Part I Syllabus – Fundamental Underlying Layers

Date	Subject	File
Week 1: 9/Jan/2023 11/Jan/2023	Introduction: course logistics and Internet history	M1-L1-Introduction.pptx
	Layered Network Architecture	First part of M1-L2-Network Layer & Physical Resilience.pptx
Week 2: 16/Jan/2023 18/Jan/2023	Physical Layer: Network Resilience	Second part of M1-L2-Network Layer & Physical Resilience.pptx
	Data link layer – Flow control	M1-L3-DLL-Flow Control.pptx
Week 3: 25/Jan/2023	Data link layer – Error control	M1-L4-DLL-Error Control.pptx
Week 4: 30/Jan/2023 01/Feb/2023	Local area network – Introduction	M1-L5-LAN-Introduction.pptx
	Local area network – MAC	M1-L6-LAN-MAC.pptx
Week 5: 06/Feb/2023 08/Feb/2023	Local area network – Ethernet	First part of M1-L7-LAN-Ethernet.pptx
	Local area network – Ethernet Evolutions	Second part of M1-L7-LAN-Ethernet.pptx
Week 6: 13/Feb/2023 15/Feb/2023	Local area network – WLAN	M1-L8-LAN-WLAN.pptx
	Mobile Access Networks	M1-L9-Mobile.pptx
Week 7: 20/Feb/2023 22/Feb/2023	E-learning for Network paradigms	M1-L10-Paradigms.pptx
	Network paradigms	M1-L10-Paradigms.pptx

Additional Materials

- The related content talked today in https://eclass.teicrete.gr/modules/document/file.php/TP326/%CE%98%CE%B5%CF%89%CF%81%CE%AF%CE%B1%20(Lectures)/Computer_Networking_A_Top-Down_Approach.pdf is as follow:
  - WiFi: 802.11 Wireless LANs: Page 526 - Page 546
  - Cellular Internet Access: Page 547 - Page 555
  - Mobility Management: Principles: Page 555 - Page 564

- You can also find other video materials about
  - 802.11 WiFI https://www.youtube.com/watch?v=t3FVP5wuG4g
  - Wireless Communication https://www.youtube.com/watch?v=8T7orRAQgic&list=PLCyR4nKNLRkFTER9ohRBnbRFK0pWe0Qtf&index=1&t=61s

Mobile Access

"The best part is there's no roaming charges!"

SC2008/CZ3006/CE3005
Computer Network

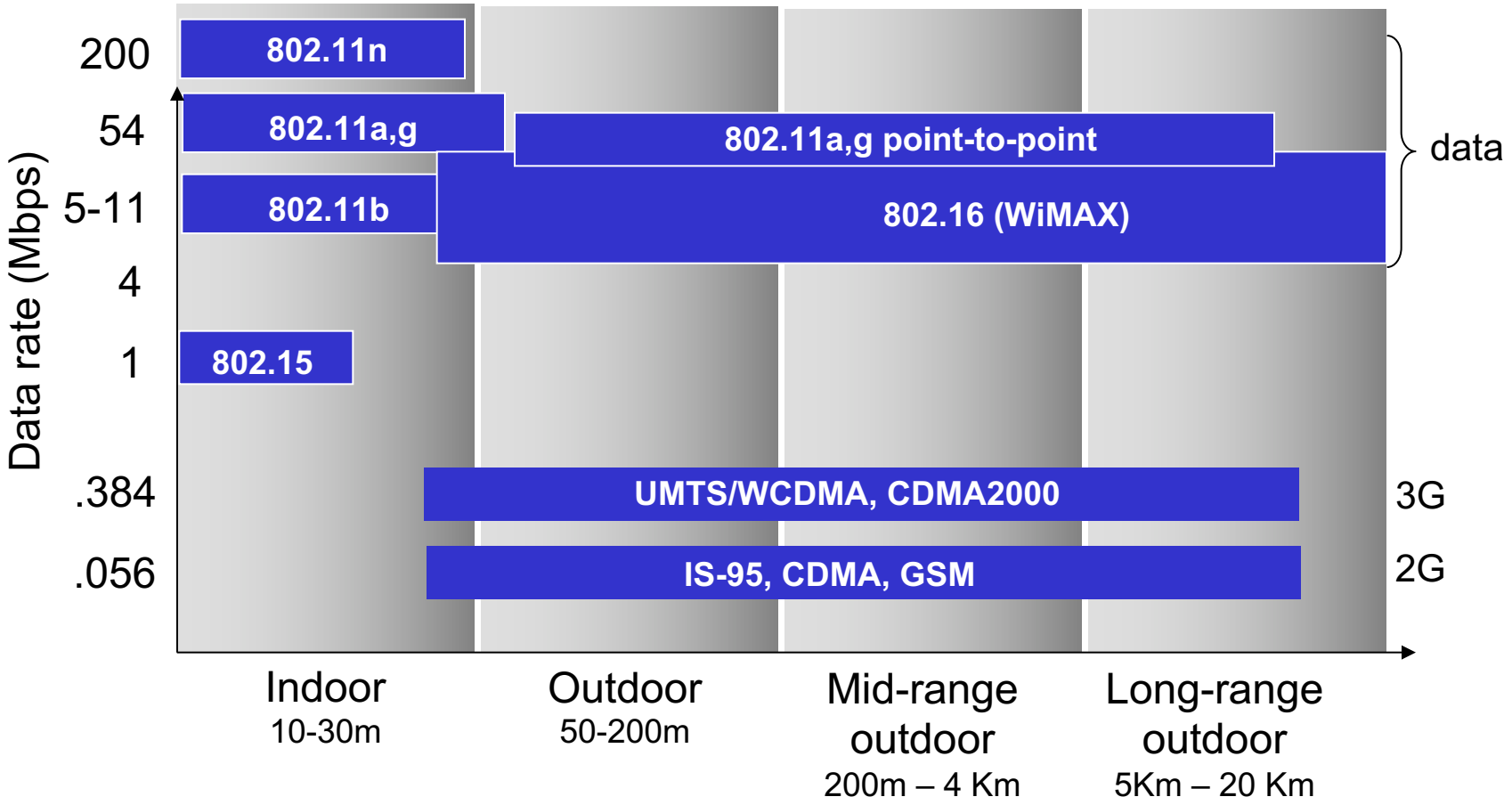
Lecture 9
Mobile Access Networks:
From 1G to 5G
(Not Examinable)

Contents

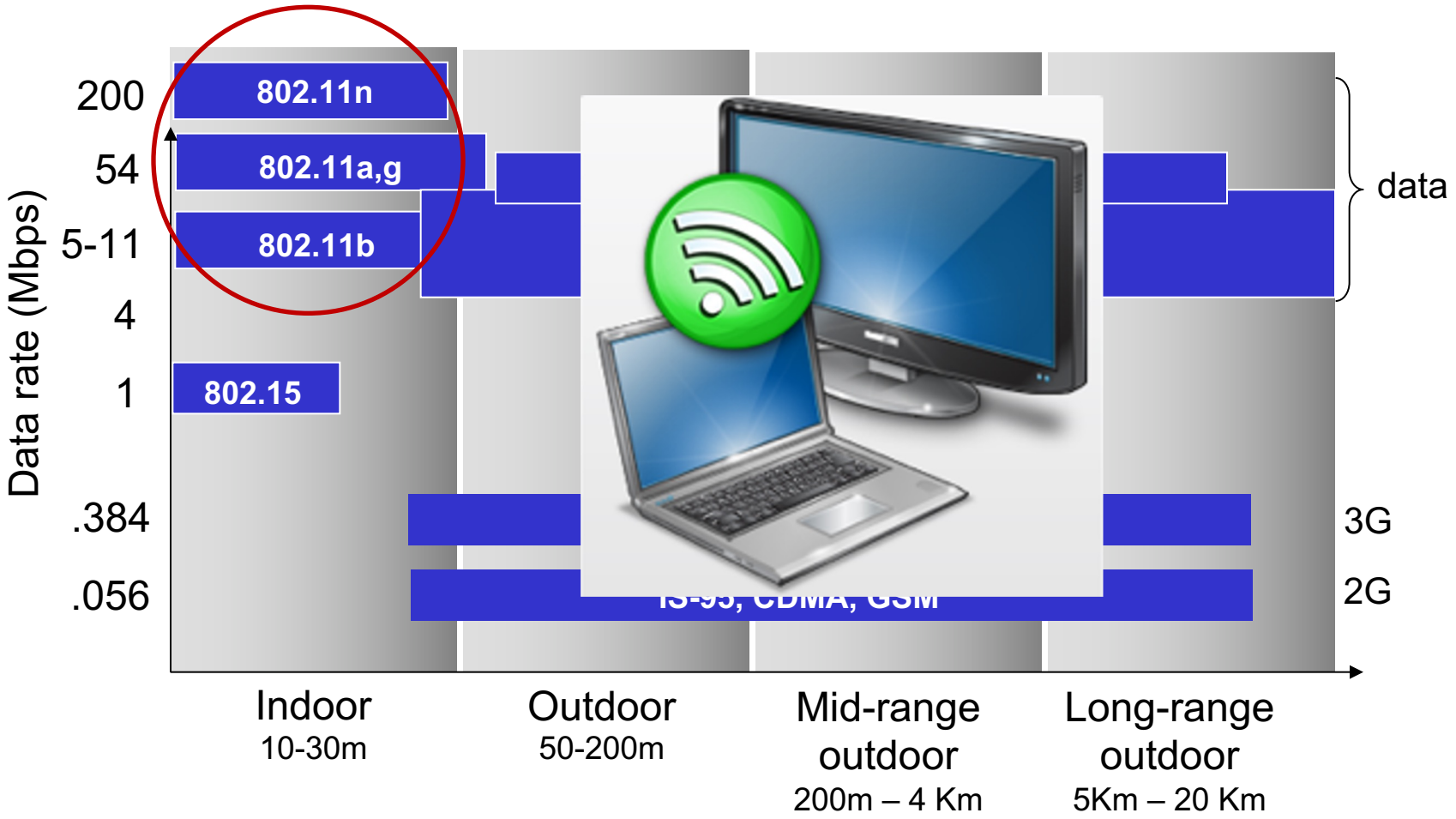
- **Wireless Link Standards**
  - 802.11 (Wi-Fi)
  - Cellular (1G to 5G)
  - 802.15 (e.g., ZigBee)
  - 802.16 (WiMax)
- **Cellular Networks**
  - Network architecture
  - MAC protocols
  - 1G to 5G
- **Mobility handling**
  - Mobility vocabulary
  - Indirect routing
  - Direct routing

