COMP 3331/9331: Computer Networks and Applications

Week 12 Wireless LAN

Reading Guide: Chapter 7, Sections 7.1 and 7.3

Wireless Networks

Background:

- # wireless (mobile) phone subscribers now exceeds # wired phone subscribers (5-to-1)!
- # wireless Internet-connected devices equals # wireline Internet-connected devices
  - laptops, Internet-enabled phones promise anytime untethered Internet access
- two important (but different) challenges
  - *wireless:* communication over wireless link
  - *mobility:* handling the mobile user who changes point of attachment to network

We will only focus on wireless challenges

Outline

7.1 Introduction

Wireless

7.3 IEEE 802.11 wireless LANs ("Wi-Fi")

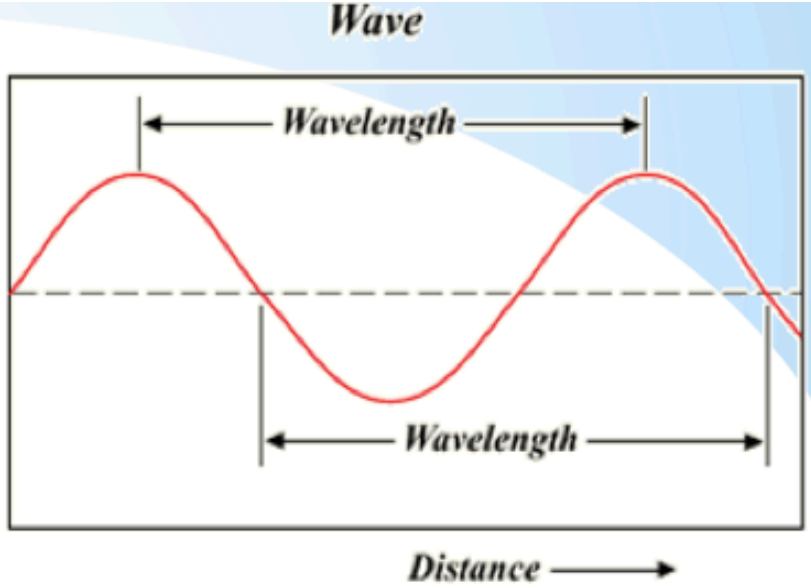
Wireless 101

- **Frequency/Wave-Length –**

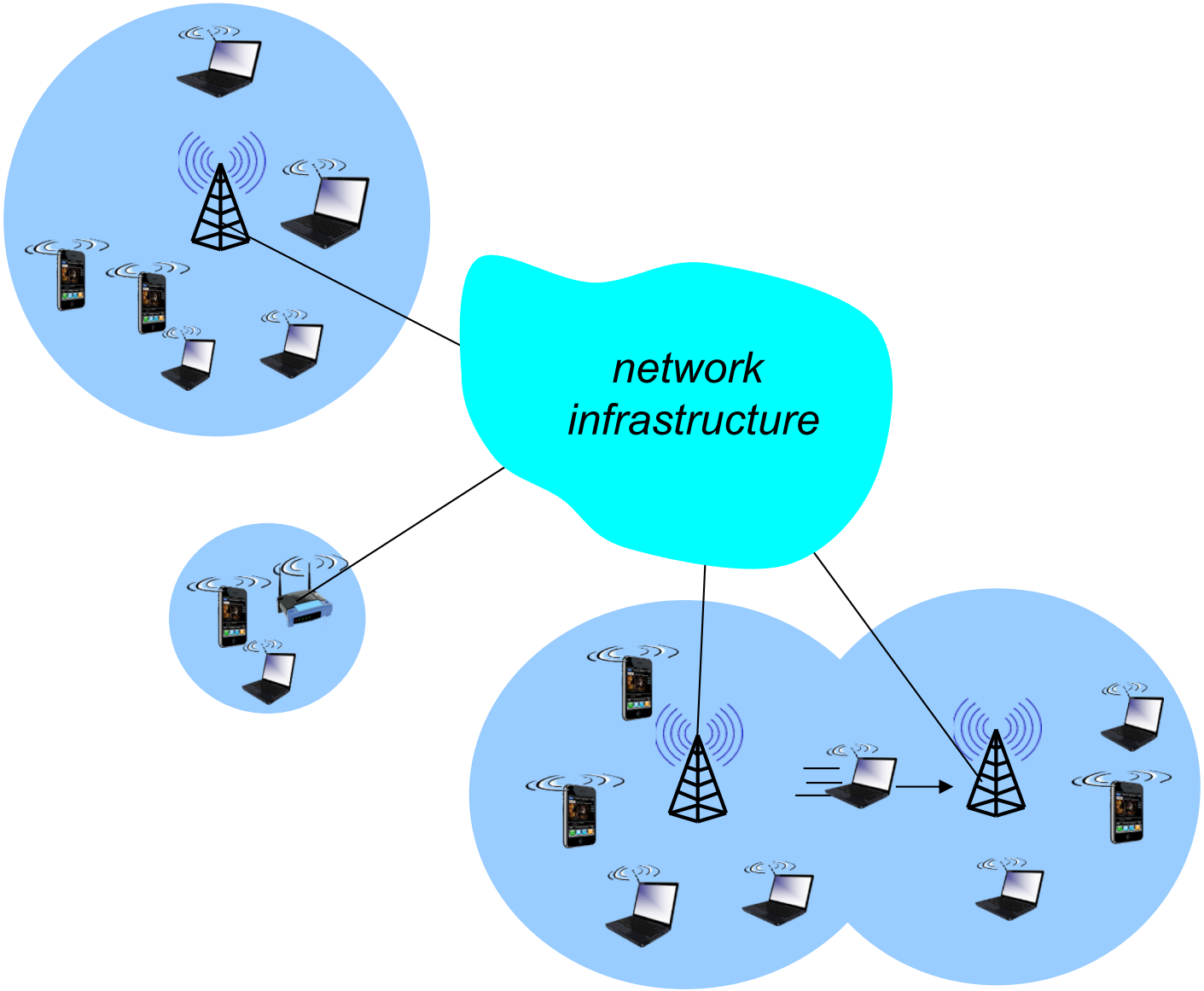
C is the speed of light
f is frequency
λ (lambda) is wavelength

Wavelength $\lambda = \frac{C}{f}$

Frequency $f = \frac{C}{\lambda}$



Elements of a wireless network



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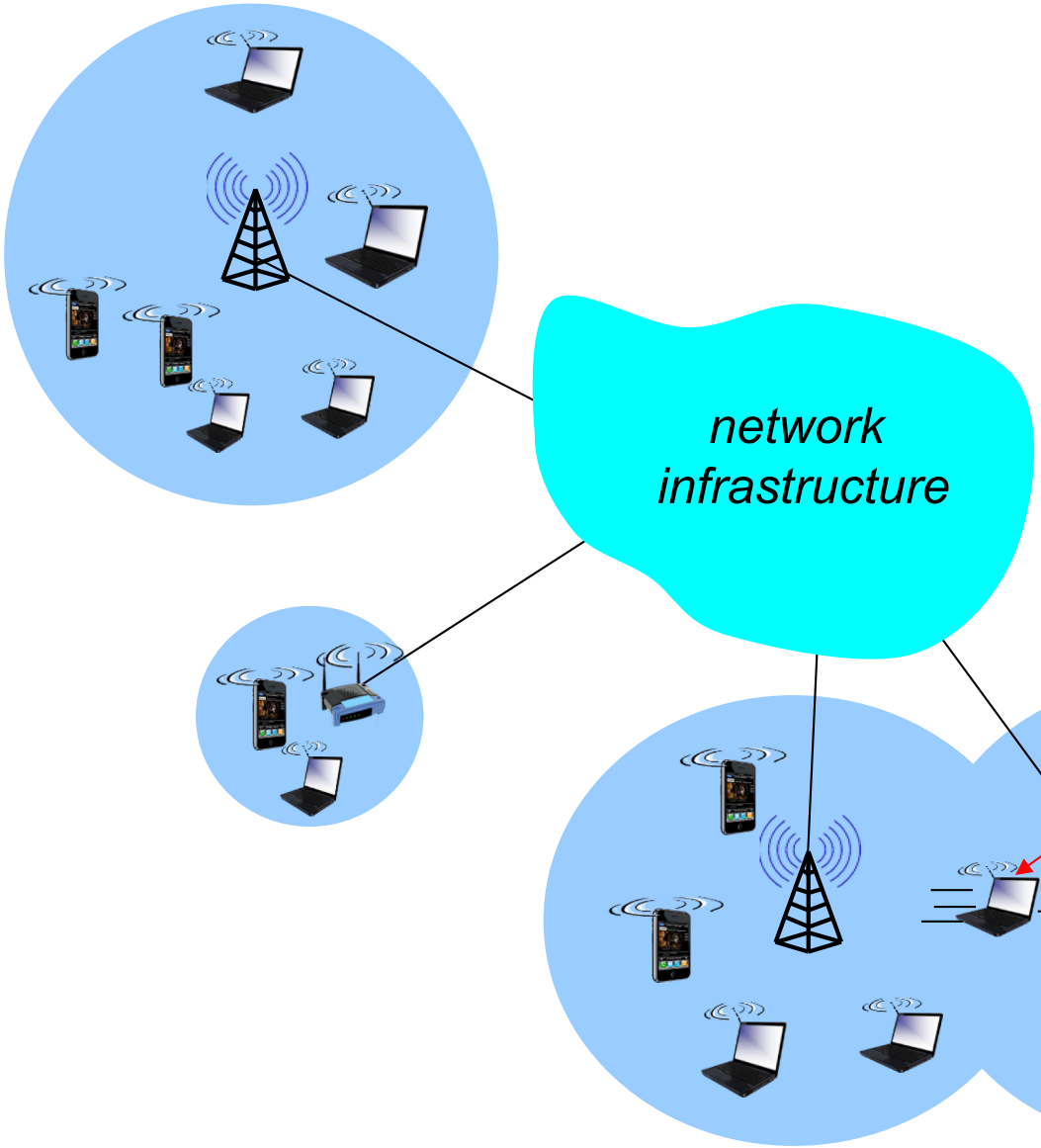
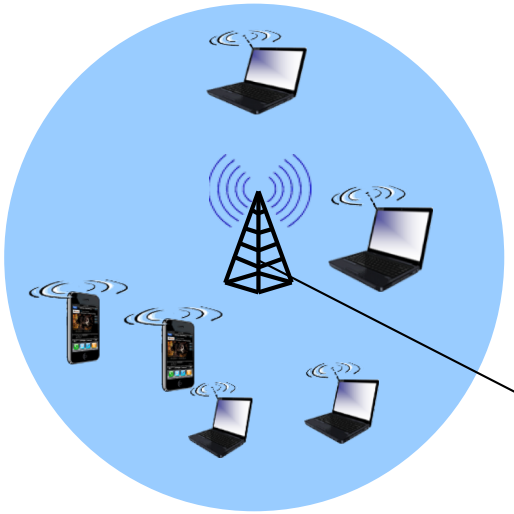


