Medium Access Control

EE450: Introduction to Computer Networks

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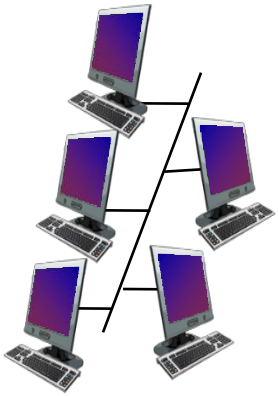
Medium Access Control

- 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

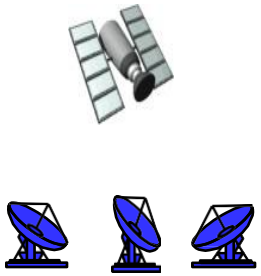
- Distributed algorithm that determines how nodes share channel, i.e., determine when node can transmit
- Communication about channel sharing must use channel itself!

Multiple Access Links



shared wire (e.g., cabled Ethernet)

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

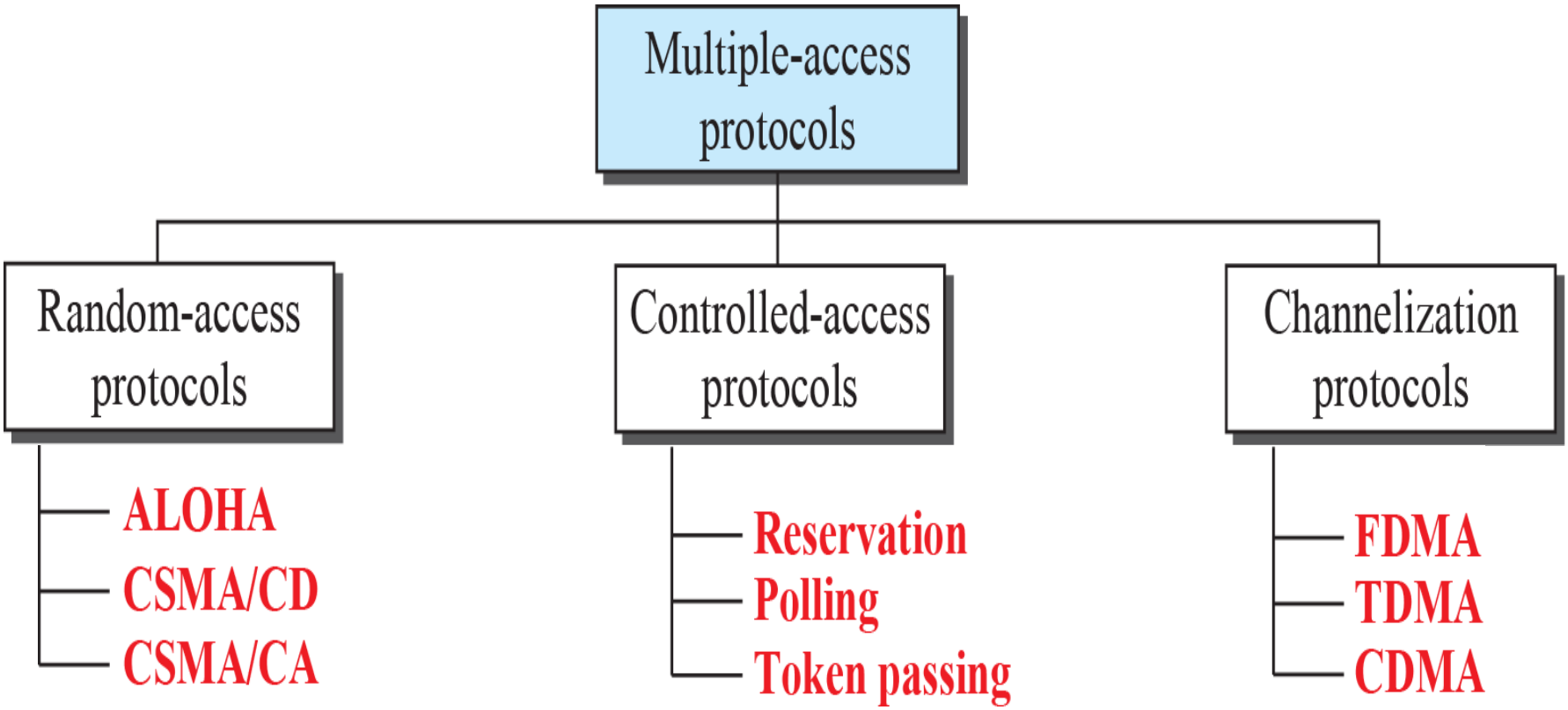


shared RF (satellite)

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



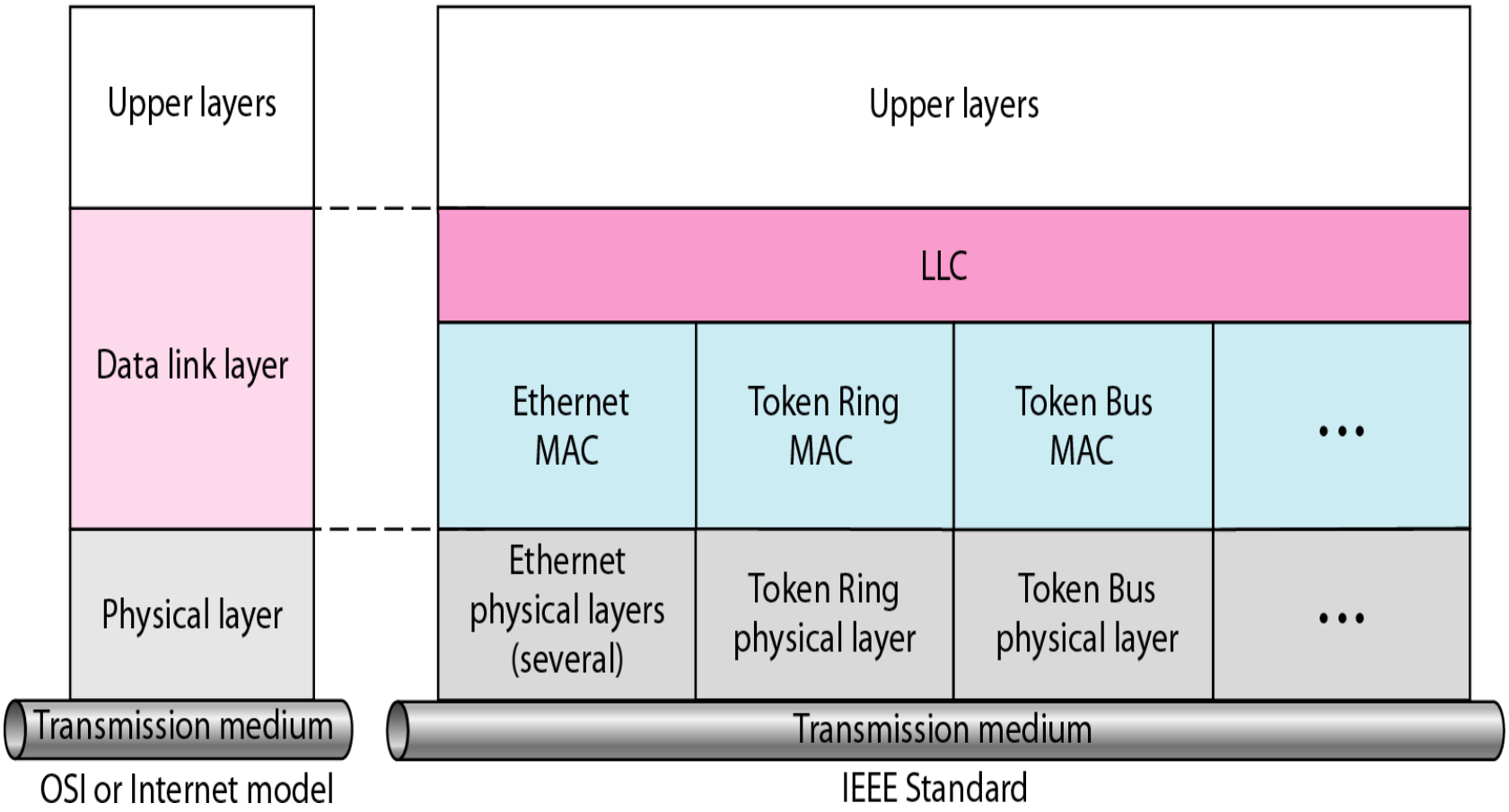
Classifications of MAC Protocols

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

IEEE802 Standards for LANs

LLC: Logical link control
MAC: Media access control



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

CSMA/CD Algorithm

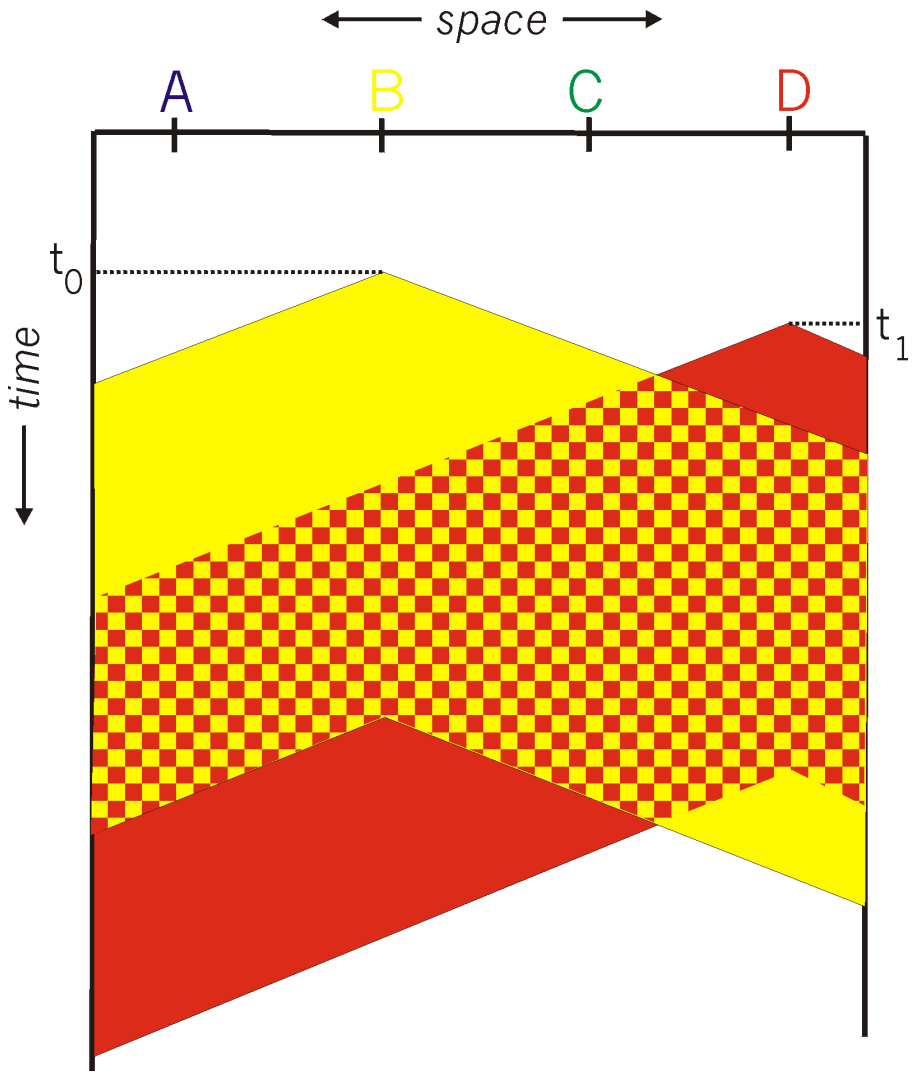
1. NIC receives Packet from network layer, creates frame
2. If NIC senses channel idle, starts frame transmission. If NIC senses channel busy, waits until channel idle, then transmits.
3. If NIC transmits entire frame without detecting another transmission, NIC is done with frame !

