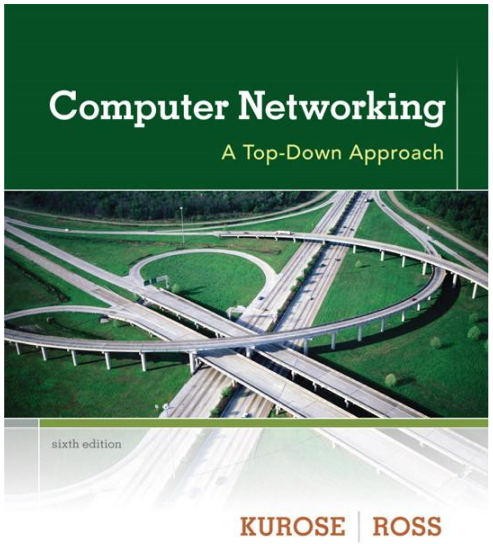
Chapter 6
Physical Layer & Wireless and Mobile Networks



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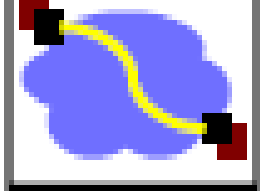
Thanks and enjoy! JFK/KWR

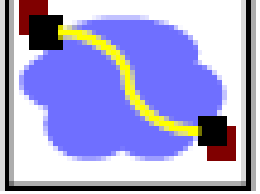
Computer Networking: A Top Down Approach
6th edition
Jim Kurose, Keith Ross
Addison-Wesley
March 2012

Transferring Information

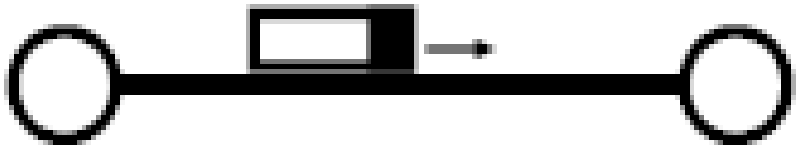


- Information transfer is a physical process
- In this class, we generally care about
  - Electrical signals (on a wire)
  - Optical signals (in a fiber)
  - Wireless signals
  - More broadly, EM waves
- Information carriers can also be
  - Sound waves
  - Quantum states
  - Ink & paper, etc.

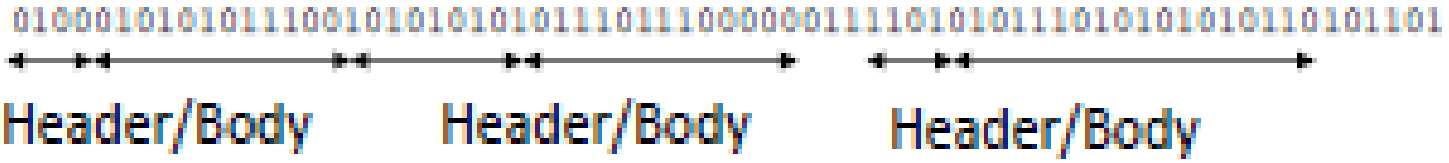
From Signals to Packets



Packet Transmission



Packets



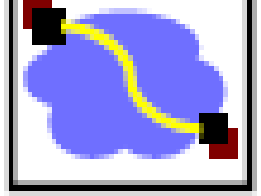
Bit Stream

0 0 1 0 1 1 1 0 0 0 1

"Digital" Signal

Analog Signal

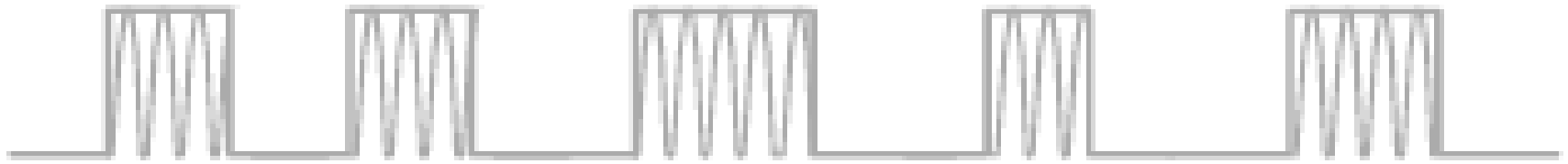
What is Modulation?



- The sender changes a signal in a way that the receiver can recognize - conveys information
- Ways to modulate a signal (think: sinusoidal wave)
  - Change frequency, phase, or amplitude
- Similar to AM/FM radio:
  - But we encode bits!
- Many forms of modulation!
  - Basic AM, FM, and PM - OK for "easy" environments
  - Wireless environments are very challenging – uses much more aggressive forms of modulation

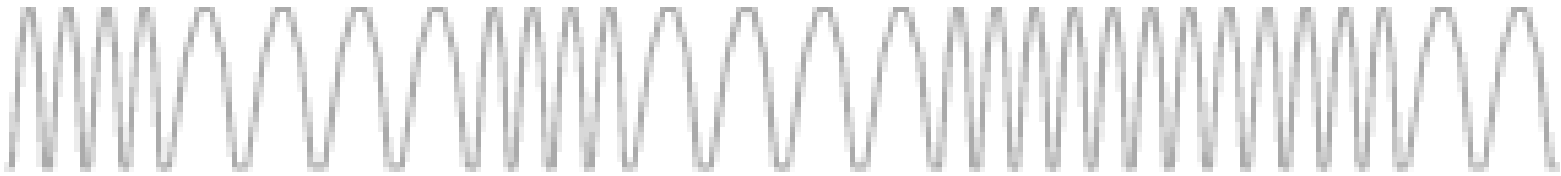
Binary Modulation

AM: change the strength of the signal



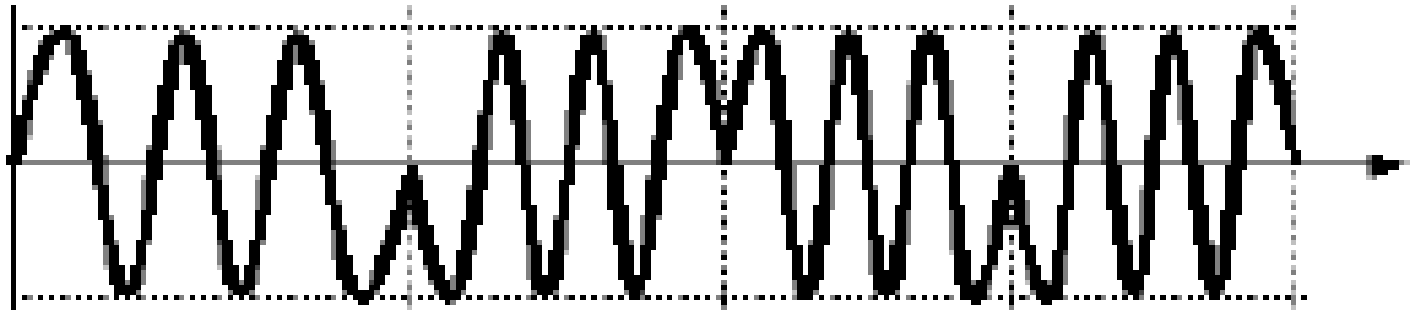
0 0 1 1 0 0 1 1 0 0 0 1 1 1 0 0 0 1 1 0 0 0 1 1 1 0

FM: change frequency:

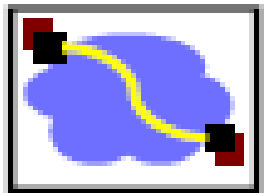


0 1 1 0 1 1 0 0 0 1

PM: change phase



Limits to Speed and Distance



- Noise: "random" energy is added to the signal.

