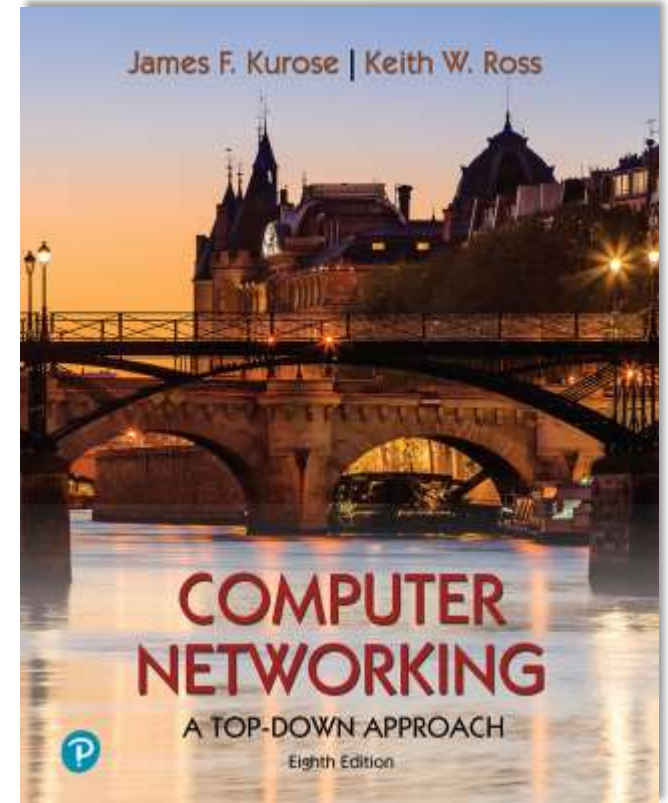# Chapter 7 Wireless and Mobile Networks

Computer Networking: A Top-Down Approach

8th edition
Jim Kurose, Keith Ross
Pearson, 2020

Chapter 7 outline
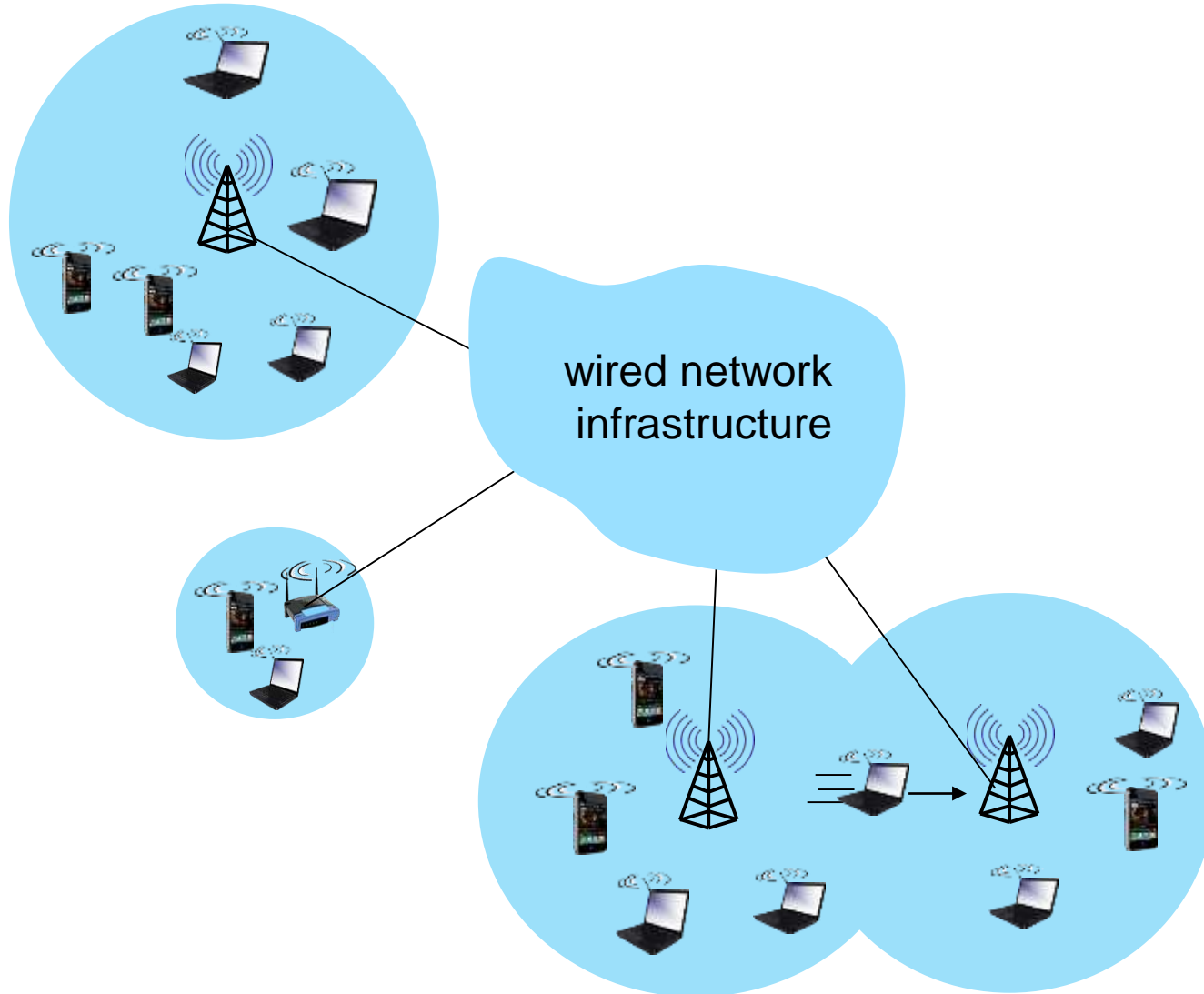

- Introduction
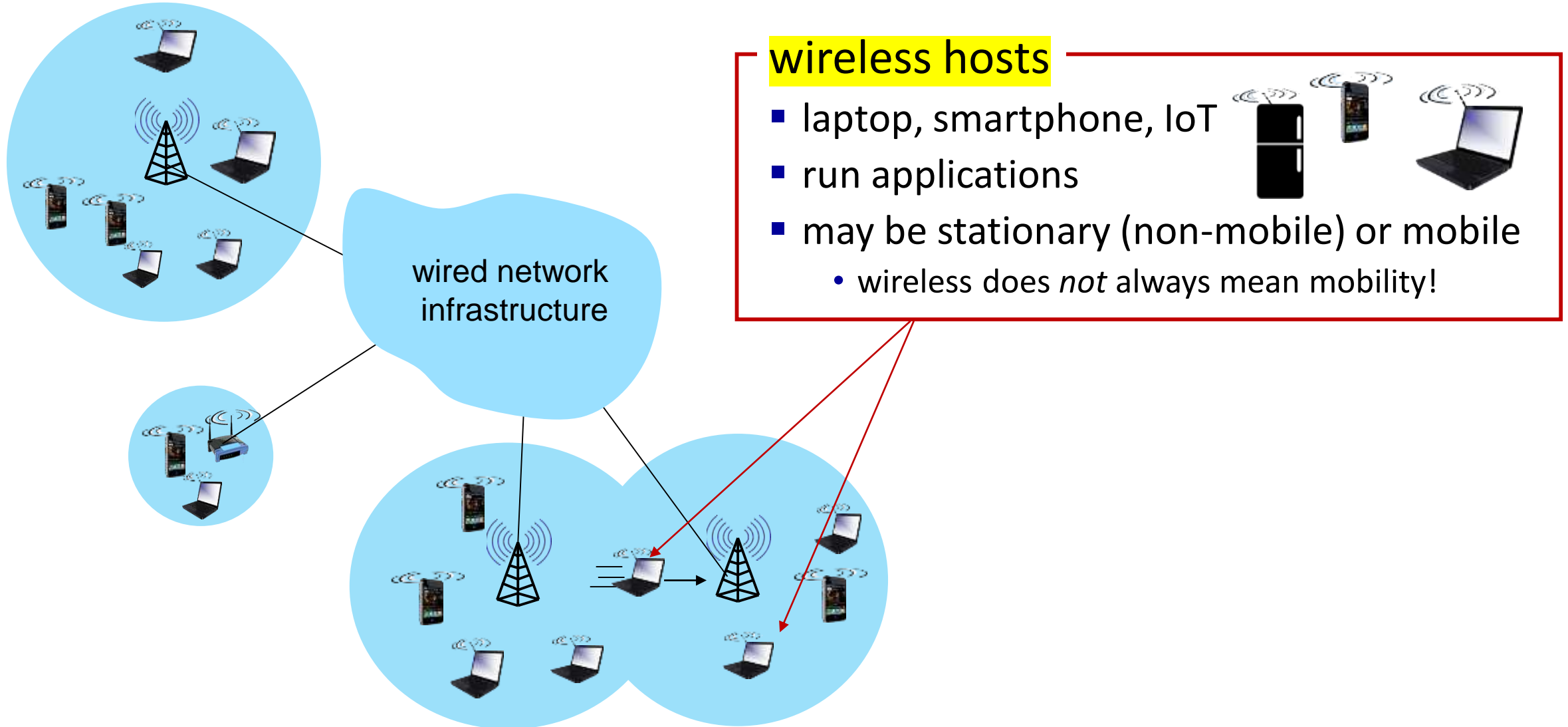
Wireless

- Wireless links and network characteristics
- WiFi: 802.11 wireless LANs

Elements of a wireless network

wired network infrastructure

Elements of a wireless network

