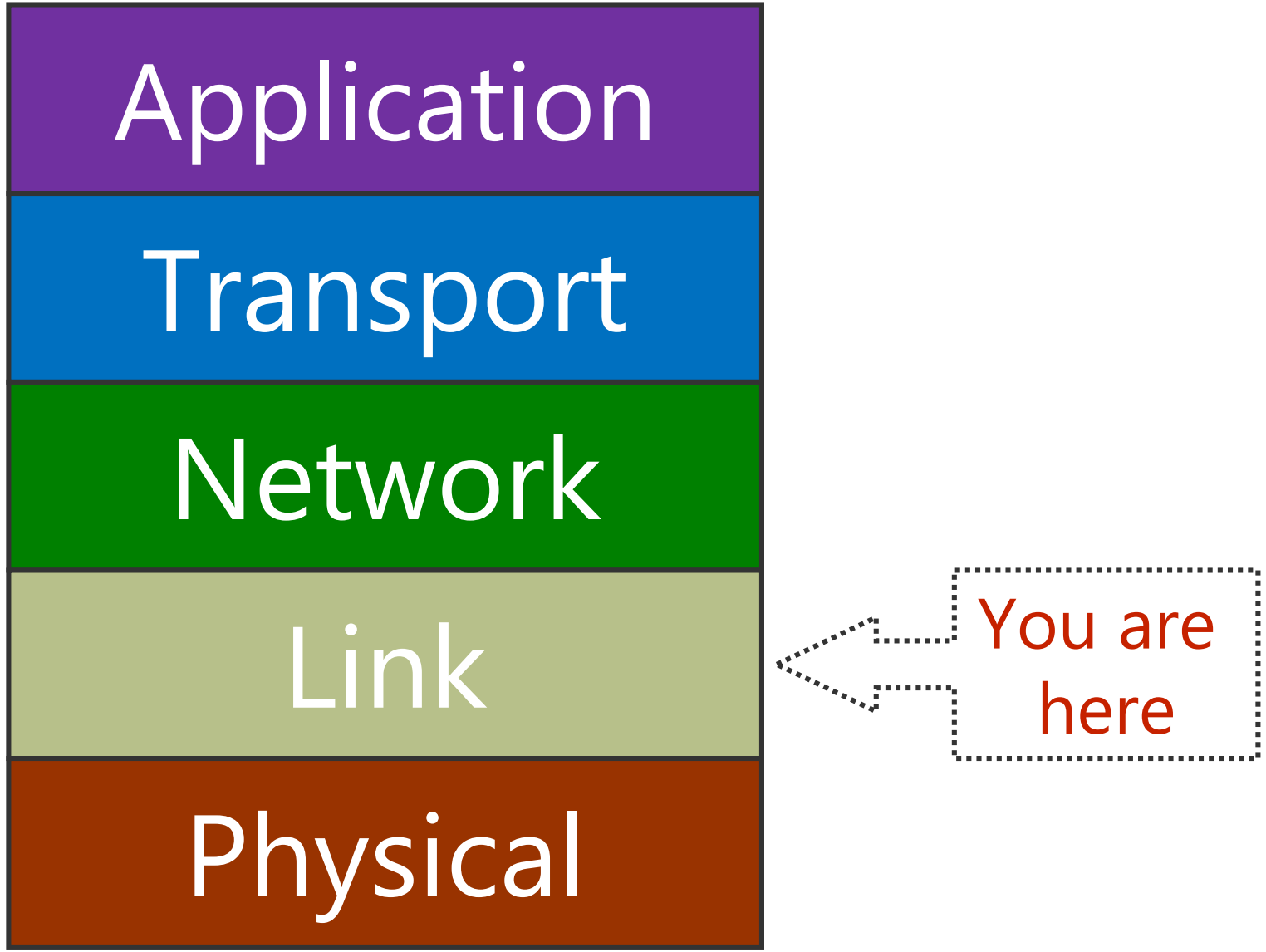
CS2105 Introduction to Computer Networks

Lecture 9

Link Layer

22 October 2018


Application
Transport
Network
Link
Physical
You are here

Learning Outcomes

After this class, you are expected to understand:

- the role of the link layer and the services it provides.
- how parity and CRC schemes work.
- different methods for accessing shared medium.
- how ALOHA, Slotted ALOHA, CSMA and CSMA/CD work.
- the framing of an Ethernet frame.