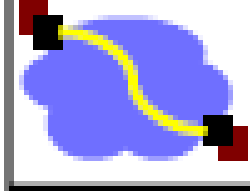
- Attenuation: some of the energy in the signal leaks away.

- Dispersion: attenuation and propagation speed are frequency dependent.

(Changes the shape of the signal)

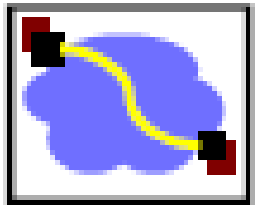
- Effects limit the data rate that a channel can sustain.
  - But affects different technologies in different ways
- Effects become worse with distance.
  - Tradeoff between data rate and distance

Supporting Multiple Channels

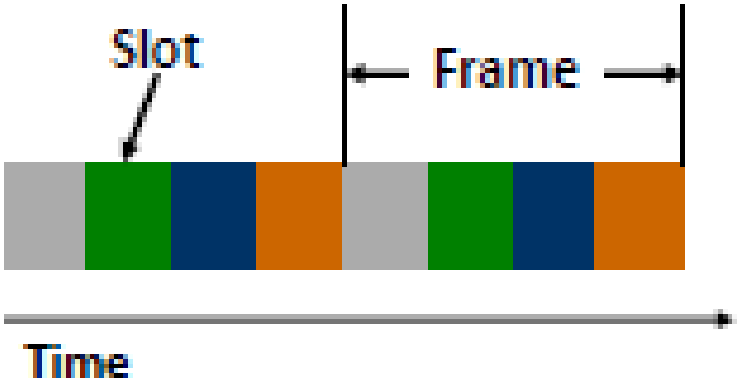


- Multiple channels can coexist if they transmit at a different frequency, or at a different time, or in a different part of the space.
  - Three dimensional space: frequency, space, time
- Space can be limited using wires or using transmit power of wireless transmitters.
- Frequency multiplexing means that different users use a different part of the spectrum.
  - Similar to radio: 95.5 versus 102.5 station
- Controlling time (for us) is a datalink protocol issue.
  - Media Access Control (MAC): who gets to send when?

Frequency versus Time-division Multiplexing



- With FDM different users use different parts of the frequency spectrum.
  - I.e. each user can send all the time at reduced rate
  - Example: roommates
- With TDM different users send at different times.
  - I.e. each user can sent at full speed some of the time
  - Example: a time-share condo
- The two solutions can be combined.



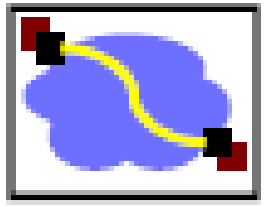
Today's Lecture

- Modulation.
- Bandwidth limitations.
- Multiplexing.
- Media: Copper, Fiber, Optical, Wireless.

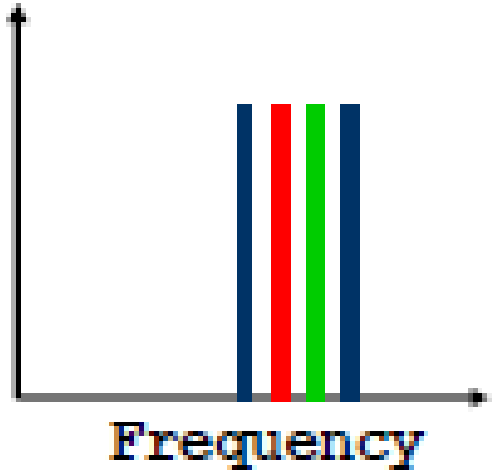
Copper Wire

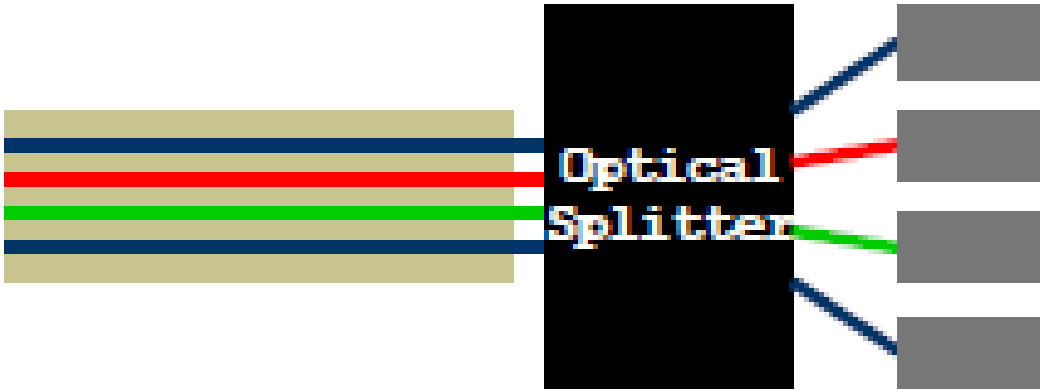
- Unshielded twisted pair (UTP)
  - Two copper wires twisted - avoid antenna effect
  - Grouped into cables: multiple pairs with common sheath
  - Category 3 (voice grade) versus category 6
  - 100 Mbit/s up to 100 m, 1 Mbit/s up to a few km
  - Cost: ~ 10cents/foot
- Coax cables.
  - One connector is placed inside the other connector
  - Holds the signal in place and keeps out noise
  - Gigabit up to a km
- Signaling processing research pushes the capabilities of a specific technology.
  - E.g. modems, use of cat 6

Wavelength Division Multiplexing



- Send multiple wavelengths through the same fiber.
  - Multiplex and demultiplex the optical signal on the fiber
- Each wavelength represents an optical carrier that can carry a separate signal.
  - E.g., 16 colors of 2.4 Gbit/second
- Like radio, but optical and much faster





