

CS450 Computer Networks

The slides used in class are derived from the slides available on our text book companion website:

http://wps.pearsoned.com/ecs_kurose_compnetw_6/

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CS450 Computer Networks

Lesson 18 - Data Link Layer –

Wireless

Order is present everywhere

Lesson 18

Overview of Wireless Networks

Our goal -- overview of the following:

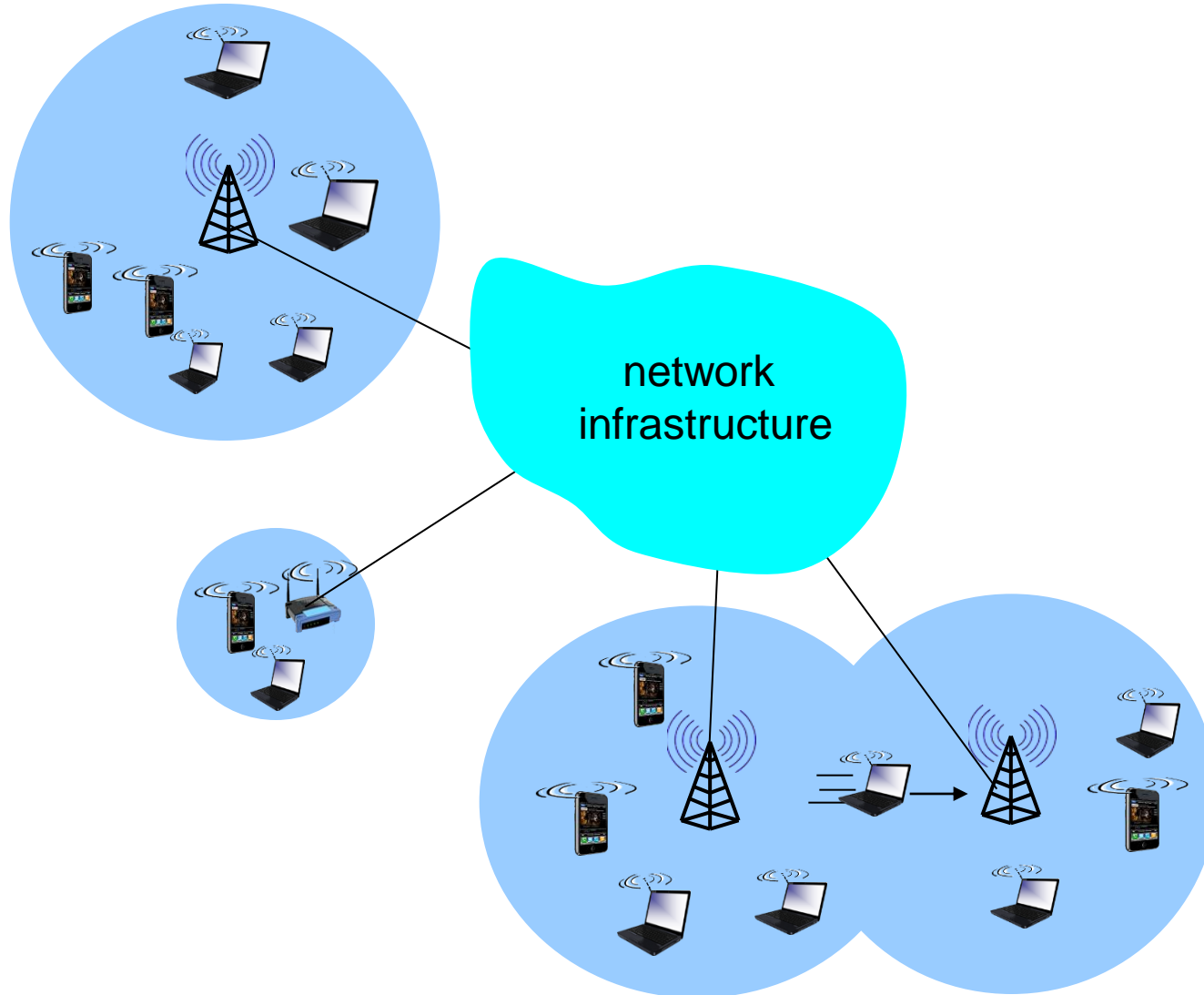
- ❖ Wireless links, characteristics
 - CDMA, TDMA, etc.
- ❖ IEEE 802.11 wireless LANs (Wi-Fi)
- ❖ Briefly consider personal area networks

Ch. 6: Wireless and Mobile Networks

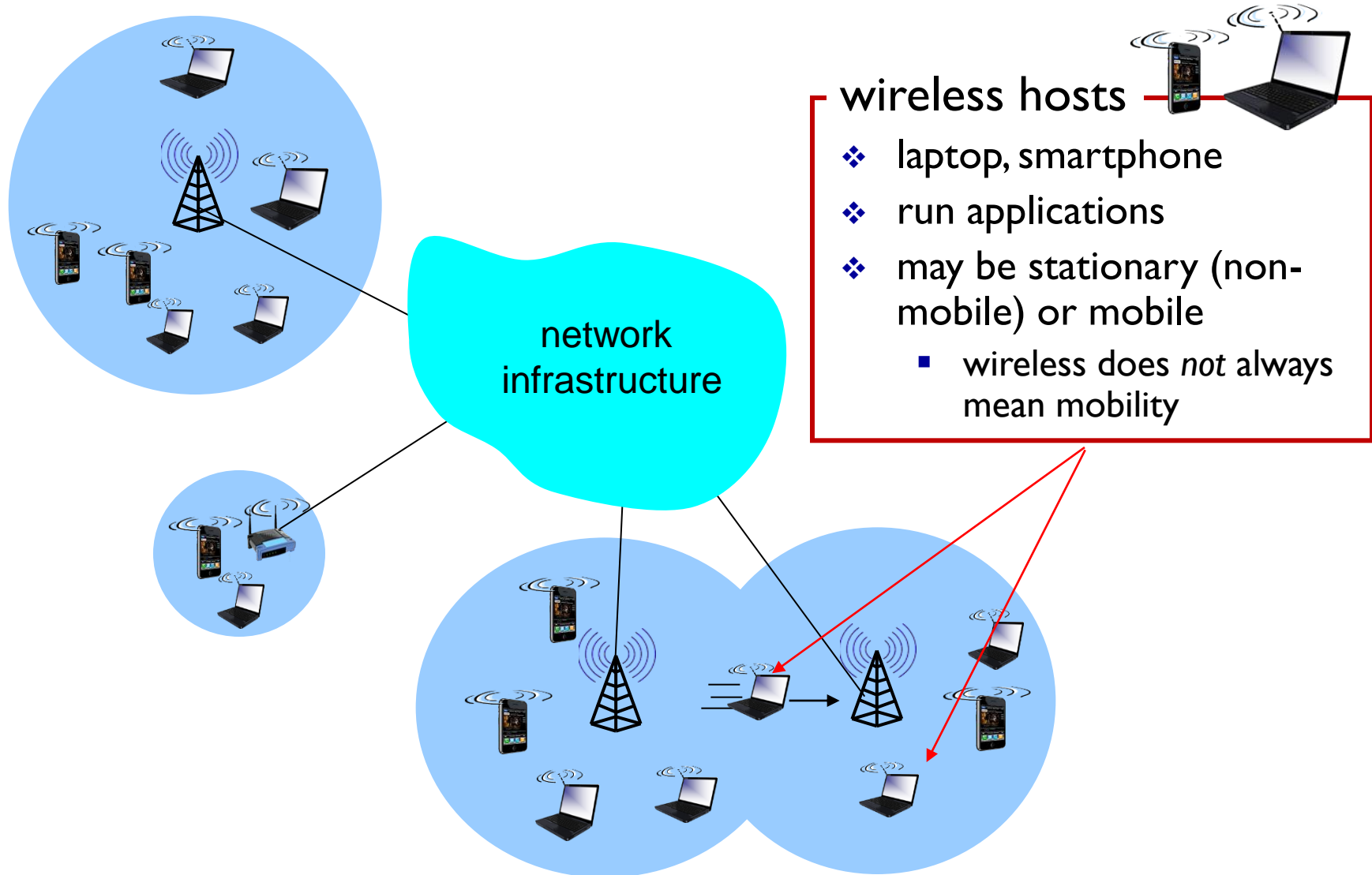
Background:

- ❖ # wireless (mobile) phone subscribers now exceeds # wired phone subscribers (5-to-1)
- ❖ # wireless Internet-connected devices equals # wireline Internet-connected devices
- ❖ two important (but different) challenges
 - *wireless*: communication over wireless link
 - *mobility*: handling the mobile user who changes point of attachment to network

