

Computer Networks
LECTURE 22
Wireless and Mobile Networks

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Announcement

For All:

Schedule URTorrent preliminary demo

<https://docs.google.com/spreadsheets/d/1LcHXW-191dSU-Z4JHocjGWHYtdJo4Za-4SkJKtyQJIU/edit?usp=sharing>

For CSC 457:

Schedule Presentation/Term Paper discussion meeting

<https://docs.google.com/spreadsheets/d/1ZQhW6Pzouk8AI93fi4-EABEngBFnJVT-yP6mYFPeGME/edit?usp=sharing>

Personal area network



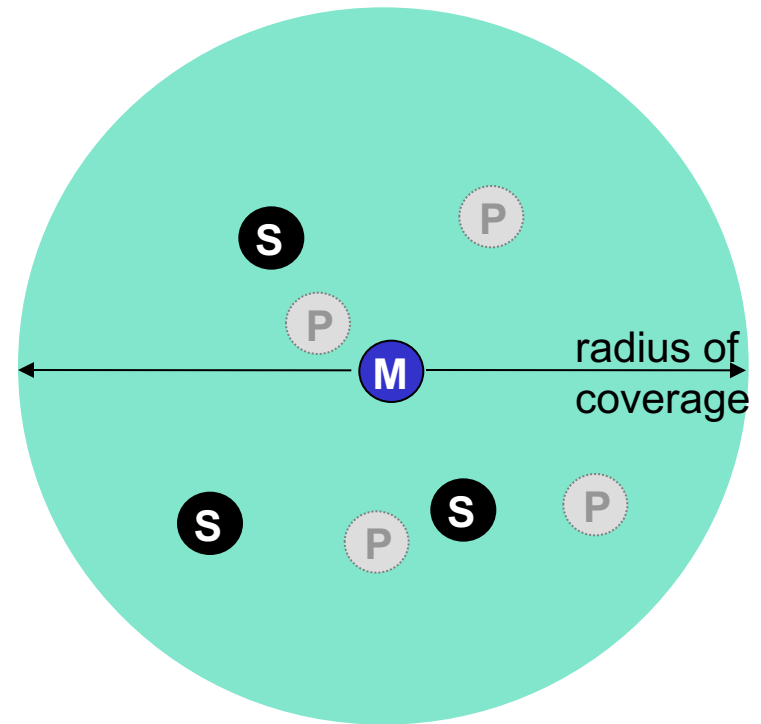
Bluetooth[®]



ZigBee[®]

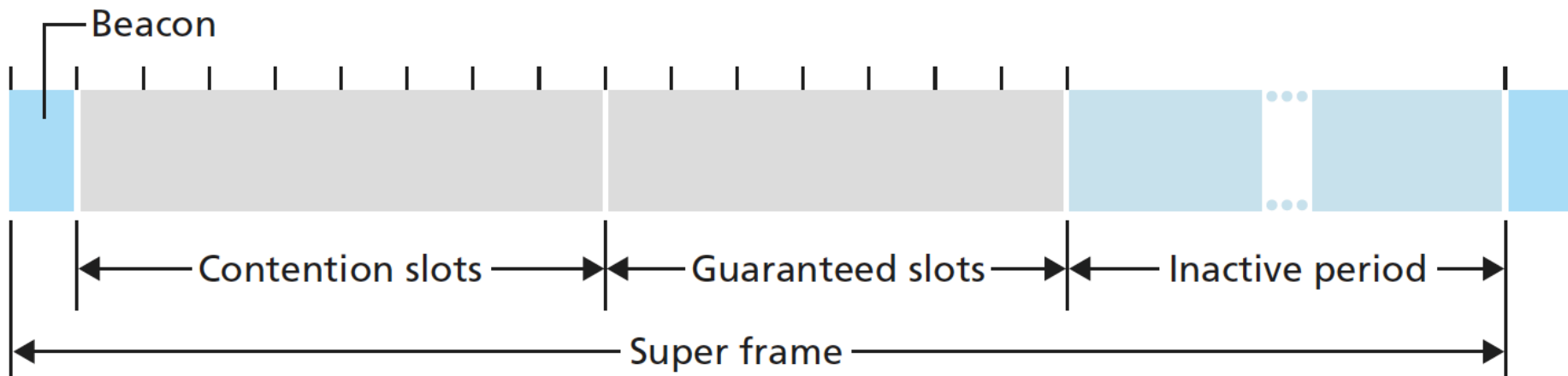
Bluetooth®

- 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
 - 8 active device
 - 255 parked device
- 802.15.1: evolved from Bluetooth specification
 - 2.4-2.5 GHz radio band
 - up to 721 kbps



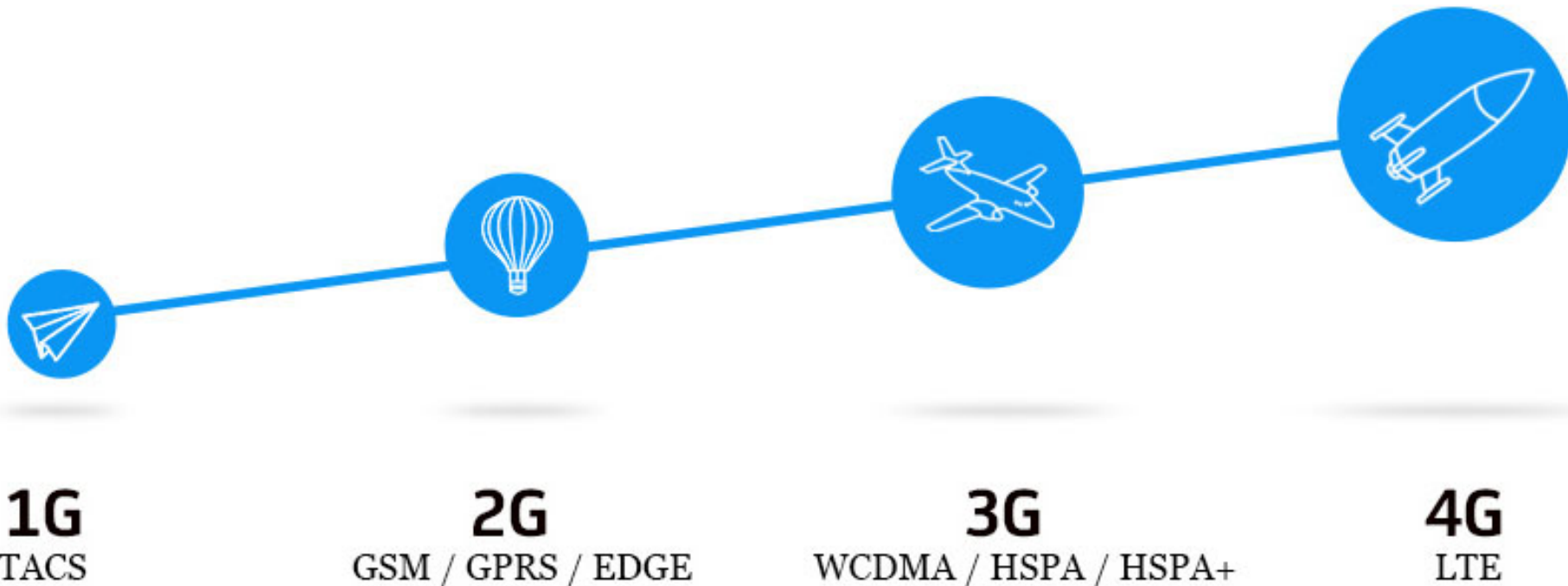
- M Master device
- S Slave device
- P Parked device (inactive)

- Low power
- Lower data rate
- Lower duty cycle
- ad hoc: no infrastructure
- reduced-function devices /full-function devices
- Zigbee 802.14.4 super-frame



Cellular Internet access

Cellular networks: Generations





6-8
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Evolution of the Mobile Phone



Motorola
8900X-2



Nokia
2146



Nokia
3210



Nokia
6210



Ericsson
T39



Alcatel
OT511



Samsung
E250



Apple
iPhone



BlackBerry
Curve 8900



Samsung
Galaxy S2



Samsung
Galaxy S4



Sony Xperia
Z Ultra



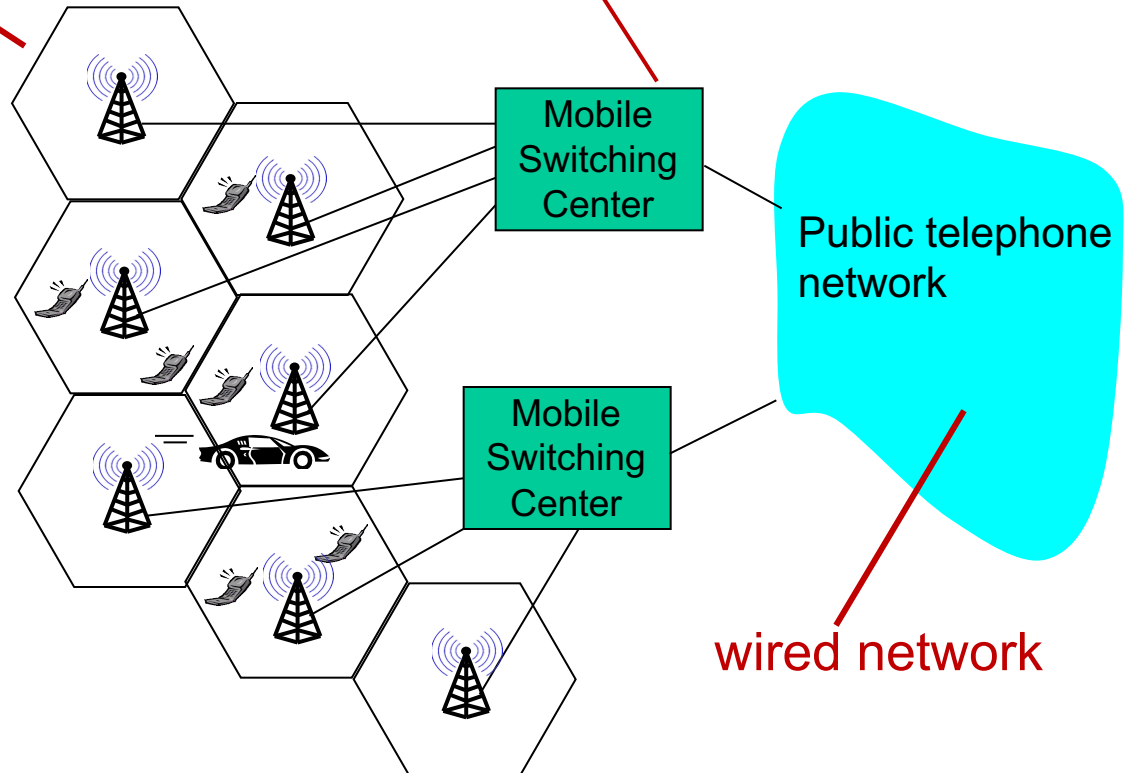
Components of cellular network architecture