Ch. 6: Wireless and Mobile 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

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

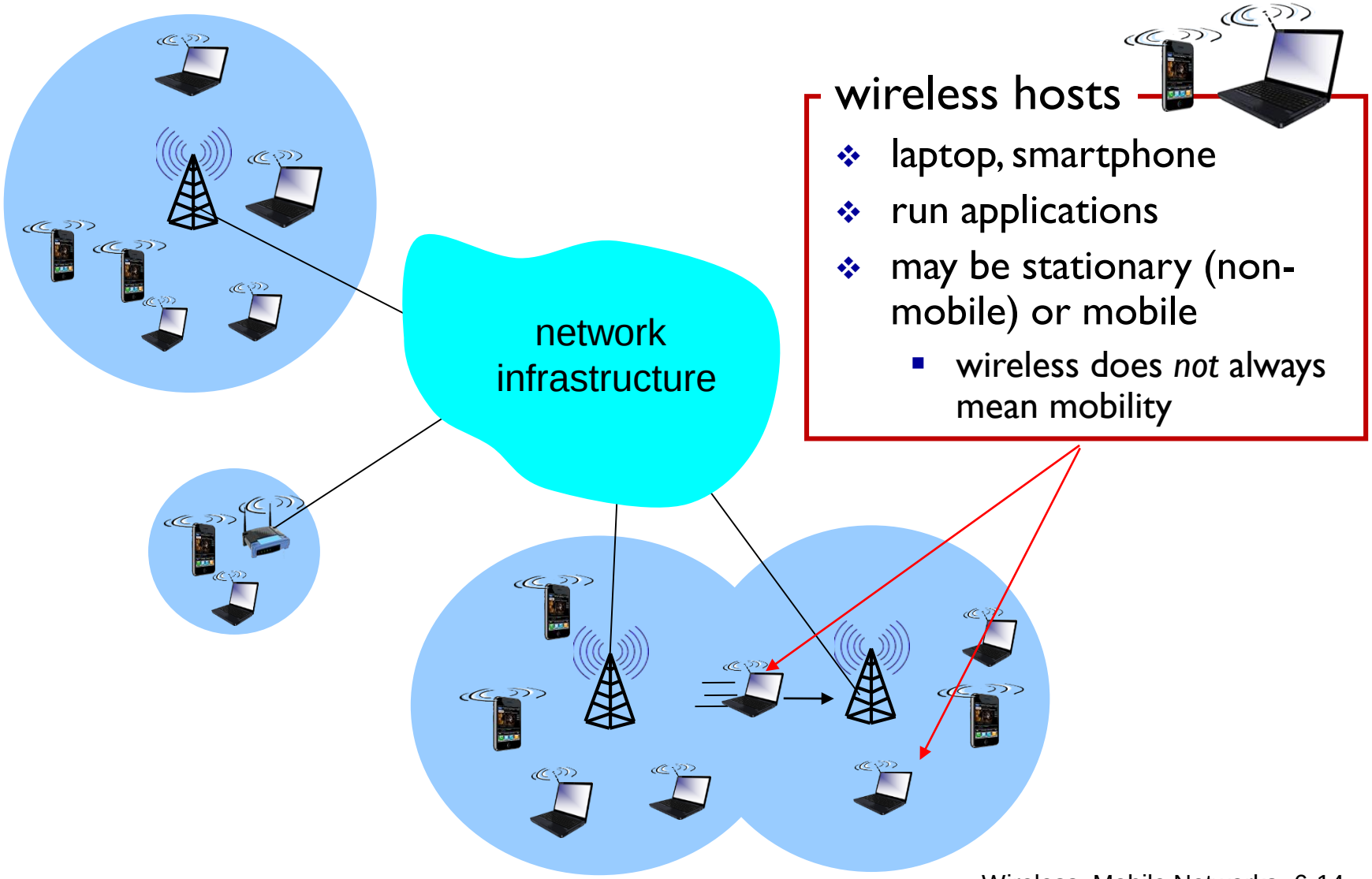
6.6 Mobile IP

6.7 Handling mobility in cellular networks

6.8 Mobility and higher-layer protocols

6.9 Summary

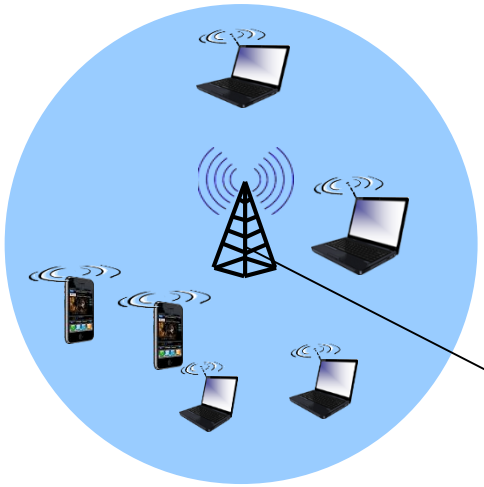
Elements of a wireless network



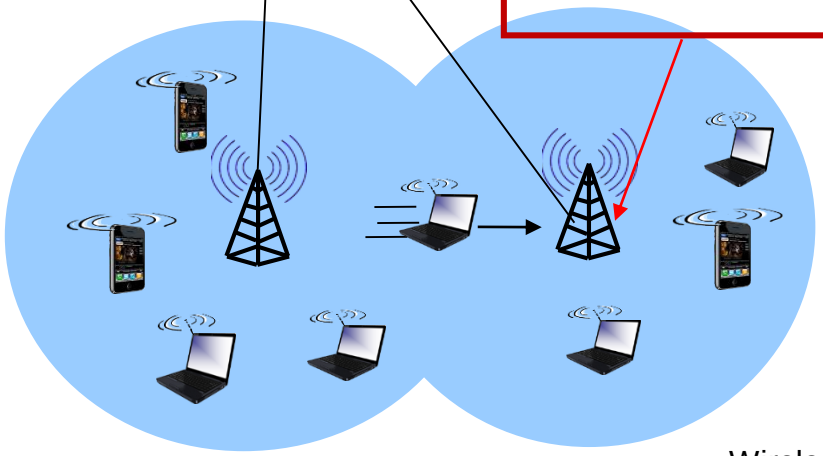
wireless hosts

- laptop, smartphone
- run applications
- may be stationary (non-mobile) or mobile
  - wireless does *not* always mean mobility

