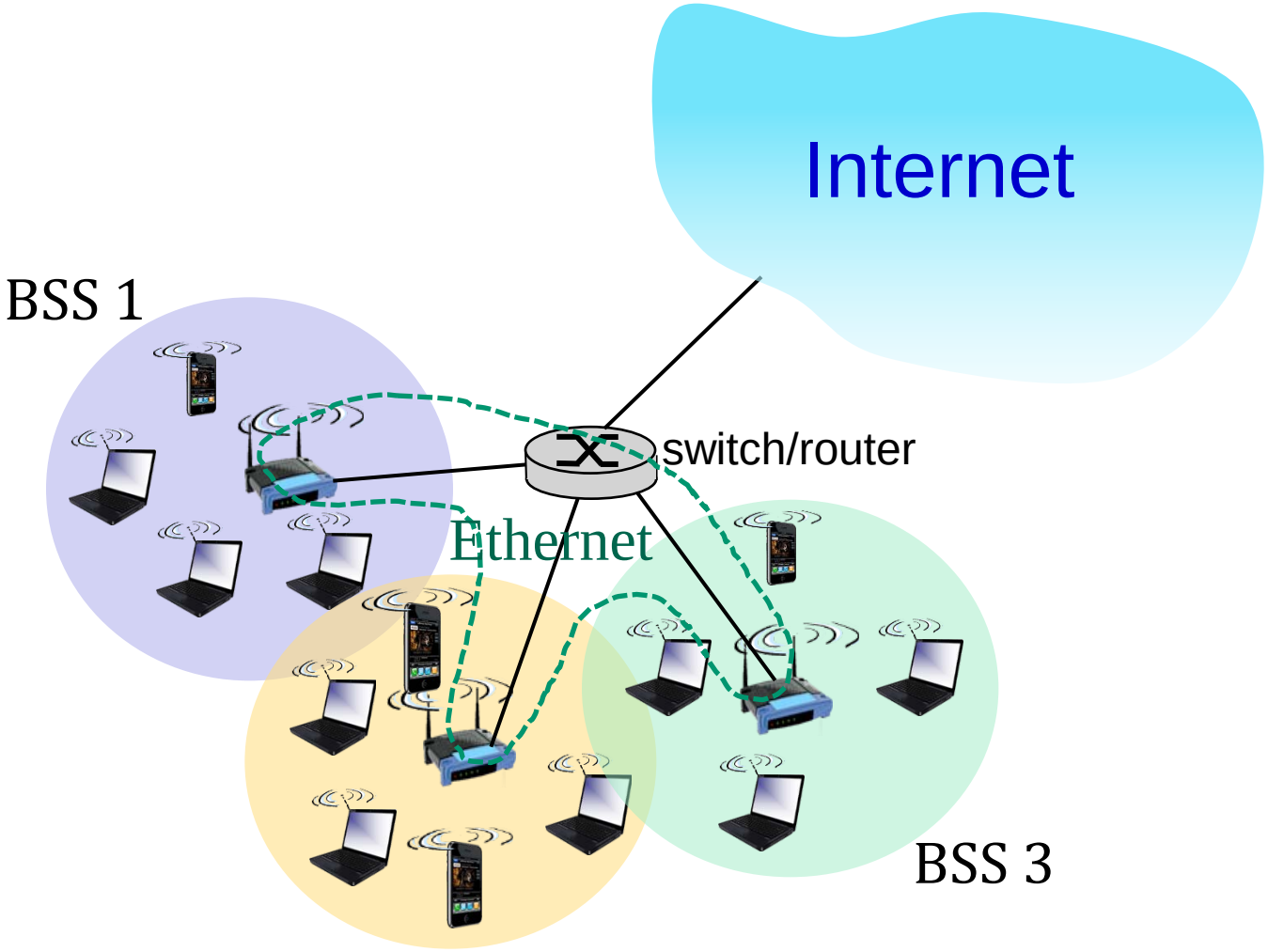
Chapter 13

Wireless LAN
(IEEE 802.11 WiFi)

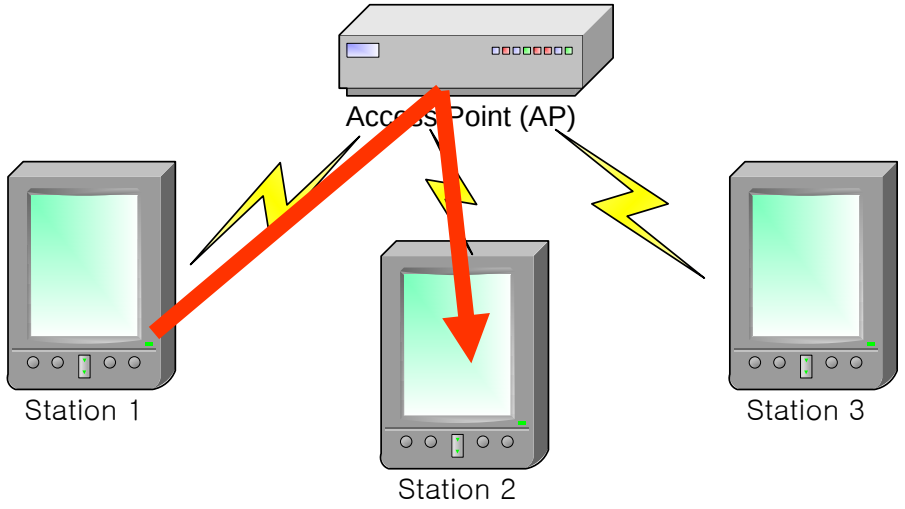
Typical 802.11 LAN Configuration



BSS: Basic Service Set

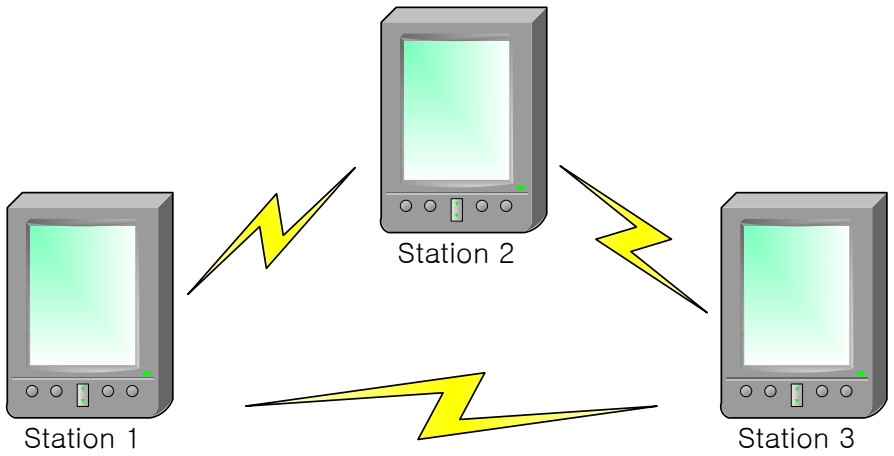
Two Modes (1)

- Infrastructure mode
  - Infrastructure Basic Service Set → BSS
  - An access point (AP) and multiple stations (STAs)
  - Every transmission is with AP; no peer-to-peer communication