wired network infrastructure

wireless hosts
- laptop, smartphone, IoT
- run applications
- may be stationary (non-mobile) or mobile
  - wireless does *not* always mean mobility!
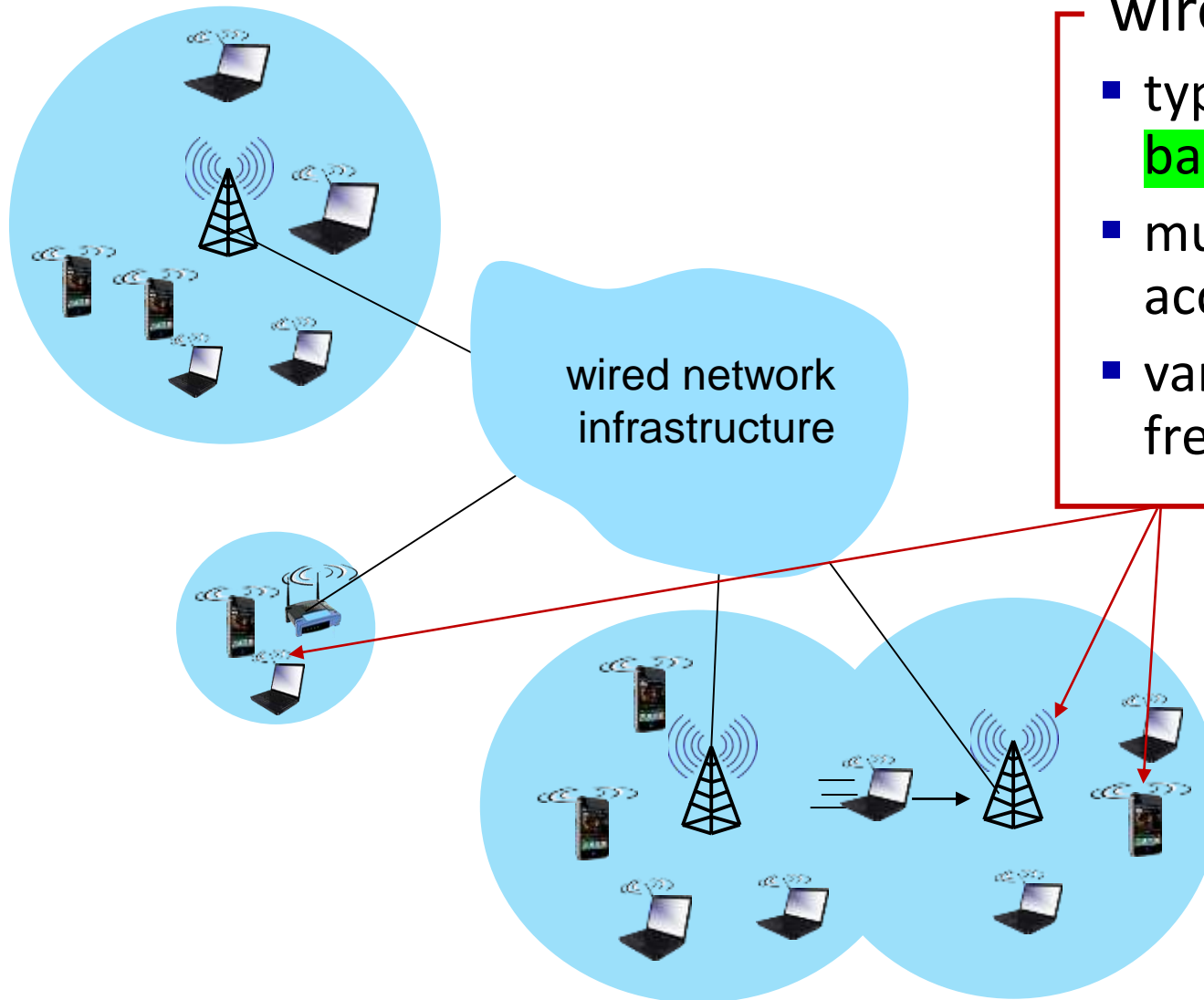
Elements of a wireless network

base station
- typically connected to wired network
- relay - responsible for sending packets between wired network and wireless host(s) in its "area"
  - e.g., cell towers, 802.11 access points

