Medium Access Control

EE450: Introduction to Computer Networks

Professor A. Zahid

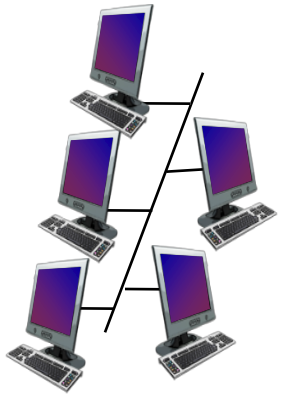
Medium Access Control

- 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

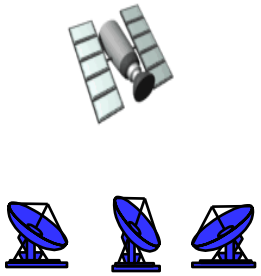
- Distributed algorithm that determines how nodes share channel, i.e., determine when node can transmit
- Communication about channel sharing must use channel itself!

Multiple Access Links



shared wire (e.g., cabled Ethernet)

shared RF (e.g., 802.11 Wi-Fi)

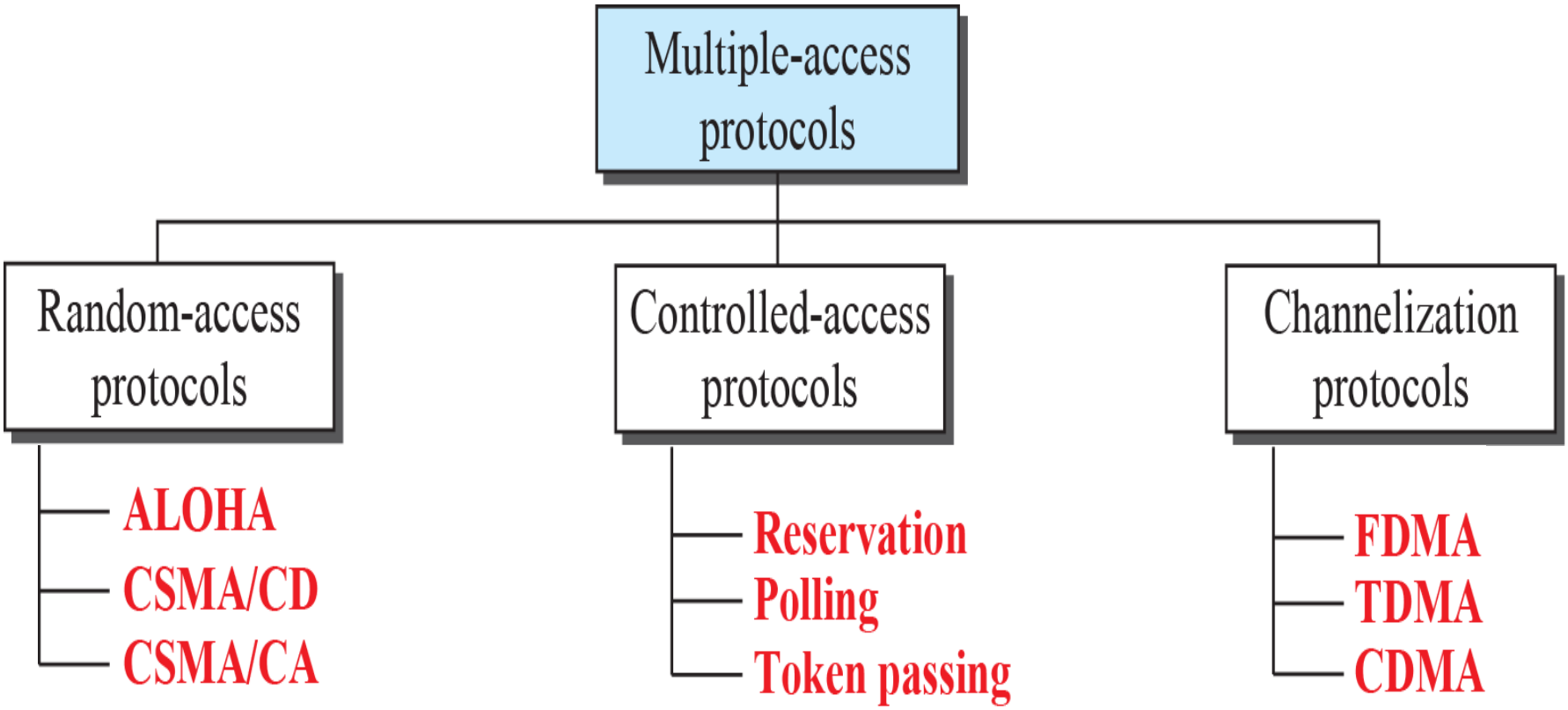


shared RF (satellite)

humans at a cocktail party (shared air, acoustical)

- Old-fashioned Ethernet
- Upstream HFC (In Cable Access Networks)
- Wi-Fi: 802.11 wireless LAN

Taxonomy of MAC Protocols

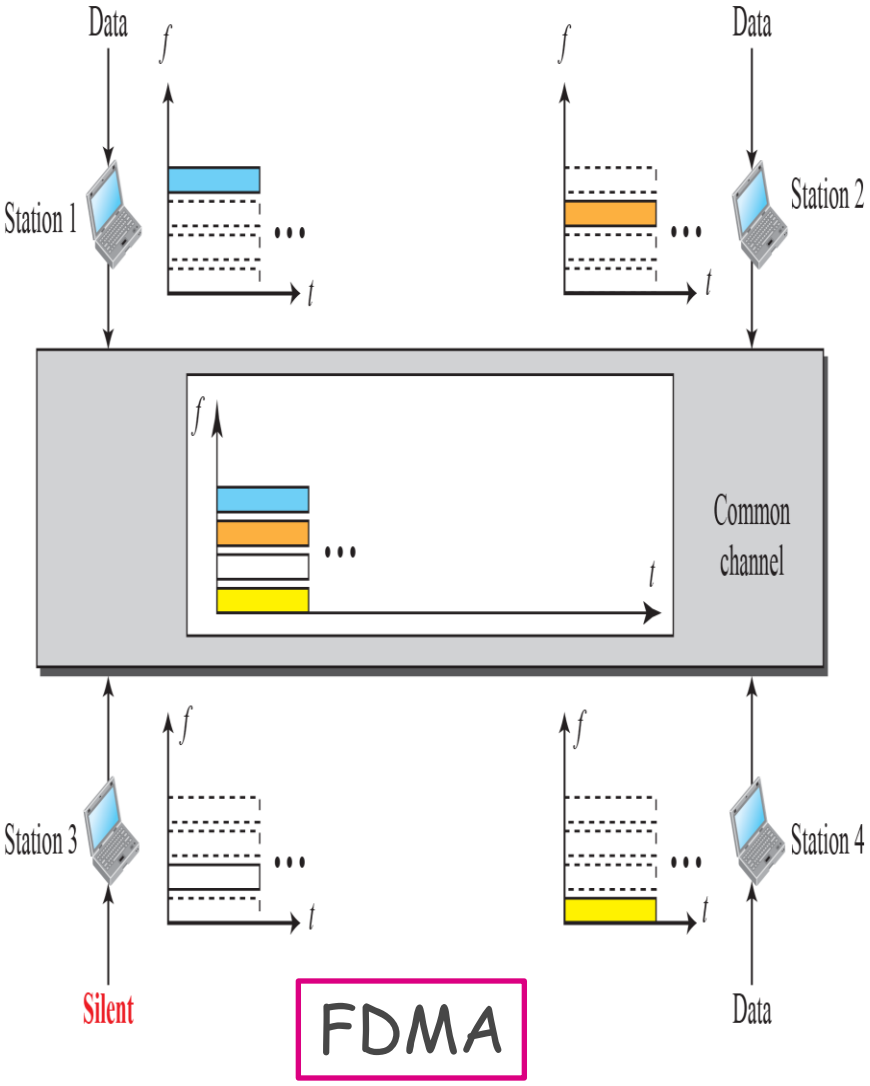


Classifications of MAC Protocols

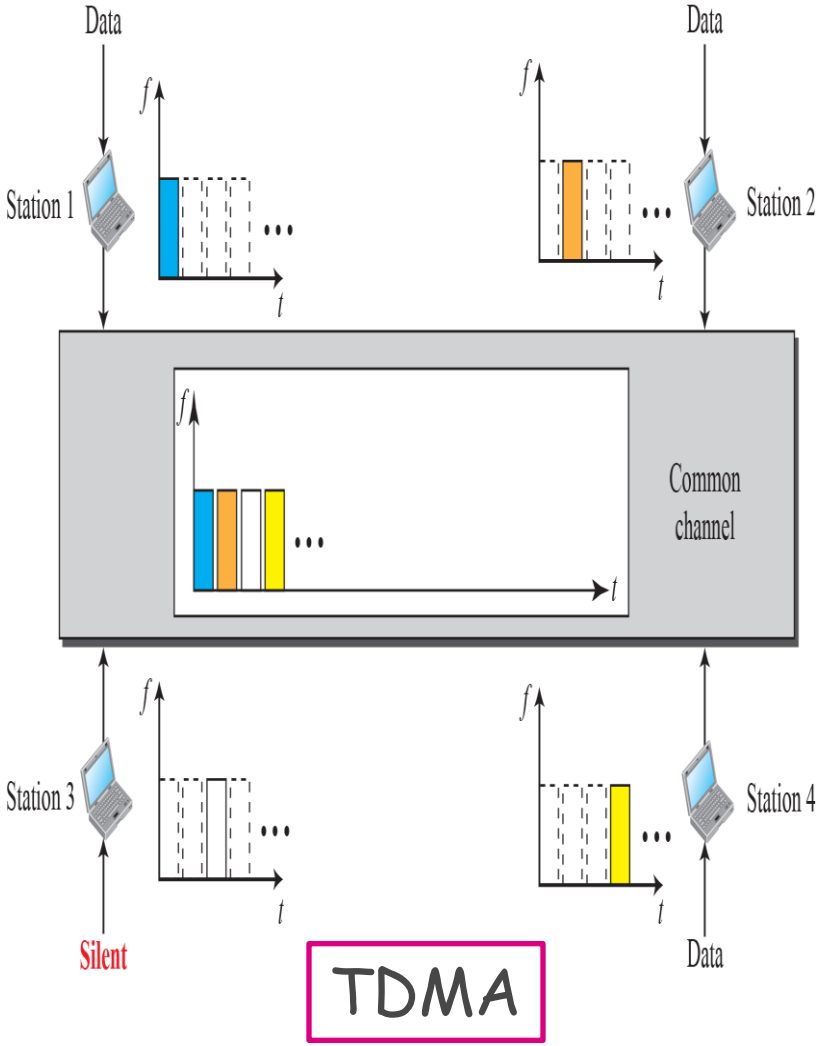
Three broad classes:

- Channel Partitioning
  - Divide channel into smaller "pieces" (time slots, frequency, code) for example TDMA, FDMA or CDMA
  - Allocate a piece to each node for exclusive use
- Random Access
  - Channel not divided, allow collisions. Examples: ALOHA, CSMA/CD, CSMA/CA
  - "Recover" from collisions for example via delayed retransmissions
- "Taking turns"
  - Nodes take turns, but nodes with more to send can take longer turns. Examples: Polling, Token Passing