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

MSC

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

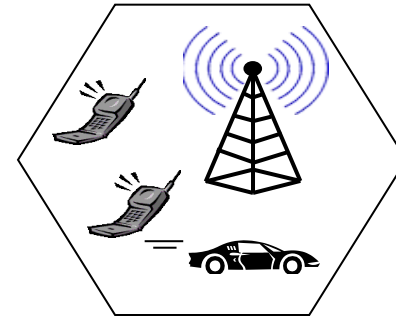


wired network

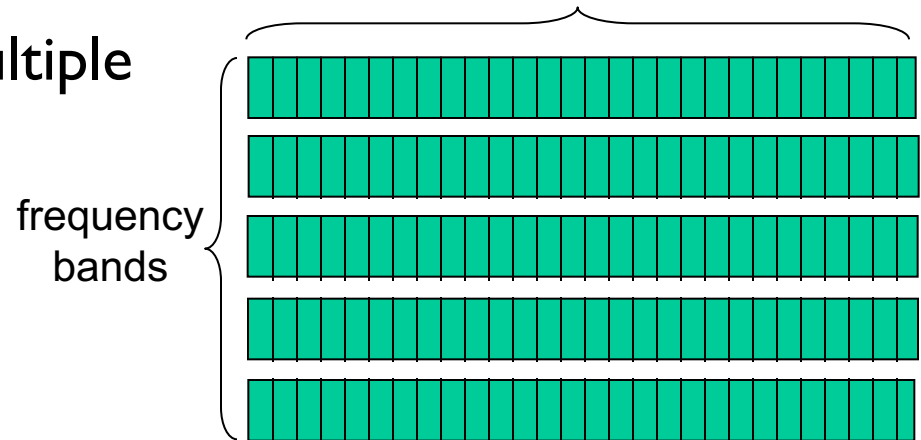
Cellular networks: the first hop

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



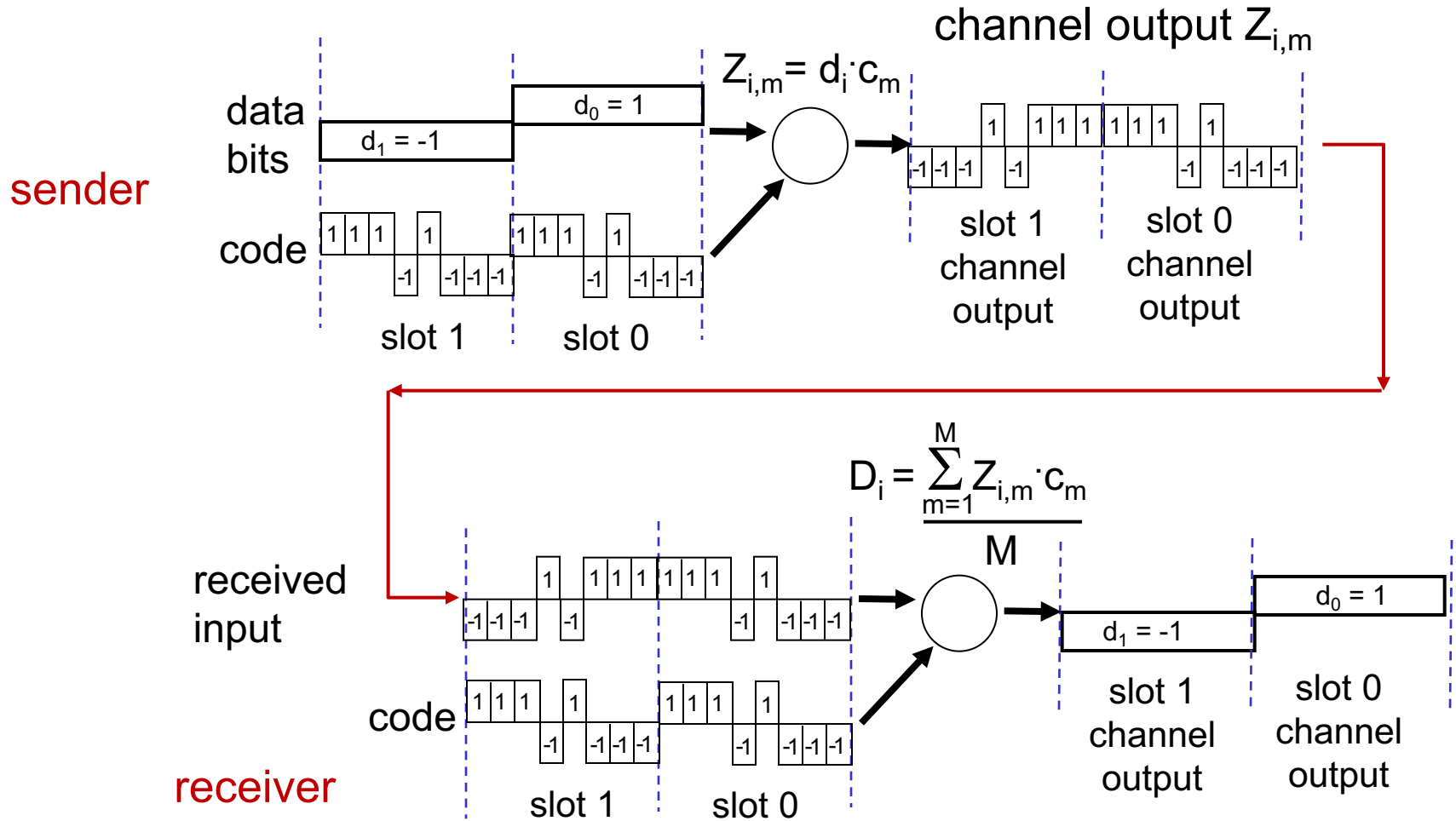
time slots



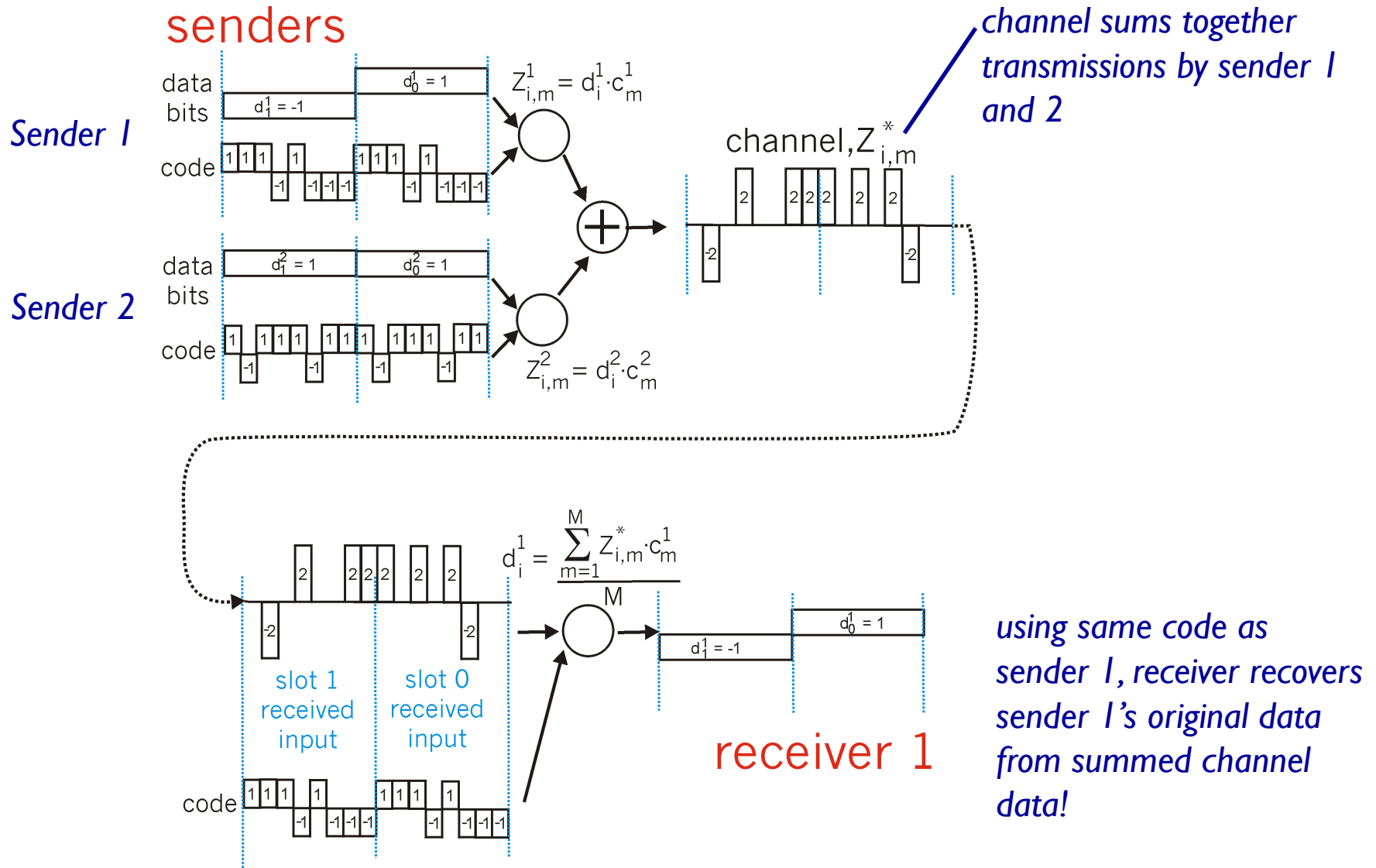
Code Division Multiple Access (CDMA)

- unique “code” assigned to each user; i.e., code set partitioning
 - all users share same frequency, but each user has 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) \times (chipping sequence)
- *decoding*: inner-product of encoded signal and chipping sequence

