

# COMP 3331/9331: Computer Networks and Applications

Week 9  
Wireless Networks

Reading Guide: Chapter 7, Sections 7.1 – 7.3



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# 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

### 7.2 Wireless links, characteristics

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

# Wireless 101

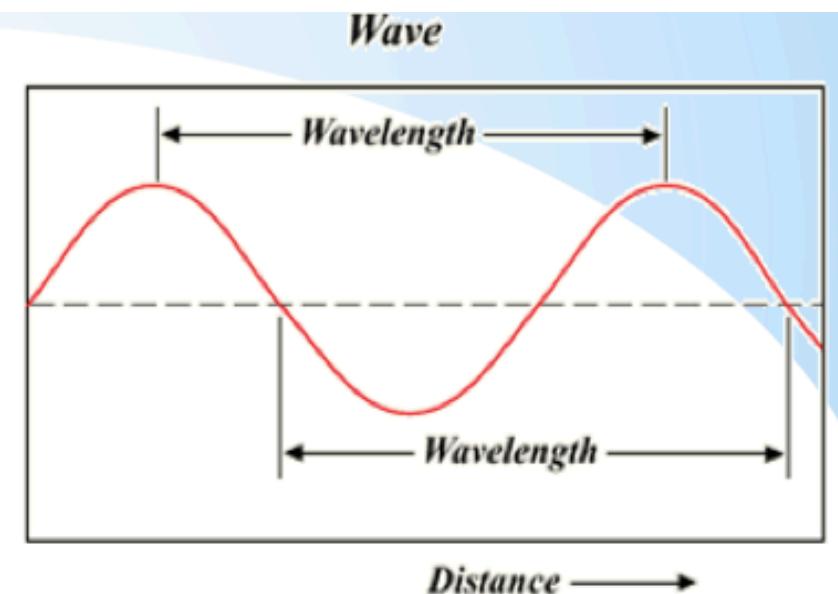
- **Frequency/Wave-Length -**

C is the speed of light

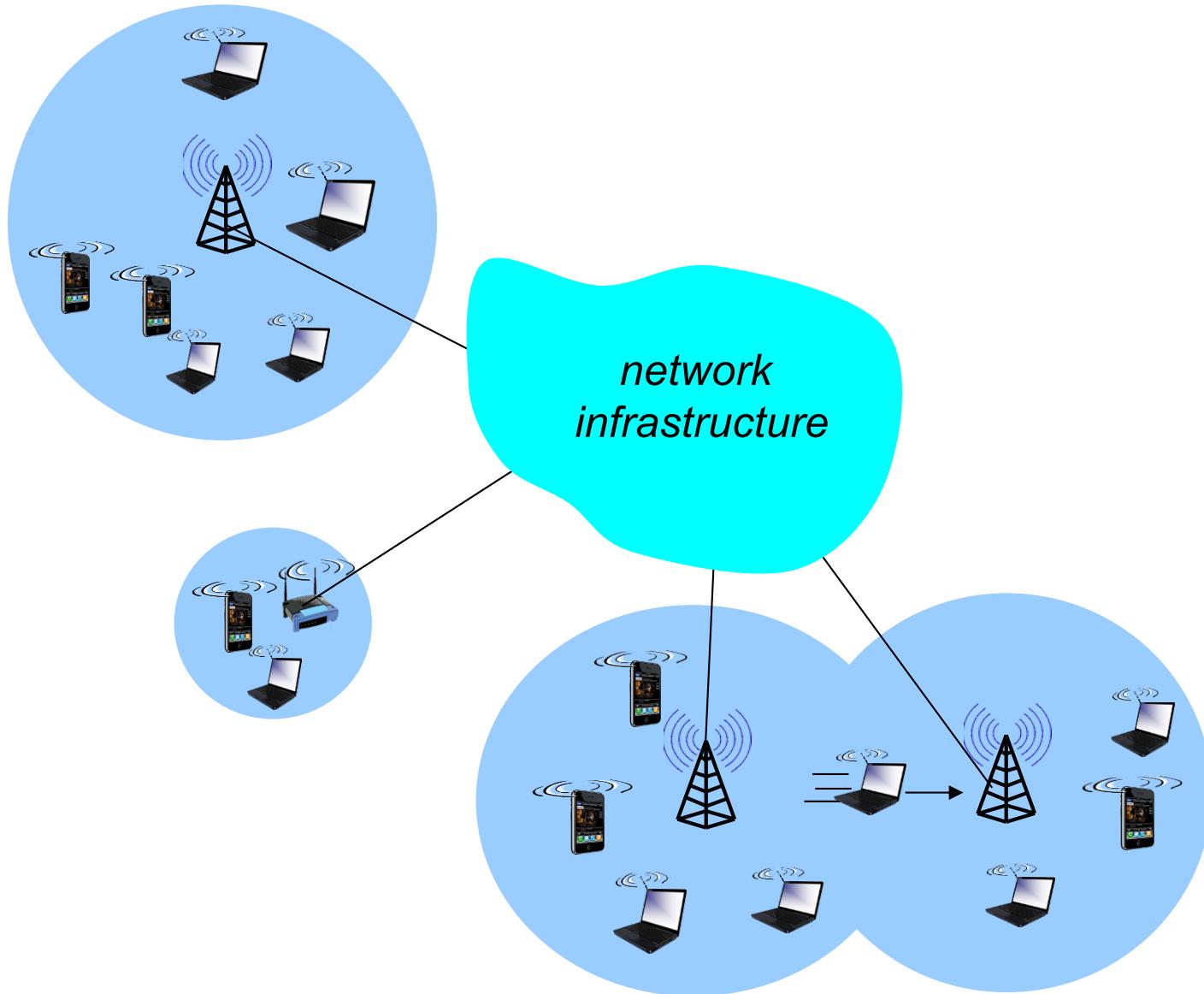
f is frequency

$\lambda$  (lambda) is wavelength

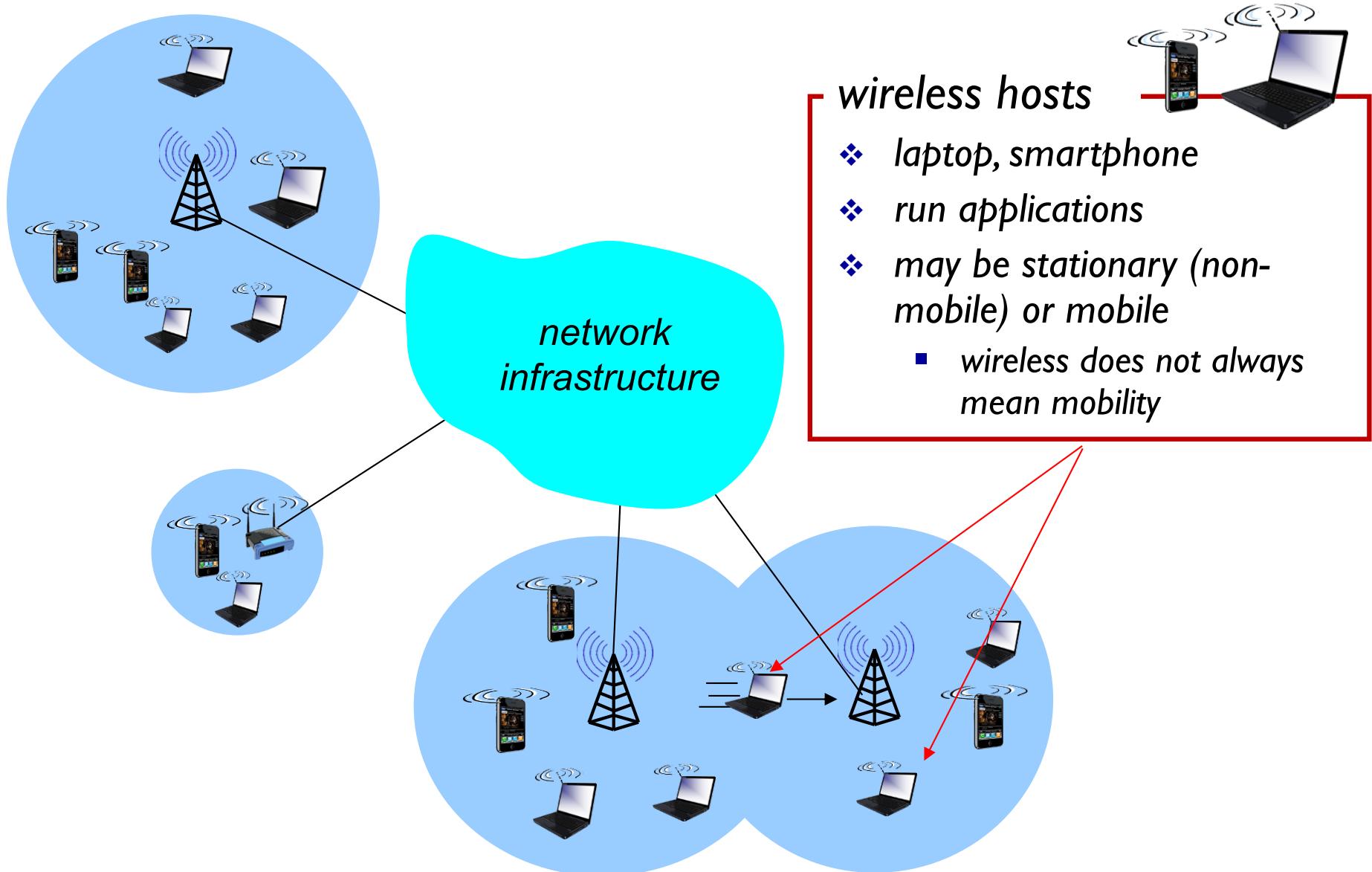
$$\text{Wavelength} \quad \text{Frequency}$$
$$\lambda = \frac{C}{f} \quad f = \frac{C}{\lambda}$$