Channel Partitioning: FDMA/TDMA



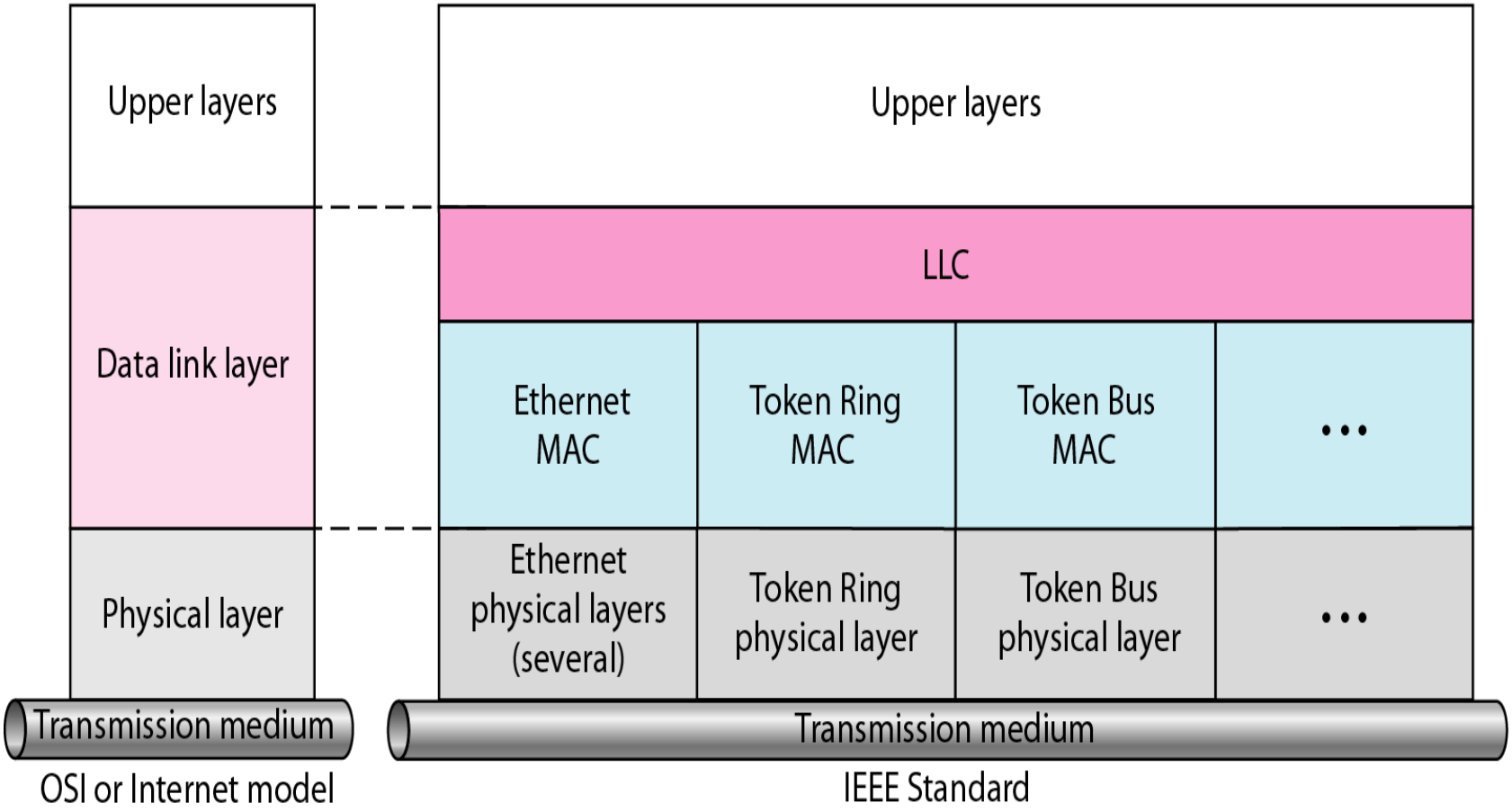
FDMA



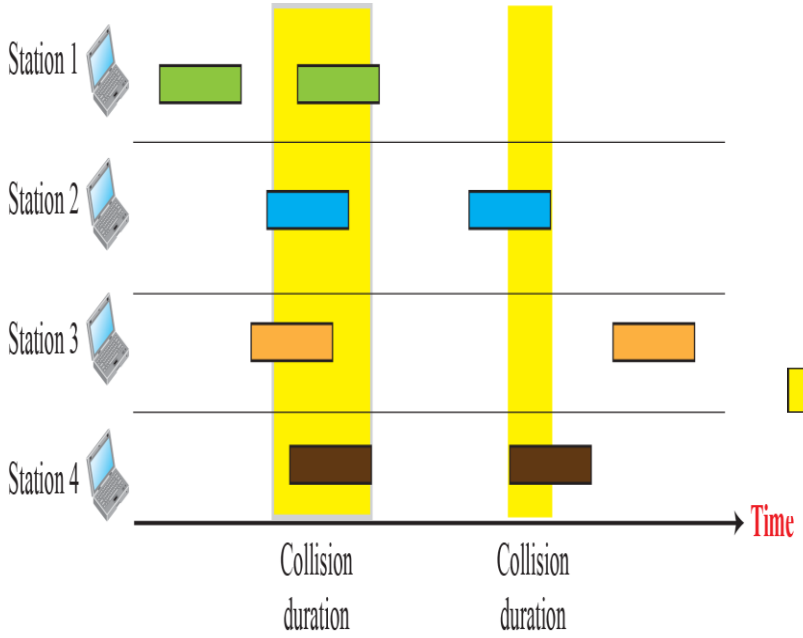
TDMA

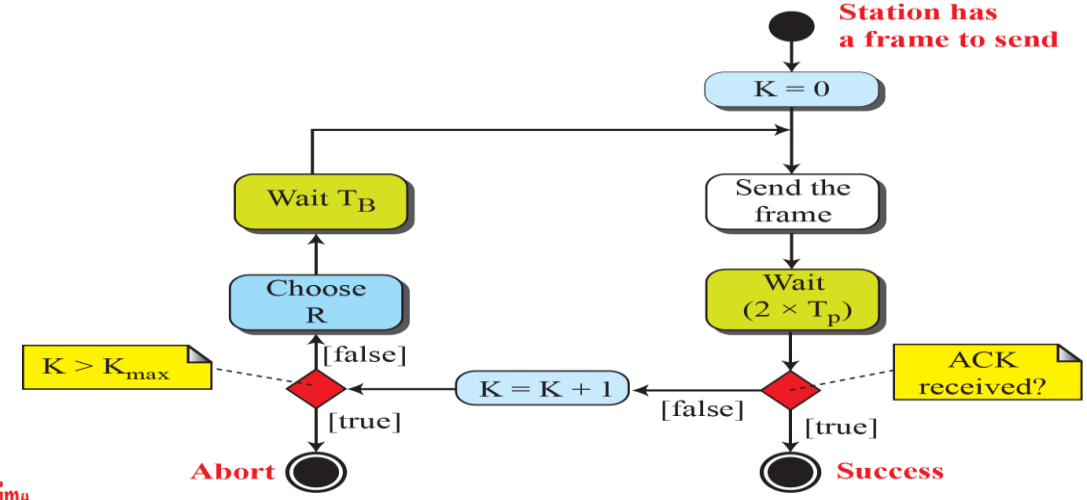
IEEE802 Standards for LANs

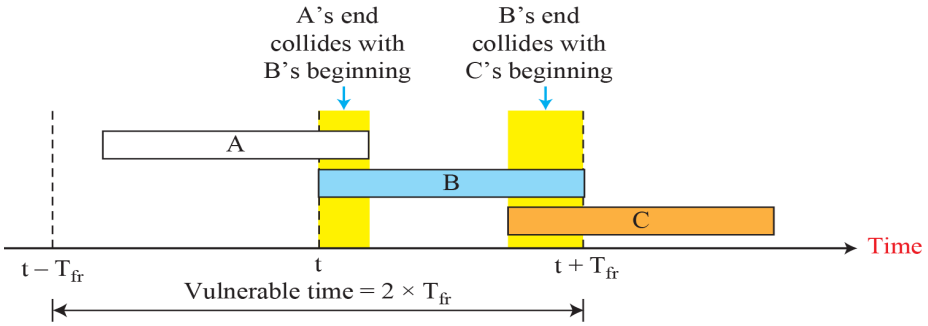
LLC: Logical link control
MAC: Media access control



Random Access Protocols: ALOHA



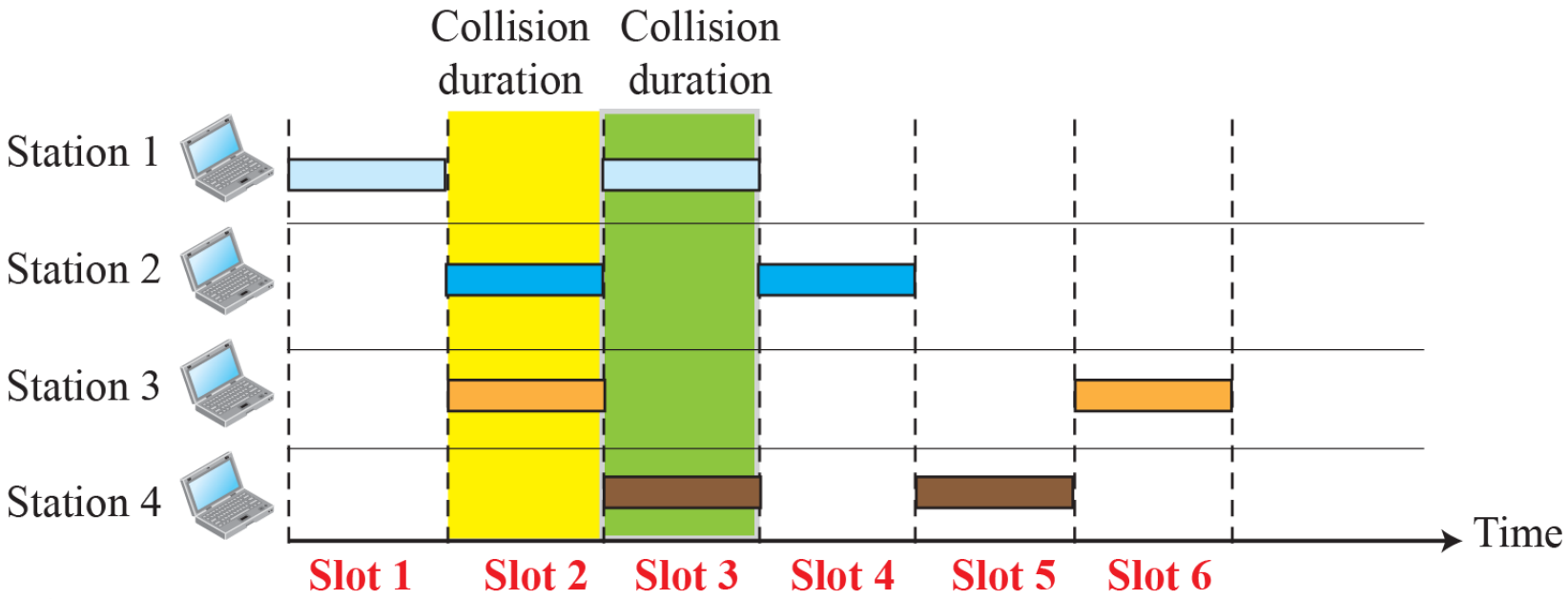




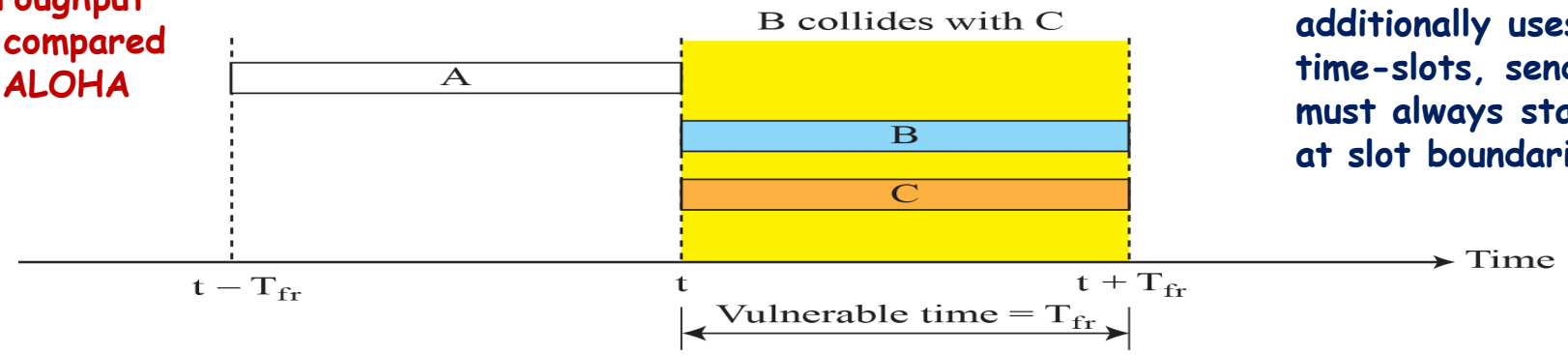
Legend

K : Number of attempts
T_p : Maximum propagation time
T_{fr}: Average transmission time
T_B: (Back-off time): $R \times T_p$ or $R \times T_{fr}$
R : (Random number): 0 to $2^K - 1$

Slotted ALOHA



Double the Throughput as compared to ALOHA



Slotted Aloha additionally uses time-slots, sending must always start at slot boundaries

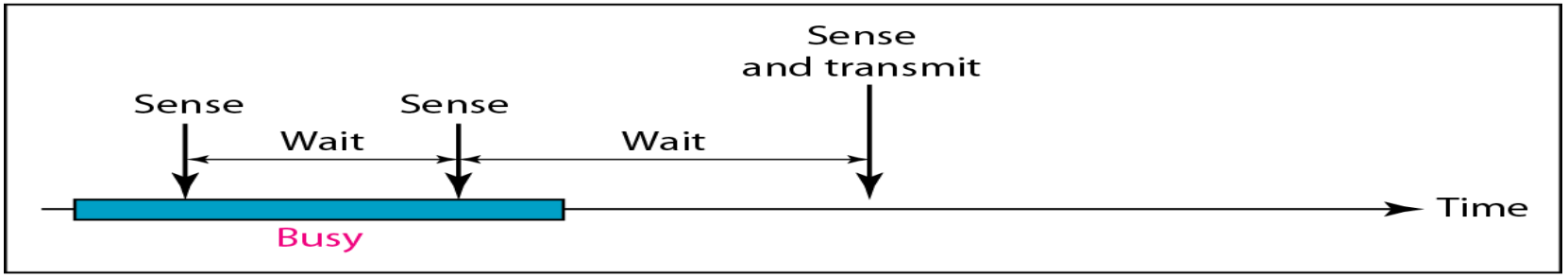
IEEE802.3 (Based on Ethernet)
"Carrier Sense Multiple Access"

Carrier Sense Multiple Access

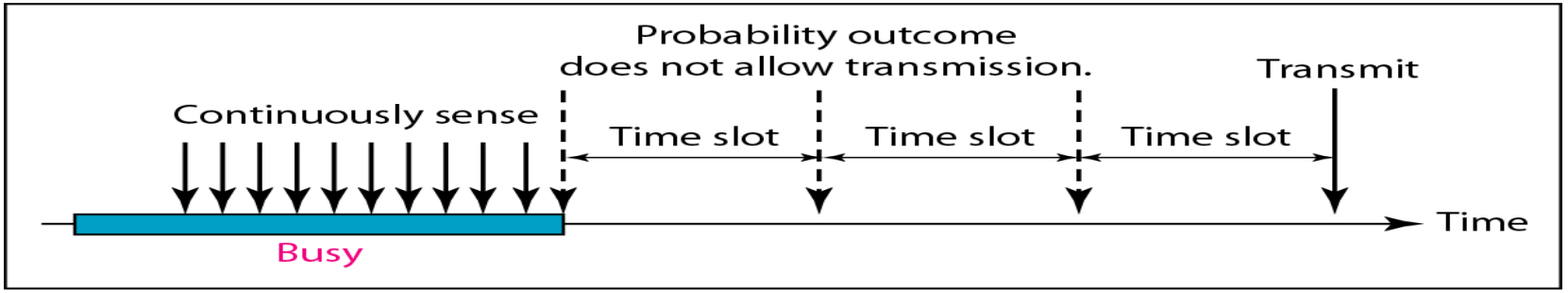
- CSMA/CD: Carrier sense, multiple access with collision detection
  - collisions detected within short time
  - colliding transmissions aborted, reducing waste
  - Persistent, non-persistent and P-persistent retransmission
- Collision Detection:
  - On baseband bus, collision produces much higher signal voltage than transmitted signal
  - For twisted pair (Hub-topology) activity on more than one port is collision

