COMP 3331/9331: Computer Networks and Applications

Week 10
Wireless Networks

Reading Guide: Chapter 7, Sections 7.1 - 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

- 7.2 Wireless links, characteristics
- 7.3 IEEE 802.11 wireless LANs ("Wi-Fi")

Wireless 101

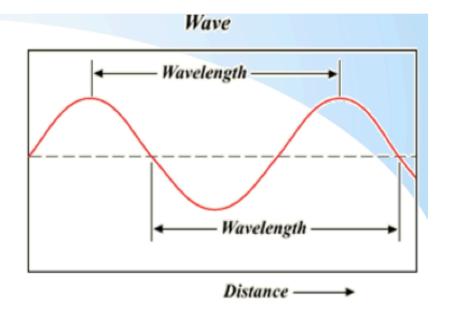
Frequency/Wave-Length -

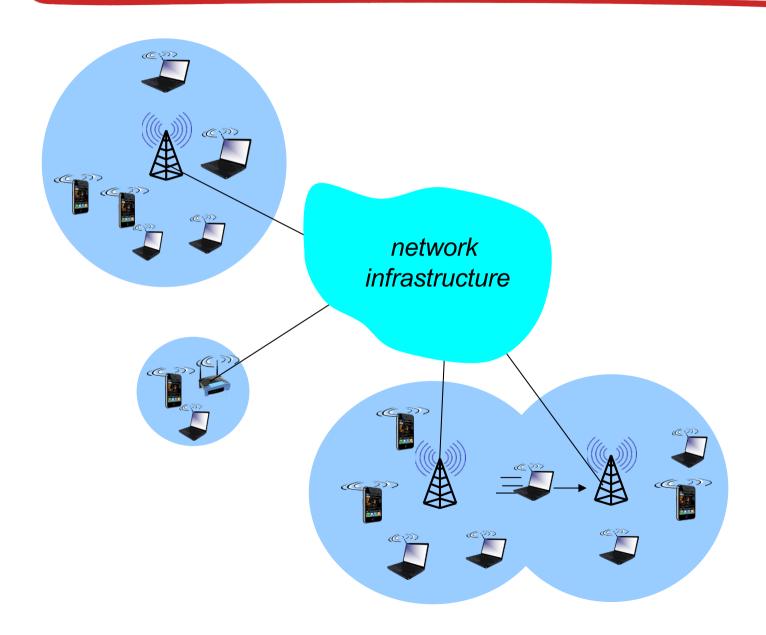
C is the speed of light f is frequency λ (lambda) is wavelength

