# Lecture 05-03: Link Layer 802.11

CS 356R

Intro to Wireless Networks

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Internet Reference Model

| Example Protocols | | Responsible for |
|---|---|---|
| FTP, HTTP, SMTP | Application | application specific needs |
| TCP, UDP | Transport | process to process data transfer |
| IP | Network | host to host data transfer across different network |
| Ethernet, WiFi | Link | data transfer between physically adjacent nodes |
| 802.3 PHY | Physical | bit-by-bit or symbol-by-symbol delivery |



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# Recap: MAC Random Access

- Alohoa
  - Pure Aloha
  - Slotted Aloha

- CSMA
  - CSMA
  - CSMA/CD
  - CSMA/CA

# CSMA/CD (Collision Detection)

- CSMA/CD: **carrier sensing, deferral as in CSMA**
  - collisions *detected* within short time
  - colliding transmissions aborted, reducing channel wastage
  - persistent or non-persistent retransmission
- **Easier in wired LANs**
  - measure signal strengths, compare transmitted, received signals
- **Harder in wireless LANs**
  - Most receivers cannot send and receive at the same time
  - receiver's channel condition is different from that of the sender

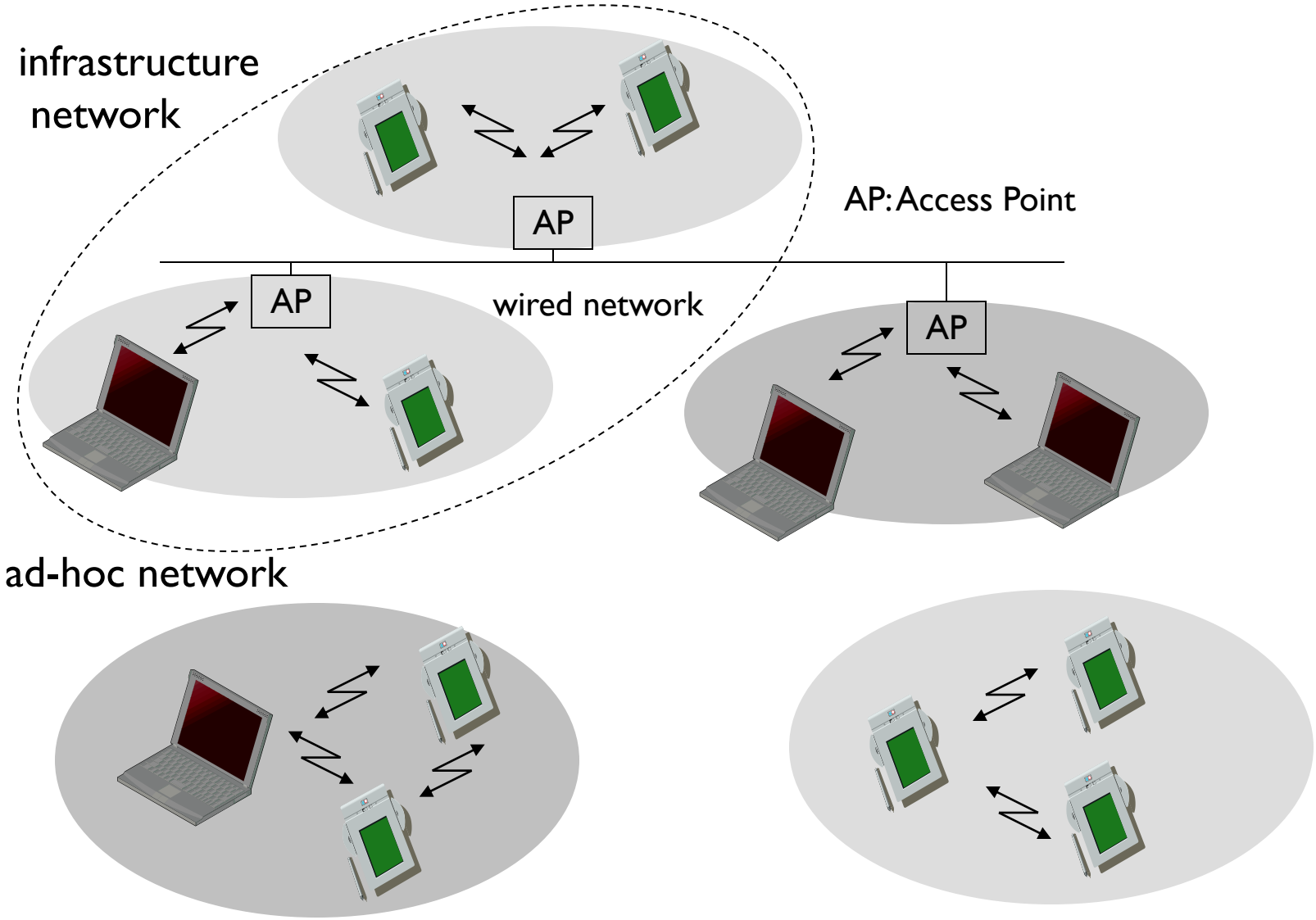
# Outline

1. Intro to IEEE 802.11 architecture

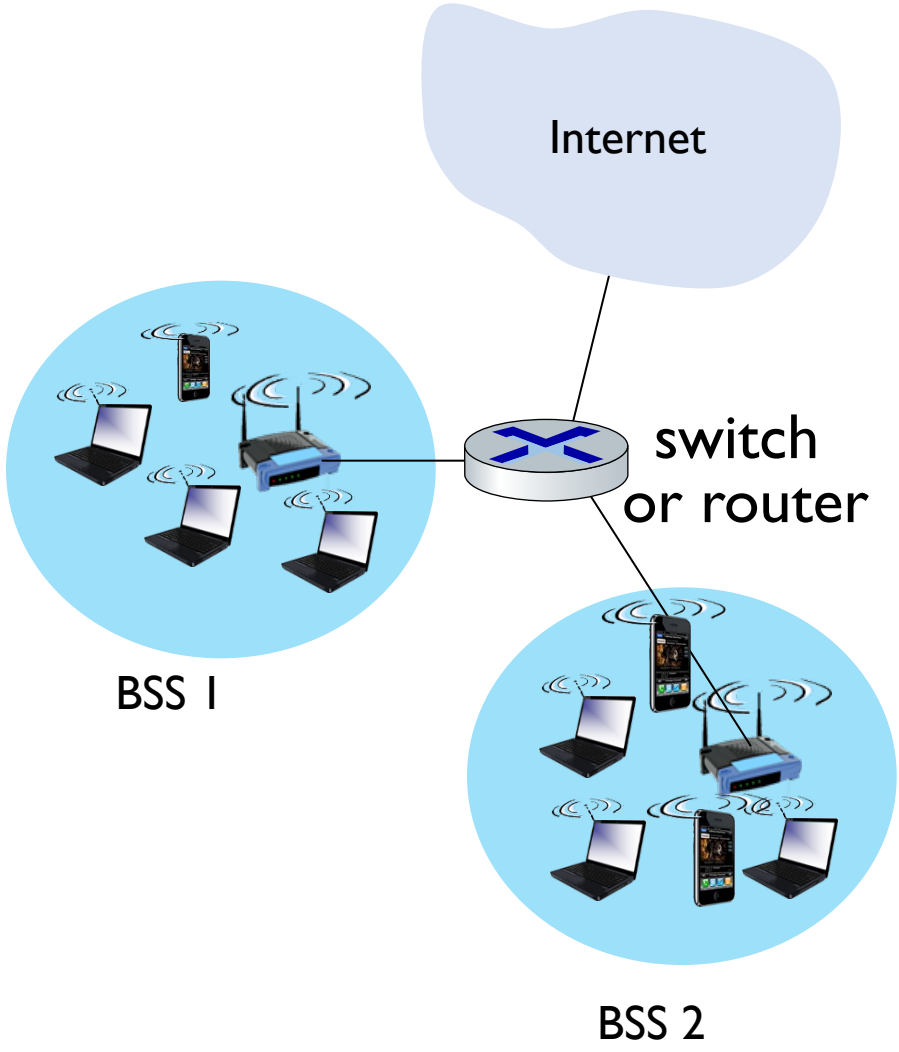
# Characteristics of wireless LANs

- **Advantages**
  - very flexible within the reception area
  - Ad-hoc networks without previous planning possible
  - (almost) no wiring difficulties (e.g. historic buildings, firewalls)
  - more robust against disasters
    - e.g., earthquakes, fire - or users pulling a plug...
- **Disadvantages**
  - Typically very low bandwidth compared to wired networks (1-10 Mbit/s) due to shared medium
  - Less reliable

