Washington University in St. Louis

Engineering

23. Managing Mobility in Wireless Networks

- Basic Issues
- Mobile IP
- Cell Phone Networks
- Mobility in GSM

Jon Turner – based on slides from Kurose & Ross

Levels of Mobility

- Stationary mobile device
  - » connects from different locations but does not move while communication is in progress
  - » "client-only" operation just requires DHCP
  - » to allow others to "reach you" at any location, need mechanism for them to learn your current location
    - mobile IP handles this by "forwarding your calls" from home net
    - application-specific solutions such as SIP registration also an option
- Moving mobile
  - » requires mechanism to disconnect from one wireless access point and connect to another as needed (handoff)
  - » speed of movement, wireless communication range are key factors when engineering solutions
    - WIFI networks with small cells and walking users
    - cell phone networks with large cells (10 km) and driving users

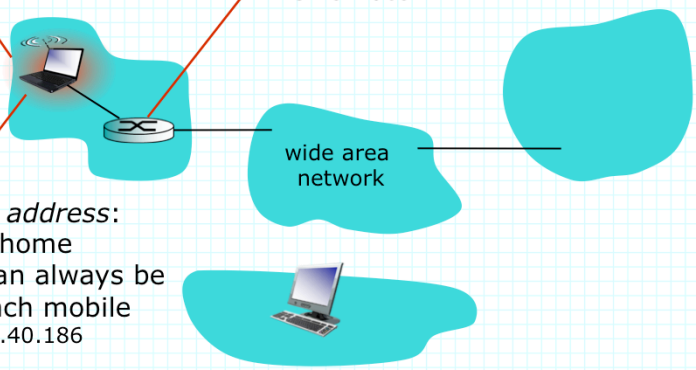
Mobile IP (RFC 3344)

- Key elements
  - » home agents, foreign agents
  - » foreign-agent registration
  - » care-of-addresses
  - » encapsulation (packet-within-a-packet)
- Three components to standard:
  - » indirect routing of datagrams
  - » agent discovery
  - » registration with home agent
- Mainly intended for communicating from different locations, not for communicating while in motion
- Requires support for permanent, globally routable IP addresses from host-to-host

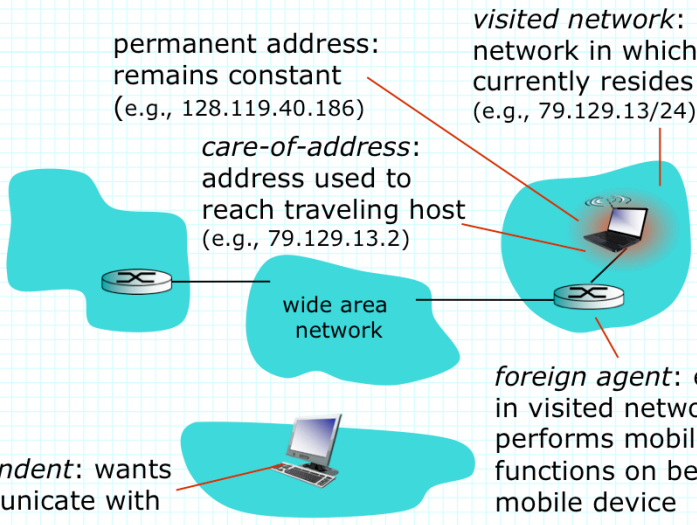
Mobile IP Terminology

home network:permanent "home" of mobile device (e.g., 128.119.40.0/24)

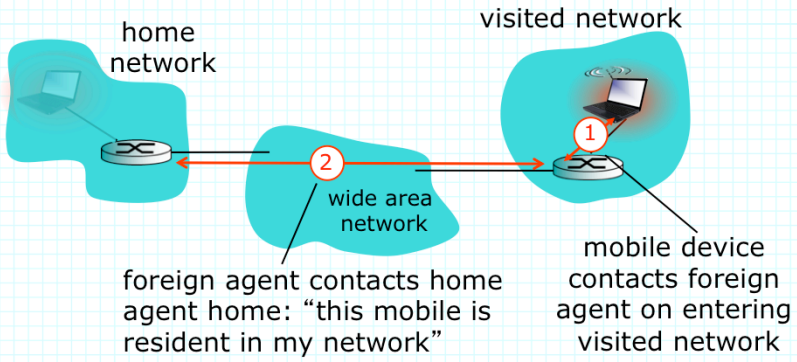
home agent: entity that will perform mobility functions on behalf of mobile, when mobile is remote