Behavior of Three Persistent Scenarios

a. 1-persistent



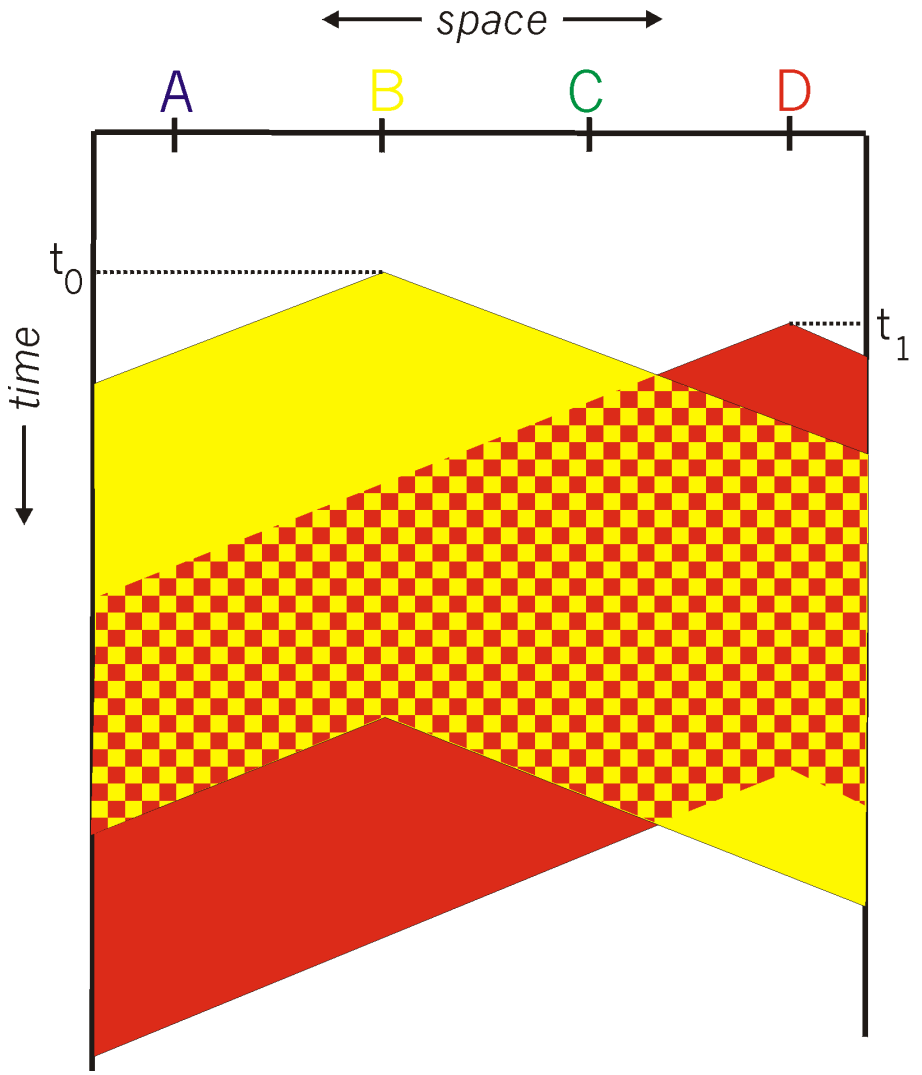
b. Nonpersistent



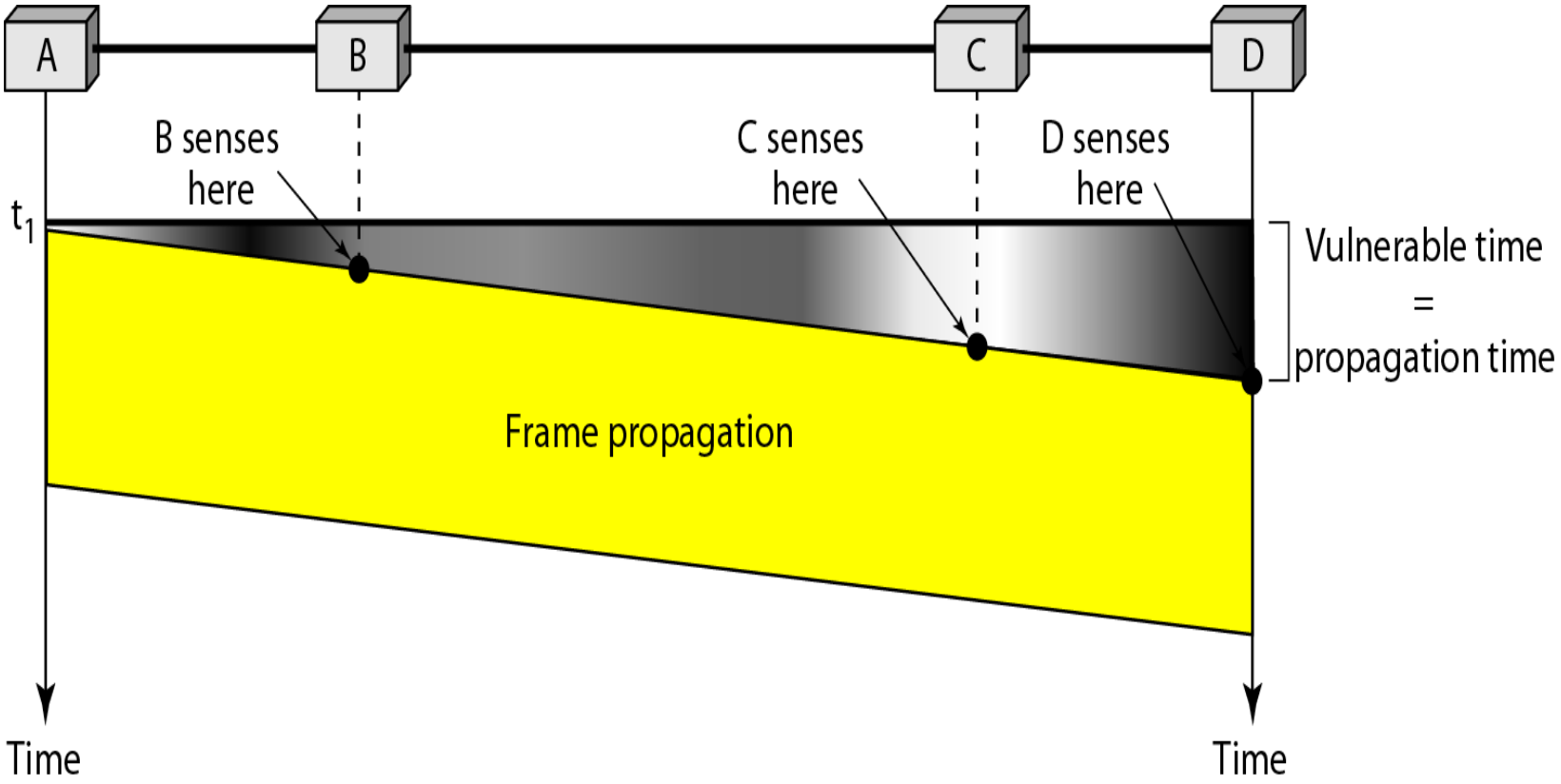
c. p-persistent

Collisions in CSMA/CD

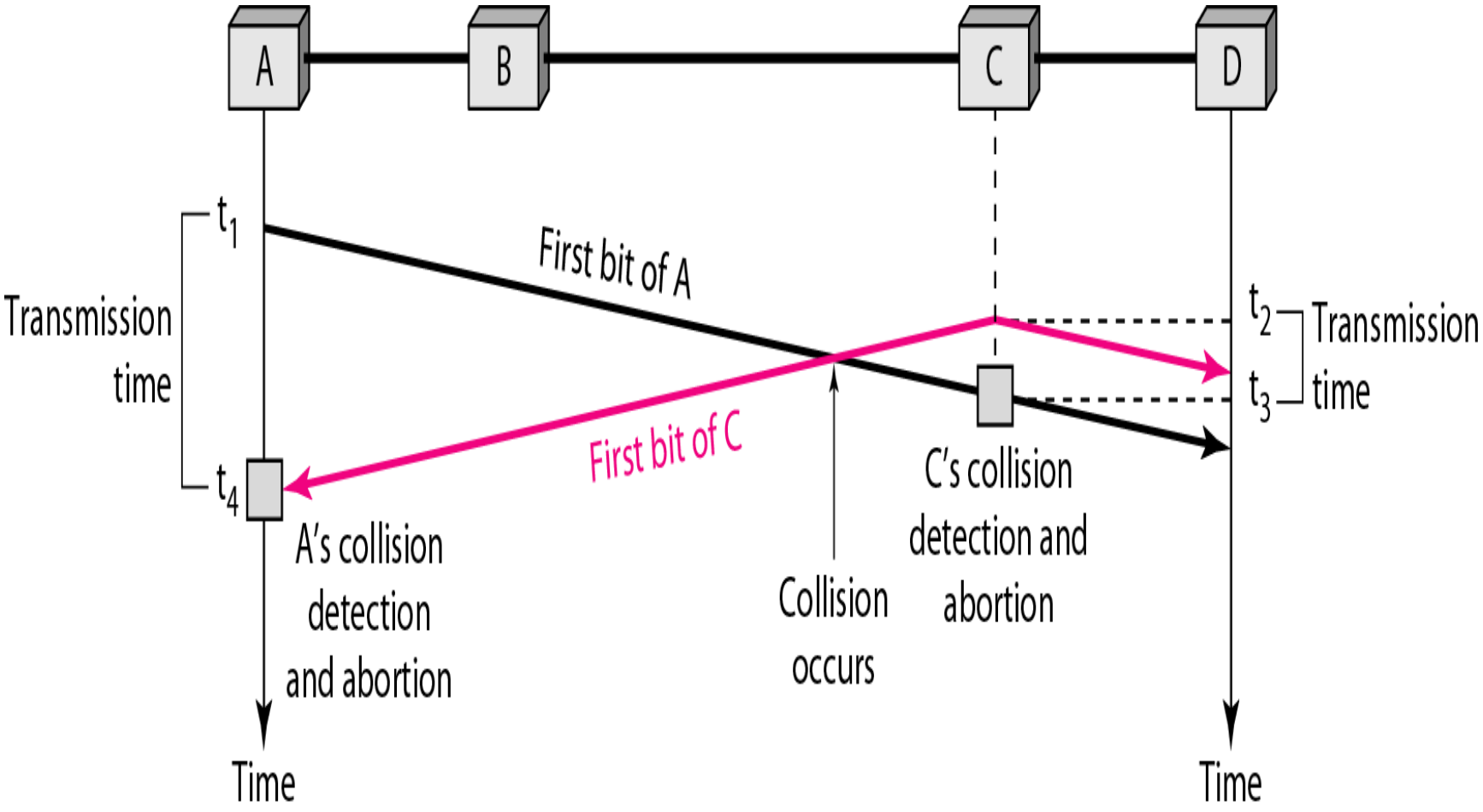
- Collisions can still occur: propagation delay means two nodes may not hear each other's transmission
- When collision occur, entire frame is wasted
- Collision is detected by comparing transmitted and received signal strengths (Hard to do in WLANs, TBD)



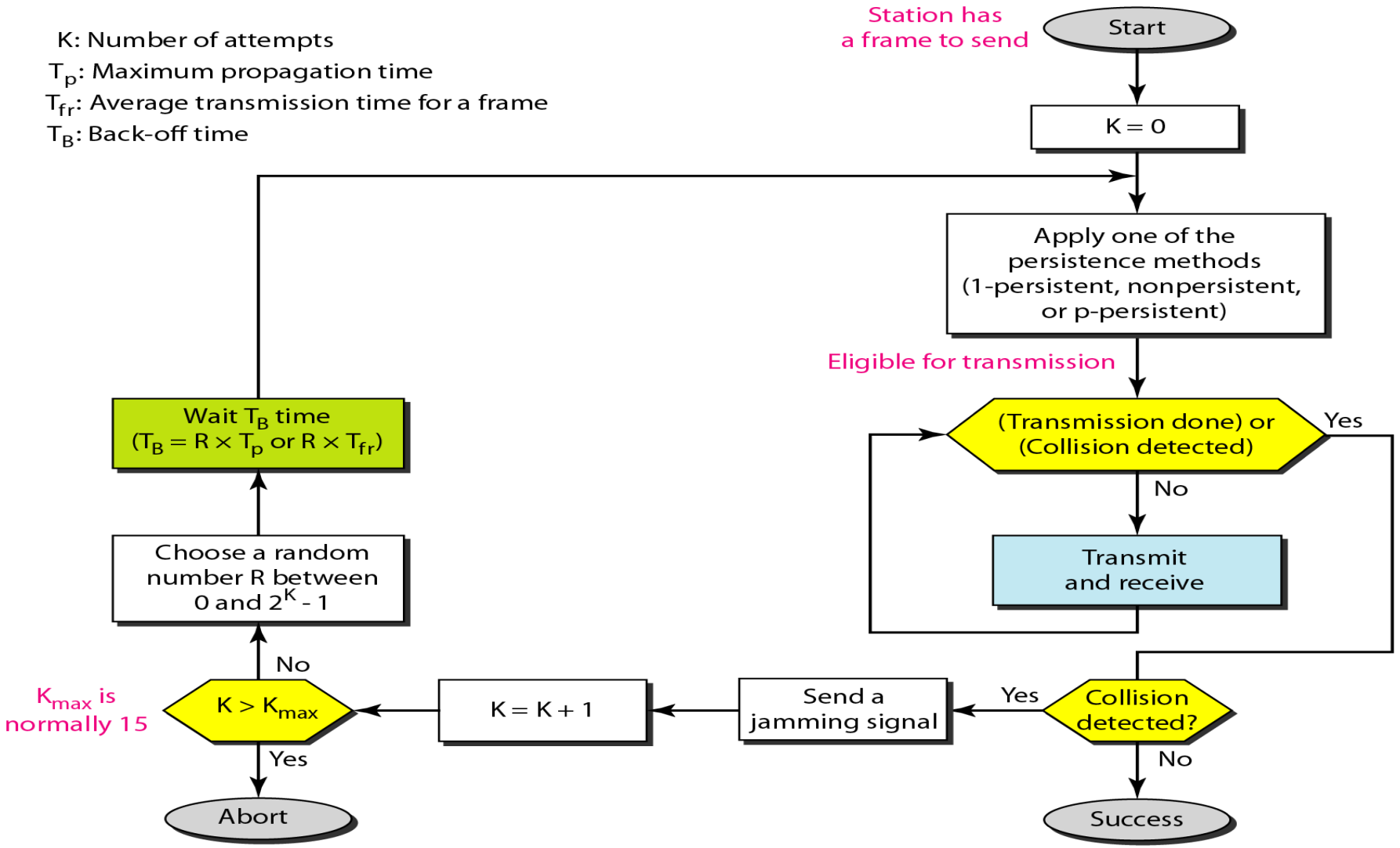
Vulnerable Time in CSMA



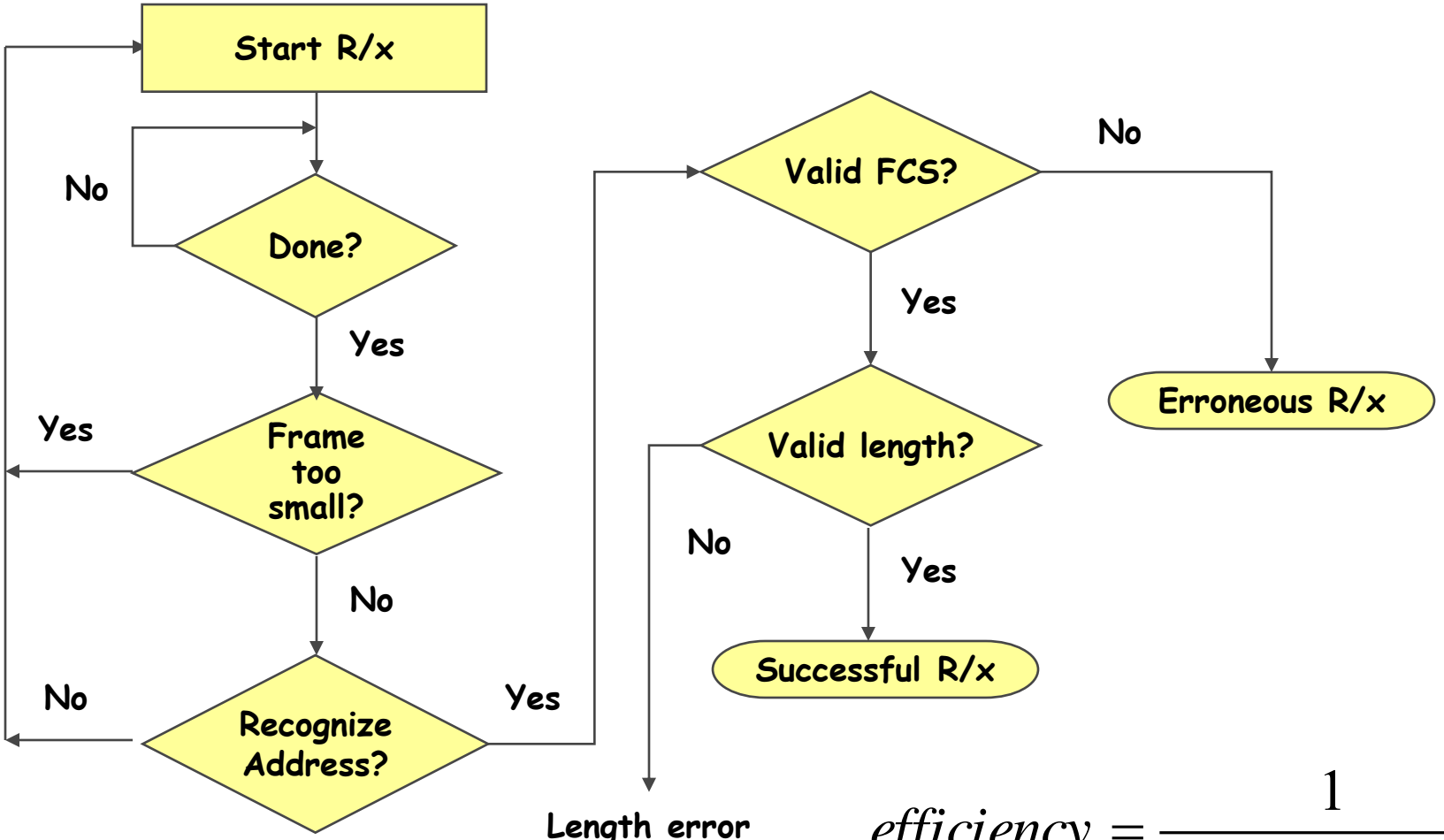
Collision Detection



Flow Chart of CSMA/CD



Receive Process in IEEE802.3



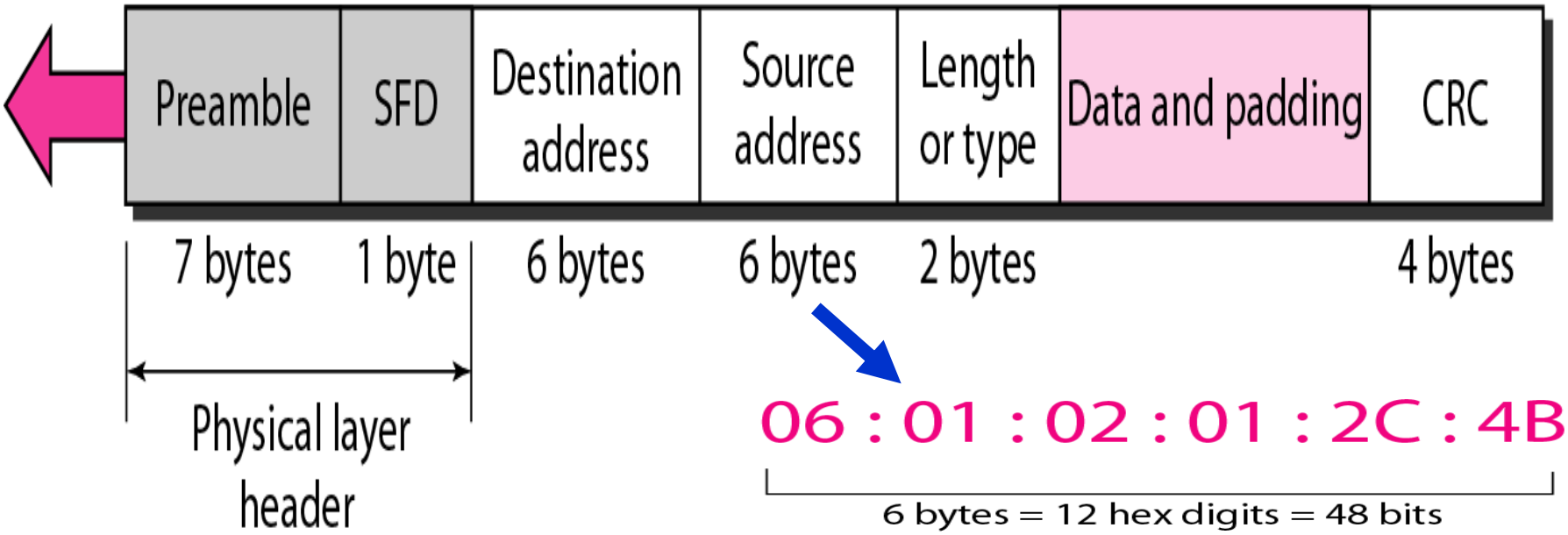
$$efficiency = \frac{1}{1 + 5t_{prop}/t_{trans}}$$

IEEE802.3 MAC Frame

Preamble: 56 bits of alternating 1s and 0s.