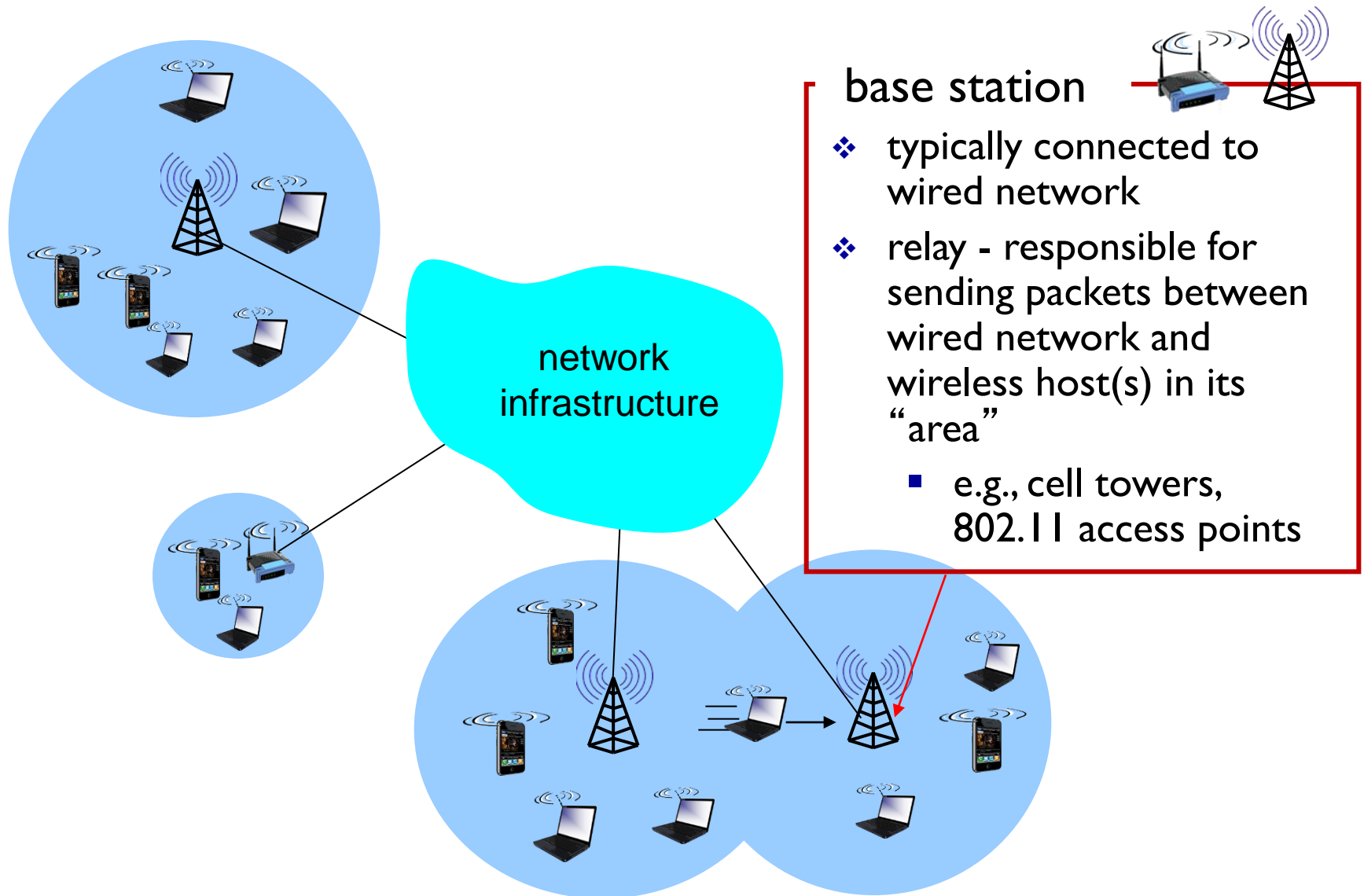
Elements of a wireless network



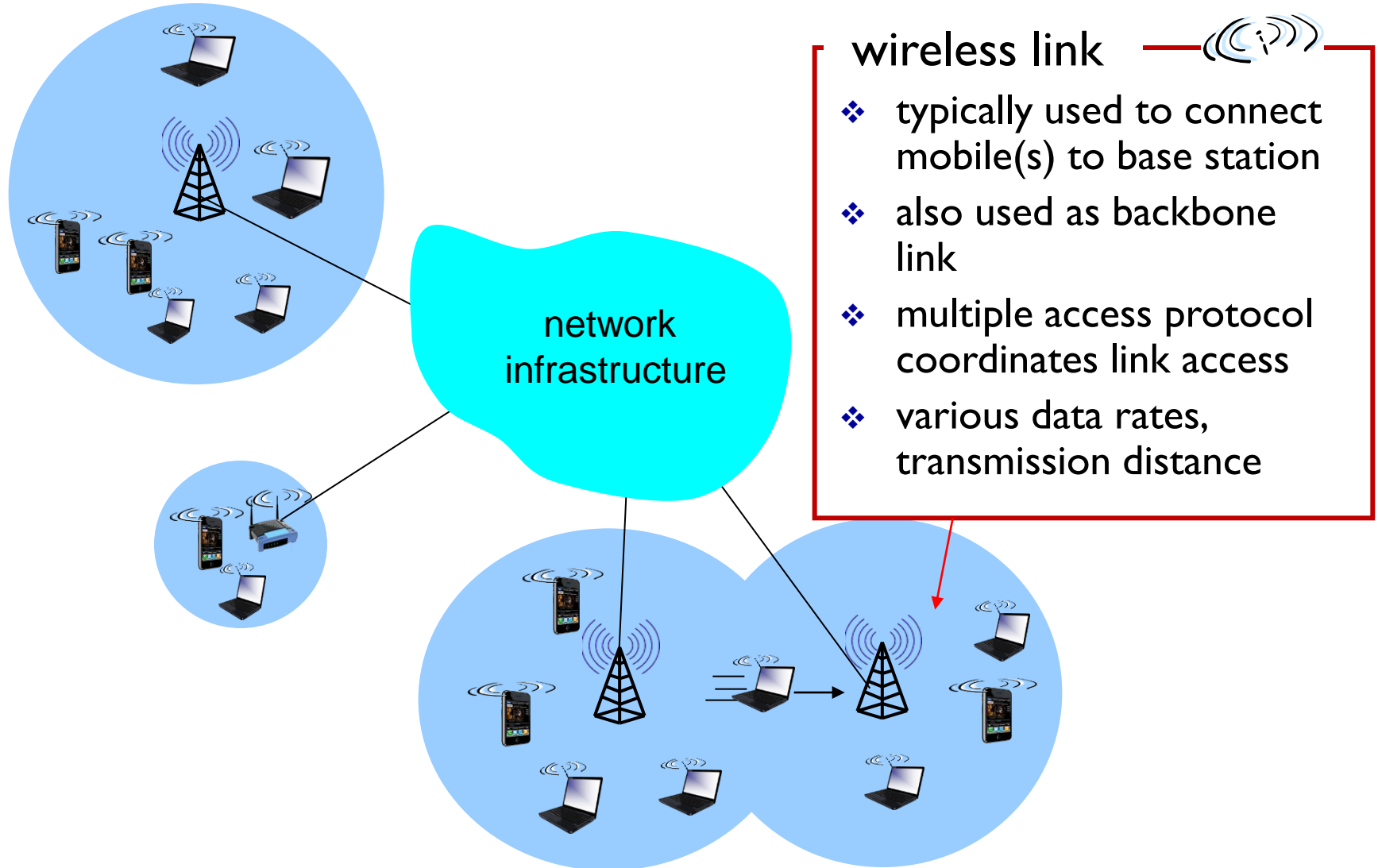
Elements of a wireless network



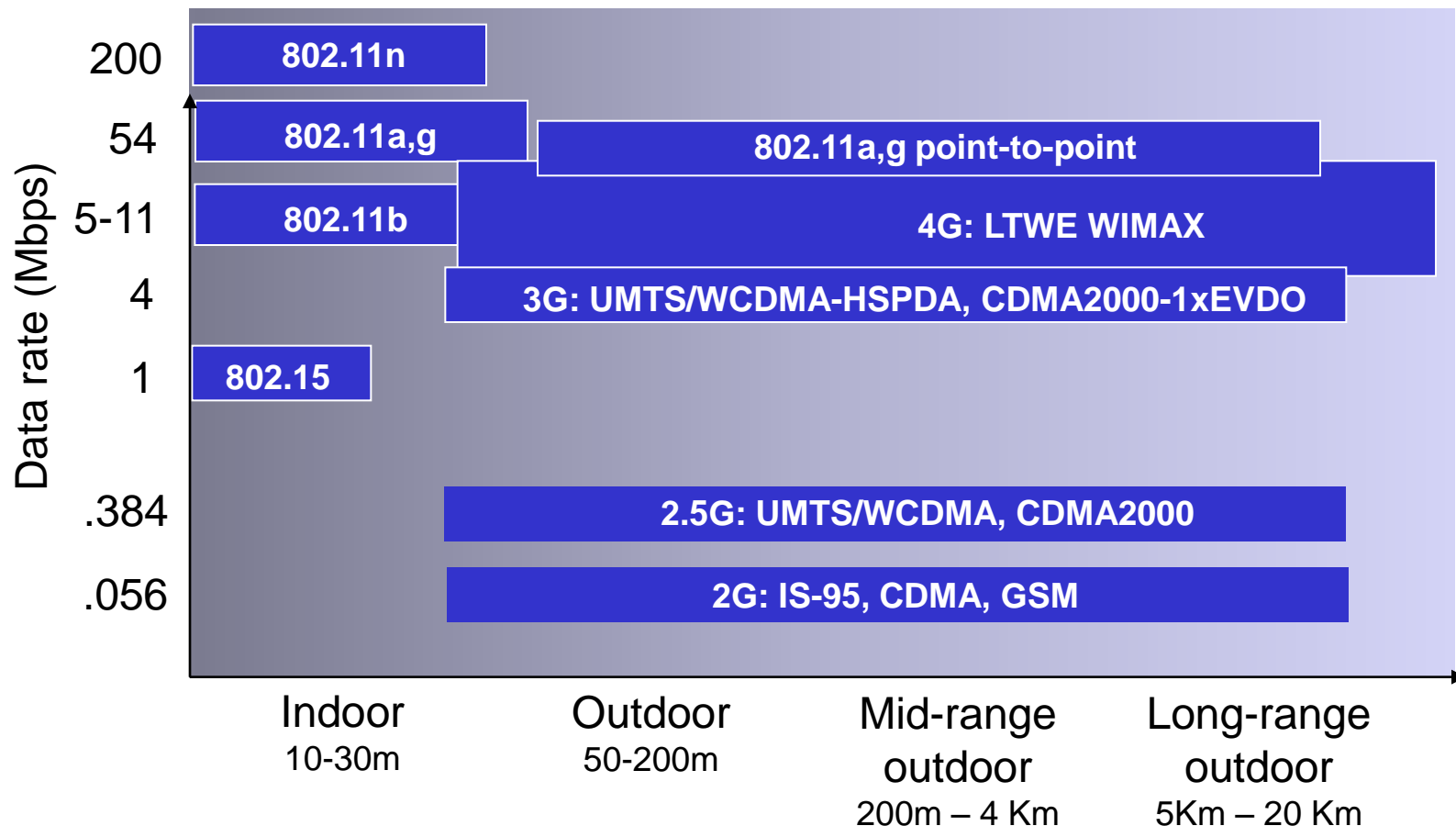
Elements of a wireless network



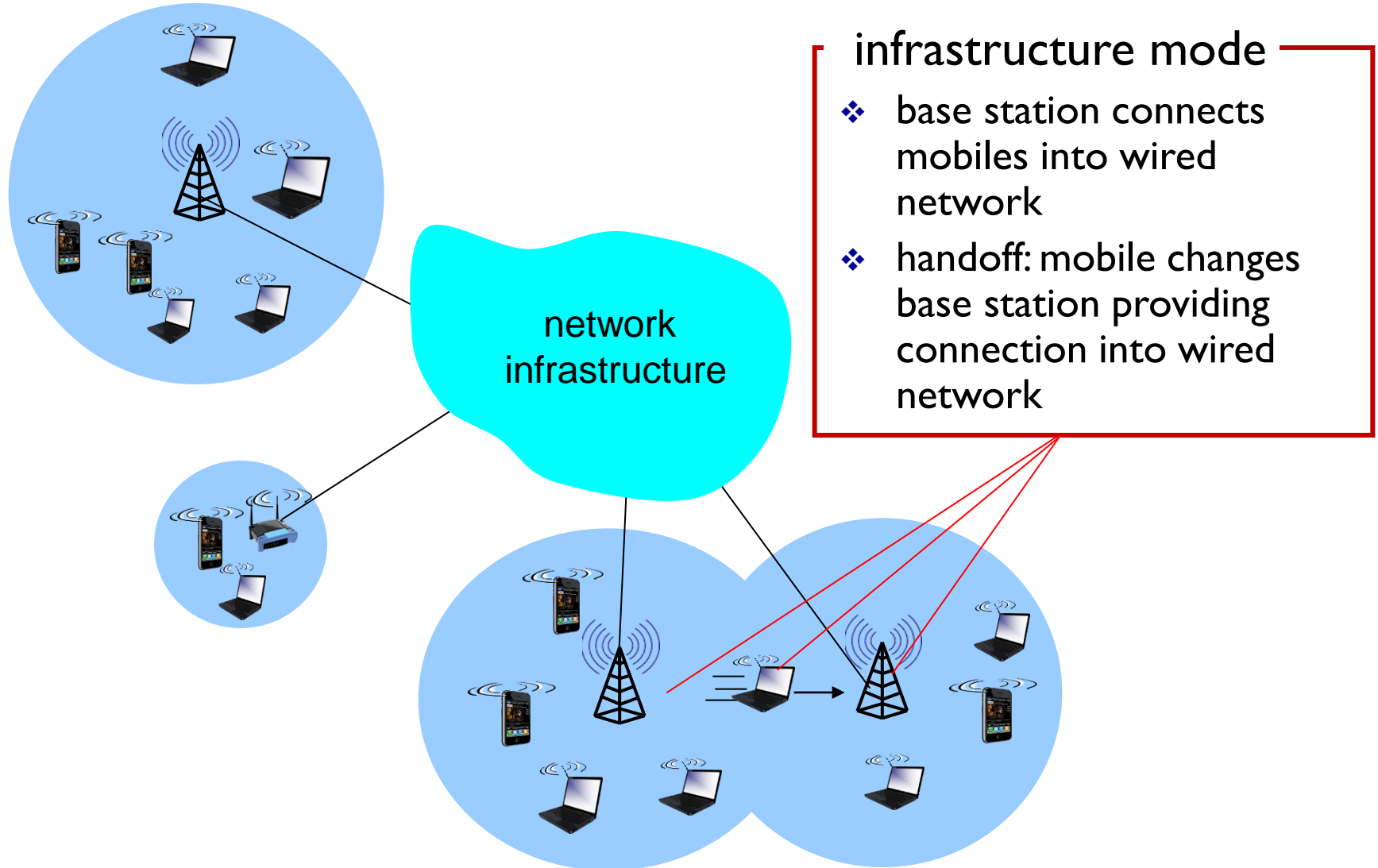
Elements of a wireless network