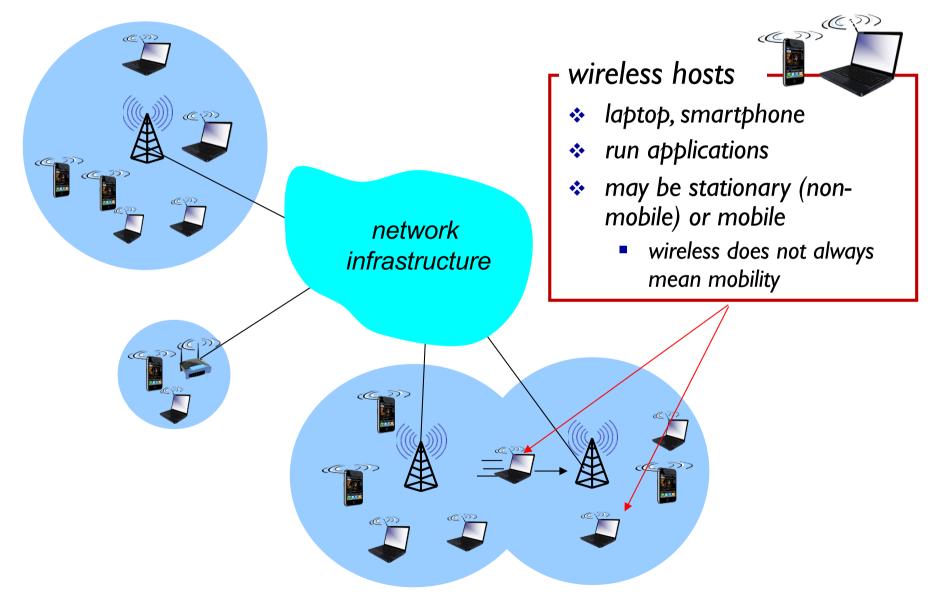
Wavelength

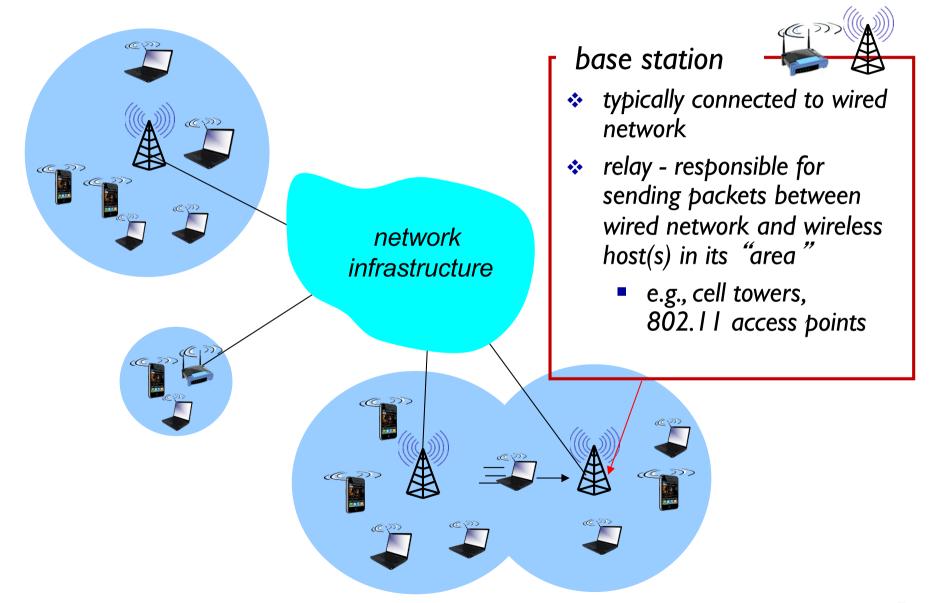
Frequency

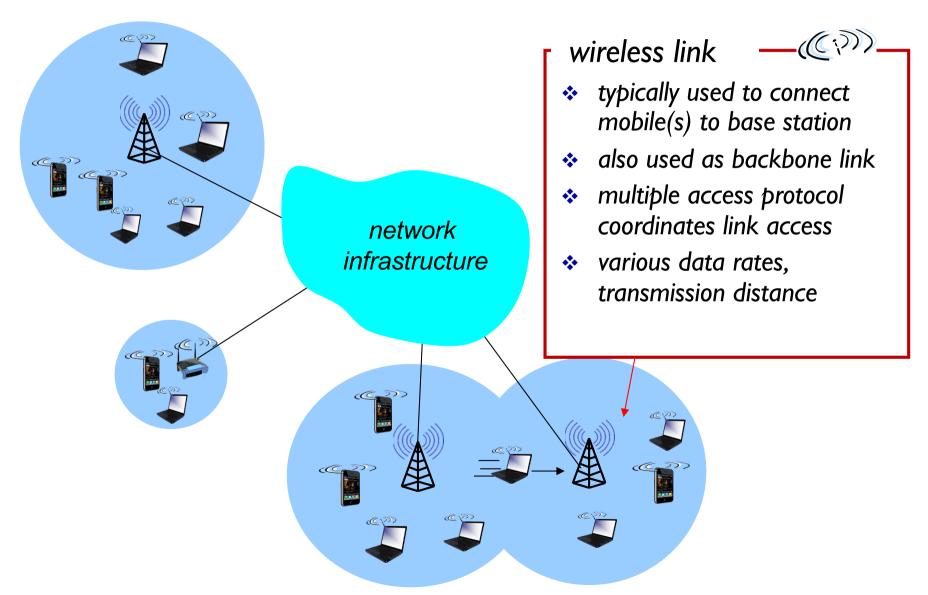
$$\lambda = \frac{C}{f} \qquad f = \frac{C}{\lambda}$$



