HDLC

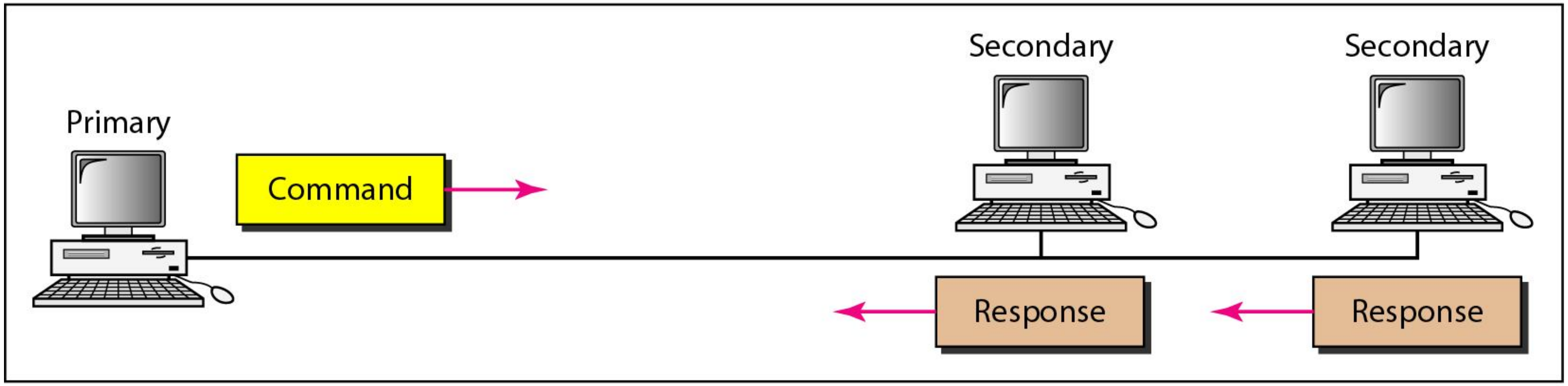
***High-level Data Link Control (HDLC)* is a *bit-oriented* protocol for communication over point-to-point and multipoint links. It implements the ARQ mechanisms**

Two types of "links":

- point-to-point
  - PPP for dial-up access
  - point-to-point link between Ethernet switch and host
- broadcast (shared wire or medium)
  - traditional Ethernet
  - upstream HFC
  - 802.11 wireless LAN