Wireless Link Standards

Characteristics of Selected Wireless Link Standards



Characteristics of Selected Wireless Link Standards



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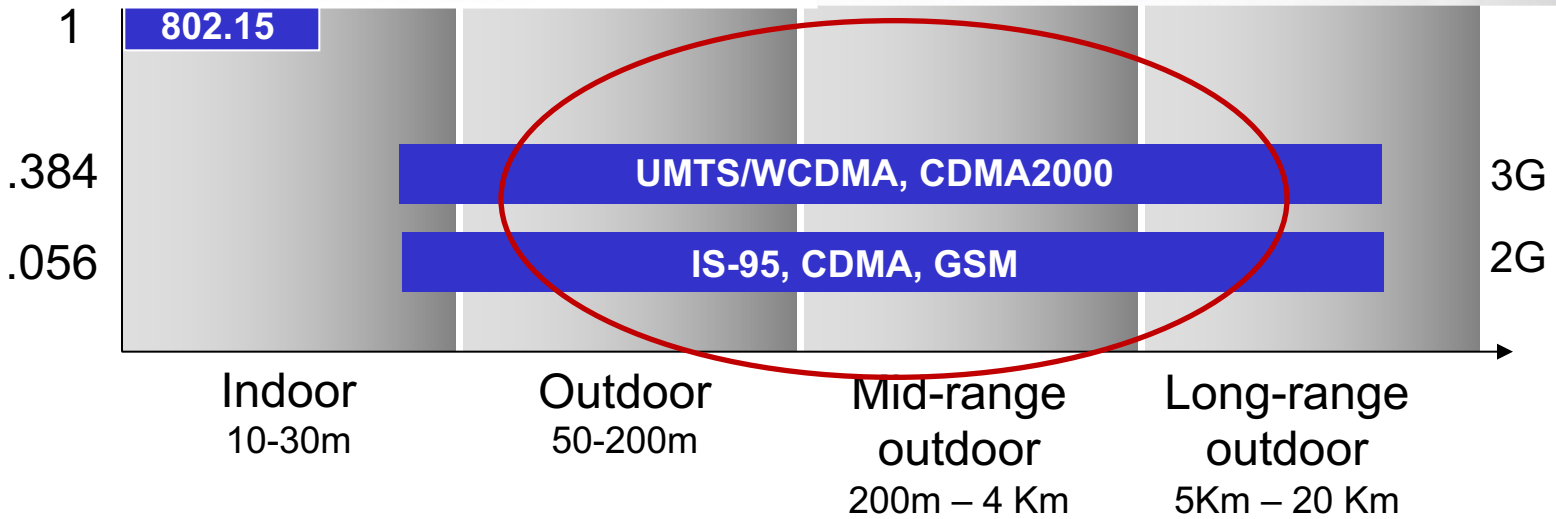

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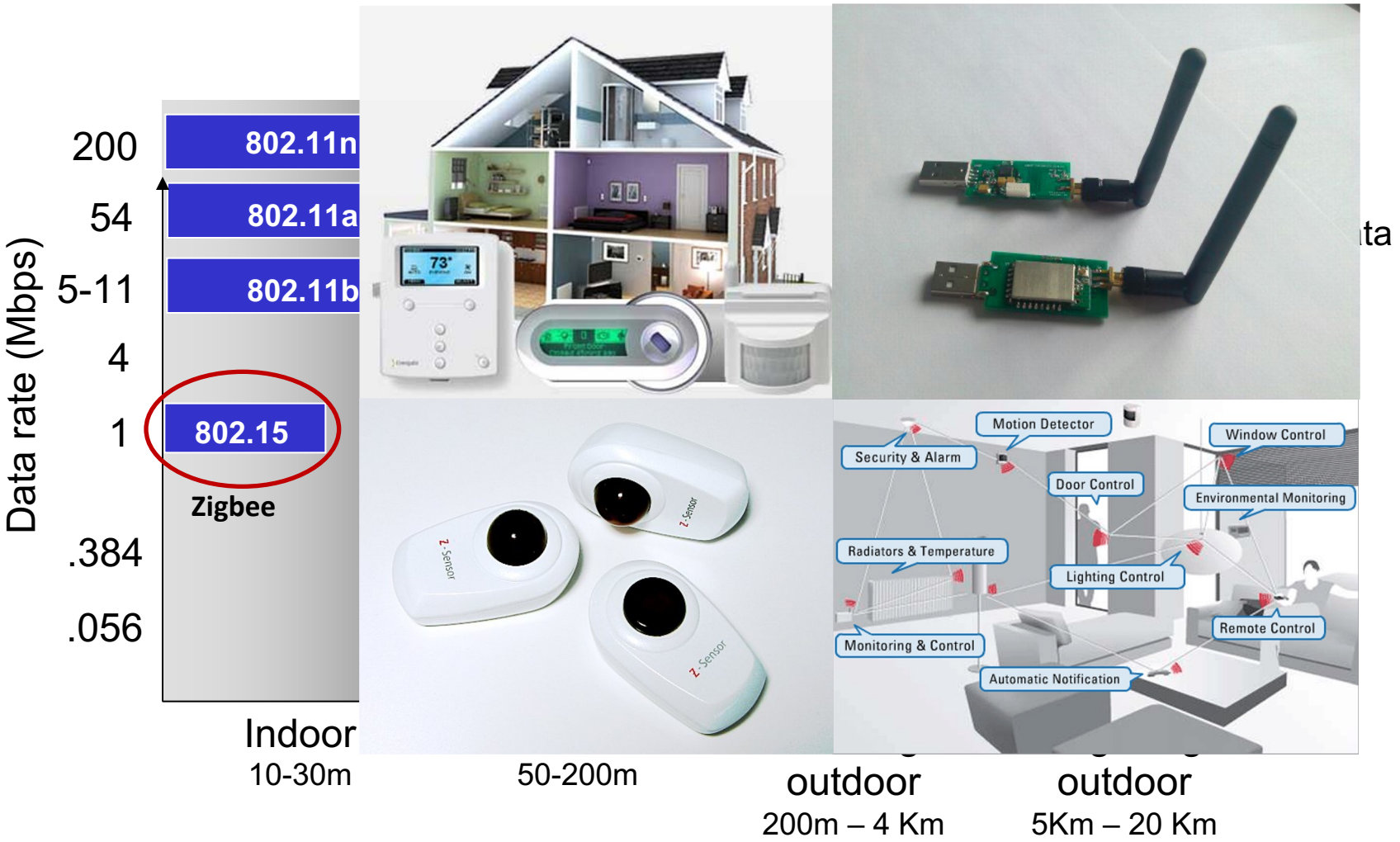