➢ No Collisions

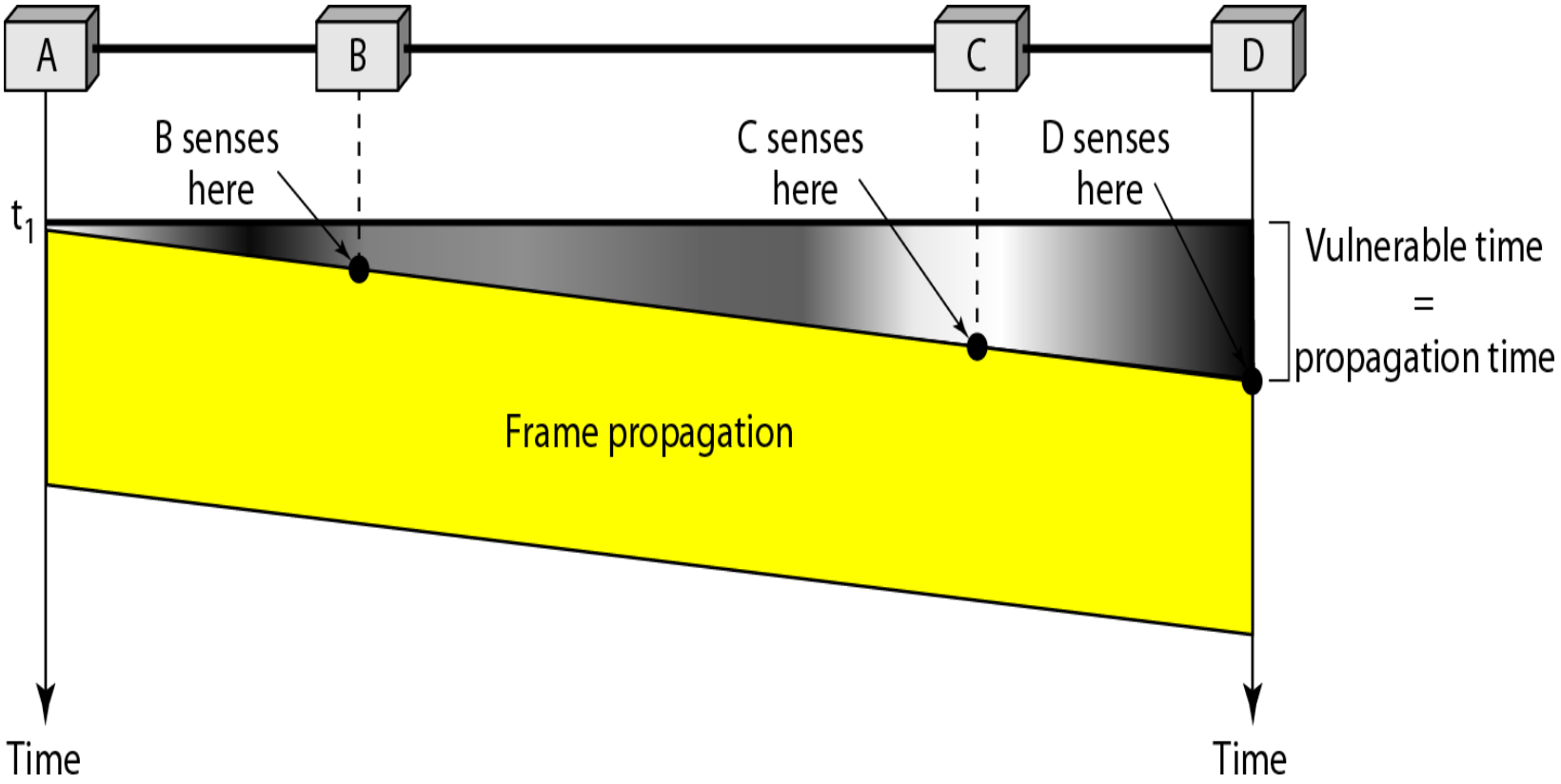
4. If NIC detects another transmission while transmitting, aborts and sends jam signal
5. After aborting, NIC enters *Binary (Exponential) Backoff:*
   - after *m*th collision, NIC chooses *K* at random from $\{0,1,2,\ldots,2^m-1\}$. NIC waits $K \cdot 512$ bit times, returns to Step 2
   - longer backoff interval with more collisions

Collisions in CSMA/CD

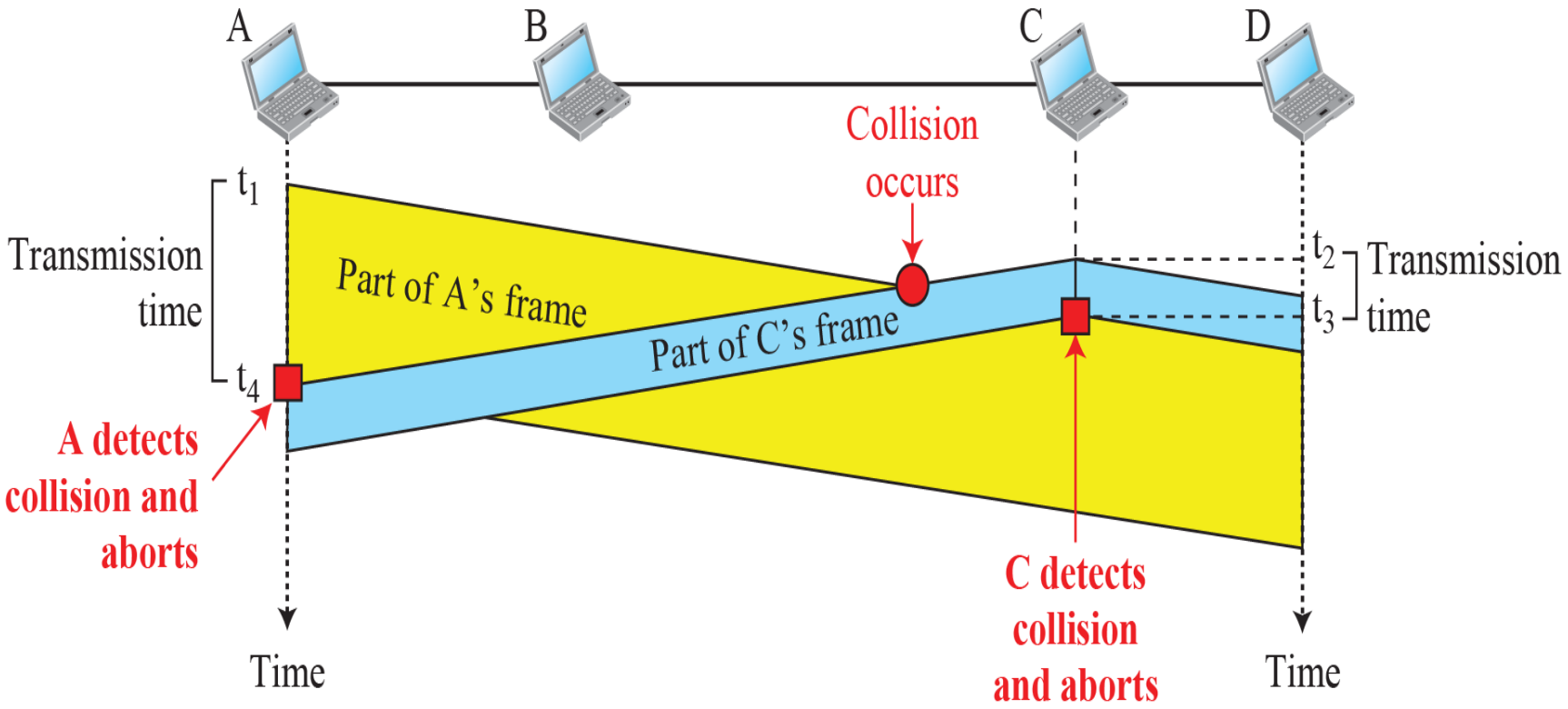
- Collisions can still occur: propagation delay means two nodes may not hear each other's transmission
- When collision occur, entire frame is wasted
- Collision is detected by comparing transmitted and received signal strengths (Hard to do in WLANs, TBD)