# Infrastructure vs. ad-hoc networks



# 802.11 LAN architecture



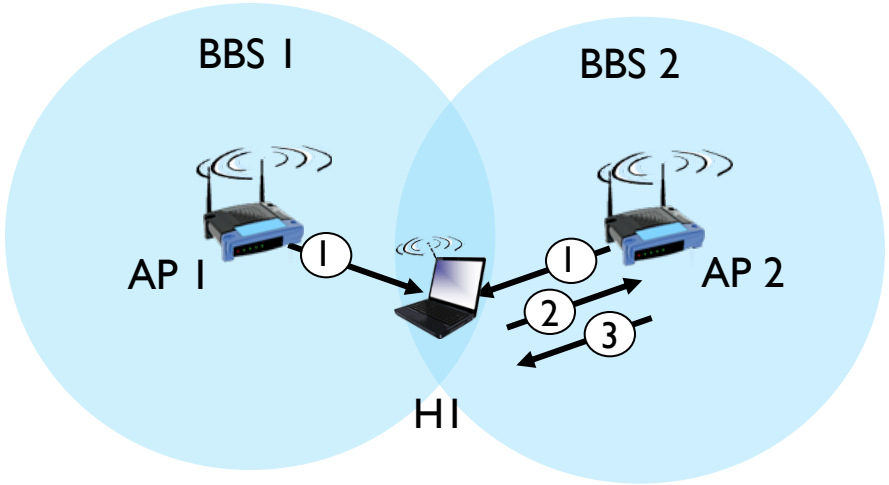

- wireless host communicates with base station
  - base station = access point (AP)
- Basic Service Set (BSS) (aka "cell") in infrastructure mode contains:
  - wireless hosts
  - access point (AP): base station
  - ad hoc mode: hosts only

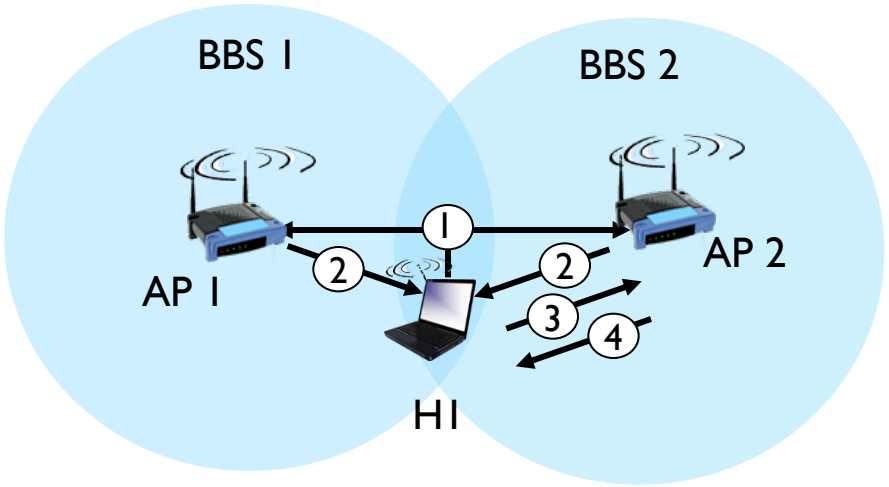
# 802.11: Channels, association

- spectrum divided into channels at different frequencies
  - AP admin chooses frequency for AP
  - interference possible: channel can be same as that chosen by neighboring AP!
- arriving 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
  - then may perform authentication [Chapter 8]
  - then typically run DHCP to get IP address in AP's subnet

BSS

# 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

# IEEE 802.11 is keep evolving!

| IEEE 802.11 standard | Year | Max data rate | Range | Frequency |
|---|---|---|---|---|
| 802.11b | 1999 | 11 Mbps | 30 m | 2.4 Ghz |
| 802.11g | 2003 | 54 Mbps | 30m | 2.4 Ghz |
| 802.11n (WiFi 4) | 2009 | 600 | 70m | 2.4, 5 Ghz |
| 802.11ac (WiFi 5) | 2013 | 3.47Gpbs | 70m | 5 Ghz |
| 802.11ax (WiFi 6) | 2020 (exp.) | 14 Gbps | 70m | 2.4, 5 Ghz |
| 802.11af | 2014 | 35 – 560 Mbps | 1 Km | unused TV bands (54-790 MHz) |
| 802.11ah | 2017 | 347Mbps | 1 Km | 900 Mhz |

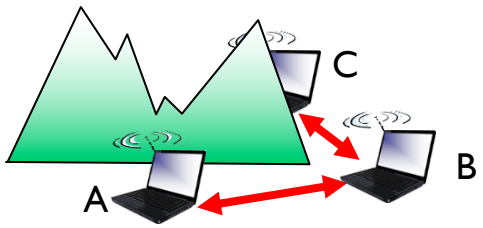
- all use CSMA/CA for multiple access, and have base-station and ad-hoc network versions

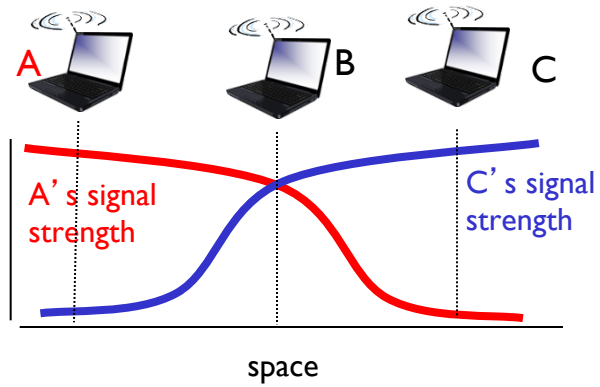
# Outline

1. Intro to IEEE 802.11 architecture
2. IEEE 802.11 MAC layer Collision Avoidance

# IEEE 802.11: multiple access

- avoid collisions: $2^+$ nodes transmitting at same time
- 802.11: CSMA - sense before transmitting
  - don't collide with detected ongoing transmission by another node
- 802.11: no collision detection!
  - difficult to sense collisions: high transmitting signal, weak received signal due to fading
  - can't sense all collisions in any case: hidden terminal, fading
  - goal: avoid collisions: CSMA/CollisionAvoidance



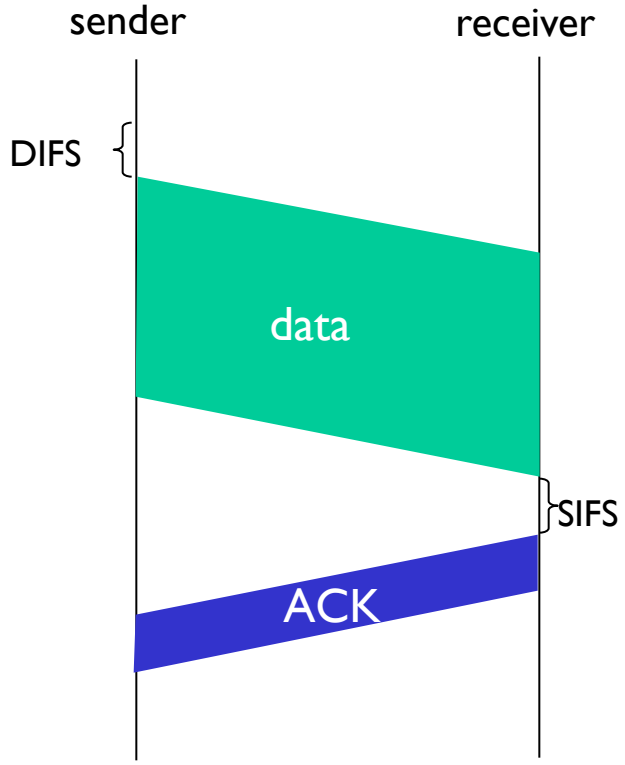



# IEEE 802.11 MAC's CSMA/CA

## 802.11 sender

1 if sense channel idle for DIFS then
    transmit entire frame (no CD)

2 if sense channel busy then
    start random backoff time
    timer counts down while channel idle
    transmit when timer expires
    if no ACK, increase random backoff interval, repeat 2

