College of Information Studies
University of Maryland Hornbake Library Building College Park, MD 20742-4345

WiFi

Session 17

INST 346

Technologies, Infrastructure and Architecture

L3 Results

Q6 Results

- 16 of 26 earned full credit
- 1: CRC works well in terrestrial point to point links, where retransmission is easy; FEC might be better for high-delay links (e.g., satellite) [also better for low signal strength settings]
- 2: Dijkstra's algorithm would not scale to Internet (flood routing, n log n computation time)

Muddiest Points
(from Point-to-Point)

- Ethernet
- Radio links
- Parity checking
- Error correction

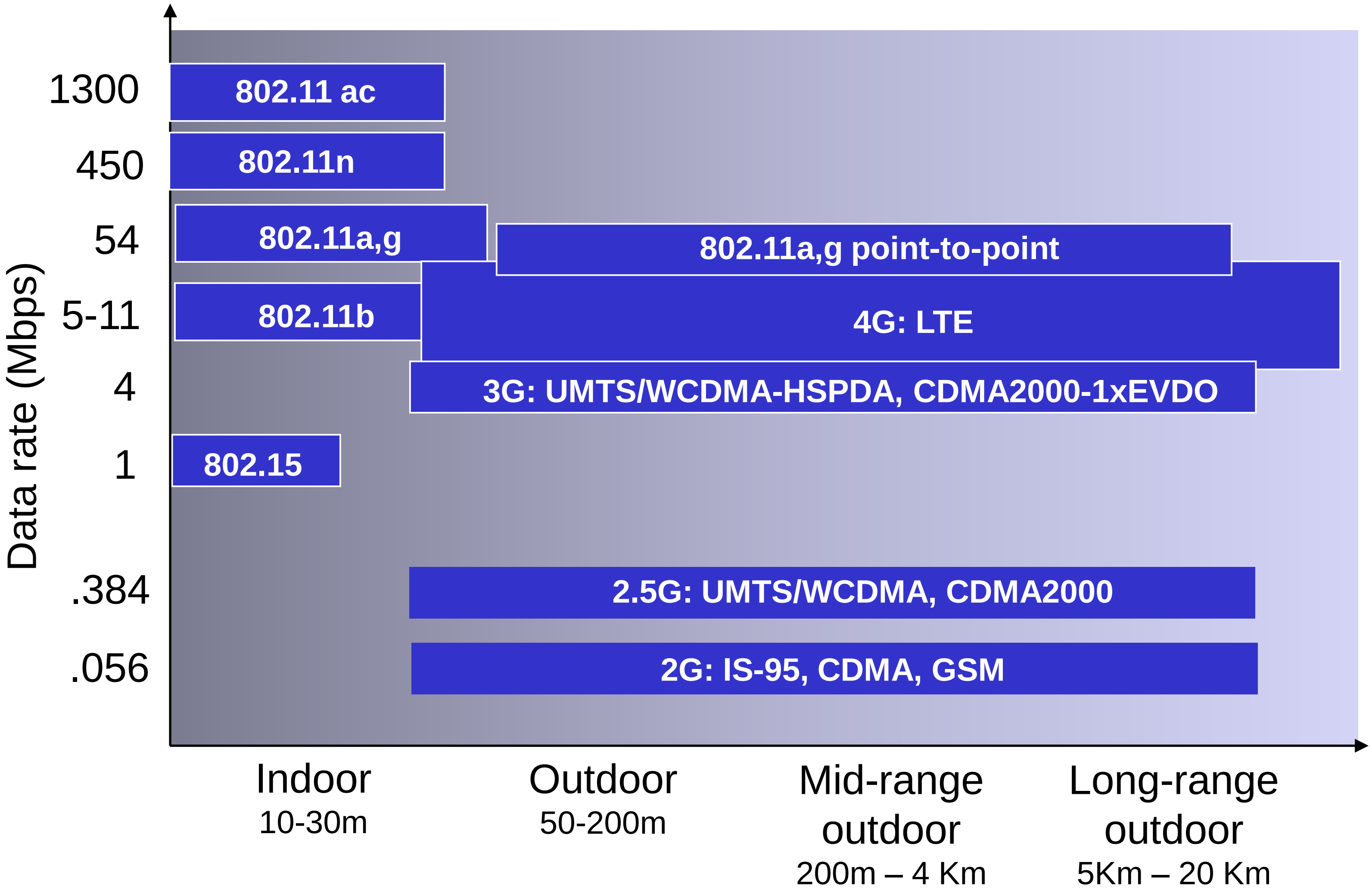
Goals for Today

- WiFi
- Getahead: Cellular networks
- L4 preview

Wireless Networks

- # wireless Internet-connected devices equals # wireline Internet-connected devices
  - laptops, tablets, phones, IOT
- two important (but different) challenges
  - *Wireless (all week):* communication over wireless link
  - *Mobility (Thursday):* handling the mobile user who changes point of attachment to network

Characteristics of selected wireless links



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 infrastructure and ad-hoc network versions

Wireless Link Characteristics (1)

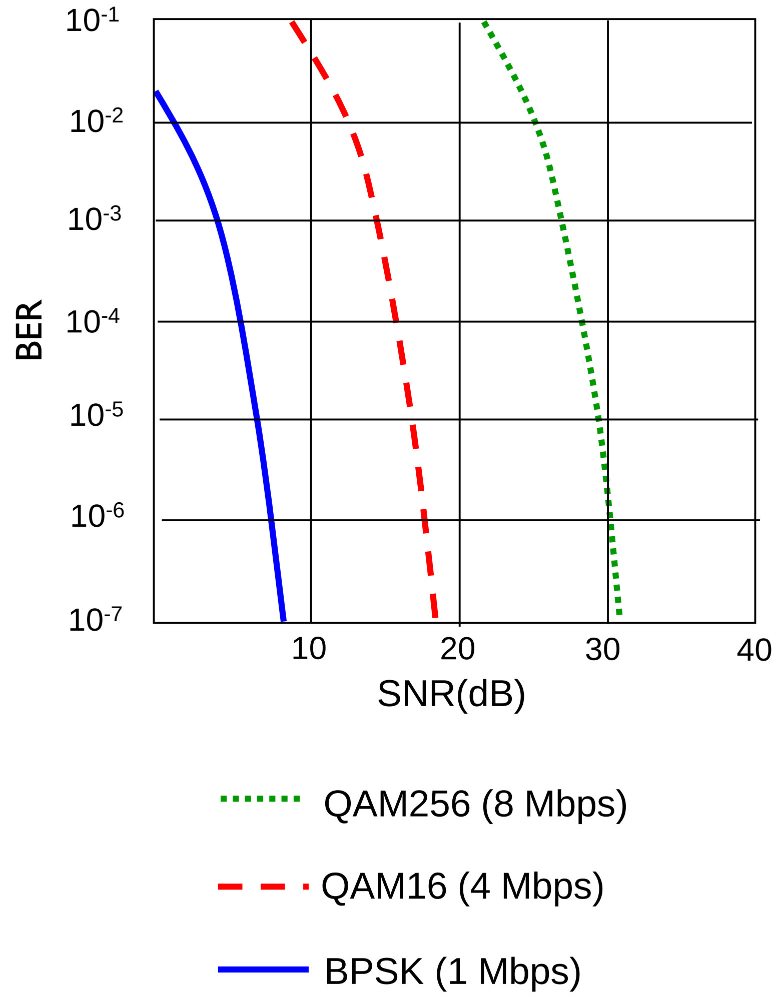
important differences from wired link ….

