UMASS AMHERST

ECE 671
Introduction to Computer Networks

Lesson 7
Data Link Layer

Rationale

- Data link layer is used by the network layer to send packets across a single link
- Data link layer implements mechanisms for sharing medium among many stations
- Data link layer is used in any transmission across the Internet

Objectives

- Analyze services and communication challenges within a data link layer
- Determine efficient use of random access protocols to transmit data across a medium
- Explain the role of Ethernet protocols within local area networks
- Research the relationship between data centers and networking

Prior Knowledge

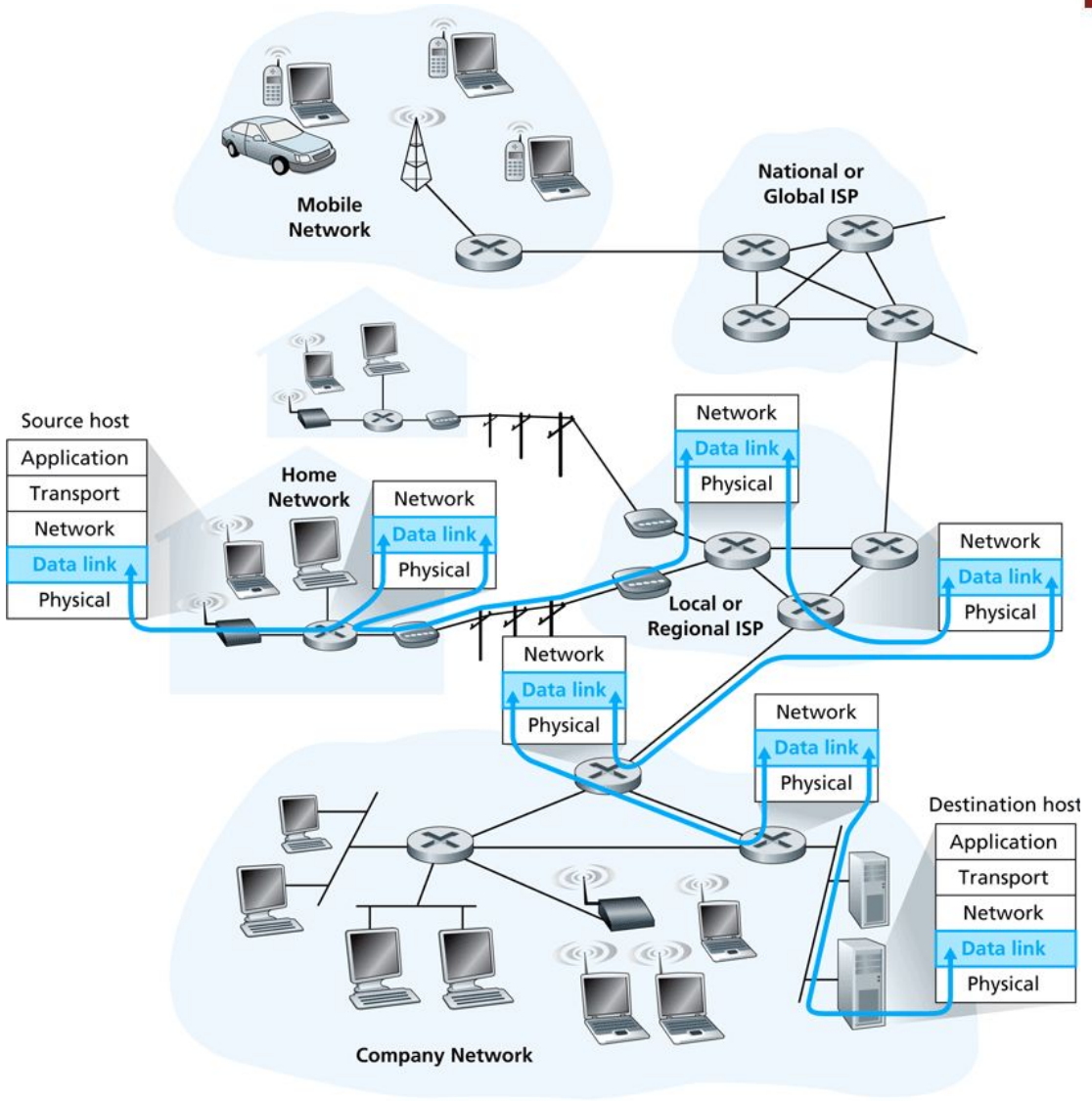
- Data link layer sends frames between neighboring nodes
  - Network layer handles global connectivity (routing and forwarding)
  - There are different types of data link layer protocols (hourglass architecture)

Orchestrated Discussion (Hand Raise): Lesson Reflection Feedback

- Discuss questions and comments on Lesson Reflection from prior lesson

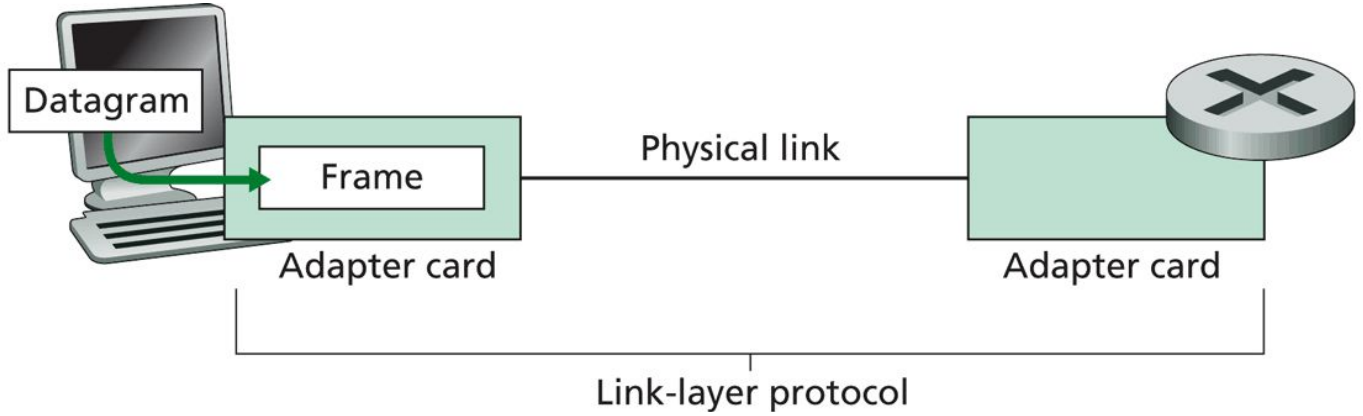
Data Link Layer

- Data links connect one device to another
  - Single network hop
  - "Neighboring" interfaces



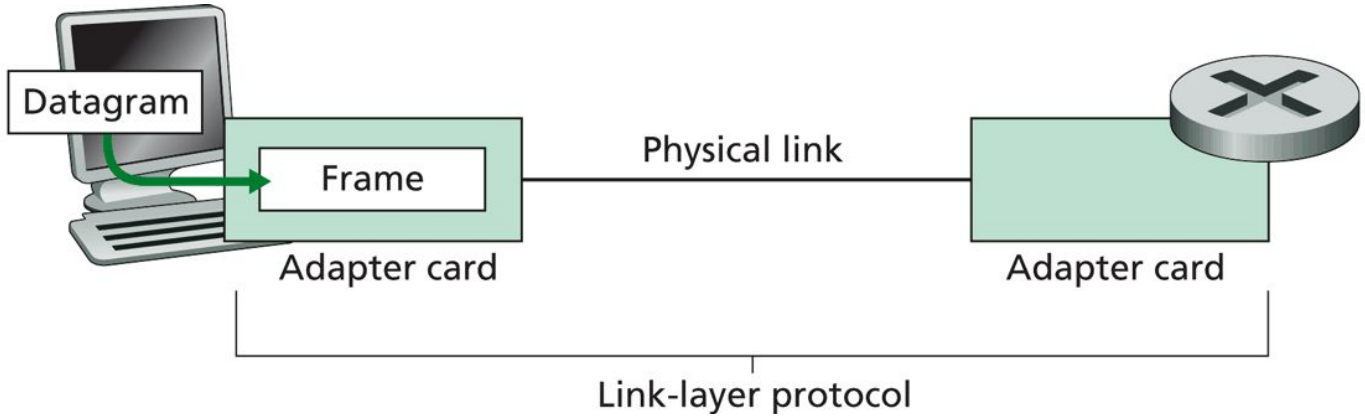
Orchestrated Discussion (Hand Raise): Data Link Layer

- Communication between "neighboring" interfaces
- What are the challenges?



