

# Wireless and Mobile Networks

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Audio/Video recordings of this lecture are available on-line at:

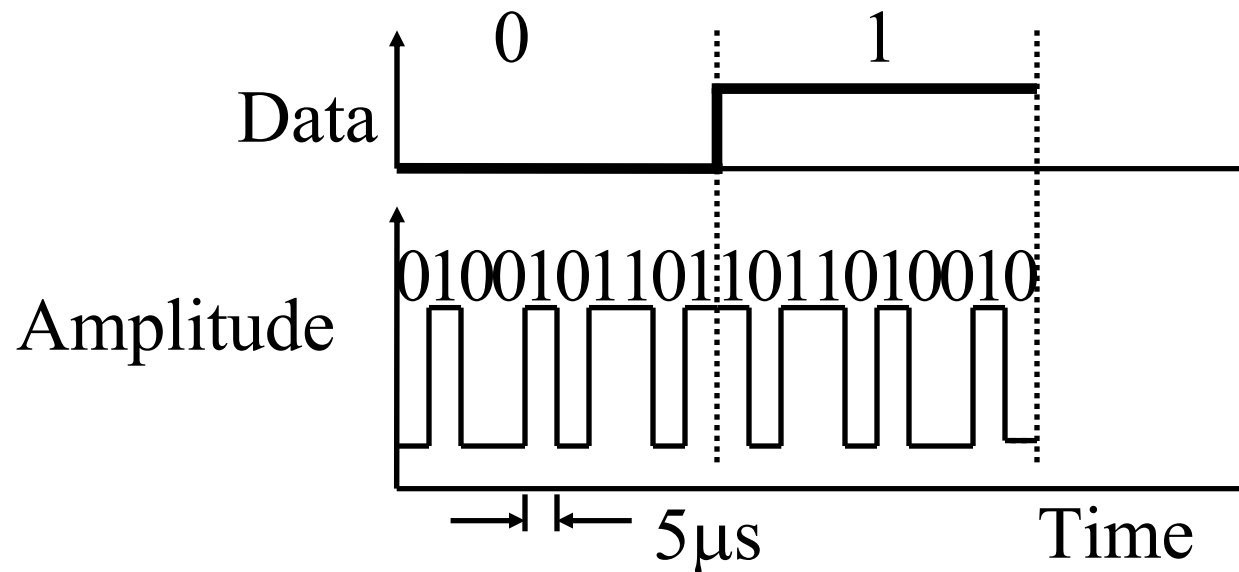
<http://www.cse.wustl.edu/~jain/cse473-11/>



1. Code Division Multiple Access
2. IEEE 802.11 Wireless LAN PHYs
3. IEEE 802.11 MAC
4. IEEE 802.11 Architecture
5. 802.11 Frame Format and Addressing
6. 802.11 Rate Adaptation and Power Management

**Note:** This class lecture is based on Chapter 6 of the textbook (Kurose and Ross) and the figures provided by the authors.

# Direct-Sequence Spread Spectrum CDMA

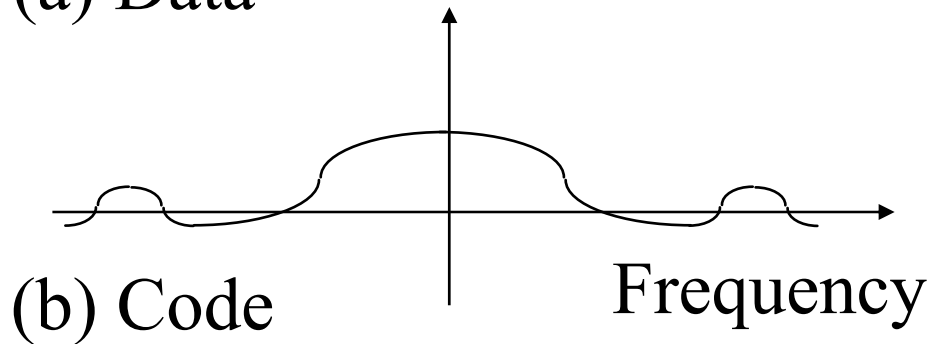
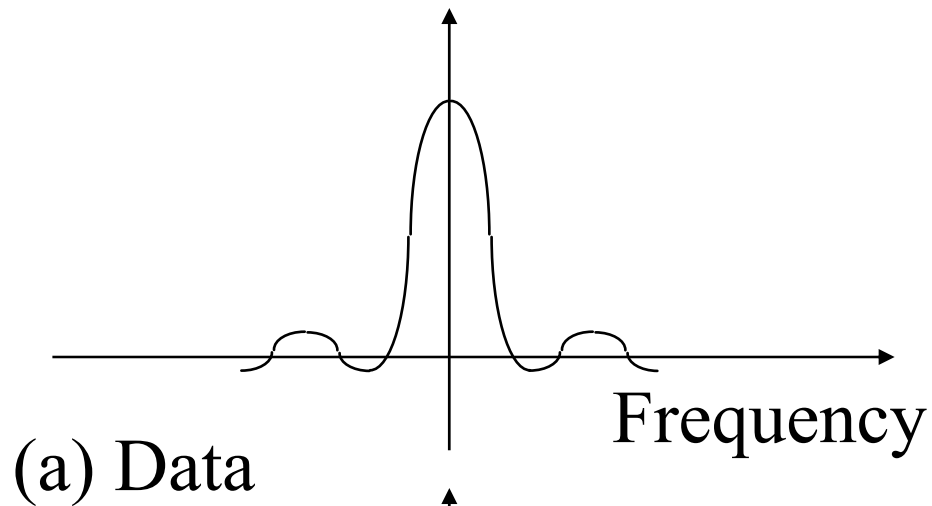
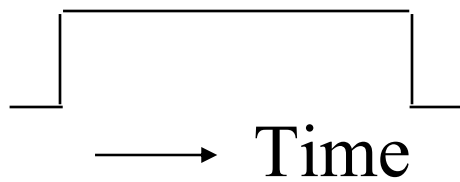


