Mobile and Sensor Systems

Lecture 2: Mobile Medium Access Control Protocols and Wireless Systems

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In this lecture

- We will describe medium access control protocols and wireless systems (wifi networks, personal area networks, cellular networks)

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Wireless Link Characteristics

Differences from wired networks:

- *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.

These characteristics make communication across (even a point to point) wireless link much more "difficult" .

Wireless Medium as Shared Medium

- The access to the wireless needs to be shared among the various transmitters.
- How?
  - Multiplexing the medium:
    - Time (fixed or dynamic)
    - Space
    - Frequency
    - Code

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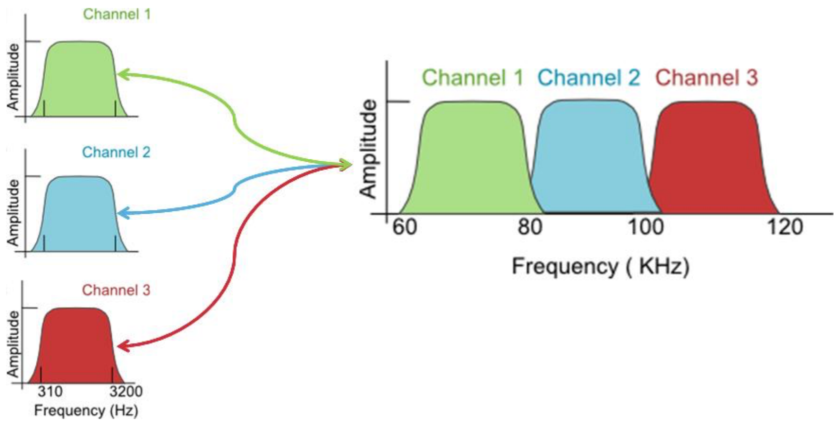
Multiplexing based Sharing

- FDMA (Frequency Division Multiple Access):
  - assign a certain frequency to a transmission channel between a sender and a receiver.
  - permanent (e.g., radio broadcast), slow hopping (e.g., GSM), fast hopping (FHSS, Frequency Hopping Spread Spectrum).



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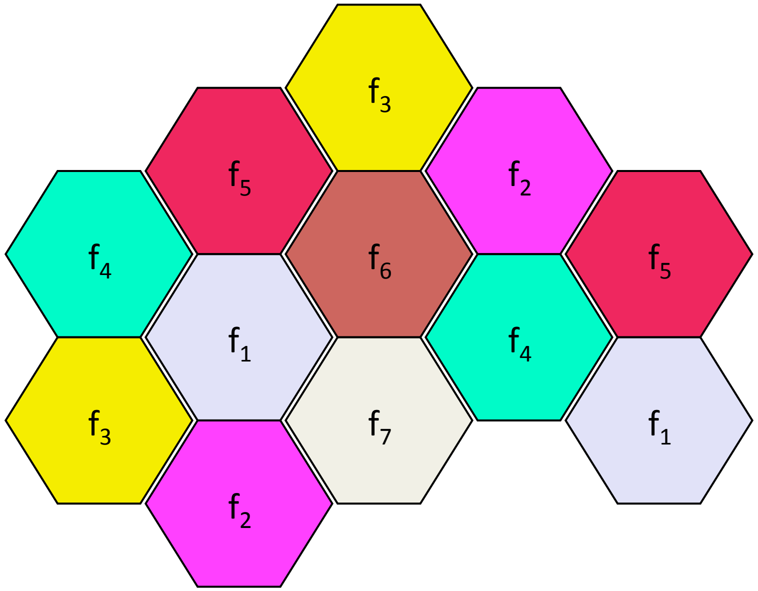
Multiplexing based Sharing

- SDMA (Space Division Multiple Access):
  - segment space into sectors, use directed antennas
  - cell structure