Figure 11.25 *Normal response mode*

a. Point-to-point



b. Multipoint

Figure 11.27 *HDLC frames*

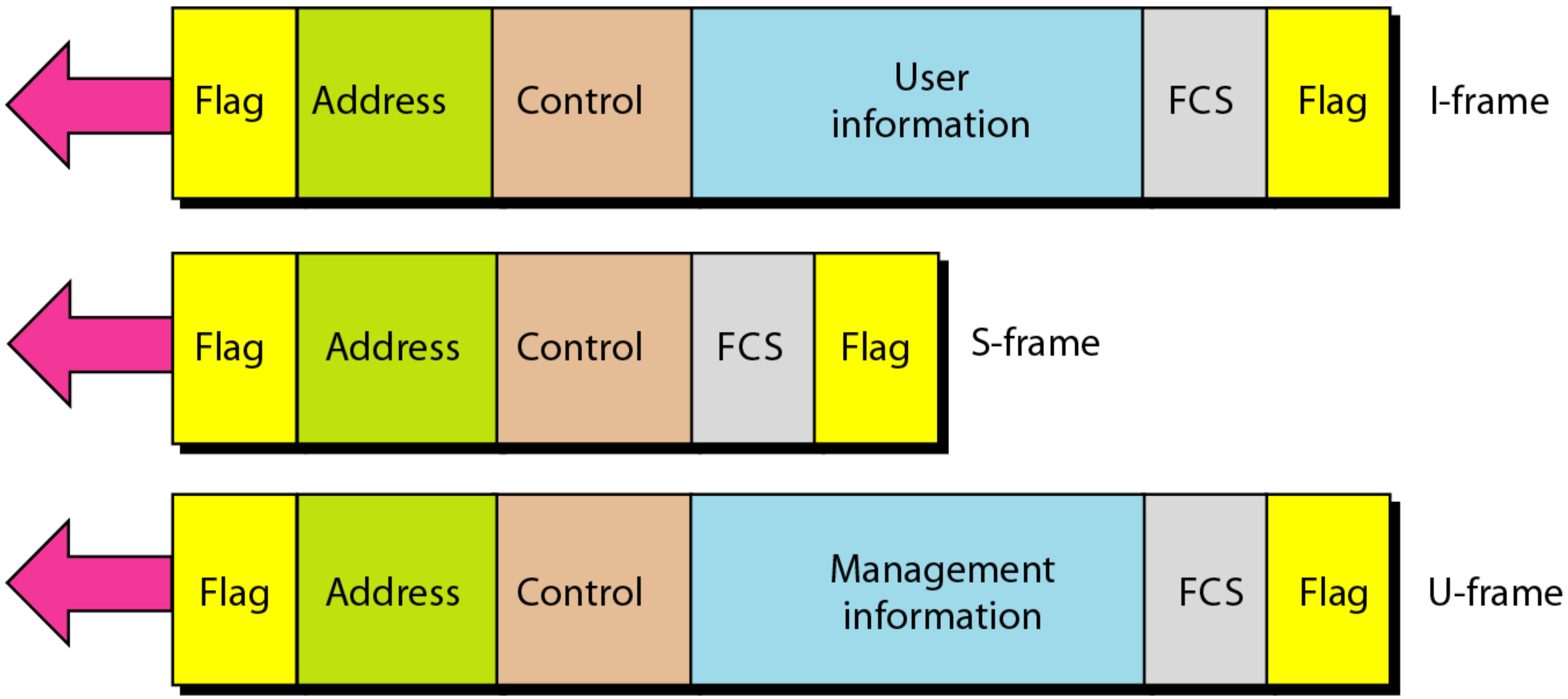


Figure 11.28 *Control field format for the different frame types*

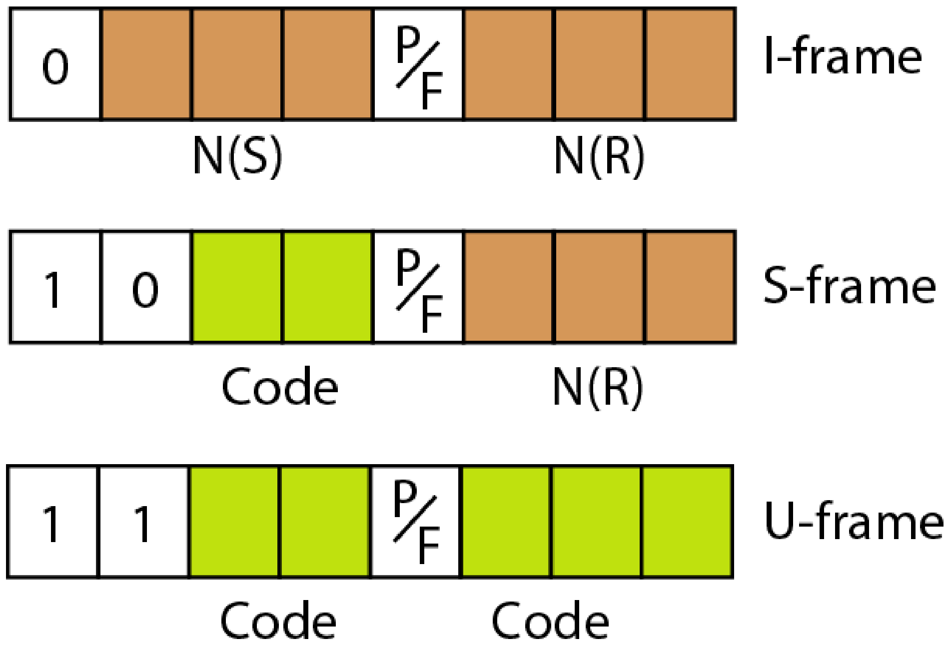


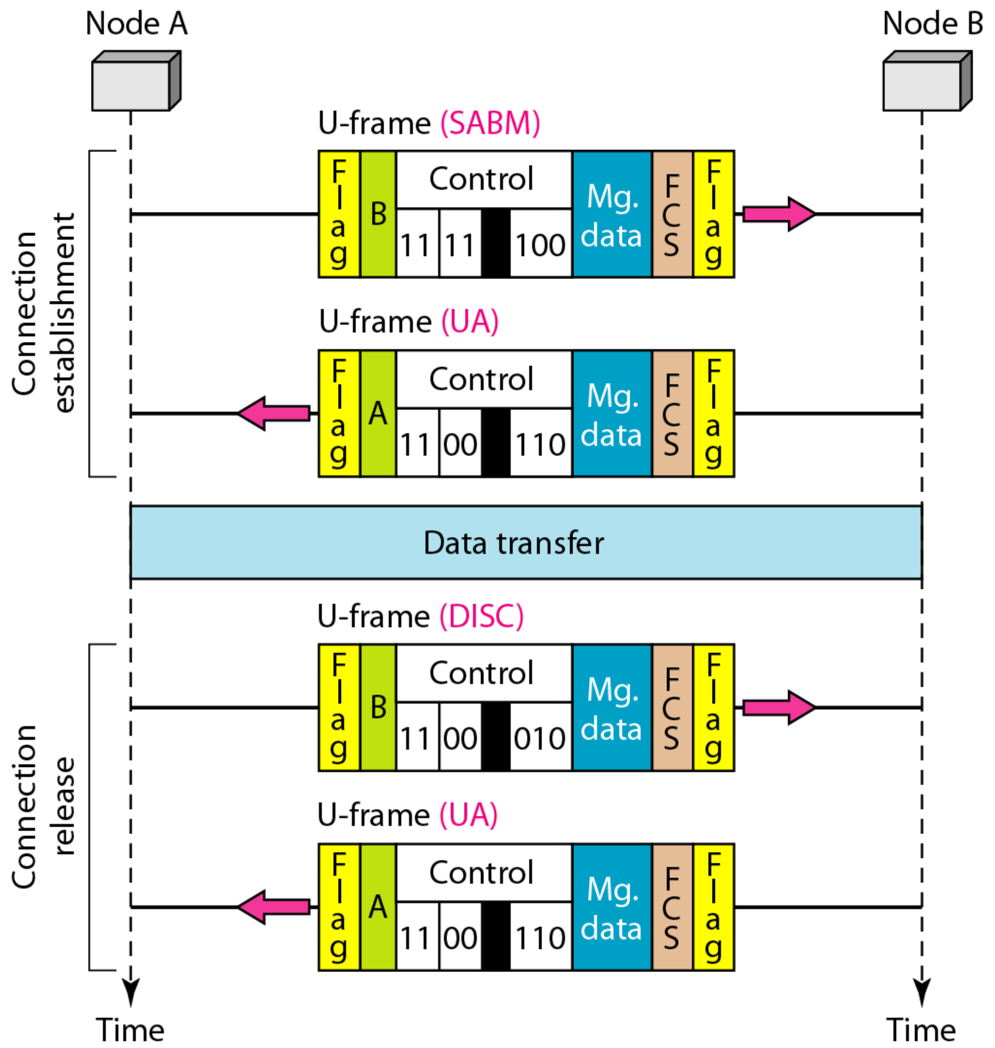
Table 11.1 ***U-frame control command and response***

Code	*Command*	*Response*	*Meaning*
00 001	SNRM		Set normal response mode
11 011	SNRME		Set normal response mode, extended
11 100	SABM	**DM**	Set asynchronous balanced mode or **disconnect mode**
11 110	SABME		Set asynchronous balanced mode, extended
00 000	UI	**UI**	Unnumbered information
00 110		**UA**	**Unnumbered acknowledgment**
00 010	DISC	**RD**	Disconnect or **request disconnect**
10 000	SIM	**RIM**	Set initialization mode or **request information mode**
00 100	UP		Unnumbered poll
11 001	RSET		Reset
11 101	XID	**XID**	Exchange ID
10 001	FRMR	**FRMR**	Frame reject

Example 11.9

Figure 11.29 shows how U-frames can be used for connection establishment and connection release. Node A asks for a connection with a set asynchronous balanced mode (SABM) frame; node B gives a positive response with an unnumbered acknowledgment (UA) frame. After these two exchanges, data can be transferred between the two nodes (not shown in the figure). After data transfer, node A sends a DISC (disconnect) frame to release the connection; it is confirmed by node B responding with a UA (unnumbered acknowledgment).