- ❑ Spreading factor = Code bits/data bit, 10-100 commercial (Min 10 by FCC), 10,000 for military
- ❑ Signal bandwidth  $>10 \times$  data bandwidth
- ❑ Code sequence synchronization
- ❑ Correlation between codes  $\Rightarrow$  Interference  $\Rightarrow$  Orthogonal

# DS Spectrum

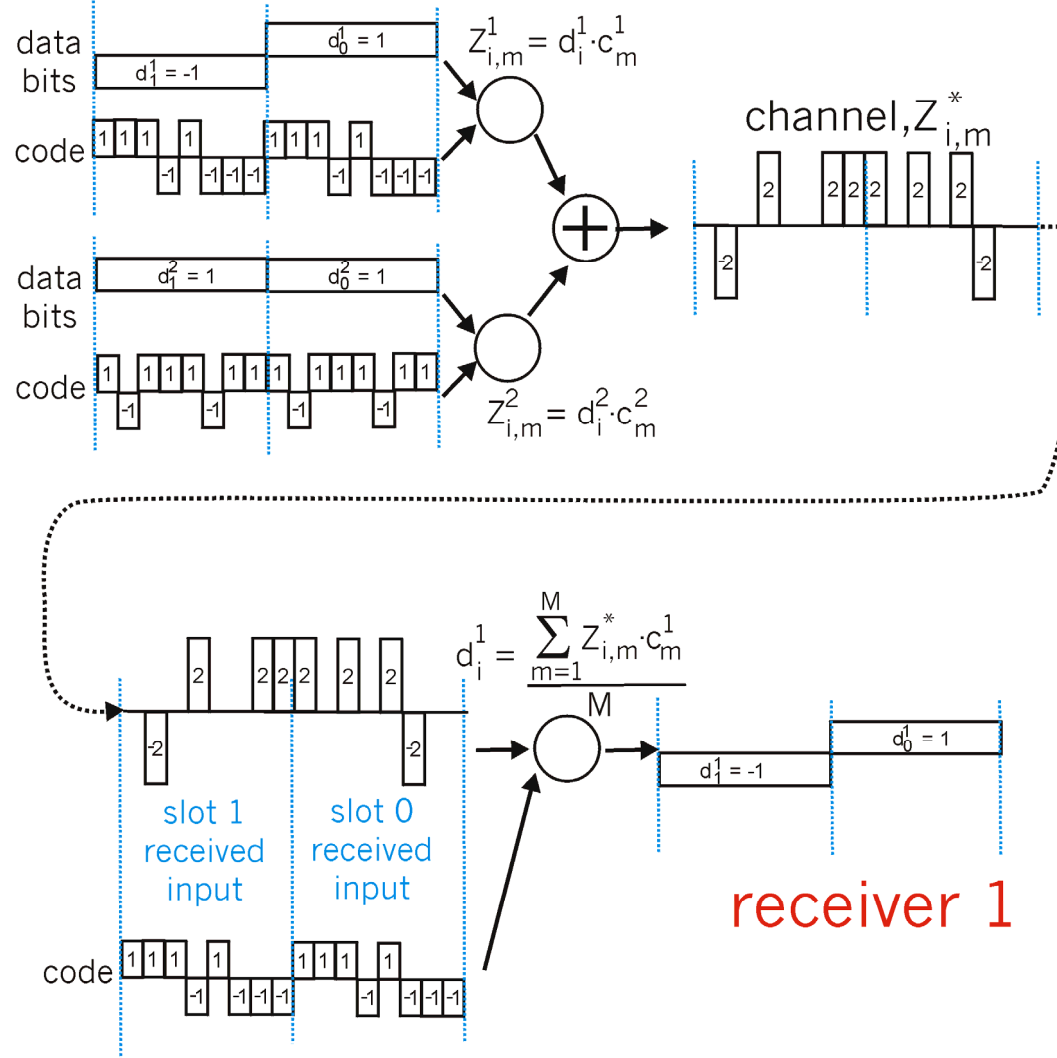
Time Domain

Frequency Domain