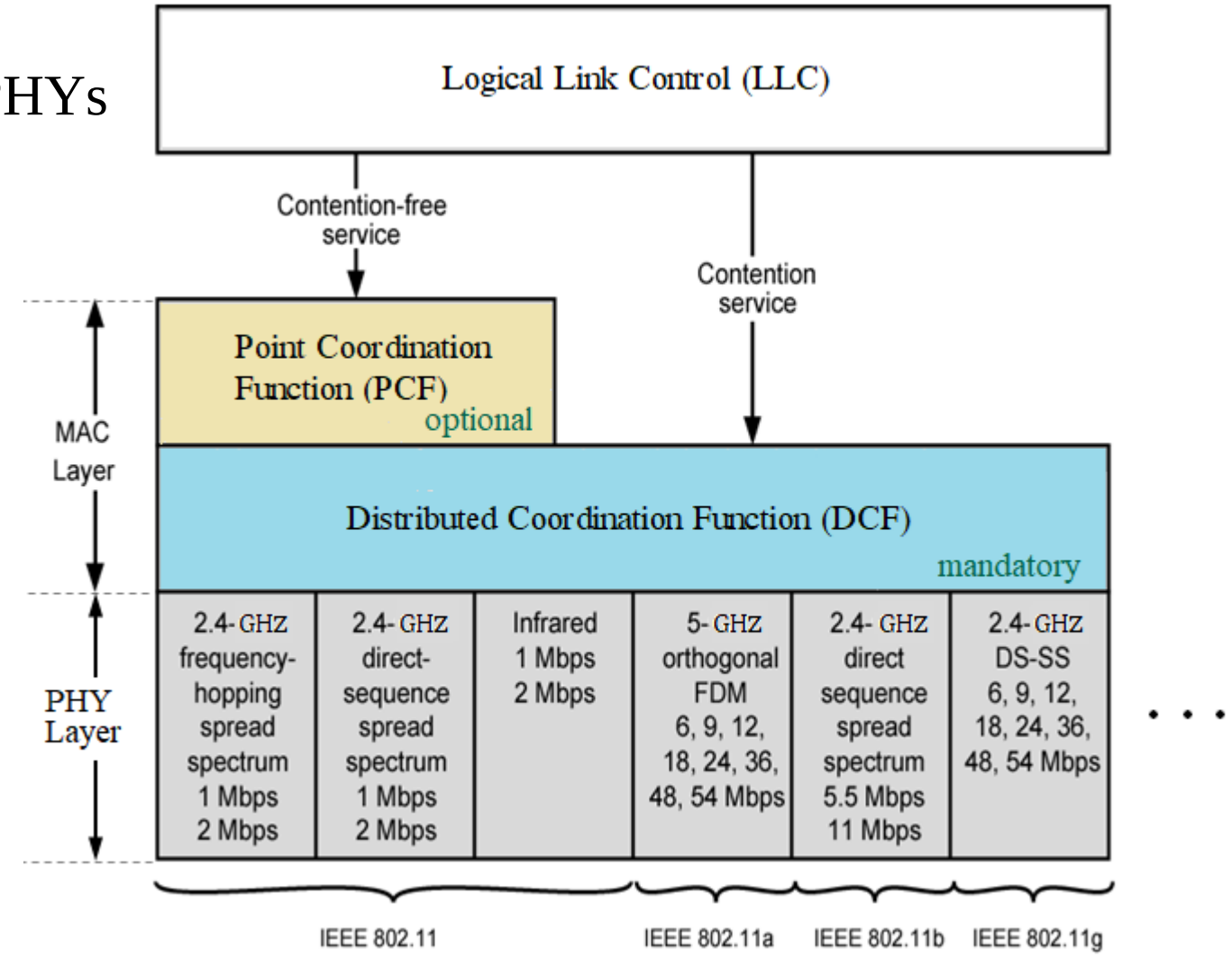
Two Modes (2)

- Ad hoc mode
  - Independent Basic Service Set → IBSS
  - Multiple stations (STAs), and no AP
  - Peer-to-peer communication only



Protocol Architecture

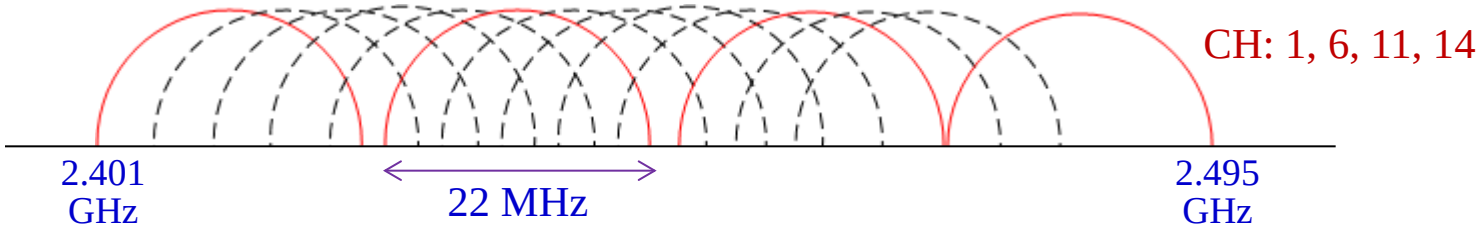
- one MAC
- multiple PHYs



Channels

- ISM (industrial, scientific and medical) band:
  - Unlicensed band
  - Commercial WLAN: 2.4 GHz, 5GHz, 6GHz band

- [Example] IEEE 802.11b
  - 2.401 GHz - 2.495GHz (2.4 GHz ISM band) spectrum divided into 14 channels (bandwidth: 20MHz) at different frequencies
  - AP admin chooses a channel for AP
  - Interference possible: channel can be same as that chosen by neighboring AP!



PHY Enhancement

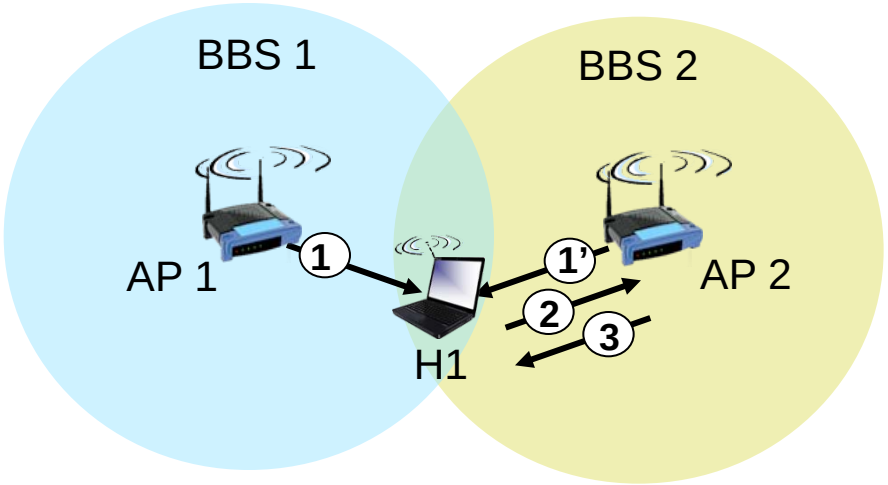
standard	802.11a	802.11b	802.11g	802.11n	802.11ac (WiFi 5)	802.11ax (WiFi 6)
Year	1999	1999	2003	2009	2013	2019
Maximum rate	54 Mbps	11 Mbps	54Mbps	600 Mbps	6.93 Gbps	9.6 Gbps
Frequency Band	5 GHz	2.4 GHz	2.4 GHz	2.4/5 GHz	5 GHz	2.4/5/6 GHz
Channel Bandwidth	20 MHz	20 MHz	20 MHz	20, 40 MHz	20, 40, 80, 160 MHz	20,40, 80, 160 MHz
Highest modulation order	64 QAM	11 CCK	64 QAM	64 QAM	256 QAM	1024 QMA
Spectrum usage	OFDM	DSSS	DSSS, OFDM	OFDM	OFDM	OFDM
Antenna configuration	1x1 SISO	1x1 SISO	1x1 SISO	Up to 4x4 MIMO	Up to 8x8 MIMO, DL MU-MIMO (4U)	Up to 8x8 MIMO, UL/DL MU-MIMO (8U)