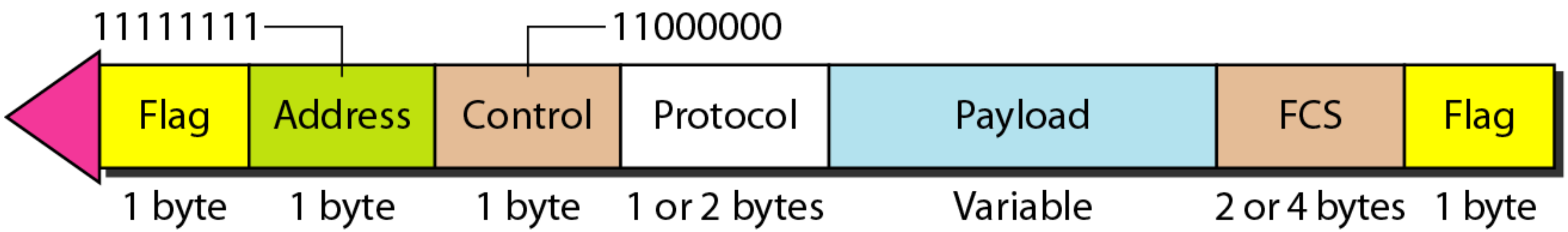
Figure 11.29 *Example of connection and disconnection*



11-7 POINT-TO-POINT PROTOCOL

Although HDLC is a general protocol that can be used for both point-to-point and multipoint configurations, one of the most common protocols for point-to-point access is the Point-to-Point Protocol (PPP). PPP is a byte-oriented protocol.

Figure 11.32 *PPP frame format*



Multiple Access protocols

- single shared broadcast channel
- two or more simultaneous transmissions by nodes: interference
  - only one node can send successfully at a 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!
- what to look for in multiple access protocols:

Ideal Mulitple 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

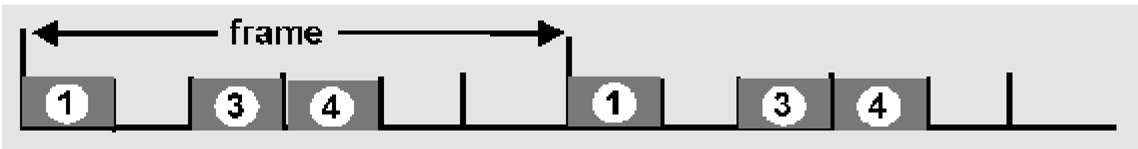
Three broad classes:

- 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"
  - tightly coordinate shared access to avoid collisions

Channel Partitioning MAC protocols: TDMA

TDMA: time division multiple access

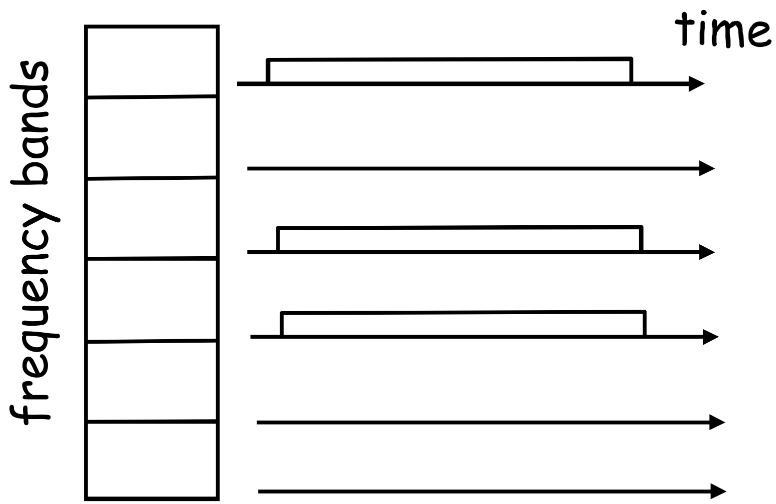
- access to channel in "rounds"
- each station gets fixed length slot (length = pkt trans time) in each round
- unused slots go idle
- example: 6-station LAN, 1,3,4 have pkt, slots 2,5,6 idle



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



Channel Partitioning (CDMA)

CDMA (Code Division Multiple Access)

- unique "code" assigned to each user; i.e., code set partitioning
- used mostly in wireless broadcast channels (cellular, satellite, etc)
- all users share same frequency, but each user has own "chipping" sequence (i.e., code) to encode data
- *encoded signal* = (original data) X (chipping sequence)
- *decoding:* inner-product of encoded signal and chipping sequence
- allows multiple users to "coexist" and transmit simultaneously with minimal interference (if codes are "orthogonal")

Problems

- FDM
- TDM

Wastage of resources when some of the users are idle.

