Link Layer

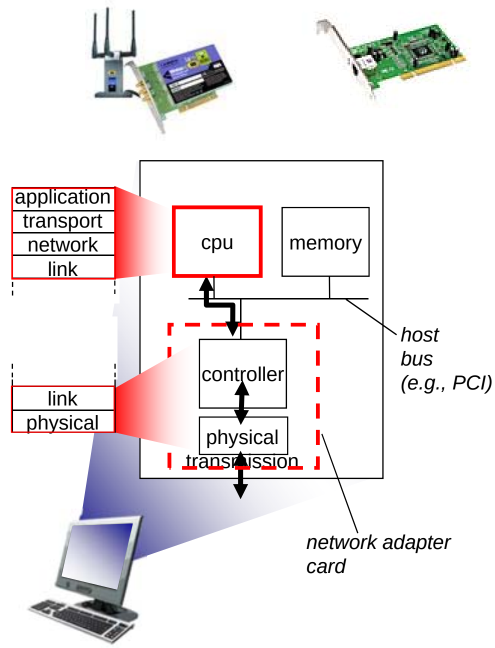
- Reference
  - Chapter 05, *Computer Networking: A Top Down Approach,* 6/E, Jim Kurose, Keith Ross, Addison-Wesley
  - Adapted from part of the slides provided by the authors

Link layer services

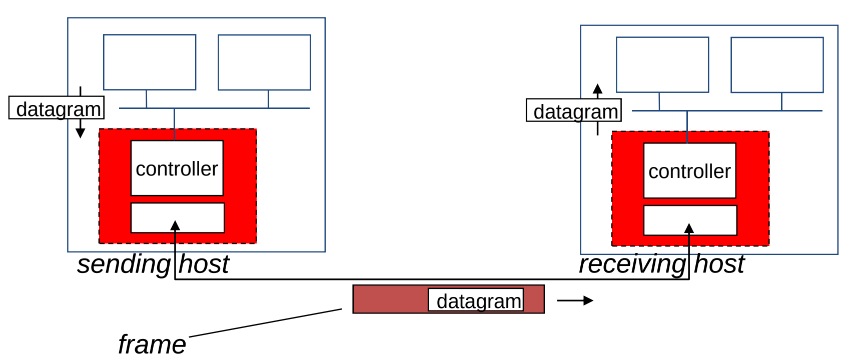
- *framing, link access:*
  - encapsulate datagram into frame, adding header, trailer
  - channel access if shared medium
  - "MAC" addresses used in frame headers to identify source, dest
- *reliable delivery between adjacent nodes*
  - seldom used on low bit-error link (fiber, some twisted pair)
  - wireless links: high error rates
- flow control:
  - pacing between adjacent sending and receiving nodes
- error detection:
  - errors caused by signal attenuation, noise.
  - receiver detects presence of errors
    - signals sender for retransmission or drops frame
- error correction:
  - receiver identifies and corrects bit error(s) without resorting to retransmission
- half-duplex and full-duplex
  - with half duplex, nodes at both ends of link can transmit, but not at same time

Where is the link layer implemented?

- in each and every host
- link layer implemented in "adaptor" (aka *network interface card* NIC) or on a chip
  - Ethernet card, 802.11 card; Ethernet chipset
  - implements link, physical layer
- attaches into host's system buses
- combination of hardware, software, firmware



Adaptors communicating



- sending side:
  - encapsulates datagram in frame
  - adds error checking bits, flow control, reliable data transmission, etc.
- receiving side
  - looks for errors, flow control, reliable data transmission, etc
  - extracts datagram, passes to upper layer at receiving side

Multiple access protocols

- single shared broadcast channel
- two or more simultaneous transmissions by nodes: interference
  - *collision* if node receives two or more signals at the same time

multiple access protocol

- distributed algorithm that determines how nodes share channel, i.e., determine when node can transmit
- communication about channel sharing must use channel itself!
  - no out-of-band channel for coordination

MAC protocols: taxonomy

three broad classes:

- *channel partitioning*
  - divide channel into smaller “pieces”: TDMA (time division multiple access), FDMA (frequency division multiple access), CDMA (code division multiple access).
  - allocate piece to node for exclusive use
- *random access*
  - channel not divided, allow collisions
  - “recover” from collisions
  - Examples: slotted ALOHA, ALOHA, CSMA, CSMA/CD used in Ethernet, CSMA/CA used in 802.11
- *“taking turns”*
  - nodes take turns, but nodes with more to send can take longer turns
  - Examples: bluetooth, FDDI, token ring

Random access protocols

- when node has packet to send
  - transmit at full channel data rate R.
  - no *a priori* coordination among nodes
- two or more transmitting nodes ➜ "collision",
- random access MAC protocol specifies:
  - how to detect collisions
  - how to recover from collisions (e.g., via delayed retransmissions)
- examples of random access MAC protocols:
  - slotted ALOHA
  - ALOHA
  - CSMA, CSMA/CD, CSMA/CA

Slotted ALOHA

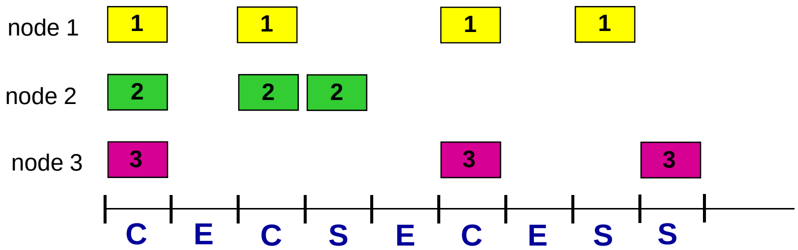
assumptions:

- all frames same size
- time divided into equal size slots (time to transmit 1 frame)
- nodes start to transmit only slot beginning
- nodes are synchronized
- if 2 or more nodes transmit in slot, all nodes detect collision

operation:

- when node obtains fresh frame, transmits in next slot
  - *if no collision:* node can send new frame in next slot
  - *if collision:* node retransmits frame in each subsequent slot with prob. ***p*** until success

Slotted ALOHA



Maximum efficiency = 0.37
at best: channel used for useful transmissions 37% of time!

