# Unit 5
# Advanced Mobile Networks

6GZ71004 ADVANCED COMPUTER NETWORKS & OPERATING SYSTEMS

DR MOHAMMAD HAMMOUDEH

# Unit Outline

Introduction

Wireless

Wireless links, characteristics
- CDMA

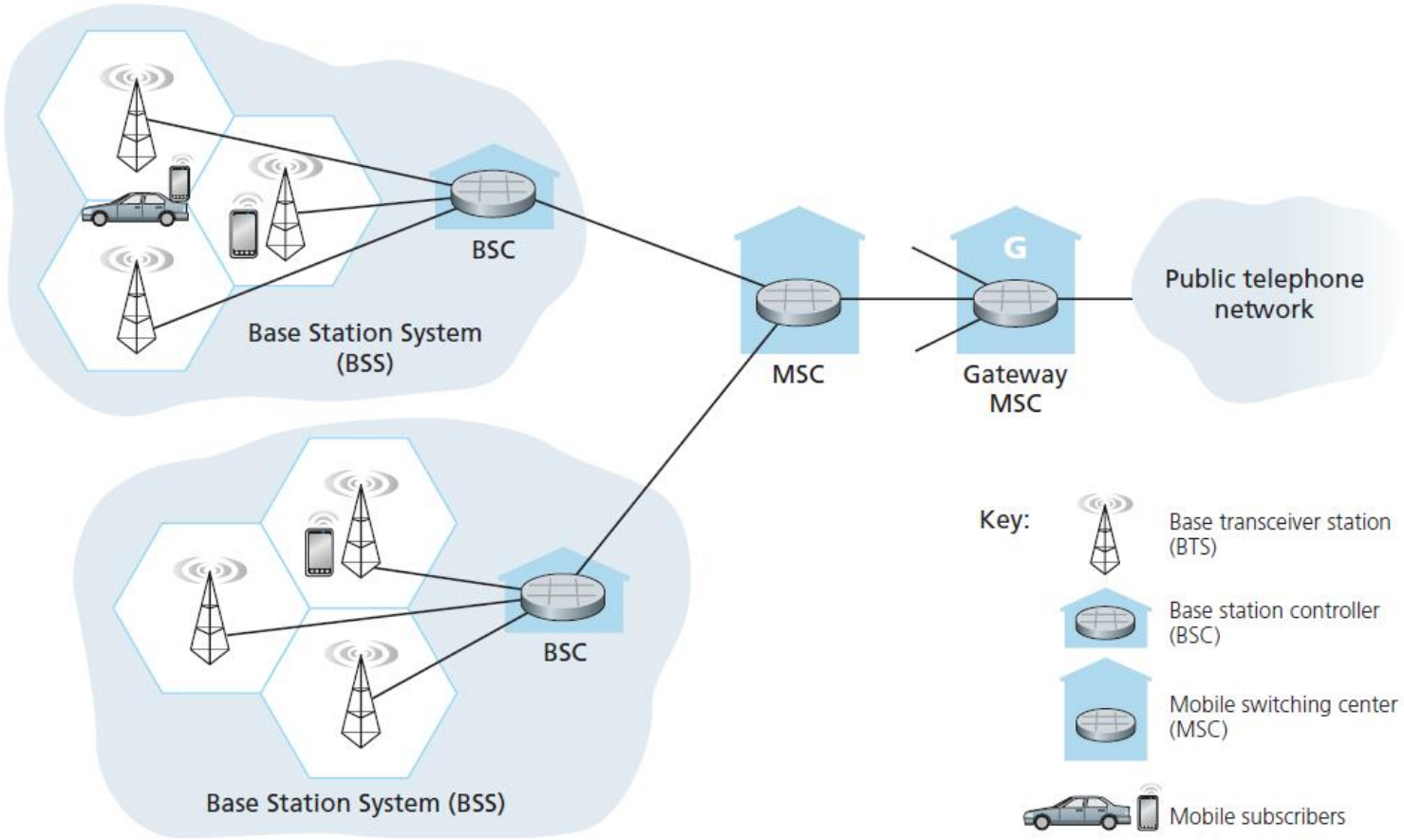
IEEE 802.11 wireless LANs ("wi-fi")

Cellular Internet Access
- architecture
- standards (e.g., GSM)

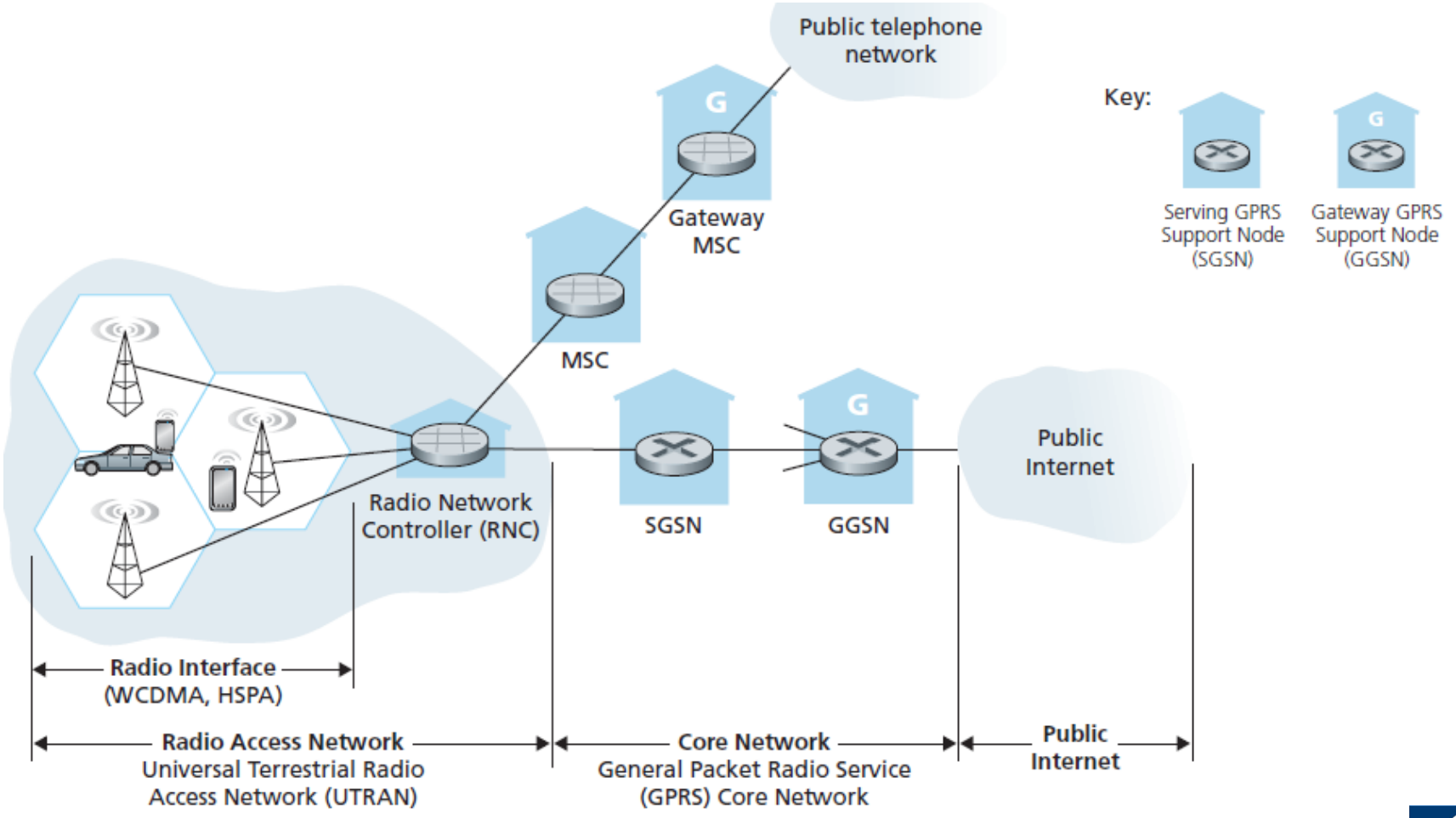
Mobility
- Principles: addressing and routing to mobile users
- Mobile IP
- Handling mobility in cellular networks
- Mobility and higher-layer protocols

