

# COMP 3331/9331: Computer Networks and Applications

Week 10

Wireless Networks

Reading Guide: Chapter 7, Sections 7.1 – 7.3

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# Wireless and Mobile Networks: context

- *more wireless (mobile) phone subscribers than fixed (wired) phone subscribers (10-to-1 in 2019)!*
- *more mobile-broadband-connected devices than fixed-broadband-connected devices (5-1 in 2019)!*
  - *4G/5G cellular networks now embracing Internet protocol stack, including SDN*
- *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

## 7.2 Wireless links, characteristics

## 7.3 IEEE 802.11 wireless LANs (“Wi-Fi”)

# Wireless 101

- **Frequency/Wave-Length** -

$C$  is the speed of light

$f$  is frequency

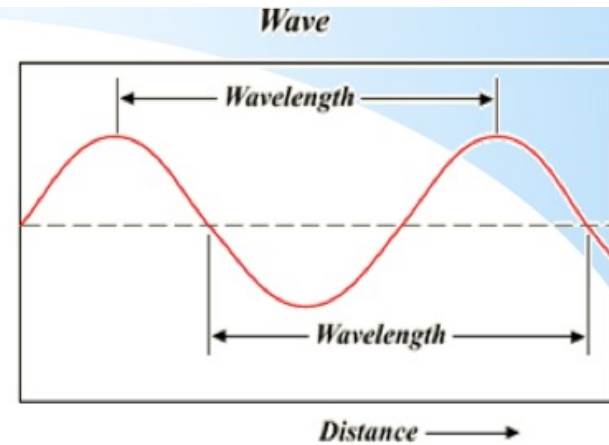
$\lambda$  (lambda) is wavelength

Wavelength

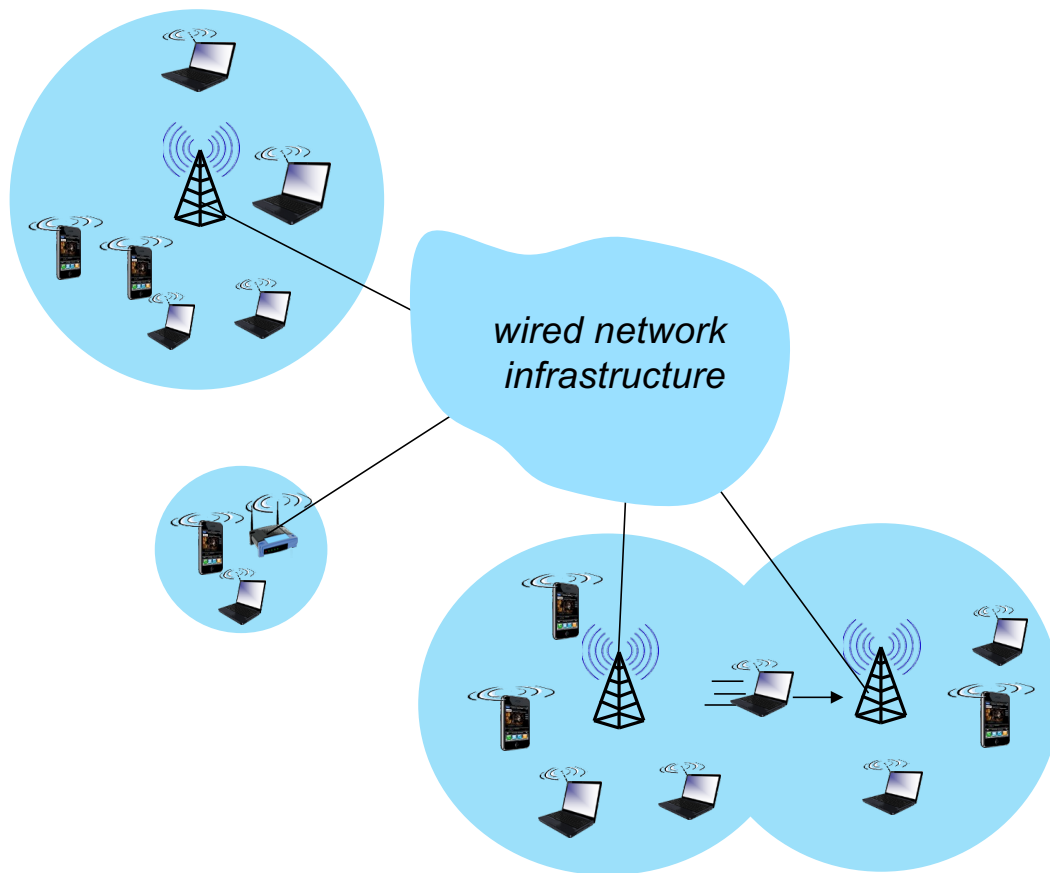
$$\lambda = \frac{C}{f}$$

Frequency

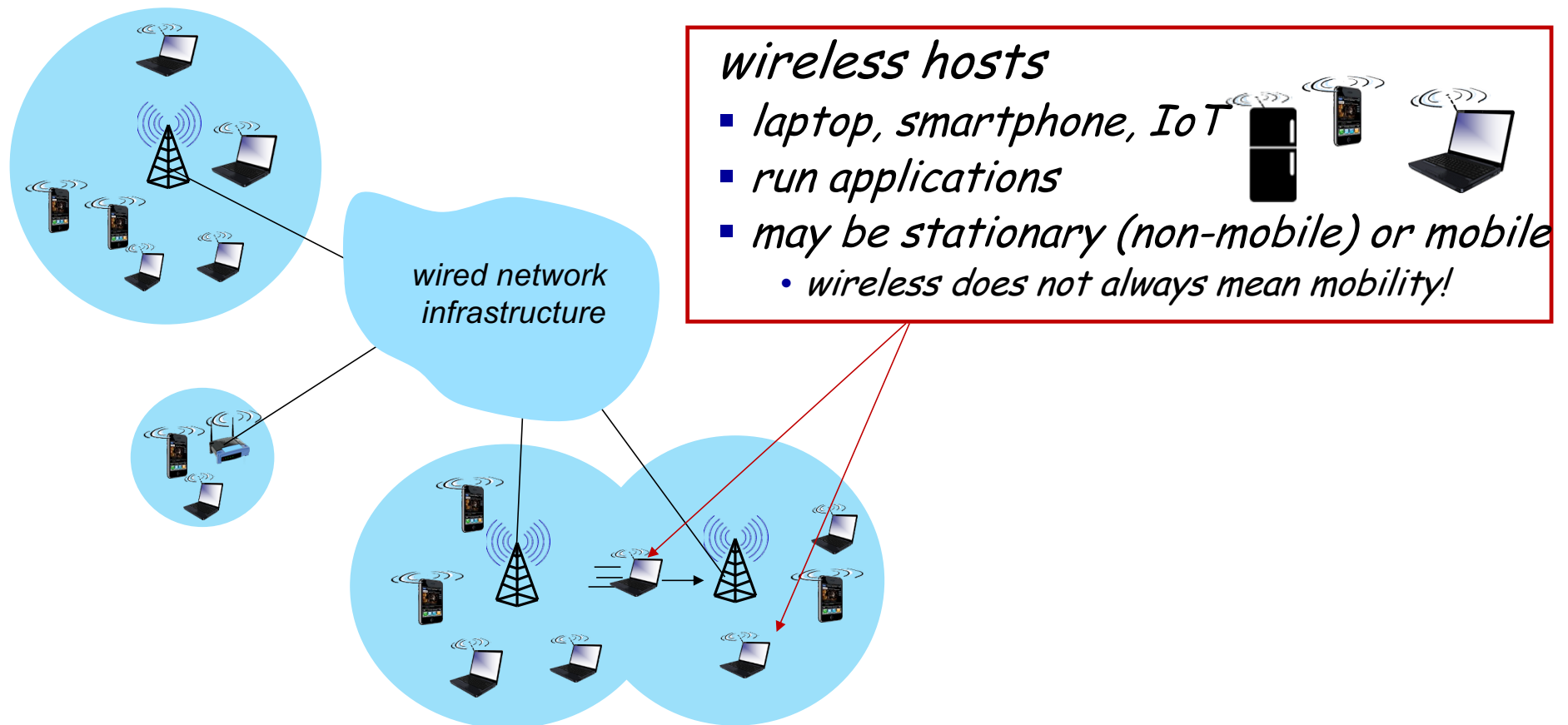
$$f = \frac{C}{\lambda}$$



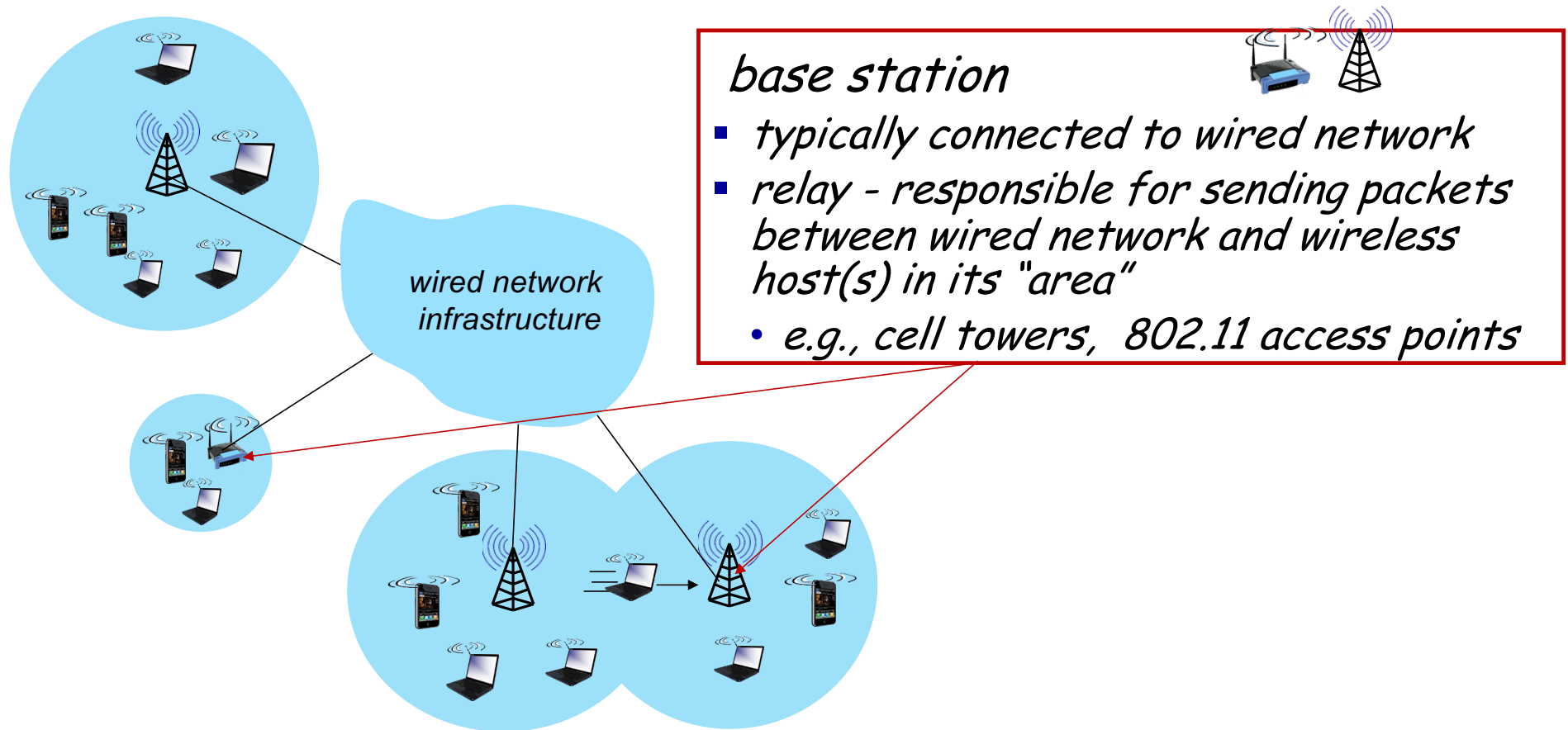
# Elements of a wireless network



# Elements of a wireless network

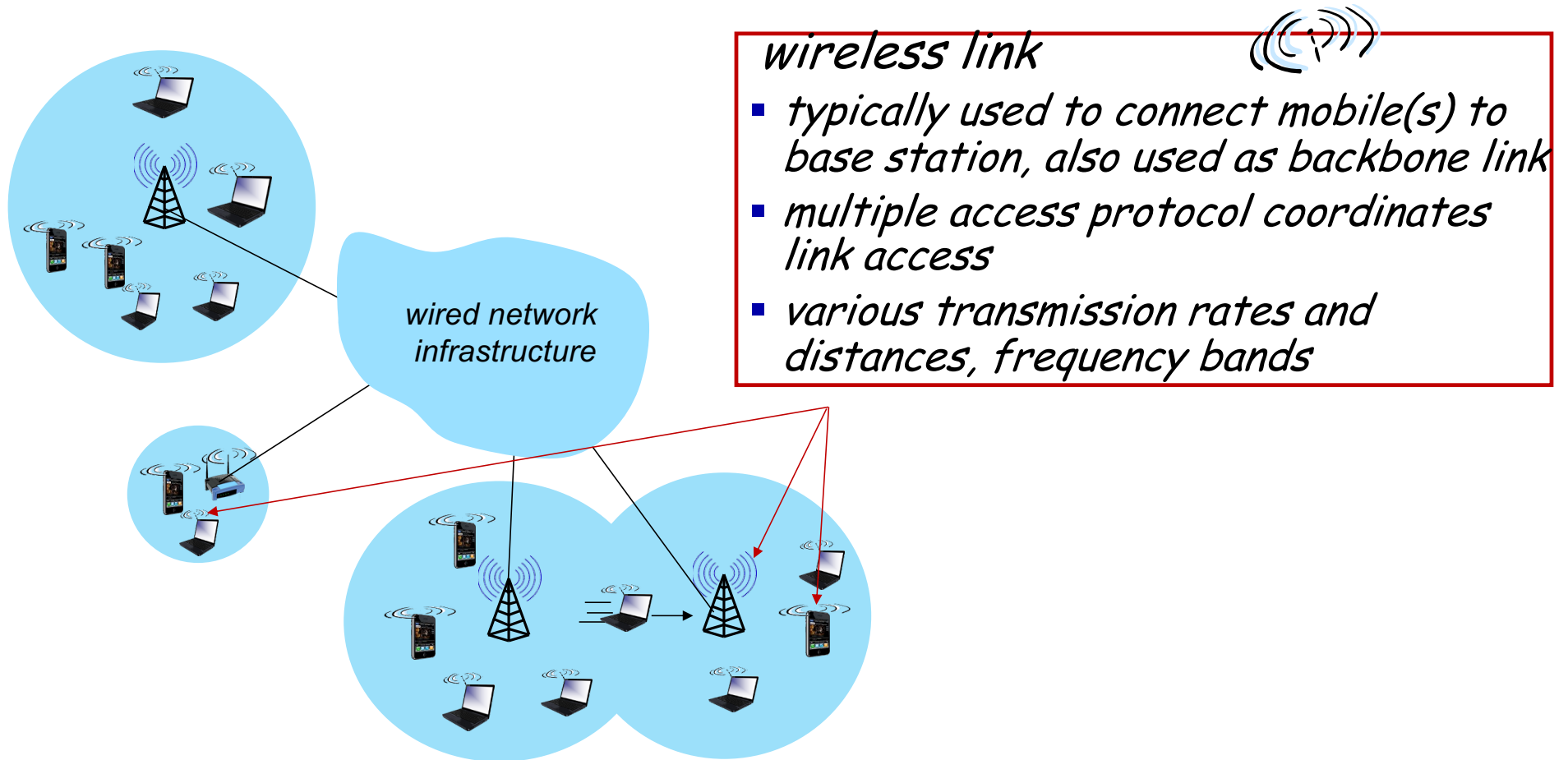


# Elements of a wireless network

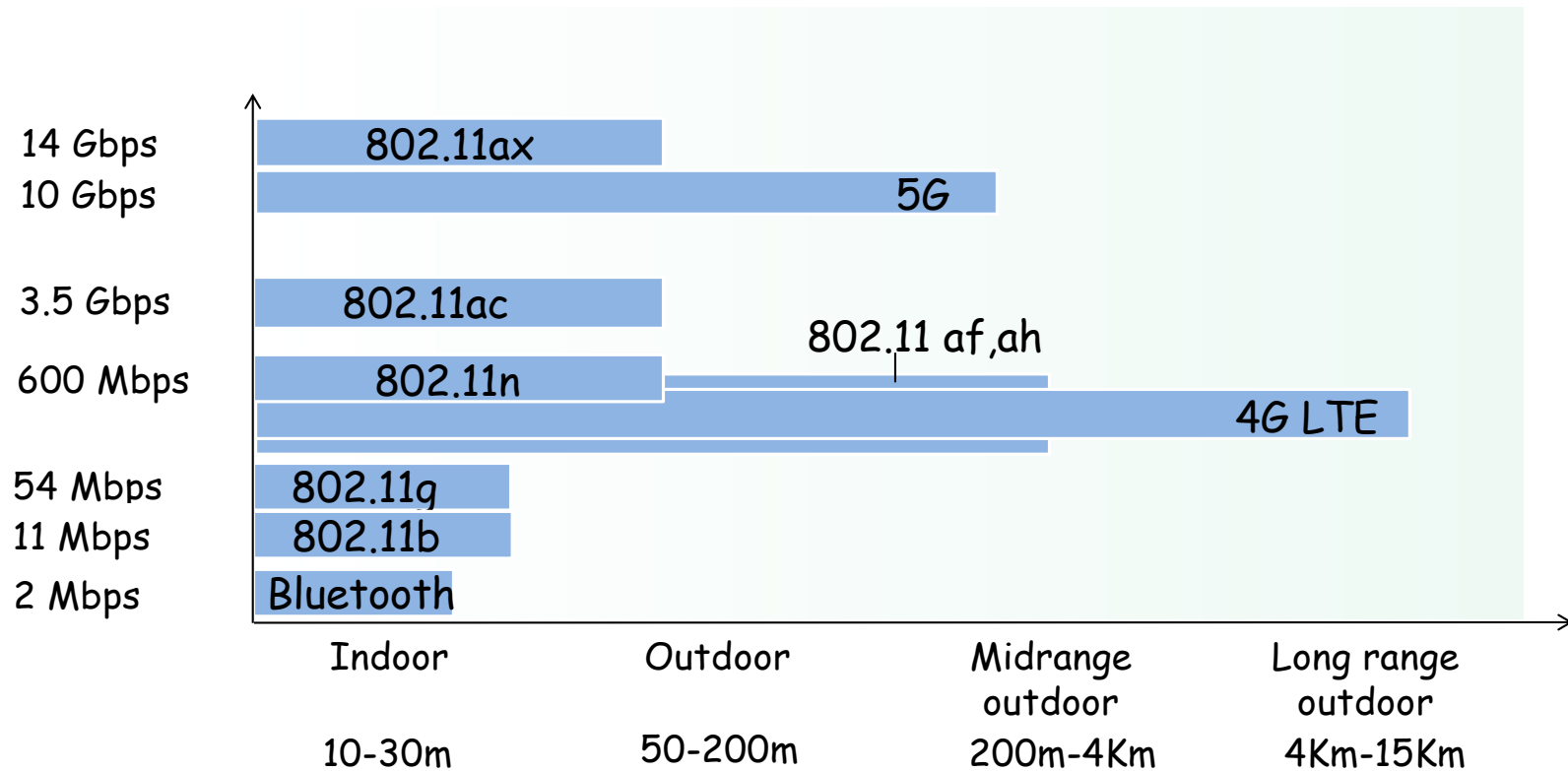




# Elements of a wireless network

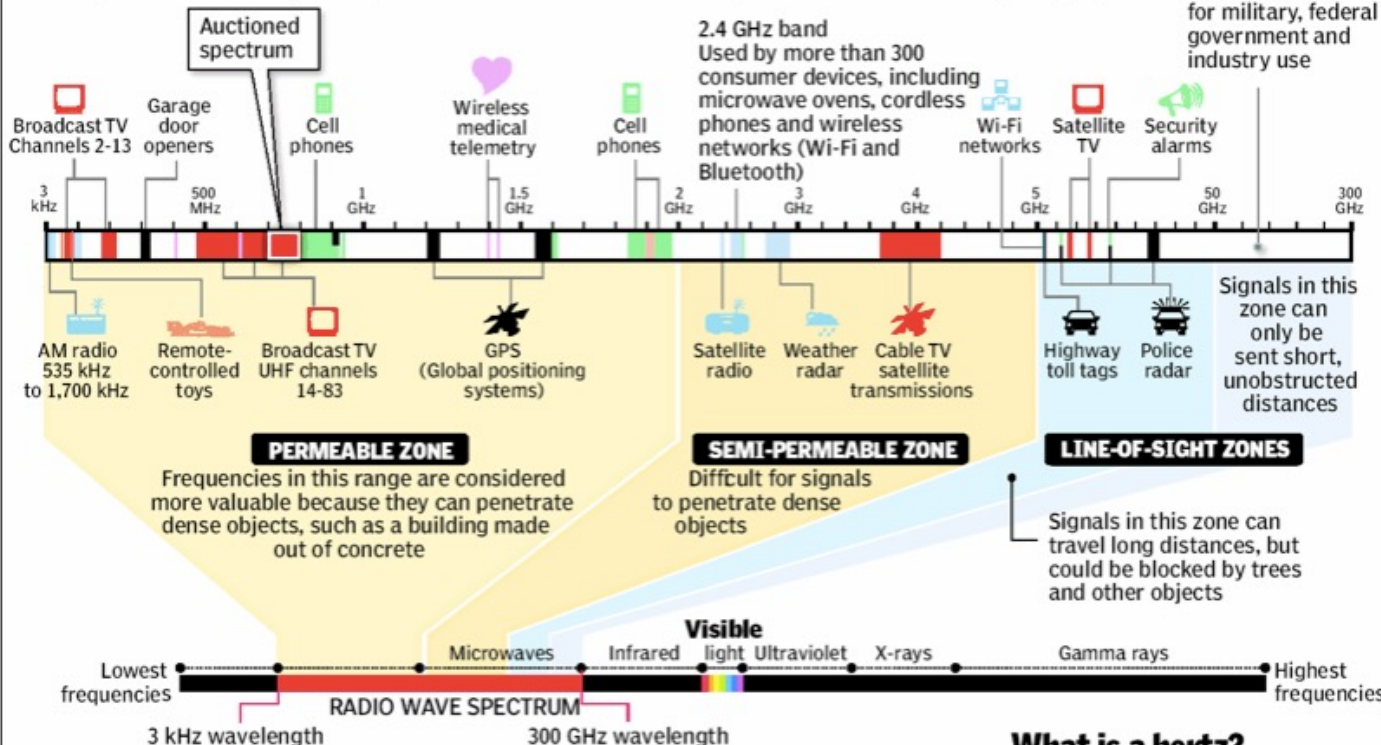


# Characteristics of selected wireless links



# Inside the radio wave spectrum

Almost every wireless technology – from cell phones