



Computer Networks

CS3611

Mobile and Wireless Networks

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The slides are adapted from those provided by Prof. J.F Kurose and K.W. Ross.

Ch. 6: Wireless and Mobile Networks

Background:

- # wireless (mobile) phone subscribers now exceeds # wired phone subscribers (5-to-1)!
- # wireless Internet-connected devices equals # wireline Internet-connected devices
 - laptops, Internet-enabled phones promise anytime untethered Internet access
- two important (but different) challenges
 - *wireless*: communication over wireless link
 - *mobility*: handling the mobile user who changes point of attachment to network

Chapter 7 outline

7.1 Introduction

Wireless

7.2 Wireless links, characteristics

- CDMA

6.73 IEEE 802.11 wireless LANs (“Wi-Fi”)

67.4 Cellular Internet Access

- architecture
- standards (e.g., 3G, LTE)

Mobility

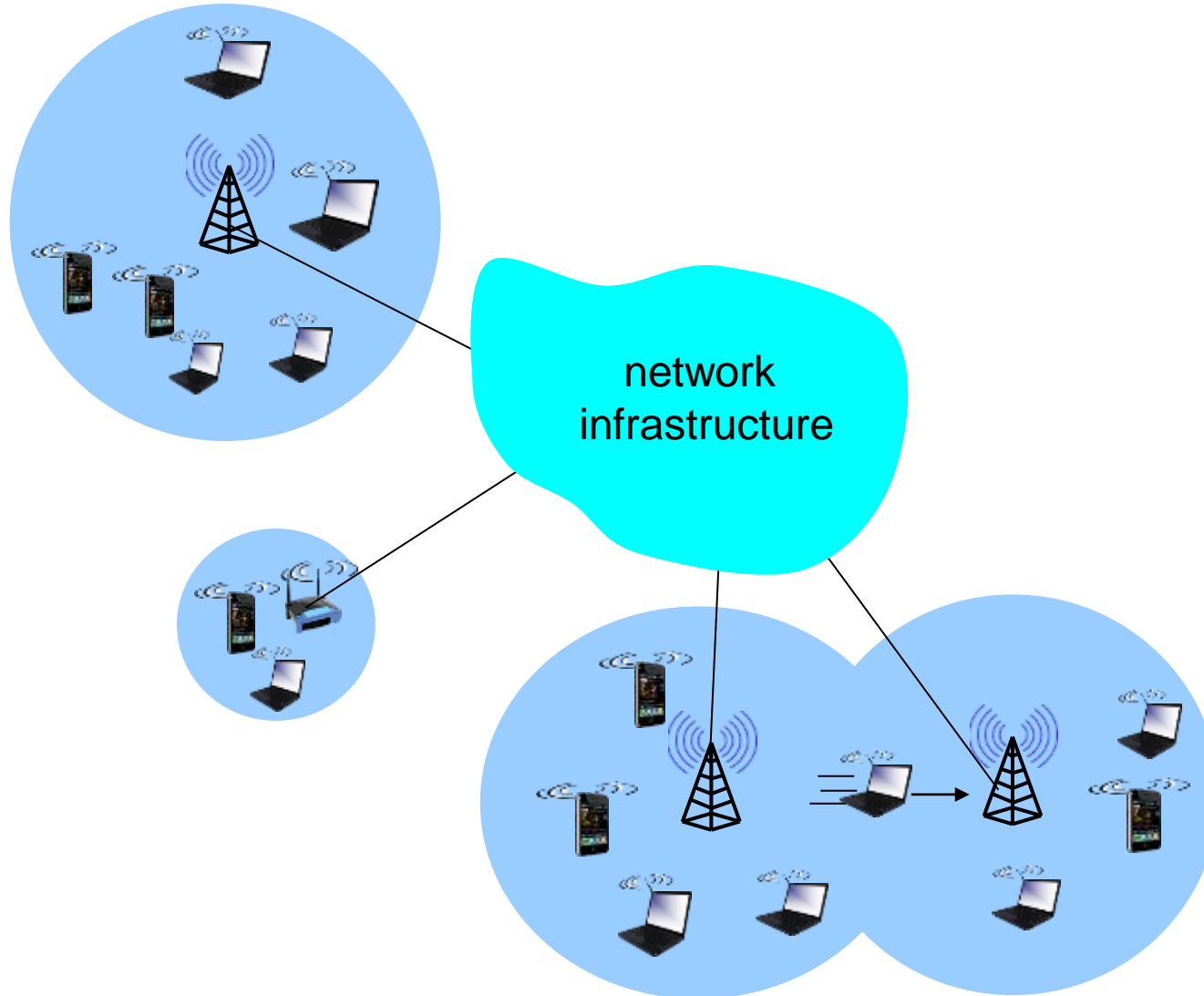
7.5 Principles: addressing and routing to mobile users

7.6 Mobile IP

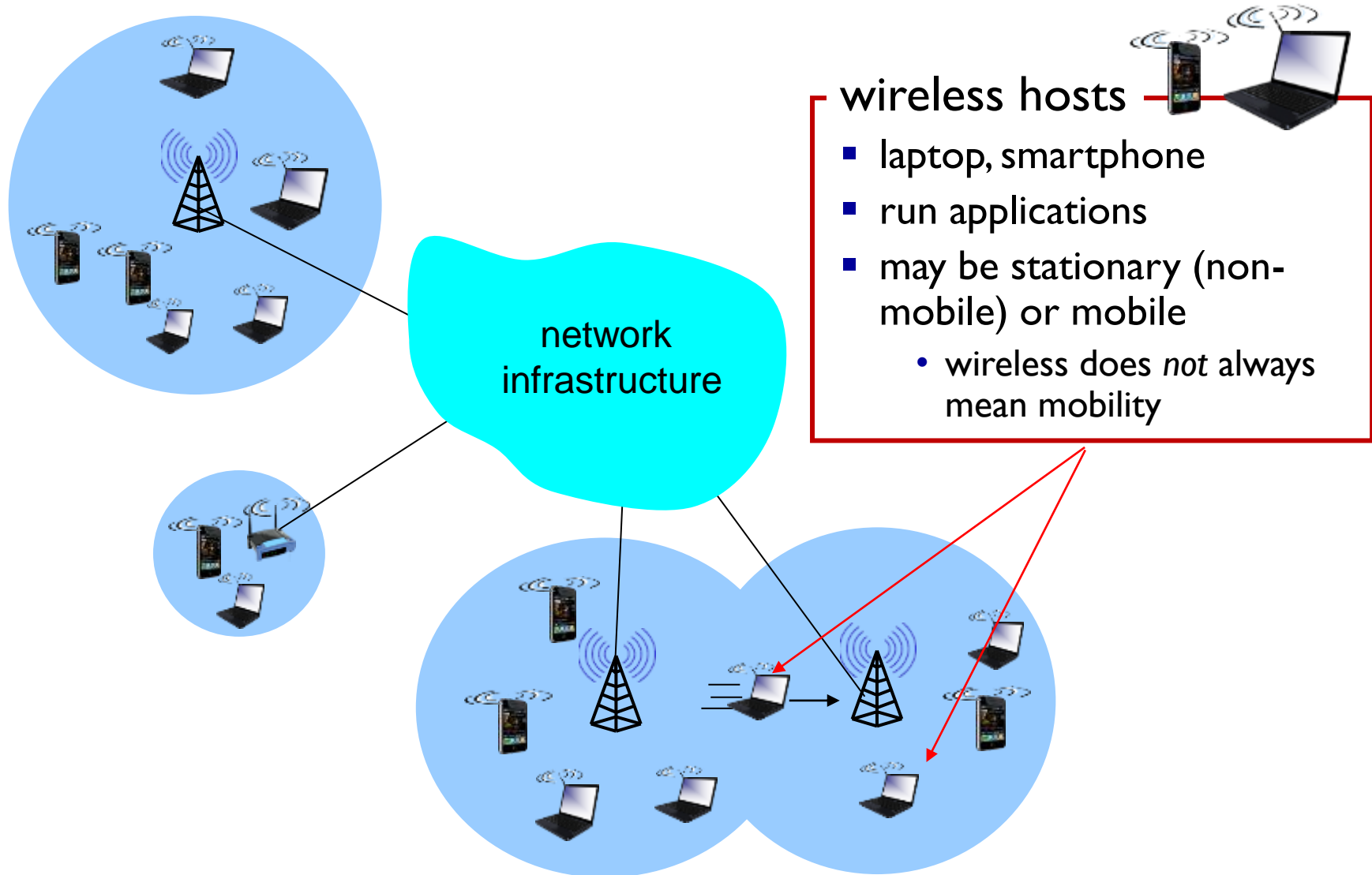
7.7 Handling mobility in cellular networks

