Lecture 24: Ethernet

CSE 123: Computer Networks

Alex C. Snoeren

Lecture 24 Overview

- Finishing up media access
  - Ethernet
  - Contention-free methods (rings)
- Moving beyond one wire
  - Link technologies have limits on physical distance
  - Also frequently on number of hosts connected

Channel Efficiency

Q: What is max fraction slots successful?

A: Suppose *n* stations have packets to send

- Each transmits in slot with probability *p*
- Prob[successful transmission], *S*, is:

$$S = p\,(1-p)^{(n-1)}$$

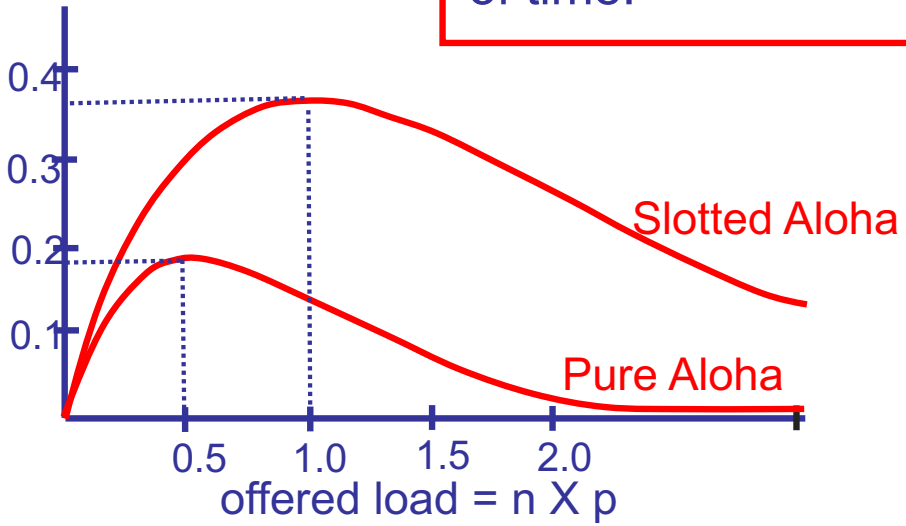
- any of *n* nodes:

S = Prob[one transmits] = $np(1-p)^{(n-1)}$

(optimal *p* as *n*->infinity = *1/n*)

= *1/e* = *.37*

At best: channel used for useful transmissions 37% of time!



Carrier Sense (CSMA)

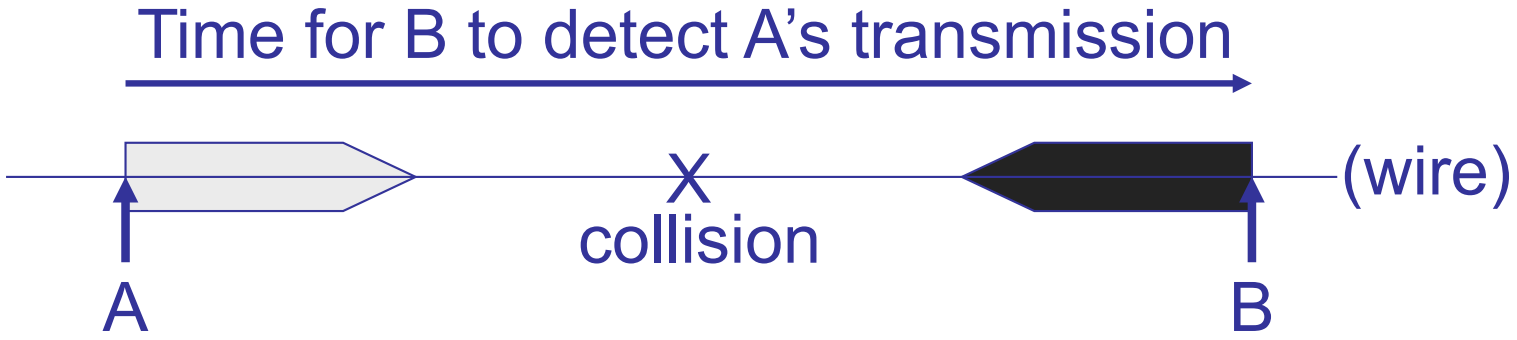
- Aloha transmits even if another host is transmitting
  - Thus guaranteeing a *collision*
- Instead, listen *first* to make sure channel is idle
  - Useful only if channel is frequently idle
  - Why?
- How long to be confident channel is idle?
  - Depends on maximum propagation delay
  - Small (<<1 frame length) for LANs
  - Large (>>1 frame length) for satellites