SFD: Start frame delimiter, flag (10101011)

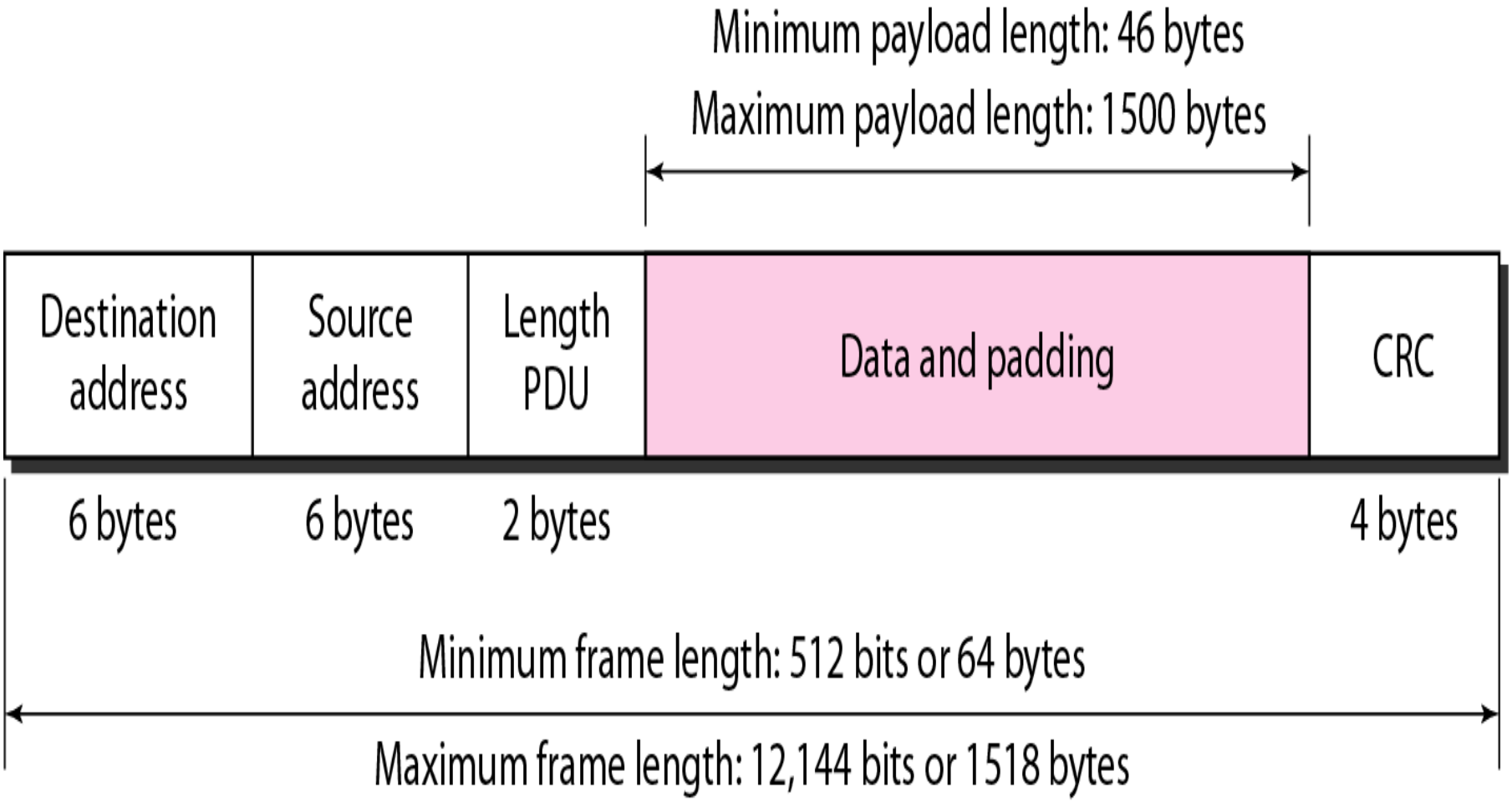
Sending adapter encapsulates IP Packet in Ethernet frame



MAC address is burned in NIC ROM (sometimes software settable)

Type: Indicate Network Layer Protocol (mostly IP)

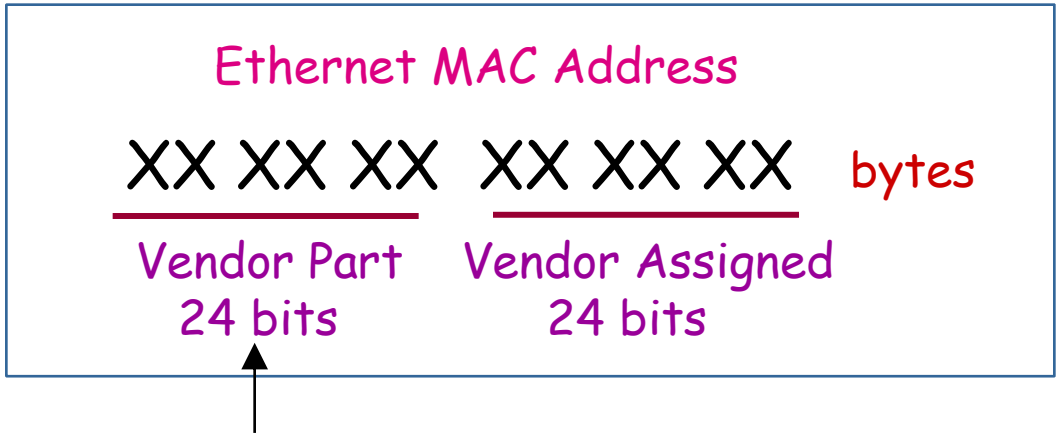
IEEE802.3 Frame Length Limits



If errors are detected,
Frame is dropped

MAC Addresses

- Source and destination MAC addresses. These are the hardware addresses. They are 48-bits long each

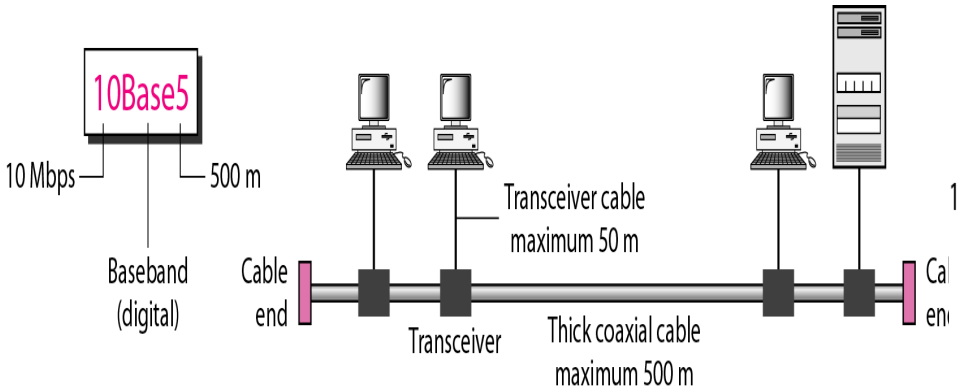


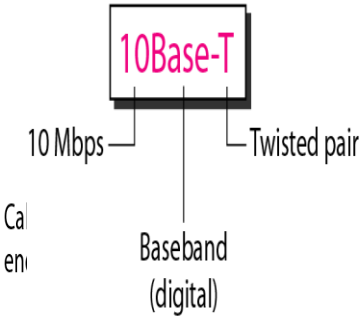
http://standards.ieee.org/regauth/oui/
http://www.cavebear.com/CaveBear/Ethernet/

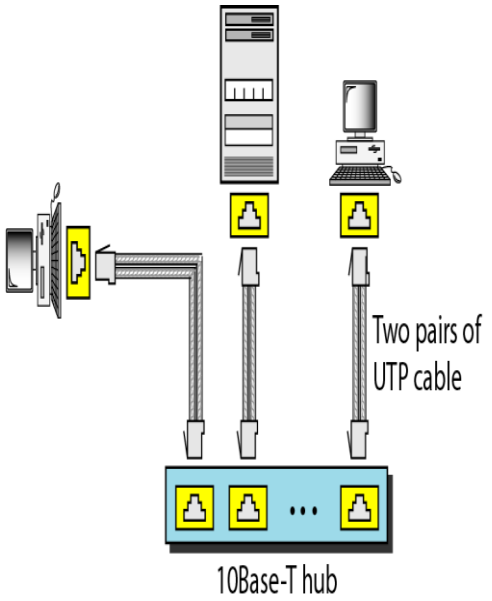
Types of MAC Addresses

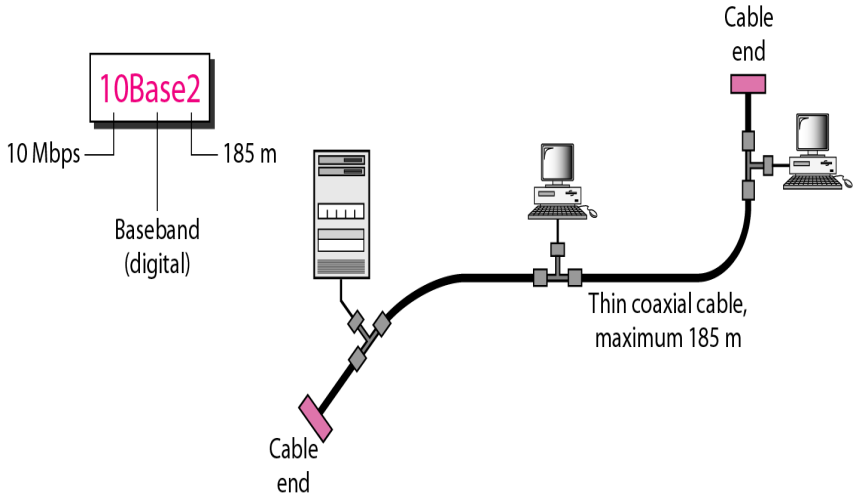
- **Unicast**: one interface to one interface
- **Broadcast**: all 1's destination address means that every attached interface to a LAN should read the frame.
  - MAC Address: FF:FF:FF:FF:FF:FF
- **Multicast**: an interface can be configured to read frames sent to one or more multicast addresses.

