Wireless Networks
(CSC-7602)
Lecture 3
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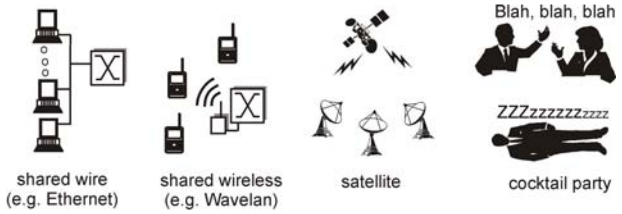
Medium Access Control

Multiple Access Links and Protocols

Two types of "links":

- point-to-point -> no need to have MAC
  - PPP for dial-up access
  - point-to-point link between Ethernet switch and host
- broadcast (shared wire or medium)
  - traditional Ethernet
  - 802.11 wireless LAN

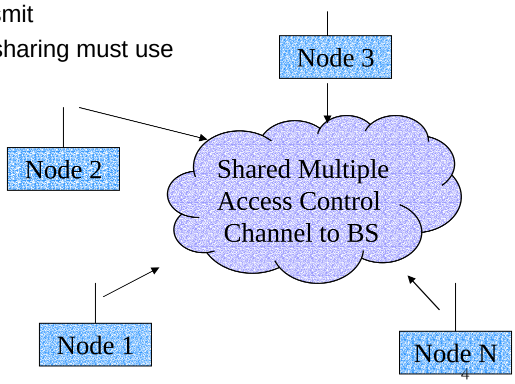


Multiple Access protocols

- single shared broadcast channel
- two or more simultaneous transmissions by nodes: interference
  - collision if node receives two or more signals at the same time

multiple access protocol

- distributed algorithm that determines how nodes share channel, i.e., determine when node can transmit
- communication about channel sharing must use channel itself!
  - no out-of-band channel for coordination



Ideal Multiple Access Protocol

Broadcast channel of rate R bps

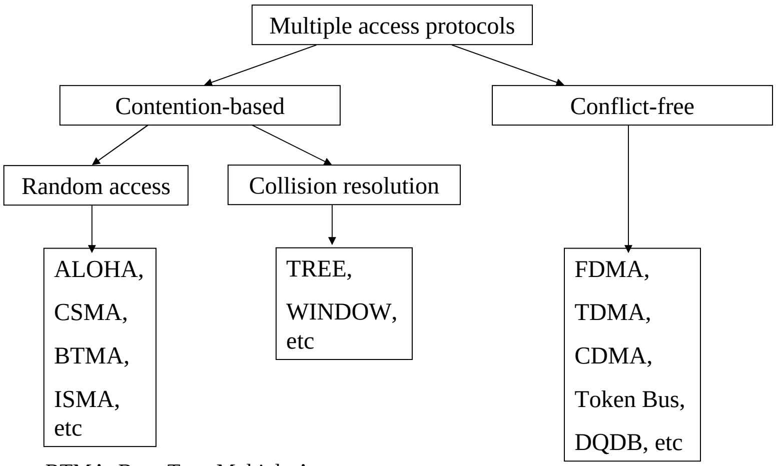
1. When one node wants to transmit, it can send at rate R.
2. When M nodes want to transmit, each can send at average rate R/M
3. Fully decentralized:
   - no special node to coordinate transmissions
   - no synchronization of clocks, slots
4. Simple

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

Classification of Multiple Access Protocols



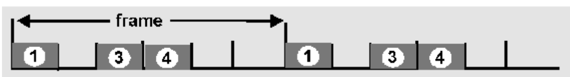
BTMA: Busy Tone Multiple Access
ISMA: Internet Streaming Media Alliance

DQDB: Distributed Queue Dual Bus

Channel Partitioning MAC protocols: TDMA

TDMA: time division multiple access

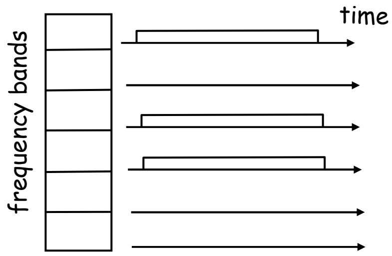
- access to channel in "rounds"
- each station gets fixed length slot (length = pkt trans time) in each round
- unused slots go idle
- example: 6-station LAN, 1,3,4 have pkt, slots 2,5,6 idle



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

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.