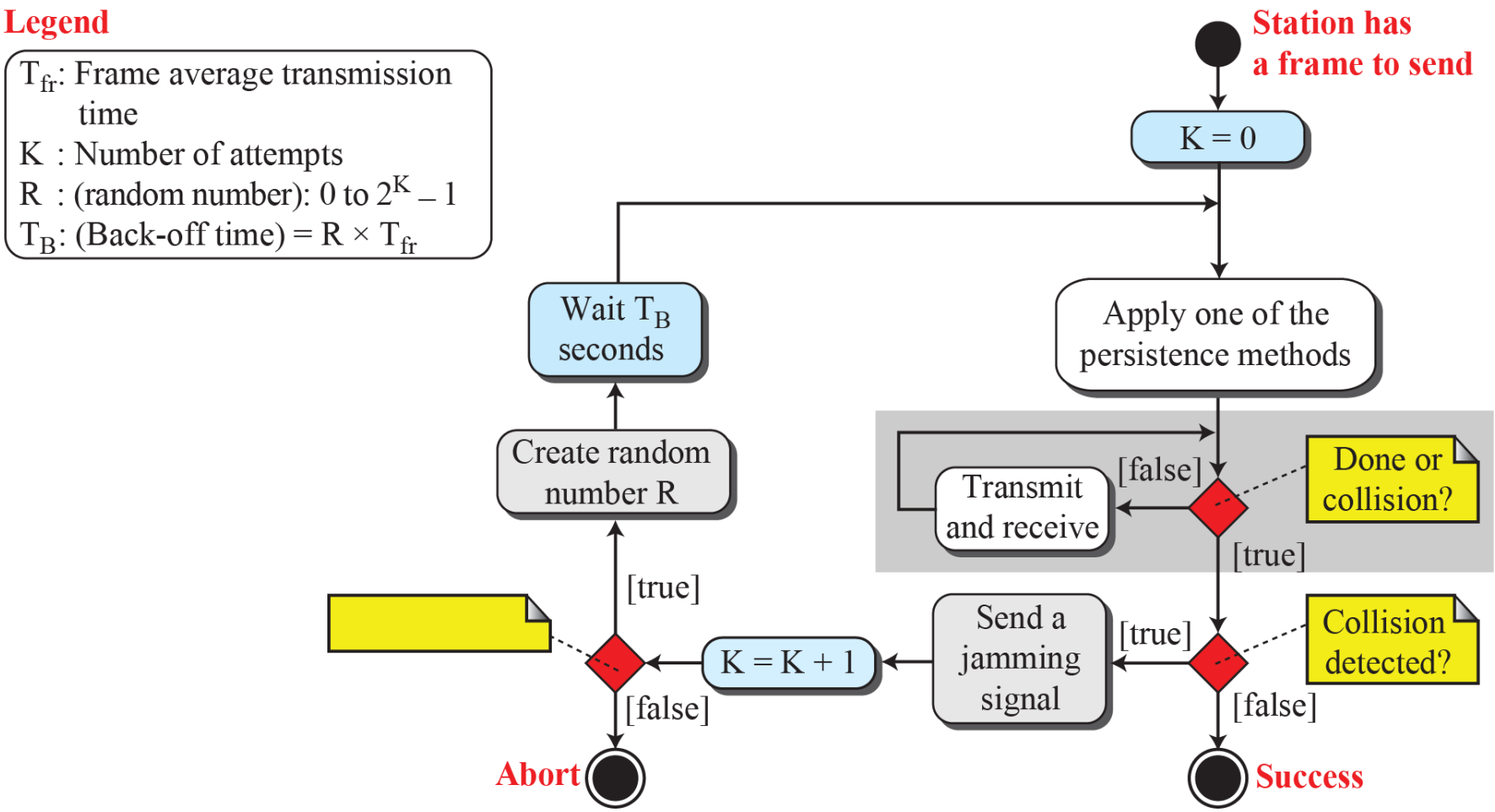
Vulnerable Time in CSMA



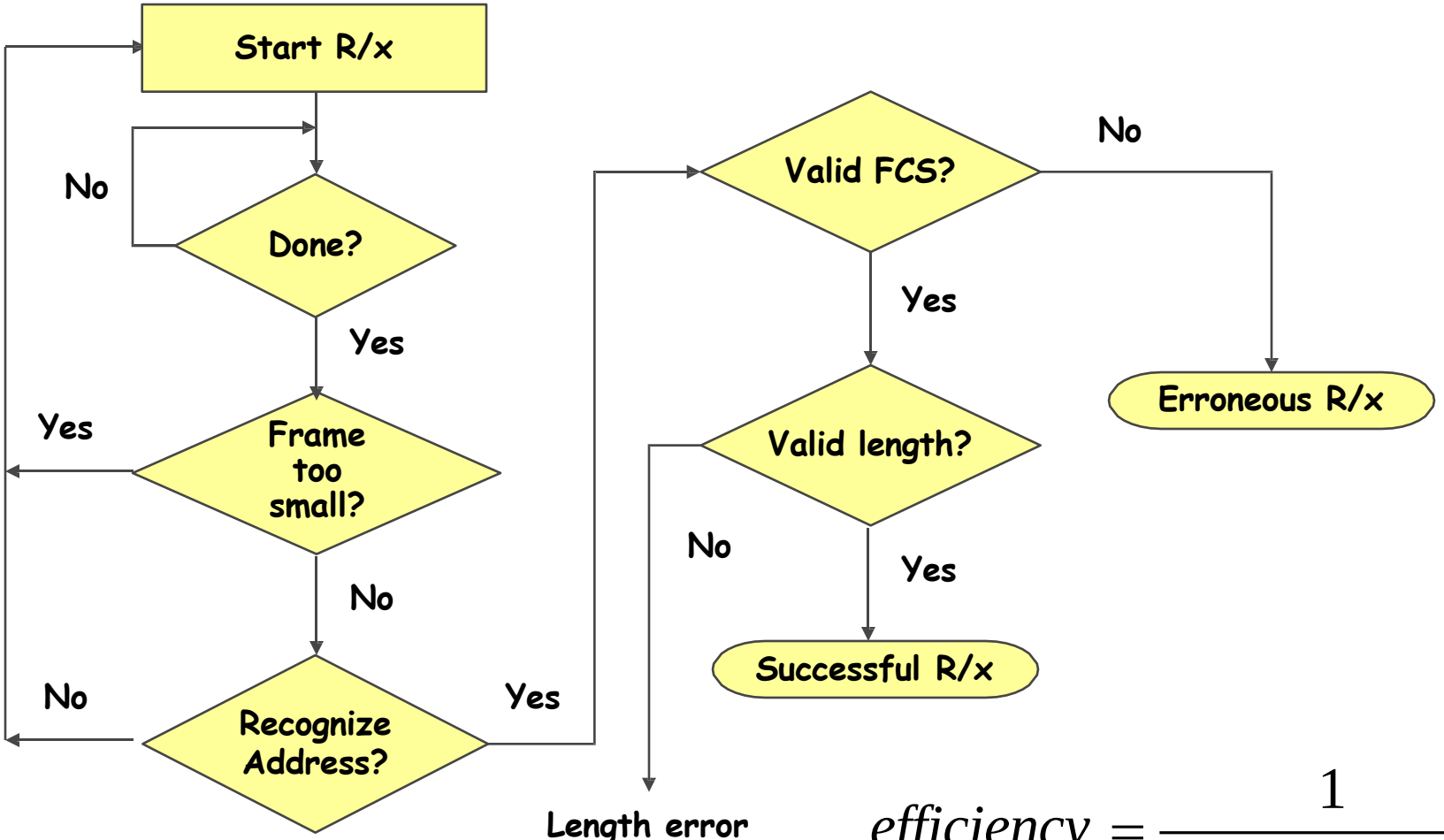
Collision Detection



Flow Chart of CSMA/CD



Receive Process in IEEE802.3



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

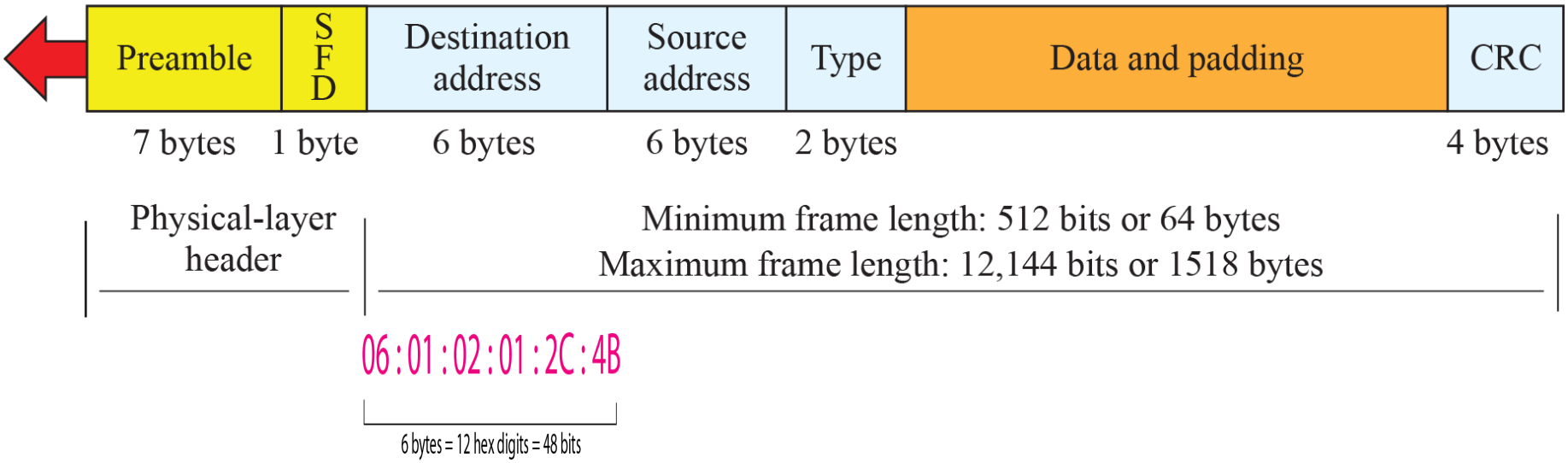
IEEE802.3 MAC Frame

Sending adapter encapsulates IP Packet in Ethernet frame

Minimum payload length: 46 bytes
Maximum payload length: 1500 bytes

Preamble: 56 bits of alternating 1s and 0s

SFD: Start frame delimiter, flag (10101011)

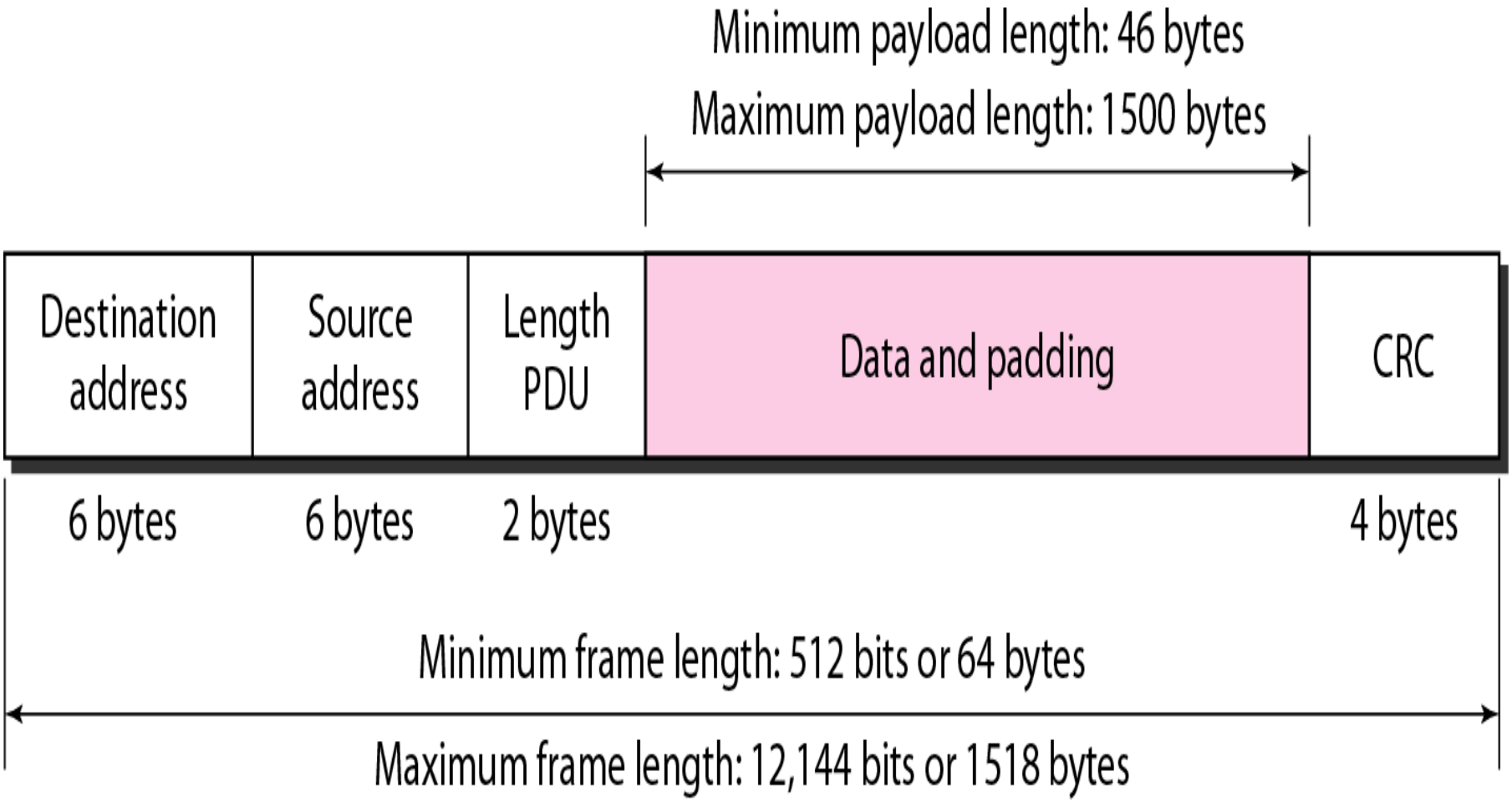


MAC address is burned in NIC ROM

Type: Indicate Network Layer Protocol (mostly IP)

A NIC card will process a frame if it recognizes its MAC address or Broadcast Address, Otherwise discards the frame

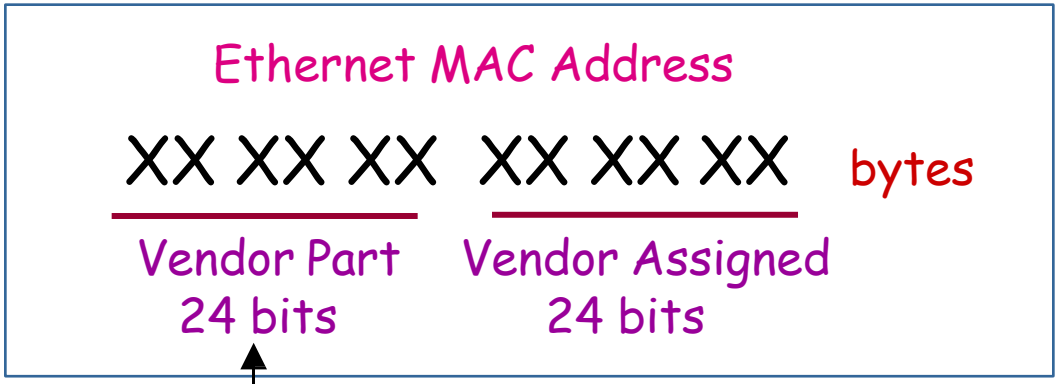
IEEE802.3 Frame Length Limits



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



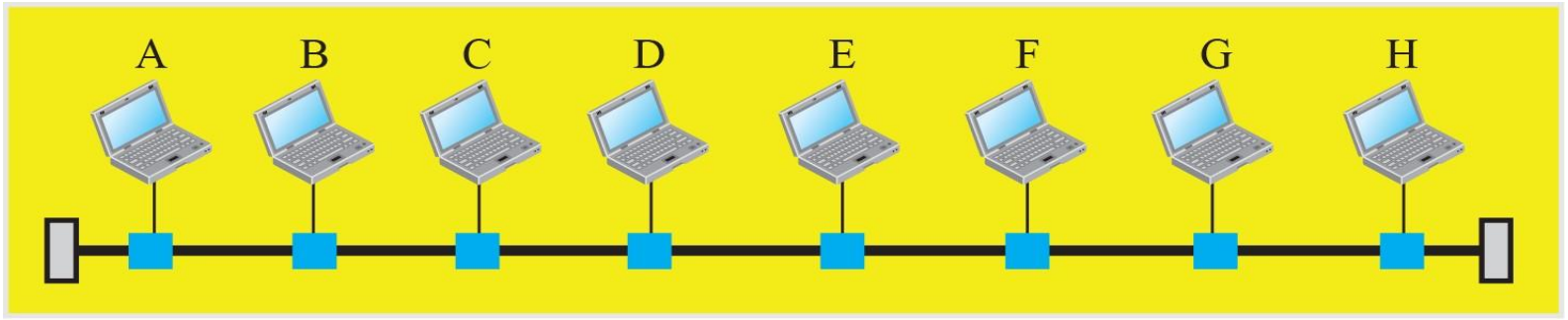
IEEE Organizationally Unique Identifier (OUI)
- allows vendor to build hardware with unique addresses