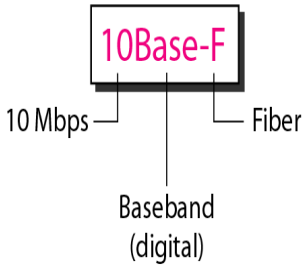
10Base? Implementations

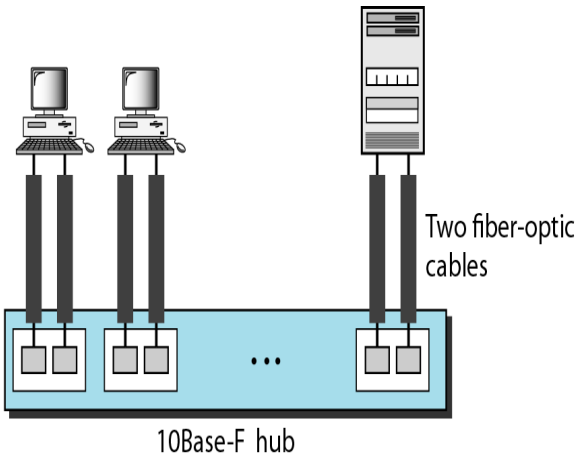




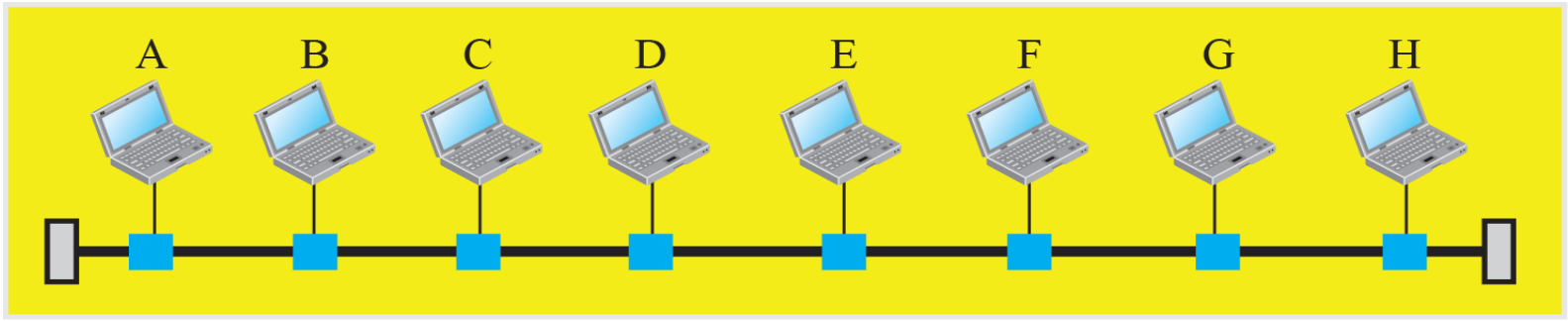




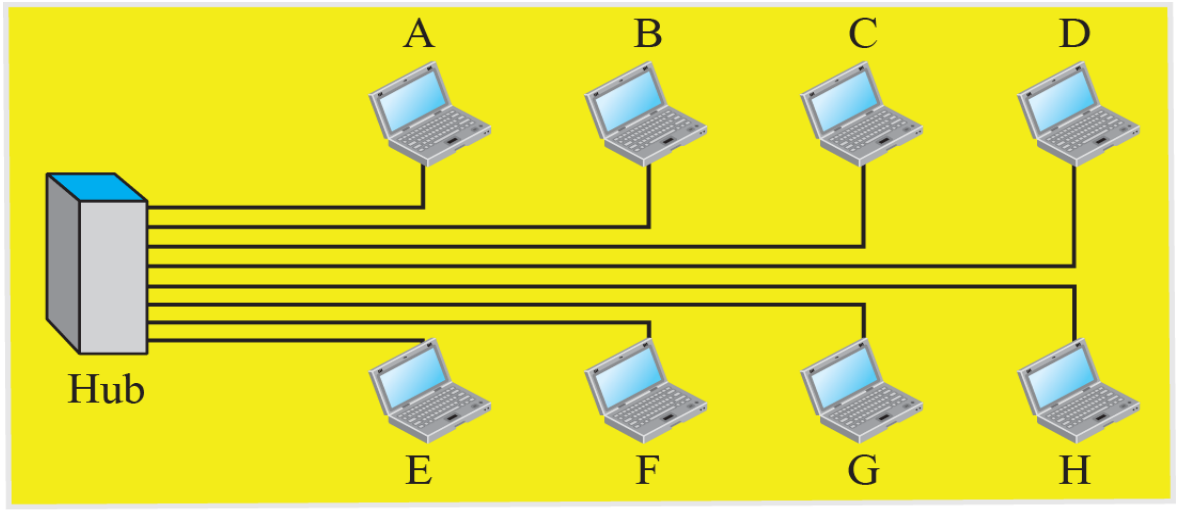




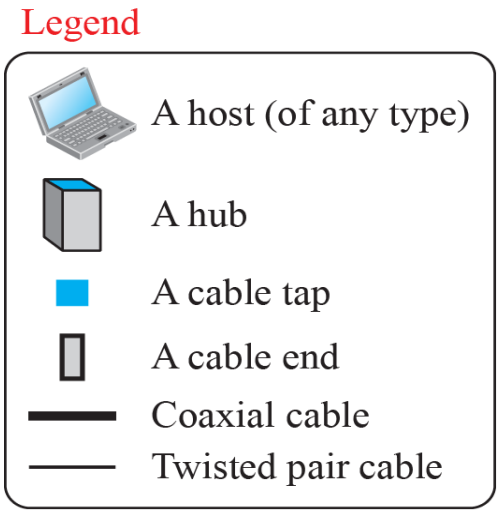
Shared Ethernet Implementations



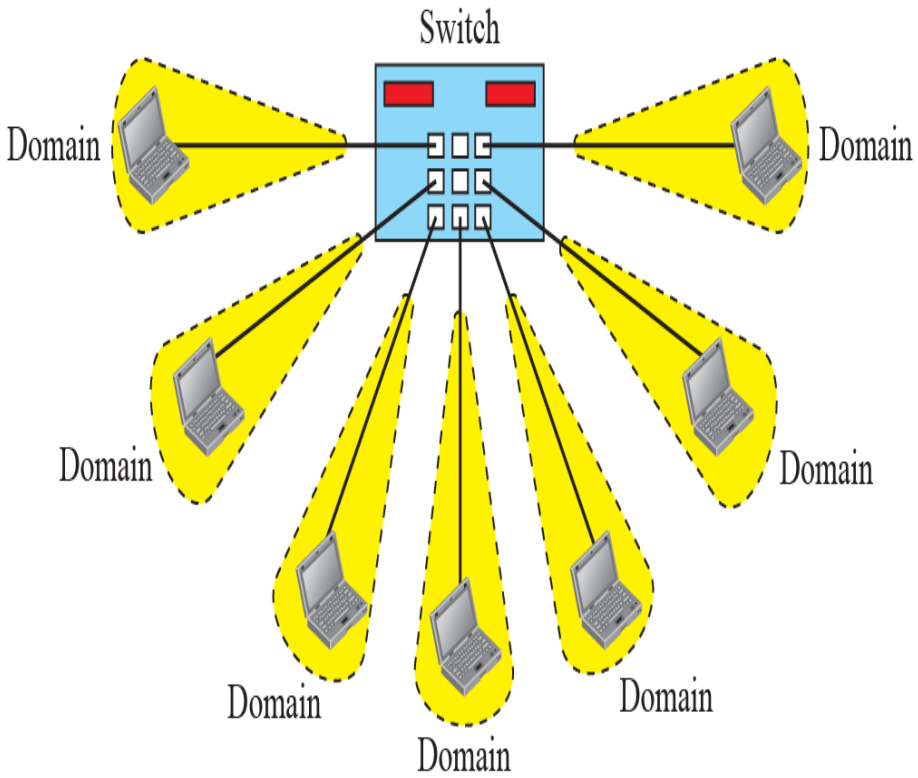
a. A LAN with a bus topology using a coaxial cable



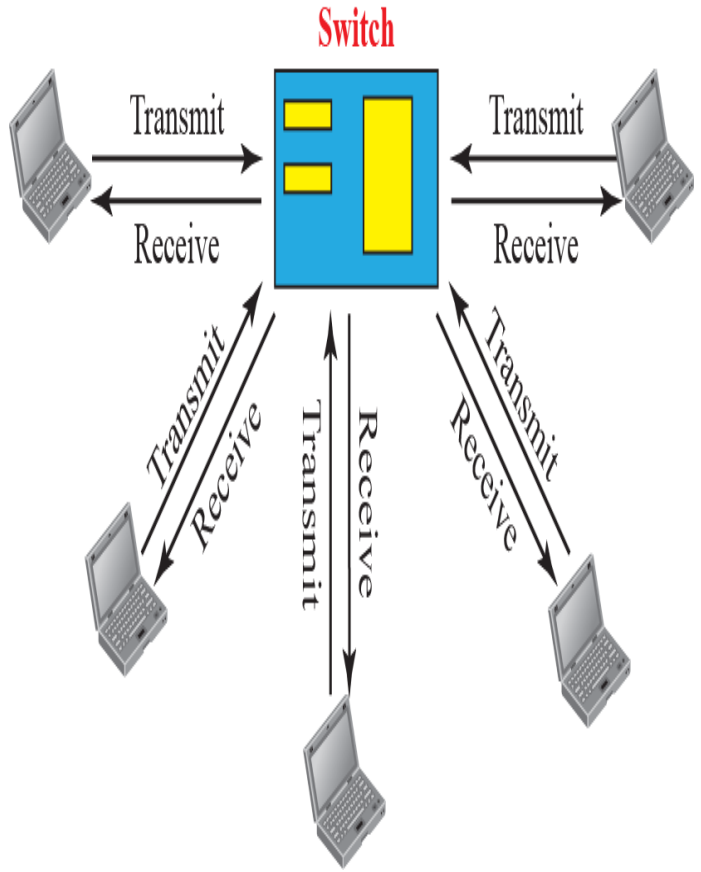
b. A LAN with a star topology using a hub



Switched Ethernet



No Collisions



Support FDX

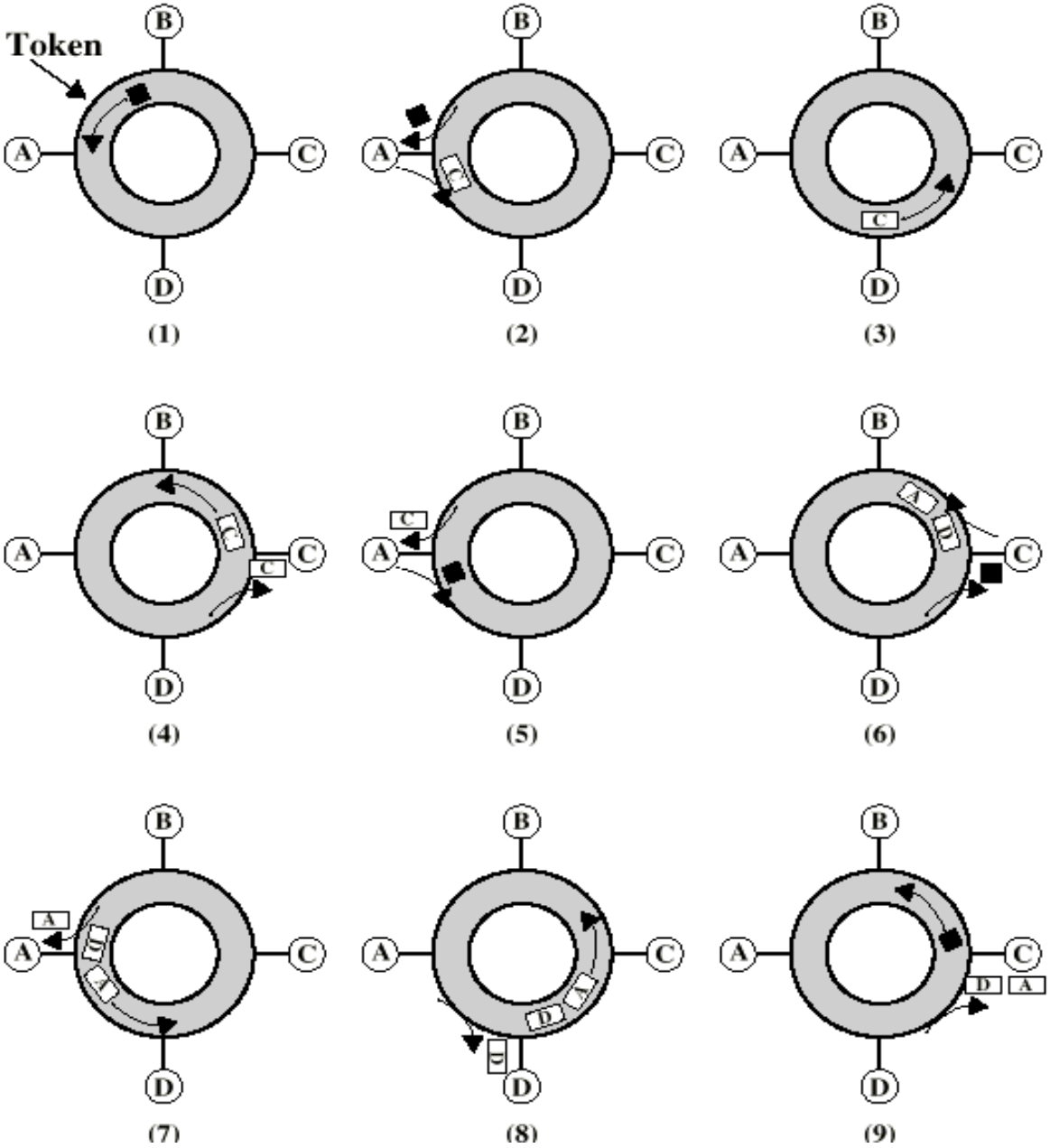
IEEE802.5 (Based on IBM) "Token-Passing Rings"

IEEE802.5 Token-Passing Rings

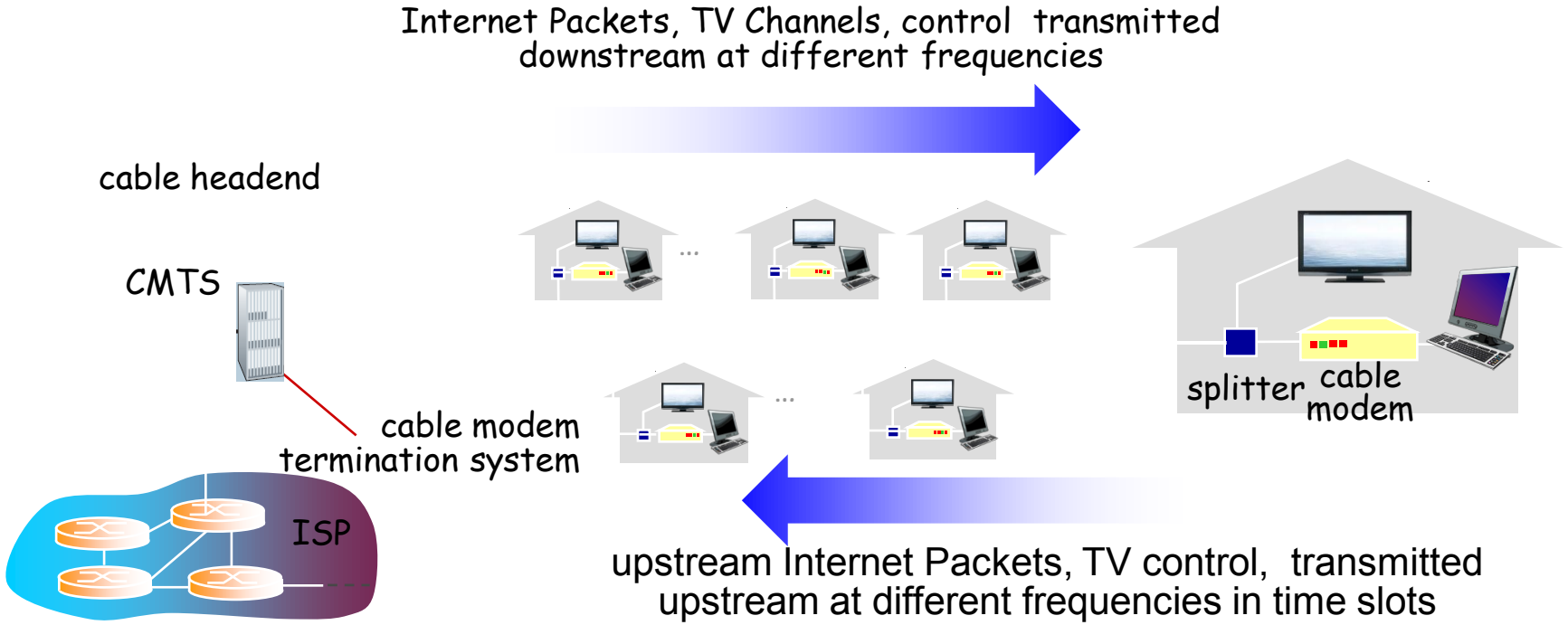
- Frames flow in one direction
- Special bit pattern (token) rotates around ring. The token is 24-bit long
- Node having a frame to transmit must capture token first
- Node must release token after done transmitting
- Node remove frame when it comes back around
- Stations get round-robin service

Token Ring

- Supports 4Mbps (UTP), 16 Mbps (STP) and 100 Mbps (Fiber)
- Token Holding Timer ~ 10 msec which limits the frame length ~ 4500 Bytes for the 4Mbps Rings and ~ 18,000 Bytes for the faster Rings



Cable Access Network



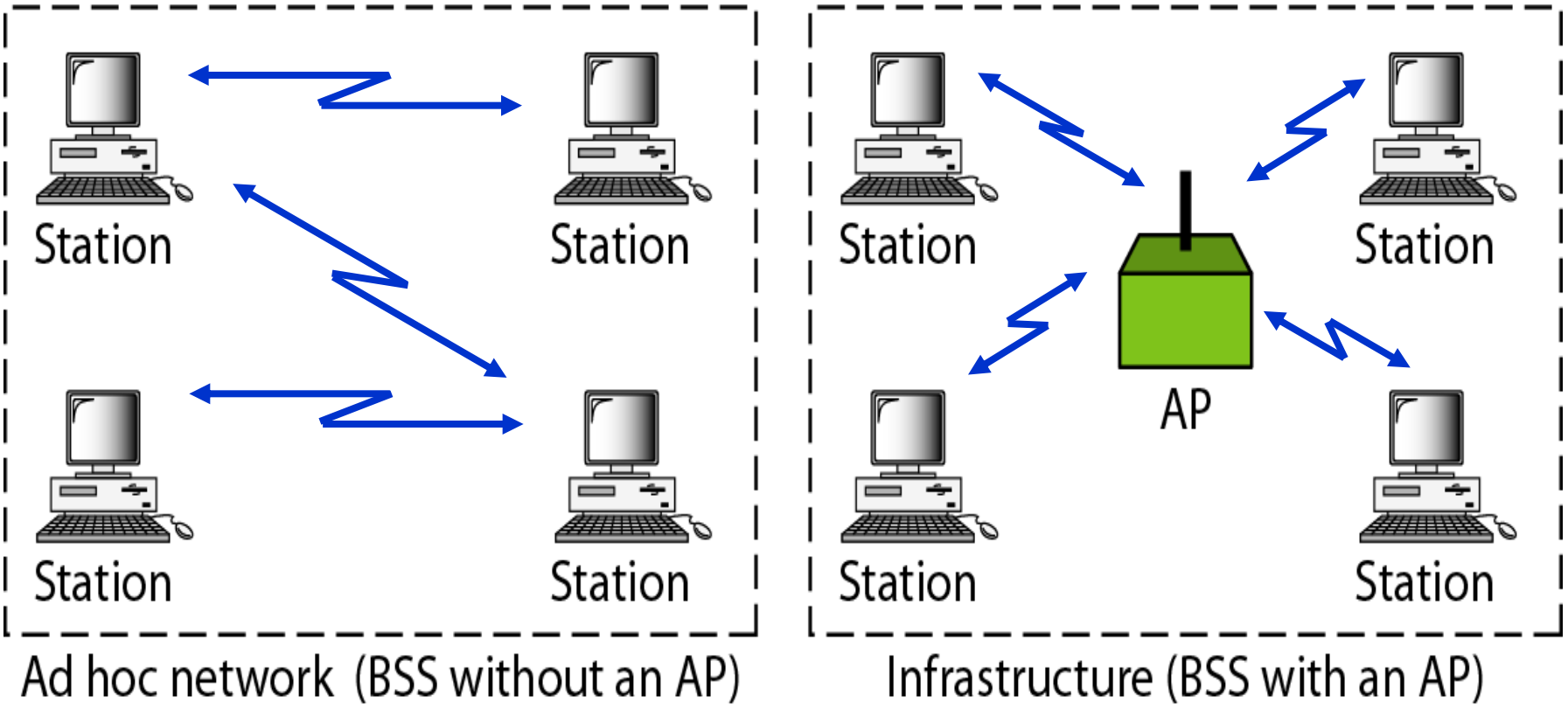
- multiple 40Mbps downstream (broadcast) channels
  - single CMTS transmits into channels
- multiple 30 Mbps upstream channels
  - multiple access: all users contend for certain upstream channel time slots (others assigned)