to garage door openers – uses radio waves to communicate. Some services, such as TV and radio broadcasts, have exclusive use of their frequency within a geographic area. But many devices share frequencies, which can cause interference. Examples of radio waves used by everyday devices are reserved for military, federal government and industry use



## The electromagnetic spectrum

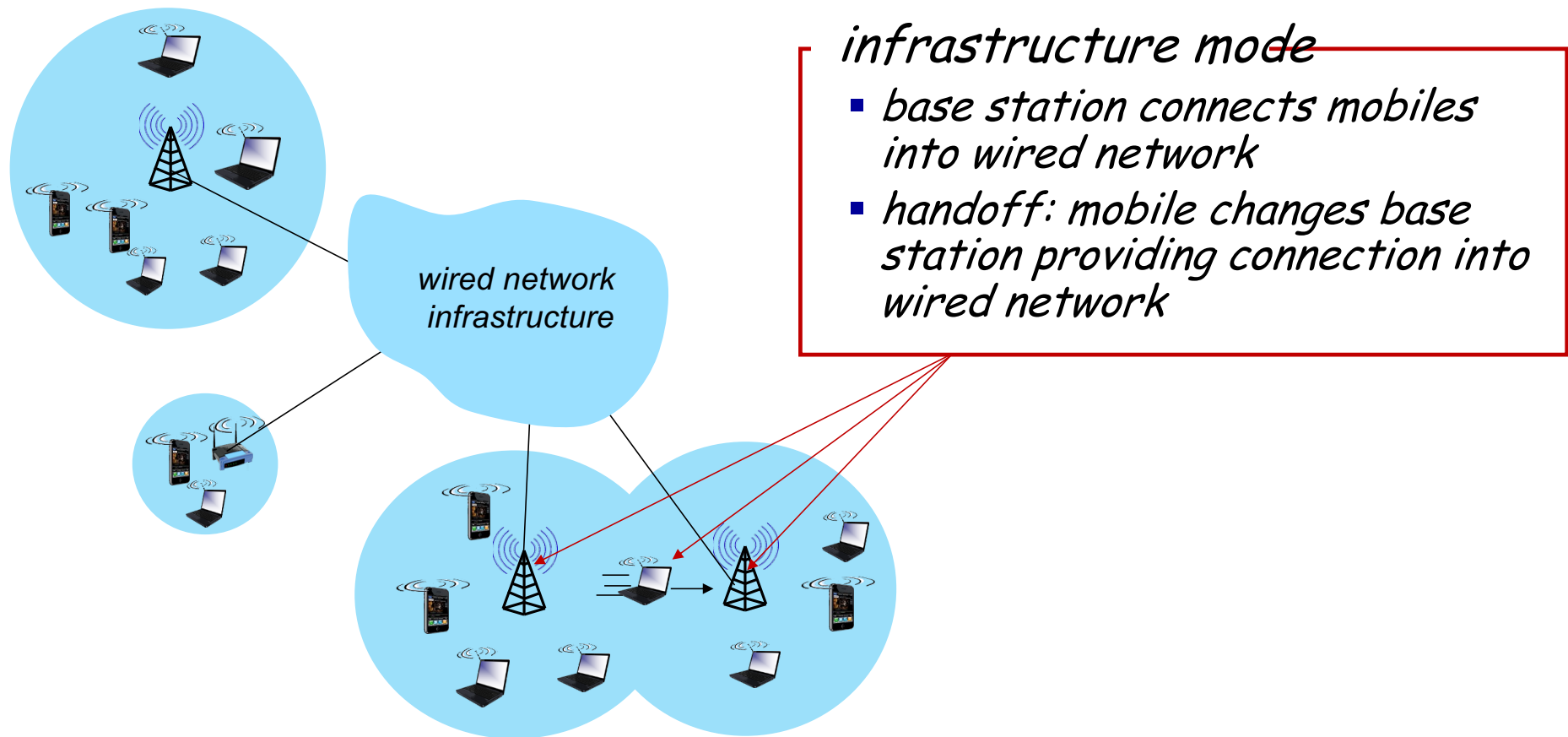
Radio waves occupy part of the electromagnetic spectrum, a range of electric and magnetic waves of different lengths that travel at the speed of light; other parts of the spectrum include visible light and x-rays; the shortest wavelengths have the highest frequency, measured in hertz