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

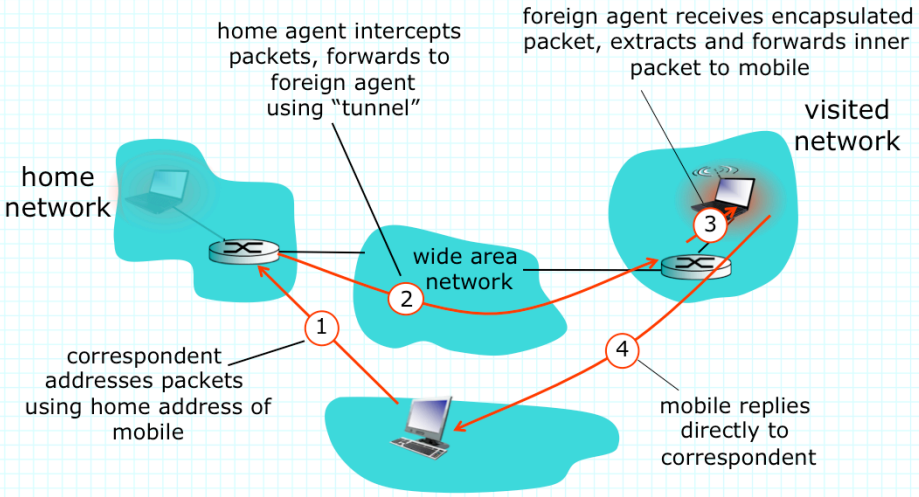

permanent address:
remains constant
(e.g., 128.119.40.186)
visited network:
network in which mobile
currently resides
(e.g., 79.129.13/24)
care-of-address:
address used to
reach traveling host
(e.g., 79.129.13.2)
wide area
network
foreign agent: entity
in visited network that
performs mobility
functions on behalf of
mobile device
correspondent: wants
to communicate with
mobile

Registration

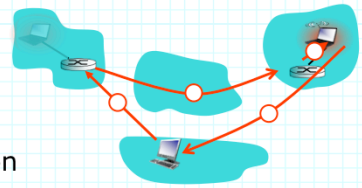


- End result:
  - » foreign agent knows about mobile
  - » home agent knows location of mobile

Mobility Via Indirect Routing



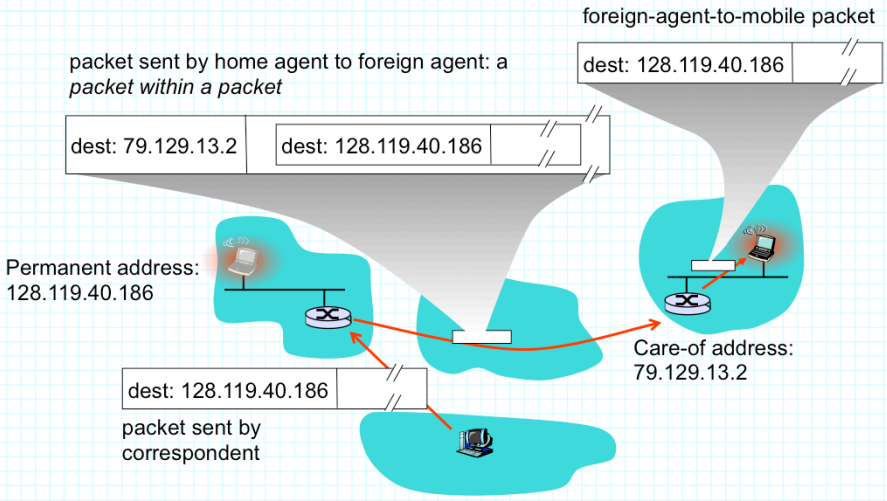
Indirect Routing Observations



- Mobile uses two addresses:
  - » permanent address: used by correspondent (hence mobile location is *transparent* to correspondent)
  - » care-of-address: used by home agent to forward datagrams to foreign agent
  - » correspondent sees only permanent address
- Foreign agent functions may be done by mobile itself
  - » if no foreign agent detected, acquire local address via DHCP and use this as care-of-address
  - » register care-of-address with home agent
- Triangle routing: correspondent-home-network-mobile
  - » less efficient than direct routing