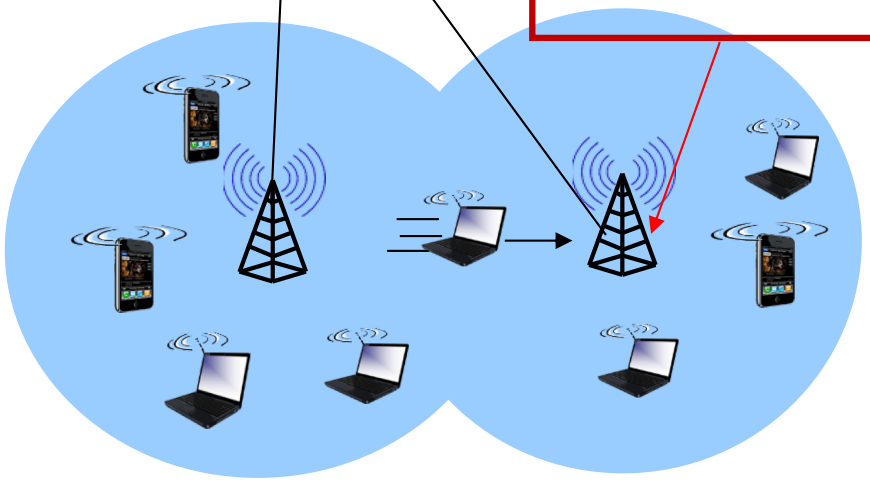
wireless hosts

- *laptop, smartphone*
- *run applications*
- *may be stationary (non-mobile) or mobile*
  - *wireless does not always mean mobility*

Elements of a wireless network



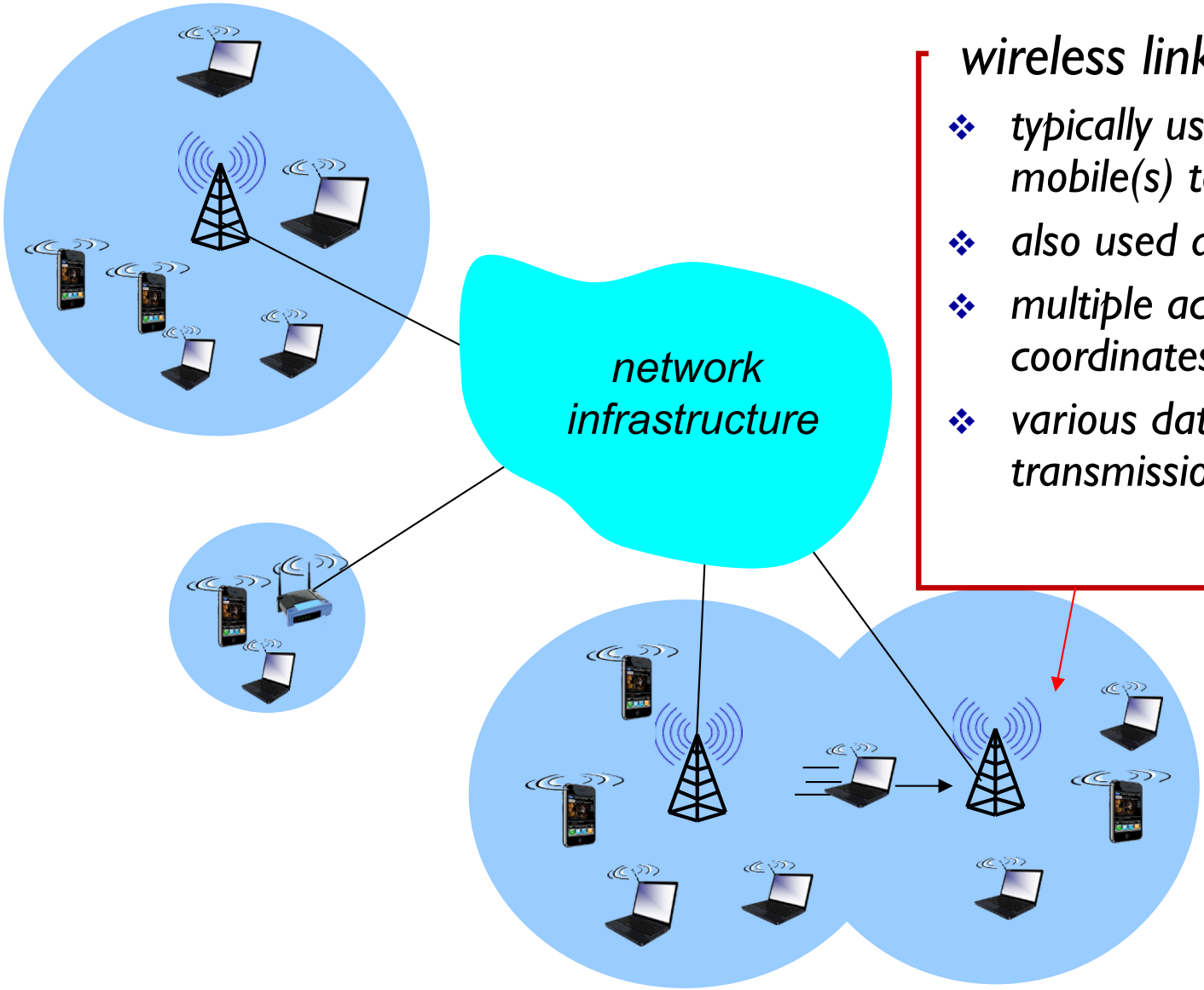
network infrastructure



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*

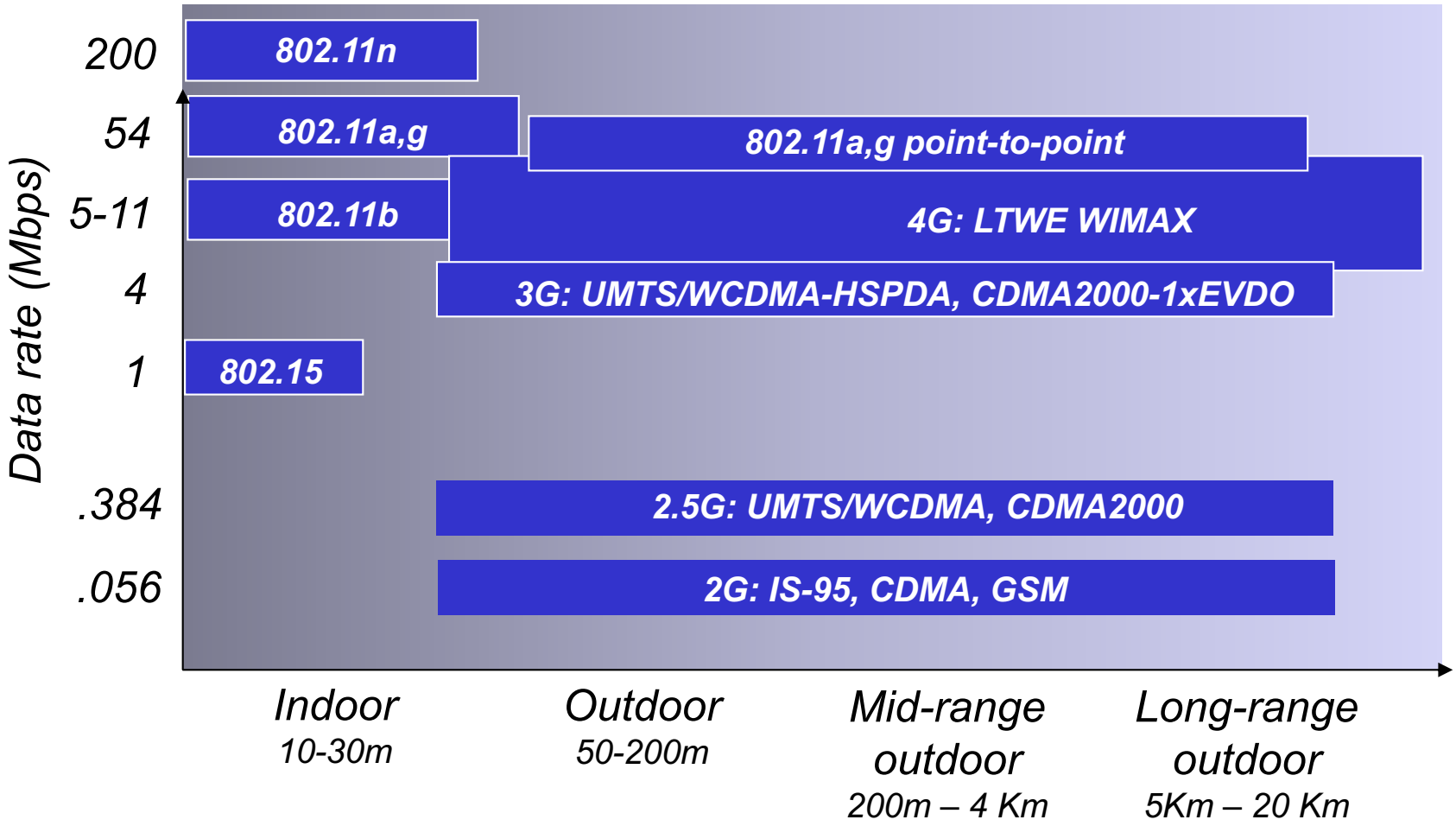
Elements of a wireless network



wireless link

- *typically used to connect mobile(s) to base station*
- *also used as backbone link*
- *multiple access protocol coordinates link access*
- *various data rates, transmission distance*