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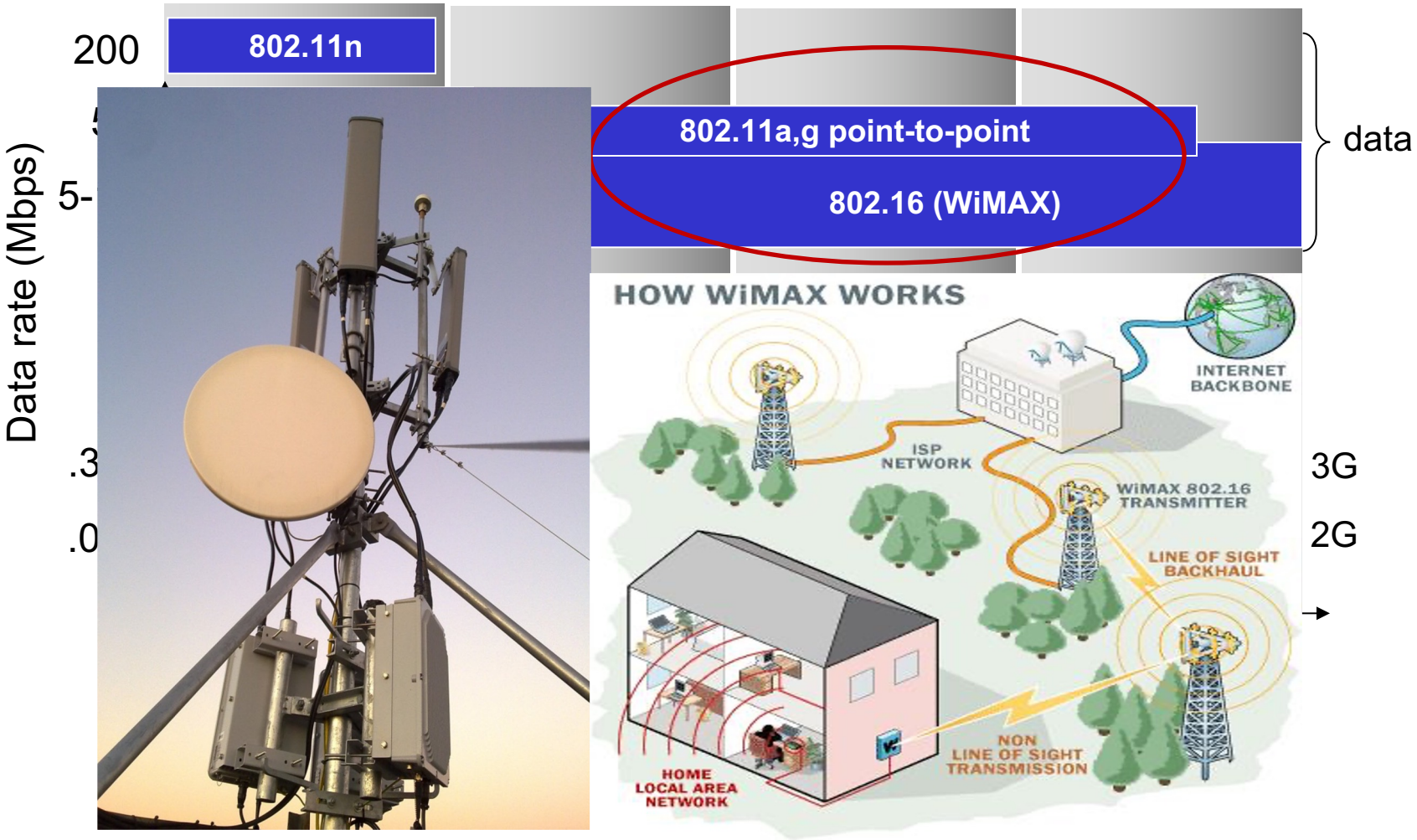
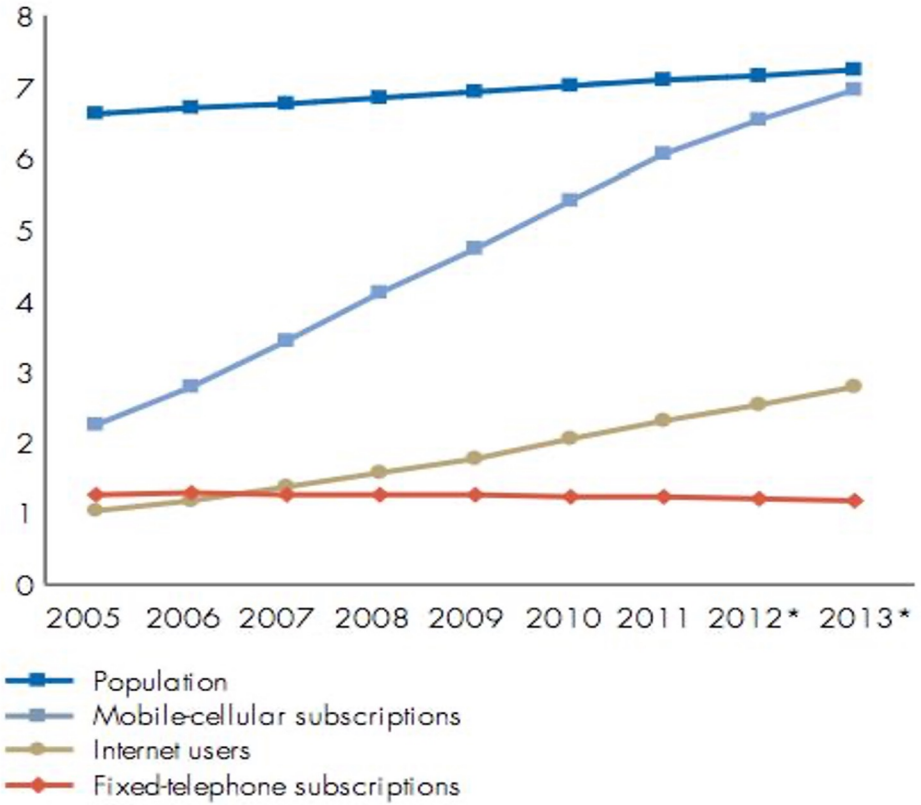


Cellular Networks: 1G to 5G

Boost of Mobiles

Estimated number of mobile-cellular subscriptions, Internet users and fixed-telephone subscriptions, 2005-2013 (Billions)



* Data for 2012 and 2013 are preliminary estimates.

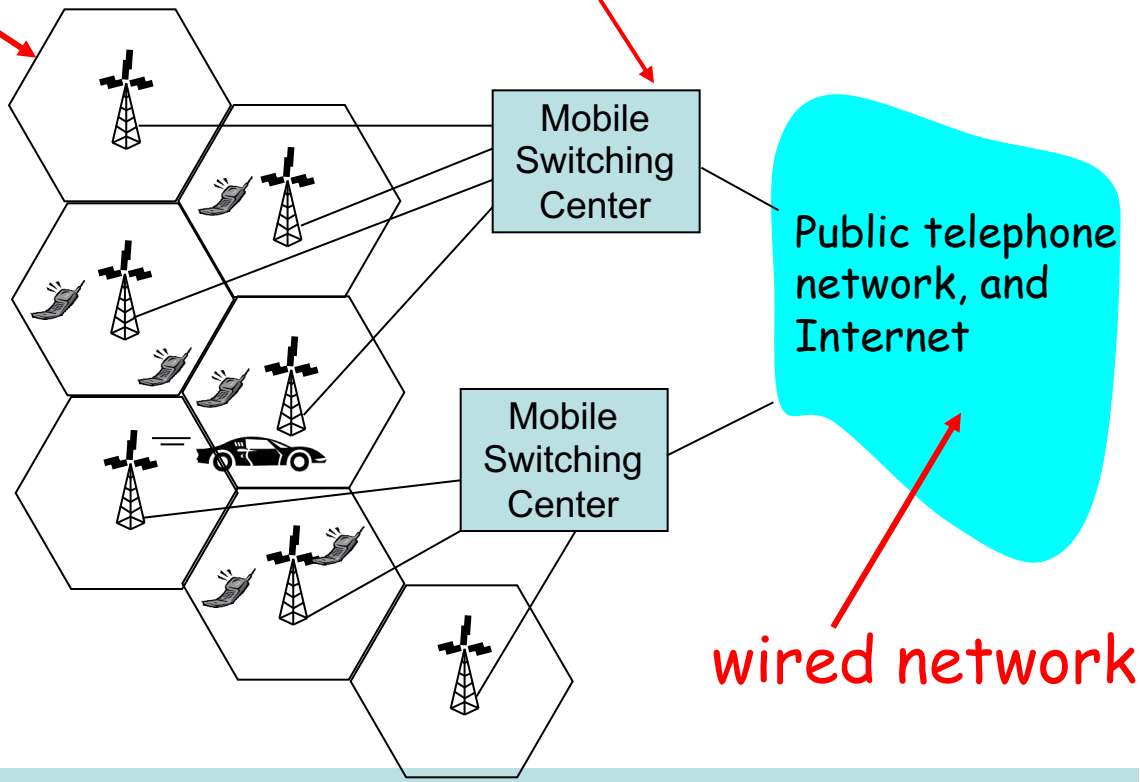
Cellular Network Architecture

MSC

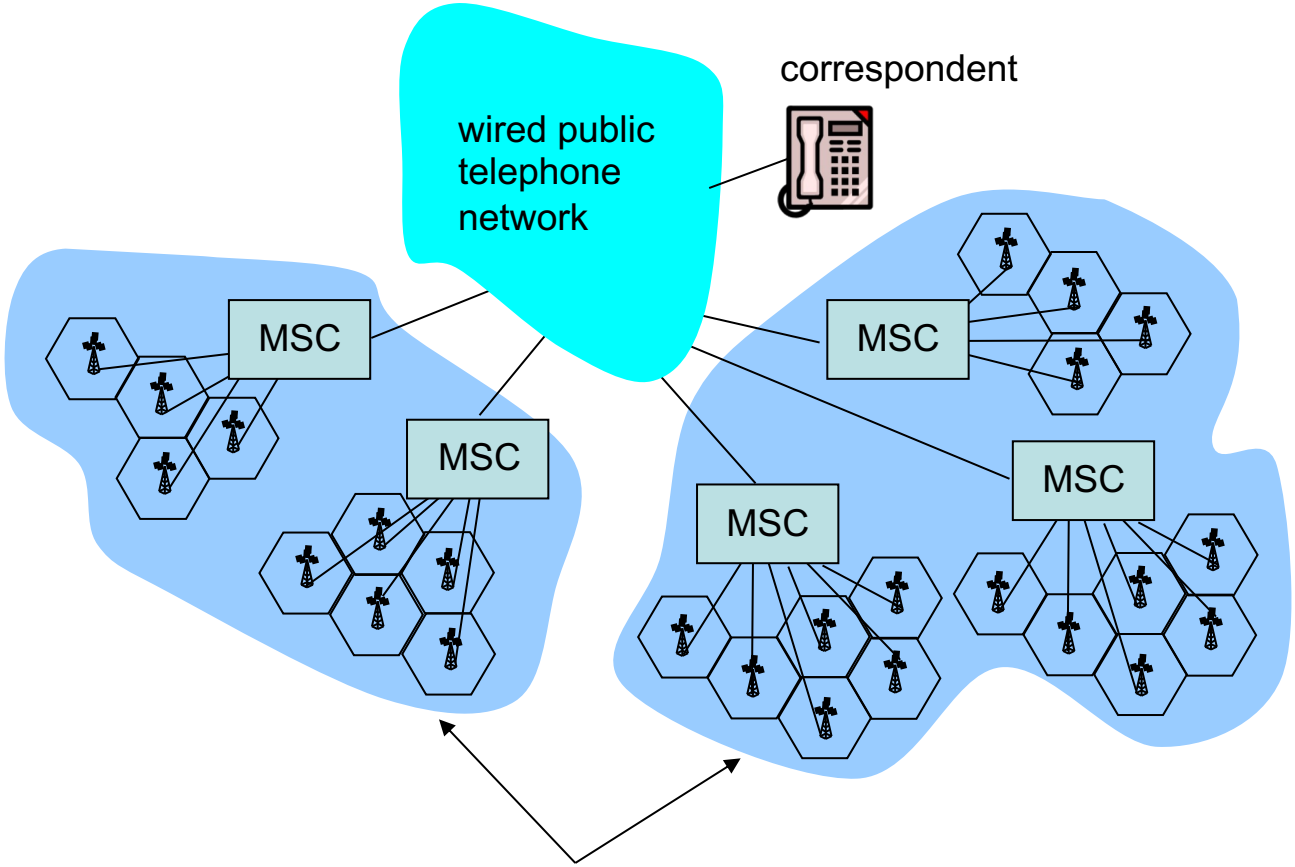
- connects cells to wide area net
- manages call setup
- handles mobility

