CSC458 - Lecture 3

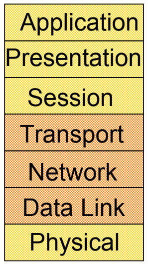
MAC Protocols

Part 1

From Aloha to Ethernet

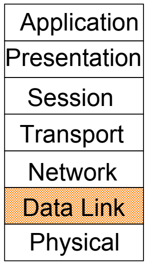
Last Time …

- Error detection and correction
- Redundant bits are added to messages to protect against transmission errors.
- Two recovery strategies are retransmissions (ARQ) and error correcting codes (FEC)
- The Hamming distance tells us how much error can safely be tolerated.



This Lecture

- Key Focus: How do multiple parties share a wire? We want the benefits of statistical multiplexing …
- This is the Medium Access Control (MAC) portion of the Link Layer
- Randomized access protocols:
  1. Aloha
  2. CSMA variants
  3. Classic Ethernet

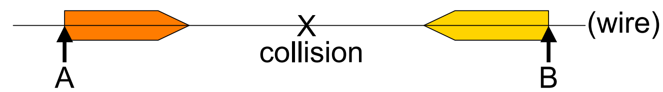


1. ALOHA

- 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)



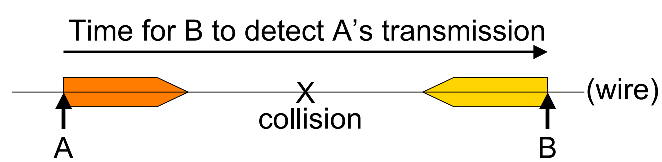
- "a" parameter: number of packets that fit on the wire
  - a = bandwidth * delay / packet size
  - Small (<<1) for LANs, large (>>1) for satellites

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 * # senders < 1; avoids collisions at cost of delay

CSMA with Collision Detection

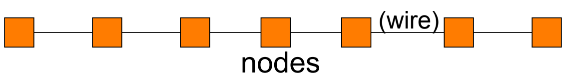
- Even with CSMA there can still be collisions. Why?



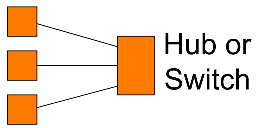
- For wired media we can detect all collisions and abort (CSMA/CD):
  - Requires a minimum frame size ("acquiring the medium")
  - B must continue sending ("jam") until A detects collision

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

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

- 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

Part 2

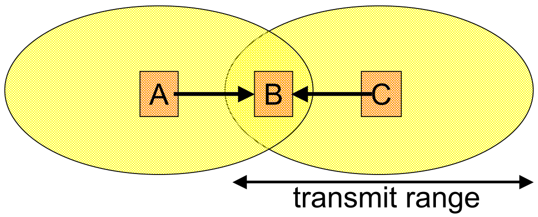
Wireless and Contention-Free Protocols

1. Wireless Communication

Wireless is more complicated than wired …

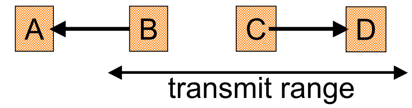
1. Cannot detect collisions
   - Transmitter swamps co-located receiver
2. Different transmitters have different coverage areas
   - Asymmetries lead to hidden/exposed terminal problems

Hidden Terminals

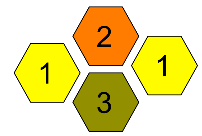


- A and C can both send to B but can't hear each other
  - A is a hidden terminal for C and vice versa
- CSMA will be ineffective – want to sense at receiver

Exposed Terminals



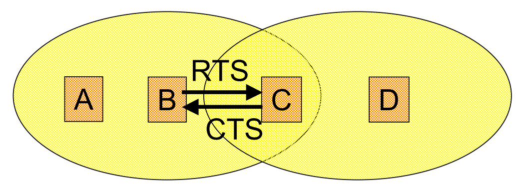
- B, C can hear each other but can safely send to A, D
- Compare to spatial reuse in cell phones:



CSMA with Collision Avoidance

- Since we can't detect collisions, we avoid them
  - CSMA/CA as opposed to CSMA/CD
  - Not greedy like Ethernet
- CS: listen before transmitting.
  - When medium busy, choose random backoff interval
  - Wait for that many idle timeslots to pass before sending
- CA: transmit short "jamming" signal before sending frame
  - essentially reserves medium, let's others know your intent to transmit
- Collisions can be inferred
  - Use CRC and ACK from receiver to infer "no collision"
  - on collision, binary exponential backoff like Ethernet