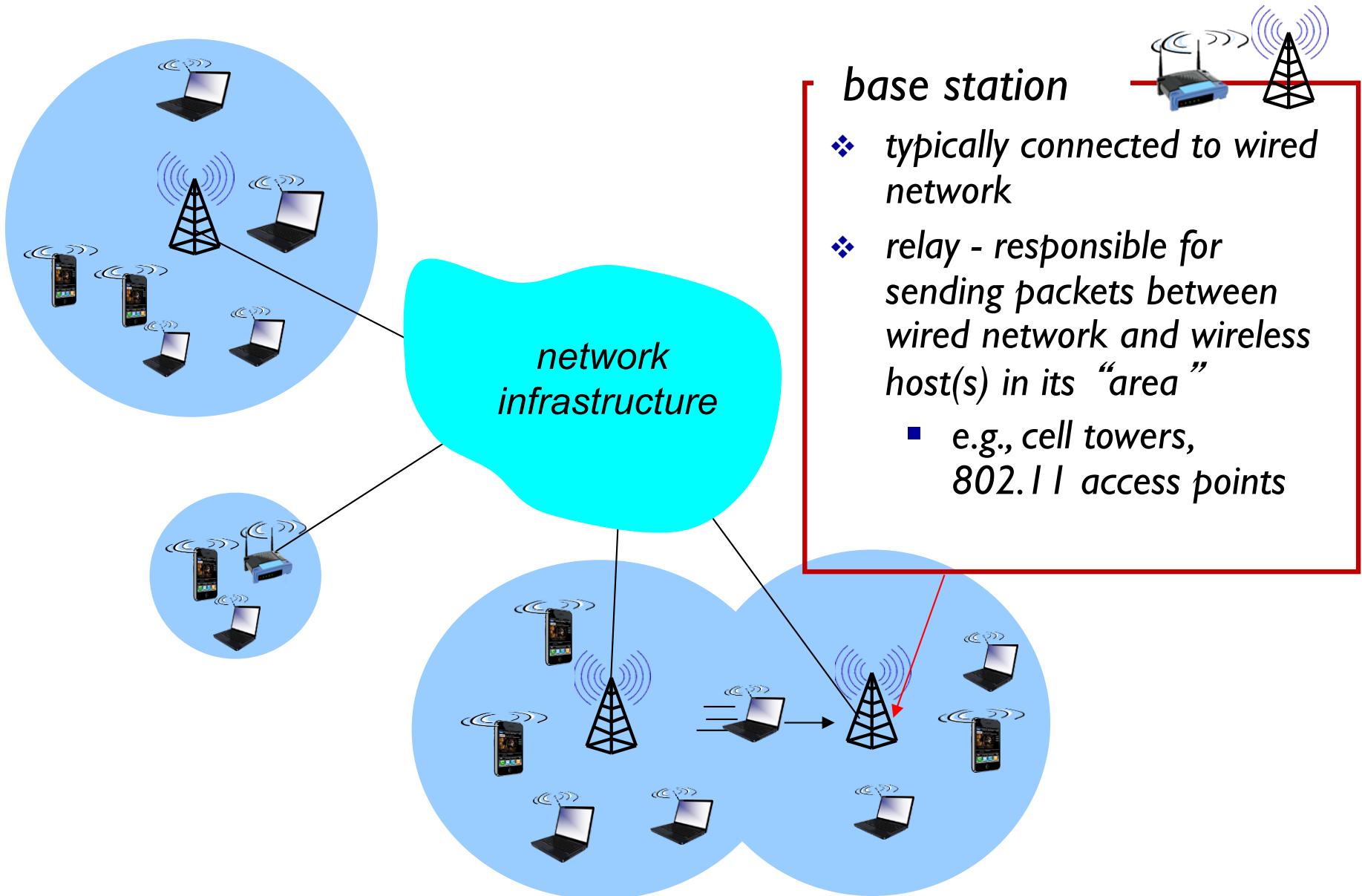
# Elements of a wireless network



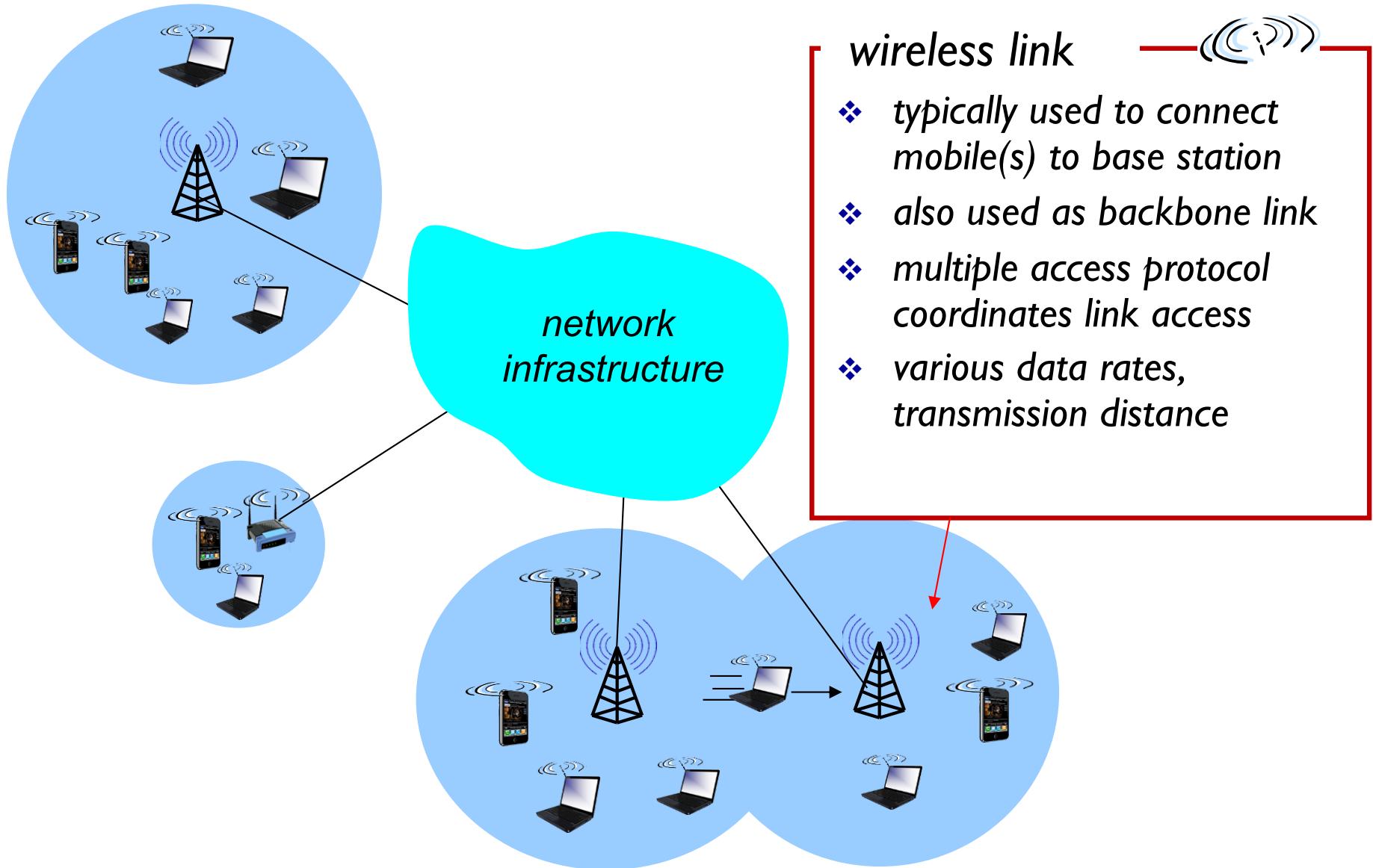
# Elements of a wireless network



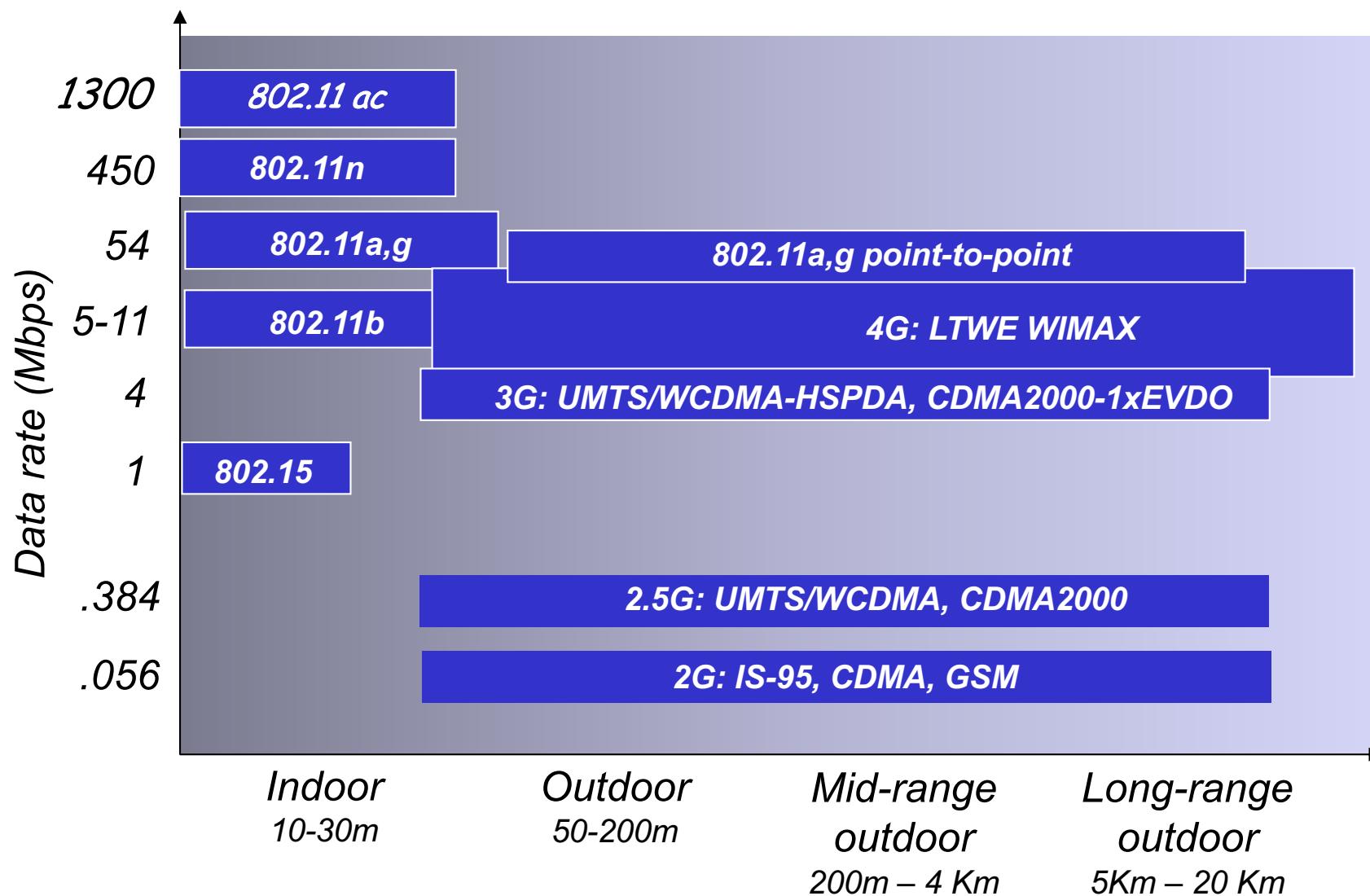
# Elements of a wireless network



# Elements of a wireless network



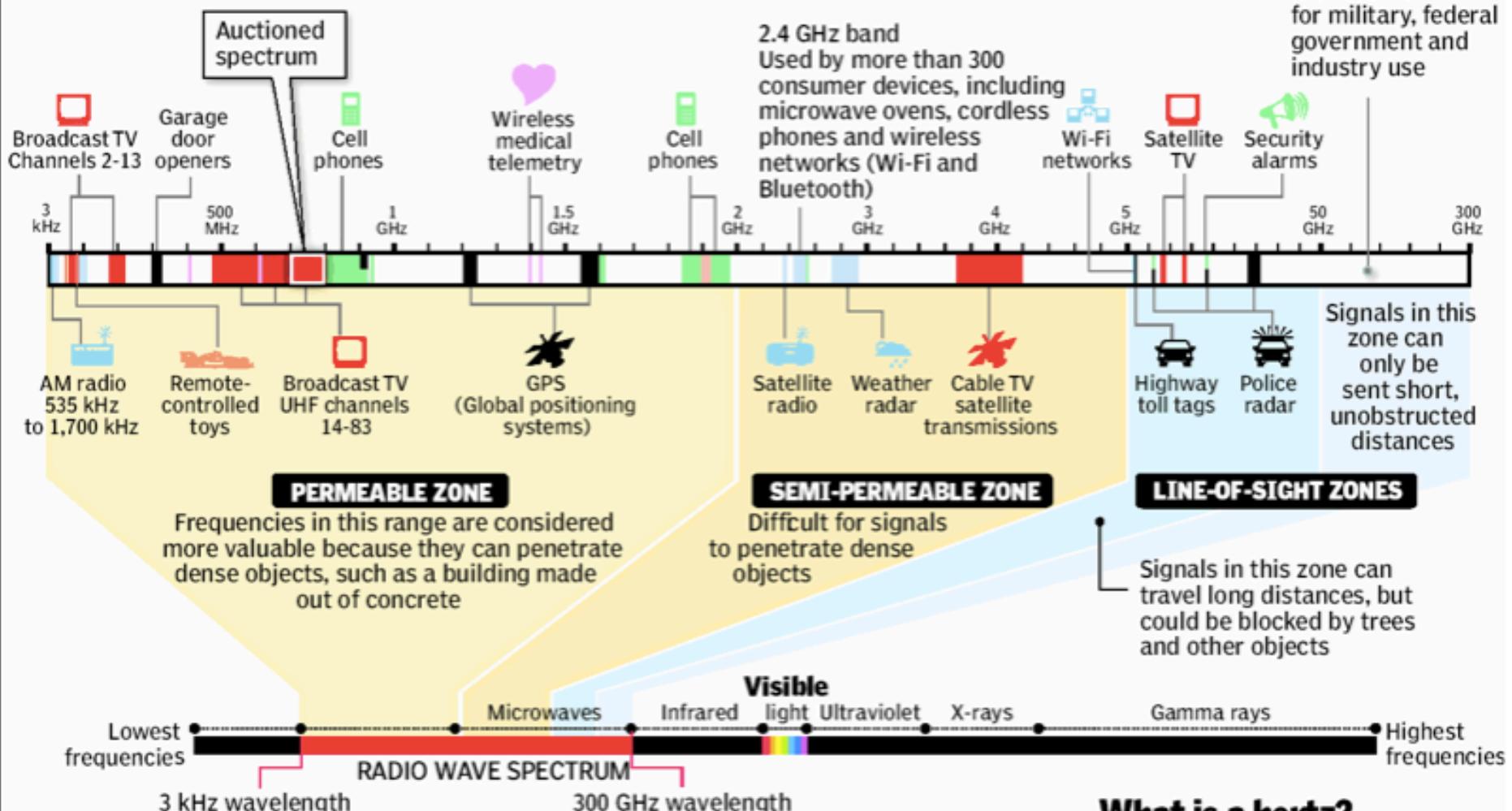
# Characteristics of selected wireless links



# Inside the radio wave spectrum

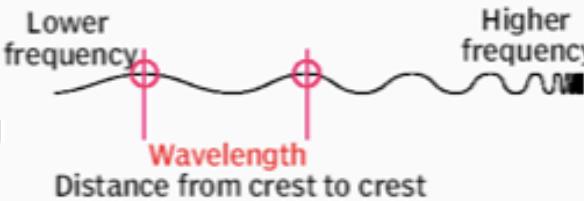
Almost every wireless technology – from cell phones to garage door openers – uses radio waves to communicate. Some services, such as TV and radio broadcasts, have exclusive use of their frequency within a geographic area. But many devices share frequencies, which can cause interference. Examples of radio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

Most of the white areas on this chart 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



## What is a hertz?

One hertz is one cycle per second. For radio waves, a cycle is the distance from wave crest to crest

