

DATA COMMUNICATION NETWORKING

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Course Book: Computer Networking, A Top-Down Approach, Kurose, Ross

Slides:

- Course book Slides
 - Slides from Princeton University COS461 Spring 2012 offering, Jennifer Rexford
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Course Overview

- **Basics of Computer Networks**
 - Internet & Protocol Stack
 - Application Layer
 - Transport Layer
 - Network Layer
 - Data Link Layer
- **Advanced Topics**
 - Case Studies of Computer Networks
 - Internet Applications
 - Network Management
 - Network Security

Wireless Networks



wireless hosts

- Laptop, smartphone
- Run applications
- May be stationary (non-mobile) or mobile
 - Wireless does *not* always mean mobility

network
infrastructure

Wireless Networks



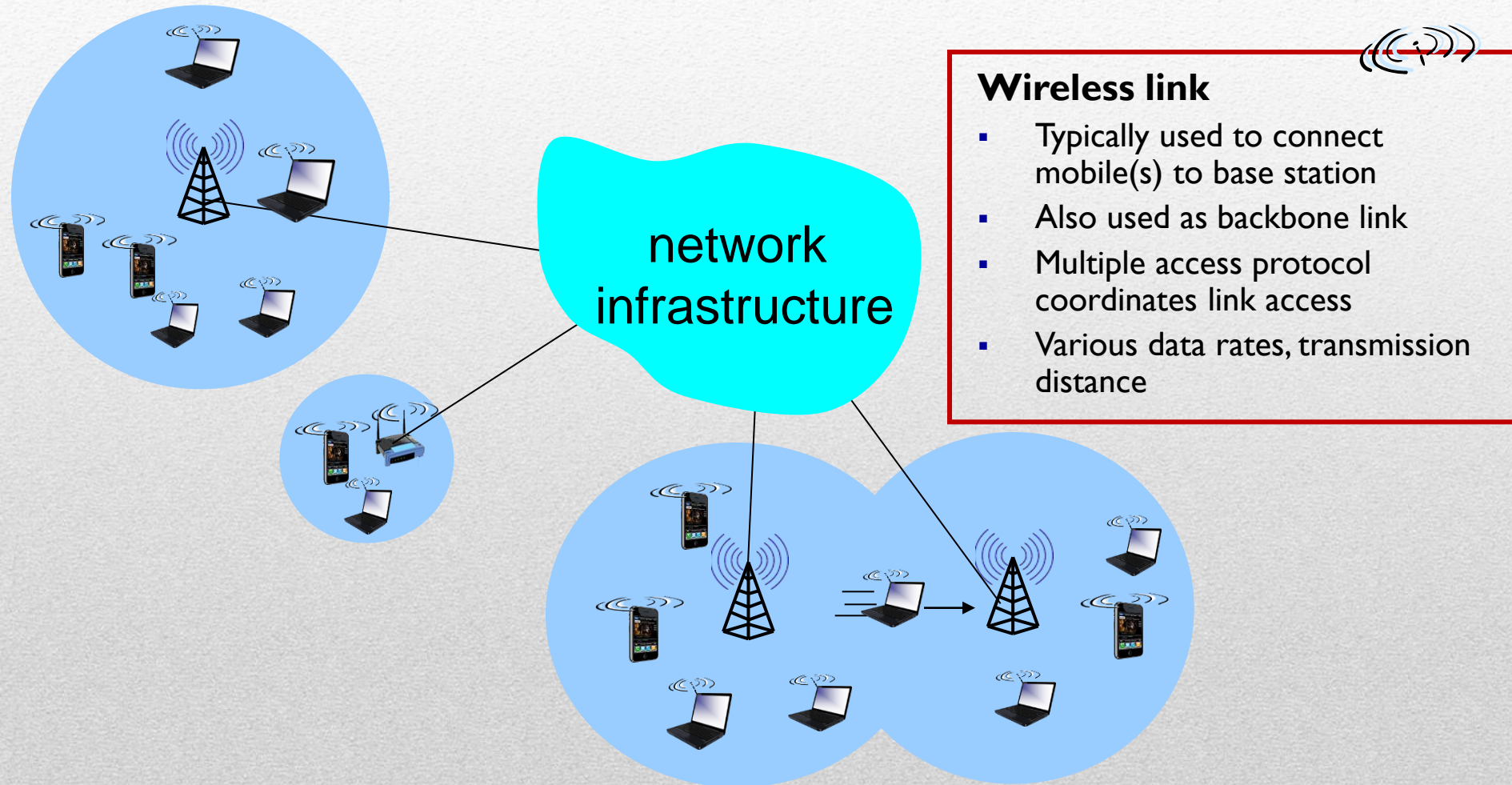
Base station

- Typically connected to wired network
- Relay - responsible for sending packets between wired network and wireless host(s) in its “area”
 - Cell towers
 - 802.11 access points