Data Link Layer

- Data link layer services
  - Framing
  - Link access
  - Flow control
  - Error detection / correctior
  - Half-duplex / full-duplex

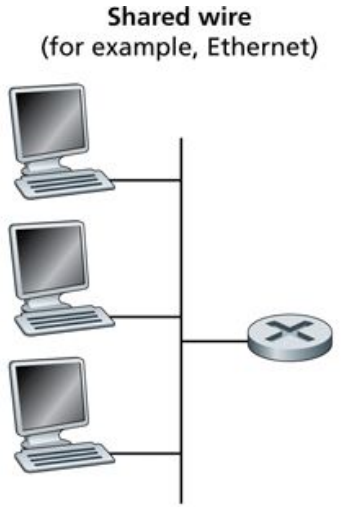


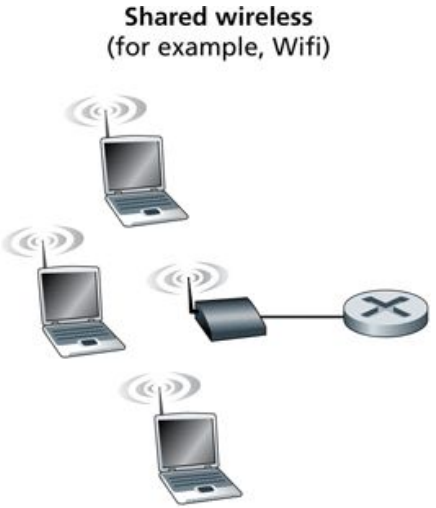
Link Access

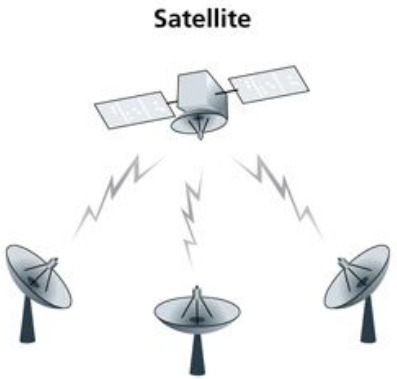
- Point-to-point guided medium is straightforward
  - One side sends, other side receives (coding, timing, etc. is handled by physical layer)
  - Duplex operation by duplicating medium
- Multiple access case is more interesting
  - Multiple nodes share guided or unguided medium
  - Need to consider:
    - Naming
    - Medium access protocol
    - “Strange” cases (e.g., hidden terminal problem)

Orchestrated Discussion (Short Answer): Multiple Access

- Many data link layers use “shared medium”
  - Shared wire
  - Shared spectrum
- Medium Access Control (MAC) important
  - How can we coordinate sharing?

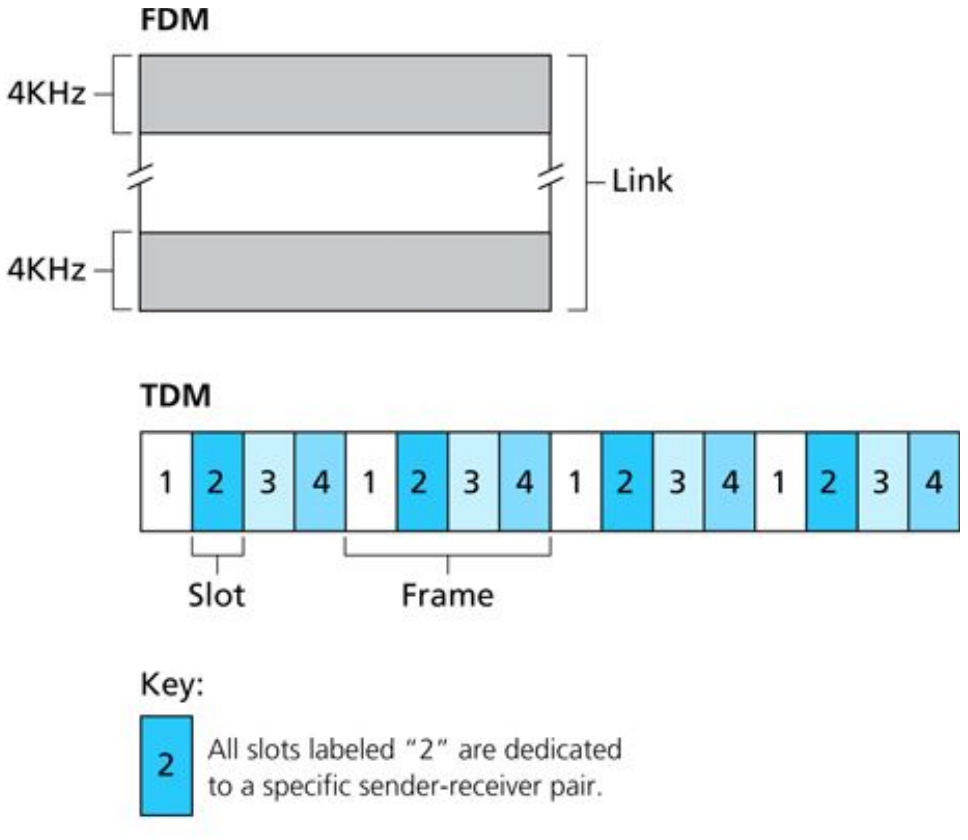






Multiple Access

- Medium Access Control Approaches:
  - Channel partitioning
    - TDM, FDM, CDMA
  - Random access protocols
    - ALOHA, CSMA/CD
  - Taking turns protocol
    - Polling, token-passing
- Channel partitioning
  - Discussed in circuit switching
- Random access used in Ethernet (CSMA/CD)
  - Widely used link layer protocol



Orchestrated Discussion (Short Answer): Medium Access Principles

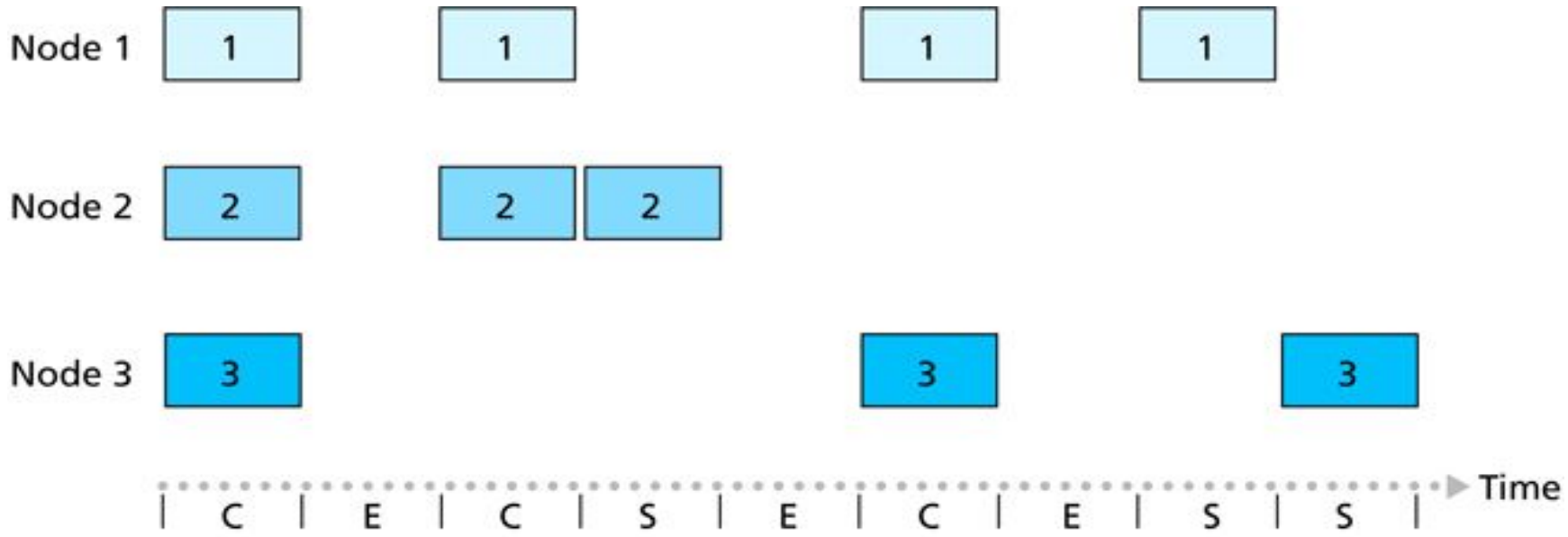
- How should nodes share a medium when using random access?

ALOHA Protocol

- ALOHA is one of first, simplest random access protocols
- "Slotted ALOHA" protocol
  - Discrete time slots
  - Each node makes random choice to transmit in slot or not
- "Pure ALOHA"
  - No time slots
  - Each note makes random choice to transmit at any time

Slotted ALOHA

- Multiple stations may send at the same time?
  - What happens if collision occurs?