Chapter 5

5.1 Introduction to the Link Layer

5.2 Error detecting and correction

5.3 Multiple access protocols

5.3.1 Channel Partitioning Protocols

5.3.2 Random Access Protocols

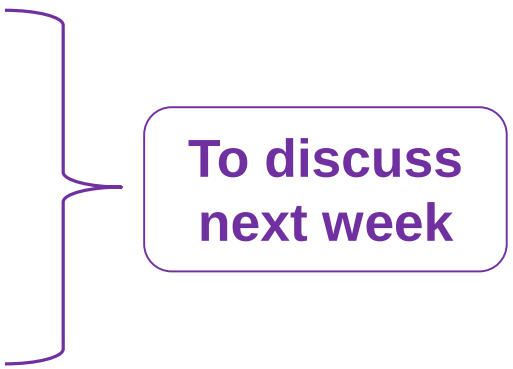
5.3.3 Taking-Turns Protocols

5.4 Switched Local Area Networks

5.4.1 Link layer addressing and ARP

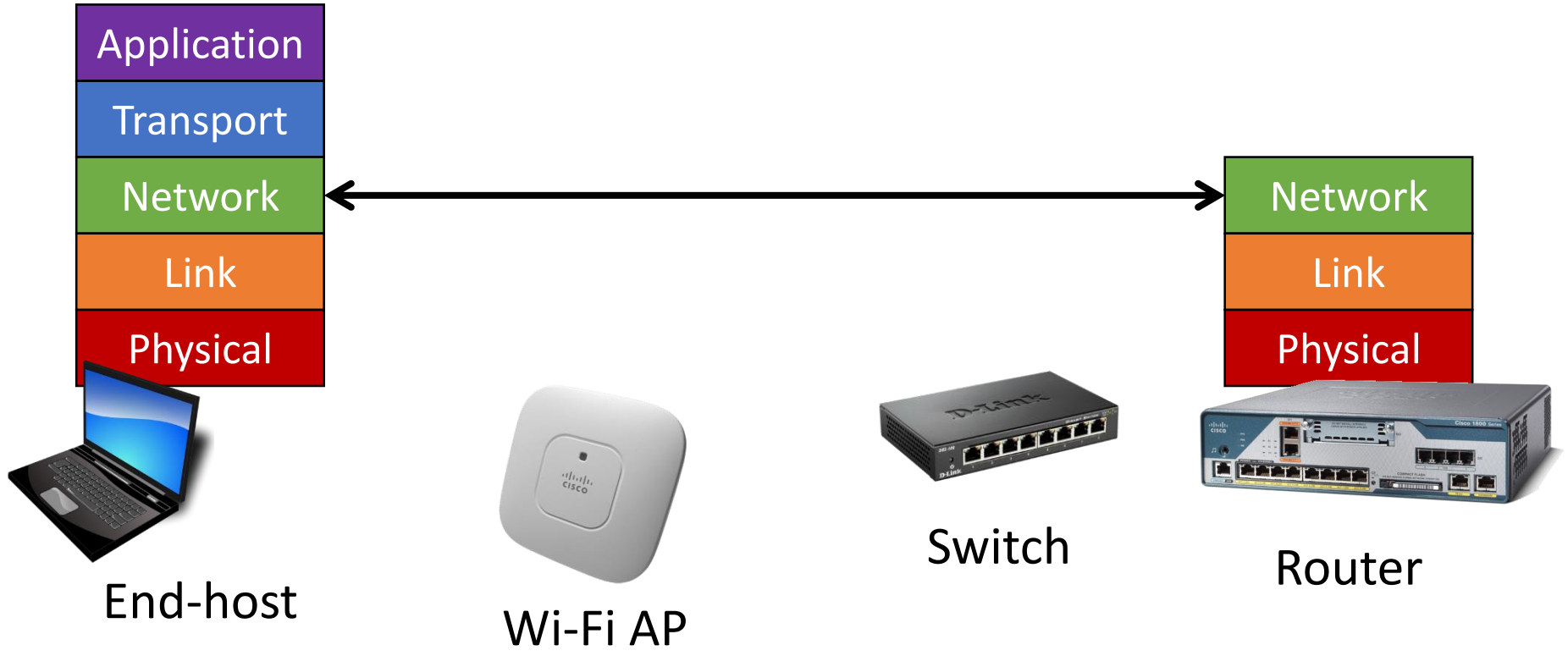
5.4.2 Ethernet

5.4.3 Link layer switches



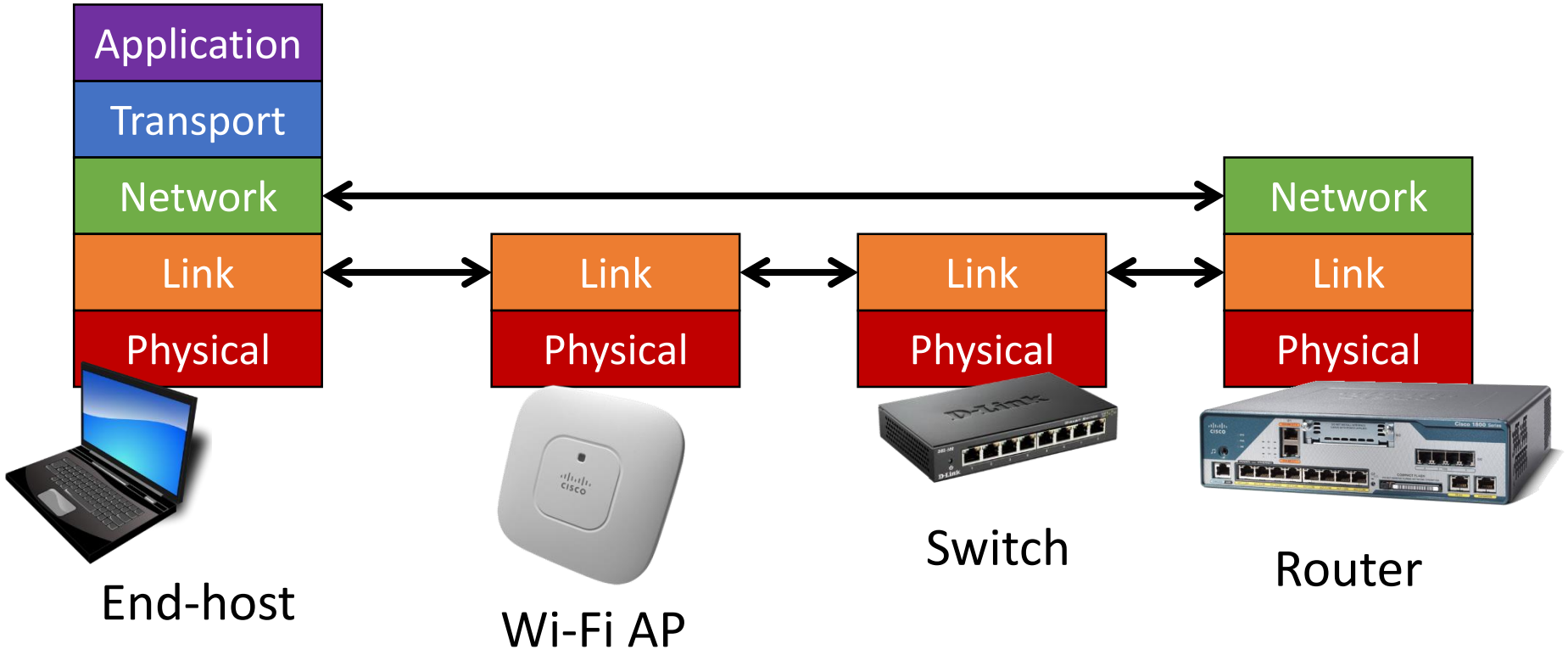
Link Layer: Introduction (1/2)

- Network layer provides communication service between any two hosts
  - But there can be multiple links between the hosts