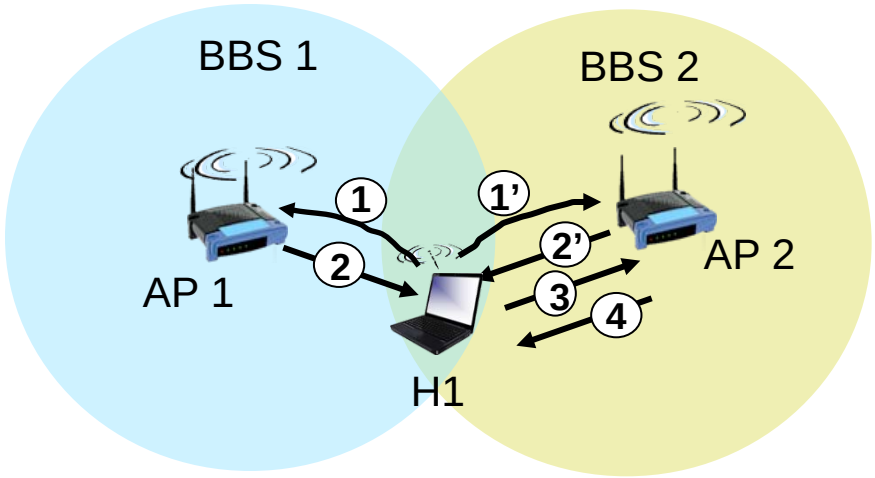
Antenna Config.

User Association

- Host (STA): must be associated with an AP
  - scans channels, for listening to beacon frames containing AP's name (SSID: service set ID) and MAC address
  - selects AP to associate with
  - may perform authentication
  - will typically run DHCP to get IP address in AP's subnet

Passive/Active Scanning





Passive scanning:

① ①' Beacon frames sent from APs by scanning each channel in sequence

② Association Request frame sent from H1 to selected AP

③ Association Response frame sent from selected AP to H1

Active scanning:

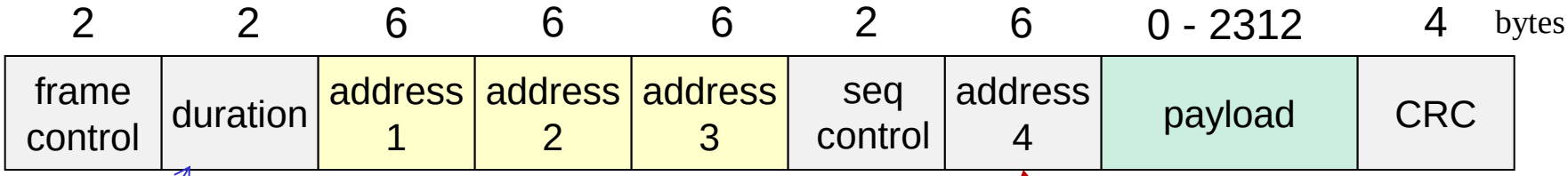
① ①' Probe Request frame for each channel broadcast from H1

② ②' Probe Response frames sent from AP

③ Association Request frame sent from H1 to selected AP

④ Association Response frame sent from selected AP to H1

MAC frame: addressing (1/2)



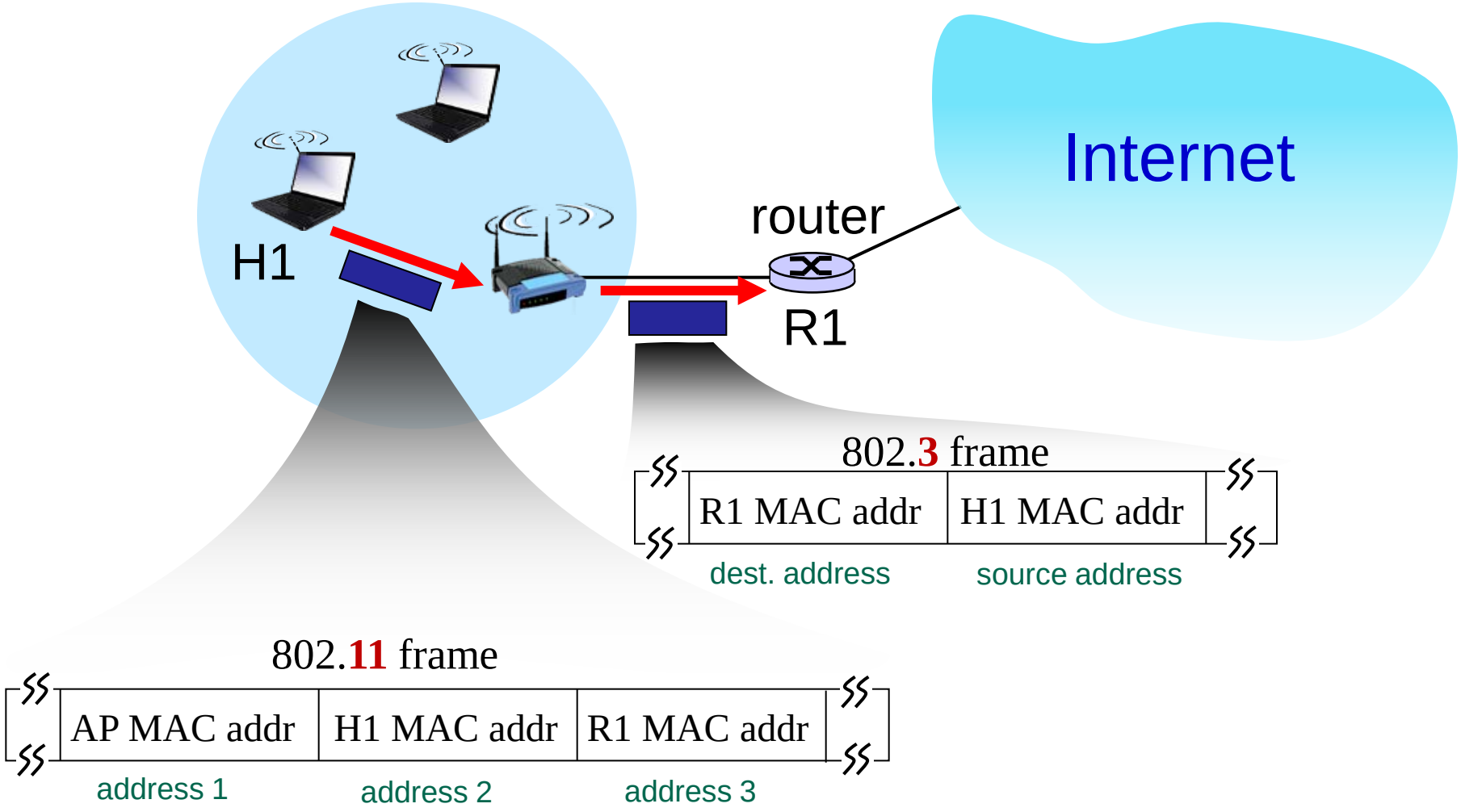
Address 1: MAC address of wireless host or AP to receive this frame (DA)