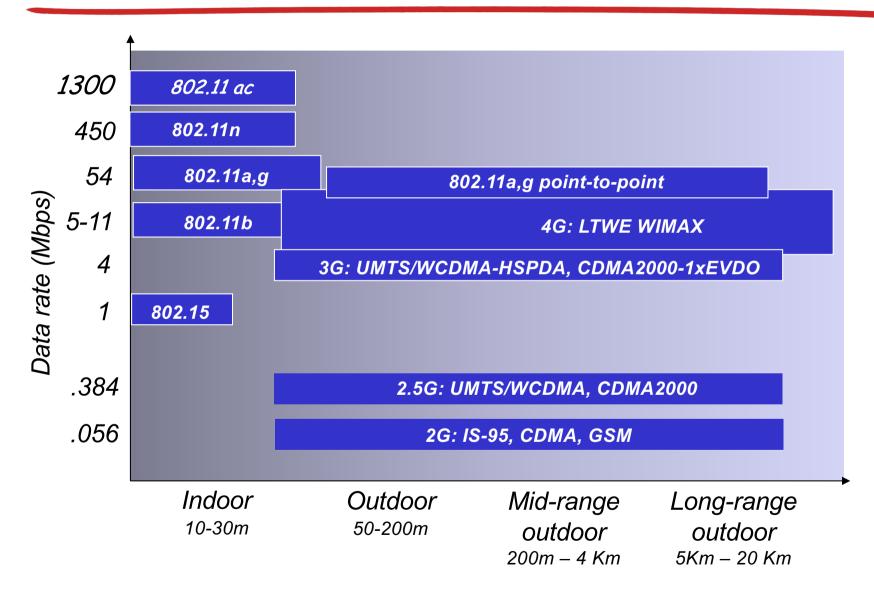








Characteristics of selected wireless links



Inside the radio wave spectrum

Graphic: Nathaniel Levine, Sacramento Bee

Almost every wireless technology - from cell phones to garage door openers - uses radio waves to communicate. Most of the white Some services, such as TV and radio broadcasts, have exclusive use of their frequency within a geographic area. areas on this chart But many devices share frequencies, which can cause interference. Examples of radio waves used by everyday devices reserved for military, federal Auctioned 2.4 GHz hand government and spectrum Used by more than 300 industry use consumer devices, including microwave ovens, cordless Garage Wireless phones and wireless Broadcast TV Cell Cell Satellite door medical Security Channels 2-13 openers phones networks (Wi-Fi and networks TV alarms phones telemetry Bluetooth) 500 kHz MHz GHz GHz GHz GHz GHz GHz GHz GHz Signals in this zone can only be AM radio GPS Satellite Remote-Broadcast TV Weather Cable TV Highway Police sent short. 535 kHz **UHF** channels toll tags controlled (Global positioning radar satellite radar radio unobstructed to 1,700 kHz tovs 14-83 systems) transmissions distances LINE-OF-SIGHT ZONES SEMT-PERMEABLE ZONE PERMEABLE ZONE Frequencies in this range are considered Difficult for signals more valuable because they can penetrate to penetrate dense Signals in this zone can dense objects, such as a building made objects travel long distances, but out of concrete could be blocked by trees and other objects Visible Infrared light Ultraviolet X-rays Microwaves Gamma rays Lowest 9 Highest frequencies frequencies RADIO WAVE SPECTRUM 3 kHz wavelength 300 GHz wavelength What is a hertz? The electromagnetic spectrum One hertz is one cycle per second. For radio waves, a cycle Higher Lower Radio waves occupy part of the electromagnetic frequency is the distance from wave crest to frequency spectrum, a range of electric and magnetic waves $\triangle M$ crest of different lengths that travel at the speed of light: 1 kilohertz (kHz) = 1,000 hertz other parts of the spectrum include visible light and Wavelength x-rays; the shortest wavelengths have the highest 1 megahertz (MHz) = 1 million hertz Distance from crest to crest frequency, measured in hertz 1 gigahertz (GHz) = 1 billion hertz Source: New America Foundation, MCT, Howstuffworks.com