Elements of a wireless network



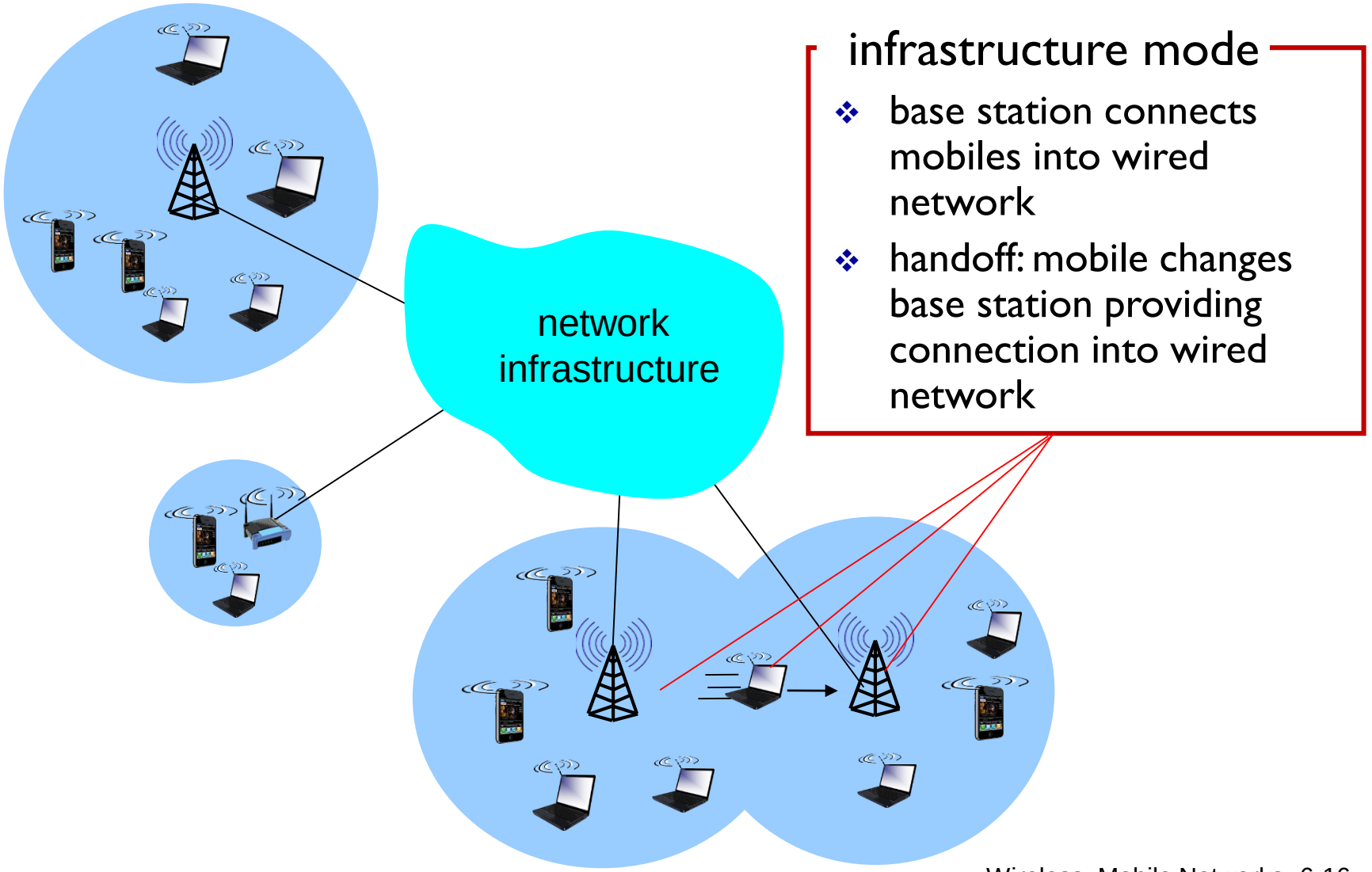
network infrastructure



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

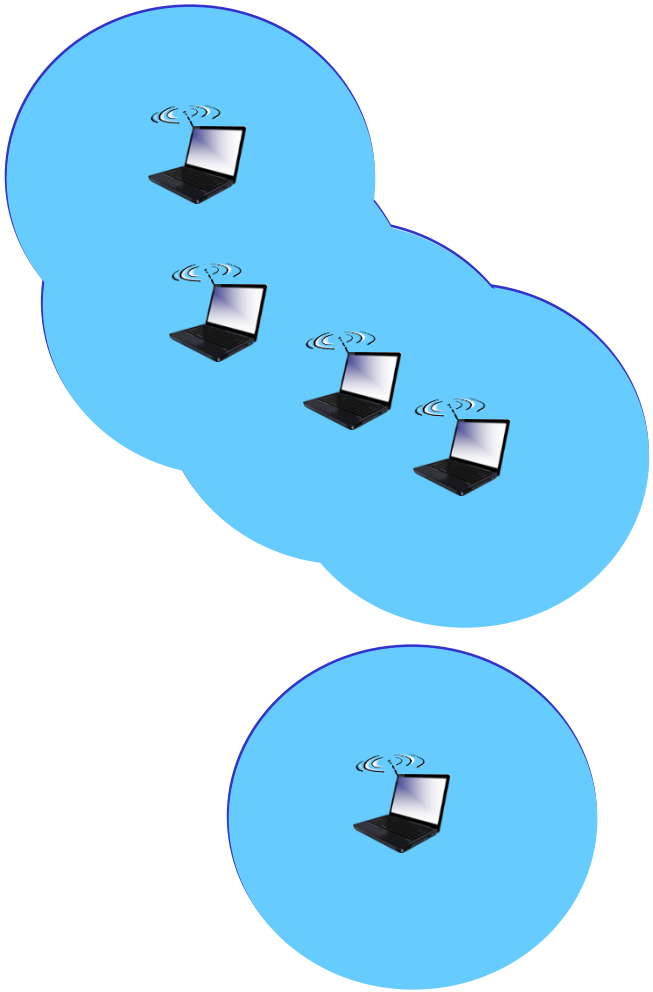
Elements of a wireless network



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

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Wireless Link Characteristics (1)

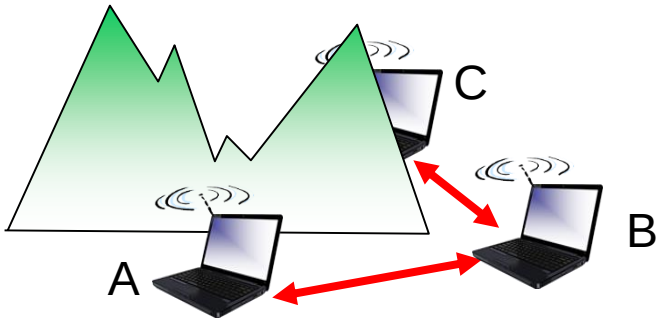
important differences from wired link ….

- *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"

