# WIRELESS & CELLULAR NETWORKS SECTIONS 7.1 TO 7.3, 7.7

CSC 249

APRIL 3, 2018

## Overview

- New challenges: wireless links and mobile hosts
- Cellular networks for Internet access
- Introduction to mobility

# CSMA/CD (Collision Detection)

CSMA/CD: carrier sensing
- collisions *detected* within short time
- colliding transmissions aborted, reducing channel wastage

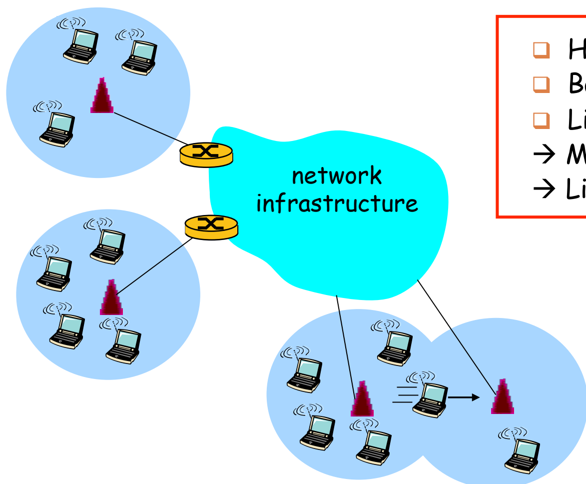
- collision detection:
  - easy in wired LANs: measure signal strengths, compare transmitted, received signals
  - difficult in wireless LANs: receiver shut off while transmitting



# Outline for Wireless (& Mobility)

- Two new challenges at the link layer…
  -
  -
- Characteristics of Wireless Links and Wireless Networks
- 802.11, WiFi, architecture and protocol
  - CSMA/CA
  - 802.11 frames

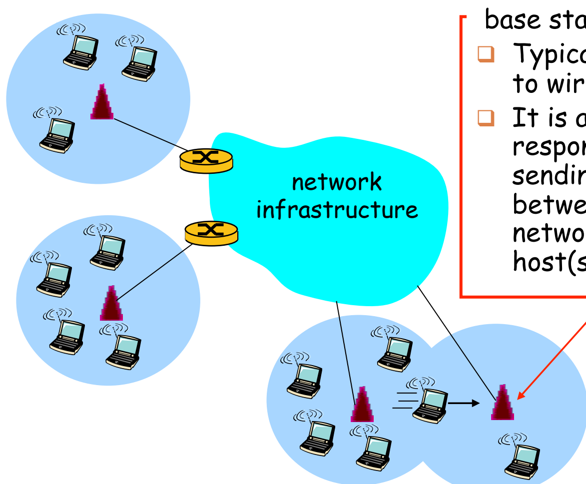
# Elements of wireless network




- Hosts
- Base station
- Link
→ Mode
→ Link char.



# Elements of wireless network: Base Station




base station
- Typically connected to wired network
- It is a relay - responsible for sending packets between wired network and wireless host(s) in its "area"

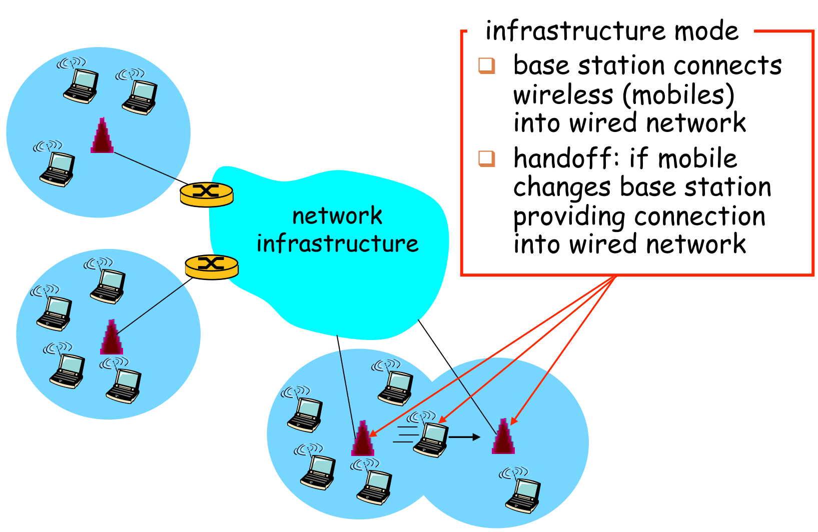
# "Modes" of Operation

- Infrastructure mode
- Ad hoc mode

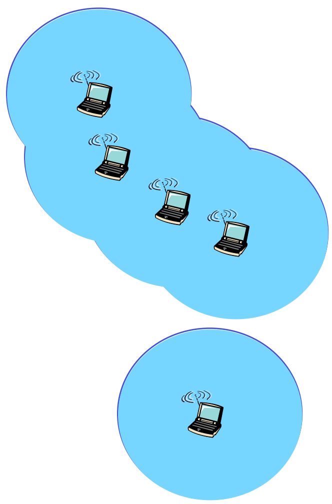
- Hypothesize strengths and weaknesses of each option?



