Lecture 9: Bridging

CSE 123: Computer Networks
Alex C. Snoeren
Lecture 9 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

● Methods to interconnect LANs
  ◆ Repeaters and bridges
  ◆ Switching
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? \(2 \times d\)

- 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 addr too)

<table>
<thead>
<tr>
<th></th>
<th>Source (6)</th>
<th>Dest (6)</th>
<th>Len (2)</th>
<th>Payload (var)</th>
<th>Pad (var)</th>
<th>CRC (4)</th>
</tr>
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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
  - Nth time \((n<10)\): wait 0, 1, \ldots, 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
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
Contestation-free Protocols

- Problem with fixed partitioning:
  - Inefficient at low load (idle channels)

- Problem with contention-based protocols:
  - Inefficient at high load (collisions)

- Ideal(?): Contestation-free protocols
  - Try to do both by explicitly taking turns
  - Can potentially also offer guaranteed bandwidth, latency, etc.
Contestion-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.

- 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

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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?
Problems with Busses

- One shared link (a bus) limits scale in terms of:
  - Distance (e.g., 2500 m for Ethernet)
  - Number of nodes (1024 nodes)
  - Performance (Capacity shared across all nodes)

- A better alternative is to have multiple busses
  - Each bus is of a limited size, scale, number of hosts, etc.

- Need the ability to connect multiple busses together
  - In other words move frames from one wire to another
Hubs/Repeaters

- Physical layer device
  - One “port” for each LAN
  - Repeat received *bits* on one port out *all* other ports
Hub Advantages

- Hubs can be arranged into hierarchies
  - Ethernet: up to four hubs between any pair of nodes

- Most of LAN continues to operate if “leaf” hub dies

- Simple, cheap
Still One Big Bus

- **Single collision domain**
  - No improvement in max throughput
  - Average throughput < as # of nodes increases
  - Why?

- **Still limited in distance and number of hosts**
  - Collision detection requirements
  - Synchronization requirements

- **Requires performance homogeneity**
  - Can’t connect 10 Mbps and 100 Mbps networks
Bridges

- **Store and forward** device
  - Data-link layer device
  - Buffers entire packet and *then* rebroadcasts it on other ports

- Creates *separate* collision domains
  - Uses CSMA/CD for access to each LAN (acts like a host)
  - Can accommodate different speed interfaces (issues?)
  - Separate CDs improves throughput (why?)

- Can significantly improve performance
  - Not all frames go everywhere. (Why did they with a hub?)
For Next Time

- Read 3.2-3.2.4 in P&D

- HW2 due next Wednesday