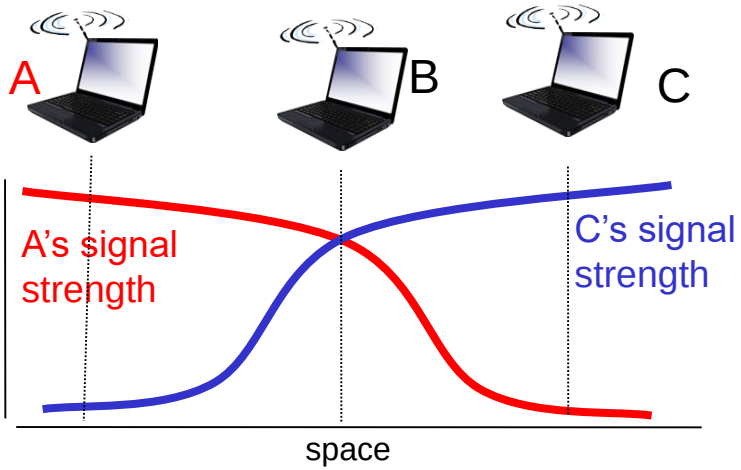
Wireless network characteristics

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



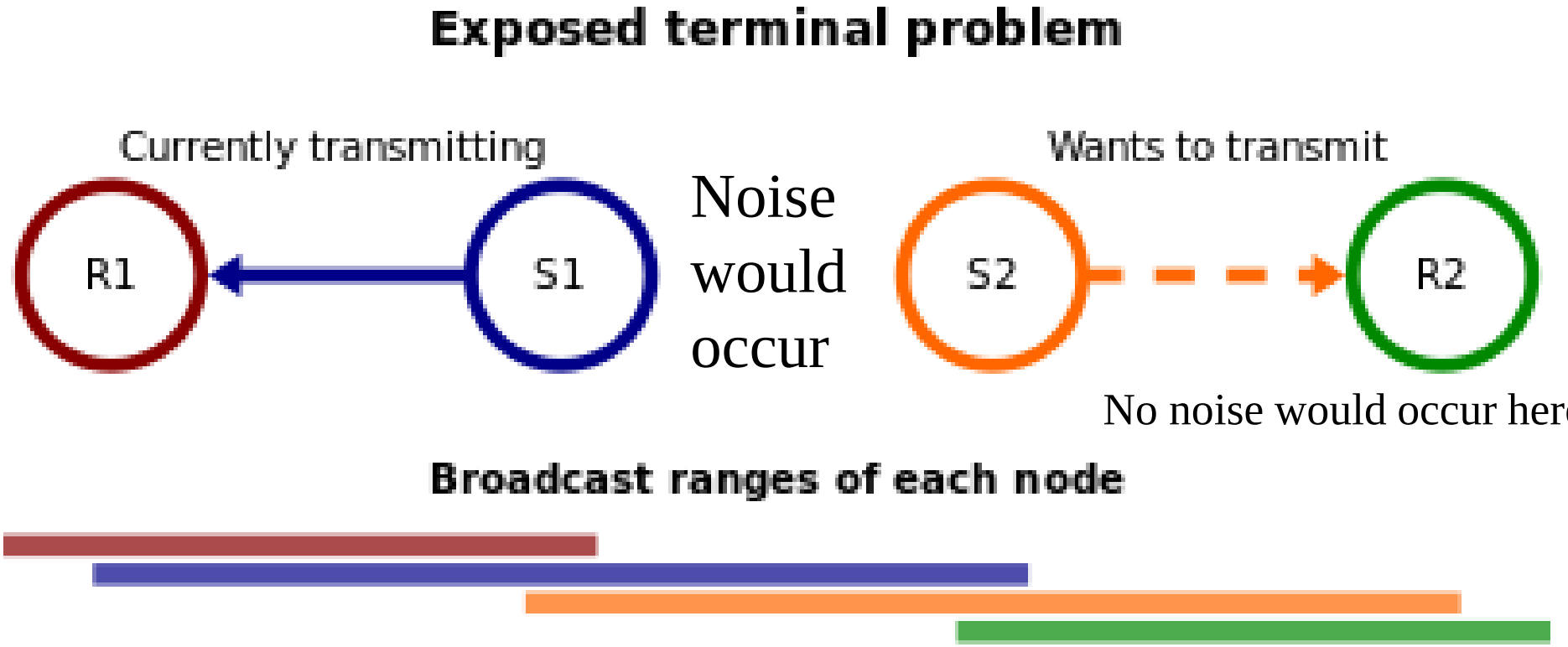
Hidden terminal problem

- 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 attenuation:

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



https://en.wikipedia.org/wiki/Exposed_node_problem

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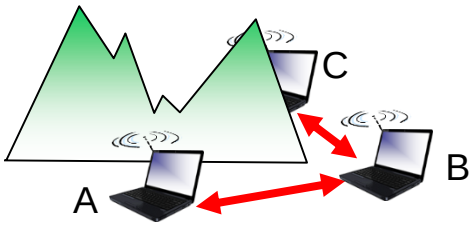
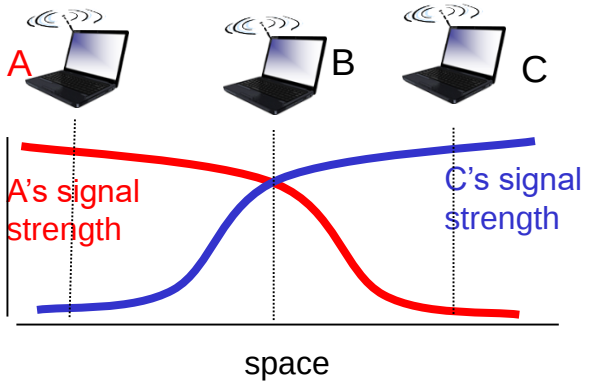
IEEE 802.11: multiple access

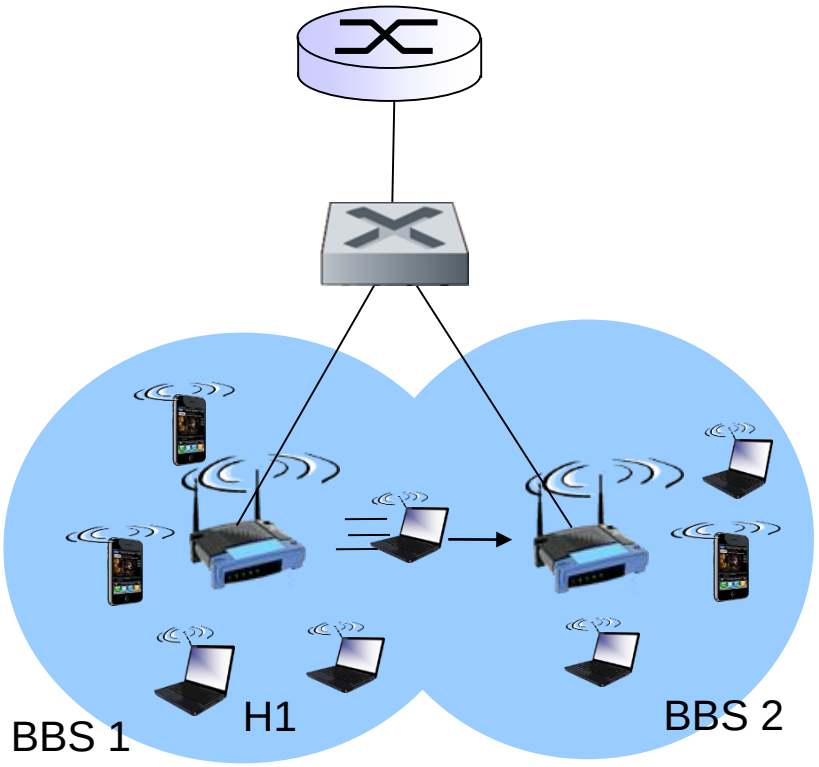
- avoid collisions: 2^+ nodes transmitting at same time
- 802.11: CSMA - sense before transmitting
  - don't collide with ongoing transmission by other node
- 802.11: *no* collision detection!
  - difficult to receive (sense collisions) when transmitting due to weak received signals (fading)
  - can't sense all collisions in any case: hidden terminal, fading
  - goal: *avoid collisions:* CSMA/C(ollision)A(voidance)





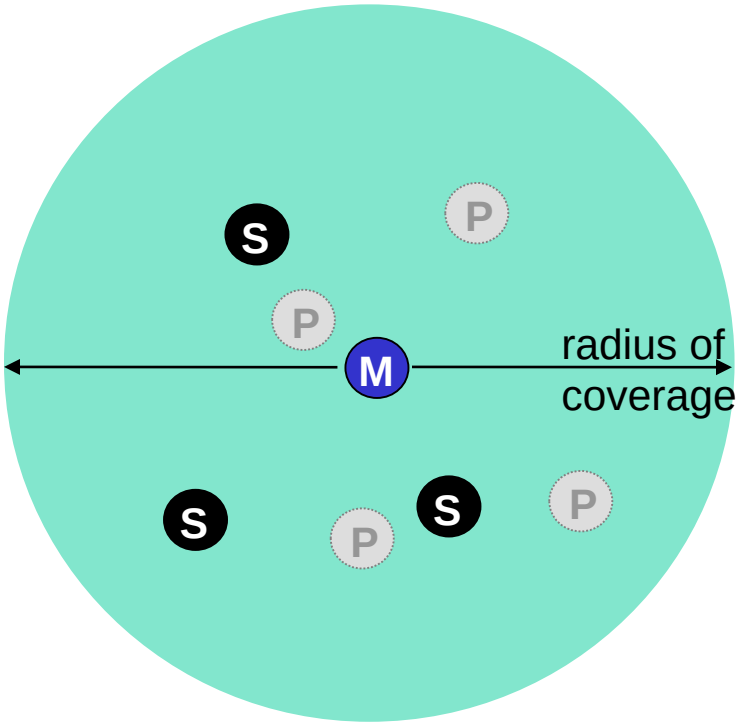
802.11: mobility within same subnet

- 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



802.15: 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



M Master device

S Slave device

P Parked device (inactive)