# Elements of wireless network: Mode 1



## Elements of wireless network: Mode 2



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 Ad Hoc Networks | No base station, no connection to larger Internet (Bluetooth) | No base station, no connection to larger Internet. May need to relay for reach other (MANET, VANET) |

# * Wireless **Link** Characteristics *

Differences from wired link ….

- Decreasing signal strength: EM signal attenuates as it propagates through matter (path loss)
- Interference from other sources: wireless network frequencies (e.g., 2.4 GHz) shared by other devices (e.g., phone, microwave)
- Multipath propagation: EM signal reflects off objects, arriving at destination at slightly different times (like echoing)

… make communication across (even a point to point) wireless link much more error-prone

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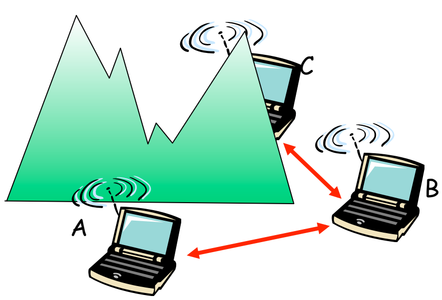
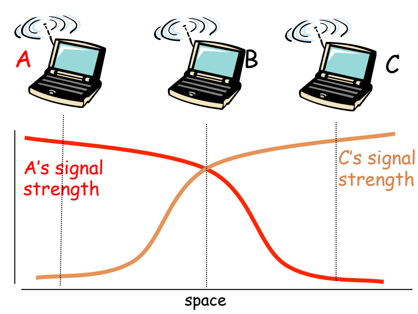
# Wireless **network** characteristics

Multiple wireless senders and receivers create additional problems (beyond multiple access):




Hidden terminal problem




Signal fading

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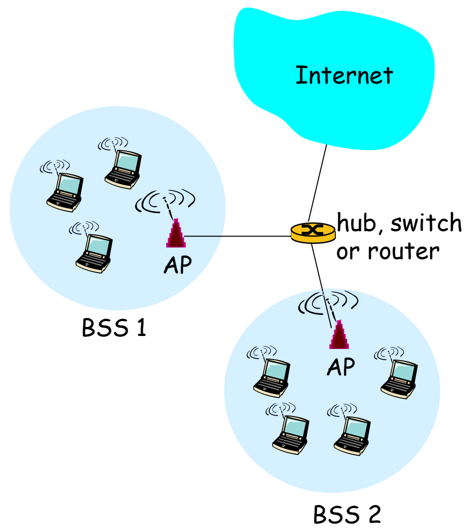
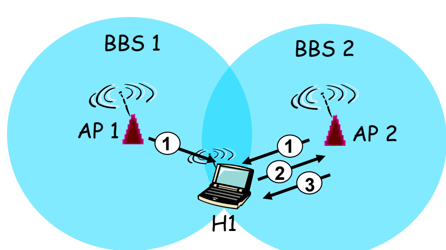
# IEEE 802.11 Wireless LAN




- 802.11 has 11 channels
- Protocol: CSMA/CA
- Architecture: BSS
- Association with an AP
  - Hosts scan channels, listening for *beacon frames* with AP's name
    - SSID - service set identifier
    - MAC address
  - Selects AP
  - Then typically run DHCP to get IP address in AP's subnet



# Our familiar "Wifi" 802.11: passive/active scanning

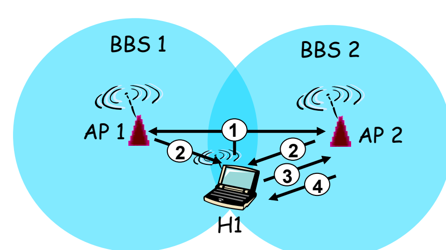



*Passive Scanning:*

(1) beacon frames sent from APs

(2) association Request frame sent: H1 to selected AP

(3) association Response frame sent: H1 to selected AP




*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: H1 to selected AP

# IEEE 802.11 Wireless LAN

Some Details:

- 11 partially overlapping channels, within the 85MHz available
  - Up to 11 Mbps for each channel
- Uses CSMA/CA for multiple access
  - CA = Collision Avoidance
- Architecture
  - wireless host communicates with base station
    - base station = access point (AP)
  - Basic Service Set (BSS) – a.k.a. "cell" – contains:
    - wireless hosts
    - access point (AP): base station

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# 802.11: "Association"

- Each host must *associate* with an AP
  - scans channels, listening for *beacon frames* containing AP's name (SSID – service set identifier) 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

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# Competing ISPs in a WiFi Cafe

- Problem:  Suppose two ISPs provide WiFi access in a café, and by chance each ISP configures its AP to operate over channel 11.
- Will the 802.11 protocol function?
- What will happen when the two stations associated with the different ISPs attempt to transmit simultaneously?
- What happens if one ISP switches to channel 1?

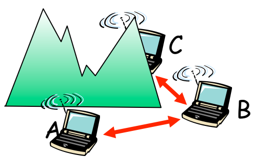


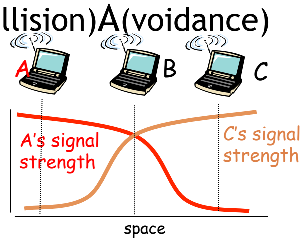
# IEEE 802.11 Questions

- Question – Compare and contrast:
  - Path loss
  - Multipath propagation
  - Interference
- Question – As a node gets further from a base station, what two actions might a base station take to minimize the probability of frame loss?

# IEEE 802.11: multiple access

- Avoid collisions: 2+ nodes transmitting at same time
- 802.11: CSMA - sense before transmitting
  - Do not collide with ongoing transmission by other node
- 802.11: *no* collision detection! → Why?
  - difficult to receive (sense collisions) when transmitting due to weak received signals (fading)
  - cannot sense all collisions: hidden terminal, fading
- Goal: *avoid collisions:* CSMA/C(ollision)A(voidance)

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# IEEE 802.11 MAC Protocol: CSMA/CA

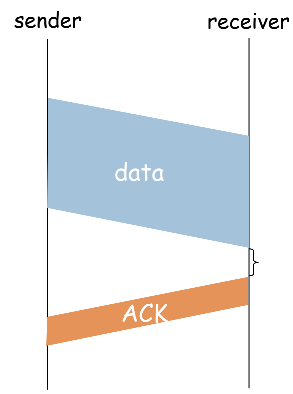
802.11 sender

1) if sense channel idle then
   transmit entire frame (no CD)

2) if sense channel busy then
   - start random backoff time
   - timer counts down while idle
   - transmit when timer expires
   - if no ACK, increase random backoff interval, repeat 2

802.11 receiver

1) if frame received OK then return ACK

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# Avoiding collisions: RTS & CTS

*New 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 are small)
- AP broadcasts clear-to-send (CTS) in response to RTS
- RTS heard by all nodes (& CTS received by all)
  - sender transmits data frame
  - other stations defer transmissions

Avoid data frame collisions completely using small reservation packets!

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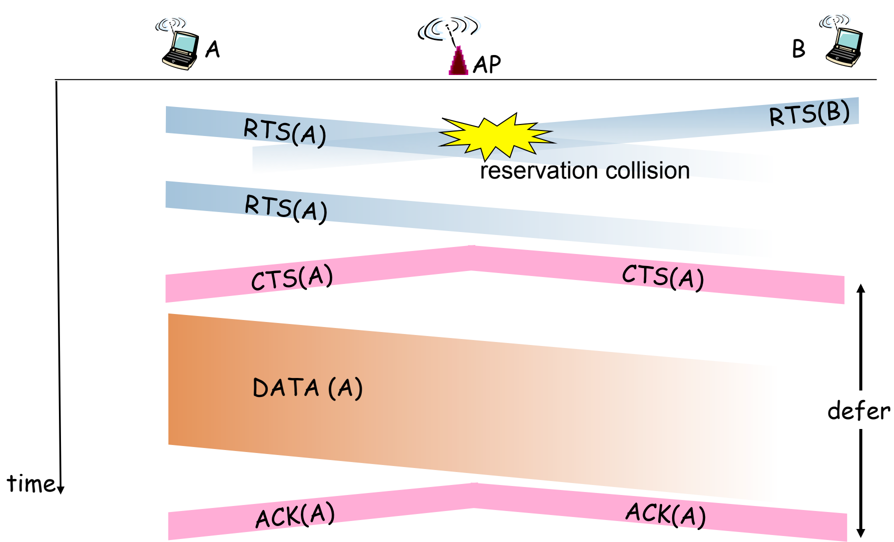
# Collision Avoidance: RTS-CTS exchange

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# Collision Avoidance Question

- Question – What might an RTS threshold be? How would it work? Why would we use one?

