Link Layer: CSMA/CD, MAC addresses, ARP

Smith College, CSC 249
March 27, 2018

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Thursday Recap

- Link layer services
- Principles for multiple access protocols
- Categories of multiple access protocols

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Recap: Random Access Protocols

- Random Access MAC Protocol specifies:
  - how to detect collisions
  - how to recover from collisions (e.g., via delayed retransmissions)
- When a node has a packet to send
  - transmit at full channel data rate R.
  - no *a priori* coordination among nodes
- two or more transmitting nodes ➜ "collision"

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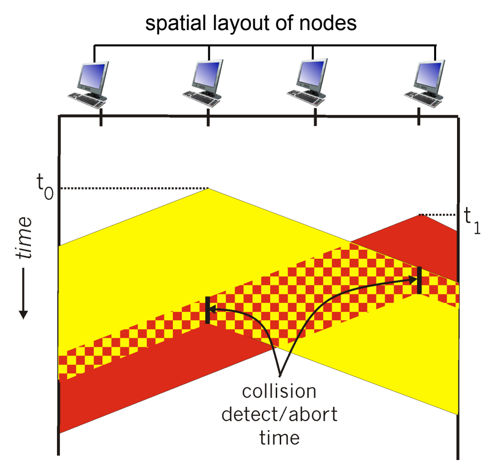
Recap: CSMA/CD (Collision Detection)



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Ethernet CSMA/CD Algorithm

- Ethernet details
  - Ethernet algorithm for CSMA/CD
  - Sensing delay
  - Jam signal
- Examples
  - Indicate impact of length of links
  - Hubs vs. Switches introduction

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Ethernet

- Connectionless: No handshaking between sending and receiving adapter
- Unreliable: receiving adapter does not send ACKs or NAKs to sending adapter
  - stream of frames passed to network layer can have gaps
  - gaps will be filled if application is using TCP
  - otherwise, application will see the gaps
- Ethernet's MAC protocol: CSMA/CD

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Ethernet CSMA/CD Features

- Adapter does not transmit if it senses that some other adapter is transmitting, that is, carrier sense
- Transmitting adapter aborts when it senses that another adapter is transmitting, that is, collision detection
- Before attempting a retransmission, adapter waits a random time, that is, random access

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Ethernet CSMA/CD algorithm

1. Adaptor receives datagram from network layer & creates frame
2. If adapter senses channel idle (senses for 96 bit-times), it starts to transmit frame. If it senses channel busy, it waits until channel is idle.
3. If adapter transmits entire frame without detecting another transmission, the adapter is done with frame.
4. If adapter detects another transmission while transmitting, it aborts and sends jam signal
5. After aborting, adapter enters **exponential backoff**:
   1. After the m^{th} collision, adapter chooses a K at random from $\{0,1,2,\ldots,2^m-1\}$.
   2. Adapter waits $K \cdot 512$ bit times and returns to Step 2

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Ethernet's CSMA/CD (more)

Jam Signal: make sure all other transmitters are aware of collision
- Ensure there was/is enough energy to be detected
- 48 bits long

Bit time: For typical 10 Mbps Ethernet, $(10 \times 10^6)^{-1} = 0.1\mu s$

If K=1023, the wait time is about 50 msec

- **csma/cd applet:**
  http://wps.aw.com/aw_kurose_network_5/111/28536/7305312.cw/index.html
  http://wps.aw.com/aw_kurose_network_3/0,9212,1406346-,00.html

Exponential Backoff:
- *Goal*: adapt retransmission attempts to estimated current load
  - heavy load = more collisions so the random wait will be longer
- first collision: choose K from {0,1}; delay is K· 512 bit transmission times
- after second collision: choose K from {0,1,2,3}…
- after ten collisions, choose K from {0,1,2,3,4,…,1023}

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Question 1a

- In CSMA/CD, after the fifth collision
  - What is the probability that a node chooses K=4?
  - How long will the adapter wait to retransmit on a 10 Mbps Ethernet?

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Question 1 (on handout)

- Nodes A and B are on a 10Mbps link with d_{prop} = 225 bit-times between nodes. If A transmits, and before it is done B begins to transmit:
  - Can A finish before it detects that B has begun?
  - (* If yes, then A believes its transmission was successful and collision-free, so will not retransmit *)
- Ethernet frame (next slides)
  - Size of Frame:
    - Header + CRC = 26 bytes
    - Data field minimum = 46 bytes (up to 1500 bytes maximum for Ethernet)

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What is a bit-time

- **Bit time** is a concept in computer networking. It is defined as the time it takes for one bit to be ejected from a Network Interface Card (NIC) operating at some predefined standard speed, such as 10 Mbit/s.
- The time is measured between the time the logical link control layer 2 sublayer receives the instruction from the operating system until the bit actually leaves the NIC.
- The bit time has nothing to do with the time it takes for a bit to travel on the network medium, but has to do with the internals of the NIC