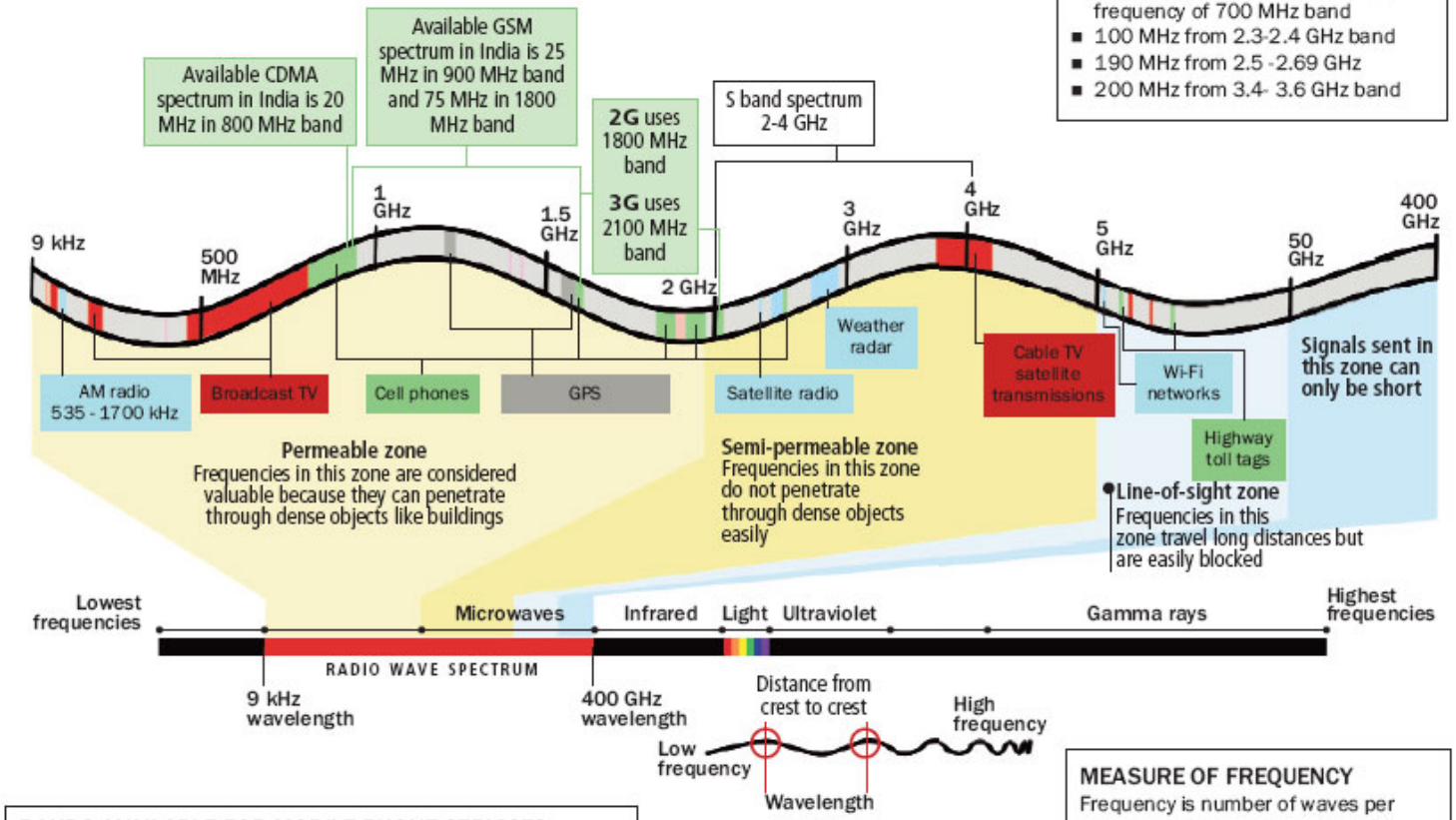
Characteristics of selected wireless links



RADIO SPECTRUM

EVOLVING MOBILE TECHNOLOGY

- 1G: Short for first generation wireless telephone technology. Mobile phone was first launched in the 1980s in this technology. Radio signals on 1G networks were analog, where information is transmitted by modulating a continuous signal, like sound waves. Used frequency band 824-894 MHz
- 2G: Short for second generation wireless telephone technology. Mobile phone in India was launched based on this technology. Radio signals on 2G networks are digital. It allows data services for mobile phones, including text messages and downloading of ringtones. Uses 1800 MHz band
- 3G: Short for third-generation wireless telephone technology. It supports services like mobile TV and high-resolution video. Uses 2.1 GHz band



BANDS AVAILABLE FOR MOBILE PHONE SERVICES

800 band = 824-844/869-889 MHz
900 band = 890-915 MHz/935-960 MHz
1800 band = 1710-1785/1805-1880 MHz
2100 band (2.1 GHz) = 1920-1980 MHz/2110-2170 MHz

WAYS TO FULFILL DEMAND

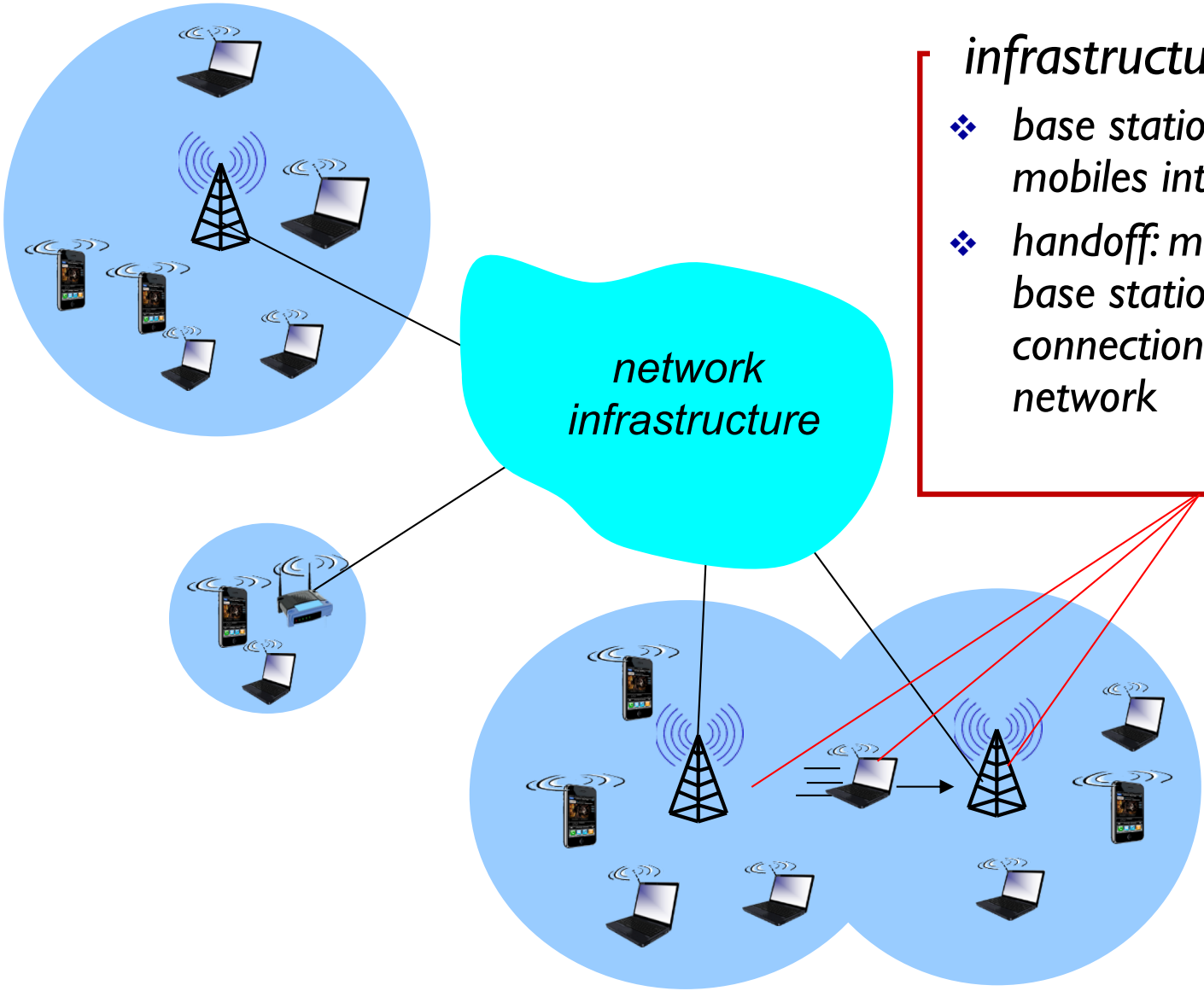
Telecom industry is looking towards new sources, including:

- 108 MHz from the broadcasting frequency of 700 MHz band
- 100 MHz from 2.3-2.4 GHz band
- 190 MHz from 2.5 -2.69 GHz
- 200 MHz from 3.4- 3.6 GHz band

MEASURE OF FREQUENCY

Frequency is number of waves per second. It is measured in hertz.
1 hertz = waves per second
1 kilohertz (kHz) = 1000 hertz
1 megahertz (MHz) = 1000 kHz
1 gigahertz (GHz) = 1000 MHz