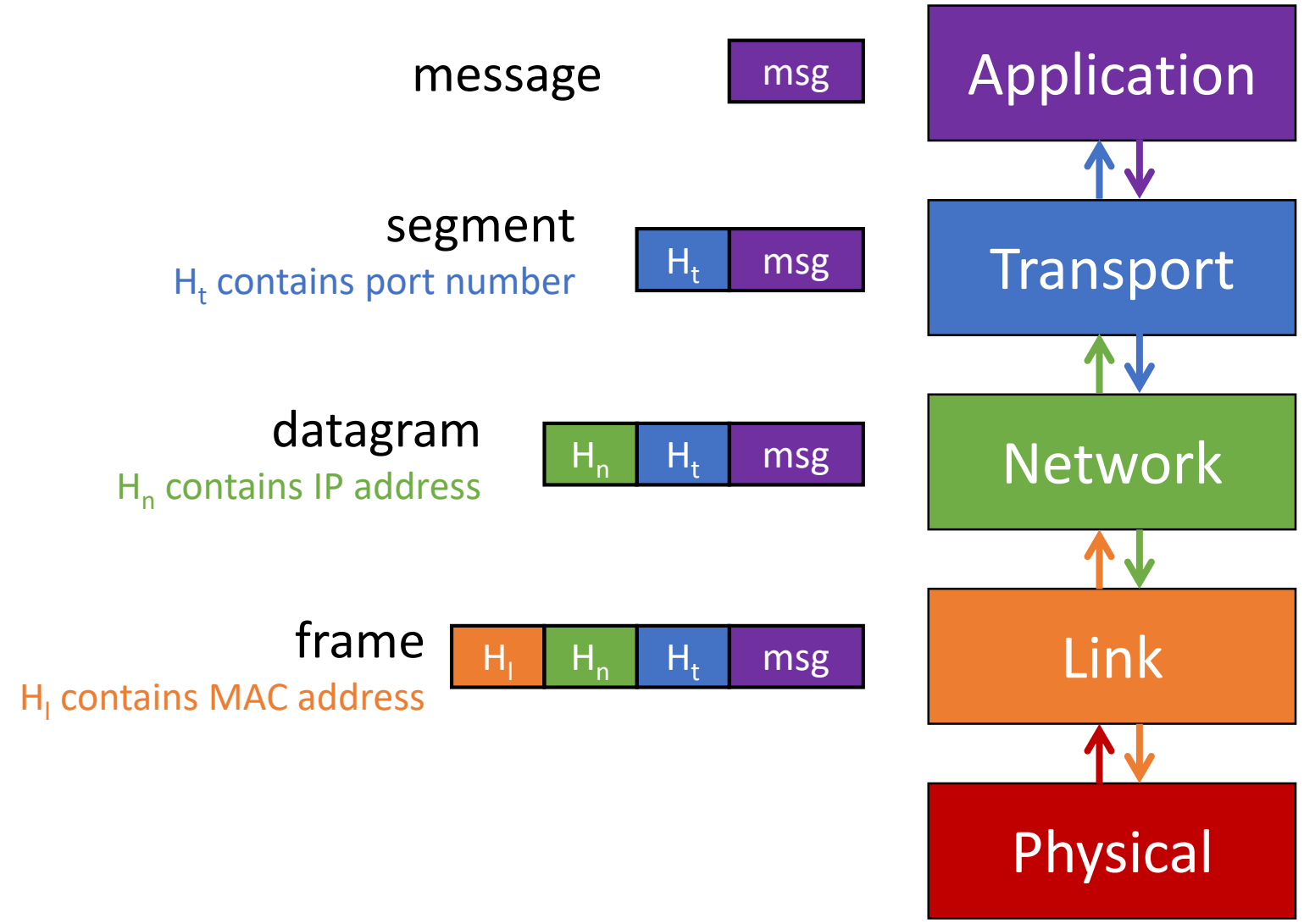


Link Layer: Introduction (2/2)

- Link layer provides node-to-node communication over a single link.
  - Different link layer protocols may be used on different links



Layering


message
msg
segment
H_t contains port number
H_t
msg
datagram
H_n contains IP address
H_n
H_t
msg
frame
H_l contains MAC address
H_l
H_n
H_t
msg
Application
Transport
Network
Link
Physical

Link Layer Services (1/2)

- Framing
  - Encapsulates datagram into frames

- Link Access Control
  - Coordinate who can transmit over a single link

humans at a cocktail party (shared air)

Link Layer Services (2/2)

- Reliable Delivery
  - Seldom used on low bit-error link (e.g., fiber)
  - Often used on error-prone links (e.g., wireless)
- Error Detection
  - Usually caused by signal attenuation or noise
  - Receiver detects error
- Error Correction
  - Receiver identifies and corrects bit error(s) without retransmission

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- 5.3.1 Channel Partitioning Protocols
- 5.3.2 Random Access Protocols
- 5.3.3 Taking-Turns Protocols

5.4 Switched Local Area Networks

- 5.4.1 Link layer addressing and ARP
- 5.4.2 Ethernet
- 5.4.3 Link layer switches

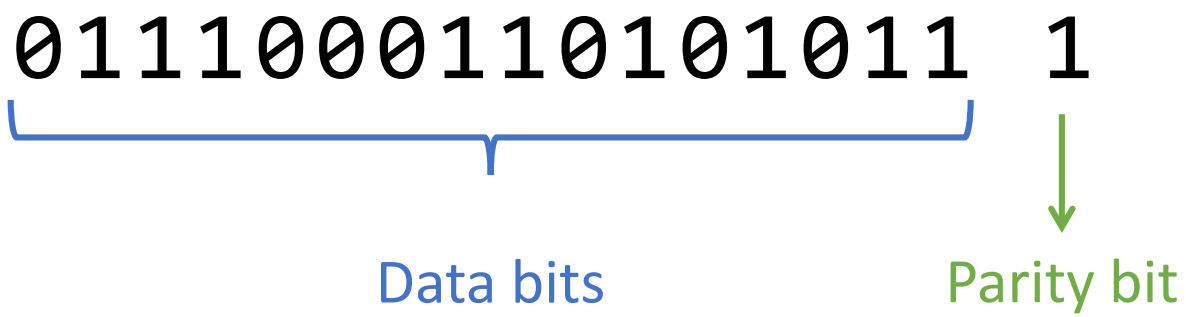
To discuss next week

Error Detection and Correction

- Checksum
  - Used in TCP/UDP/IP
- Parity Checking
- CRC (*Cyclic Redundancy Check*)
  - Commonly used in link layer

Parity Bit (1/2)

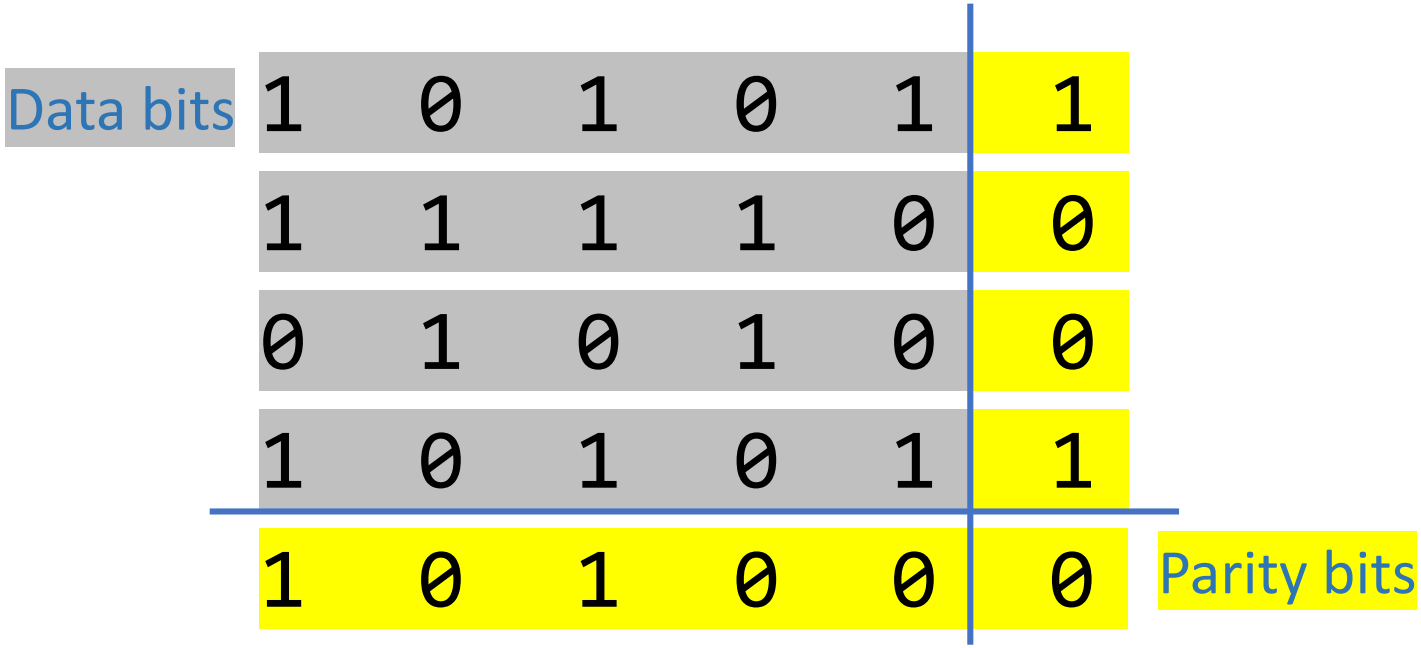
- Single bit parity
  - Can detect single bit errors in data
  - Odd vs Even