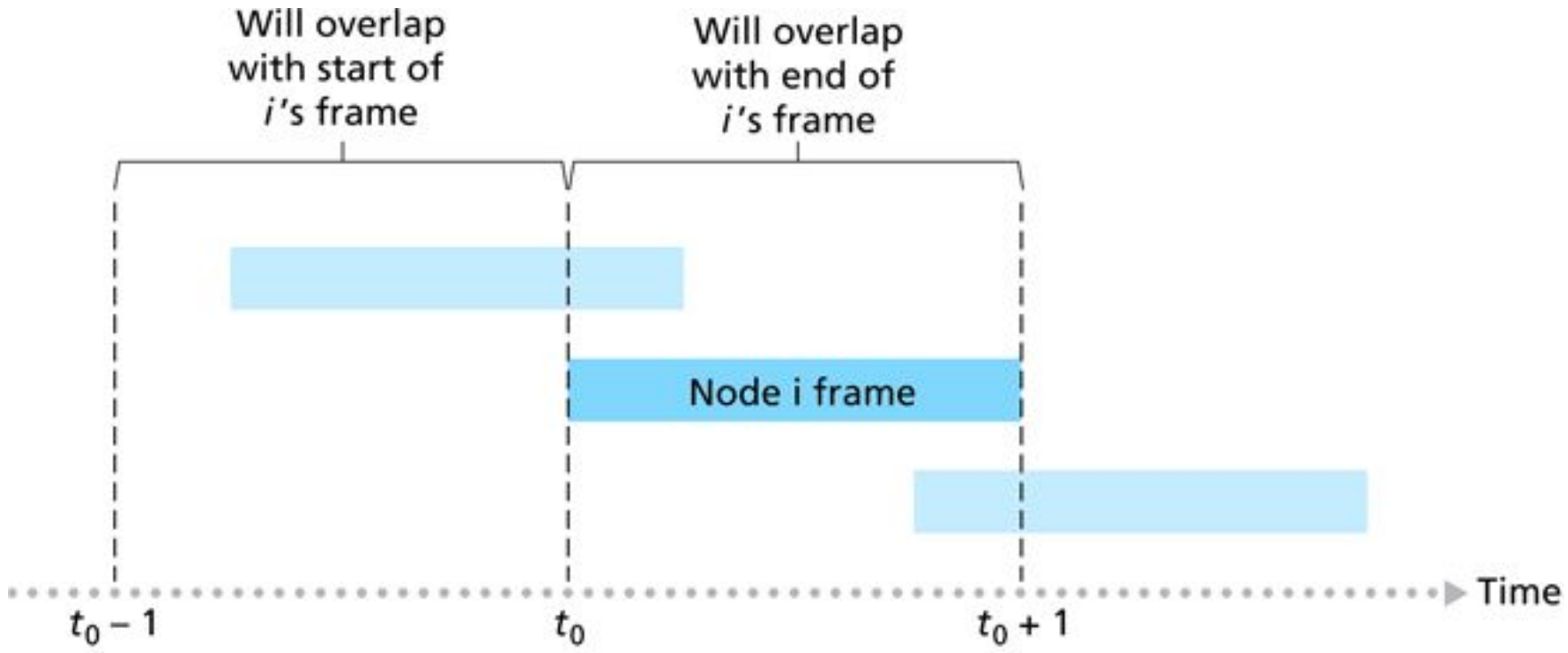


Key:

C = Collision slot
E = Empty slot
S = Successful slot

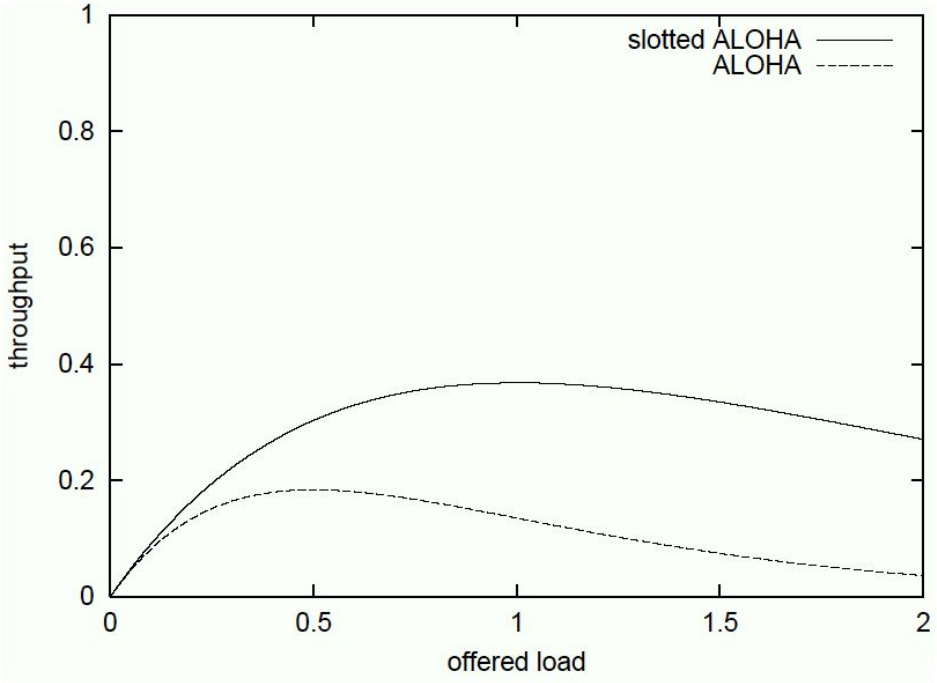
Pure ALOHA

- Station can send whenever it is ready
  - Avoids synchronization challenge in Slotted ALOHA



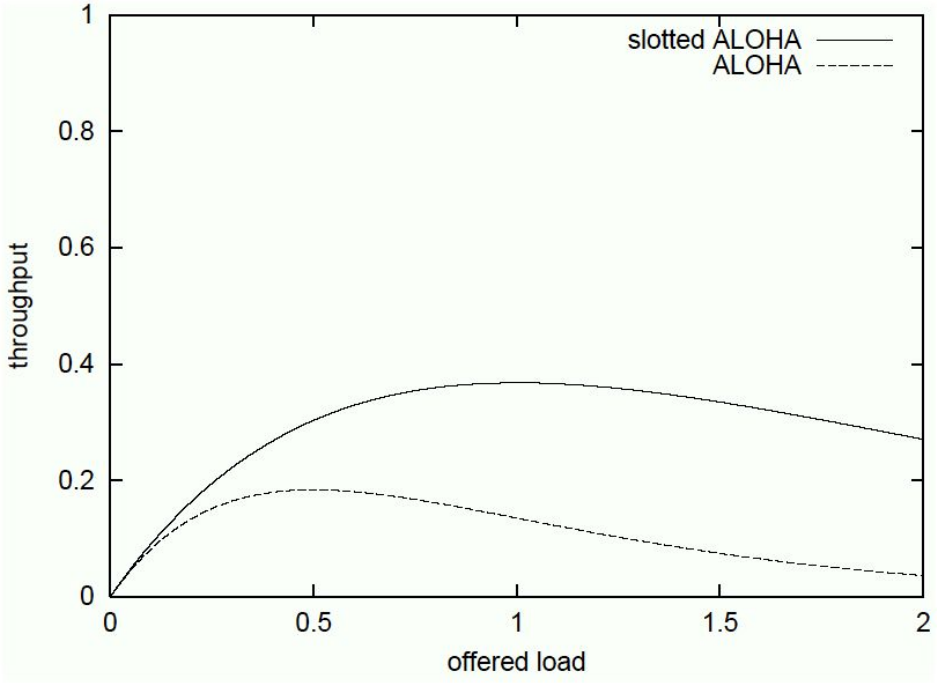
Poll: Analysis of ALOHA

- How does performance differ (pure vs. slotted)?