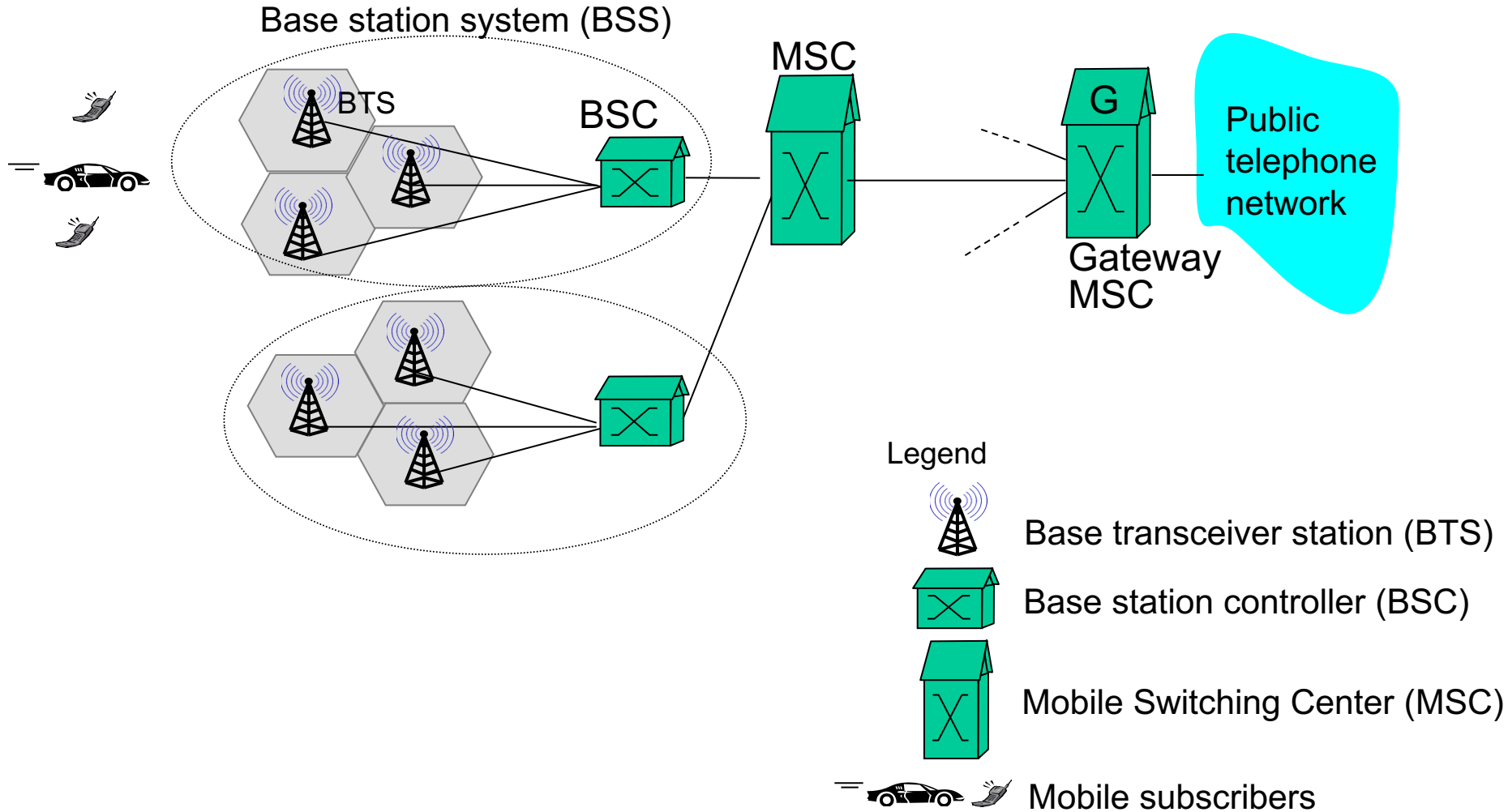
CDMA encode/decode



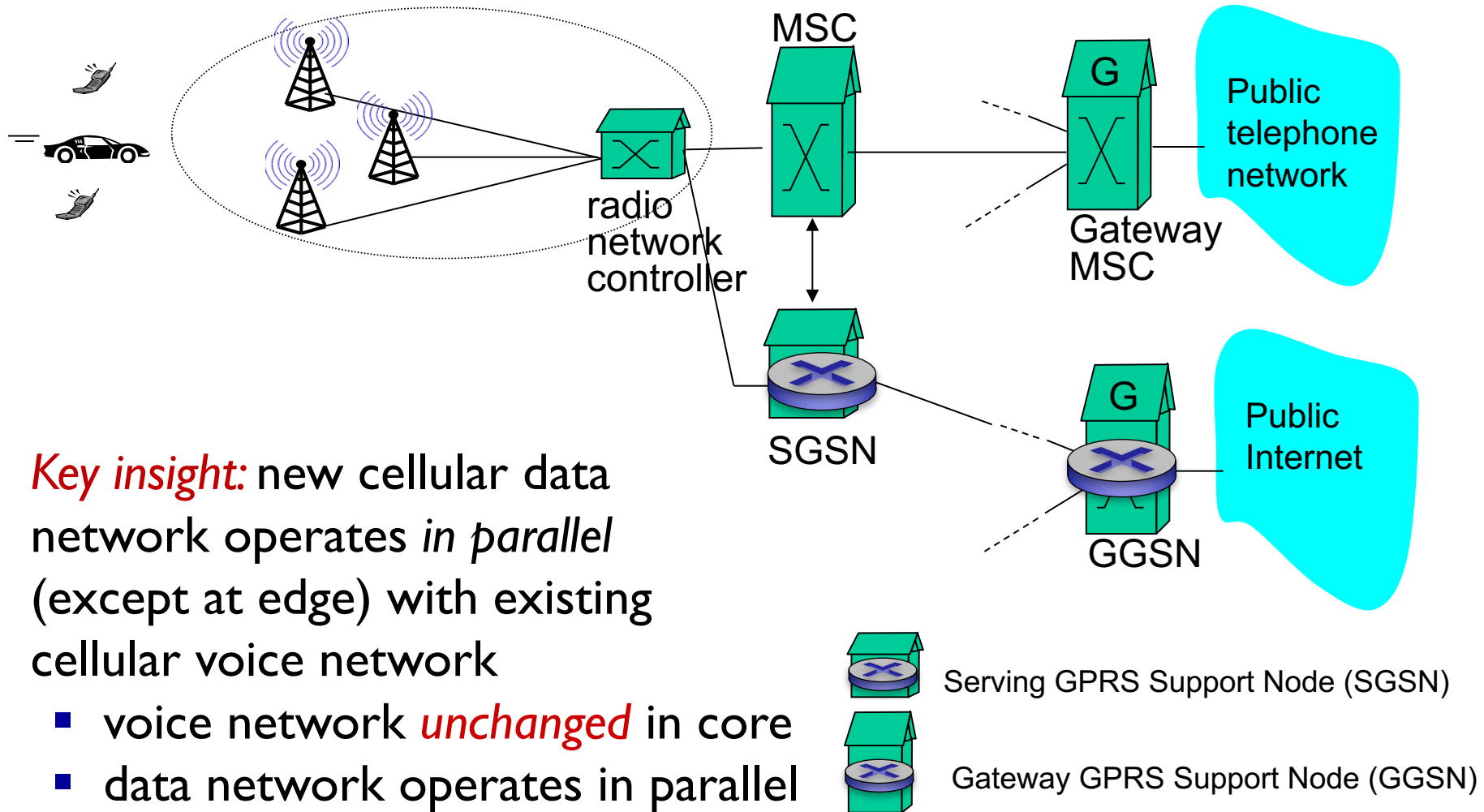
CDMA: two-sender interference



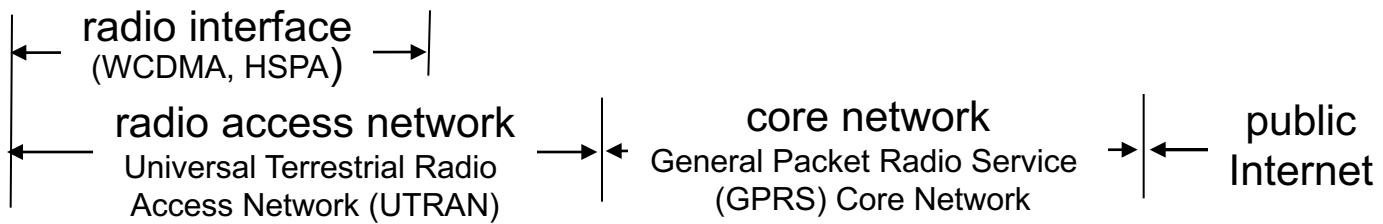
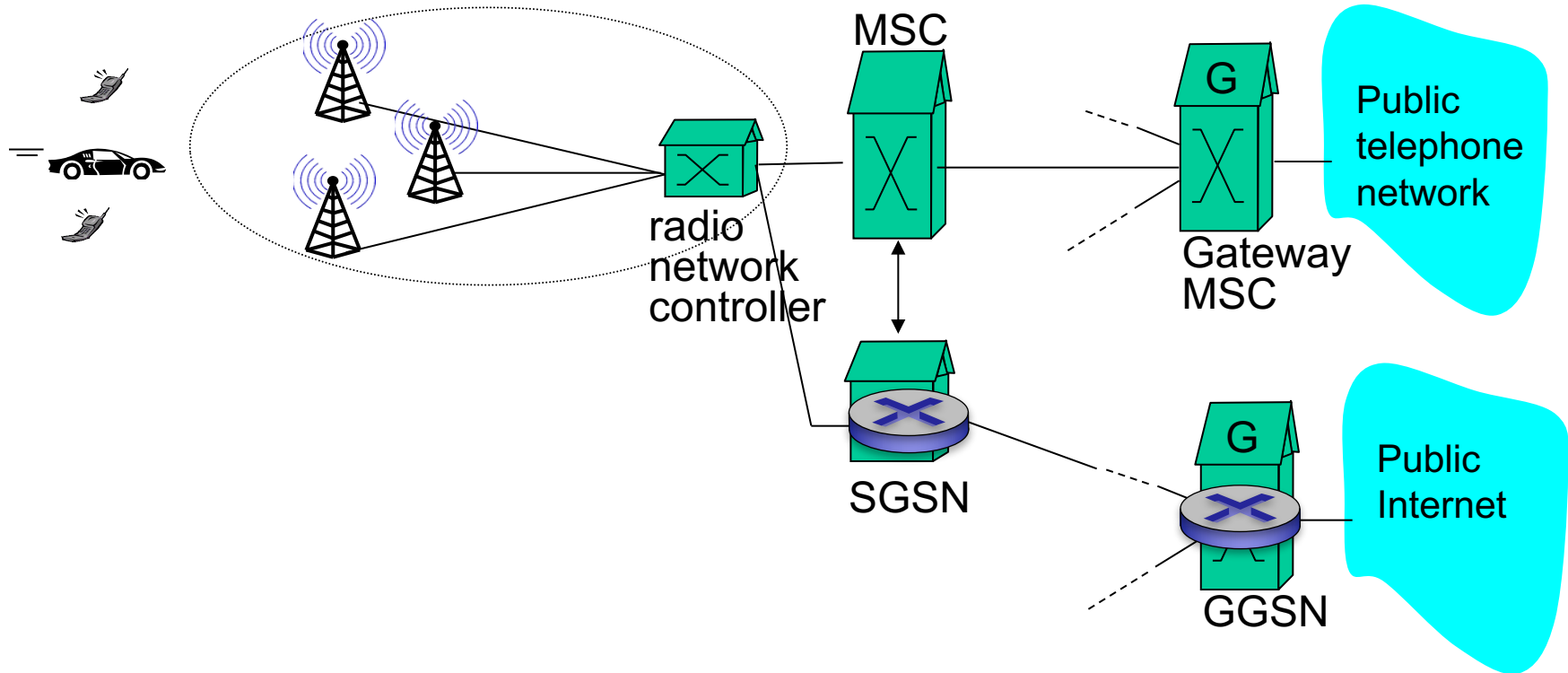
2G (voice) network architecture