IEEE 802.11
Wireless LANs (Wi-Fi)

Ad-hoc vs. Infrastructure WLANs

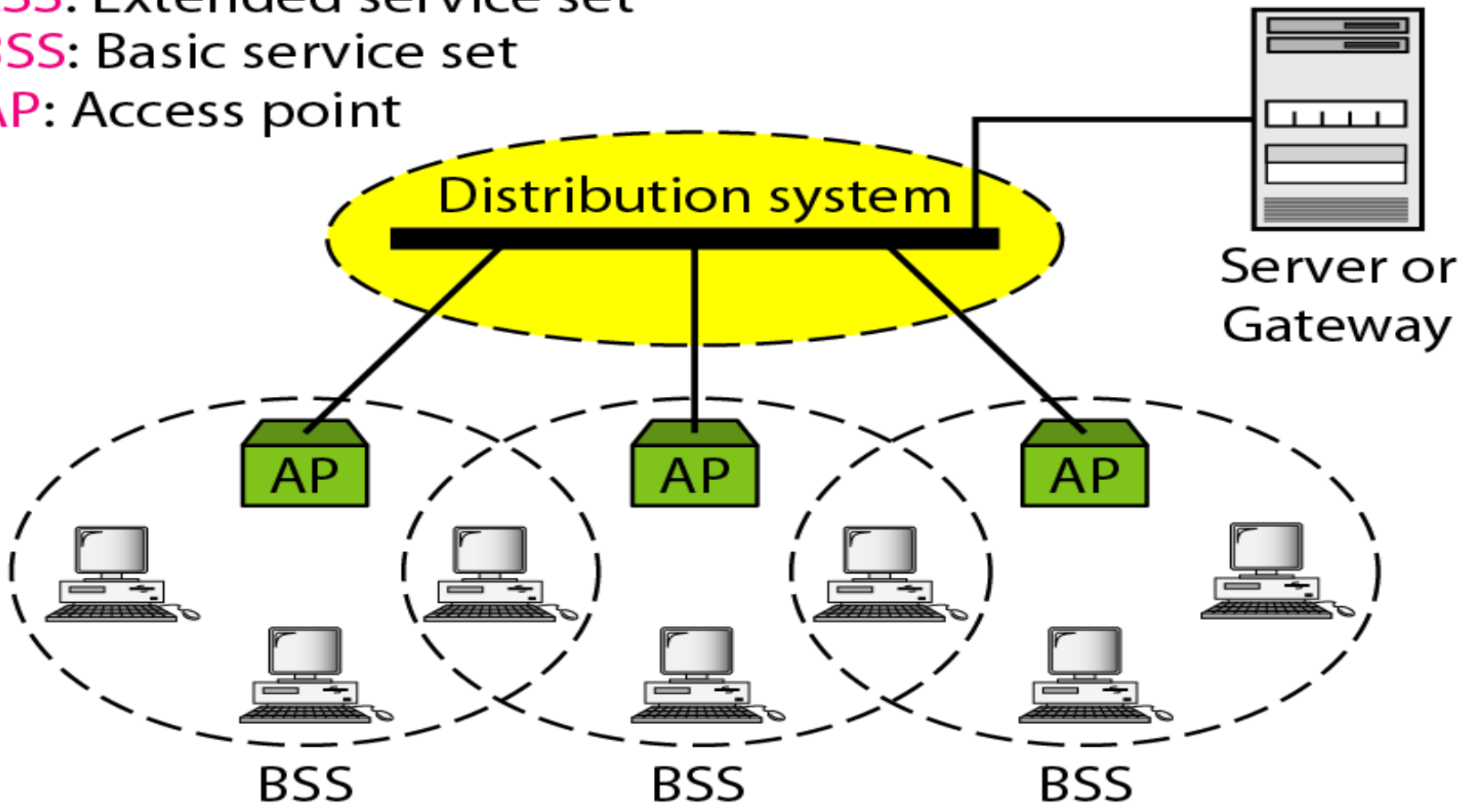
BSS: Basic service set

AP: Access point

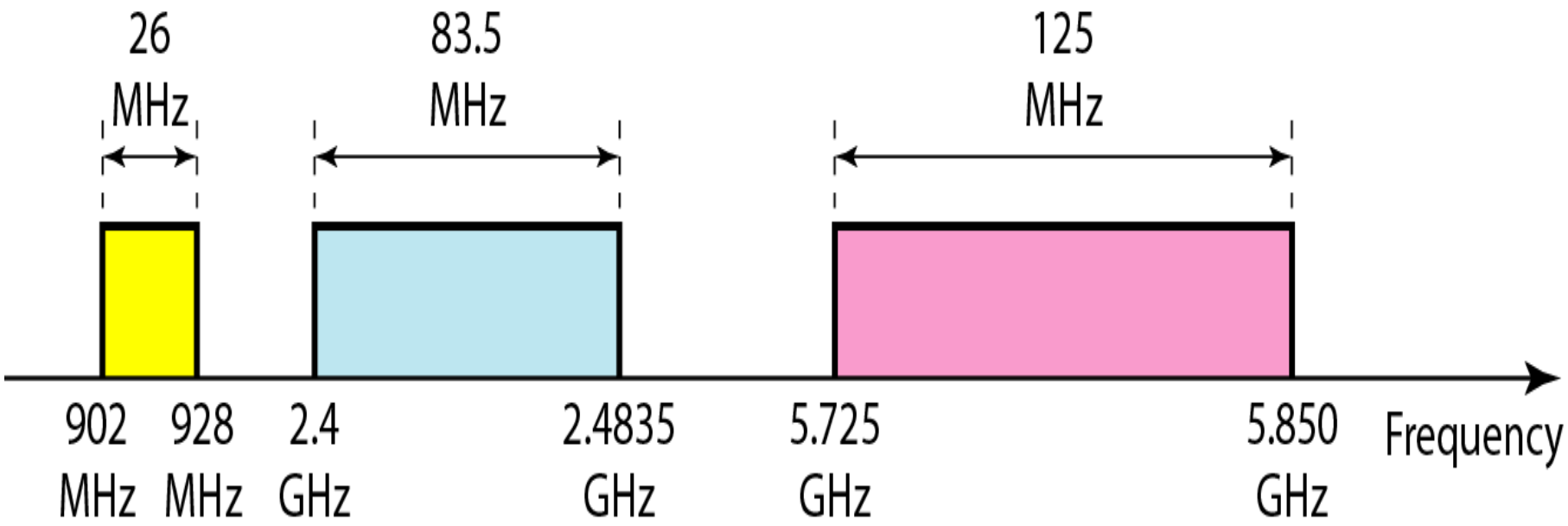


Extended Service Sets

ESS: Extended service set
BSS: Basic service set
AP: Access point



Unregulated Band (ISM)



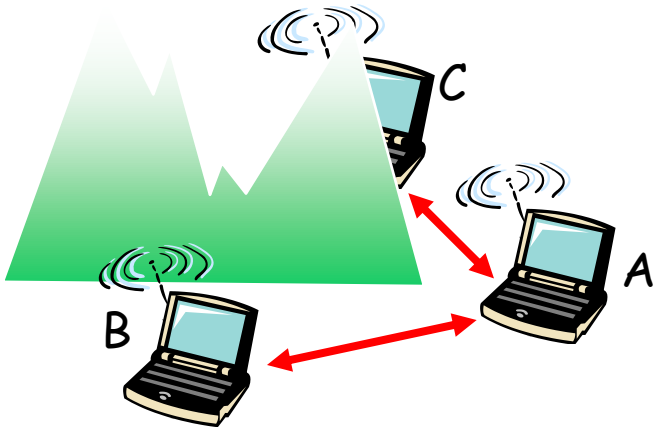
ISM: Industrial, Scientific and Medical band

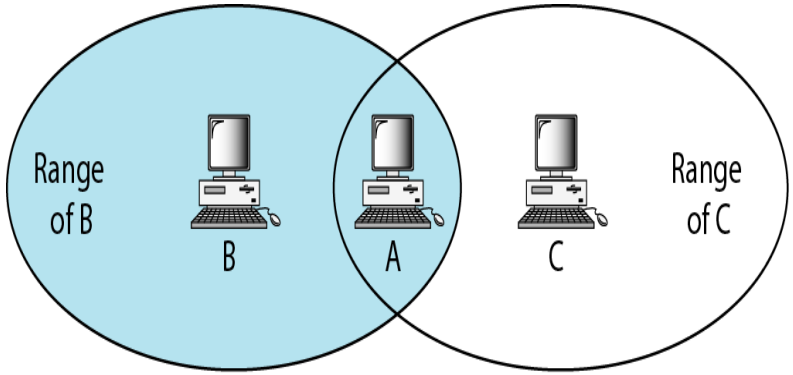
Wireless Link Characteristics

- Differences from wired link ….
  - Decreased Signal Strength: Radio signal attenuates as it propagates through matter (path loss)
  - Interference from other sources: standardized wireless network frequencies (e.g., 2.4 GHz) shared by other devices (e.g., phone); devices (motors) interfere as well
  - Multipath propagation: Radio signal reflects off objects ground, arriving ad destination at slightly different times

Hidden Terminal Problem

- Hidden terminal problem
  - B, A hear each other
  - C, A hear each other
  - B, C can not hear each other
  - Means B, C unaware of their interference at A

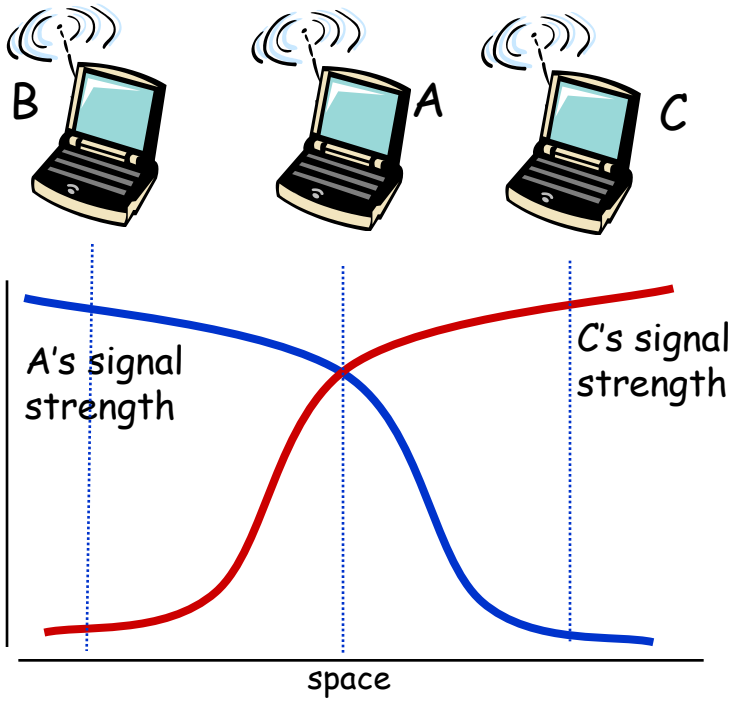




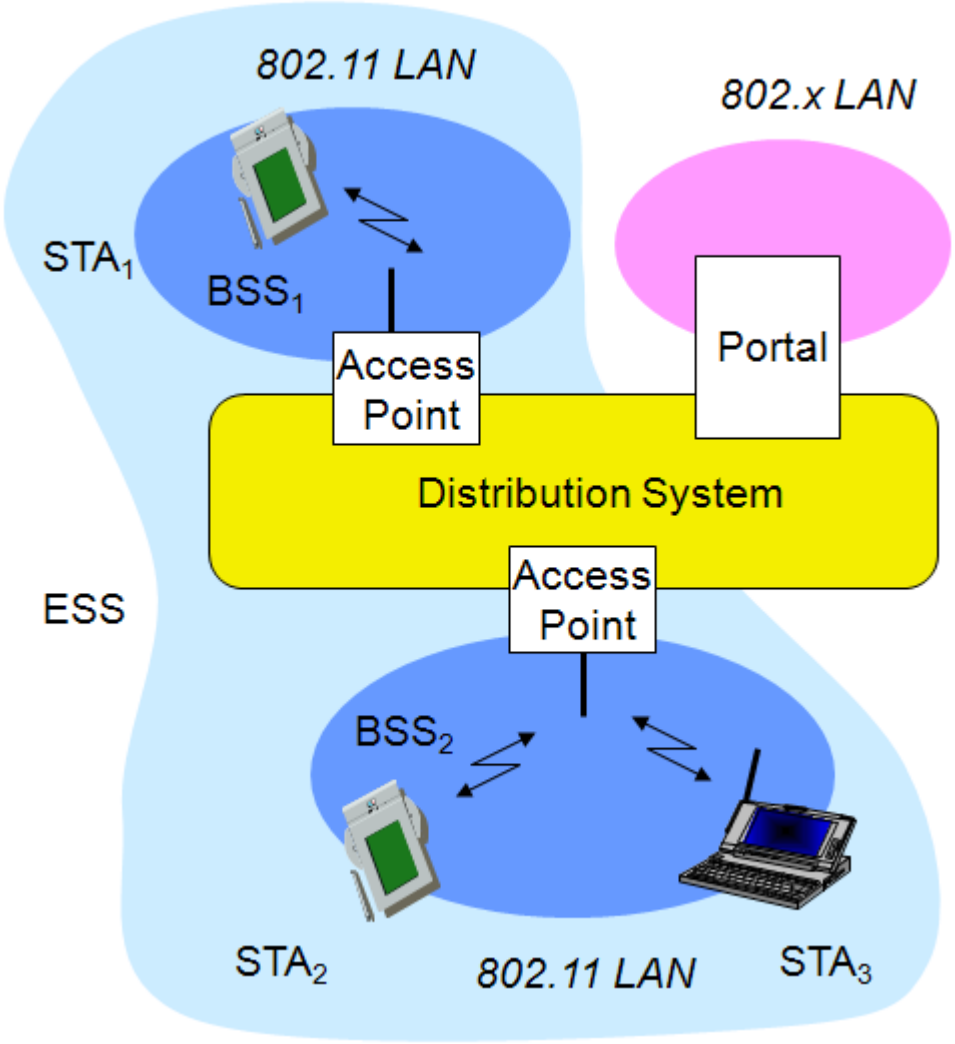
B and C are hidden from each other with respect to A.