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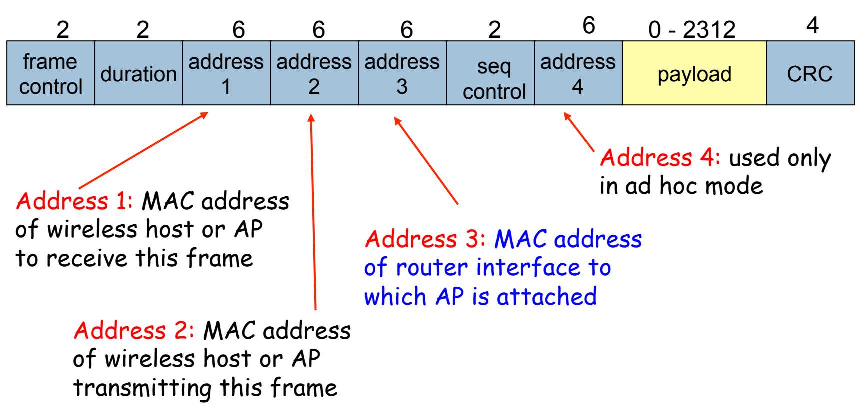
# 802.11 frame: addressing

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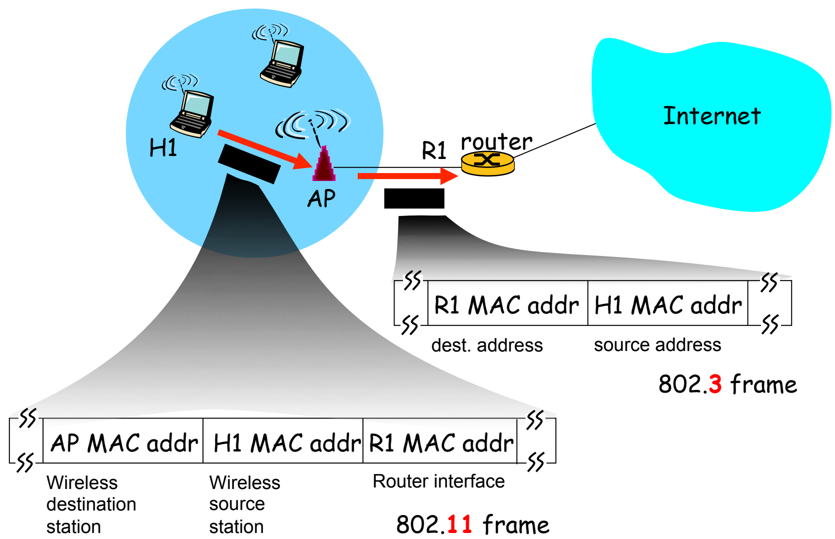
# 802.11 frame: addressing

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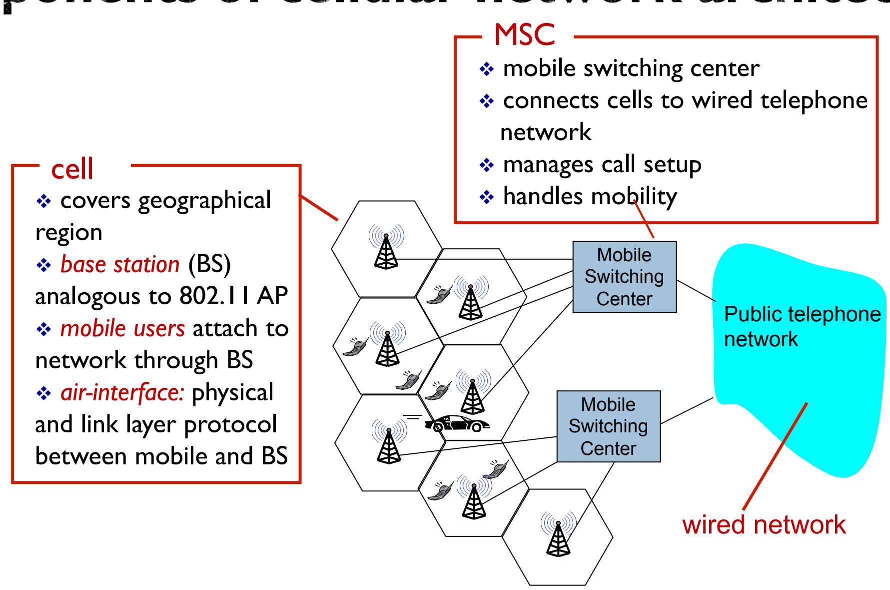
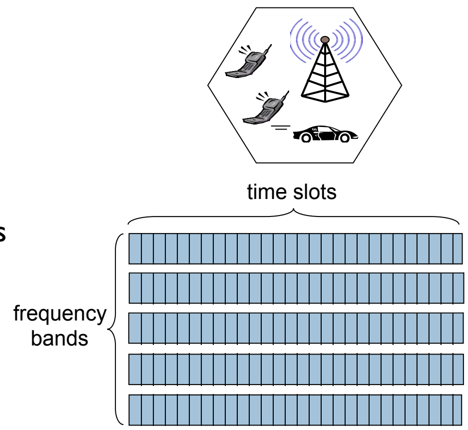
# Components of cellular network architecture