7.8 Mobility and higher-layer protocols

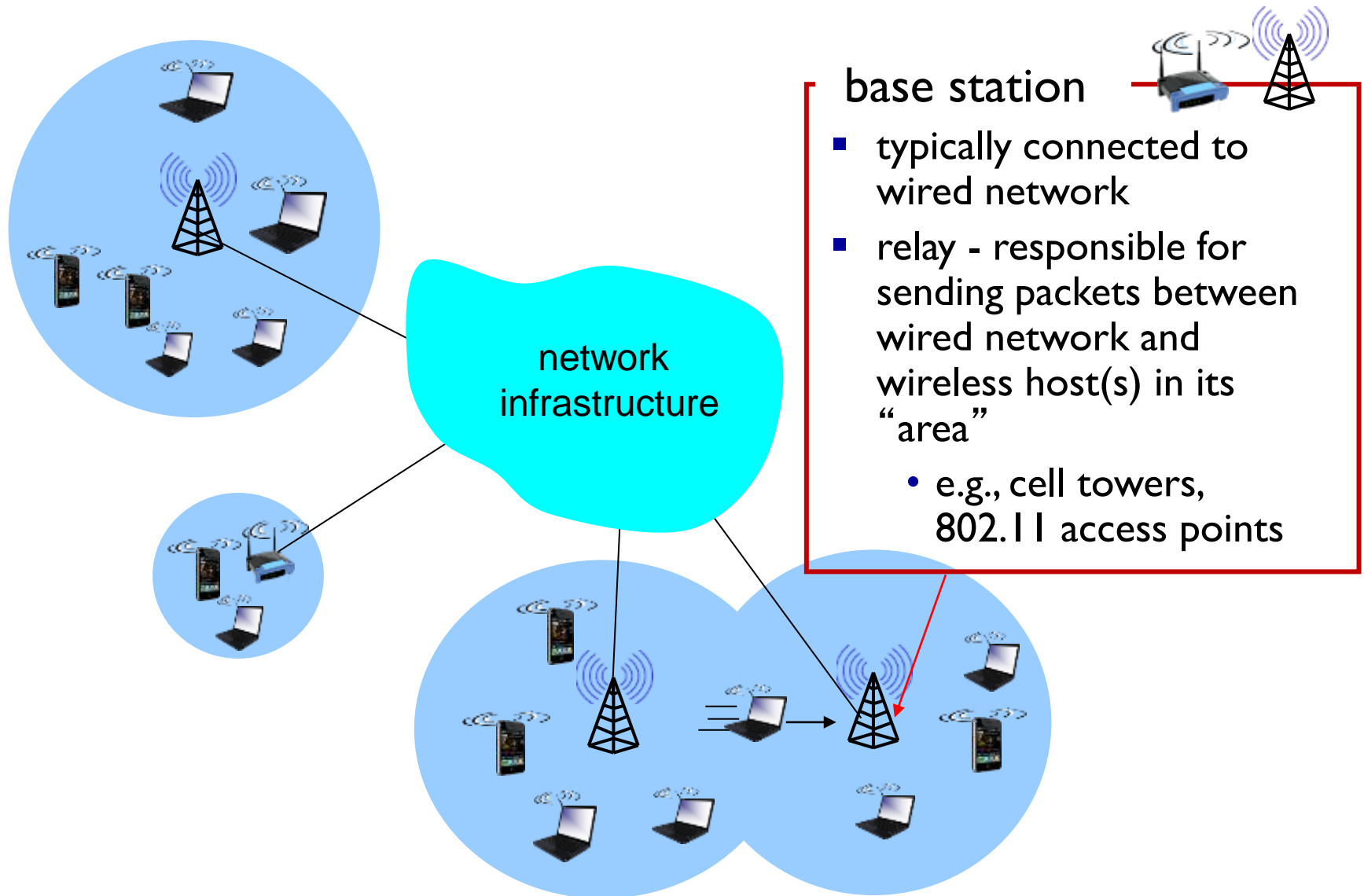
Elements of a wireless network



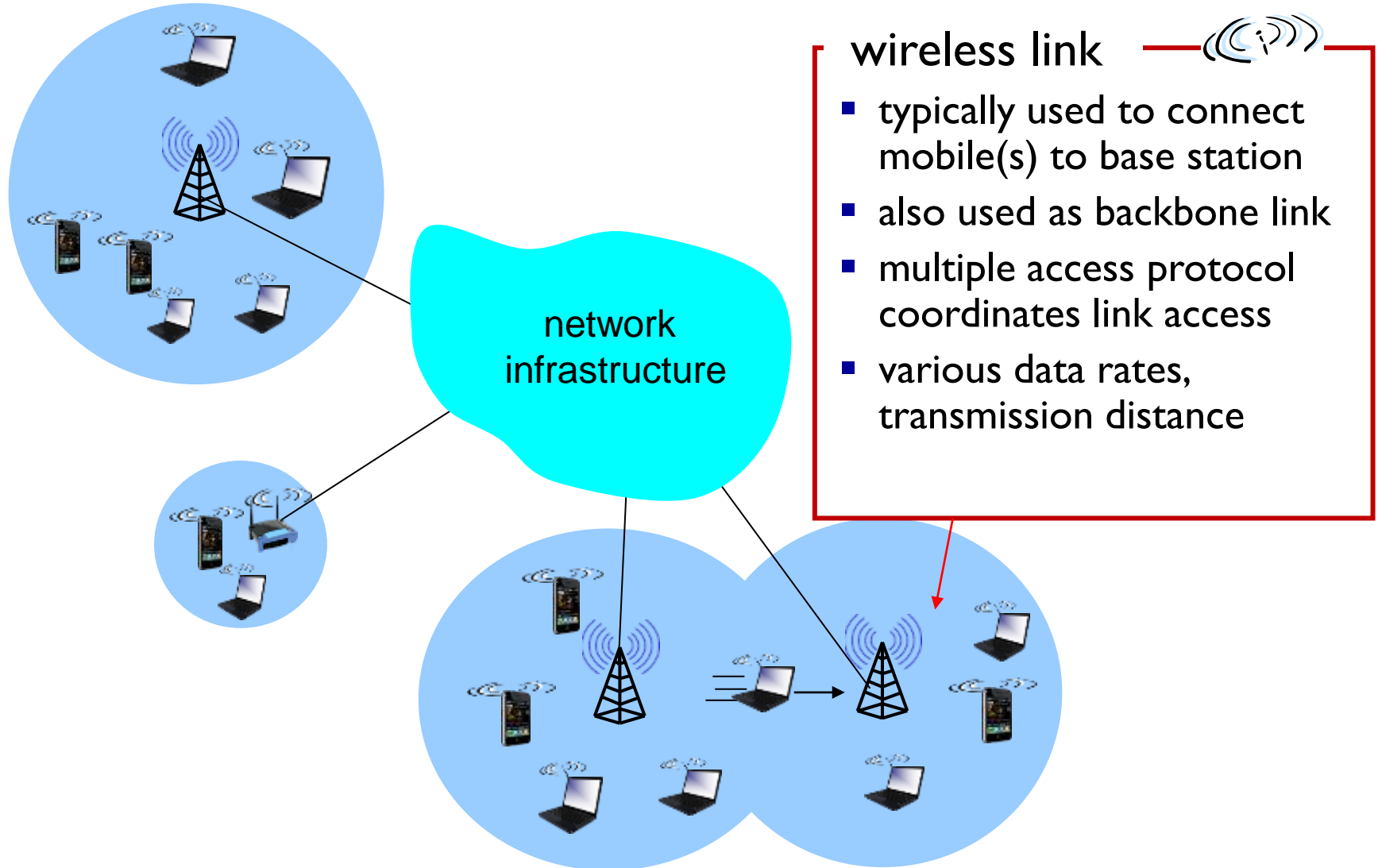
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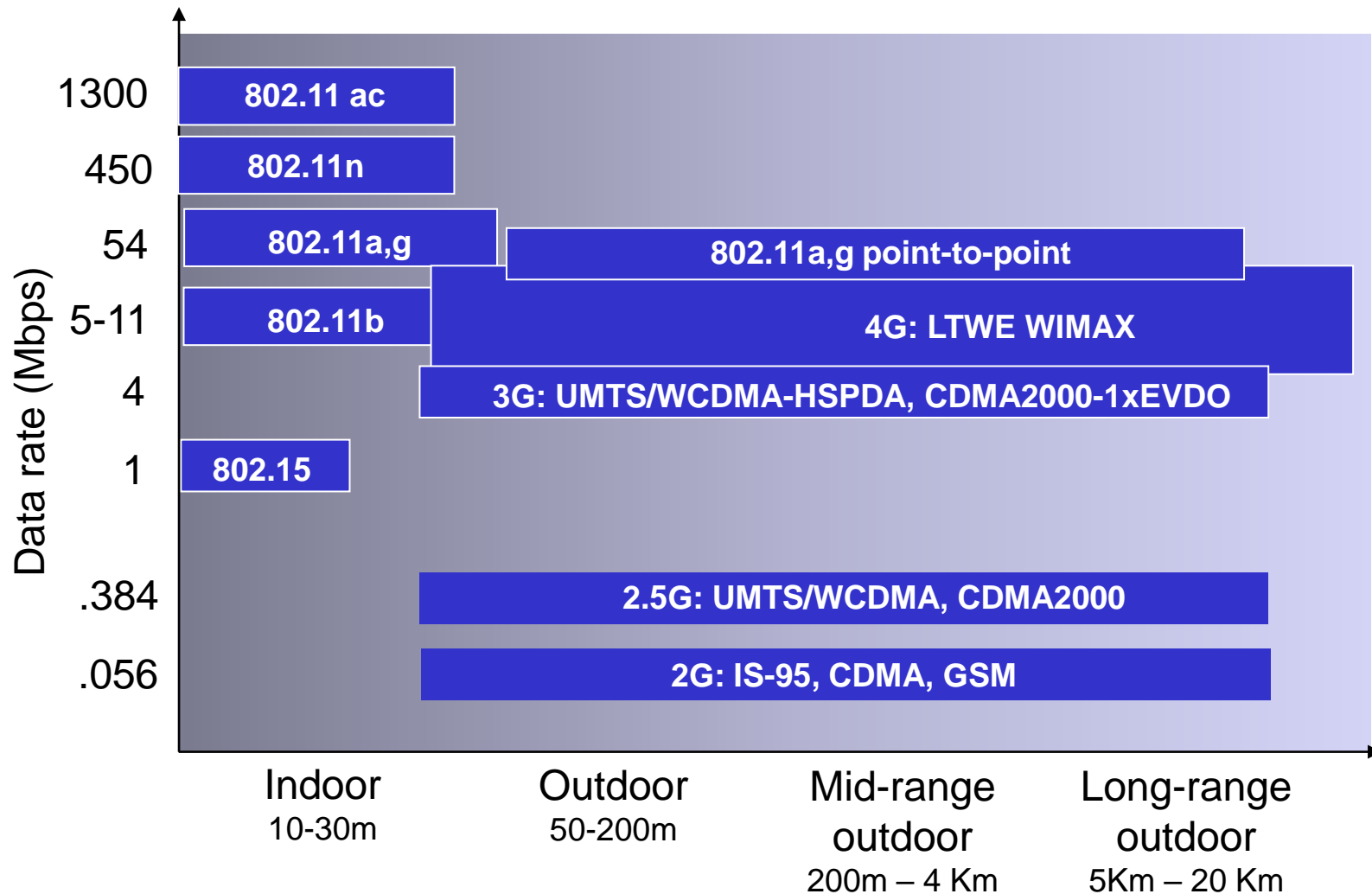
