



## 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, freq. bands 2,5,6 idle

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## Channel Partitioning MAC protocols: C (code) DMA

- use coding to partition channel
- 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 code1 X code2 = 0).
- combined signal is "data1 X code1 + data2 X code2"

How many codes?

Noise resistance.

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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)

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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

**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 (assuming each node always has 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  $1/e \approx .37$ 
  - successful channel transmissions at 37% of the 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  $n \rightarrow \infty$  ...

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

**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

**chance of collision:**  
depends on distance & propagation speed

**collision:**  
entire packet transmission time wasted

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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 too many people are talking so no one can hear clearly, 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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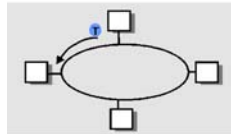
## "Centrally Controlled" MAC protocols

### Polling:

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

### Token passing:

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



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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
- Comparison on performance and robustness

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