ECCS-3631
Networks and Data Communications

Module 3-2
MAC Protocols

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Multiple Access Links and Protocols

Two types of Network Links:

point-to-point link

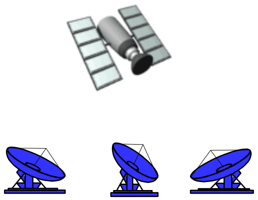
- PPP for dial-up access
- point-to-point link between Ethernet switch, host

broadcast (shared wire or medium)

- The term broadcast is used here because when any one node transmits a frame, the channel broadcasts the frame and each of the other nodes receives a copy.
- old-fashioned Ethernet
- 802.11 wireless LAN

shared wire (e.g., cabled Ethernet)

shared RF (e.g., 802.11 WiFi)



shared RF (satellite)

humans at a cocktail party (shared air, acoustical)

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

MAC Protocols: Categories

three broad classes:

channel partitioning

- divide channel into smaller "pieces" (time slots, frequency, code)
- allocate a piece to a node for exclusive use

random access

- channel not divided, allow collisions
- "recover" from collisions

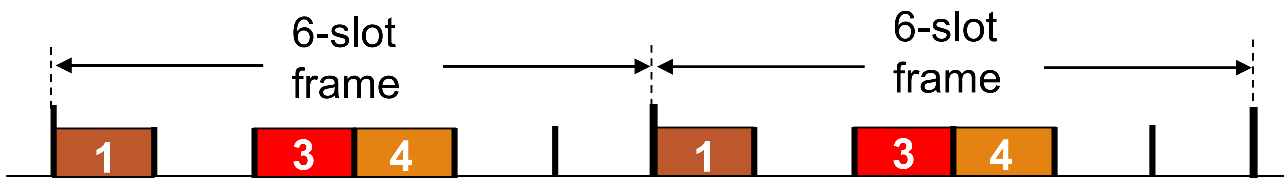
"taking turns"

- nodes take turns, but nodes with more data to send can take longer turns

Time Division Multiple Access (TDMA)

TDMA: time division multiple access

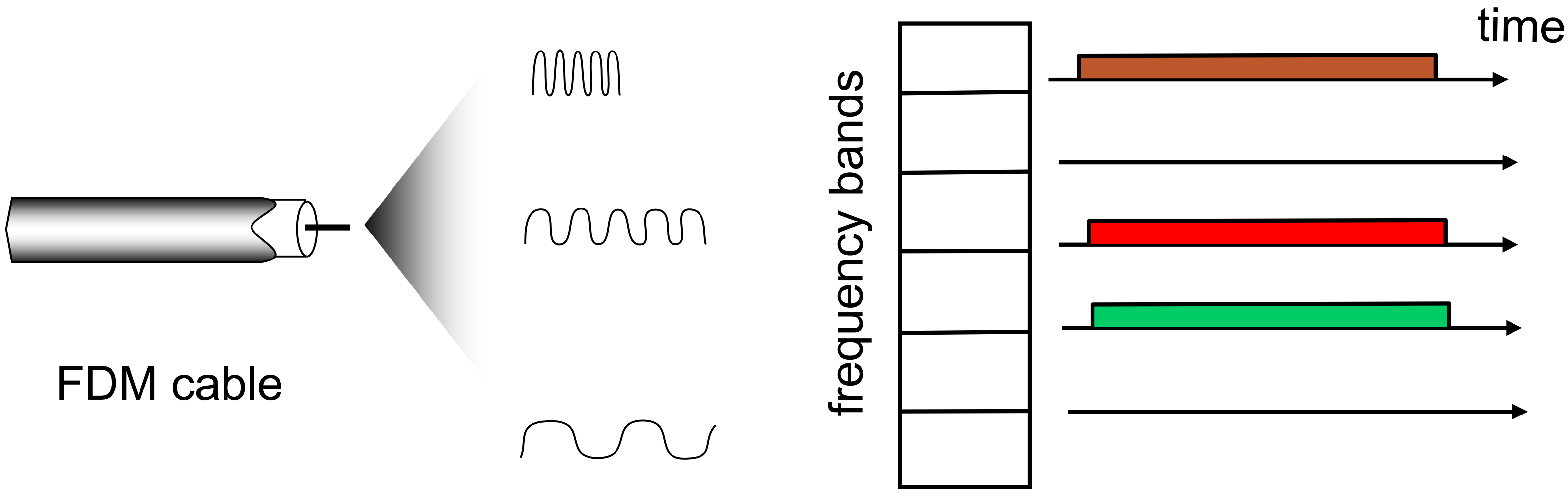
- access to channel in "rounds"
- each station gets fixed length slot (length = packet transmission time) in each round
- unused slots go idle
- example: 6-station LAN, 1,3,4 have packets to send, slots 2,5,6 idle