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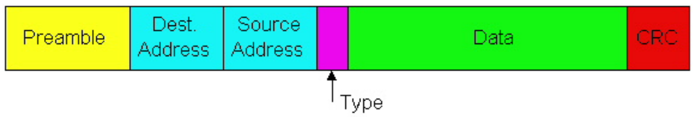
Ethernet Frame Structure

Sending adapter encapsulates IP datagram (or other network layer protocol packet) in Ethernet frame



- Preamble = 8 bytes:
  - 7 bytes with pattern 10101010 followed by one byte with pattern 10101011
  - used to synchronize receiver & sender clocks
- Addresses: 6 bytes each
  - if adapter receives frame with matching destination address, or with broadcast address (*e.g.,* ARP packet), it passes data in frame to network layer protocol
  - otherwise, adapter discards frame
- Type = 2 bytes (higher layer protocol: IPv4, IPv6, ARP ...)
- CRC = 4 bytes, checked at receiver

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Question 1 con't

- Nodes A and B are on a 10Mbps link with d_{prop} = 225 bit-times. If A transmits, and before it is done B begins to transmit:
  - Can A finish before it detects that B has begun?
  - (What is the worst case scenario?)
- Ethernet frame = 26 bytes + 46 bytes = 576 bits

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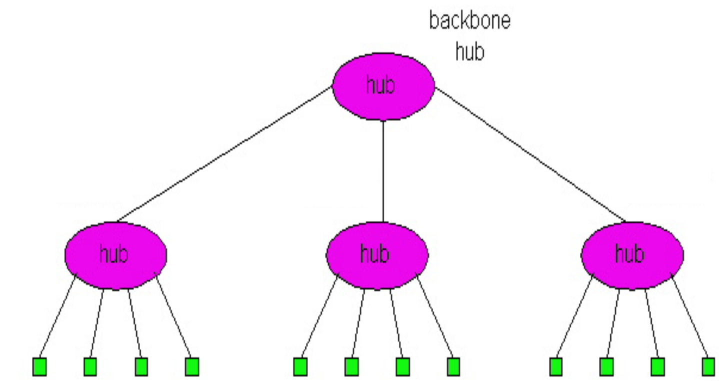
Link Layer



Ethernet Connections: Hubs

Hubs are physical-layer repeaters:

- bits coming from one link go out all other links
- …at the same rate
- …no buffering (no store-and-forward)
- …no CSMA/CD at hub

- A physical layer device – examines no headers
  - Extends max distance between nodes – **good**
  - Creates one large collision domain – **bad**

Question 2 (parts 1 and 2)

- Suppose two nodes, *A* and *B*, are attached to opposite ends of a 900 m cable, and that they each have one frame of 1,000 **bits** (including all headers and preambles) to send to each other.
  - Both nodes attempt to transmit at time t=0.
  - There are four hubs between *A* and *B*, each inserting a 20-bit delay.
  - Assume the transmission rate is 10 Mbps, and CSMA/CD with backoff intervals of multiples of 512 bits is used.
  - After the 1st collision, *A* draws K=0 and *B* draws K=1 in the exponential backoff protocol. Ignore the jam signal and the 96 bit-time delay.

1. What is the one-way propagation delay (including hub delays) between *A* and *B* in seconds? Assume that the signal propagation speed is $2*10^8$ m/sec.
2. At what time (in seconds) is *A*'s packet completely delivered to *B*?
   - → For this problem, recall chapter 1, four sources of delay.
   - → Propagation + transmission = d/s + L/R
   - → Now we have: (time allocated to collision) + d/s + L/R

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Question 2 (part 3)

- *A* and *B*, are attached to 900 m cable, each have one frame of 1,000 **bits** to send.
  - Both nodes attempt to transmit at time t=0.
  - There are four hubs between *A* and *B*, each inserting a 20-bit delay.
  - Transmission rate is 10 Mbps, and backoff intervals of multiples of 512 bits are used.
  - After the 1st collision, *A* draws K=0 and *B* draws K=1 in the exponential backoff protocol. Ignore the jam signal and the 96 bit-time delay.

3. Now only *A* has a packet to send and the hubs are replaced with switches. Each switch has a 20-bit processing delay in addition to a store-and-forward delay. At what time, in seconds, is *A*'s packet delivered at *B*?

