ICS 451: Today's plan

- Medium Access Control
- ALOHA Net
- Carrier Sense Multiple Access (CSMA)
  - with Collision Detection (CSMA/CD)
  - with Collision Avoidance (CSMA/CA)

Medium Access Control (MAC)

- shared medium: who gets to send when?
  - older ethernet had a shared coaxial cable
  - 802.11 shares the wireless spectrum
- bus topology: all hosts send on same cable
- ring topology: each host receives from its clockwise predecessor, sends to its successor
- star topology: a hub in the “middle” connects all the hosts to each other
- each host may be a router

Sharing Access

- multiple senders sending on the same medium at the same time cause a *collision*:
  - no receiver can decode either message
- deterministic sharing:
  - a mechanism guarantees at most one sender
- stochastic (probabilistic) sharing:
  - collisions are handled gracefully
- stochastic sharing is easier
  - may be more efficient

Example of Deterministic Sharing

- Frequency Division Multiplexing (FDM)
- each sender is assigned a frequency
  - really a range of frequencies, e.g. 2.4-2.5GHz
- since there is only one sender on each frequency, there can be no collisions
- receiver must tune in to the sender's frequency

- on optic fibers, Wavelength Division Multiplexing, WDM

Example of Deterministic Sharing

- Time Division Multiplexing (TDM)
- each sender is assigned a time slot
  - e.g. telephone, one byte every 125μs
- only that sender can send during that time
- someone else sends in the next byte slot
- 30x 64Kb/s synchronous (8000 Bytes/s) channels are multiplexed into a single 2Mb/s E1 channel
- *signaling* allocates these slots to conversations

Problems with Deterministic Sharing

- deterministic sharing works best when the bandwidth needs of each sender are fixed
- but computers send in bursts
- it is better to allocate bandwidth as needed
- a lesson ISPs don't seem to have learned
  - because harder to do differential charging

    (same was true for telephone companies)

ALOHA net

- packet radio technology at UHM
- logical star topology with a central hub
- two channels:
  - one for sending from the terminals to the hub
    - collisions can only happen on this channel
  - one for transmissions from the hub
- hub verifies all received packets
  - discards any with errors
  - acknowledges correctly received packts
- terminal must retransmit unacked packets

ALOHA retransmissions

- a packet may be lost for many reasons
- one of them is collisions
- in case of collision, terminals must retransmit
  - but should not retransmit at the same time!
  - so should wait a random interval
- transmission fails after N unsuccessful retransmissions

ALOHA performance

- if few terminals are trying to transmit, collisions are unlikely, and Aloha works well
- if many terminals are trying to transmit, collisions are likely and no traffic gets through
- best performance is at about 18% traffic load
  - about 1/6 of the potential bandwidth!
  - if time is slotted, the performance can double
    - because a collision does not take up two slots

Carrier Sense Multiple Access

- a signal is encoded by a *carrier* frequency
- in ALOHA, a terminal cannot tell that other terminals are transmitting
- on a shared wire, it should be possible to tell
- also sometimes possible in 802.11/WiFi
- while anyone is transmitting, wait
  - persistent CSMA: when they are done, transmit
  - non-persistent CSMA: a random time later, check again, transmit if free

may reach ~50-80% of channel capacity

CSMA on wired networks

- on a wire, everyone receives everything sent
- so everyone can detect collisions
  - even the sender
  - sender stops sending immediately
- the time to collision detection depends on the length of the wire (and the speed of light)
  - CSMA/CD (collision detection)
  - a jamming signal on the wire guarantees everyone sees the collision (acks not needed)

CSMA/CD requirements

- minimum frame size (*b* bits or *m* meters)
  - smaller frames might collide without everyone detecting the collisions
  - with *c* the speed of light (in the medium) and *T* the bits/second, $m = b \times c / T$
- maximum size of shared medium (less than *m*)
  - in larger networks, the collision might only occur in part of the network
  - actually, size required to be less than m/2
- a *slot time* is b / T

Ethernet CSMA/CD

- minimum frame size is 60 bytes/480 bits
- for 10Mb/s Ethernet, slot time is 48μs
  - for 100Mb/s Ethernet, slot time is 4.8μs
- assume c on the wire is 200m/μs

  ~300m/μs in vacuum
- maximum size for 10Mb/s Ethernet is 200m/μs x 48μs / 2 = 4,800m or 5km
  - 500m for 100Mb/s Ethernet

Ethernet Retransmission

- after a collision, wait 0 or 1 slot times
- after the same packet has collided again, wait 0, 1, 2, or 3 slot times, chosen at random
- double the maximum waiting time after each collision
  - up to 1,024 slot times
- transmission fails after 16 attempts
- Binary Exponential Backoff
  - also used in TCP

802.11 CSMA

- wireless medium, sender can't detect collision
- each frame acknowledged by receiver
  - separate ack frames
- sender listens before transmission
  - a short interval (SIFS) before sending an ack
  - before sending a data packet, either
    - a medium interval (DIFS) if there was no collision
    - a longer interval (EIFS) if collision was detected

802.11 CSMA/CA

- sender can reserve channel:
  - Request to Send, RTS frame
  - receiver replies with Clear to Send, CTS frame
- anyone in range of RTS or CTS avoids sending
- RTS/CTS are optional in 802.11
  - more useful for larger packets

Summary

- ALOHA is simple: transmit when ready
  - retransmit if necessary
  - still used, e.g. in satellite networks
  - used to reserve voice channels, so efficiency is not paramount
- Carrier sense allows higher efficiencies
  - best on a wire: quick collision detection and retransmission
  - CA similar, but slower overall, more overhead