cell

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

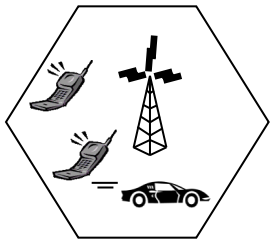


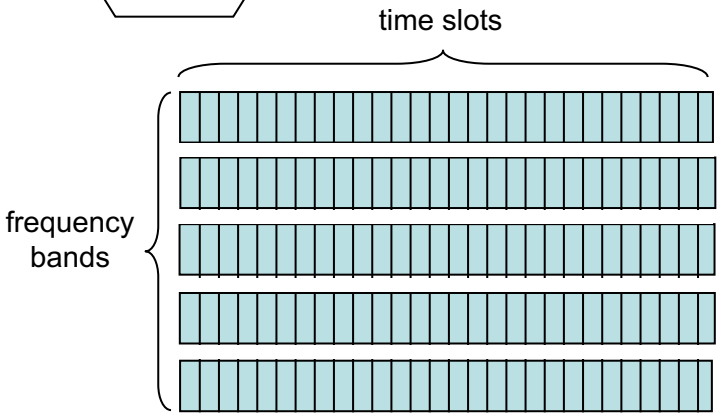
Interconnection of Cellular Networks

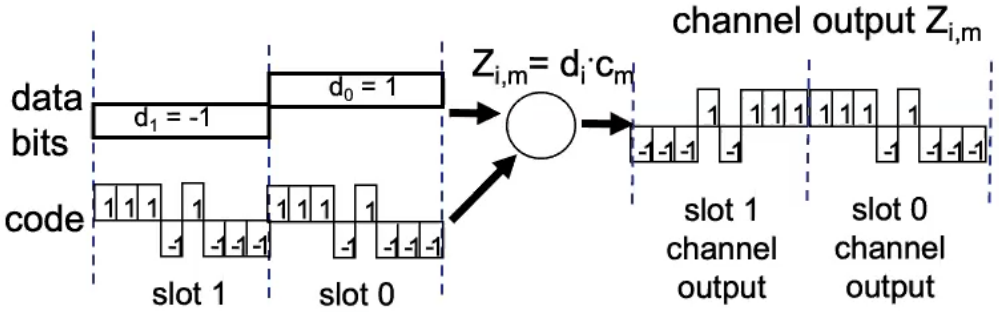


Cellular Network: The First Hop

- **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

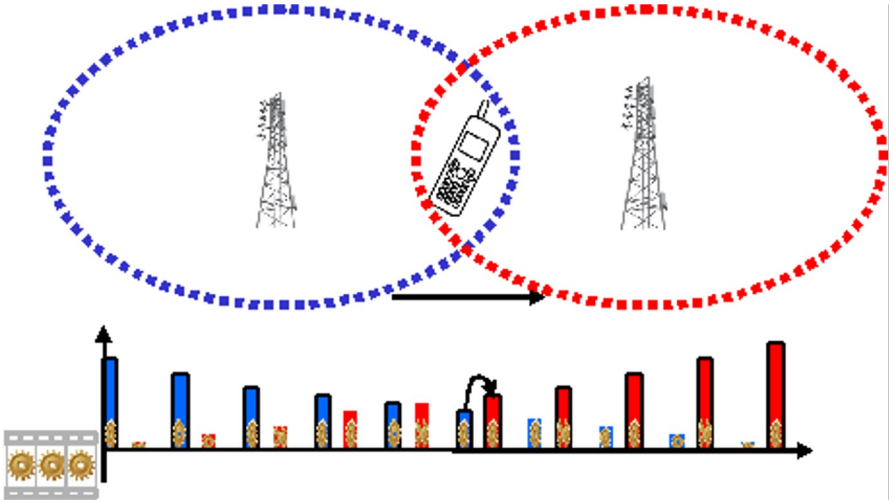




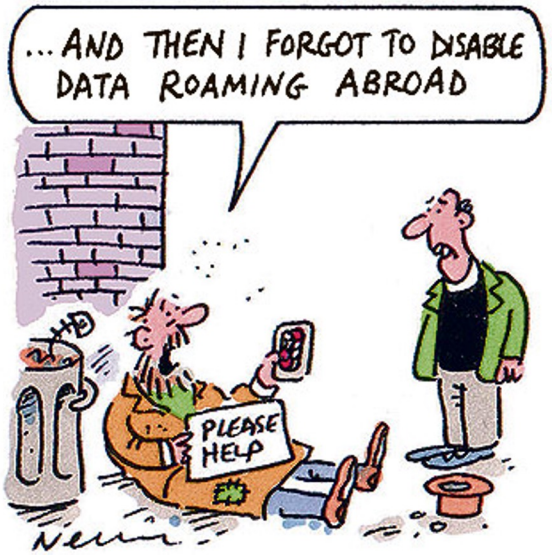


Handover and Roaming

- **Handover:** transfer a call or data session from one cell to another within the same cellular network
  - Handled by Mobile Switching Center (MSC), no charge
- **Roaming:** the mobile moves from its home cellular network to a foreign network



Handover



Roaming

Cellular Standards: Brief Survey

1G: analog, 3 decades ago

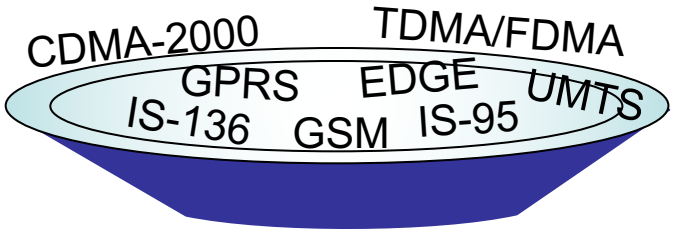
2G/2.5G: 50-384kbps, 2 decades ago

3G: up to 14Mbps
4G: up to 300Mbps
Last decade

5G: up to 430Mbps using sub-6GHz
up to 10Gbps using >24GHz
From 2019

Cellular Standards: Brief Survey

- **2G systems: voice channels**
  - IS-136 TMDA: combined FDMA/TDMA (North America)
  - GSM (global system for mobile communications): combined FDMA/TDMA
    - Most widely deployed
  - IS-95 CDMA: code division multiple access