0111000110101011	No error
0111010110101011	Error detected
0111000110011011	Error not detected

Parity Bit (2/2)

- 2D Parity
  - Can detect and correct single bit errors in data
  - Can detect any two bits errors in data



Cyclic Redundancy Check (CRC)

$$D2^r + R = kG$$

- D: data bits, viewed as a binary number
- G: a chosen generator of $r + 1$ bits
  - Agreed by sender and receiver beforehand
- R: remainder of $D2^r / G$
  - Generate CRC of r bits

❖Done in base-2 arithmetic without carry or borrow

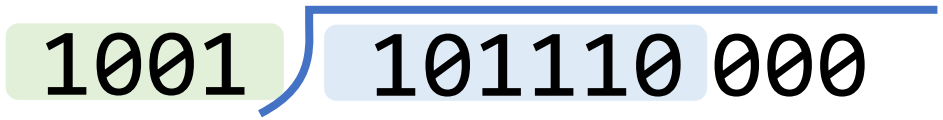
`0+0 = 0  0+1=1  1+0=1  1+1=0`

CRC Example

$r = 3$

$G = 1001$

$D = 101110$



CRC Example

- Sender sends $D2^r + R$

  `101110011`

- Receiver knows G, divides $D2^r + R$ by G
  - If zero, no error

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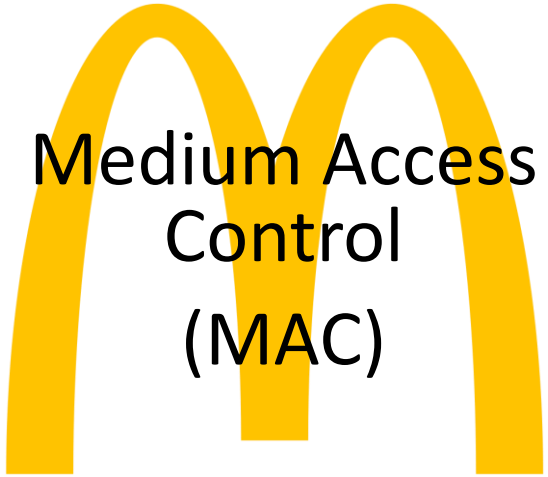
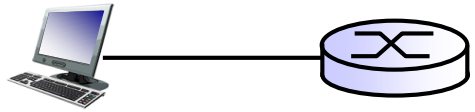


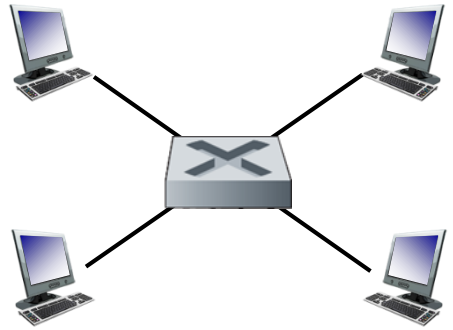
To discuss next week

Types of Network Links

- Type 1: point-to-point link
  - Sender and receiver connected by a dedicated link
  - No need for MAC
  - Example: PPPoE, SLIP



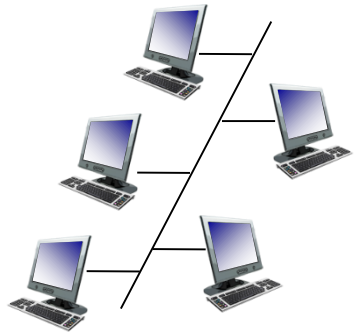
A host connects to router through a dedicated link



A point-to-point link between Ethernet switch and a host

- Type 2: broadcast link (shared medium)
  - All nodes receive a copy of message sent
  - Example: ethernet, 802.11, wireless networks

802.11 Wi-Fi



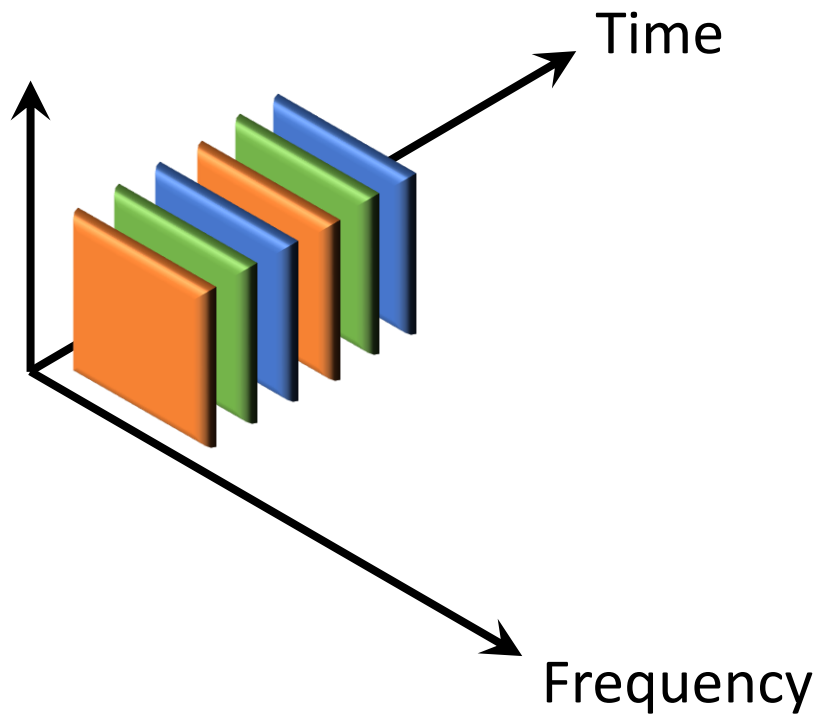
Ethernet with bus topology

Multiple Access Protocol

- Distributed algorithm that determines how nodes share channels
- Coordination must use the channel itself
  - No out-of-band channel signalling
- Three broad classes:
  - Channel Partitioning
  - Take Turns
  - Random Access

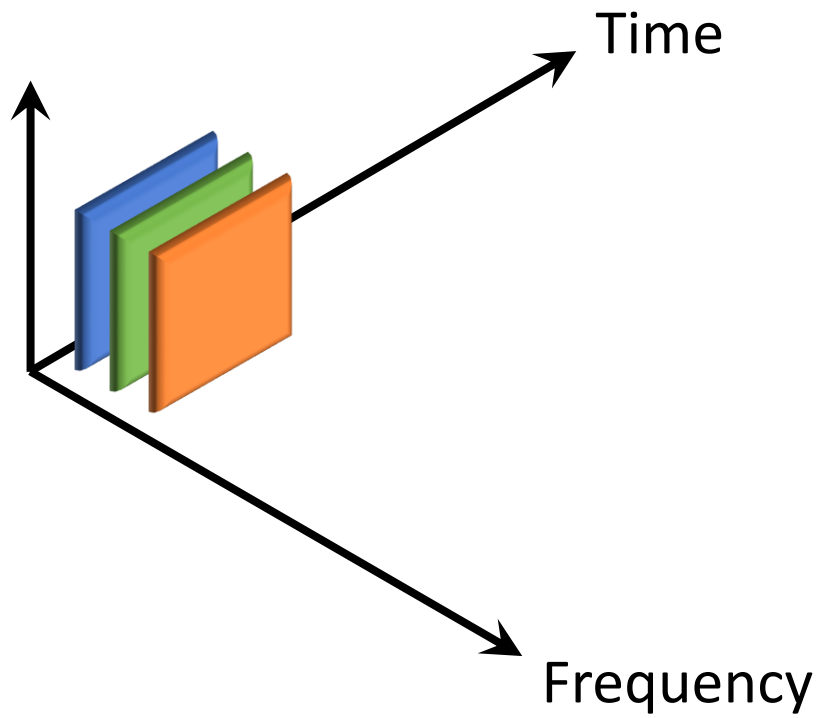
Channel Partitioning Protocols

- Time-Division Multiple Access
  - Access channel in “rounds”
  - Each node gets fixed length slot in each round
  - Unused slots go idle