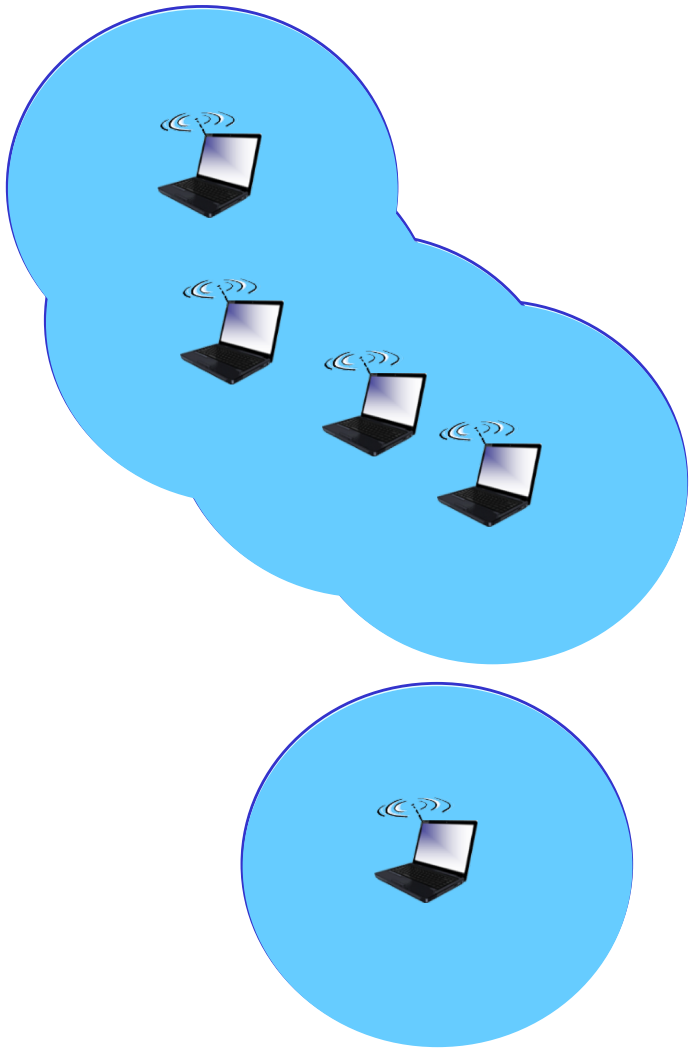
Elements of a wireless network



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, WiMAX, 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*

Outline

7.1 Introduction

Wireless

7.3 IEEE 802.11 wireless LANs ("Wi-Fi")

Wireless Link Characteristics (1)

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 ground, arriving ad destination at slightly different times

…. make communication across (even a point to point) wireless link much more "difficult"

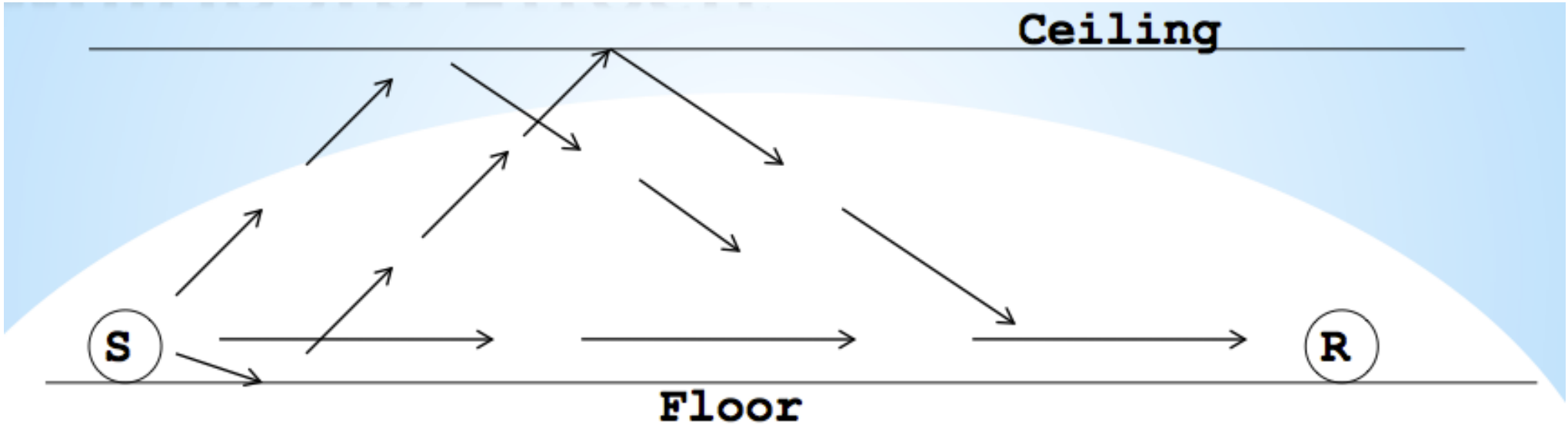
Path Loss/Path Attenuation

- Free Space Path Loss
  - d: distance
  - λ: wavelength
  - f: frequency
  - c: speed of light

$$\mathrm{FSPL} = \left(\frac{4\pi d}{\lambda}\right)^2 = \left(\frac{4\pi df}{c}\right)^2$$

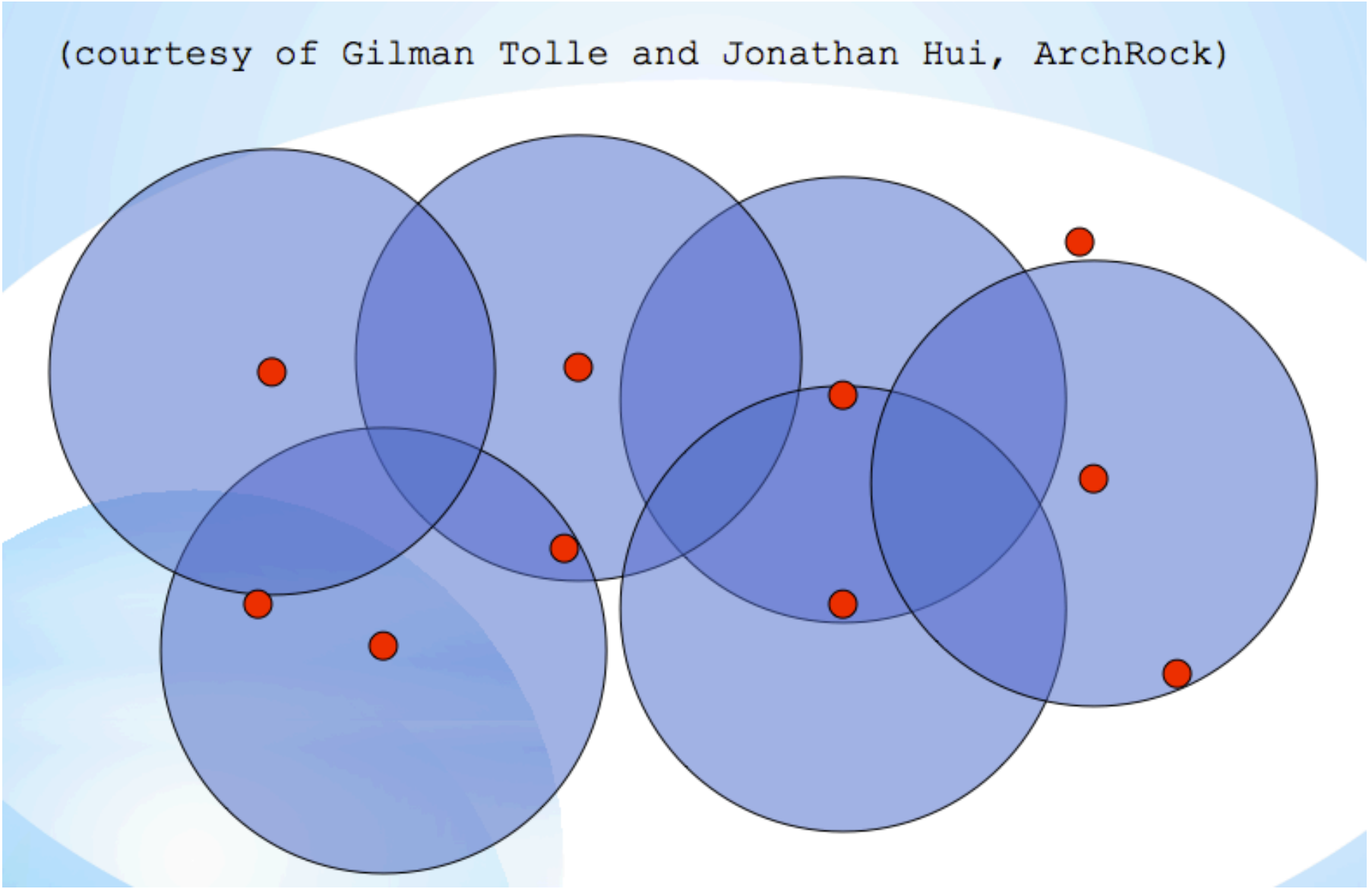
- Reflection, Diffraction, Absorption
- Terrain contours (urban, rural, vegetation)
- Humidity