# Cellular networks: the first hop

Two techniques for sharing mobile and base station radio spectrum

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




# CDMA vs. GSM – Multiple Access Technologies

- 4G is somewhat replacing this technology split of 3G
- CDMA (Code Division Multiple Access)
  - Owned by Qualcomm
  - Sprint, Verizon, US Cellular us CDMA
  - Difficult to transmit voice and data simultaneously
- GSM (Global System for Mobiles)
  - Uses ‘time division’
  - Created by an industry consortium
  - AT&T and T-Mobile use
  - And the technology most of the world uses
  - Simultaneous voice and data is defined as part of the technology

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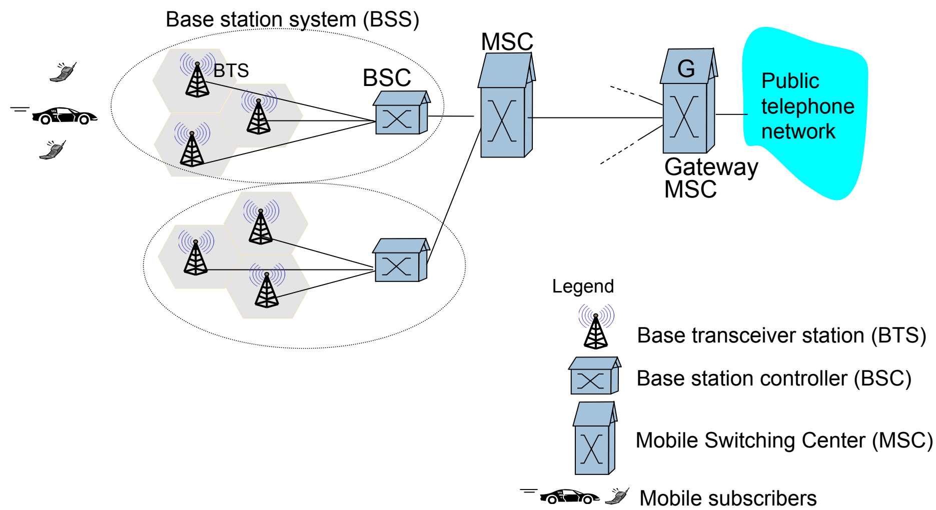
# Discussion

1) What are important differences between 3G and 4G cellular networks?
   - In 3G architecture, there are separate network components and paths for voice and data, i.e., voice goes through public telephone network, whereas data goes through public Internet. 4G architecture is a unified, all-IP network architecture, i.e., both voice and data are carried in IP datagrams to/from the wireless device to several gateways and then to the rest of the Internet.
   - The 4G network architecture clearly separates data and control plane, which is different from the 3G architecture.

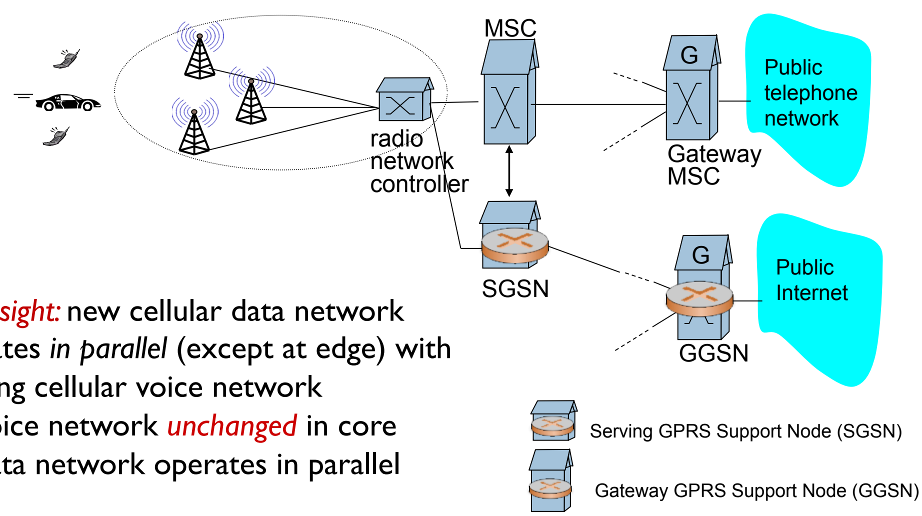
# Discussion

2) What is the role of the “core network” in the 3G cellular data architecture?
   - The 3G core cellular data network connects (radio) access networks to the public Internet. The core network interoperates with components of the existing cellular voice network (in particular, the MSC)