Analysis of ALOHA

- How does performance differ (pure vs. slotted)?
  - Maximum throughput:
    - Slotted ALOHA: 37%
      - At 100% network load
    - Pure ALOHA: 18%
      - At 50% network load
  - Note “collapse” at higher loads



CSMA/CD Protocol

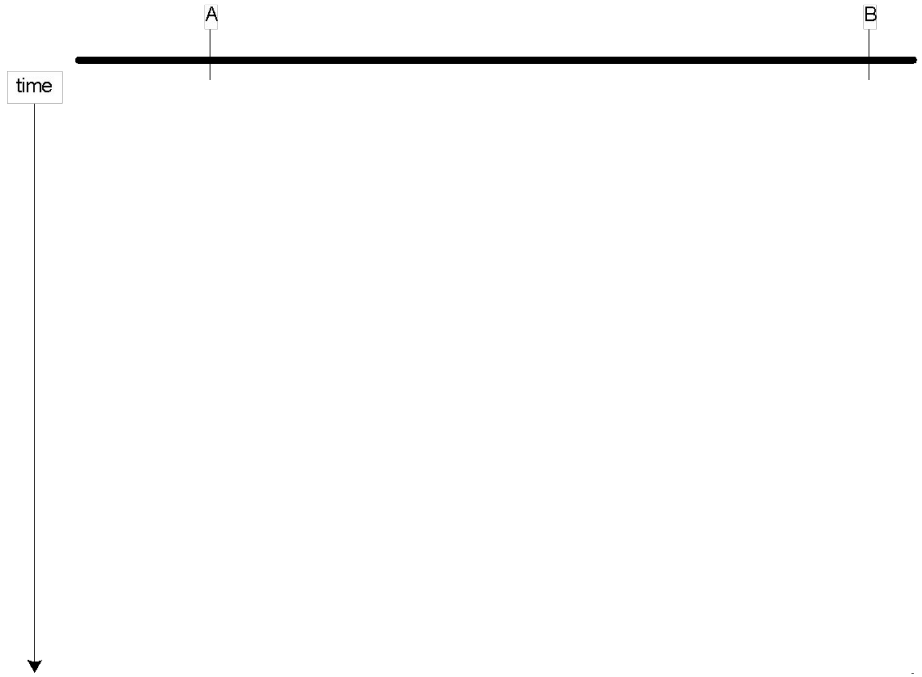
- How can we improve ALOHA?
  - Don’t send when somebody else has already started
  - Stop when interference is already happening
    - Why do we need to do that if we don’t start sending when somebody else sends?
- Carrier Sensing (CS)
  - Listen on channel
  - Only send when nobody else is transmitting
- Collision Detection (CD)
  - Listen to own transmission on channel
  - If garbled then stop transmitting

Orchestrated Discussion (Hand Raise): Carrier Sensing

- Carrier Sensing check if medium is available before transmitting
  - Avoid collision with ongoing transmission
- Even at the data link layer, signal propagation delay matters
  - Typically: 2/3 speed of light of light (~200,000km/s)
- Propagation delay may cause collisions on medium
  - Even if all stations check to see if medium is available

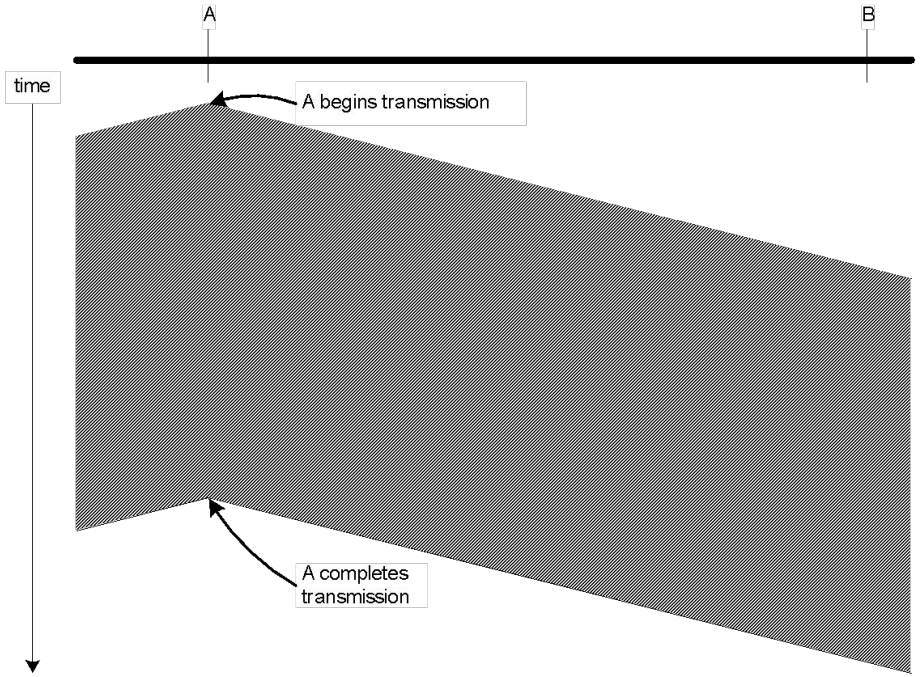
Whiteboard: Signal Propagation

- Space-time diagram illustrates events
  - Slope of lines determined by propagation speed
- Draw transmission from A to B:



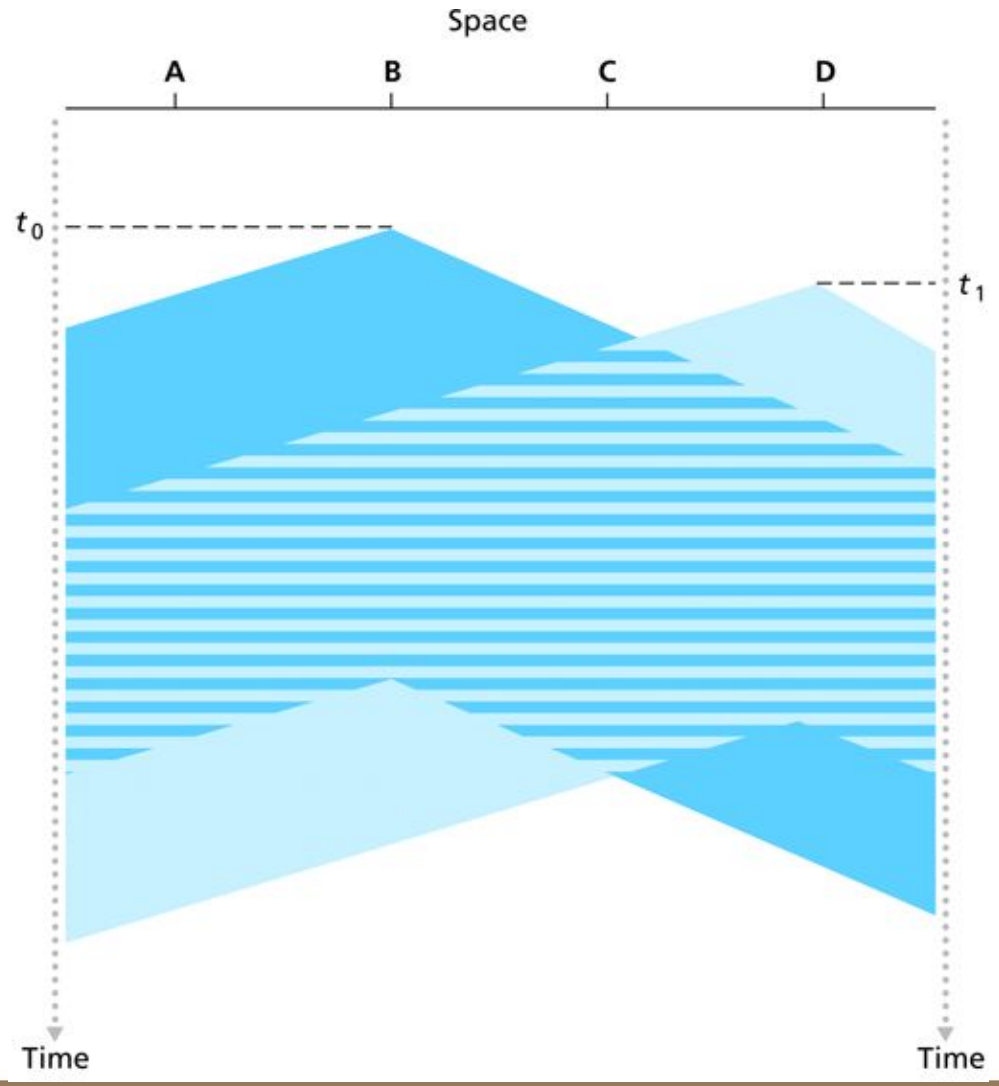
Signal Propagation

- Space-time diagram illustrates events
  - Slope of lines determined by propagation speed
- Draw transmission from A to B



