uses remainder as the check value
- Preset number is chosen so that remainder is the correct number of bits
- Modes:
  - CRC-16 (~99.998% error detection rate)
  - CRC-32 (>99.99999% error detection rate)

Error Correction

- Once detected, errors must be corrected
- Error correction techniques
  - Retransmission (or backward error correction)
    - Retransmission is simple and most common
    - Automatic Repeat reQuest (ARQ)
      - Stop-and-wait ARQ
      - Continuous ARQ
    - This can also provide flow control by limiting the number of messages sent
  - Forward error correction
    - Receiving device can correct messages without retransmission

Error Correction

- Stop-and-wait ARQ
  1. Receiver receives frame and sends:
     - Acknowledgement (ACK) if no error
     - Negative acknowledgement (NAK) if error
  2. If NAK, sender re-sends data



Error Correction

- Stop-and-wait ARQ
  3. If no ACK or NAK, Sender retransmits frame after "timeout"
  4. If no ACK, sender re-sends data, receiver sends ACK and deletes duplicate frame

Sender

Receiver

Error Correction

Sender

Receiver

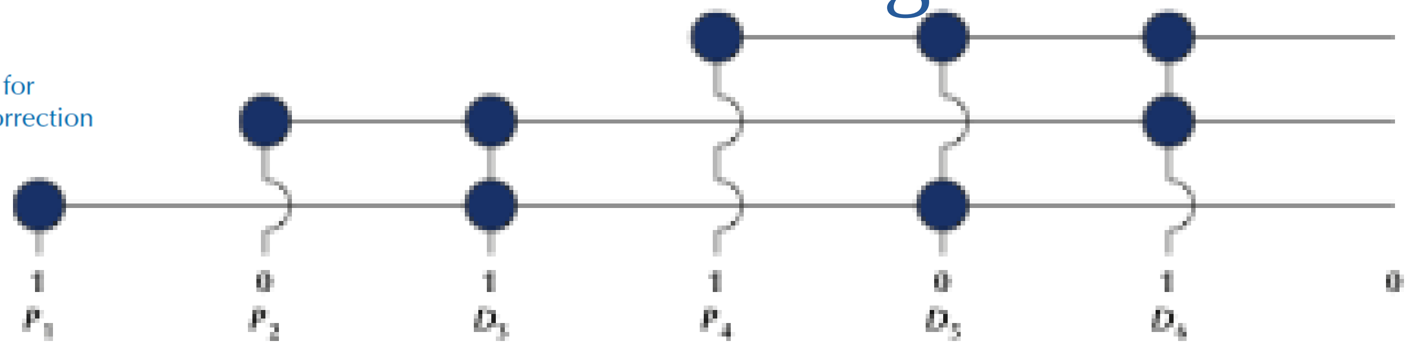
- Continuous ARQ
  - Sender does not wait for ACKs before sending more data
  - "Sliding window" is number of frames allowed to be unacknowledged by receiver
  - Agreed upon by sender and receiver

Error Correction

- Forward error correction
  - Includes a certain level of redundancy in transmitted data so that receiving device can correct errors
  - Does not require retransmission
  - Used only when retransmission is impossible, very costly, or time consuming (e.g., satellite connections)

Error Correction - Hamming Code

FIGURE 4-6
Hamming code for forward error correction



Checking relations between parity bits (P) and data bits (D)

Each data bit figures into three EVEN parity bit calculations

√ = Corresponding parity check is correct

X = Corresponding parity check fails

P_4	P_2	P_1	Determines in which bit the error occured
√	√	√	no error
√	√	X	P_1
√	X	√	P_2
√	X	X	D_3
X	√	√	P_4
X	√	X	D_5
X	X	√	D_6
X	X	X	D_7

Interpreting parity bit patterns

If any one bit (parity or data) changes → change in data bit can be detected and corrected