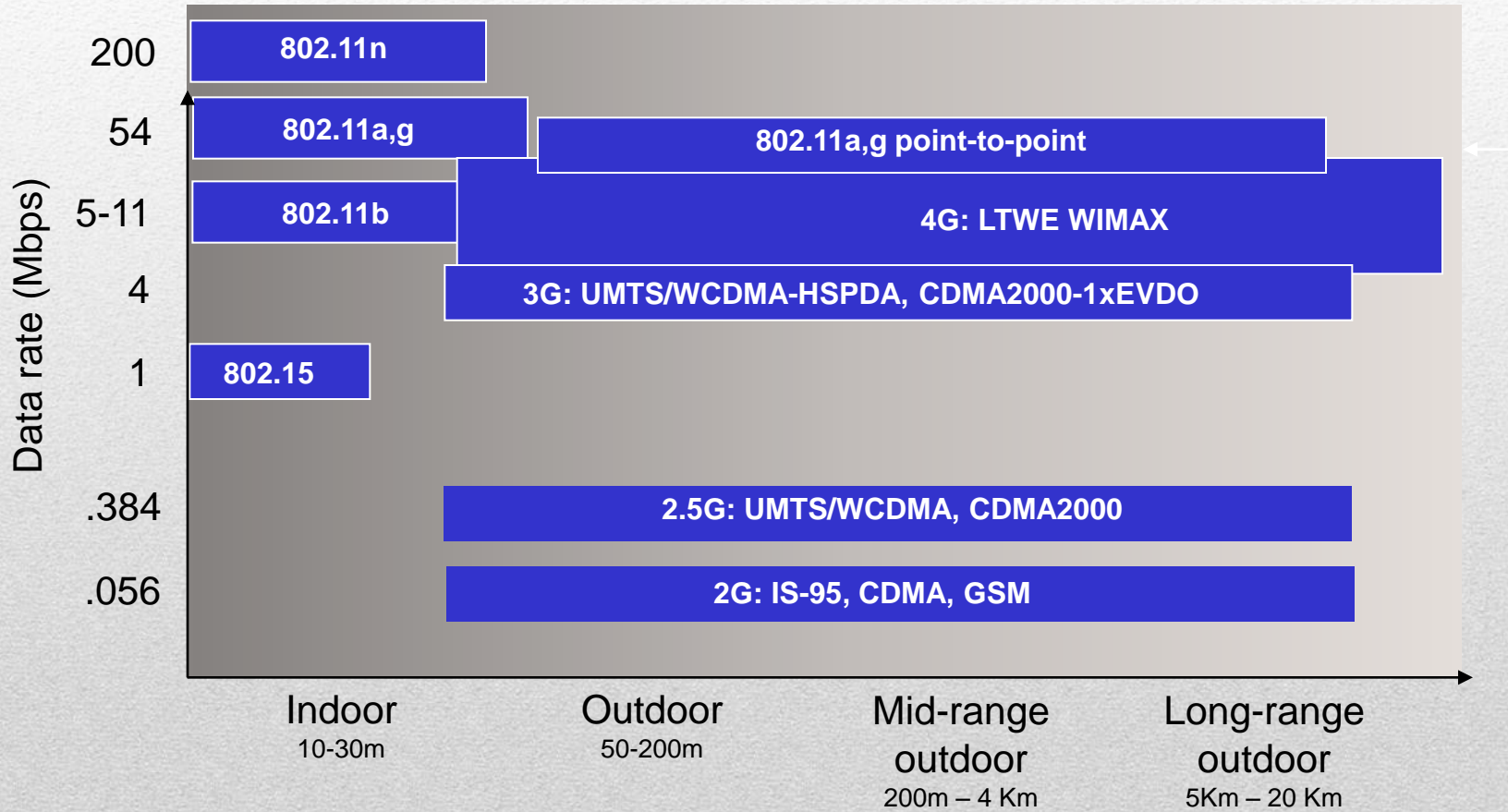
The diagram illustrates a central network infrastructure, represented by a cyan cloud labeled "network infrastructure". This central hub is connected to four distinct network areas, each enclosed in a light blue circle. The top-left circle shows a cell tower connected to several laptops and smartphones. The bottom-left circle shows a wireless router connected to a smartphone and a laptop. The bottom-right circle shows two overlapping cell tower coverage areas, with a laptop moving between them, indicating a handoff. The bottom-center circle shows a single cell tower connected to several smartphones and laptops. Lines connect the central infrastructure cloud to each of these four network areas.