Summary

# Components of cellular network architecture



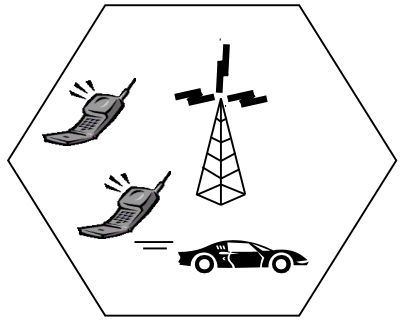
# 3G Cellular Data Networks: Extending the Internet to Cellular Subscribers

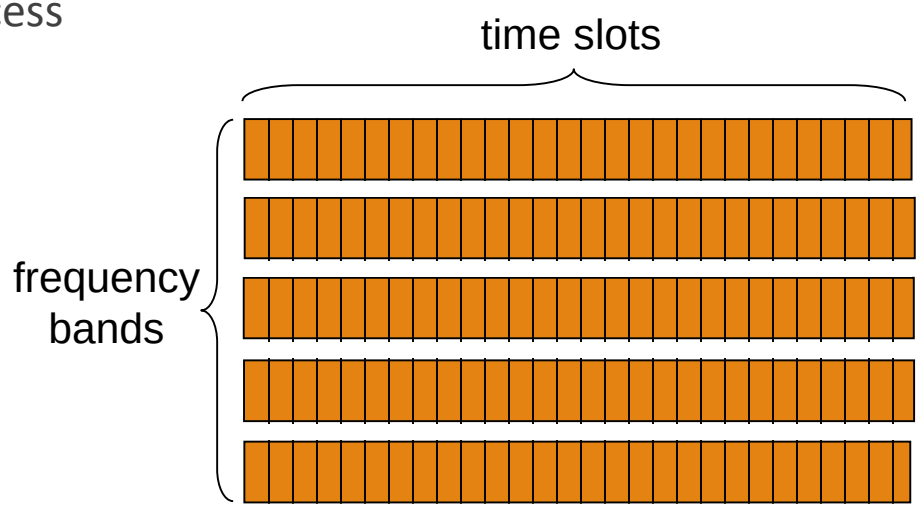


# Cellular networks: the first hop

Two techniques for sharing mobile-to-BS radio spectrum

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

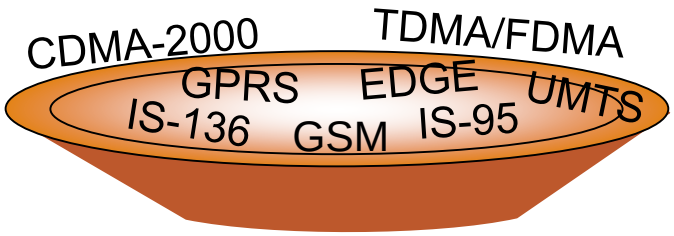




# Cellular standards: brief survey

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



# Cellular standards: brief survey

2.5 G systems: voice and data channels

- for those who can't wait for 3G service: 2G extensions
- general packet radio service (GPRS)
  - evolved from GSM
  - data sent on multiple channels (if available)
- enhanced data rates for global evolution (EDGE)
  - also evolved from GSM, using enhanced modulation
  - data rates up to 384K
- CDMA-2000 (phase 1)
  - data rates up to 144K
  - evolved from IS-95

# Cellular standards: brief survey

3G systems: voice/data

- Universal Mobile Telecommunications Service (UMTS)
  - data service: High Speed Uplink/Downlink packet Access (HSDPA/HSUPA): 3 Mbps
- CDMA-2000: CDMA in TDMA slots
  - data service: 1xEvolution Data Optimized (1xEVDO)  up to 14 Mbps

# Cellular standards: brief survey

## 4G: LTE

- Evolved Packet Core (EPC): unifies the separate circuit-switched cellular
  - voice network and the packet-switched cellular data network
  - it is an “all-IP” network in that both voice and data will be carried in IP datagrams.
- LTE Radio Access Network.: LTE uses a combination of FDM and TDM on the downstream channel, known as orthogonal frequency division multiplexing (OFDM)
  - each active mobile node is allocated one or more $0.5\ ms$ time slots in one or more of the channel frequencies
  - multiple-input, multiple output (MIMO) antennas
  - maximum data rate for an LTE user 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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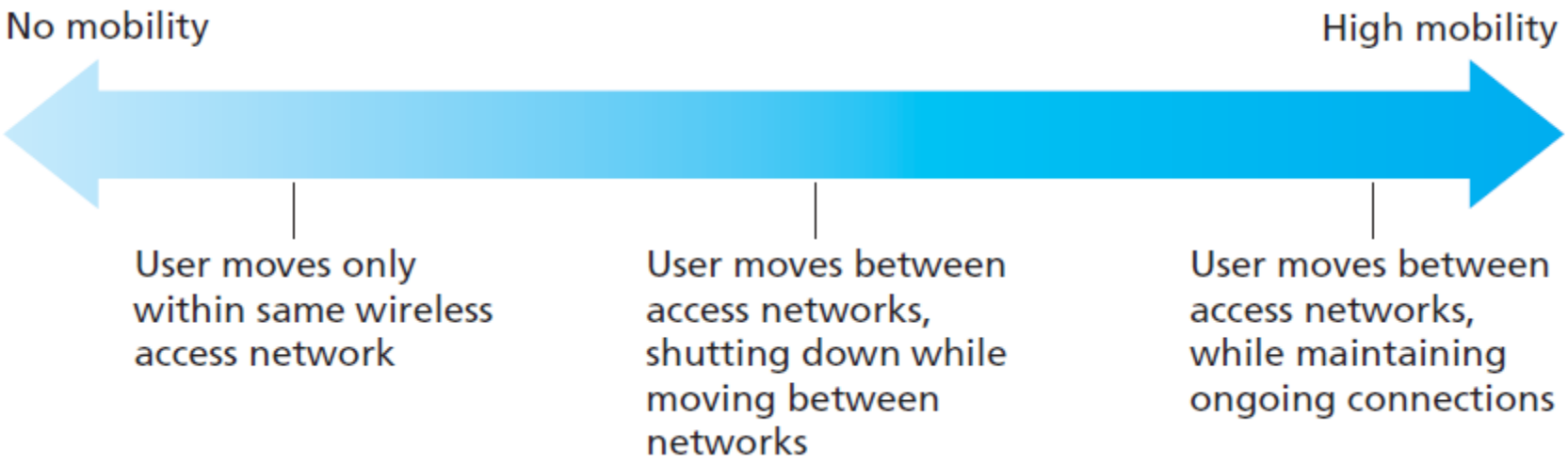
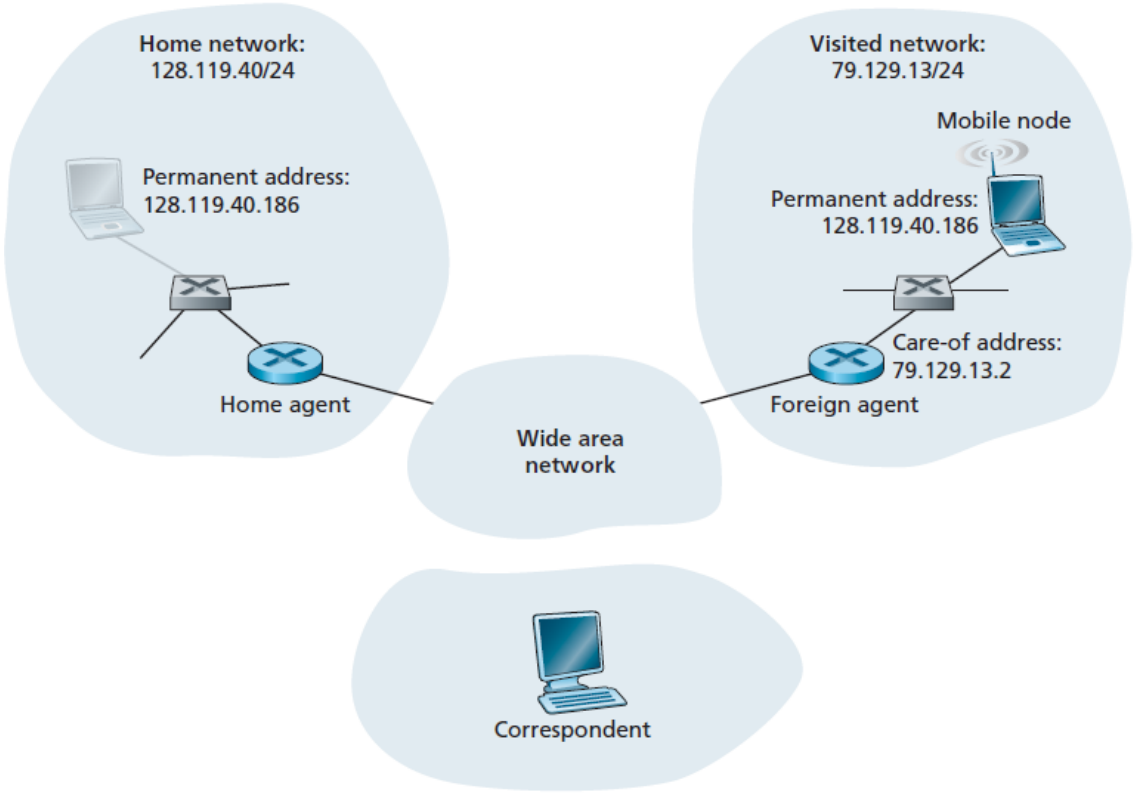
# What is mobility?

