

Multiple Access Protocol

Multiple access protocol:

- distributed algorithm that determines how nodes share channel, i.e., determine when nodes can transmit
- communication about channel sharing must use channel itself!

Objectives:

- Performance – for a multiple access channel of rate R bps:
 - when one node wants to transmit, it can send at rate R
 - when M nodes want to transmit, each can send at average rate R/M
- Robustness
 - no special node to coordinate transmissions
 - no synchronized clocks

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Types of Multiple Access Protocols

Three broad classes:

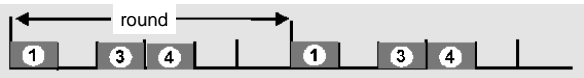
- **Channel partitioning**
 - divide channel into smaller “pieces” (time slots, frequency, code)
 - allocate piece to node for exclusive use
- **Random access**
 - channel not divided, allow collisions
 - “recover” from collisions
- **Centrally controlled/coordinated**
 - centrally coordinate shared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

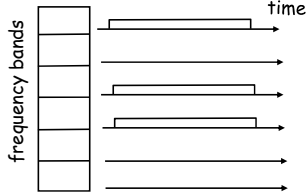


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Channel Partitioning MAC protocols: FDMA

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

sender

data bits $d_{i,m}$

code c_m

$Z_{i,m} = d_{i,m} \cdot c_m$

channel output $Z_{i,m}$

slot 1 channel output

slot 0 channel output

slot 1 received input

slot 0 received input

code c_m

receiver

$d_i = \sum_{m=1}^M Z_{i,m} \cdot c_m$

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CDMA: Two-sender Interference

- allow multiple users to transmit simultaneously (if code1 X code2 = 0).
- combined signal is "data1 X code1 + data2 X code2"

senders

data bits $d_{i,1}$ $d_{i,2}$

code c_1 c_2

$Z_{i,m}^1 = d_{i,1} \cdot c_m^1$

$Z_{i,m}^2 = d_{i,2} \cdot c_m^2$

channel, $Z_{i,m}^+$

slot 1 received input

slot 0 received input

code c_m

receiver 1

$d_i^+ = \sum_{m=1}^M Z_{i,m}^+ \cdot c_m^1$

How many non-interfering channels can you have?

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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

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 $1/e = .37$
 - 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 $[t_0-1, t_0+1]$

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Pure Aloha Efficiency

$P(\text{success by given node}) = P(\text{node transmits}) \times$
 $P(\text{no other node transmits in } [t_0-1, t_0]) \times$
 $P(\text{no other node transmits in } [t_0, t_0+1])$
 $= p \cdot (1-p)^{N-1} \cdot (1-p)^{N-1}$
 $= p \cdot (1-p)^{2(N-1)}$

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

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.

What if your packet transmission completes before signal from another packet arrives?

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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 but sometimes close!**
- Robustness (decentralization):
 - no special node to coordinate transmissions
 - no synchronized clocks except for slotted ALOHA

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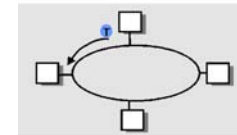
“Centrally Controlled” MAC protocols

Polling:

- control node “invites” regular nodes to transmit in turn
- concerns:
 - single point of failure (control node)
 - 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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