CS 332
Computer Networks
Wireless Networks

Professor Szajda

Chapter 6: Wireless and Mobile Networks

Background:

- # wireless (mobile) phone subscribers have exceeded # wired phone subscribers for a while now!
- computer nets: laptops, smartphones, tablets provide anytime untethered Internet access
- two important (but different) challenges
  - communication over wireless link
  - handling mobile user who changes point of attachment to network
    - What exactly do we mean by "mobile" anyway?

Chapter 6 outline

6.1 Introduction

Wireless

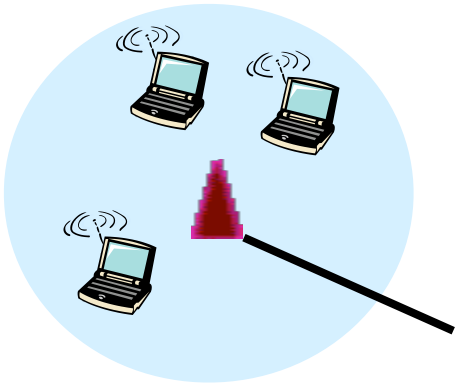
- 6.2 Wireless links, characteristics
  - CDMA
- 6.3 IEEE 802.11 wireless LANs ("wi-fi")
- 6.4 Cellular Internet Access
  - architecture
  - standards (e.g., GSM)

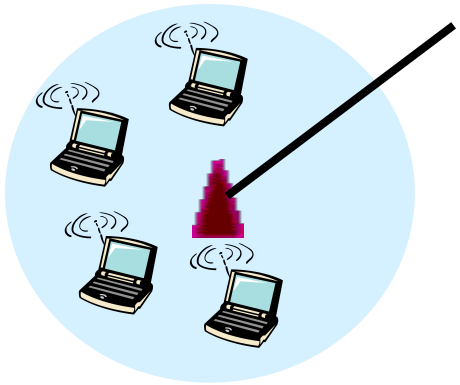
Mobility

- 6.5 Principles: addressing and routing to mobile users
- 6.6 Mobile IP
- 6.7 Handling mobility in cellular networks
- 6.8 Mobility and higher-layer protocols

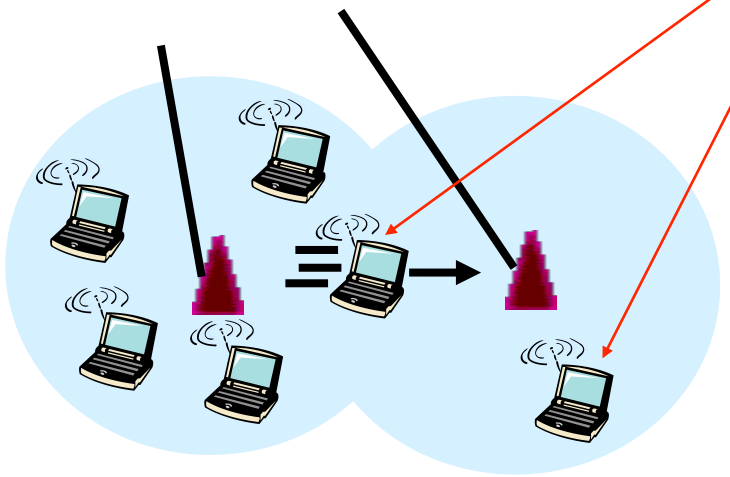
6.9 Summary

Elements of a wireless network





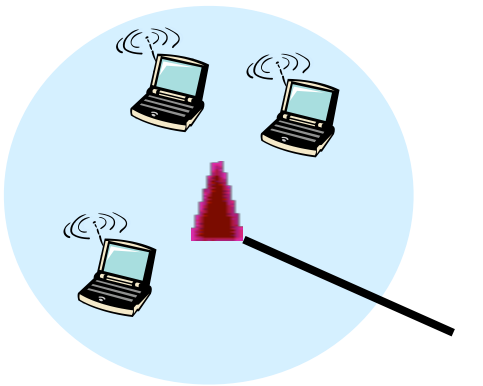
network
infrastructure

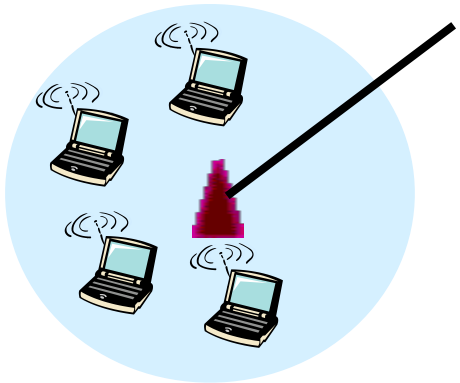


wireless hosts

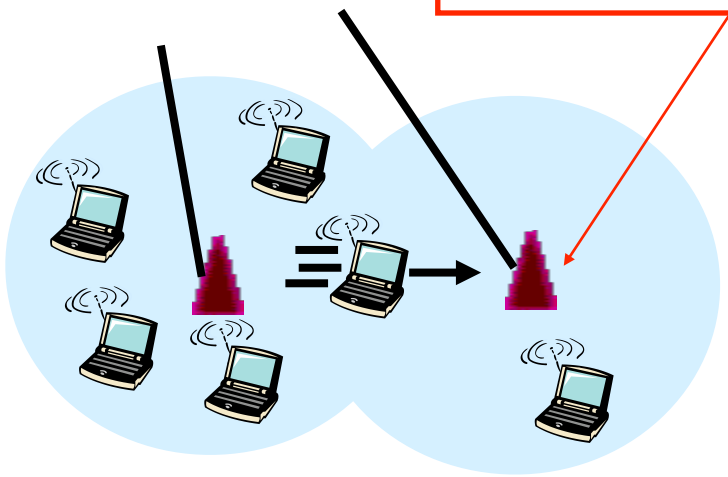
- laptop, PDA, IP phone
- run applications
- may be stationary (non-mobile) or mobile
  - wireless does not always mean mobility

Elements of a wireless network





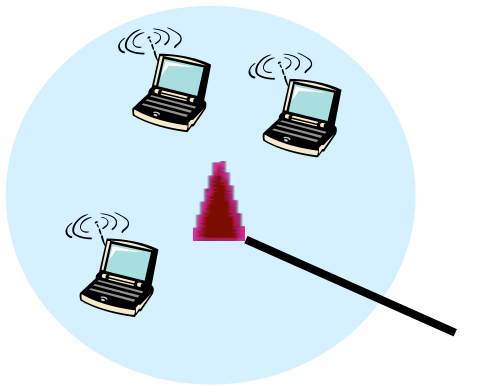
network infrastructure

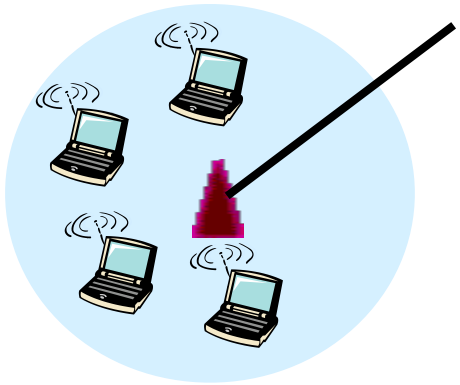


base station

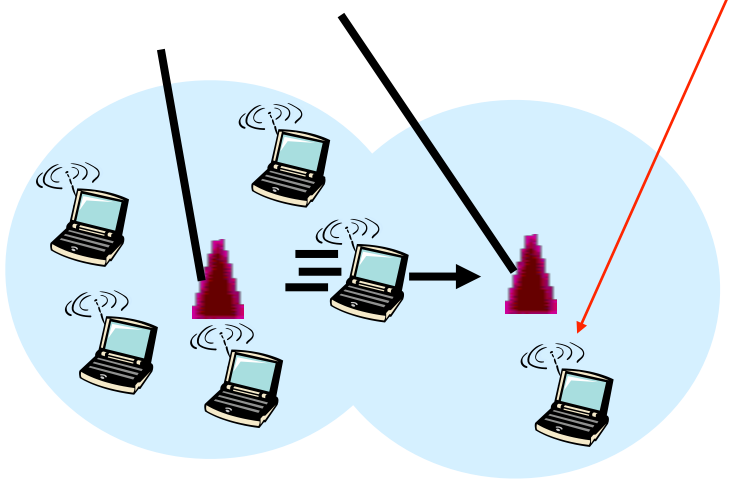
- typically connected to wired network
- relay - responsible for sending packets between wired network and wireless host(s) in its "area"
  - e.g., cell towers, 802.11 access points

