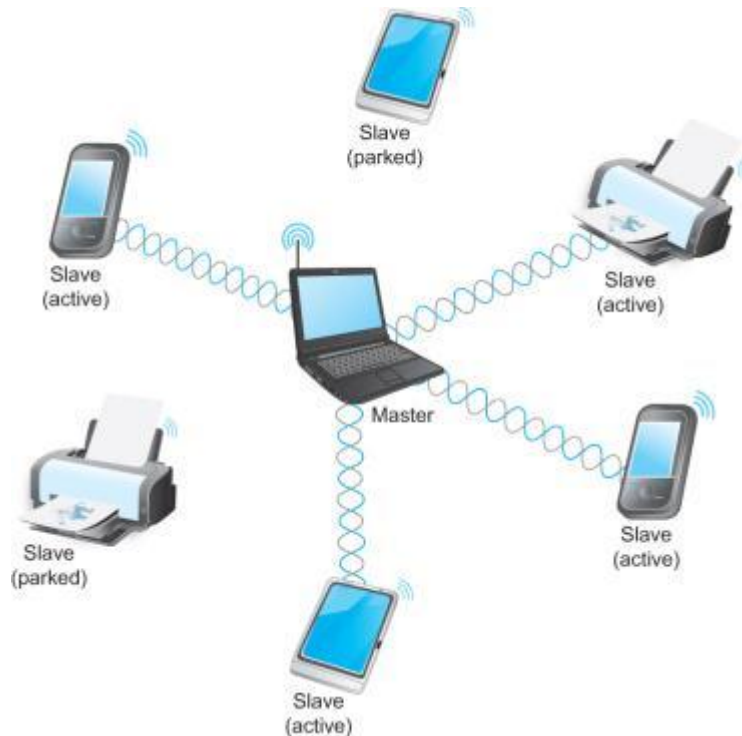


Bluetooth, cellular networks, mobility



Computer Networking: A Top Down Approach

6th edition

Jim Kurose, Keith Ross

Addison-Wesley

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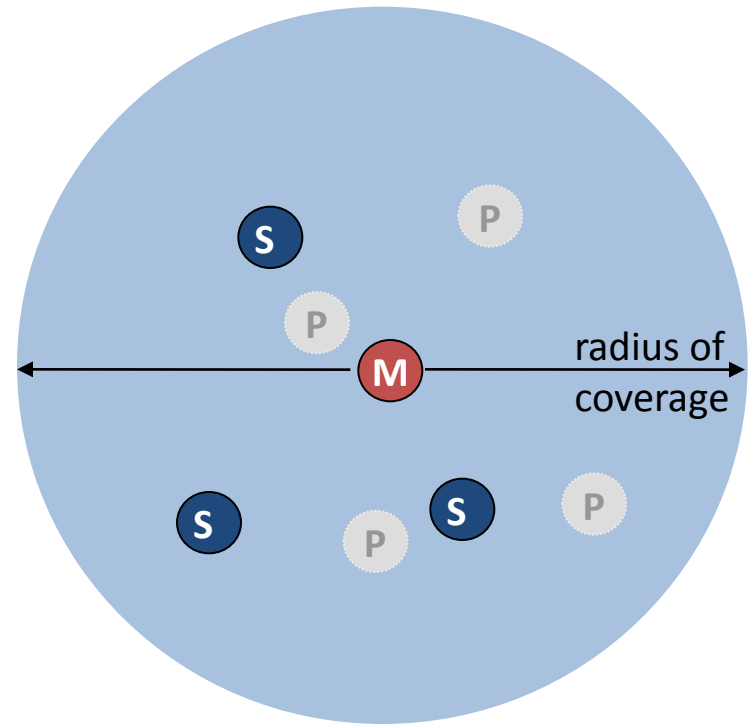





Overview

- Personal Area Networks (PANs)
 - Really short haul, low-bandwidth link
 - Replacement for cables
 - 802.15, Bluetooth
- Cellular data networks
 - Voice and data services
 - 1G, 2G, 3G, 4G
- Mobility
 - Handling users on the move
 - Mobile IP



- Bluetooth wireless
 - 802.15.1
 - Replace wired connections
 - Connect **small, battery-powered devices**
 - **Short range** (<10m)
 - **Low bandwidth** (1-3 Mbps)
 - 2.45 GHz license exempt band



-  Master device
-  Slave device
-  Parked device (inactive)



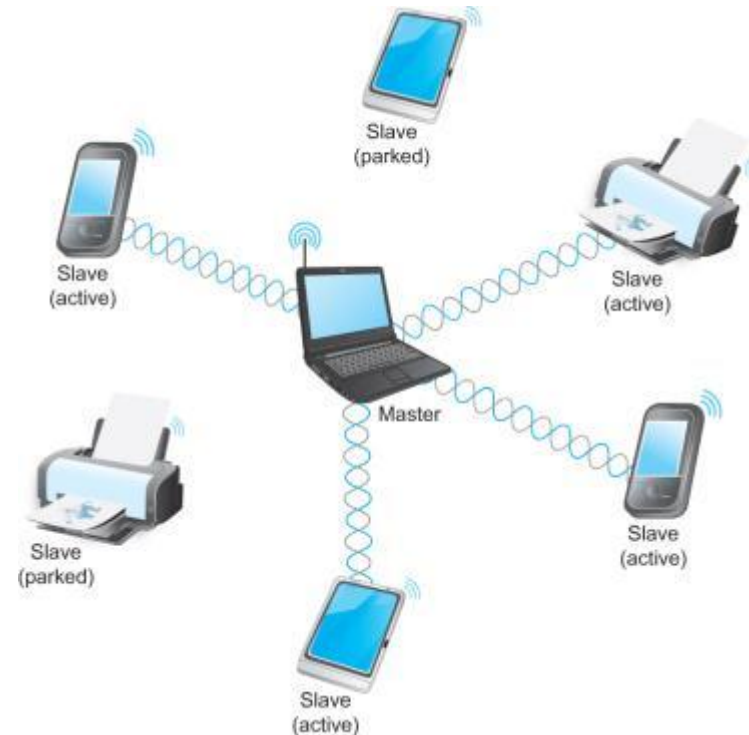
- Piconet

- Master device

- Initiates all communication

- Slave devices

- Up to seven
 - Only talk to master
 - Can be parked, inactive low-power state
 - Up to 255 parked devices





- Profiles

- Bluetooth SIG specifies supported applications as profiles (currently 25):

- **Intercom** - two telephones connect as walkie-talkies
 - **Headset/hands-free** - headset to base station
 - **Human interface device** - connect keyboard/mouse
 - **Networking** - share files
 - **Dial-up networking** - use phone as a modem
 - ...

- Conway's law in action?

"organization which design systems...are constrained to produce designs which are copies of the communication structures of these organization."