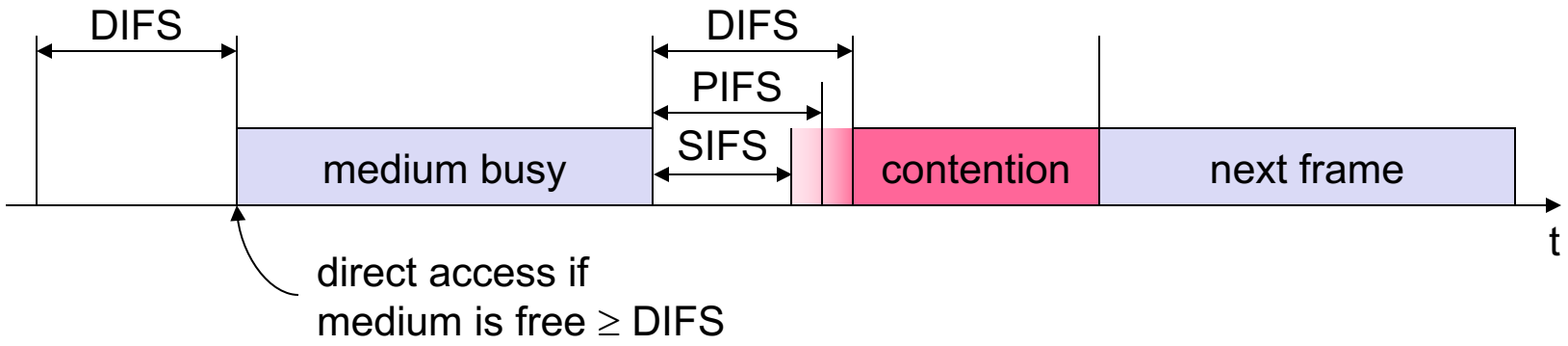



## 802.11 receiver

if frame received OK
    return ACK after SIFS (ACK needed due to hidden terminal problem)

# IEEE 802.11 MAC's CSMA/CA

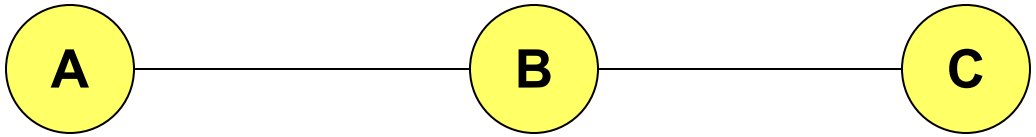
- **Based on priorities, frames have different spacing**
  - defined through different inter frame spaces
  - no guarantee, hard priorities
  - Highest priority: SIFS (Short Inter Frame Spacing)
    - For ACK, CTS, polling response
  - Medium priority: PIFS (Point Coordination Function IFS)
    - for time-bounded service using PCF
  - Lowest priority: DIFS (DCF, Distributed Coordination Function IFS)
    - For asynchronous data service



# Physical carrier sensing is not enough to avoid collision

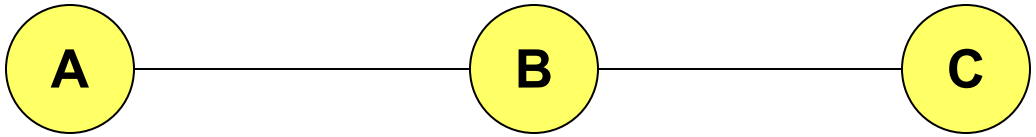
- Why?

# Hidden Terminal Problem



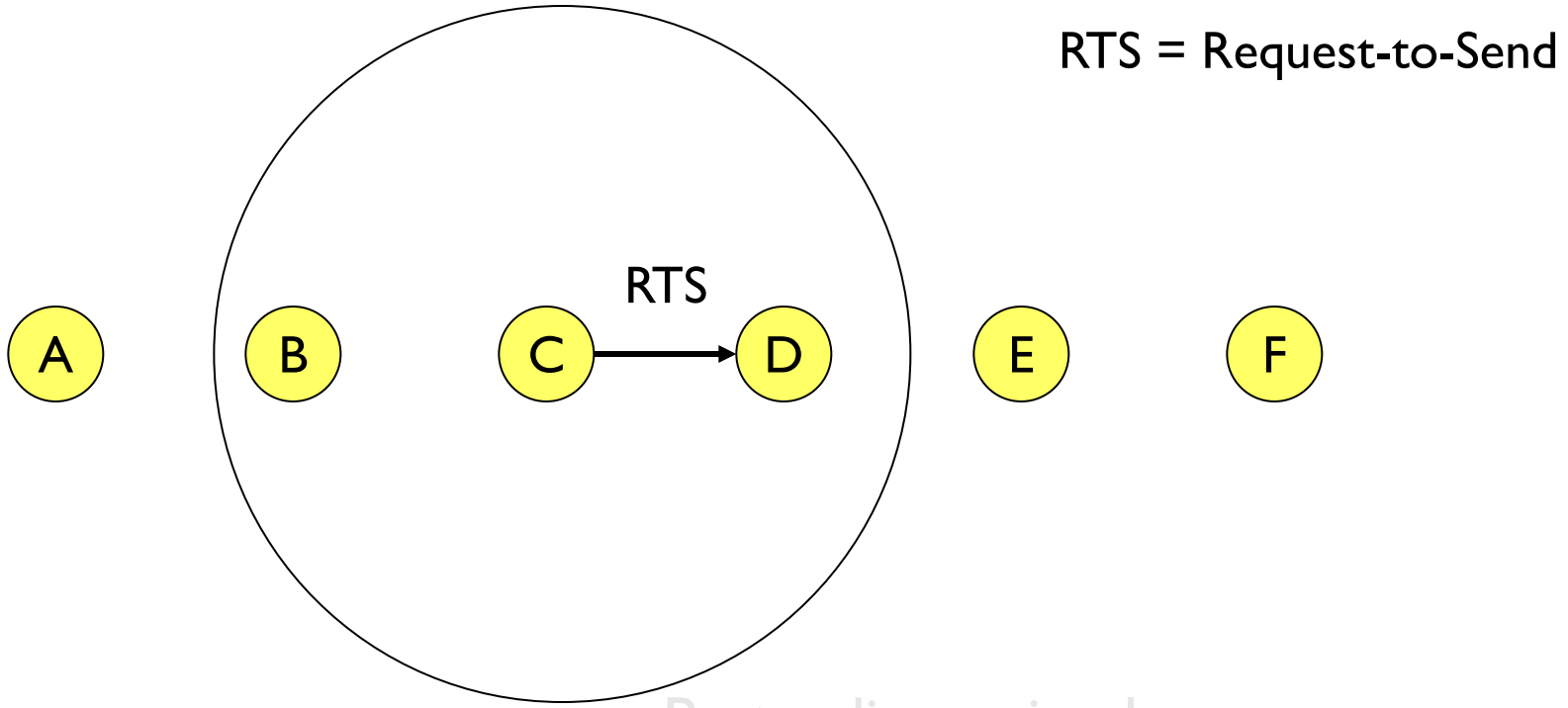

- B can communicate with both A and C
- A and C cannot hear each other
- Problem
  - When A transmits to B, C cannot detect the transmission using the carrier sense mechanism
  - If C transmits, collision will occur at node B
- Solution
  - Hidden sender C needs to defer

# Solution for Hidden Terminal Problem: Virtual Carrier Sensing




- When A wants to send a packet to B, A first sends a Request-to-Send (RTS) to B
- On receiving RTS, B responds by sending Clear-to-Send (CTS), provided that A is able to receive the packet
- When C overhears a CTS, it keeps quiet for the duration of the transfer
  - Transfer duration is included in both RTS and CTS