1 kilohertz (kHz) = 1,000 hertz

1 megahertz (MHz) = 1 million hertz

1 gigahertz (GHz) = 1 billion hertz

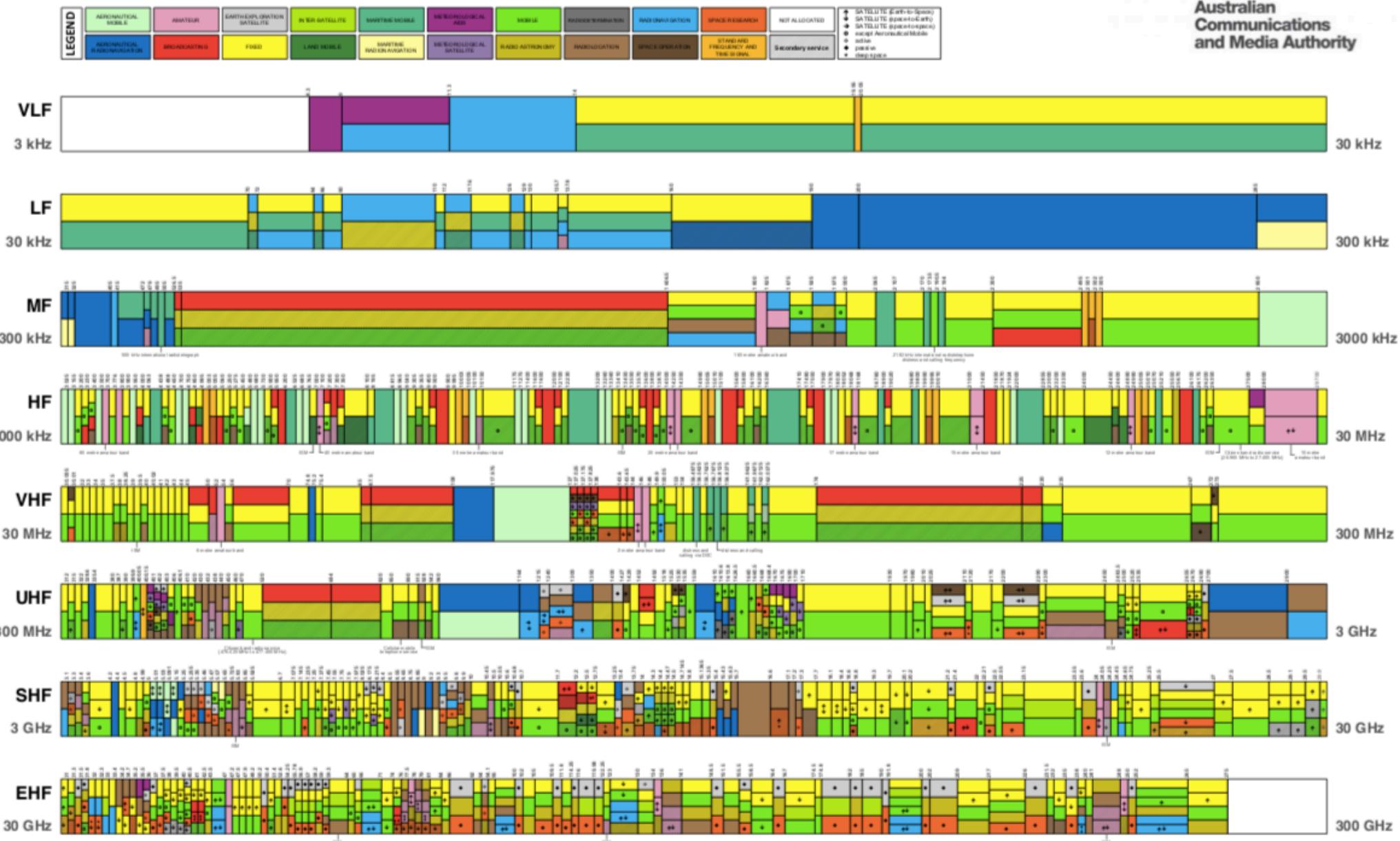
# Australian radiofrequency spectrum allocations chart



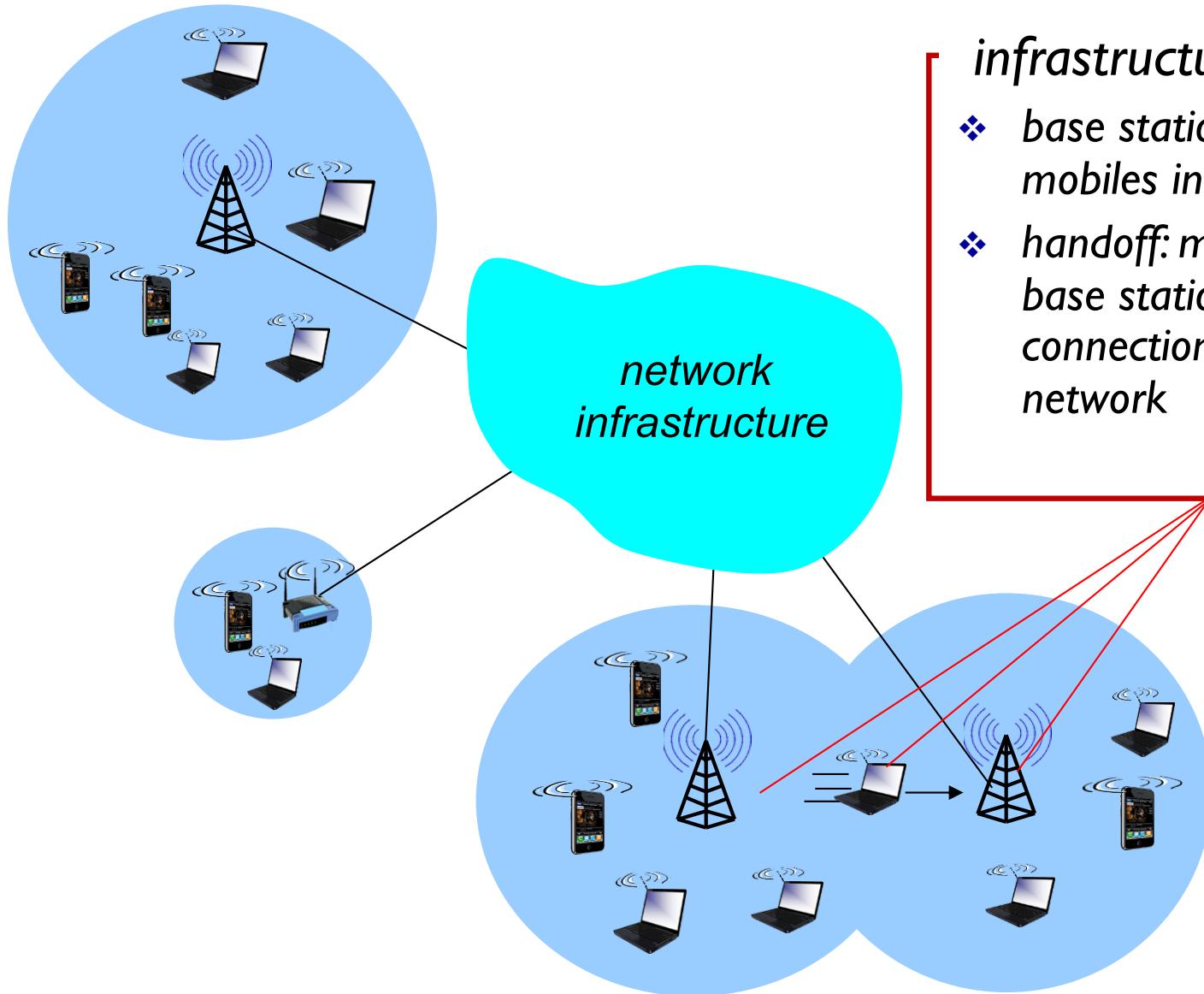
Australian Government



Australian  
Communications  
and Media Authority



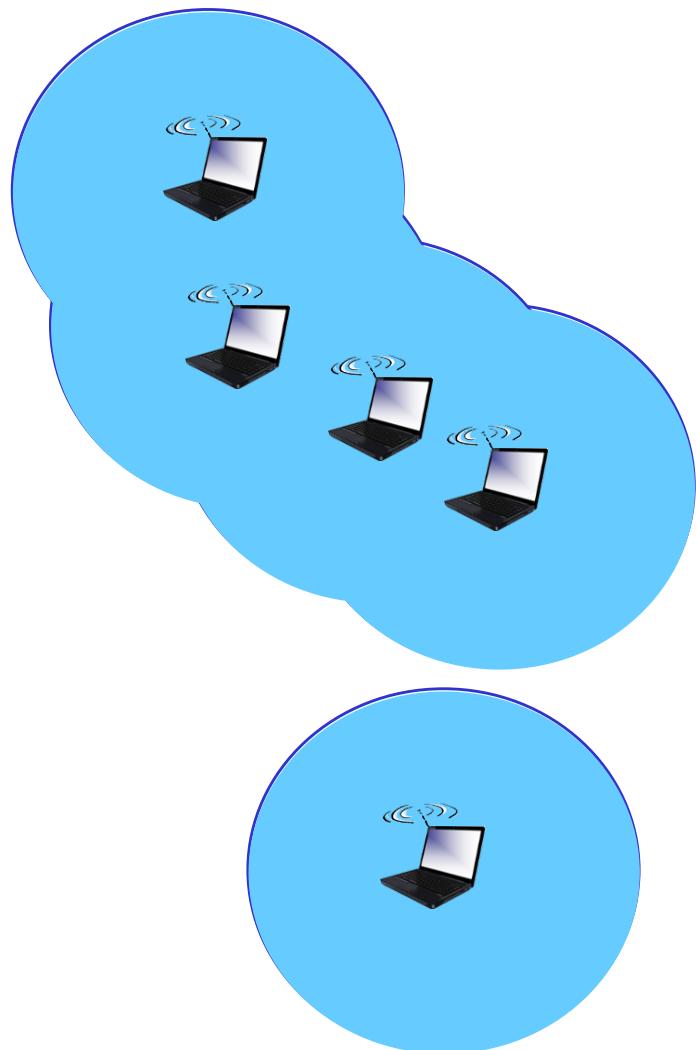
# Elements of a wireless network



## *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

	<i>single hop</i>	<i>multiple hops</i>
<i>infrastructure</i> (e.g., APs)	<i>host connects to base station (WiFi, WiMAX, 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 other a given wireless node MANET, VANET</i>

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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*: 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 at 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