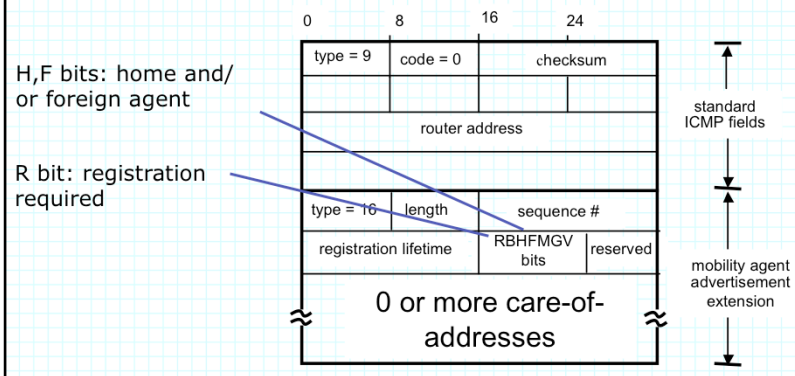
8

Mobile IP: Indirect Routing

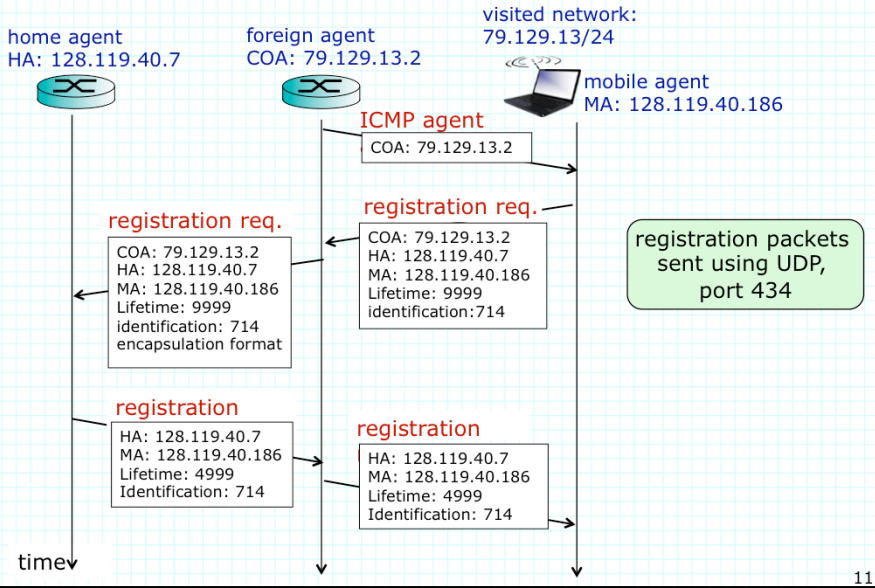


Mobile IP: Agent Discovery

- *Agent advertisement:* foreign/home agents advertise service by broadcasting ICMP messages (type field=9)



Mobile IP: Registration Example



11

Obstacles to Mobile IP Deployment

- Requires widespread support in access routers
  - » to serve as home agents and foreign agents
- Requires support in most widely used operating systems
  - » IOS, Android, Windows, Linux
- Shortage of IPv4 addresses
  - » mobile IP nodes need permanent, public IP addresses
    - not directly compatible with common usage of NAT
  - » need IPv6 before large-scale deployment of mobile IP
- Competing solutions to mobility problem
  - » DHCP, SIP, Skype for "stationary mobile"
- Chicken-and-egg problem
  - » little motivation to use it until there are apps that require it
- Potential for cell phone carriers to support it