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

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

Address 4: used only in ad hoc mode

MAC frame: addressing (2/2)

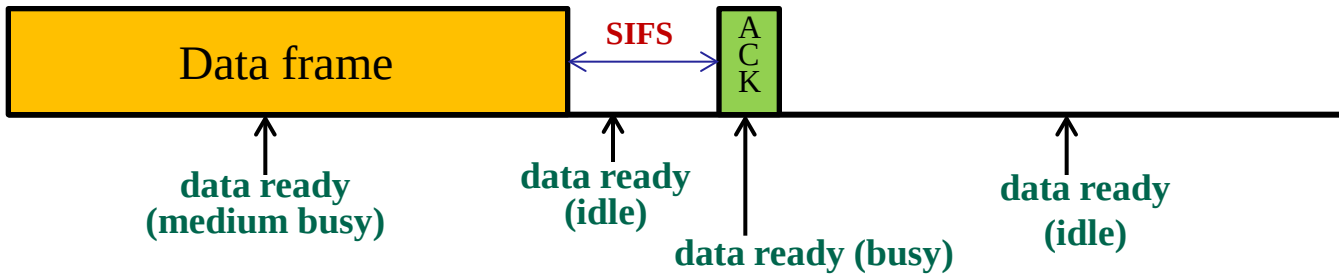


Two Coordination Functions

- Distributed Coordination Function (DCF)
  - For distributed contention-based channel access
  - CSMA/CA (Collision Avoidance)
    - similar to IEEE 802.3 Ethernet CSMA/CD
  - Mandatory
- Point Coordination Function (PCF)
  - For centralized contention-free channel access
  - Optional

DCF Design Policy: Collision Avoidance

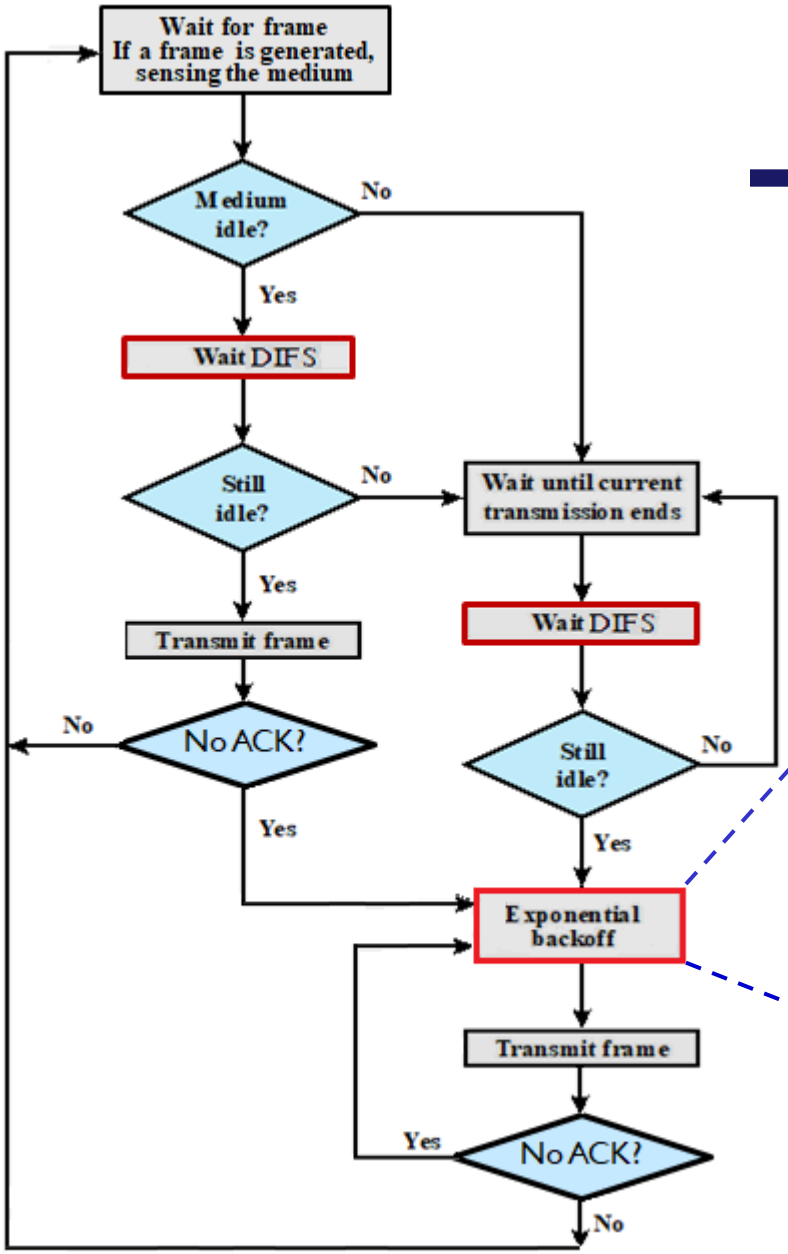
- Avoid collision as much as possible
  - ① let Receiver send ACK without collision
    - How: ACK transmission just after data transmission
      - ⇒ Stop & Wait transmission