$\lambda$ : wavelength

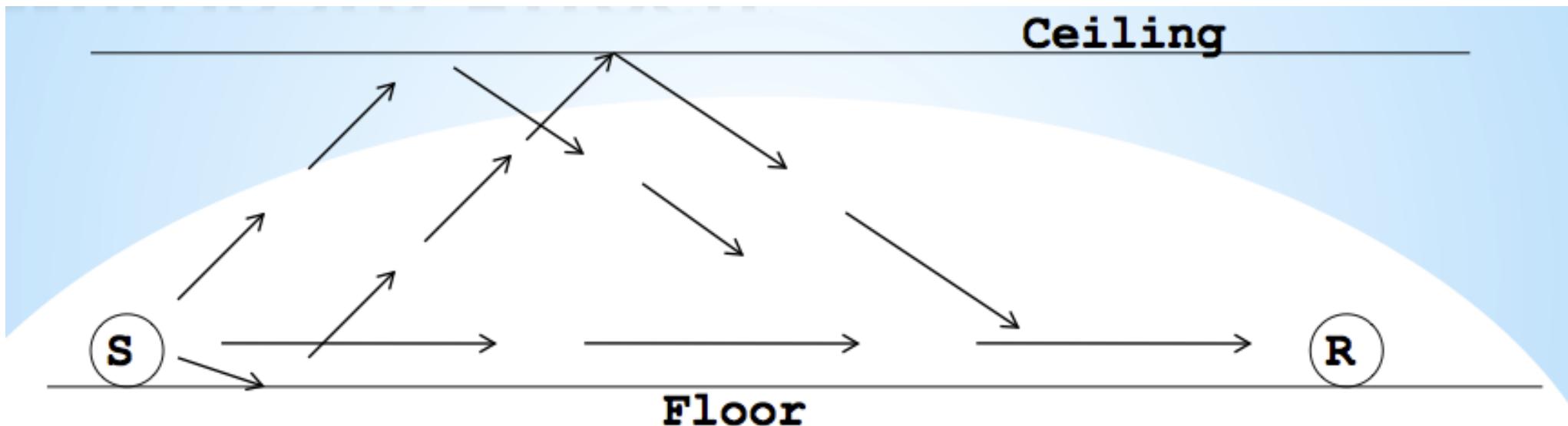
f: frequency

c: speed of light

$$\begin{aligned} \text{FSPL} &= \left( \frac{4\pi d}{\lambda} \right)^2 \\ &= \left( \frac{4\pi df}{c} \right)^2 \end{aligned}$$

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

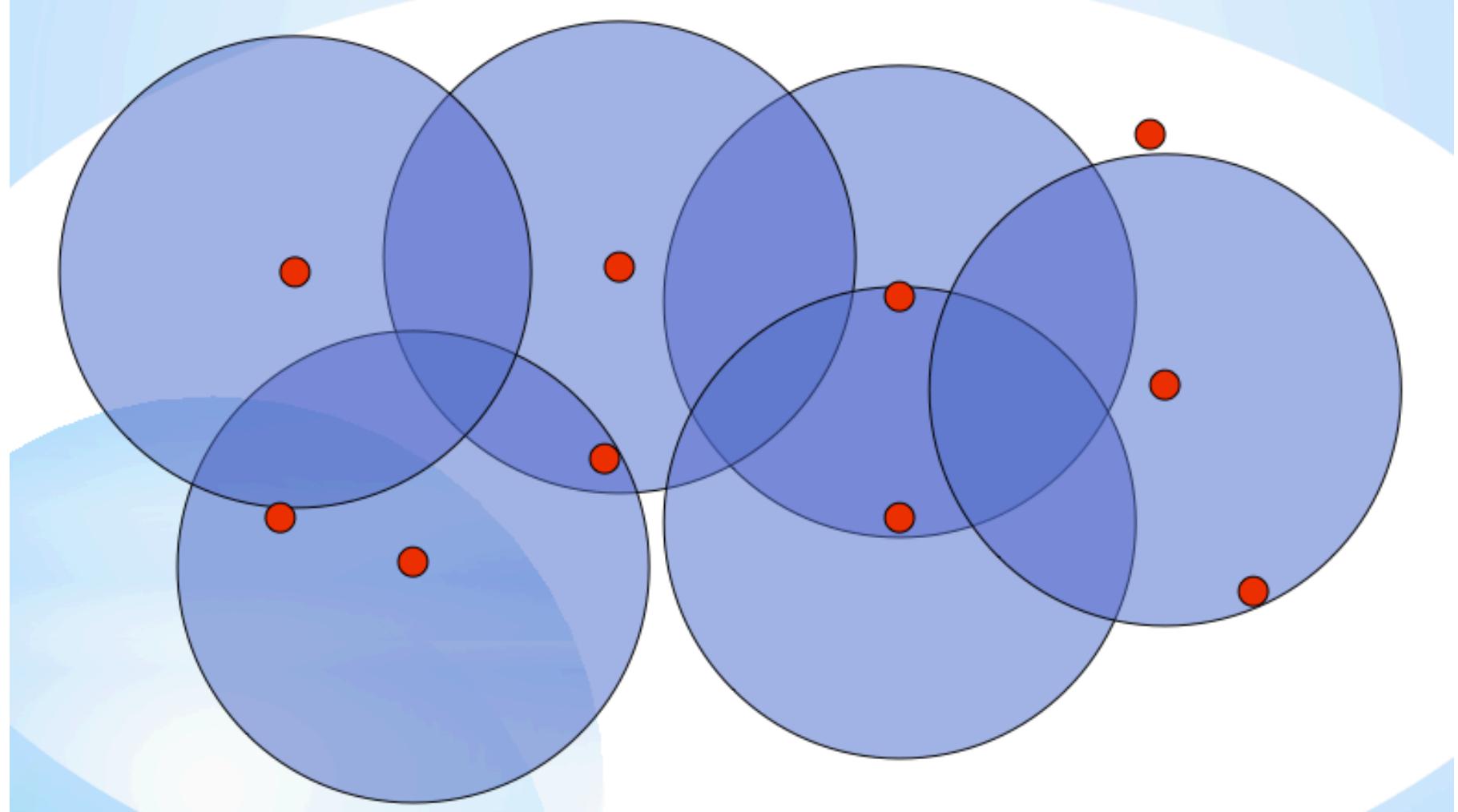
# Multipath Effects



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

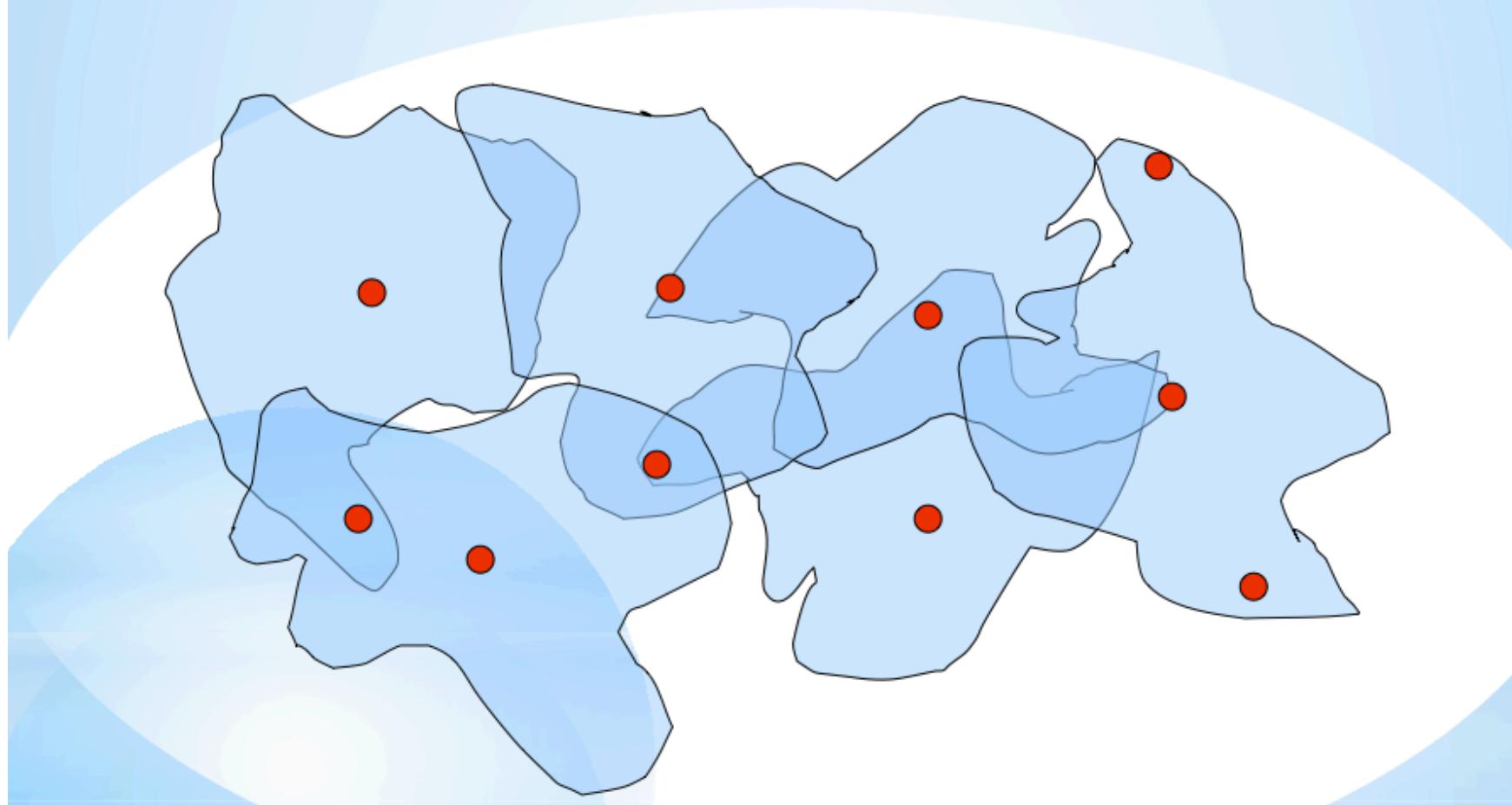
# Ideal Radios

(courtesy of Gilman Tolle and Jonathan Hui, ArchRock)