Retransmission Options

- non-persistent CSMA
  - Give up, or send after some random delay
  - Problem: may incur larger delay when channel is idle
- 1-persistent CSMA
  - Send as soon as channel is idle
  - Problem: blocked senders all try to send at once
- *P*-persistent CSMA
  - If idle, send packet with probability *p*; repeat
  - Make sure ($p * n$) < 1

Jamming

- Even with CSMA there can still be collisions. Why?



- If nodes can detect collisions, abort! (CSMA/CD)
  - Requires a minimum frame size ("acquiring the medium")
  - *B* must continue sending ("jam") until *A* detects collision

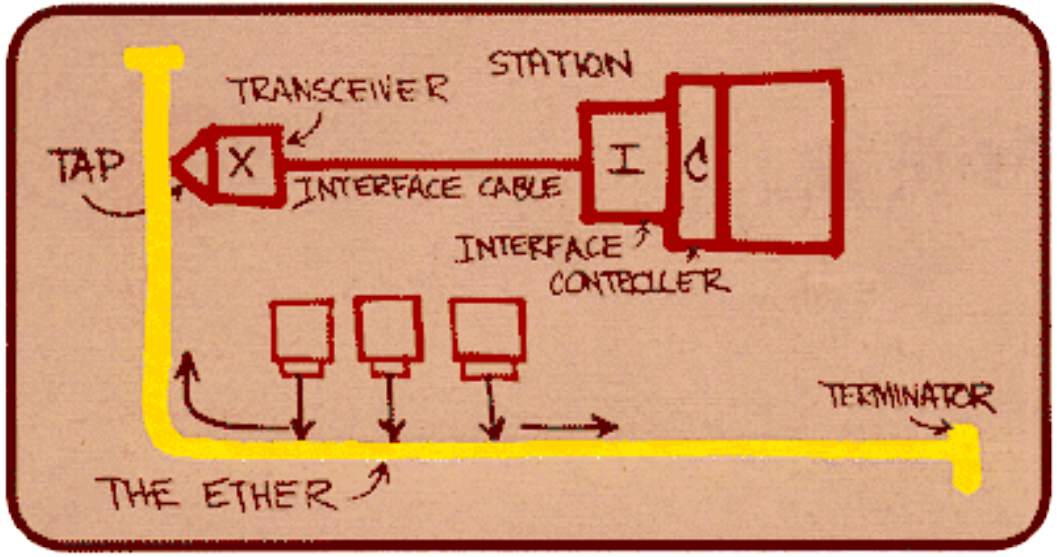
- Requires a full duplex channel
  - Wireless is typically half duplex; need an alternative

Collision Detection (CD)

- How can A know that a collision has taken place?
  - Worst case:
    - » Latency between nodes A& B is d
    - » A sends a message at time t and B sends a message at t + d – epsilon (just before receiving A's message)
  - B knows there is a collision, but not A… A must keep transmitting until it can tell if a collision occurred
  - How long? *2 * d*
- IEEE 802.3 Ethernet specifies max value of *2d* to be 51.2us
  - This relates to maximum distance of 2500m between hosts
  - At 10Mbps it takes 0.1us to transmit one bit so 512 bits take 51.2us to send
  - So, Ethernet frames must be at least 64B (512 bits) long
    - » Padding is used if data is too small
- Send jamming signal to insure all hosts see collision
  - 48 bit signal