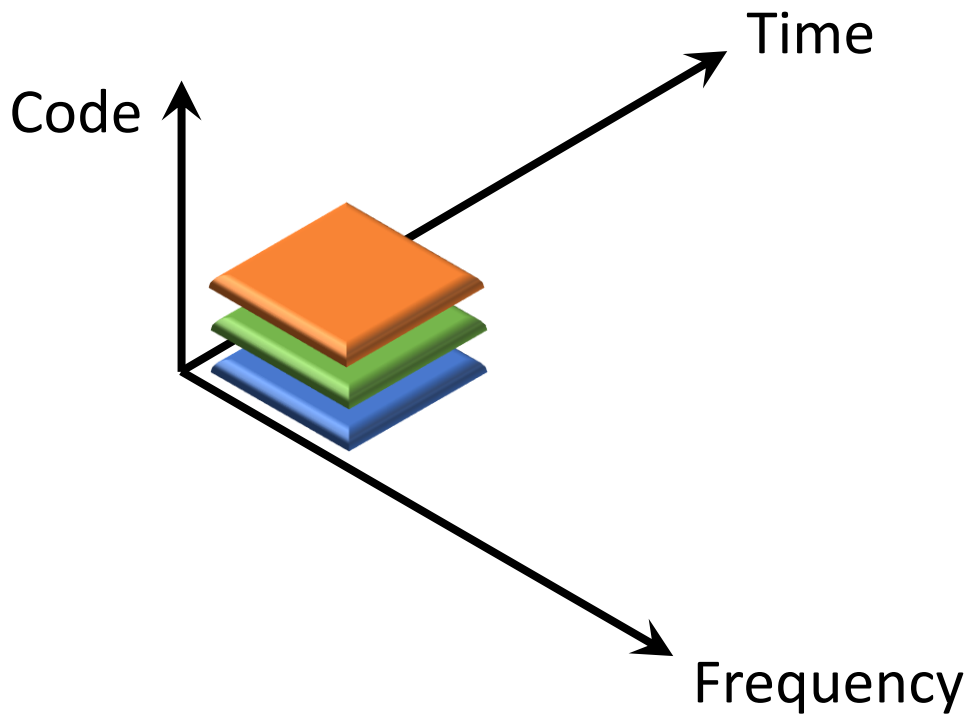
Channel Partitioning Protocols

- Frequency-Division Multiple Access
  - Channel spectrum is divided into frequency bands
  - Each node gets fixed frequency band
  - Unused frequency bands go idle



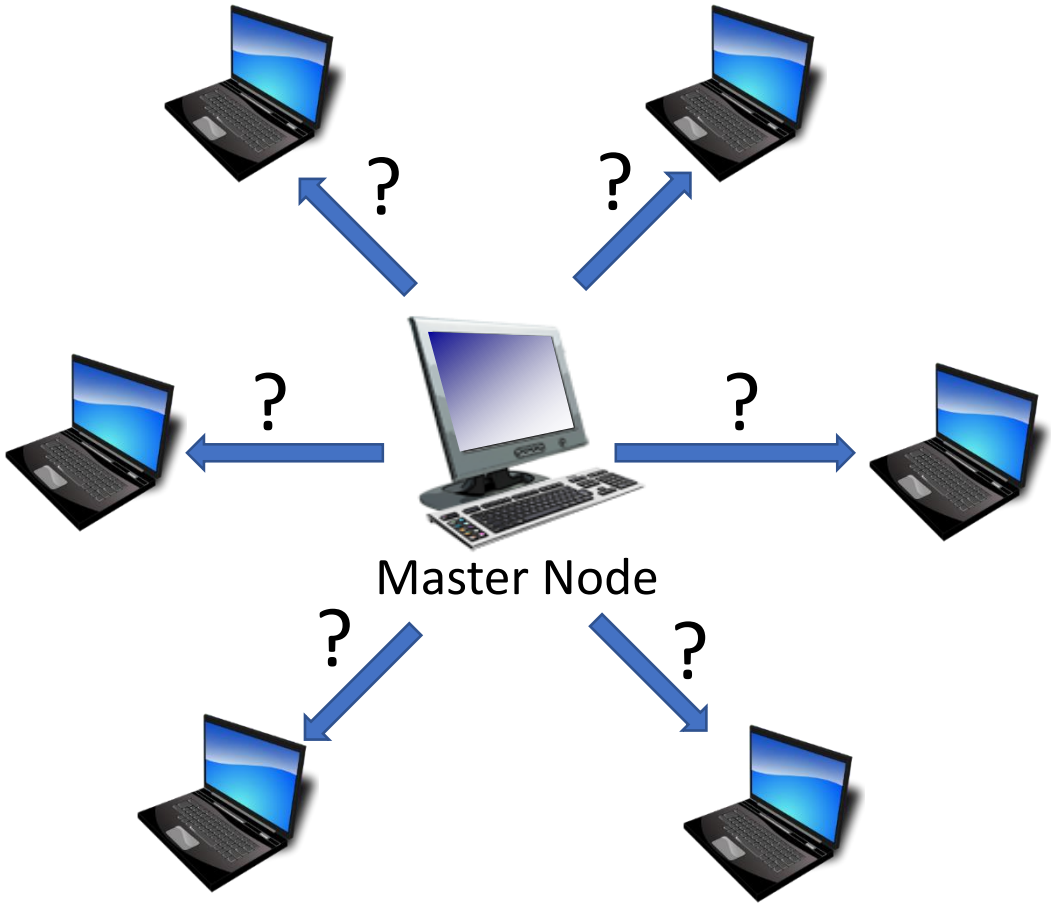
Channel Partitioning Protocols

- Code-Division Multiple Access
  - Uses orthogonal codes with wide spectrum
  - Each node gets fixed codes
  - Unused codes go idle



Taking Turns

- Polling
  - Master node “invites” slave nodes to transmit in turn
  - Concerns:
    - Polling overhead
    - Single point of failure (master node)
  - Example:
    - 802.15 Bluetooth
    - USB