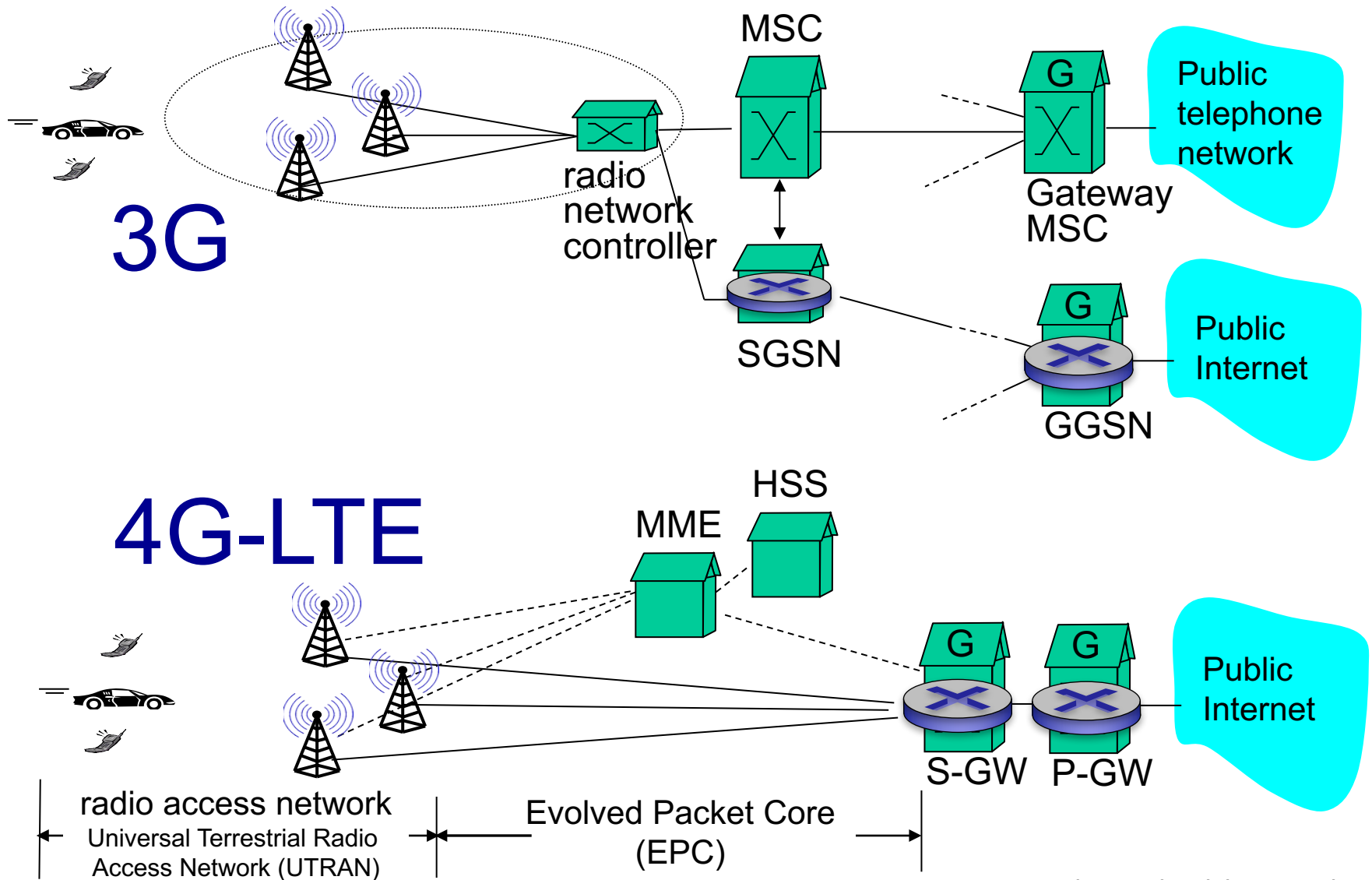
3G (voice+data) network architecture



3G (voice+data) network architecture

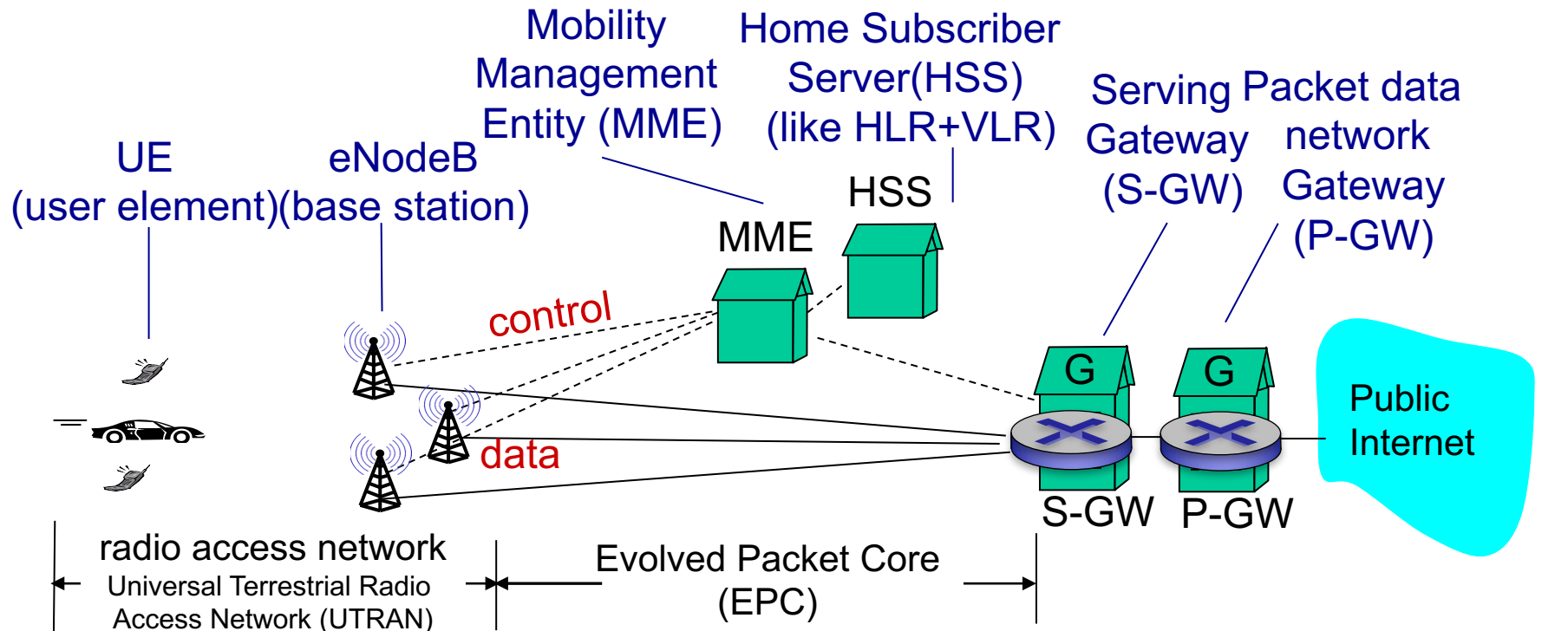


3G versus 4G LTE network architecture



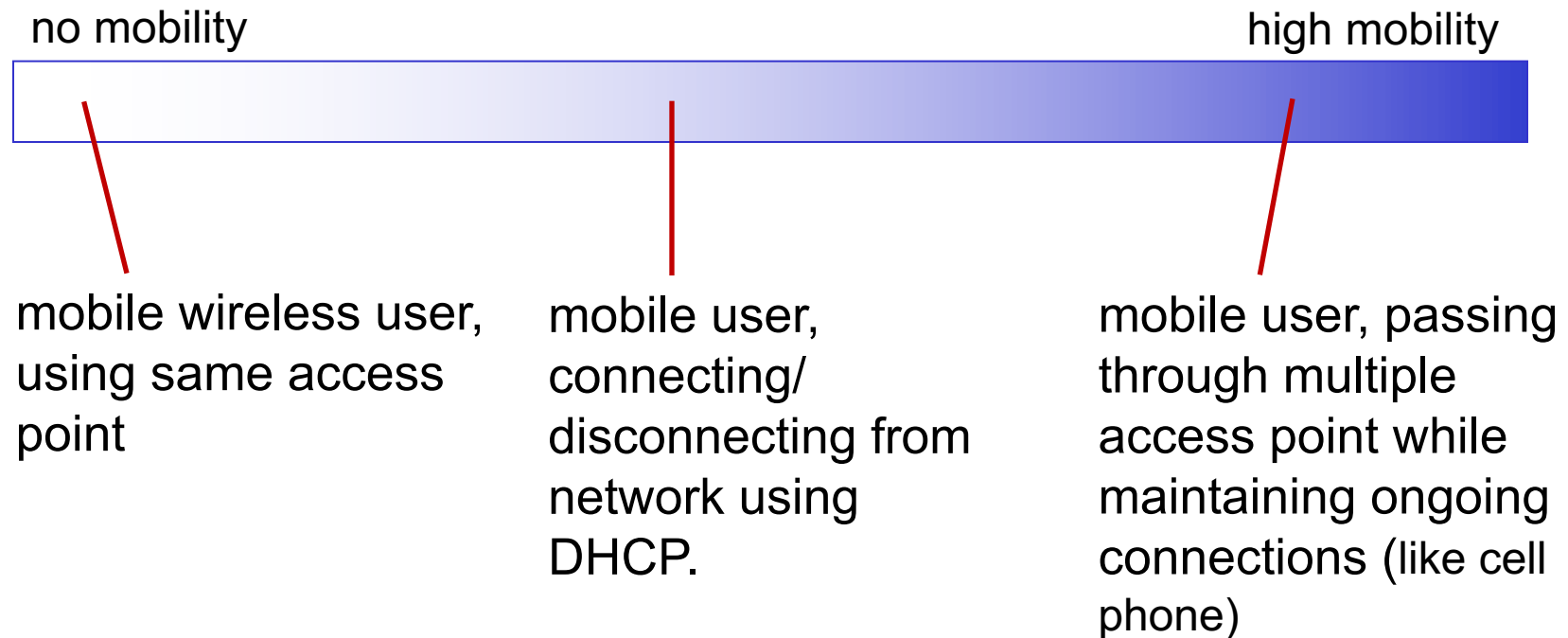
4G: differences from 3G

- 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



What is mobility?

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

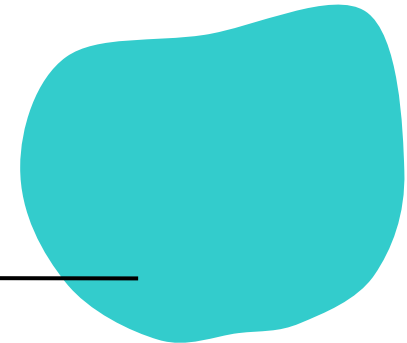
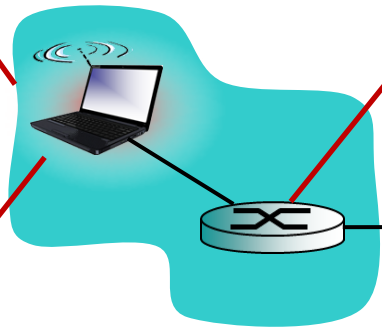


Mobility: vocabulary

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

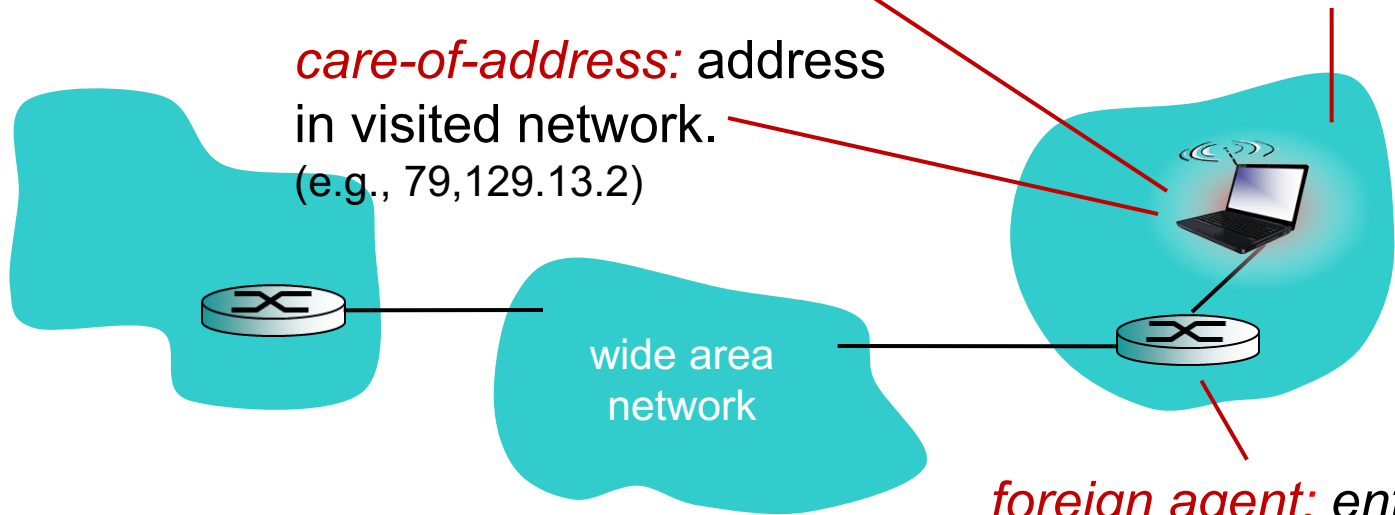


Mobility: more vocabulary

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.