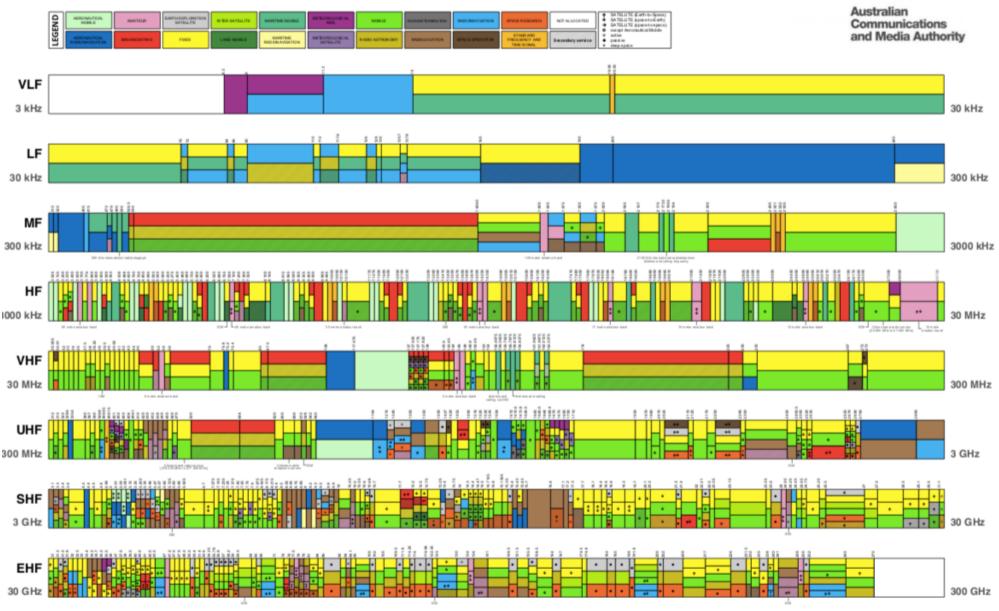
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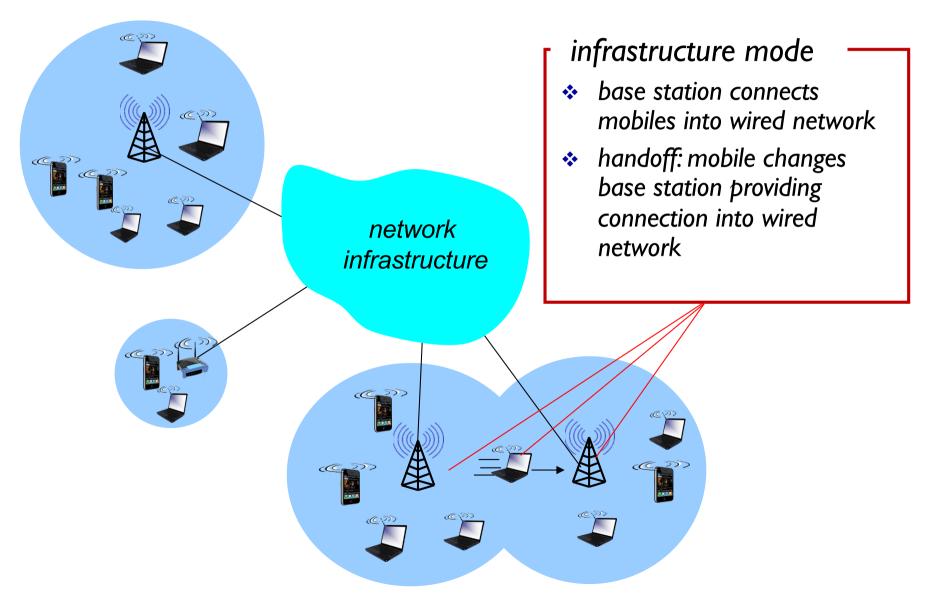
Australian radiofrequency spectrum