- *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 ad destination at slightly different times

…. make communication across (even a point to point) wireless link much more difficult

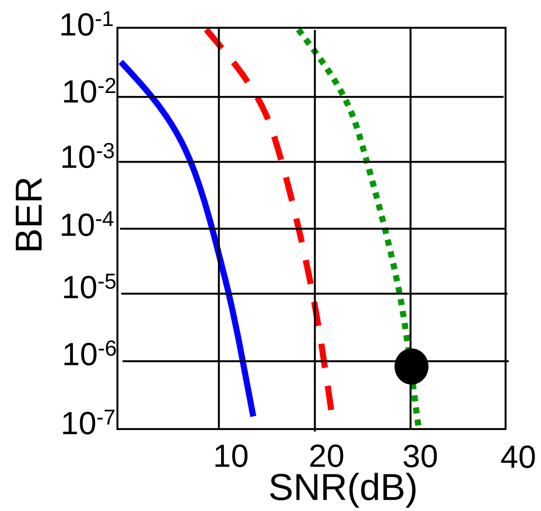
Wireless Link Characteristics (2)

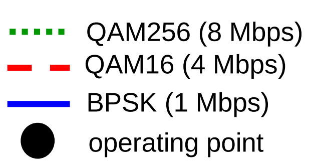
- SNR: signal-to-noise ratio
  - larger SNR – easier to extract signal from noise (a "good thing")
- *SNR versus Bit Error Rate tradeoff*
  - *given a physical layer:*
    - increase power -> increase SNR
    - Increase SNR -> decrease BER
  - *given the actual SNR:*
    - choose the physical layer with the highest throughput that meets the Bit Error Rate target
- SNR may change with mobility
  - dynamically adapt physical layer (modulation technique, data rate)



Adaptive Rate Selection

- base station, mobile dynamically change transmission rate (physical layer modulation technique) as mobile host moves

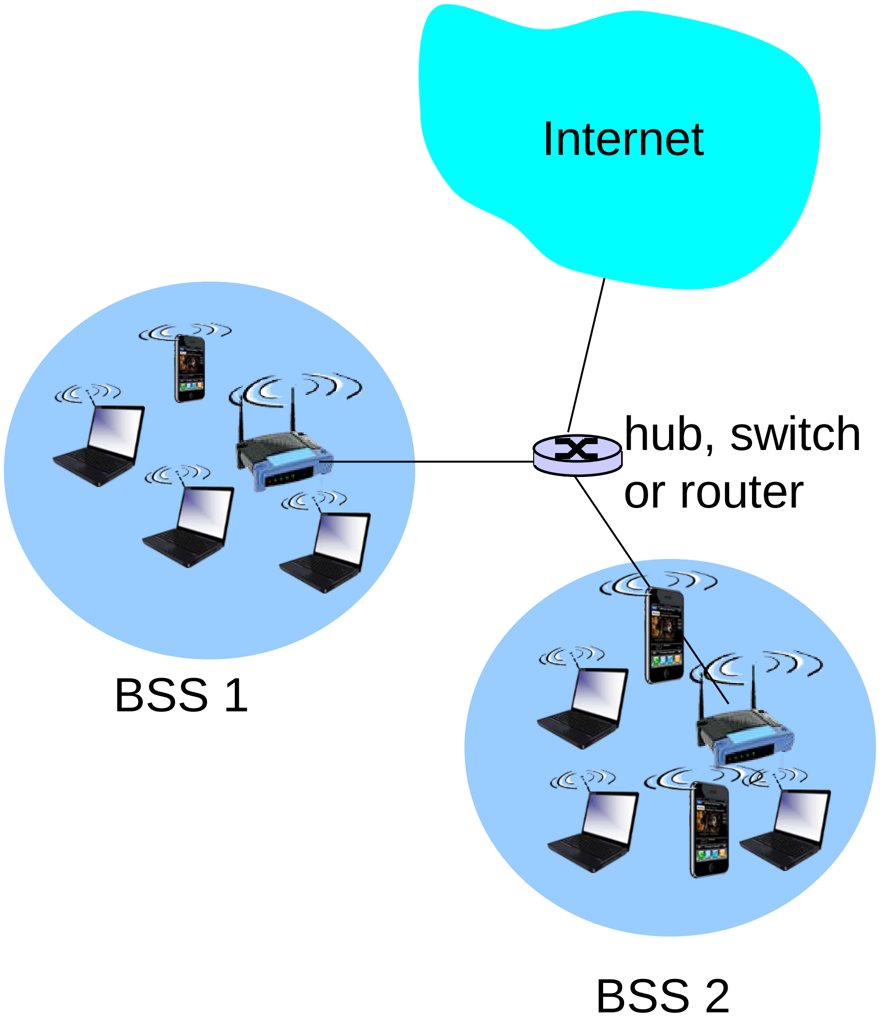




1. SNR decreases, BER increases as host moves away from base station

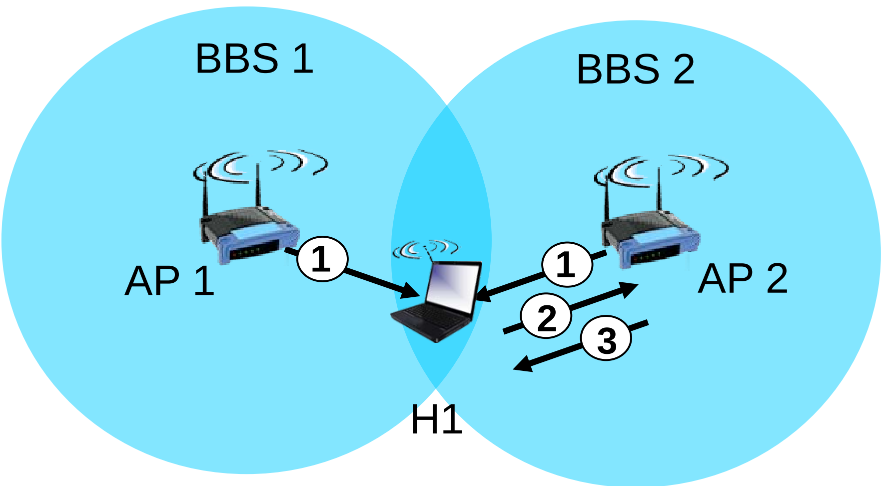
2. When BER becomes too high, switch to lower transmission rate but with lower BER

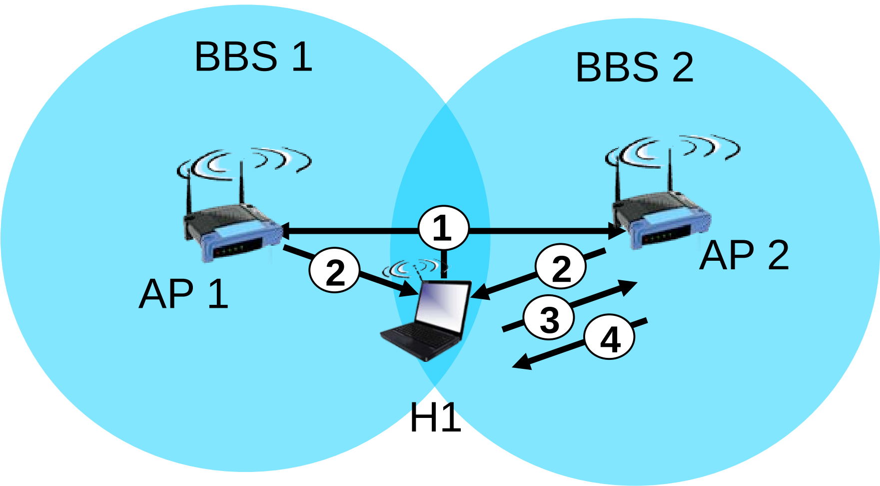
802.11 LAN architecture



- wireless host communicates with base station ("Access Point" (AP))
- Basic Service Set (BSS) in infrastructure mode contains:
  - wireless hosts
  - access point

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

802.11: Channels, association

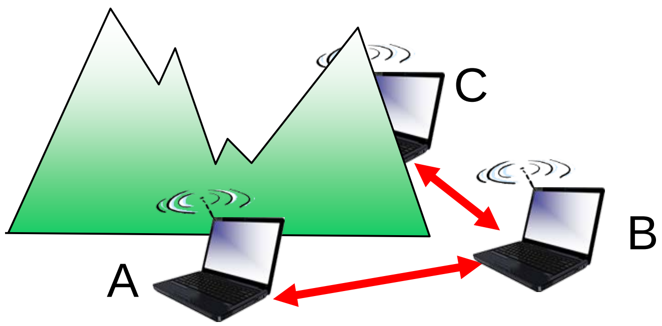
- 802.11b: 2.4GHz-2.485GHz spectrum divided into 11 channels at different frequencies
  - AP admin chooses frequency for AP
  - interference possible: channel can be same as that chosen by neighboring AP!
- host: must *associate* with an AP
  - scans channels, listening for *beacon frames* containing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