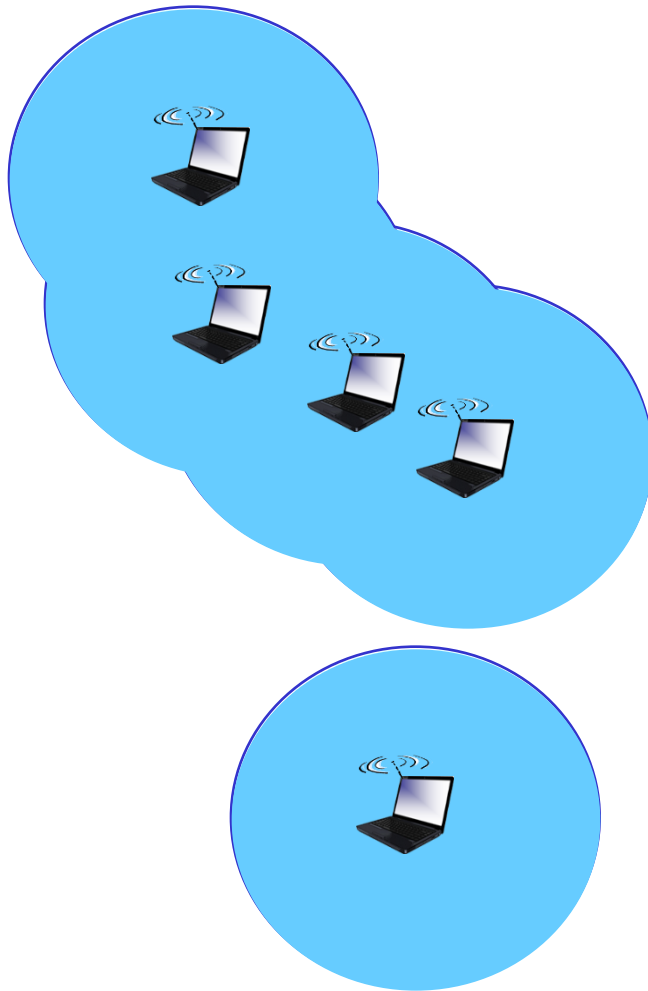
Characteristics of selected wireless links



Elements of a wireless network



Elements of a wireless network



ad hoc mode

- ❖ no base stations
- ❖ nodes can only transmit to other nodes within link coverage
- ❖ nodes organize themselves into a network: route among themselves