# Two Sender CDMA Example

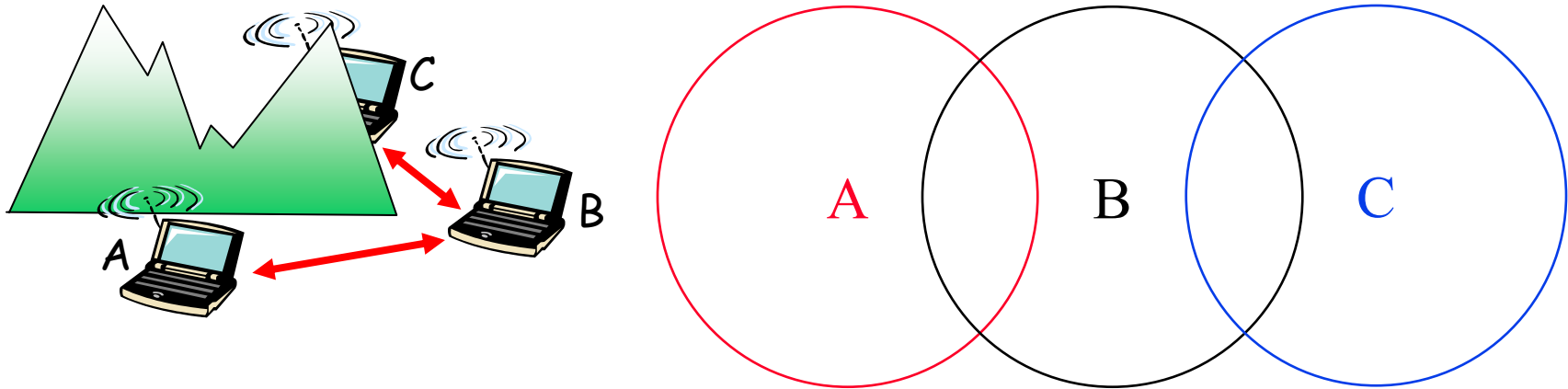
senders



## Homework 6A

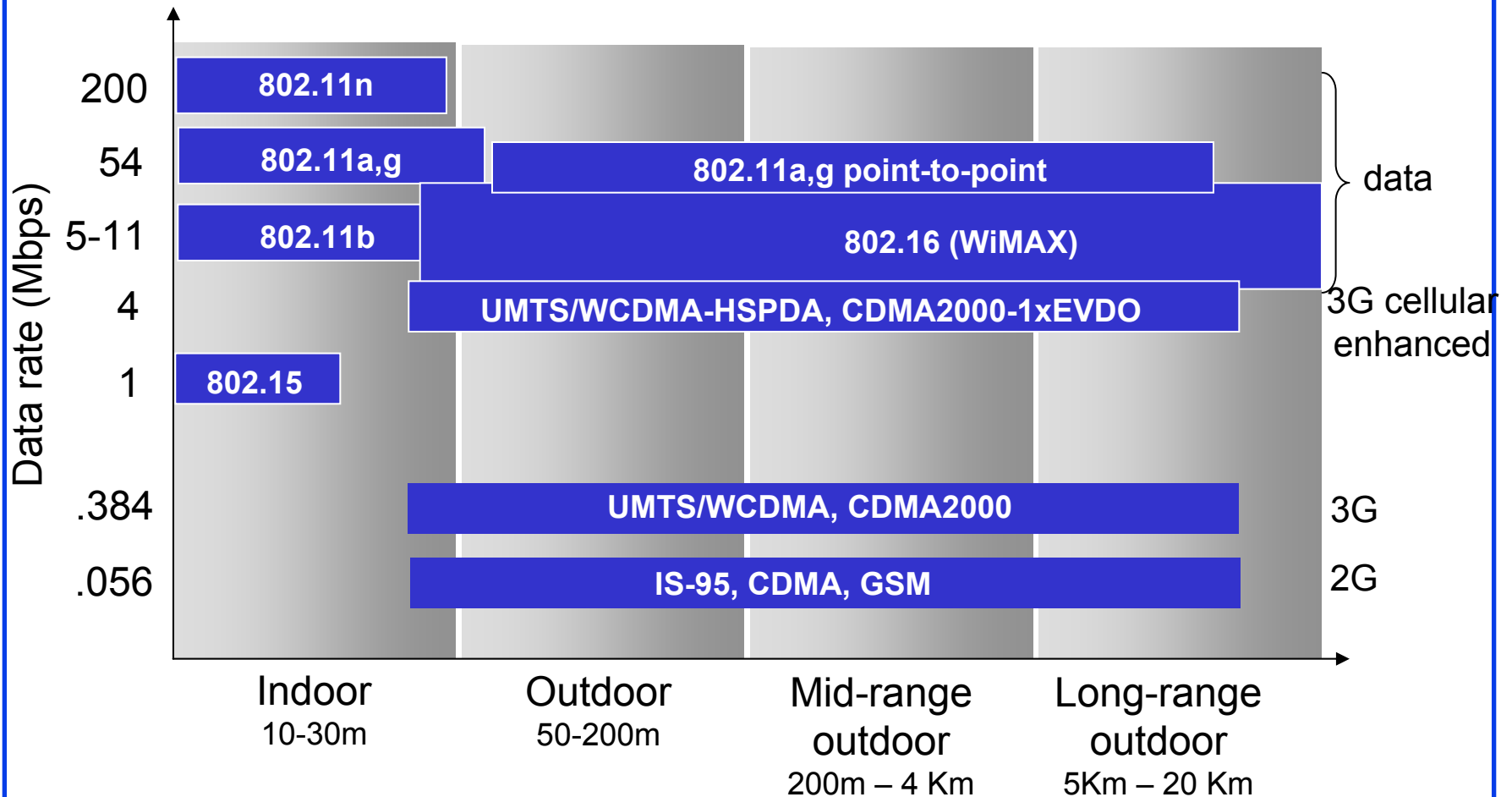
- Two CDMA sender use the codes of  $(1, -1, 1, -1)$  and  $(-1, 1, -1, 1)$ . First sender transmits data bit 1 while the 2<sup>nd</sup> transmits  $-1$  at the same time. What is the combined signal waveform seen by a receiver? Draw the waveform.