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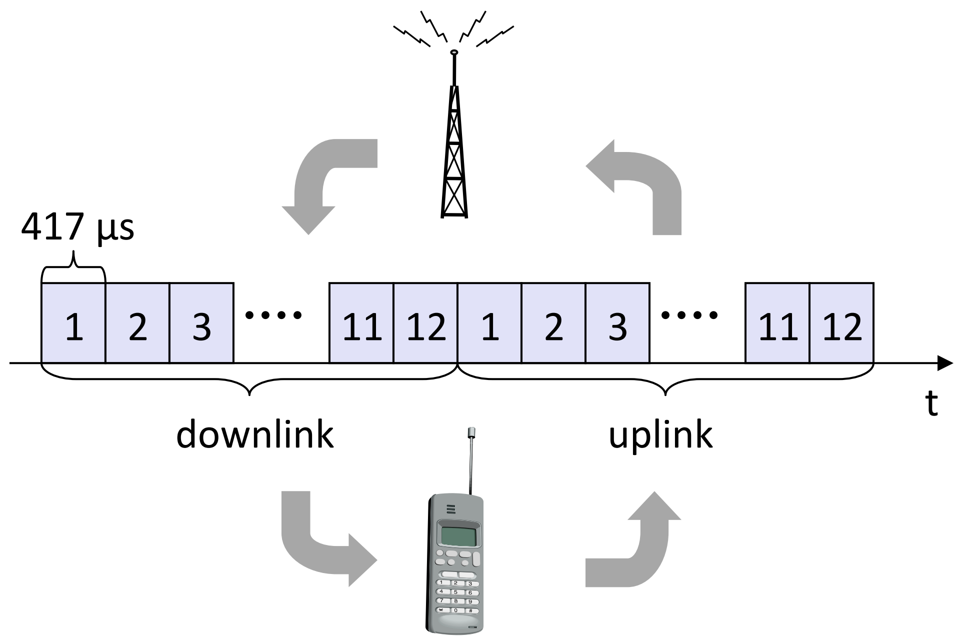
Multiplexing based Sharing

- TDMA (Time Division Multiple Access):
  - assign the fixed sending frequency to a transmission channel between a sender and a receiver for a certain amount of time.



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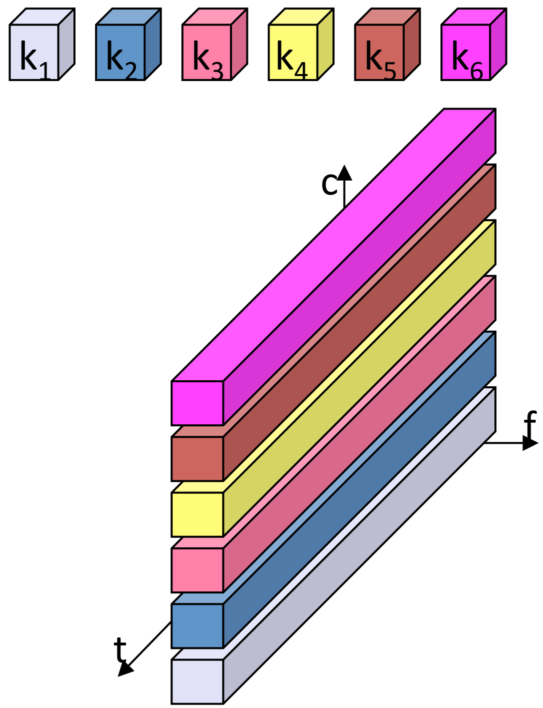
Multiplexing based Sharing

- CDMA (Code Division Multiple Access)
  - Assign a code to each sender so that all of a sender's transmissions is on a unique "dimension"



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Limitations of multiplexing

- Multiplexing is one way to share the medium through the definition of "channels".
- Once channels are established, packets will be sent through that:
  - Might be a bit rigid as a method; for example, frequency division multiplexing would have issues with large numbers of users.
  - Also depending on traffic and time some users might want to send more or less;
- More ad hoc approaches exist which allow channels to be shared in a "statistical" way.

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Review: Ethernet Medium Access Control (MAC)

- In Ethernet based fixed networks where you have wires between computers:
- CS (Carrier Sense): listen for others' transmissions before transmitting; defer to others you hear.
- CD (Collision Detection): as you transmit, listen and verify you hear exactly what you send; if not, back off random interval, within exponentially longer range each time you transmit unsuccessfully.

Can CD be applied on wireless networks?

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Can we apply the same MAC protocols in wireless?

- Problems in wireless networks:
  - signal strength decreases proportionally to the square of the distance;
  - the sender would apply CS and CD, but collisions happen at the receiver;
  - it might be the case that a sender cannot "hear" the collision, i.e., CD does not work;
  - furthermore, CS might not work if, e.g., a terminal is "hidden".