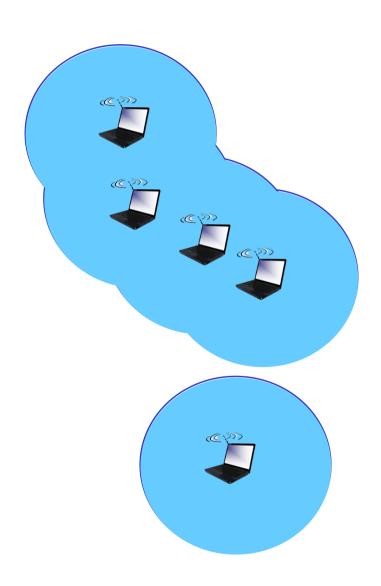




allocations chart







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

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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"

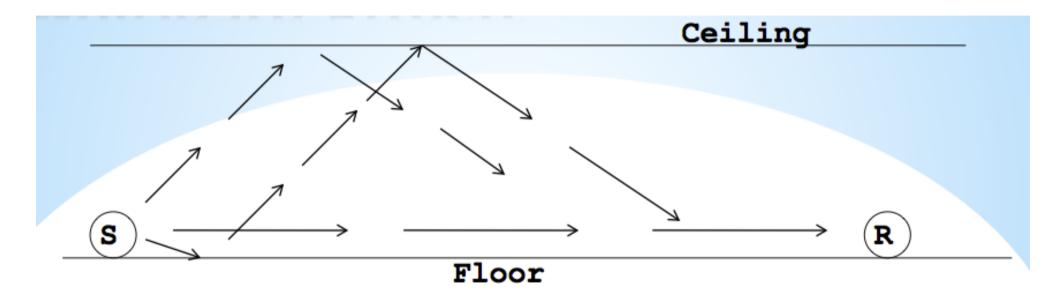
Path Loss/Path Attenuation

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

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

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

Multipath Effects

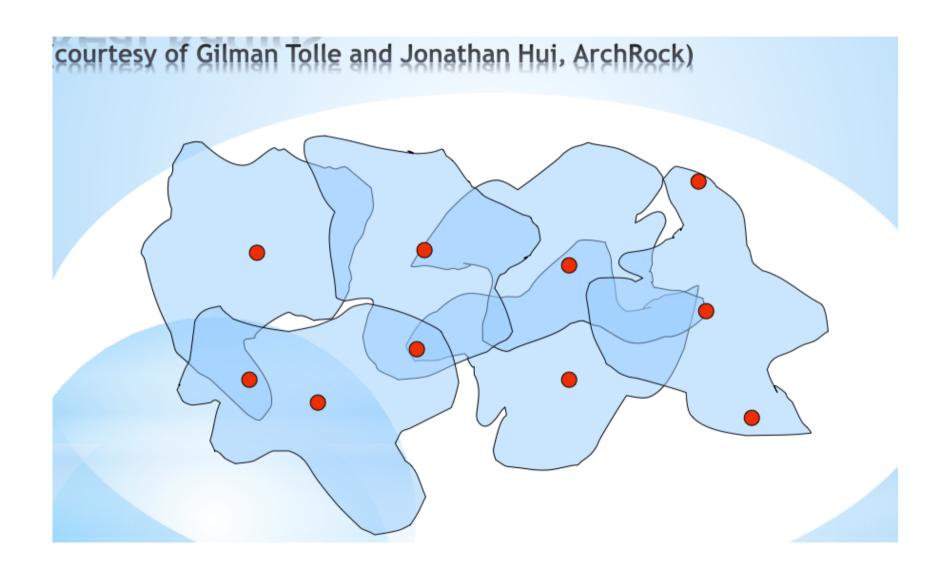


- Signals bounce off surface and interfere (constructive or destructive) with one another
- Self-interference