# IEEE 802.11 Virtual Carrier Sensing



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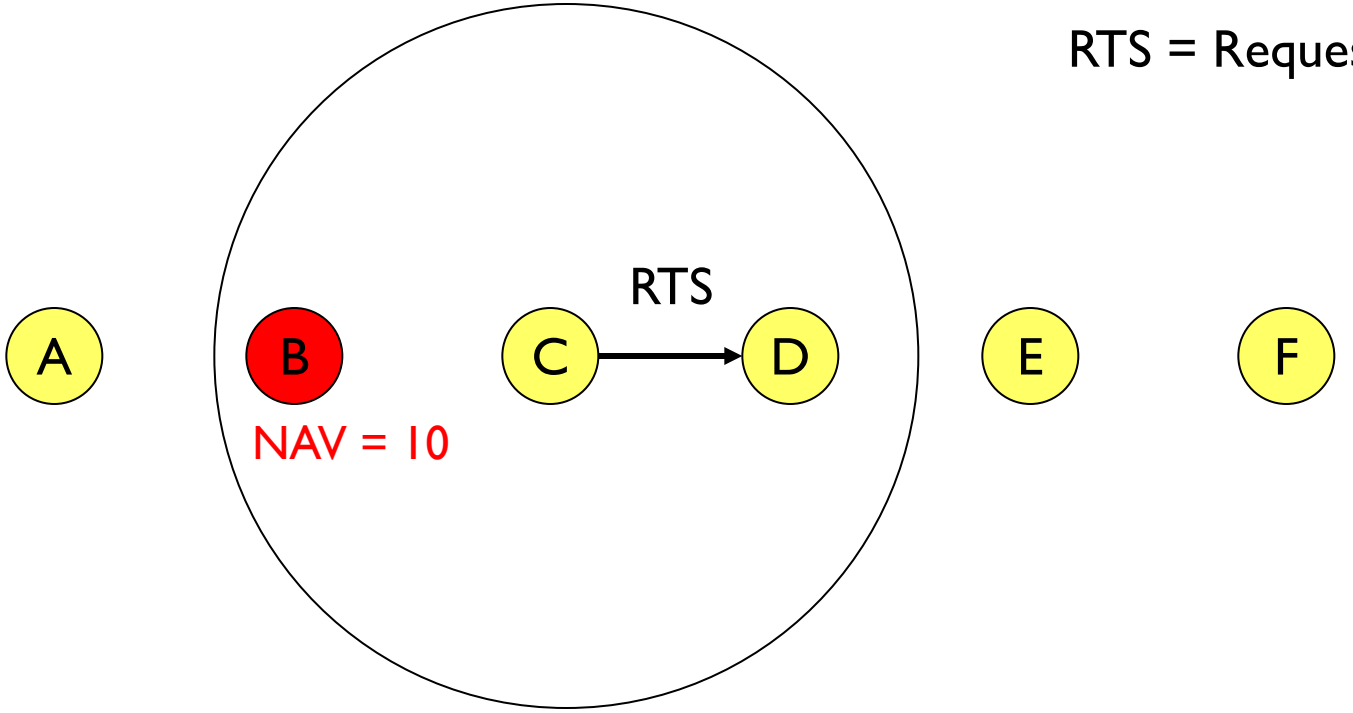
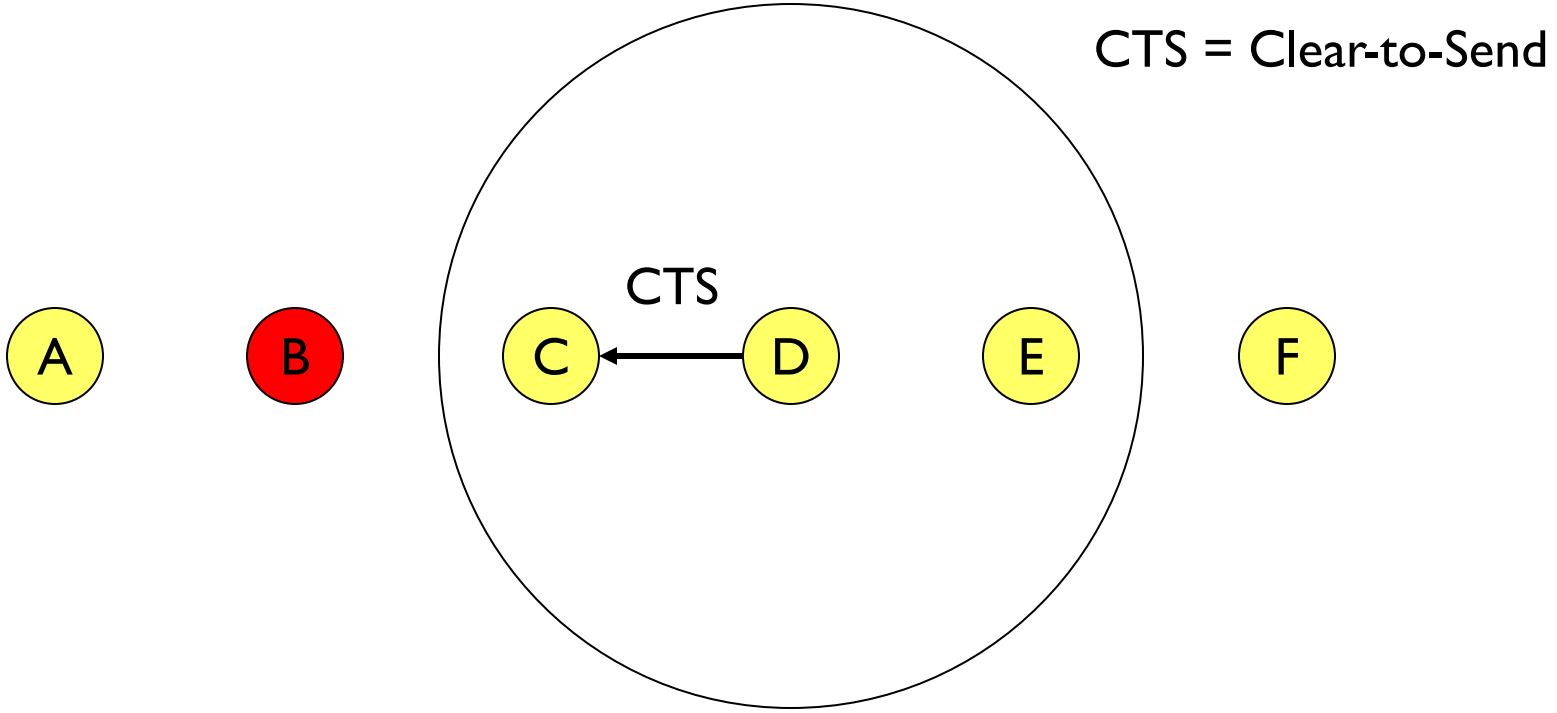