# Hidden Node Problem



- ❑ B and A can hear each other  
B and C can hear each other  
A and C cannot hear each other  
⇒ C is hidden for A and vice versa
- ❑ C may start transmitting while A is also transmitting  
A and C can't detect collision.
- ❑ Only the receiver can help avoid collisions

# Characteristics of Selected Wireless Link Standards

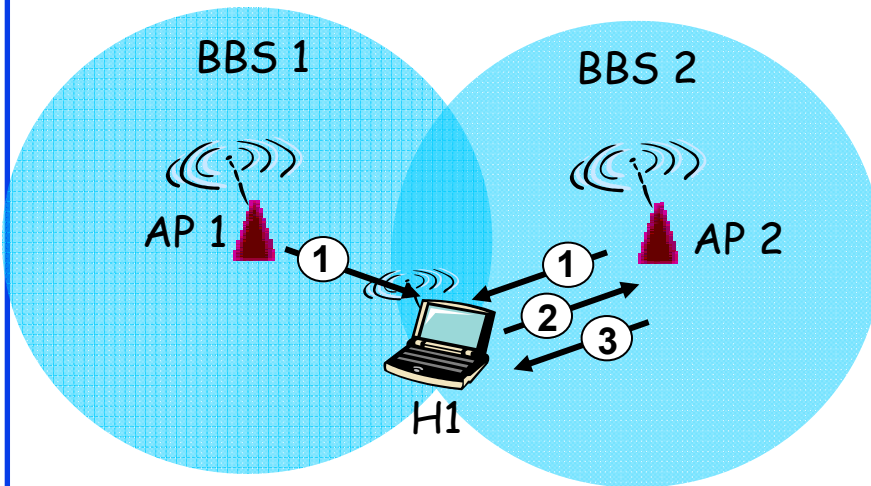




# IEEE 802.11 Wireless LAN PHYs

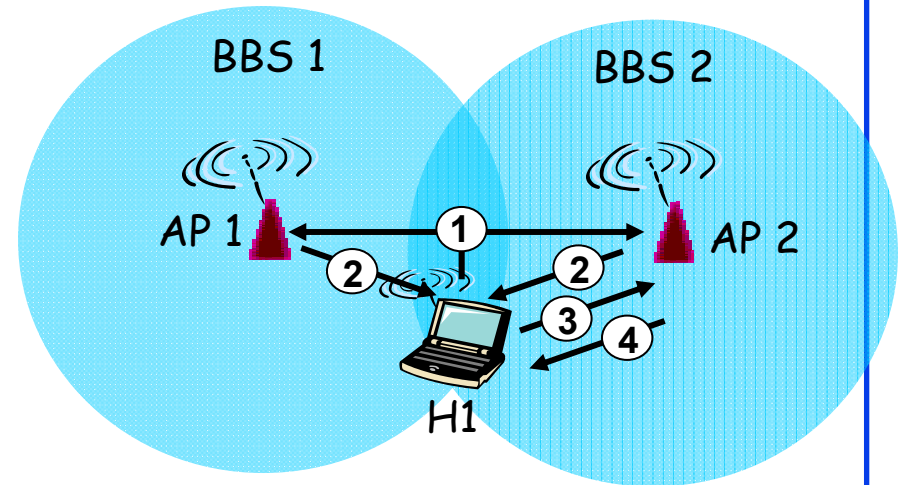
- ❑ **802.11**: 2.4 GHz, 1-2 Mbps
- ❑ **802.11b**: 2.4 GHz, 11 Mbps nominal
  - ❑ Direct sequence spread spectrum (DSSS) in physical layer
  - ❑ All hosts use the same chipping code
- ❑ **802.11a**: 5.8 GHz band, 54 Mbps nominal
- ❑ **802.11g**: 2.4 GHz band, 54 Mbps nominal
- ❑ **802.11n**: 2.4 or 5.8 GHz, Multiple antennae, up to 200 Mbps
- ❑ These are different PHY layers. All have the same MAC layer.
- ❑ All use CSMA/CA for multiple access
- ❑ All have base-station and ad-hoc network versions
- ❑ Supports multiple priorities
- ❑ Supports time-critical and data traffic
- ❑ Power management allows a node to doze off