# 2G (voice) network architecture



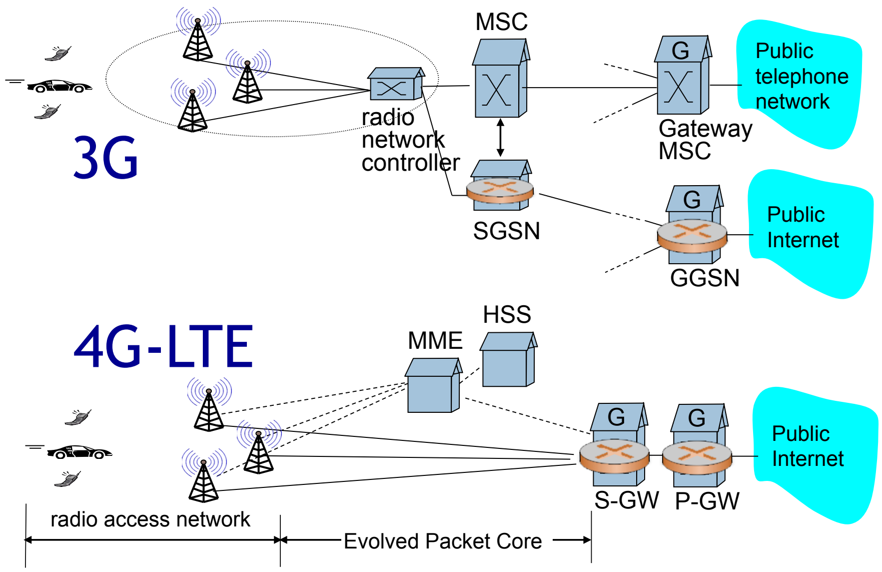

# 3G (voice+data) network architecture




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

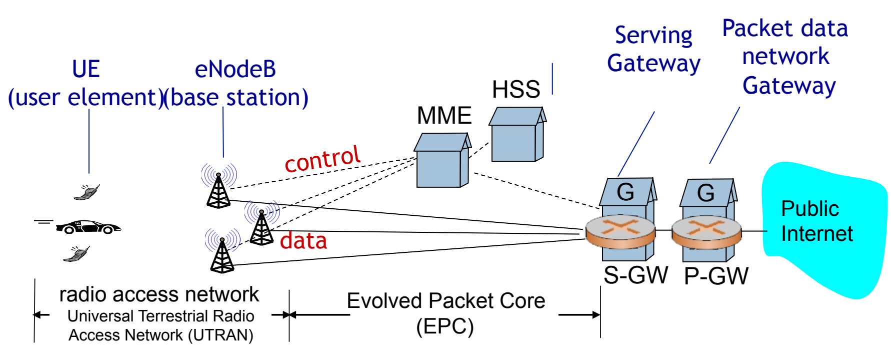
- voice network *unchanged* in core
- data network operates in parallel