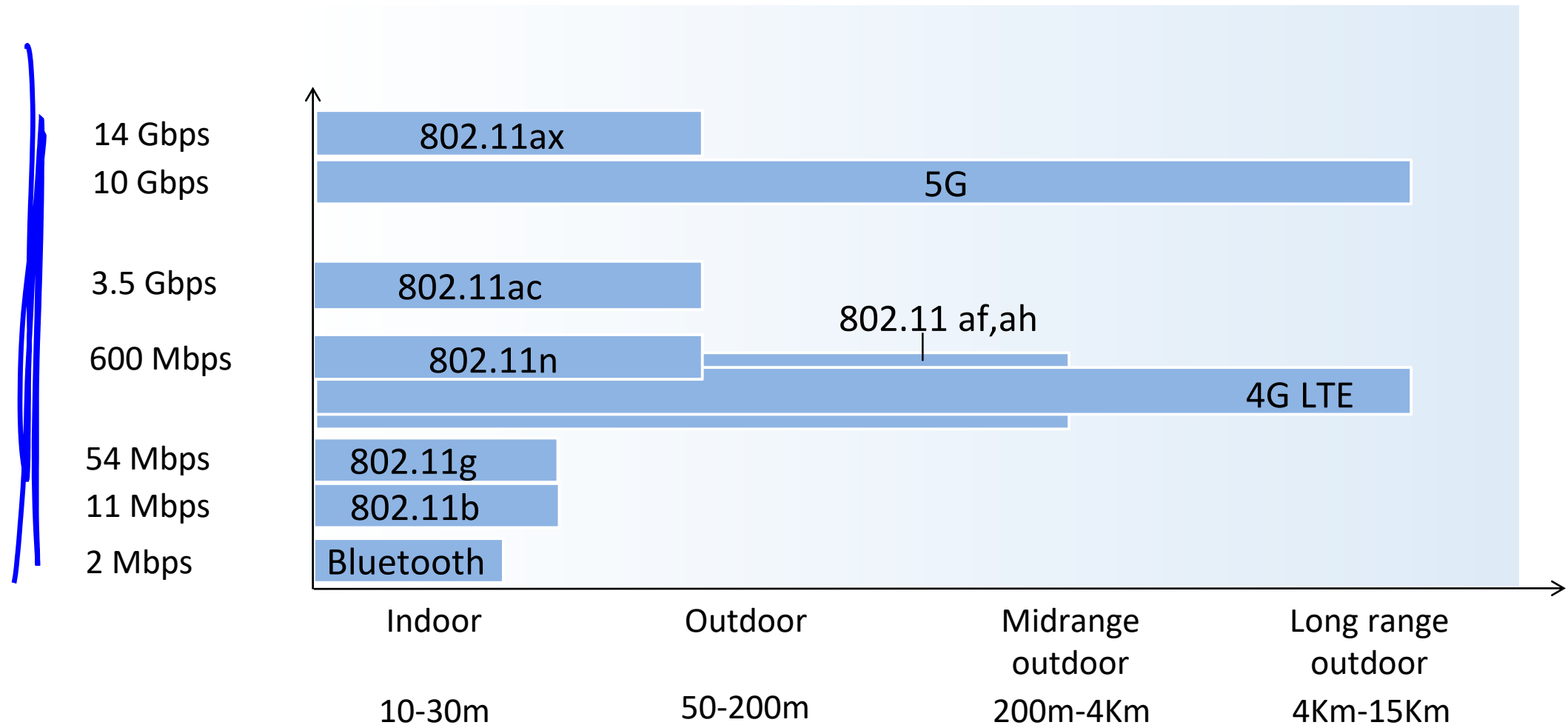wired network infrastructure

Elements of a wireless network

wireless link
- typically **used to connect mobile(s) to base station**, also used as backbone link
- multiple access protocol coordinates link access
- various transmission rates and distances, frequency bands

wired network infrastructure

Characteristics of selected wireless links
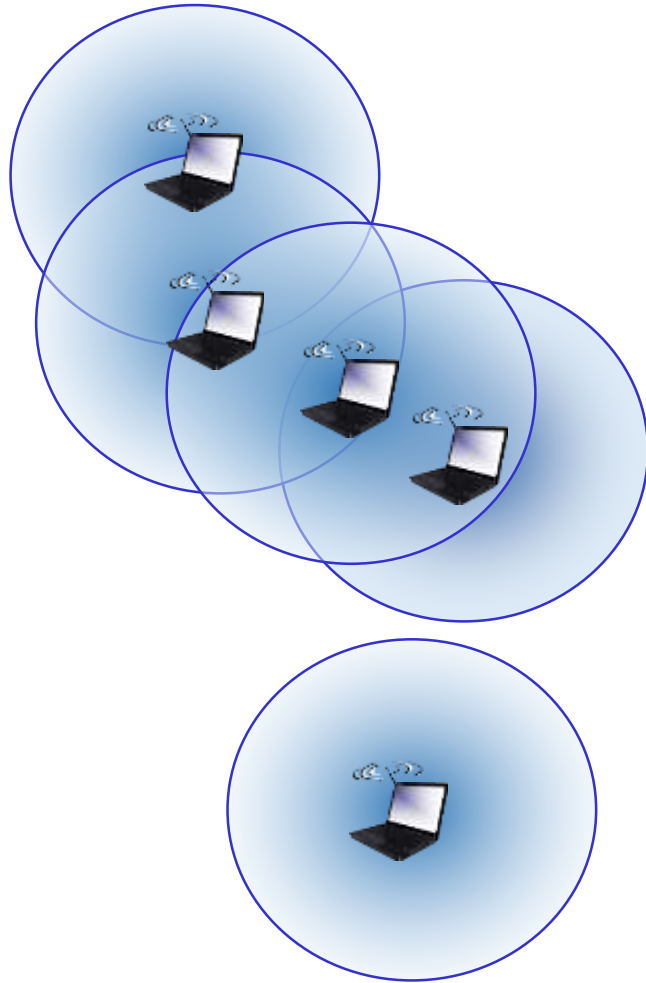
Elements of a wireless network
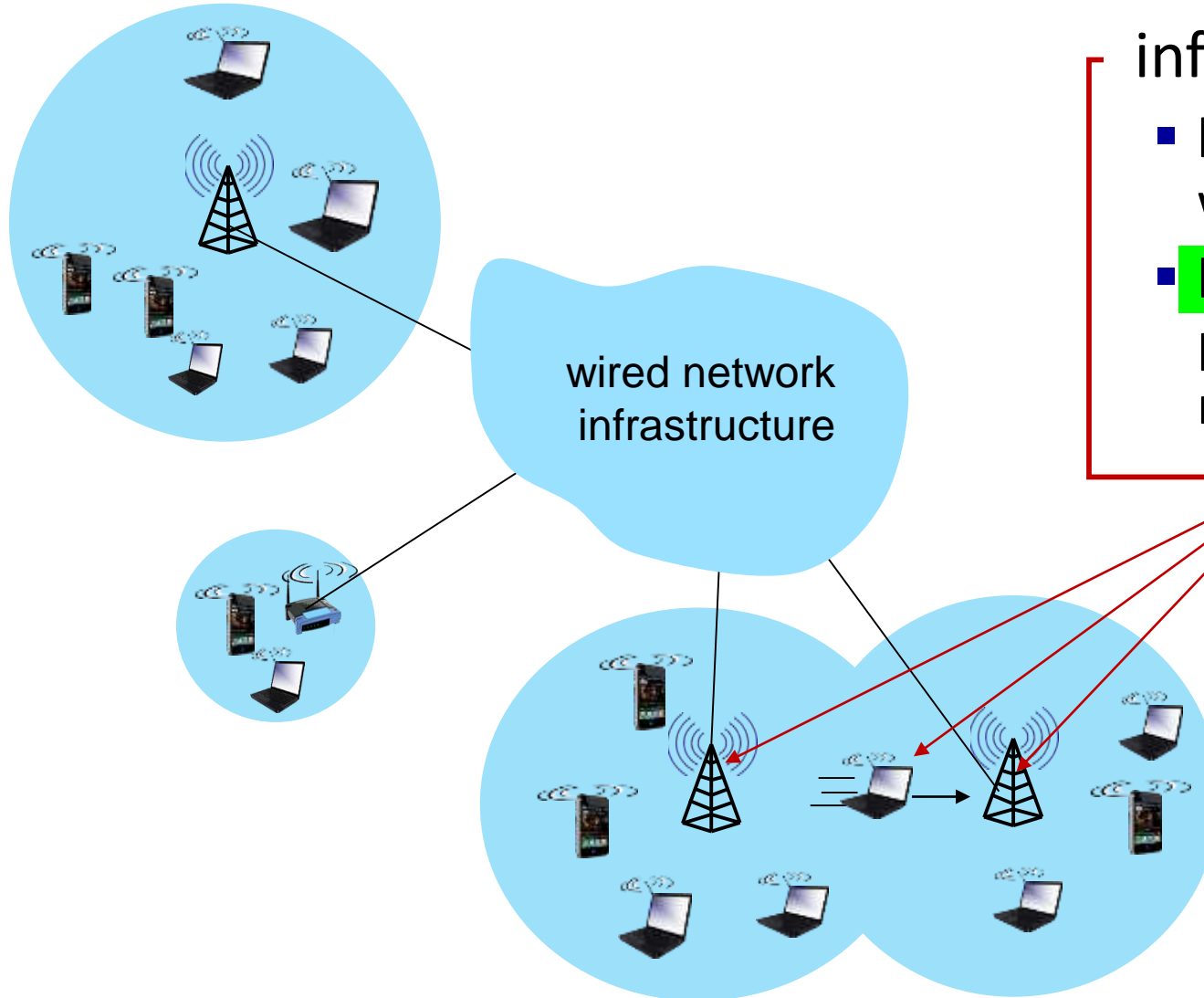
infrastructure mode
- base station connects mobiles into wired network
- handoff: mobile changes base station providing connection into wired network