# 802.11: Passive/Active Scanning



## Passive Scanning:

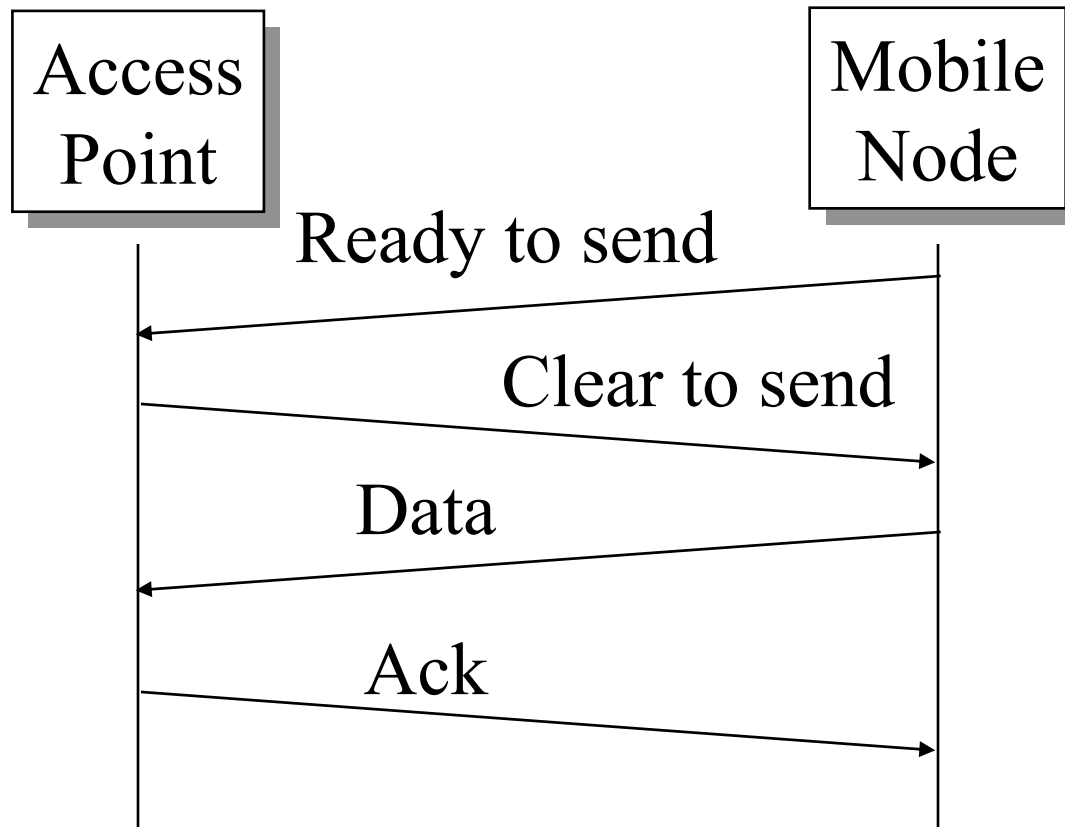
- (1) Beacon frames sent from APs
- (2) Association Request frame sent: H1 to selected AP
- (3) Association Response frame sent: selected AP to H1



## Active Scanning:

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

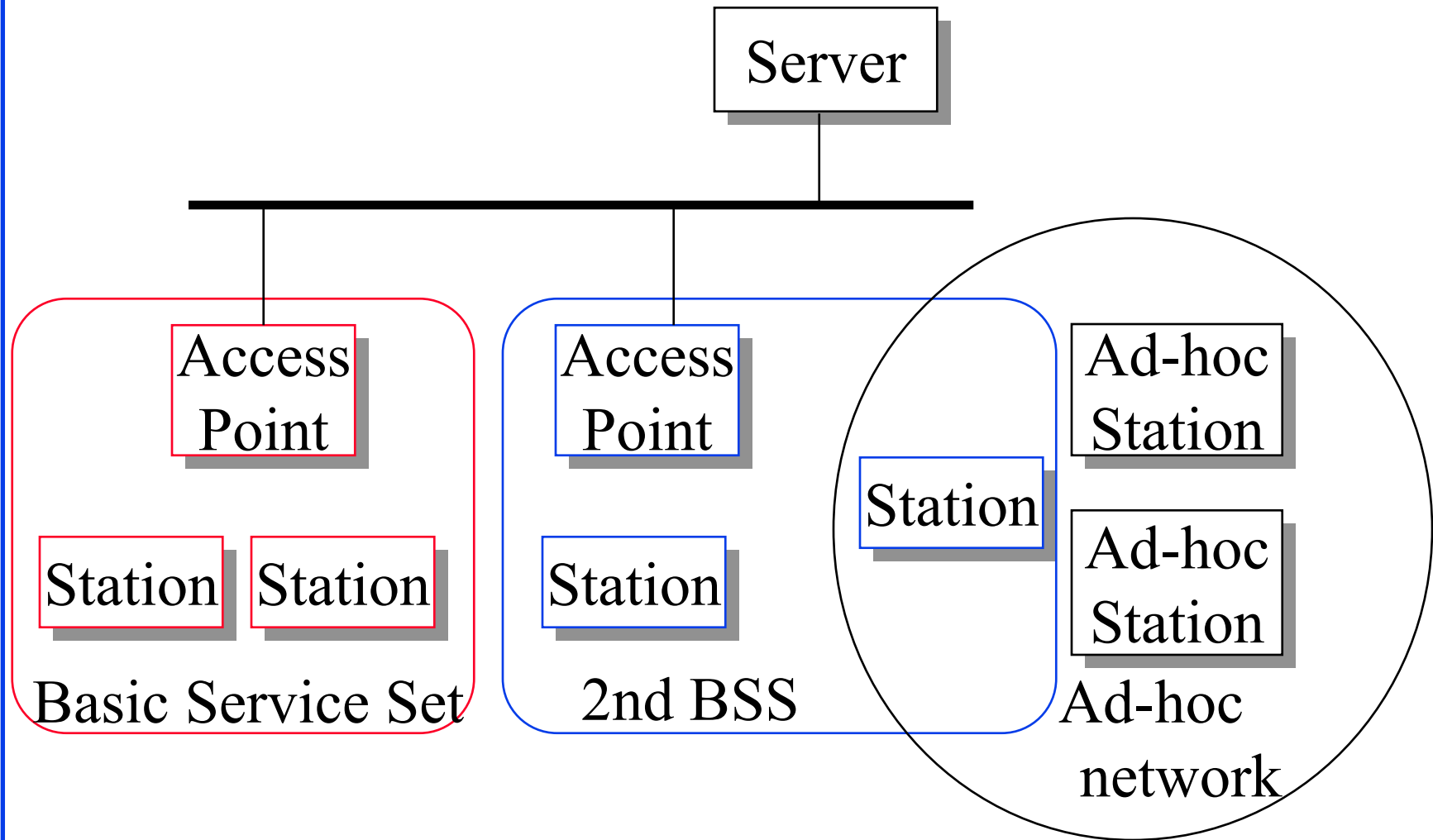
# 4-Way Handshake



# IEEE 802.11 MAC

- ❑ Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA)
- ❑ Listen before you talk. If the medium is busy, the transmitter backs off for a random period.
- ❑ Avoids collision by sending a short message: Ready to send (RTS)  
RTS contains dest. address and duration of message.  
Tells everyone to backoff for the duration.
- ❑ Destination sends: Clear to send (CTS)
- ❑ Can not detect collision  $\Rightarrow$  Each packet is acked.
- ❑ MAC level retransmission if not acked.