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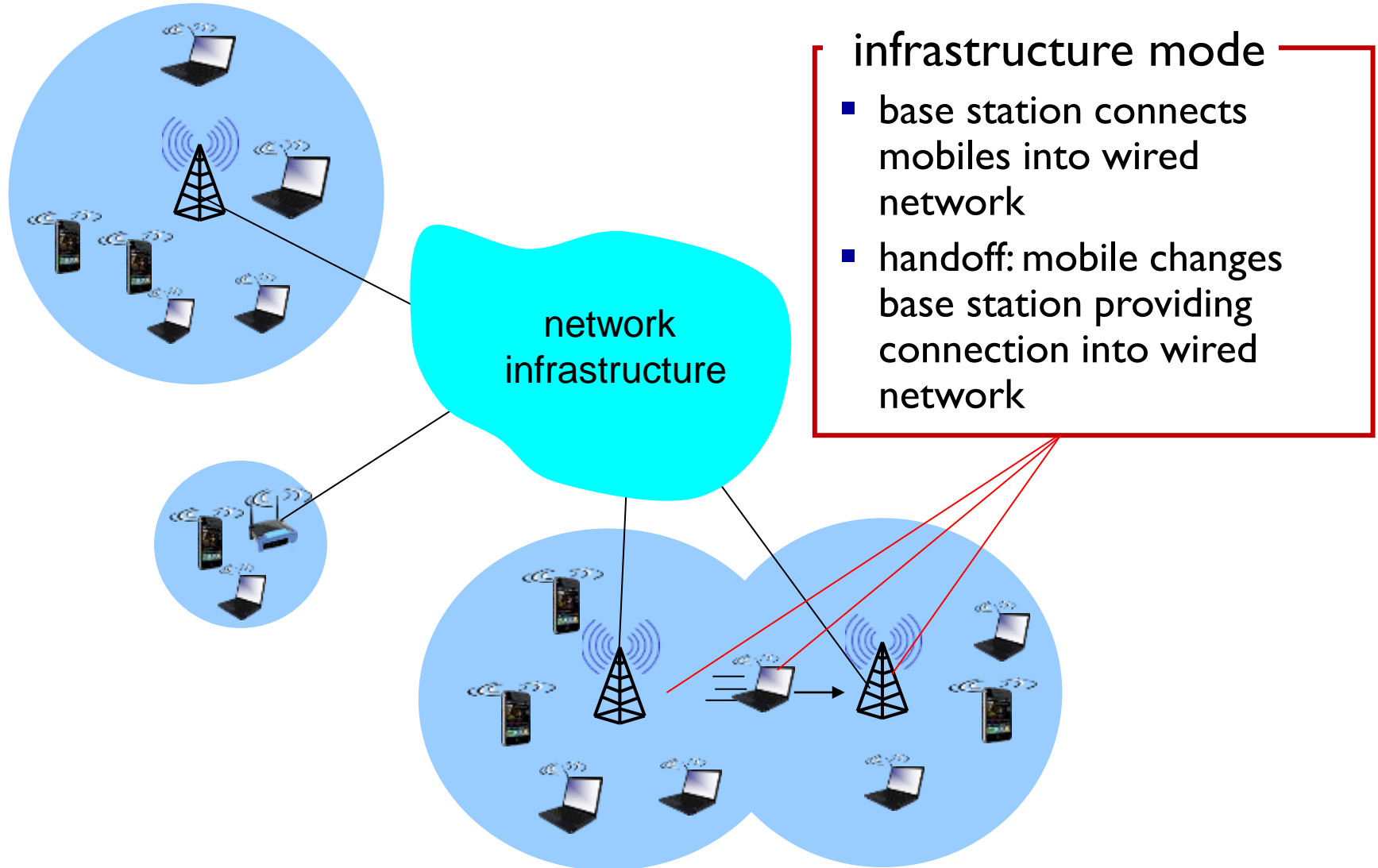
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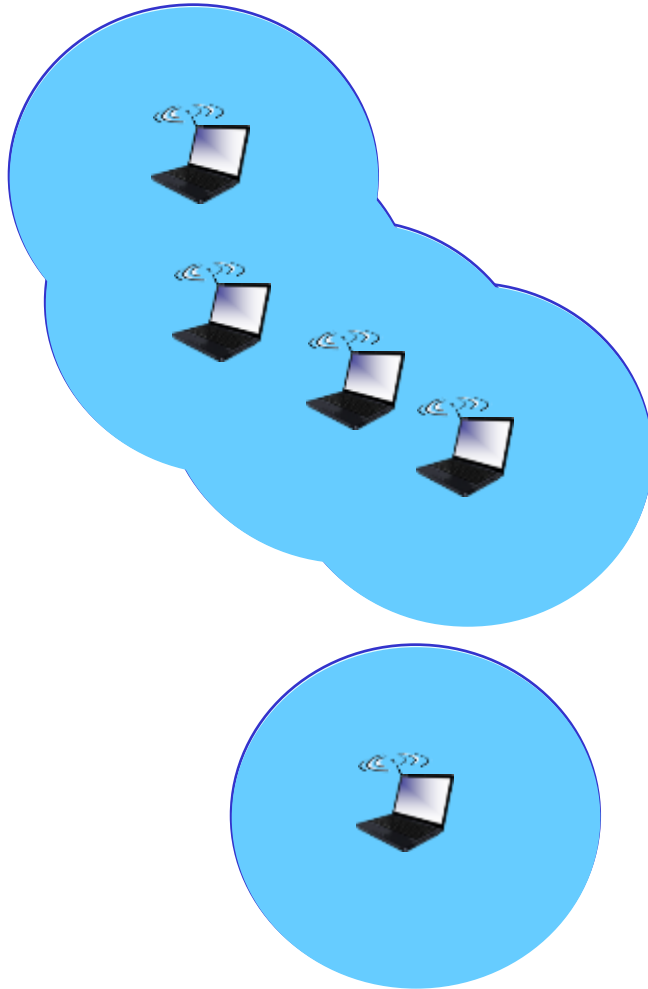
Characteristics of selected wireless links