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

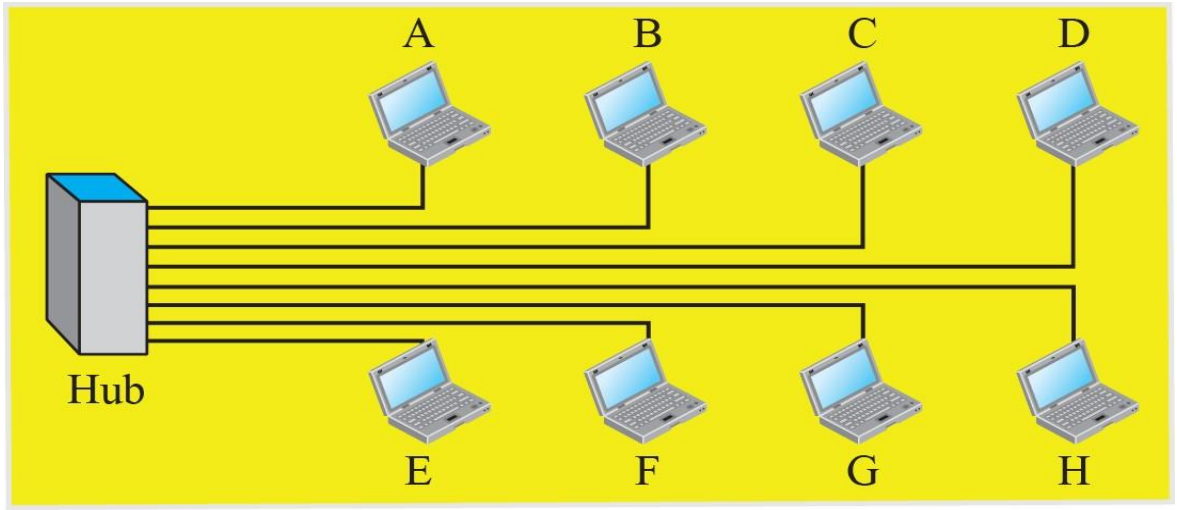
Types of MAC Addresses

- 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.

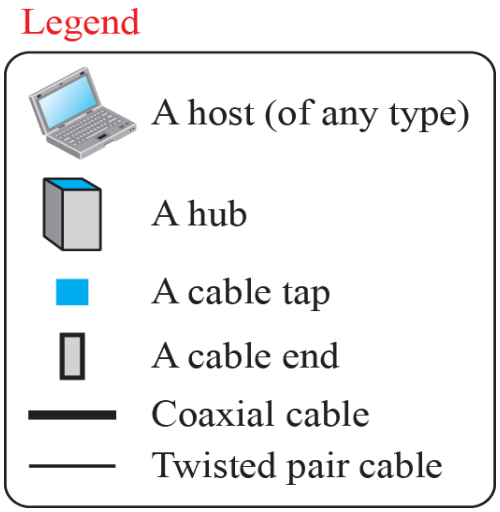
Shared Ethernet Implementations



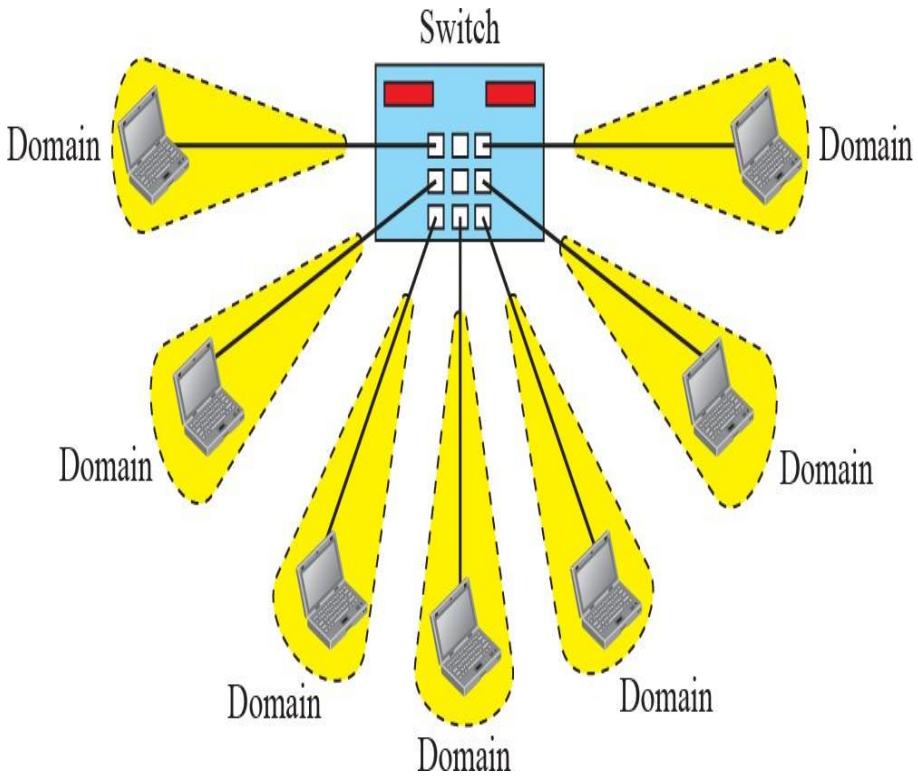
a. A LAN with a bus topology using a coaxial cable



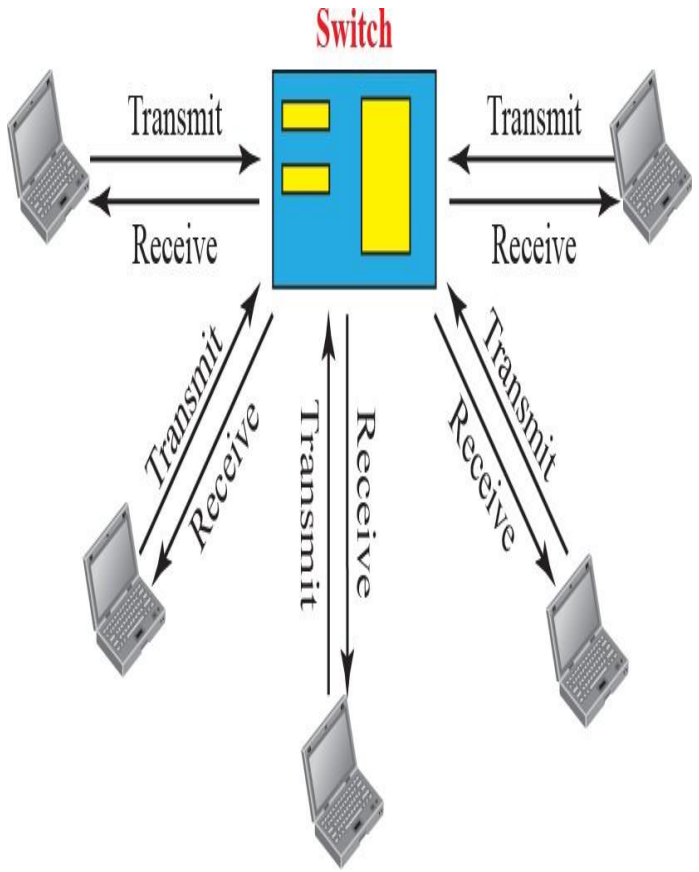
b. A LAN with a star topology using a hub



Switched Ethernet



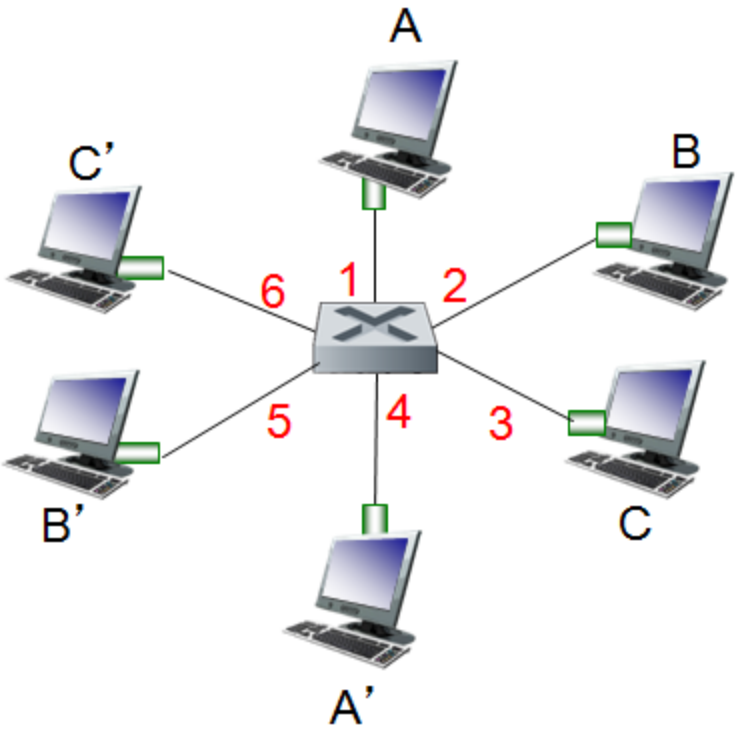
No Collisions



Support FDX

Ethernet Switch

- link-layer device: takes an *active* role
  - store, forward Ethernet frames
  - examine incoming frame's MAC address, selectively forward frame to one-or-more outgoing links when frame is to be forwarded on segment
- *transparent*
  - hosts are unaware of presence of switches
- *plug-and-play, self-learning*
  - switches do not need to be configured
- switch *learns* which hosts can be reached through which interfaces
  - when frame received, switch "learns" location of sender: incoming LAN segment
  - records sender/location pair in switch table

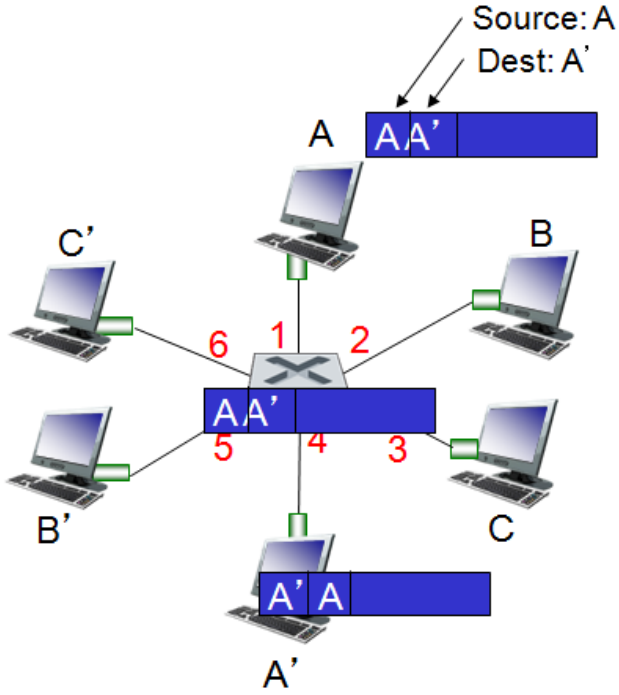


switch with six interfaces (1,2,3,4,5,6)

Filtering/Forwarding/Flooding

when frame received at switch:

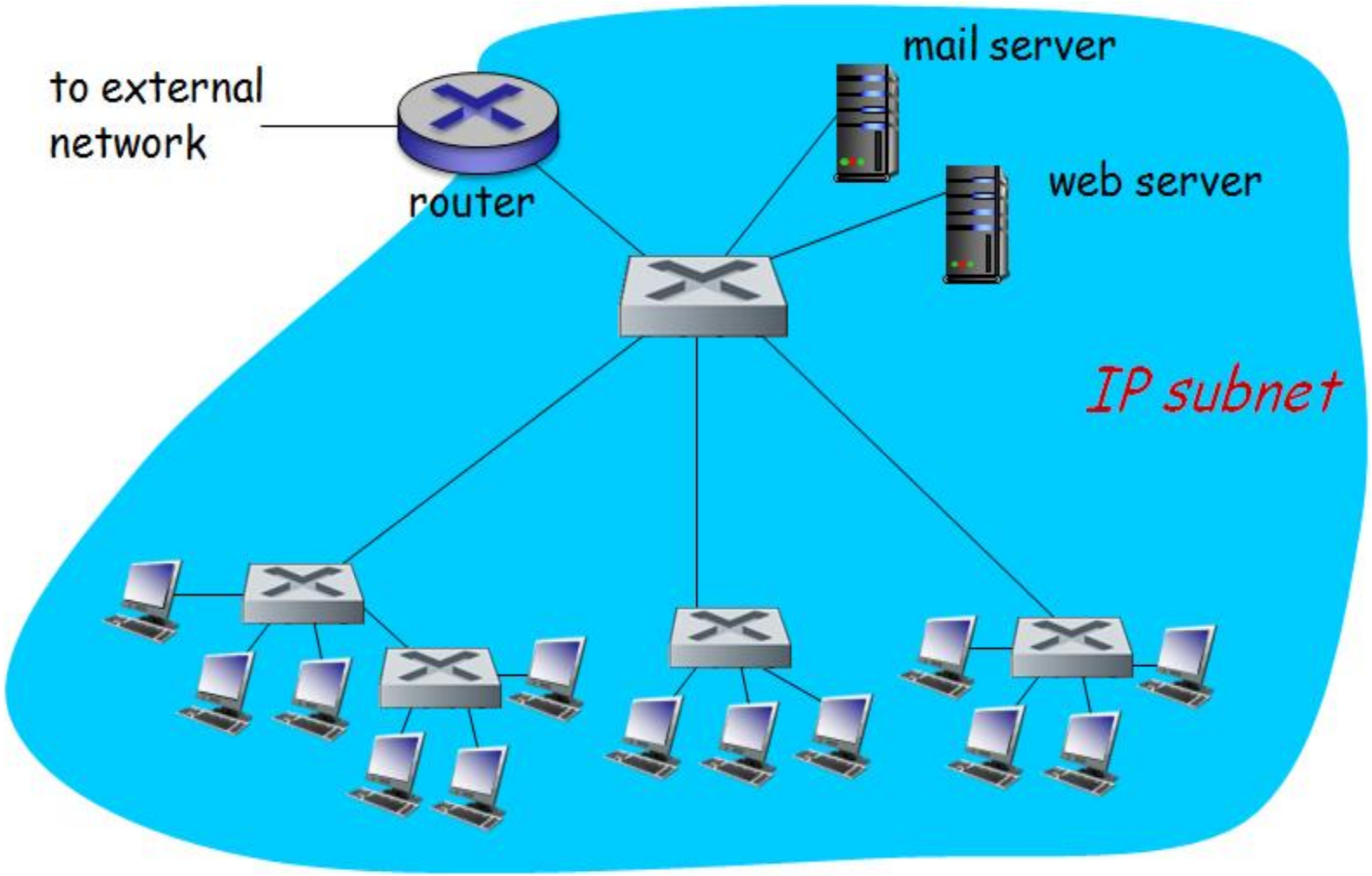
1. record incoming link, MAC address of sending host
2. index switch table using MAC destination address
3. if entry found for destination
   then {
   if destination on segment from which frame arrived
   then drop frame
   else forward frame on interface indicated by entry
   }
   else flood /* forward on all interfaces except arriving interface */



MAC addr	interface	TTL
A	1	60
A'	4	60

switch table (initially empty)

Institutional Network

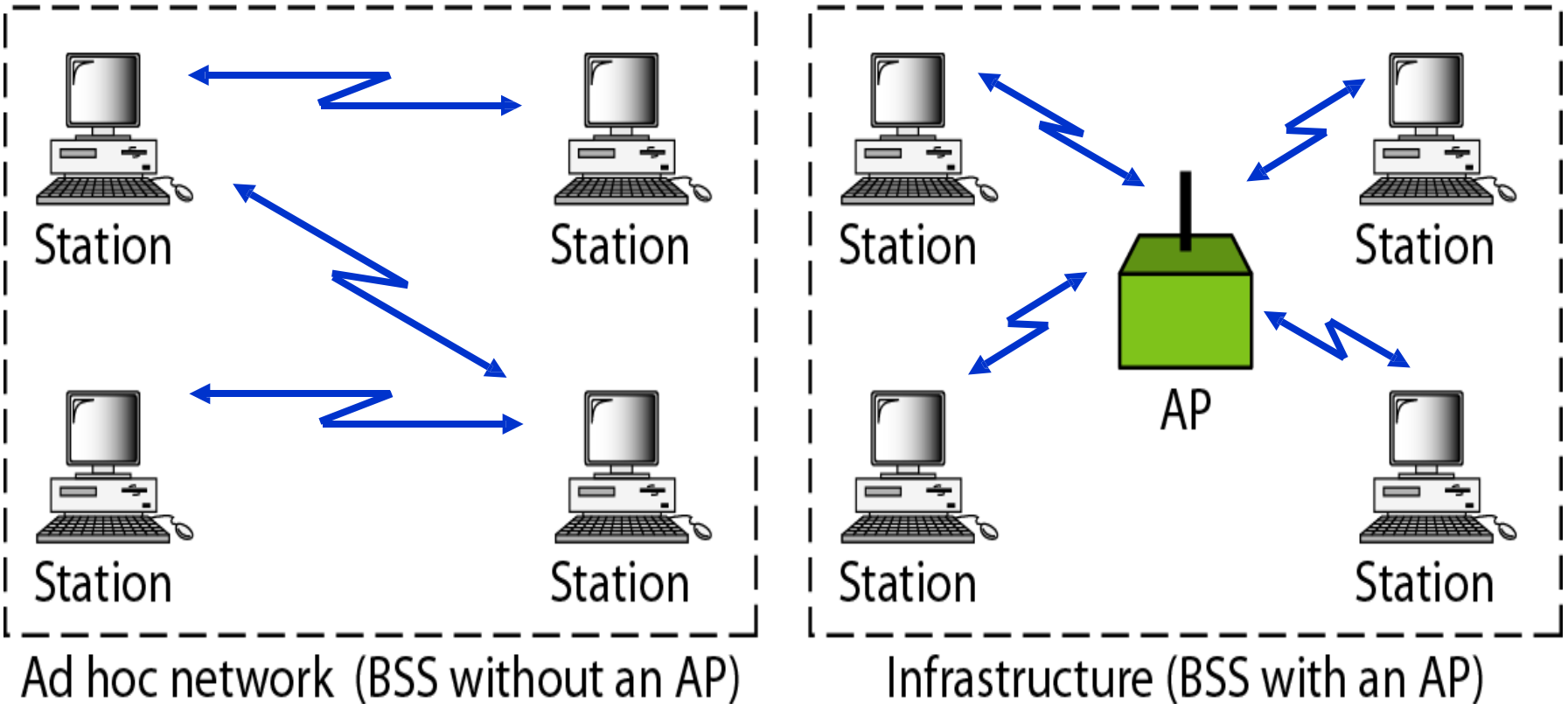


IEEE 802.11
Wireless LANs (Wi-Fi)

Ad-hoc vs. Infrastructure WLANs

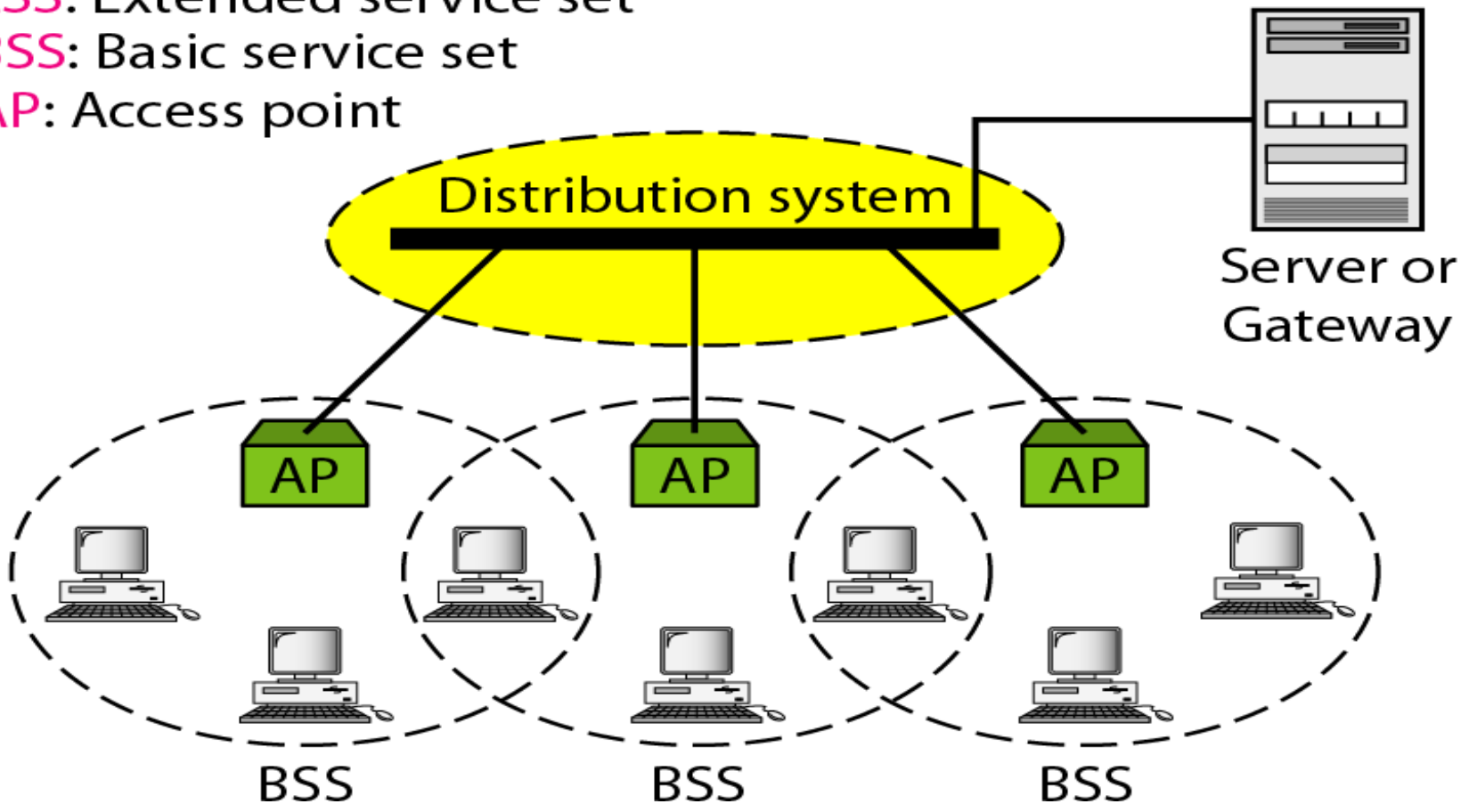
BSS: Basic service set

AP: Access point

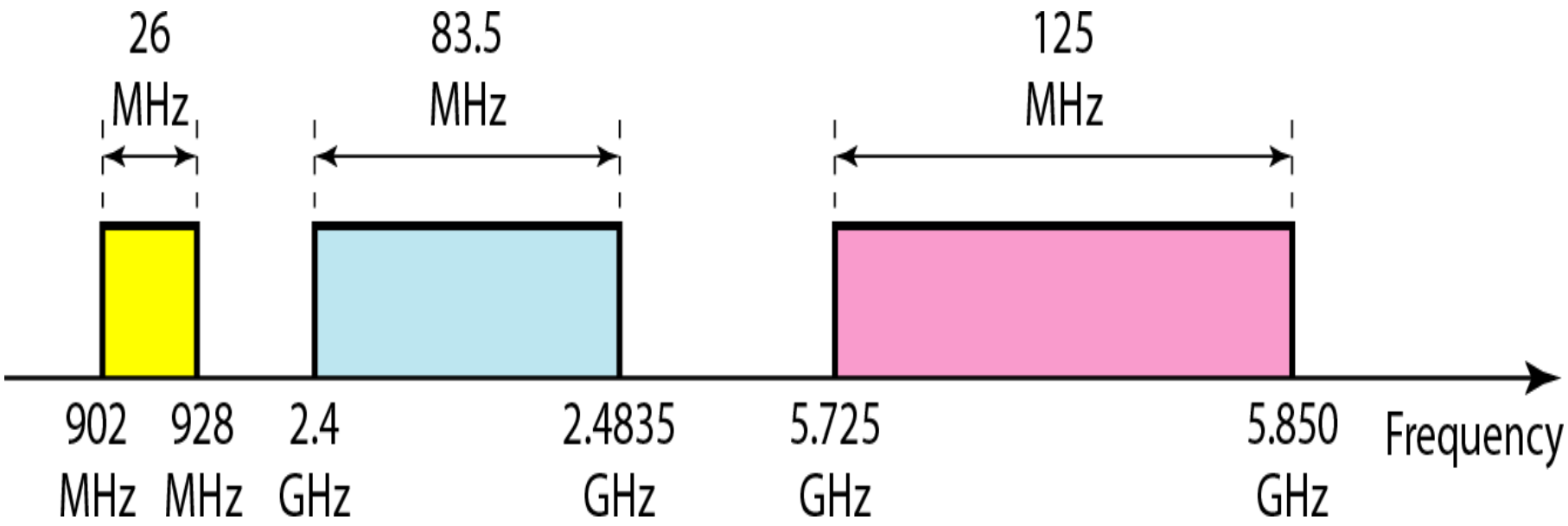


Extended Service Sets

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



Unregulated Band (ISM)