network
infrastructure

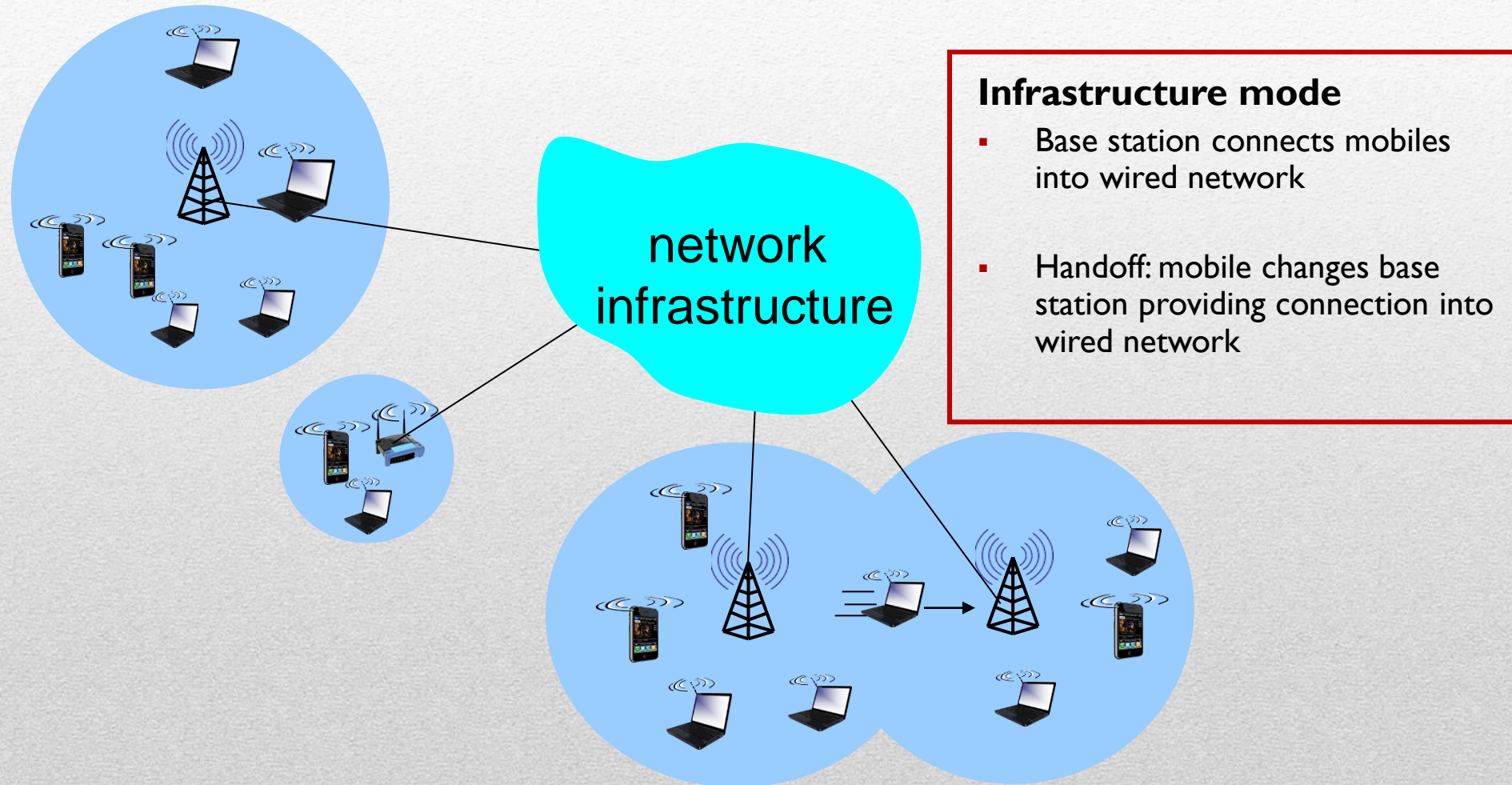
Wireless Networks



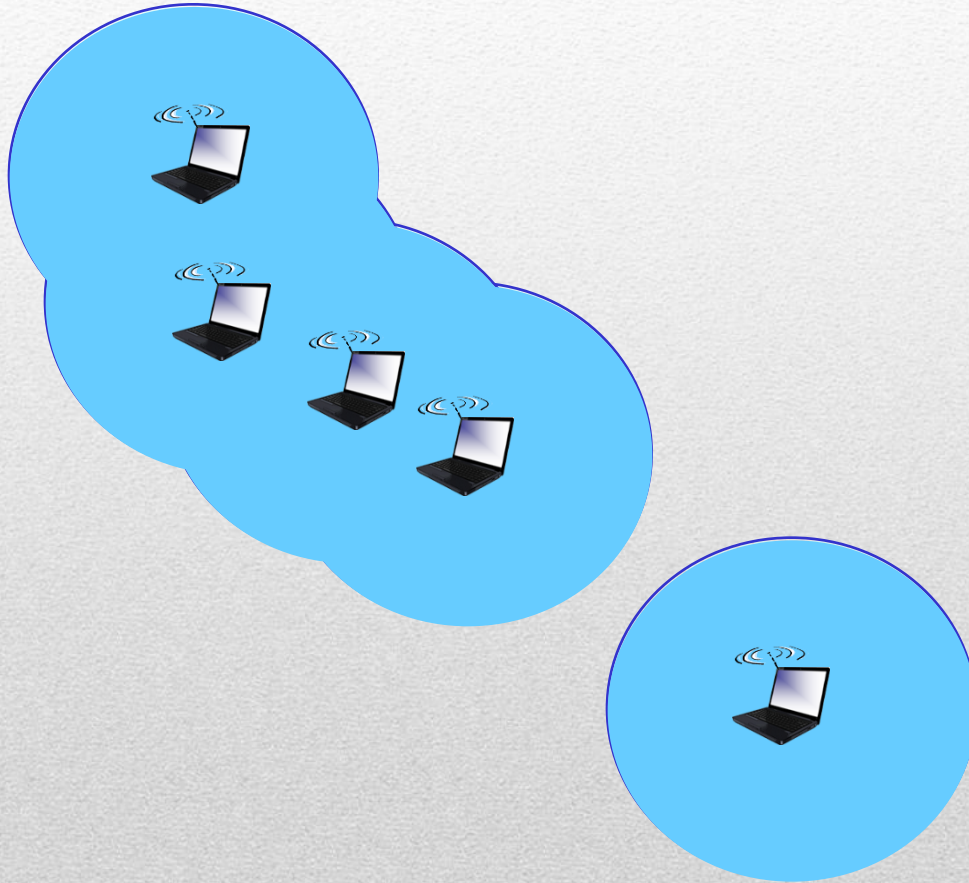
Wireless Links



Wireless Networks



Wireless Networks



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: <i>mesh net</i>