What if the number of users increase

Systems in which multiple users share a common channel in a way that can lead to conflicts are called contention systems.

Basic Assumptions

1. Station model : N independent stations. Once a frame has been generated, the station is blocked, does nothing until the frame has been successfully transmitted
2. Single Channel : All stations can transmit on it and all can recv from it.
3. Collisions : when more than one station try to transmit a frame and they overlap in time, both of them are garbled and we say that a collision has occurred. Both the frames must be transmitted again.. There are no errors other than collision

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

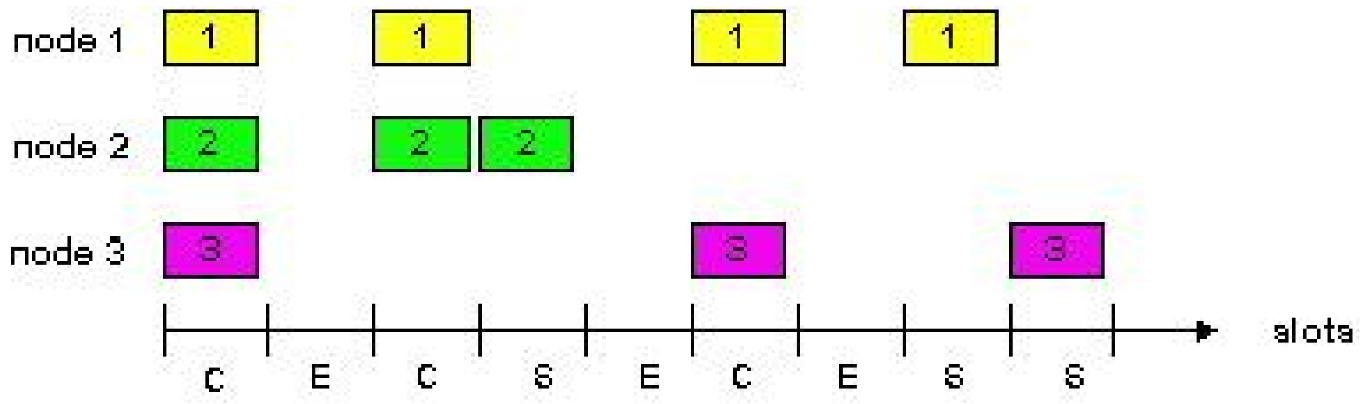
Assumptions

- 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

Slotted Aloha efficiency

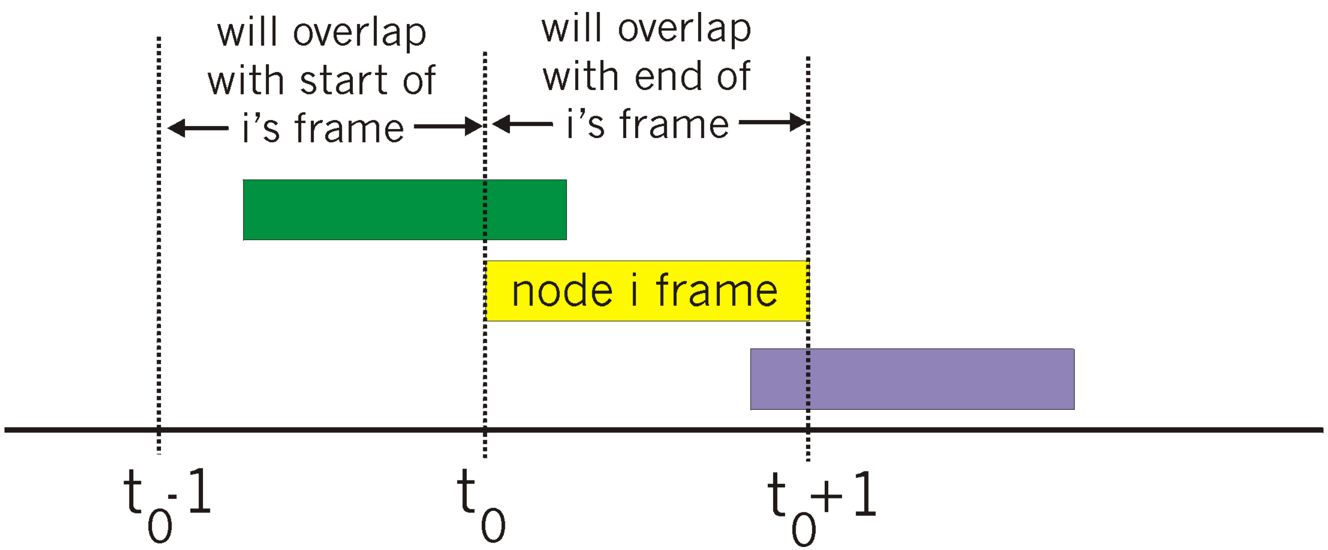
Efficiency is the long-run fraction of successful slots when there's many nodes, each with many frames to send