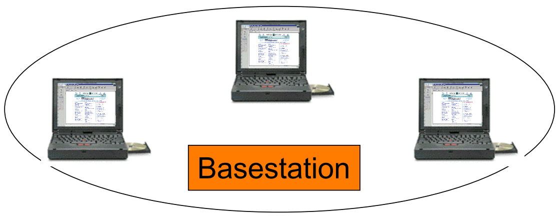
RTS / CTS Protocols (MACA)



1. B stimulates C with Request To Send (RTS)
2. A hears RTS and defers to allow the CTS
3. C replies to B with Clear To Send (CTS)
4. D hears CTS and defers to allow the data
5. B sends to C

802.11 Wireless LANs

- Emerging standard with a bunch of options/features …



- Wireless plus wired system or pure wireless (ad hoc)
- Avoids collisions (CSMA/CA (p-persistence), RTS/CTS)

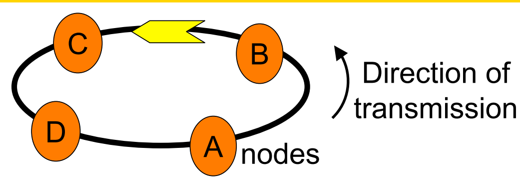
802.11 Standards out there

- 802.11b
  - 2.4GHz unlicensed radio spectrum
  - Up to 11Mbps
- 802.11a
  - 5GHz range
  - Up to 54Mbps
- 802.11g
  - 2.4 GHz
  - Up to 54Mbps
- All use CSMA/CA for multiple access
- Options RTS/CTS
- All have base-station and ad-hoc network versions

2. Contention-free Protocols

- Collisions are the main difficulty with random schemes
  - Inefficiency, limit to scalability
- Q: Can we avoid collisions?
- A: Yes. By taking turns or with reservations
  - Token Ring / FDDI, DQDB
- More generally, what else might we want?
  - Deterministic service, priorities/QOS, reliability

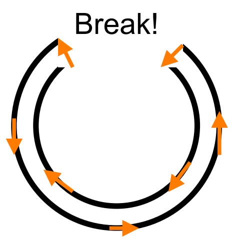
Token Ring (802.5)



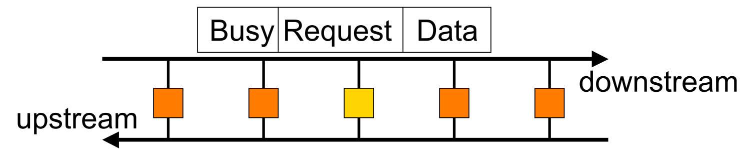
- Token rotates permission to send around node
- Sender injects packet into ring and removes later
  - Maximum token holding time (THT) bounds access time
  - Early or delayed token release
  - Round robin service, acknowledgments and priorities
- Monitor nodes ensure health of ring

FDDI (Fiber Distributed Data Interface)

- Roughly a large, fast token ring
  - 100 Mbps and 200km vs 4/16 Mbps and local
  - Dual counter-rotating rings for redundancy
  - Complex token holding policies for voice etc. traffic
- Token ring advantages
  - No contention, bounded access delay
  - Supports fair, reserved, priority access
- Disadvantages
  - Complexity, reliability, scalability



DQDB (Distributed Queue Dual Bus)



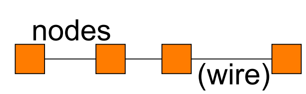
- Two unidirectional buses that carry fixed size cells
  - Cells are marked busy/free and can signal a request too
- Nodes maintain a distributed FIFO queue
  - By sending requests they are reserving future access

DQDB Algorithm

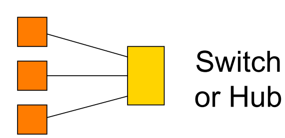
- Two counters per direction (UP, DN)
  - RC (request count), CD (countdown)
- Consider sending downstream (DN):
  - Always have RC count UP requests, minus free DN cells if larger than zero
  - This is a measure of how many others are waiting to send
  - To send, copy RC to CD and set RC to zero, then decrement CD for each free DN cell, send when zero
  - This waits for earlier requests to be satisfied before sending
- Highly scalable, efficient, but not perfectly fair

Modern Ethernet

- A key concern is manageability
  - centralized vs. distributed layout
- Another is performance scalability
  - Switches vs. Hubs



Classic Ethernet (10Mbps)



Fast Ethernet (100Mbps)
Gigabit Ethernet (1Gbps)

Key Concepts

- Wireless communication is relatively complex
  - No collision detection, hidden and exposed terminals
- There are contention-free MAC protocols
  - Based on turn taking and reservations, not randomization