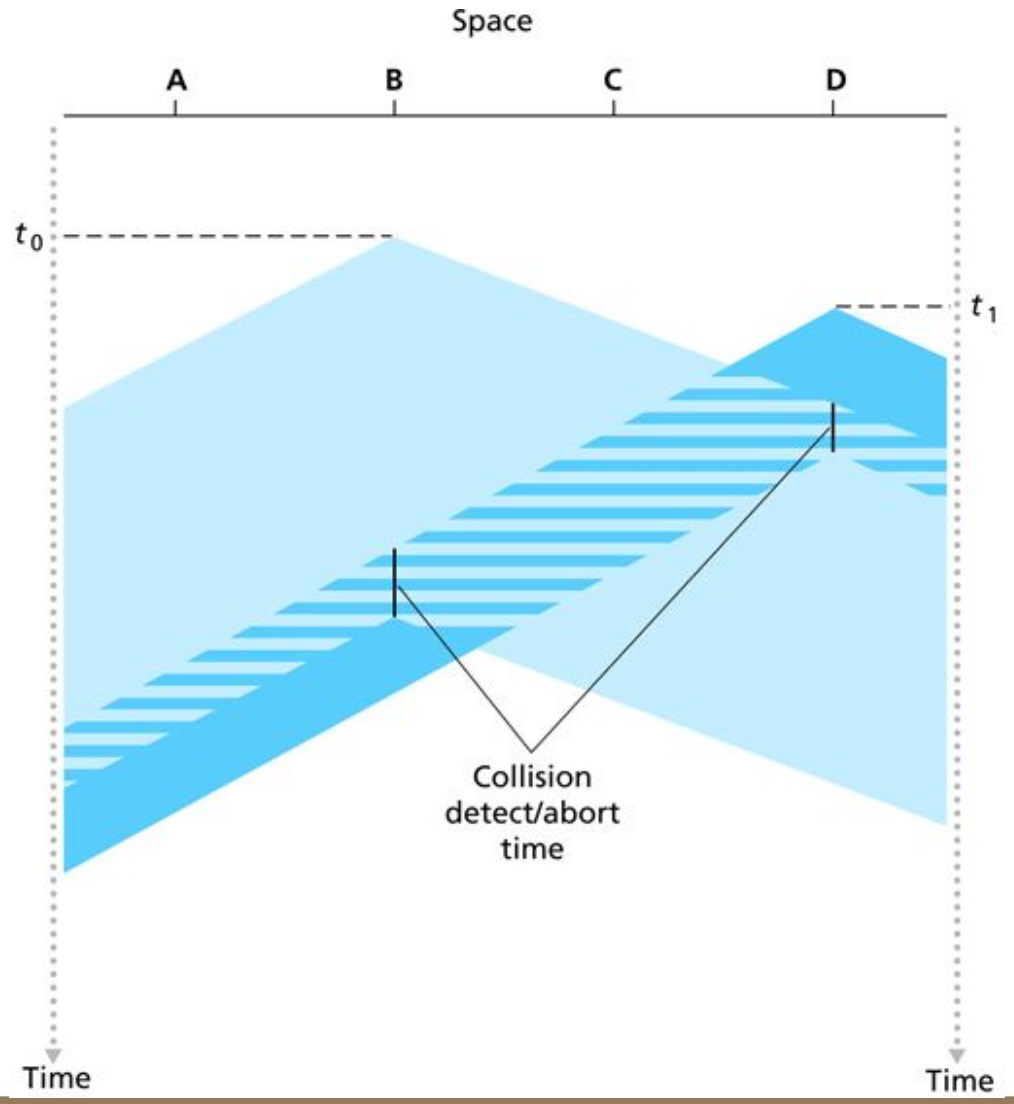
Carrier Sensing

- Collisions occur despite Carrier Sensing
  - Stations may start sending nearly at the same time
  - Propagation delay causes other transmission to show up later
- "Collided" signal cannot be recovered



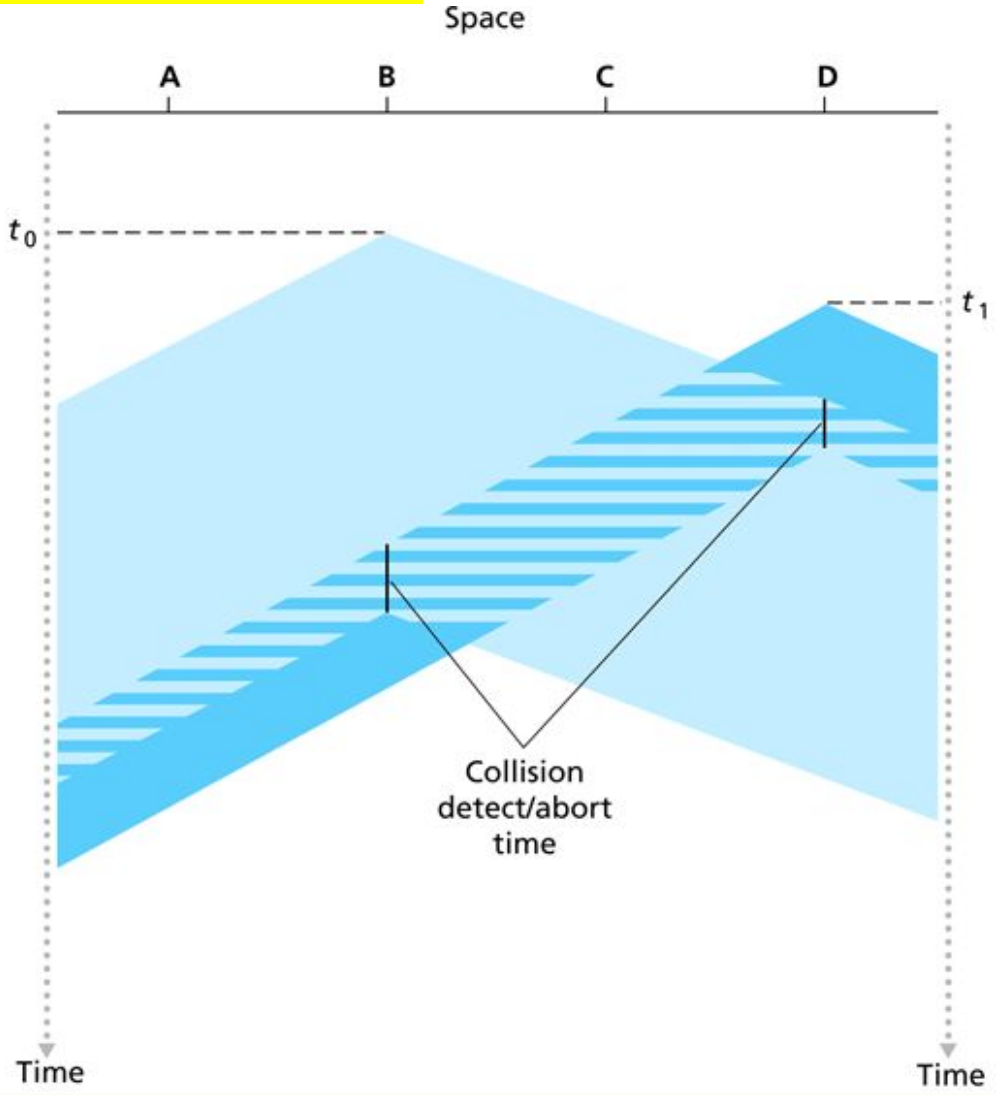
Collision Detection

- Collision detection reduces useless transmissions
  - Retransmission can be started sooner
- How can we guarantee that collision is detected?
  - Why is this necessary?