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, cellular) which connects to larger Internet	host may have to relay through several wireless nodes to connect to larger Internet: *mesh net*
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

Chapter 7 outline

- Introduction

Wireless

- Wireless links and network characteristics
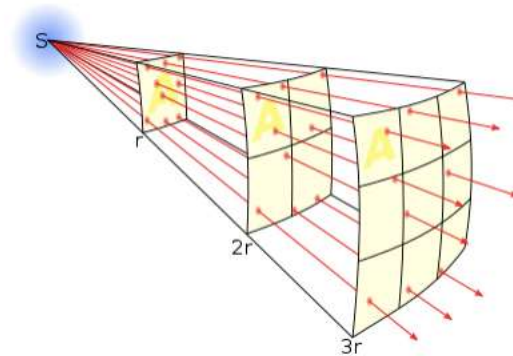
- WiFi: 802.11 wireless LANs

Wireless link characteristics: fading (attenuation)

Wireless radio signal attenuates (loses power) as it propagates (free space "path loss")

Free space path loss ~ $(fd)^2$
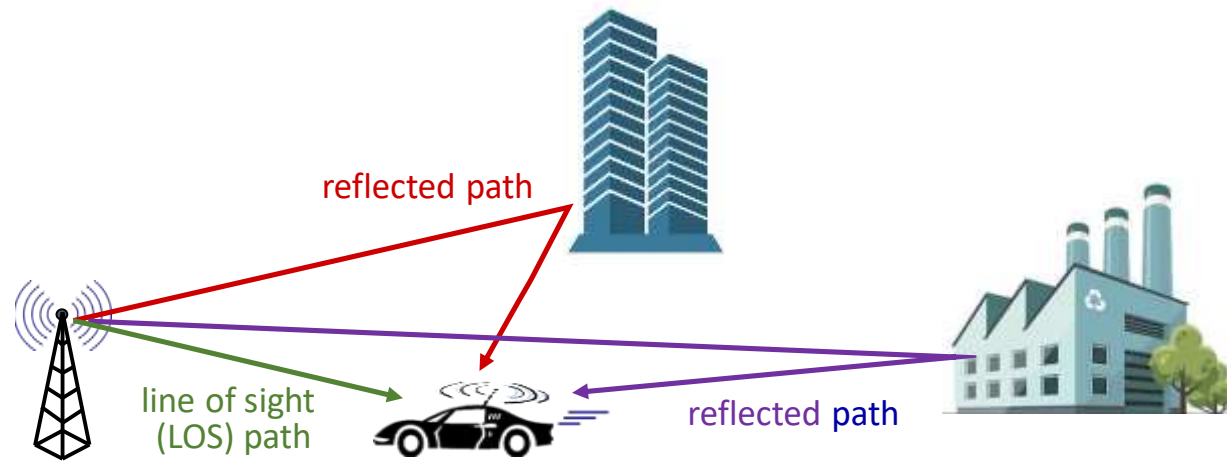
f: frequency
d: distance

higher frequency or longer distance ➡ larger free space path loss

Wireless link characteristics: multipath

multipath propagation: radio signal reflects off objects ground, built environment, arriving at destination at slightly different times

reflected path

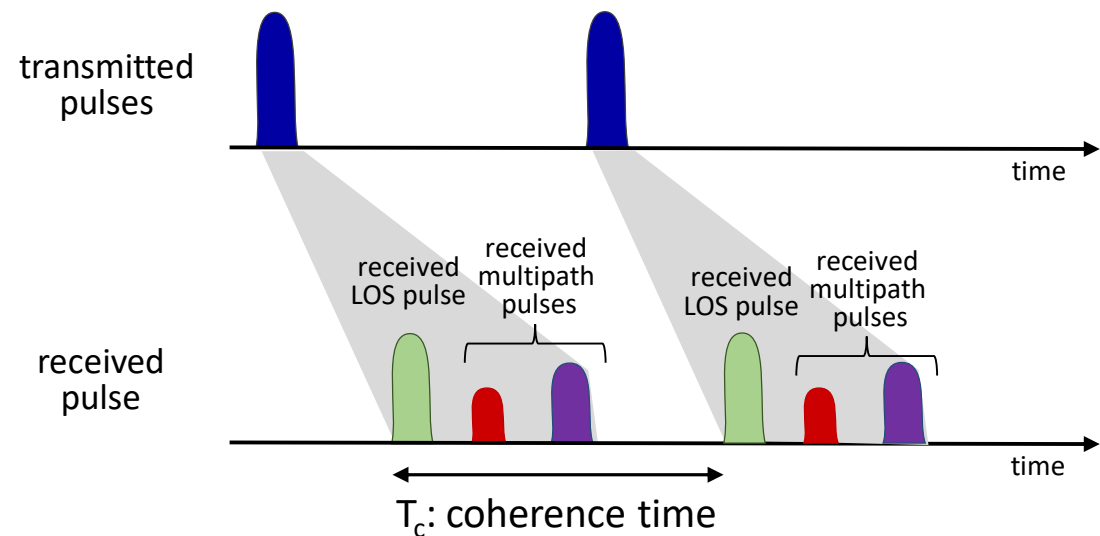line of sight (LOS) path

reflected path

Wireless link characteristics: multipath

multipath propagation: radio signal reflects off objects ground, built environment, arriving at destination at slightly different times

transmitted pulses

time

received pulse

received LOS pulse

received multipath pulses

received LOS pulse

received multipath pulses

time

T_c: coherence time

Coherence time:
- amount of time bit is present in channel to be received
- influences maximum possible transmission rate, since coherence times can not overlap
- inversely proportional to
  - frequency
  - receiver velocity

Wireless link characteristics: noise

- **interference from other sources on** wireless network frequencies: motors, appliances