Elements of a wireless network



Elements of a wireless network



ad hoc mode

- no base stations
- nodes can only transmit to other nodes within link coverage
- nodes organize themselves into a network: route among themselves

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Wireless Link Characteristics (I)

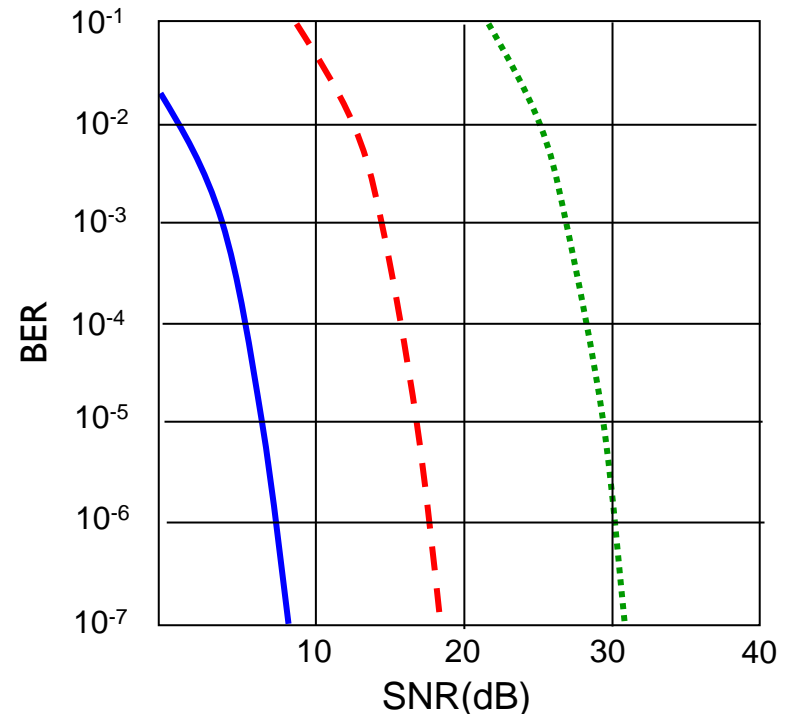
important differences from wired link

- *decreased signal strength*: radio signal attenuates as it propagates through matter (path loss)
- *interference from other sources*: standardized wireless network frequencies (e.g., 2.4 GHz) shared by other devices (e.g., phone); devices (motors) interfere as well
- *multipath propagation*: radio signal reflects off objects ground, arriving at destination at slightly different times

.... make communication across (even a point to point) wireless link much more “difficult”

Wireless Link Characteristics (2)

- SNR: signal-to-noise ratio
 - larger SNR – easier to extract signal from noise (a “good thing”)
- *SNR versus BER tradeoffs*
 - *given physical layer*: increase power \rightarrow increase SNR \rightarrow decrease BER
 - *given SNR*: choose physical layer that meets BER requirement, giving highest throughput
 - SNR may change with mobility: dynamically adapt physical layer (modulation technique, rate)

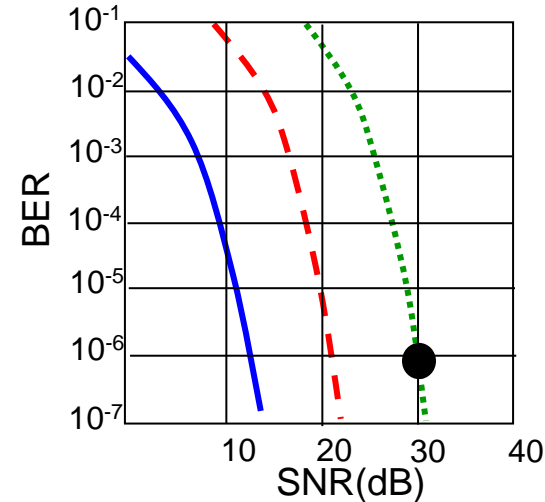
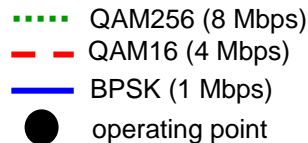


..... QAM256 (8 Mbps)
- - - QAM16 (4 Mbps)
— BPSK (1 Mbps)

Rate Adaptation

Rate adaptation

- base station, mobile dynamically change transmission rate (physical layer modulation technique) as mobile moves, SNR varies



- SNR decreases, BER increase as node moves away from base station
- When BER becomes too high, switch to lower transmission rate but with lower BER

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Mobility

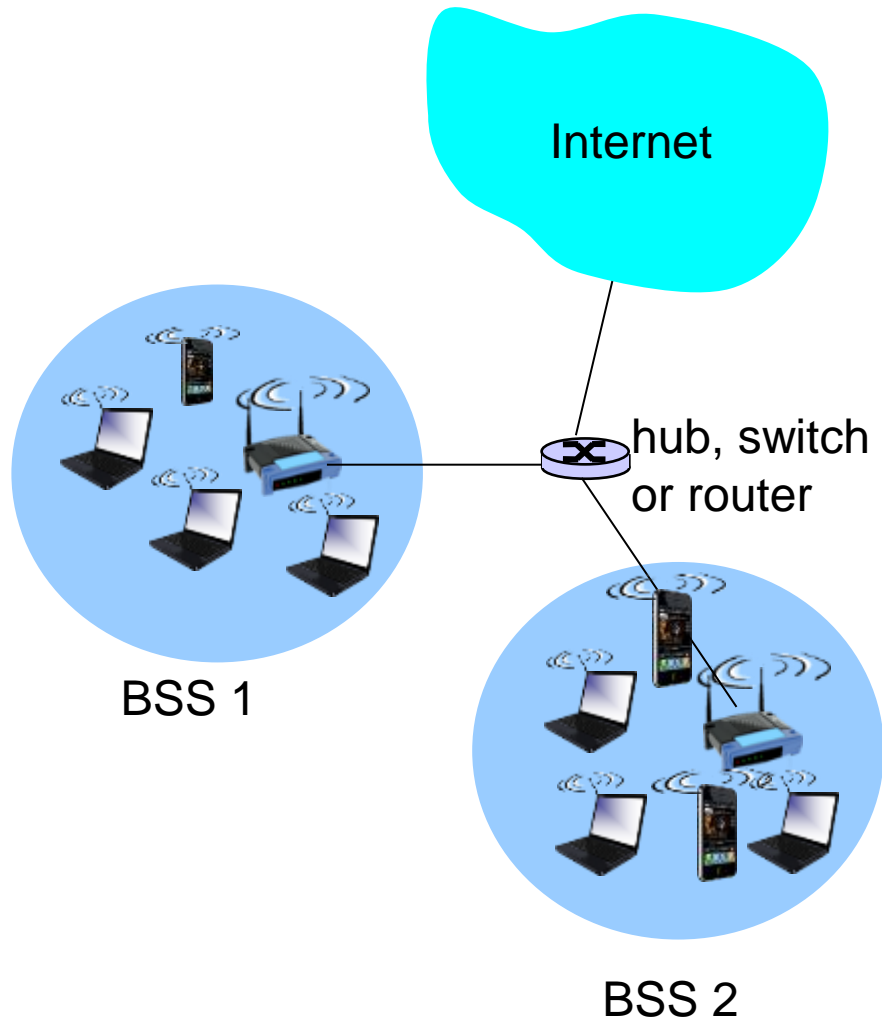
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802.11 LAN architecture