- Suppose N nodes with many frames to send, each transmits in slot with probability *p*
- prob that 1st node 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 $Np(1-p)^{N-1}$
- For many nodes, take limit of $Np^*(1-p^*)^{N-1}$ as N goes to infinity, gives 1/e = .37

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) $\cdot$

P(no other node transmits in $[p_0-1,p_0]$ $\cdot$

P(no other node transmits in $[p_0-1,p_0]$

$= p \cdot (1-p)^{N-1} \cdot (1-p)^{N-1}$

$= p \cdot (1-p)^{2(N-1)}$

... choosing optimum p and then letting n -> infty ...

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

Even worse !

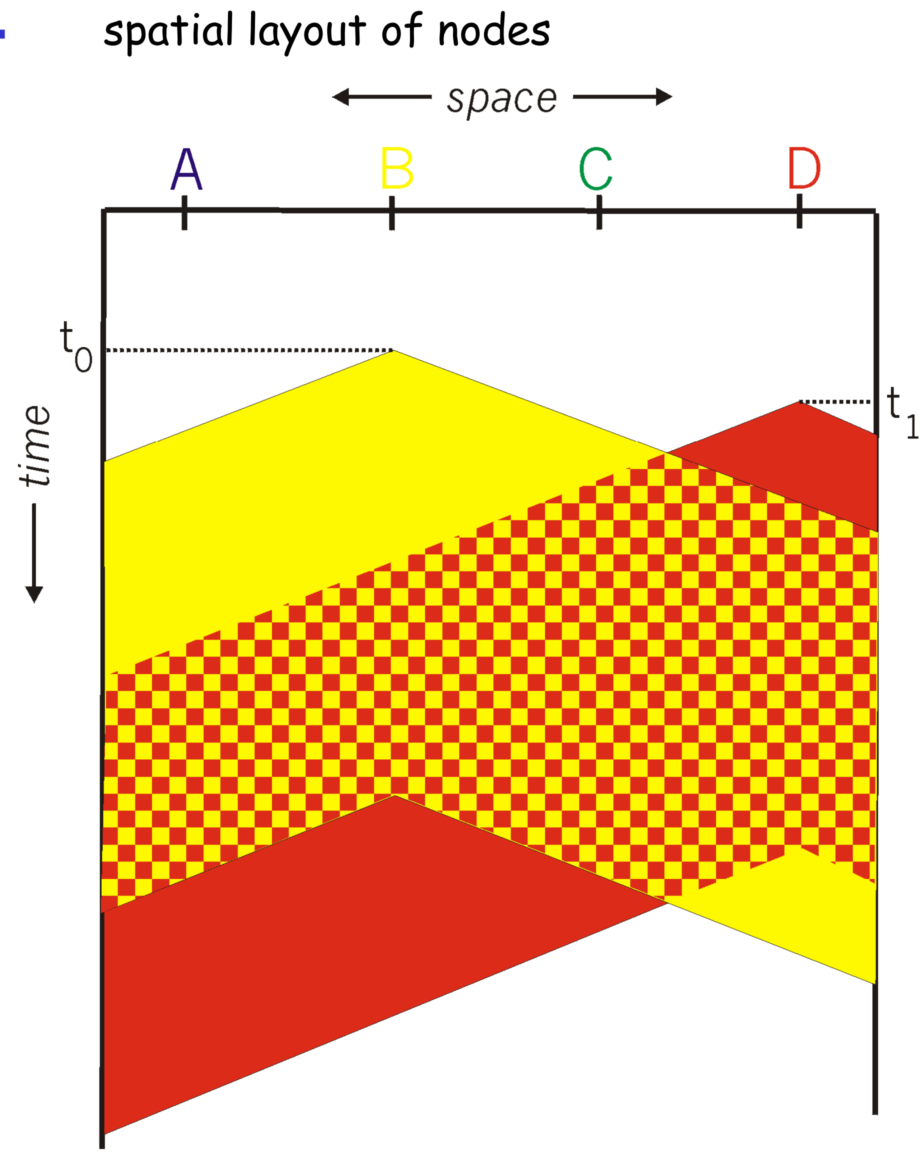
CSMA (Carrier Sense Multiple Access)

