Lecture 8: Carrier Sense Multiple Access

CSE 123: Computer Networks
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HW 2 due next Wednesday
Lecture 8 Overview

- Methods to share physical media: **multiple access**
  - Random access

- Channelizing mechanisms

- Contention-based mechanisms
  - Aloha
  - Ethernet
Partitioning Visualization

FDMA

TDMA

CDMA

Courtesy Takashi Inoue
Problem w/Channel partitioning

- Not terribly well suited for random access usage
  - Why?

- Instead, design schemes for more common situations
  - Not all nodes want to send all the time
  - Don’t have a fixed number of nodes

- Potentially higher throughput for transmissions
  - Active nodes get full channel bandwidth
Aloha

- Designed in 1970 to support wireless data connectivity
  - Between Hawaiian Islands—rough!

- Goal: distributed access control (no central arbitrator)
  - Over a shared broadcast channel

- Aloha protocol in a nutshell:
  - When you have data **send it**
  - If data doesn’t get through (receiver sends acknowledgement) then **retransmit after a random delay**
  - Why not a fixed delay?
Collisions

- Frame sent at $t_0$ collides with frames sent in $[t_0-1, t_0+1]$
  - Assuming unit-length frames
  - Ignores propagation delay
Slotted Aloha

- Time is divided into equal size slots (frame size)
- Host wanting to transmit starts at start of next slot
  - Retransmit like w/Aloha, but quantize to nearest next slot
- Requires time synchronization between hosts

Success (S), Collision (C), Empty (E) slots
Q: What is max fraction slots successful?
A: Suppose $n$ stations have packets to send
   - Each transmits in slot with probability $p$
   - $\text{Prob[successful transmission]}, S, \text{ is:}$

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

   - any of $n$ nodes:

   $$S = \text{Prob[one transmits]} = np(1-p)^{n-1}$$
   (optimal $p$ as $n \to \infty = 1/n$)
   $$= 1/e = .37$$

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 $(p \times n) < 1$
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

- 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... B must keep transmitting so A knows that its packet has collided
  - 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 and 10Gbps flavors (40/100G in development)

- 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
  - Nth 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
Ethernet Performance

- Much better than Aloha or CSMA in practice

- Source of protocol inefficiency: 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
For Next Time

- Read 3-3.2 in P&D
- Keep going on the project…
- Really, have a great weekend!