- wireless host communicates with base station
 - **base station = access point (AP)**
- **Basic Service Set (BSS)** (aka “cell”) in infrastructure mode contains:
 - wireless hosts
 - access point (AP): base station
 - ad hoc mode: hosts only

IEEE 802.11 Wireless LAN

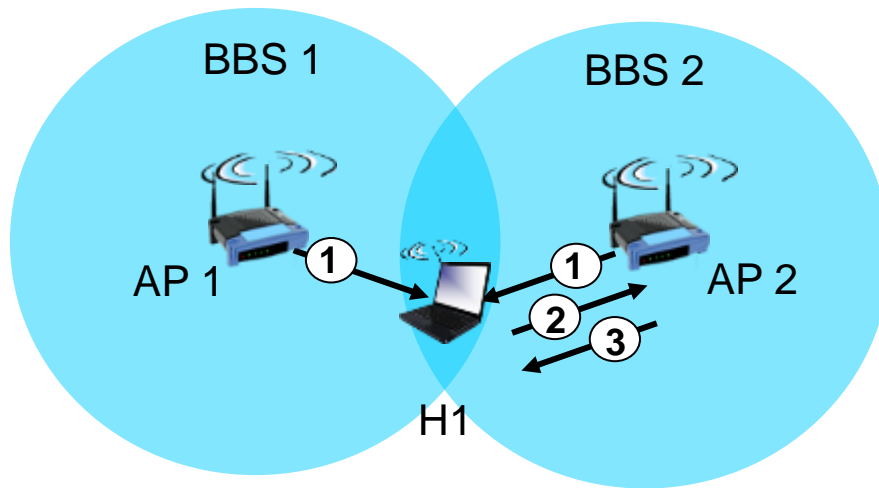
| IEEE 802.11 standard | Year | Max data rate | Range | Frequency |
|----------------------|-------------|---------------|-------|------------------------------|
| 802.11b | 1999 | 11 Mbps | 30 m | 2.4 Ghz |
| 802.11g | 2003 | 54 Mbps | 30m | 2.4 Ghz |
| 802.11n (WiFi 4) | 2009 | 600 | 70m | 2.4, 5 Ghz |
| 802.11ac (WiFi 5) | 2013 | 3.47Gpbs | 70m | 5 Ghz |
| 802.11ax (WiFi 6) | 2020 (exp.) | 14 Gbps | 70m | 2.4, 5 Ghz |
| 802.11af | 2014 | 35 – 560 Mbps | 1 Km | unused TV bands (54-790 MHz) |
| 802.11ah | 2017 | 347Mbps | 1 Km | 900 Mhz |

- all use CSMA/CA for multiple access, and have base-station and ad-hoc network versions

802.11: Channels, association

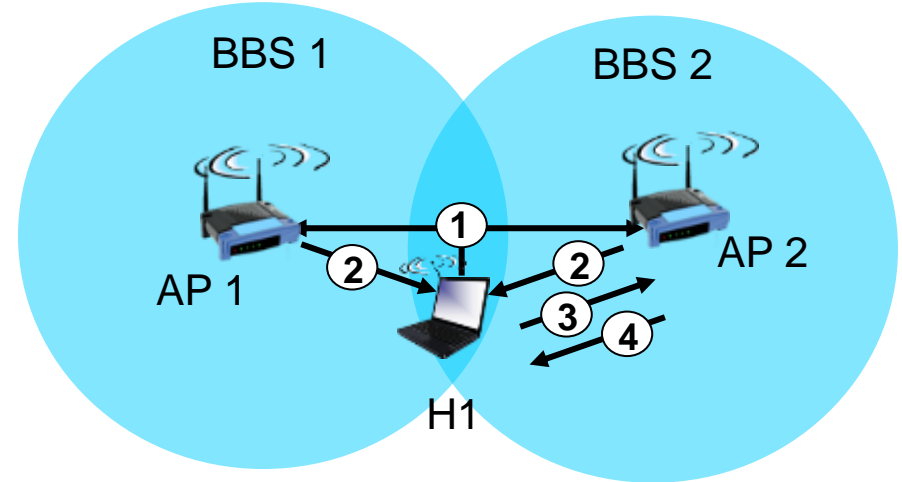
- 802.11b: 2.4GHz-2.485GHz spectrum divided into 11 channels at different frequencies
 - AP admin chooses frequency for AP
 - interference possible: channel can be same as that chosen by neighboring AP!
- host: must *associate* with an AP
 - scans channels, listening for *beacon frames* containing AP's name (SSID) and MAC address
 - selects AP to associate with
 - may perform authentication [Chapter 8]
 - will typically run DHCP to get IP address in AP's subnet

802.11: passive/active scanning



passive scanning:

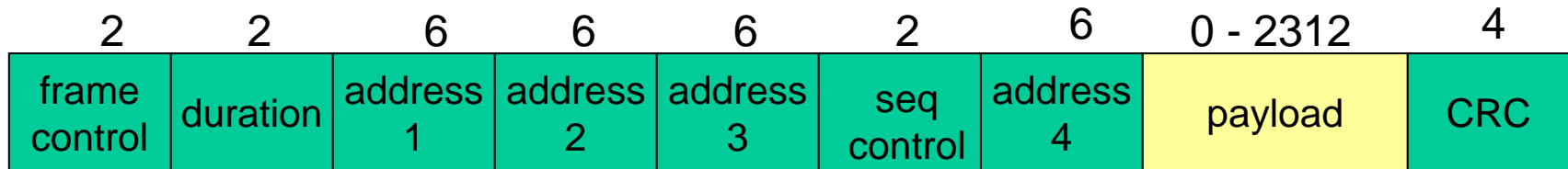
- (1) beacon frames sent from APs
- (2) association Request frame sent: H1 to selected AP
- (3) association Response frame sent from selected AP to H1



active scanning:

- (1) Probe Request frame broadcast from H1
- (2) Probe Response frames sent from APs
- (3) Association Request frame sent: H1 to selected AP
- (4) Association Response frame sent from selected AP to H1