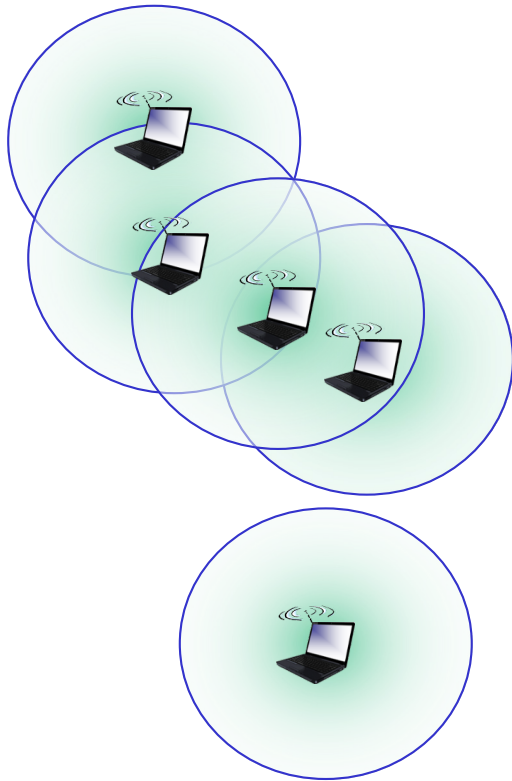
Source: New America Foundation, MCT, Howstuffworks.com  
Graphic: Nathaniel Levine, Sacramento Bee

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# Elements of a wireless network



# Elements of a wireless network

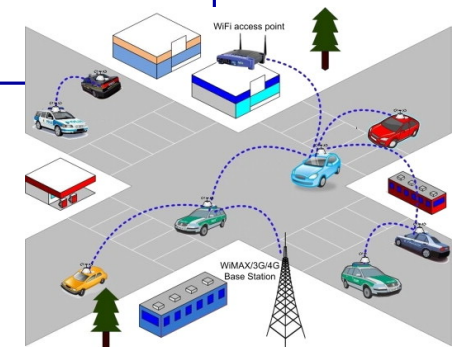


## *ad hoc mode*

- *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

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



# Outline

## 7.1 Introduction

## Wireless

## 7.2 Wireless links, characteristics

## 7.3 IEEE 802.11 wireless LANs (“Wi-Fi”)

# Wireless link characteristics (I)

*important differences from wired link ....*

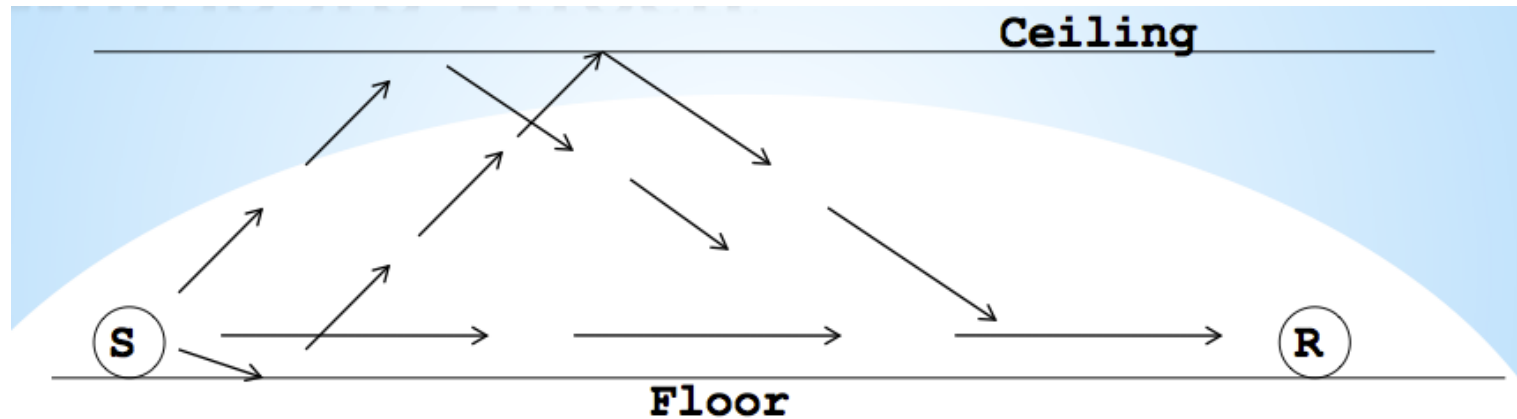
- **decreased signal strength:** radio signal attenuates as it propagates through matter (path loss)
- **interference from other sources:** wireless network frequencies (e.g., 2.4 GHz) shared by many devices (e.g., WiFi, cellular, motors): interference
- **multipath propagation:** radio signal reflects off objects ground, arriving at destination at slightly different times