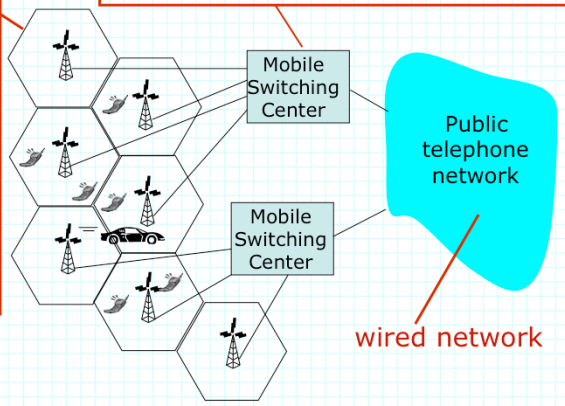
Beyond Stationary Mobile

- Mobility within 802.11 networks
  - » moving device can disconnect from one AP, connect to another
    - MAC address remains the same; switches learn new location
  - » if both APs in same IP subnet, no need to change IP address
    - so ongoing TCP sessions not affected
- Moving mobile IP hosts
  - » moving host detects and registers with new foreign agent after connecting to new AP
  - » new foreign agent registers with home network which starts forwarding packets through new foreign agent
- Mobility in cell phone networks
  - » cell phone networks engineered for rapid mobility
  - » large cells reduce frequency of handoffs
    - also, more powerful radios and use of licensed spectrum
    - but, smaller cells required in densely populated areas

Cellular Network Architecture

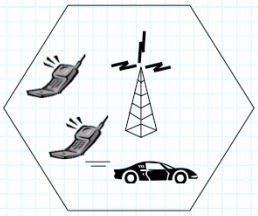
MSC
- connects cells to wired tel. net.
- manages call setup
- handles mobility
- can cover large area (whole city)

cell
- covers geographical region (≈10 km)
- *base station* (BS) analogous to WIFI AP
- *mobile users* attach to network thru BS
- *air-interface:* link and physical layer protocol between mobile and BS



Cellular Networks: the First Hop

- Two techniques for sharing mobile-to-BS radio spectrum
  - » CDMA: code division multiple access
  - » combined FDMA/TDMA
    - divide spectrum in frequency channels
    - divide each channel into time slots
  - » mobile devices communicate over assigned channels



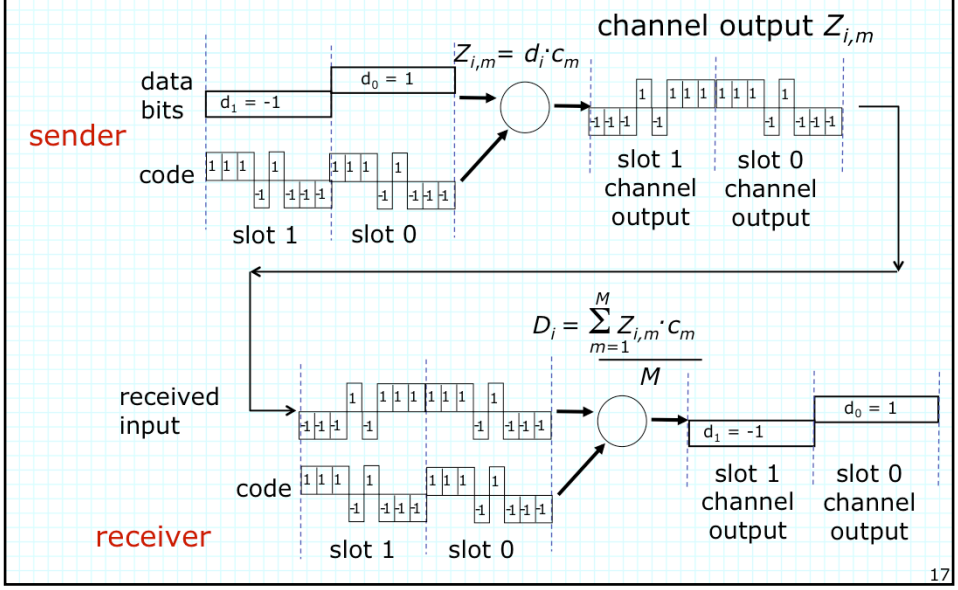
- Why not contention-based methods like CSMA/CA?
  - » poor fit for cell-phone environment
    - many users and large cells (e.g. 10 km across) would require high bandwidth and frequent contention
    - CSMA is inefficient unless packet transmission time is much larger than signal propagation time
  - » more susceptible to noise/interference