Signal Fading

- Signal fading:
  - A, B can hear each other
  - A, C can hear each other
  - B, C can not hear each other interfering at A
  - Signal losses its strength as distance increases

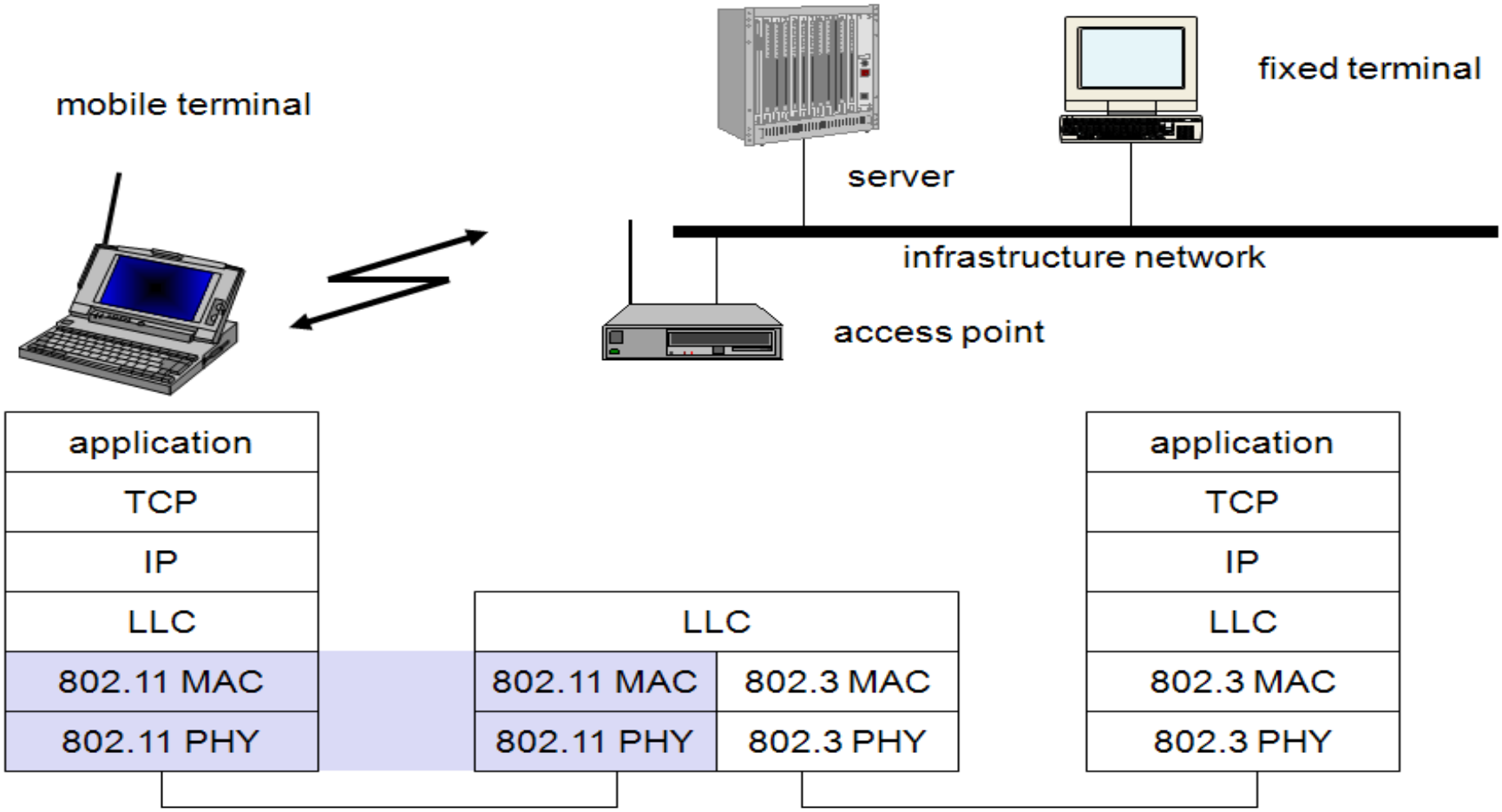


802.11 Infrastructure Network



- Station (STA)
  - terminal with access mechanisms to the wireless medium and radio contact to the access point
- Basic Service Set (BSS)
  - group of stations using the same radio frequency
- Access Point
  - station integrated into the wireless LAN and the distribution system
- Portal (Bridge/Router)
  - to other (wired) networks
- Distribution System
  - interconnection network to form one logical network (EES: Extended Service Set) based on several BSS

802.11 in the TCP/IP Stack



IEEE 802.11 Wireless LAN

802.11b

- 2.4-5 GHz unlicensed spectrum
- up to 11 Mbps
- direct sequence spread spectrum (DSSS) in physical layer
  - all hosts use same chipping code

802.11a

- 5-6 GHz range
- up to 54 Mbps

802.11g

- 2.4-5 GHz range
- up to 54 Mbps

802.11n: multiple antennae

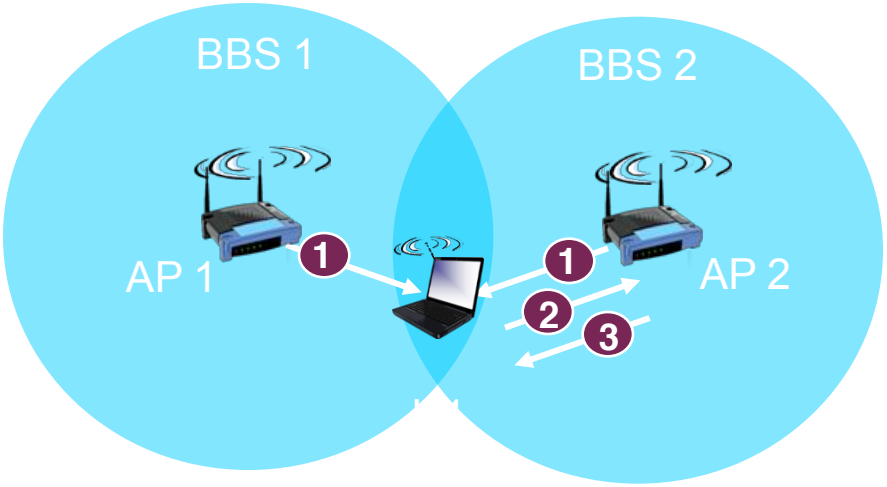
- 2.4-5 GHz range
- up to 200 Mbps

- all use CSMA/CA for multiple access
- all have base-station and ad-hoc network versions

Channel Association

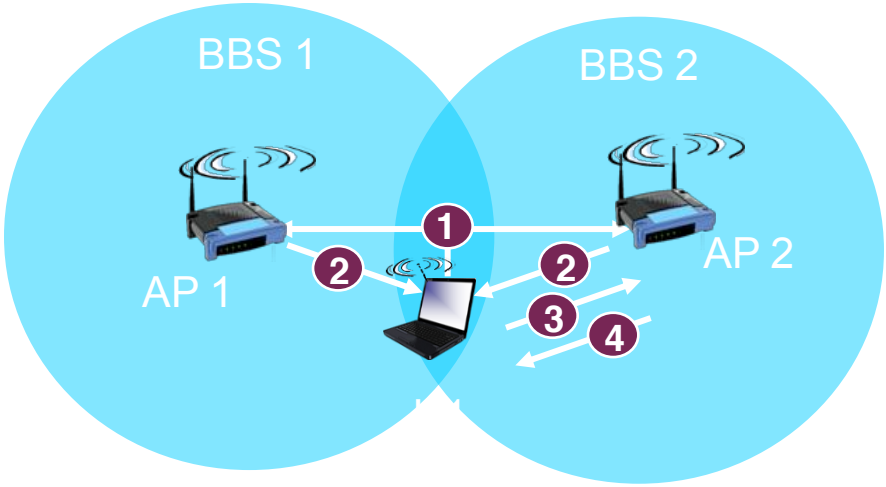
- 802.11b: 2.4GHz-2.485GHz spectrum divided into 11 channels at different frequencies
  - AP admin chooses frequency for AP
  - Interference possible: channel can be same as that chosen by neighboring AP!
- Host: must *associate* with an AP
  - Scans channels, listening for Beacon frames containing AP's name (SSID) and MAC address
  - Selects AP to associate with
  - May perform authentication
  - Run DHCP to get IP address in AP's subnet

802.11: Passive/Active scanning



passive scanning:

(1) beacon frames sent from APs
(2) association Request frame sent: H1 to selected AP
(3) association Response frame sent from selected AP to H1



active scanning:

(1) Probe Request frame broadcast from H1
(2) Probe Response frames sent from APs
(3) Association Request frame sent: H1 to selected AP
(4) Association Response frame sent from selected AP to H1

IEEE802.11 MAC Protocol

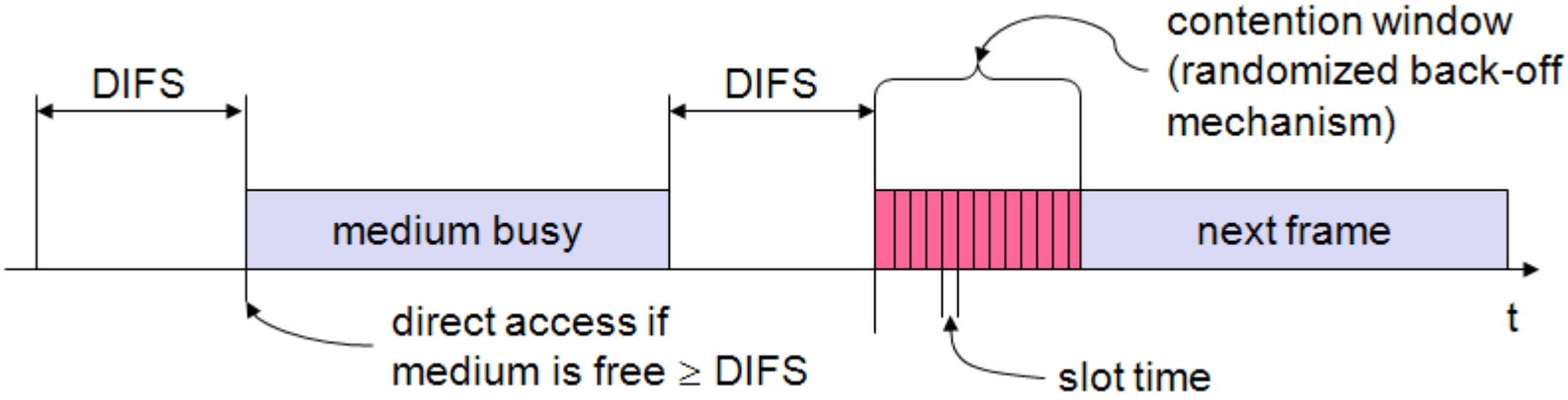
- Avoid collisions: 2+ nodes transmitting at same time
- 802.11: CSMA - sense before transmitting
  - Don't collide with other transmissions
- 802.11: No collision detection!
  - Difficult to receive (sense collisions) when transmitting due to weak received signals (fading)
  - Can't sense all collisions in any case: hidden terminal, fading
  - Goal: avoid collisions: CSMA/C(ollision)A(voidance)

802.11 MAC Procedures

- Traffic services
  - Asynchronous Data Service (mandatory) – DCF
  - Time-Bounded Service (optional) - PCF
- Access methods
  - DCF CSMA/CA (mandatory)
    - collision avoidance via randomized back-off mechanism
    - ACKs for data frames (not for broadcasts)
  - DCF w/ RTS/CTS (optional)
    - avoids hidden terminal problem
  - PCF (optional)
    - access point polls terminals according to a list

Distributed Coordination Function

DCF: CSMA/CA



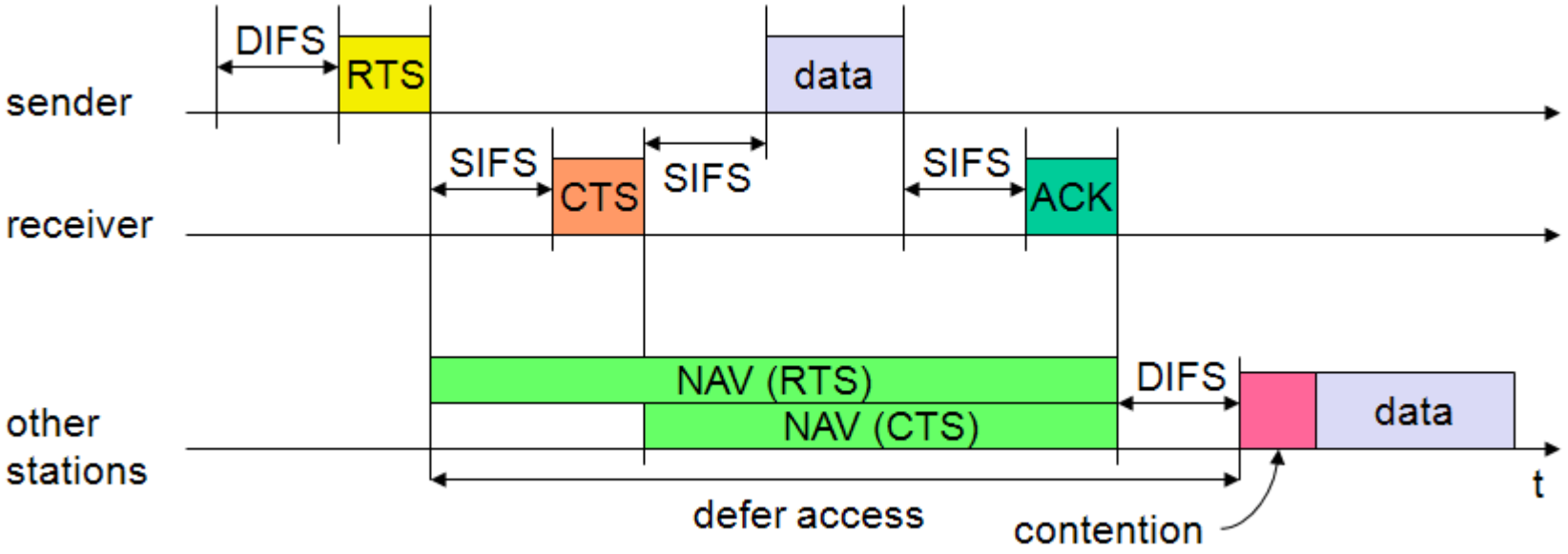
- station ready to send starts sensing the medium (Carrier Sense based on CCA, Clear Channel Assessment)
- if the medium is free for the duration of an Inter-Frame Space (IFS), the station can start sending (IFS depends on service type)
- if the medium is busy, the station has to wait for a free IFS, then the station must additionally wait a random back-off time (collision avoidance, multiple of slot-time)
- if another station occupies the medium during the back-off time of the station, the back-off timer stops (fairness)

Avoiding Collisions

- Idea: allow sender to "reserve" channel rather than random access of data frames: avoid collisions of long data frames
- Sender first transmits small request-to-send (RTS) frames to BS using CSMA
  - RTSs may still collide with each other (but they're short)
- BS broadcasts clear-to-send CTS in response to RTS
- CTS heard by all nodes
  - Sender transmits data frame
  - Other stations defer transmissions

avoid data frame collisions completely using small reservation packets!