Multipath Effects

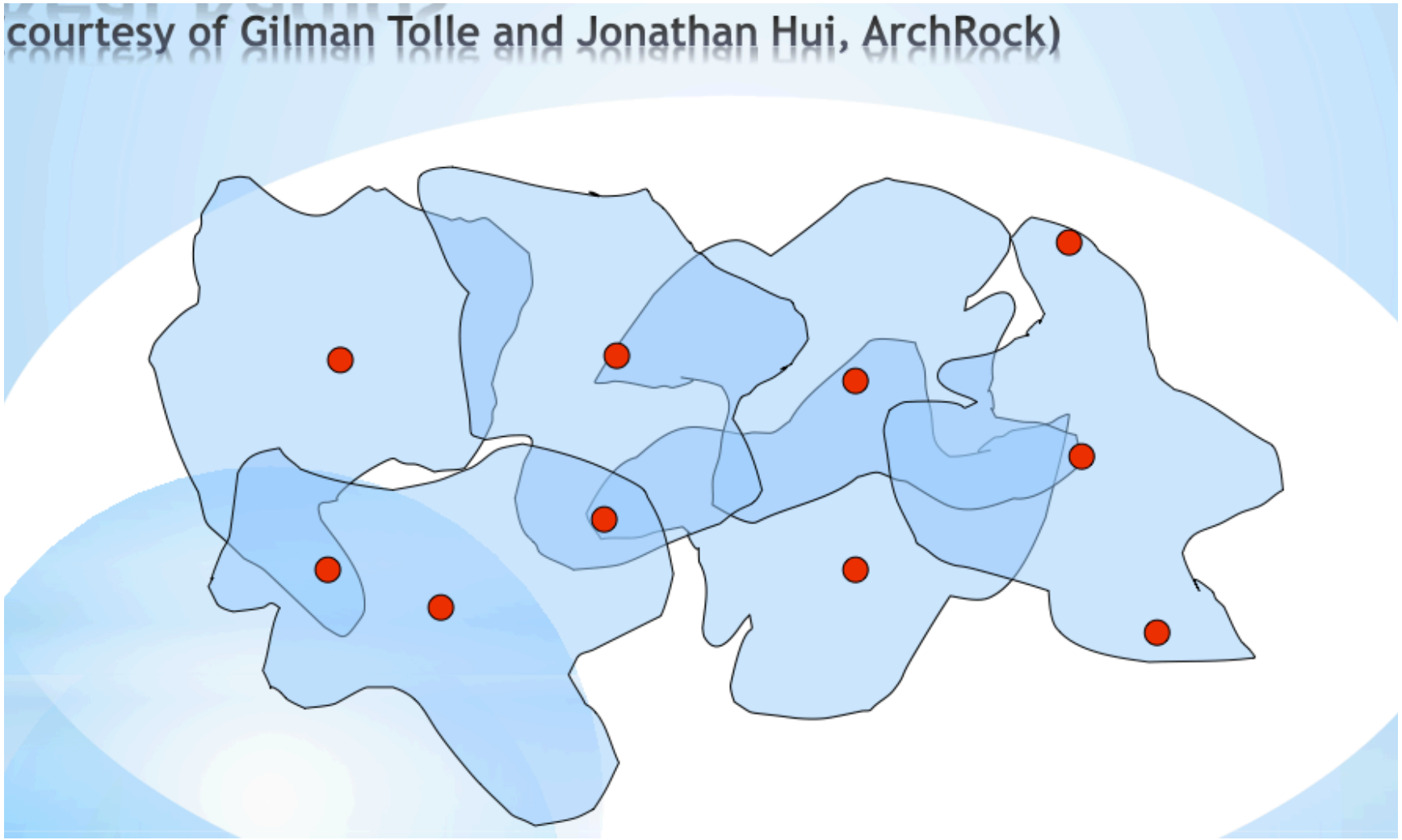


- Signals bounce off surface and interfere (constructive or destructive) with one another
- Self-interference

Ideal Radios

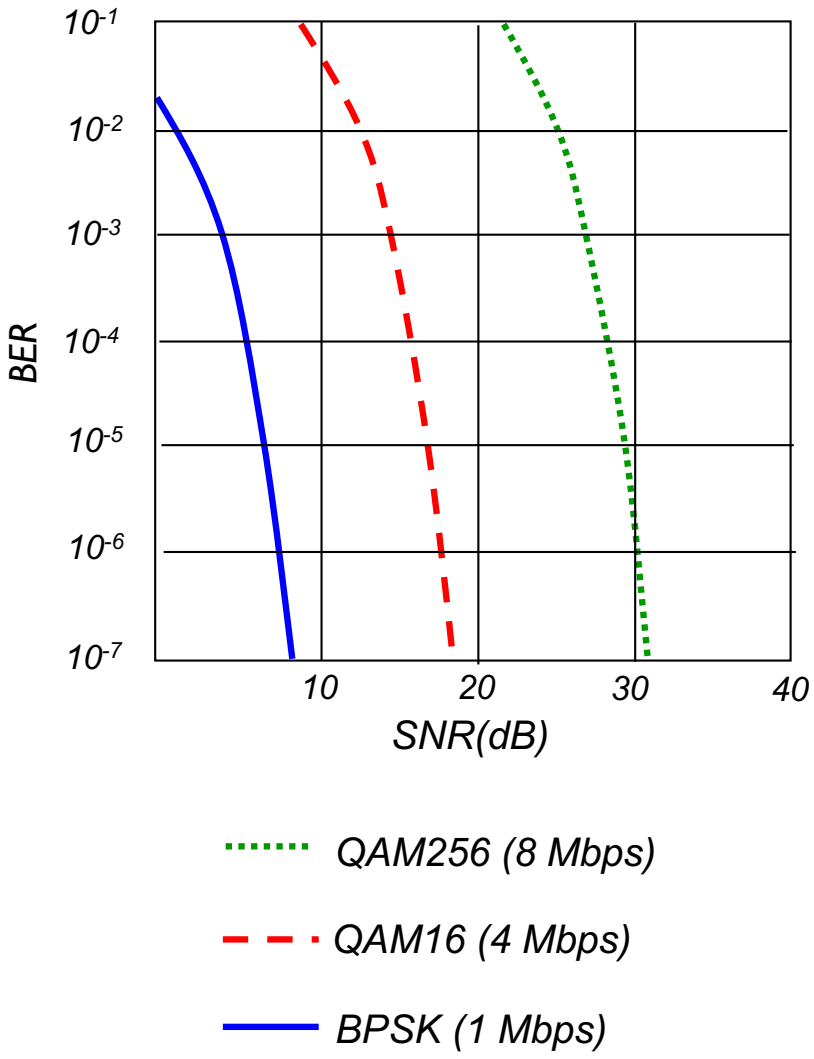


Real Radios



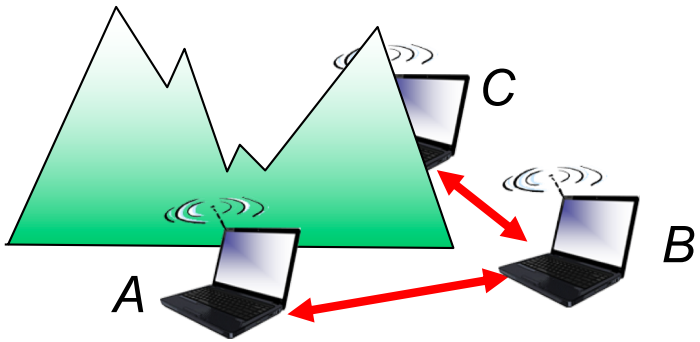
Wireless Link Characteristics (2)

- 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 -> increase SNR->decrease BER
  - *given SNR:* choose physical layer that meets BER requirement, giving highest thruput
    - SNR may change with mobility: dynamically adapt physical layer (modulation technique, rate)



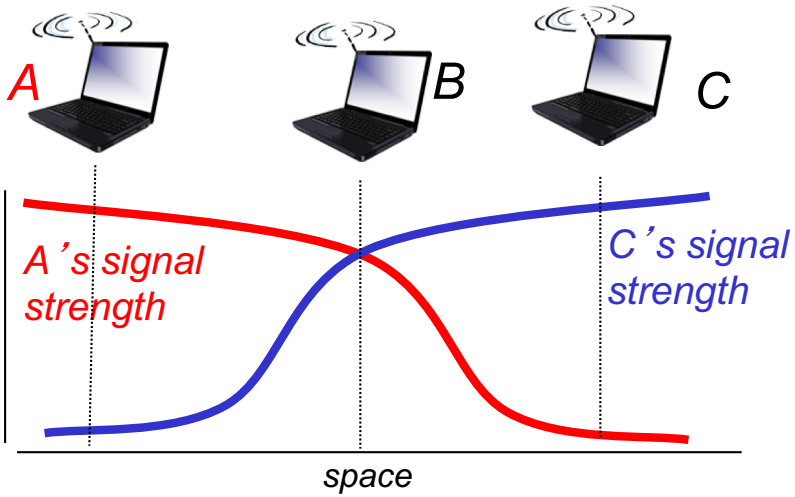
Wireless network characteristics

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*
- *Carrier sense will be ineffective*

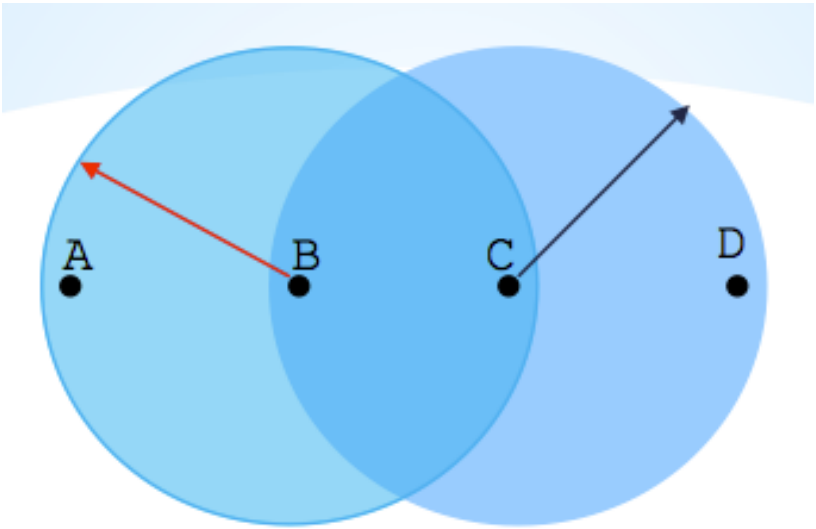


Signal attenuation:

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

Wireless network characteristics

- Exposed Terminals



- Node B sends a packet to A; C hears this and decides not to send a packet to D (despite the fact that this will not cause interference) !!
- Carrier sense would prevent a successful transmission

IEEE 802.11 Wireless LAN

802.11b

- 2.4-5 GHz unlicensed spectrum
- up to 11 Mbps
- direct sequence spread spectrum (DSSS) in physical layer
  - all hosts use same chipping code