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





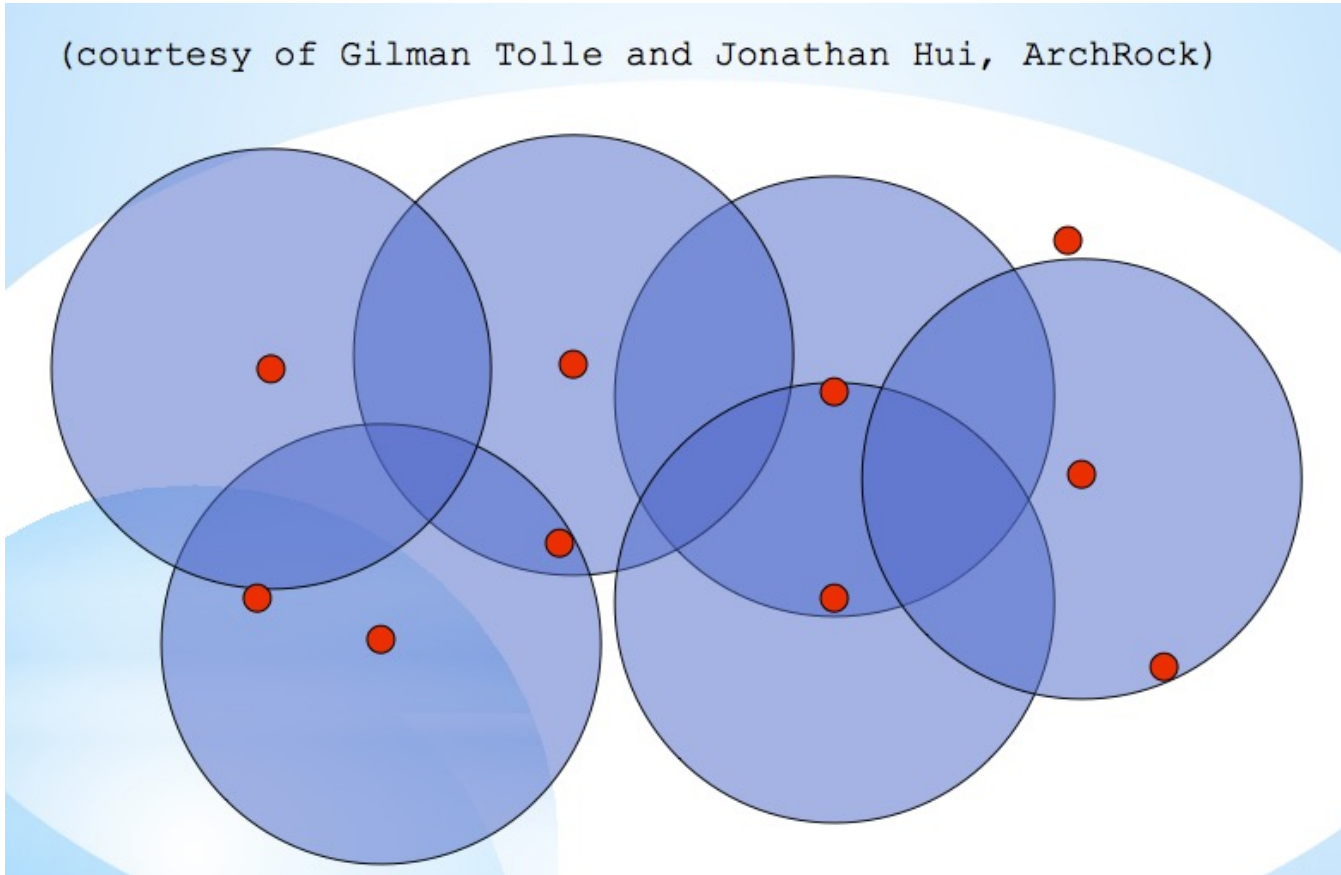
# Multipath Effects



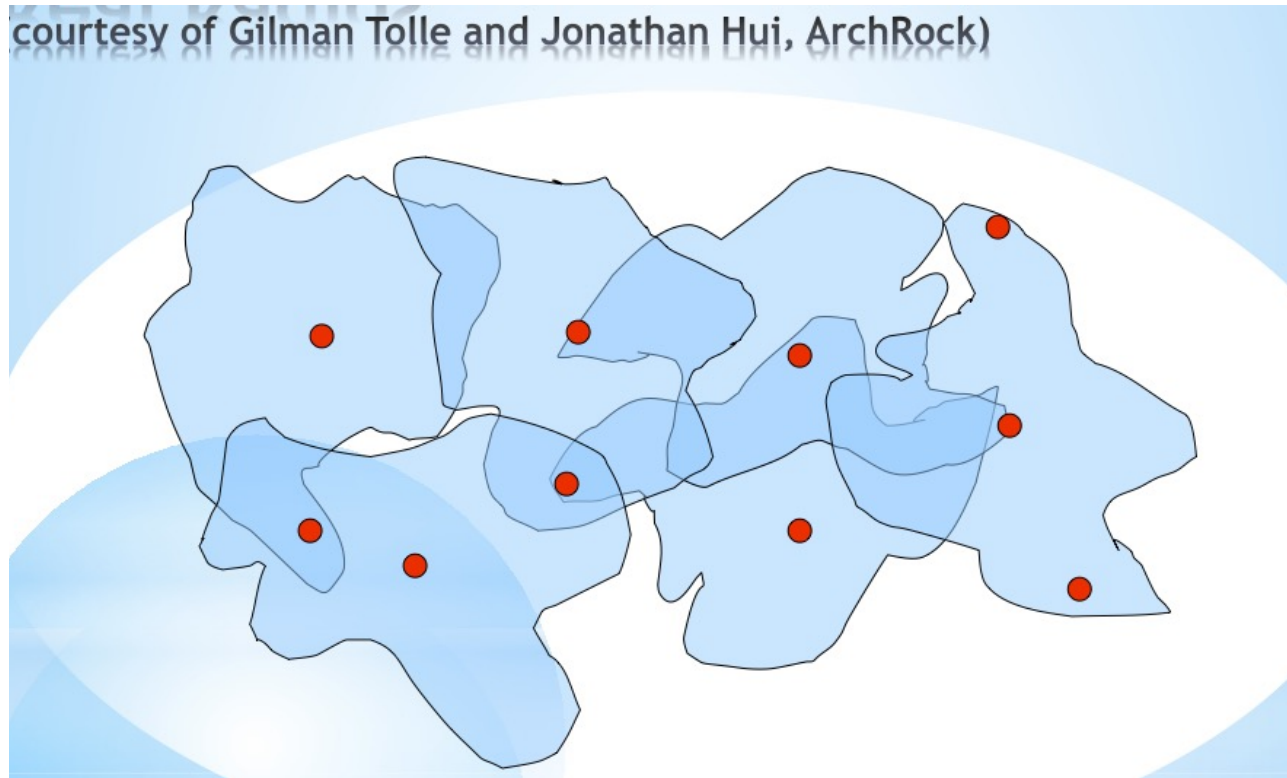
- ❖ Signals bounce off surface and interfere (constructive or destructive) with one another
- ❖ Self-interference

# Ideal Radios

(courtesy of Gilman Tolle and Jonathan Hui, ArchRock)



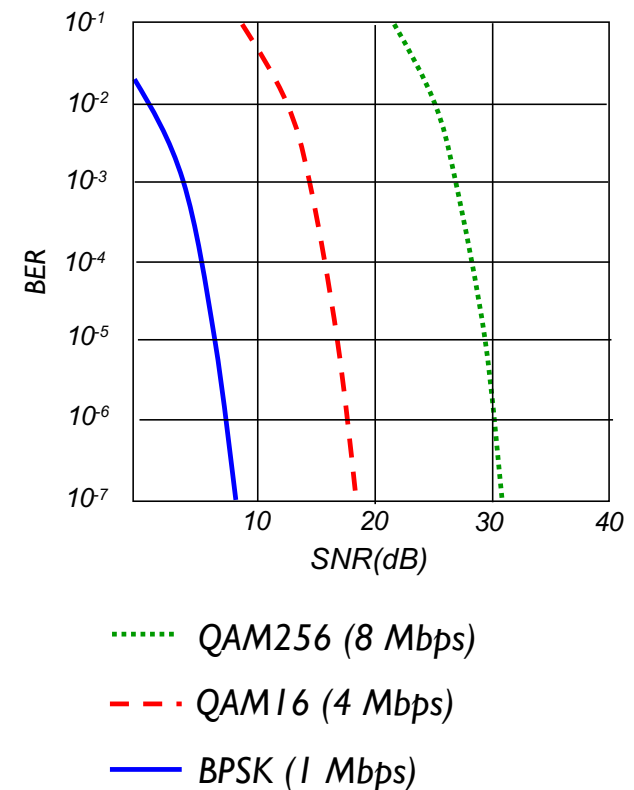
# Real Radios



## Wireless link characteristics (2)

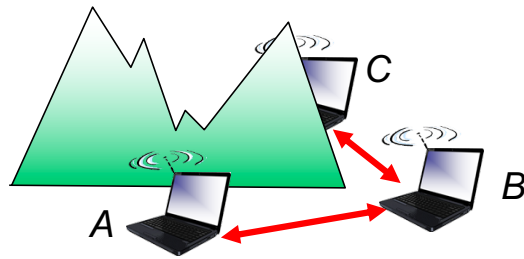
- *SNR: signal-to-noise ratio*
  - larger SNR – easier to extract signal from noise (a “good thing”)
- *SNR versus BER tradeoffs*
  - given physical layer: increase power -> increase SNR->decrease BER
  - given SNR: choose physical layer that meets BER requirement, giving highest throughput
    - SNR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

*BER: Bit Error Rate*



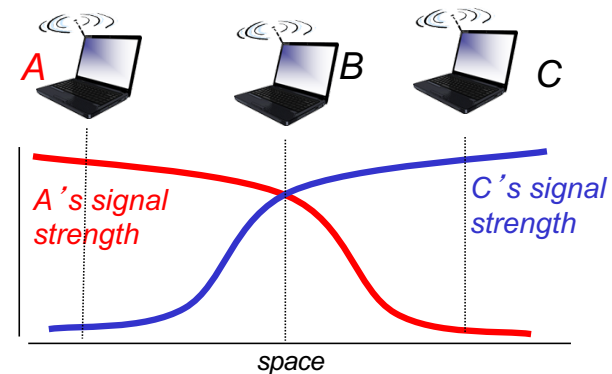
## Wireless link characteristics (3)

Multiple wireless senders, 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*