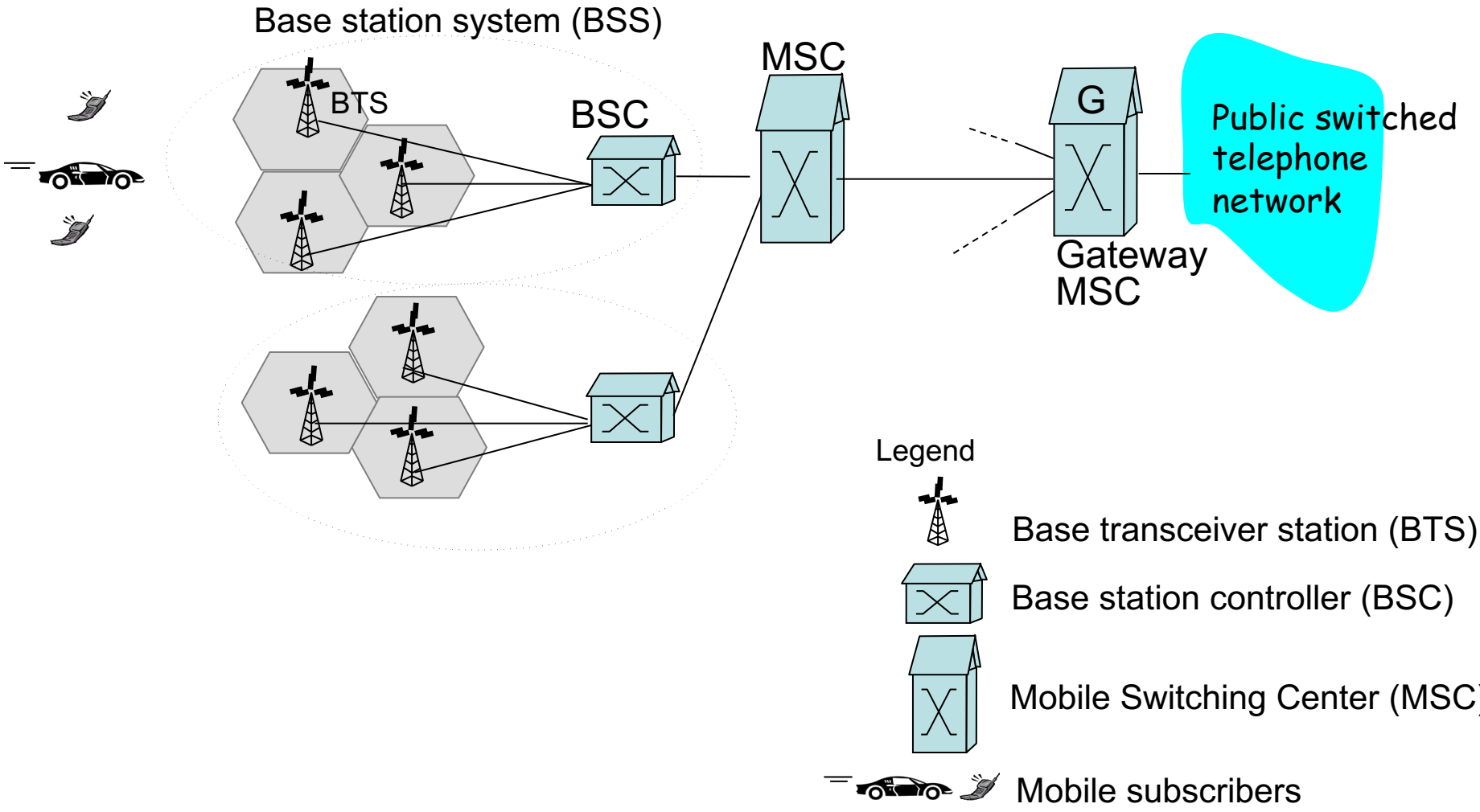


Don't drown in a bowl of alphabet soup: use this for reference only

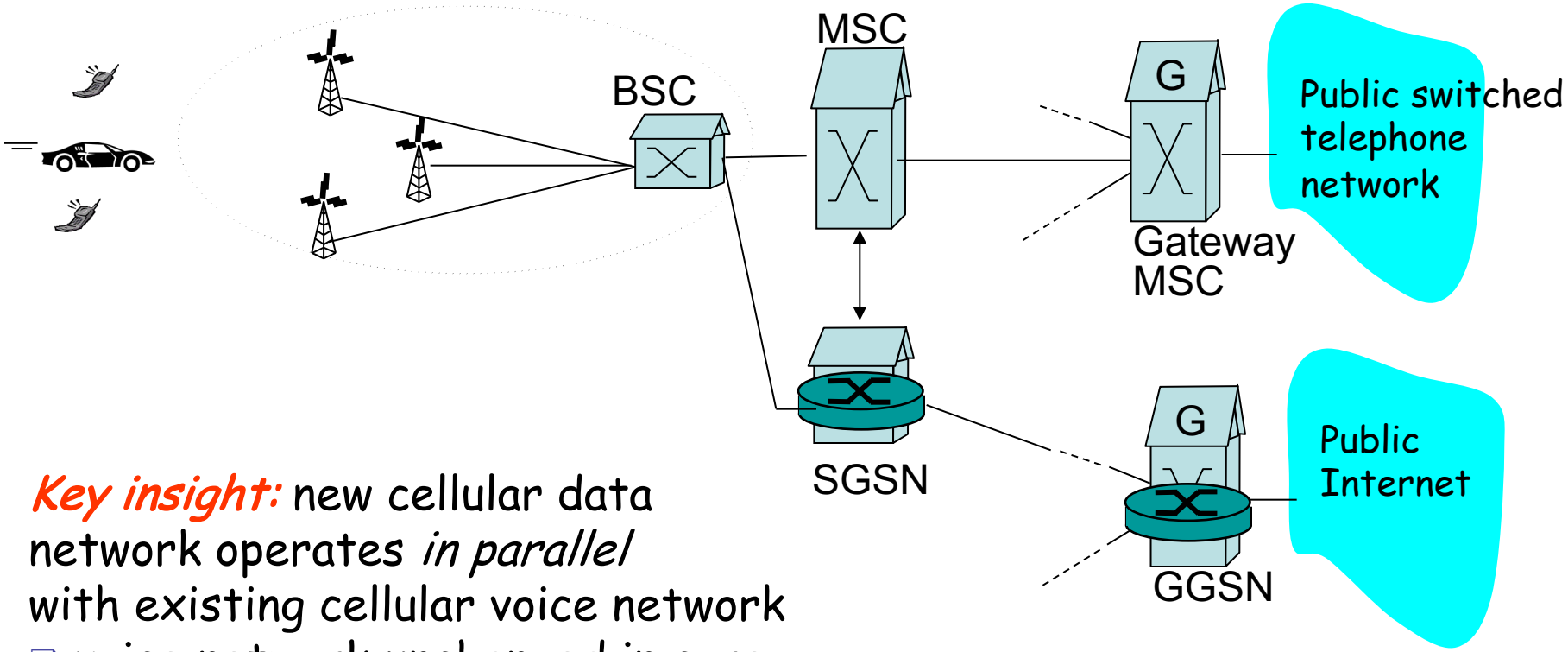
Cellular Standards: Brief Survey

- **2.5G systems: voice and data channels**
  - 2G extensions: for those who can't wait for 3G
  - 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 384kbps
  - CDMA-2000 (phase 1)
    - Data rates up to 144kbps
    - Evolved from IS-95

2G (voice) Network Architecture



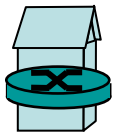
2.5G (Voice+Data) Network Architecture



Key insight: new cellular data network operates *in parallel* with existing cellular voice network

- voice network unchanged in core
- data network operates in parallel


Serving GPRS Support Node (SGSN)


Gateway GPRS Support Node (GGSN)

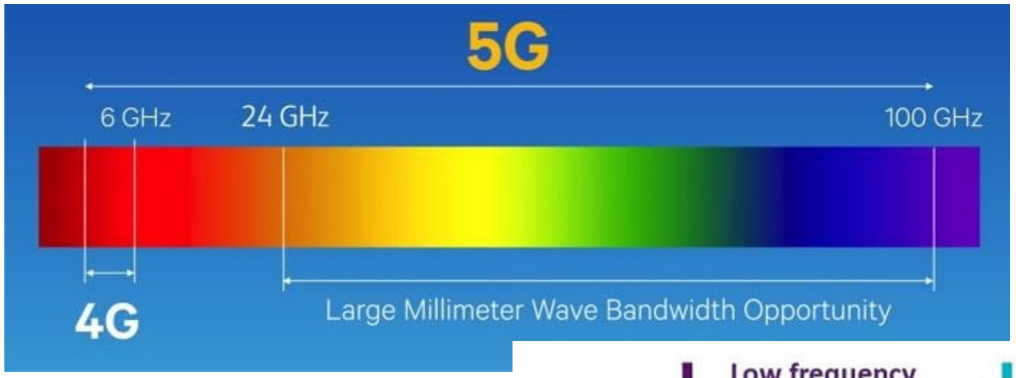
Cellular Standards: Brief Survey

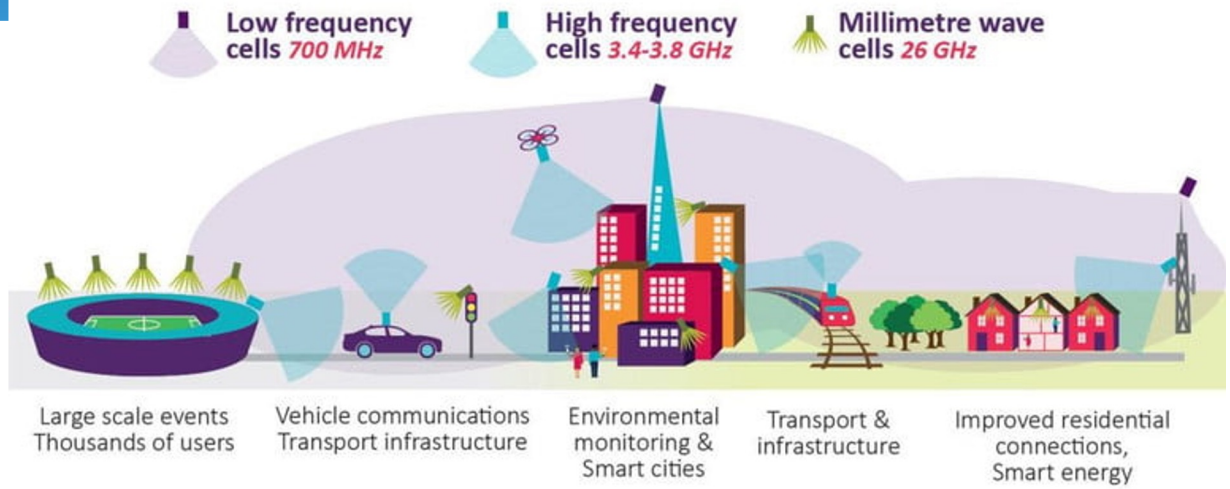
- **3G systems: voice + data**
  - Universal Mobile Telecommunications Service (UMTS)
  - CDMA in TDMA slots
  - Data service: up to 14 Mbps

- **4G systems: data**
  - All-IP network: voice in data packets
  - New wireless access technologies: OFDM, MIMO, etc
  - Data rate: up to 300 Mbps

Cellular Standards: Brief Survey

- **5G systems: massive data**
  - Microwaves (4G) + millimeter waves (high bandwidth)