802.11a

- 5-6 GHz range
- up to 54 Mbps

802.11g

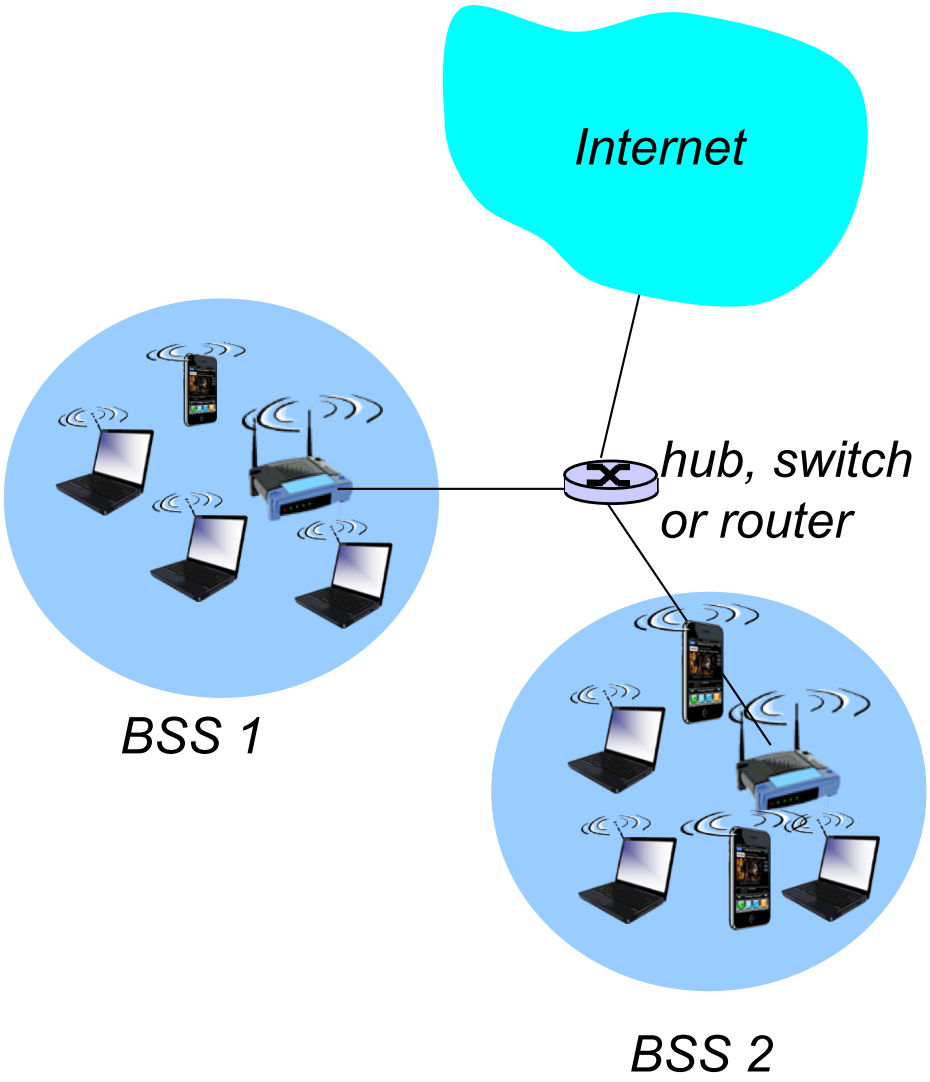
- 2.4-5 GHz range
- up to 54 Mbps

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

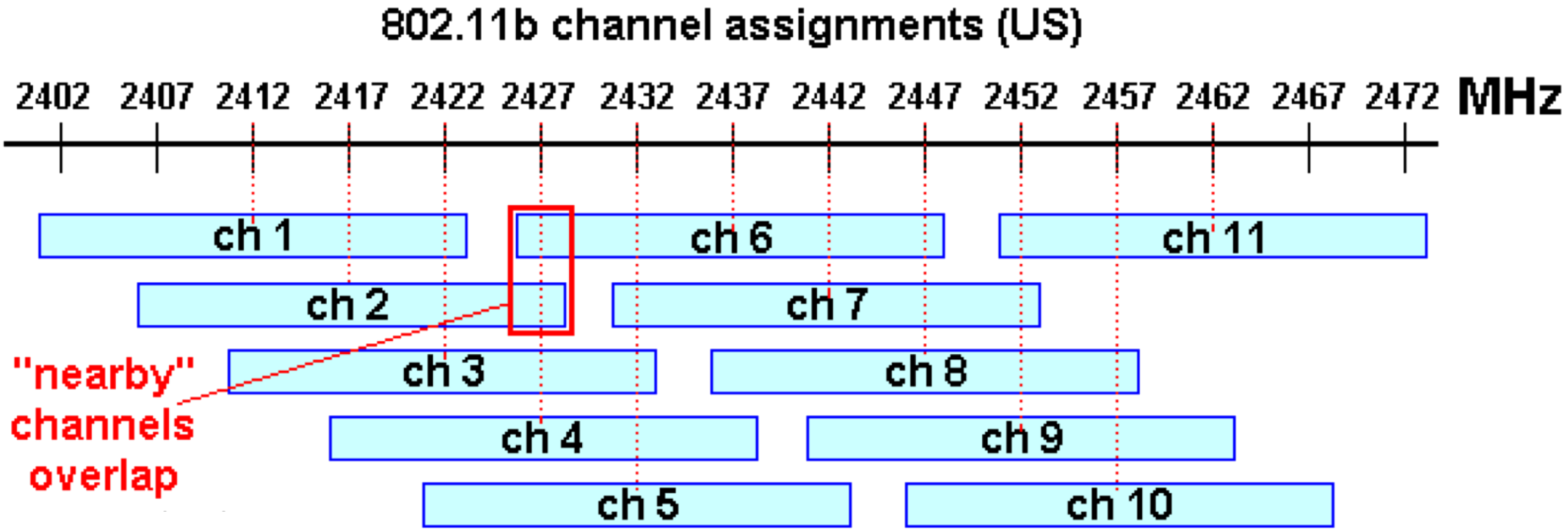


- *wireless host communicates with base station*
  - *base station = access point (AP)*
- *Basic Service Set (BSS) (aka "cell") in infrastructure mode contains:*
  - *wireless hosts*
  - *access point (AP): base station*
  - *ad hoc mode: hosts only*

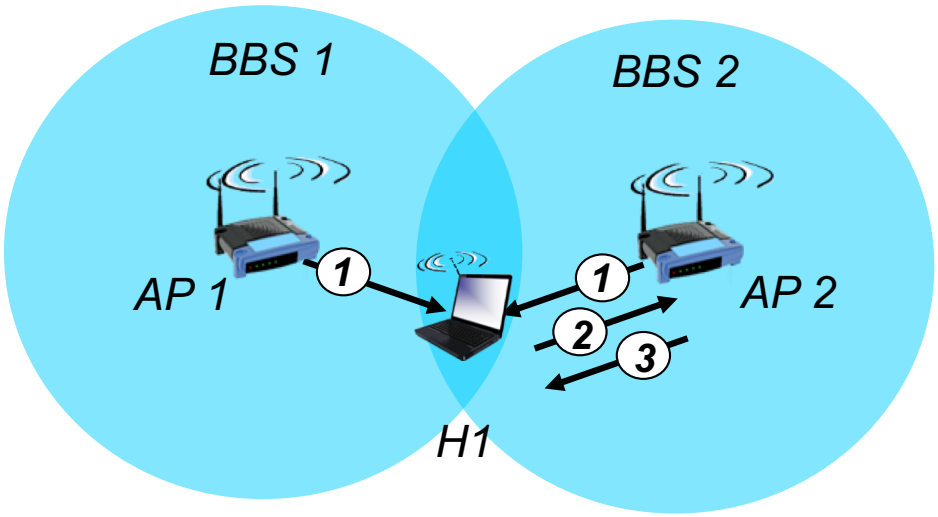
802.11: Channels, association

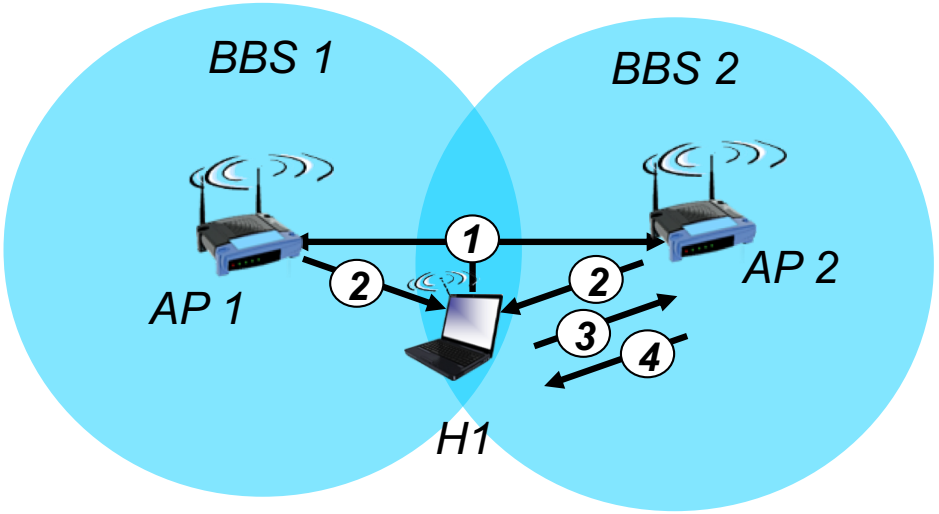
- 802.11b: 2.4GHz-2.485GHz spectrum divided into 11 channels at different frequencies
  - AP admin chooses frequency for AP
  - interference possible: channel can be same as that chosen by neighboring AP!
- host: must *associate* with an AP
  - scans channels, listening for *beacon frames* containing AP's name (SSID) 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