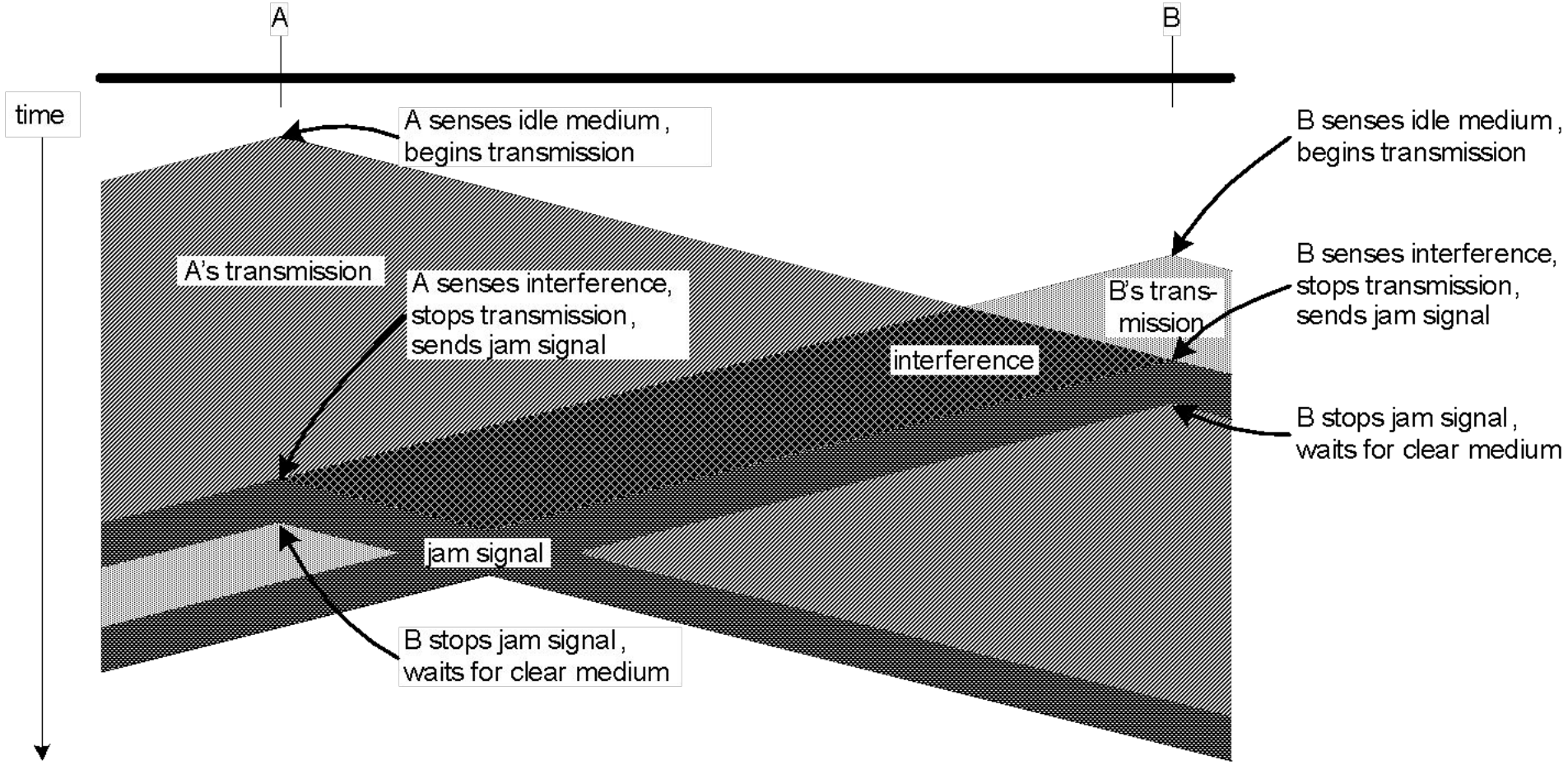
Whiteboard: Collision Detection

- How can we guarantee that collision is detected?
  - Packet must be at least as long as twice the propagation delay between stations with maximum separation
- 10 Mbps Ethernet
  - Packet length:
    - 64 bytes
  - Maximum distance:
    - 2.5 km



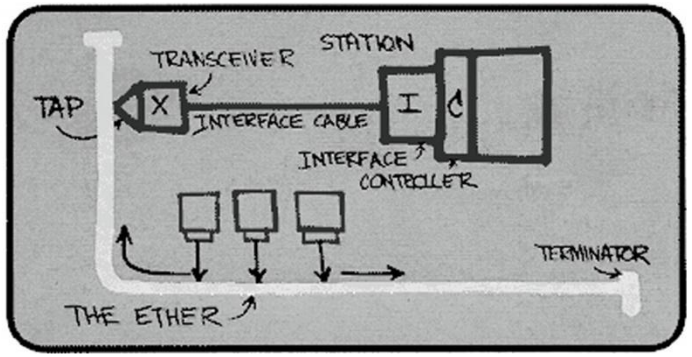
CSMA/CD Example

- **Complete example of CSMA/CD interaction:**



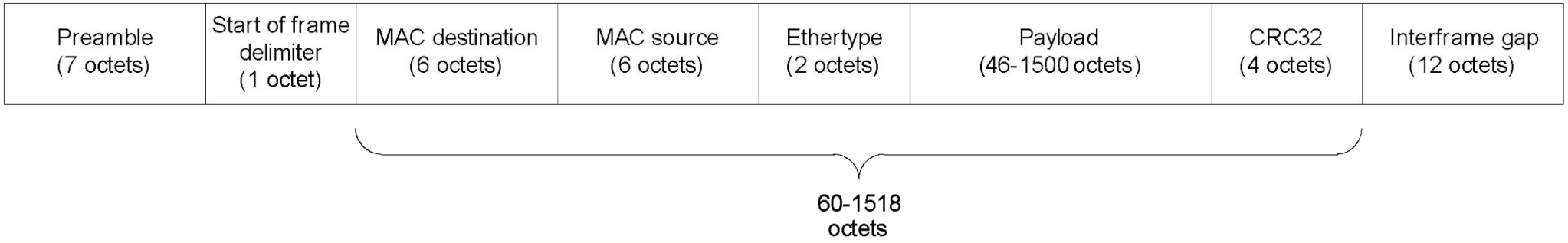
Ethernet

- IEEE 802.3 protocol
- Medium access with CSMA/CD
  - Carrier Sense Multiple Access / Collision Detection
- Truncated exponential backoff
  - Wait for random number of 512 bit-times
  - After c collisions: uniform distribution over $[0\ldots2^{\min\{c,10\}}-1]$
  - After 16 collisions: transmission aborted
- Limitations
  - Max 2.5km of cable, thus RTT limited to 51.2µs
  - Corresponds to 64 bytes @ 10Mbps



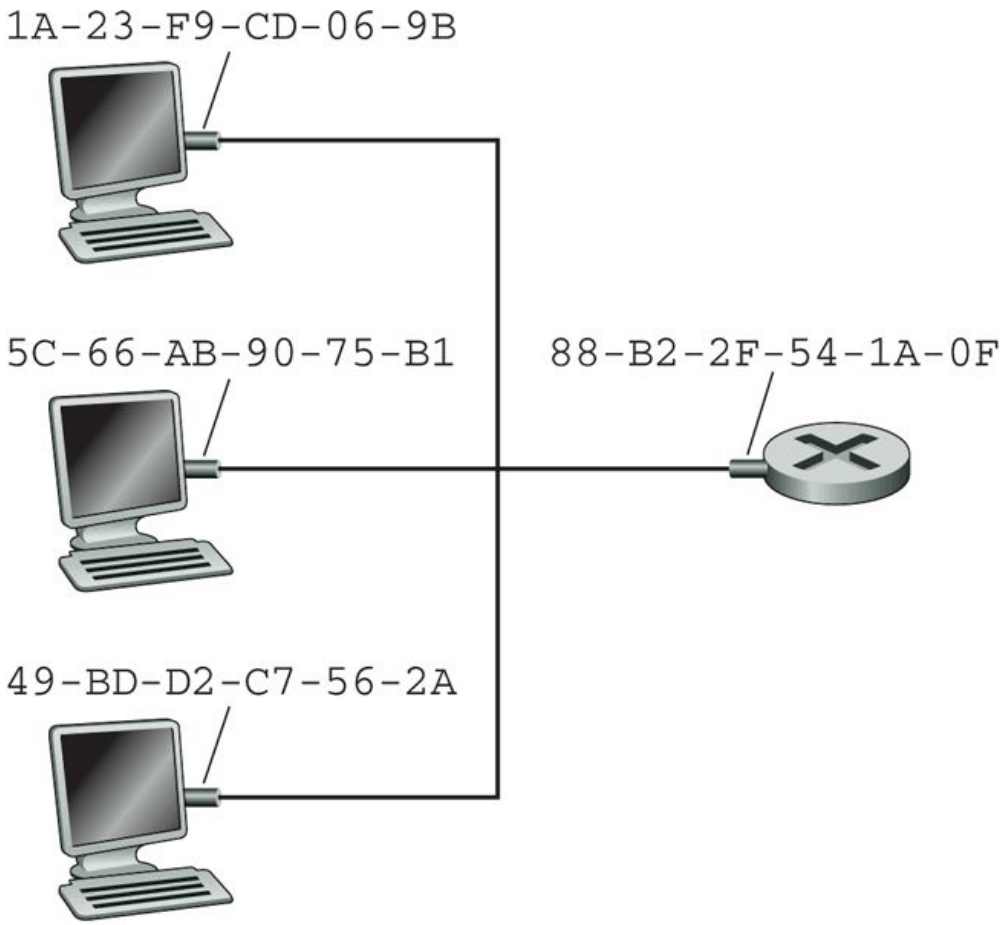
Ethernet

- Frame format:
  - Preamble synchronized receiver
  - Type identifies network layer protocol
  - CRC for error detection
- Addressing
  - Globally unique 48-bit address
  - First 24 bits identify vendor