# 3G versus 4G LTE network architecture

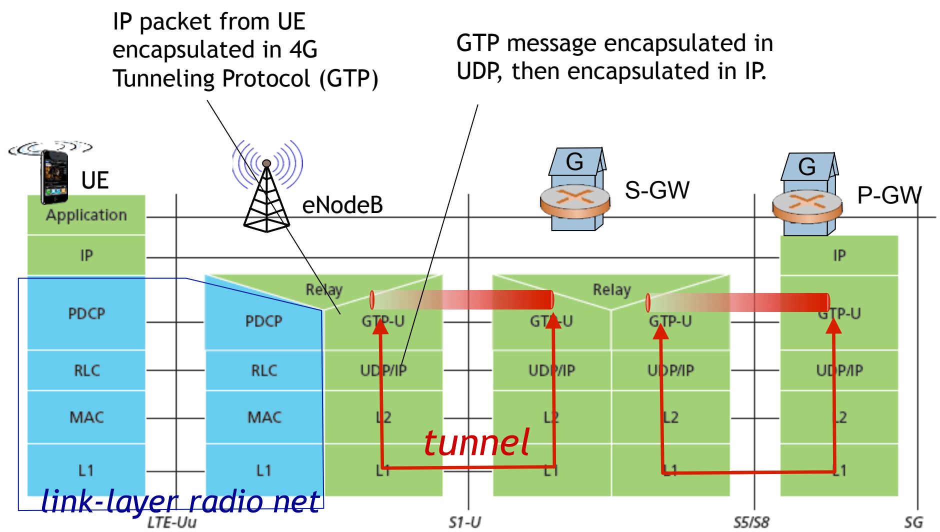



# 4G: differences from 3G

- 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



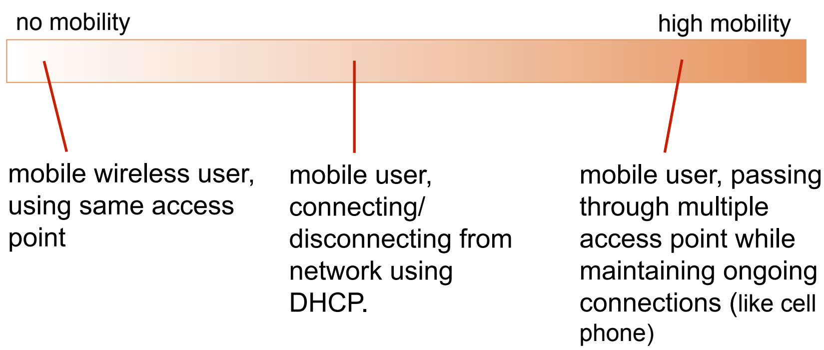
# Cellular Service + Tunneling:



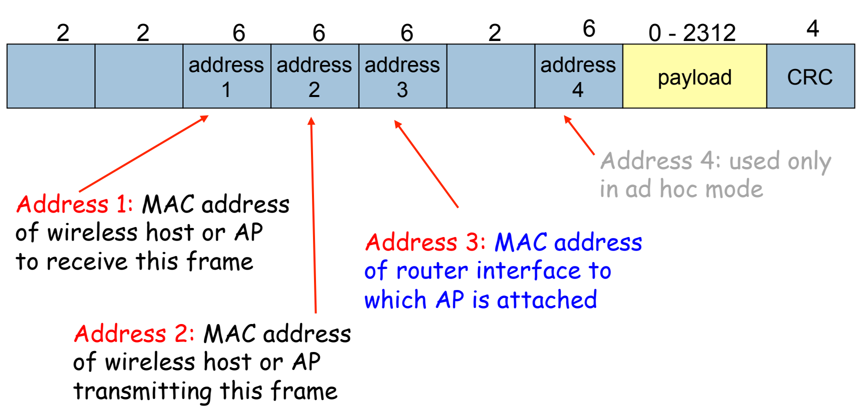

# Mobility…

# What is mobility?

- Spectrum of mobility, from the *network* perspective:




# Wireless: 802.11 frame: addressing

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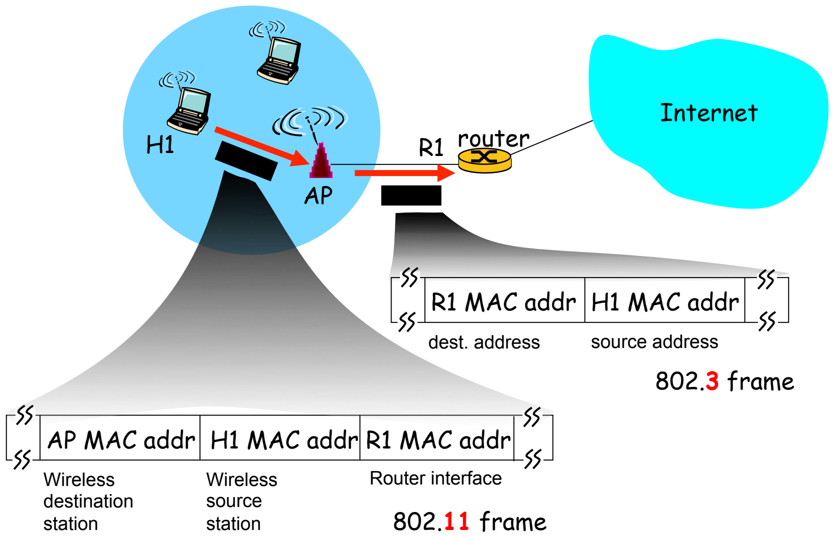
# 802.11 frame: addressing