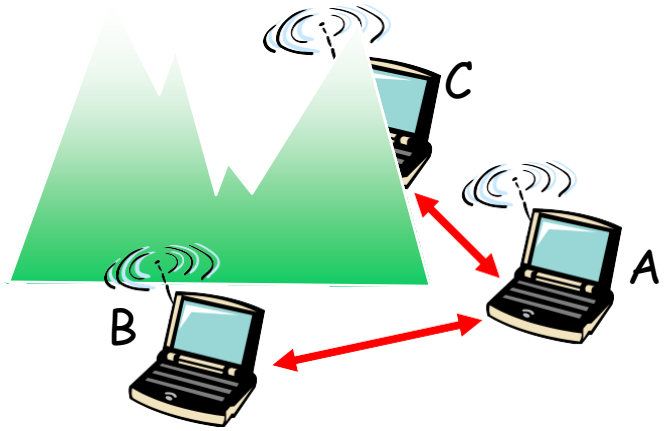
ISM: Industrial, Scientific and Medical band

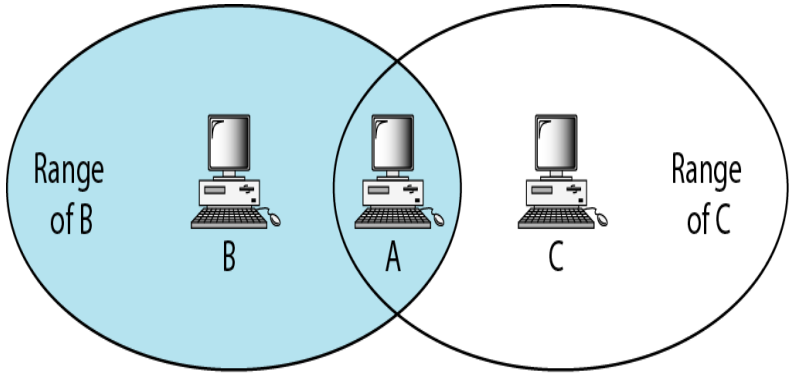
Wireless Link Characteristics

- 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

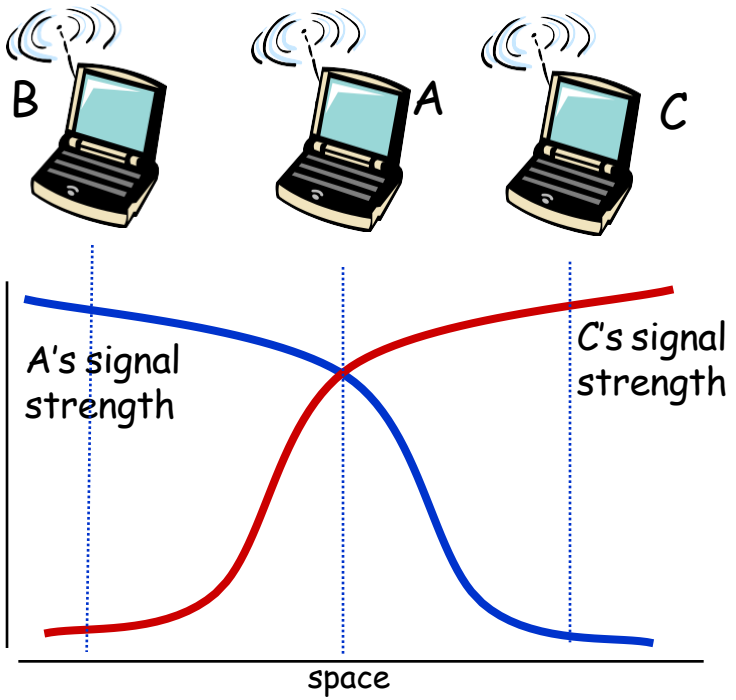




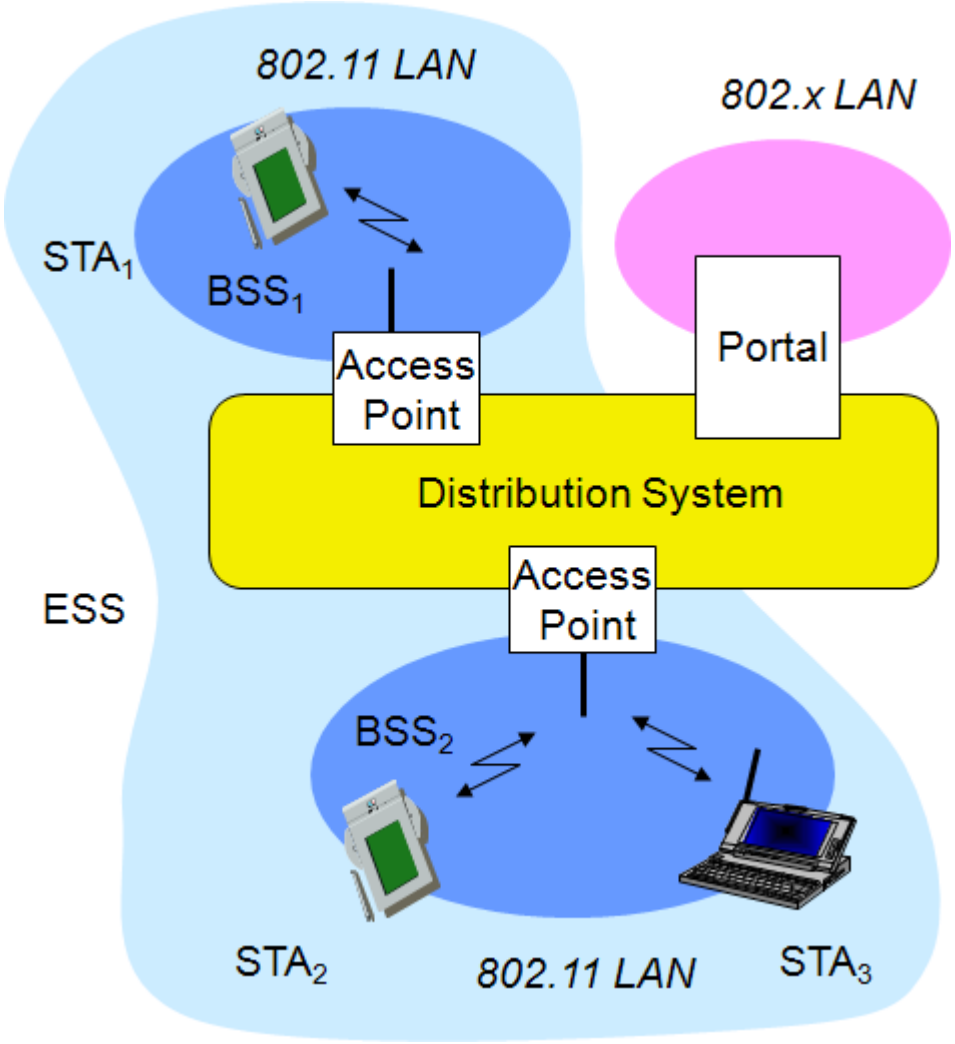
B and C are hidden from each other with respect to A.

