

Types of Multiple Access Protocols

Three broad classes:

- **Channel partitioning**
 - divide channel into smaller "pieces" (time slots, frequency, code)
 - allocate piece to node for exclusive use
- **Random access**
 - channel not divided, allow collisions
 - "recover" from collisions
- **Centrally controlled/coordinated**
 - centrally coordinate shared access to avoid collisions

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Channel Partitioning MAC protocols: TDMA

TDMA: time division multiple access

- access to channel in "rounds"
- each station gets fixed length slot (length = pkt trans time) in each round
- unused slots go idle
- example: 6-station LAN, 1,3,4 have pkt, slots 2,5,6 idle

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Channel Partitioning MAC protocols: FDMA

FDMA: frequency division multiple access

- channel spectrum divided into frequency bands
- each station assigned fixed frequency band
- unused transmission time in frequency bands go idle
- example: 6-station LAN, 1,3,4 have pkt, frequency bands 2,5,6 idle

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Channel Partitioning MAC protocols: C (code) DMA

- use coding to allow multiple simultaneous transmissions without interference
- each user has its unique code
 - **encoded signal:** (original data) X (code)
 - **decoding:** (encoded signal) X (code)
- inner product
 - all codes consist of 1, -1 bits
 - any bit sequence multiplying itself becomes 1

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CDMA: Two-sender Interference

- allows multiple users to transmit simultaneously (if codex X codey = 0).
- combined signal is "data X codex + datay X codey"

What is really good about it compared to TDMA?

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How good are Channel Partitioning Protocols?

- Performance - for a multiple access channel of rate R bps:
 - when all M nodes want to transmit, each can send at rate R/M
 - when one node wants to transmit, it can send at rate R/M

Inefficient!
- Robustness
 - no special node to coordinate transmissions
 - synchronized clocks for all but FDMA

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Random Access Protocols

- When node has data to send
 - transmit at full channel data rate R.
 - no *a priori* coordination among nodes
- Two or more transmitting nodes -> "collision",
- Random access protocol specifies:
 - how to detect collisions
 - how to recover from collisions (e.g., via delayed retransmissions)
- Examples of random access protocols:
 - slotted ALOHA, ALOHA
 - CSMA, CSMA/CD

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Slotted ALOHA (Abramson)

Assumptions

- all frames same size
- time is divided into equal size slots, time to transmit 1 frame
- nodes start to transmit frames only at beginning of slots (nodes are synchronized!)
- if 2 or more nodes transmit in slot, all nodes detect collision

Operation

- when node obtains fresh frame, it transmits in next slot
- no collision, node can send new frame in next slot
- if collision, node retransmits frame in each subsequent slot with probability p until success
- why not retransmit right away?

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Slotted ALOHA

node 1: 1, 1, 1, 1

node 2: 2, 2, 2

node 3: 3, 3, 3

C E C S E C E S S

slots

Pros

- single active node can continuously transmit at full rate of channel

Cons

- wasting slots (collisions, idle slots)
- require nodes to be synchronized

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Slotted Aloha Efficiency

Efficiency is the long-run fraction of successful slots when there are many nodes, each with many frames to send

- Suppose N nodes with many frames to send, each transmits in slot with probability p
- prob that one particular node has success in a slot
 - $p(1-p)^{N-1}$
- prob that some node has a success
 - $Np(1-p)^{N-1}$

- For max efficiency with N nodes, find p^* that maximizes $Np(1-p)^{N-1}$
 - find p^* for N=1 and N=2?
 - find p^* for any N?
- For many nodes, take limit of $Np^*(1-p^*)^{N-1}$ as N goes to infinity, gives $1/e \approx .37$
 - At best:** channel used for useful transmissions 37% of time!

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Pure (unslotted) ALOHA

- Unslotted Aloha: no synchronization
- When frame first arrives, transmit immediately
- Collision probability increases:
 - frame sent at t_0 collides with other frames sent in $[t_0-1, t_0+1]$

will overlap with start of i's frame

will overlap with end of i's frame

node i frame

t_0-1 t_0 t_0+1

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Pure Aloha Efficiency

$$P(\text{success by given node}) = P(\text{node transmits}) \times P(\text{no other node transmits in } [p_0-1, p_0]) \times P(\text{no other node transmits in } [p_0, p_0+1])$$

$$= p \cdot (1-p)^{N-1} \cdot (1-p)^{N-1} = p \cdot (1-p)^{2(N-1)}$$

choosing optimum p and then letting $n \rightarrow \infty$...

$$= 1/(2e) = .18$$

Half as efficient as slotted Aloha!

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CSMA (Carrier Sense Multiple Access)

CSMA: listen before transmit:

- If channel sensed idle: transmit entire frame
- If channel sensed busy: defer transmission

- Human analogy: listen before speaking!

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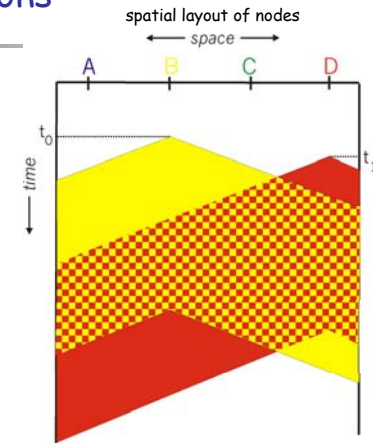
CSMA Collisions

collisions can still occur:

propagation delay means
two nodes may not hear
each other's transmission

collision:
entire packet transmission
time wasted

note:
collision probability depends on
distance & propagation speed



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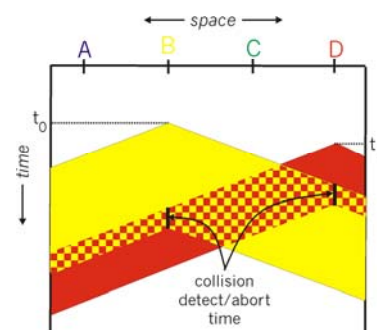
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CSMA/CD (Collision Detection)

CSMA/CD: carrier sensing,
same as in CSMA

- collisions detected within short time
- colliding transmissions aborted, reducing channel wastage

- Human analogy: if someone else begins talking at the same time, stop talking.



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How good are Random Access Protocols?

- Performance - for a multiple access channel of rate R bps:
 - when one node wants to transmit, it can send at full rate R .
 - when all M nodes want to transmit, each can send at average rate less than R/M . **Not ideal!**
- Robustness (decentralization):
 - no special node to coordinate transmissions
 - no synchronized clocks except for slotted ALOHA

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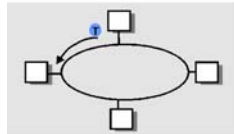
"Centrally Controlled" MAC protocols

Polling:

- master node "invites" slave nodes to transmit in turn
- concerns:
 - polling overhead (bandwidth & latency)
 - single point of failure (master)

Token passing:

- control **token** passed from one node to next sequentially.
- transmit only when holding the token
- concerns:
 - token overhead (bandwidth & latency)
 - single point of failure (token)



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Summary of MAC protocols

- Channel partitioning
 - Time Division, Frequency Division, Code Division
- Random access
 - ALOHA, S-ALOHA, CSMA, CSMA/CD
- Centrally controlled
 - polling from a central site
 - controlled by a token

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