Only works for one bit errors

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Error Correction

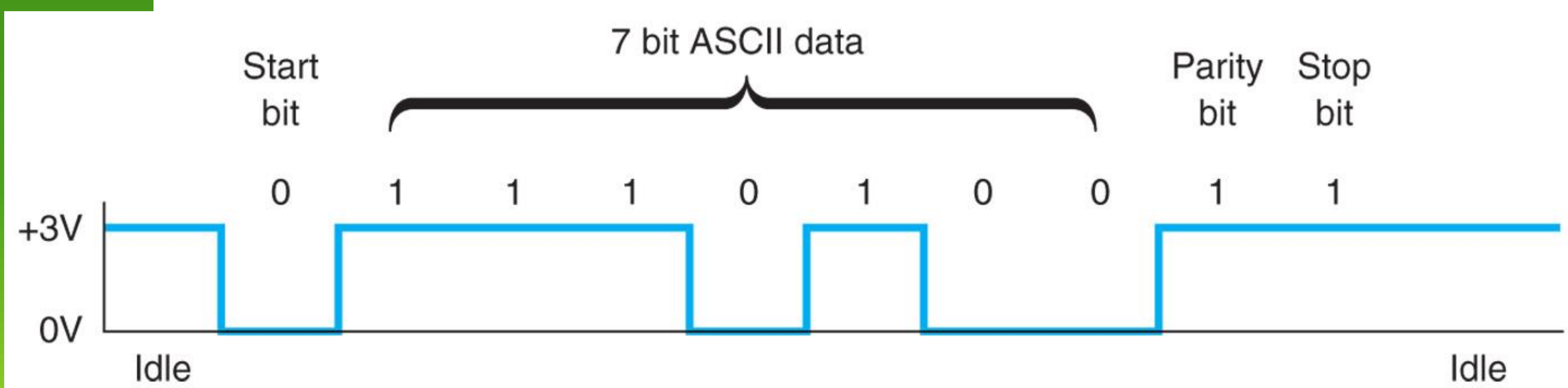
- Error control in practice
  - On wired connections, errors are quite rare
  - Most data link layer software today does not correct errors, only detect them and discard frames with errors
  - Error correction must then be done at a higher layer (Transport)

Data Link Protocols

- Classification
  - Asynchronous transmission
  - Synchronous transmission
- Protocols differ by
  - Message delineation
  - Frame length
  - Frame field structure

Data Link Protocols

- Asynchronous serial transmission (async)
  - Old protocol (e.g., used in teletype)
  - Transmits one character at a time
  - Delineation indicated by start and stop bits



Data Link Protocols

- Synchronous transmission
  - Data sent in a large block called a frame
  - Includes addressing information
  - Includes synchronization characters to let the receiver know when data transmission begins
  - Example protocols: SDLC, HDLC, Ethernet, PPP