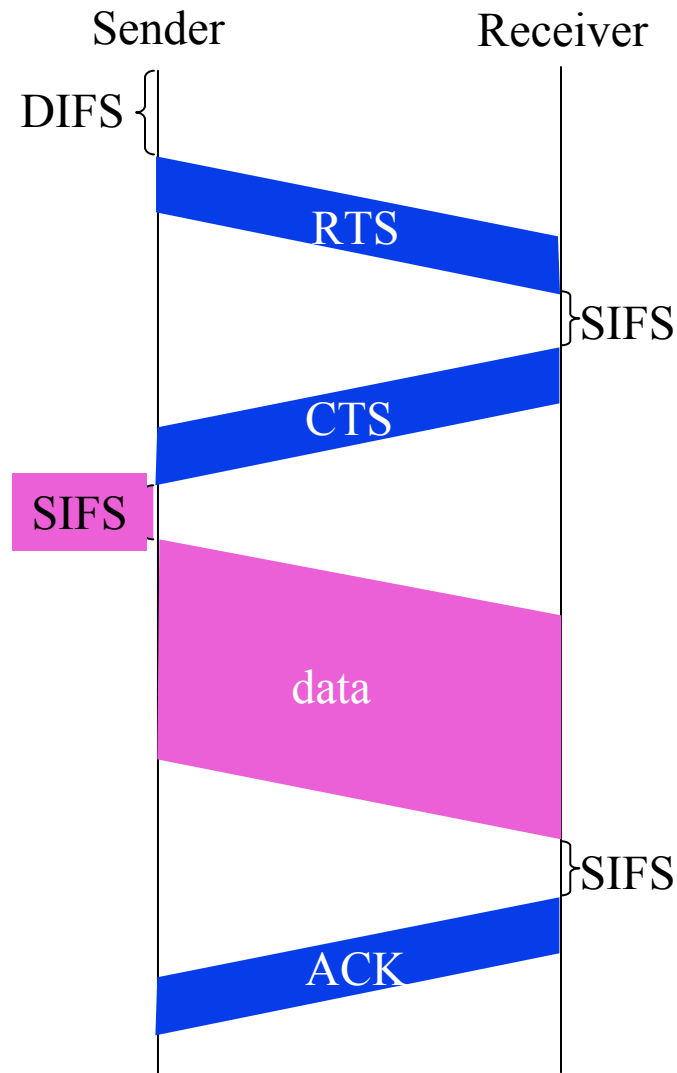
# IEEE 802.11 Architecture



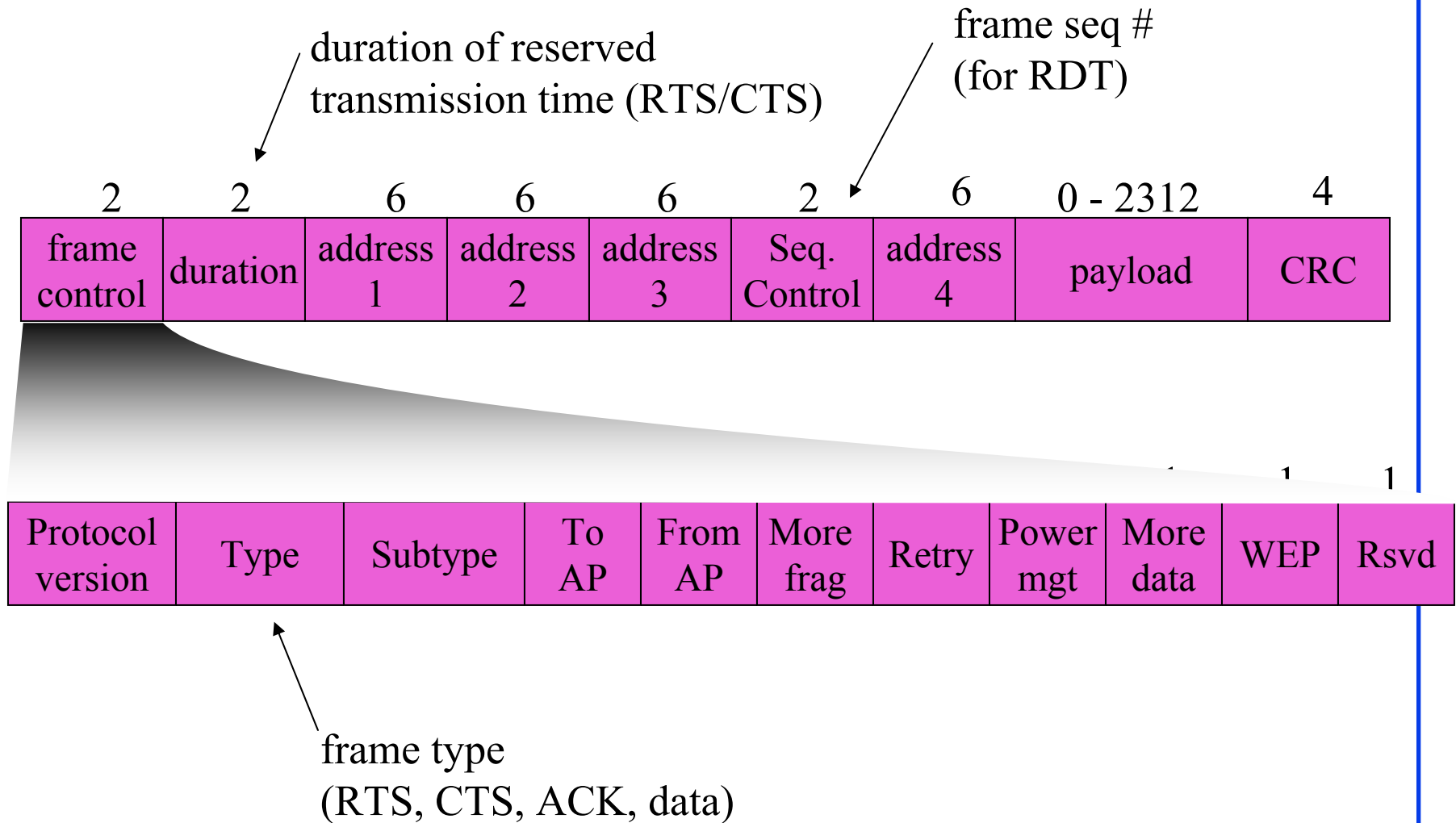
## Architecture (Cont)