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

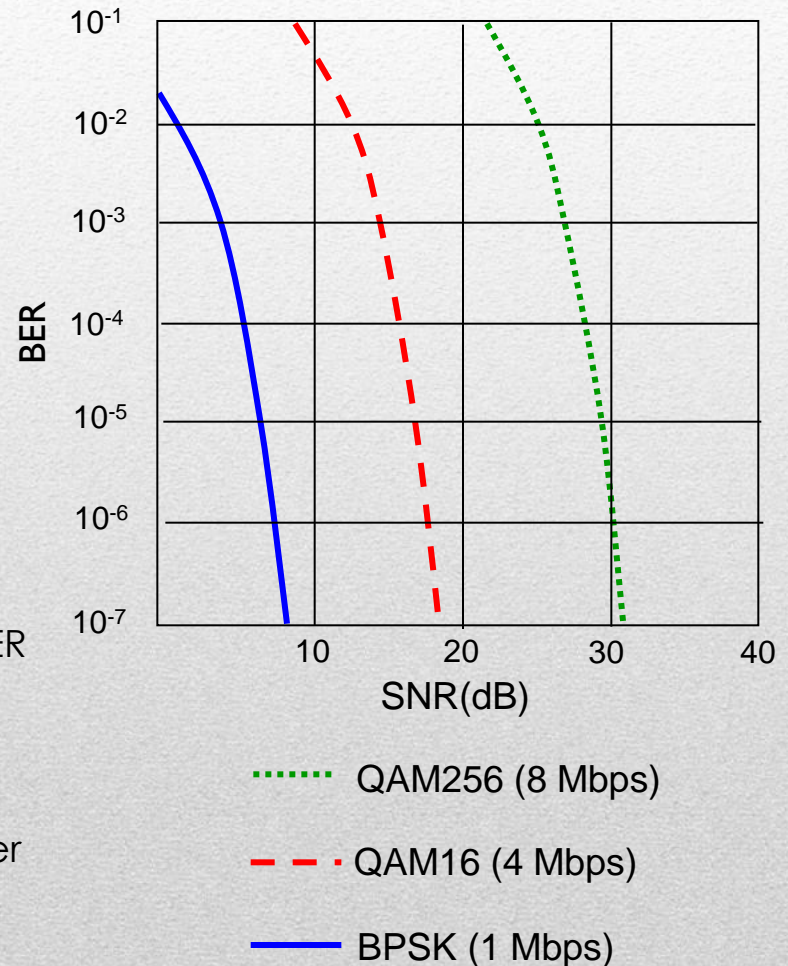
Important differences from wired link

- **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”