Elements of a wireless network





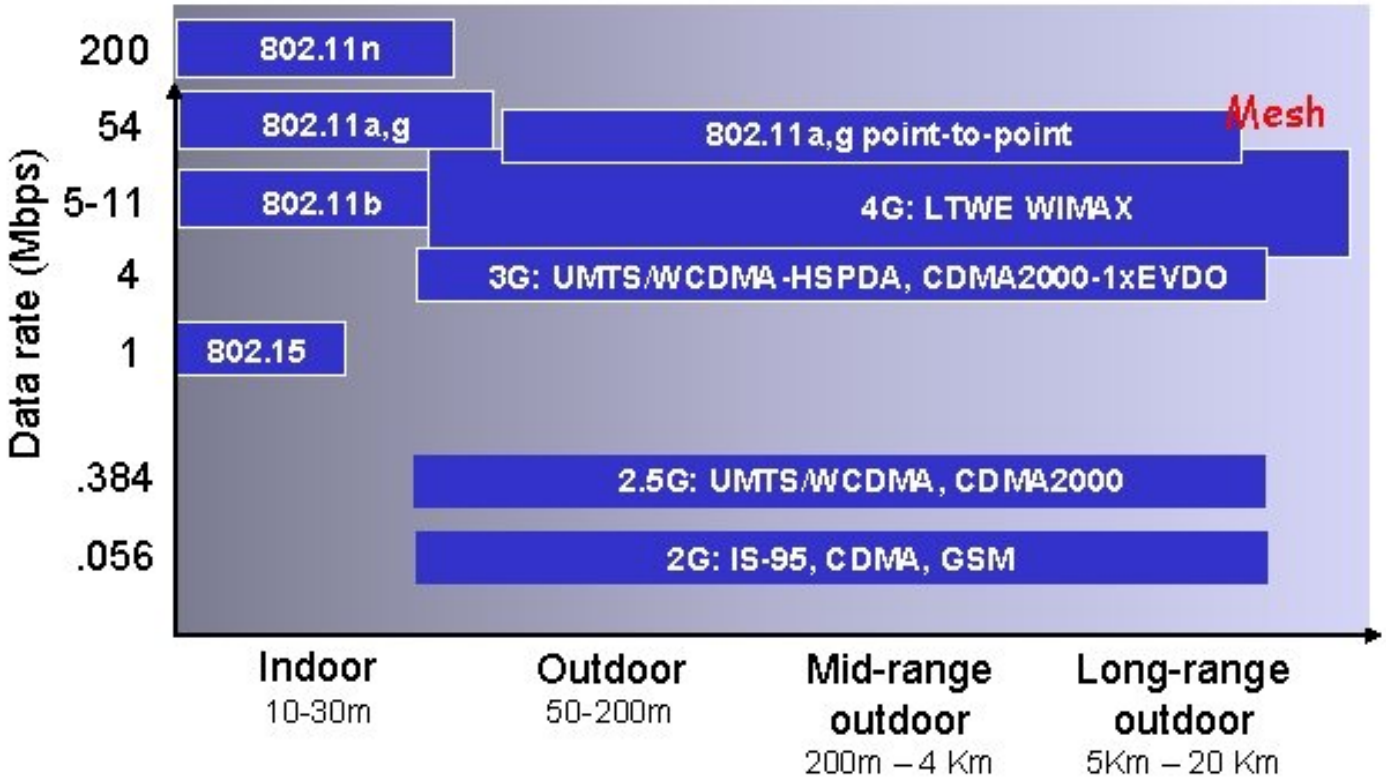
network infrastructure



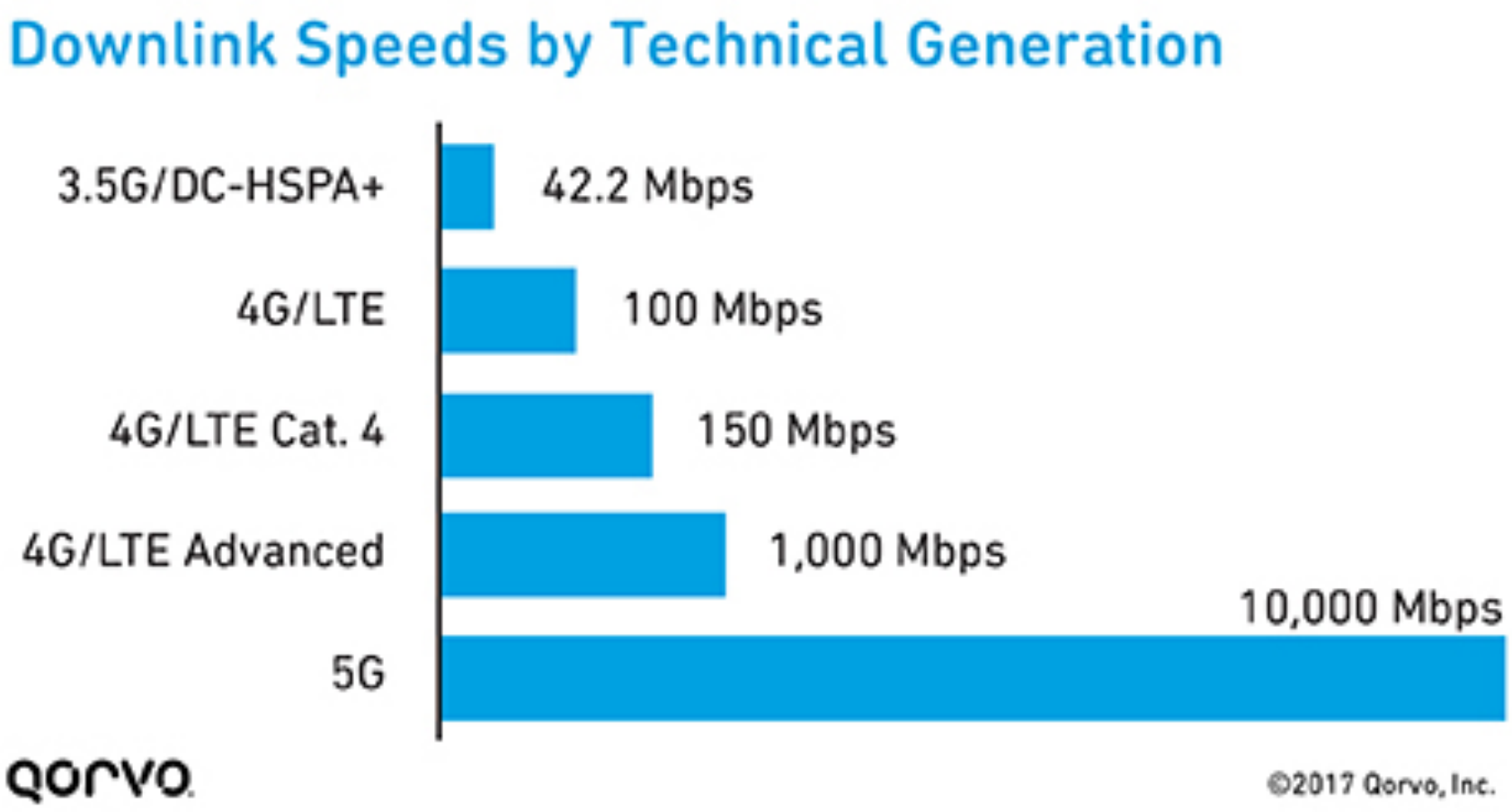
wireless link

- 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 link standards



Update!


Downlink Speeds by Technical Generation
3.5G/DC-HSPA+
42.2 Mbps
4G/LTE
100 Mbps
4G/LTE Cat. 4
150 Mbps
4G/LTE Advanced
1,000 Mbps
5G
10,000 Mbps
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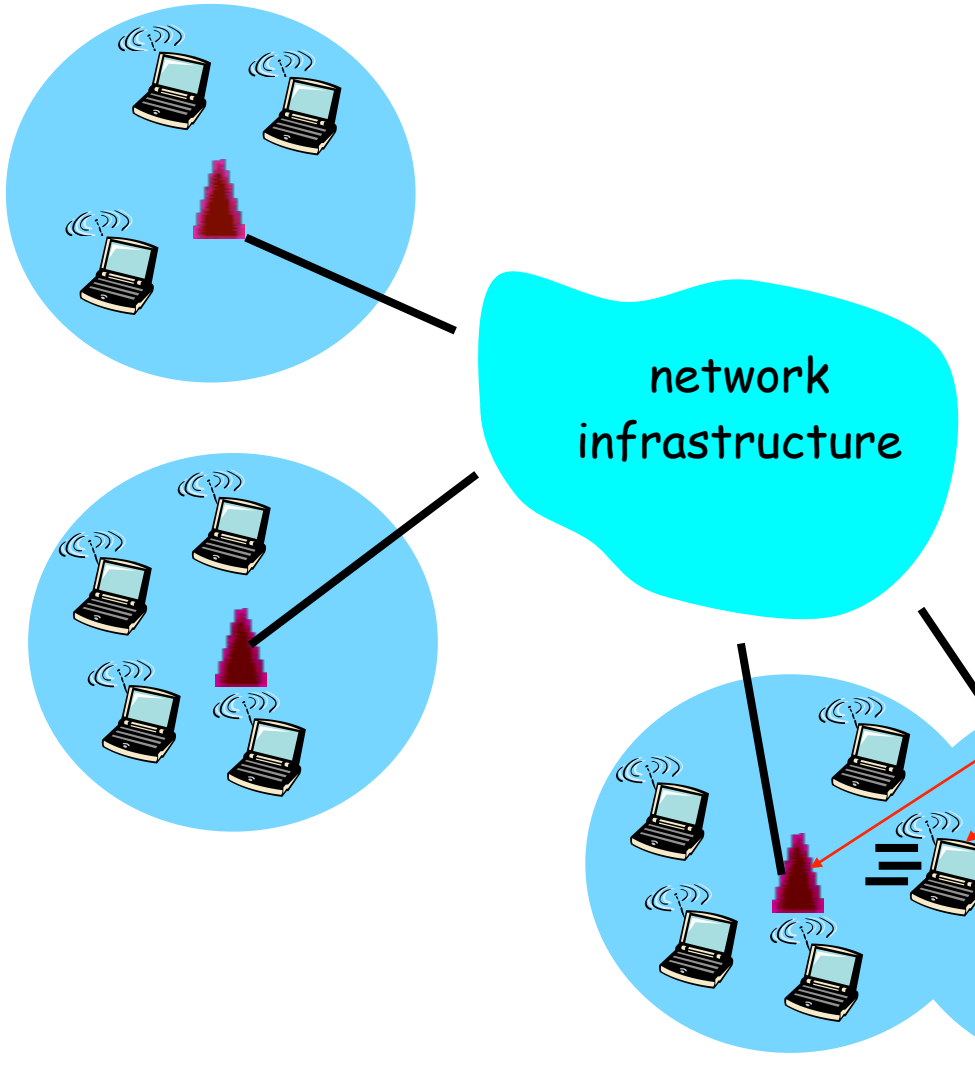
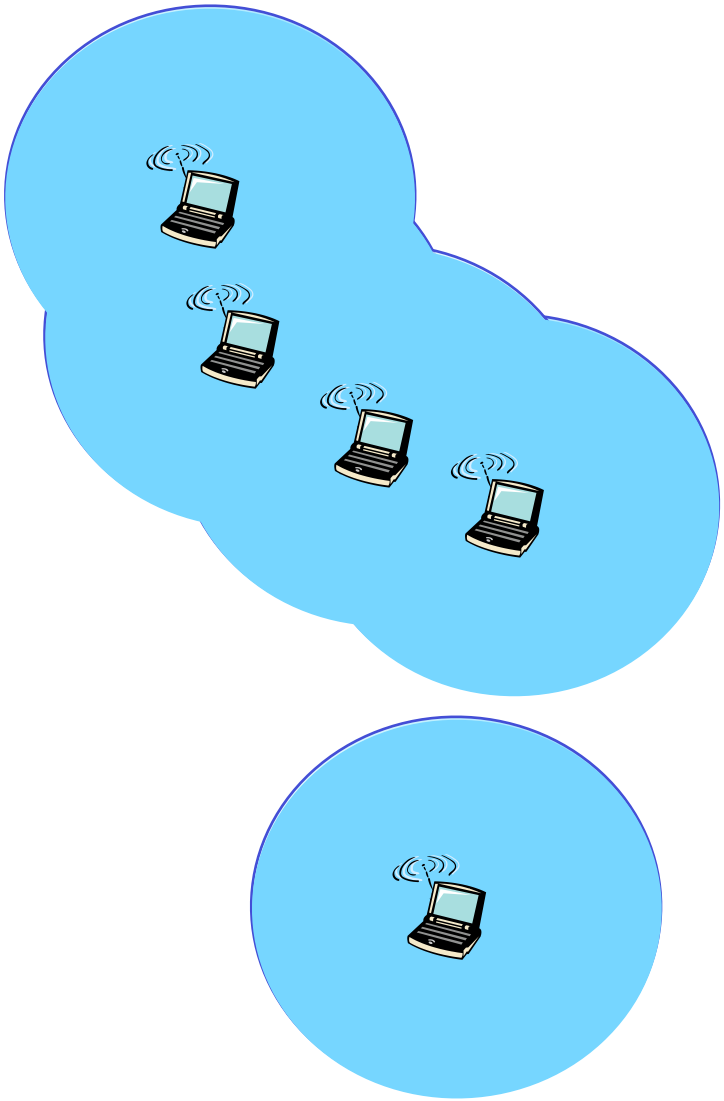
Elements of a wireless network