- ❑ Basic Service Area (BSA) = Cell
- ❑ Each BSA may have several wireless LANs
- ❑ Extended Service Area (ESA) = Multiple BSAs interconnected via Access Points (AP)
- ❑ Basic Service Set (BSS)  
= Set of stations associated with an AP
- ❑ Extended Service Set (ESS)  
= Set of stations in an ESA
- ❑ Ad-hoc networks coexist and interoperate with infrastructure-based networks.

# Transmission Example

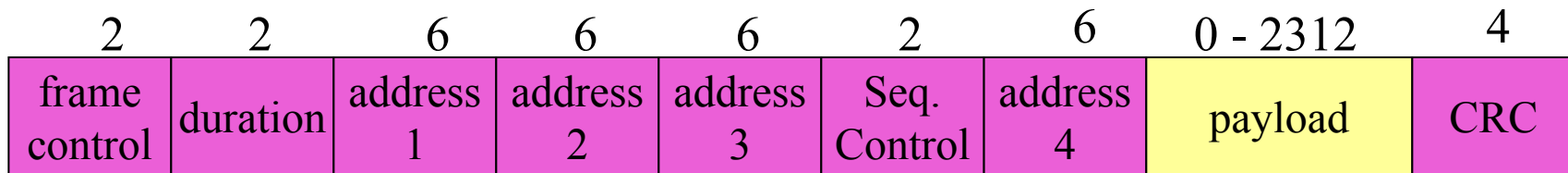


# 802.11 Frame Format





# 802.11 Frame Addressing



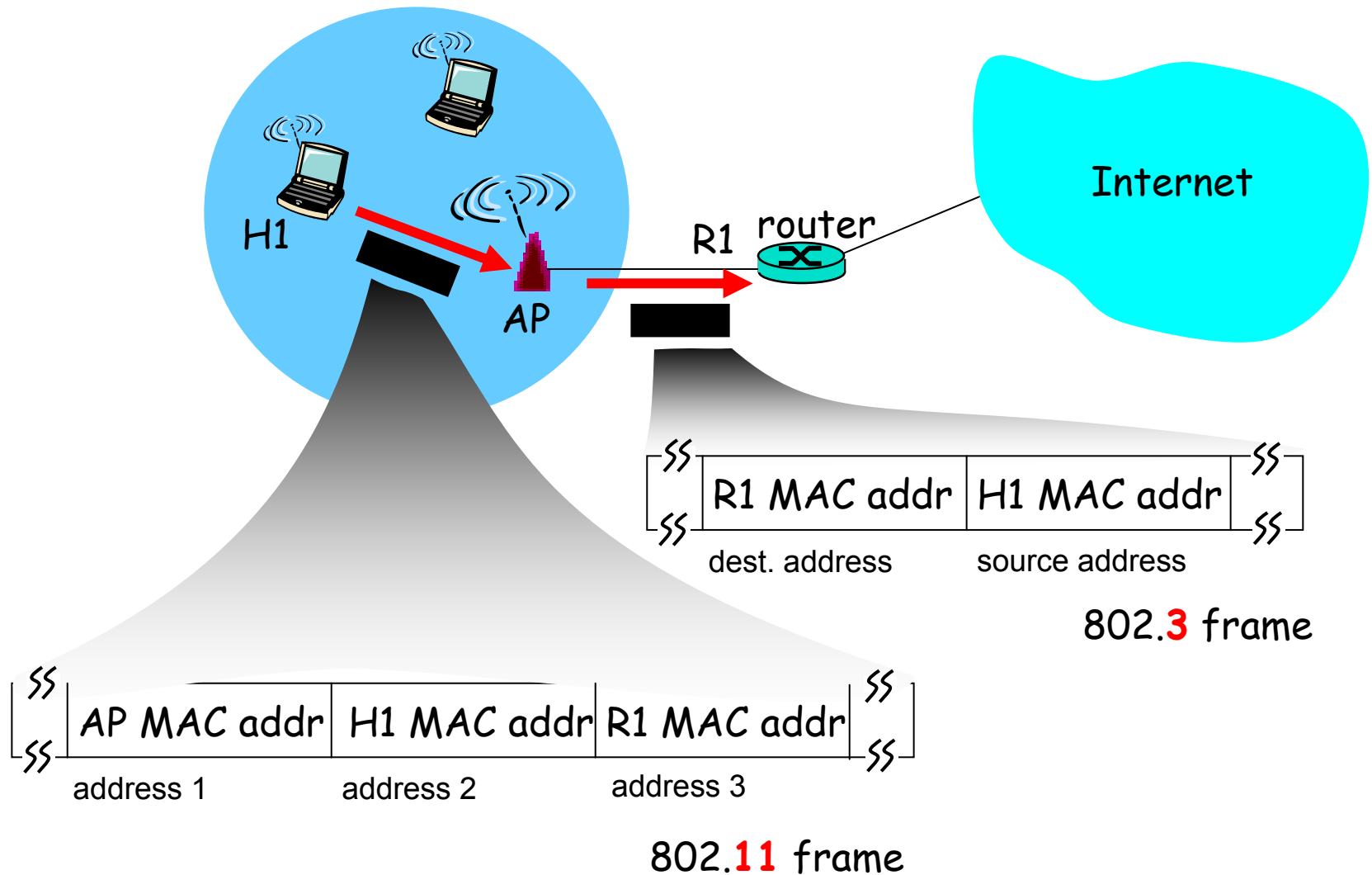
**Address 1:** MAC address of wireless host or AP to receive this frame