802.11 frame: addressing



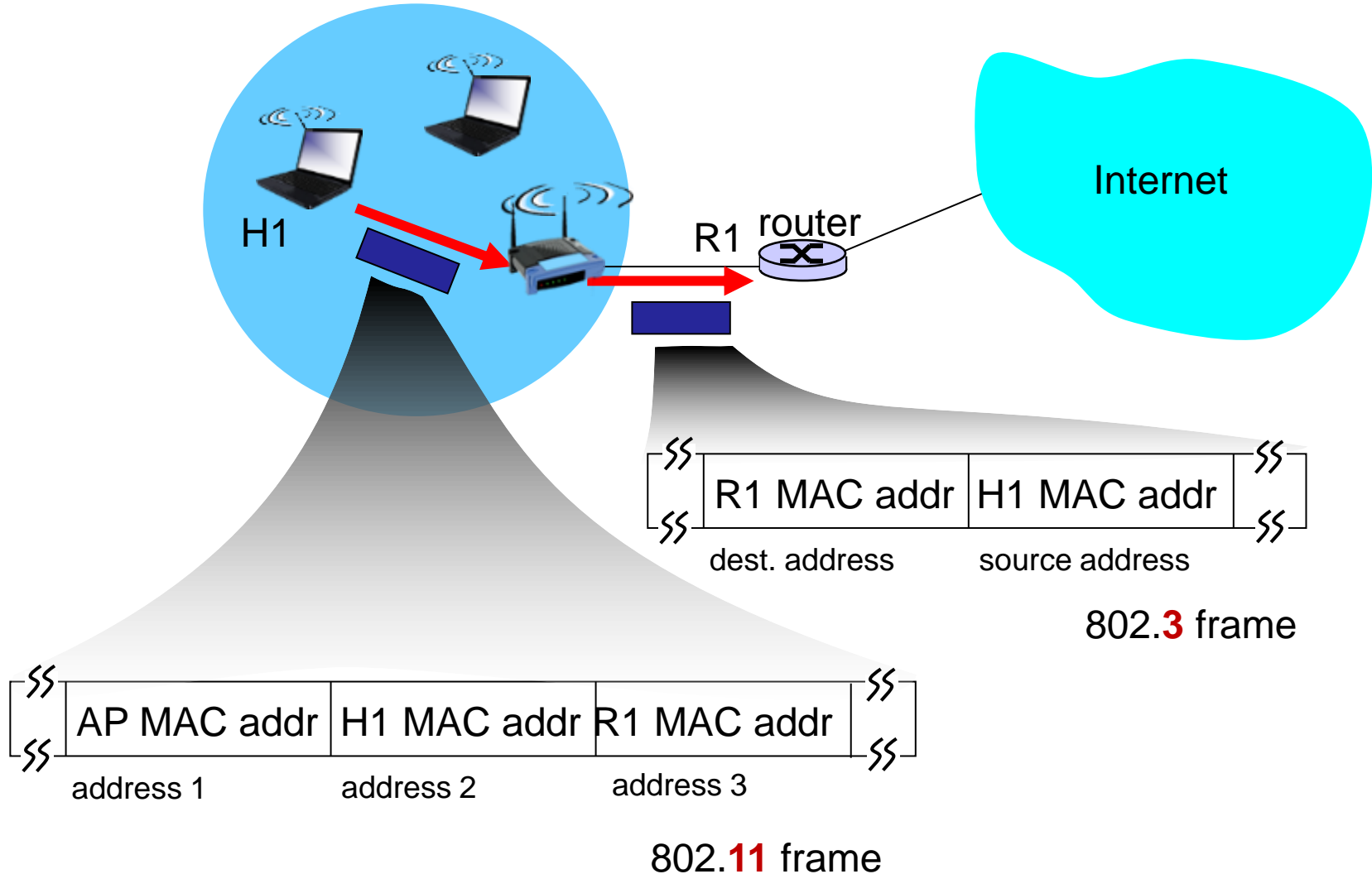
Address 1: MAC address of wireless host or AP to receive this frame

Address 2: MAC address of wireless host or AP transmitting this frame

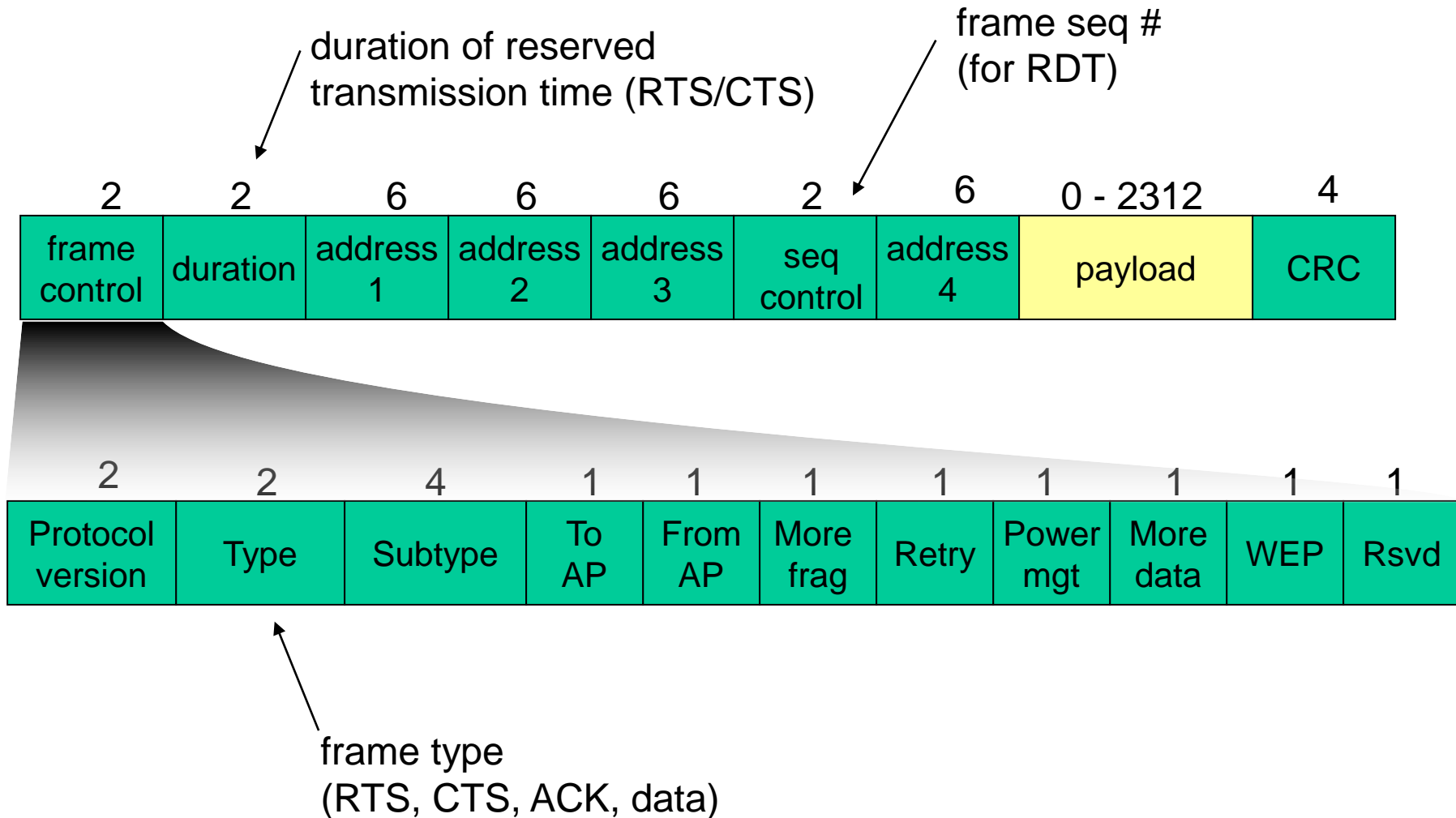
Address 3: MAC address of router interface to which AP is attached