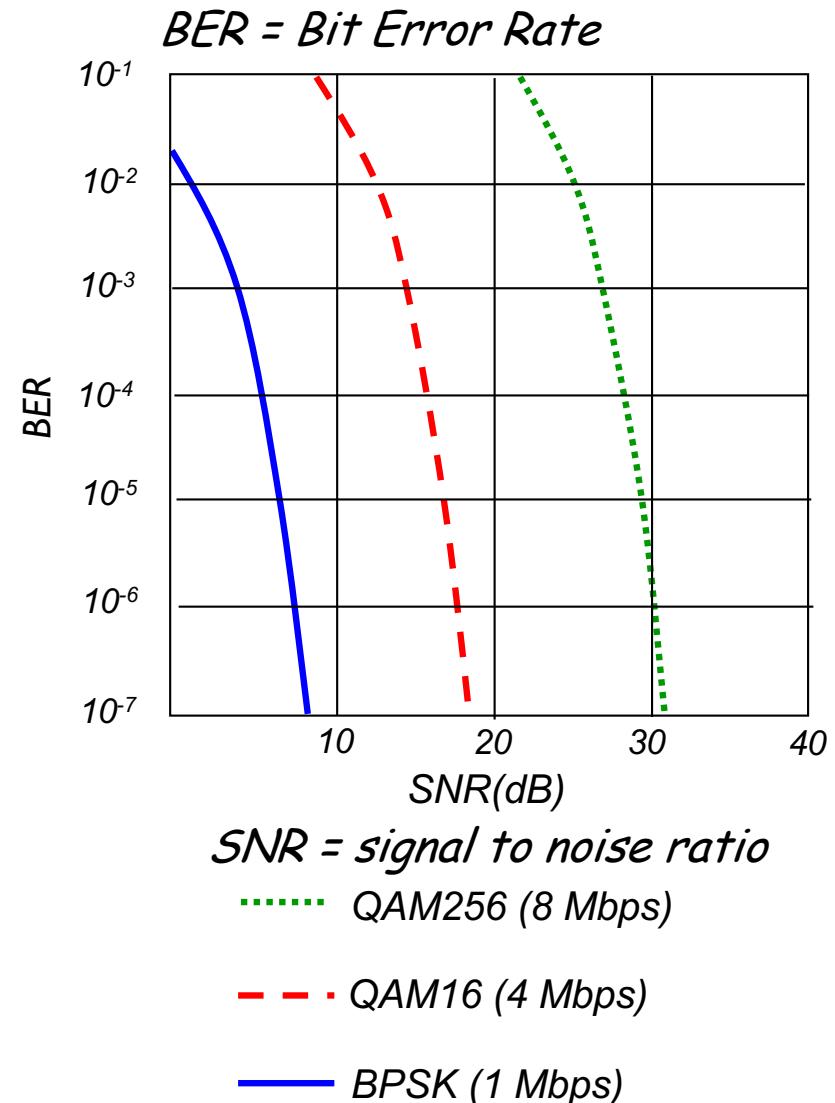
# Real Radios

courtesy of Gilman Tolle and Jonathan Hui, ArchRock)



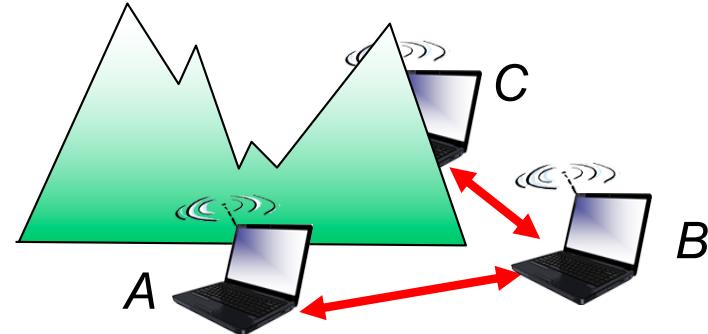
# Wireless Link Characteristics (2)

- ❖ 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, rate)