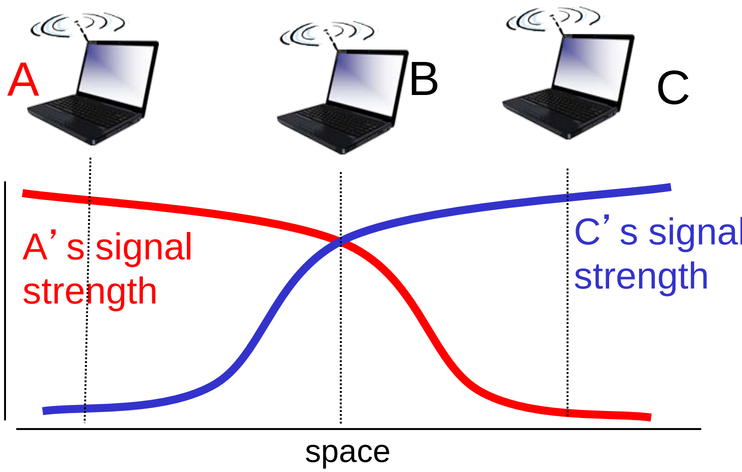
IEEE 802.11: multiple access

- avoid collisions: 2^+ nodes transmitting at same time
- CSMA - sense before transmitting
  - don't collide with ongoing transmission by other node
  - May not sense some senders: "hidden terminal problem"
- *no* collision detection!
  - difficult to receive (sense collisions) when transmitting due to weak received signals (fading)
  - goal: *avoid collisions:* CSMA/CA (Collision Avoidance)

The Hidden Terminal Problem

Multiple **wireless** senders and receivers create additional problems"





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

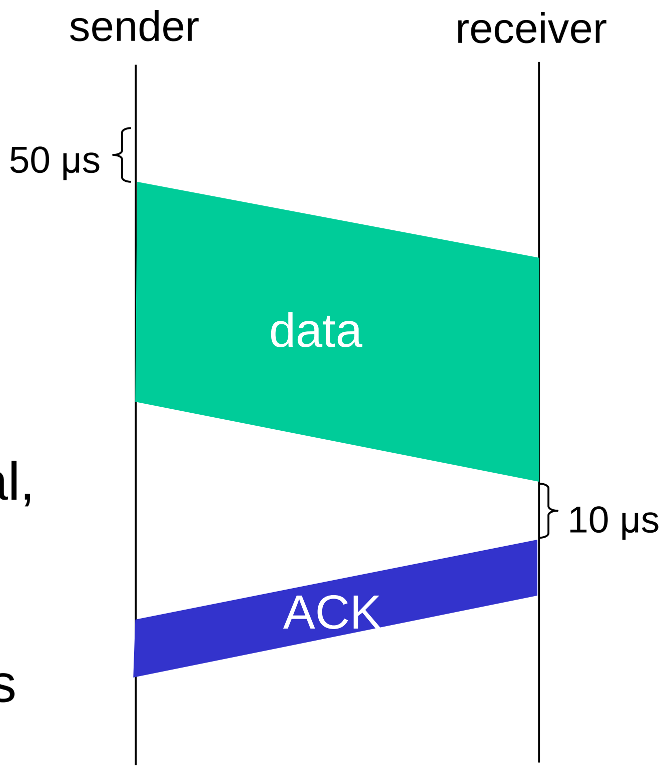
IEEE 802.11 MAC Protocol: CSMA/CA

802.11 sender

- if channel idle for 50 μs Distributed Coordination Function (DCF) Inter-Frame Space (DIFS) then
  - transmit entire frame
- if 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

802.11 receiver

- if frame received OK, return ACK after 10 μs "Short Inter-Frame Space" (SIFS)
  - ACK is needed due to hidden terminal problem



DIFS and SIFS delays are for 802.11b

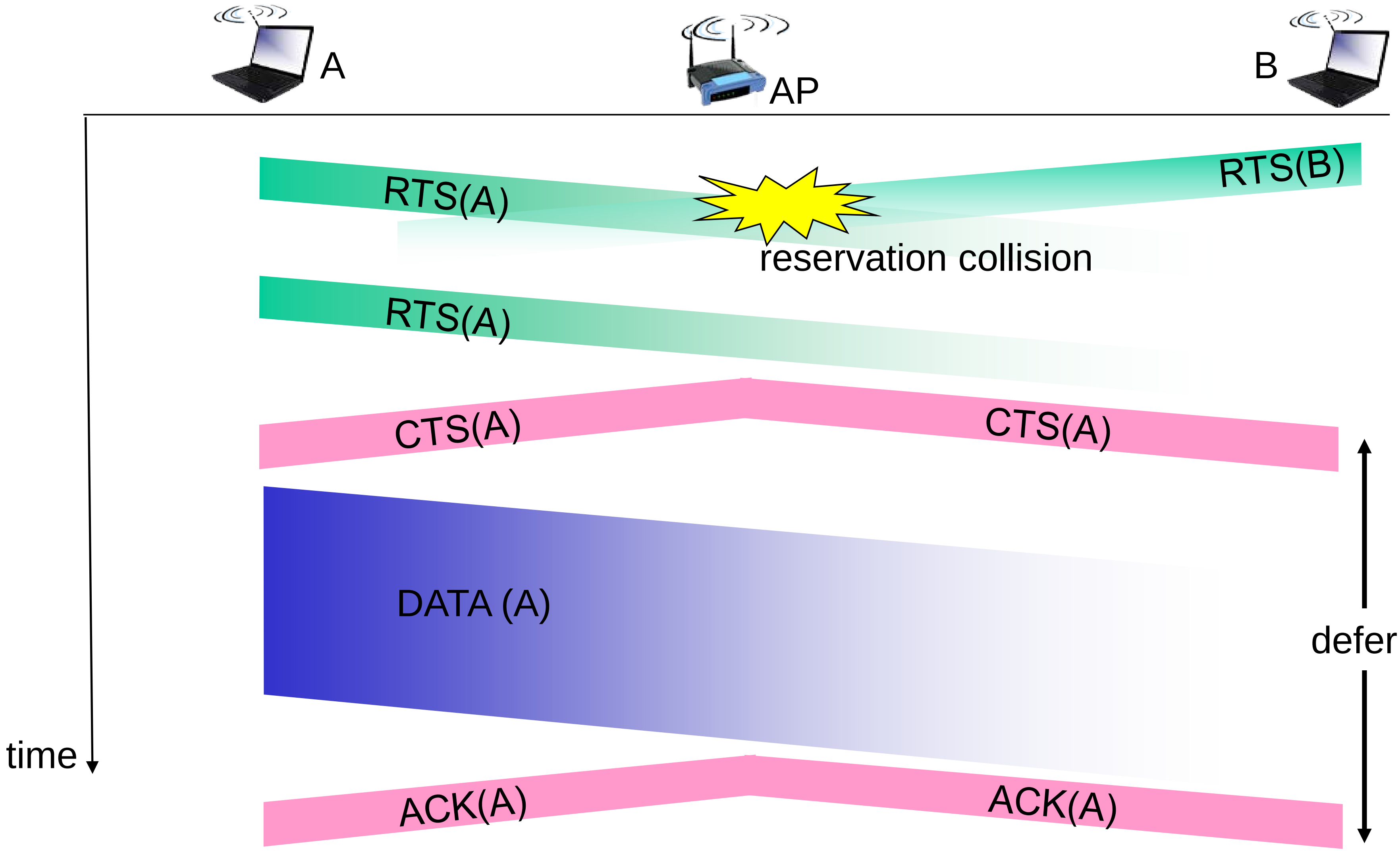
Channel Reservations

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

RTS fits inside DIFS, but CTS costs time
Only worth it for long packets with frequent collisions

Collision Avoidance: RTS-CTS exchange



802.11 frame: addressing

frame control	duration	address 1	address 2	address 3	seq control	address 4	payload	CRC
2	2	6	6	6	2	6	0 - 2312	4