802.11b channels



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

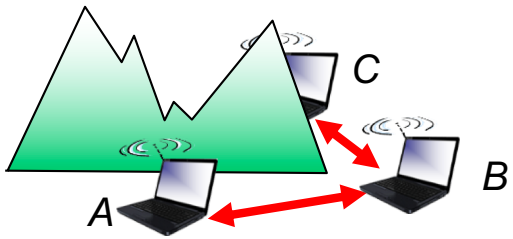
(2) Probe Response frames sent from APs

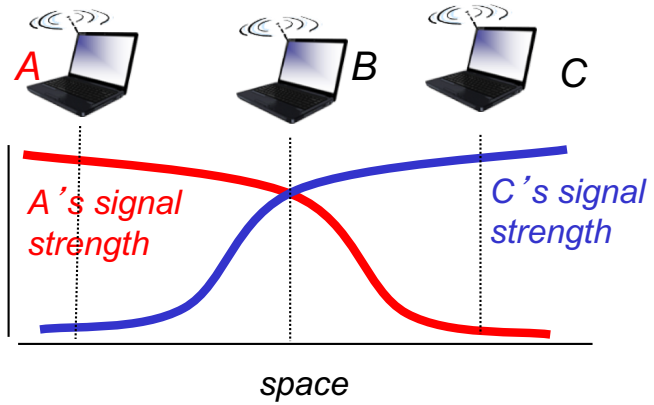
(3) Association Request frame sent: H1 to selected AP

(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/C(ollision)A(voidance)





Multiple access: Key Points

- No concept of a global collision
  - Different receivers hear different signals
  - Different senders reach different receivers
- Collisions are at receiver, not sender
  - Only care if receiver can hear the sender clearly
  - It does not matter if sender can hear someone else
  - As long as that signal does not interfere with receiver
- Goal of protocol
  - Detect if receiver can hear sender
  - Tell senders who might interfere with receiver to shut up

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

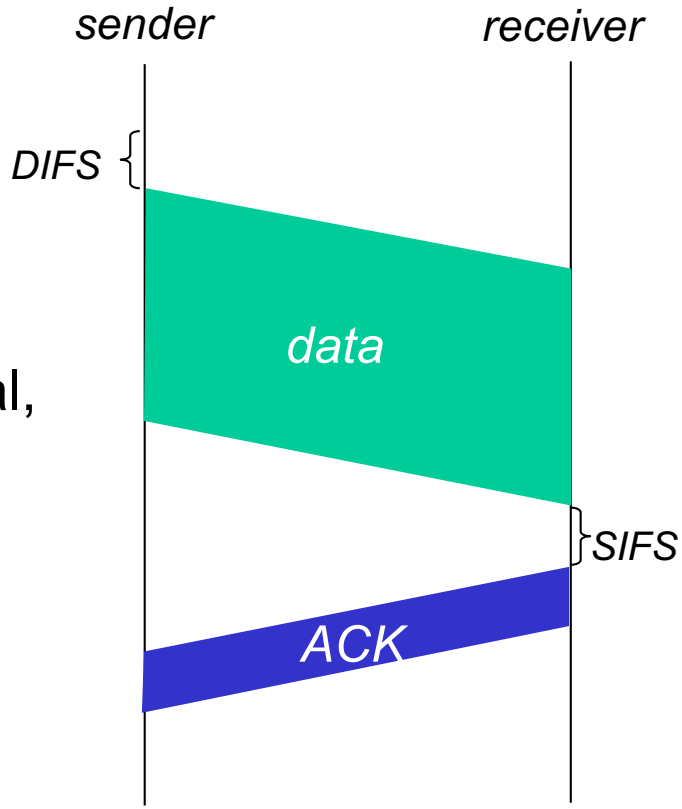
transmit when timer expires

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)



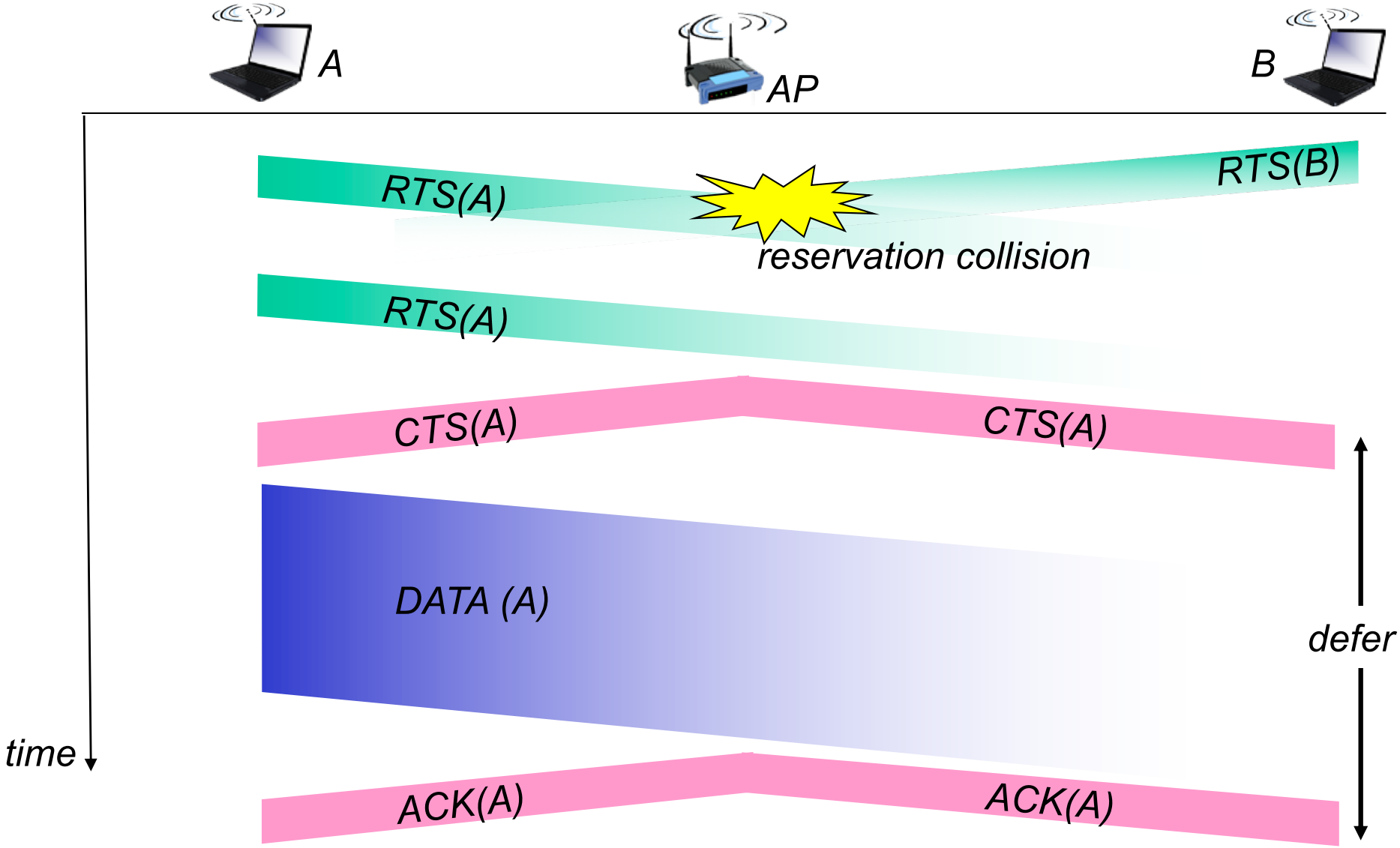
Avoiding collisions (more)

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

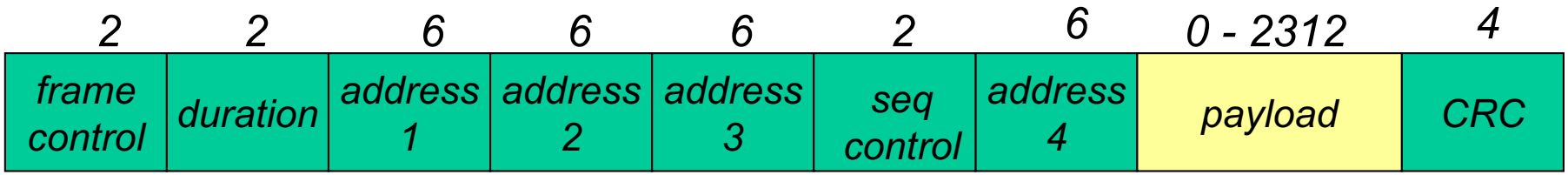
- sender first transmits *small* request-to-send (RTS) packets to BS using CSMA
  - RTSs may still collide with each other (but they're short)
- BS broadcasts clear-to-send CTS in response to RTS
- CTS heard by all nodes
  - sender transmits data frame
  - other stations defer transmissions

avoid data frame collisions completely using small reservation packets!