Wireless network taxonomy

	single hop	multiple hops
infrastructure (e.g., APs)	host connects to base station (WiFi, WiMAX, cellular) which connects to larger Internet	host may have to relay through several wireless nodes to connect to larger Internet: <i>mesh net</i>
no infrastructure	no base station, no connection to larger Internet (Bluetooth, ad hoc nets)	no base station, no connection to larger Internet. May have to relay to reach other a given wireless node MANET, VANET

Wireless Link Characteristics (I)

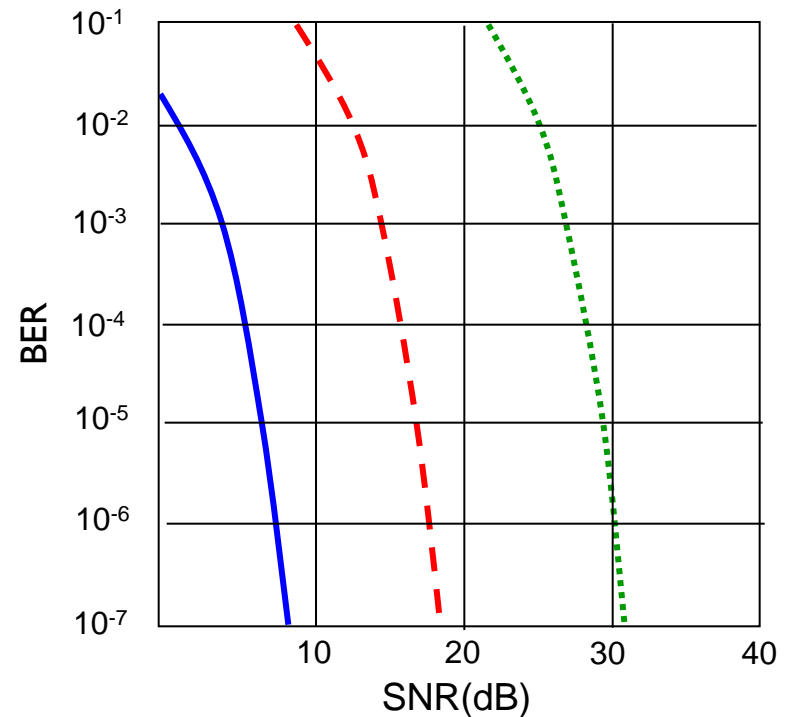
important differences from wired link

- *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 and ground, arriving at destination at slightly different times

.... make communication across (even a point to point) wireless link much more “difficult”

Wireless Link Characteristics (2)

- ❖ SNR: signal-to-noise ratio
 - larger SNR – easier to extract signal from noise (a “good thing”)
- ❖ *SNR versus BER tradeoffs*
 - *given physical layer*: increase power \rightarrow increase SNR \rightarrow decrease BER
 - *given SNR*: choose physical layer that meets BER requirement, giving highest throughput
 - SNR may change with mobility: dynamically adapt physical layer (modulation technique, rate)



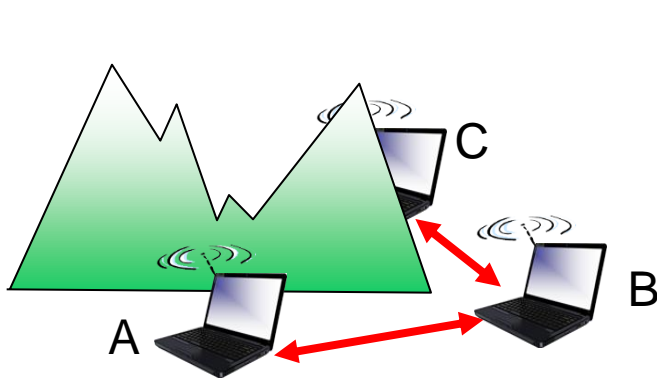
..... QAM256 (8 Mbps)

- - - QAM16 (4 Mbps)

— BPSK (1 Mbps)

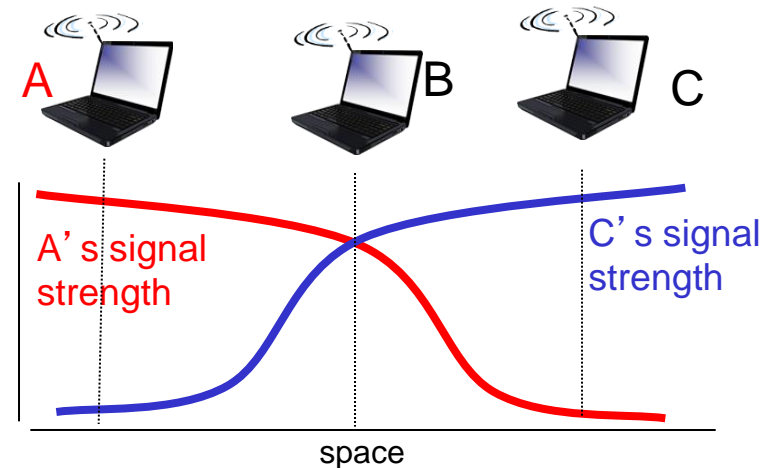
Wireless network characteristics

Multiple wireless senders and receivers create additional problems (beyond multiple access):



Hidden terminal problem

- ❖ B, A hear each other
- ❖ B, C hear each other
- ❖ A, C can not hear each other means A, C unaware of their interference at B



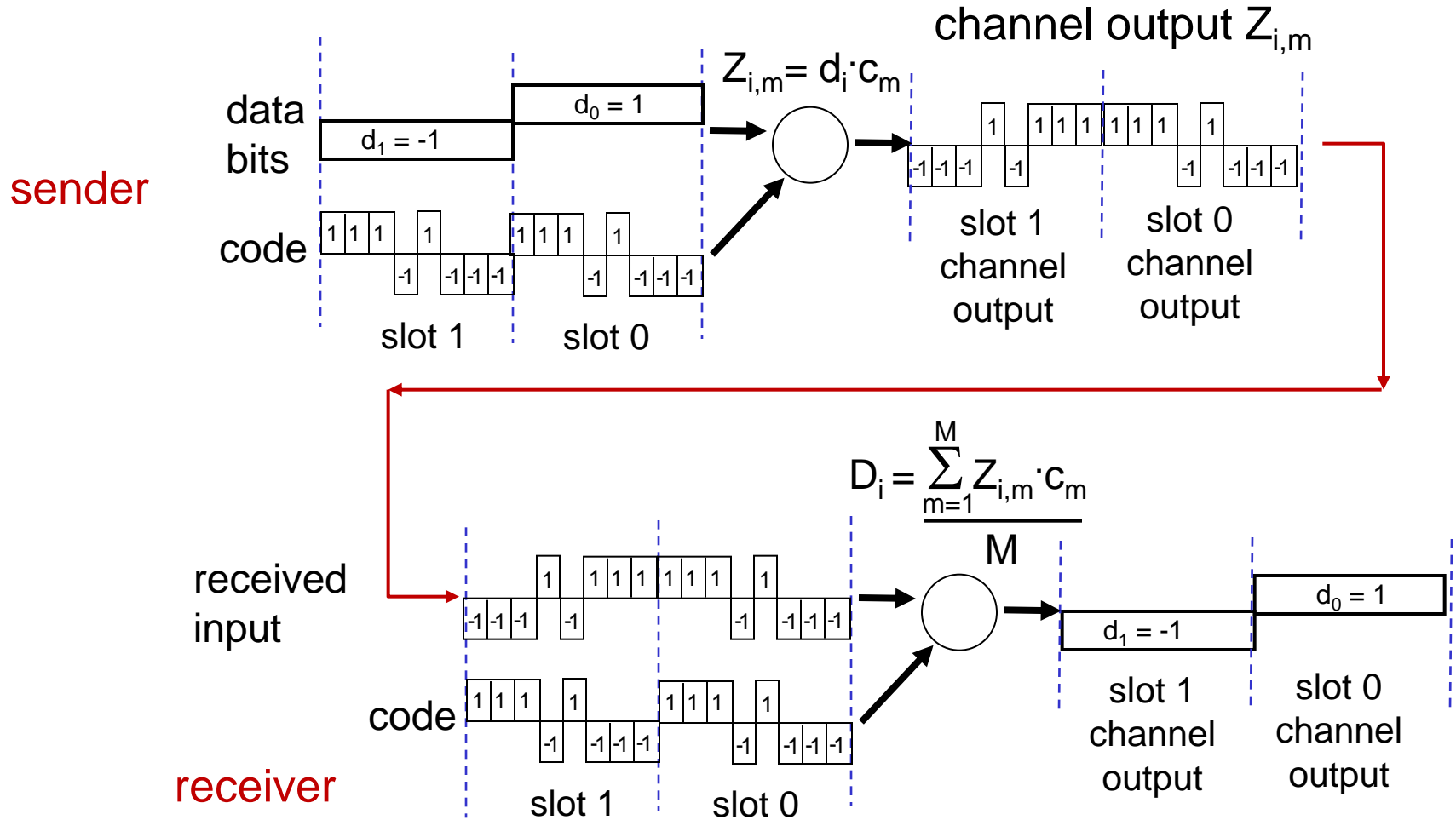
Signal attenuation:

- ❖ B, A hear each other
- ❖ B, C hear each other
- ❖ A, C can not hear each other interfering at B

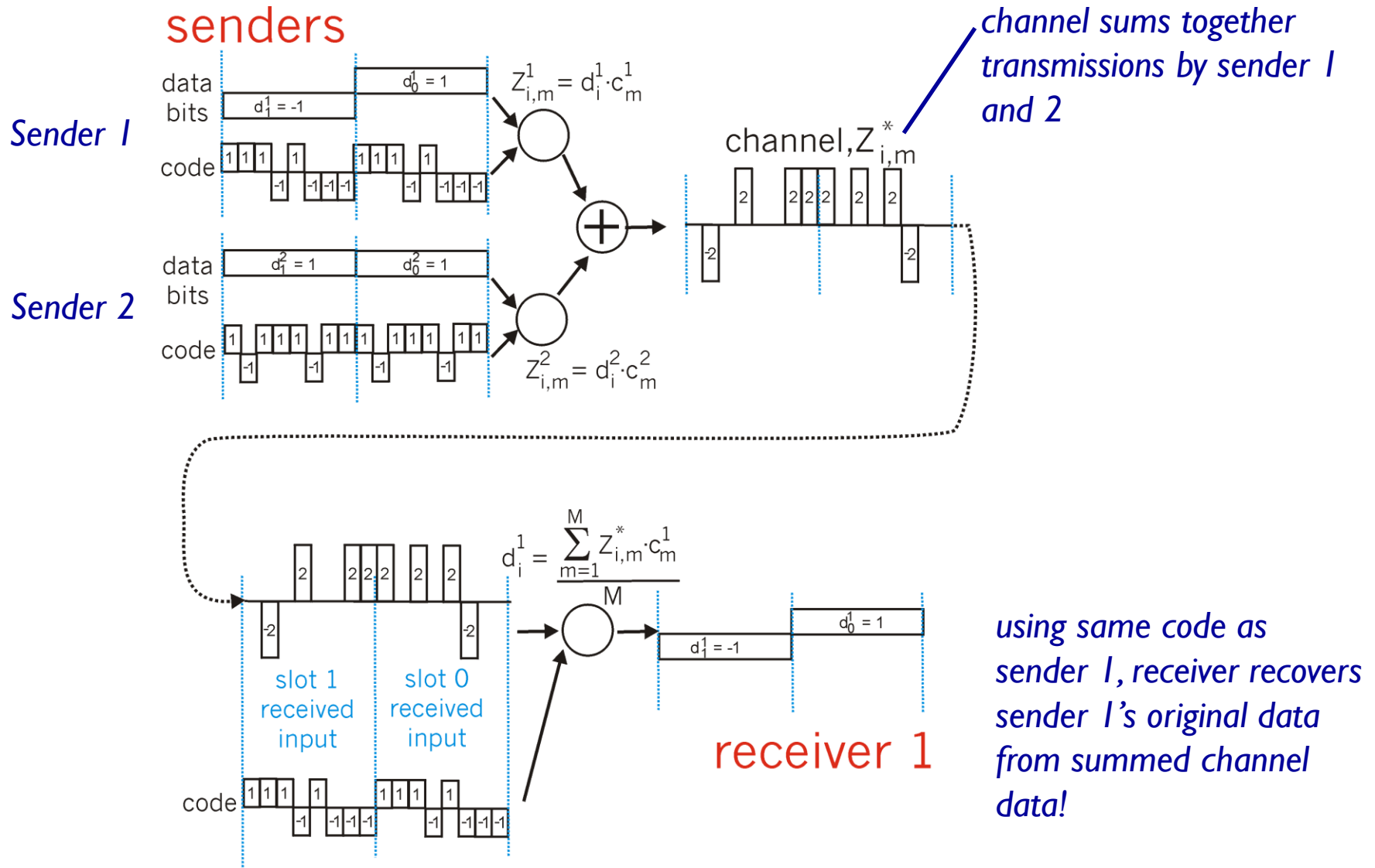
Code Division Multiple Access (CDMA)

- ❖ unique “code” assigned to each user; i.e., code set partitioning
 - all users share same frequency, but each user has own “chipping” sequence (i.e., code) to encode data
 - allows multiple users to “coexist” and transmit simultaneously with minimal interference (if codes are “orthogonal”)
- ❖ *encoded signal* = (original data) \times (chipping sequence)
- ❖ *decoding*: inner-product of encoded signal and chipping sequence

CDMA encode/decode



CDMA: two-sender interference



IEEE 802.11 Wireless LAN

802.11b

- ❖ 2.4-5 GHz unlicensed spectrum
- ❖ up to 11 Mbps
- ❖ all hosts use same chipping code

802.11a

- 5-6 GHz range
- up to 54 Mbps

802.11g

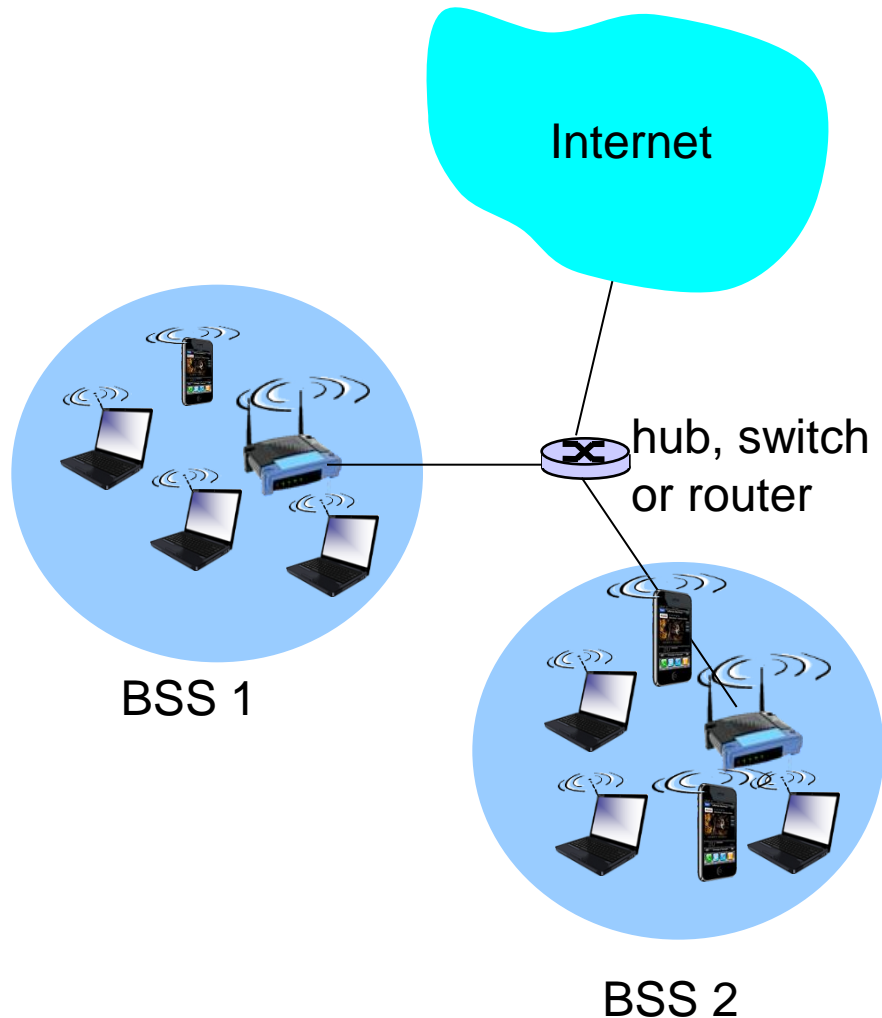
- 2.4-5 GHz range
- up to 54 Mbps

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

802.11 LAN architecture

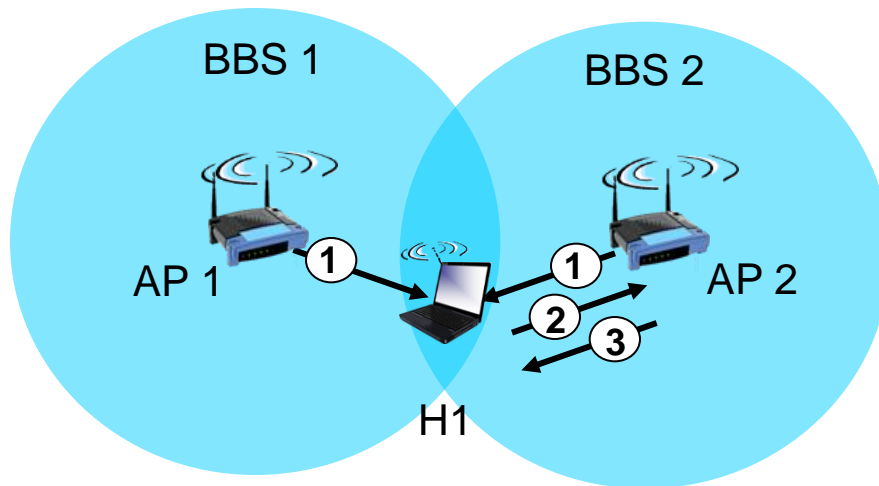


- ❖ wireless host communicates with base station
 - base station = access point (AP)
- ❖ **Basic Service Set (BSS)** (aka “cell”) in infrastructure mode contains:
 - wireless hosts
 - access point (AP): base station
 - ad hoc mode: hosts only