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

Wireless Link Characteristics

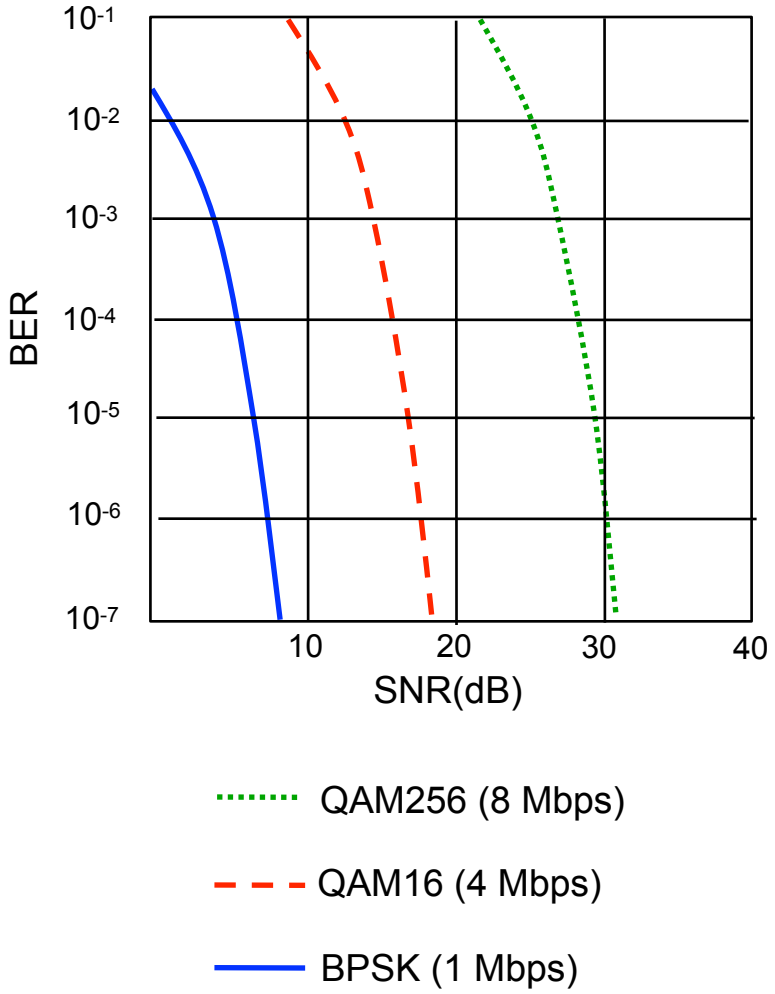
Differences from wired link ….

- 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"

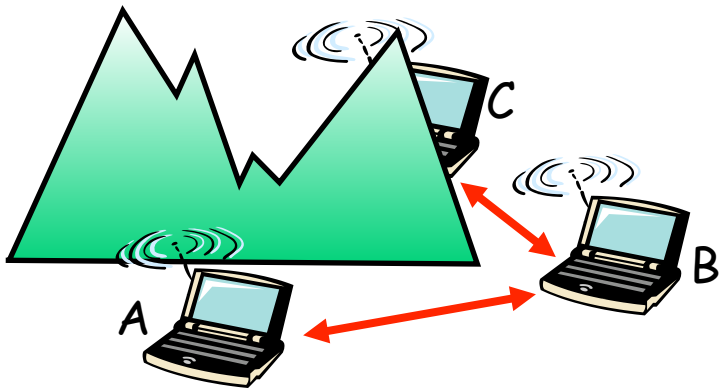
Wireless Link Characteristics

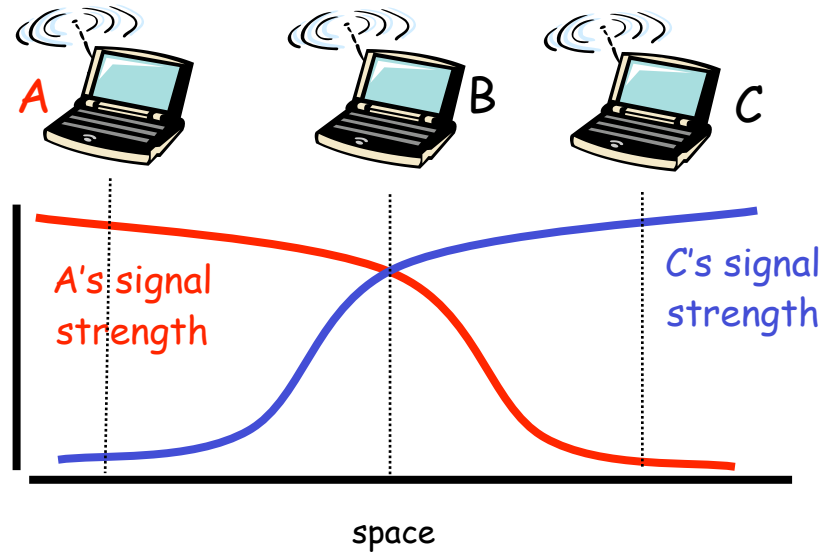
- SNR: signal-to-noise ratio
  - larger SNR – easier to extract signal from noise (a "good thing")
- SNR versus BER tradeoffs
  - given physical layer: increase power -> increase SNR->decrease BER
  - given SNR: choose physical layer that meets BER requirement, giving highest throughput
    - SNR may 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

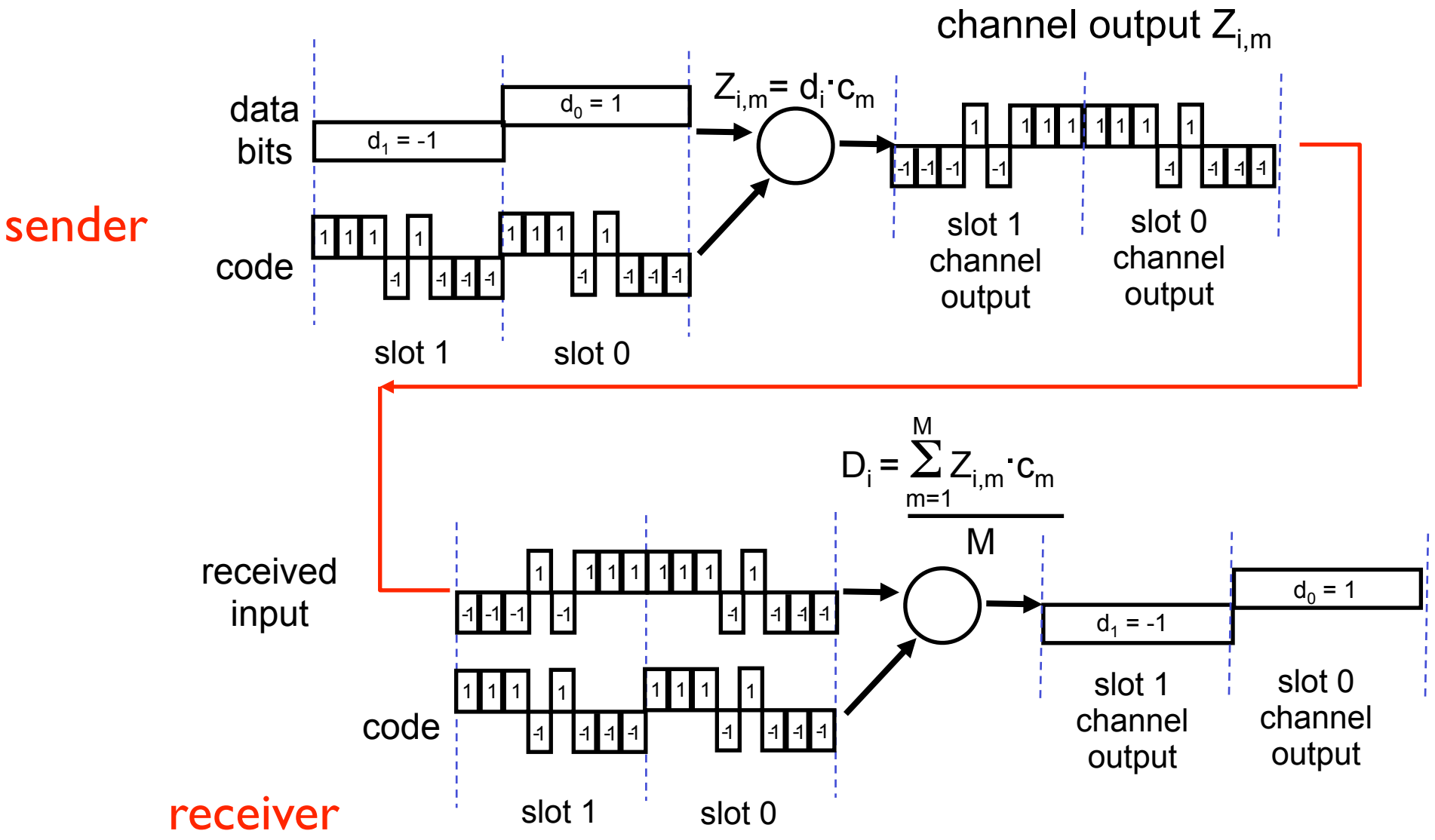
Signal fading:

- B, A hear each other
- B, C hear each other
- A, C can not hear each other interferring at B

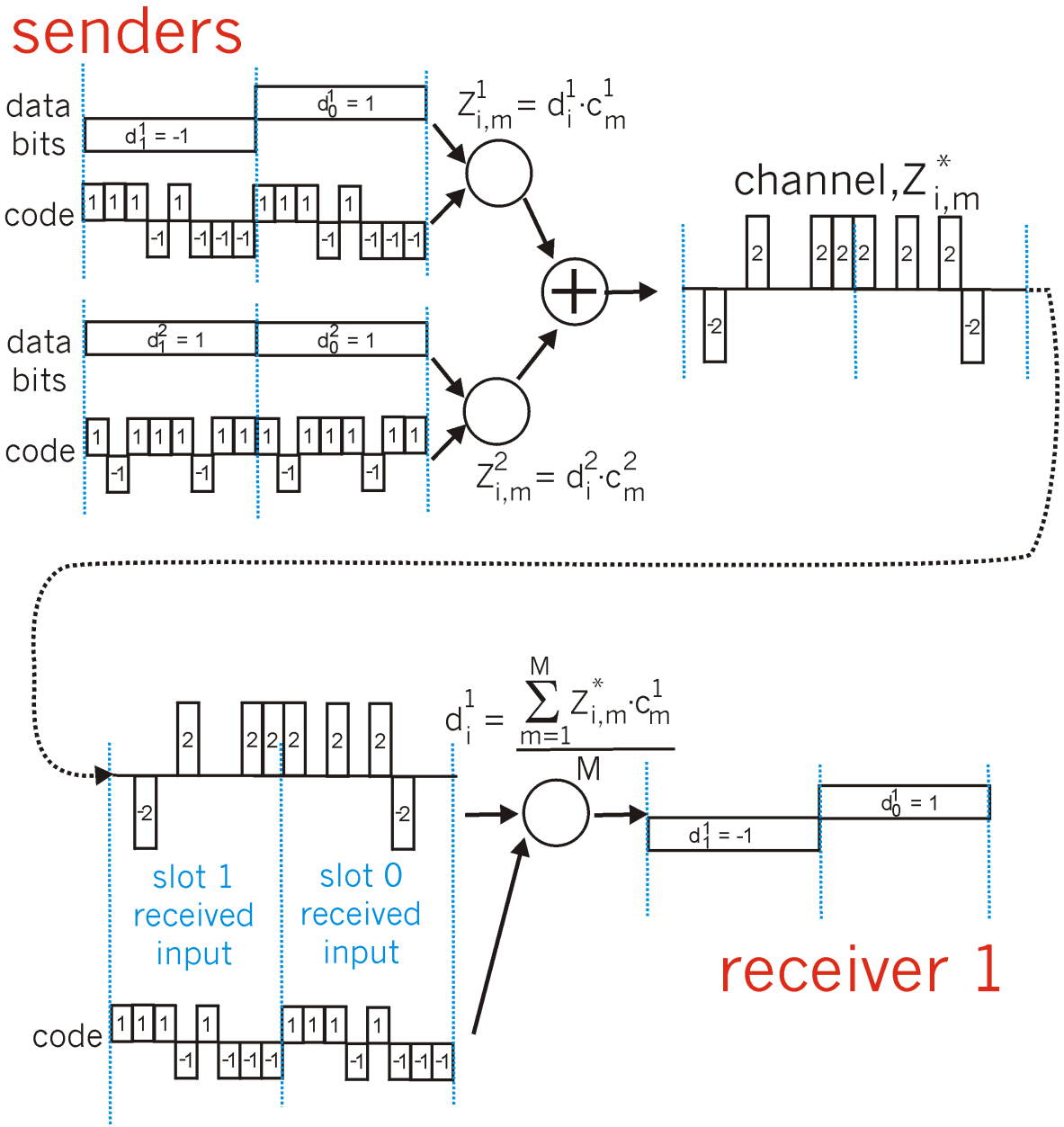
Code Division Multiple Access (CDMA)

- used in several wireless broadcast channels (cellular, satellite, etc) standards
- unique "code" assigned to each user; i.e., code set partitioning
- all users share same frequency, but each user has own "chipping" sequence (i.e., code) to encode data
- encoded signal = (original data) X (chipping sequence)
- decoding: inner-product of encoded signal and chipping sequence
- allows multiple users to "coexist" and transmit simultaneously with minimal interference (if codes are "orthogonal")

CDMA Encode/Decode



CDMA: two-sender interference



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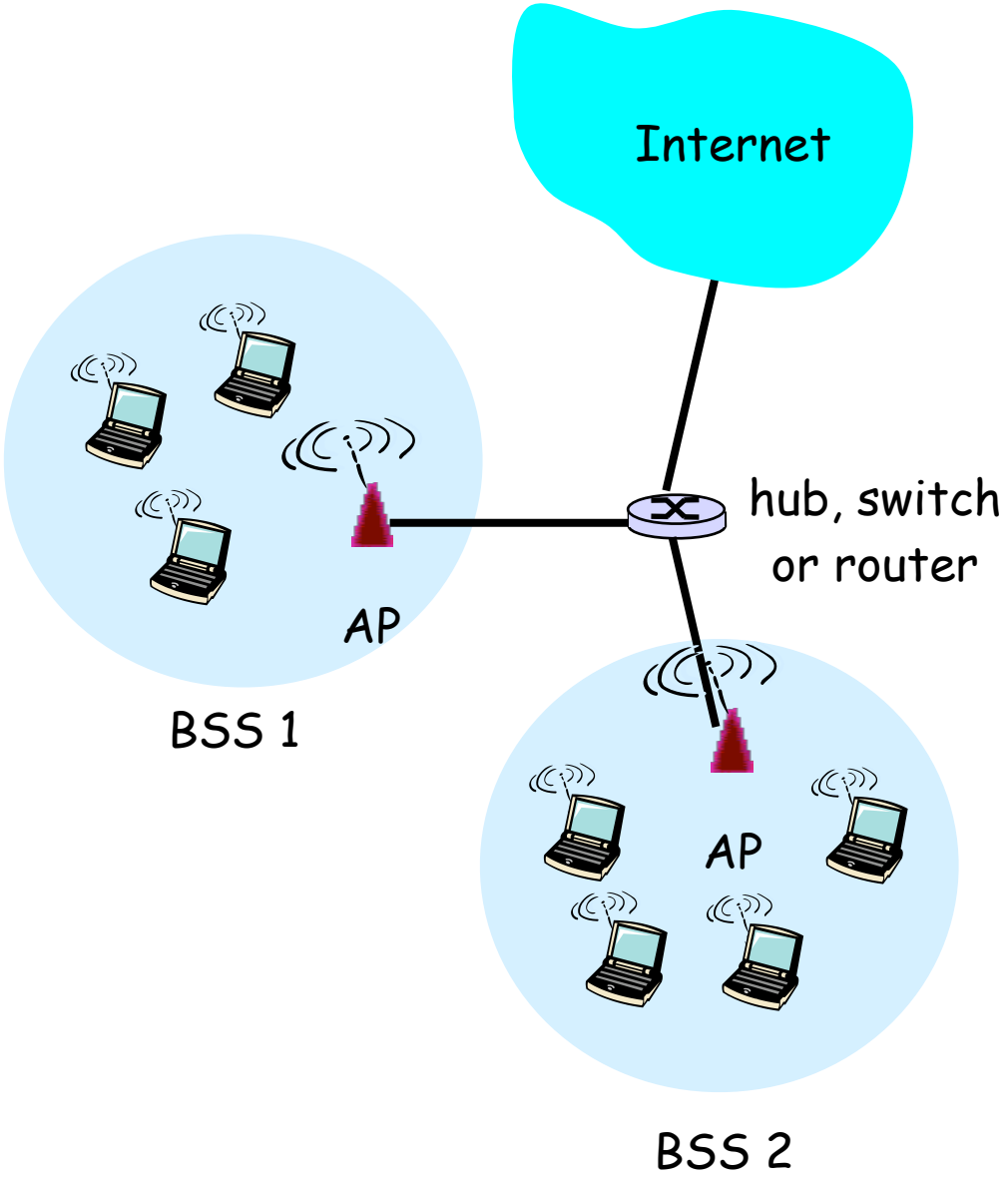
IEEE 802.11 Wireless LAN

- 802.11b
  - 2.4-5 GHz unlicensed radio spectrum
  - up to 11 Mbps
  - direct sequence spread spectrum (DSSS) in physical layer
    - all hosts use same chipping code
  - widely deployed, using base stations
- 802.11a
  - 5-6 GHz range
  - up to 54 Mbps
- 802.11g
  - 2.4-5 GHz range
  - up to 54 Mbps
- All use CSMA/CA for multiple access
- All have base-station and ad-hoc network versions