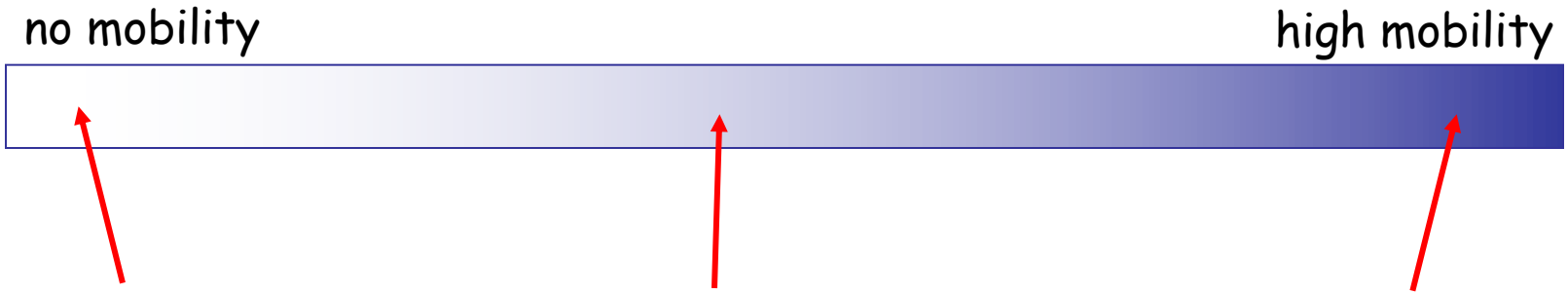




Mobility (Roaming) Handling

What Is Mobility?

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



mobile wireless user, using same point of access

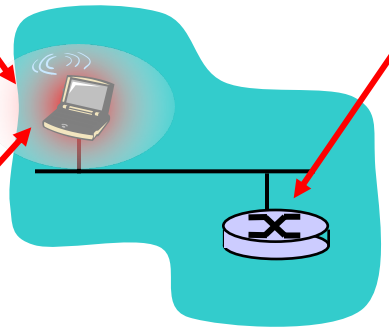
mobile user, connecting/ disconnecting from network using DHCP.

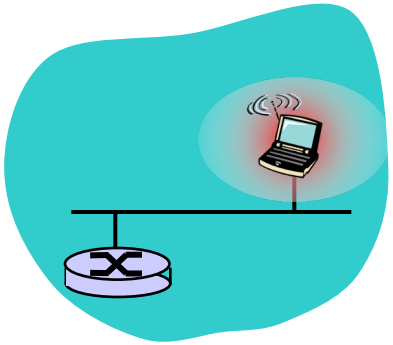
mobile user, passing through multiple points of access while maintaining ongoing connections (like cell phone)

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



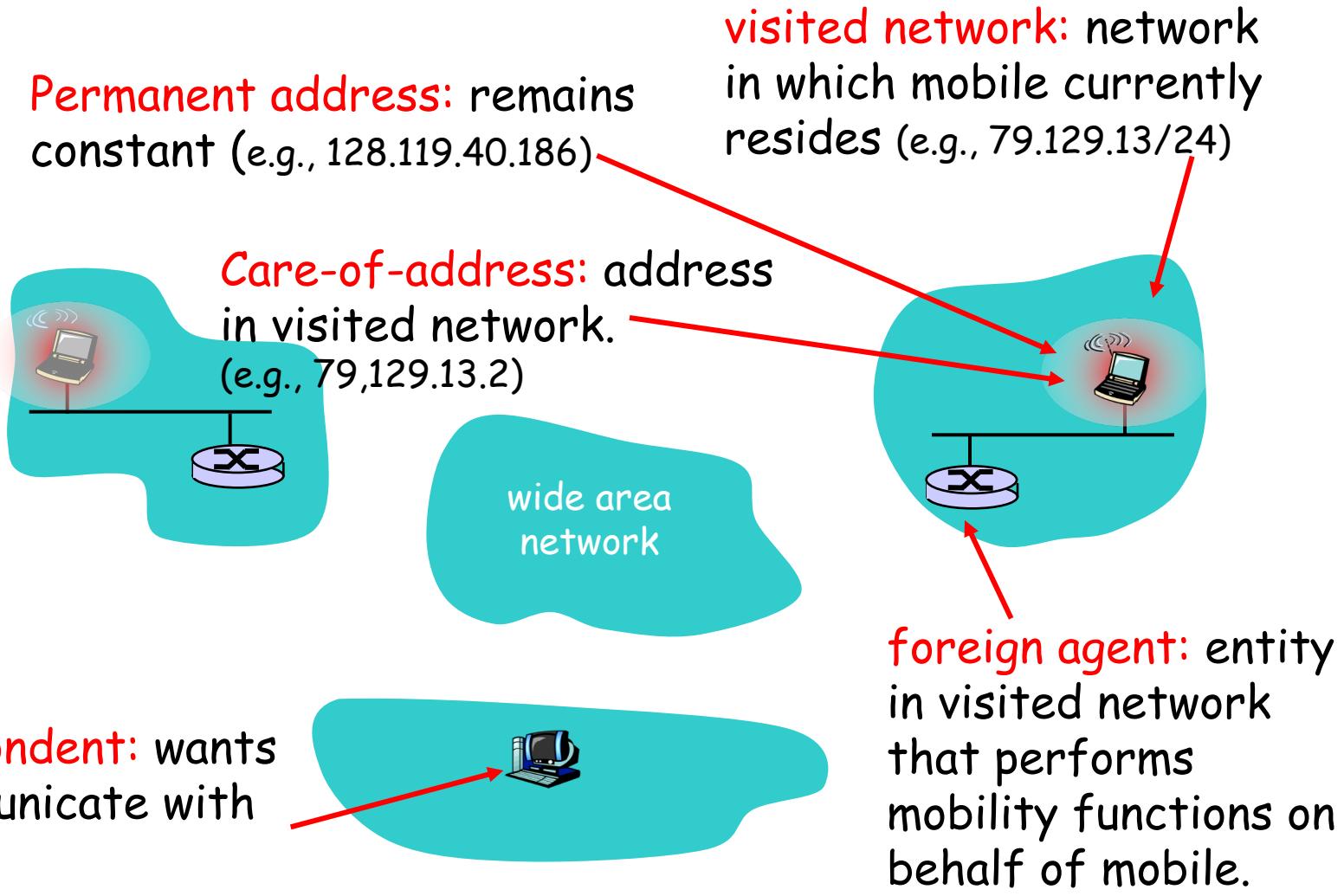


wide area network

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

correspondent

Mobility: Vocabulary



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

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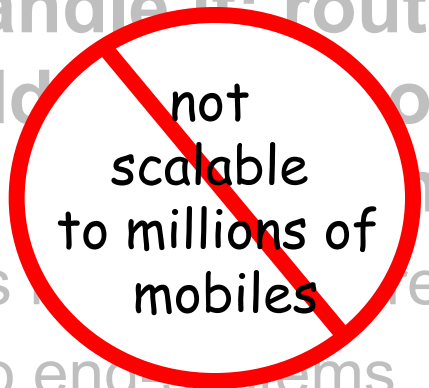