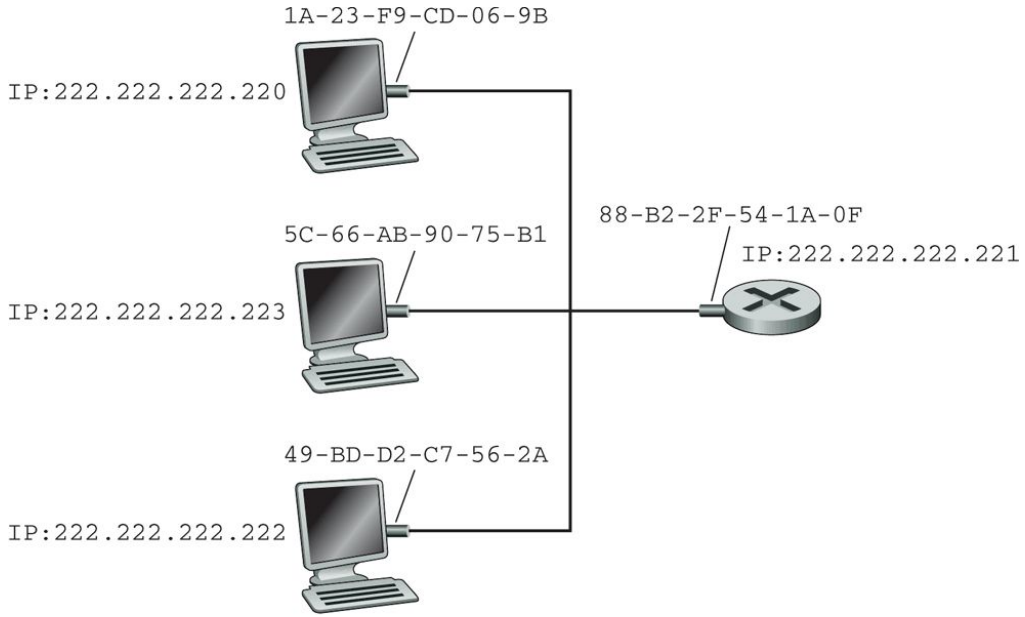
Ethernet

- Example of Ethernet addresses in network
  - Often referred to as “MAC addresses”
- How can node associate network layer (IP) addresses with MAC addresses?
  - MAC address structure does not follow hierarchical IP address allocation



Address Resolution Protocol

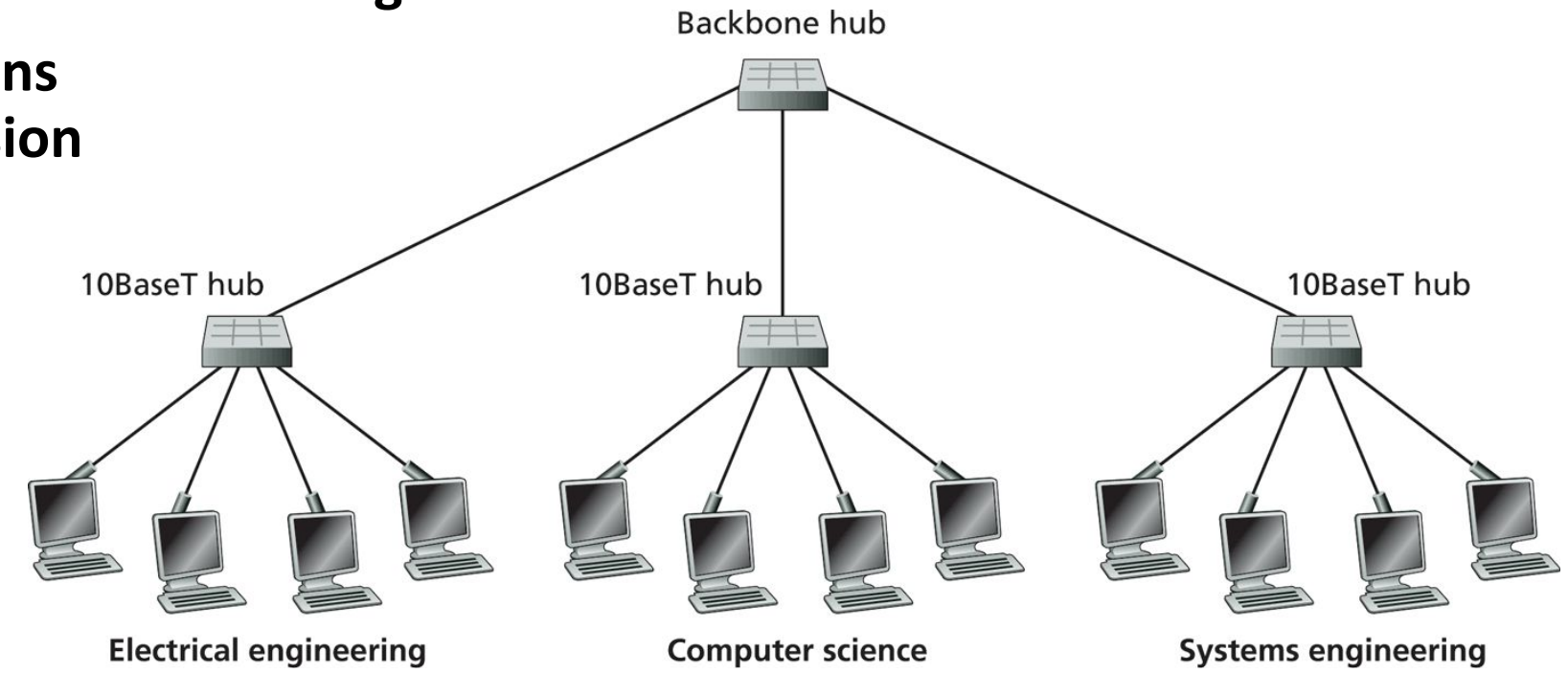
- Problem: what is Ethernet address of destination?
- ARP protocol
  - Broadcast of request for Ethernet address of given IP address
  - Response from anybody
- ARP table maintains entries
  - Timeout ensures adaptation to reconfigurations



IP Address	MAC Address	TTL
222.222.222.221	88-B2-2F-54-1A-0F	13:45:00
222.222.222.223	5C-66-AB-90-75-B1	13:52:00

LAN Architecture

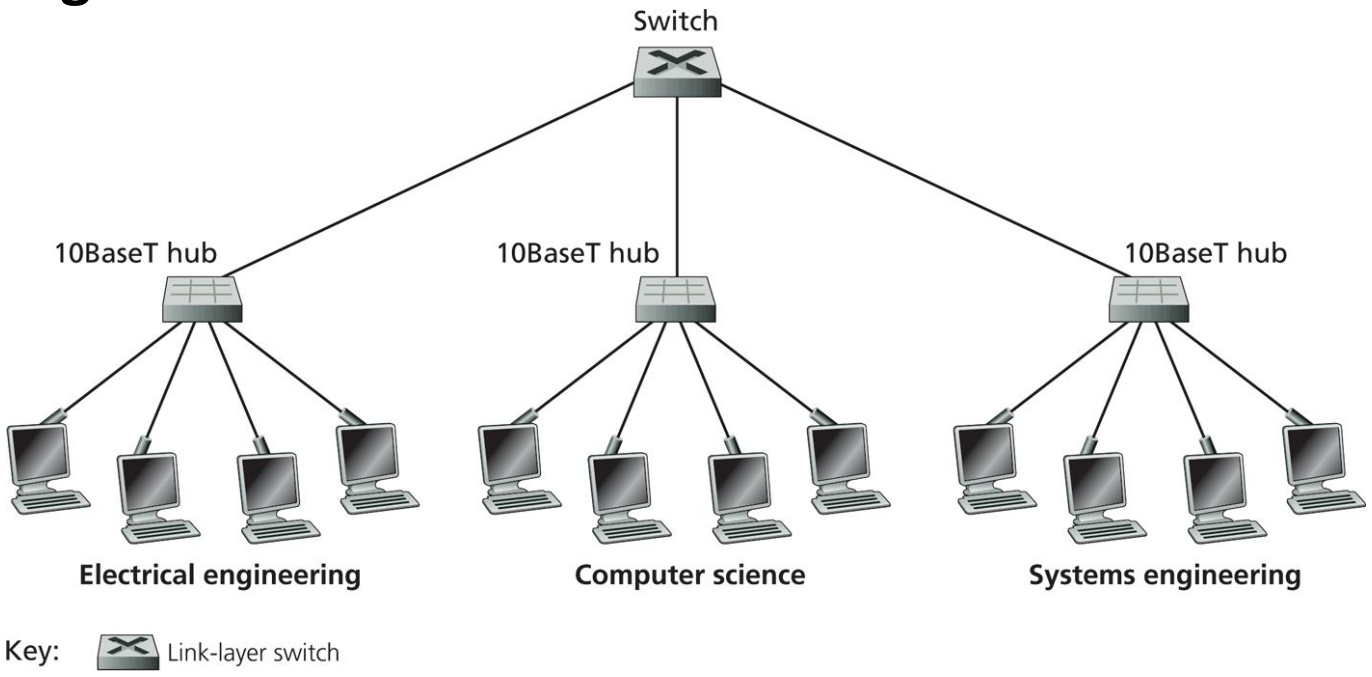
- LAN consists of several segments
  - Hubs connect Ethernet segments
- Hub connections maintain collision domain