- Radio layer
 - 79 bands, 1 Mhz each, 2402-2480 Mhz
 - Spread spectrum, frequency hopping
 - 625 μ s per slot
 - Master transmits only in odd time slots
 - Slave uses even, but only when asked by master
 - Early version collided with 802.11
 - Bluetooth amended to avoid channels with RF signals
 - Bandwidth
 - Bluetooth 1.0, FSK 1-bit symbol, 1 Mbps
 - Bluetooth 2.0, PSK 2-3 bits symbol, 2-3 Mbps

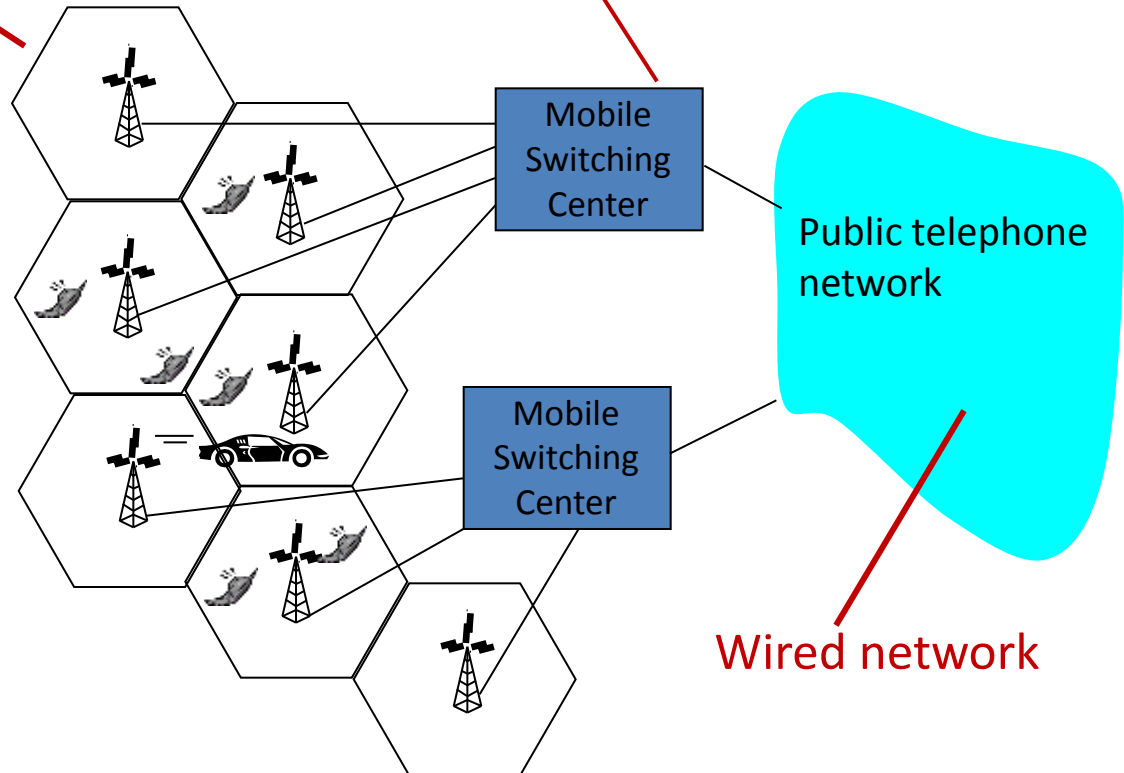
Components of cellular network

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

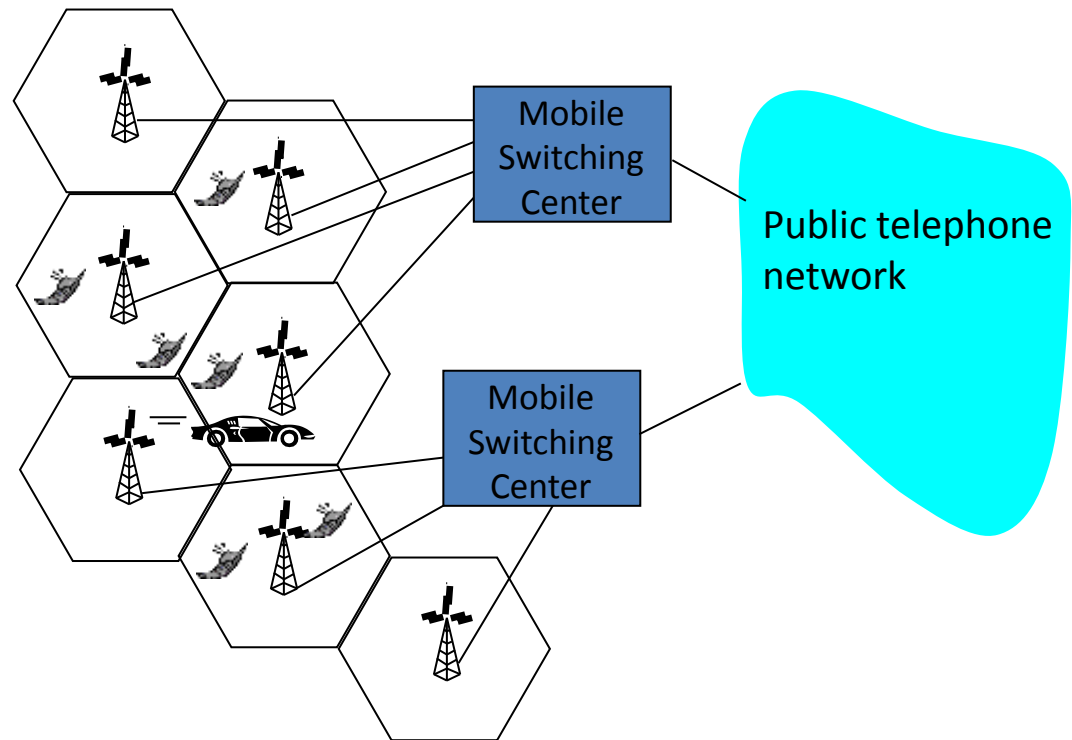
- ❖ Connects cells to wired tel. net.
- ❖ Manages call setup (more later!)
- ❖ Handles mobility (more later!)



Wired network

Mobile telephone system

- Generations:
 - 1G, analog voice
 - 2G, digital voice, SMS
 - 3G, digital voice and data
 - 4G, faster data



1G

- Mobile radiotelephones
 - Maritime and military, early 20th century
 - 1946 first car-based system in St. Louis
 - Single channel, push-to-talk
- Improved Mobile Telephone System (IMTS)
 - 1960s
 - One channel send, one channel receive
 - 23 channels, 150-450 Mhz
 - Single hilltop transmitter



1G

- Advanced Mobile Phone System (AMPS)

- 1980s

- Divide region into **cells**

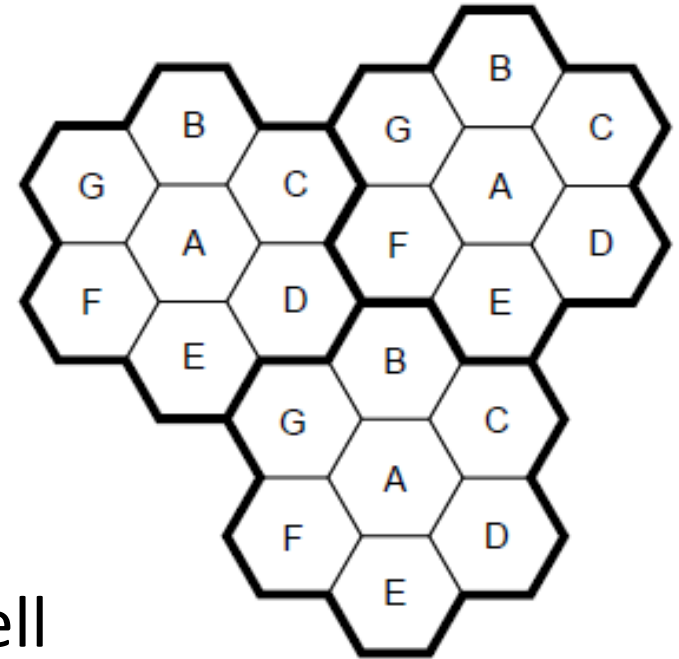
- 10-20 km
 - Different frequencies per cell
 - Increased capacity
 - Reduced transmit power?

