Reading and Homework

• Reading
  – Ch. 8: Sections 8.1-8.2 only
  – Ch. 9: Entire chapter

• Homework
  – Problems related to Ch. 8 have been posted
  – Ch. 9 (Part 1): P9.2-9.5
Local Area Networks (1/2)

• Local area network (LAN)
  – Limited geographical coverage
    • Often situated within a single building
    • Coverage typically on the order of 10s of meters
    • Geographical coverage may be increased via extended LAN (Ch. 9)
  – Ownership by a single organization
  – Low bit-error rates (i.e., reliable link)
  – Simple network topologies (i.e., single-hop)
    • Frames may be delivered directly by layer 2 (data link control) address
    • Routing protocol not needed within LAN

Local Area Networks (2/2)

• Typical commercial LAN standards and implementations
  – Token ring, e.g., IEEE 802.5
  – Fiber distributed data interface (FDDI)
  – Ethernet – IEEE 802.3
  – “Wireless LAN”, e.g., Wi-Fi – IEEE 802.11
Data Link Layer Partition

- Data link control layer may be sub-divided into two sub-layers:
  - Logical link control (LLC)
    - Error recovery
    - Flow control
  - Medium access control (MAC)
    - Link management
    - Frame format
    - Addressing
Ethernet (1/11)

- Originally developed at Xerox
- Deployed now under the specification of the IEEE 802.3 standards family
- Dominant LAN MAC architecture since the 1980s
- Supports access to a shared medium by multiple stations
  - Contention-based implementation
  - Switched implementation

Ethernet (2/11)

- Contention-based implementation
  - Carrier sense multiple access with collision detection (CSMA/CD)
    - E.g., stations access a shared coaxial cable via wire taps
    - E.g., connected via twisted pair cable to a common hub
Ethernet – Contention-Based Implementation (3/11)

• Carrier sense
  – Each station listens to the channel for transmissions on the shared medium
  – No transmission attempt is made while the channel is sensed to be active due to another station transmitting

• Collision detection
  – While transmitting, a station continues to listen to the channel
    • If no other station transmits, then a station will hear (i.e., receive) its own transmission
    • If another station transmits then received sequence will not match the transmitted sequence → collision
  – Stop transmission upon collision detection

Ethernet – Contention-Based Implementation (4/11)

• Binary exponential backoff
  – Time is divided into $b$ discrete time slots, each of length $2^k \tau$, where $\tau$ is the maximum propagation between hosts connected to the medium
    • After the $k^{th}$ collision, $1 \leq k \leq 10$, for a packet is detected, the station waits for some random number of time slots ($b$) in the range 0 to $2^{k-1}$
    • For $11 \leq k \leq 16$, the number of time slots is chosen randomly in the range of 0 to 1023
    • If $k > 16$, transmission failure is declared and the packet is discarded
  – Station then waits $b$ time slots (after sensing channel as idle) before reattempting transmission
Ethernet – Contention-Based Implementation (5/11)

• Ethernet link management operation
  – Sense medium and transmit if idle, otherwise, wait until medium becomes idle and transmit immediately
  – For first $\delta = 2 \times \tau$ time units of transmission, listen to determine if collision has occurred
    • If no collision occurs, bus acquisition has been achieved $\rightarrow$ stop listening and continue transmission
    • If collision occurs, stop packet transmission and transmit a jamming signal $\rightarrow$ Then wait a random amount of time and reattempt transmission

Ethernet – Contention-Based Implementation (6/11)

• Why $2 \times \tau$ time units?
  – Let $\tau$ be the maximum propagation delay between any two stations, A and B
  – Suppose A begins transmission at time $t_0$
  – By time $t_0 + \tau$, station B will hear the transmission
  – However, suppose B begins transmission at time $t_0 + \tau - \varepsilon$, A will not hear the transmission by B until $t_0 + 2 \times \tau - \varepsilon$
  – Thus, need $2 \times \tau$ time slots to detect simultaneous transmissions
Ethernet (7/11)

• Switched Ethernet
  – Twisted pair wire connection between each host and a port on an Ethernet switch
  – High-speed contention-free backplane connecting switch cards
  – Ports on individual cards may either buffered to support contention-free operation or form a local collision domain

Ethernet (8/11)

• Operating rates
  – 10Mbps
  – 100Mbps (fast Ethernet – IEEE 802.3u)
  – 1000Mbps = 1Gbps (Gigabit Ethernet – IEEE 802.3z)

• Minimum frame size
  – Frame needs to be long enough so that collisions may be detected before frame transmission is complete
  – Original standard specified minimum frame size of 64 bytes to support operation on 2500m cable
    Also helps RX to distinguish short data frames from noise
Ethernet (9/11)

- Frame format for IEEE 802.3
  - **Preamble**: 7 bytes of alternating 1 and zeros to allow RX clock synchronization with the TX
  - **Destination Address**: 6 byte field where the MSB is 0 for ordinary, network interface card (NIC), addresses and 1 for group (i.e., multicast) or broadcast addressing
  - **Source Address**: Address for the packet point of LAN entry (last bits 46 correspond to NIC ID)

\[
\begin{array}{cccccc}
\text{Preamble} & \text{Destination Address} & \text{Source Address} & \text{Data} & \text{Pad} & \text{FCS} \\
7 & 6 & 2 & 1500 & 46 & 4 \\
\end{array}
\]

- **SoF**: Start of frame indicator, set to 10101011
- **Data**: 1 to 1500 bytes of message content from higher layer protocols and application
- **Length**: 2 byte field to indicate the length of the Data field
- **Pad**: 0 to 46 bytes inserted into the frame to ensure that the frame length is at least 64 bytes
- **FCS**: 4 byte CRC on entire frame (excludes Preamble and SoF)

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Ethernet (10/11)

- Frame format for IEEE 802.3 (continued)
  - **SoF**: Start of frame indicator, set to 10101011
  - **Data**: 1 to 1500 bytes of message content from higher layer protocols and application
  - **Length**: 2 byte field to indicate the length of the Data field
  - **Pad**: 0 to 46 bytes inserted into the frame to ensure that the frame length is at least 64 bytes
  - **FCS**: 4 byte CRC on entire frame (excludes Preamble and SoF)
Ethernet (11/11)

• Reasons for Ethernet’s success
  – **Simplicity**: Early implementations required only NICs and BNC connector (no smart network devices) → cheap, easy to maintain and scalable
  – **Interoperability**: Ethernet is connectionless, making it a natural medium for IP (to be discussed in Ch. 9) which is also connectionless
  – **Flexibility**: Transmissions speeds have evolved from 10Mbps to 1000Mbps and hub and switch technologies have been developed that did not require changes to the protocol, NIC design or drivers (i.e., *backwards compatible*)

Ethernet Homework Overview (1/2)

• P1: Stations A and B begin transmitting as soon as the link is sensed idle
  – Station B transmits before A (Which station is closer C: A or B?)
  – At least 2 collisions occur due to transmission and retransmission attempts by A and B
  – Station A completes successful transmission prior to B

Draw timeline showing the sequence of events that yield the above scenario
Ethernet Homework Overview (2/2)

• P2: What is the maximum permissible separation between transmitting stations for 100Mbps and 1000Mbps Ethernet?
  – Assume contention-based operation (rather than switched Ethernet mode)
  – Hint: Must consider the round trip propagation delay separating a pair of stations
  – Looking at this problem from a different angle, what would the minimum frame sizes have to be for 100Mbps and 1000Mbps Ethernet if the systems were required to support station separations of up to 1km?