Frequency Division Multiple Access (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 packet to send, frequency bands 2,5,6 idle



WiFi Channels

Channel	F_0 (MHz)	Frequency Range (MHz)
1	2412	2401–2423
2	2417	2406–2428
3	2422	2411–2433
4	2427	2416–2438
5	2432	2421–2443
6	2437	2426–2448
7	2442	2431–2453
8	2447	2436–2458
9	2452	2441–2463
10	2457	2446–2468
11	2462	2451–2473

Code Division Multiple Access (CDMA)

- CDMA assigns a different code to each node
- Each node uses its unique code to encode the data bits
- Different nodes can transmit simultaneously, using same time and frequency

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:

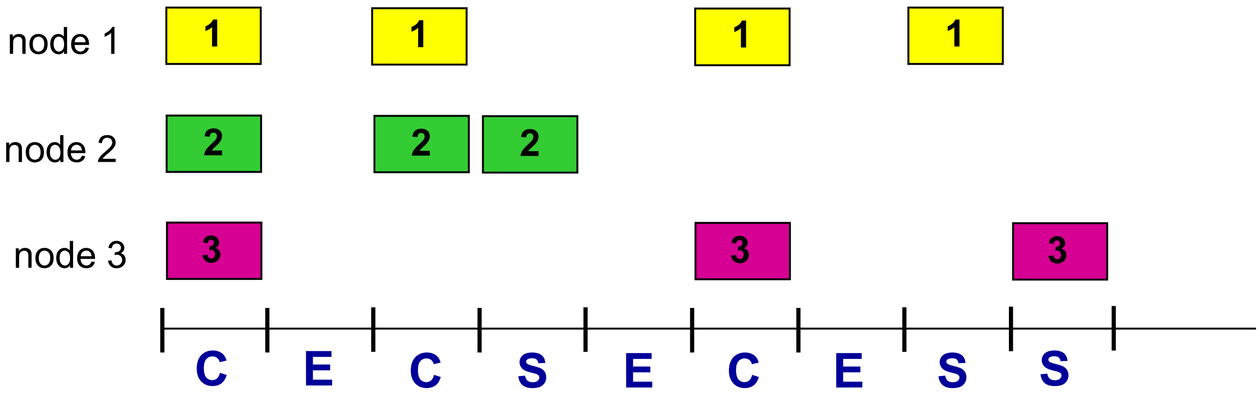
- all frames same size
- time divided into equal size slots (time to transmit 1 frame)
- nodes start to transmit only slot beginning
- nodes are synchronized
- if 2 or more nodes transmit in slot, all nodes detect collision

operation:

when node obtains fresh frame, transmits in next slot

- *if 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



C: Collision

E: Idle Slot

S: Successful Transmission

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
- Requires clock synchronization to find starting point of slot

Slotted ALOHA: Efficiency

efficiency: long-run fraction of successful slots (many nodes, all with many frames to send)

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

- max efficiency: find p^* that maximizes $Np(1-p)^{N-1}$
- for many nodes, take limit of $Np^*(1-p^*)^{N-1}$ as N goes to infinity, gives:

max efficiency = 1/e = .37

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

!

Slotted ALOHA: Efficiency

efficiency: long-run fraction of successful slots
(many nodes, all with many frames to send)

- max efficiency:

max efficiency = 1/e = .37

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

!