- Device controlled by single cell

- **Handoff** when base station notices weak signal

- Frequency division multiplexing

- Around 45 calls per cell



1G

- AMPS

- Analog transmission

- Each phone

- 32-bit serial #, 10-digit phone #

- To place a call:

- Sends identify and destination # on access channel
 - Base station responds with allocated idle channel

- To receive a call:

- Base station broadcasts packet on paging channel of cell in which phone currently registered
 - All phones listen on paging channel
 - Negotiate idle channel via access channel



2G

- 2nd generation wireless

- Digital voice

- 1990s

- Various systems:

- GSM (Global System for Mobile communications)

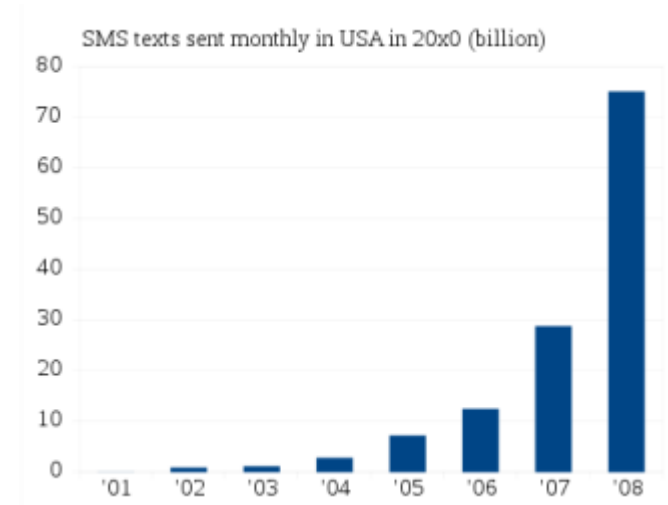
- CDMA (Code Division Multiple Access)

- iDEN (Nextel)

- Short Message Service (SMS)

- High cell densities

- GSM, CDMA, EDGE, GPRS



3G

- 3rd generation wireless
 - Digital voice and data
 - Early 2000's
 - ITU's IMT-2000 vision:
 - Go into service in 2000
 - Reality: at least a few years late
 - Frequency of 2000 Mhz all over the world
 - Reality: only China allocated spectrum
 - Bandwidth of 2000 kbps
 - Reality: peak data rates ~200 kbps
 - UTMS, CDMA2000, EVDO



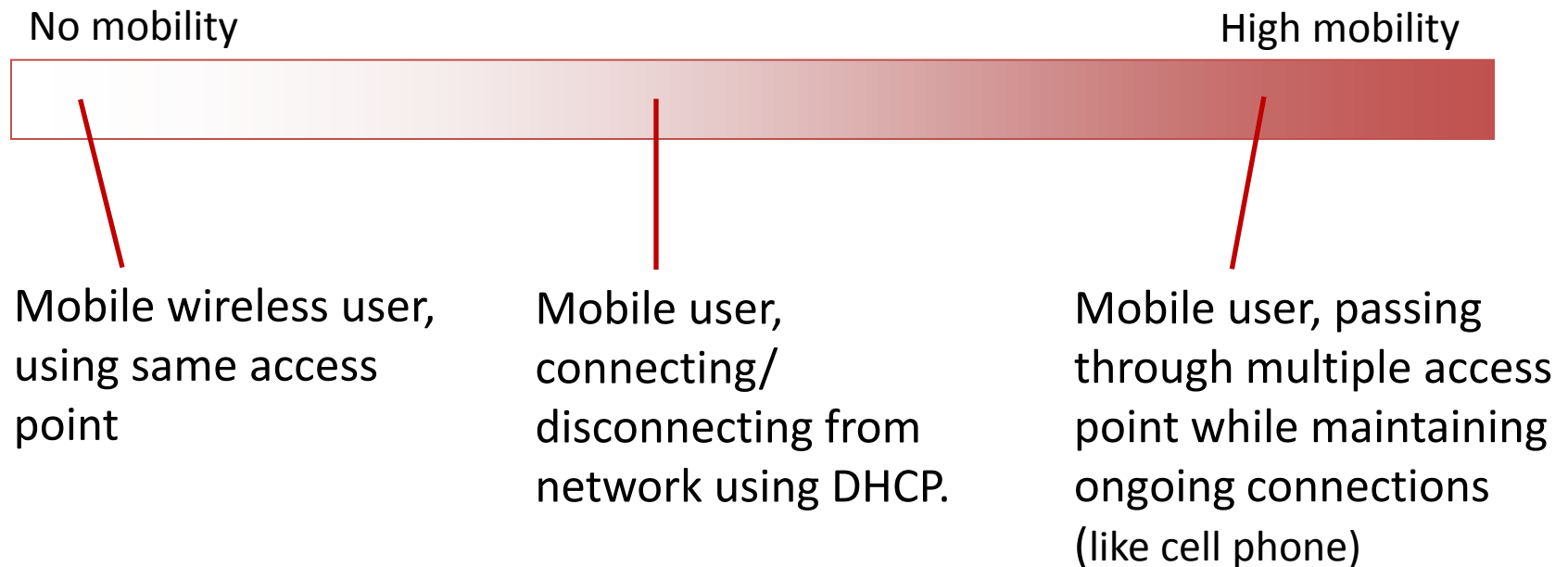
4G

- 4th Generation wireless
 - Fast data
 - Long term evolution (LTE)
 - Verizon, AT&T
 - 12 Mbps downstream, 5 Mbps upstream
 - HSPA+
 - T-Mobile, AT&T
 - 21 Mbps downstream, 6 Mbps upstream
 - WiMAX (802.16)
 - Sprint, Nextel
 - 10 Mbps downstream, 6 Mbps upstream



What is mobility?

❖ Spectrum of mobility, from the *network* perspective:



Mobility: vocabulary

Home network:

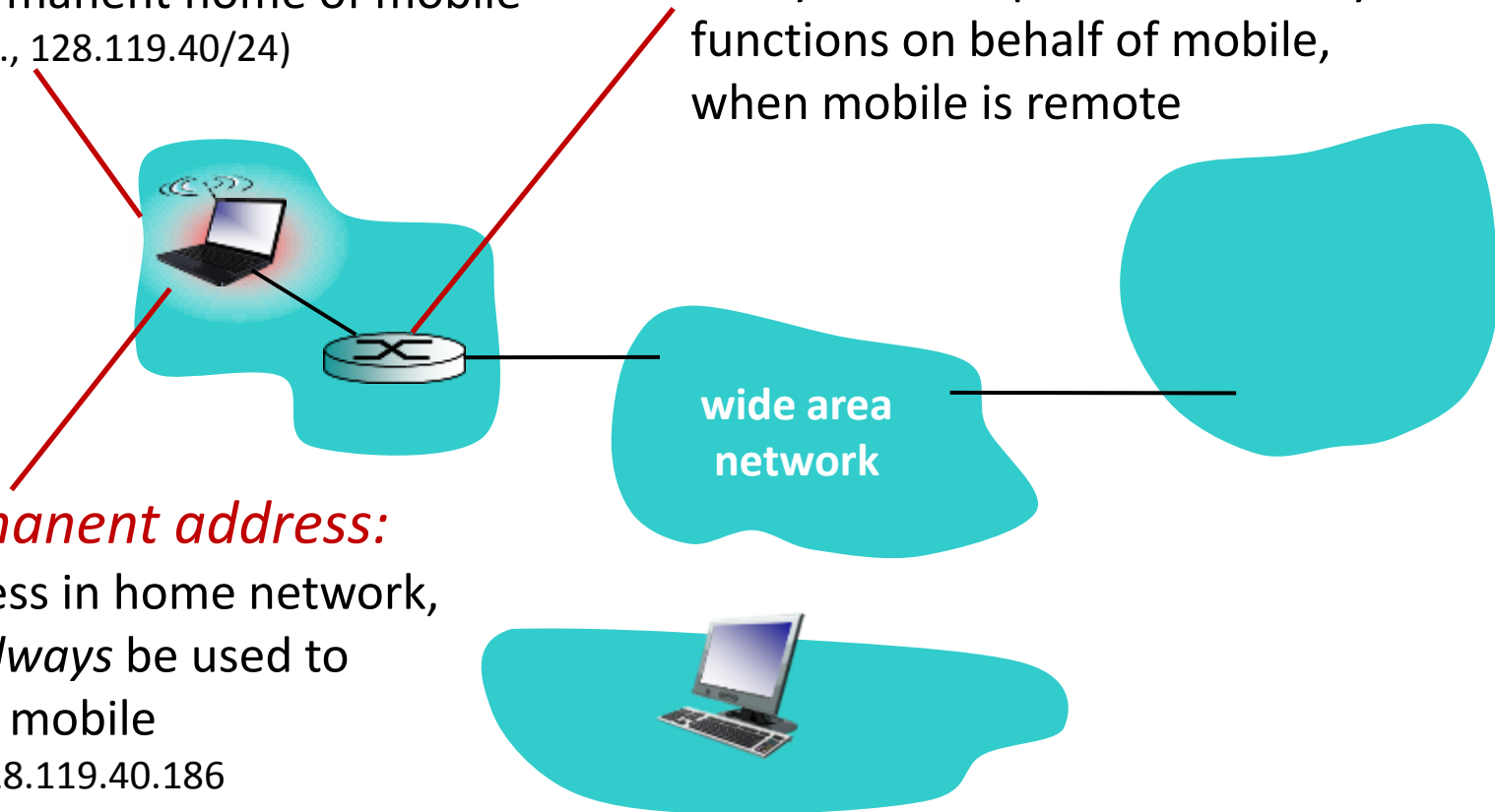
Permanent home of mobile
(e.g., 128.119.40/24)

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:

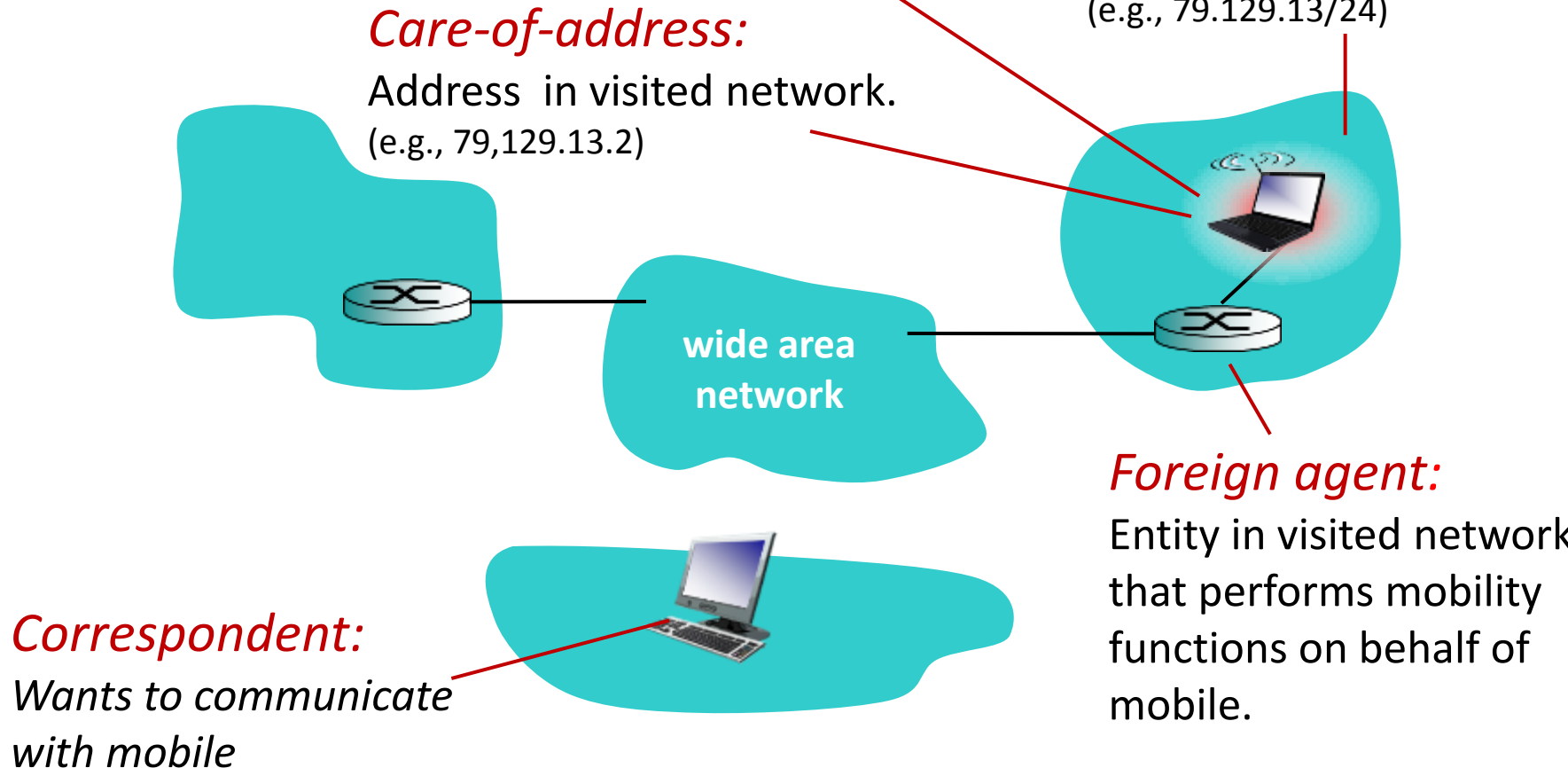
Remains constant
(e.g., 128.119.40.186)

Care-of-address:

Address in visited network.
(e.g., 79.129.13.2)

Visited network:

Network in which mobile
currently resides
(e.g., 79.129.13/24)