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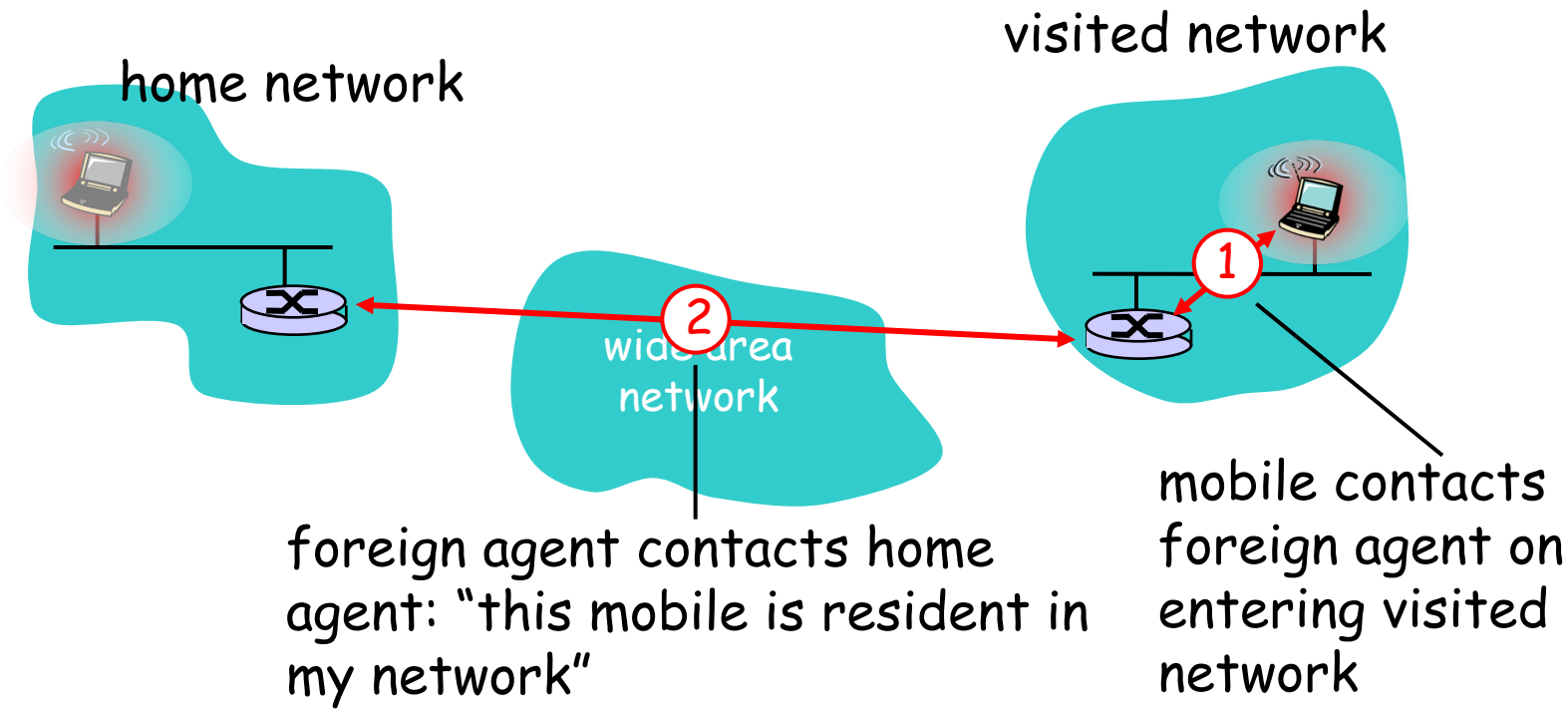
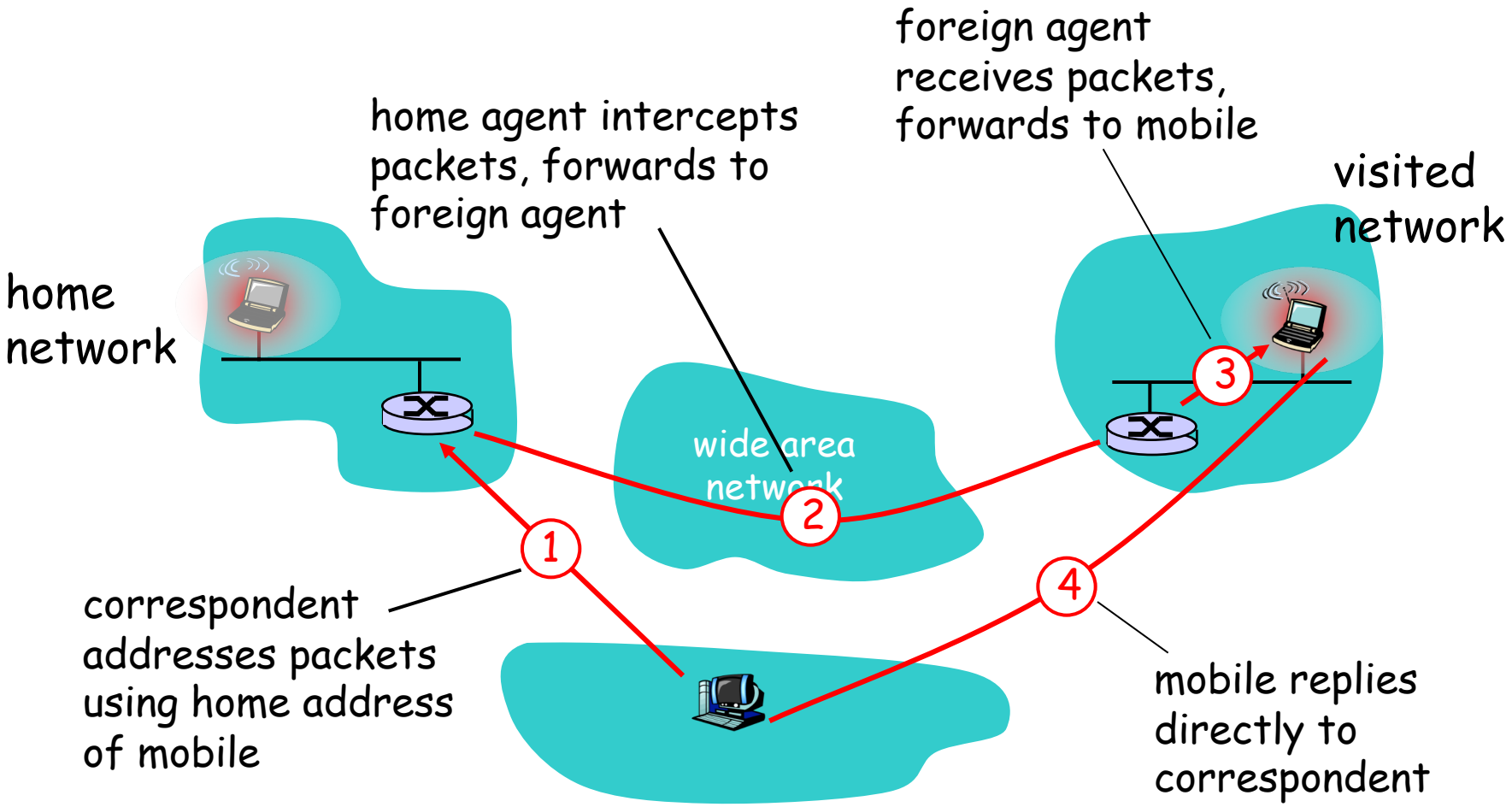
Mobility: Registration



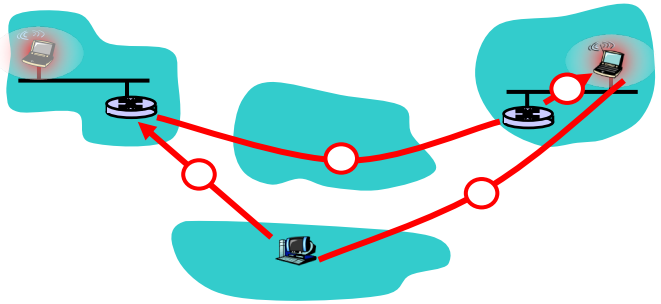
- **End result:**
  - Foreign agent knows about mobile
  - Home agent knows location of mobile

Mobility via Indirect Routing



Indirect Routing: Comments

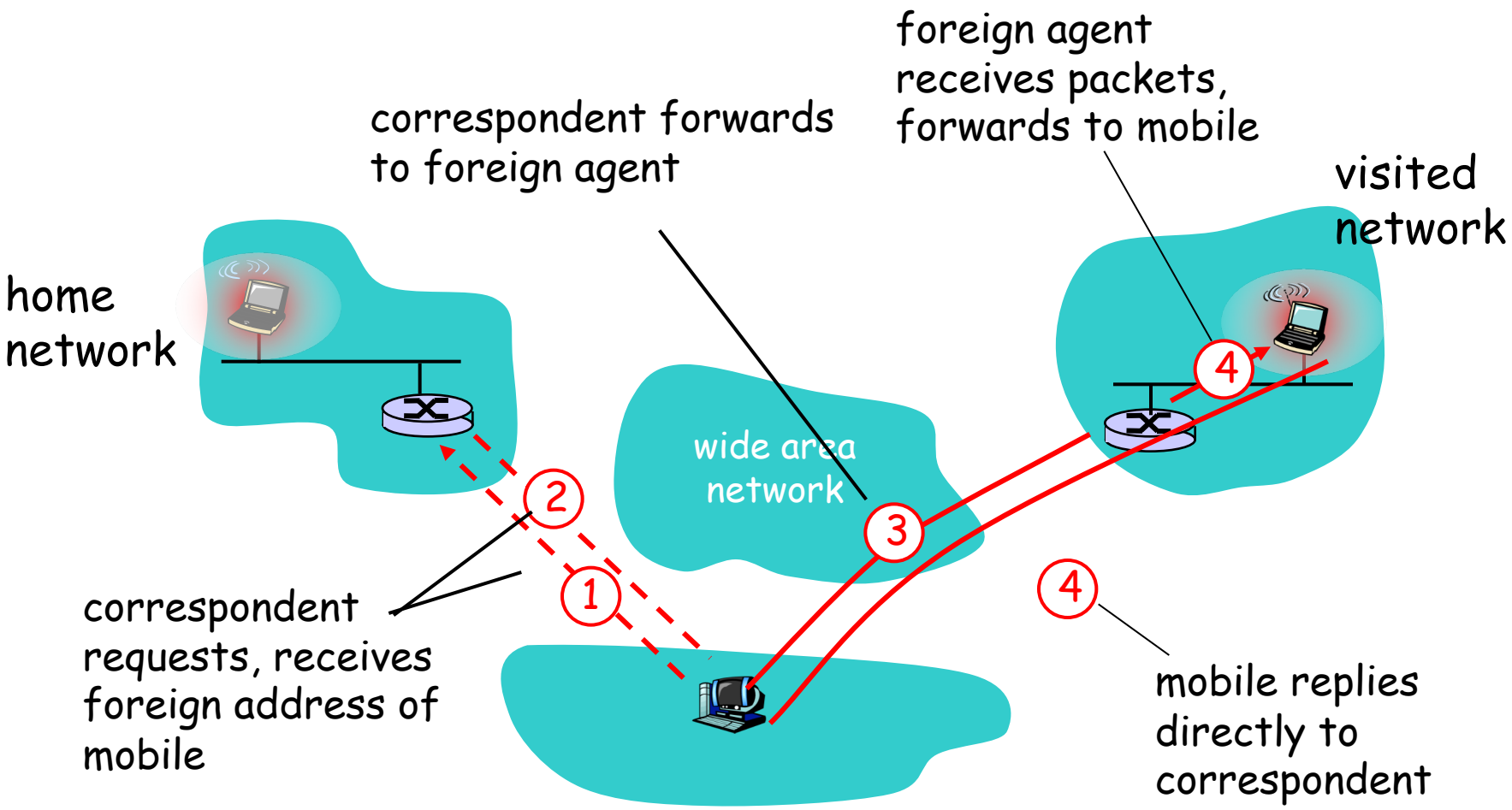
- **Mobile uses two addresses**
  - Permanent address: used by correspondent (hence mobile location is transparent to correspondent)
  - Care-of-address (Foreign address): used by home agent to forward datagrams to mobile
- **Triangle routing: correspondent-home network-mobile**
  - Inefficient when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