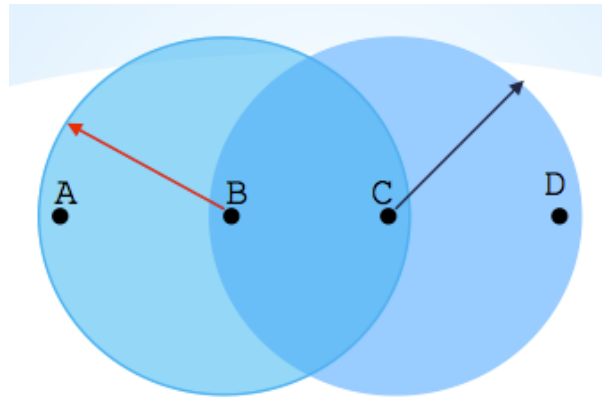


### *Signal attenuation:*

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

## 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

# Outline

7.1 Introduction

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7.2 Wireless links,  
characteristics

7.3 IEEE 802.11 wireless  
LANs (“Wi-Fi”)

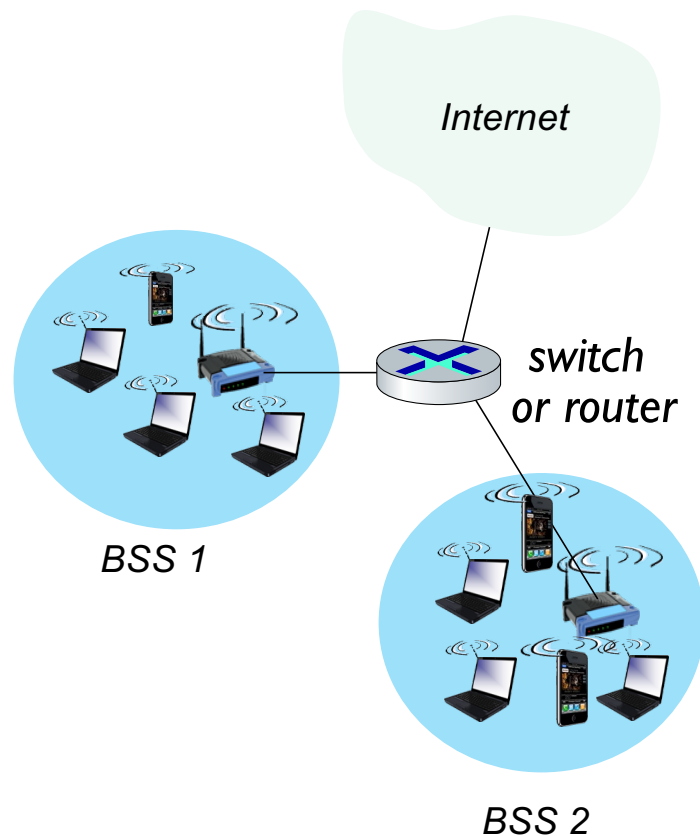
# IEEE 802.11 Wireless LAN

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)	2021	14 Gbps	70m	2.4, 5 Ghz
802.11af	2014	35 – 560 Mbps	1 Km	unused TV bands (54-790 MHz)
802.11ah (WiFi Halow)	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



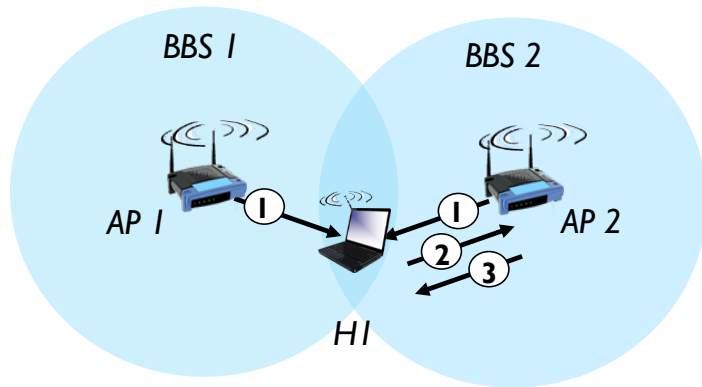
- *wireless host communicates with base station*
  - *base station = access point (AP)*
- *Basic Service Set (BSS) (aka "cell") in infrastructure mode contains:*
  - *wireless hosts*
  - *access point (AP): base station*
  - *ad hoc mode: hosts only*

## 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 [Security]
  - then typically run DHCP to get IP address in AP's subnet

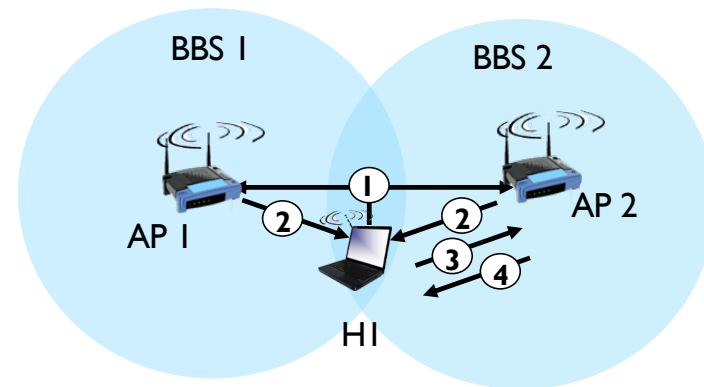


# 802.11: passive/active scanning



## *passive scanning:*

- (1) beacon frames sent from APs
- (2) association Request frame sent: HI to selected AP
- (3) association Response frame sent from selected AP to HI

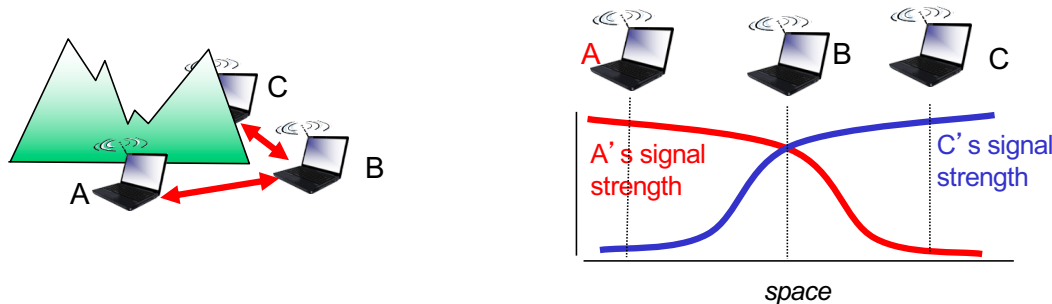


## *active scanning:*

- (1) Probe Request frame broadcast from HI
- (2) Probe Response frames sent from APs
- (3) Association Request frame sent: HI to selected AP
- (4) Association Response frame sent from selected AP to HI

# IEEE 802.11: multiple access

- *avoid collisions: 2<sup>+</sup> 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*