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

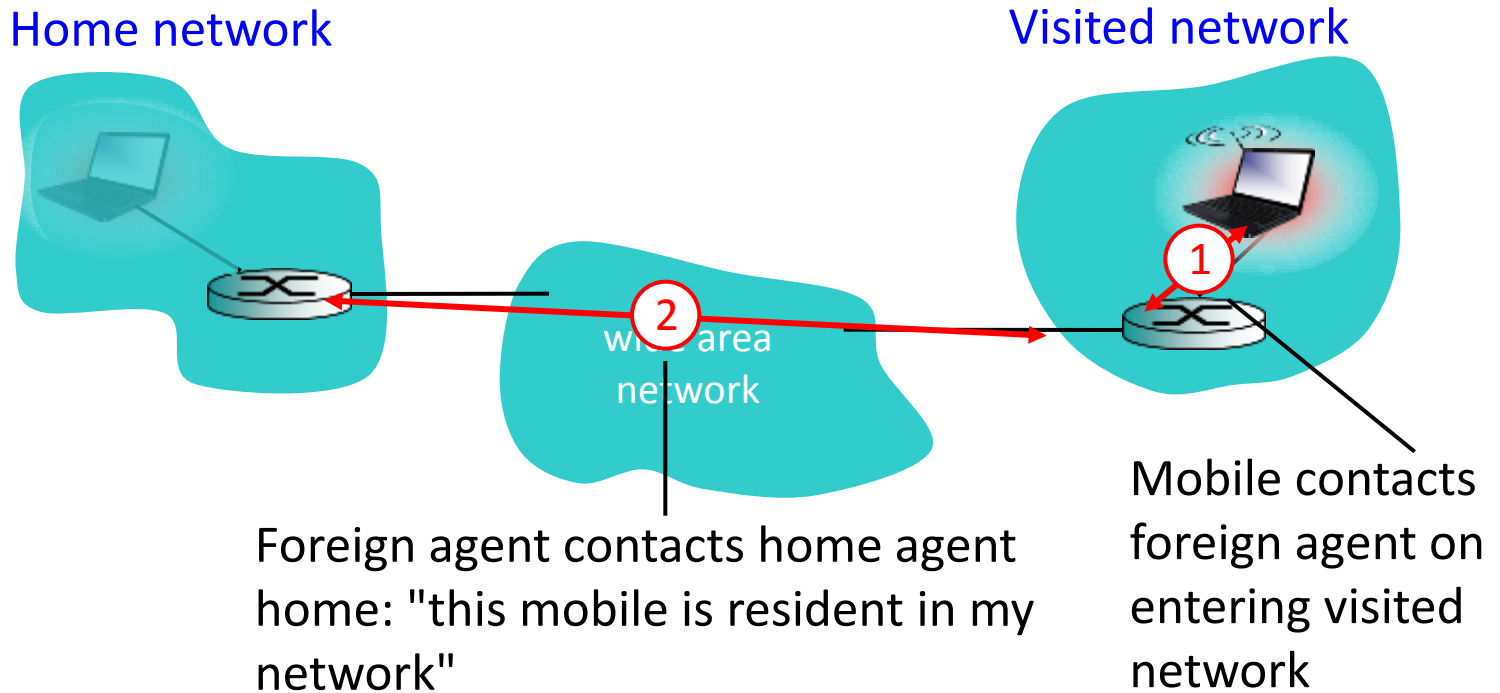
❖ *Let routing handle it:*

- Routers advertise current address of mobile-nodes-in-residence via not scalable table exchange
- Routing table to millions of mobiles are 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

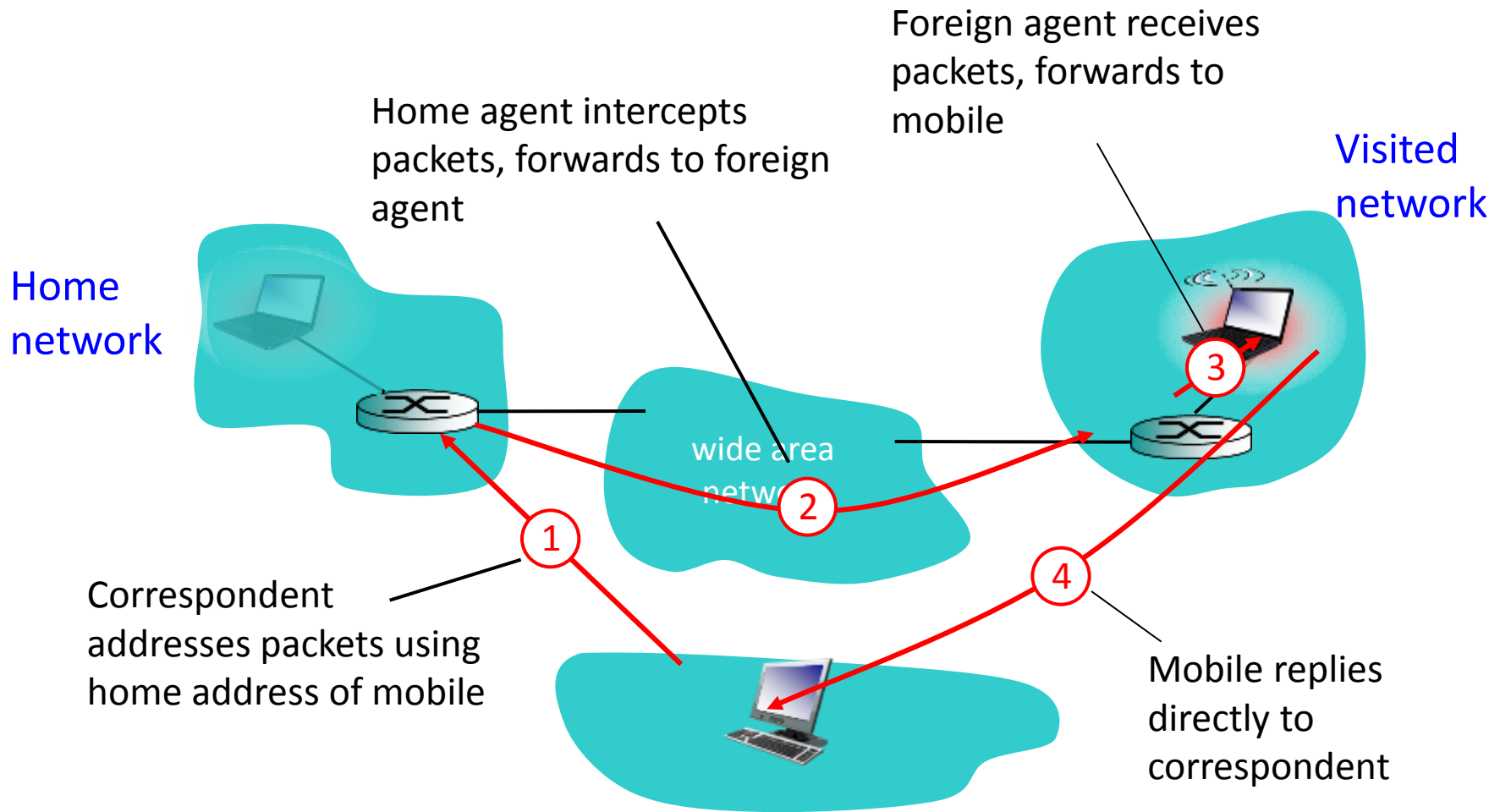
Mobility: registration



End result:

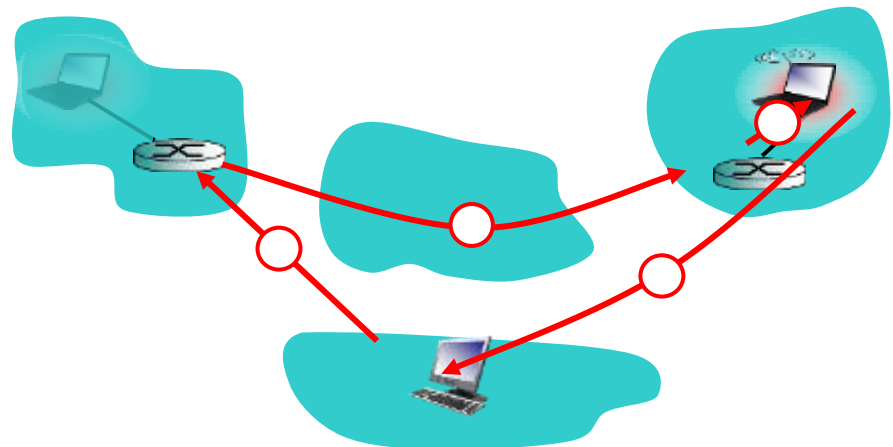
- ❖ Foreign agent knows about mobile
- ❖ Home agent knows location of mobile