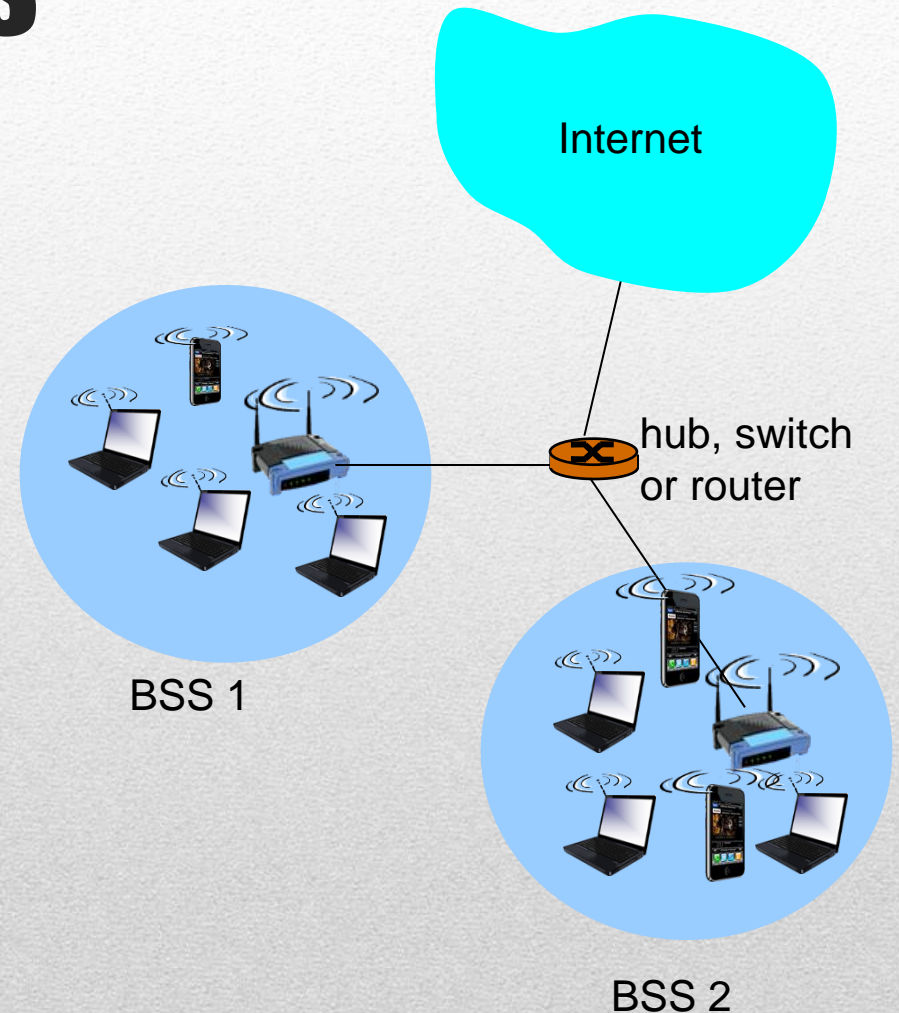
Wireless Link Characteristics

- **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)



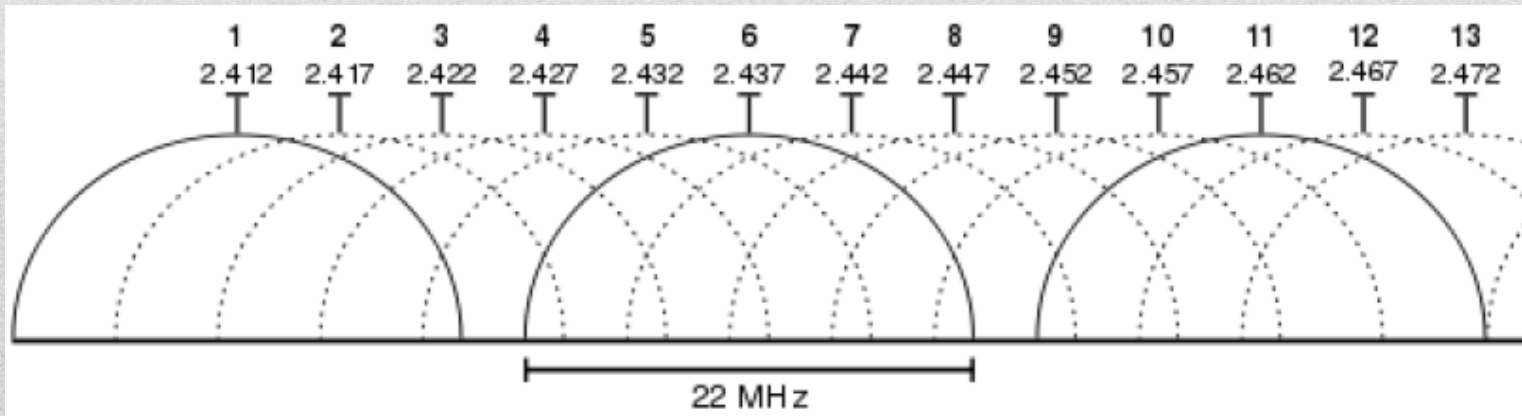
Wireless LANs

- **Wireless host communicates with base station**
 - Base station = access point (AP)
- **Basic Service Set (BSS) in infrastructure mode contains:**
 - Wireless hosts
 - Access point (AP)
 - Base station
- **Ad hoc mode contains:**
 - Hosts only

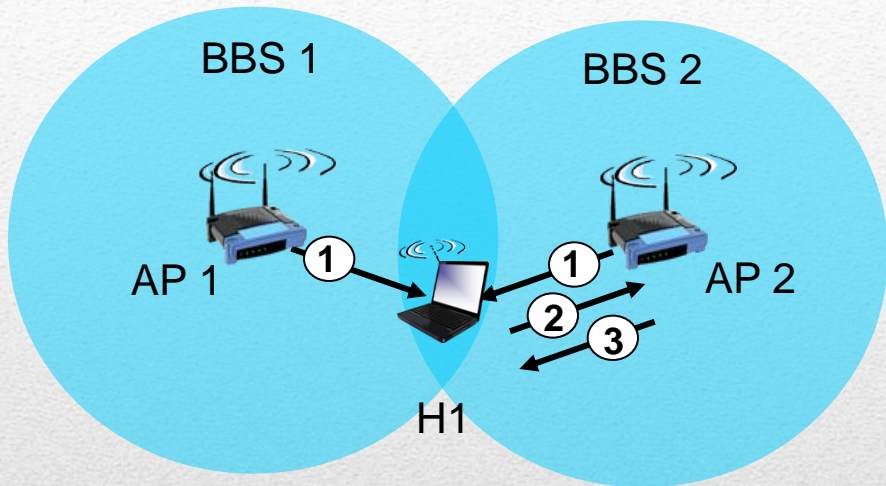


Wireless Link Characteristics

- **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
 - Channels have overlap
 - Network administrator chooses frequency for AP
 - Interference if channel is same as neighboring AP