spectrum of mobility, from the *network* perspective:



# Mobility: Vocabulary



# How do *you* contact a mobile friend:

Consider friend frequently changing addresses, how do you find her?

- search all phone books?
- call her parents?
- expect her to let you know where he/she is?

# Mobility: approaches

*Let routing handle it:* routers advertise permanent address of mobile-nodes-in-residence via usual routing table exchange.

- routing tables indicate where each mobile located
- no changes to end-systems

*Let end-systems handle it:*

- *indirect routing:* communication from correspondent to mobile goes through home agent, then forwarded to remote
- *direct routing:* correspondent gets foreign address of mobile, sends directly to mobile

# Mobility: approaches

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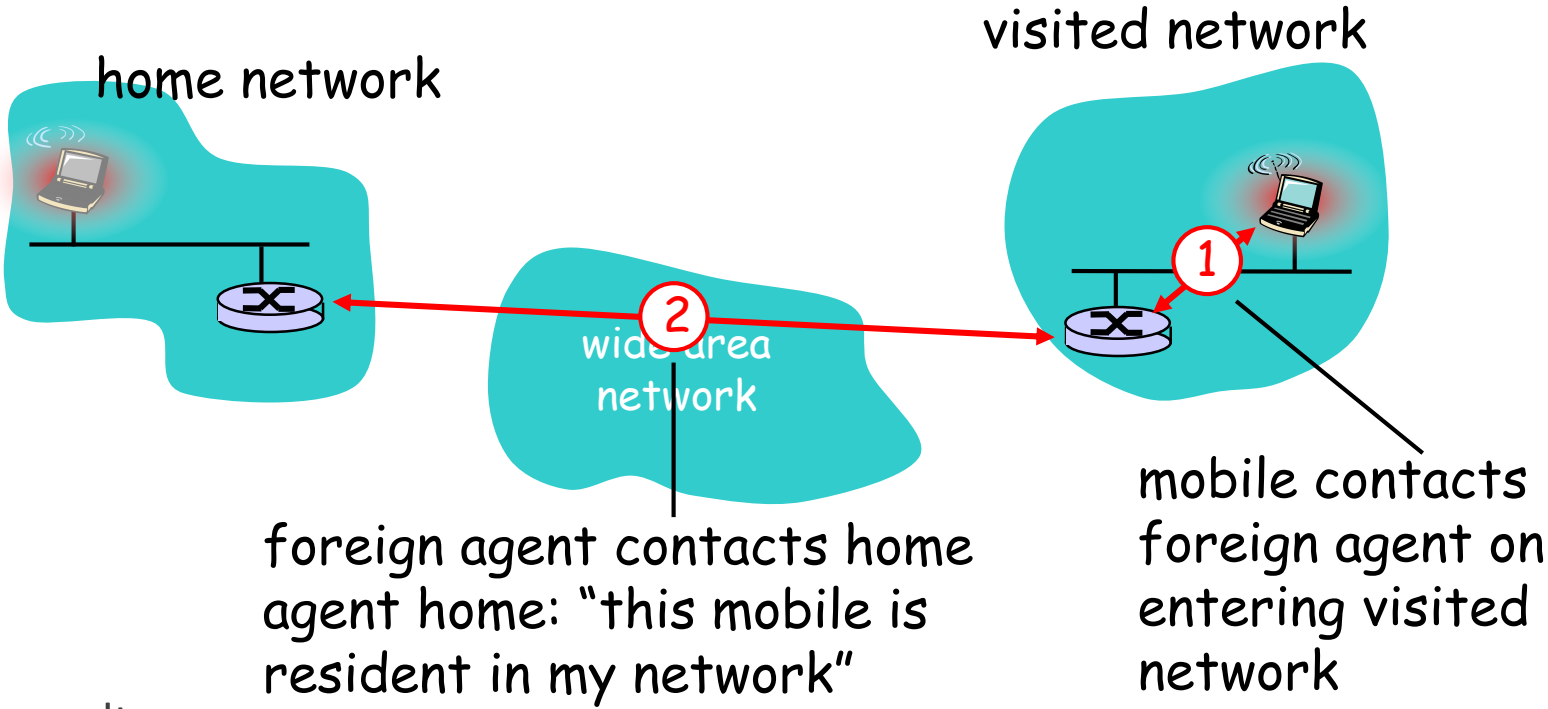
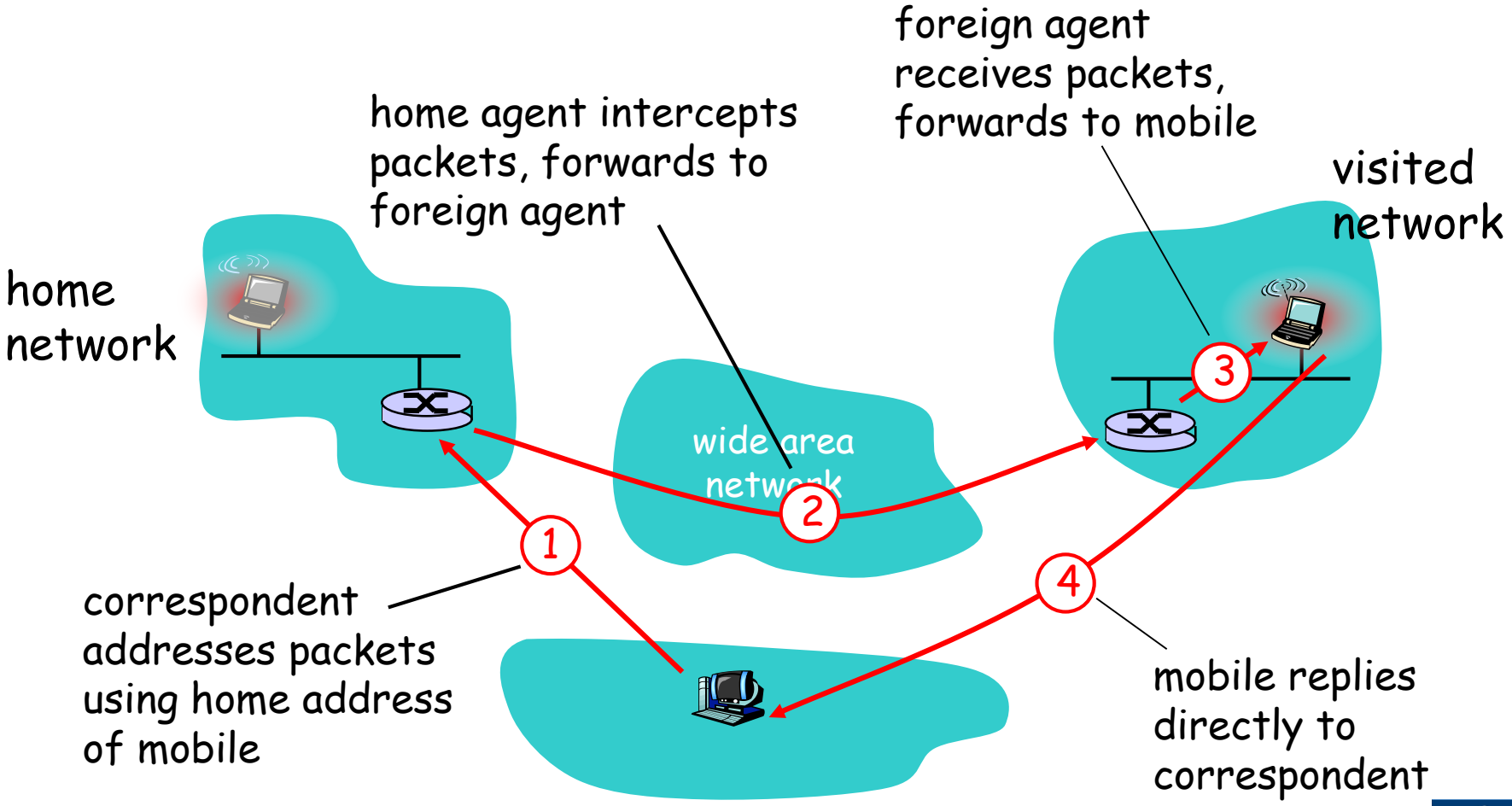
# Mobility: registration