Code Division Multiple Access (CDMA)

- Unique "code" assigned to each user; i.e., code set partitioning
  - » all users share same frequency, but each user may have 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:* take inner-product of encoded signal and chipping sequence
- Some systems use same chipping sequence for all users
  - » means only one sender at a time
  - » still useful, because more robust to interference than direct modulation

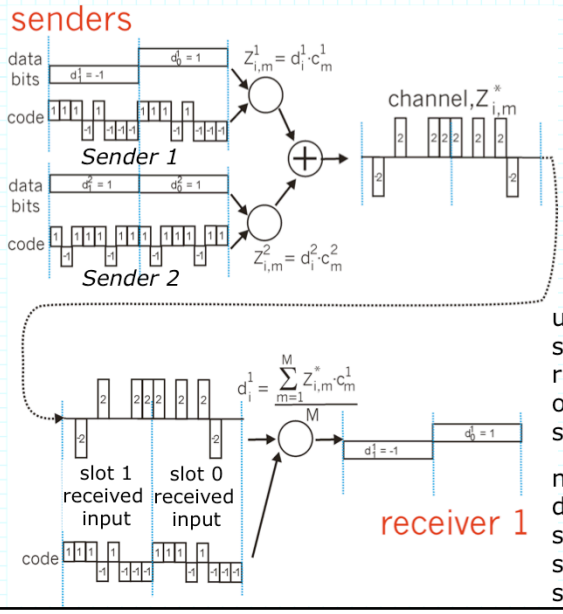
16

CDMA Encode/Decode



17

CDMA with Two Senders



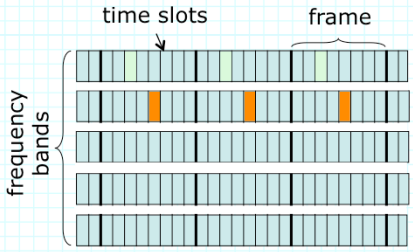
channel sums together transmissions by sender 1 and 2

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

note: can correctly determine transmitted bits so long as competing signal does not change sign of received values

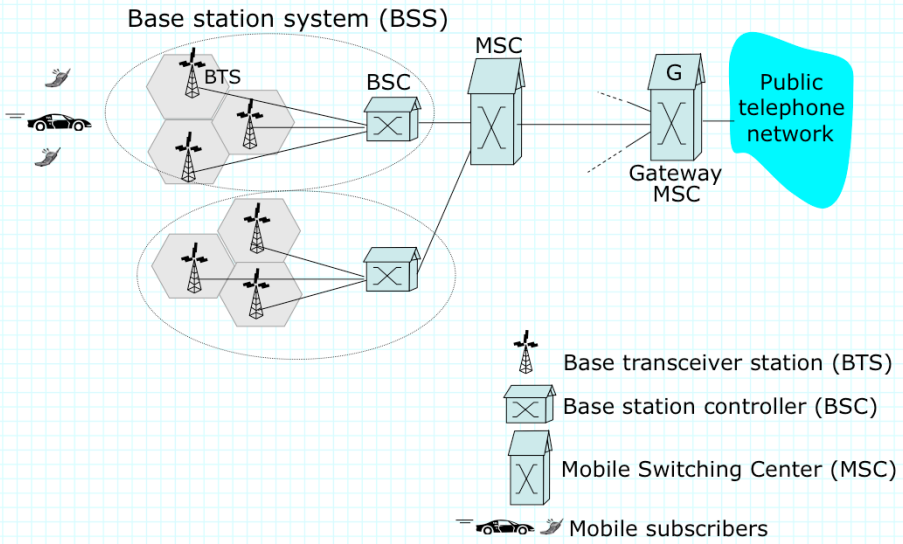
FDMA/TDMA

- FDMA
  - » separate radio frequency bands
  - » "tune-in" to selected band
- TDMA
  - » repeating pattern of timeslots
  - » mobile device uses assigned timeslot in each frame
  - » requires synchronization with precision that is small fraction of time slot duration (<10%)