Address 4: used only in ad hoc mode

802.11 frame: addressing

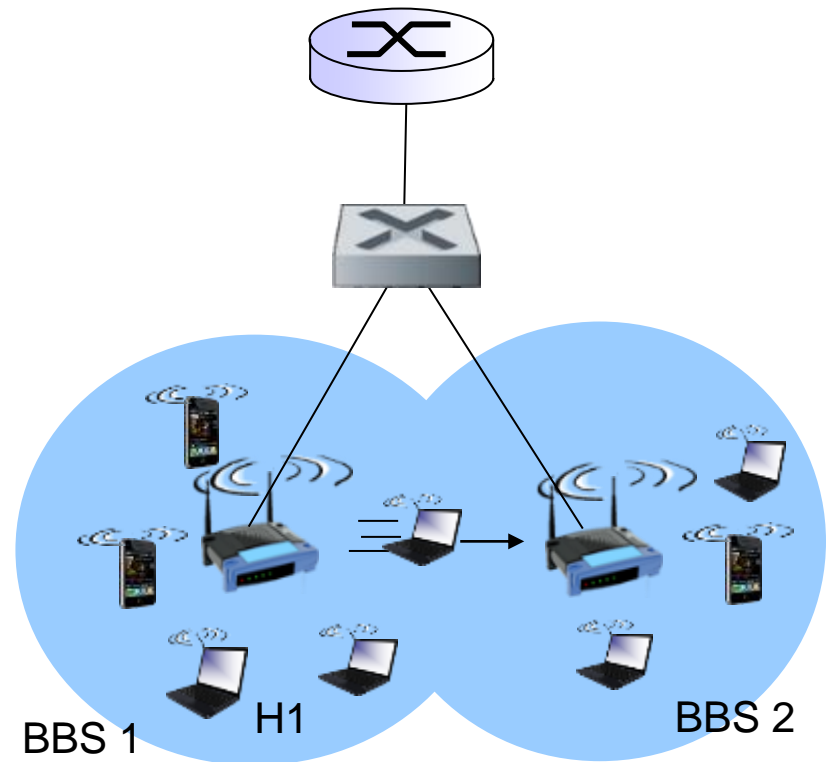


802.11 frame: more



802.11: mobility within same subnet

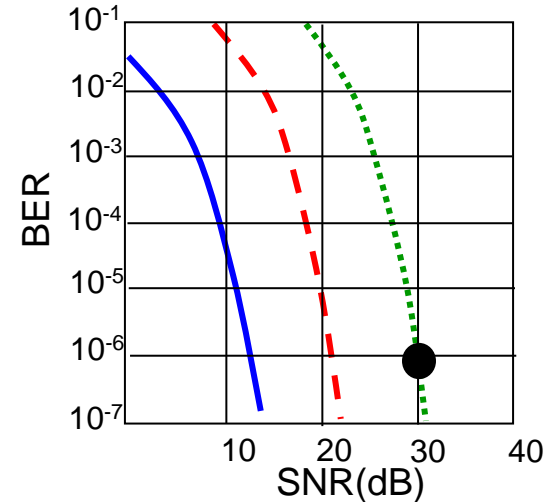
- HI remains in same IP subnet: IP address can remain same
- switch: which AP is associated with HI?
 - self-learning (Ch. 5): switch will see frame from HI and “remember” which switch port can be used to reach HI



802.11: advanced capabilities

Rate adaptation

- base station, mobile dynamically change transmission rate (physical layer modulation technique) as mobile moves, SNR varies



- QAM256 (8 Mbps)
- - - QAM16 (4 Mbps)
- BPSK (1 Mbps)
- operating point

1. SNR decreases, BER increase as node moves away from base station
2. When BER becomes too high, switch to lower transmission rate but with lower BER

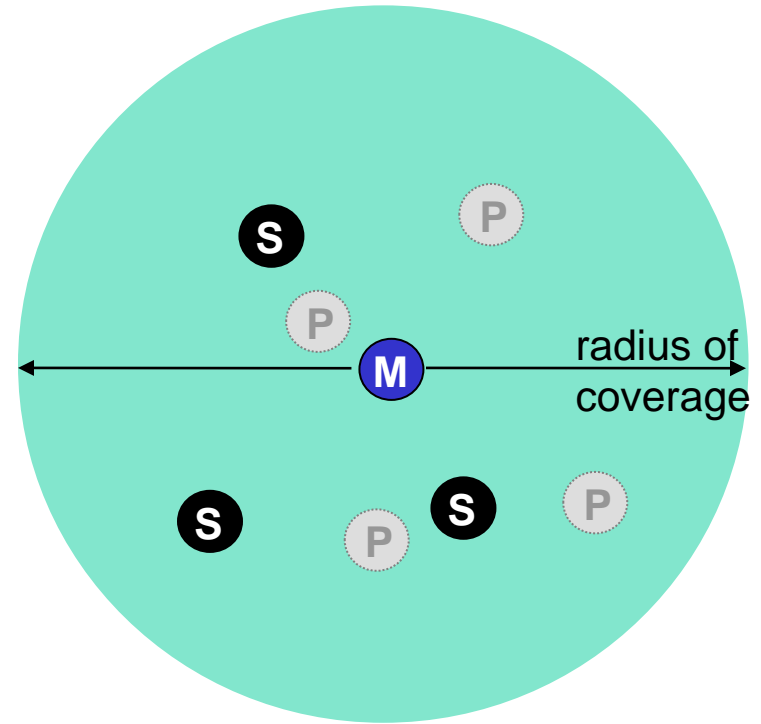
802.11: advanced capabilities

power management

- node-to-AP: “I am going to sleep until next beacon frame”
 - AP knows not to transmit frames to this node
 - node wakes up before next beacon frame
- beacon frame: contains list of mobiles with AP-to-mobile frames waiting to be sent
 - node will stay awake if AP-to-mobile frames to be sent; otherwise sleep again until next beacon frame

802.15: personal area network

- 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
- 802.15: 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)

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- architecture
- standards (e.g., 3G, LTE)

Mobility

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7.8 Mobility and higher-layer protocols

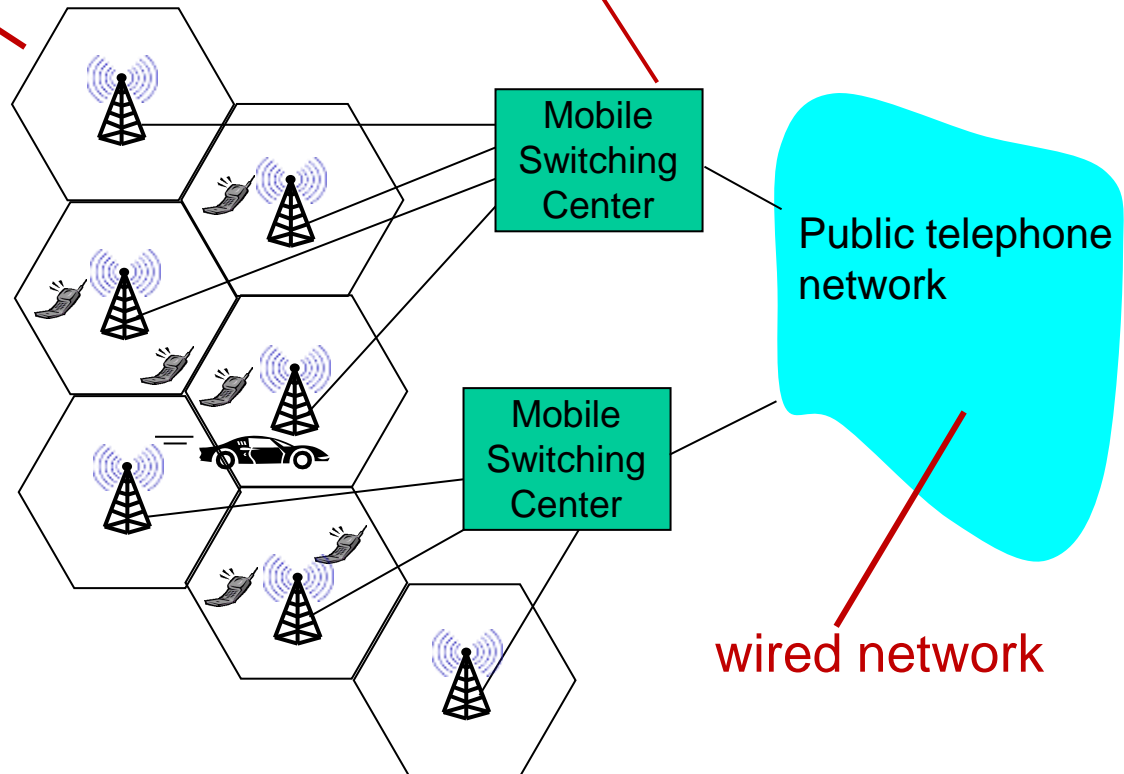
Components of cellular network architecture

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

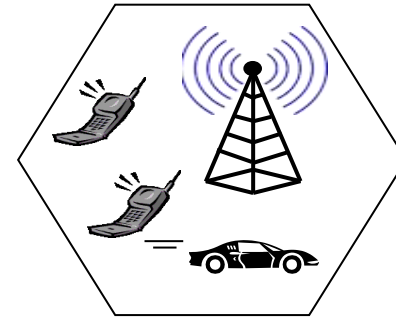
- ❖ connects cells to wired tel. net.
- ❖ manages call setup (more later!)
- ❖ handles mobility (more later!)