802.11 LAN architecture

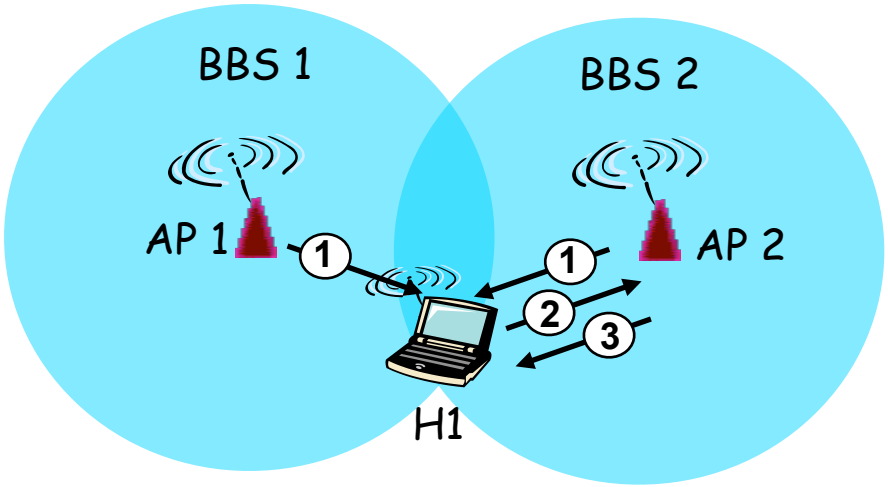


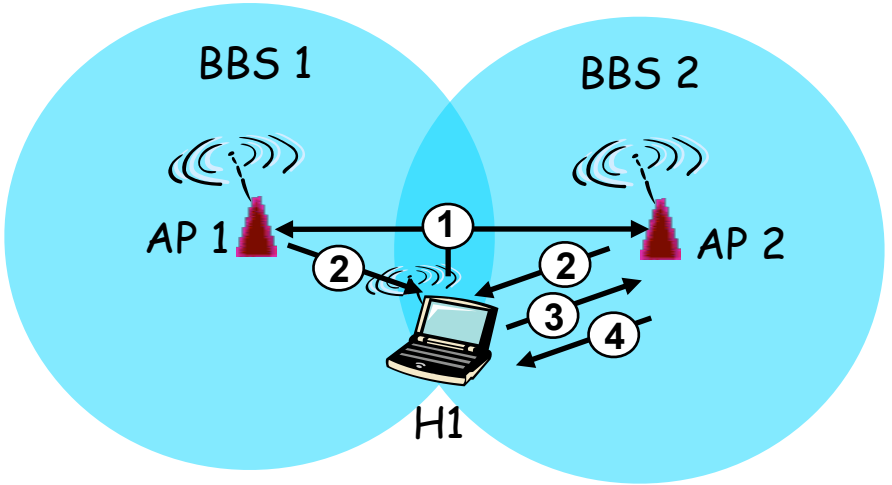
- wireless host communicates with base station
  - base station = access point (AP)
- Basic Service Set (BSS) (aka "cell") in infrastructure mode contains:
  - wireless hosts
  - access point (AP): base station
  - ad hoc mode: hosts only

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 (service set identifier (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

802.11: Passive/Active Scanning





Passive Scanning:

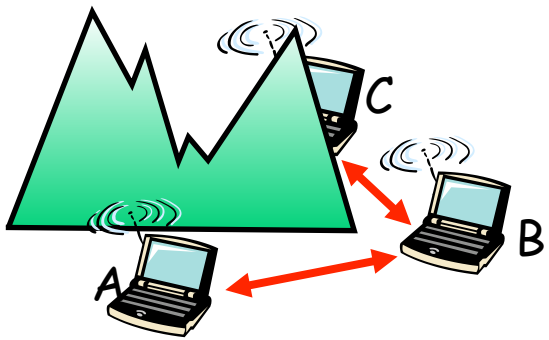
(1) beacon frames sent from APs
(2) association Request frame sent: H1 to selected AP
(3) association Response frame sent: selected AP to H1

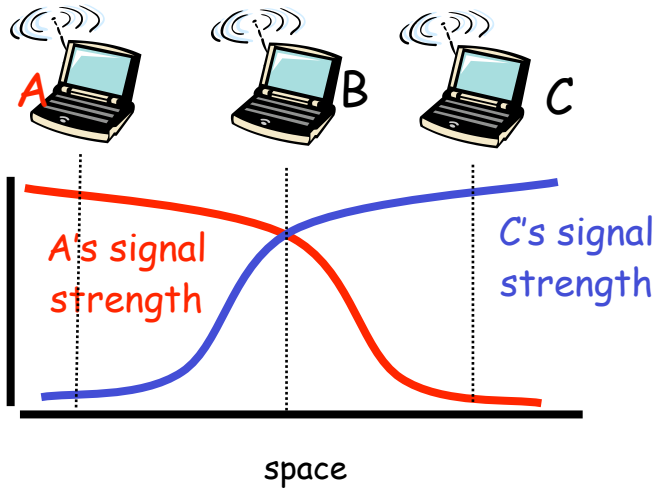
Active Scanning:

(1) Probe Request frame broadcast from H1
(2) Probes response frame sent from APs
(3) Association Request frame sent: H1 to selected AP
(4) Association Response frame sent: 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)





IEEE 802.11 MAC Protocol: CSMA/CA

802.11 sender

Distributed inter-frame space

1 if sense channel idle for DIFS then

transmit entire frame (no CD)

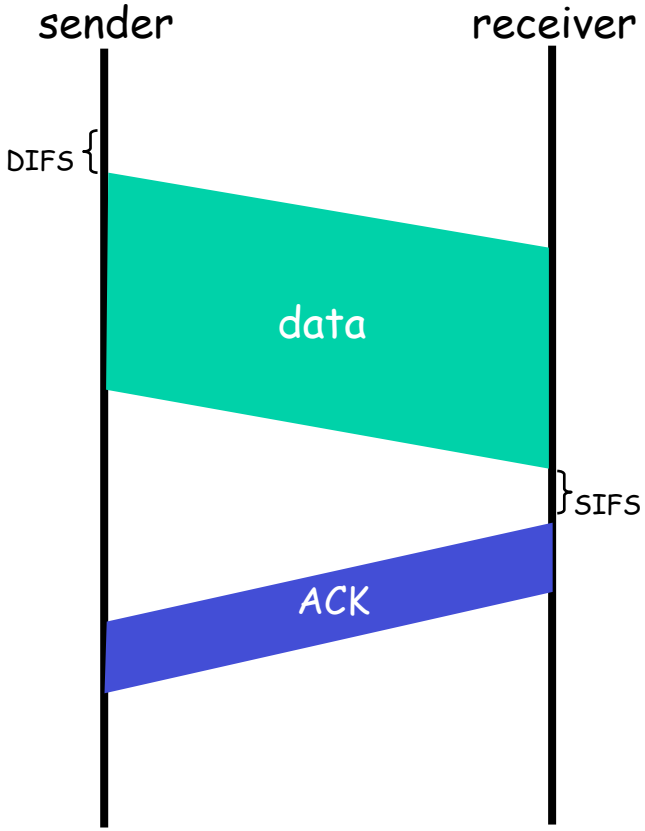
2 if sense channel busy then

select random backoff time

when channel sensed idle, and after DIFS, timer counts down as long as channel remains sensed idle (freeze timer if channel sensed busy)

transmit when timer expires

if no ACK, increase random backoff interval, repeat 2



802.11 receiver

short inter-frame space

- if frame received OK

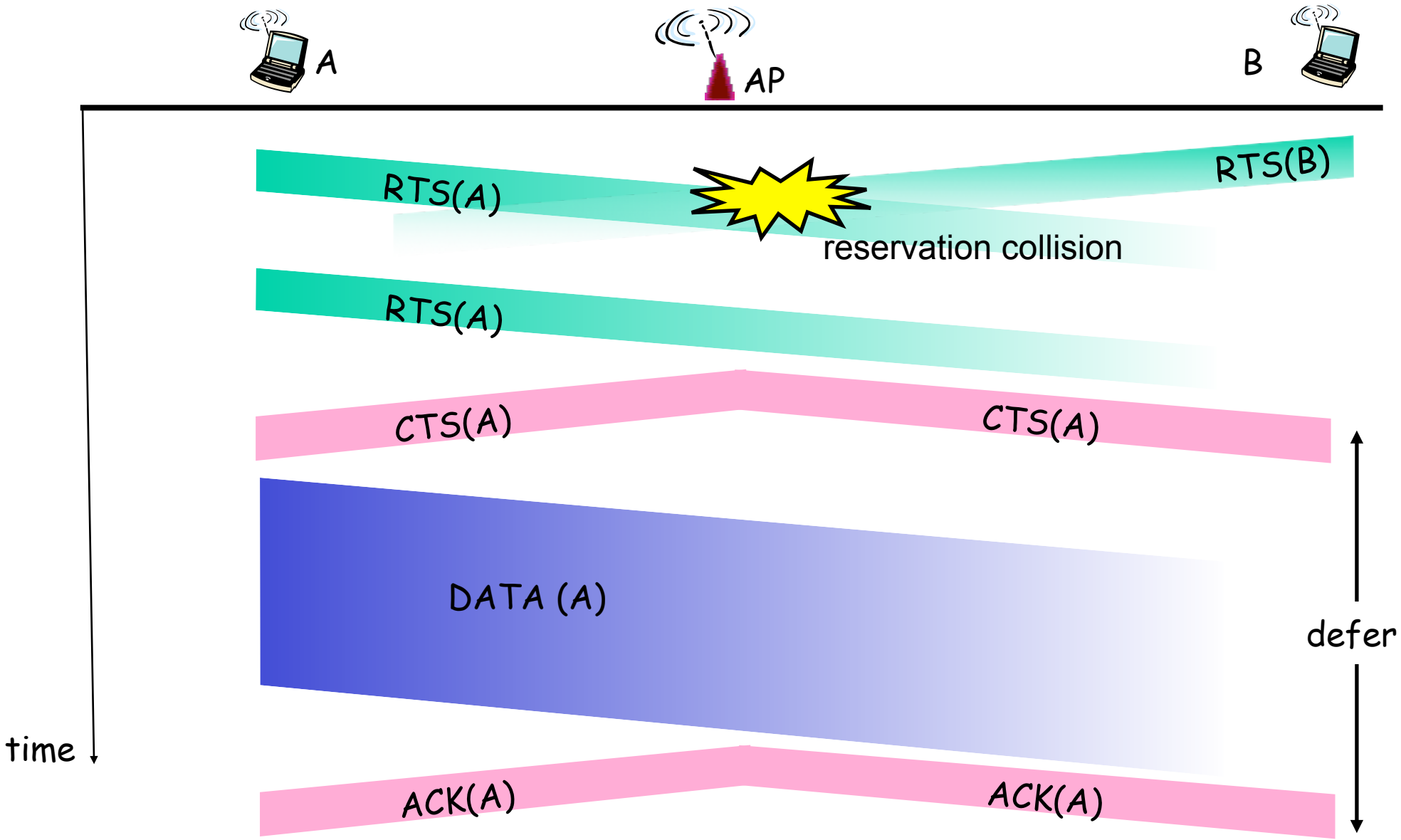
Avoiding collisions (more)

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

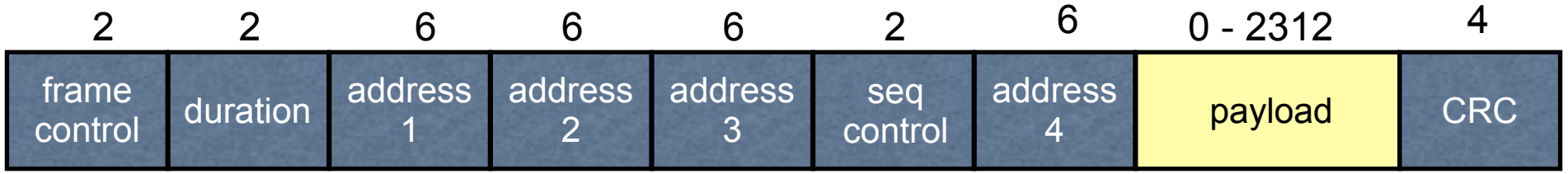
- sender first transmits small request-to-send (RTS) packets to BS using CSMA
  - RTSs may still collide with each other (but they're short)
- BS broadcasts clear-to-send CTS in response to RTS
- RTS heard by all nodes
  - sender transmits data frame
  - other stations defer transmissions

Avoid data frame collisions completely using small reservation packets!

