Stuff

- Project phase III out, due April 25.
- Guest lecturer next Tues: Vern Paxson on Network Security.
- Lecture today:
  - Finish multiple access
  - Link layer addressing
  - Hub vs Switch

Ethernet uses CSMA/CD

- No slots
- adapter doesn't 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

Ethernet CSMA/CD algorithm

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

Ethernet's CSMA/CD (more)

Jam Signal: make sure all other transmitters are aware of collision; 48 bits

Bit time: .1 microsec for 10 Mbps Ethernet ;
for K=1023, wait time is about 50 msec

Exponential Backoff:

- *Goal*: adapt retransmission attempts to estimated current load
  - heavy load: 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}

CSMA/CD efficiency

- T_{prop} = max prop between 2 nodes in LAN
- t_{trans} = time to transmit max-size frame

$$\text{efficiency} = \frac{1}{1 + 5t_{prop} / t_{trans}}$$

- Efficiency goes to 1 as t_{prop} goes to 0
- Goes to 1 as t_{trans} goes to infinity
- Much better than ALOHA, but still decentralized, simple, and cheap

"Taking Turns" MAC protocols

channel partitioning MAC protocols:
- share channel efficiently and fairly at high load
- inefficient at low load: delay in channel access, 1/N bandwidth allocated even if only 1 active node!

Random access MAC protocols
- efficient at low load: single node can fully utilize channel
- high load: collision overhead

"taking turns" protocols

look for best of both worlds!

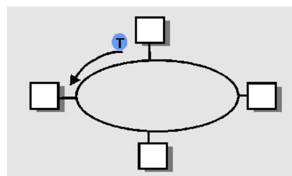
"Taking Turns" MAC protocols

Polling/Scheduling:

- master node "invites" slave nodes to transmit in turn
- concerns:
  - polling overhead
  - latency
  - single point of failure (master)

Token passing (token ring, FDDI):

- control **token** passed from one node to next sequentially.
- token message
- concerns:
  - token overhead
  - latency
  - single point of failure (token)



Summary of MAC protocols

- What do you do with a shared media?
  - Channel Partitioning, by time, frequency or code
    - Time Division, Frequency Division
  - Random partitioning (dynamic),
    - ALOHA, S-ALOHA, CSMA, CSMA/CD
    - carrier sensing: easy in some technologies (wire), hard in others (wireless)
    - CSMA/CD used in Ethernet
    - CSMA/CA used in 802.11
  - Taking Turns
    - polling from a central site, token passing

Link Layer

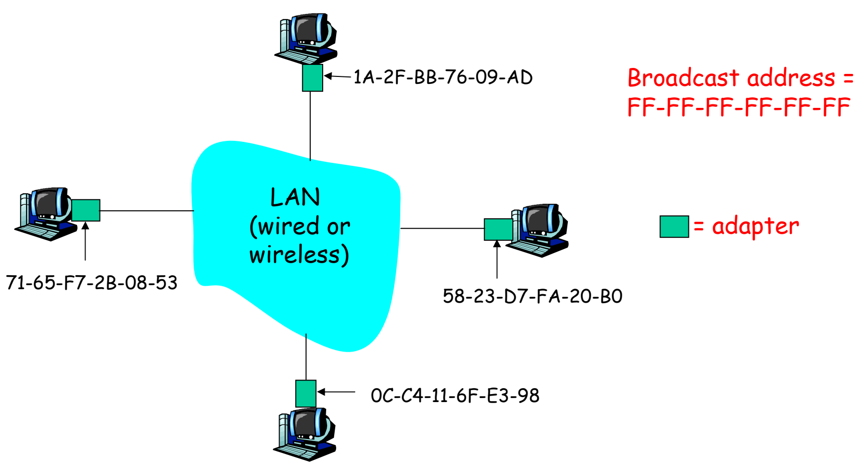
- Introduction and services
- Error detection and correction
- Multiple access protocols
- Ethernet
- Link-Layer Addressing
- Hubs and Switches

MAC Addresses and ARP

- 32-bit IP address:
  - *network-layer* address
  - used to get datagram to destination IP subnet
- MAC (or LAN or physical or Ethernet) address:
  - used to get frame from one interface to another physically-connected interface (same network)
  - 48 bit MAC address (for most LANs) burned in the adapter ROM