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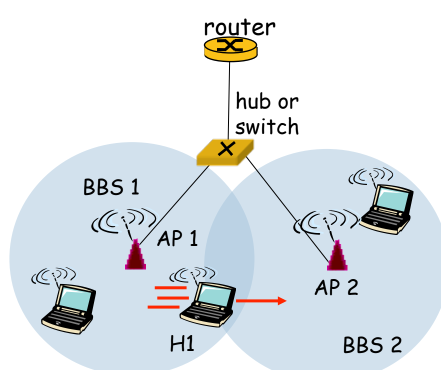
# 802.11: mobility within same subnet

- H1 remains in same IP subnet: IP address will remain same
- How does the switch find H1 as it changes association from AP1 to AP2?
  - self-learning: switch will see frame from H1 and update switch table with the port to be used to reach H1

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## Same-Subnet Mobility Question

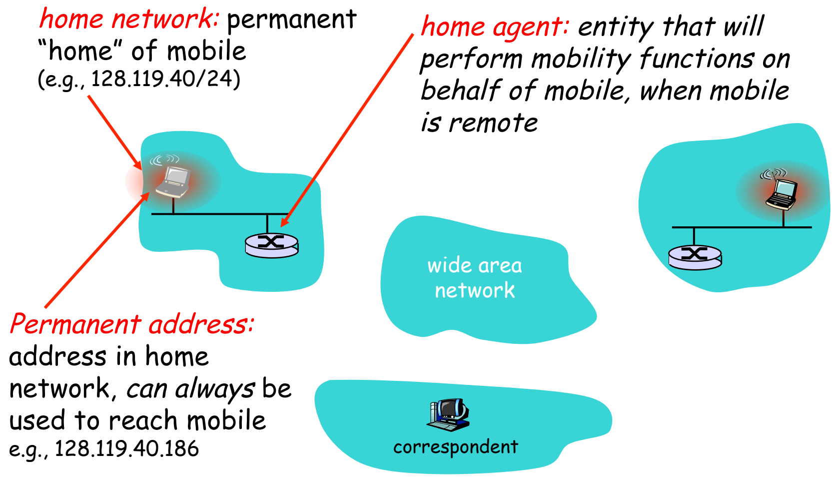
- Assume a subnet with two access points (AP) that are connected by a switch
- A wireless station moves from one BSS to another
- Why does the newly associated AP need to send a frame with a “spoofed MAC address” to the switch in order for the switch to properly forward subsequent frames?



## Same-Subnet Mobility Question

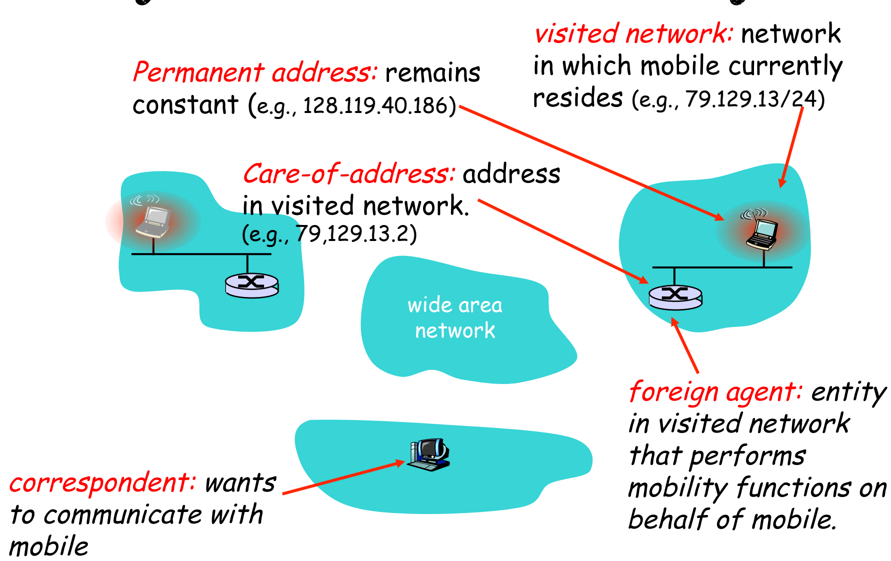
- Initially the switch has an entry in its forwarding table which associates the wireless station with the earlier AP.
- When the wireless station associates with the new AP, the new AP creates a frame with the wireless station’s MAC address (‘spoofing’ the address) and broadcasts the frame.
- The frame is received by the switch. This forces the switch to update its forwarding table, so that frames destined to the wireless station are sent via the new AP.

# Mobility: vocabulary






# Mobility: more vocabulary



# Summary

- Wireless issues
  - Link characteristics
  - Network characteristics
  - Association with Access Point (AP)
  - csma/ca
    - Collision Avoidance
    - RTS/CTS
  - Framing – addresses used
- Cellular networks
- Introduction to mobility

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