Collision Avoidance: RTS-CTS exchange



802.11 Frame: addressing



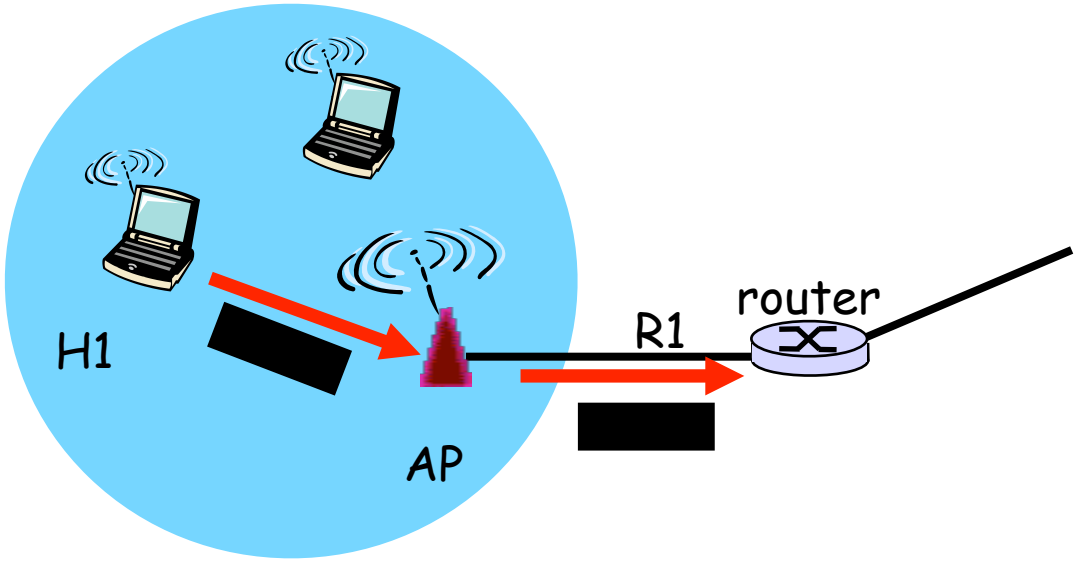
Address 1: MAC address of wireless host or AP to receive this frame

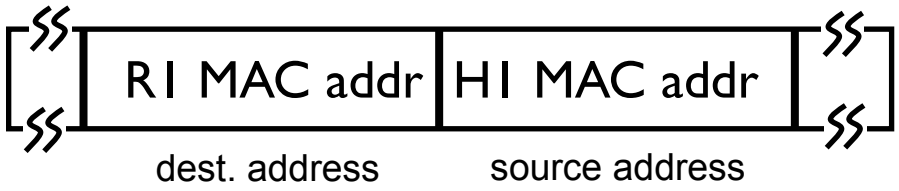
Address 2: MAC address of wireless host or AP transmitting this frame