LAN Addresses and ARP

Each adapter on LAN has unique LAN address

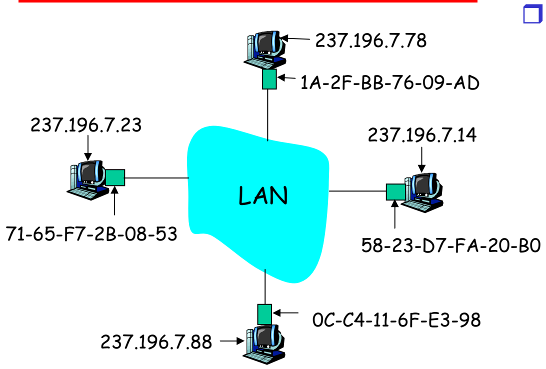


LAN Address (more)

- MAC address allocation administered by IEEE
- manufacturer buys portion of MAC address space (to assure uniqueness)
- Analogy:
  - (a) MAC address: like Social Security Number
  - (b) IP address: like postal address
- MAC flat address ➜ portability
  - can move LAN card from one LAN to another
- IP hierarchical address NOT portable
  - depends on IP subnet to which node is attached

ARP: Address Resolution Protocol

Question: how to determine MAC address of B knowing B's IP address?



- Each IP node (Host, Router) on LAN has ARP table
- ARP Table: IP/MAC address mappings for some LAN nodes

  < IP address; MAC address; TTL>

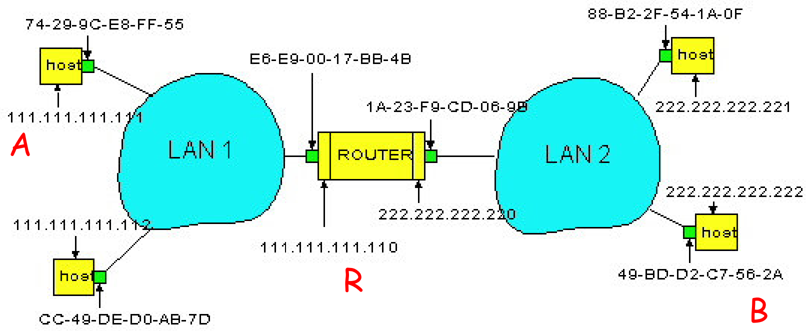
  - TTL (Time To Live): time after which address mapping will be forgotten (typically 20 min)

ARP protocol: Same LAN (network)

- A wants to send datagram to B, and B's MAC address not in A's ARP table.
- A broadcasts ARP query packet, containing B's IP address
  - Dest MAC address = FF-FF-FF-FF-FF-FF
  - all machines on LAN receive ARP query
- B receives ARP packet, replies to A with its (B's) MAC address
  - frame sent to A's MAC address (unicast)
- A caches (saves) IP-to-MAC address pair in its ARP table until information becomes old (times out)
  - soft state: information that times out (goes away) unless refreshed
- ARP is "plug-and-play":
  - nodes create their ARP tables without intervention from net administrator

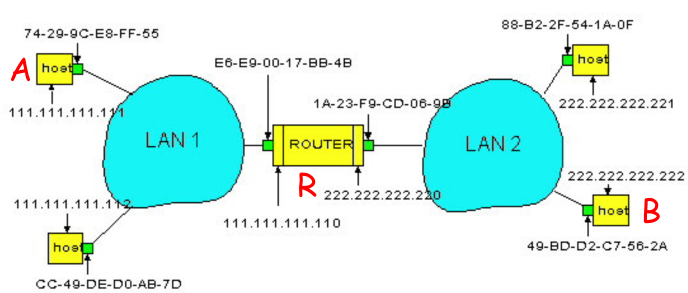
Routing to another LAN

walkthrough: send datagram from A to B via R
assume A know's B IP address



- Two ARP tables in router R, one for each IP network (LAN)

- A creates datagram with source A, destination B
- A uses ARP to get R's MAC address for 111.111.111.110
- A creates link-layer frame with R's MAC address as dest, frame contains A-to-B IP datagram
- A's adapter sends frame
- R's adapter receives frame
- R removes IP datagram from Ethernet frame, sees its destined to B
- R uses ARP to get B's MAC address
- R creates frame containing A-to-B IP datagram sends to B



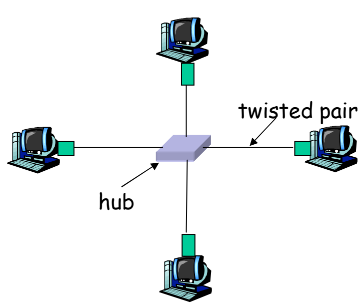
Link Layer

- Introduction and services
- Error detection and correction
- Multiple access protocols
- Ethernet
- Link-Layer Addressing
- Hubs and Switches

