CSC2209
Computer Networks

MAC Protocols + Routing

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• TONS seminar Fridays at 3pm in BA1170
• “Balancing distance and lifetime in delay constrained multihop wireless networks”. Ben Liang ECE U. of T.

• Start brainstorming project ideas!
  – Lots of suggestions available
    • Project suggestion on course’s website
    • News writeups contain suggestions
    • Lectures’ slides contain suggestions
Question

• Would it be useful to setup a 1-2 hour meeting to discuss project suggestions?
  – Serves to bring everyone on the same page

• If yes, when?
Outline

1. ALOHA
2. CSMA MAC protocols
3. Ethernet
4. Measured capacity of an Ethernet
1. ALOHA

• Wireless links between the Hawaiian islands in the 70s
• Want distributed allocation
  – no special channels, or single point of failure

• Aloha protocol:
  – Just send when you have data!
  – There will be some collisions of course …
  – Detect errored frames and retransmit a random time later

• Simple, decentralized and works well for low load
  – For many users, analytic traffic model, max efficiency is 18%
2. Carrier Sense Multiple Access

- We can do better by listening before we send (CSMA)
  - good defense against collisions only if “a” is small (LANs)

\[ a = \text{bandwidth} \times \text{delay} / \text{packet size} \]

- “a” parameter: number of packets that fit on the wire
  - Small (<<1) for LANs, large (>>1) for satellites
What if the Channel is Busy?

• 1-persistent CSMA
  – Wait until idle then go for it
  – Blocked senders can queue up and collide

• non-persistent CSMA
  – Wait a random time and try again
  – Less greedy when loaded, but larger delay

• p-persistent CSMA
  – If idle send with prob $p$ until done; assumed slotted time
  – Choose $p$ so $p \times \#\text{senders} < 1$; avoids collisions at cost of delay
CSMA with Collision Detection

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

  Time for B to detect A’s transmission

  A collision B

  X

  (wire)

• For wired media we can detect all collisions and abort (CSMA/CD):
  – Requires a minimum frame size (“acquiring the medium”)
  – B must continue sending (“jam”) until A detects collision
3. Classic Ethernet

- IEEE 802.3 standard wired LAN (1-persistent CSMA/CD)
- Classic Ethernet: 10 Mbps over coaxial cable
  - baseband signals, Manchester encoding, preamble, 32 bit CRC

- Newer versions are much faster
  - Fast (100 Mbps), Gigabit (1 Gbps)
- Modern equipment isn’t one long wire
  - hubs and switches
Modern (Ethernet II) Frames

- Min frame 64 bytes, max 1500 bytes
- Max length 2.5km, max between stations 500m (repeaters)
- Addresses unique per adaptor; 6 bytes; globally assigned
- Broadcast media is readily tapped:
  - Promiscuous mode; multicast addresses
Binary Exponential Backoff

• Build on 1-persistent CSMA/CD
• On collision: jam and exponential backoff
  – Jamming: send 48 bit sequence to ensure collision detection
• Backoff:
  – First collision: wait 0 or 1 frame times at random and retry
  – Second time: wait 0, 1, 2, or 3 frame times
  – Nth time (N<=10): wait 0, 1, …, $2^N$-1 times
  – Max wait 1023 frames, give up after 16 attempts
  – Scheme balances average wait with load
Ethernet Capture

• Randomized access scheme is not fair

• Stations A and B always have data to send
  – They will collide at some time
  – Suppose A wins and sends, while B backs off
  – Next time they collide and B’s chances of winning are halved!
Ethernet Performance

• Much better than Aloha or CSMA!
  – Works very well in practice

• Source of protocol inefficiency: collisions
  – More efficient to send larger frames
    • Acquire the medium and send lots of data
  – Less efficient as the network grows in terms of frames
    • recall “a” = delay * bandwidth / frame size
    • “a” grows as the path gets longer (satellite)
    • “a” grows as the bit rates increase (Fast, Gigabit Ethernet)
Key Concepts

- Ethernet (CSMA/CD): randomness can lead to an effective distributed means of sharing a channel
4. Measured Capacity of Ethernet

- Systematic Ethernet evaluation
- Contributions:
  - Measured-based analysis of performance
  - Present implementation issues
  - “Systems-approach to networking”
- Non-contributions:
  - Synthetic measurements
Theoretical Studies’ Limitations

- Unrealistic assumptions:
  - Infinite populations, Poisson arrivals, uniform packet sizes, worst-case analysis

- Inconsistent definitions of offered load:
  - Flow control not considered

- Average case vs. worst-case
  - The average load is really low

- Myths:
  - Ethernet saturates at an offered load of 37%
  - Latency shoots up after 37%
Findings

• Ethernet performs well under high load
  – Xput fall with # of hosts
  – Fairness increases with # of hosts
  – Latency increases linearly with # of hosts

• Bimodal packet size distribution
  – Even a few packets can boost utilization

• Problems due to implementation
  – Buggy firmware (garbled packets, broadcast storm)
  – Linear back-off instead of exponential
What’s Missing?
What’s Missing?

• “Semi-experimental” study
  – Is this science or engineering?
• Only considered balanced topologies
  – Unequal clusters can lead to unfairness
• Only considered aggregate statistics
  – Do corner-cases occur?
Ethernet Trends

- Newer standards: 100Mbps (Fast Ethernet), 1Gbps, 10Gbps
- Switch rather than contention:
  - Is contention relevant anymore?
- Reasons for success:
Ethernet Trends

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- Switch rather than contention:
  - Is contention relevant anymore?
- Reasons for success:
  - Low connection cost
  - Robustness
  - Flexible (protocol changes are easy)
Cable Modems (DOCSIS)

- Broadcast medium for hosts don’t hear each other (head-end coordination)
- Downstream: head-end coordination
- Upstream: reserve slots with ALOHA
Research on Wired MAC’s anymore

• Ideas?
Research on Wired MAC’s anymore

• Ideas?

• Sure: faster MACs are being proposed all the time:
  – How would a 1Tbps MAC work?
    • Build a simulator??? How?!
Next class

• Papers review

• Review due at 11am