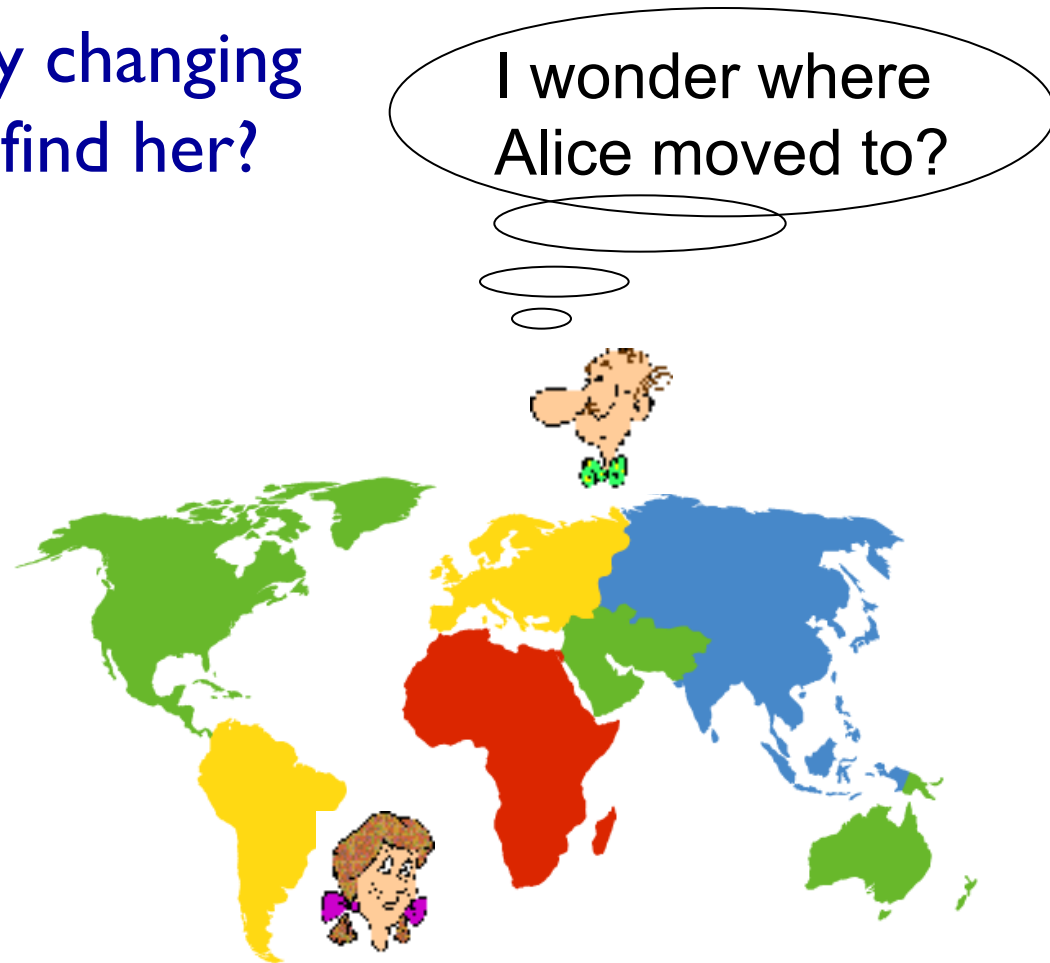
correspondent: wants to communicate with mobile



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?
- Facebook!



Mobility: approaches

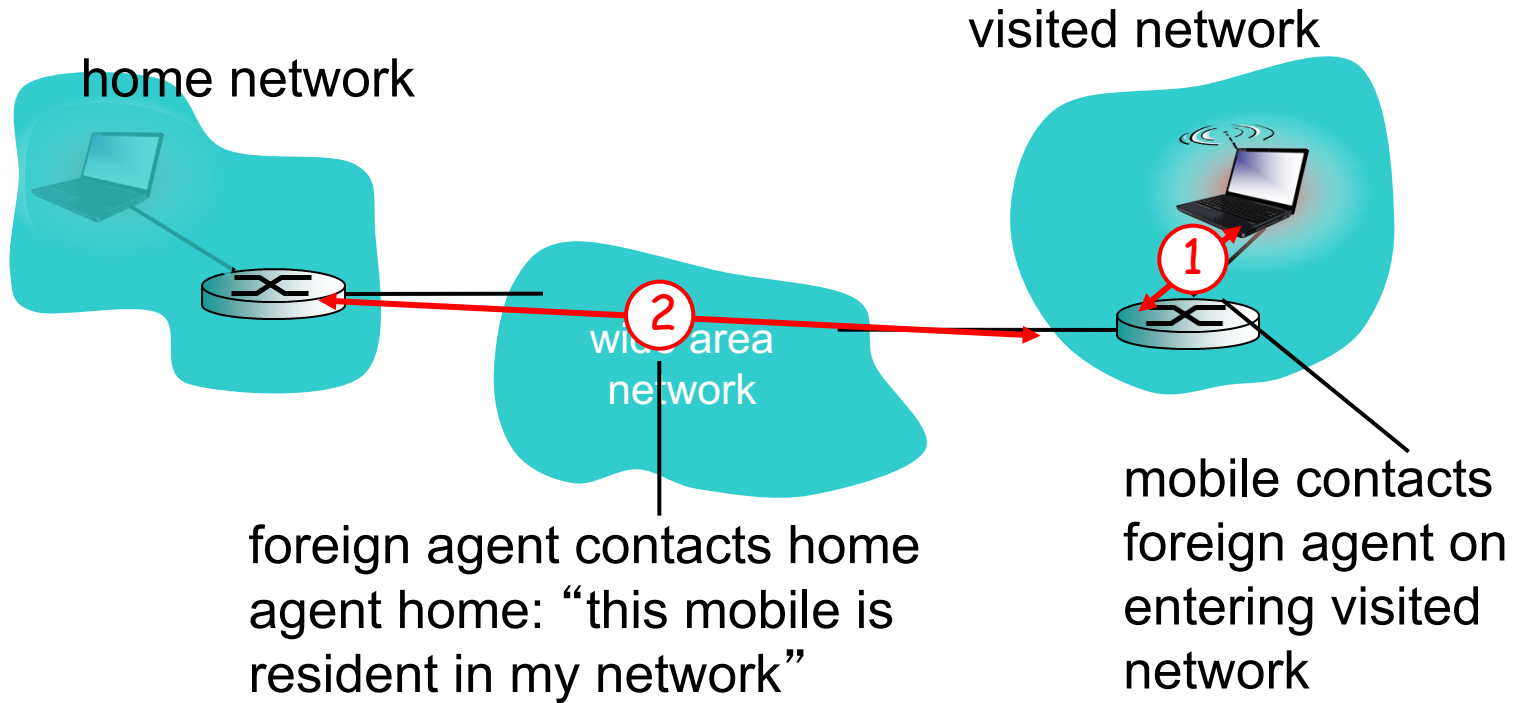
- *let routing handle it:* routers advertise permanent address of mobile-nodes-in-residence via usual routing table exchange.
 - routing tables indicate where each mobile located
 - no changes to end-systems
- *let end-systems handle it:*
 - *indirect routing:* communication from correspondent to mobile goes through home agent, then forwarded to remote
 - *direct routing:* correspondent gets foreign address of mobile, sends directly to mobile

Mobility: approaches

- *let routing handle it:* routers advertise permanent address of mobile, mobile advertises current residence via usual routing table exchange
 - routing table exchange where each mobile located
 - no changes to 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

not
scalable
to millions of
mobiles

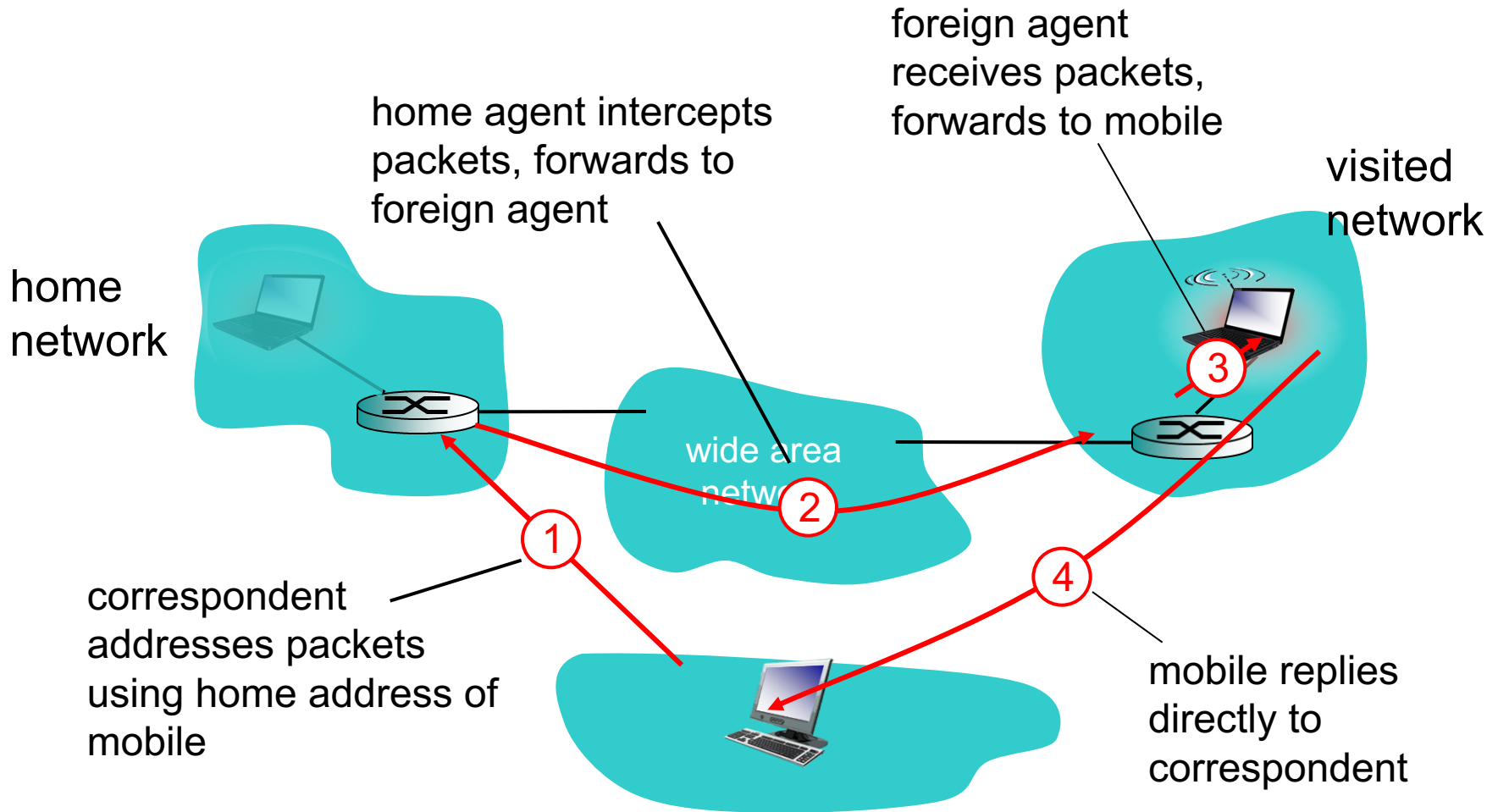
Mobility: registration



end result:

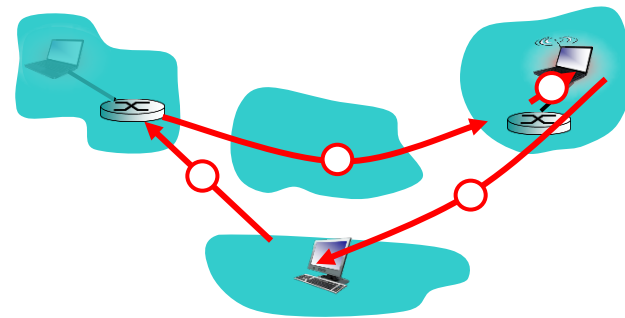
- foreign agent knows about mobile
- home agent knows location of mobile