Pure (unslotted) ALOHA

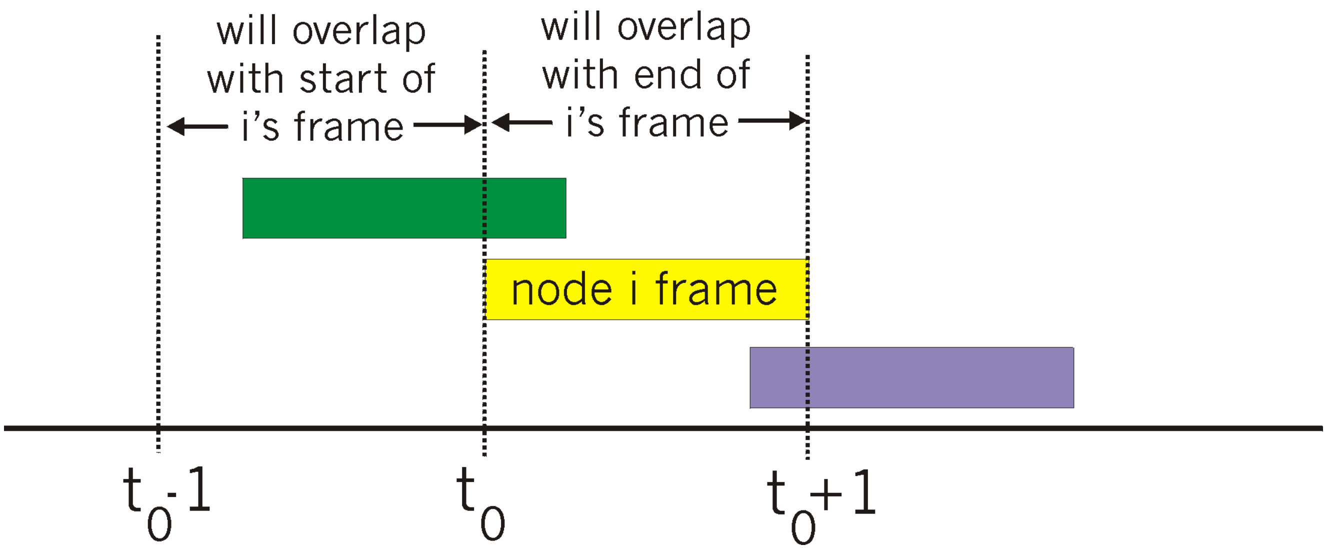
unslotted Aloha: simpler, no clock synchronization

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) $\cdot$

P(no other node transmits in $[t_0\text{-}1, t_0]$ $\cdot$

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 $n \longrightarrow \infty$

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

even *worse* than slotted Aloha!

Pure ALOHA efficiency

Maximum efficiency of Pure ALOHA:

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

even *worse* than slotted Aloha!
Slotted ALOHA has efficiency of 37%,
nearly double than that of Pure ALOHA

CSMA (Carrier Sense Multiple Access)

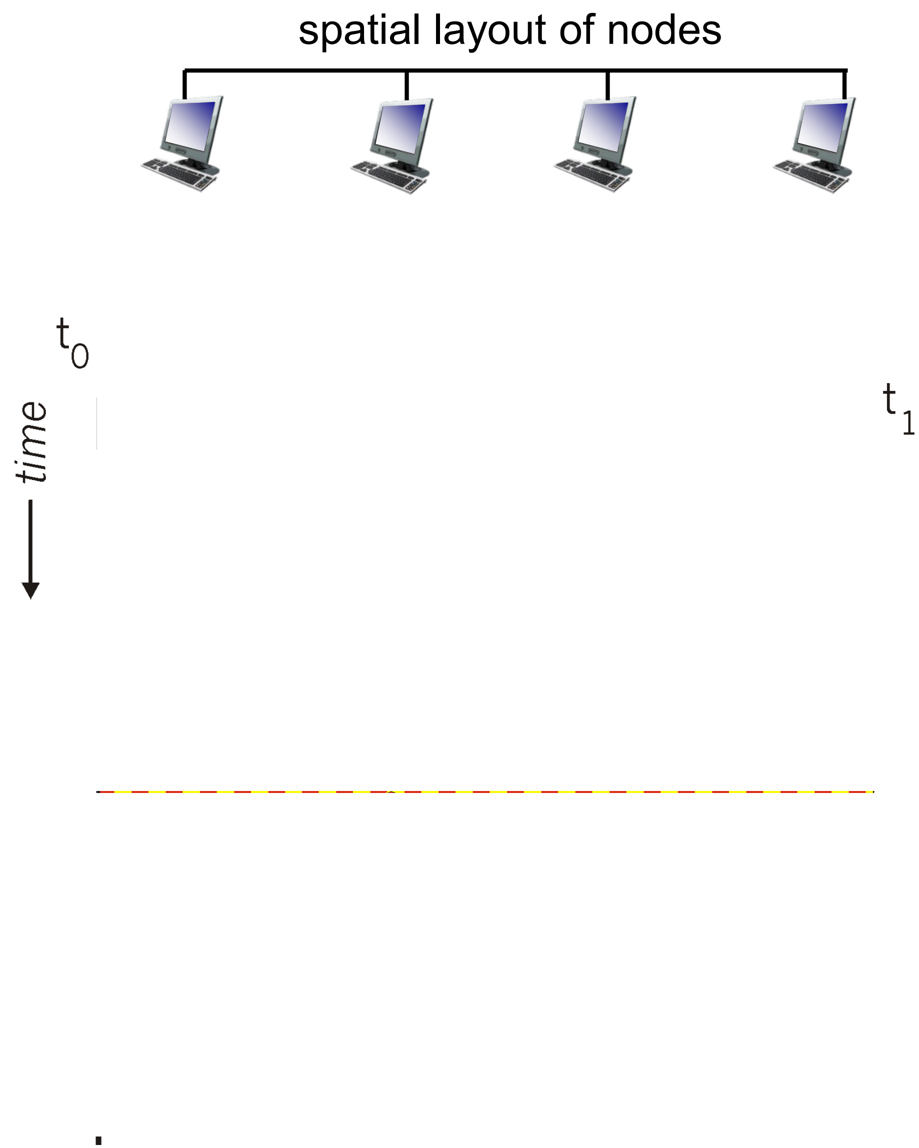
CSMA: listen before transmit:

if channel sensed idle: transmit entire frame

if channel sensed busy, defer transmission

human analogy: don't interrupt others!

CSMA Collisions



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

collision: entire packet transmission time wasted

- distance & propagation delay play role in determining collision probability. The longer this propagation delay, the larger the chance that a carrier-sending node is not yet to sense a transmission that has already begun at another node.

CSMA/CD (Collision Detection)

CSMA/CD: carrier sensing, deferral as in CSMA

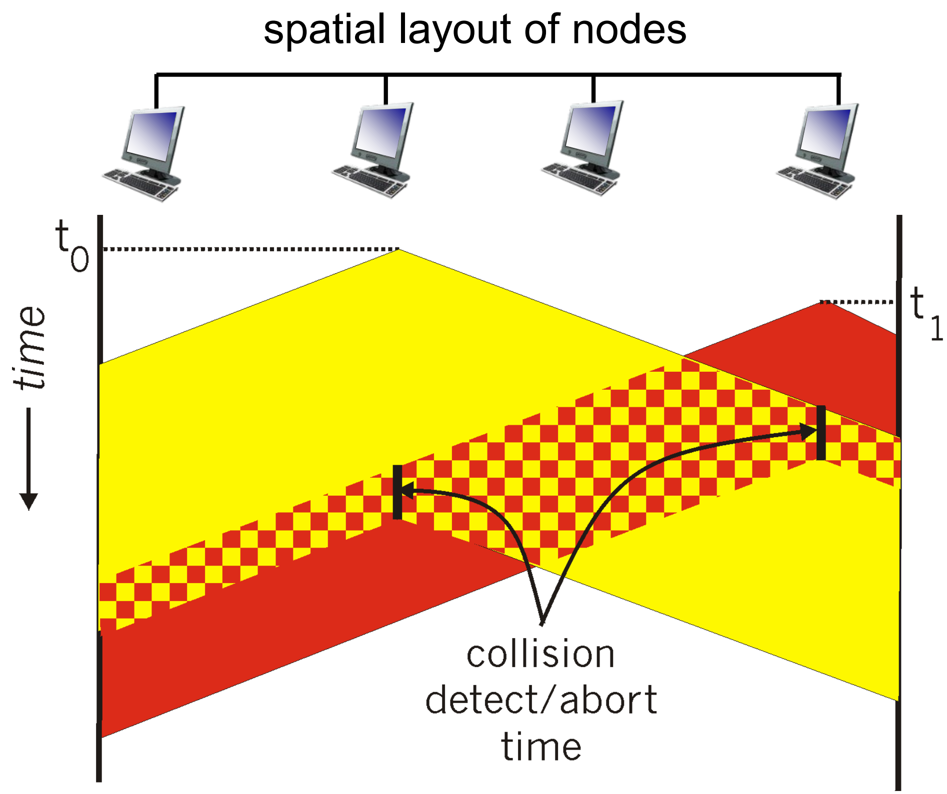
- collisions *detected* within short time
- colliding transmissions aborted, reducing channel wastage

collision detection:

- easy in wired LANs: measure signal strengths, compare transmitted, received signals
- difficult in wireless LANs: received signal strength overwhelmed by local transmission strength

human analogy: the polite conversationalist

CSMA/CD (Collision Detection)



Ethernet CSMA/CD algorithm

1. NIC receives datagram from network layer, creates frame
2. If NIC senses channel idle, starts frame transmission. If NIC senses channel busy, waits until channel idle, then transmits.
3. If NIC transmits entire frame without detecting another transmission, NIC is done with frame !
4. If NIC detects another transmission while transmitting, aborts the transmission
5. After aborting, NIC enters *binary (exponential) backoff:*
   - after *m*th collision, NIC chooses *K* at random from $\{0,1,2, \ldots, 2^m-1\}$. NIC waits $K \cdot 512$ bit times, returns to Step 2
   - longer backoff interval with more collisions

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!