DCF w/RTS & CTS



- Station send RTS with reservation parameter (amount of time the data frame needs the medium) after waiting for DIFS
- Acknowledgement via CTS after SIFS by receiver (if ready to receive)
- Sender can now send data at once, acknowledgement via ACK
- Other stations store medium reservations distributed via RTS and CTS

Collision Avoidance using RTS/CTS

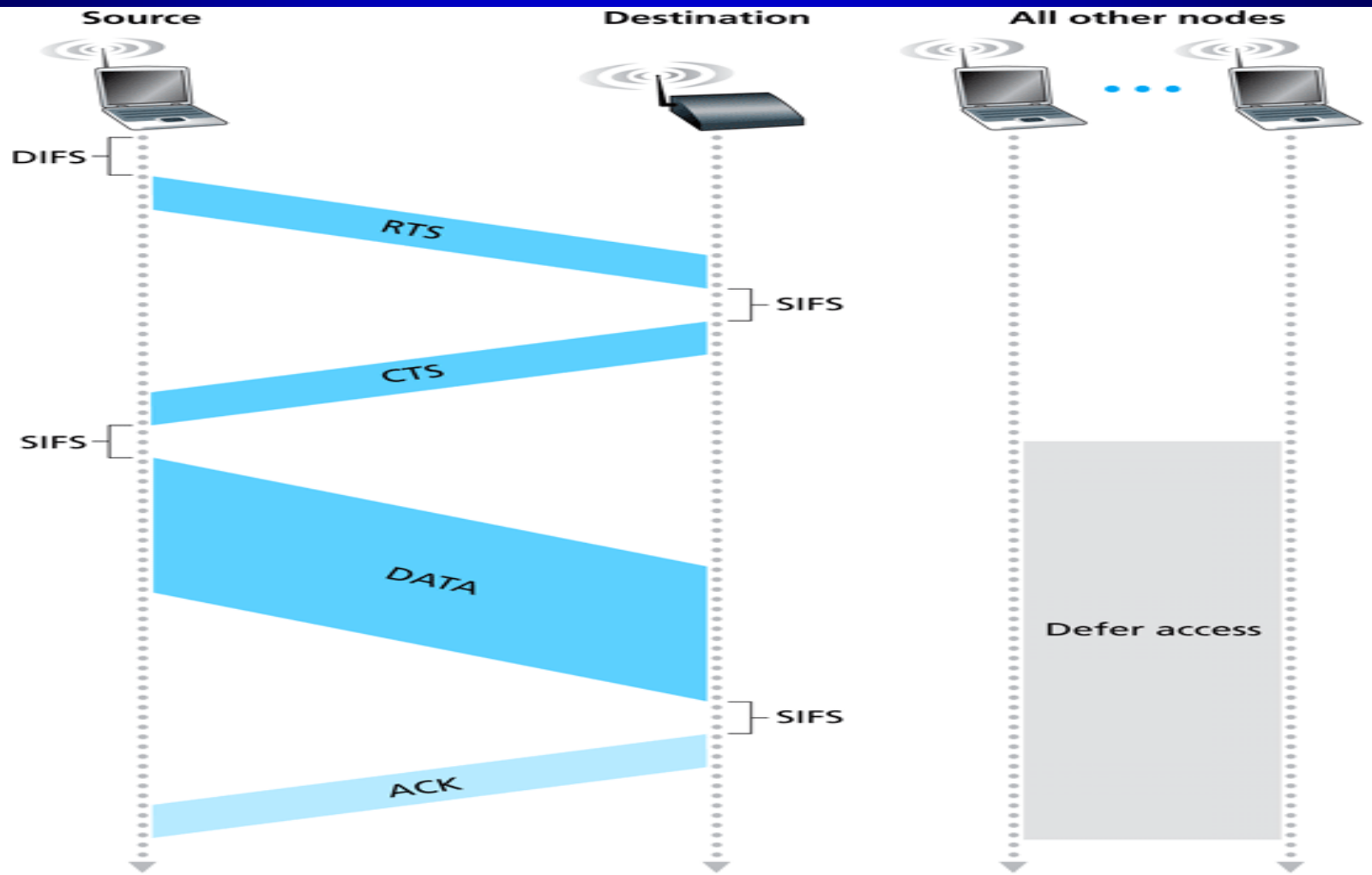
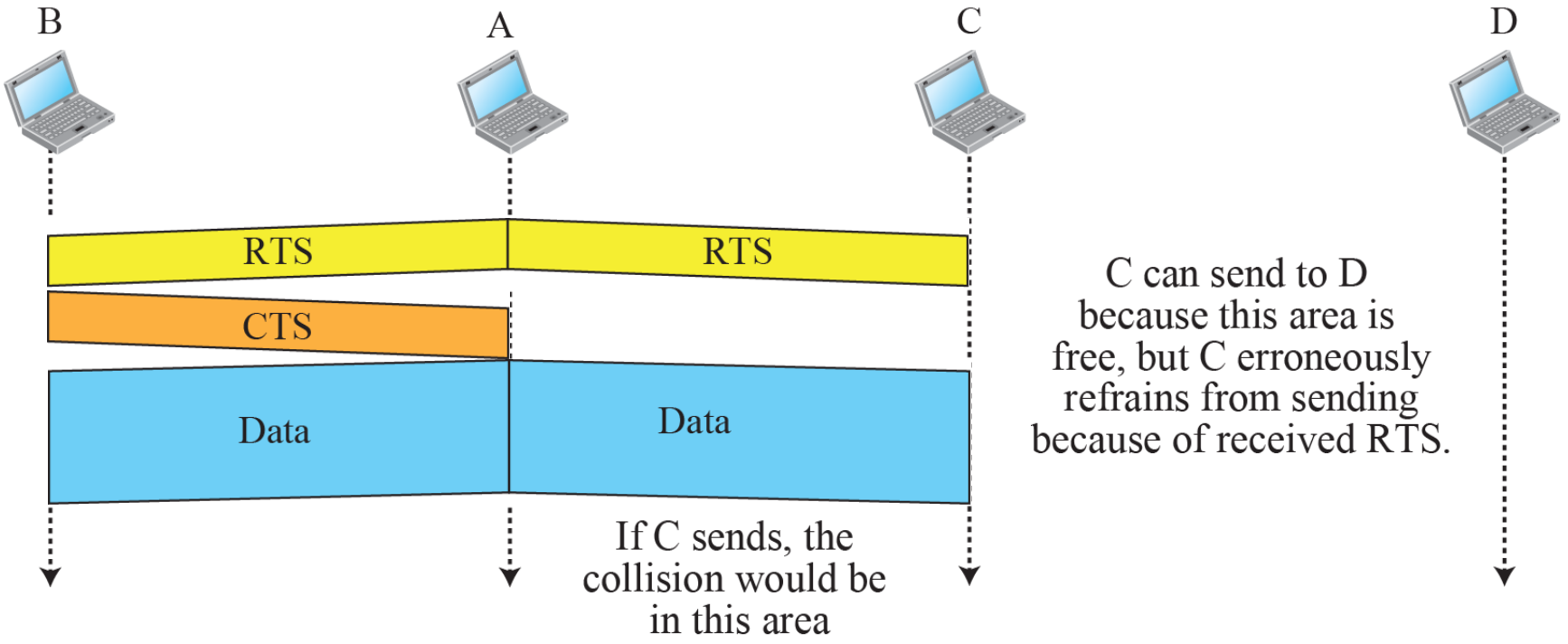
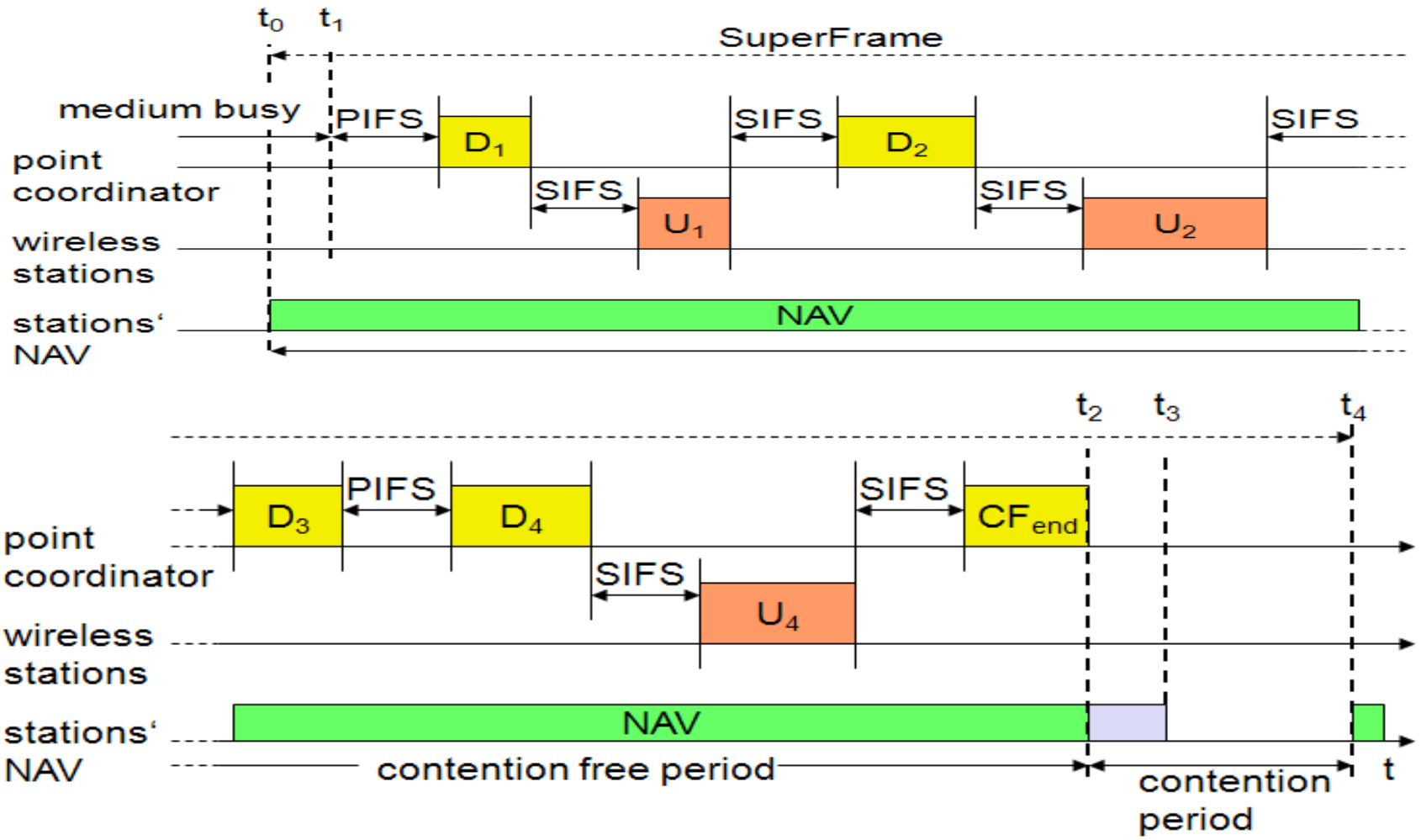


Figure 6.12 ◆ Collision avoidance using the RTS and CTS frames

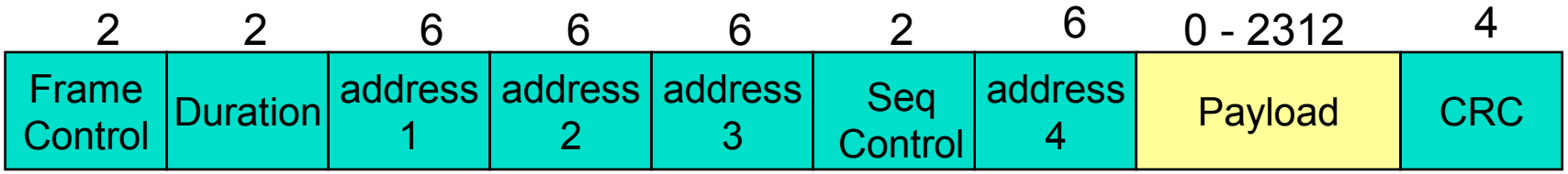
Exposed Terminal Problem



802.11 PCF (Point Coordination Function)



IEEE802.11 Frame Structure



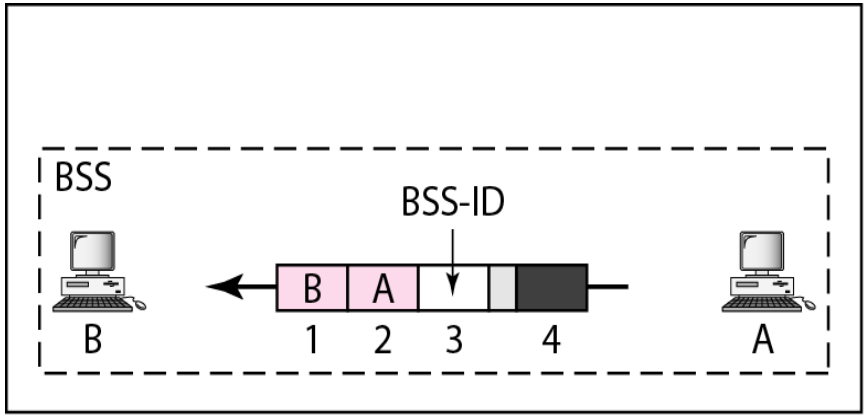
Address 1: MAC address of wireless host or AP to receive this frame

Address 2: MAC address of wireless host or AP transmitting this frame

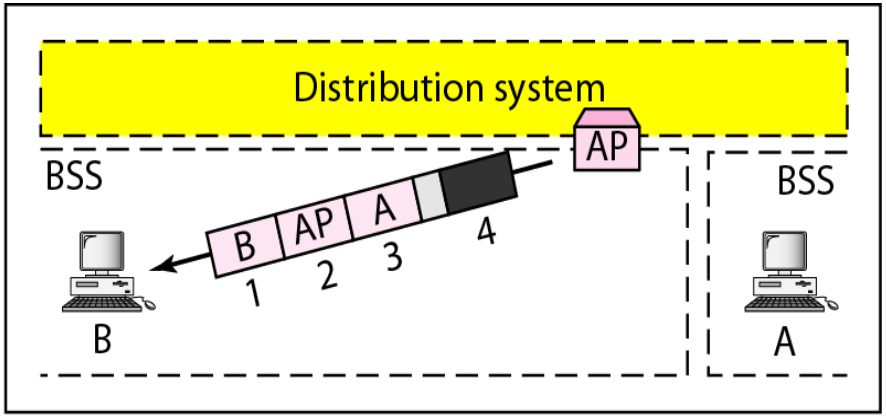
Address 3: MAC address of router interface to which AP is attached

Address 4: used only in ad hoc mode

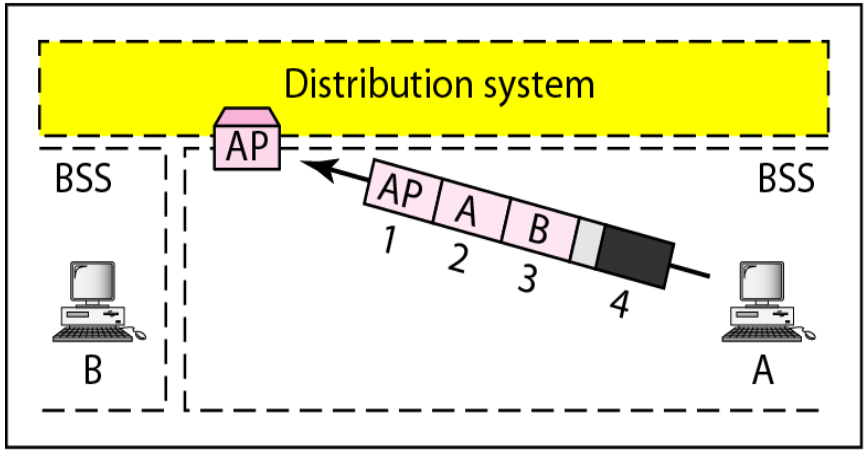
Addressing Mechanisms



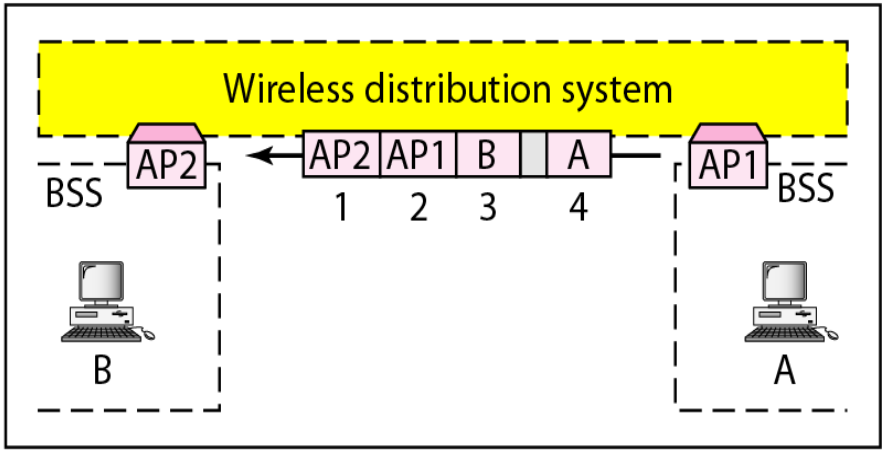
a. Case 1



b. Case 2



c. Case 3



d. Case 4

IEEE802.11 Frame Addressing