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

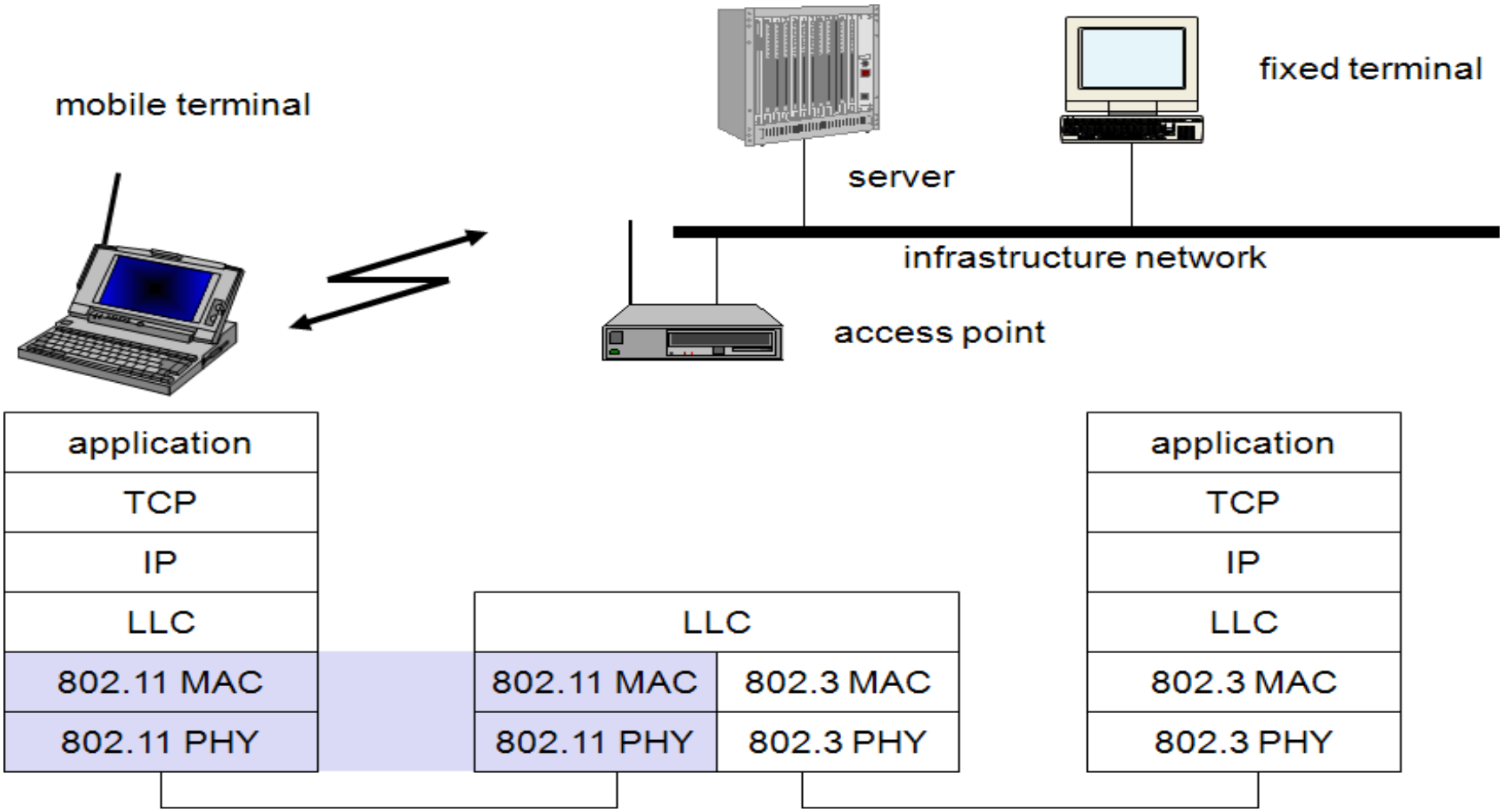


802.11 Infrastructure Network



- 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

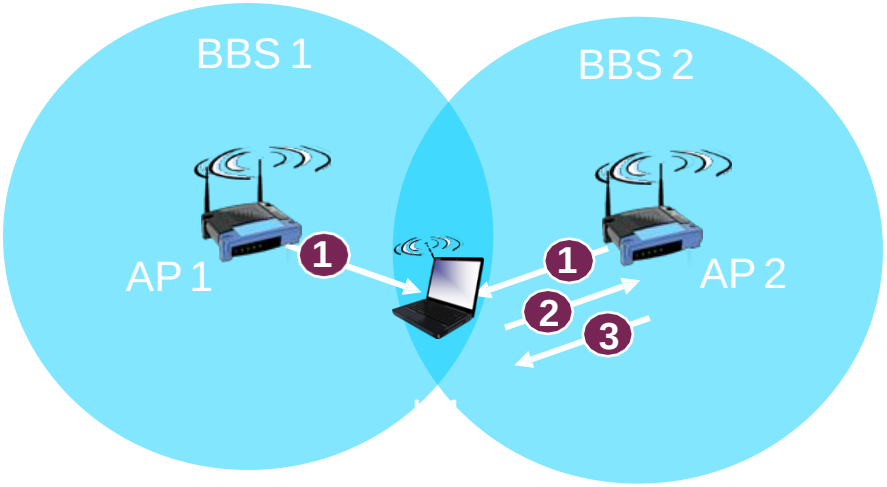
802.11 in the TCP/IP Stack

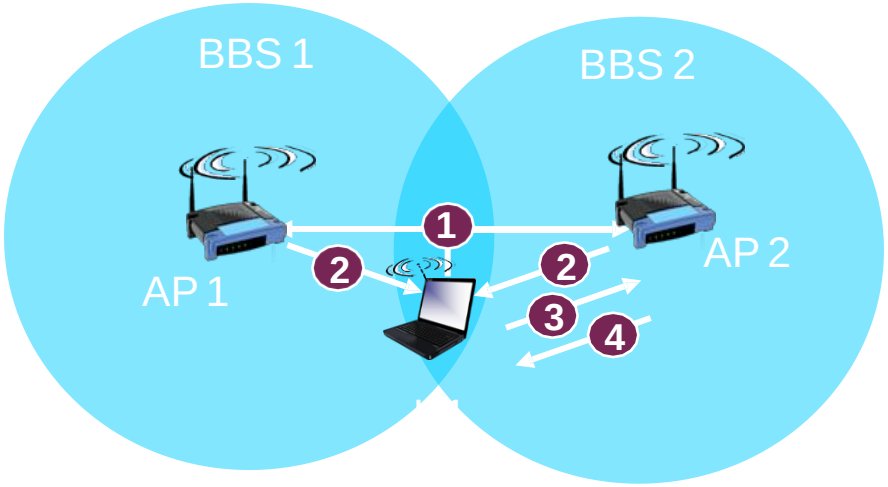


Channel Association

- 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

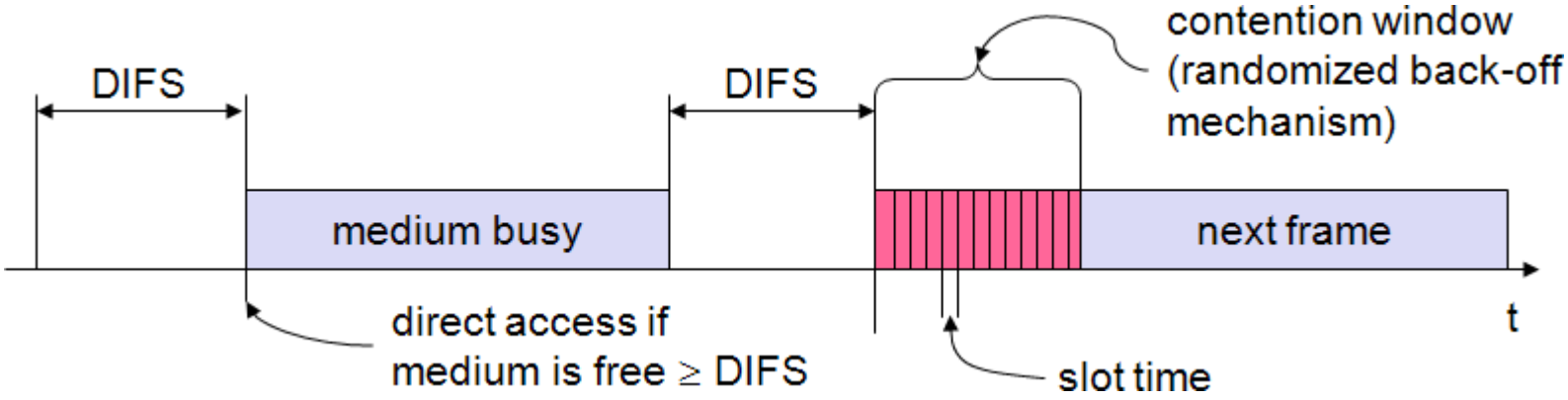
IEEE802.11 MAC Protocol

- 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

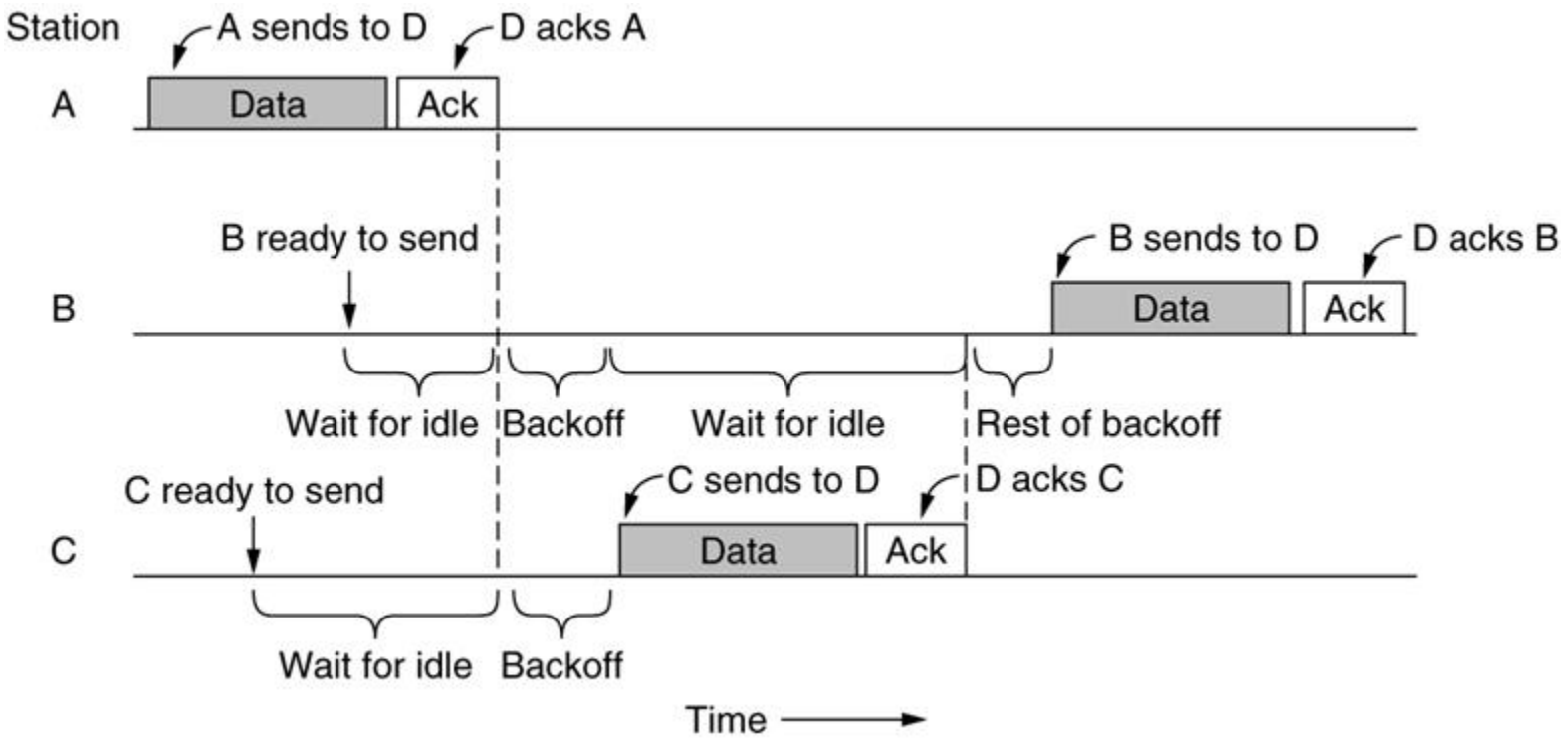
- Traffic services
  - Asynchronous Data Service (mandatory) – DCF
  - Time-Bounded Service (optional) - PCF
- Access methods
  - DCF CSMA/CA (mandatory)
    - collision avoidance via randomized back-off mechanism
    - ACKs for data frames (not for broadcasts)
  - DCF w/ RTS/CTS (optional)
    - avoids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

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)