CSMA: listen before transmit:

- If channel sensed idle: transmit entire frame
- If channel sensed busy, defer transmission

- Human analogy: don't interrupt others!

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

CSMA/CD (Collision Detection)

CSMA/CD: carrier sensing, deferral as in CSMA

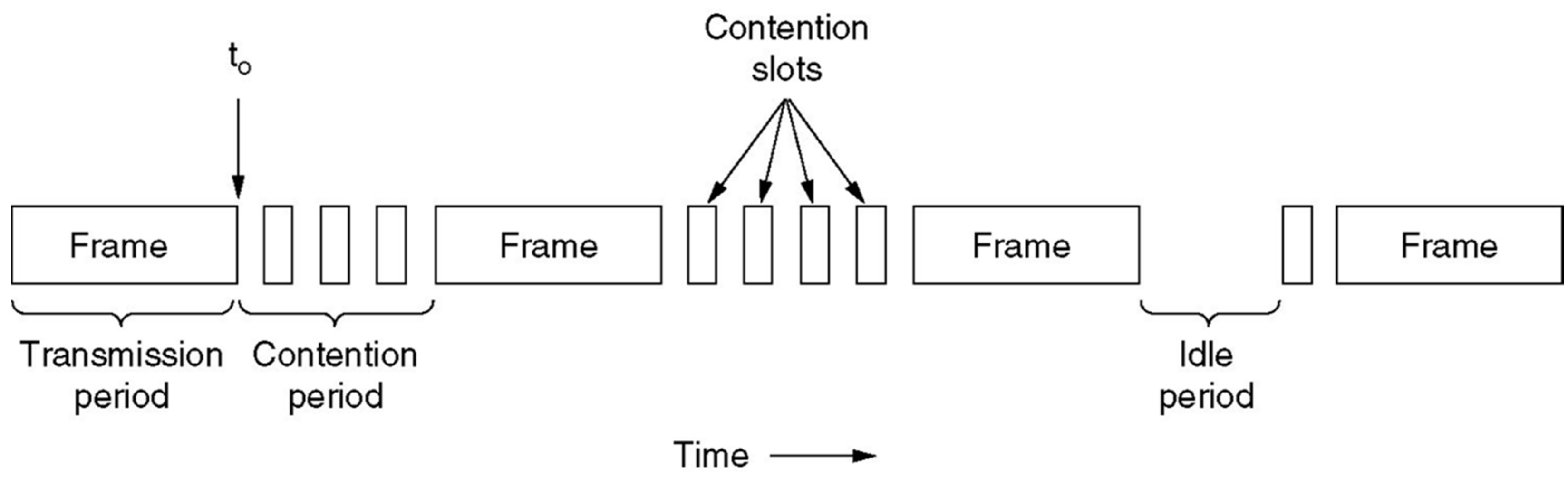
- collisions *detected* within short time
- colliding transmissions aborted, reducing channel wastage

- collision detection:
  - easy in wired LANs: measure signal strengths, compare transmitted, received signals
  - difficult in wireless LANs: receiver shut off while transmitting
- human analogy: the polite conversationalist

CSMA/CD (Collision Detection)