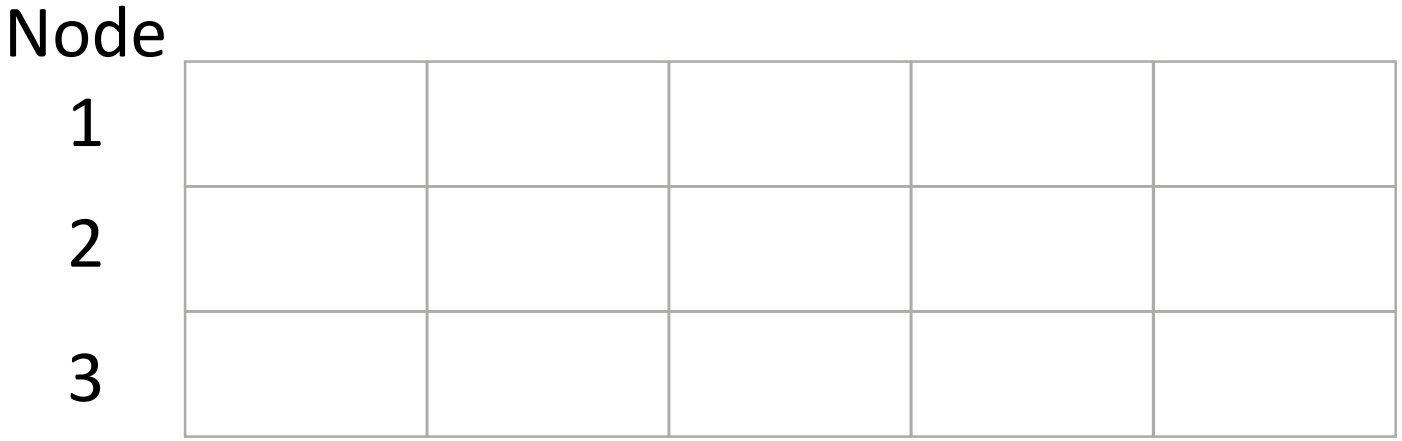


Taking Turns

- Token Passing
  - Control token is passed from one node to the next sequentially
  - Concerns:
    - Polling overhead
    - Latency
    - Single point of failure
  - Example:
    - 802.5 Token Ring Protocol

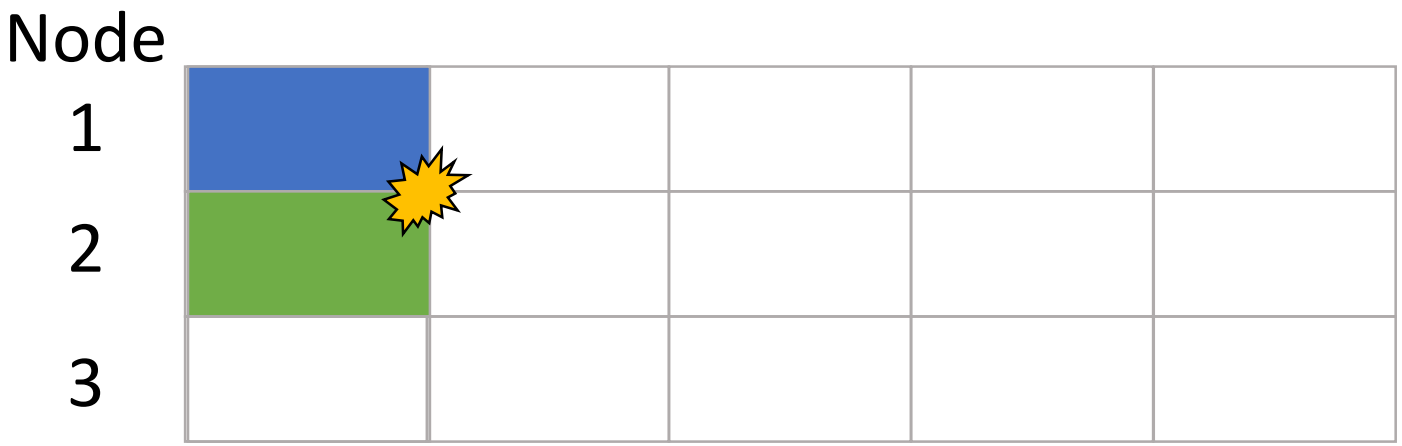
Random Access Protocols

- Slotted ALOHA
  - Fixed slots to transmit
    - Any node can send at any slot (start/stop within slot)
  - No *a priori* coordination among nodes
    - Collision may occur



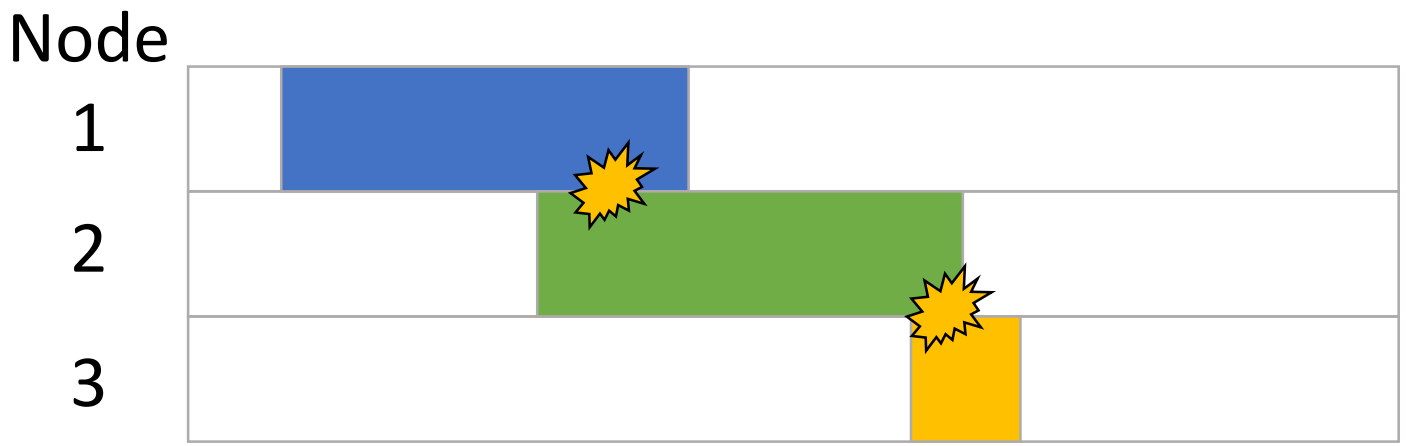
Random Access Protocols

- Slotted ALOHA
  - How to detect collisions?
    - Listens to channel while transmitting
  - How to recover from collisions?
    - Send in next slot with probability p



