

Wireless Networks

(CSC-7602)

Lecture 3

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Medium Access Control

Ideal Multiple Access Protocol

Broadcast channel of rate R bps

1. When one node wants to transmit, it can send at rate R .
2. When M nodes want to transmit, each can send at average rate R/M
3. Fully decentralized:
 - no special node to coordinate transmissions
 - no synchronization of clocks, slots
4. Simple

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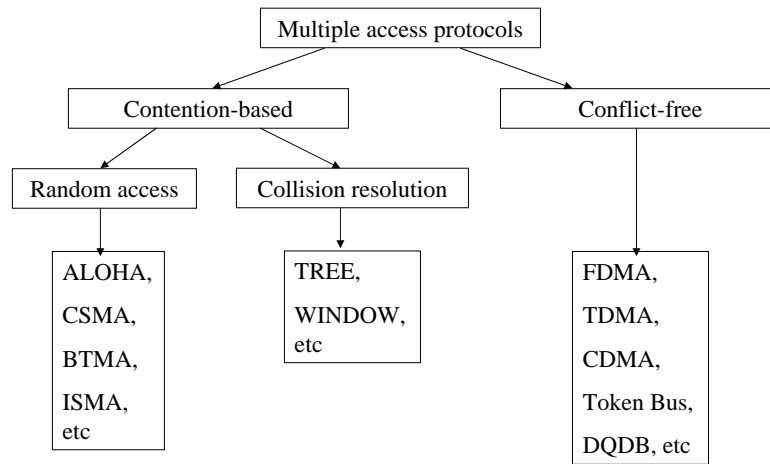
MAC Protocols: a taxonomy

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
- **"Taking turns"**
 - Nodes take turns, but nodes with more to send can take longer turns

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Classification of Multiple Access Protocols



BTMA: Busy Tone Multiple Access
ISMA: Internet Streaming Media Alliance

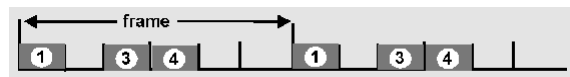
DQDB: Distributed Queue Dual Bus

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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



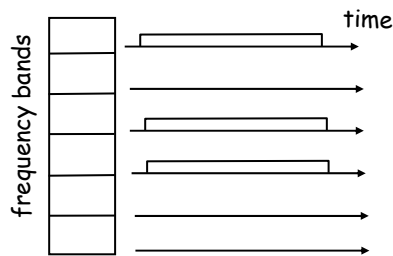
- TDM (Time Division Multiplexing): channel divided into N time slots, one per user; inefficient with low duty cycle users and at light load.

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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



- FDM (Frequency Division Multiplexing): frequency subdivided.

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Random Access Protocols

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

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Slotted ALOHA

Assumptions

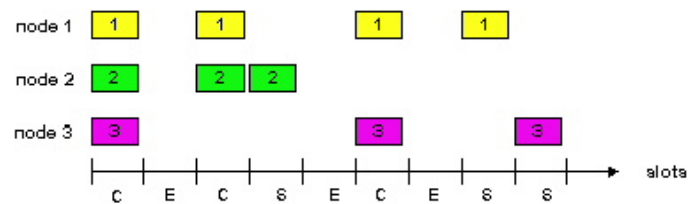
- all frames same size
- time is divided into equal size slots, time to transmit 1 frame
- nodes start to transmit frames only at beginning of slots
- nodes are synchronized
- if 2 or more nodes transmit in slot, all nodes detect collision

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 prob. p until success

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Slotted ALOHA



Pros

- single active node can continuously transmit at full rate of channel
- highly decentralized: only slots in nodes need to be in sync
- simple

Cons

- collisions, wasting slots
- idle slots
- nodes may be able to detect collision in less than time to transmit packet
- clock synchronization

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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 node 1 has success in a slot = $p(1-p)^{N-1}$
- prob that any node has a success = $Np(1-p)^{N-1}$

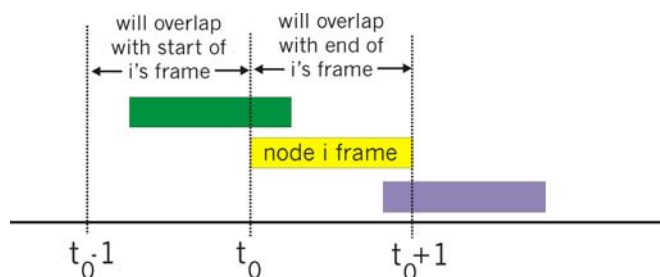
- For max efficiency with N nodes, find p^* that maximizes $Np(1-p)^{N-1}$
 - Optimal $P^* = 1/N$
- For many nodes, take limit of $Np^*(1-p^*)^{N-1}$ as N goes to infinity, gives $1/e = .37$
 - Maximum = $(1-1/N)^N / (1-1/N)^1$

At best: channel used for useful transmissions 37% of time!

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Pure (unslotted) ALOHA

- unslotted Aloha: simpler, 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

$$\begin{aligned}
 P(\text{success by given node}) &= P(\text{node transmits}) \times \\
 &\quad P(\text{no other node transmits in } [t_0-1, t_0]) \times \\
 &\quad P(\text{no other node transmits in } [t_0, t_0+1]) \\
 &= p \cdot (1-p)^{N-1} \cdot (1-p)^{N-1} \\
 &= p \cdot (1-p)^{2(N-1)} \\
 &\quad \dots \text{ choosing optimum } p \text{ and then letting } n \rightarrow \text{infty} \dots \\
 &= 1/(2e) = .18
 \end{aligned}$$

Even worse !