End result:

1. Foreign agent knows about mobile
2. Home agent knows location of mobile

# Mobility via Indirect Routing

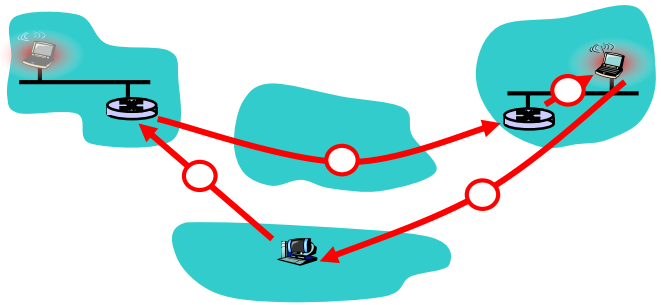


# Indirect Routing: comments

- 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 mobile
- foreign agent functions may be done by mobile itself
- triangle routing: correspondent-home-network-mobile
  - inefficient when

  correspondent, mobile

  are in same network



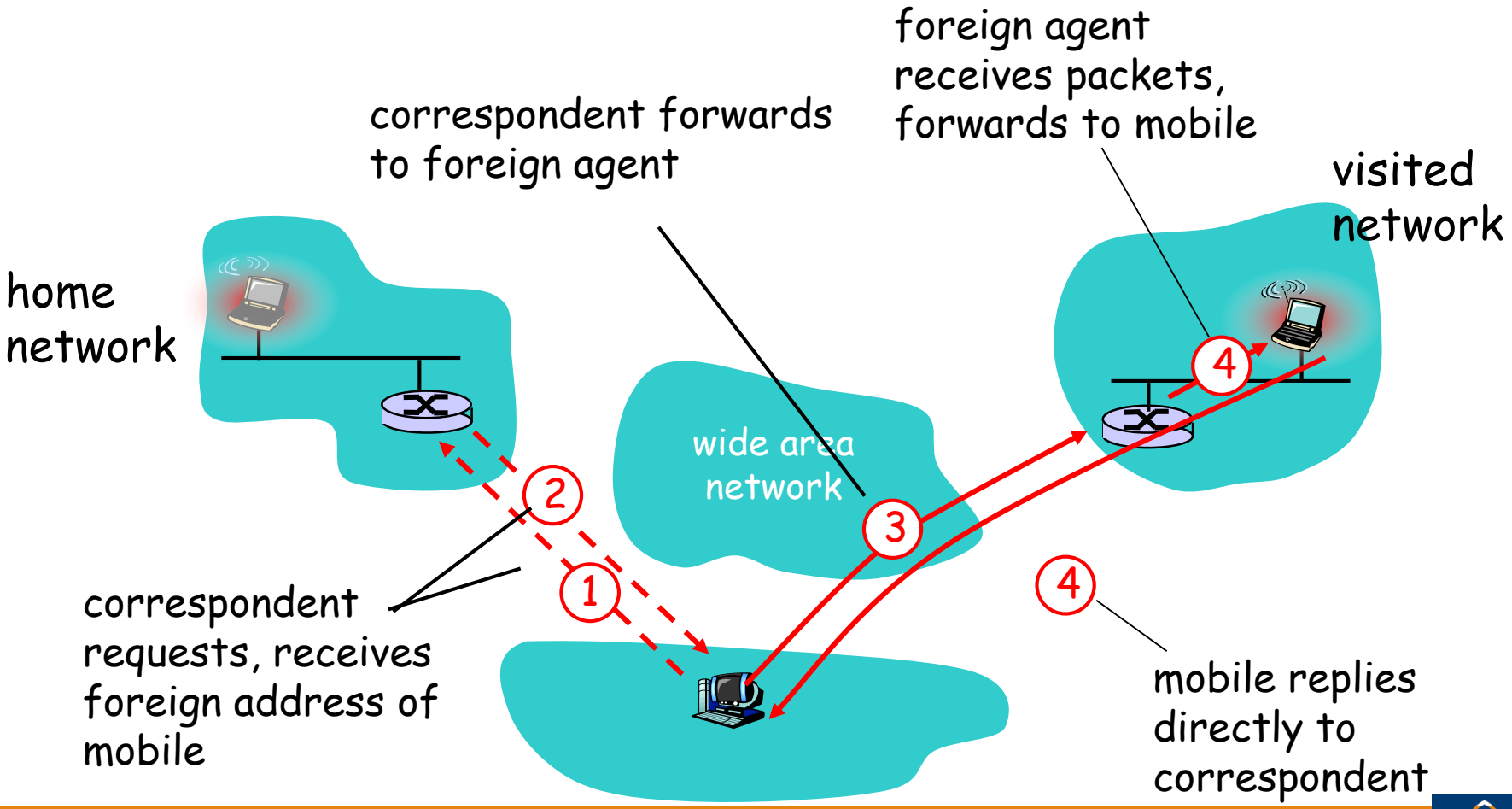
# Indirect Routing: moving between networks

suppose mobile user moves to another network

- registers with new foreign agent
- new foreign agent registers with home agent
- home agent update care-of-address for mobile
- packets continue to be forwarded to mobile (but with new care-of-address)

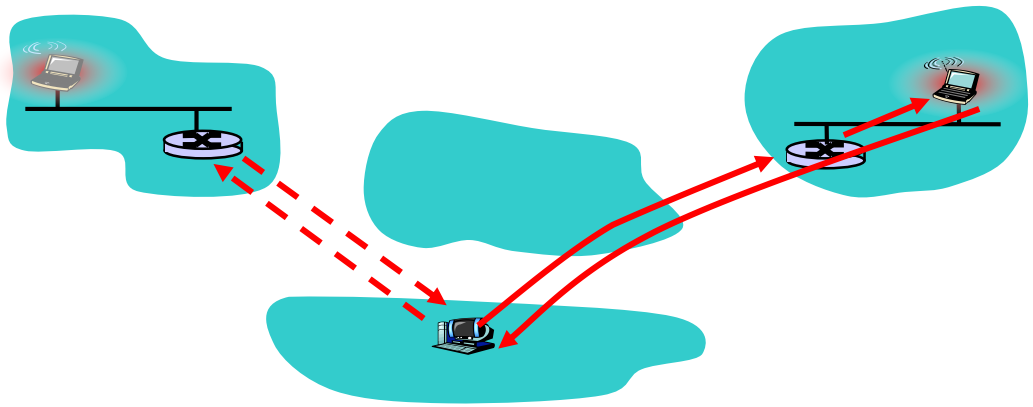
mobility, changing foreign networks transparent: *on going connections can be maintained!*