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

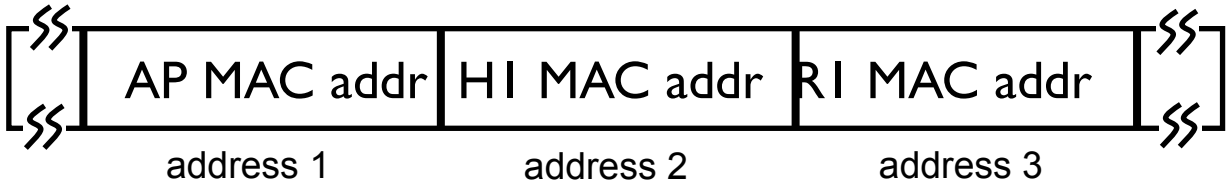
Address 4: used only in ad hoc mode

802.11 Frame: Addressing



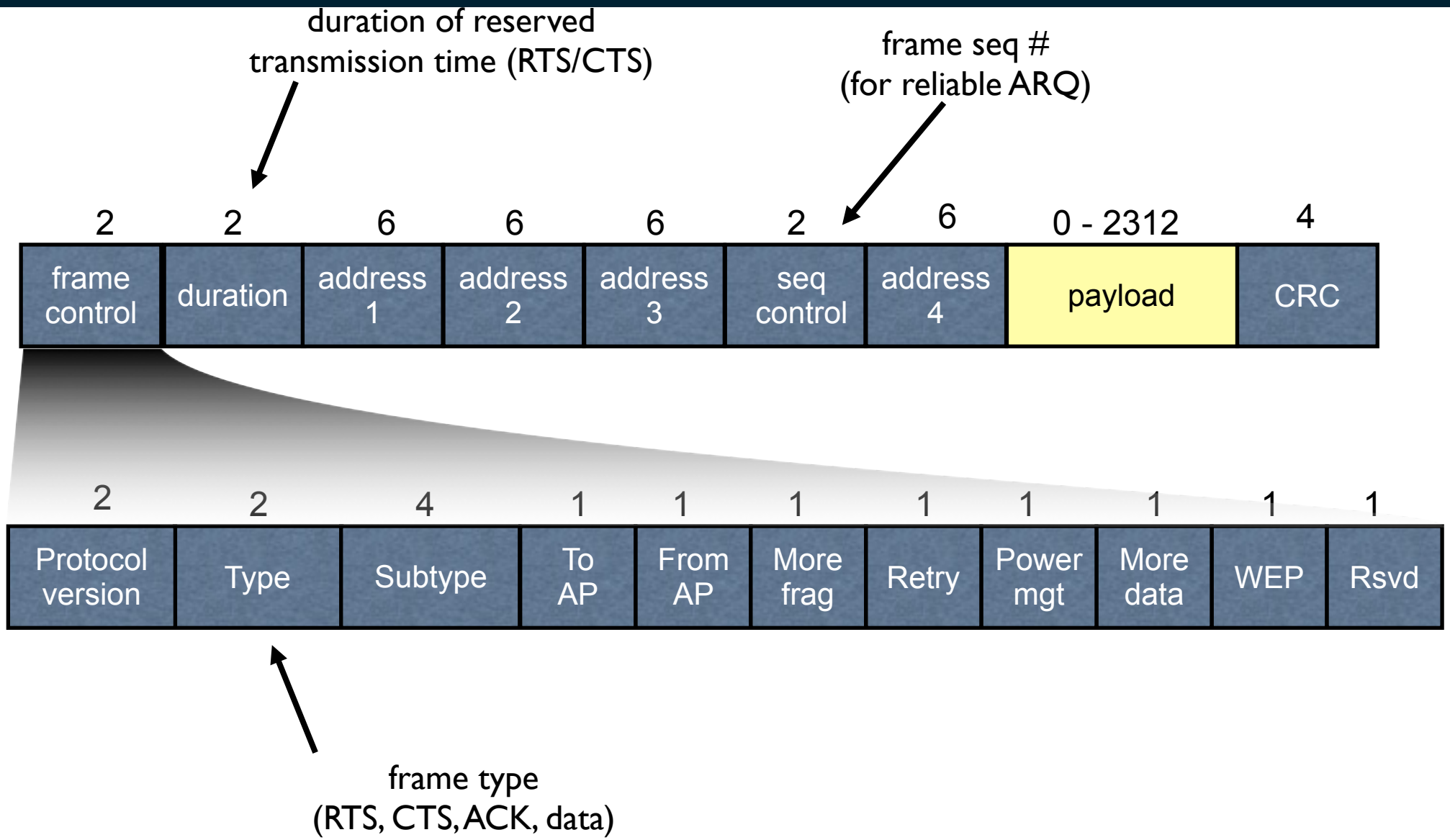


802.3 frame



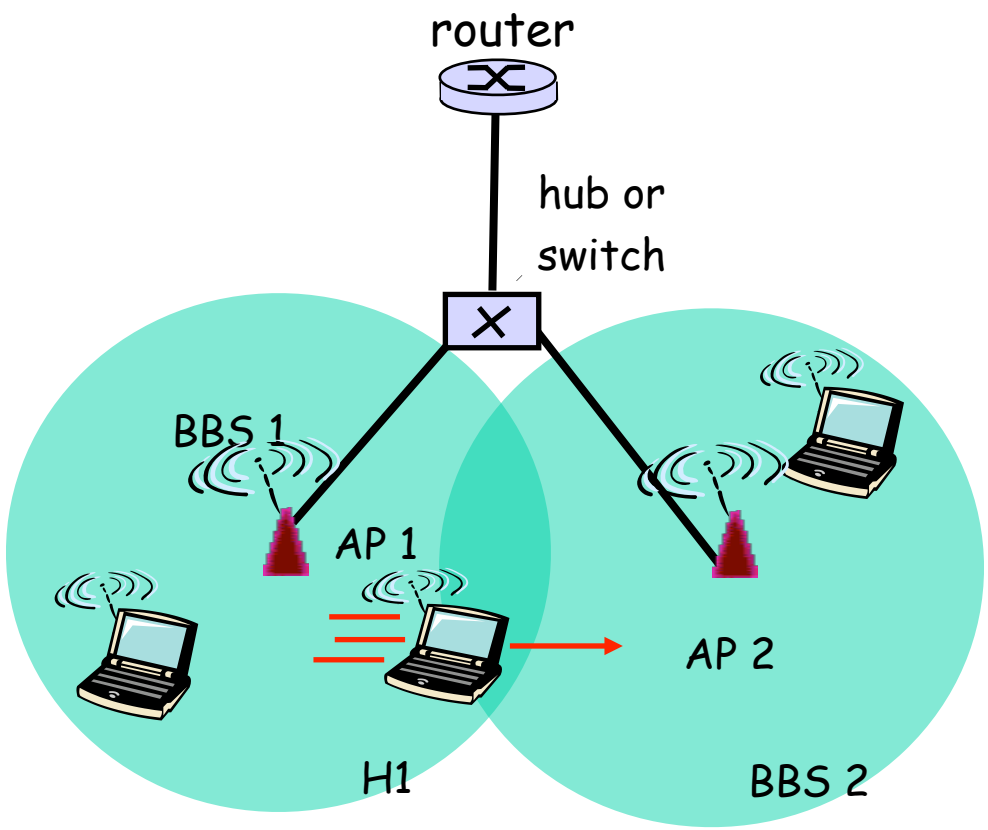
802.11 frame

802.11 Frame: More



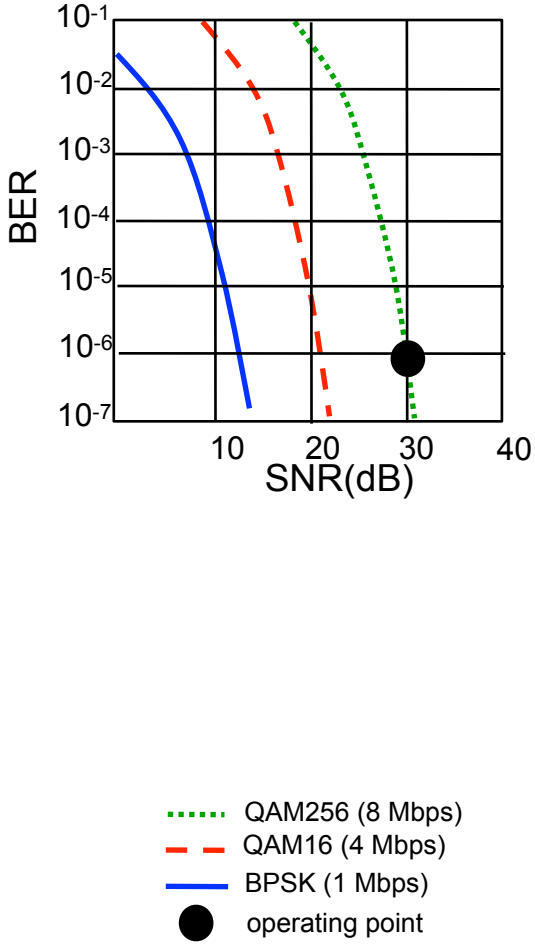
802.11 Mobility within same subnet

- 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

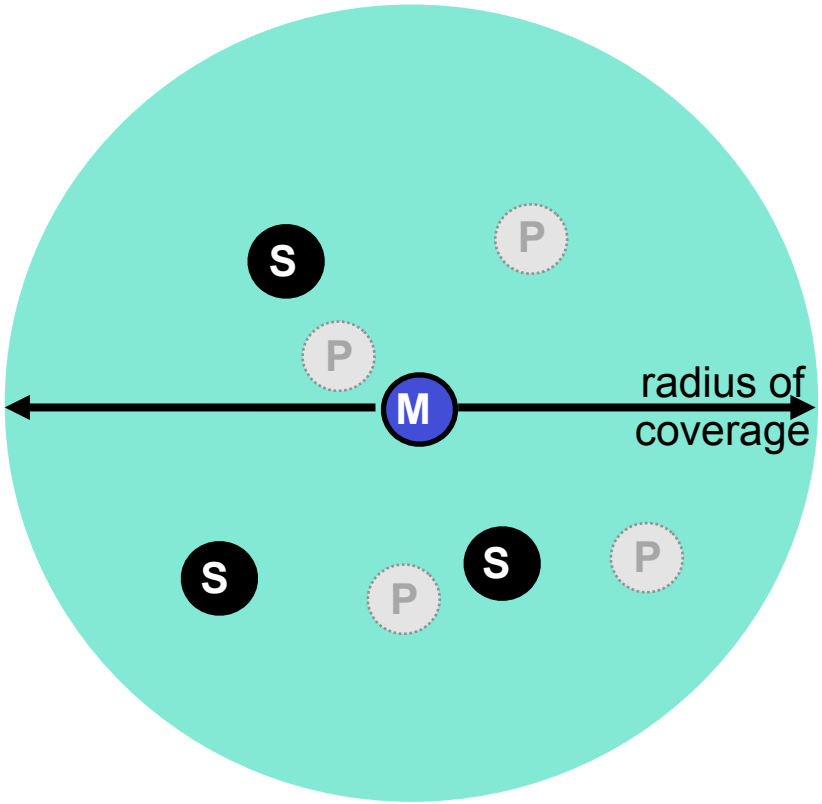
802.11: Advanced Capabilities

- 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

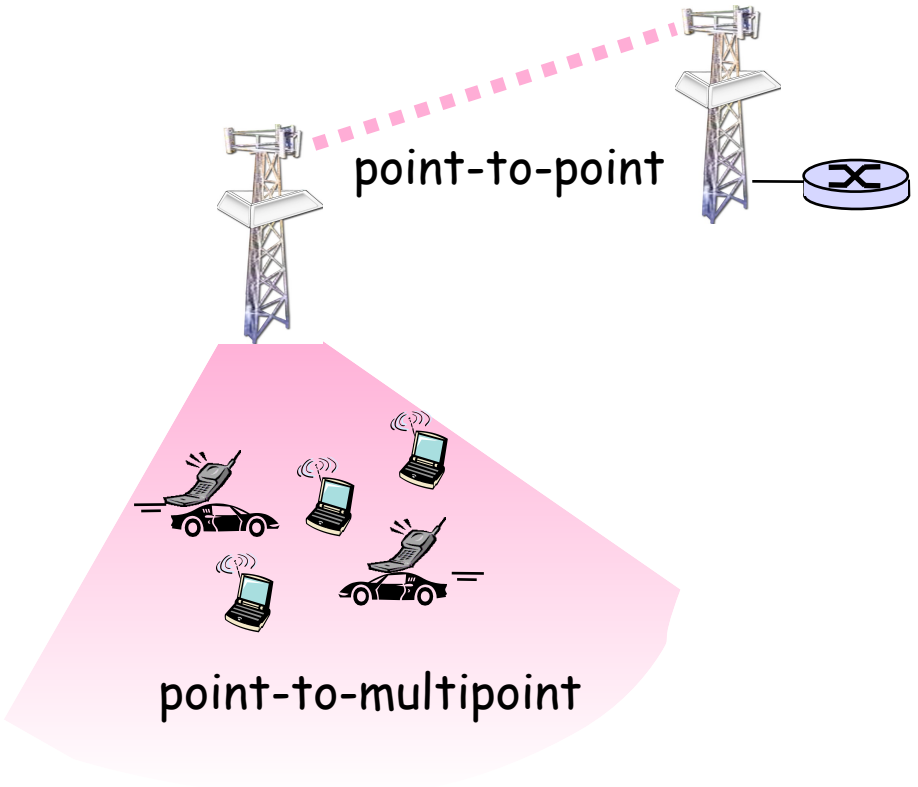
802.15: Personal Area Network

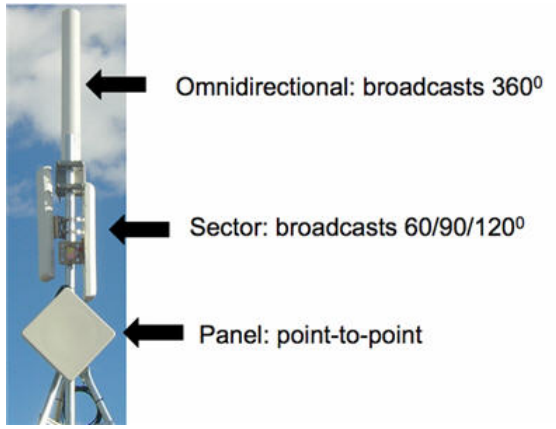
- less than 10 m diameter
- replacement for cables (mouse, keyboard, headphones)
- ad hoc: no infrastructure
- master/slaves:
  - slaves request permission to send (to master)
  - master grants requests
- 802.15: evolved from Bluetooth specification
  - 2.4-2.5 GHz radio band
  - up to 721 kbps



802.16: WiMAX (Worldwide Interop. for Microw. Access)

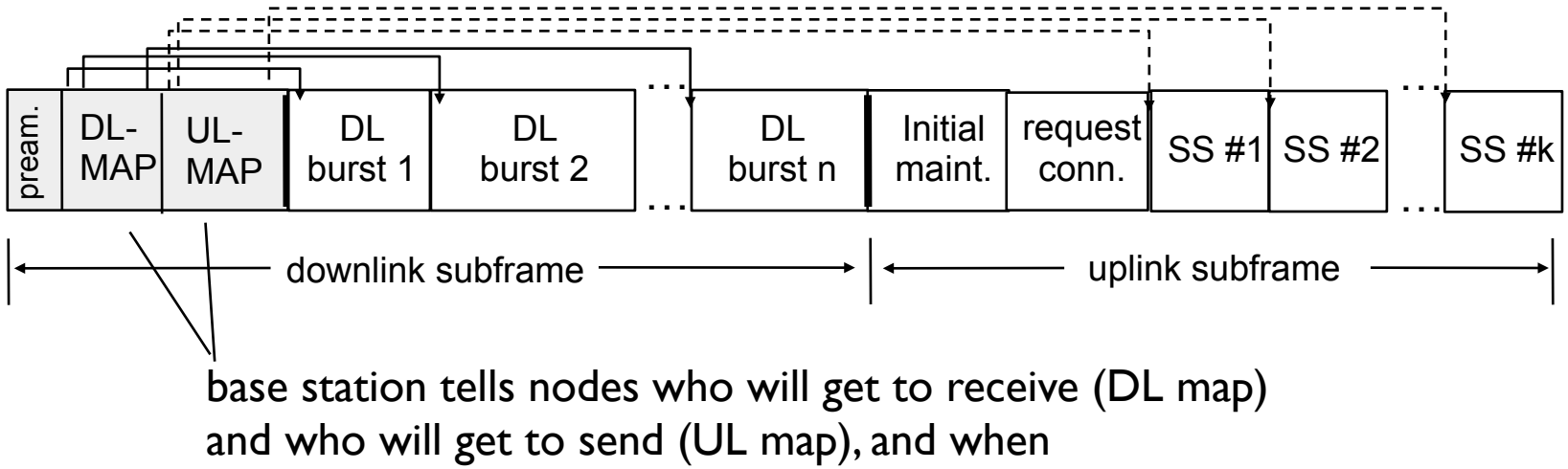
- like 802.11 & cellular: base station model
  - transmissions to/from base station by hosts with omnidirectional antenna
  - base station-to-base station backhaul with point-to-point antenna
- unlike 802.11:
  - range ~ 6 miles ("city rather than coffee shop")
  - ~14 Mbps