NAV = remaining duration to keep quiet

# IEEE 802.11 Virtual Carrier Sensing



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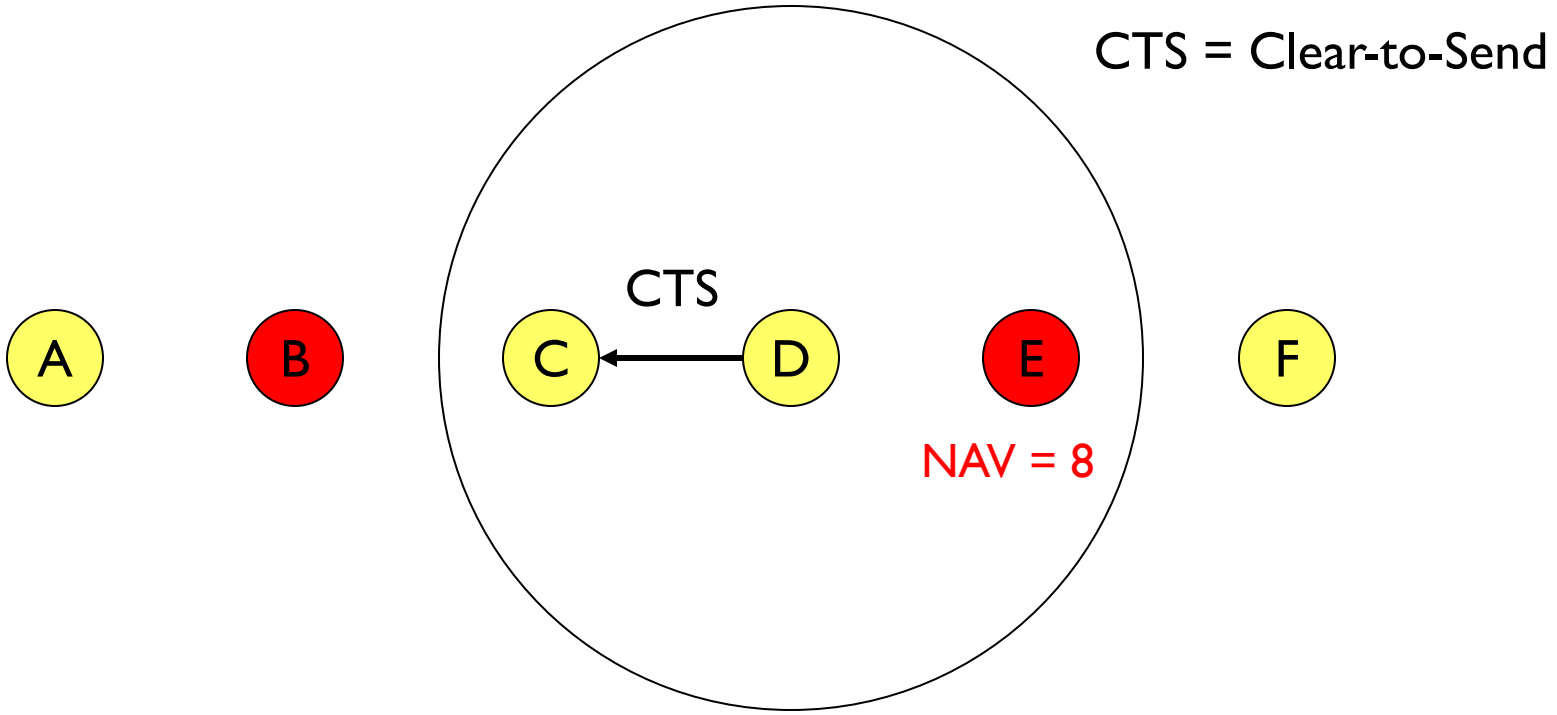
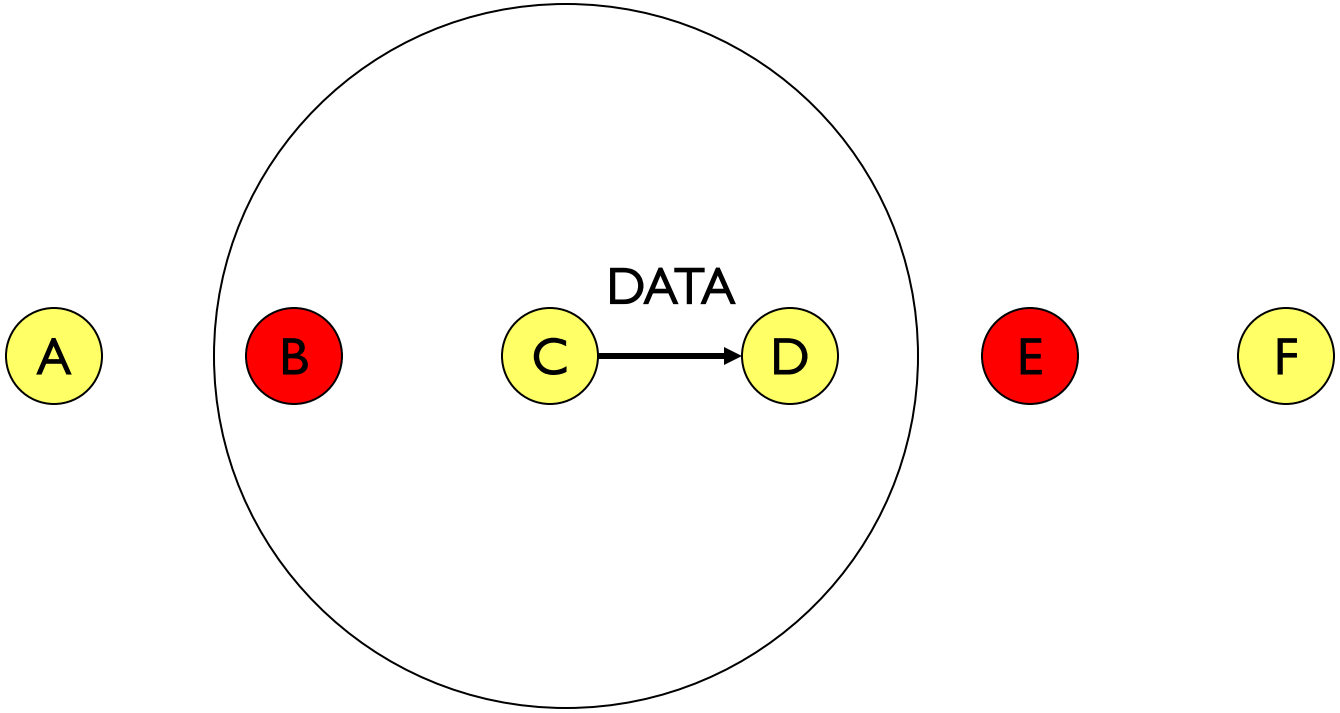
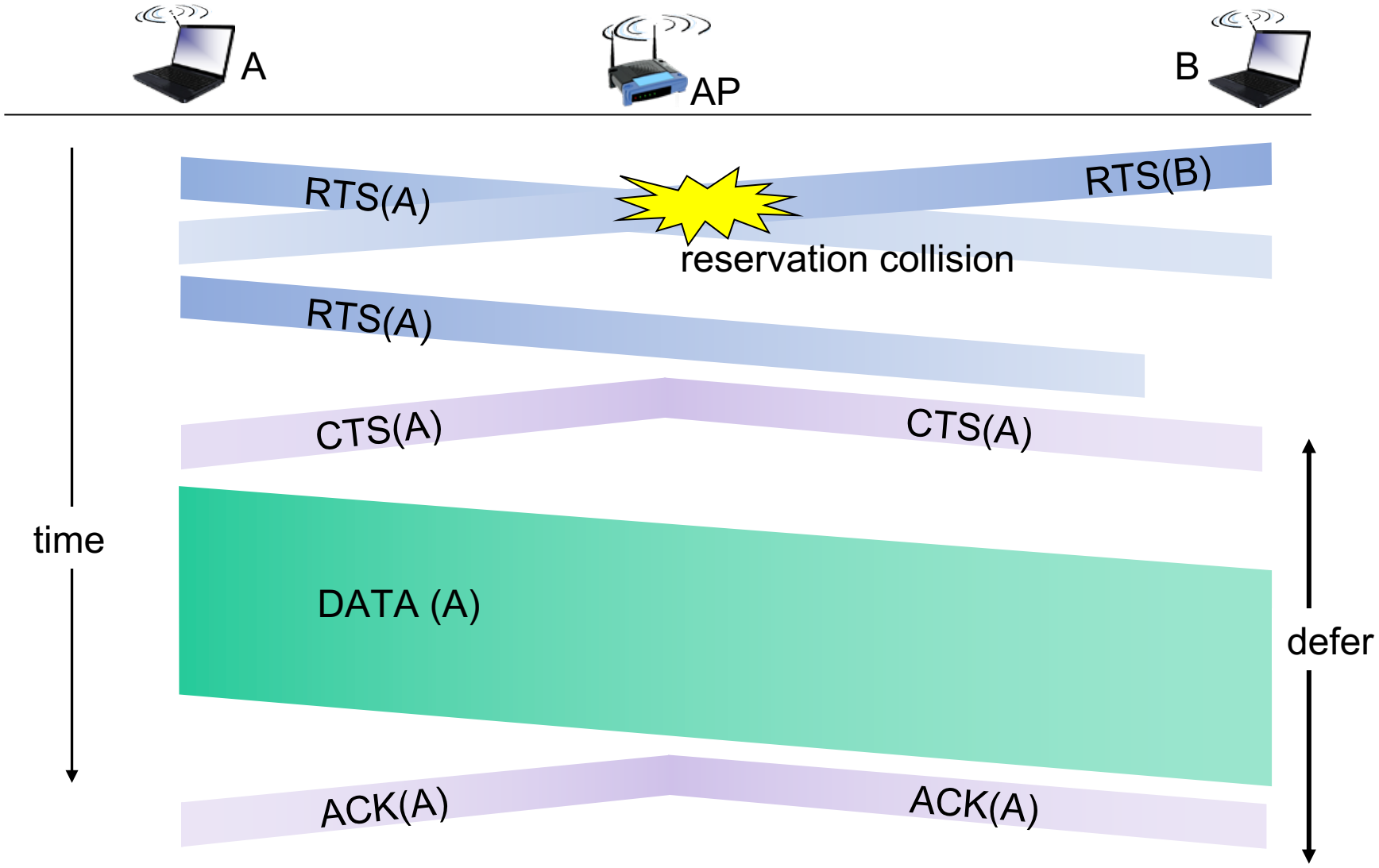


# IEEE 802.11 Virtual Carrier Sensing

- DATA packet follows CTS. Successful data reception acknowledged using ACK.