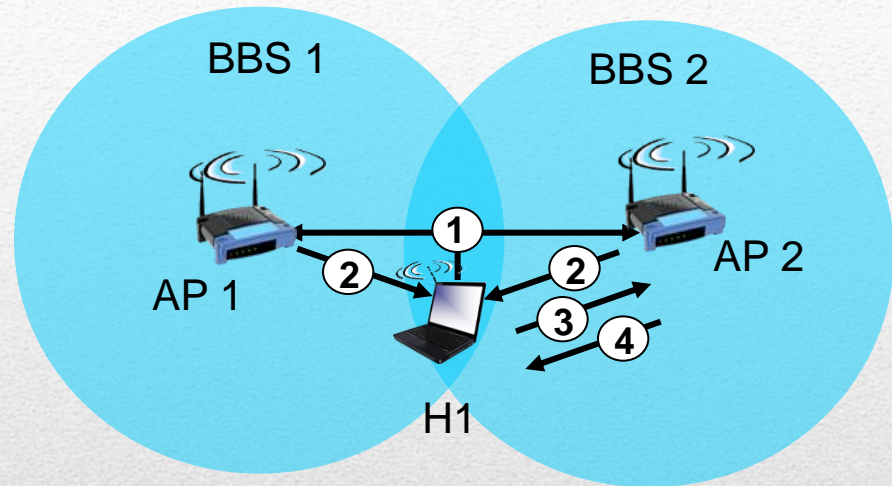


Passive/Active Scanning



Passive scanning

- Beacon frames sent from APs
- Association Request frame sent: H1 to selected AP
- Association Response frame sent from selected AP to H1



Active scanning

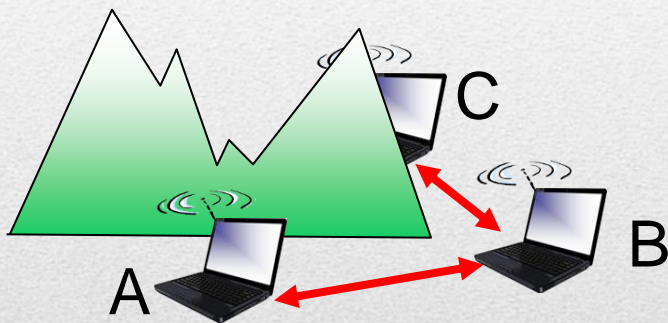
- Probe Request frame broadcast from H1
- Probe Response frames sent from APs
- Association Request frame sent: H1 to selected AP
- Association Response frame sent from selected AP to H1

WLAN Characteristics

- 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/CA

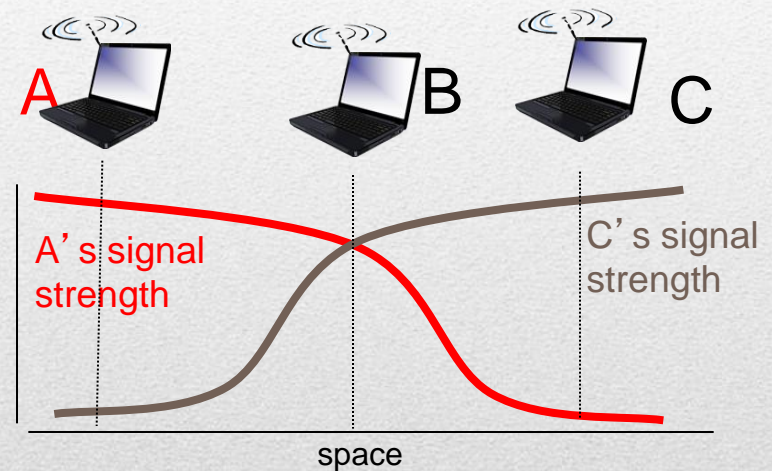
WLAN Characteristics

Multiple wireless senders and receivers create additional problem (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