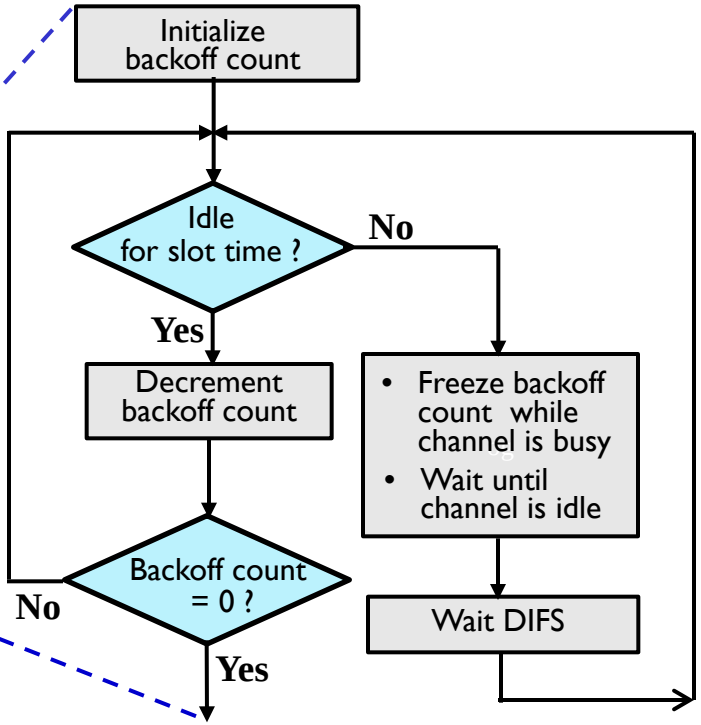


Even when medium idle, STA must wait for the longer time than SIFS
DIFS

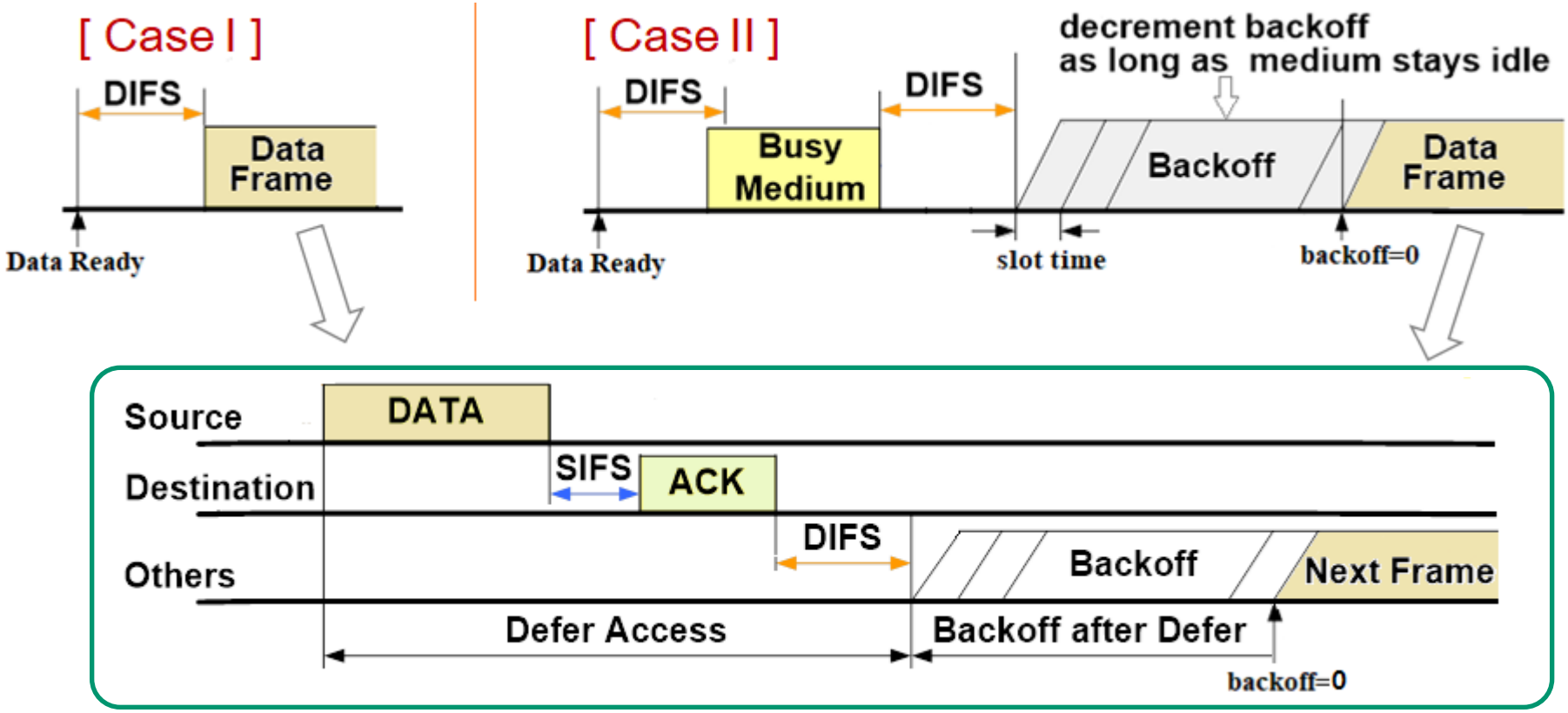
  - ② Reduce collision among STAs that wait until medium becomes idle
    - How: Backoff from their first transmissions

DCF


Wait for frame
If a frame is generated, sensing the medium
Medium idle?
No
Yes
Wait DIFS
Still idle?
No
Yes
Wait until current transmission ends
Transmit frame
Wait DIFS
No
No ACK?
Still idle?
No
Yes
Yes
Exponential backoff
Transmit frame
Yes
No ACK?
No

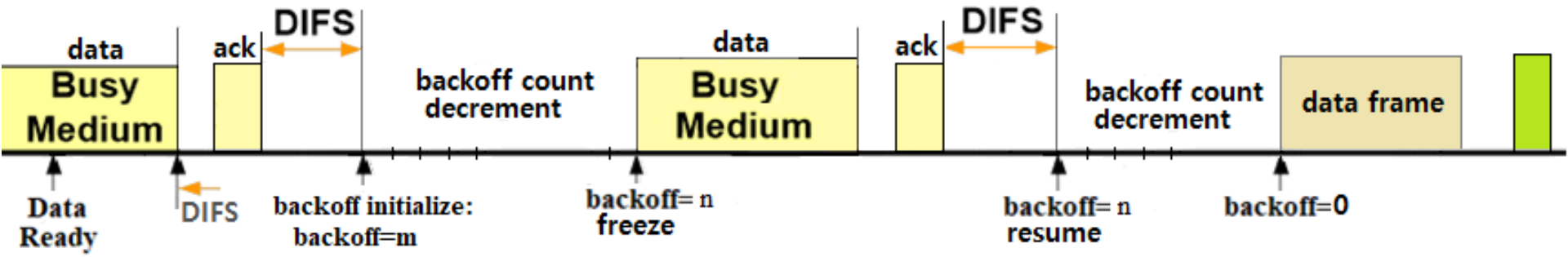

Initialize backoff count
Idle for slot time ?
No
Yes
Decrement backoff count
Freeze backoff count while channel is busy
Wait until channel is idle
Backoff count = 0 ?
No
Yes
Wait DIFS