802.11: Channels, association

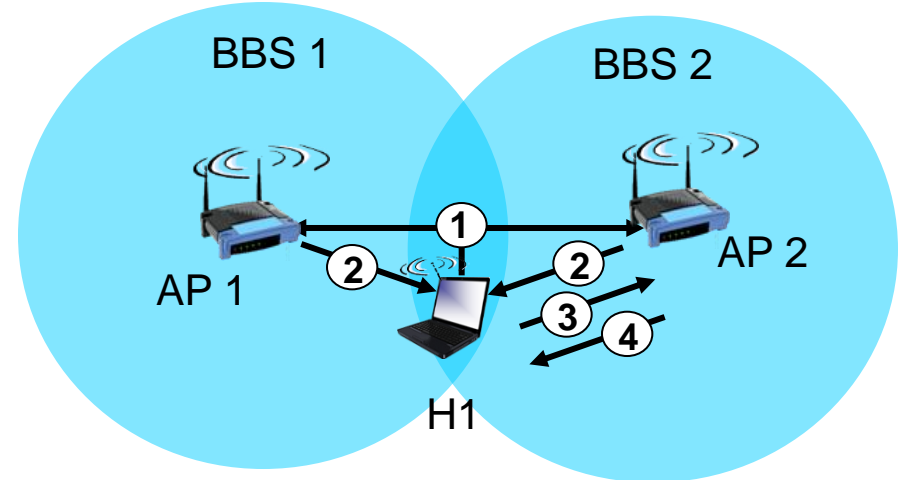
- ❖ 802.11b: 2.4GHz-2.485GHz spectrum divided into 11 channels at different frequencies
 - AP admin chooses frequency for AP
 - interference possible: channel can be same as that chosen by neighboring AP!
- ❖ host: must *associate* with an AP
 - scans channels, listening for *beacon frames* containing AP's name (SSID – Service Set ID) and MAC address
 - selects AP to associate with
 - may perform authentication [Chapter 8]
 - will typically 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

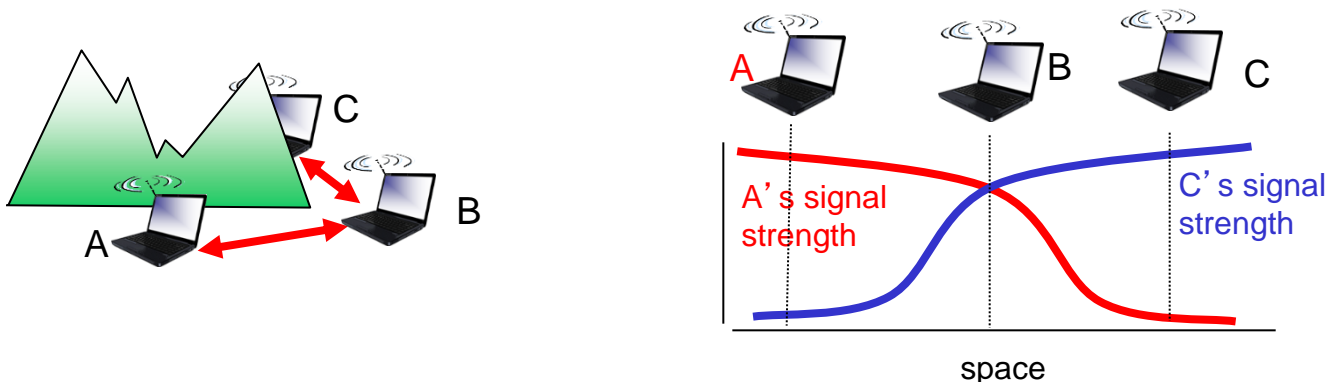


active scanning:

- (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

IEEE 802.11: multiple access

- ❖ avoid collisions: 2^+ nodes transmitting at same time
- ❖ 802.11: CSMA - sense before transmitting
 - don't collide with ongoing transmission by other node
- ❖ 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/CA (Collision Avoidance)



802.11: multiple access

- ❖ We can not be sure that we will hear all collisions so we try to avoid them.
- ❖ **Can you think of a human analogy for how to accomplish this?**

802.11: multiple access

❖ Collision Avoidance – Human analogies

- When you hear that no one is talking - wait for a short amount of time before you speak - **Distributed Interframe Spacing**
- If you hear that someone is talking – count for a random backoff time
- only increment your count when you hear no one talking– in other words – don't use the silent time immediately, keep counting down for your turn
- Wait for an acknowledgement after you speak.
- Listeners wait for short time before speaking the ack - **Short Interframe Spacing**
- If no acknowledgement – repeat yourself
- If you have a long speech ask the moderator if it is ok – **Request to Send** to AP and **Clear to Send** from AP to reserve your time

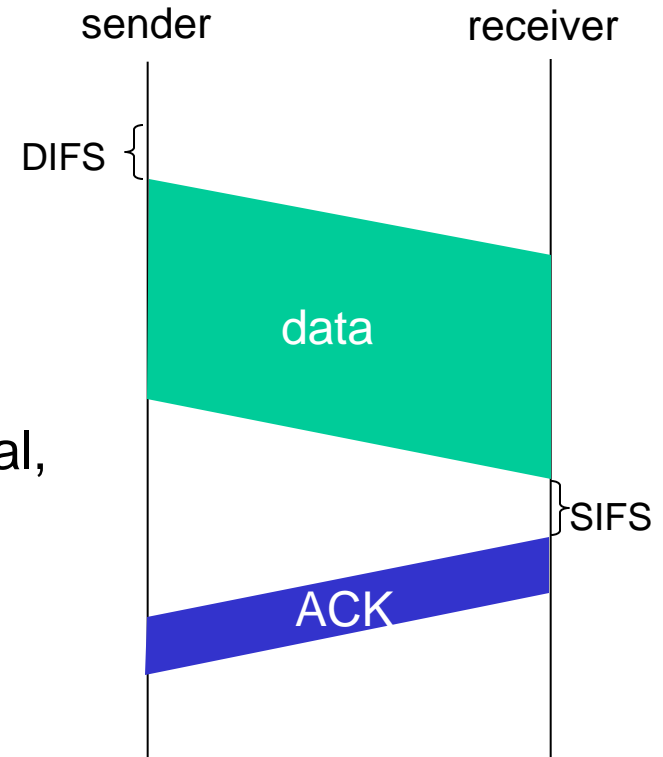
IEEE 802.11 MAC Protocol: CSMA/CA

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)