Data Link Protocols

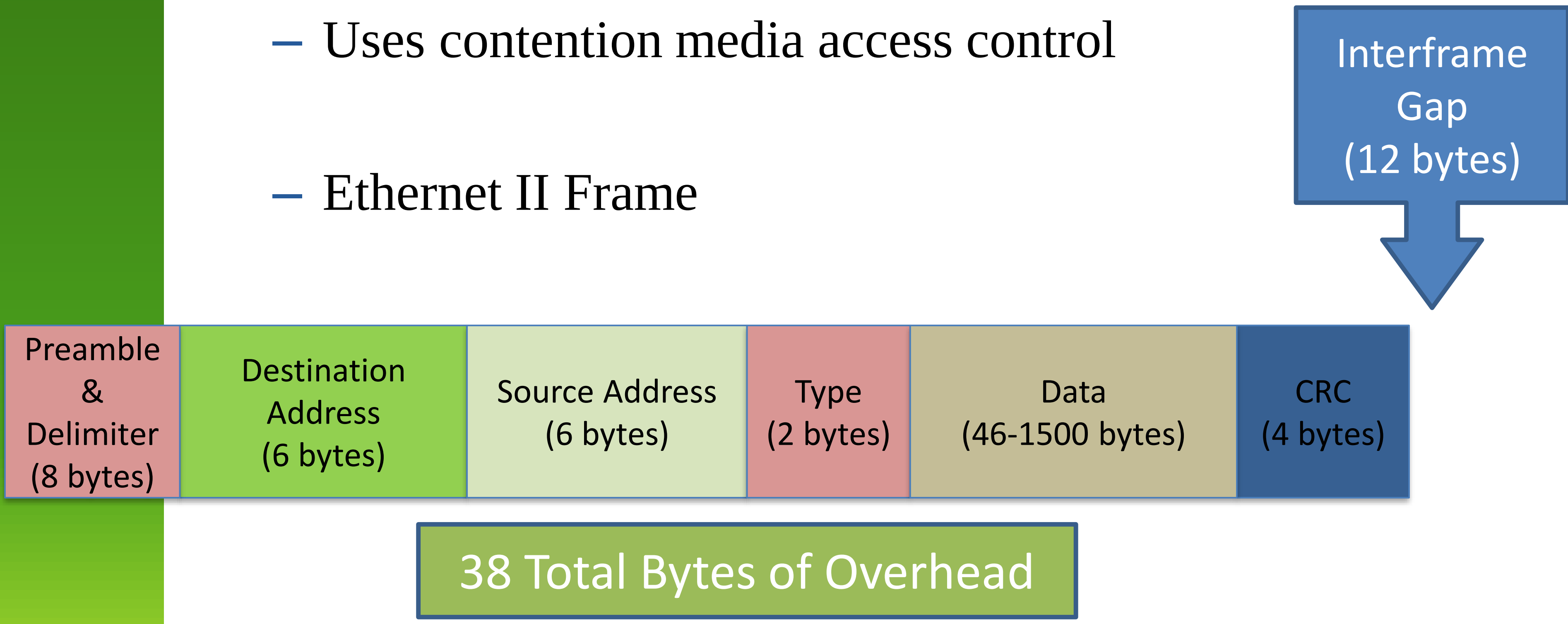
- Synchronous Data Link Control (SDLC)
  - Synchronous bit-oriented protocol developed by IBM
  - Uses bit stuffing (zero insertion) to overcome transparency problem

Flag (8 bits)	Address (8 bits)	Control (8 bits)	Data (variable)	CRC-32 (32 bites)	Flag (8 bits)

Data Link Protocols

- Ethernet
  - IEEE 802.3 standard and Ethernet II
  - Most widely used LAN protocol
  - Uses contention media access control

  - Ethernet II Frame



Data Link Protocols

- Point-to-point protocol (PPP)
  - Common WAN protocol

Flag (1 byte)	Address (1 byte)	Control (1 byte)	Protocol (2 bytes)	Data (variable)	CRC (2 or 4 bytes)	Flag (1 byte)

Transmission Efficiency

- Protocol design contributes to network efficiency
- Transmission Efficiency

$$= \frac{\#\ of\ information\ bits\ (or\ bytes)}{\#\ of\ information + overhead\ bits\ (or\ bytes)}$$