- **SNR: signal-to-noise ratio**
  - larger SNR – easier to extract signal from noise (a "good thing")

- **SNR versus BER tradeoff**
  - *given physical layer:* increase power -> increase SNR->decrease BER
  - SNR may change with mobility: dynamically adapt physical layer (modulation technique, rate)

······ QAM256 (8 Mbps)

- - - QAM16 (4 Mbps)

——— BPSK (1 Mbps)
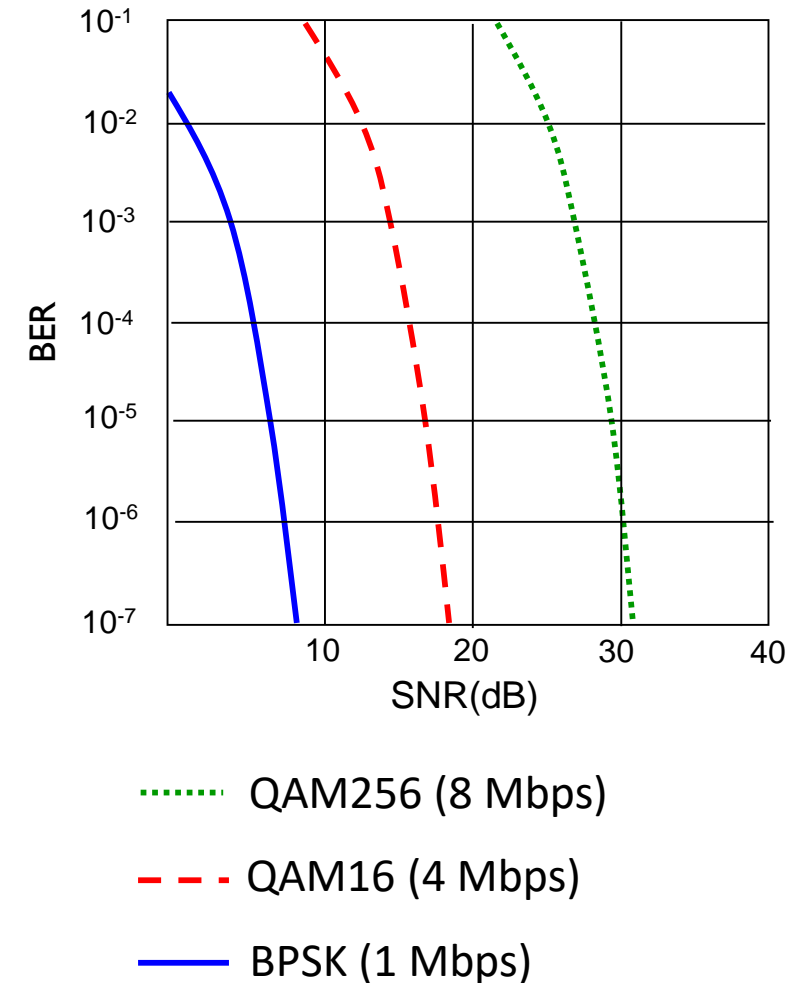
Wireless link characteristics: hidden terminals

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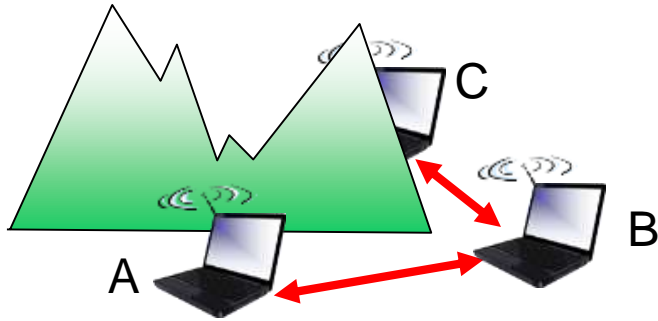
- B, A hear each other
- B, C hear each other
- A, C can not hear each other means A, C unaware of their interference at B

Attenuation also causes "hidden terminals"
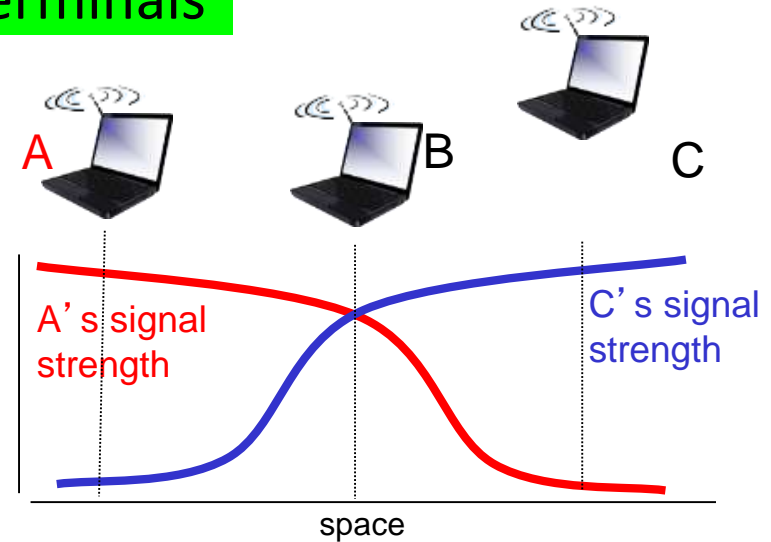
- B, A hear each other
- B, C hear each other
- A, C can not hear each other interfering at B

Chapter 7 outline

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- WiFi: 802.11 wireless LANs

IEEE 802.11 Wireless LAN

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

802.11 LAN architecture

Internet

switch
or router

BSS 1

BSS 2
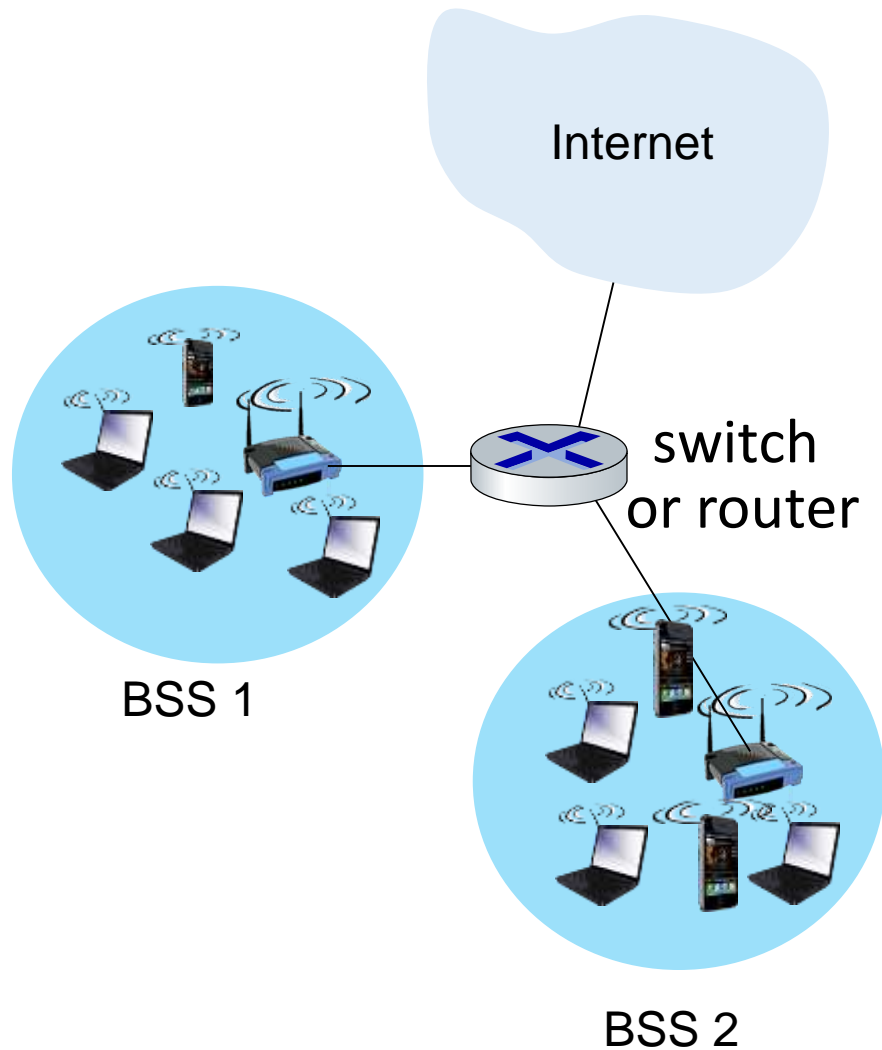
- wireless host communicates with base station
  - base station = access point (AP)
- Basic Service Set (BSS) (aka "cell") in infrastructure mode contains:
  - wireless hosts
  - access point (AP): base station
  - ad hoc mode: hosts only