# 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

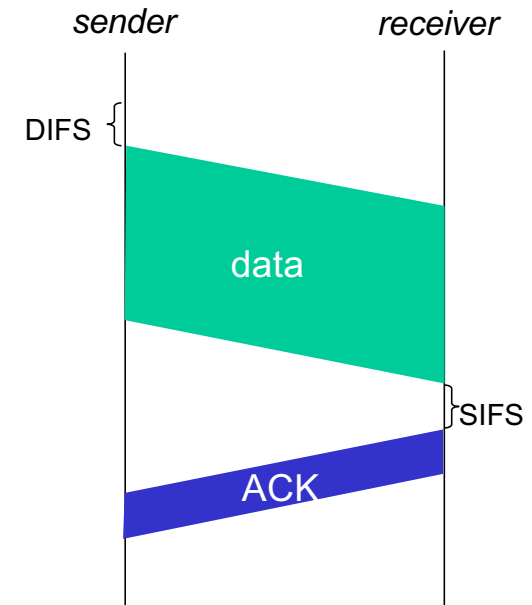
# IEEE 802.11 MAC Protocol: CSMA/CA

## 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, double random backoff interval, repeat 2

## 802.11 receiver

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

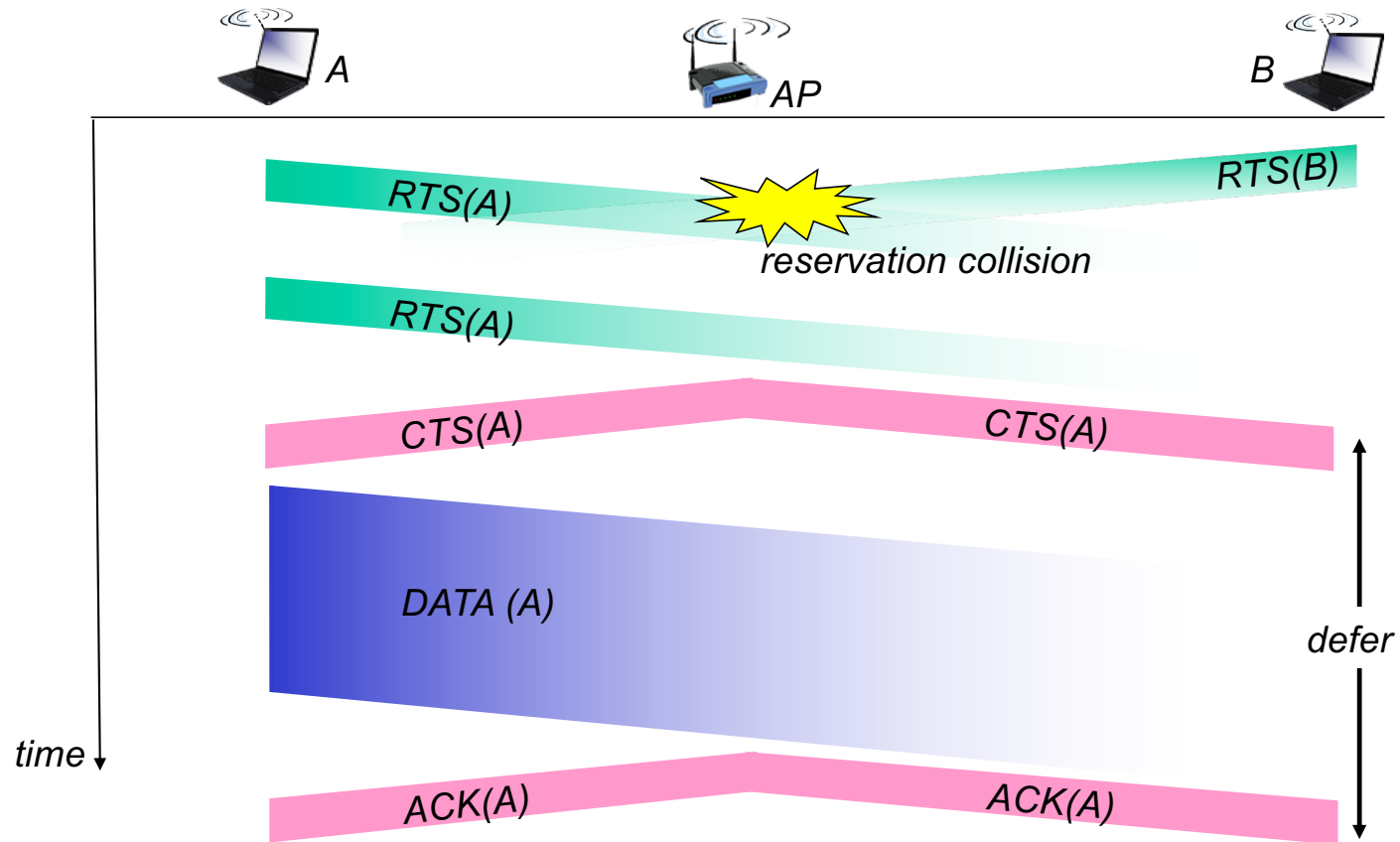


# Avoiding collisions (more)

*idea: sender “reserves” channel use for data frames using small reservation packets*

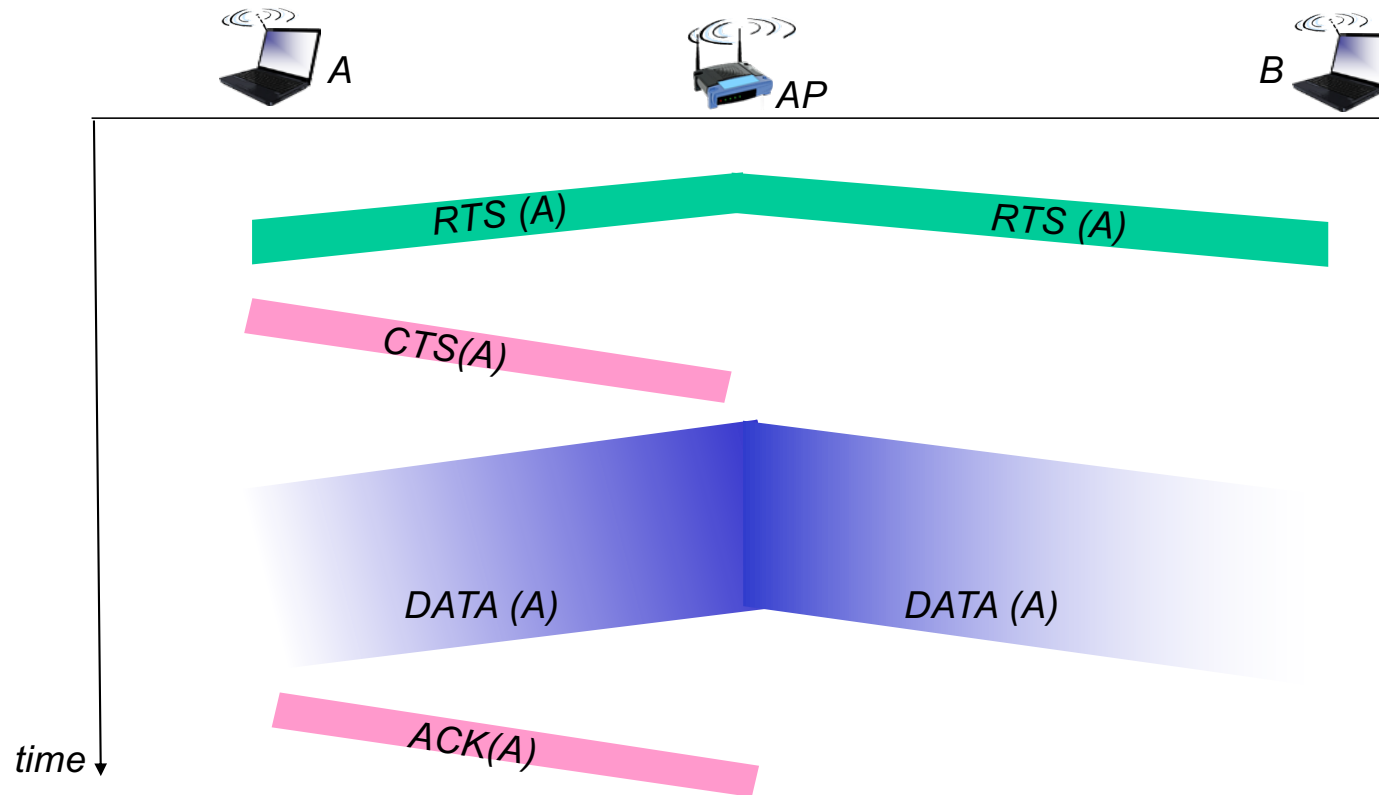
- *sender first transmits small request-to-send (RTS) packet to BS using CSMA*
  - *RTSs may still collide with each other (but they’re short)*
- *BS broadcasts clear-to-send CTS in response to RTS*
- *CTS heard by all nodes*
  - *sender transmits data frame*
  - *other stations defer transmissions*