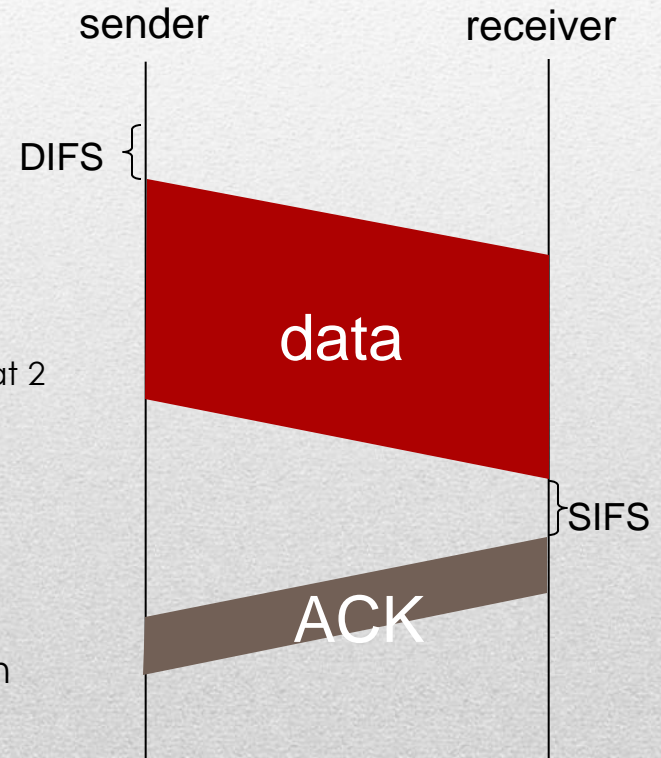
802.11 CSMA/CA

802.11 sender

- One if sense channel idle for **DIFS** then
 - Transmit entire frame (no CD)
- Two 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

- 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!

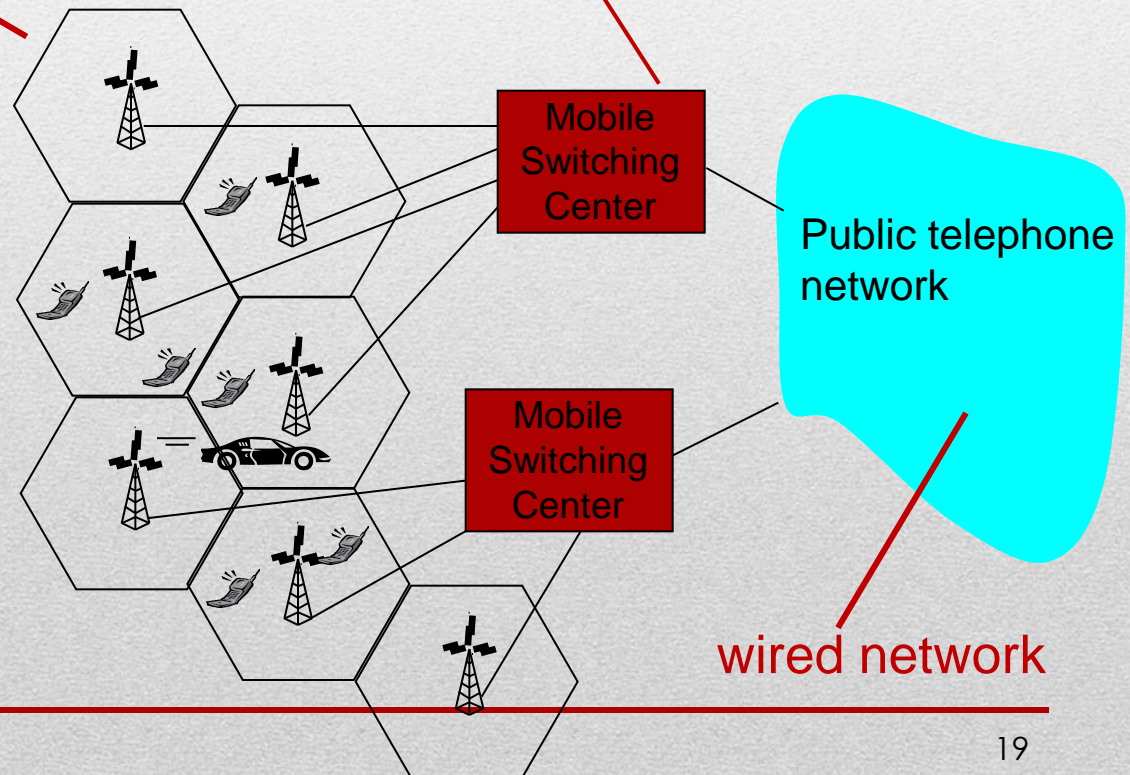
Cellular Networks

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

MSC

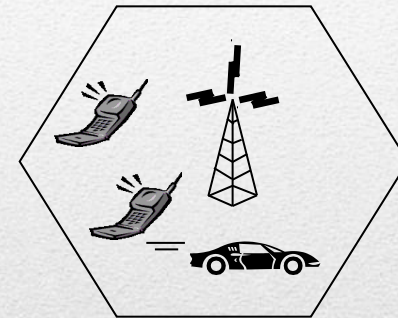
- Connects cells to wired tel. net.
- Manages call setup (more later!)
- Handles mobility (more later!)