Ideal Radios

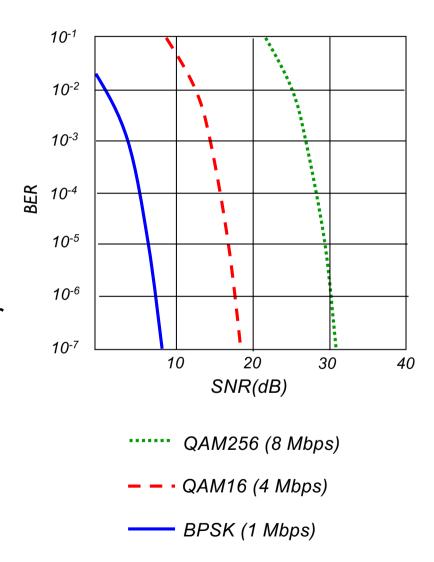
(courtesy of Gilman Tolle and Jonathan Hui, ArchRock)

Real Radios



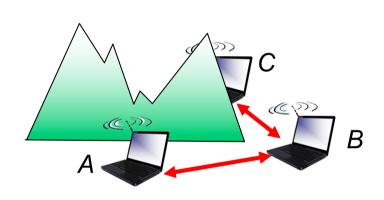
Wireless Link Characteristics (2)

- 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 thruput
 - SNR may change with mobility: dynamically adapt physical layer (modulation technique, rate)



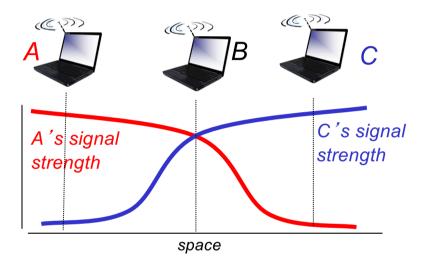
Wireless network characteristics

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

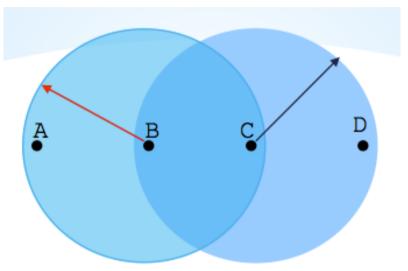


Signal attenuation:

- 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

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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

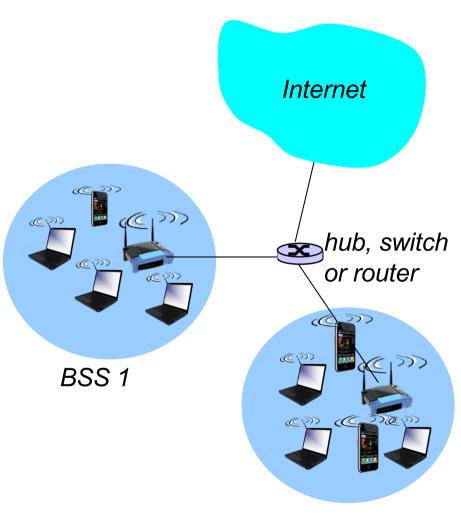
- 5-6 GHz range
- up to 54 Mbps

802.11g

- 2.4-5 GHz range
- up to 54 Mbps
- 802. I In: 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