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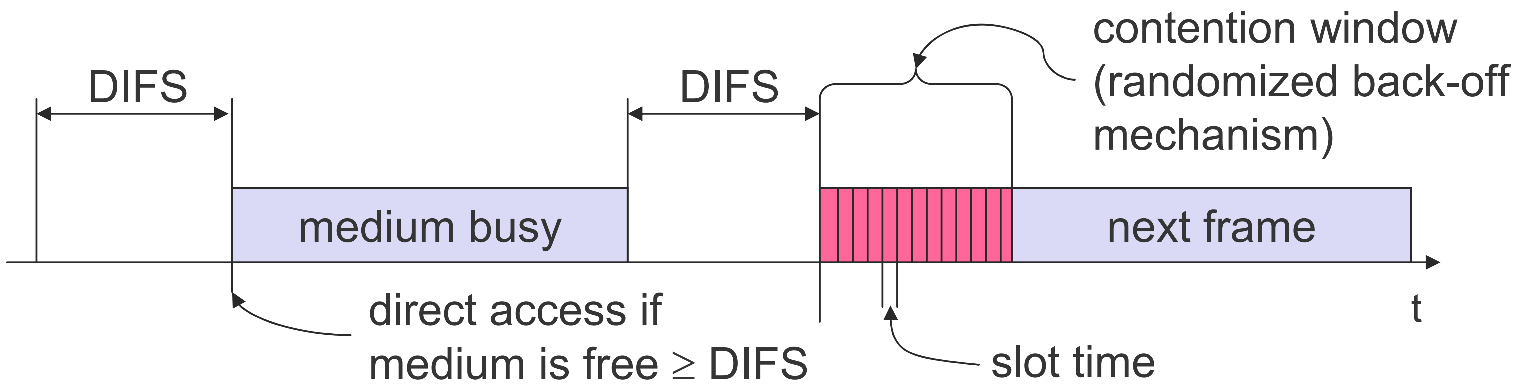
CSMA/CA: Carrier Sensing Multiple Access Protocol with Collision Avoidance



CSMA/CA: sense medium. If free transmit (although this might generate collision at the receiver). If not, wait with a back off strategy. Transmit when medium is sensed free.

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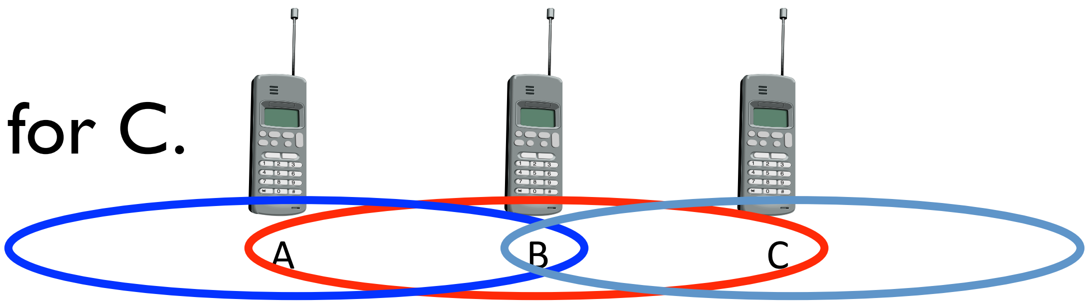
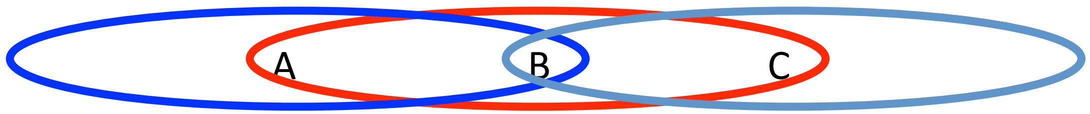
Hidden Terminal

- Hidden terminals:
  - A sends to B, C cannot receive from A.
  - C wants to send to B, C senses a "free" medium (CS fails).
  - Collision at B, A cannot receive the collision (CD fails).
  - A is "hidden" for C.



Exposed Terminal

- Exposed terminals:
  - B sends to A, C wants to send to another terminal (not A or B).
  - C has to wait, CS signals a medium in use.
  - but A is outside the radio range of C, therefore waiting is not necessary.
  - C is "exposed" to B.