# Mobility via Direct Routing



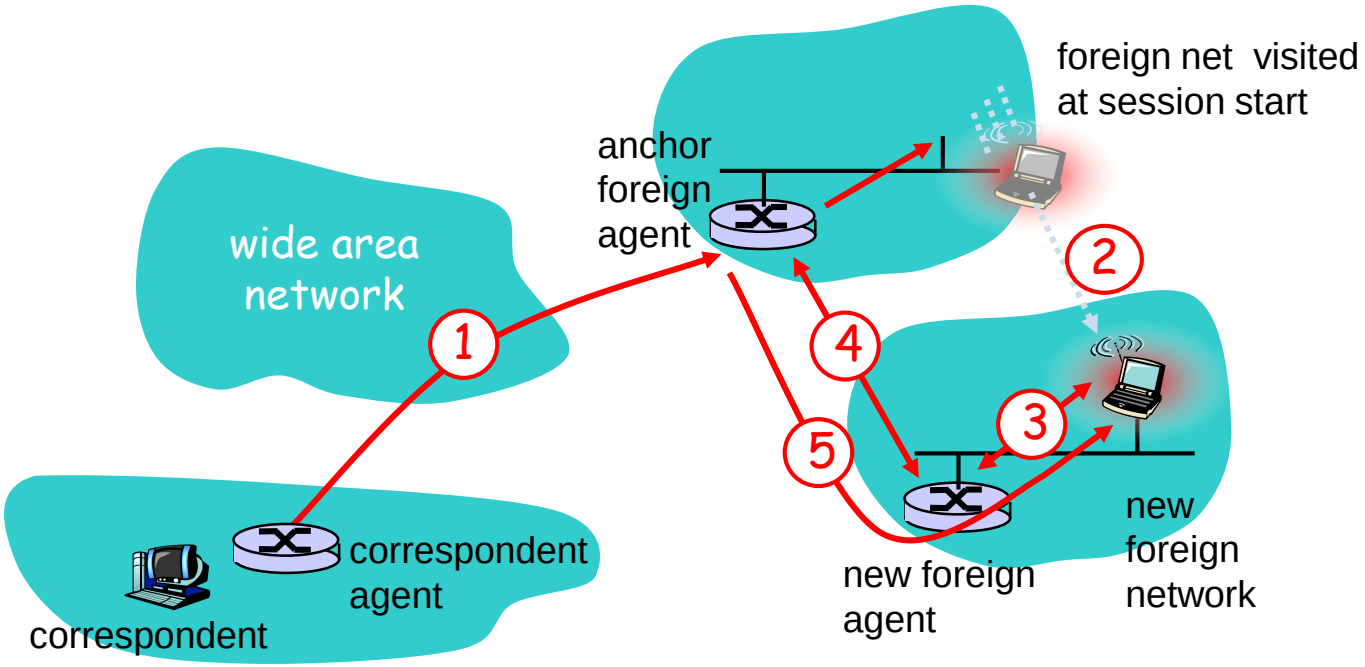
# Mobility via Direct Routing: comments

- overcome triangle routing problem
- non-transparent to correspondent: correspondent must get care-of-address from home agent
  - what if mobile changes visited network?



# Accommodating mobility with direct routing

- anchor foreign agent: FA in first visited network
- data always routed first to anchor FA
- when mobile moves: new FA arranges to have data forwarded from old FA (chaining)



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# Mobile IP

RFC 3344

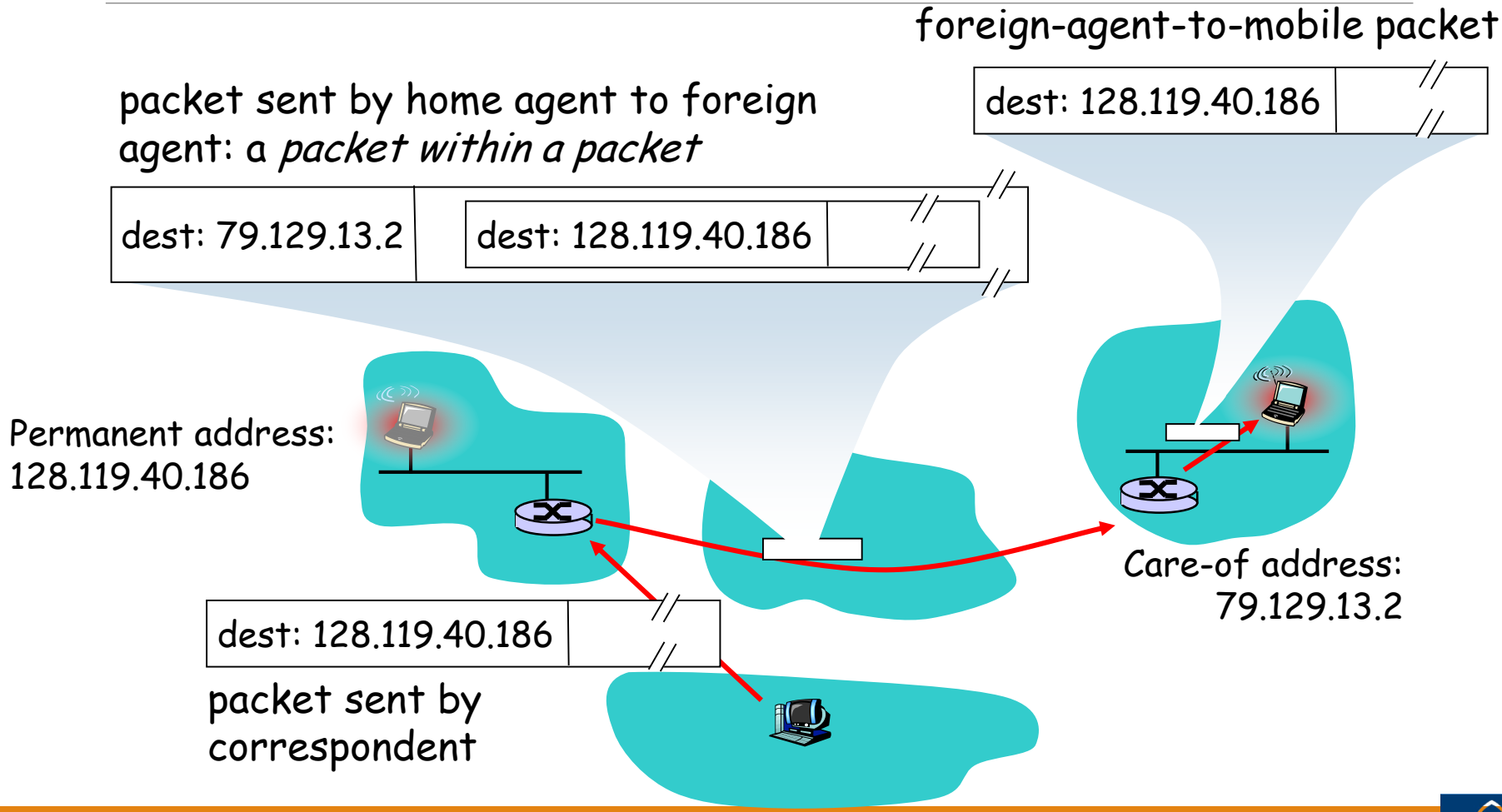
has many features we've seen:

- home agents, foreign agents, foreign-agent registration, care-of-addresses, encapsulation (packet-within-a-packet)

three components to standard:

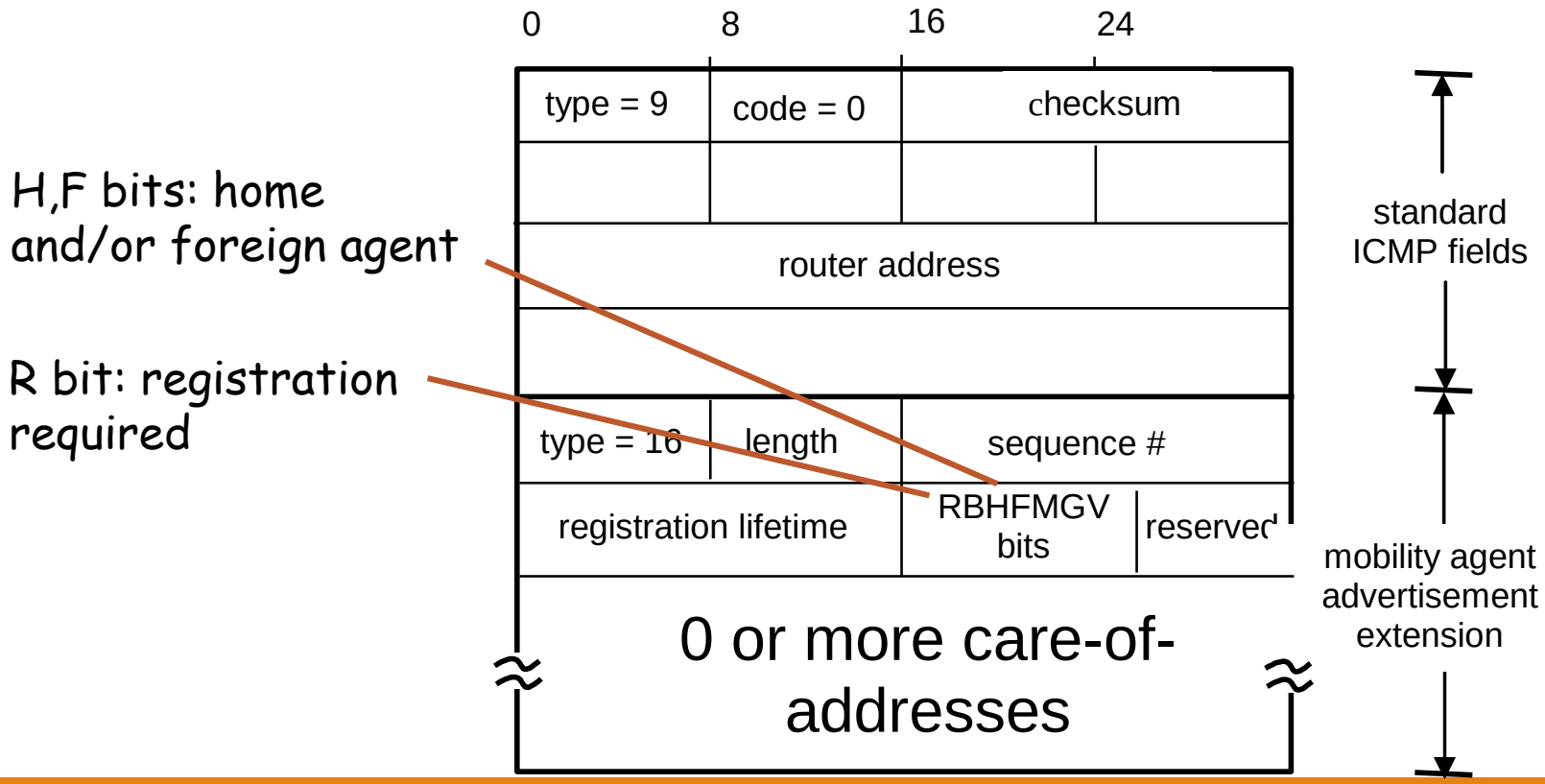
- indirect routing of datagrams
- agent discovery
- registration with home agent

# Mobile IP: indirect routing

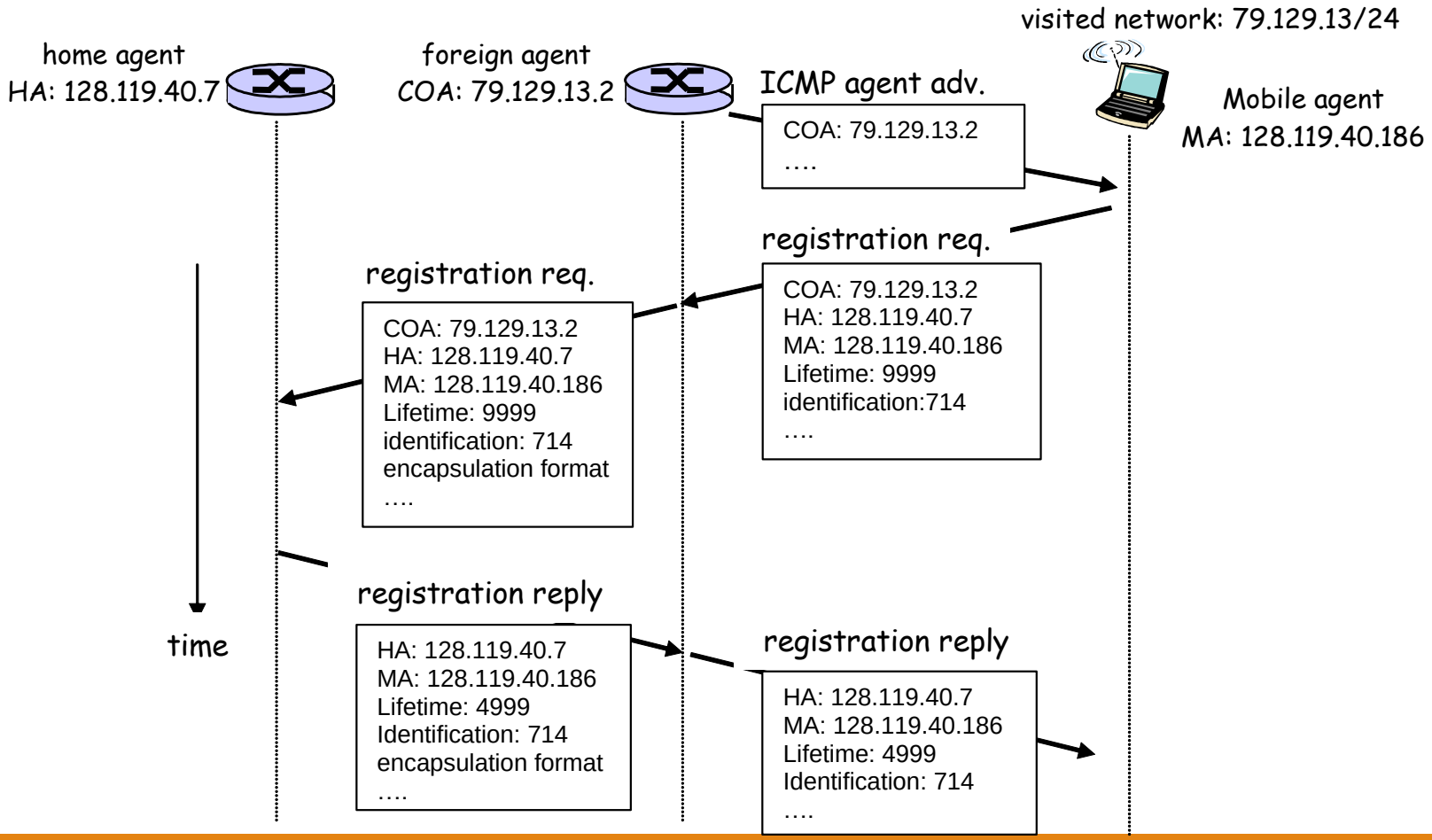


# Mobile IP: agent discovery

agent advertisement: foreign/home agents advertise service by broadcasting ICMP messages (typefield = 9)