Sending a Frame in CSMA/CA

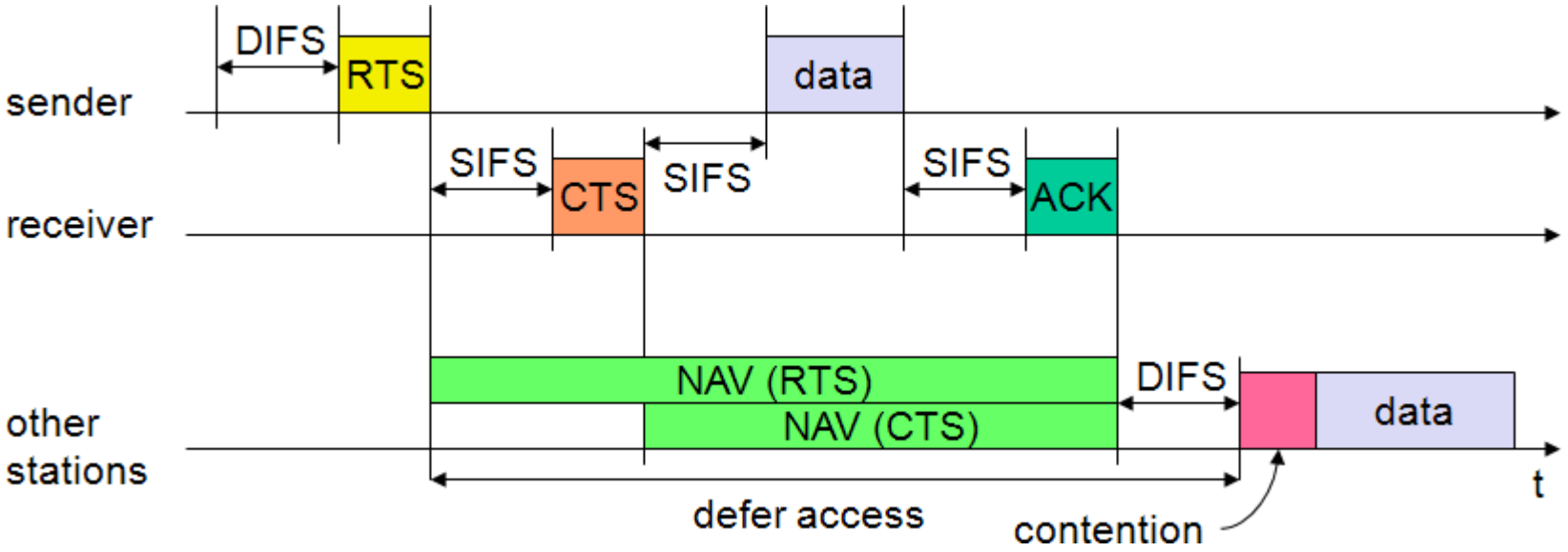


Avoiding Collisions

- 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

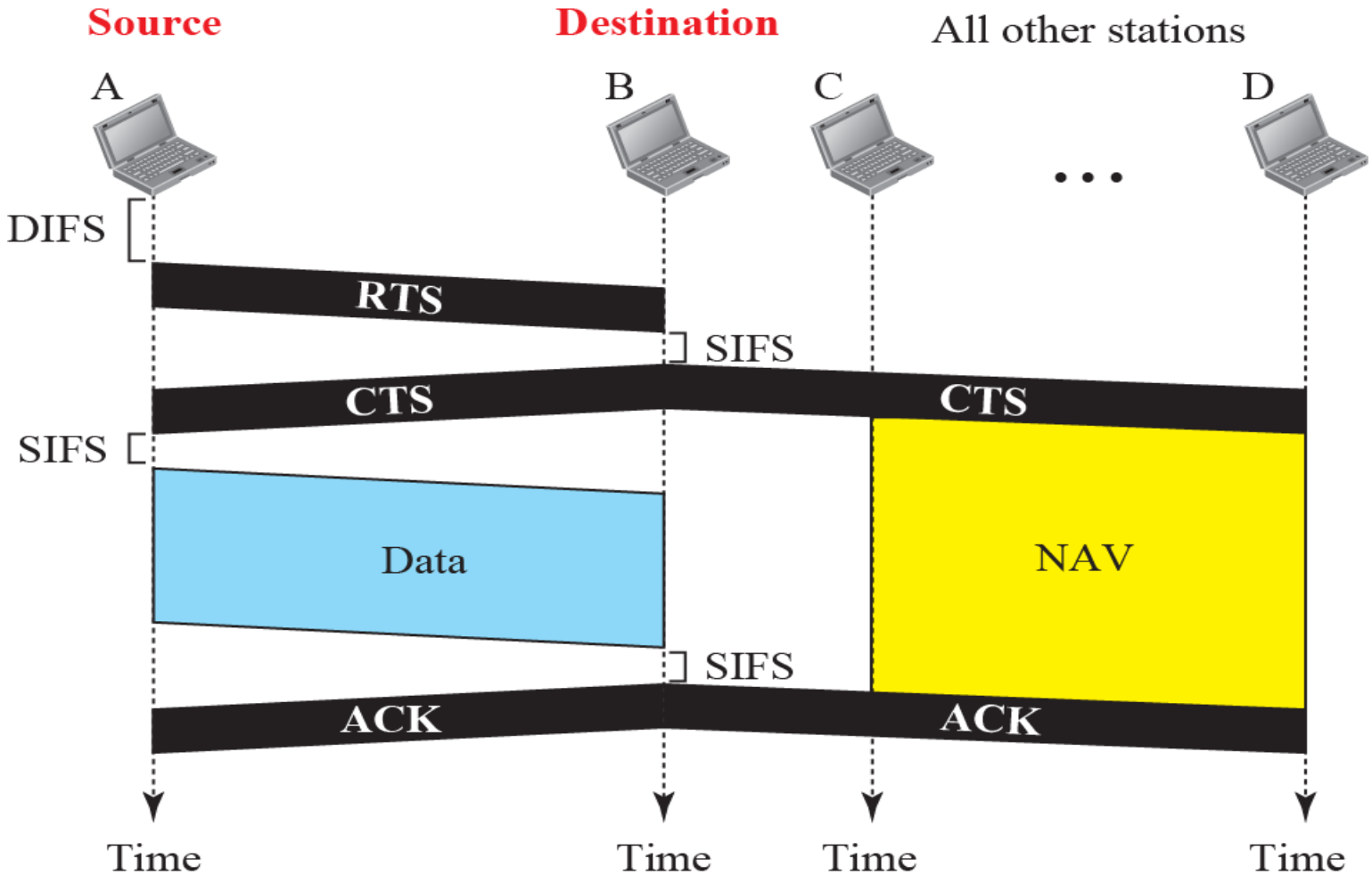
avoid data frame collisions completely using small reservation packets!

DCF w/RTS & CTS

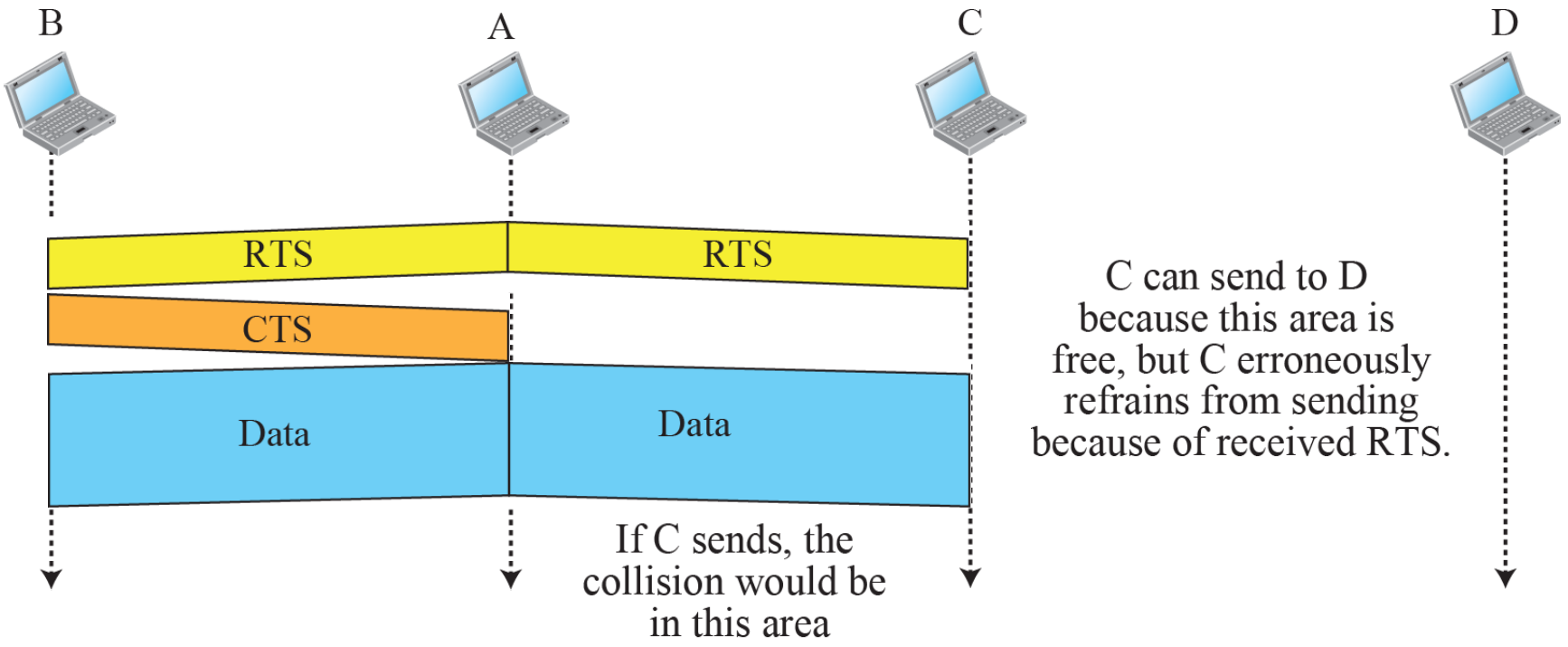


- Station send RTS with reservation parameter (amount of time the data frame needs the medium) after waiting for DIFS
- Acknowledgement via CTS after SIFS by receiver (if ready to receive)
- Sender can now send data at once, acknowledgement via ACK
- Other stations store medium reservations distributed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

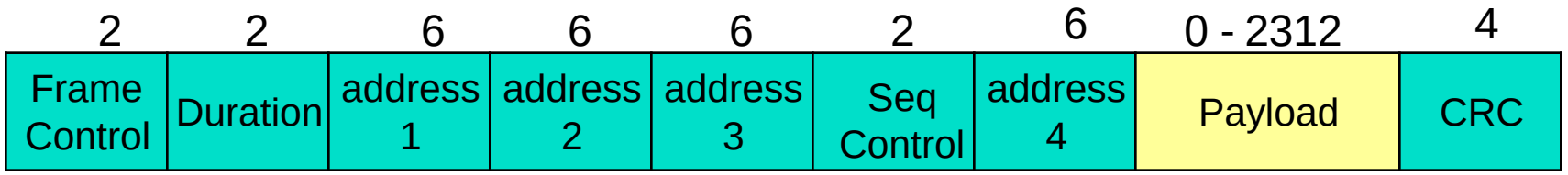
Collision Avoidance using RTS/CTS



Exposed Terminal Problem



IEEE802.11 Frame Structure



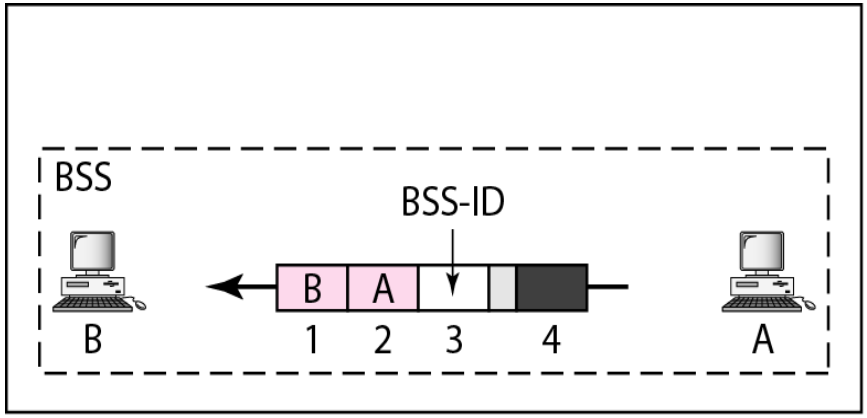
Address 1: MAC address of wireless host or AP to receive this frame

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

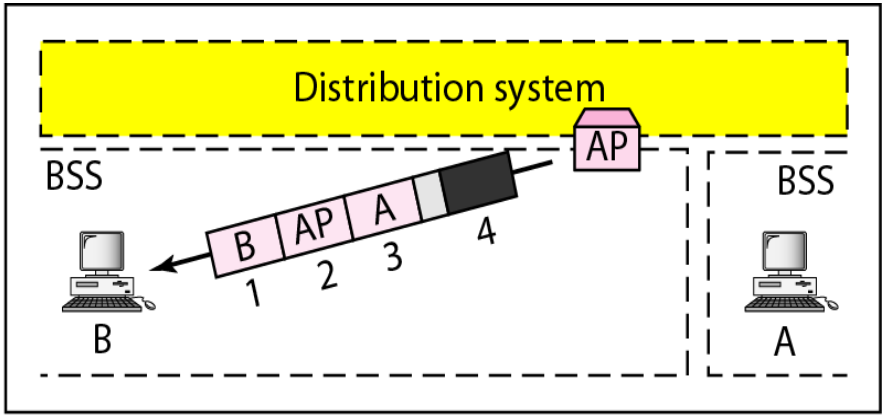
Address 3: MAC address of router interface to which AP is attached

Address 4: used only in ad hoc mode

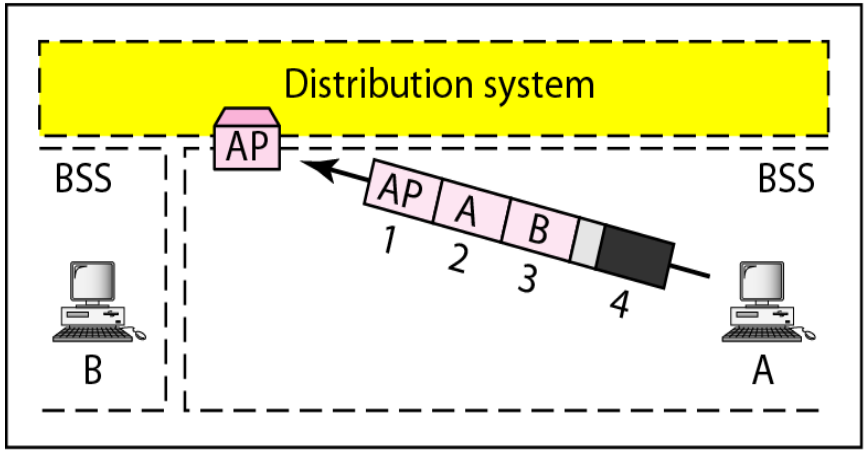
Addressing Mechanisms



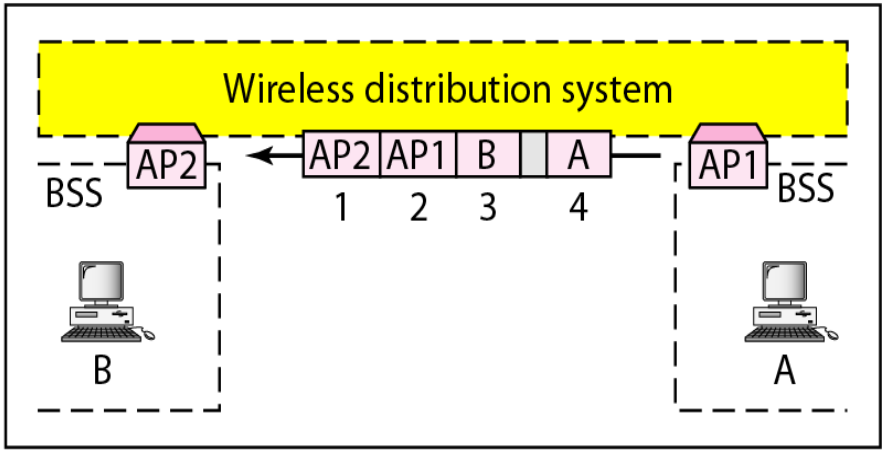
a. Case 1



b. Case 2



c. Case 3



d. Case 4

IEEE802.11 Frame Addressing