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MAC Address

- 32-bit IP address:
  - *network-layer* address
  - used to get datagram to destination IP subnet
- MAC (or LAN, physical, Ethernet, hardware) address:
  - function: *get frame from one interface to another physically-connected interface (same network)*
  - 48 bit MAC address (for most LANs)
    - burned in NIC ROM
    - Written out as xx-xx-xx-xx-xx-xx in 'hexadecimal,' base 16, so each numeral represents 4 bits
    - *e.g., 45-3A-CD-28-5F-40*

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MAC Addresses in Hexadecimal

- 1001 1000 0110 1110 1011 1010 in base 2
- 9 8 6 14 __ __ in decimal for each nibble
- 9 8 6 E __ __ in hexadecimal

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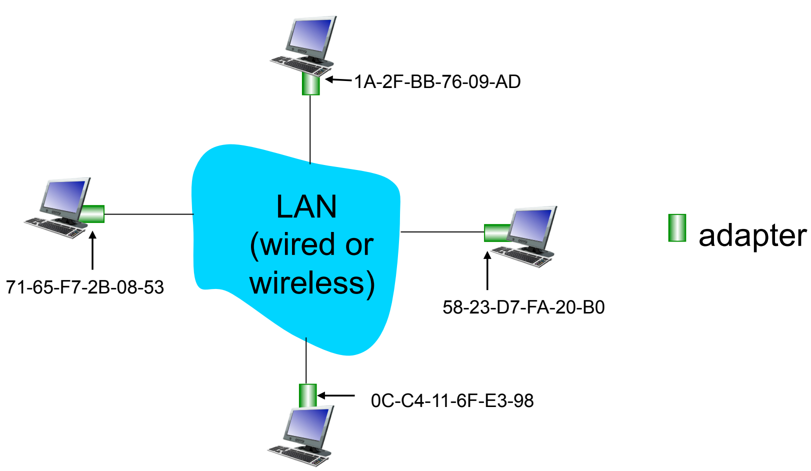
MAC v. IP Addresses

- MAC address allocation administered by IEEE
- Each manufacturer buys a portion of MAC address space (to assure uniqueness)
- MAC flat address ➜ portability
  - can move card from one LAN to another
  - no hierarchical structure to addresses
- Note: IP addresses are NOT portable
  - Hierarchical; and geographic significance
  - Depends on IP subnet to which node is attached

MAC addresses and ARP

each adapter on a LAN has unique *MAC* address



Delivering a datagram: Single Subnet

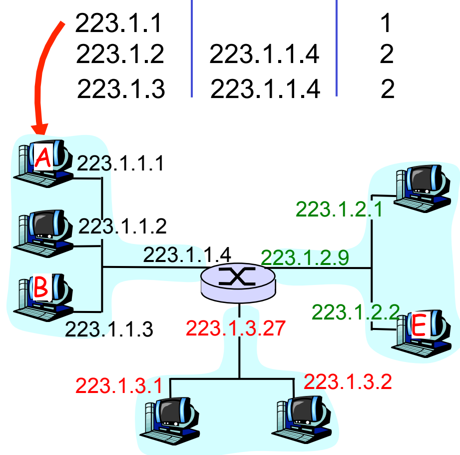
misc fields	223.1.1.1	223.1.1.3	data

Starting at A, given IP datagram addressed to B:

- Look up IP address of B
- Find B is on same subnet as A
- Link layer will send datagram directly to B inside link-layer frame
  - B and A are directly connected
- Remember definition of SUBNET?

routing table in A

Dest. Net.	next router	Nhops
223.1.1		1
223.1.2	223.1.1.4	2
223.1.3	223.1.1.4	2



Delivering a datagram: Different Subnet

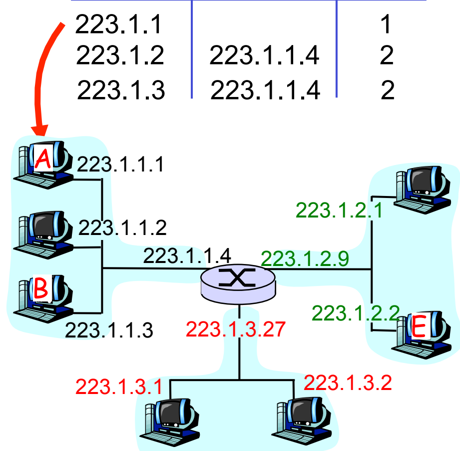
misc fields	223.1.1.1	223.1.2.2	data

Starting at A, dest. E:

- Look up network address of E
- E on *different* subnet
  - A, E not directly attached
- Routing table: next hop router to E is 223.1.1.4
- Link layer sends datagram to router 223.1.1.4 inside link-layer frame
- Datagram arrives at 223.1.1.4
- Process continues…..

routing table in A

Dest. Net.	next router	Nhops
223.1.1		1
223.1.2	223.1.1.4	2
223.1.3	223.1.1.4	2



Chapter 6: Summary

- Link layer technologies
  - Ethernet
  - MAC addresses
  - switched LANS