- Async Effiency = 8/(8+3) = 0.73 = 73%

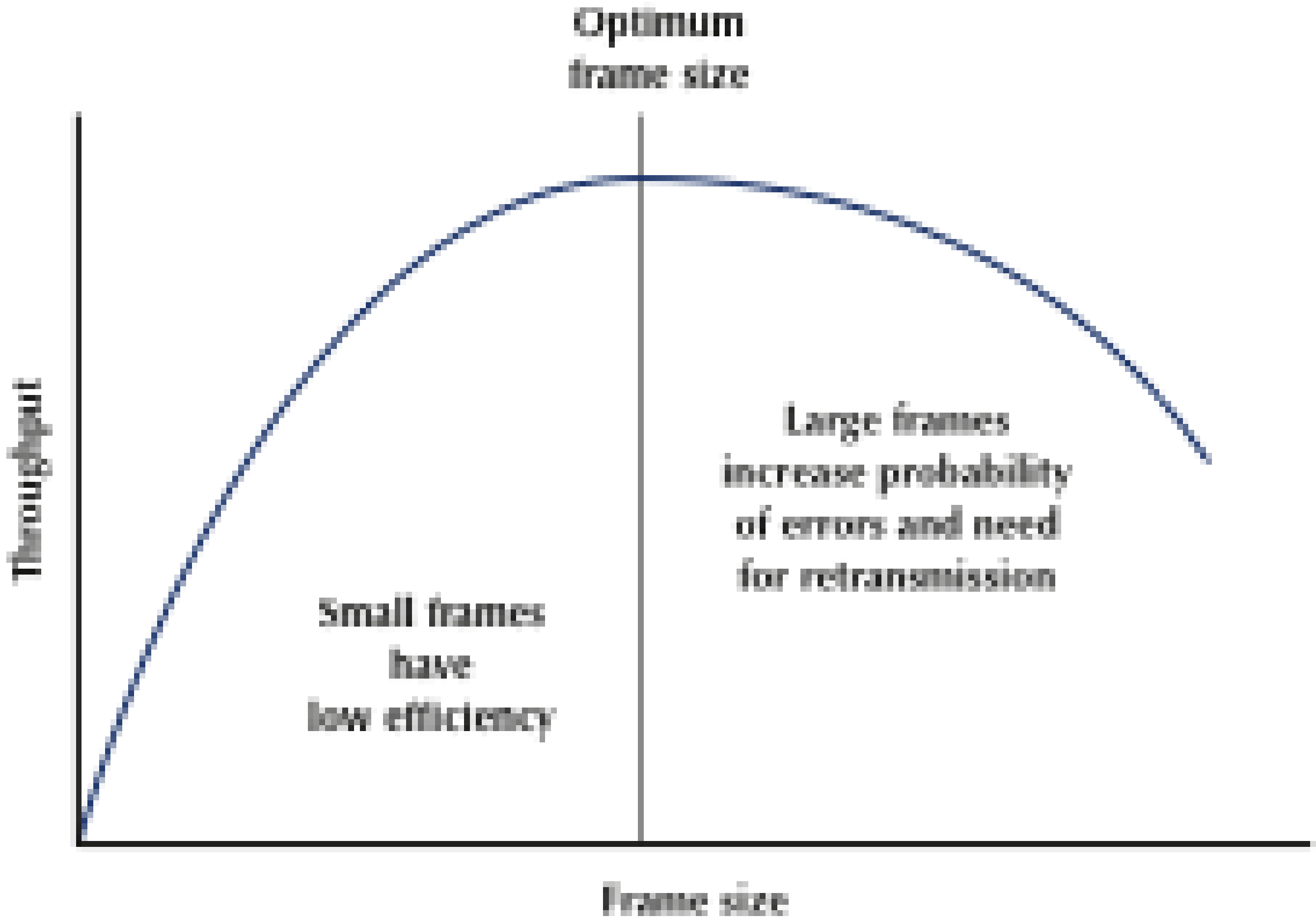
- How can we increase efficiency?
  - Increase Data bits
  - Decrease Overhead bits

- What is the efficiency if you send 342 bytes over Ethernet II?
- What is the efficiency if you send 722 bytes over Ethernet II?

Data Link Protocols

FIGURE 4-12

Frame size effects on throughput



Throughput

- More complicated than simple protocol efficiency because it depends on the retransmission rate, transmission rate, and delay
- **Transmission Rate of Information Bits (TRIB)** is a measure of the effective # of bits transmitted in a unit of time

Throughput

- $$\text{TRIB} = \frac{K(M - C)(1 - P)}{(M/R) + T}$$

- K = information bits per character
- M = frame length in characters
- R = data transmission rate in characters/sec
- C = average number of non-information characters per frame (control characters)
- P = probability that a frame will require retransmission
- T = time delay between frames (in seconds)

Implications for Management

- Industry has seen a rapid consolidation in the number of data link layer protocols
- Use fewer, well-established protocols for simpler network management, greater access to trained experts, and less expensive equipment