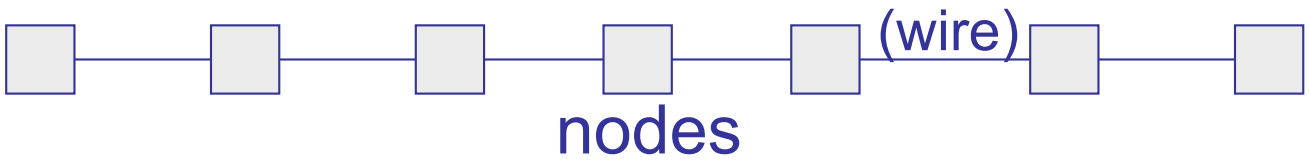
Ethernet

- First local area network (LAN)
  - Developed in early ’70s by Metcalfe and Boggs at PARC
  - Originally 1Mbps, now supports 10Mbps, 100Mbps, 1Gbps 10Gbps, 40Gbps, and 100Gbps flavors (400G in dev)
- Currently *the* dominant LAN technology
  - Becoming the dominant WAN technology



Classic Ethernet

- IEEE 802.3 standard wired LAN
  (modified 1-persistent CSMA/CD)
- Classic Ethernet: 10 Mbps over coaxial cable
  - All nodes share same wire
  - Max length 2.5km, max between stations 500m



- Framing
  - Preamble, 32-bit CRC, variable length data
  - Unique 48-bit address per host (bcast & multicast addrs too)

Preamble (8)	Source (6)	Dest (6)	Len (2)	Payload (var)	Pad (var)	CRC (4)

Ethernet improvements

- Problems with random delay with fixed mean
  - Few senders = unnecessary delay
  - Many senders = unnecessary collisions
- Binary exponential back-off balances delay w/load
  - First collision: wait 0 or 1 min frame times at random, retry
  - Second time: wait 0, 1, 2, or 3 times
  - *N*th time (*n*<=10): wait 0, 1, …, 2^n-1 times
  - Max wait 1023 frames; give up after 16 attempts

Capture Effect

- Randomized access scheme is not fair
- Suppose stations *A* and *B* always have data to send
  - They *will* collide at some time
  - Both pick random number of "slots" (0, 1) to wait
  - Suppose *A* wins and sends
  - Next time they collide, *B*'s chance of winning is halved
    - » *B* will select from 0,1,2,3 due to exponential back-off
- *A* keeps winning: said to have captured the channel

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Ethernet Performance

- Much better than Aloha or CSMA in practice
- Source of protocol inefficiency: still collisions
  - More efficient to send larger frames
    - » Acquire the medium and send lots of data
  - Less efficient if
    - » More hosts – more collisions needed to identify single sender
    - » Smaller packet sizes – more frequent arbitration
    - » Longer links – collisions take longer to observe, more wasted bandwidth

Contention-free Protocols

- Problem with fixed partitioning:
  - Inefficient at low load (idle channels)
- Problem with contention-based protocols:
  - Inefficient at high load (collisions)
- Ideal(?): Contention-free protocols
  - Try to do both by explicitly taking turns
  - Can potentially also offer guaranteed bandwidth, latency, etc.