Distributed Coordination Function

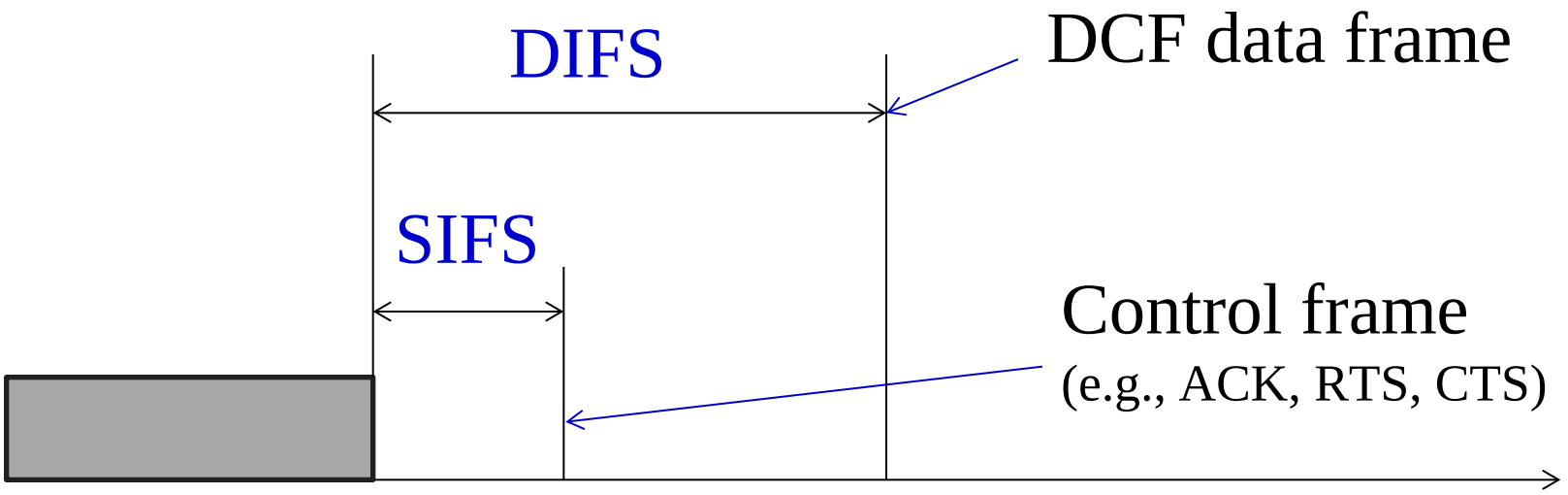


- Stop and Wait ARQ
  - Receiver of a directed frame returns an ACK
  - If ACK not received, sender retransmits after another backoff
  - ❖ Basic data transfer involves exchange of two frames

Example: DCF data frame transmission



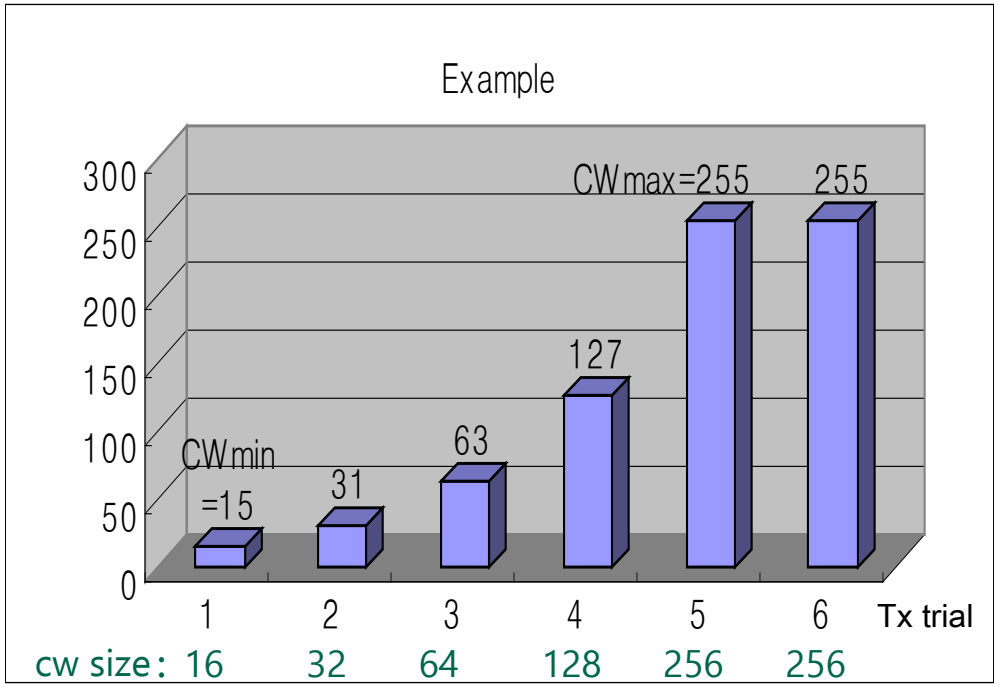
IFS (Inter Frame Space)



The shorter IFS, the higher channel access priority

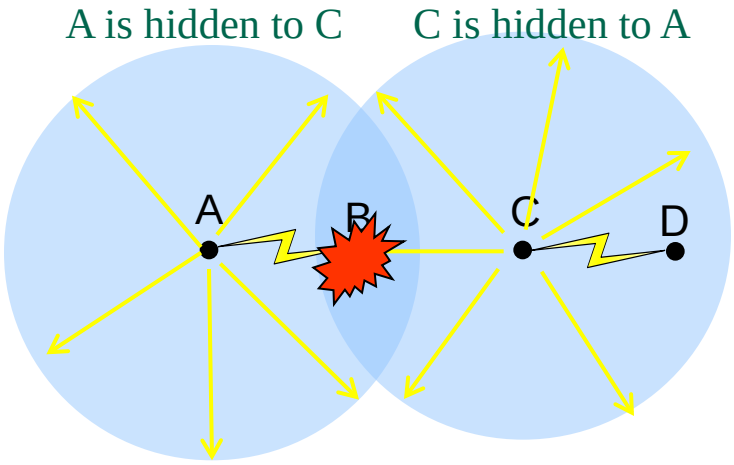
Exponential Backoff

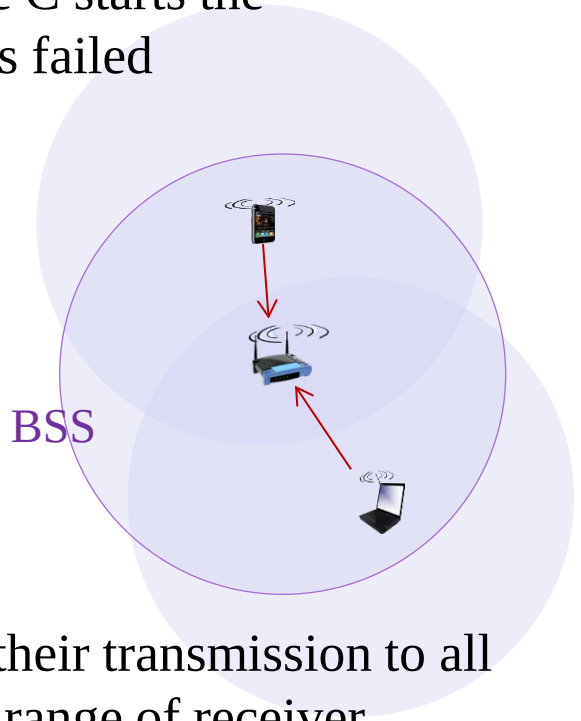
- Backoff Counter is randomly selected from [0,CW],
  - Contention window is [0,CW], contention window size = CW+1
  - CWmin ≤ CW ≤ CWmax
- For each unsuccessful frame transmission, contention window size is doubled
  - CW ← 2 CW+1
- Reduces the collision probability



