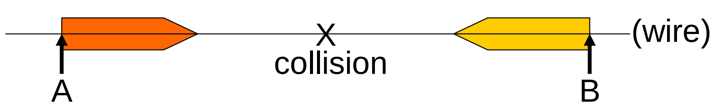
CSE/EE 461 – 10/15/04
CSMA/CD, Wireless and Contention-Free Protocols

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

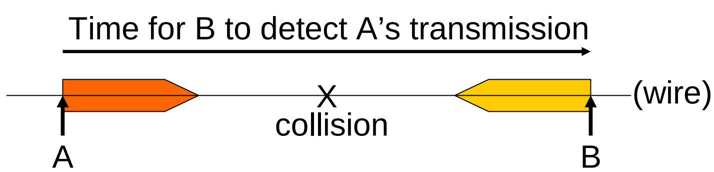
What if the Channel is Busy?

- 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

L6.3

CSMA with Collision Detection

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

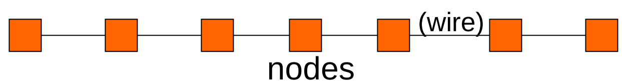


- For wired media we can detect all collisions and abort (CSMA/CD):
  - Requires a minimum frame size ("acquiring the medium")
  - B must continue sending ("jam") until A detects collision

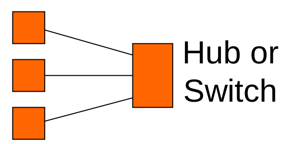
L6.4

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



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Ethernet Frames

Preamble (8)	Source (6)	Dest (6)	Len (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; globally assigned
- Broadcast media is readily tapped:
  - Promiscuous mode; multicast addresses

L6.6

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

L6.7

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!

L6.8

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 minimum frame size
    - *Contention period* "a" = delay / (frame size * transmission rate)
    - "a" grows as the path gets longer (satellite)
    - "a" grows as the bit rates increase (Fast, Gigabit Ethernet)

L6.9

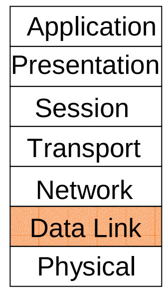
Key Concepts

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

L6.10

More on multiple-access schemes

1. Wireless schemes
2. Contention-free protocols



L6.11

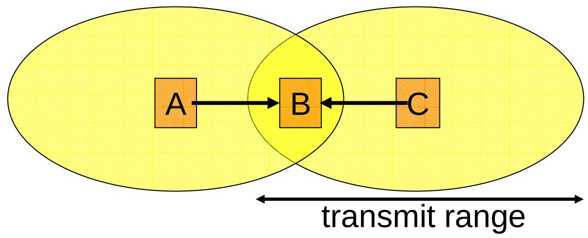
1. Wireless Communication

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

L6.12

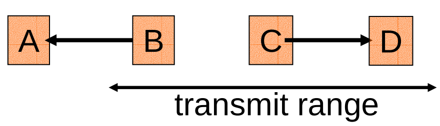
Hidden Terminals



- 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

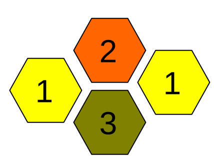
L6.13

Exposed Terminals



- B, C can hear each other but can safely send to A, D

- Compare to spatial reuse in cell phones:



L6.14

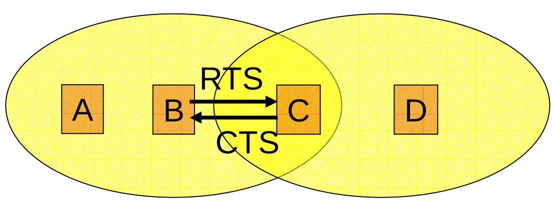
CSMA with Collision Avoidance

- Since we can't detect collisions, we avoid them
  - CSMA/CA as opposed to CSMA/CD
  - Not greedy like Ethernet

- When medium busy, choose random backoff interval
  - Wait for that many idle timeslots to pass before sending
  - Remember p-persistence … a refinement
- When a collision is inferred, retransmit with binary exponential backoff (like Ethernet)
  - Use CRC and ACK from receiver to infer "no collision"
  - Again, exponential backoff helps us adapt "p" as needed

L6.15

RTS / CTS Protocols (MACA)

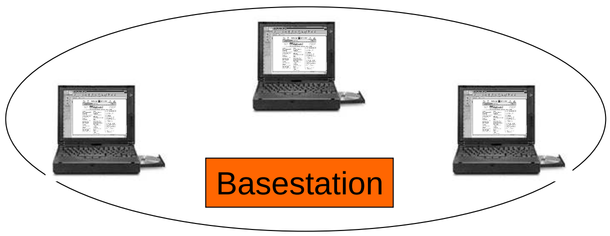


1. B stimulates C with Request To Send (RTS)
2. A hears RTS and defers to allow the CTS
3. C replies to B with Clear To Send (CTS)
4. D hears CTS and defers to allow the data
5. B sends to C

L6.16

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)
- Built on new links (spread spectrum, or diffuse infrared)

L6.17

2. Contention-free Protocols

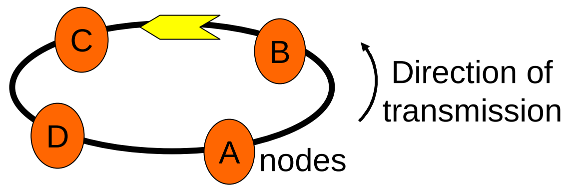
- Collisions are the main difficulty with random schemes
  - Inefficiency, limit to scalability

- 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

L6.18

Token Ring (802.5)

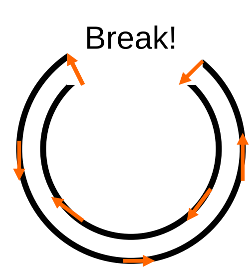


- Token rotates permission to send around node
- Sender injects packet into ring and removes later
  - Maximum token holding time (THT) bounds access time
  - Early or delayed token release
  - Round robin service, acknowledgments and priorities
- Monitor nodes ensure health of ring

L6.19

FDDI (Fiber Distributed Data Interface)

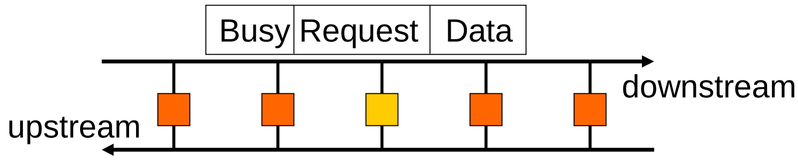
- Roughly a large, fast token ring
  - 100 Mbps and 200km vs 4/16 Mbps and local
  - Dual counter-rotating rings for redundancy
  - Complex token holding policies for voice etc. traffic



- Token ring advantages
  - No contention, bounded access delay
  - Support fair, reserved, priority access
- Disadvantages
  - Complexity, reliability, scalability

L6.20

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

L6.21

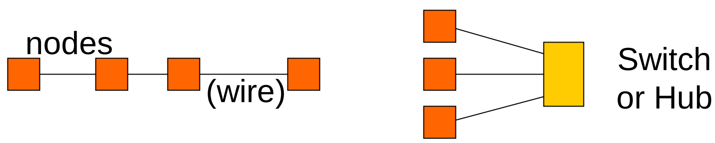
DQDB Algorithm

- 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, 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

L6.22

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)

L6.23

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

L6.24