Hubs

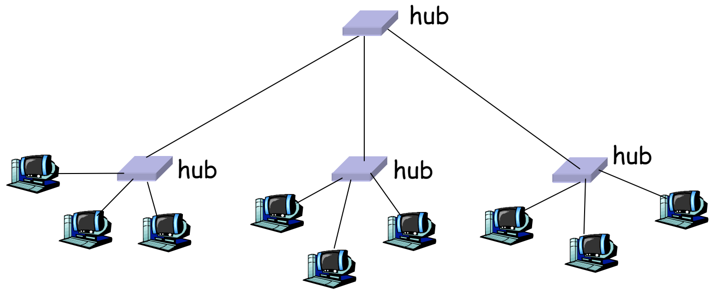
Hubs are essentially physical-layer repeaters:

- bits coming from one link go out all other links
- at the same rate
- no frame buffering
- no CSMA/CD at hub: adapters detect collisions
- provides net management functionality



Interconnecting with hubs

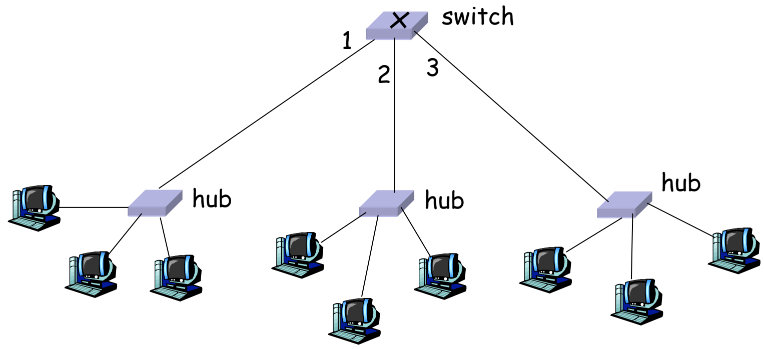
- Backbone hub interconnects LAN segments
- Extends max distance between nodes
- But individual segment collision domains become one large collision domain
- Can't interconnect 10BaseT & 100BaseT



Switch

- Link layer device
  - stores and forwards Ethernet frames
  - examines frame header and selectively forwards frame based on MAC dest address
  - when frame is to be forwarded on segment, uses CSMA/CD to access segment
- transparent
  - hosts are unaware of presence of switches
- plug-and-play, self-learning
  - switches do not need to be configured

Forwarding



• How do determine onto which LAN segment to forward frame?

Self learning

- A switch has a switch table
- entry in switch table:
  - (MAC Address, Interface, Time Stamp)
  - stale entries in table dropped (TTL can be 60 min)
- switch *learns* which hosts can be reached through which interfaces
  - when frame received, switch "learns" location of sender: incoming LAN segment
  - records sender/location pair in switch table

Filtering/Forwarding

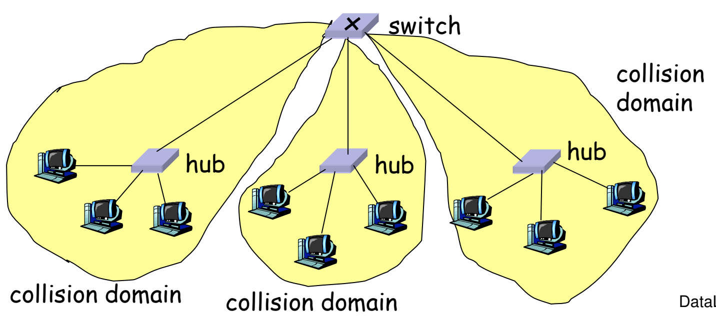
When switch receives a frame:

index switch table using MAC dest address
if entry found for destination
then{
if dest on segment from which frame arrived
then drop the frame
else forward the frame on interface indicated
}
else flood

forward on all but the interface on which the frame arrived

Switch: traffic isolation

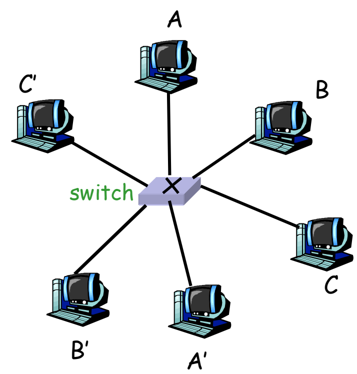
- switch installation breaks subnet into LAN segments
- switch filters packets:
  - same-LAN-segment frames not usually forwarded onto other LAN segments
  - segments become separate collision domains



Switches: dedicated access

- Switch with many interfaces
- Hosts have direct connection to switch
- No collisions; full duplex

Switching: A-to-A' and B-to-B' simultaneously, no collisions



Institutional network