Mobility via indirect routing



Indirect Routing: comments

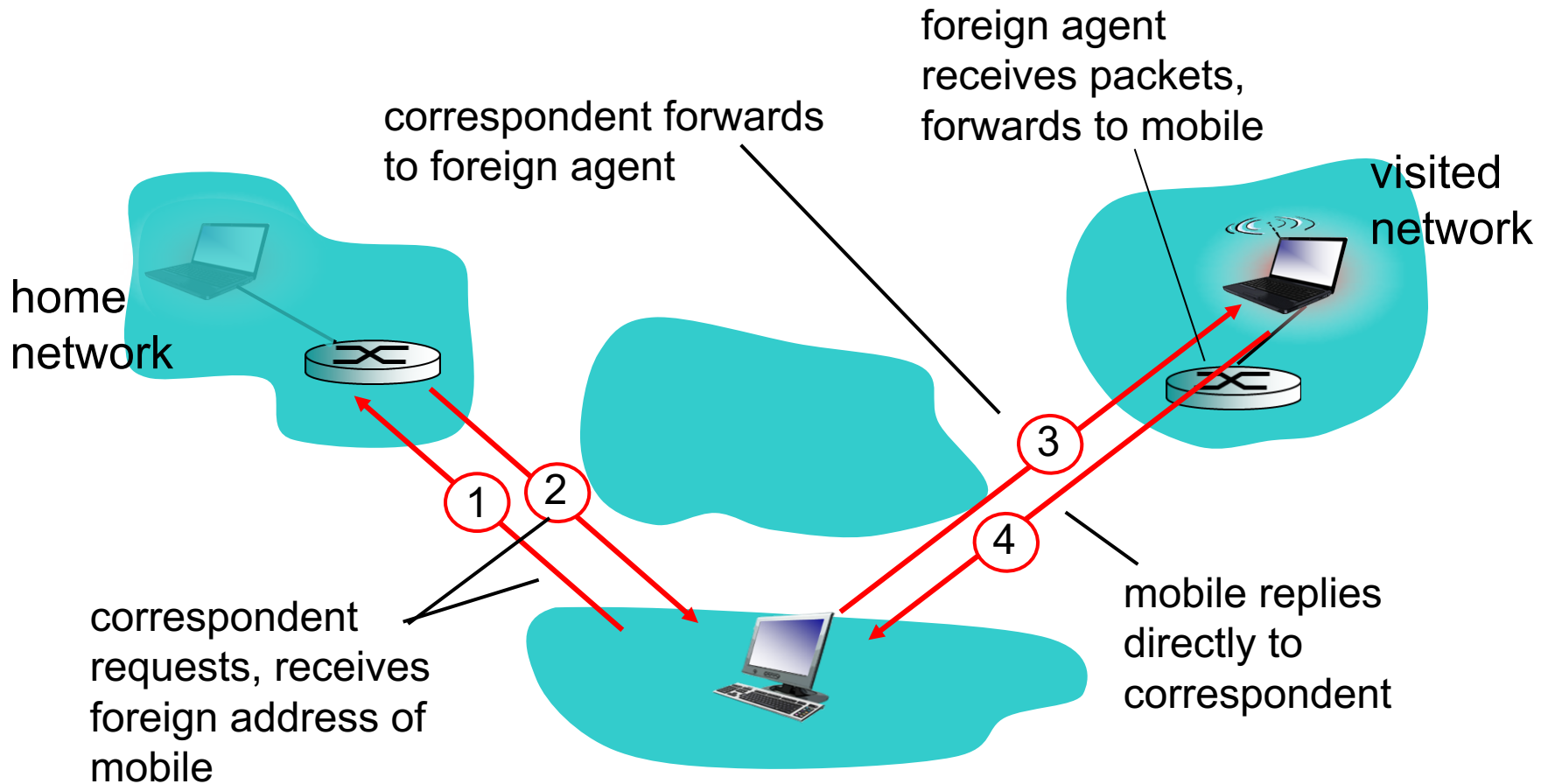
- mobile uses two addresses:
 - **permanent address**: used by correspondent (hence mobile location is *transparent* to correspondent)
 - **care-of-address**: used by home agent to forward datagrams to mobile
- foreign agent functions may be done by mobile itself
- **triangle routing**: correspondent-home-network-mobile
 - inefficient when correspondent, mobile are in same network



Indirect routing: moving between networks

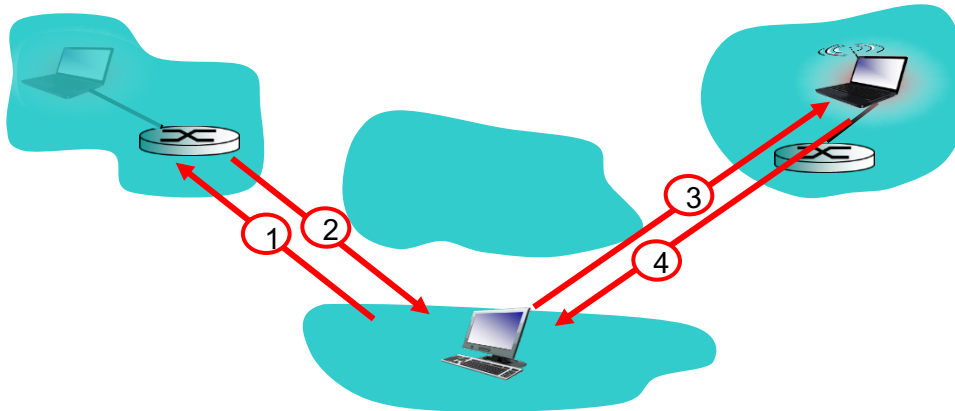
- suppose mobile user moves to another network
 - registers with new foreign agent
 - new foreign agent registers with home agent
 - home agent update care-of-address for mobile
 - packets continue to be forwarded to mobile (but with new care-of-address)
- mobility, changing foreign networks transparent: *on going connections can be maintained!*

Mobility via direct routing



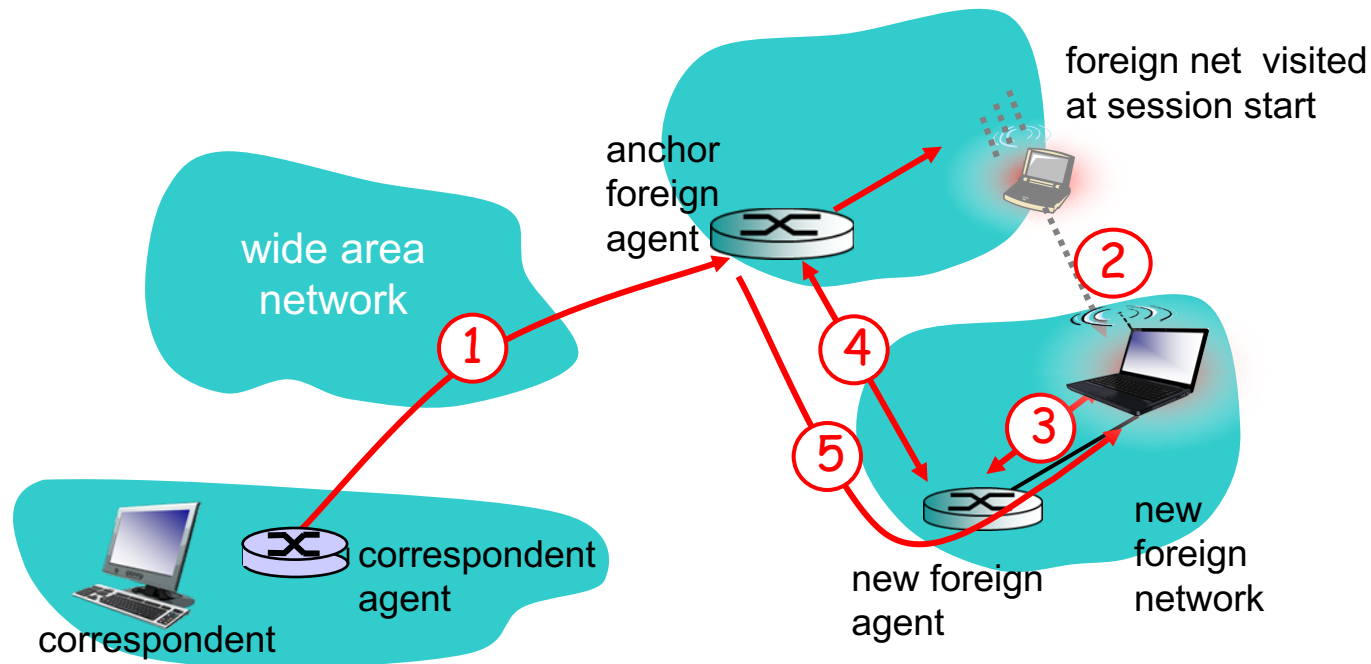
Mobility via direct routing: comments

- 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

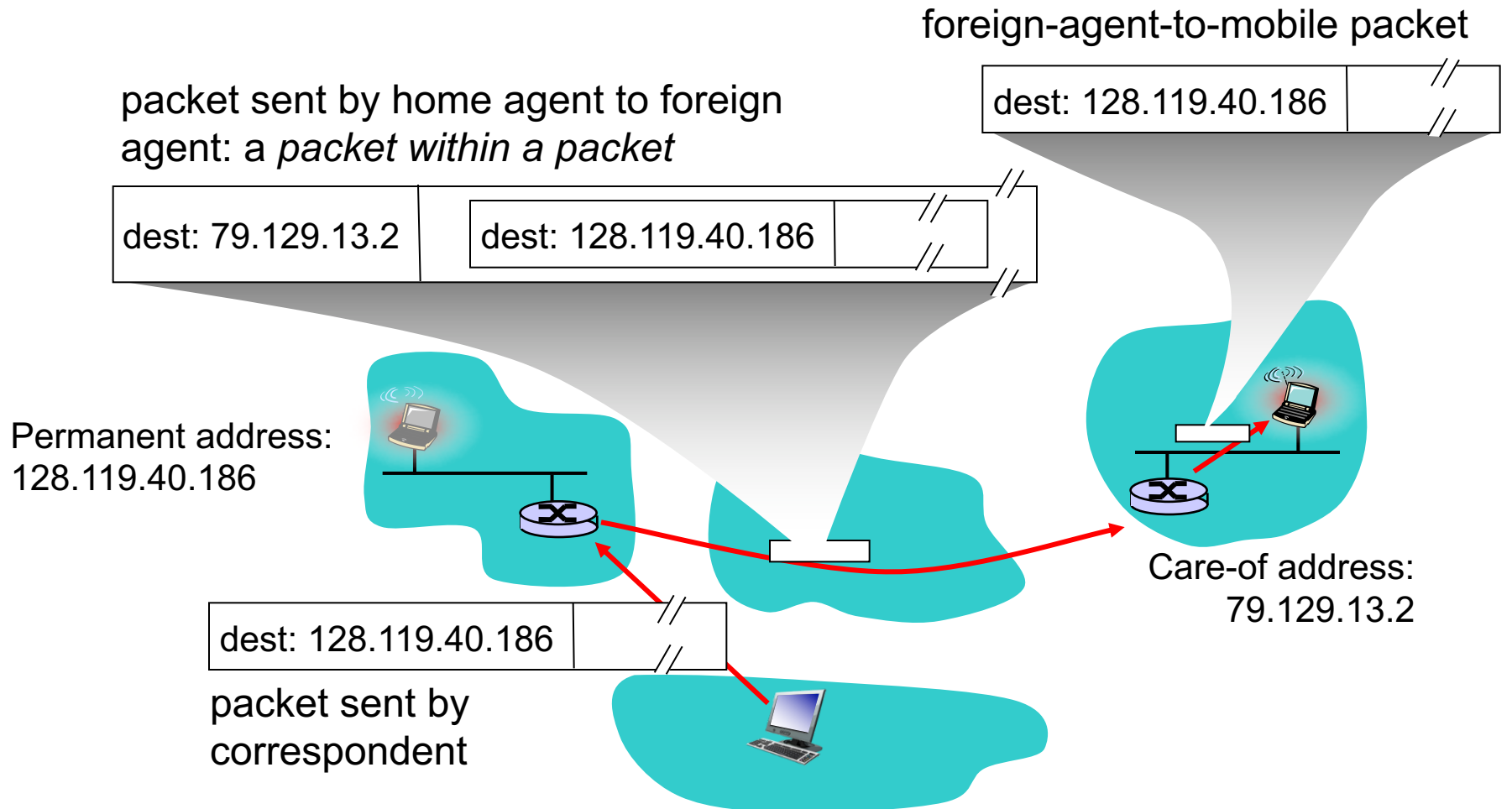
- **anchor foreign agent**: FA in first visited network
- data always routed first to anchor FA
- when mobile moves: new FA arranges to have data forwarded from old FA (chaining)