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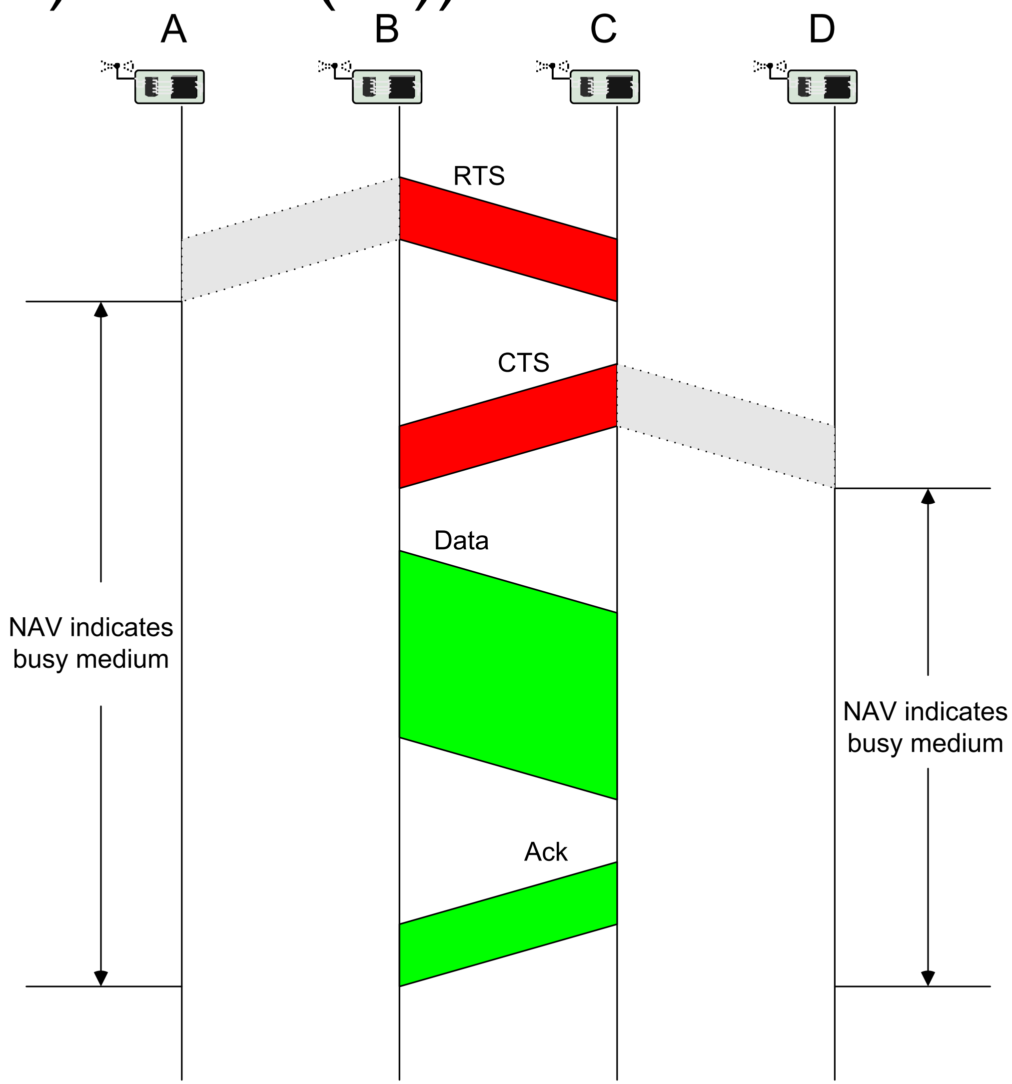
Multiple Access with Collision Avoidance (for Wireless): MACA(W))

- Sender B asks receiver C whether C is able to receive a transmission ***Request to Send (RTS).***
- Receiver C agrees, sends out a ***Clear to Send*** (***CTS***).
- Potential interferers overhear either RTS or CTS and know about impending transmission and for how long it will last.
  - Store this information in a ***Network Allocation Vector.***
- B sends, C acks:

! ***MACA(W) protocol*** (used e.g. in ***IEEE 802.11***).



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MACA(W)

- Absent CTS, sender backs off exponentially before retrying.
- RTS and CTS can still themselves collide at their receivers; less chance as they're short.

- **What's the effect on exposed terminal problem?**

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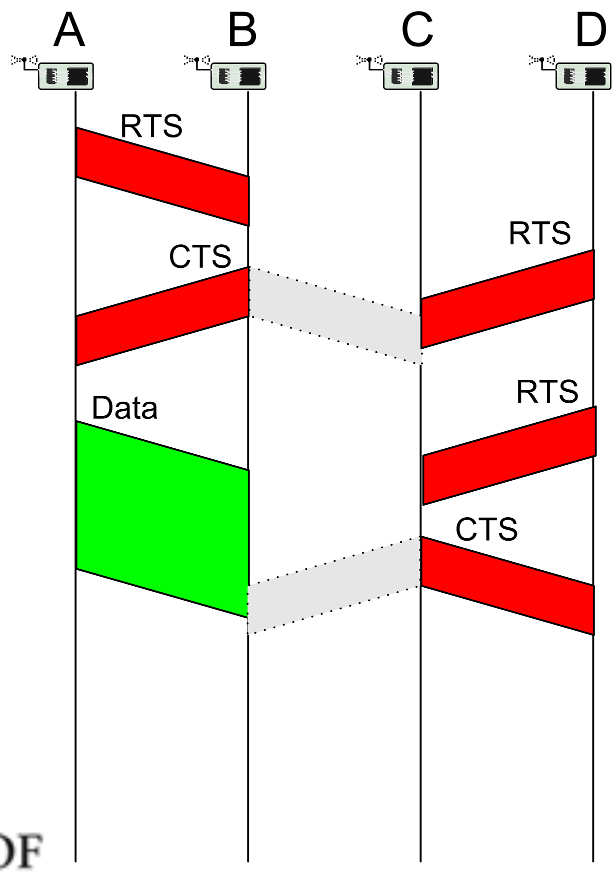
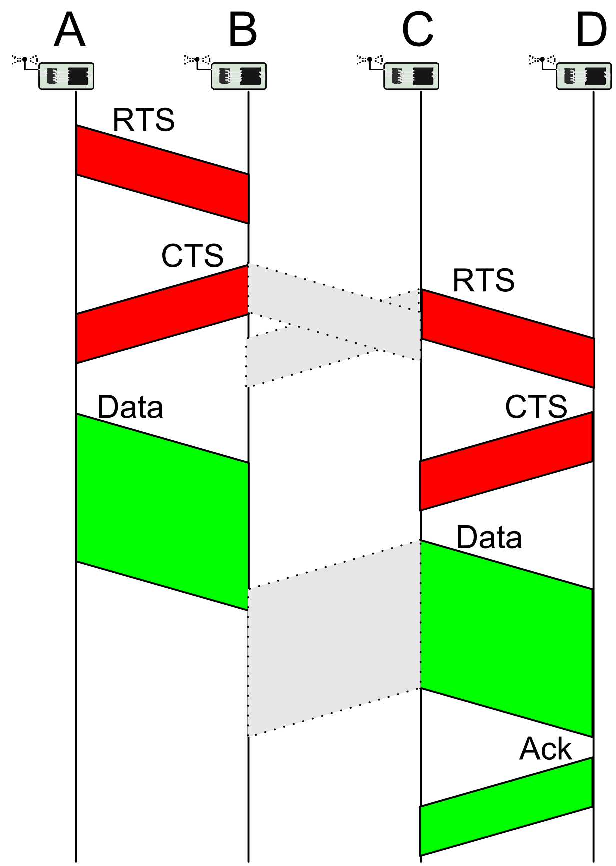
RTS/CTS