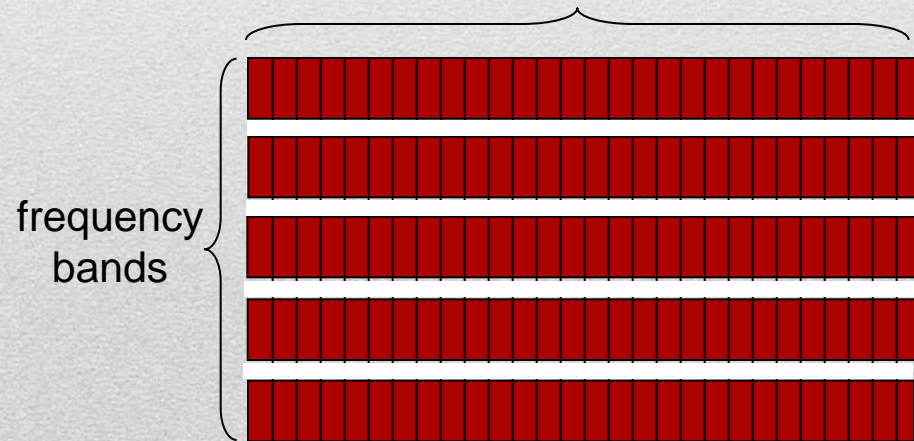
Cellular Networks

Two techniques for sharing mobile-to-BS radio spectrum

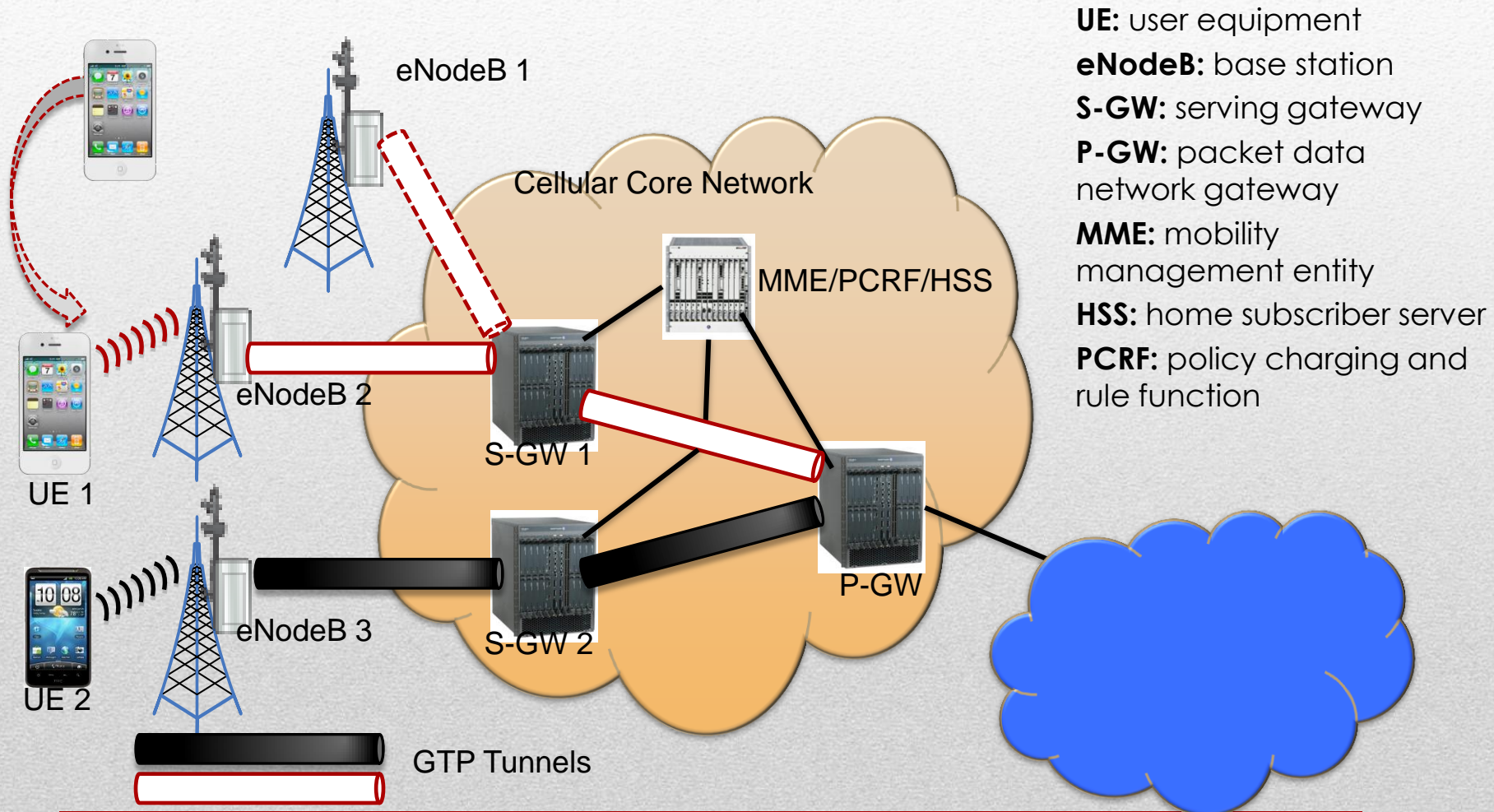
- Combined FDMA/TDMA: divide spectrum in frequency channels, divide each channel into time slots
- CDMA: code division multiple access



time slots



LTE: Long Term Evolution



LTE: Long Term Evolution