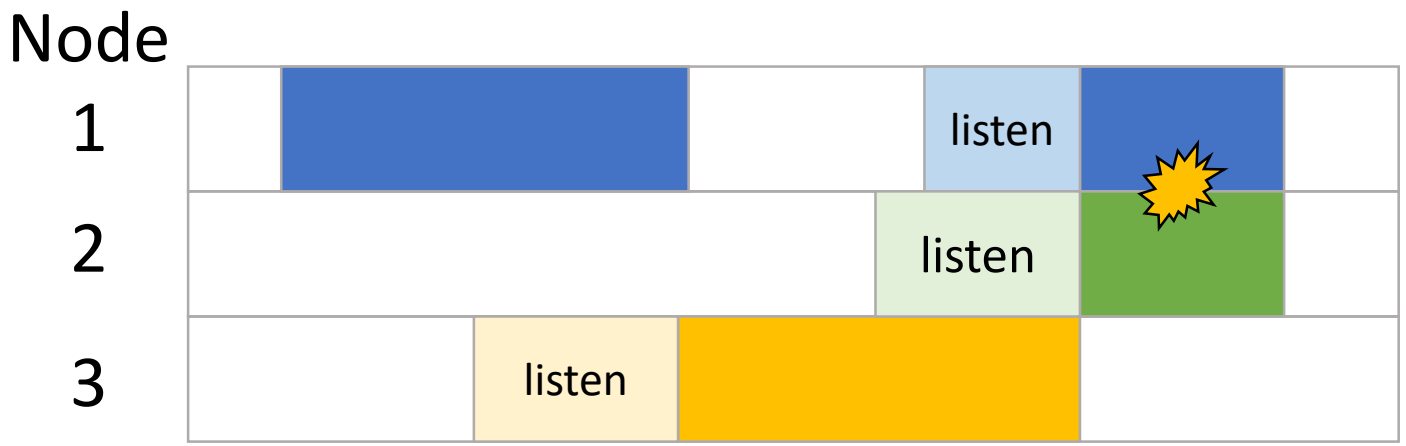
Random Access Protocols

- Pure ALOHA
  - No slots, no synchronization
    - Transmit immediately on demand
  - Not very smart. Why?



Random Access Protocols

- Carrier Sense Multiple Access (CSMA)
  - Theory: sense channel before transmission
    - Human analogy: don’t interrupt others!
  - Practice: collision may still occur



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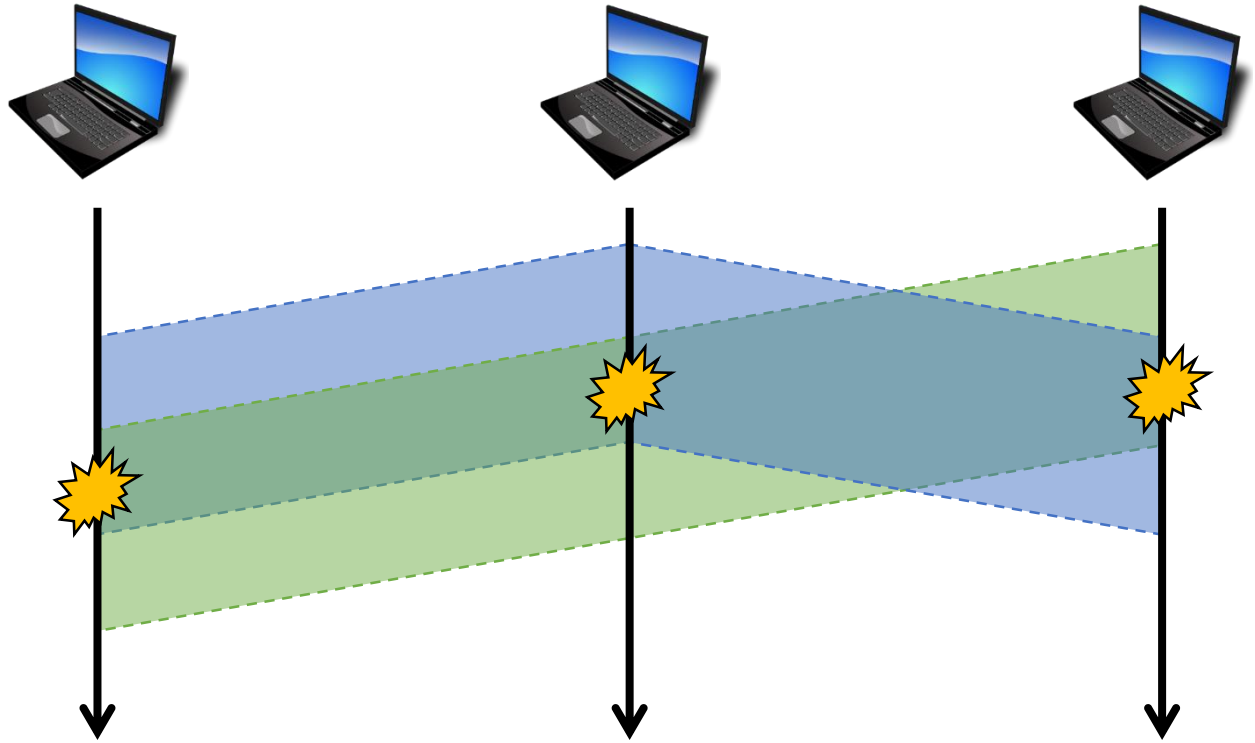
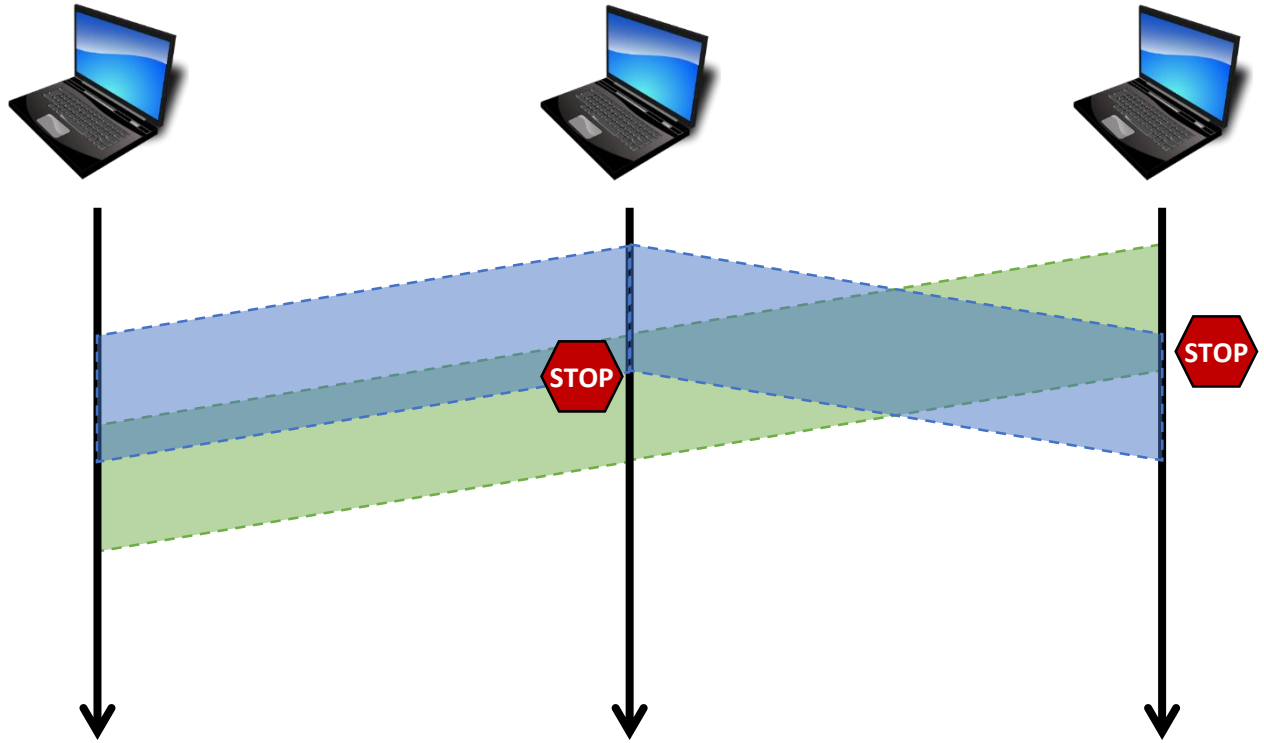