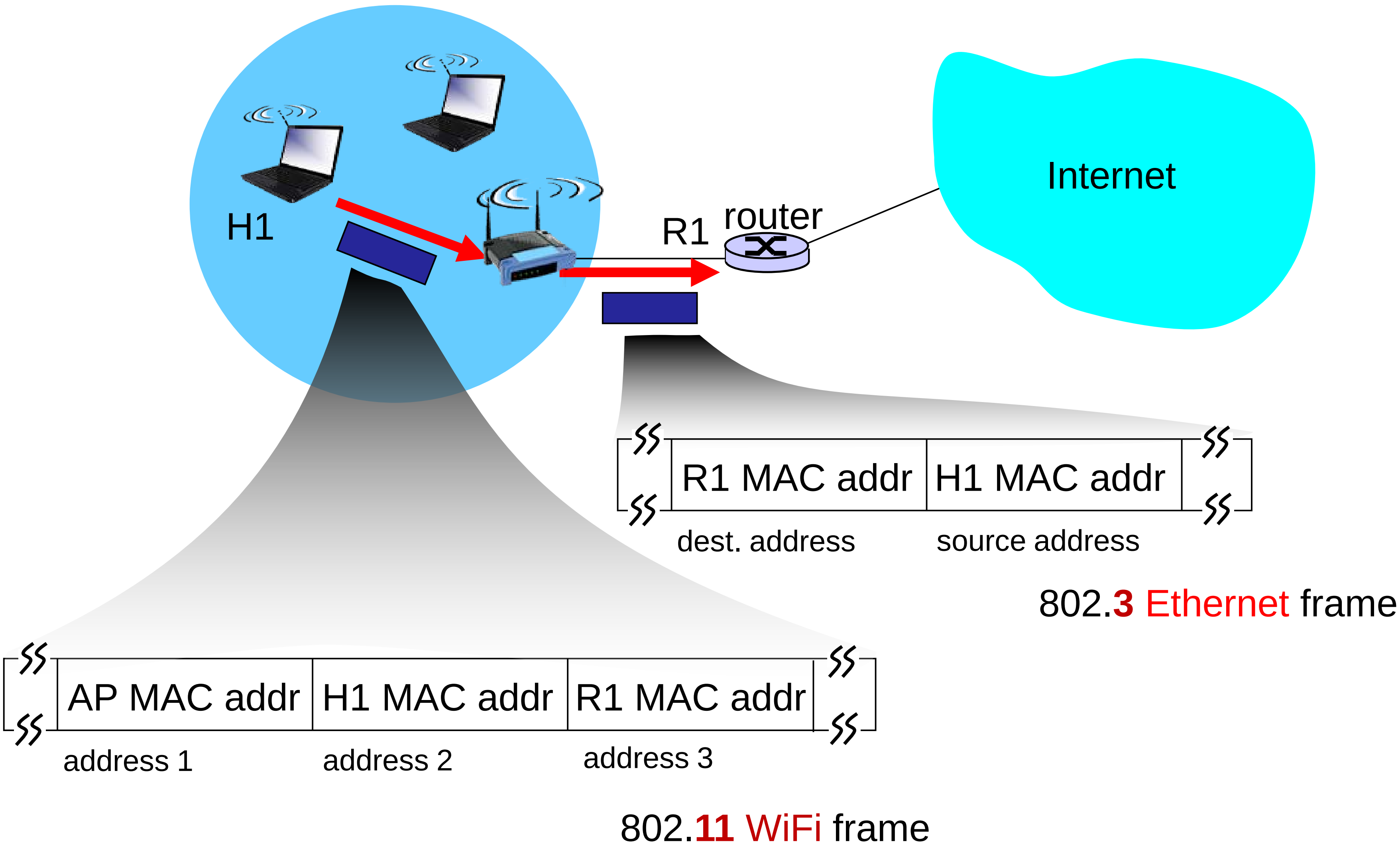
Address 1: MAC address of wireless host or AP to receive this frame

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

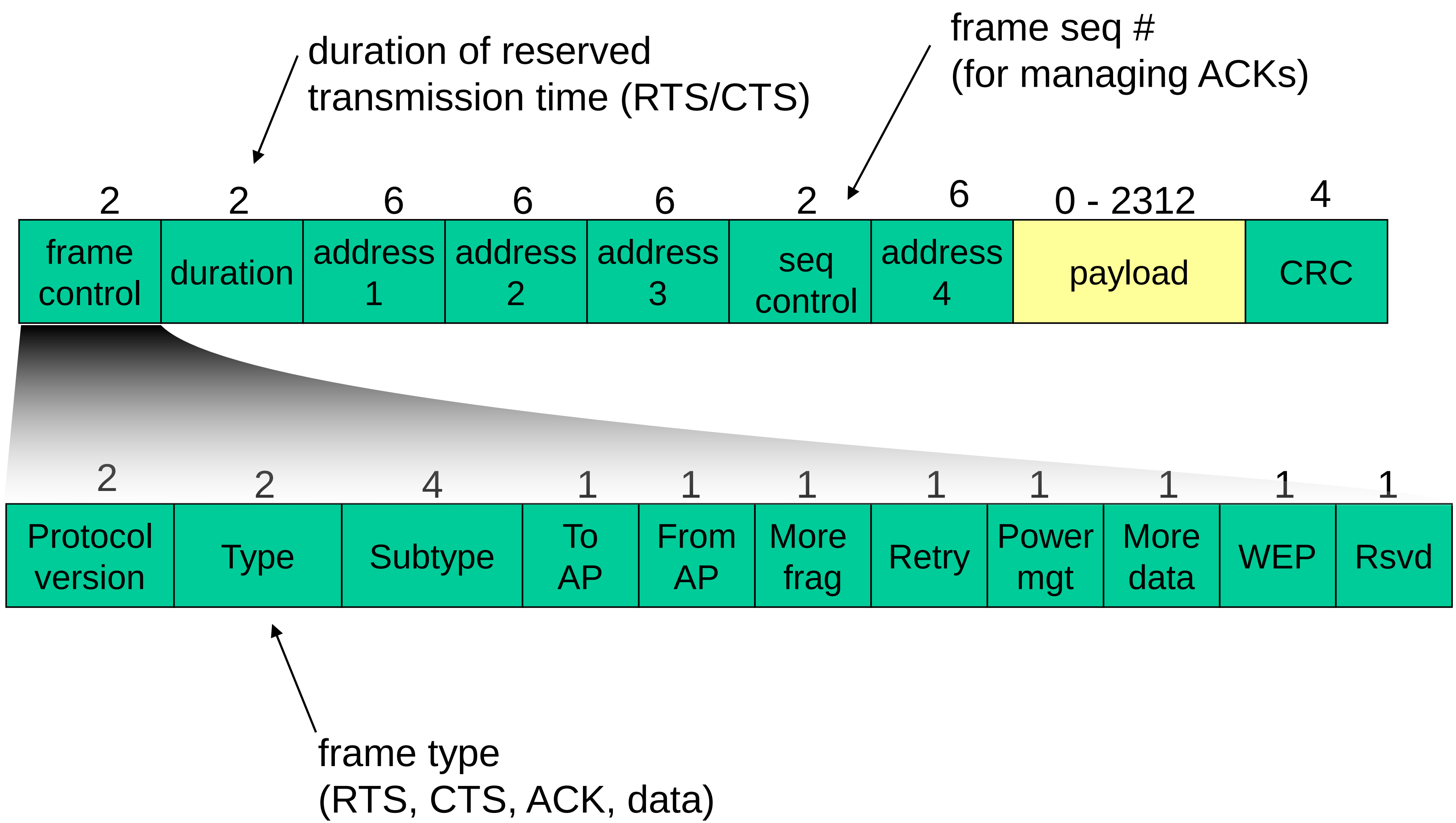
Address 3: MAC address of router interface to which AP is attached

Address 4: used only in ad hoc mode

802.11 frame: addressing

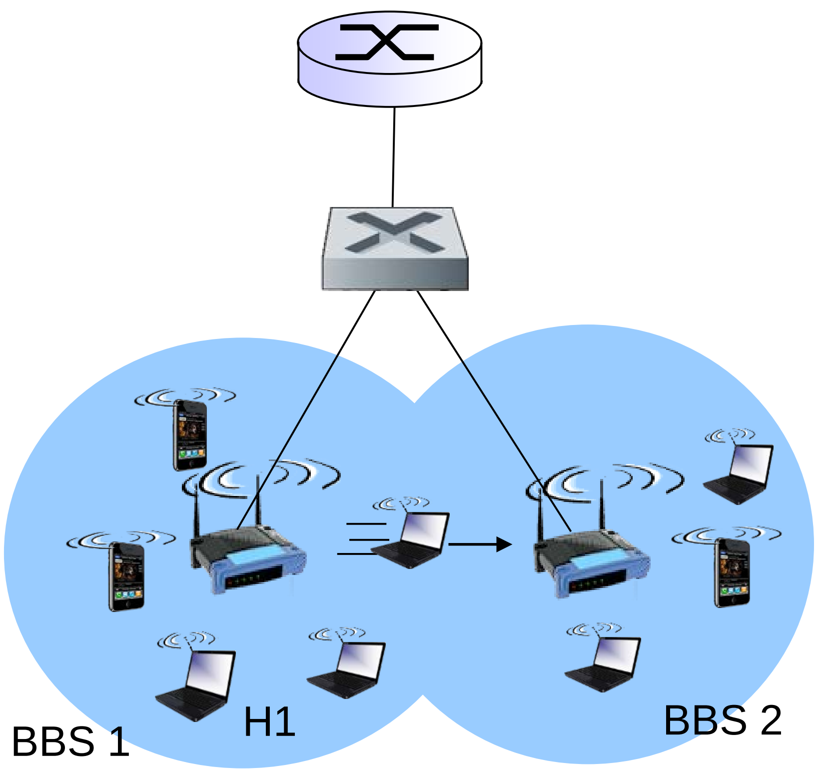


802.11 frame: more



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: switch will see the first frame from H1 through the new AP and "remember" which switch port can be used to reach H1