Mobility via indirect routing



Indirect routing: comments

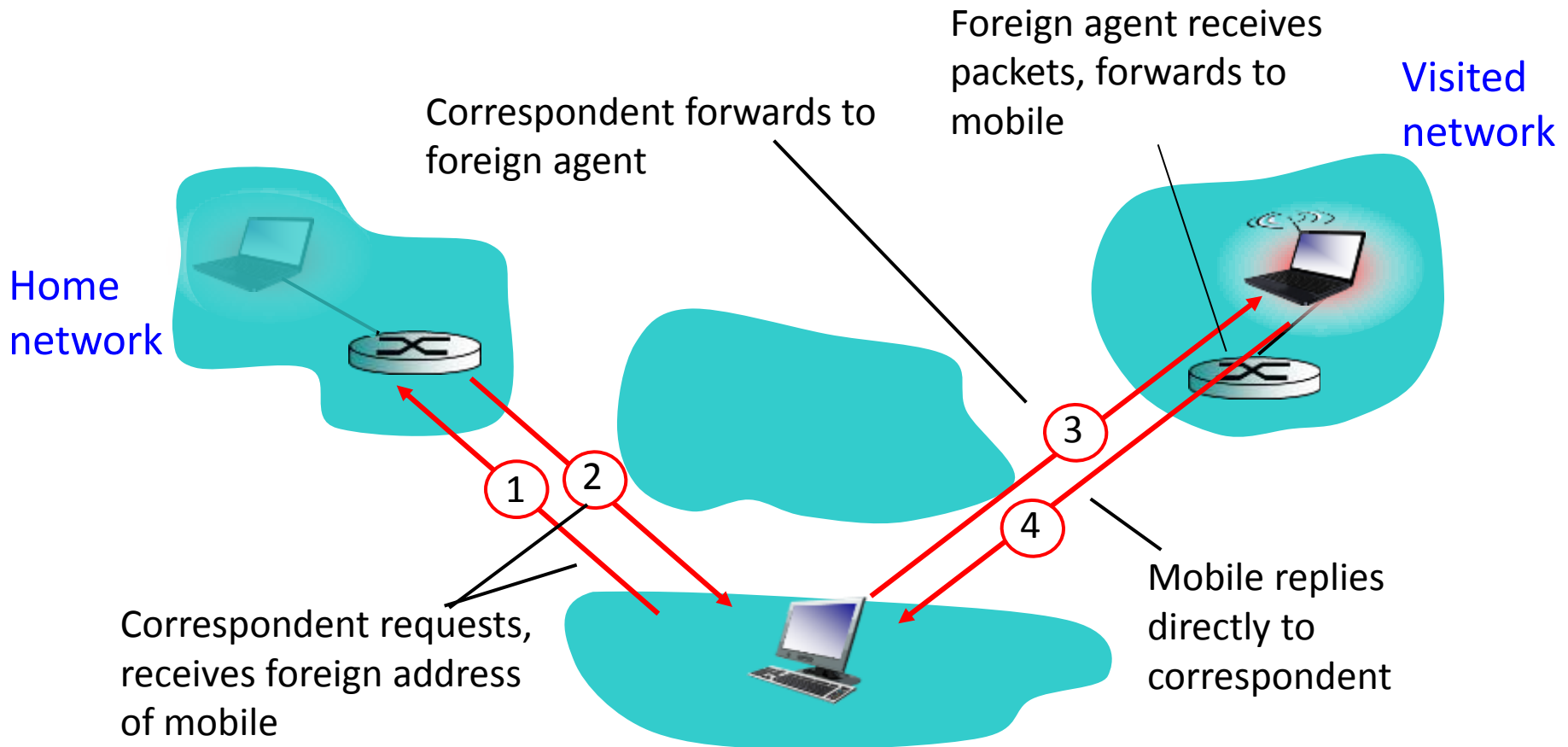
- ❖ Mobile uses two addresses:
 - **Permanent address:** used by correspondent (hence mobile location is *transparent* to correspondent)
 - **Care-of-address:** used by home agent to forward datagrams to mobile
- ❖ Foreign agent functions may be done by mobile itself
- ❖ **Triangle routing:** correspondent-home-network-mobile
 - Inefficient when correspondent, mobile are in same network