BSS 2

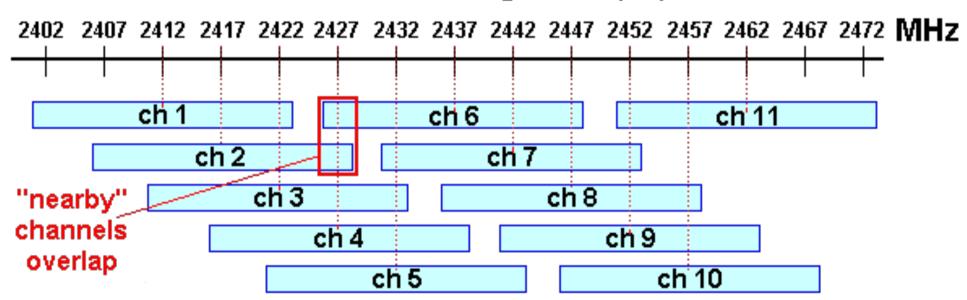
- wireless host communicates with base station
 - base station = access point (AP)
- * Basic Service Set (BSS) (aka "cell") in infrastructure mode contains:
 - wireless hosts
 - access point (AP): base station
 - ad hoc mode: hosts only

802.11: Channels, association

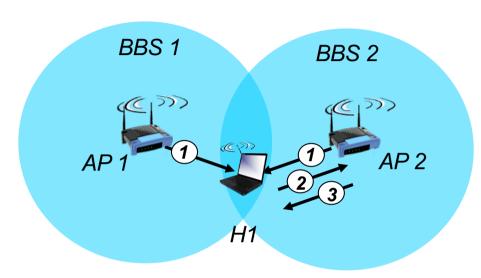
- 802.11b: 2.4GHz-2.485GHz spectrum divided into 11 channels at different frequencies
 - AP admin chooses frequency for AP
 - interference possible: channel can be same as that chosen by neighboring AP!
- host: must associate with an AP
 - scans channels, listening for beacon frames containing AP's name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

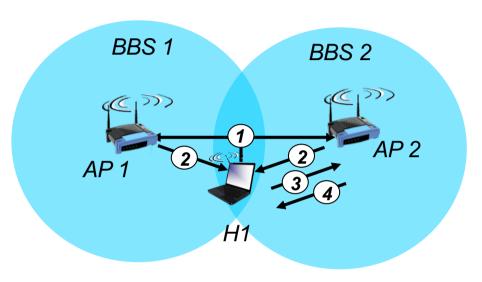
802. I I b channels

802.11b channel assignments (US)



802. I I: passive/active scanning





passive scanning:

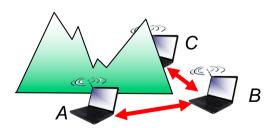
- (1) beacon frames sent from APs
- (2) association Request frame sent: H1 to selected AP
- (3) association Response frame sent from selected AP to H I

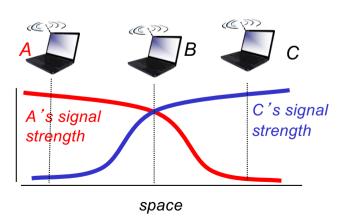
active scanning:

- (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

<u>Distributed Coordination Function (DCF)</u> 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