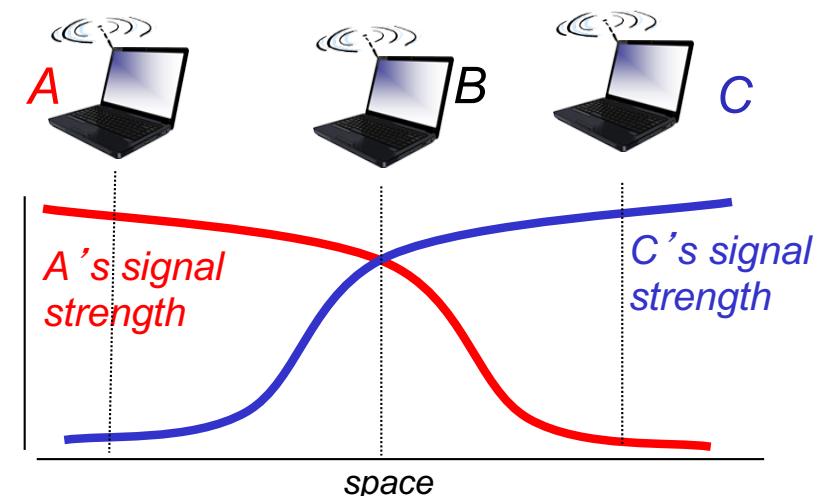
# Wireless network characteristics

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

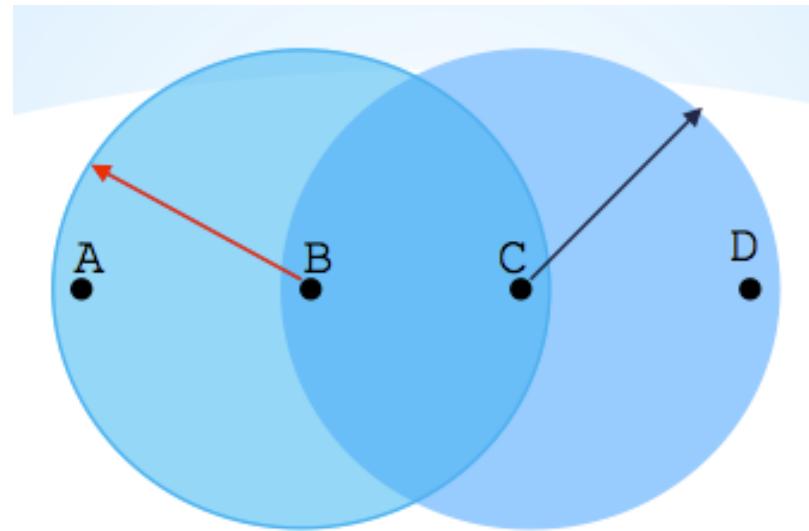


## Signal attenuation:

- ❖ 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

# Outline

7.1 Introduction

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

# 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

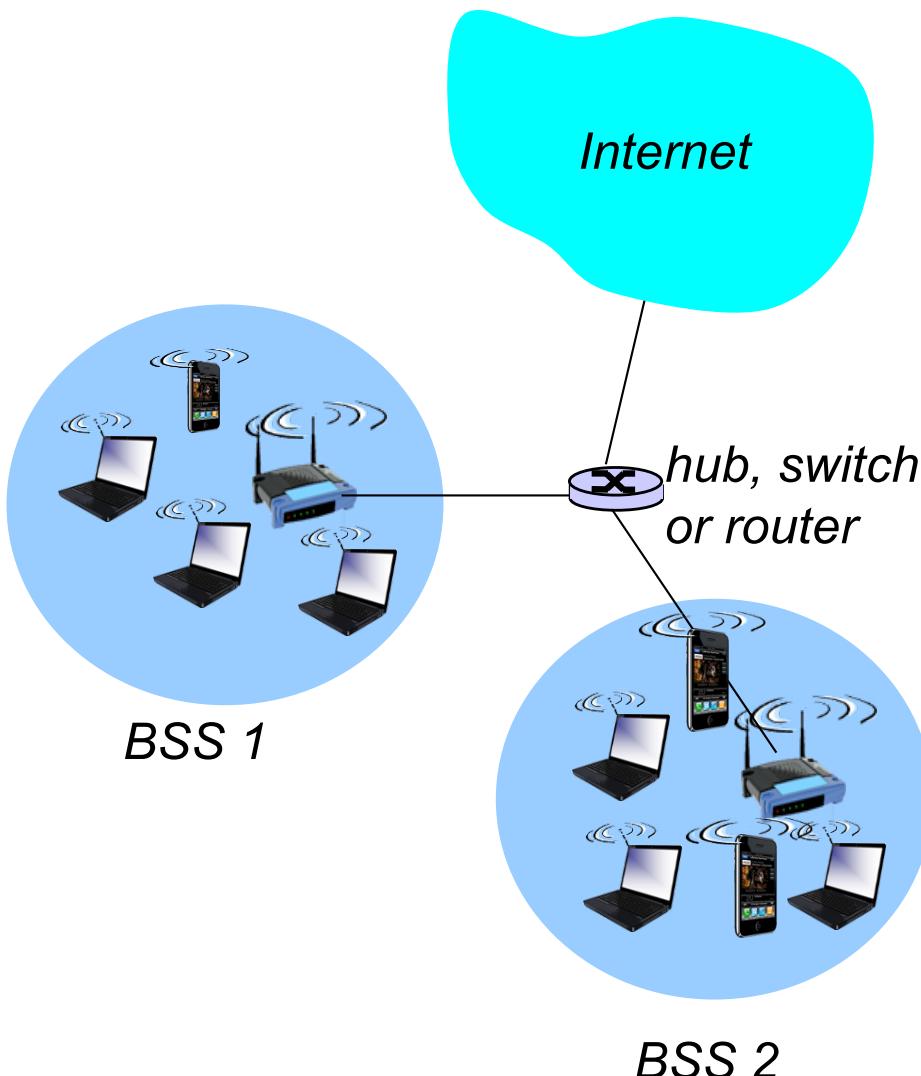
- 2.4-5 GHz range
- up to 54 Mbps

## 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

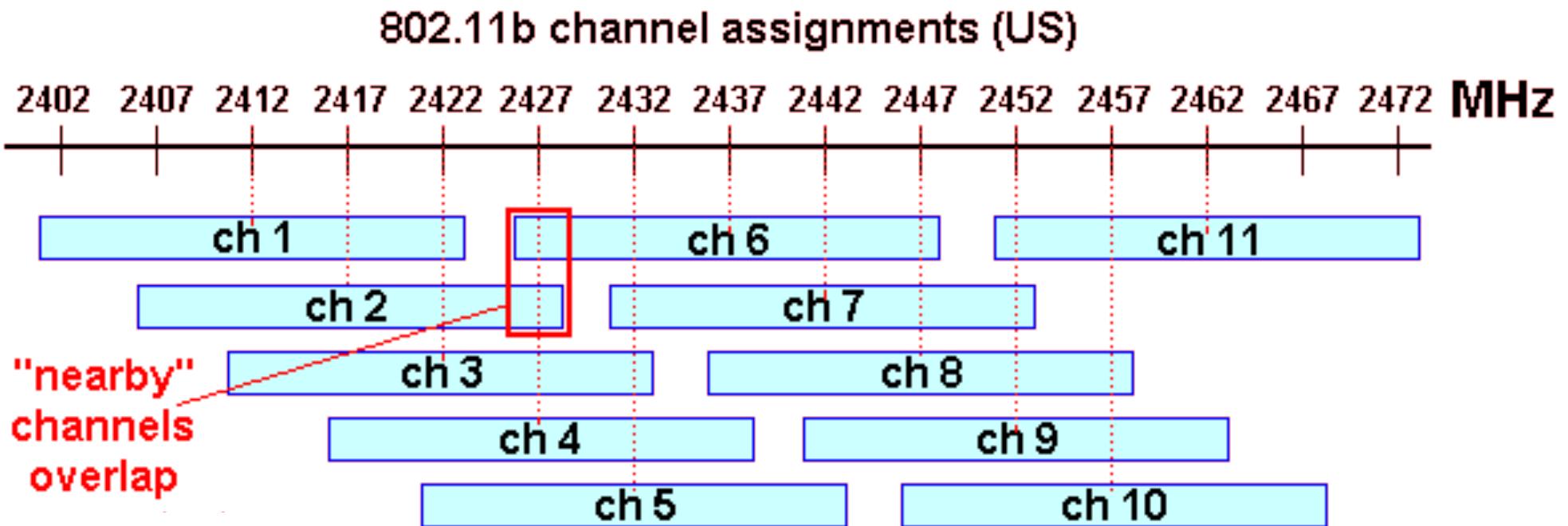


- ❖ wireless host communicates with base station
  - base station = access point (AP)
- ❖ **Basic Service Set (BSS) (aka “cell”) in infrastructure mode contains:**
  - wireless hosts
  - access point (AP): base station
  - ad hoc mode: hosts only

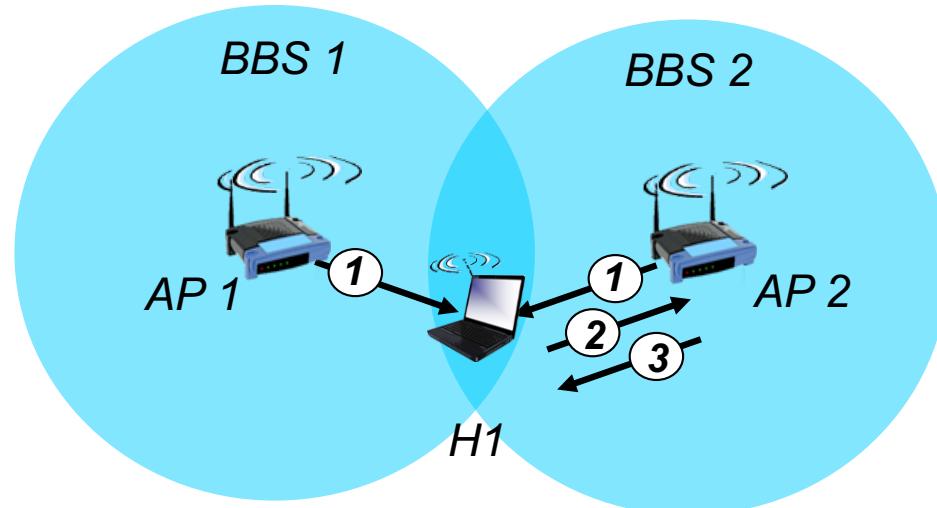
# 802.11: Channels, association

- ❖ 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

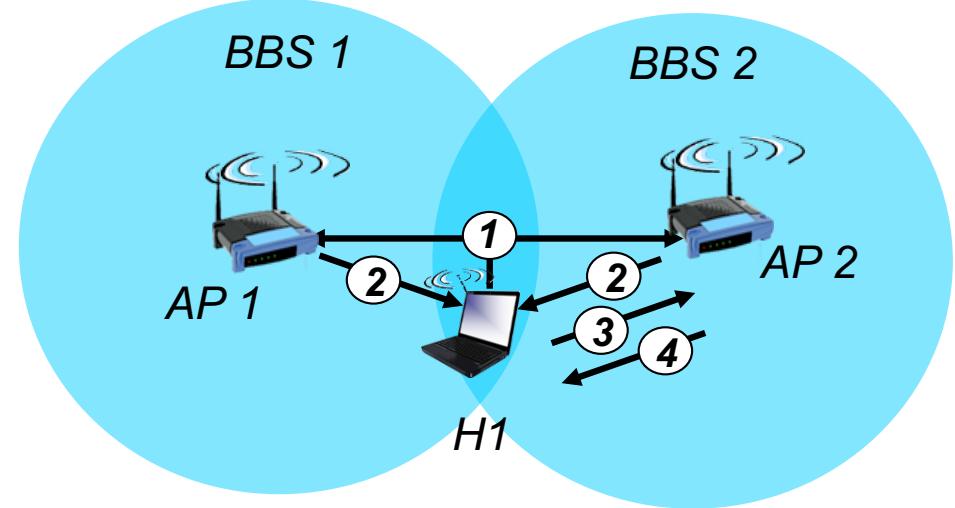


# 802.11: passive/active scanning



## 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*

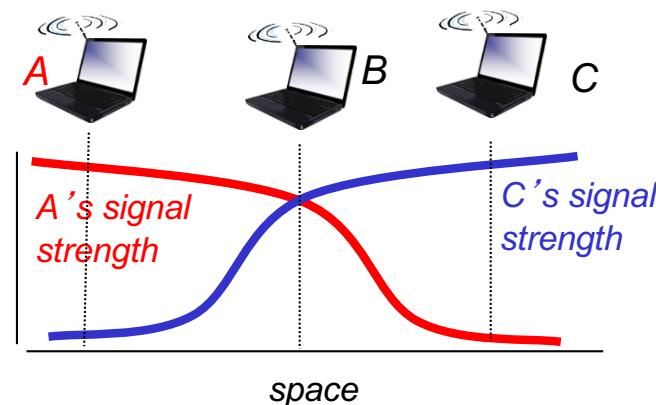
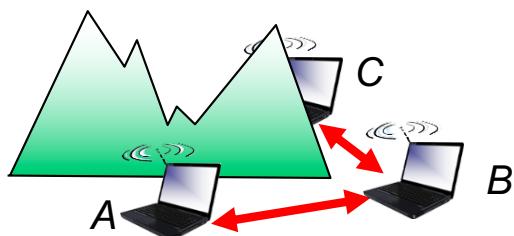