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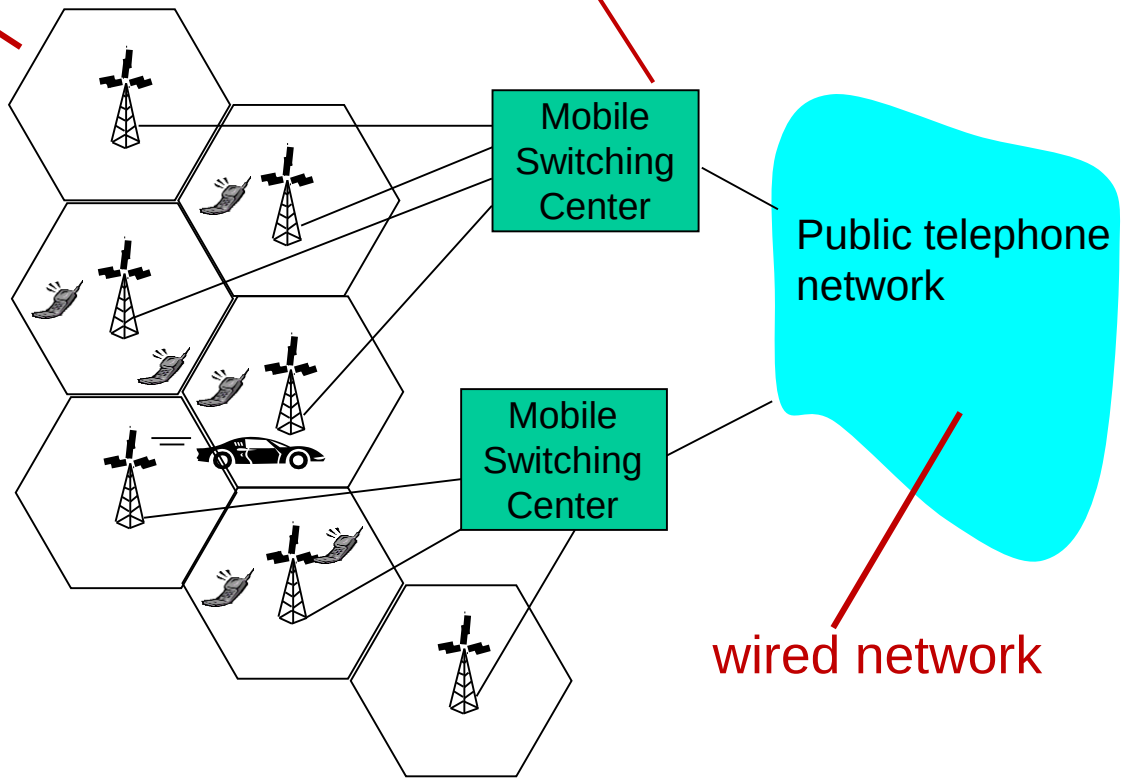
Components of cellular network architecture

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

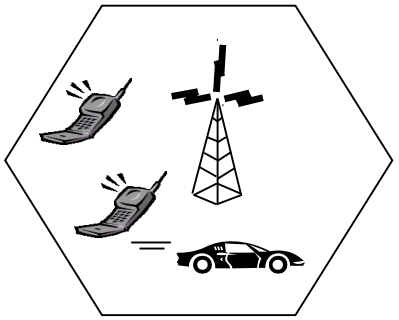
cell
- covers geographical region
- *base station* (BS) analogous to 802.11 AP
- *mobile users* attach to network through BS
- *air-interface:* physical and link layer protocol between mobile and BS

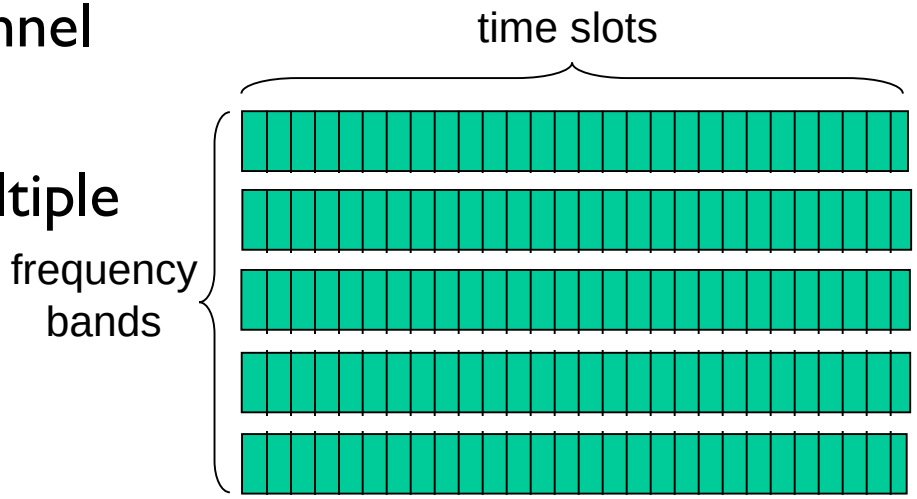


Cellular networks: the first hop

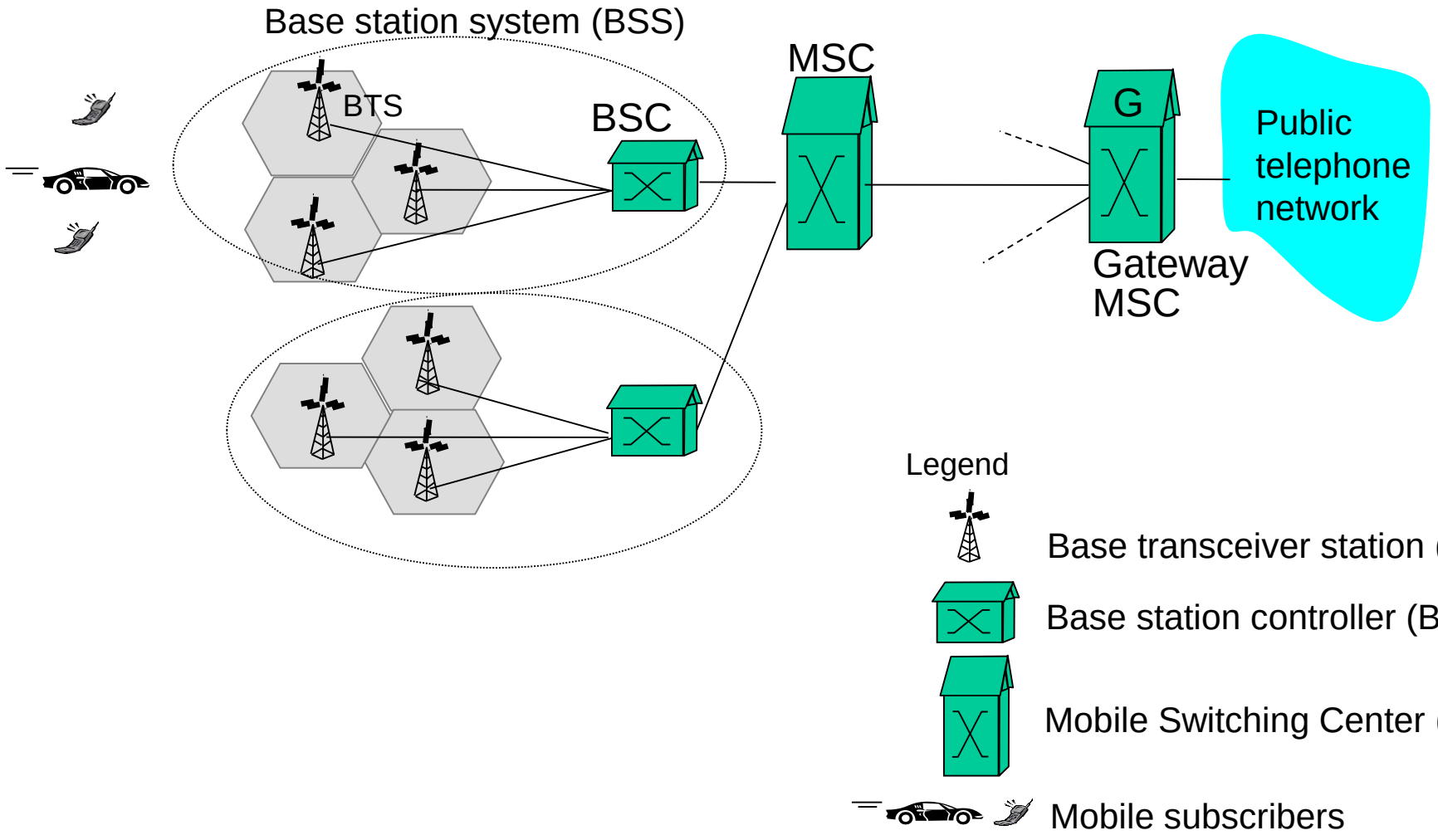
Two techniques for sharing mobile-to-BS radio spectrum