Indirect routing: moving 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

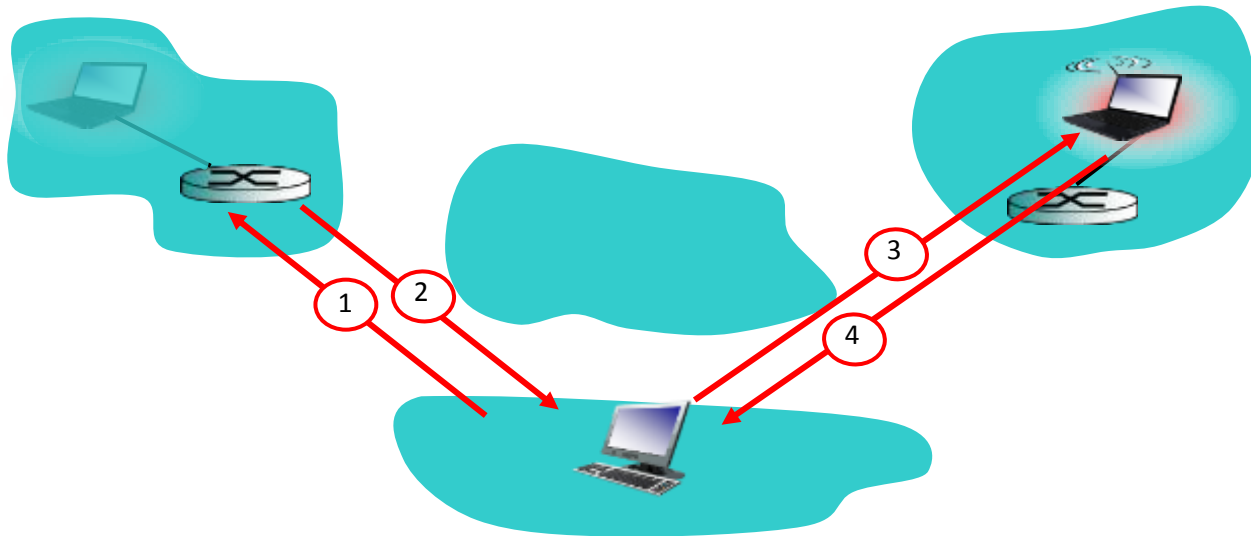


Direct routing: comments

❖ Overcome triangle routing problem

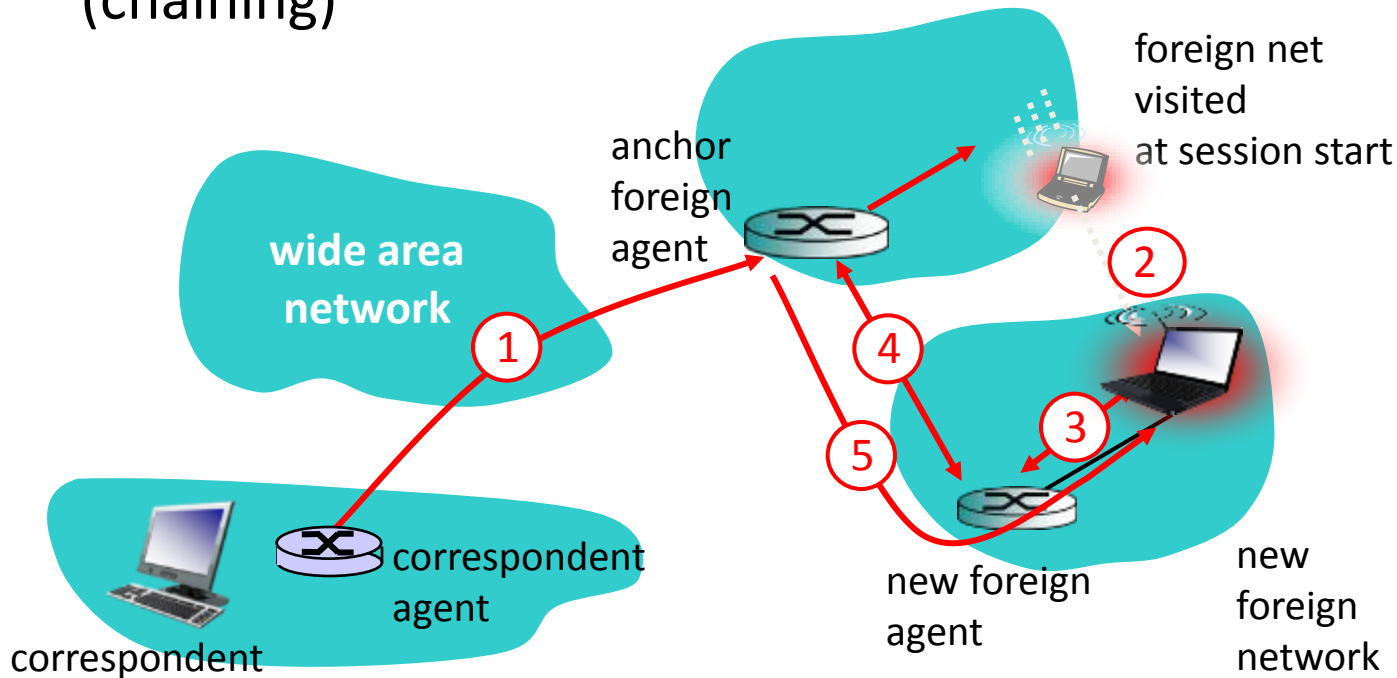
❖ *Non-transparent to correspondent:*

- Correspondent must get care-of-address from home agent
- What if mobile changes visited network?



Handling mobility with direct routing

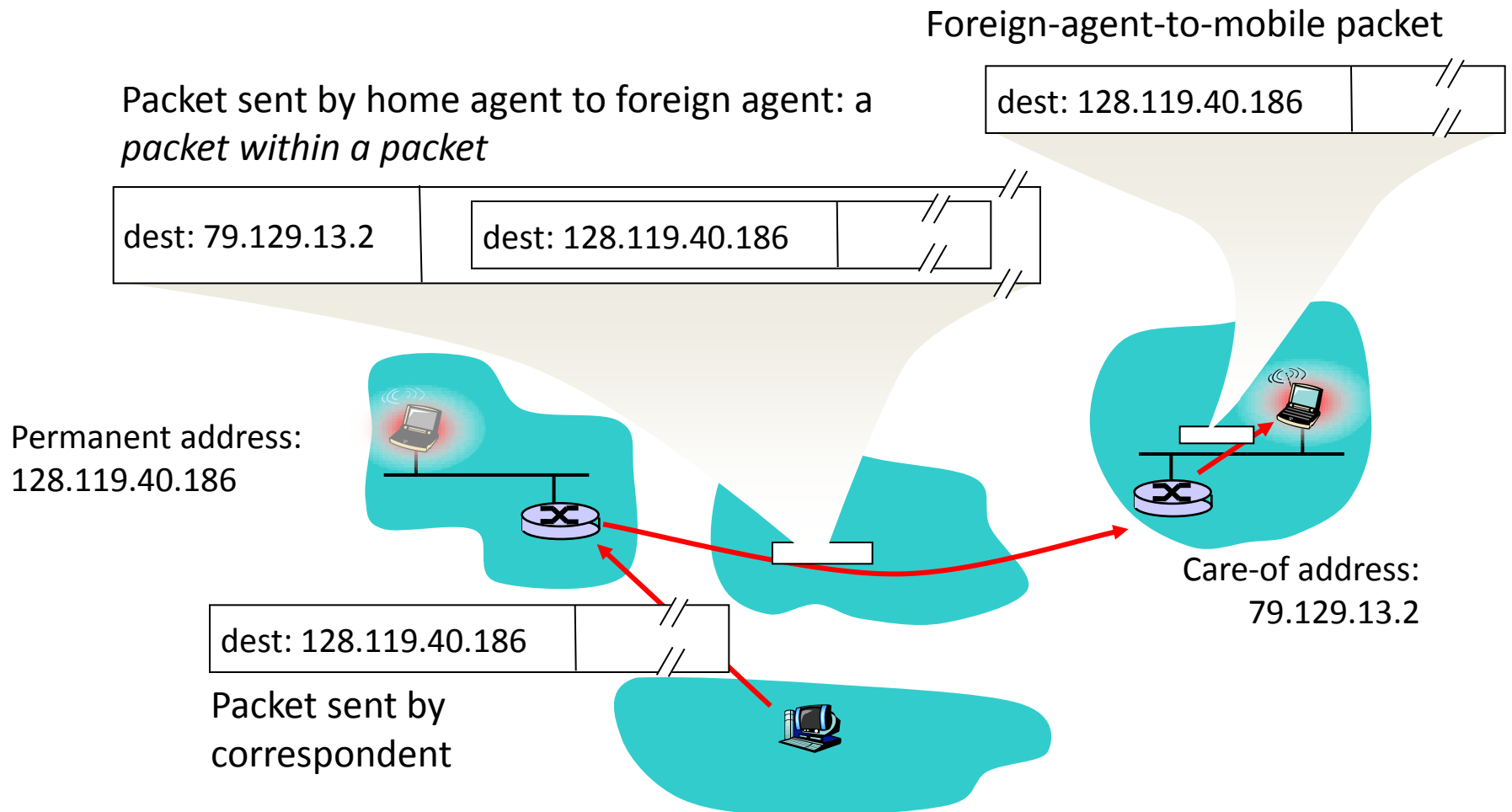
- ❖ Anchor foreign agent:
 - FA in first visited network
- ❖ Data always routed first to anchor FA
- ❖ When mobile moves:
 - New FA arranges to have data forwarded from old FA (chaining)