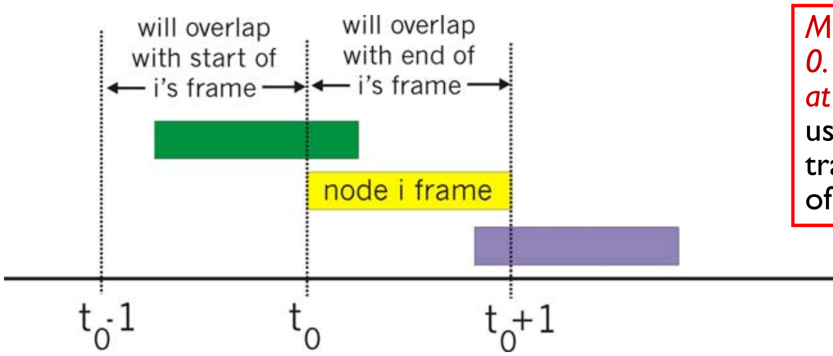
Pros:

- single active node can continuously transmit at full rate of channel
- highly decentralized: only slots in nodes need to be in sync
- simple

Cons:

- collisions, wasting slots
- idle slots
- nodes may be able to detect collision in less than time to transmit packet
- clock synchronization

Pure (unslotted) ALOHA



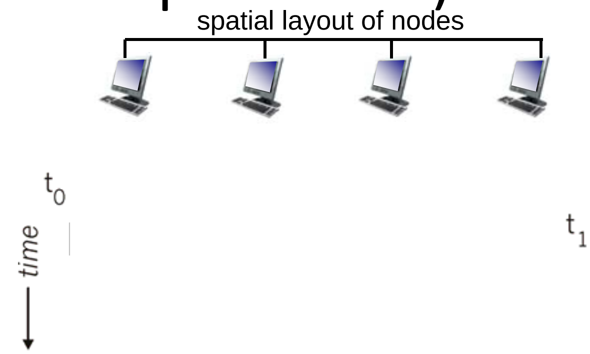
Maximum efficiency = 0.18
at best: channel used for useful transmissions 18% of time!

- unslotted Aloha: simpler, no synchronization
- when frame first arrives
  - transmit immediately
- collision probability increases:
  - frame sent at t_0 collides with other frames sent in $[t_0-1,t_0+1]$

CSMA (carrier sense multiple access)

CSMA: listen before transmit:

- if channel sensed idle: transmit entire frame
- if channel sensed busy, defer transmission
- collisions *can* still occur: propagation delay means two nodes may not hear each other's transmission
- collision: entire packet transmission time wasted
  - distance & propagation delay play role in in determining collision probability



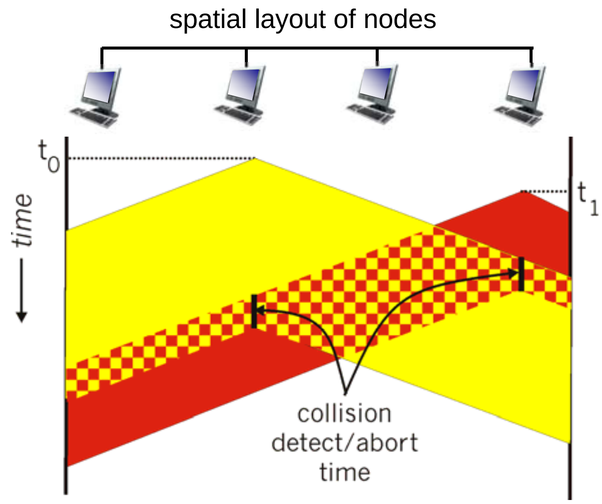
CSMA/CD (collision detection)

CSMA/CD: carrier sensing, deferral as in CSMA

- collisions *detected* within short time
- colliding transmissions aborted, reducing channel wastage

- collision detection:
  - easy in wired LANs: measure signal strengths, compare transmitted, received signals
  - difficult in wireless LANs: received signal strength overwhelmed by local transmission strength

CSMA/CD (collision detection)



Ethernet CSMA/CD algorithm

1. NIC receives datagram from network layer, creates frame
2. If NIC senses channel idle, starts frame transmission. If NIC senses channel busy, waits until channel idle, then transmits.
3. If NIC transmits entire frame without detecting another transmission, NIC is done with frame!
4. If NIC detects another transmission while transmitting, aborts and sends jam signal
5. After aborting, NIC enters *binary (exponential) backoff:*
   - after *m*th collision, NIC chooses *K* at random from *{0,1,2, …, 2^m-1}*. NIC waits K·512 bit times, returns to Step 2
   - longer backoff interval with more collisions