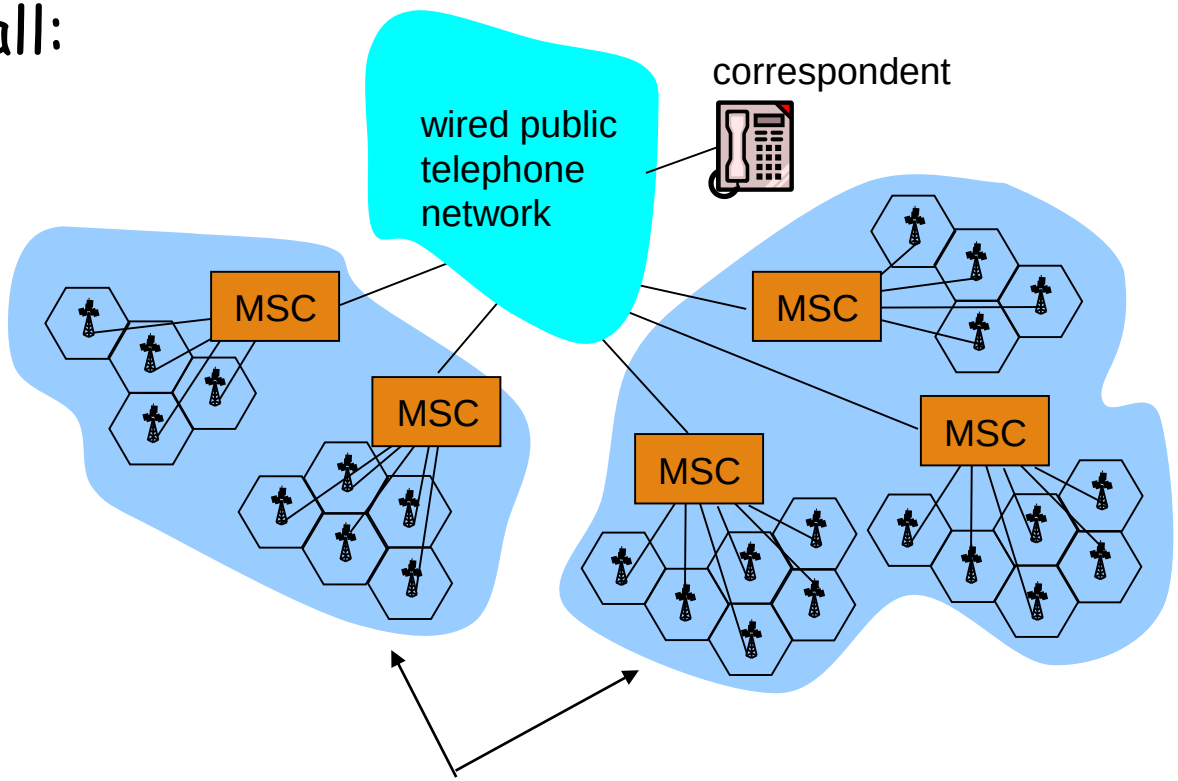


# Mobile IP: registration example



# Components of cellular network architecture

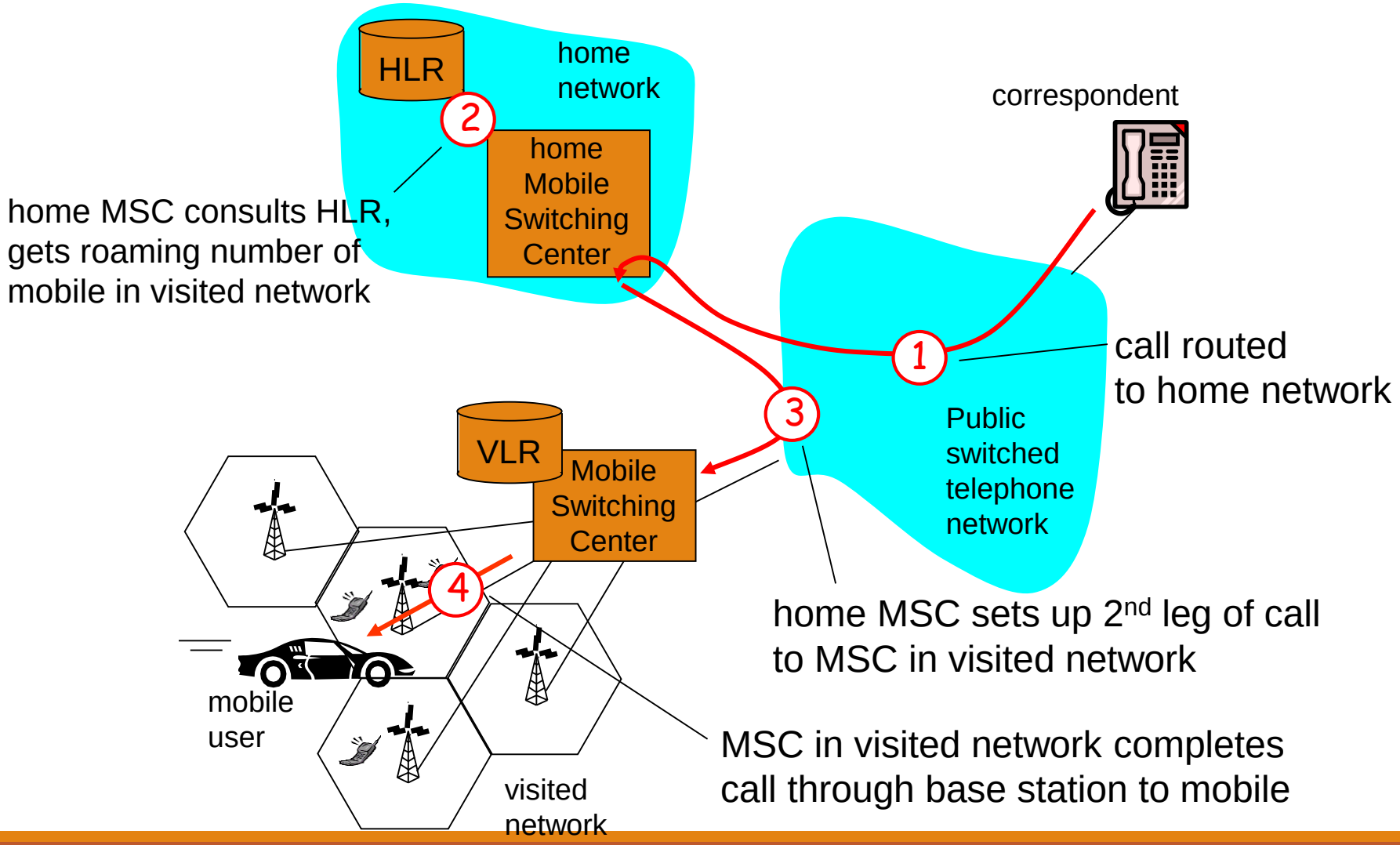
recall:



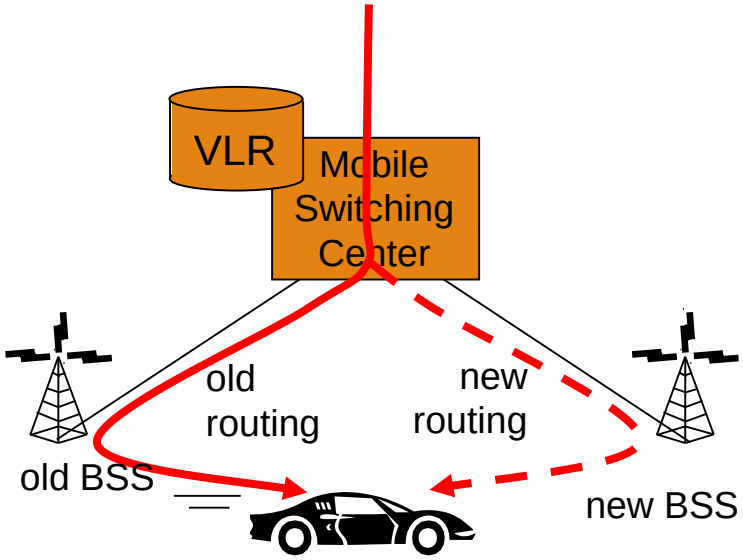
# Handling mobility in cellular networks

- *home network:* network of cellular provider you subscribe to (e.g., EE, 3, giffgaff)
  - *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
  - could be home network