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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: don't interrupt others!

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Nonpersistent/x-persistent CSMA Protocols

- Nonpersistent CSMA Protocol:
 - Step 1:** If the medium is idle, transmit immediately
 - Step 2:** If the medium is busy, wait a random amount of time and repeat **Step 1**
 - Random backoff reduces probability of collisions
 - Waste idle time if the backoff time is too long

- 1-persistent CSMA Protocol:
 - Step 1:** If the medium is idle, transmit immediately (with prob. 1)
 - Step 2:** If the medium is busy, continue to listen until medium becomes idle, and then transmit immediately
 - There will always be a collision if two nodes want to retransmit (usually you stop transmission attempts after few tries)

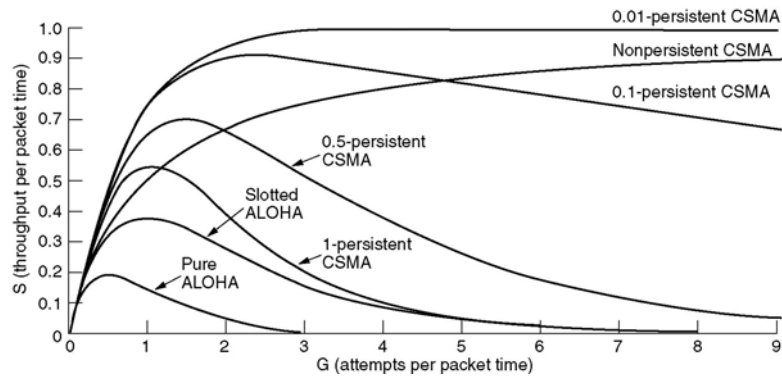
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Nonpersistent/x-persistent CSMA Protocols

- p-persistent CSMA Protocol:
 - Step 1:** If the medium is idle, transmit with probability p , and delay propagation delay for one packet with probability $(1-p)$ for worst case
 - Step 2:** If the medium is busy, continue to listen until medium becomes idle, then go to **Step 1**
 - Step 3:** If transmission is delayed by one time slot, continue with **Step 1**
 - A good tradeoff between nonpersistent and 1-persistent CSMA

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Efficiency



Comparison of the channel utilization versus load for various random access protocols.

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CSMA collisions

collisions can still occur:

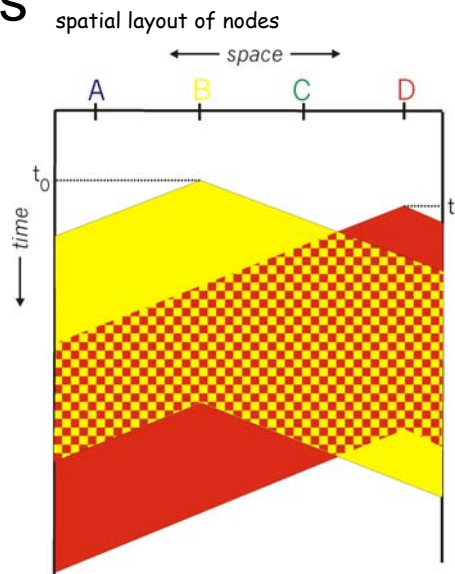
propagation delay means
two nodes may not hear
each other's transmission

collision:

entire packet transmission
time wasted

note:

role of distance & propagation
delay in determining collision
probability



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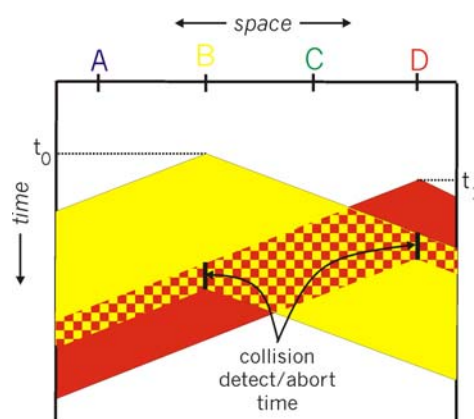
CSMA/CD (Collision Detection)

CSMA/CD: carrier sensing, deferral as in CSMA

- collisions *detected* within short time
- colliding transmissions aborted, reducing channel wastage
- collision detection:
 - easy in wired LANs: measure signal strengths, compare transmitted, received signals
 - difficult in wireless LANs: receiver should shut off while transmitting

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CSMA/CD collision detection



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“Taking Turns” MAC protocols

channel partitioning MAC protocols:

- share channel efficiently and fairly at high load
- inefficient at low load: delay in channel access, 1/N bandwidth allocated even if only 1 active node!

Random access MAC protocols

- efficient at low load: single node can fully utilize channel
- high load: collision overhead

“taking turns” protocols

look for best of both worlds!

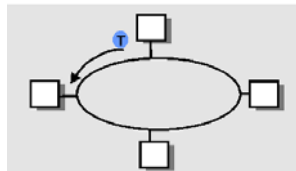
“Taking Turns” MAC protocols

Polling:

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

Token passing:

- control **token** passed from one node to next sequentially.
- token message
- concerns:
 - token overhead
 - latency
 - single point of failure (token)



Summary of MAC protocols

- What do you do with a shared media?
 - Channel Partitioning, by time, frequency or code
 - Time Division, Frequency Division
 - Random partitioning (dynamic),
 - ALOHA, S-ALOHA, CSMA, CSMA/CD
 - carrier sensing: easy in some technologies (wire), hard in others (wireless)
 - CSMA/CD used in Ethernet
 - CSMA/CA used in 802.11
 - Taking Turns
 - polling from a central site, token passing