Hidden Terminal Problem

- Basic data transfer involves exchange of two frames (data, ACK)
- Hidden terminal problem
  - Nodes A and C are hidden to each other
  - When node A is transmitting to node B, if node C starts the transmission to D, the transmission to node B is failed



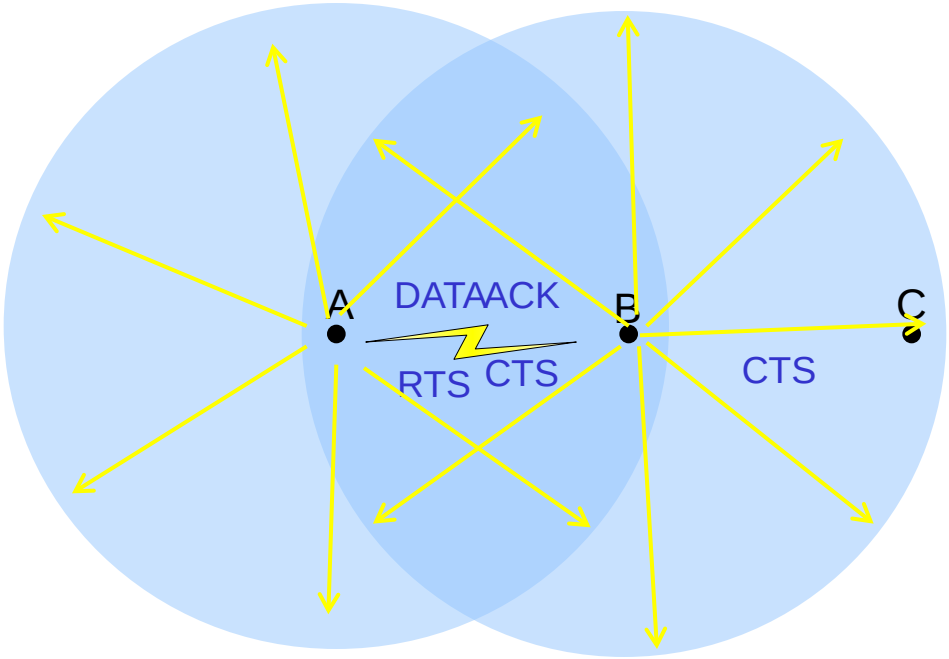


- Solution: the sender and receiver nodes inform their transmission to all stations within both the range of sender and the range of receiver

  by exchanging RTS and CTS frame in advance,

Four frame exchange

- RTS → CTS → Data → ACK
  - RTS (request to send) alerts all stations within range of sender that exchange is under way
  - CTS (clear to send) alerts all stations within range of receiver

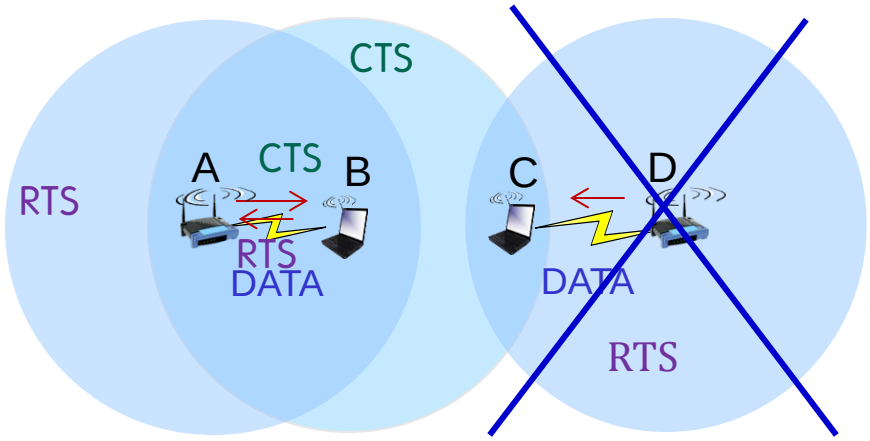


Data Transmission from node A (STA) to node B (AP)

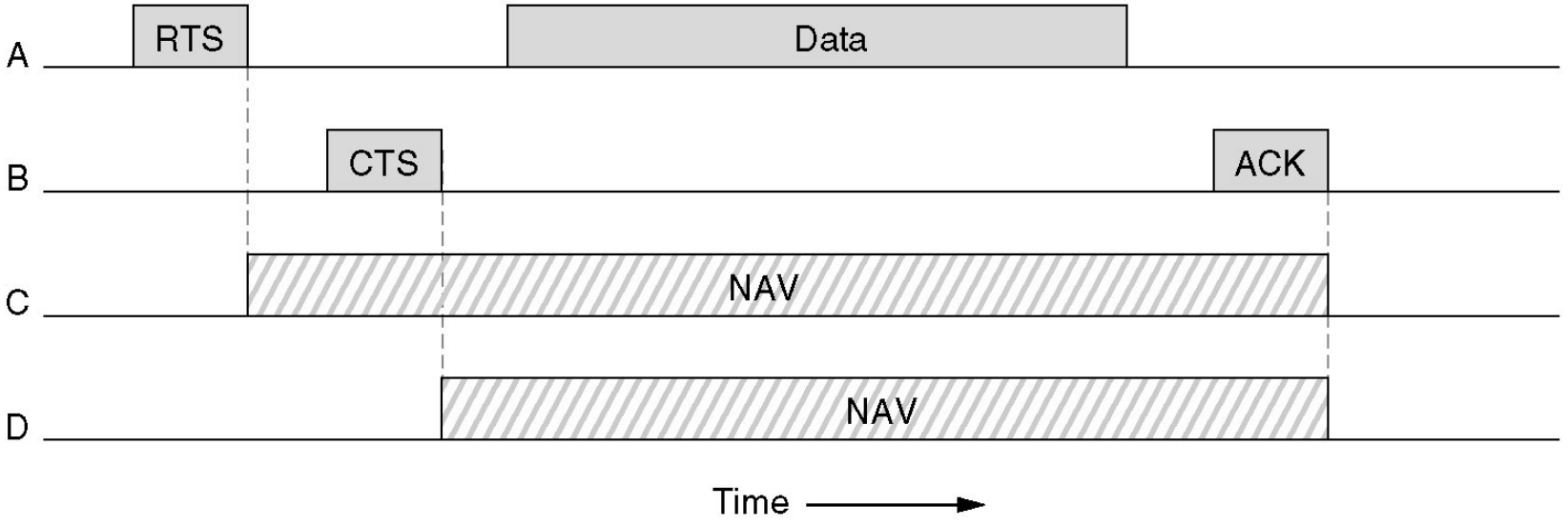
- RTS/CTS exchange is the required function of MAC but may be disabled