Indirect Routing: Moving Between Networks

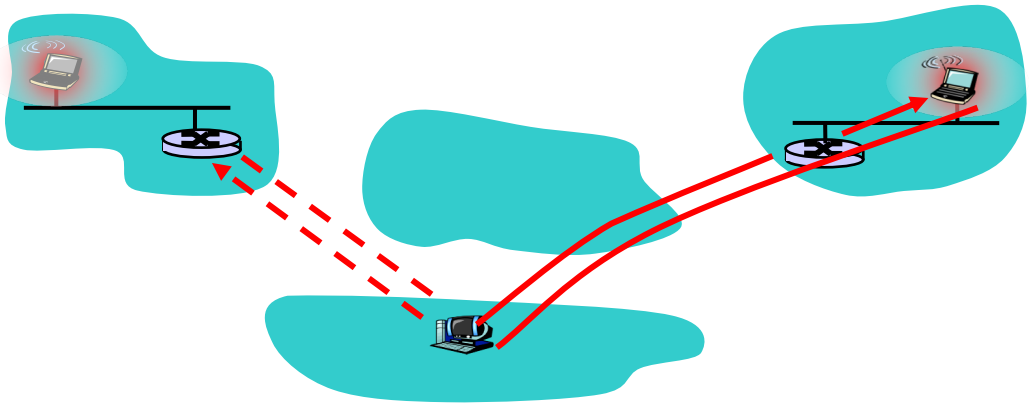
- **Suppose mobile user moves to another network**
  - Register with new foreign agent
  - New foreign agent registers with home agent
  - Home agent update care-of-address for mobile
  - Packets continue to be forwarded to mobile (but with new care-of-address)
- **Mobility, changing foreign networks**
  - Transparent: ongoing connections can be maintained!

Mobility via Direct Routing



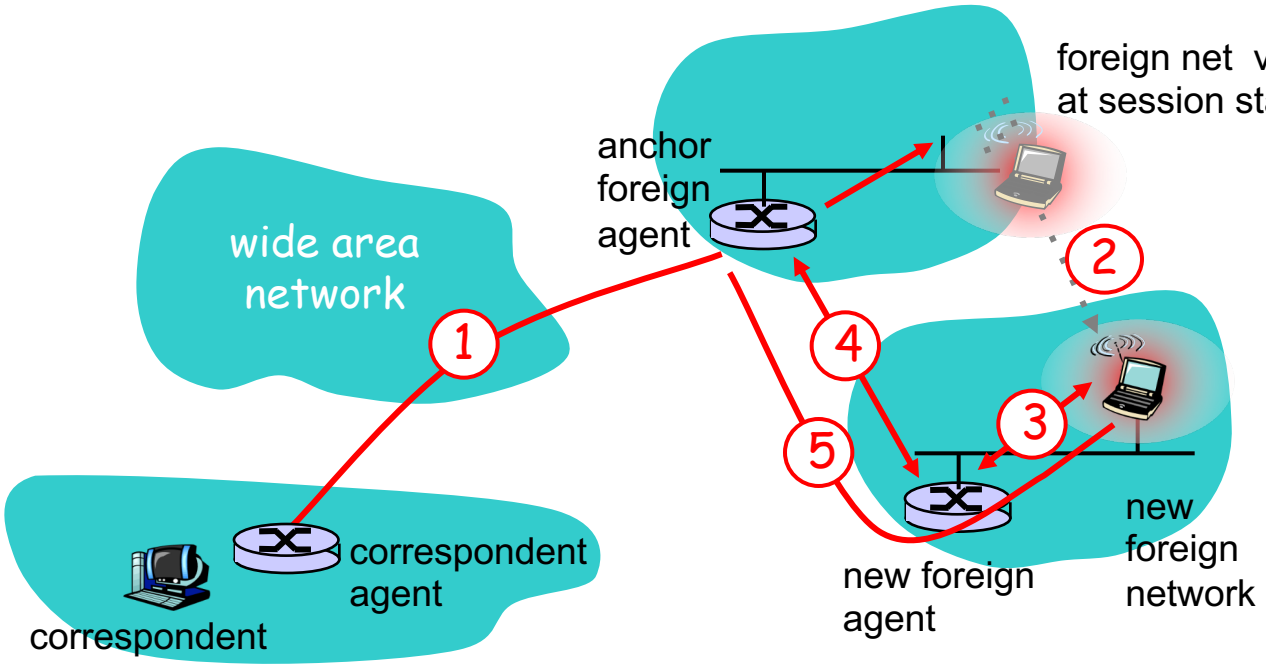
Mobility via Direct Routing: Comments

- **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

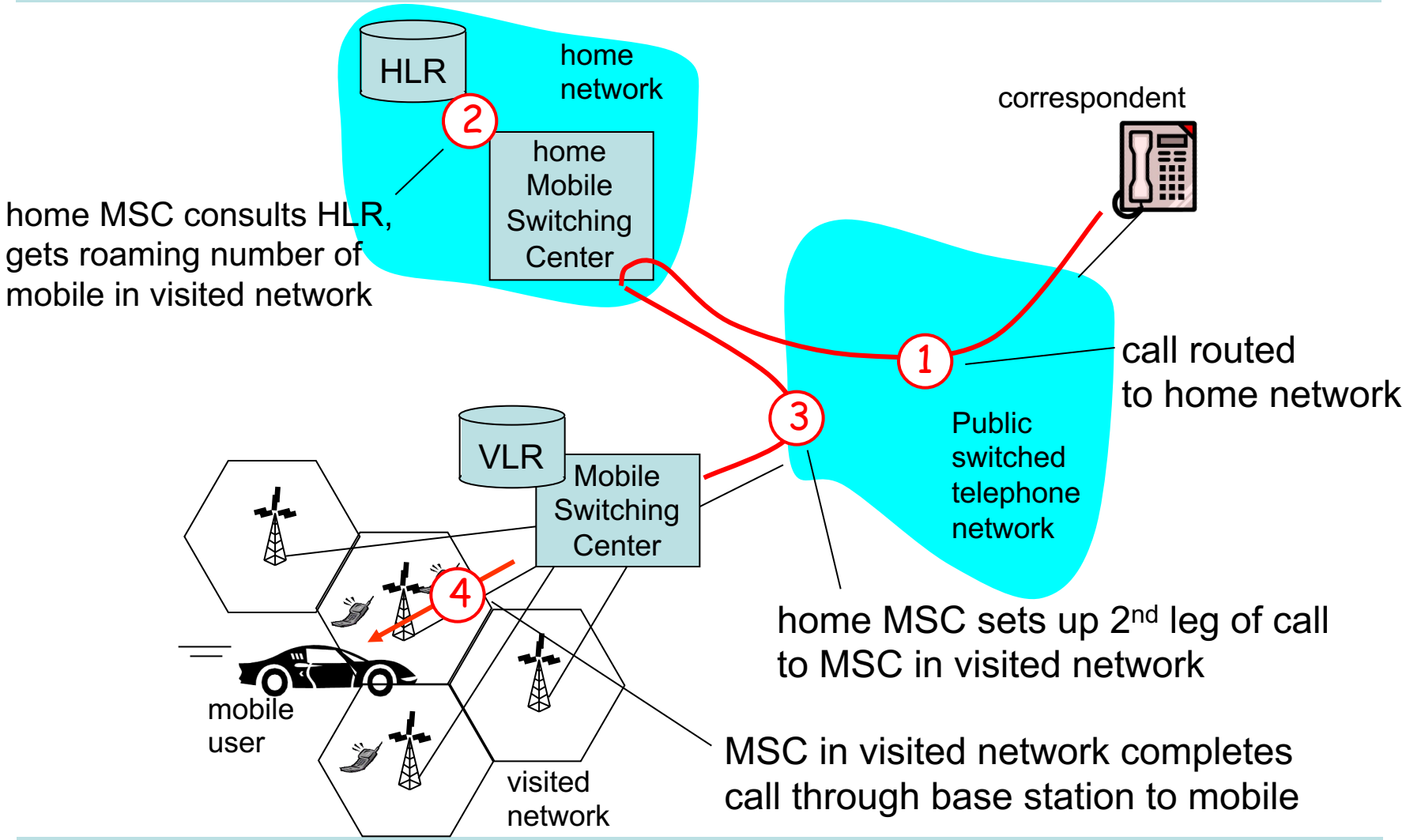
- Anchor foreign agent: FA in first visited network
- Data always routed first to anchor FA
- When mobile moves: new FA arranges to have data forwarded from old FA (chaining)



Handling Mobility in Cellular Networks

- **Home network: network of cellular provider you subscribe to (e.g., SingTel, M1)**
  - 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



Wireless, Mobility: Impact on Higher Layer Protocols

- **Logically, impact should be minimal …**
  - Best effort service model remains unchanged
  - Higher layers 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
  - Delay impairments for real-time traffic
  - Limited bandwidth of wireless links

Learning Objectives

- **Wireless Link Standards**
  - Read the characteristics of the standards
- **Cellular Networks**
  - Understand the network architecture
  - Understand the key features of 1G to 5G
- **Mobility (roaming) handling**
  - Read mobility vocabulary
  - Understand indirect and direct routing