- RTS/CTS ameliorate, but do not solve hidden/exposed terminal problems.
- Example problem cases:





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The 802.11 Protocol

- 802.11 uses 2 modes of operation: a basic CSMA/CA (in base station mode) and the RTS/CTS mode.
- Generally 802.11 drivers leave the RTS/CTS off by default.
- Also tests in practice show that hidden terminal might not be a problem in most cases as interference range is more than double communication range. Consider A->B<-C when A transmits it is very likely C can sense A's carrier directly.

IEEE 802.11 Wireless LAN

- 802.11b
  - 2.4-5 GHz unlicensed spectrum
  - up to 11 Mbps
- 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 have base-station and ad-hoc network versions

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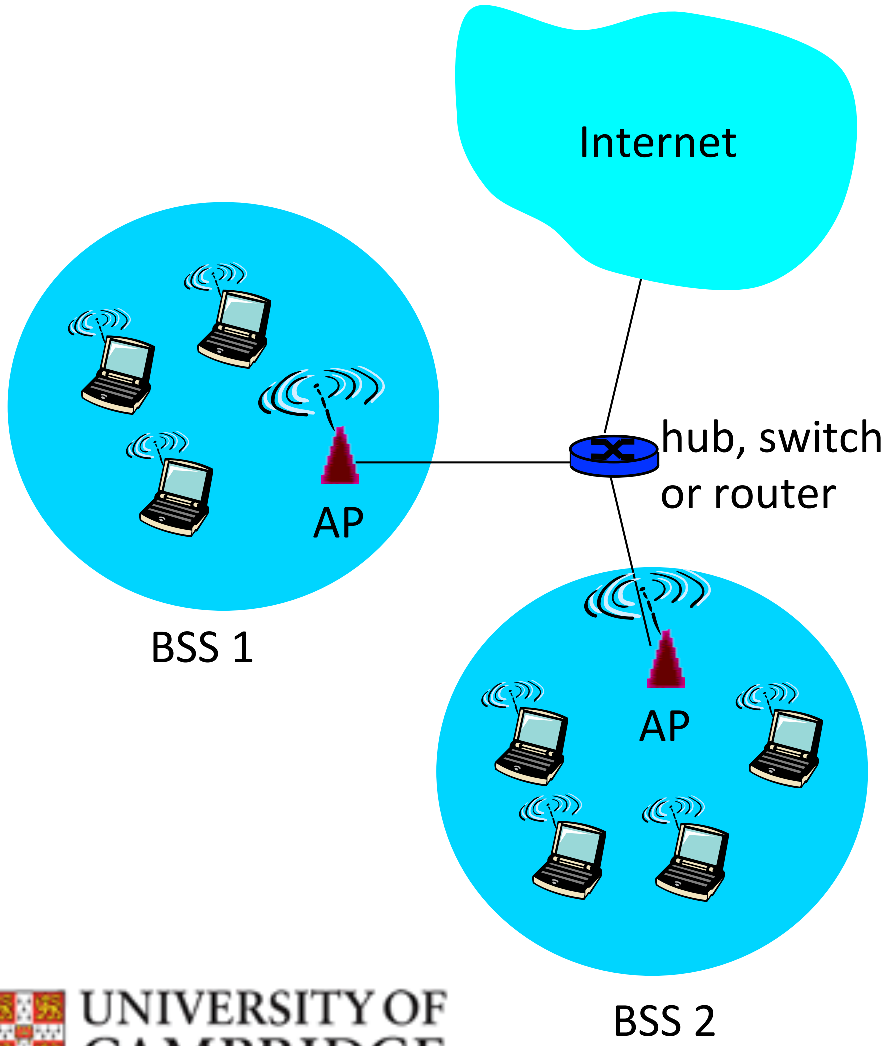
802.11 LAN Architecture



- 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

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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.
  - will typically run DHCP to get IP address in AP's subnet.