Contention-free Approaches

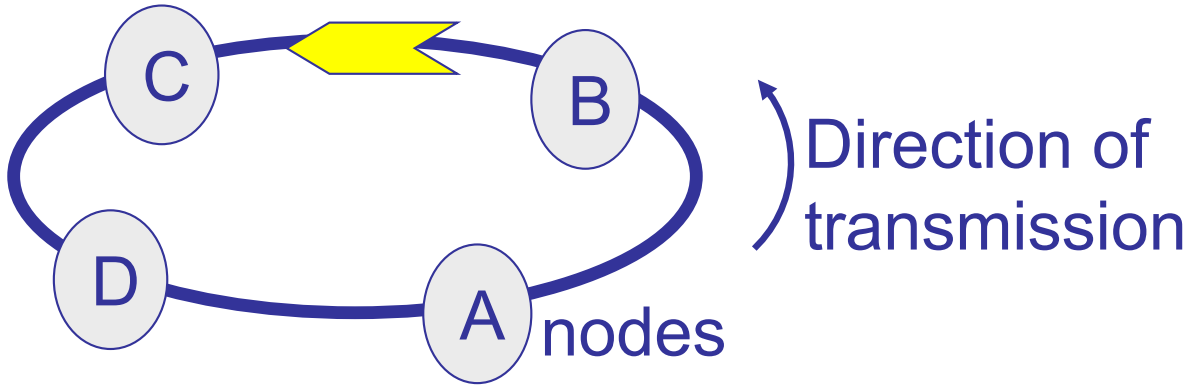
Polling

- Master node "invites" slave nodes to transmit in turn
  - Request to Send (RTS), Clear to Send (CTS) messages
- Problems:
  - Polling overhead
  - Latency
  - Single point of failure (master)

Token Passing

- Control **token** passed from one node to next sequentially.
- Point-to-point links can be fast
- Problems:
  - Token overhead
  - Latency
  - Single point of failure (token)

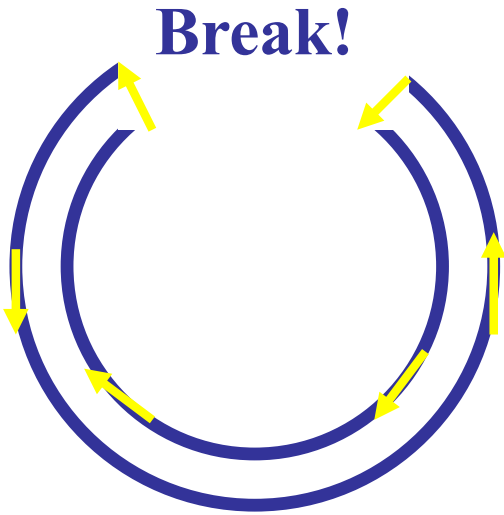
Token Ring (802.5)



- Token rotates “permission to send” around nodes
- Sender injects packet into ring and removes later
  - Maximum token holding time (THT) bounds access time
  - Early or delayed token release
  - Round robin service, acknowledgments and priorities
- Monitor nodes ensure health of ring (alerts on failures)

FDDI
(Fiber Distributed Data Interface)

- Roughly a large, fast token ring
  - First real use of fiber optics in a LAN
  - 100 Mbps and 200km (FDDI) vs 4/16 Mbps and local (802.5)
  - Dual counter-rotating rings for redundancy
  - Complex token holding policies for voice etc. traffic
- Token ring advantages
  - No contention, bounded access delay
  - Support fair, reserved, priority access
- Disadvantages
  - Complexity, reliability, scalability



Why Did Ethernet Win?

- Failure modes
  - Token rings – network unusable
  - Ethernet – node detached
- Good performance in common case
- Completely distributed, easy to maintain/administer
- Easy incremental deployment
- Volume → lower cost → higher volume ….

Summary of Media Access

- How to divide shared channel among different users
  - Fixed partitioning (FDMA, TDMA, CDMA)
    - » Guaranteed bandwidth for each user, but wasteful when not used and can't allocate different bandwidth to different users
  - Contention-based protocols (CSMA, CSMA/CD)
    - » Try and backoff if fail; dynamic allocation of bandwidth on demand, works well at load load but collisions a problem at high load
  - Contention-free protocols (Token Ring, FDDI, RTS/CTS)
    - » Explicit turn-taking; strong guarantees on access time and can make bandwidth guarantees, but complex and fragile to failure
- But… aren't there limits to what we can do with one shared channel?

For Next Time

- NO CLASS ON MONDAY
- Homework 3 due on Wednesday
- Read 2.7 in P&D