802.11: Channels

- **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!

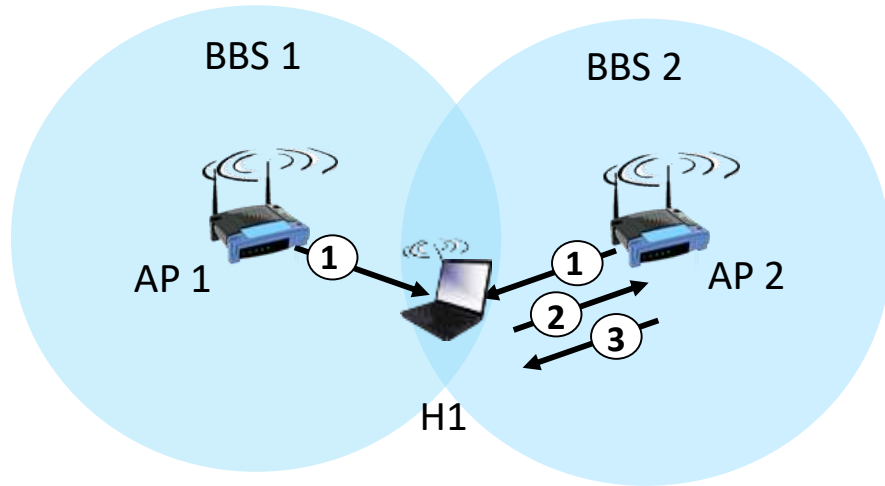**Example: 2.4 GHz**
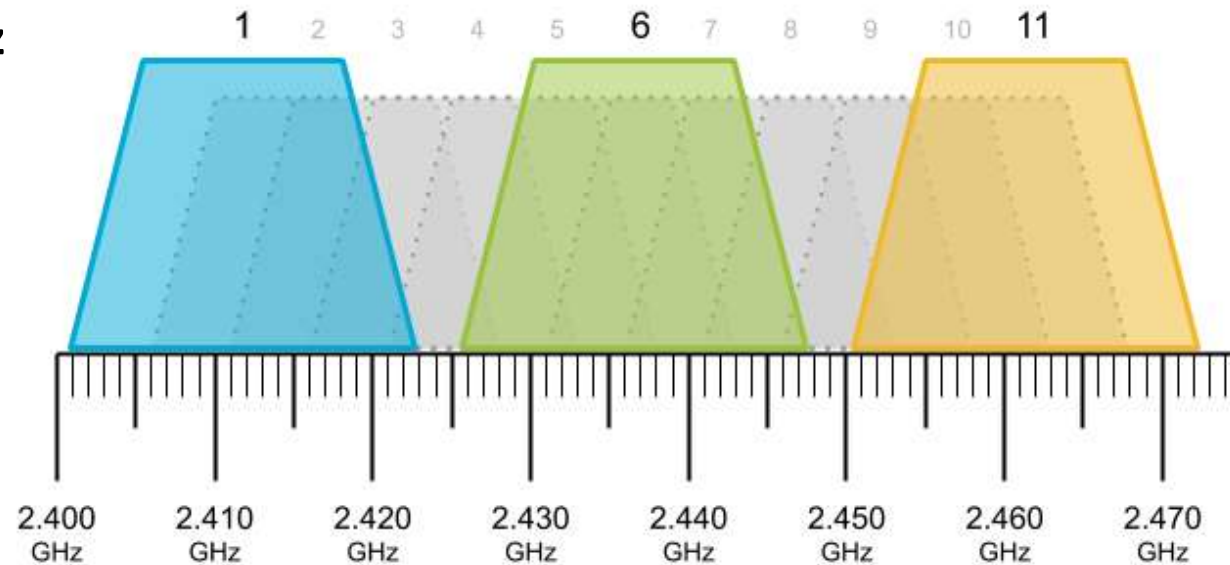
802.11: Association

- **<mark>arriving host: must associate with an AP</mark>**
  - 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
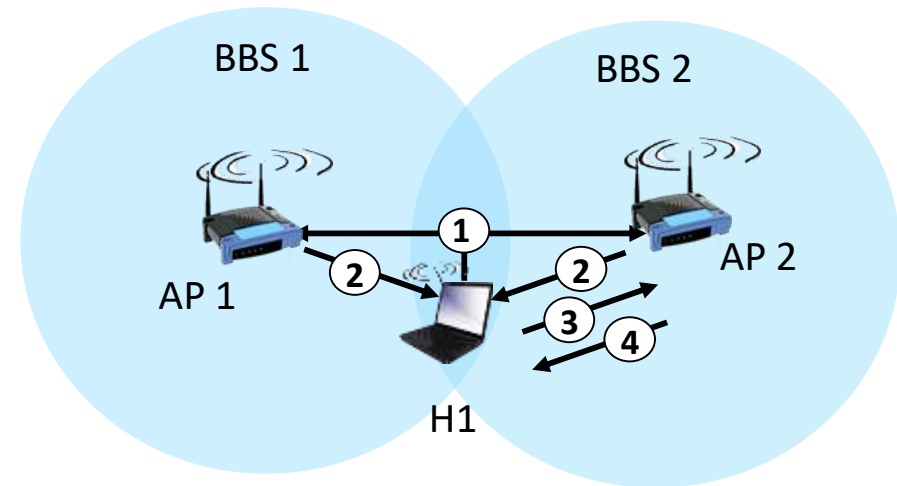

passive scanning:

(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: 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
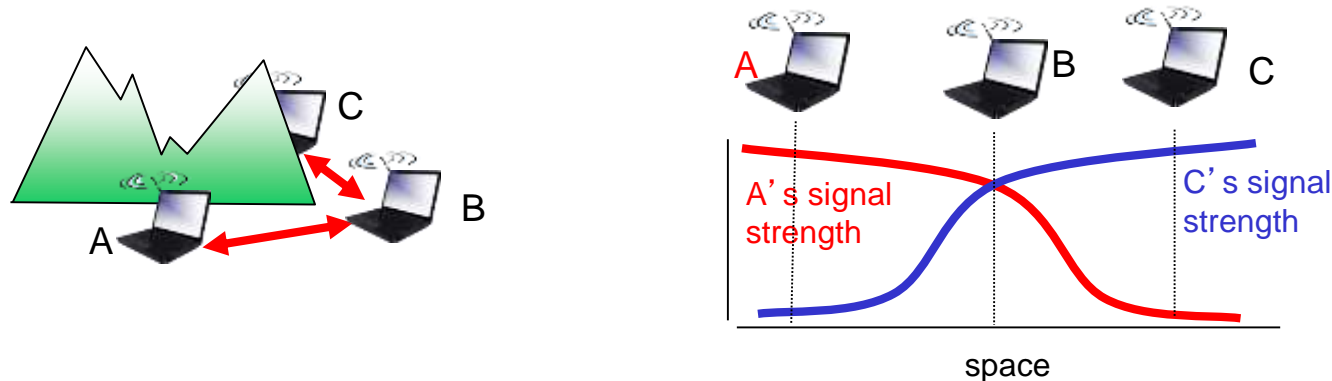
IEEE 802.11 MAC Protocol: CSMA/CA

802.11 sender

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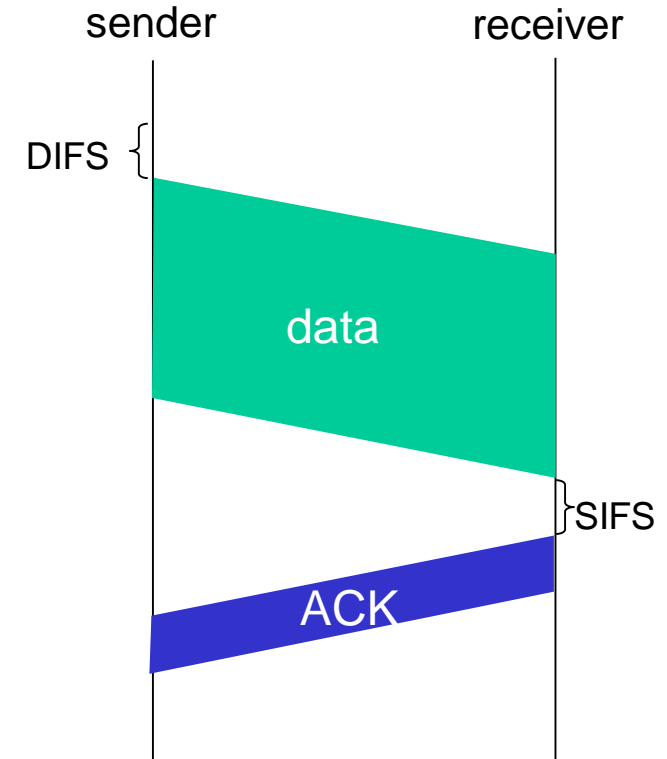   transmit entire frame (no CD)

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)

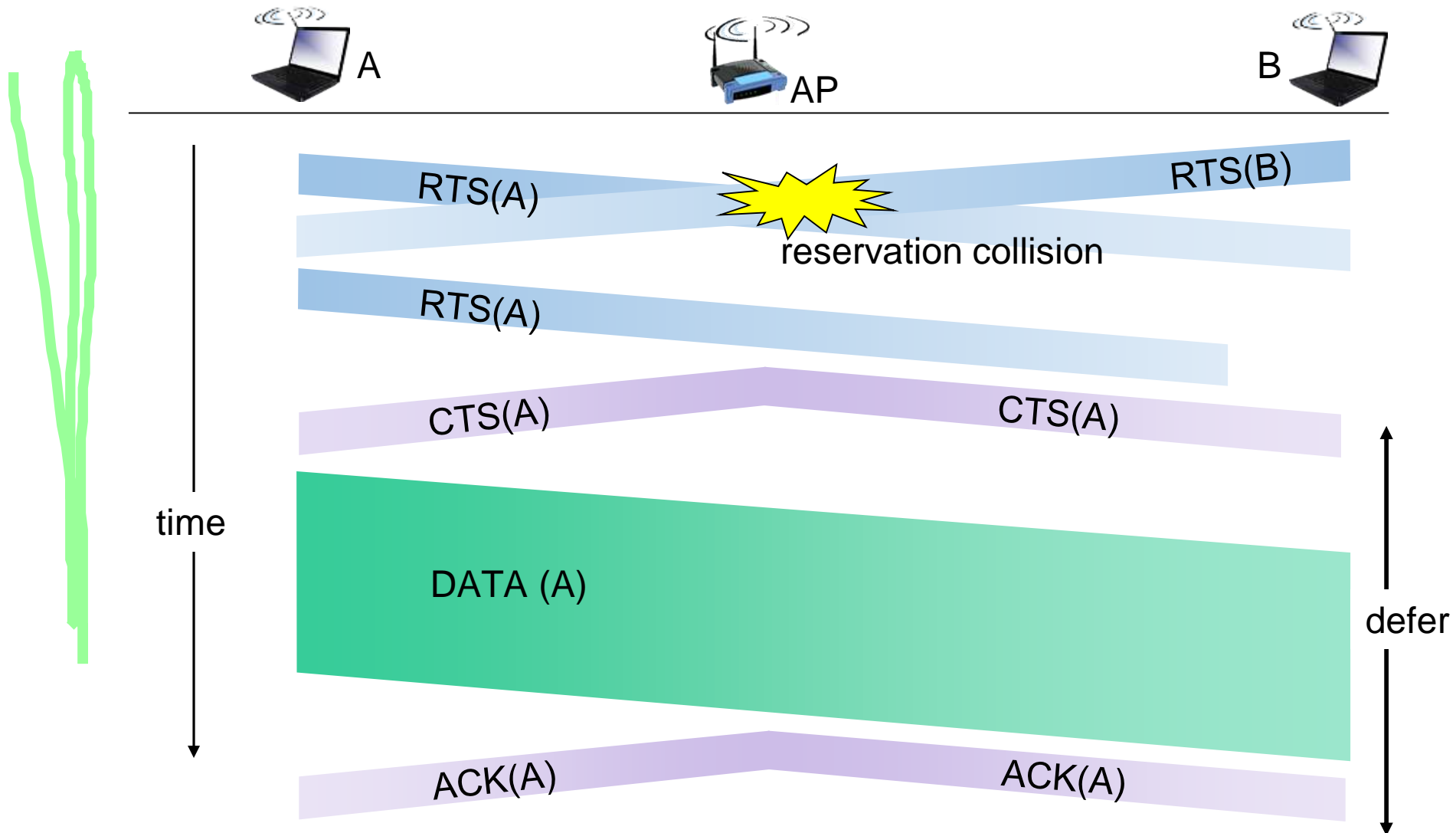idea: sender "reserves" channel use for data frames using small reservation packets

- sender first transmits *small* request-to-send (RTS) packet to BS
  - 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