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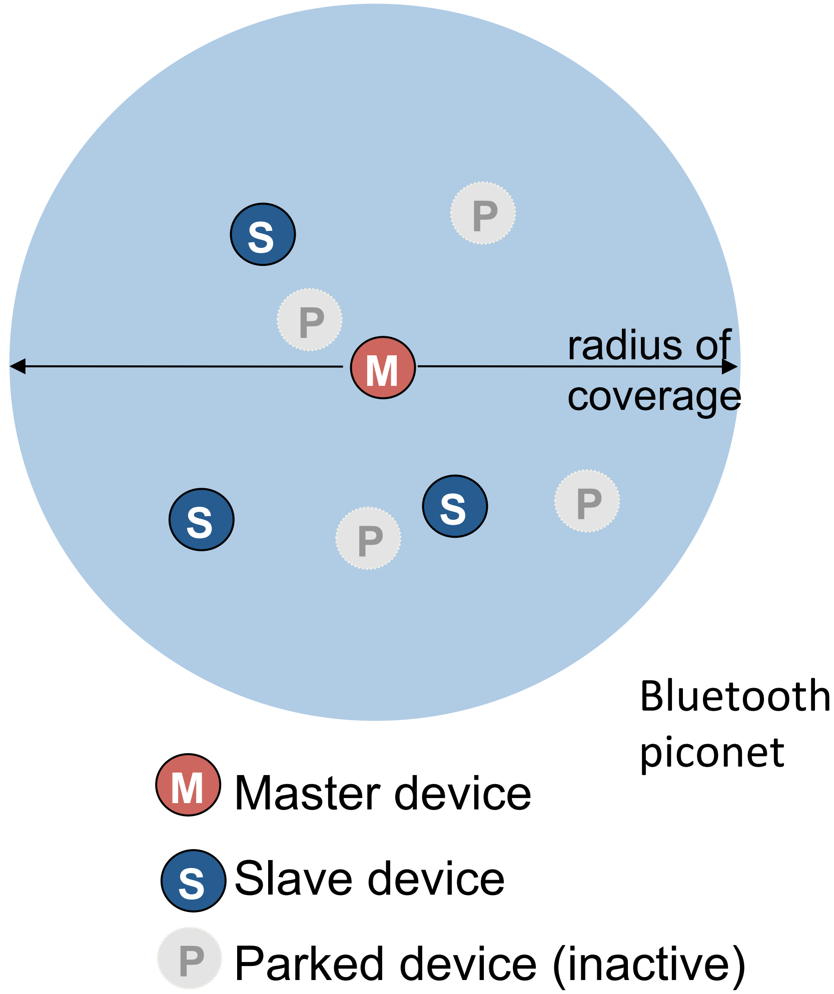
802.15: Personal Area Networks

- Less than 10m diameter.
- Ad hoc: no infrastructure.
- Master/slaves architecture:
  - slaves request permission to send (to master).
  - master grants requests.
- 802.15: evolved from Bluetooth specification.



Bluetooth and Zigbee

- Two main short-range technologies:
  - Bluetooth (802.15.1)
  - Zigbee (802.15.4)
- Bluetooth provides a "cable replacement" data rate of over a Megabit per second.
- Zigbee is targeted at lower-powered, lower-data-rate, lower-duty-cycle applications:
  - Environmental sensors
  - Security devices
  - Wall-mounted devices
  - …