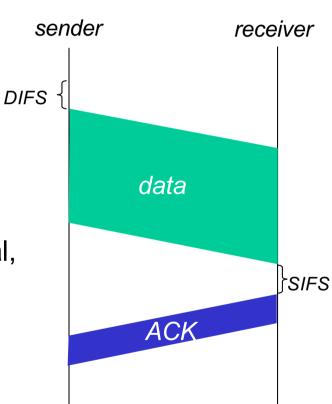
802.11 receiver

- 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



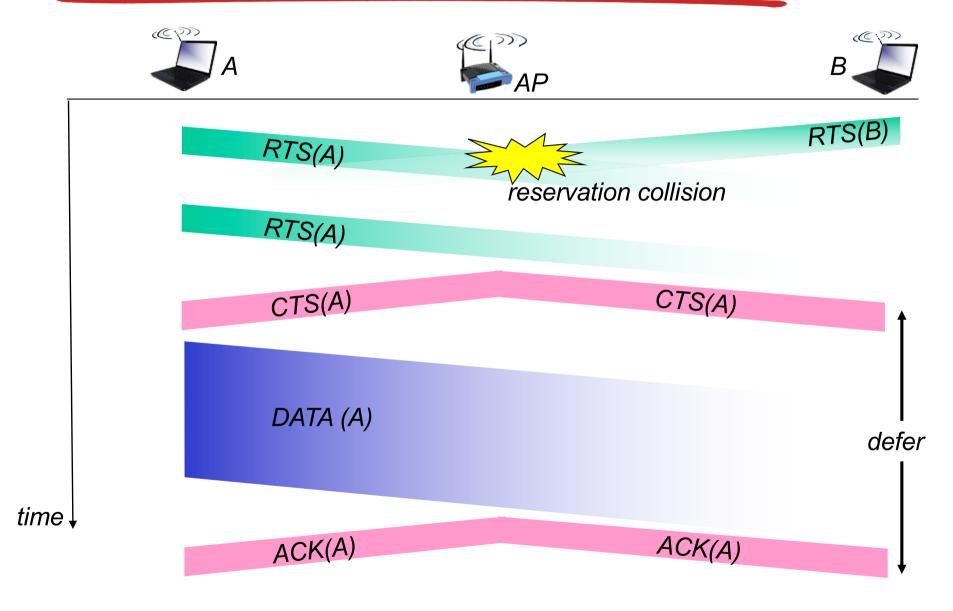
Avoiding collisions (more)

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

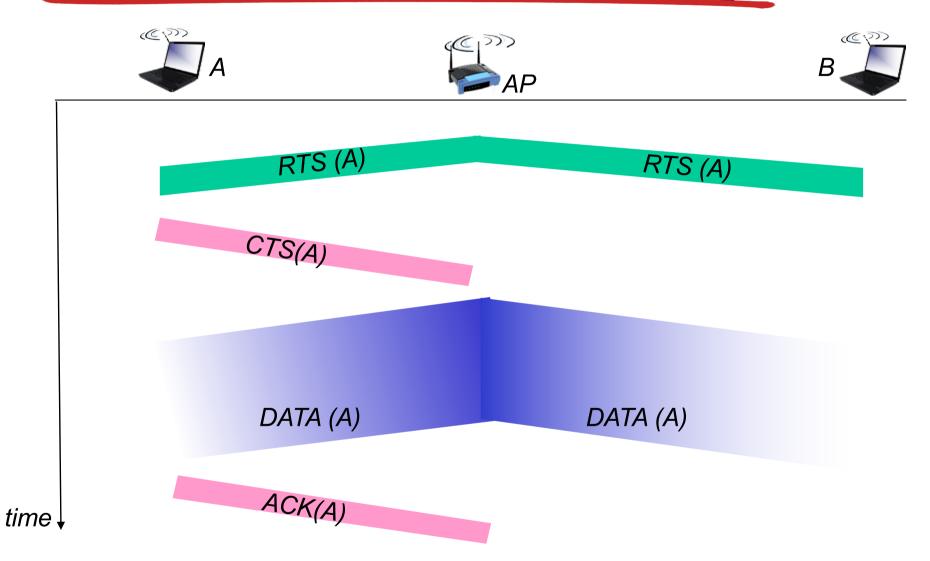
- sender first transmits small request-to-send (RTS) packets to BS using CSMA
 - RTSs may still collide with each other (but they' re short)
- BS broadcasts clear-to-send CTS in response to RTS
- CTS heard by all nodes
 - sender transmits data frame
 - other stations defer transmissions

avoid data frame collisions completely using small reservation packets!

Collision Avoidance: RTS-CTS exchange



Collision Avoidance: RTS-CTS exchange



Summary

Wireless

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



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