Collision Avoidance: RTS-CTS exchange



802.11 frame: addressing



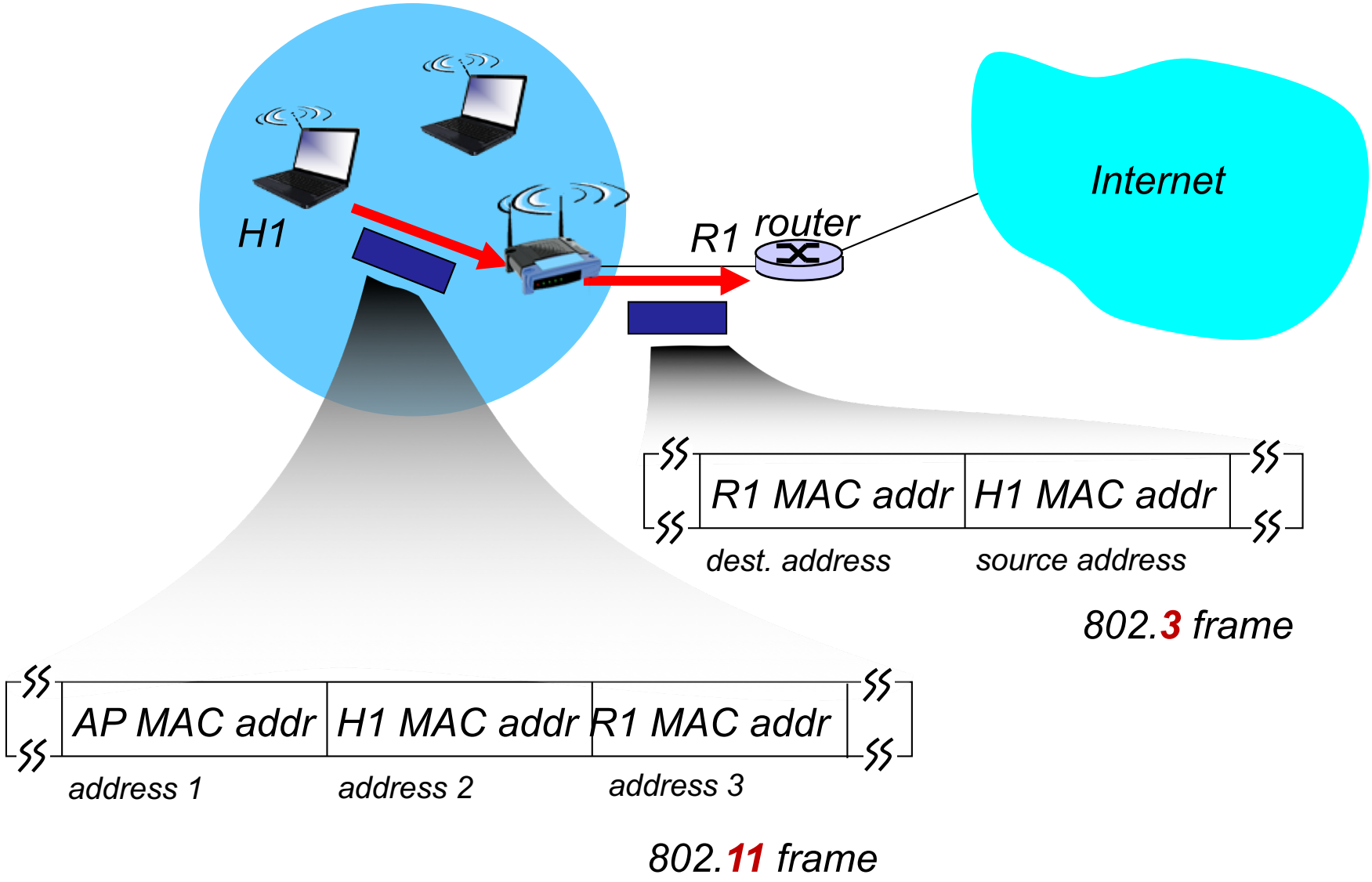
Address 1: MAC address of wireless host or AP to receive this frame

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

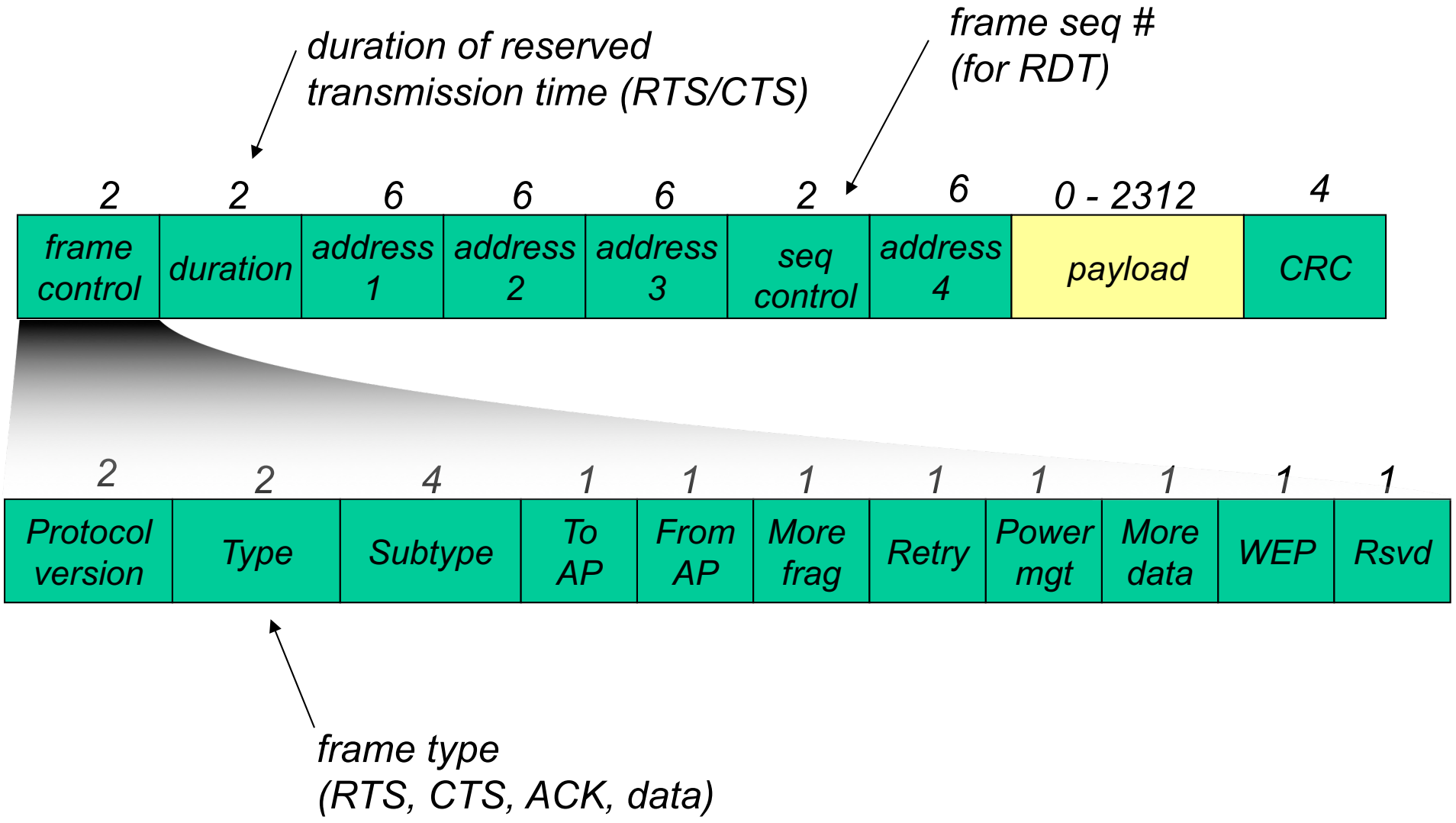
Address 3: MAC address of router interface to which AP is attached

Address 4: used only in ad hoc mode

802.11 frame: addressing

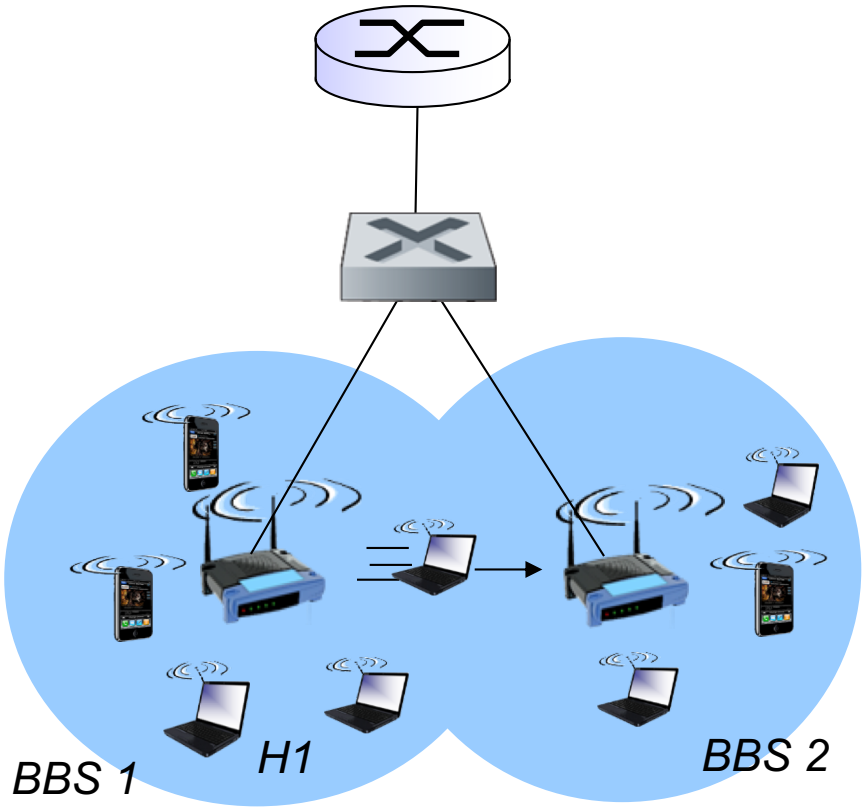


802.11 frame: more



802.11: mobility within same subnet

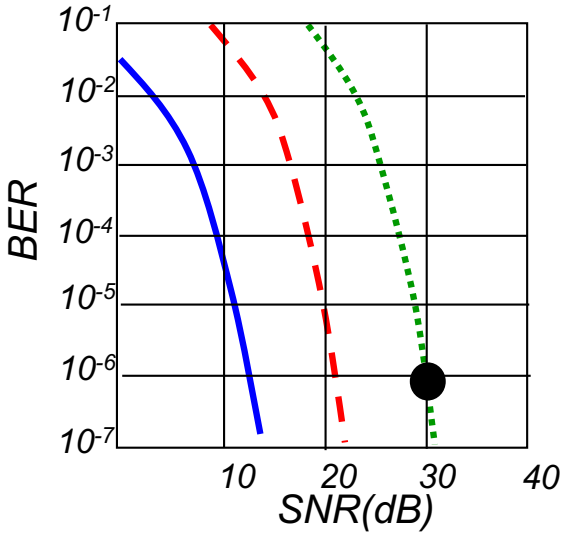
- H1 remains in same IP subnet: IP address can remain same
- switch: which AP is associated with H1?
  - self-learning (Ch. 5): switch will see frame from H1 and "remember" which switch port can be used to reach H1

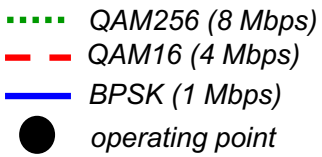


802.11: advanced capabilities

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*