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

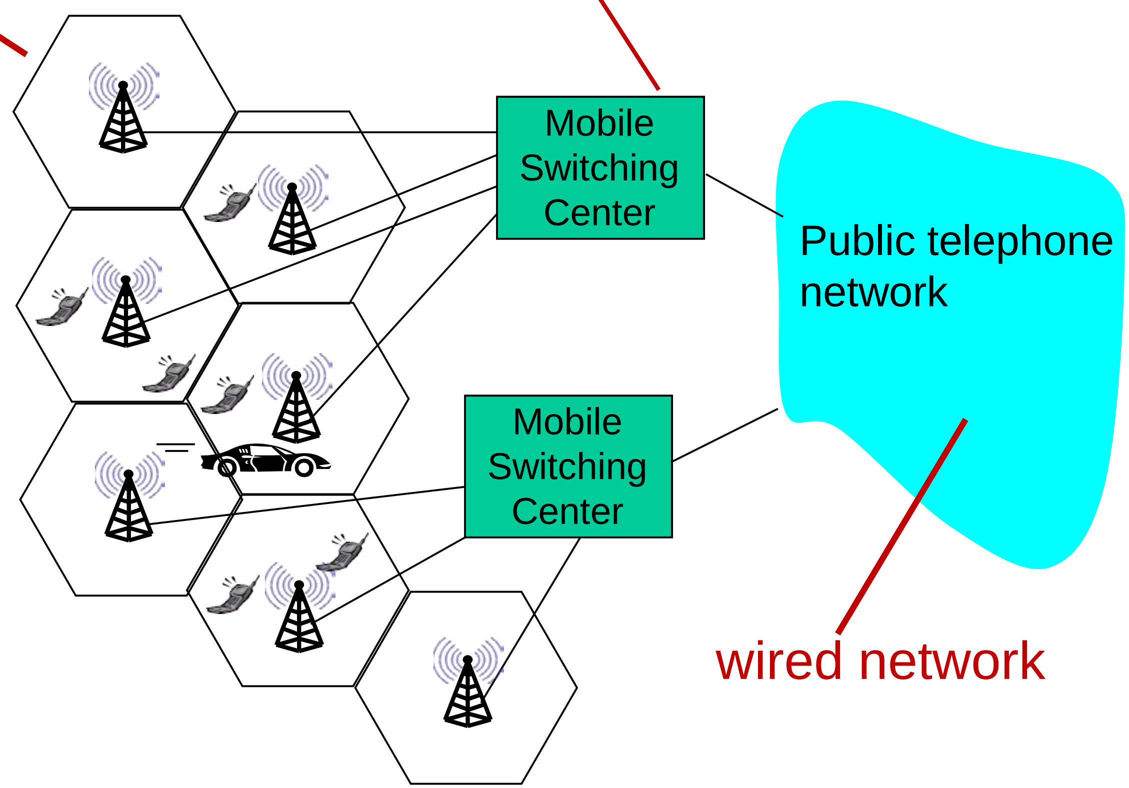
Wireless network taxonomy

	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)	

Components of cellular network architecture

MSC
- connects cells to wired tel. net.
- manages call setup (more later!)
- handles mobility (more later!)

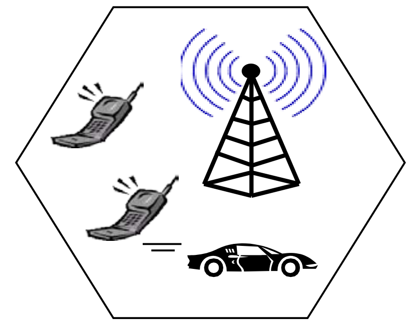
cell
- covers geographical region
- *base station* (BS) analogous to 802.11 AP
- *mobile users* attach to network through BS
- *air-interface:* physical and link layer protocol between mobile and BS