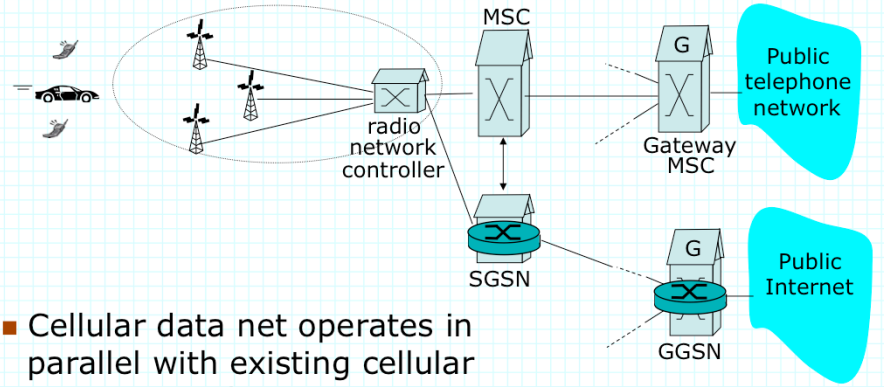
- Channel assignment controlled by cellular network
  - » devices request access using a special control channel
    - contention for control channel can lead to collisions, but because channel rates are limited, acceptable efficiency is possible
  - » devices may be assigned multiple channels to enable higher data rates

2G (Voice) Network Architecture



Washington University in St. Louis | Engineering

3G Voice/Data Network Architecture



- Cellular data net operates in parallel with existing cellular voice network
  - » only wireless access is shared
  - » voice network unchanged in core

Serving GPRS Support Node (SGSN)

Gateway GPRS Support Node (GGSN)

21

4G Long-Term Evolution (LTE)

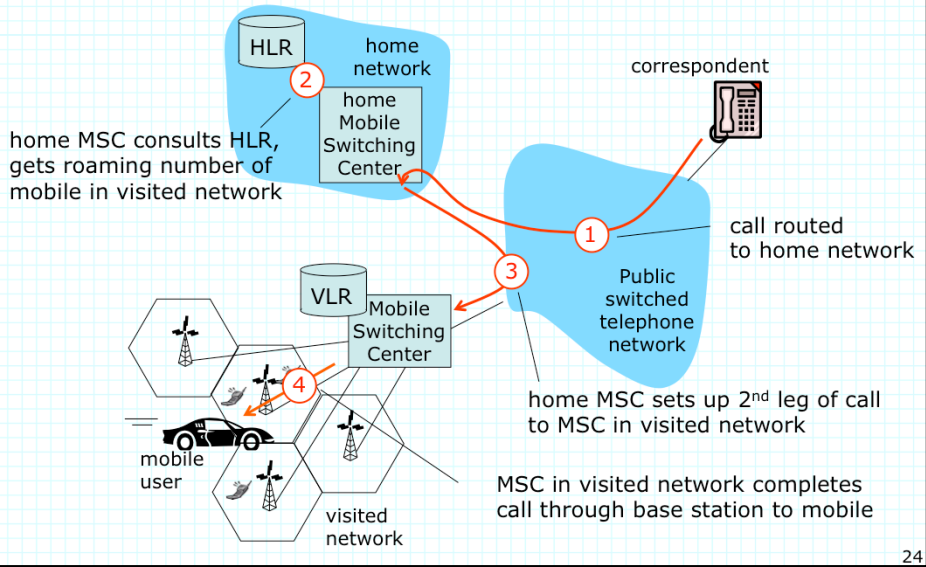
- Evolved Packet Core (EPC)
  - » objective is to transition to all IP network using standard IETF protocols (SIP, RTP, etc.)
  - » special handling of voice calls to ensure low delay
    - separate high priority queues; possibly explicit reservation
- LTE Radio Access
  - » increases data rates
    - users can achieve up to 100 Mb/s downstream, 50 Mbp/s upstream when using 20 MHz of radio spectrum
  - » uses combination of FDM and TDM
    - users allocated multiple timeslots across multiple frequencies – may change dynamically based on traffic
  - » also uses MIMO (multiple-input, multiple-output) antennas
    - signals sent over multiple antennas, received on multiple antennas
    - allows application of more sophisticated signal processing