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

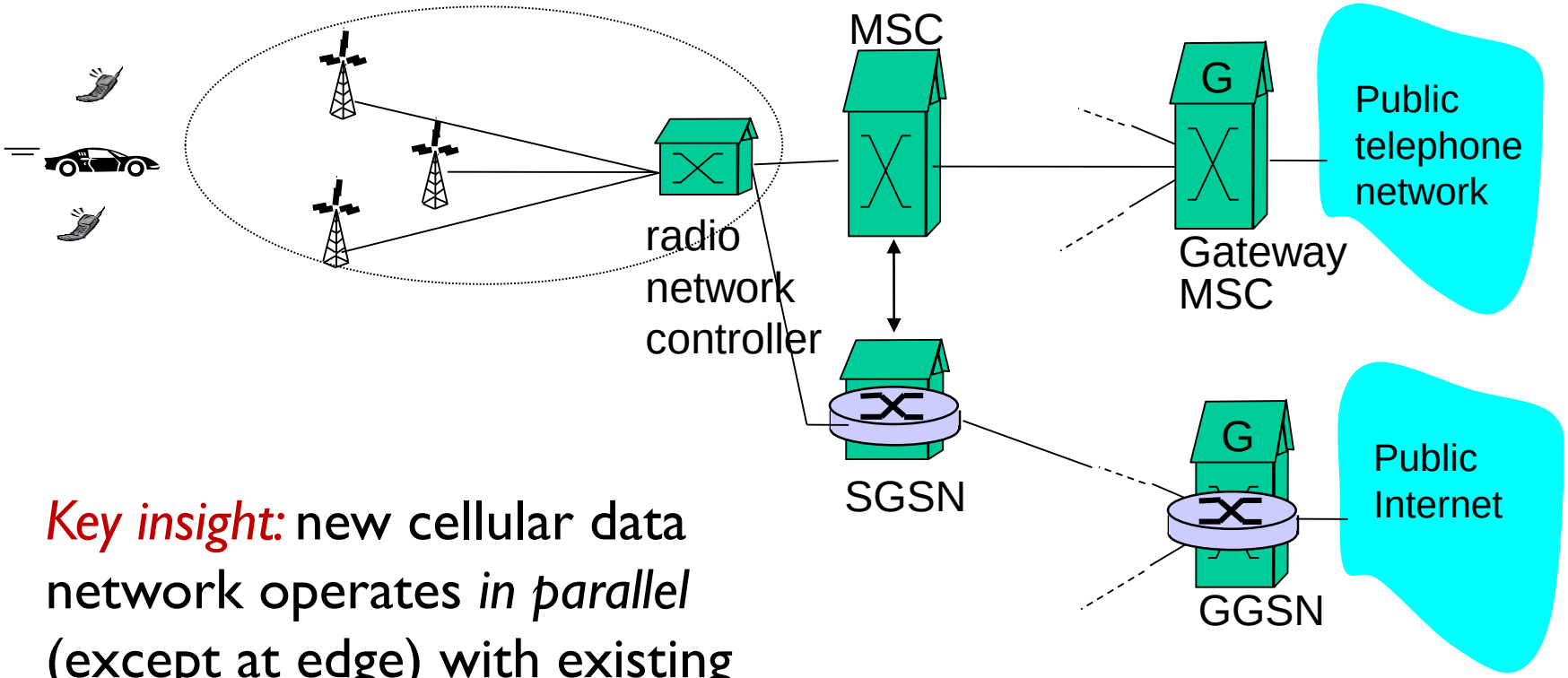




2G (voice) network architecture



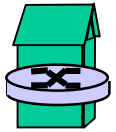
3G (voice+data) network architecture



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


Serving GPRS Support Node (SGSN)


Gateway GPRS Support Node (GGSN)

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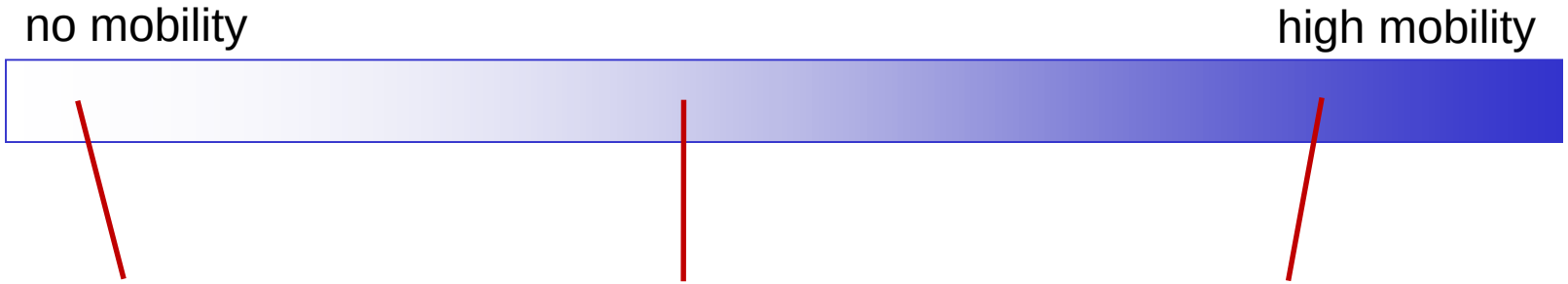
What is mobility?