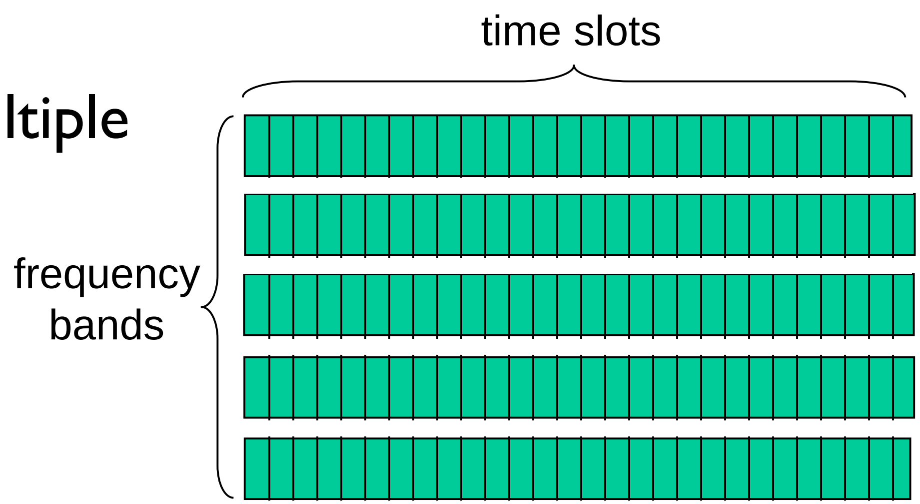


Cellular networks: the first hop

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

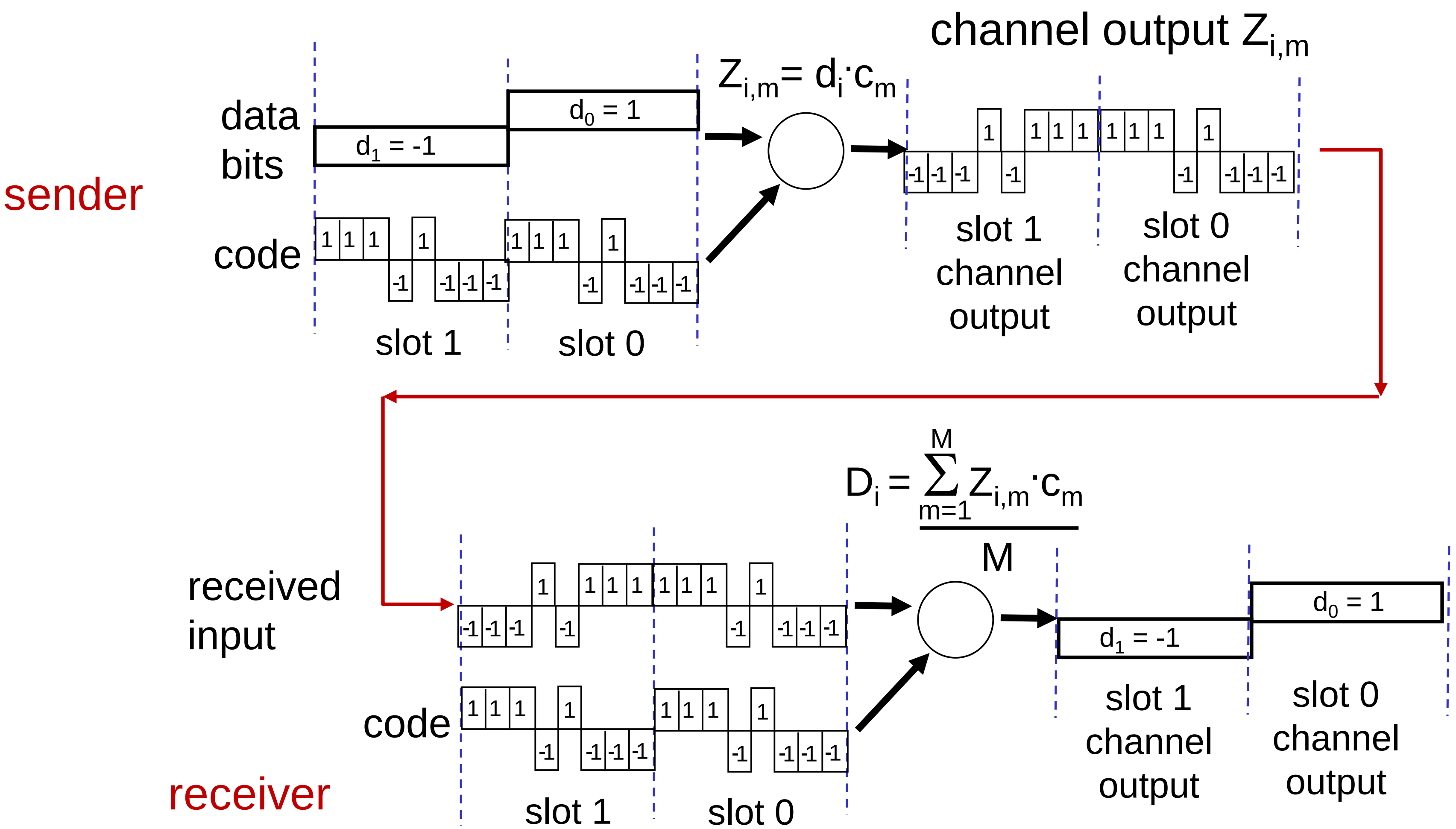




Code Division Multiple Access (CDMA)

- 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
  - allows multiple users to "coexist" and transmit simultaneously with minimal interference (if codes are "orthogonal")
- *encoded signal* = (original data) X (chipping sequence)
- *decoding:* inner-product of encoded signal and chipping sequence