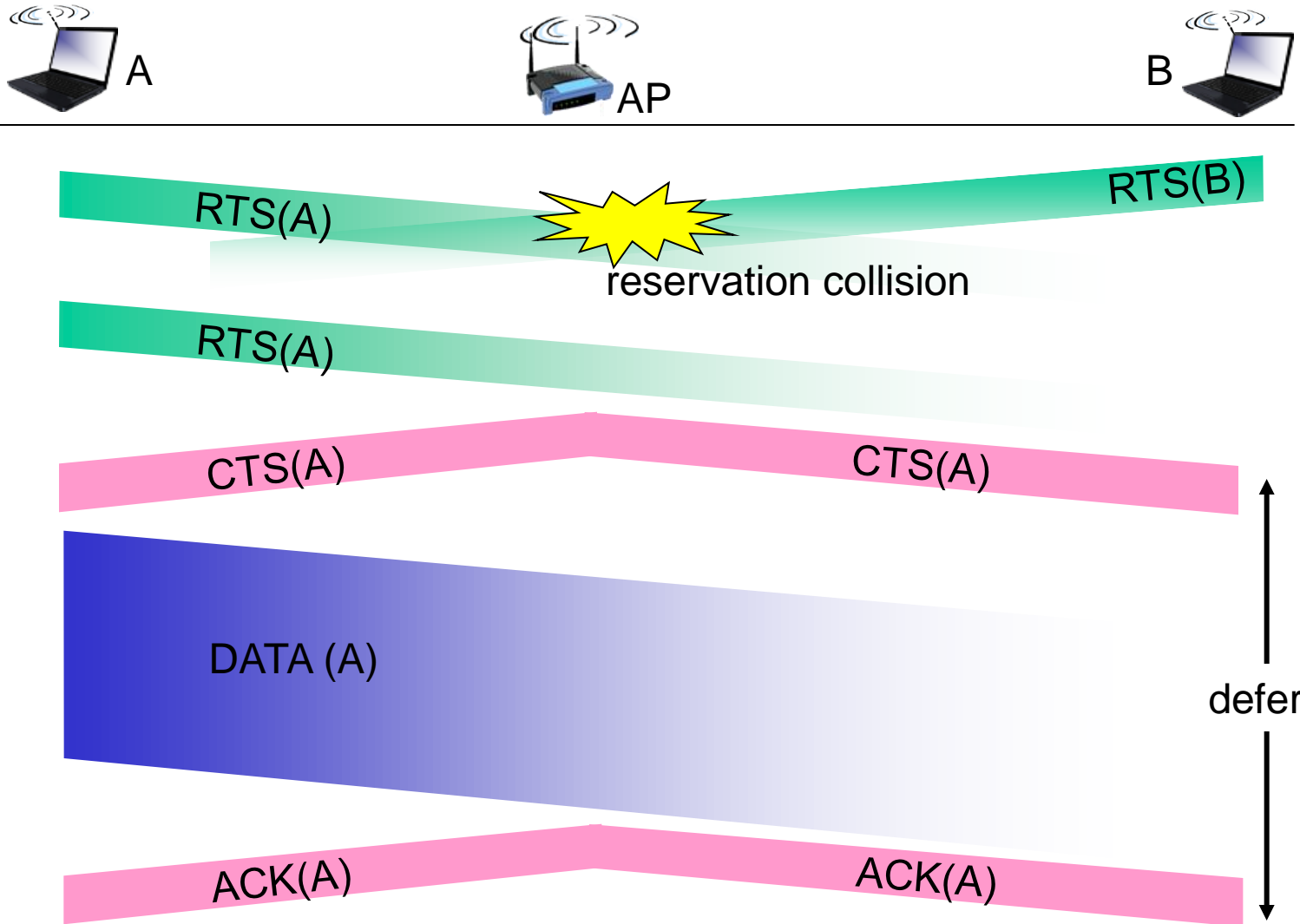
Avoiding collisions (more)

idea: allow sender to “reserve” channel rather than random access of data frames: avoid collisions of long data frames

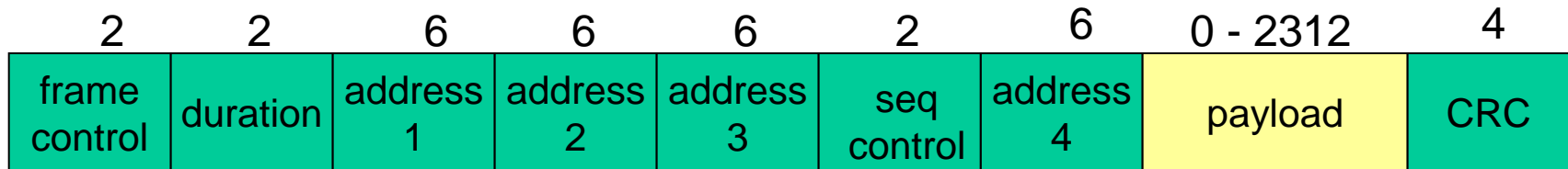
- ❖ sender first transmits *small* request-to-send (RTS) packets to BS using CSMA
 - RTSs may still collide with each other (but they’re short)
- ❖ BS broadcasts clear-to-send CTS in response to RTS
- ❖ CTS heard by all nodes
 - sender transmits data frame
 - other stations defer transmissions

*avoid data frame collisions completely
using small reservation packets!*

Collision Avoidance: RTS-CTS exchange



802.11 frame: addressing



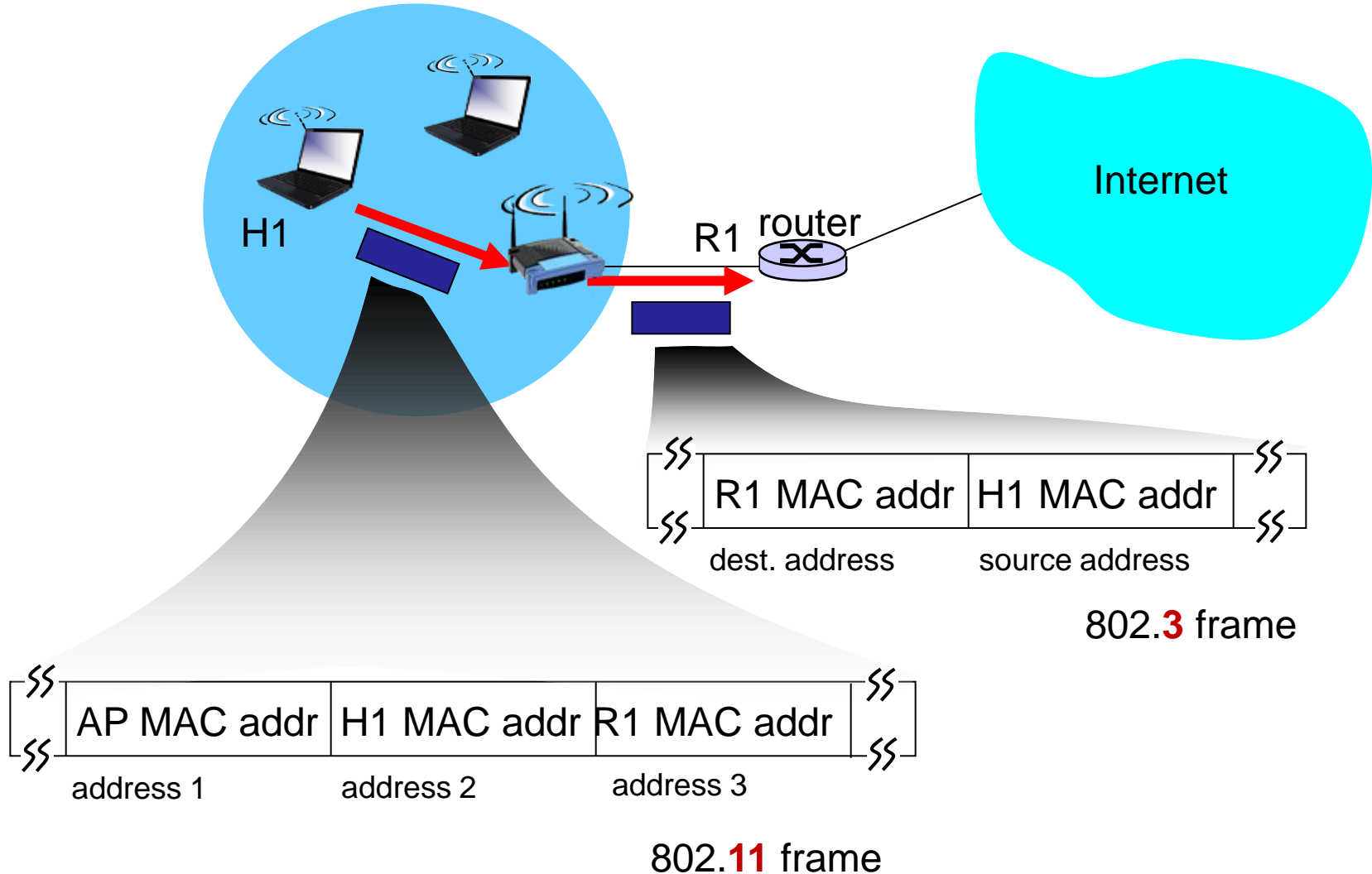
Address 1: MAC address of wireless host or AP to receive this frame