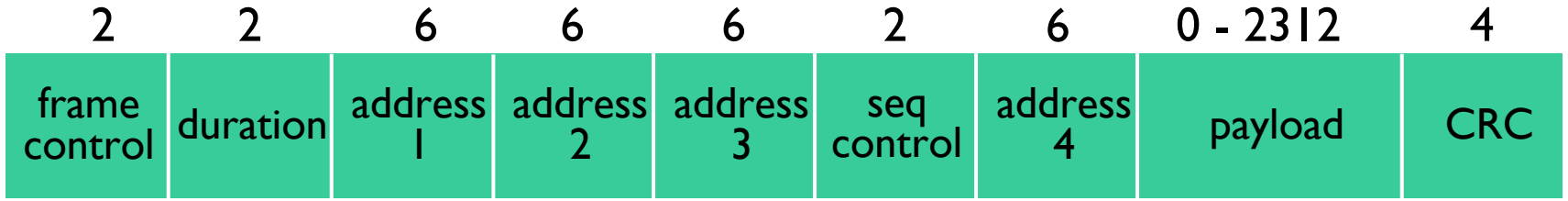
# Collision Avoidance: RTS-CTS exchange



# Outline

1. IEEE 802.11 architecture
2. IEEE 802.11 MAC layer Collision Avoidance
3. IEEE 802.11 addressing

# 802.11 frame: addressing



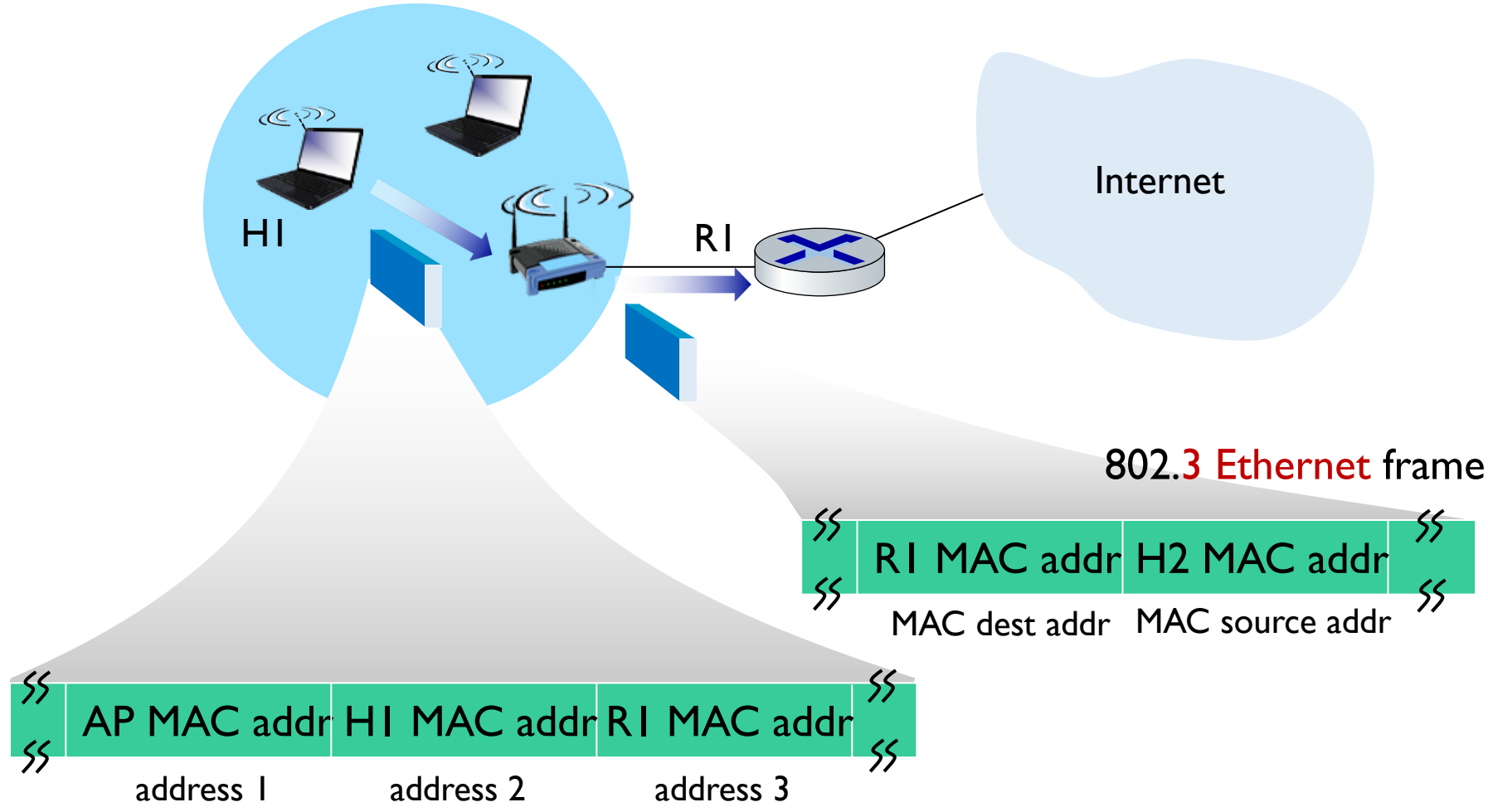

Address 1: MAC address of wireless host or AP to receive this frame

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

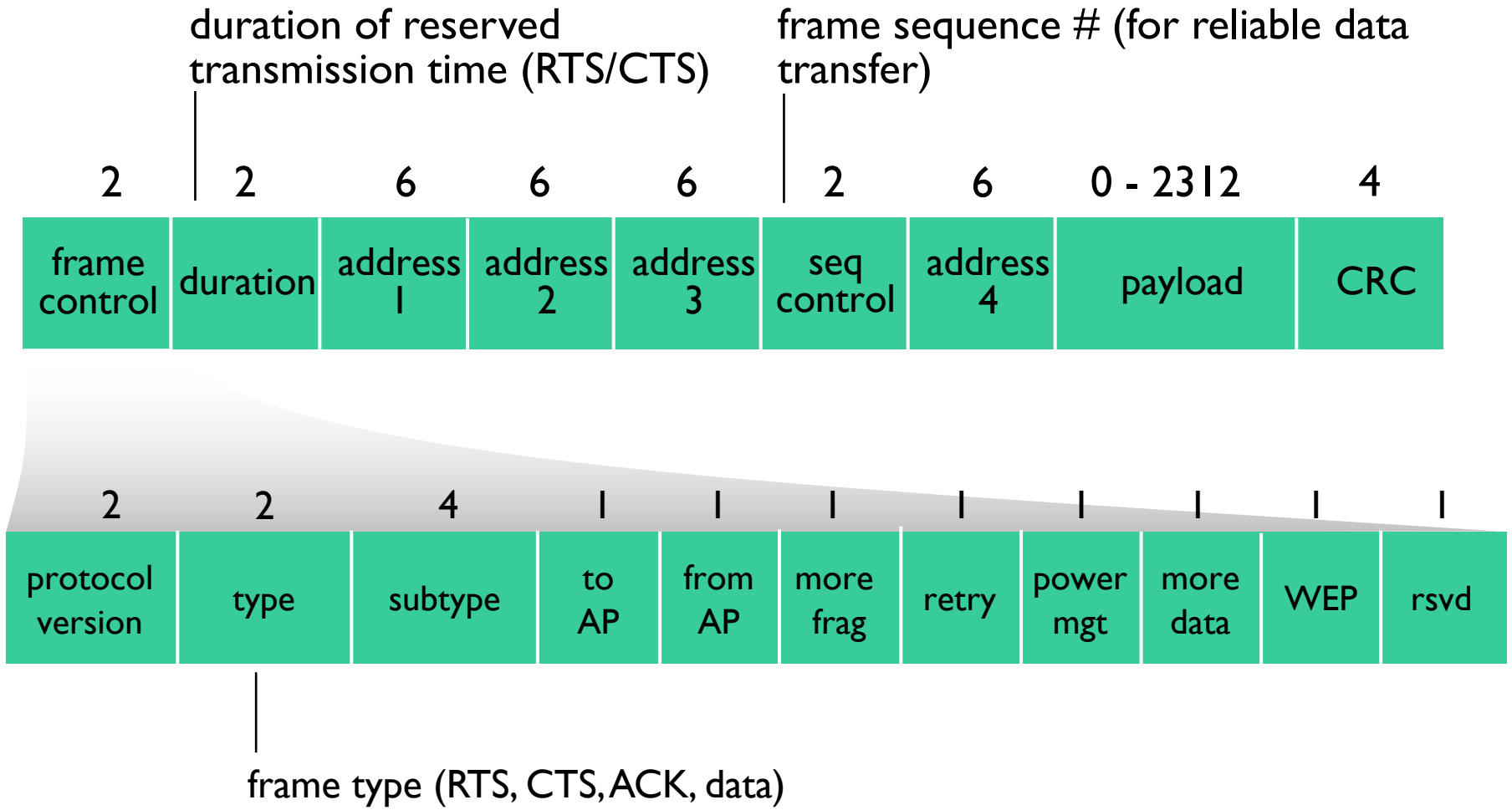
Address 3: MAC address of router interface to which AP is attached