802.16: WiMAX: Downlink, Uplink Scheduling

- transmission frame
  - down-link subframe: base station to node
  - uplink subframe: node to base station
- WiMAX standard provides mechanism for scheduling, but not scheduling algorithm



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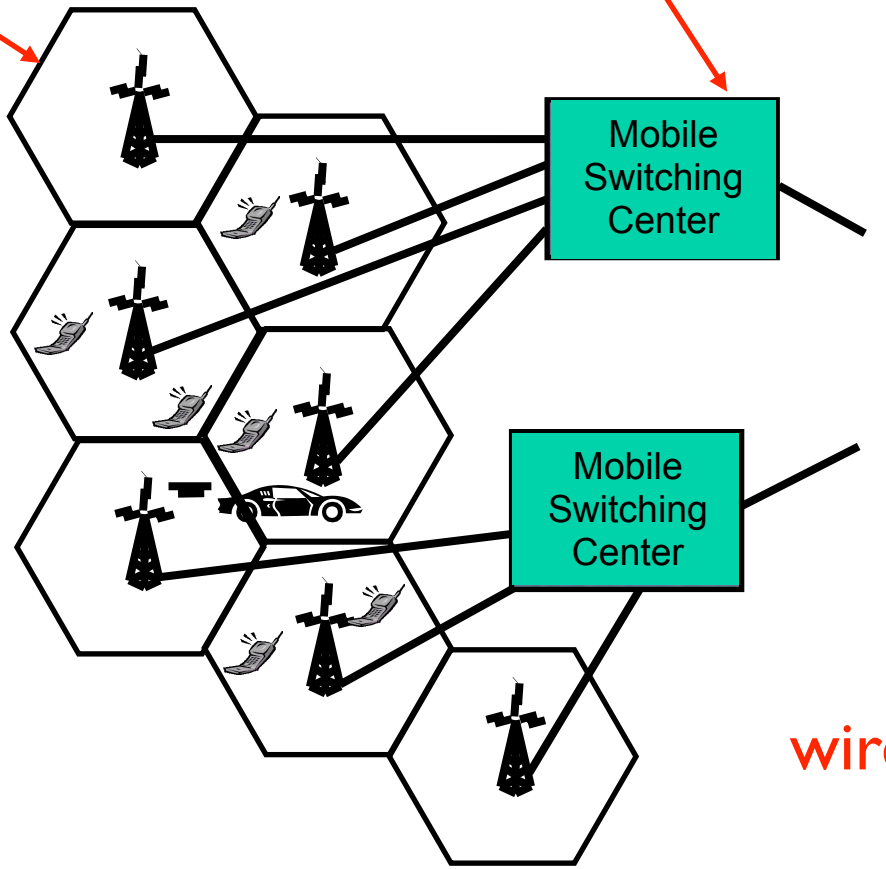
Components of Cellular Network Architecture

MSC
- connects cells to wide area net
- manages call setup (more later!)
- handles mobility (more later!)

cell
- covers geographical region
- base station (BS) analogous to 802.11 AP
- mobile users attach to network through BS
- air-interface: physical and link layer protocol between mobile and BS



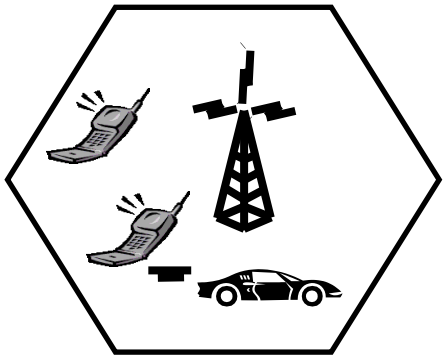
Public telephone network, and Internet

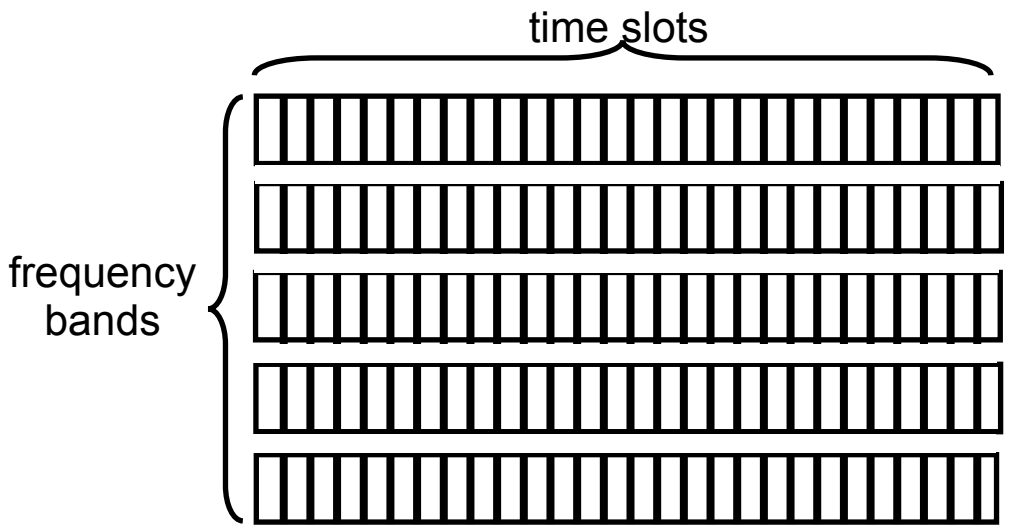
wired network

Cellular networks: the first hop

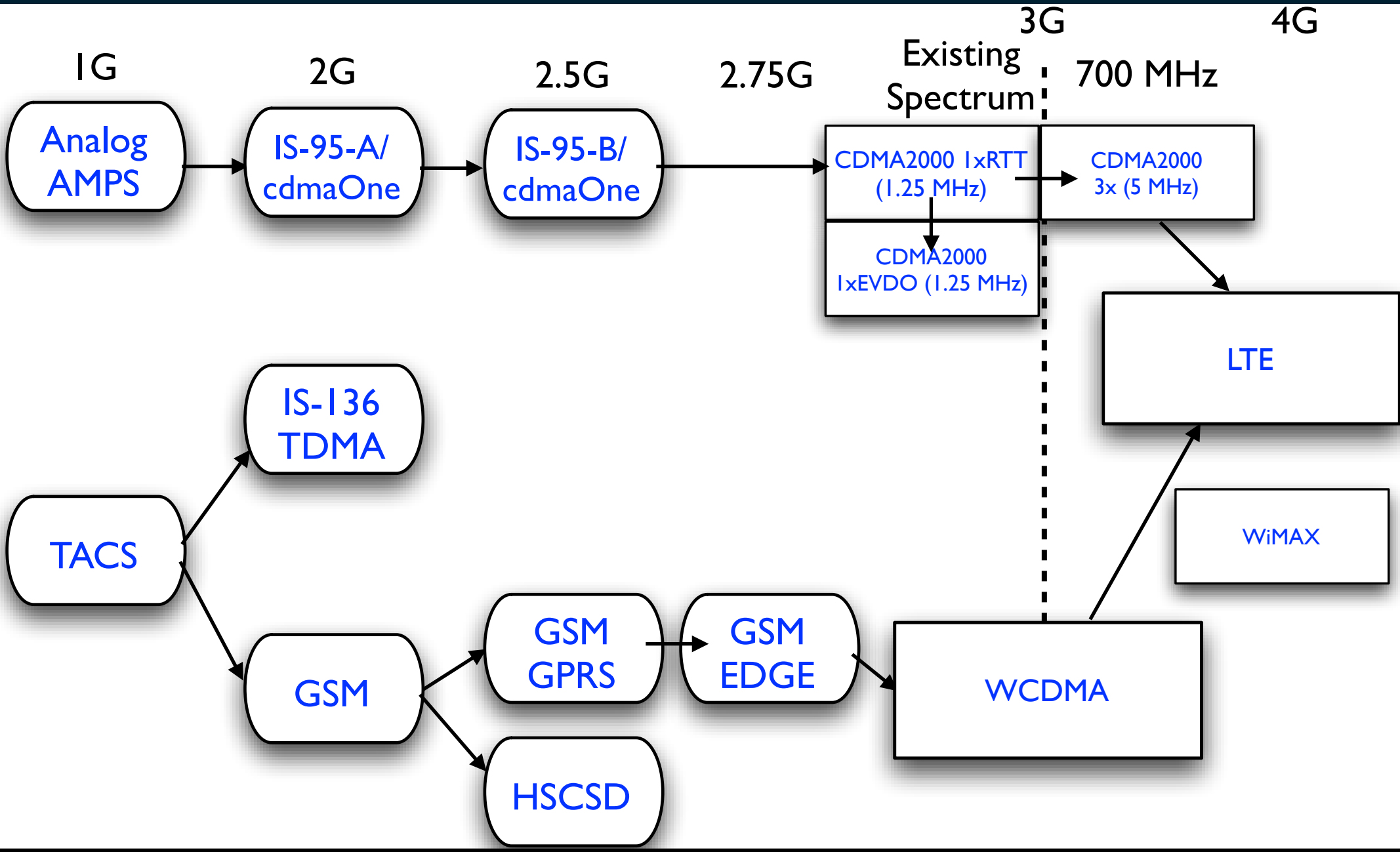
Two techniques for sharing mobile-to-BS radio spectrum

- combined FDMA/TDMA: divide spectrum in frequency channels, divide each channel into time slots
- CDMA: code division multiple access





Wireless Standards Evolution to 4G



Next Time

- Read Sections 6.5-6.8
  - Mobility