Random Access Protocols

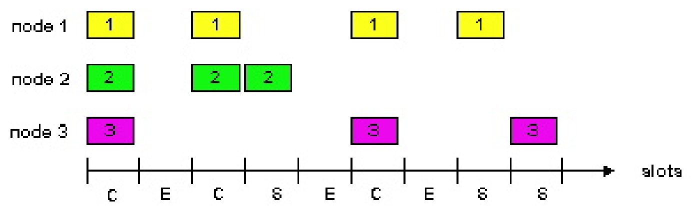
- When node has packet to send
  - transmit at full channel data rate R.
  - no *a priori* coordination among nodes
- two or more transmitting nodes ➜ "collision",
- random access MAC protocol specifies:
  - how to detect collisions
  - how to recover from collisions (e.g., via delayed retransmissions)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

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

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

Slotted Aloha efficiency

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

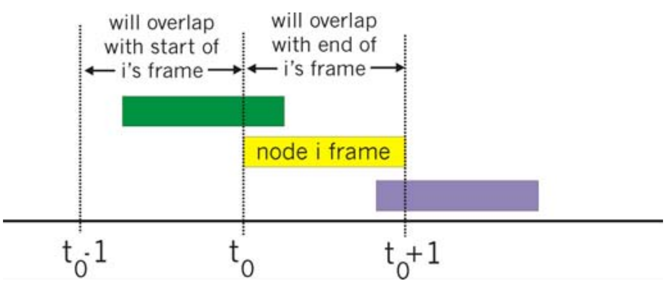
- Suppose N nodes with many frames to send, each transmits in slot with probability *p*
- prob that node 1 has success in a slot = $p(1-p)^{N-1}$
- prob that any node has a success = $Np(1-p)^{N-1}$

- 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 $= (1-1/N)^{N-1}$
    $= (1-1/N)^N / (1-1/N)^1$

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

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 $[t_0-1, t_0+1]$



Pure Aloha efficiency

P(success by given node) = P(node transmits) X

P(no other node transmits in $[t_0-1,t_0]$ X

P(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 -> infty ...

= 1/(2e) = .18

Even worse !

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!

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:

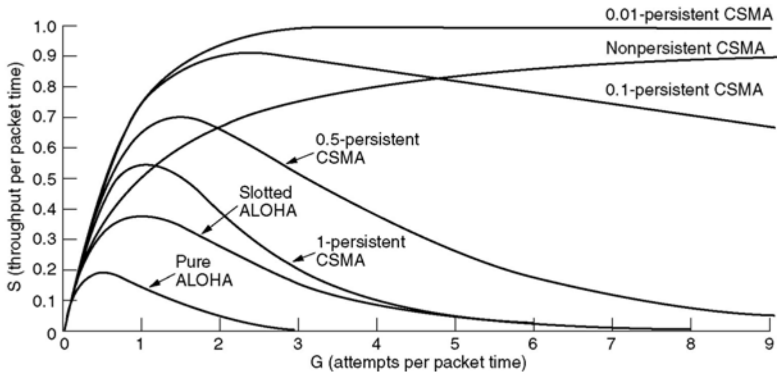
Step 1: If the medium is idle, transmit with probability p, and delay for worst case propagation delay for one packet with probability (1-p)

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

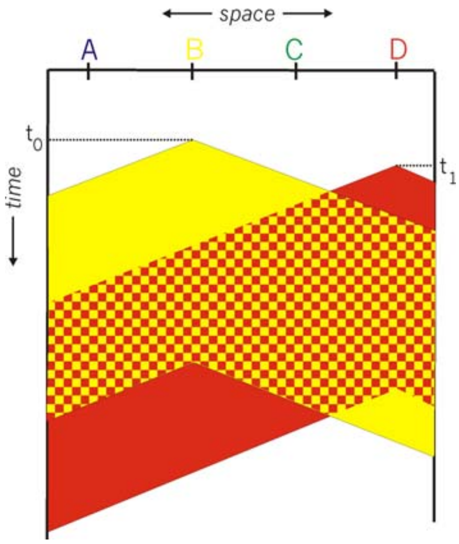
Efficiency



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

CSMA collisions

spatial layout of nodes



collisions *can* still occur:
propagation delay means two nodes may not hear each other's transmission

collision:
entire packet transmission time wasted

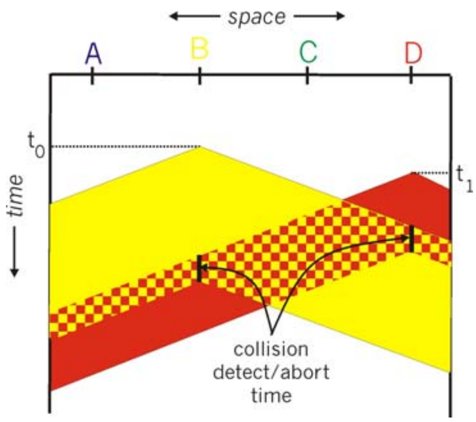
note:
role of distance & propagation delay in determining collision probability

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

CSMA/CD collision detection



"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

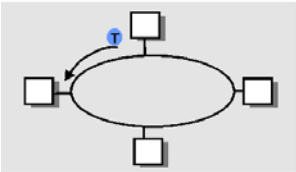
"taking turns" protocols

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