Address 4: used only in ad hoc mode

# 802.11 frame: addressing



# 802.11 frame: addressing



# Outline

1. IEEE 802.11 architecture
2. IEEE 802.11 channel association
3. IEEE 802.11 MAC layer Collision Avoidance
4. IEEE advanced features

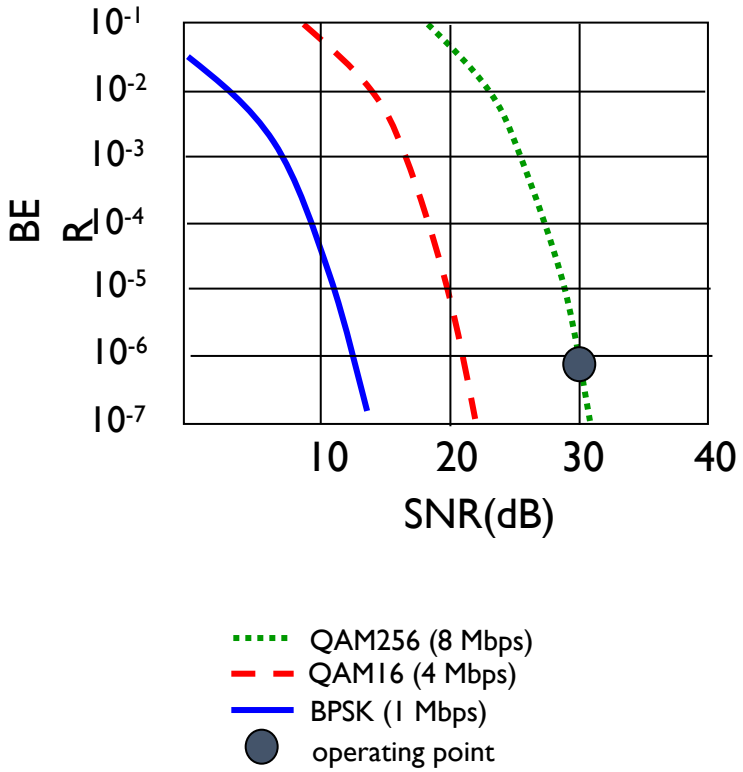
# 802.11: advanced capabilities

## Rate adaptation

- base station, mobile dynamically change transmission rate (physical layer modulation technique) as mobile moves, SNR varies

1. SNR decreases, BER increase as node moves away from base station

2. When BER becomes too high, switch to lower transmission rate but with lower BER



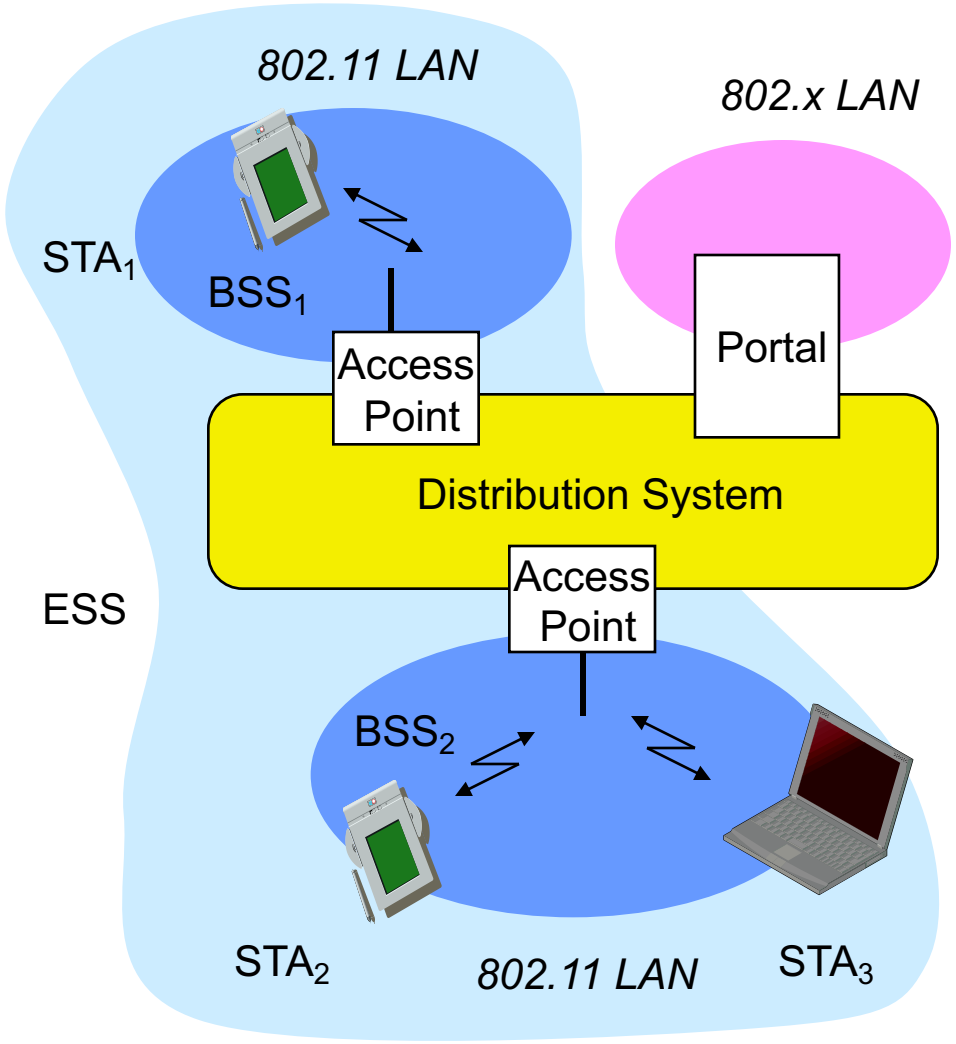
# 802.11: advanced capabilities

## power management

- node-to-AP: "I am going to sleep until next beacon frame"
  - AP knows not to transmit frames to this node
  - node wakes up before next beacon frame
- beacon frame: contains list of mobiles with AP-to-mobile frames waiting to be sent
  - node will stay awake if AP-to-mobile frames to be sent; otherwise sleep again until next beacon frame