# GSM: indirect routing to mobile

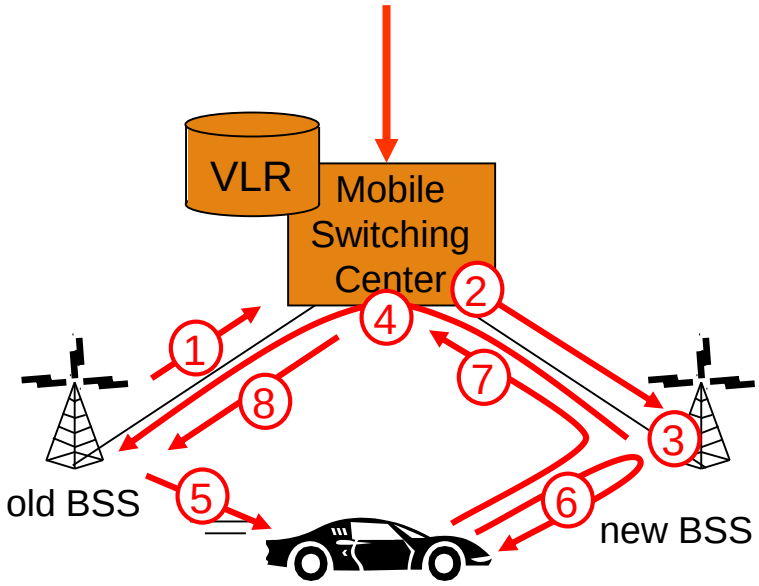


# GSM: handoff with common MSC



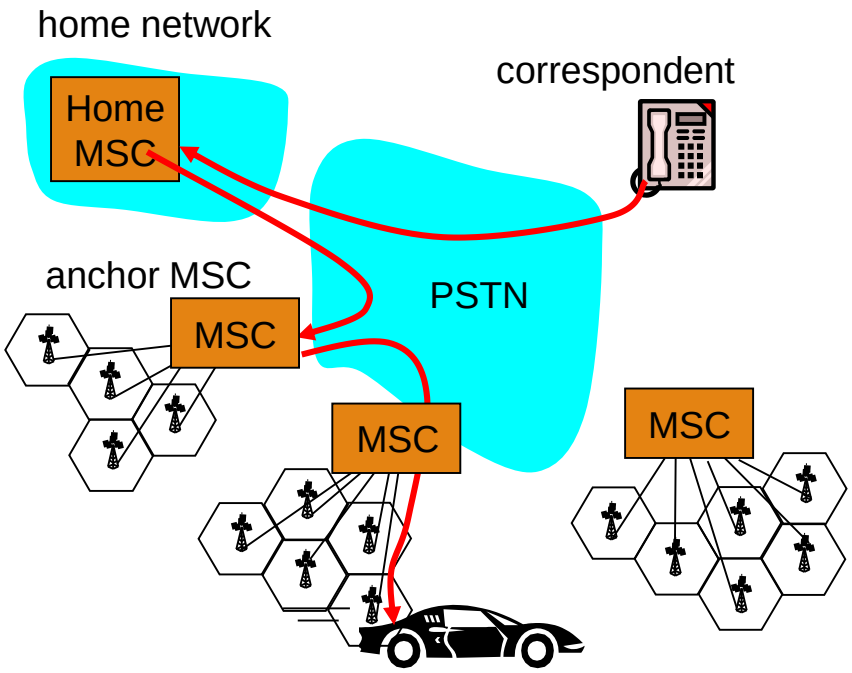

- Handoff goal: route call via new base station (without interruption)
- reasons for handoff:
  - stronger signal to/from new BSS (continuing connectivity, less battery drain)
  - load balance: free up channel in current BSS
  - GSM doesn't mandate why to perform handoff (policy), only how (mechanism)
- handoff initiated by old BSS

# GSM: handoff with common MSC




1. The old BS informs the visited MSC that a handoff is to be performed & the BS to which the mobile is to be handed off.
2. The visited MSC initiates path setup to the new BS, allocating the resources needed to carry the rerouted call.
3. The new BS allocates and activates a radio channel for use by the mobile.
4. The new BS signals back to the visited MSC and the old BS that the visited-MSC-to-new-BS path has been established.
5. The mobile is informed that it should perform a handoff.
6. The mobile and the new BS exchange messages to fully activate the new channel in the new BS.
7. The mobile sends a handoff complete message to the new BS, which is forwarded up to the visited MSC.
8. The resources allocated along the path to the old BS are then released.

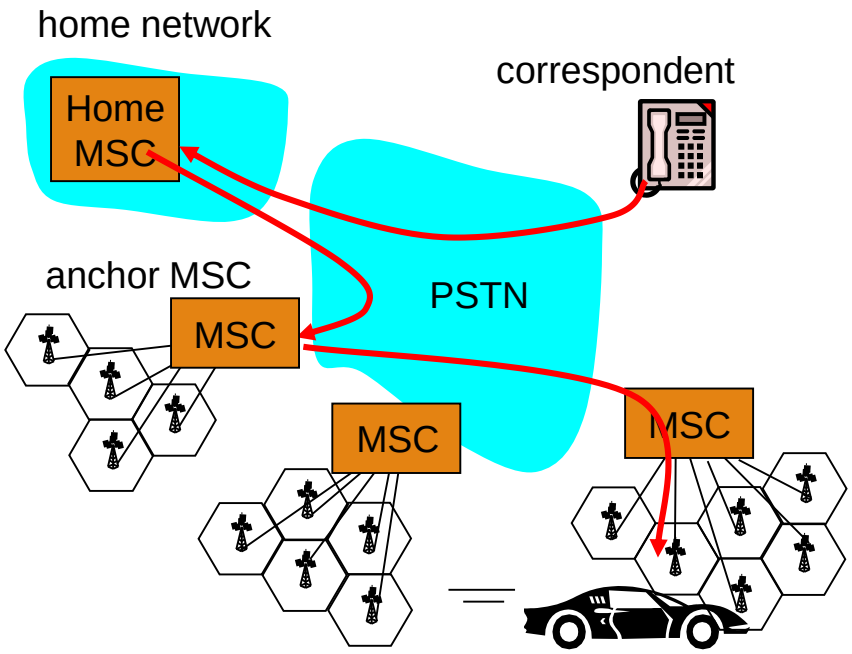
# GSM: handoff between MSCs




(a) before handoff

- *anchor MSC:* first MSC visited during cal
  - call remains routed through anchor MSC
- new MSCs are added on to MSC chain as mobile moves to new MSC

# GSM: handoff between MSCs




(b) after handoff

- *anchor MSC:* first MSC visited during cal
  - call remains routed through anchor MSC
- new MSCs are added on to MSC chain as mobile moves to new MSC
- IS-41 allows optional path minimization step to shorten multi-MSC chain

# Mobility: GSM versus Mobile IP

| GSM element | Comment on GSM element | Mobile IP element |
|---|---|---|
| **Home system** | Network to which mobile user's permanent phone number belongs | **Home network** |
| **Gateway Mobile Switching Center, or "home MSC". Home Location Register (HLR)** | Home MSC: point of contact to obtain routable address of mobile user. HLR: database in home system containing permanent phone number, profile information, current location of mobile user, subscription information | **Home agent** |
| **Visited System** | Network other than home system where mobile user is currently residing | **Visited network** |
| **Visited Mobile services Switching Center. Visitor Location Record (VLR)** | Visited MSC: responsible for setting up calls to/from mobile nodes in cells associated with MSC. VLR: temporary database entry in visited system, containing subscription information for each visiting mobile user | **Foreign agent** |
| **Mobile Station Roaming Number (MSRN), or "roaming number"** | Routable address for telephone call segment between home MSC and visited MSC, visible to neither the mobile nor the correspondent. | **Care-of-address** |

# 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

# Reading

Researchers realized in the early to mid 1990s that given high bit error rates on wireless links and the possibility of handoff loss, TCP's congestion-control response could be problematic in a wireless setting. Three broad classes of approaches are possible for dealing with this problem:

- *Local recovery*
- *TCP sender awareness of wireless links*
- *Split-connection approaches*

# Unit 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, CDMA-2000, UMTS)

## Mobility

principles: addressing, routing to mobile users
- home, visited networks
- direct, indirect routing
- care-of-addresses

case studies
- mobile IP
- mobility in GSM

impact on higher-layer protocols