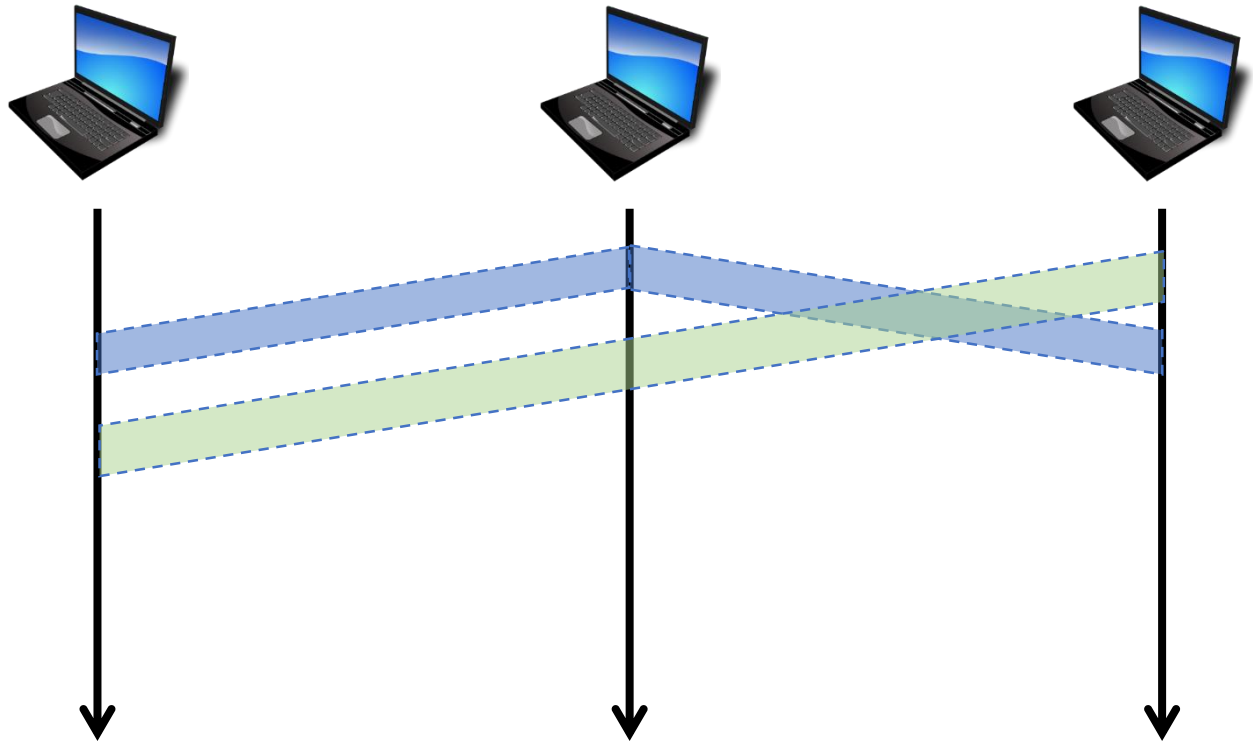
Random Access Protocols

- CSMA/CD (Collision Detection)
  - Theory: stop talking once collision is detected
    - Reduce channel wastage
    - Retransmit after a random amount of time



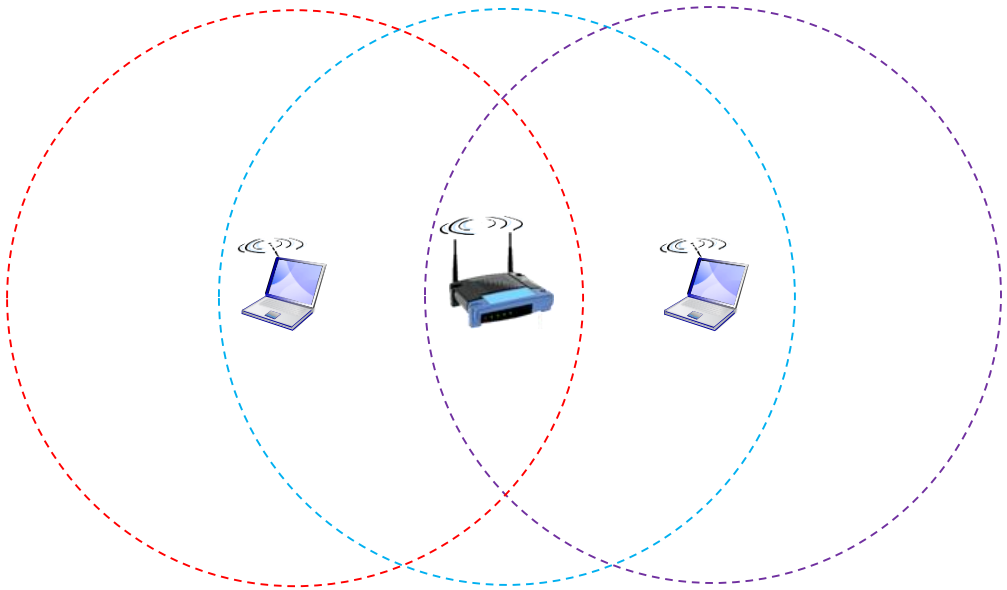
Random Access Protocols

- CSMA/CD (Collision Detection)
  - Problem: what if frame size is too small?



Random Access Protocols

- CSMA/CA (Collision Avoidance)
  - Problem: difficult to detect collision in wireless LAN (802.11)
  - Theory:
    - Request to send/clear to send (RTS/CTS)
    - ACK for received frame



Hidden node problem
(two laptops cannot
detect each other)

Retransmission Algorithm

- Binary Exponential Backoff
  - Slotted ALOHA
    - Retransmission based on a fixed probability p
  - CSMA/CD
    - At n^{th} consecutive collision: $m = \min(n, 10)$
    - Pick $k \in \{0,1, \ldots, 2^{m-1}\}$, wait $512 \times k$ bit-time
  - Example:
    - 1^{st} collision, pick k from $\{0,1\}$
    - 2^{nd} collision, pick k from $\{0,1,2\}$
    - 3^{rd} collision, pick k from $\{0,1,2,3,4\}$
    - …
    - $\geq 10^{th}$ collision, pick k from $\{0,1,2,3, \ldots, 1024\}$

Ethernet

Ethernet Framing

- Preamble:
  - 7 bytes of `10101010` followed by `10101011`
  - Used for hardware clock synchronization
- MAC Addresses:
  - 6 bytes each
- Type:
  - Indicate higher level protocol
  - Mostly IP, but others include Novell IPX, Apple Talk, etc
- CRC:
  - Error detection and correction

Summary

- Medium Access Control
  - Channel Partitioning
    - Divide channel by time (TDMA), frequency (FDMA), code (CDMA)
  - Random Access
    - ALOHA, S-ALOHA, CSMA
    - CSMA/CD: ethernet
    - CSMA/CA: 802.11 Wi-Fi
  - Taking Turns
    - Polling by master node: Bluetooth
    - Token passing: token ring
- Ethernet Framing