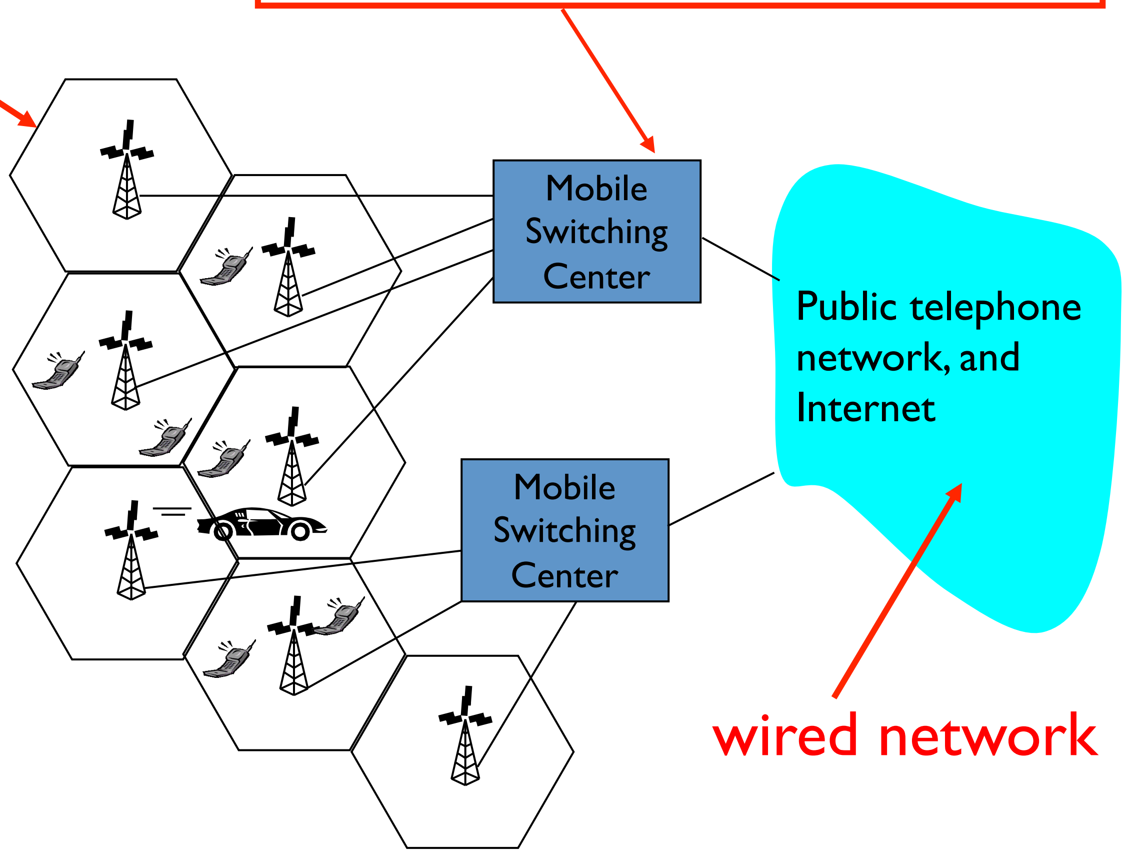
Components of cellular network architecture

MSC

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

cell

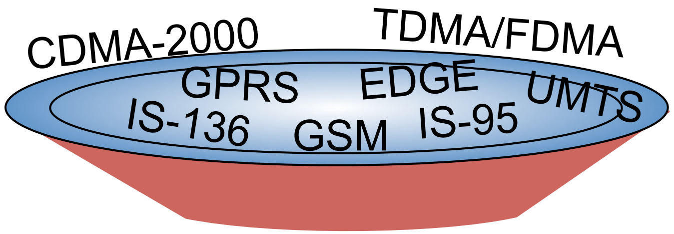
- covers geographical region
- *base station* (BS) analogous to 802.11 AP
- *mobile users* attach to network through BS
- *air-interface:* physical and link layer protocol between mobile and BS



Cellular standards: brief survey

2G systems: voice channels

- IS-136 TDMA: combined FDMA/TDMA (North America)
- GSM (global system for mobile communications): combined FDMA/TDMA
  - most widely deployed
- IS-95 CDMA: code division multiple access



Don't drown in a bowl of alphabet soup: use this for reference only

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Cellular standards: brief survey

2.5 G systems: voice and data channels

ie extends 2G for Internet usage without touching the core.

- 2G extensions
  - general packet radio service (GPRS)
    - evolved from GSM
    - IP datagrams carrying FDM/TDM channels are forwarded to a Serving GPRS Support Node (SGSN) instead of the MSC and then on to the Internet
  - enhanced data rates for global evolution (EDGE)
    - also evolved from GSM, using enhanced modulation
    - data rates up to 384K

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Cellular standards: brief survey

3G systems: voice/data

- Universal Mobile Telecommunications Service (UMTS)

  – It uses CDMA on TDMA slots available on multiple frequencies.