Polling Protocol:

master node "invites" slave nodes to transmit in turn

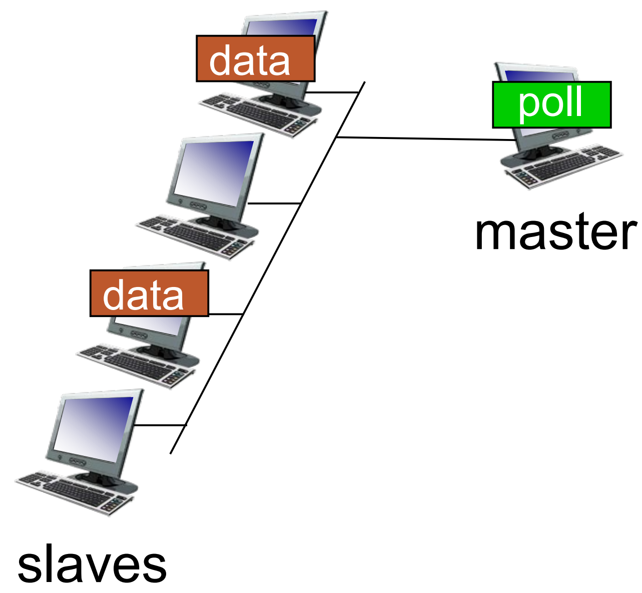
typically used with "dumb" slave devices

concerns:

- polling overhead
- latency
- single point of failure (master)
- Bluetooth protocol uses polling

Taking-Turns: Polling Protocol

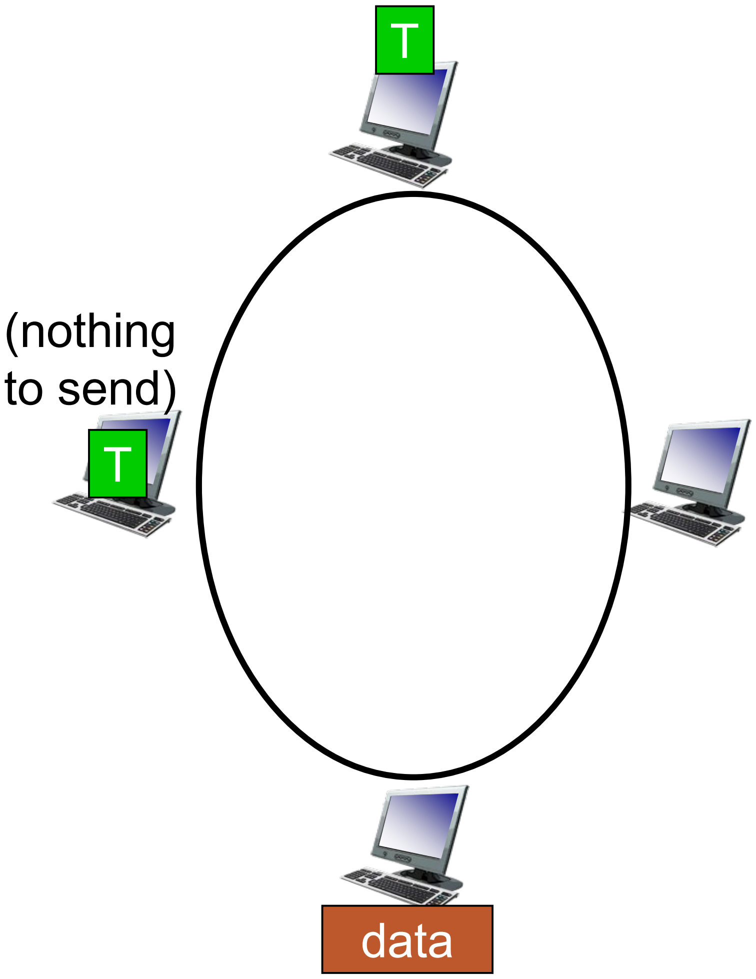
- The polling protocol requires
- one of the nodes to be designated as a master node. The master node first sends a message to node 1. After node 1 transmits some frames, the master node tells node 2 it (node 2) can transmit.
- The master node can determine
- when a node has finished sending its frames by observing the lack of a signal on the channel.
- The procedure continues in this manner, with the master node polling each
- of the nodes in a cyclic manner.



Taking-Turns: Token-Passing Protocol

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

channel partitioning, by time, frequency or code

- Time Division, Frequency Division, Code Division

random access (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 central site, token passing
- Bluetooth, FDDI, token ring