22

Handling Mobility in Cellular Networks

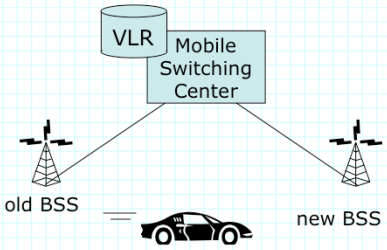
- *Home network*: network of cellular provider you subscribe to (e.g., Sprint PCS, Verizon)
  - » *home location register* (*HLR*): database in home network containing permanent cell phone #, profile information (services, preferences, billing), information about current location (could be in another network)
- *Visited network*: network in which mobile currently resides
  - » *visitor location register* (*VLR*)*:* database with entry for each user currently in network
  - » note: mobile could be away from home location, but still within the home network

Indirect Routing to Mobile



Handoff with Common MSC

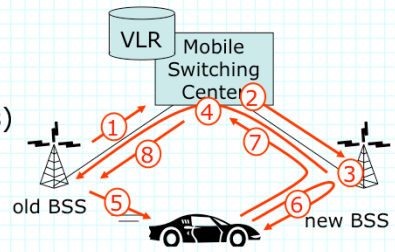
- Handoff goal
  - » route call via new base station (without interruption)
- Reasons for handoff
  - » stronger signal to/from new BSS (continuing connectivity, less battery drain)
  - » load balance: free up channel in current BSS
  - » network operator sets policies that control when handoff occurs
- Handoff initiated by old BSS



Handoff Details

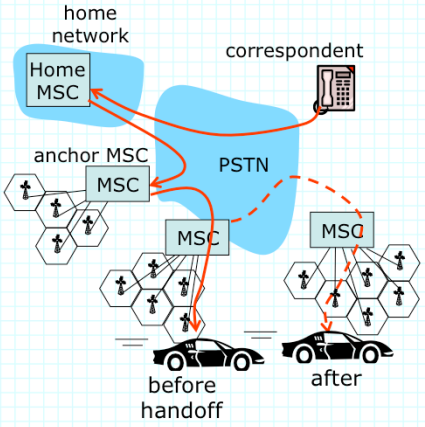
1. Old BSS informs MSC of impending handoff, provides list of possible new BSSs
2. MSC sets up path (allocates resources) to new BSS
3. New BSS allocates radio channel for use by mobile
4. New BSS signals MSC, old BSS when ready
5. Old BSS tells mobile to perform handoff to new BSS
6. Mobile, new BSS signal to activate new channel
7. Mobile informs MSC via new MSS when handoff complete and MSC re-routes call

8 MSC-old-BSS resources released



GSM: Handoff Between MSCs

- Anchor MSC: first MSC visited during call
  - » call remains routed through anchor MSC
- New MSCs add on to end of MSC chain as mobile moves to new MSC
  - » occurs infrequently as MSCs generally cover large area
  - » optional path minimization step to shorten multi-MSC chain



Mobility and Higher Layer Protocols

- Logically, impact of mobility *should* be minimal …
  - » for IP, best effort service model remains unchanged
  - » TCP and UDP can (and do) run over wireless, mobile
    - for TCP, address used by mobile device must not change while connection is active
    - mobile IP can maintain TCP connections of mobile devices if access networks support it
- Performance issues in wireless networks
  - » 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 unnecessarily
  - » delay impairments for real-time traffic
  - » limited bandwidth of wireless links

28