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

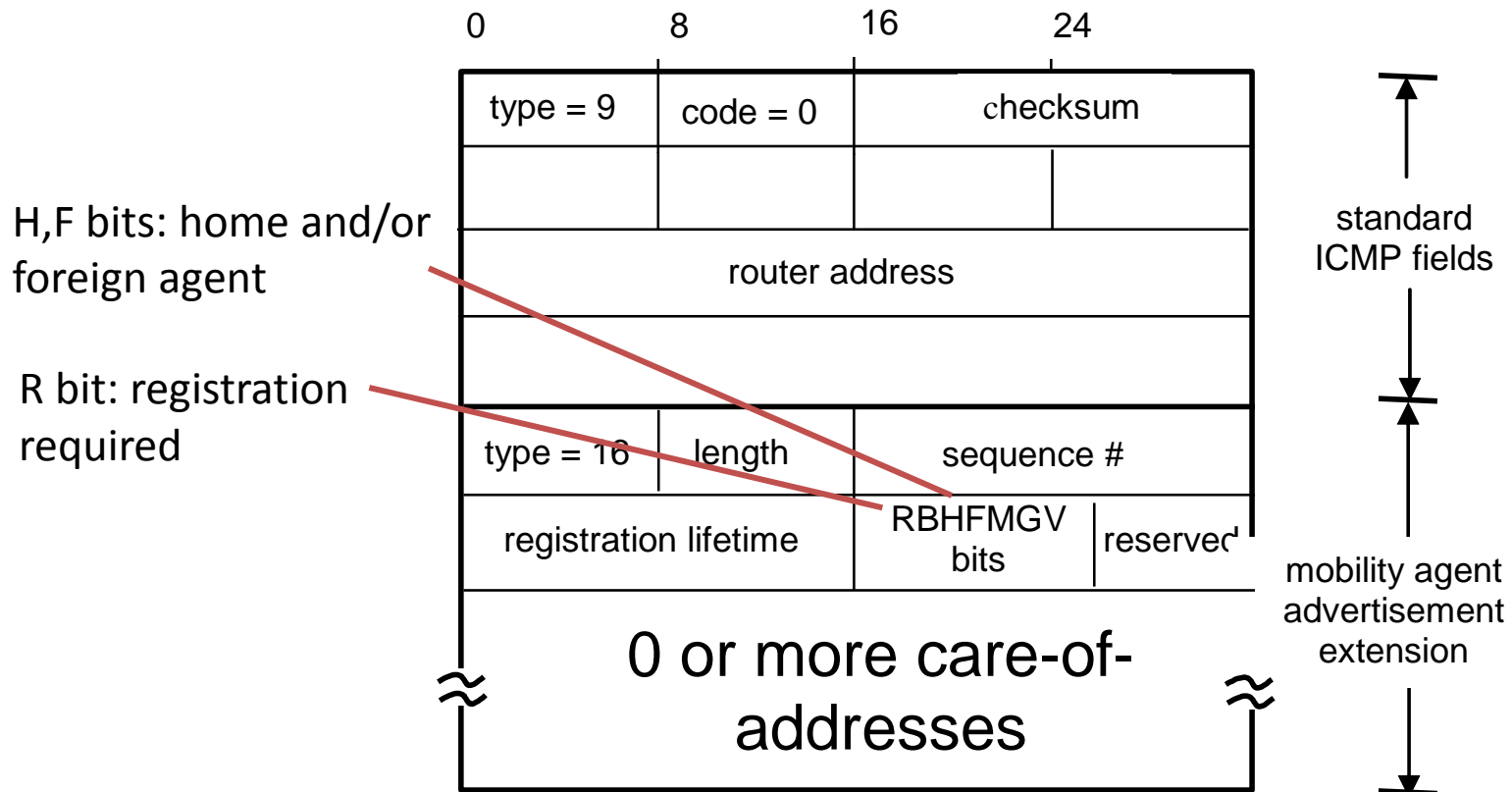
Mobile IP: indirect routing



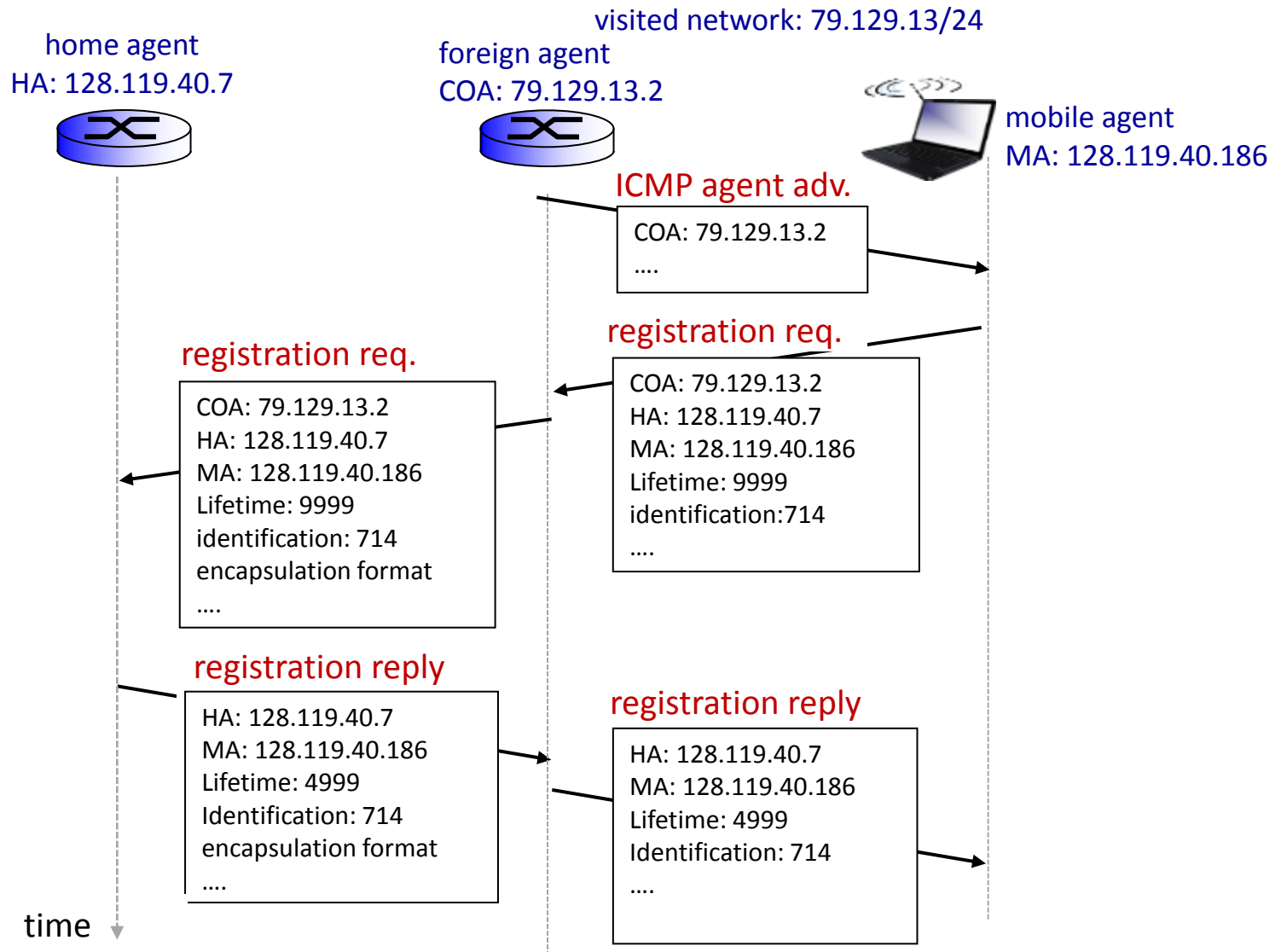
Mobile IP: agent discovery

❖ *Agent advertisement:*

- Foreign/home agents advertise service by broadcasting ICMP messages (typefield = 9)



Mobile IP: registration example



Mobility: impact on high layers

- 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

Summary

- Bluetooth
 - Used to connect nearby devices
- Cellular networking
 - Voice and data services
 - 1G, 2G, 3G, 4G
- Mobility
 - How to handle host moving between networks
 - Mobile IP