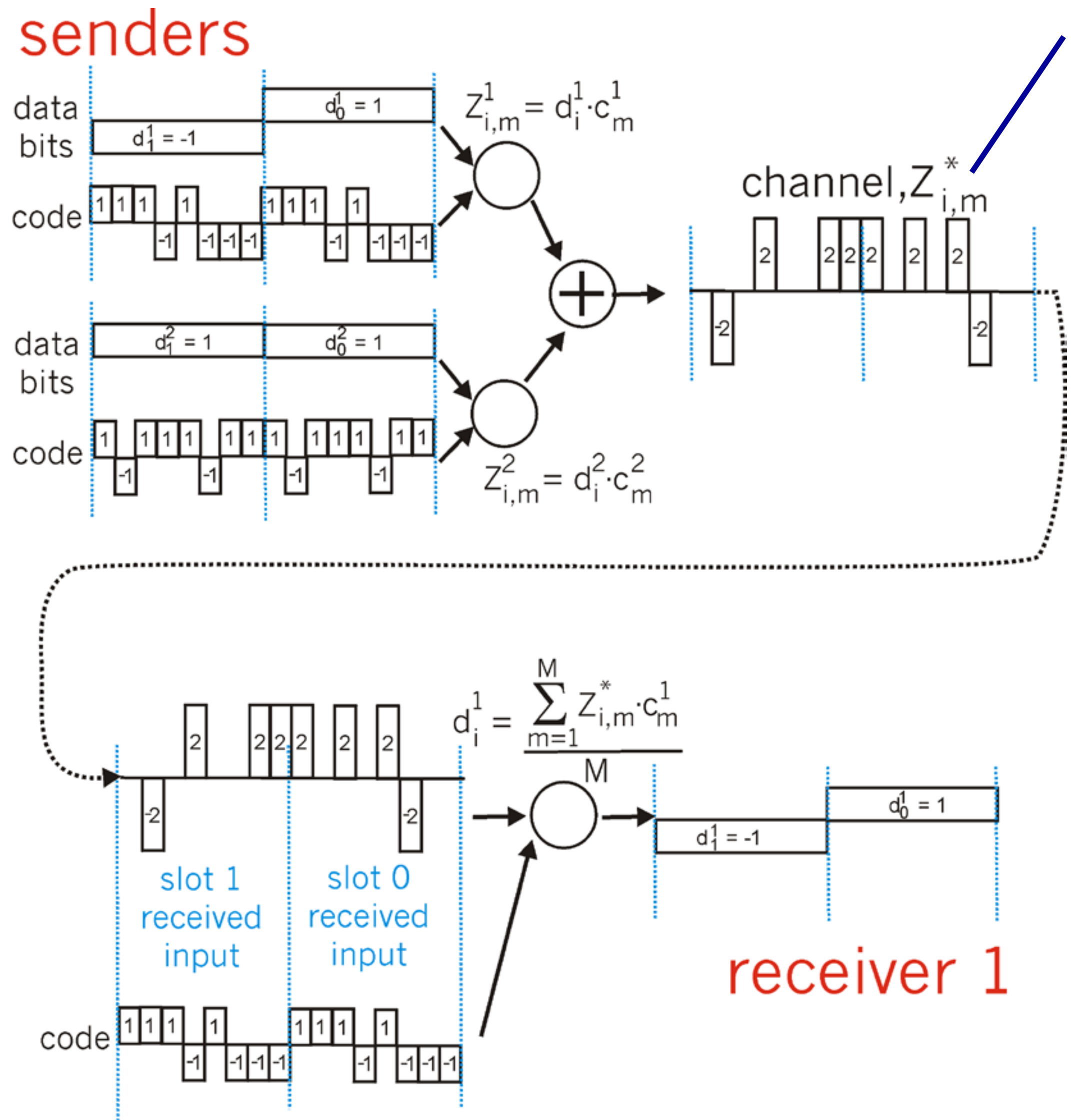
CDMA encode/decode



CDMA: two-sender interference

Sender 1

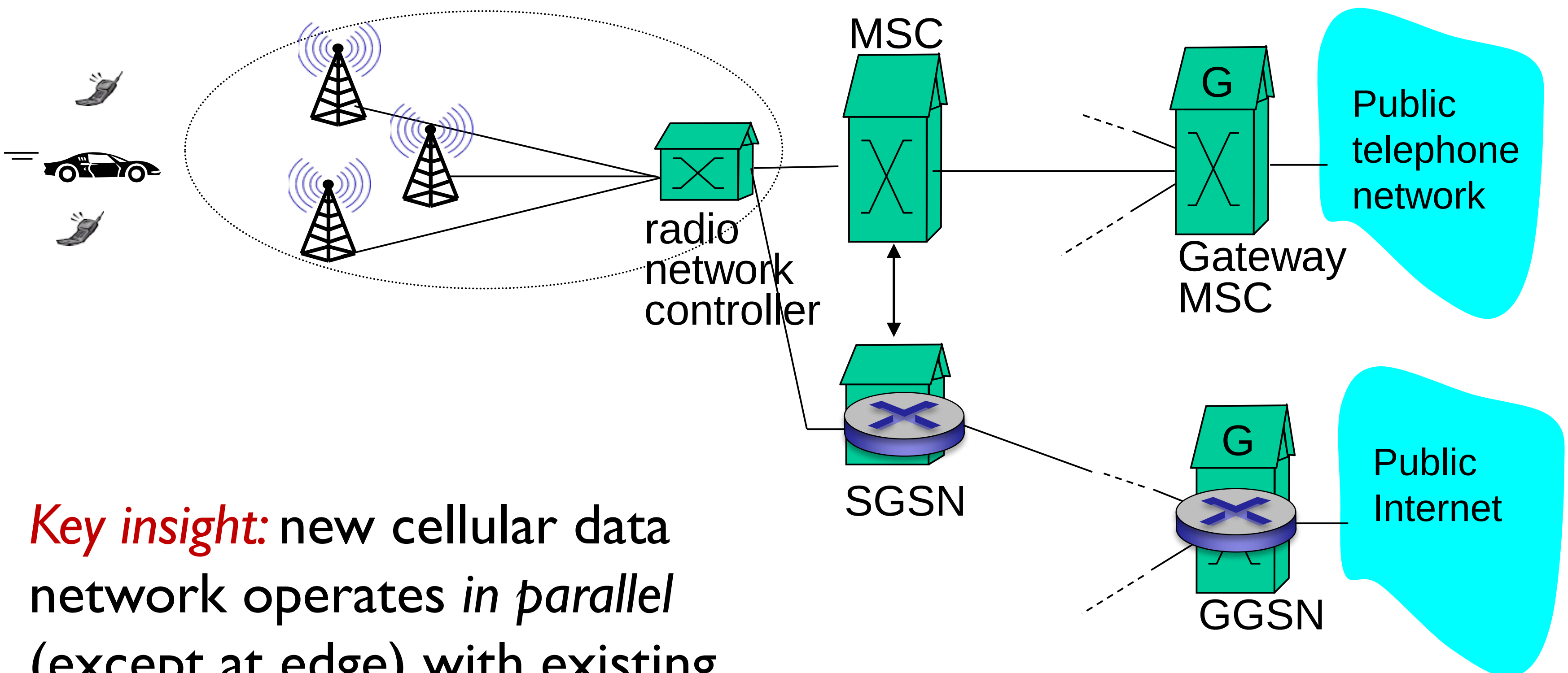
Sender 2



channel sums together transmissions by sender 1 and 2

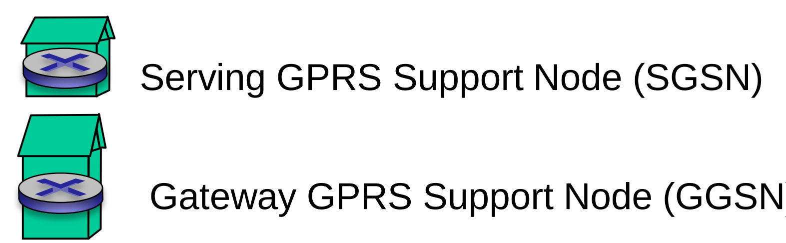
using same code as sender 1, receiver recovers sender 1's original data from summed channel data!

3G (voice+data) network architecture

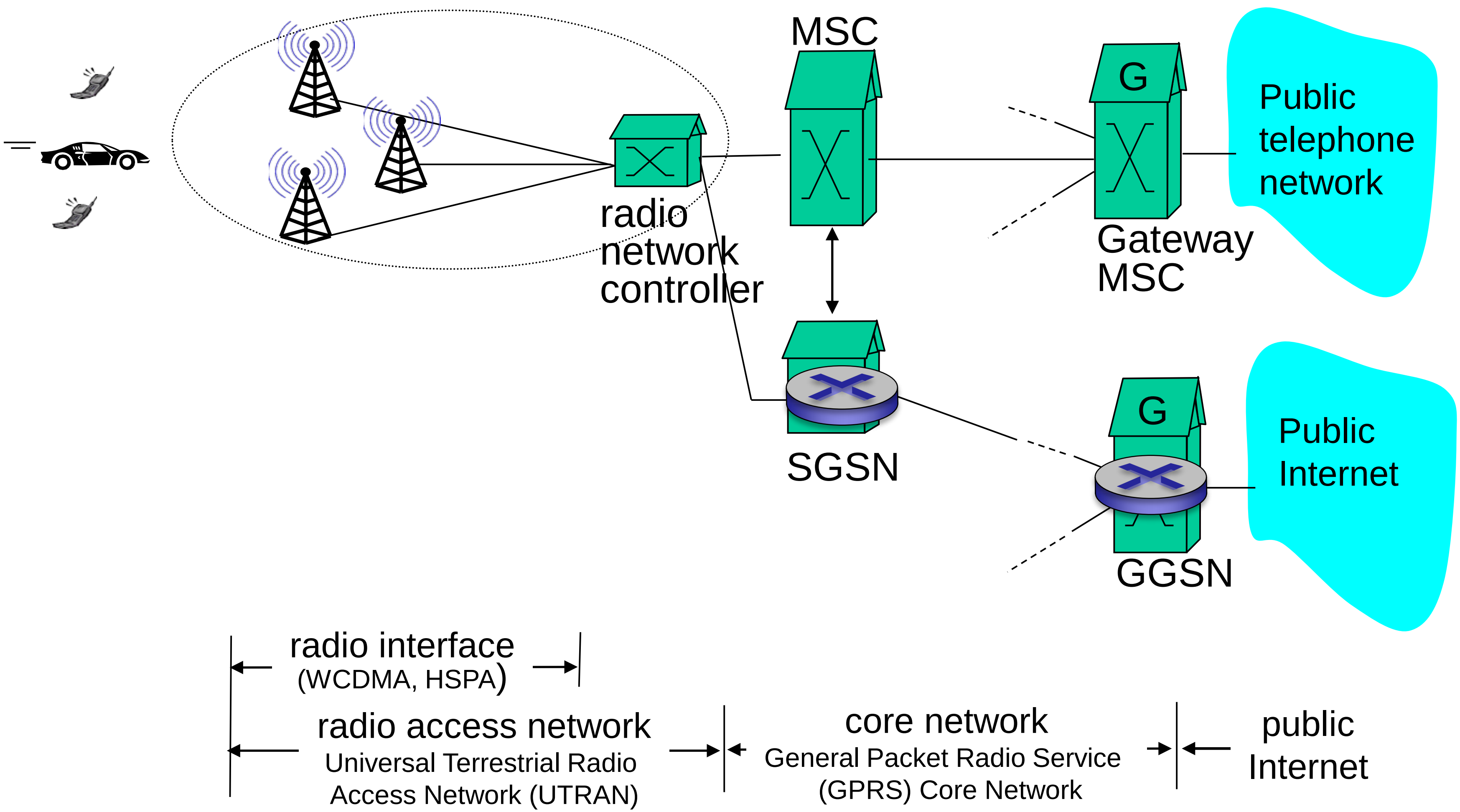


Key insight: new cellular data network operates *in parallel* (except at edge) with existing cellular voice network

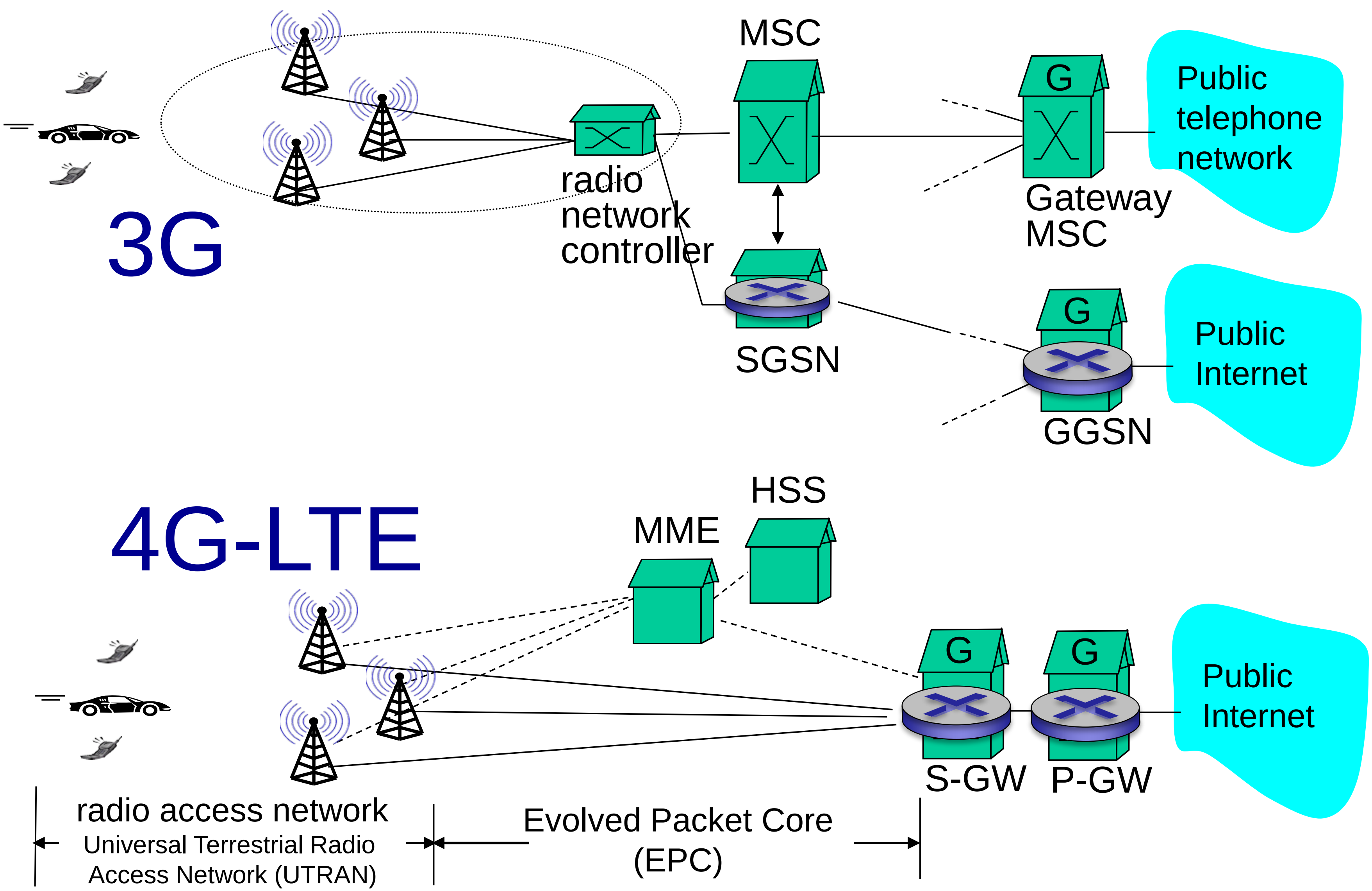
- voice network *unchanged* in core
- data network operates in parallel