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



mobile wireless user, using same access point

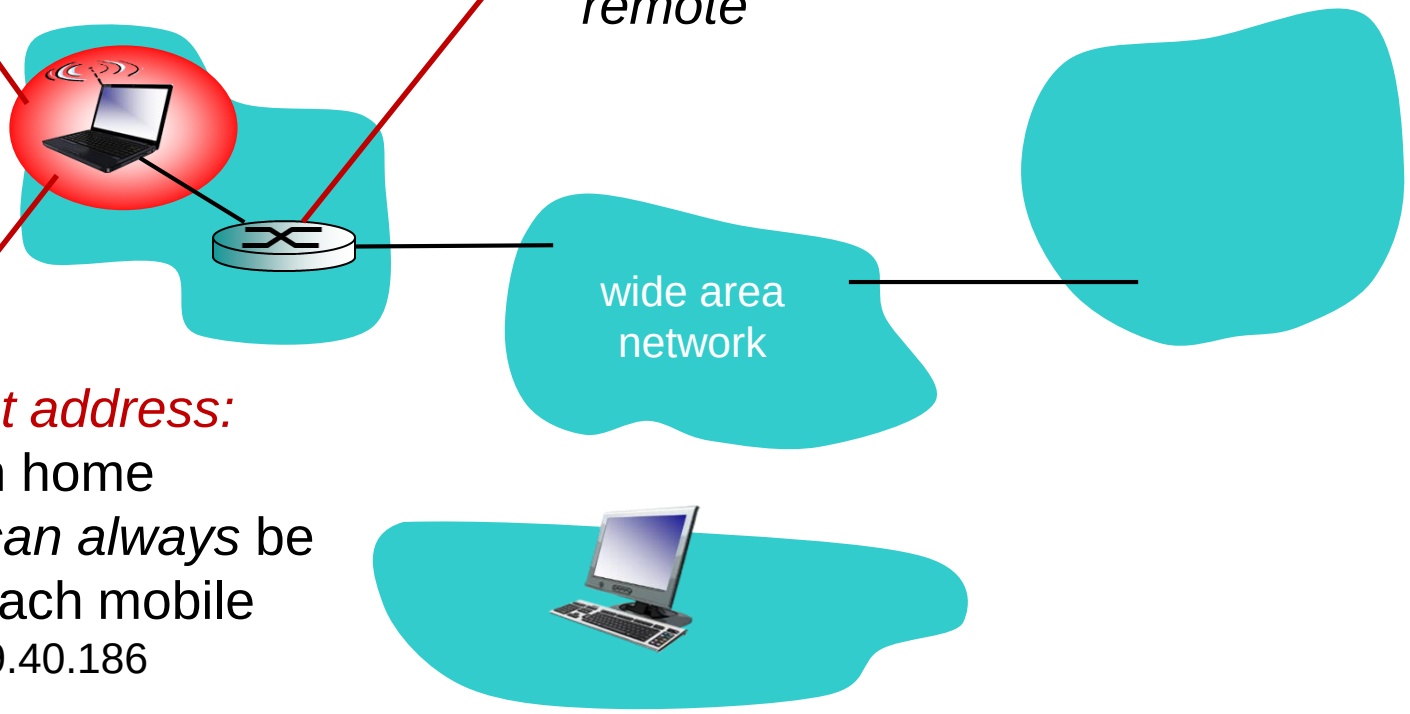
mobile user, connecting/ disconnecting from network using DHCP.

mobile user, passing through multiple access point while maintaining ongoing connections (like cell phone)

Mobility: vocabulary

home network: permanent "home" of mobile
(e.g., 128.119.40/24)

home agent: entity that will perform mobility functions on behalf of mobile, when mobile is remote



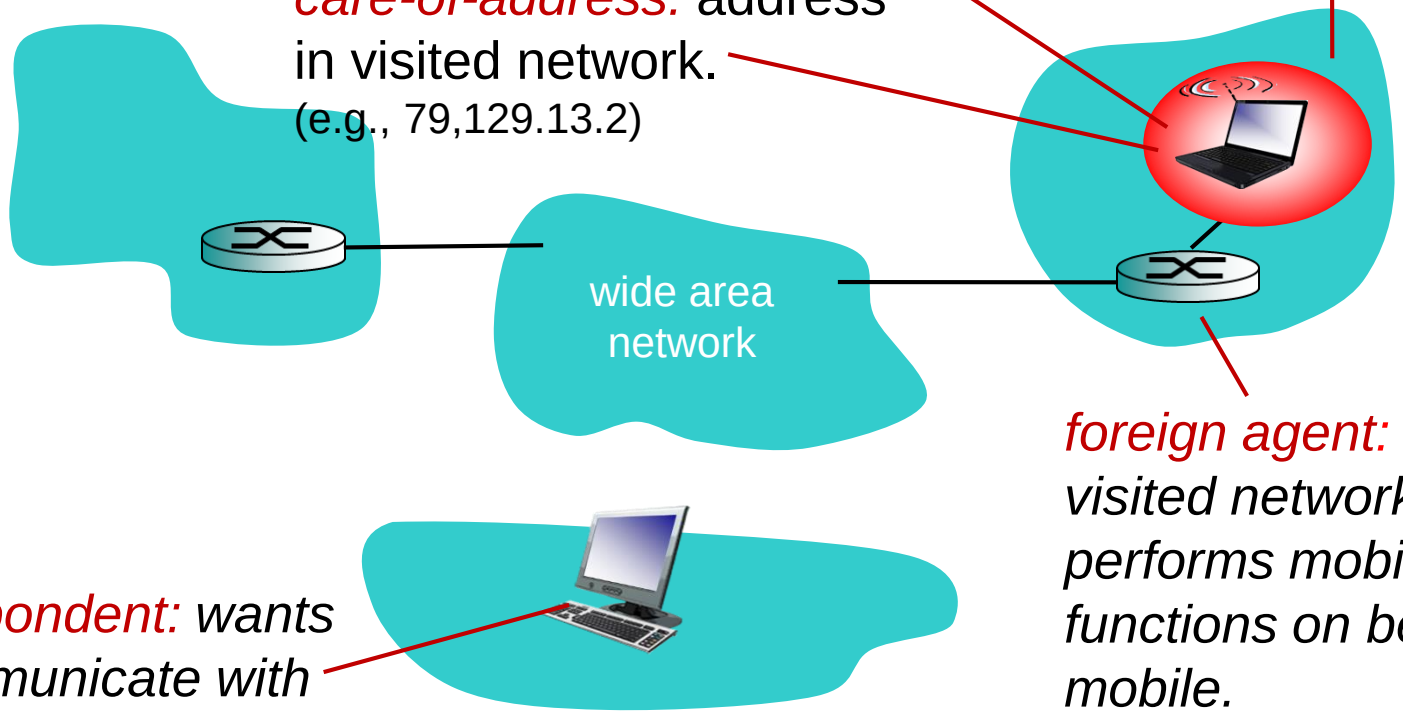
permanent address: address in home network, *can always* be used to reach mobile
e.g., 128.119.40.186

Mobility: more vocabulary

permanent address: remains constant (e.g., 128.119.40.186)

visited network: network in which mobile currently resides (e.g., 79.129.13/24)

care-of-address: address in visited network. (e.g., 79,129.13.2)



foreign agent: *entity in visited network that performs mobility functions on behalf of mobile.*

correspondent: *wants to communicate with mobile*

Wireless, mobility: impact on higher layer protocols

- logically, impact *should* be minimal …
  - best effort service model remains unchanged
  - TCP and UDP can (and do) run over wireless, mobile
- … but performance-wise:
  - packet loss/delay due to bit-errors (discarded packets, delays for link-layer retransmissions), and handoff
  - TCP interprets loss as congestion, will decrease congestion window un-necessarily
  - delay impairments for real-time traffic
  - limited bandwidth of wireless links

Chapter 6 summary

Wireless

- wireless links:
  - capacity, distance
  - channel impairments
  - CDMA
- IEEE 802.11 ("Wi-Fi")
  - CSMA/CA reflects wireless channel characteristics
- cellular access
  - architecture
  - standards (e.g., GSM, 3G, 4G LTE)

Mobility

- principles: addressing, routing to mobile users
- impact on higher-layer protocols