Collision Avoidance: RTS-CTS exchange

802.11 frame: addressing

2	2	6	6	6	2	6	0 - 2312	4
frame control	duration	address 1	address 2	address 3	seq control	address 4	payload	CRC
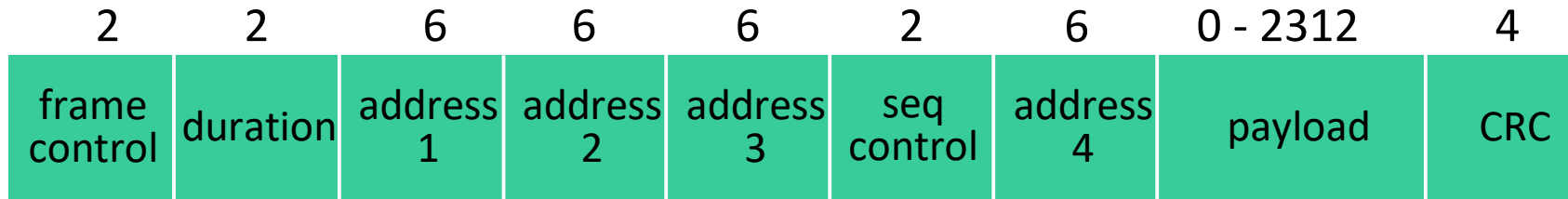
Address 1: MAC address of wireless host or AP to receive this frame

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

Internet

802.3 Ethernet frame

R1 MAC addr	H2 MAC addr
MAC dest addr	MAC source addr

AP MAC addr	H1 MAC addr	R1 MAC addr
address 1	address 2	address 3

802.11 WiFi *frame*

802.11 frame: addressing

duration of reserved transmission time (RTS/CTS)

frame sequence # (for reliable data transfer)

2	2	6	6	6	2	6	0 - 2312	4
frame control	duration	address 1	address 2	address 3	seq control	address 4	payload	CRC

2	2	4	1	1	1	1	1	1	1	1
protocol version	type	subtype	to AP	from AP	more frag	retry	power mgt	more data	WEP	rsvd

frame type (RTS, CTS, ACK, data)

802.11: advanced capabilities
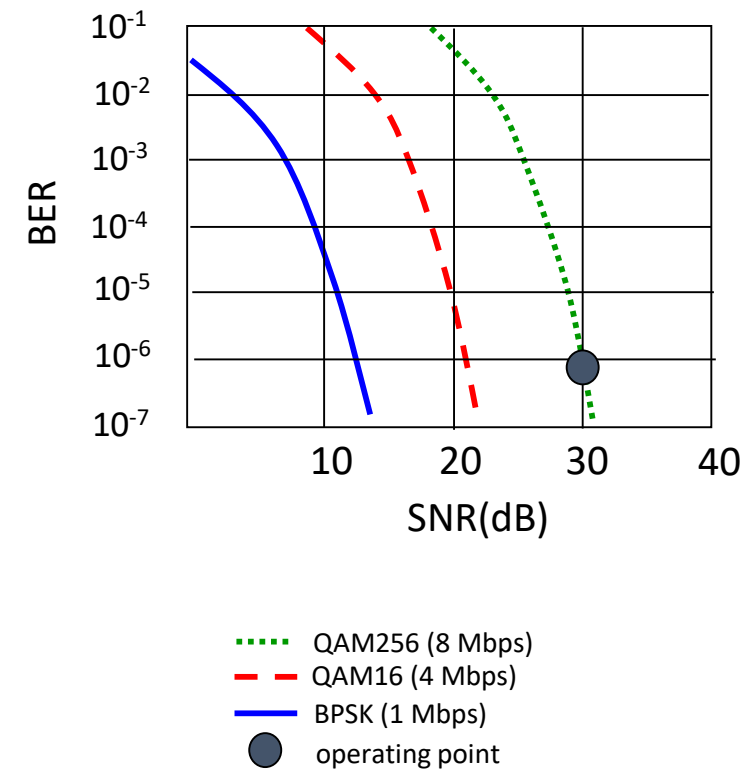
Rate adaptation

- **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

QAM256 (8 Mbps)
QAM16 (4 Mbps)
BPSK (1 Mbps)
operating point

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

# Chapter 7 outline

- Introduction

Wireless

- Wireless links and network characteristics
- WiFi: 802.11 wireless LANs
- Bluetooth

Personal area networks: Bluetooth

- less than 10 m diameter

- replacement for cables (mouse, keyboard, headphones)

- ad hoc: no infrastructure

- 2.4-2.5 GHz ISM radio band, up to 3 Mbps

- master controller / client devices:
  - master polls clients, grants requests for client transmissions

radius of coverage

M master controller

C client device

P parked device (inactive)
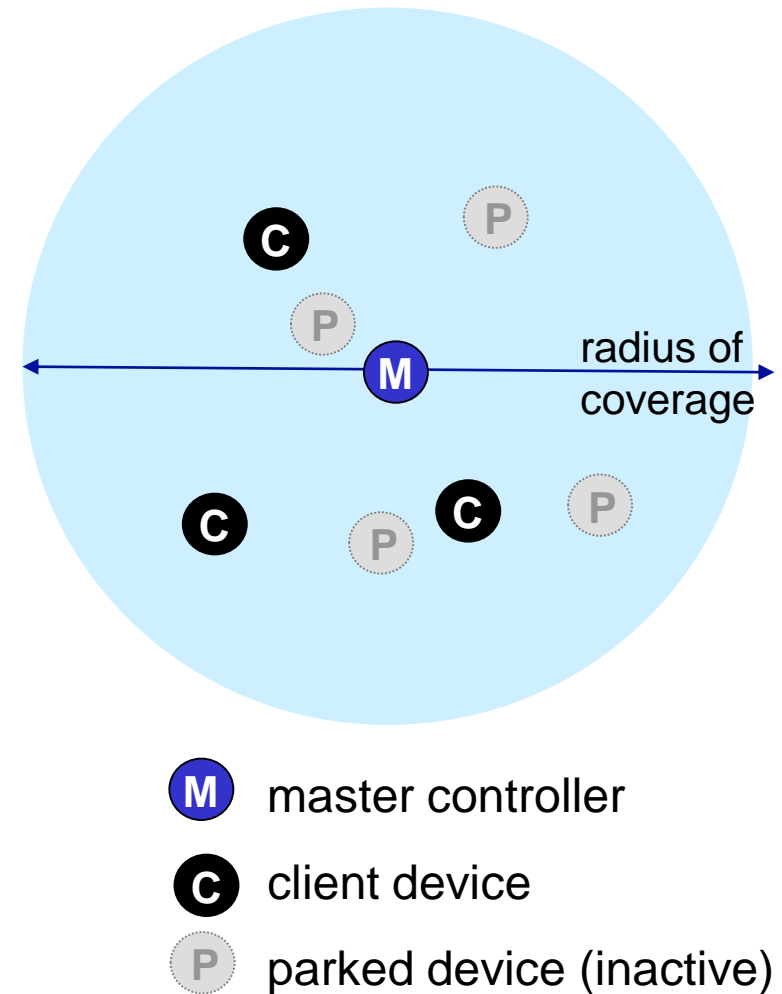
Personal area networks: Bluetooth

- **TDM**, 625 μsec sec. slot

- **FDM**: sender uses **79 frequency channels in known, pseudo-random order** slot-to-slot (spread spectrum)
  - other devices/equipment not in piconet only interfere in some slots

- **parked mode**: clients can "go to sleep" (park) and **later wakeup (to preserve battery**)

- **bootstrapping: nodes self-assemble (plug and play) into piconet**

radius of coverage

M master controller

C client device

P parked device (inactive)