## Collision Avoidance: RTS-CTS exchange

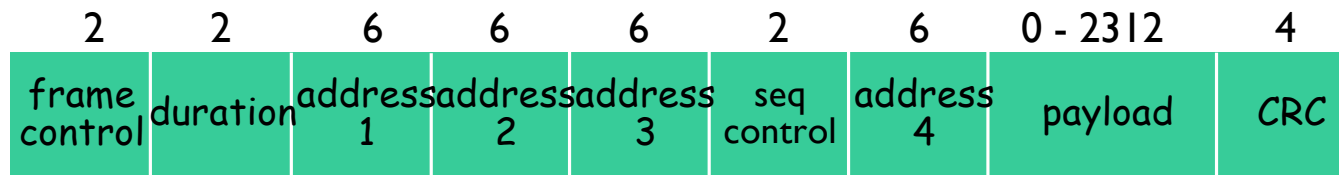




## Collision Avoidance: RTS-CTS exchange



## 802.11 frame: addressing



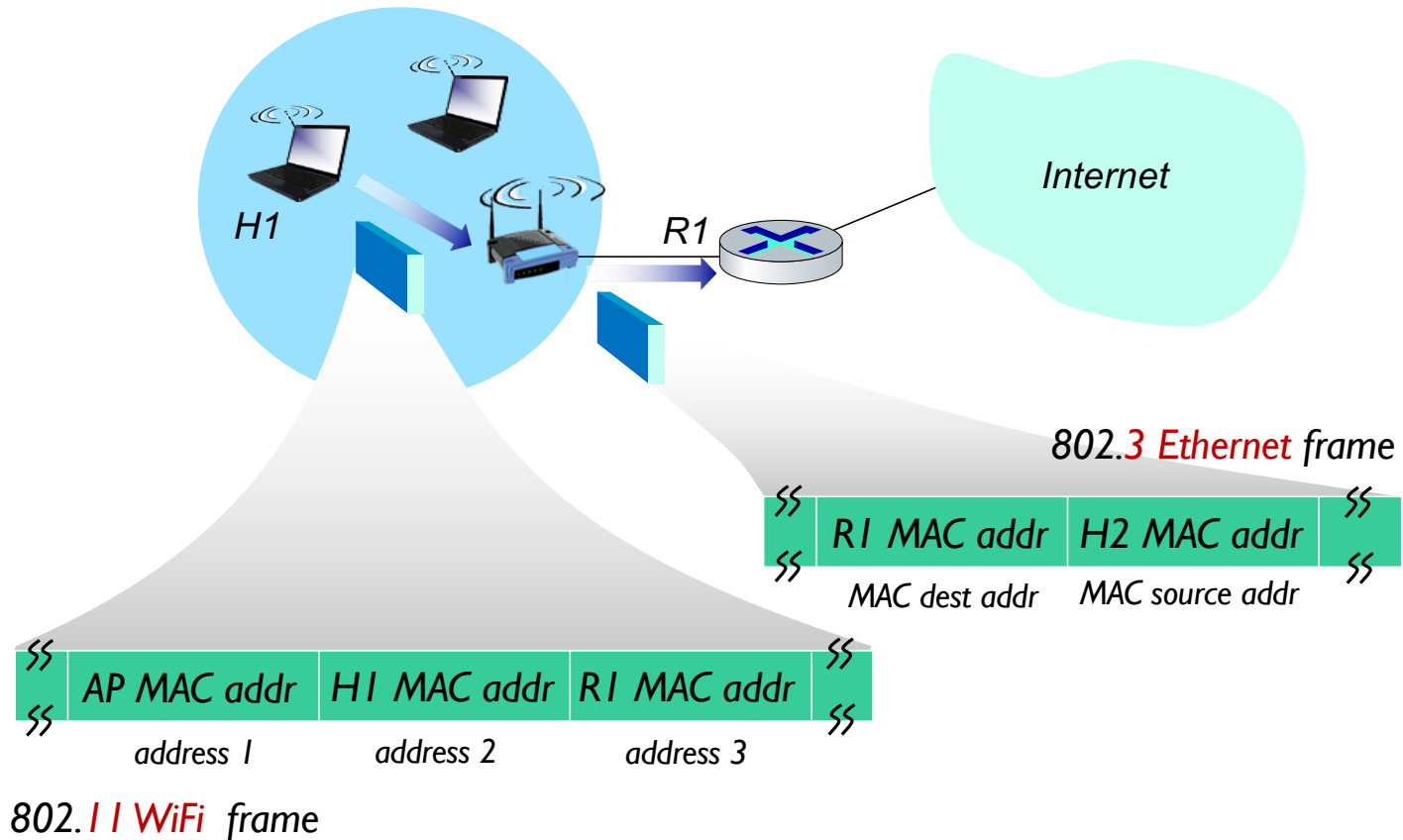
*Address 1: MAC address of wireless host or AP to receive this frame*

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

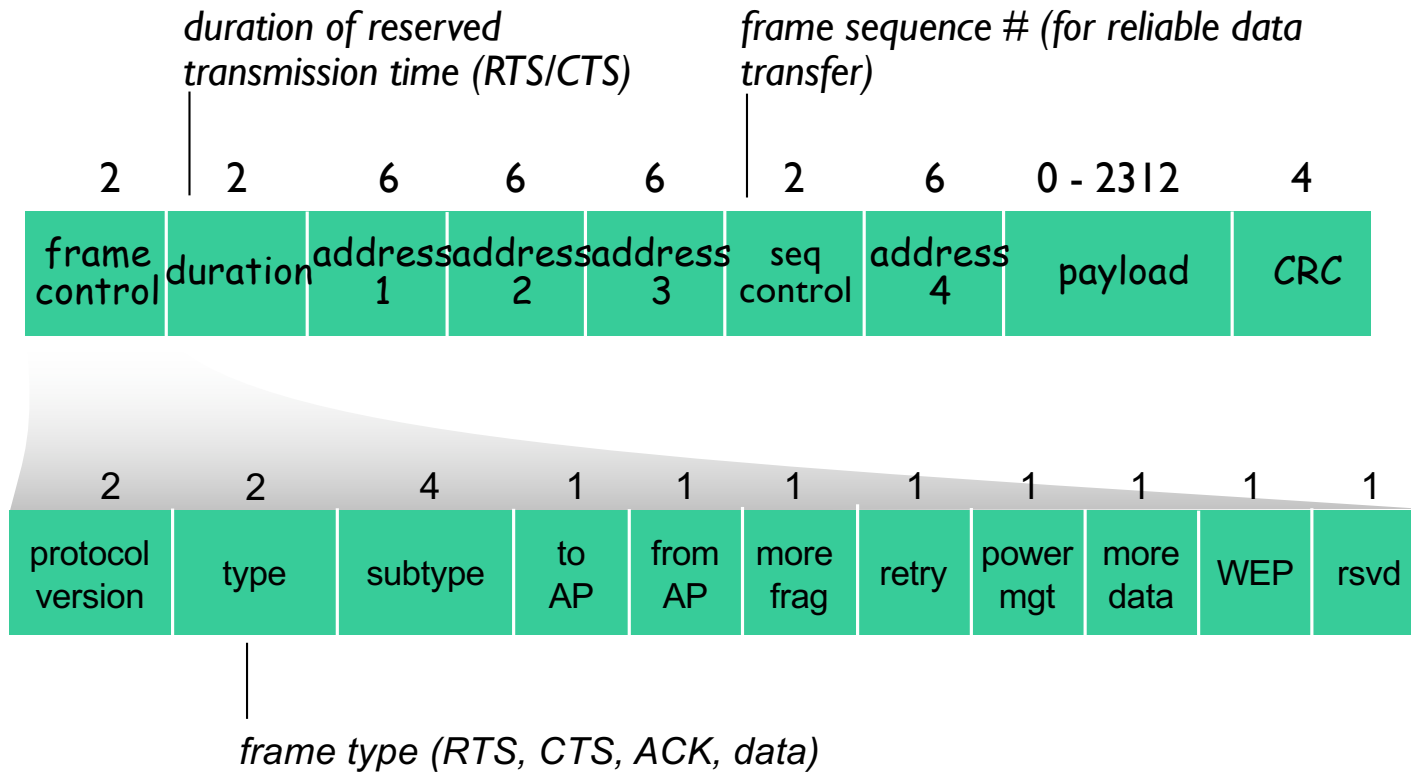
*Address 3: MAC address of router interface to which AP is attached*

*Address 4: used only in ad hoc mode*

# 802.11 frame: addressing



# 802.11 frame: addressing



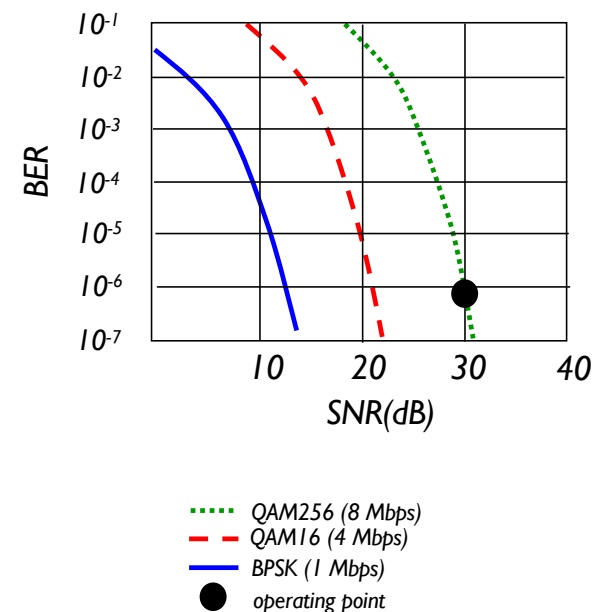
# 802.11: advanced capabilities

## 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



# Quiz

The following is the correct sequence of message exchanges as per the reservation process of 802.11 CSMA/CA

- A. RTS->CTS->DATA->CTS
- B. CTS->RTS->DATA->ACK
- C. RTS->CTS->DATA->ACK
- D. RTS->ACK->DATA->CTS

# Quiz

❖ Which multiple access technique is used by IEEE 802.11?

A. CSMA/CD

B. Slotted ALOHA

C. CSMA/CA

D. TDMA

E. FDMA

# Summary

## *Wireless*

- ❖ wireless links:
  - capacity, distance
  - channel impairments
- ❖ IEEE 802.11 (“Wi-Fi”)
  - CSMA/CA reflects wireless channel characteristics