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

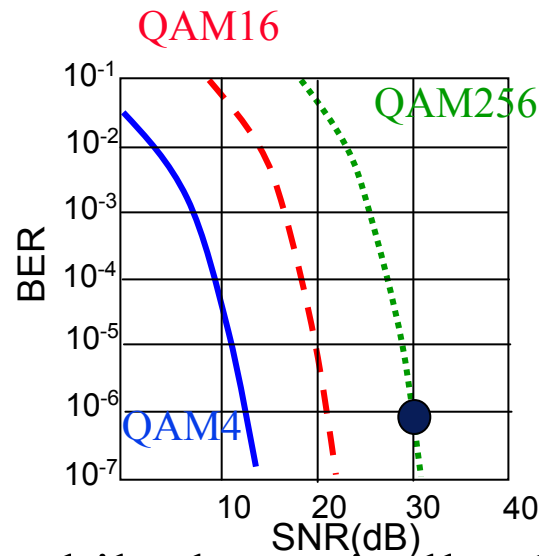
**Address 3:** MAC address of router interface to which AP is attached

**Address 4:** used only in ad hoc mode

# 802.11 Frame Addressing (Cont)



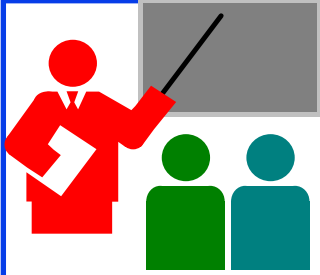
# 802.11 Rate Adaptation



- ❑ Base station and mobile dynamically change transmission rate (physical layer modulation technique) as mobile moves, SNR varies
- ❑ SNR decreases  $\Rightarrow$  BER increase as node moves away from base station
- ❑ When BER becomes too high, switch to lower transmission rate but with lower BER

# Power Management

- ❑ A station can be in one of three states:
  - ❑ Transmitter on
  - ❑ Receiver only on
  - ❑ Dozing: Both transmitter and receivers off.
- ❑ Access point (AP) buffers traffic for dozing stations.
- ❑ AP announces which stations have frames buffered.  
Traffic indication map included in each beacon.  
All multicasts/broadcasts are buffered.
- ❑ Dozing stations wake up to listen to the beacon.  
If there is data waiting for it, the station sends a poll frame to get the data.



# IEEE 802.11 LAN: Review

1. Code Division Multiple Access uses multiple chips to encode each bit
2. IEEE 802.11 PHYs: 11, 11b, 11g, 11a, 11n, ...
3. IEEE 802.11 MAC uses CSMA/CA with a 4-way handshake: RTS, CTS, data, and ack
4. IEEE 802.11 network consists of extended service set consisting of multiple basic service sets each with an AP.
5. 802.11 Frame Format has 4 addresses and includes final destination's MAC which may not be wireless
6. 802.11 has automatic rate adaptation based on error rate. Power management allows stations to sleep.

# Review Exercises

- ❑ Try in a group. Do not submit.
- ❑ Review questions: R1-R8, R9-R11
- ❑ Problems: P1, P2, P3, P4, P5 (Skip P6, P7, P8)
- ❑ Read Pages 523 through 554 (Section 6-1 through 6.3.5)

## Homework 6B

- ❑ Submit answer to following (modified problem P7)
- ❑ Suppose an 802.11b station is configured to always reserve the channel with the RTS/CTS sequence. Suppose this station suddenly wants to transmit 1,000 bytes of data, and all other stations are idle at this time. Using SIFS of 10us and DIFS of 50us, and ignoring propagation delay and assuming no bit errors, calculate the time required to transmit the frame and receive the acknowledgment. Assume a frame without data (RTS/CTS/Ack) is 32 bytes long and the transmission rate is 11 Mbps.