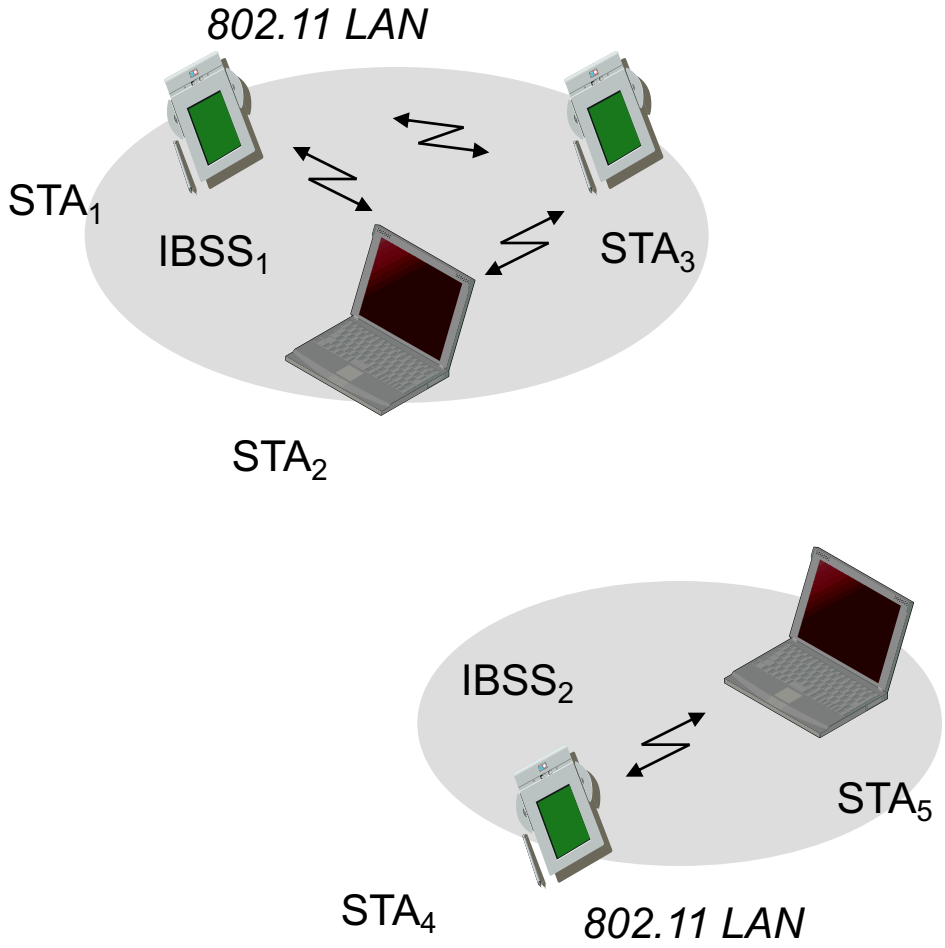
# Backup Slides

# 802.11: Infrastructure



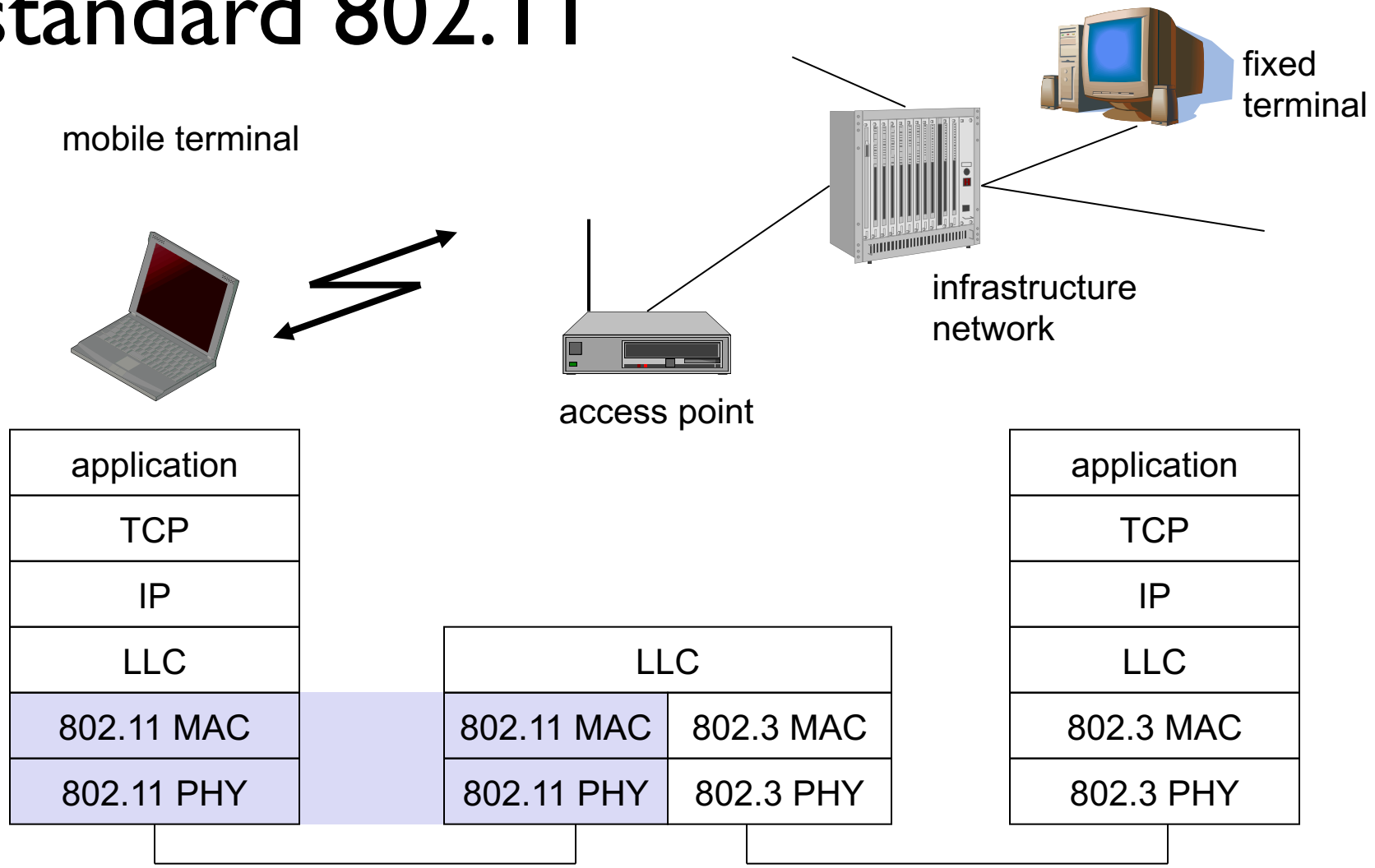

- **Station (STA)**
  - terminal with access mechanisms to the wireless medium and radio contact to the access point
- **Access Point**
  - station integrated into the wireless LAN and the distribution system
- **Basic Service Set (BSS)**
  - group of stations using the same AP
- **Portal**
  - bridge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

# 802.11: Ad hoc mode




- **Direct communication within a limited range**
  - Station (STA): terminal with access mechanisms to the wireless medium
  - Independent Basic Service Set (IBSS): group of stations using the same network

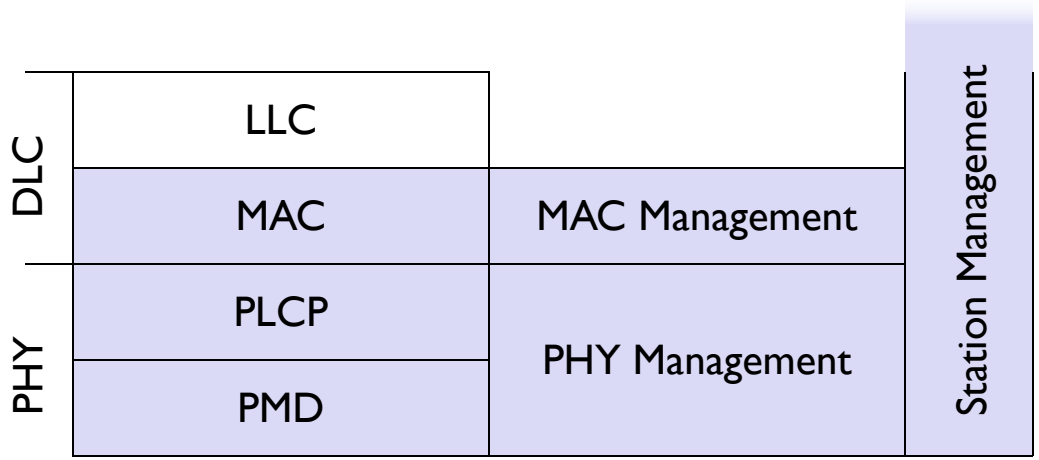
# IEEE standard 802.11



# 802.11 - Layers and functions

- MAC
  - access mechanisms, fragmentation, error control, encryption
- MAC Management
  - synchronization, roaming, power management

- PLCP Physical Layer Convergence Protocol
  - clear channel assessment signal (carrier sense)
- PMD Physical Medium Dependent
  - modulation, coding
- PHY Management
  - channel selection
- Station Management
  - coordination of all management functions



# Acknowledgements

Slides are adopted from Kurose' Computer Networking Slides