## active scanning:

- (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

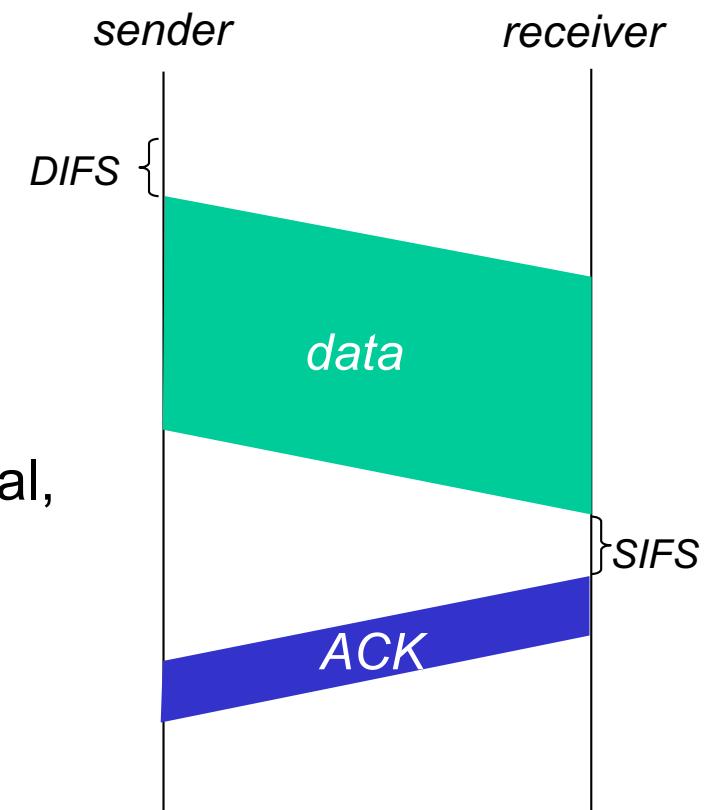
## Distributed Coordination Function (DCF)

### 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)



**DIFS** = DCF Inter Frame space

**SIFS** = Short Inter Frame Space

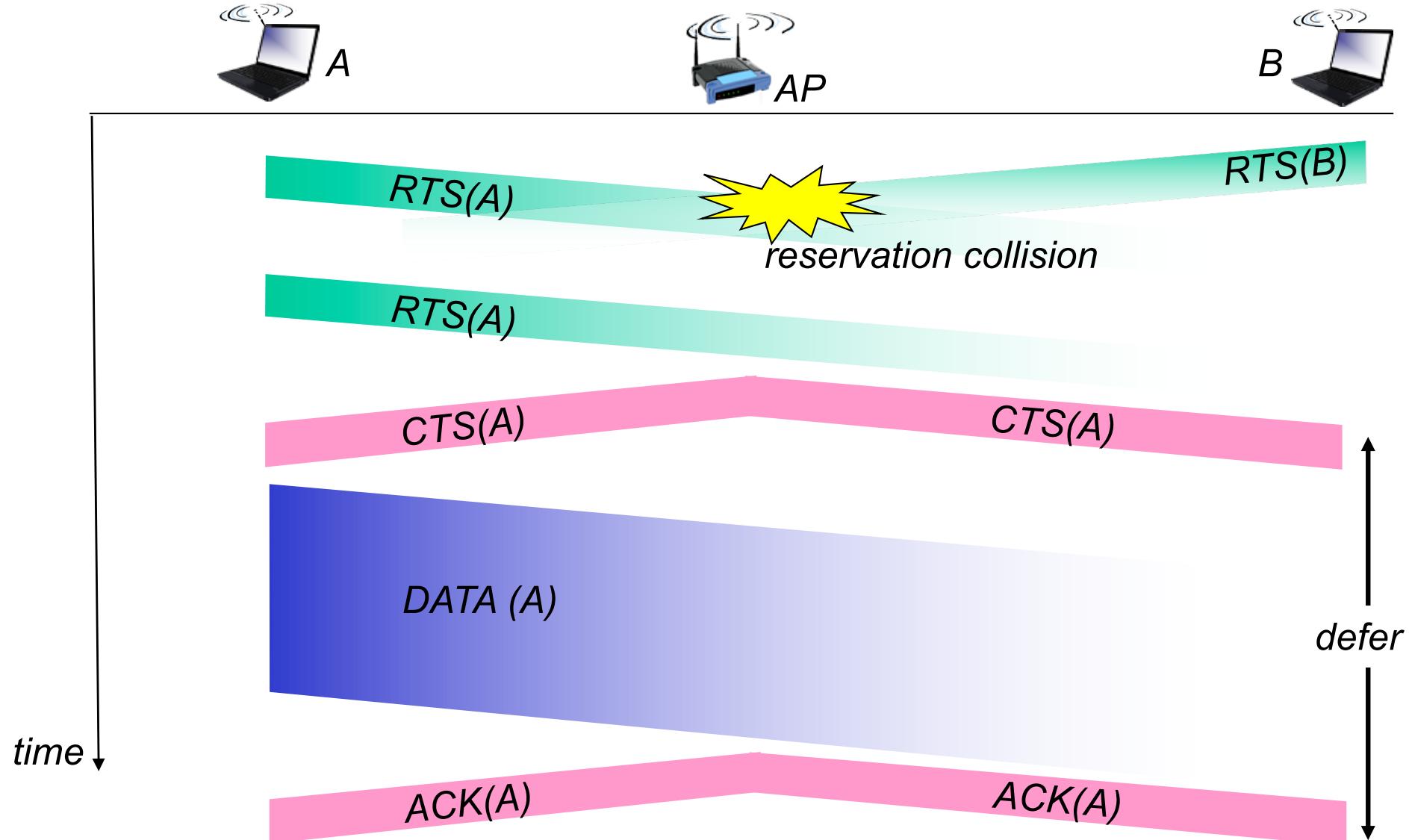
# Avoiding collisions (more)

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

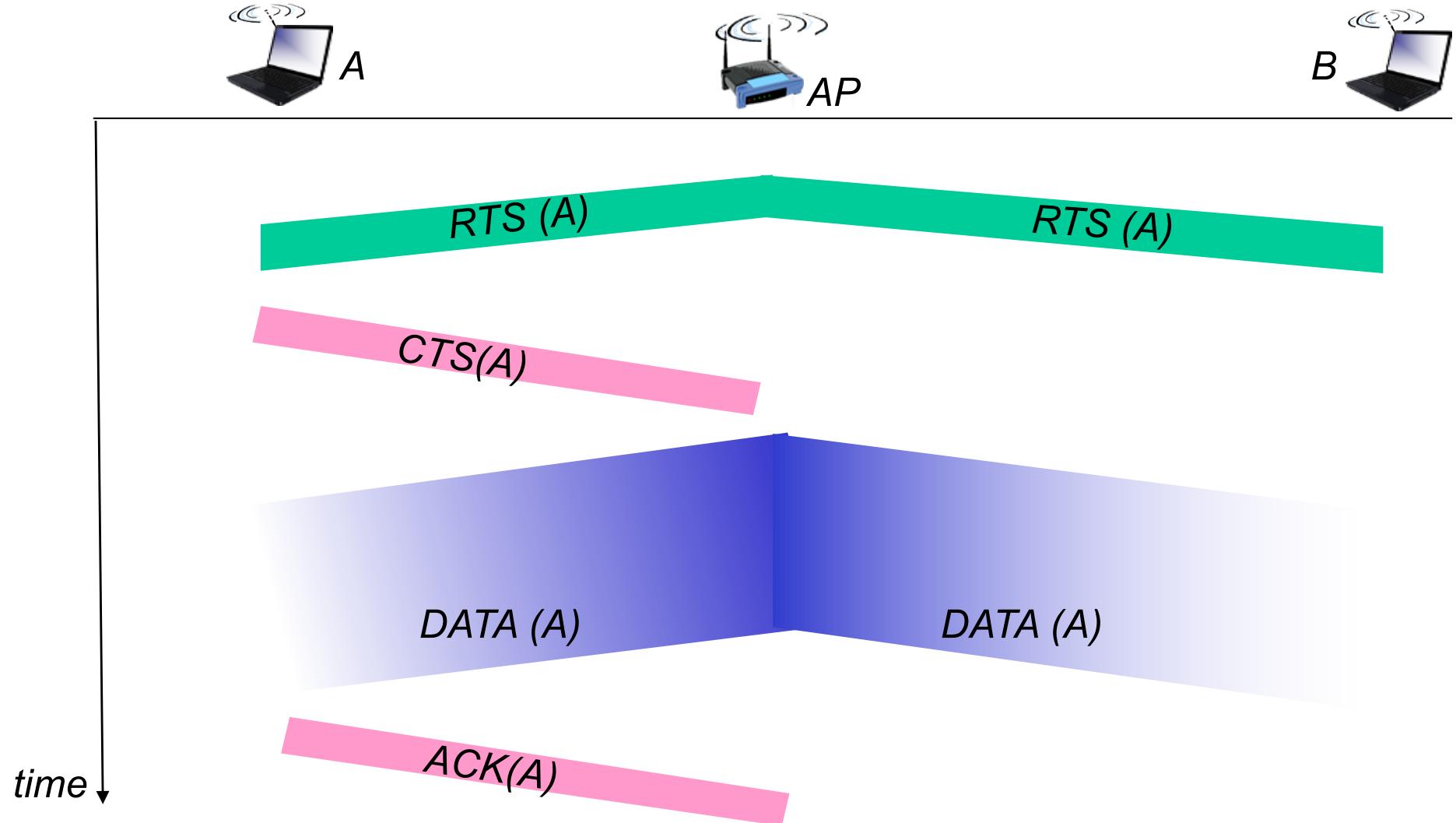
- ❖ sender first transmits *small* request-to-send (RTS) packets to BS using CSMA
  - RTSs may still collide with each other (but they’re short)
- ❖ BS broadcasts clear-to-send CTS in response to RTS
- ❖ CTS heard by all nodes
  - sender transmits data frame
  - other stations defer transmissions
- ❖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

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

# Collision Avoidance: RTS-CTS exchange



# Collision Avoidance: RTS-CTS exchange



# 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