    - data service: High Speed Uplink/Downlink packet Access (HSDPA/HSUPA) up to 14 Mbps

Handling mobility in cellular networks

- *home network:* network of cellular provider you subscribe to (e.g.,Vodafone, O2, etc.)
  - *home location register (HLR):* database in home network containing permanent cell phone #, profile information (services, preferences, billing), information about current location (could be in another network)
- *visited network:* network in which mobile currently resides
  - *visitor location register (VLR):* database with entry for each user currently in network

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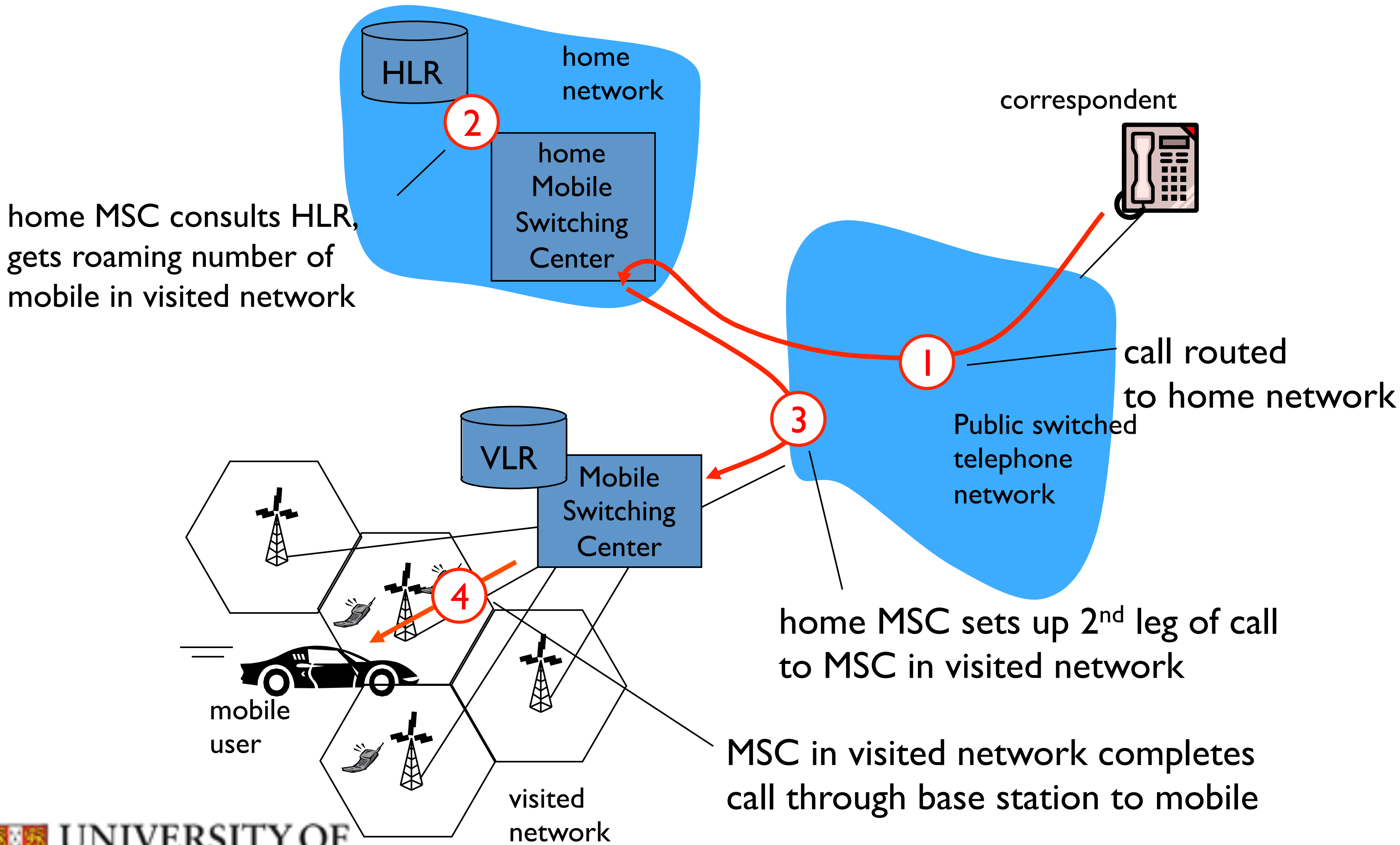
GSM: Indirect Routing to Mobile



3G Networks

- 3G core network connects radio access networks to the public Internet.
- Given the considerable amount of existing infrastructure, the approach taken by the designers of 3G data services was to leave the existing core GSM cellular network untouched.
- Cellular data functionality was added in parallel to the existing cellular network.

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LTE-4G Networks

- Currently being deployed around the world.
- Main differences with 3G are in the network core (“all-IP network” for voice and data) and radio access.
- The maximum data rate for LTE (long-term evolution) is 100 Mbps in the downstream direction and 50 Mbps in the upstream direction, when using 20 MHz worth of wireless spectrum.

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WiMAX

- An additional 4G wireless technology is WiMAX (which stands for World Interoperability for Microwave Access).
- LTE has significant more momentum.

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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.

Reference

- Chapter 6 of James F. Kurose and Keith W. Ross. Computer Networking. A Top Down Approach 6th Edition Pearson 2012.
- Schiller, J. (2003). Mobile communications. Pearson (2nd ed.).

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