Mobile IP

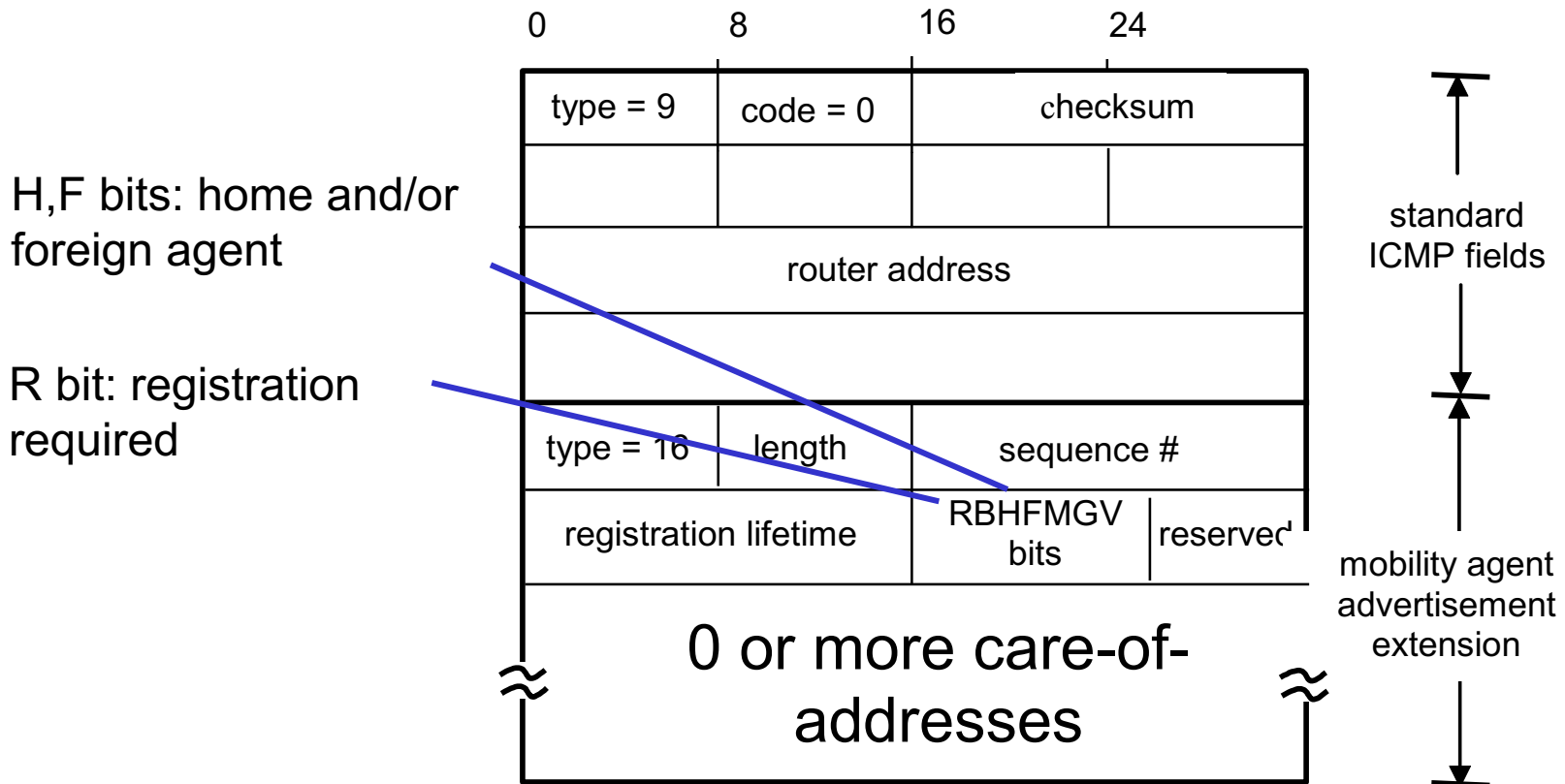
- **RFC 3344**
- has many features we've seen:
 - home agents
 - foreign agents
 - foreign-agent registration
 - care-of-addresses, encapsulation (packet-within-a-packet)
- three components to standard:
 - **indirect routing** of datagrams
 - **agent discovery**
 - **registration** with home agent

Mobile IP: indirect routing

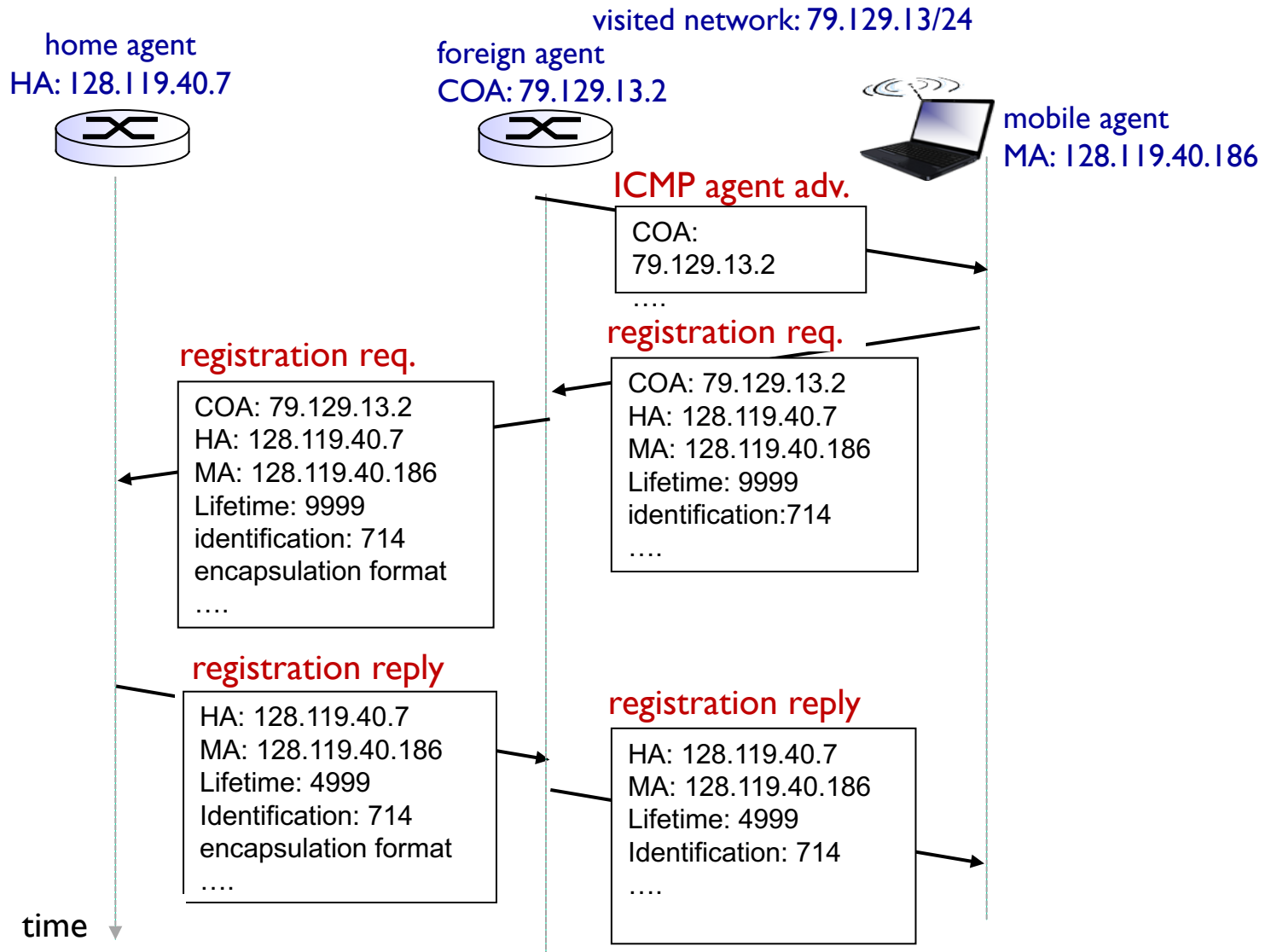


Mobile IP: agent discovery

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

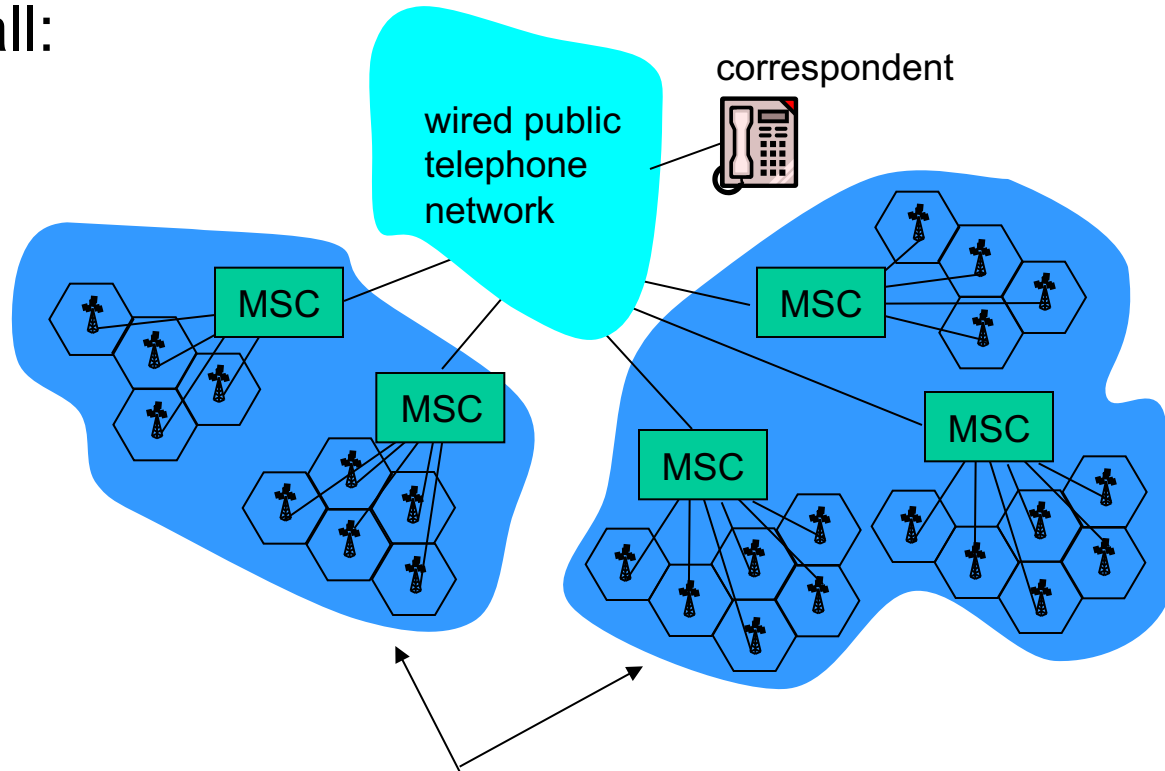


Mobile IP: registration example



Components of cellular network architecture

recall:

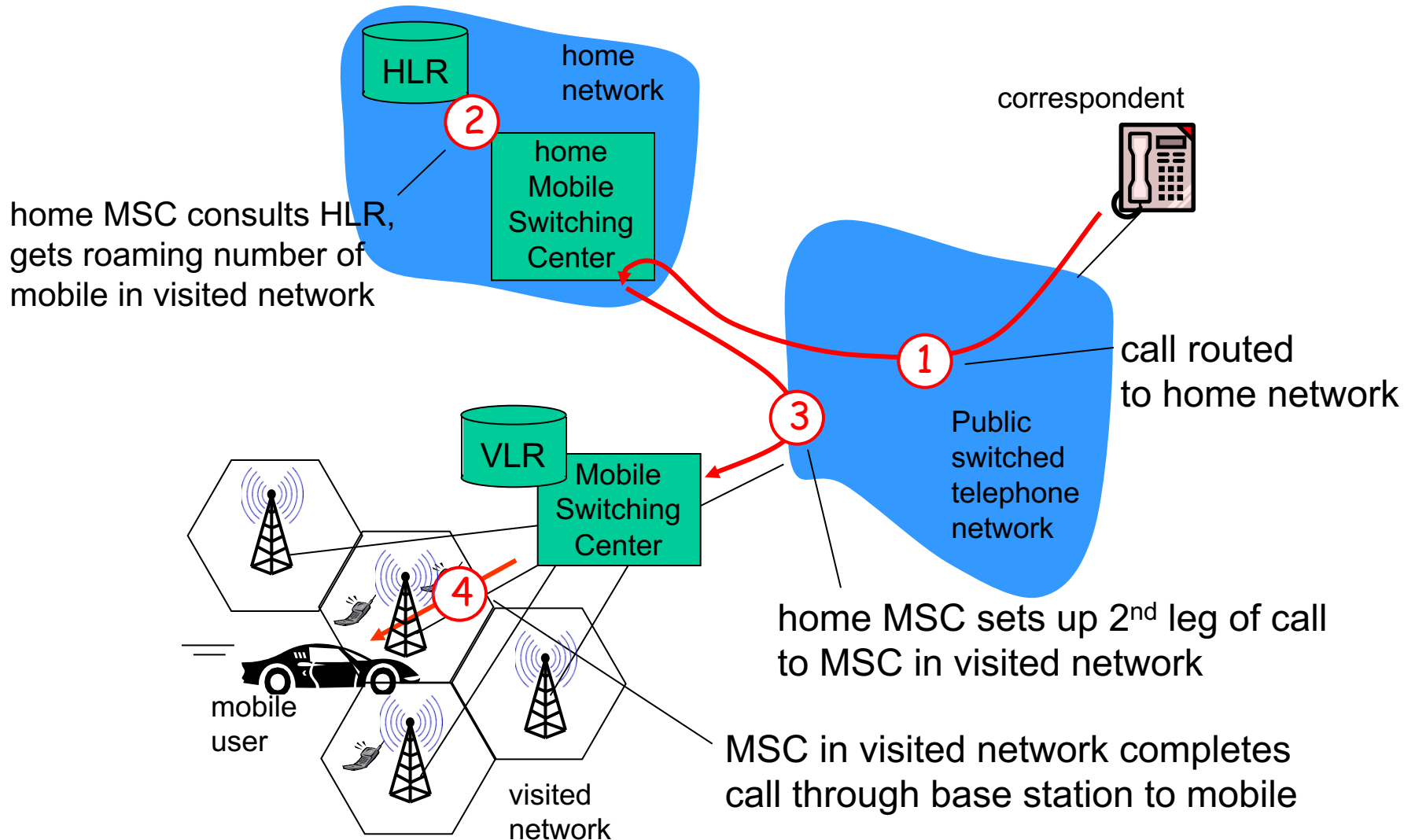


different cellular networks,
operated by different providers

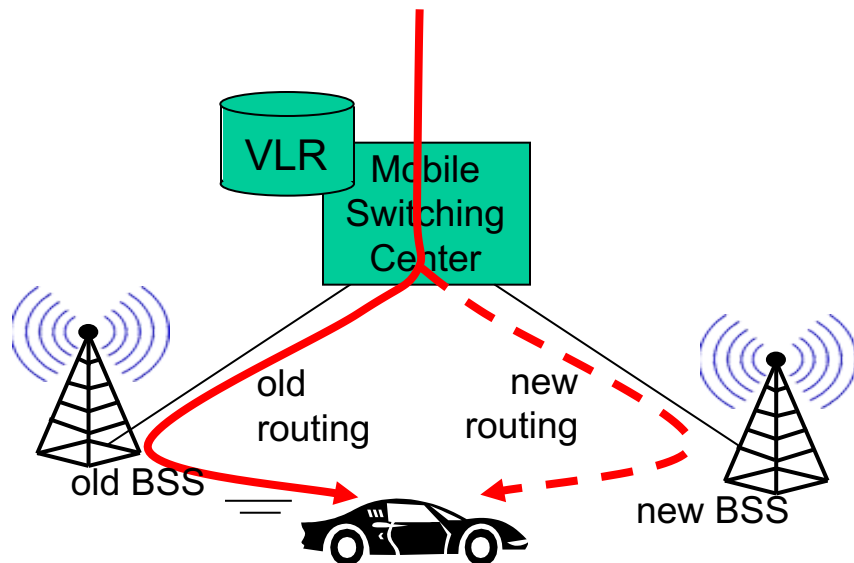
Handling mobility in cellular networks

- *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

GSM: indirect routing to mobile

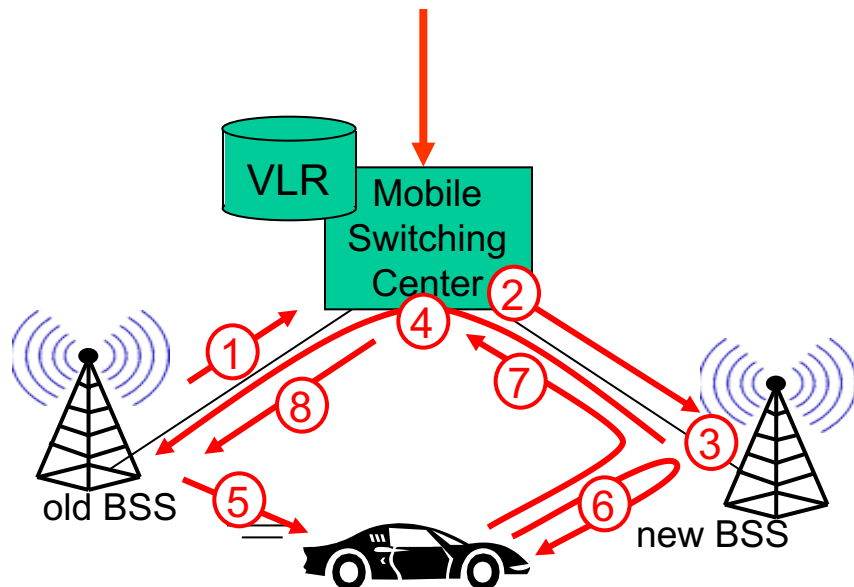


GSM: handoff with common MSC



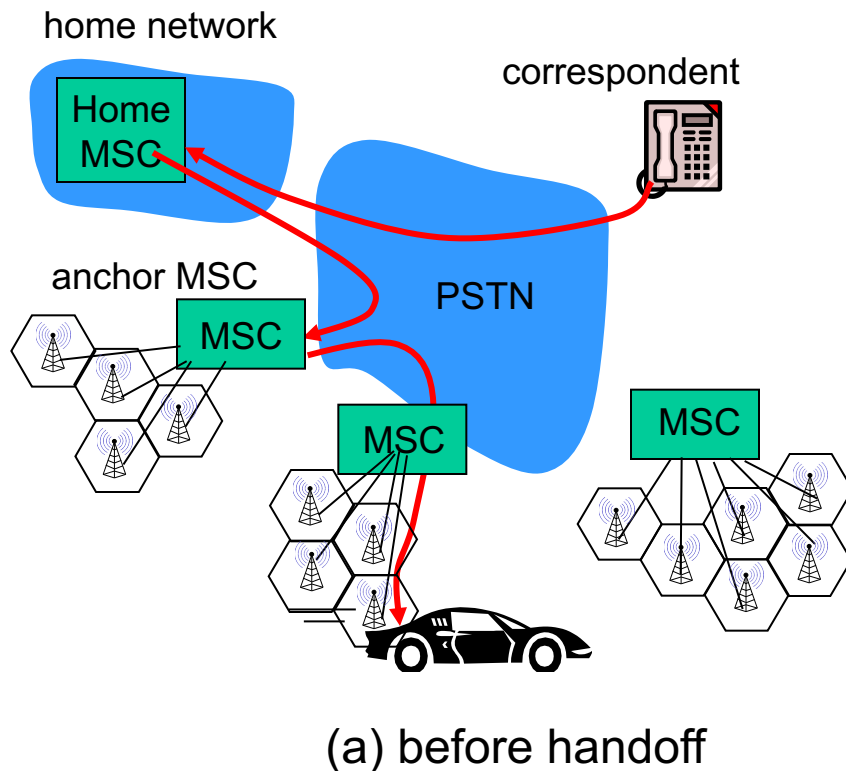
- *handoff goal*: route call via new base station (without interruption)
- reasons for handoff:
 - **stronger signal** to/from new BSS (continuing connectivity, less battery drain)
 - **load balance**: free up channel in current BSS
 - GSM doesn't mandate why to perform handoff (policy), only how (mechanism)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

GSM: handoff with common MSC



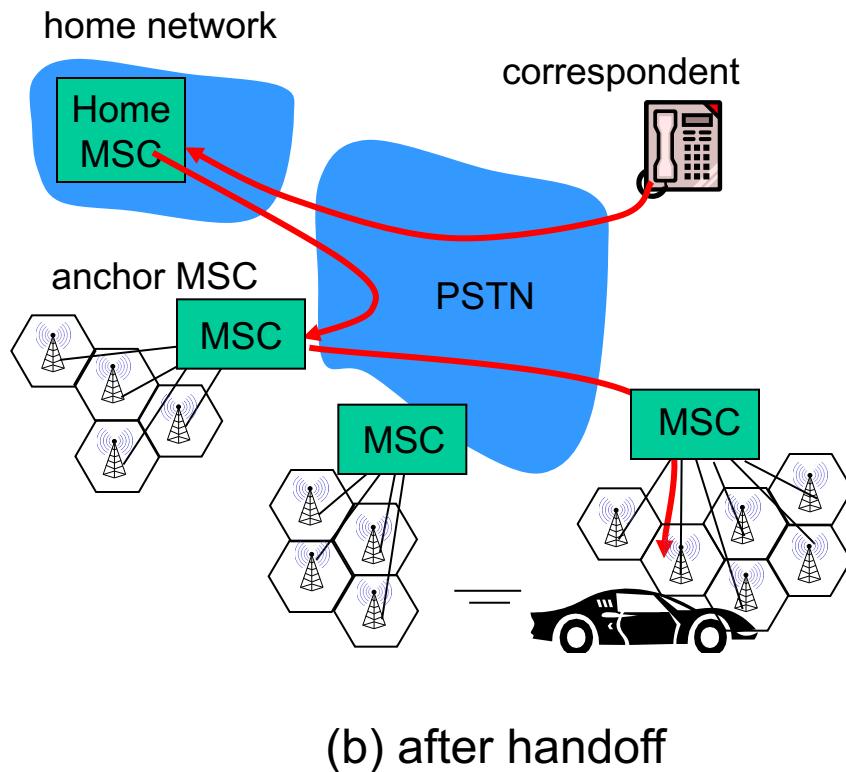
1. old BSS informs MSC of impending handoff, provides list of 1+ new BSSs
2. MSC sets up path (allocates resources) to new BSS
3. new BSS allocates radio channel for use by mobile
4. new BSS signals MSC, old BSS: ready
5. old BSS tells mobile: perform handoff to new BSS
6. mobile, new BSS signal to activate new channel
7. mobile signals via new BSS to MSC: handoff complete. MSC reroutes 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
- optional path minimization step to shorten multi-MSC chain

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
- optional path minimization step to shorten multi-MSC chain

Mobility: cellular versus Mobile IP

cellular element	Comment on cellular 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

Chapter 7 summary

Wireless

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

Mobility

- principles: addressing, routing to mobile users
 - home, visited networks
 - direct, indirect routing
 - care-of-addresses
- case studies
 - mobile IP
 - mobility in GSM

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