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

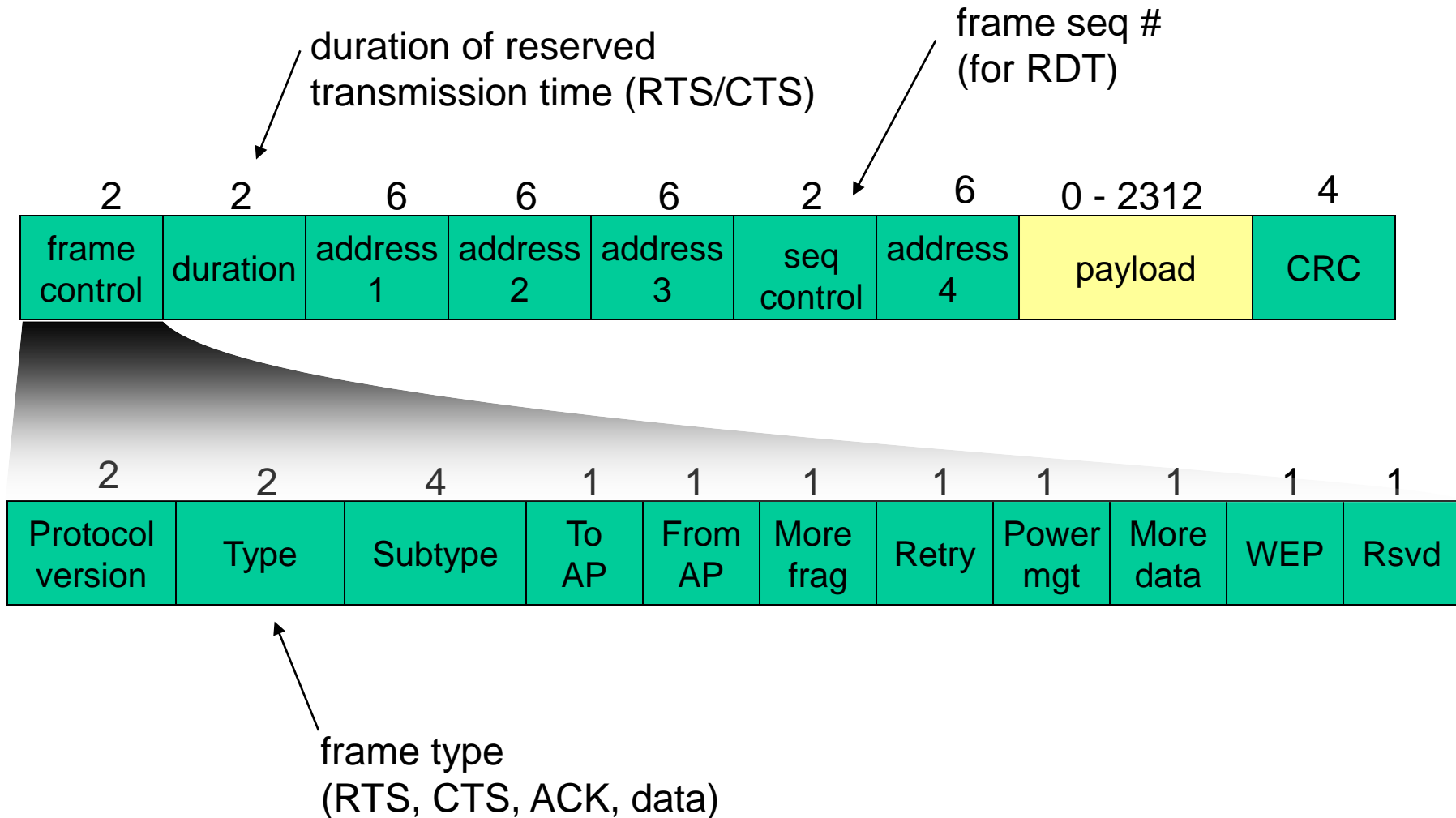
Address 3: MAC address of router interface to which AP is attached

Address 4: used only in ad hoc mode

802.11 frame: addressing

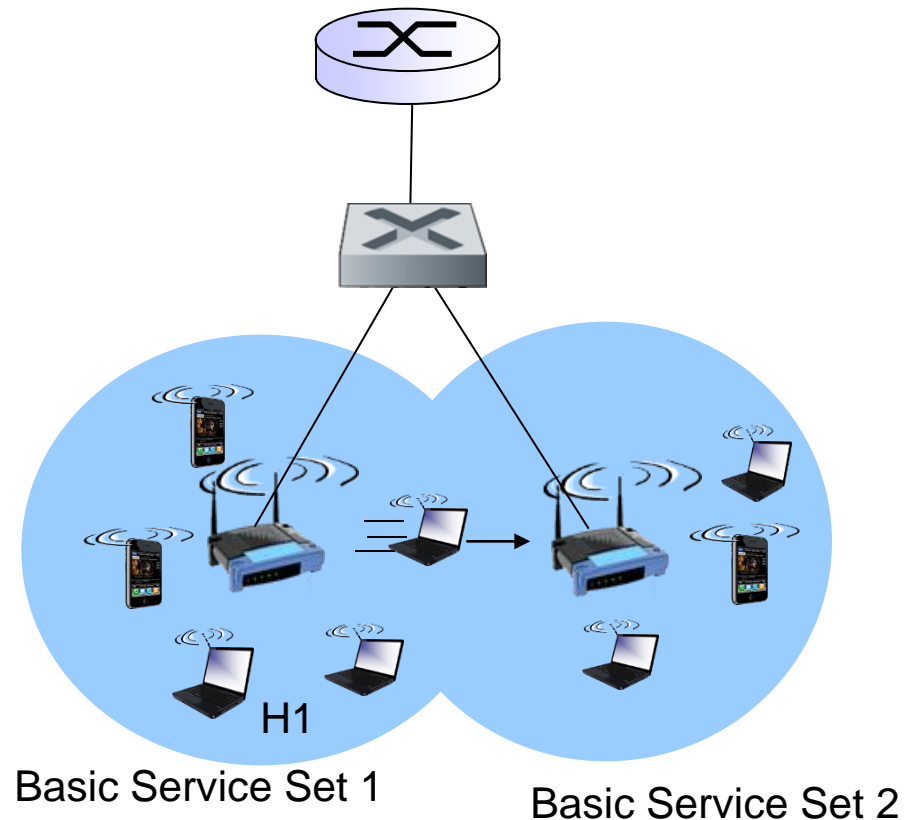


802.11 frame: more



802.11: mobility within same subnet

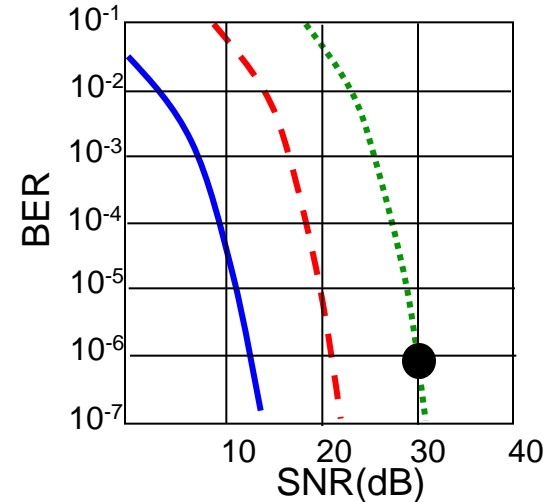
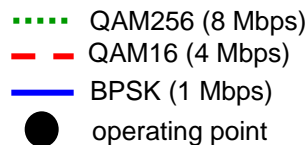
- ❖ HI remains in same IP subnet: IP address can remain same
- ❖ switch: which AP is associated with HI?
 - self-learning: switch will see frame from HI and “remember” which switch port can be used to reach HI



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

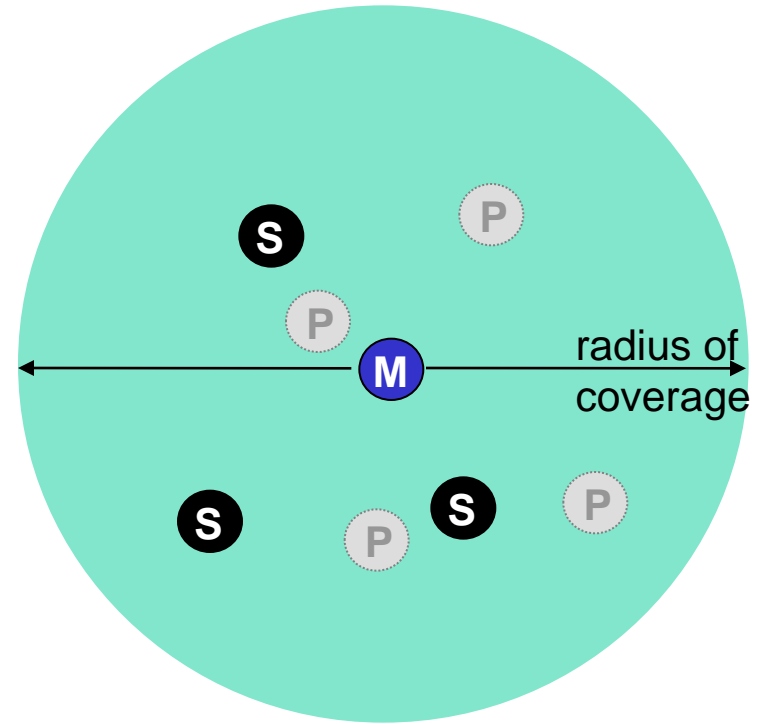
802.11: advanced capabilities

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

802.15: personal area network

- ❖ less than 10 m diameter
- ❖ replacement for cables (mouse, keyboard, headphones)
- ❖ ad hoc: no infrastructure
- ❖ master/slaves:
 - slaves request permission to send (to master)
 - master grants requests
- ❖ 802.15: evolved from Bluetooth specification
 - 2.4-2.5 GHz radio band
 - up to 721 kbps



- M** Master device
- S** Slave device
- P** Parked device (inactive)

Lesson 18 Overview of Wireless Networks

Summary:

- ❖ More robust link layer protocols (802.11x) needed for the wireless physical layer.
 - Connection (a host associates with an AP)
 - AP translates to/from WiFi and Ethernet
 - Error detection, error correction and reliable data transfer done at the link layer