LAN Architecture

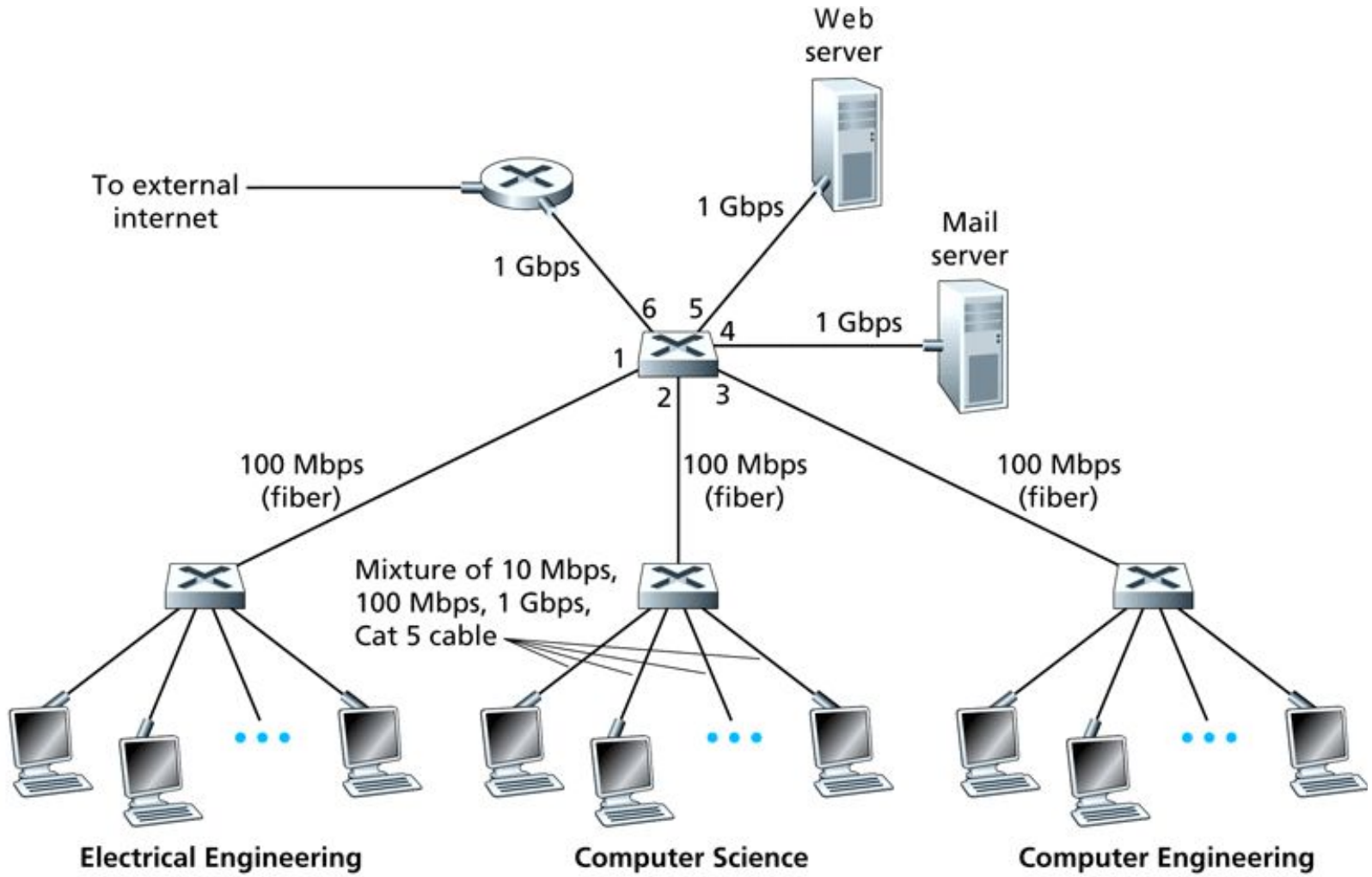
- Switches separate collision domains
- Filtering and forwarding
  - Switch "knows" where frame should go
  - Switch table
- More later…

Address	Interface	Time
01-12-23-34-45-56	2	9:39
62-FE-F7-11-89-A3	1	9:32
7C-BA-B2-B4-91-10	3	9:36
....	....	....



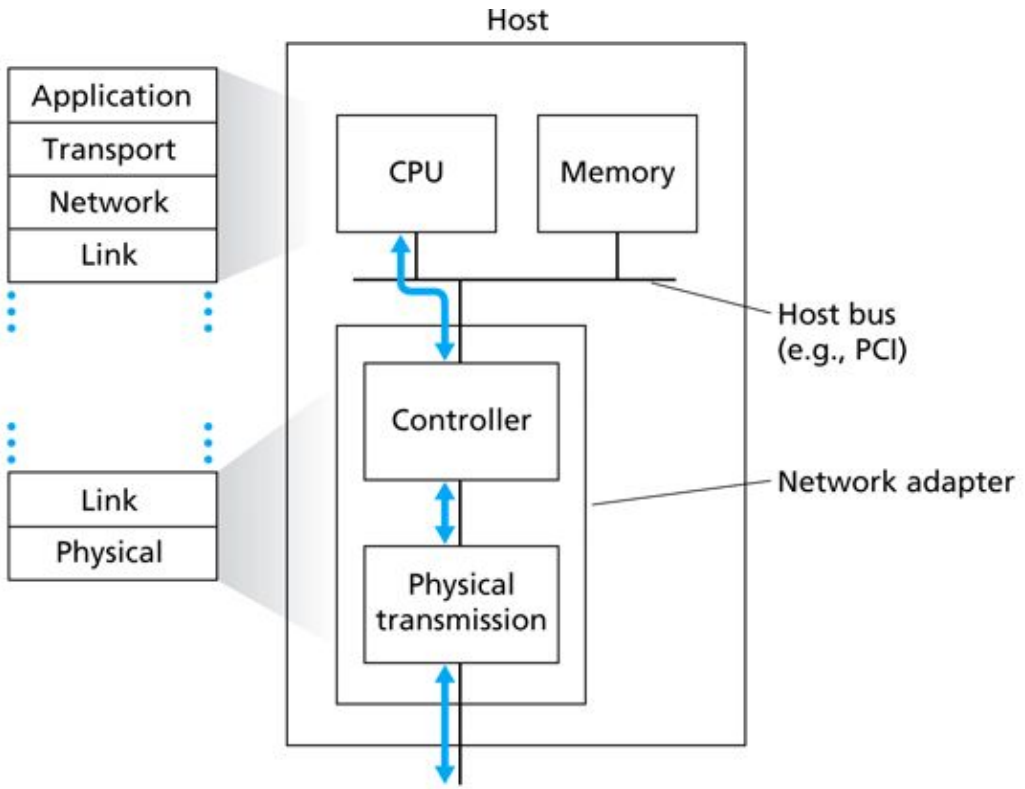
LAN Architecture

- **Example with heterogeneous links**



Network Interface Cards

- Implementation of NIC
  - Adapter connected to processor via bus
- NIC implements many functions in hardware
  - Error detection
  - Retransmission
  - Direct Memory Access (DMA)
- More later…



Physical Layer

- Physical layer in network protocol stack
  - Encoding of bits on medium
- Physical layer heavily dependent on medium
  - Electrical wire
  - Optical fiber
  - Wireless
- Physical layer is more aligned with other areas
  - Wireless transmission studied in communications area
- In this course, we do not explore physical layer

Student Team Presentation: Data Center Networking

- What is a data center? How are networks in data centers used/structured/implemented? What interesting point have you learned about data center networking?
- Prepare 10-minute presentation by next lesson
  - 2 teams will get to present
- Suggested source:
  - Kurose & Ross pages 495–500
  - Videos:
    - https://www.youtube.com/watch?v=XZmGGAbHqa0
    - https://www.youtube.com/watch?v=0uRR72b_qvc
  - Any other source (please specify in your presentation)

Group Discussion and Report Back (Short Answer): Team Presentation

- **Discuss the topic of this assignment with your group and begin preparing a short presentation. This assignment will be continued outside the classroom. Report any questions your group may have to the Instructor.**

Summary of Lesson

- Data link layer
- Random access protocols
- ALOHA
- CSMA/CD
- Ethernet

Post-work for Lesson 7

Lesson Reflection

- After the Live Lecture, you will reflect on what you learned. Then, you will answer questions and share your observations. Go to the online classroom to view the questions and submit your responses.

Presentation (Data Center Networking)

- After the Live Lecture, you will complete and submit a presentation file. Go to the online classroom to view and submit the presentation file.

To Prepare for the Next Lesson

- Complete and submit the Post-work for Lesson 7.
- Read the Required Readings for Lesson 8.
- Complete the Pre-work for Lesson 8.

Go to the online classroom for details.