3G (voice+data) network architecture

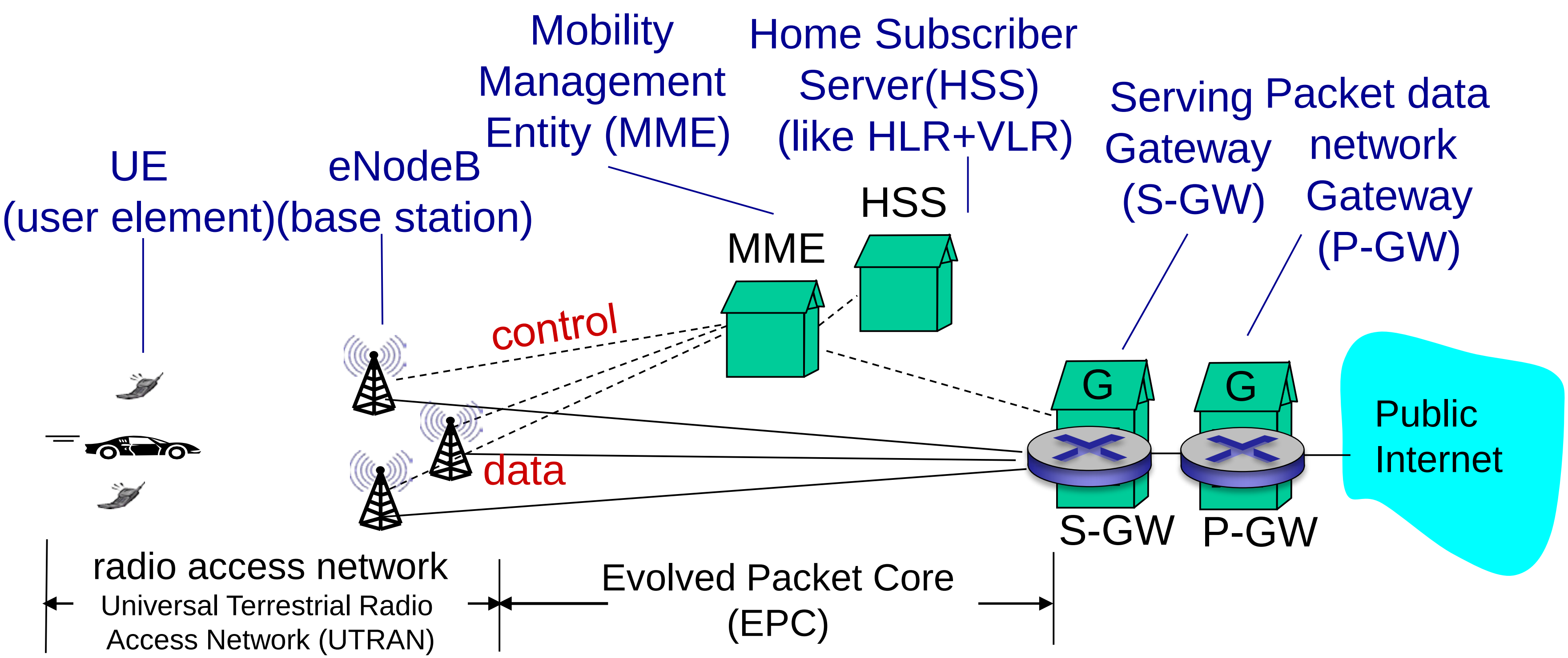


3G versus 4G LTE network architecture

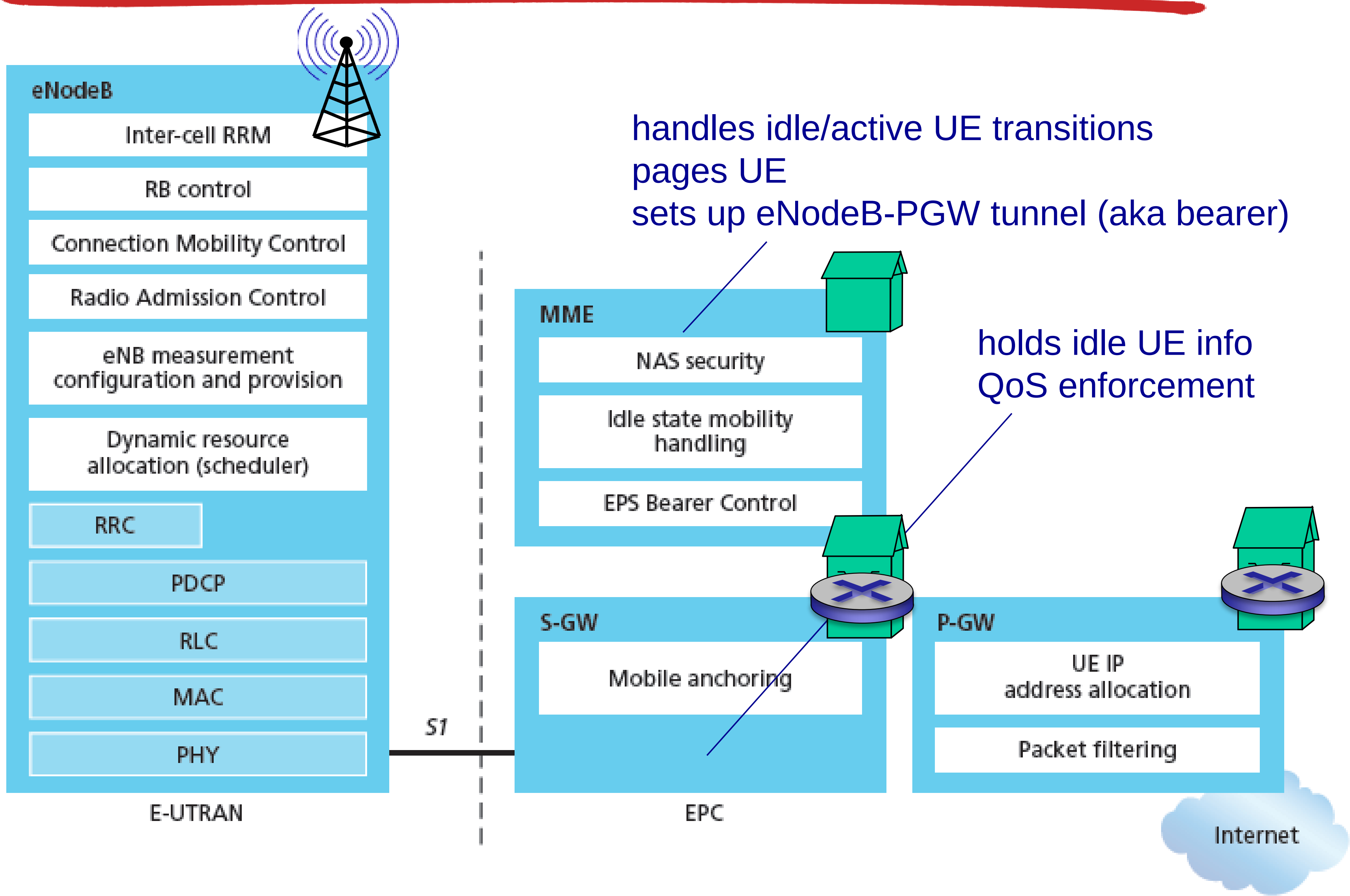


4G: differences from 3G

- all IP core: IP packets tunneled (through core IP network) from base station to gateway
- no separation between voice and data – all traffic carried over IP core to gateway



Functional split of major LTE components



L4 Preview

Before You Go

On a sheet of paper, answer the following (ungraded) question (no names, please):

What was the muddiest point in today's class?