- Suppose after a station has finished sending its frame, say at time to, other stations try to sense the channel for collision. In case, collision is detected, it refrains from transmitting, waits for a random amount of time and tries again.
- The above procedure is repeated until the station gets a chance to transmit its frame.
- If a station detects collision in the midway of generating its frame, it stops immediately rather than generating the entire frame.
- Widely used
- Also in Ethernet LAN

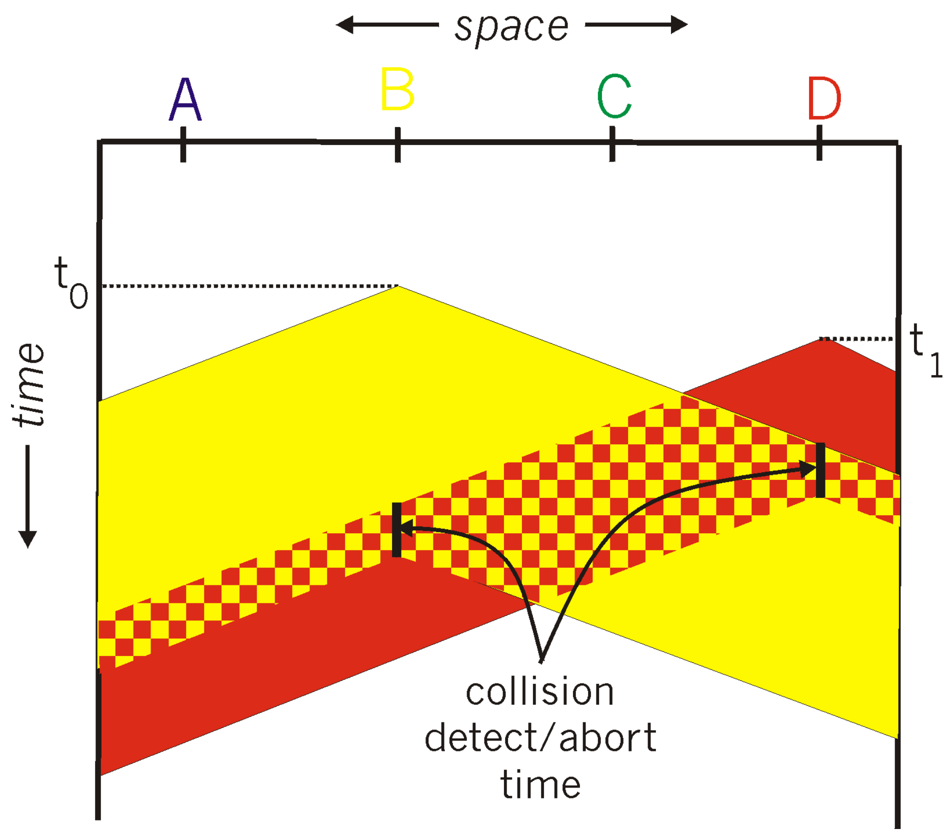
CSMA/CD can be in one of three states: contention, transmission, or idle.



What should be the size of the contention interval?

- How long does it take for a channel to detect a collision (max time)?
  - Let the time it takes for a signal to travel between the two farthest stations, say A and B, is t
  - At t0, A starts transmitting.
  - At t-epsilon, an instant before the signal reaches B, B also starts transmitting, collision occurs
  - But the collided signal reaches back to A not before additional t time .. I.e. at an instant 2t-epsilon
- Hence it takes about 2t time for A to detect a collision
- Hence the contention interval must be 2t.

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!

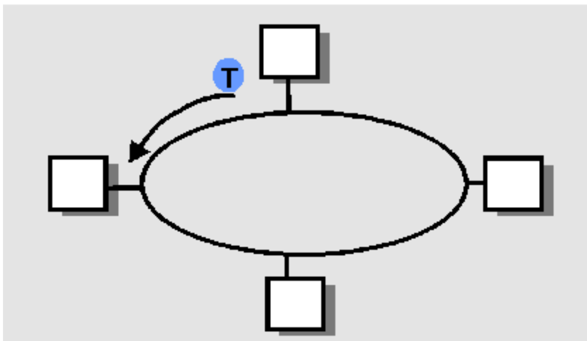
"Taking Turns" MAC protocols

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,Code 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
  - Taking Turns
    - polling from a central site, token passing