Exposed Terminal problem

- RTS/CTS exchange for solving the hidden terminal problem incurs the exposed terminal problem
- Exposed Terminal Problem
  - Transmission from node D to node C does not disturb the transmission from node A to node B
  - However, the node C rejects the transmission request from node D, by not sending CTS



Virtual Carrier Sensing (NAV)



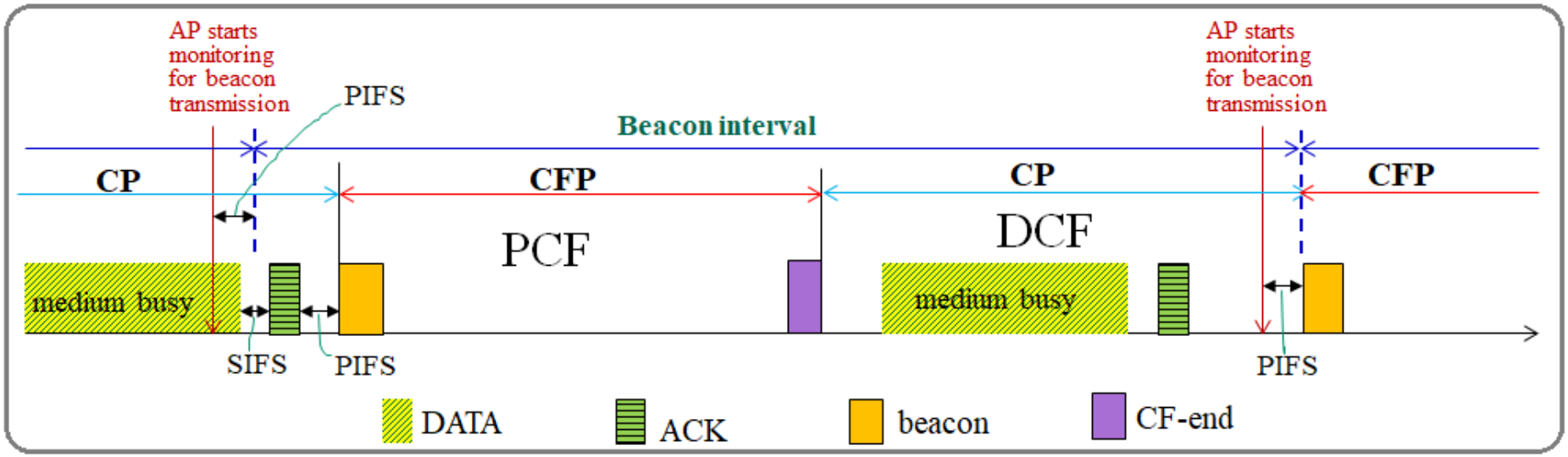
NAV: network allocation vector,
Duration value of MAC frame header

802.11 DCF Features

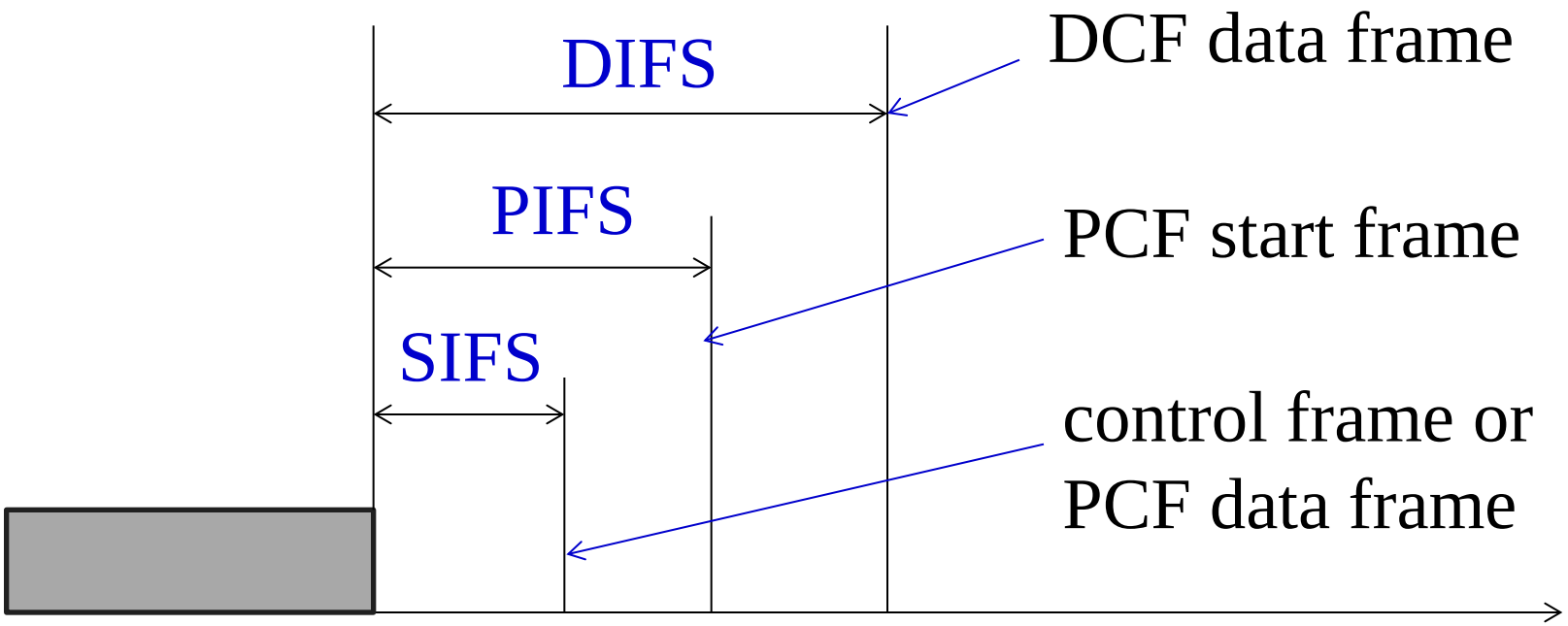
- Contention-fee ACK transmission: Reduce contentions
  - ACK: higher access priority than data frames
  - ACK transmission of the receiver just after data frame transmission of the sender: Stop and Wait (SIFS)
  - The transmitters should wait DIFS before transmission on idle channel
- Collision avoidance among STAs waiting for data frame transmission
  - Backoff even before their first transmission trials
  - Trying to be fair:
    - freeze a backoff count during channel busy
    - reinitialize the backoff count only after collision
- Virtual carrier sensing
  - Reduce the energy consumption by avoiding the physical carrier sensing

Point Coordination Function (PCF)

- In infrastructure mode only
  - Point Coordinator (PC) resides in AP
- Alternating Contention-Free Period (CFP) and Contention Period (CP)
  - CFP: all transmissions governed by AP, in polling-based manner
  - CP: each station having data traffic contends for acquiring the medium access right, according to DCF protocol



IFS


DIFS
PIFS
SIFS
DCF data frame
PCF start frame
control frame or
PCF data frame

Contention Free Operation of PCF

- Poll-and-response MAC for nearly isochronous service
- Two consecutive frames are separated by SIFS
- CFP lengths depend on traffic amount
  - Maximum length announced by AP; used for setting NAV