Cellular networks: the first hop

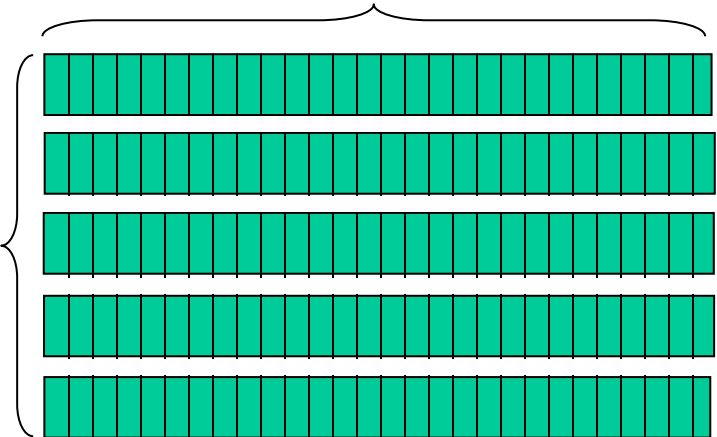
Two techniques for sharing mobile-to-BS radio spectrum

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

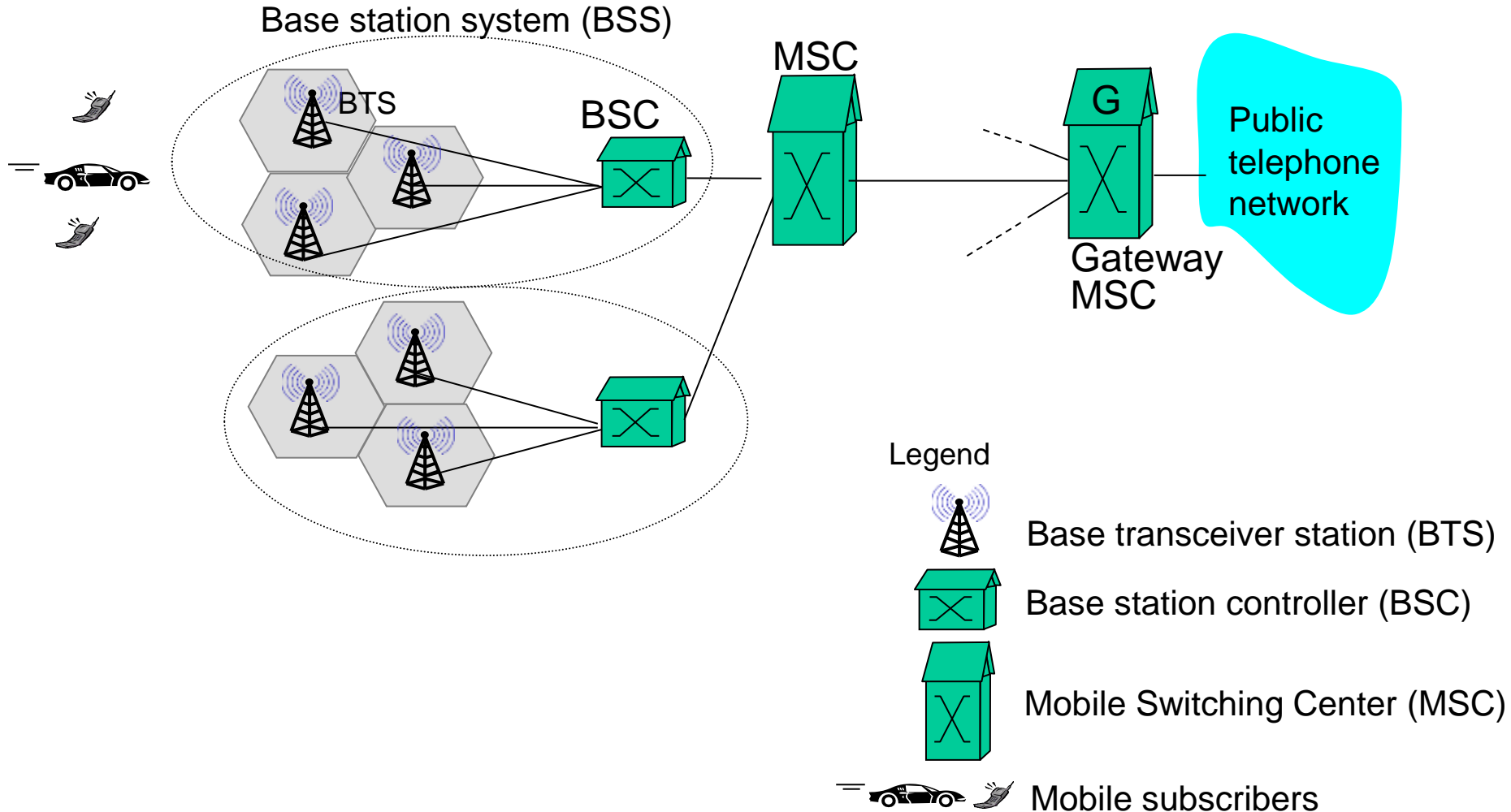


time slots

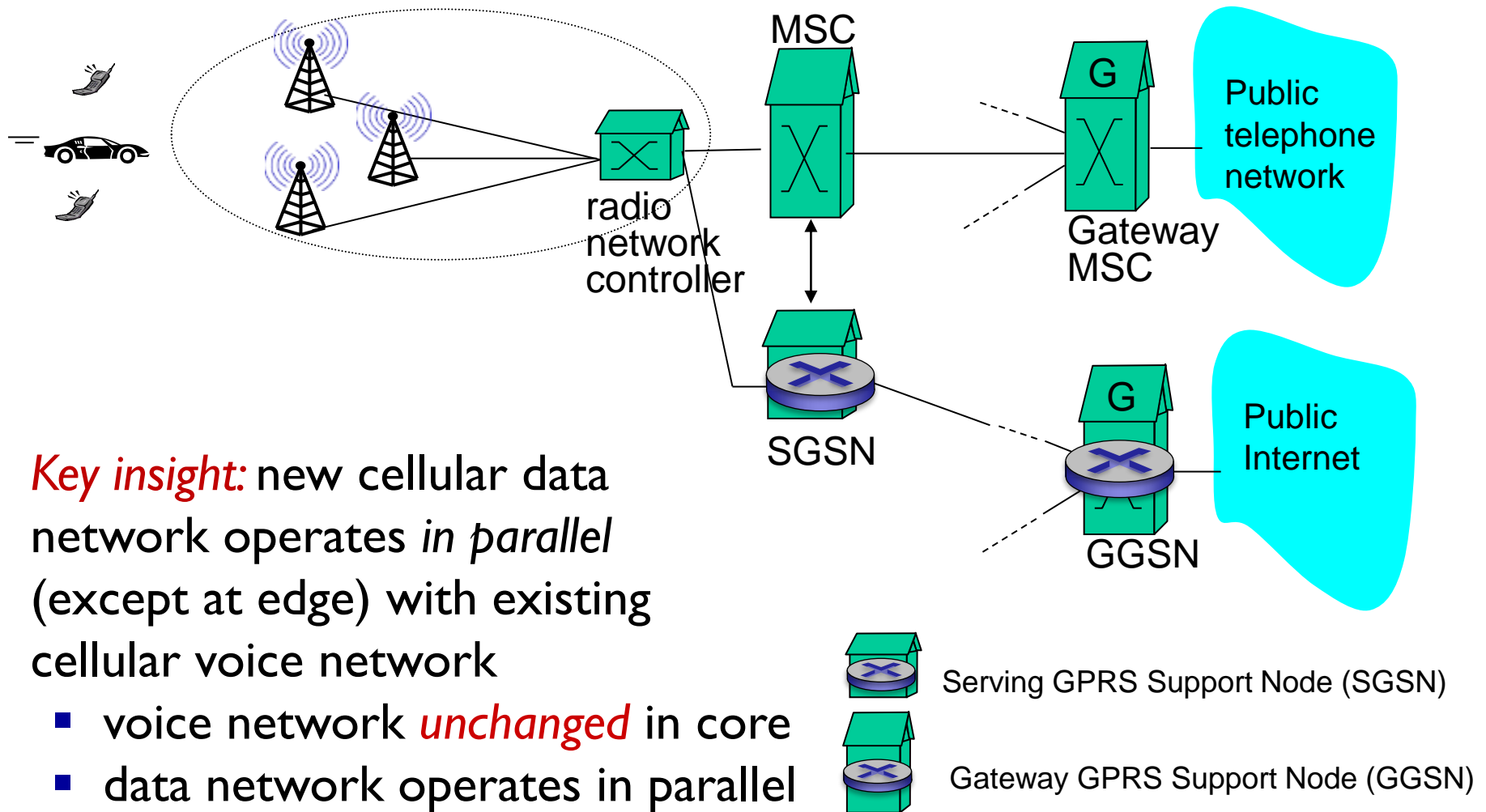
frequency bands



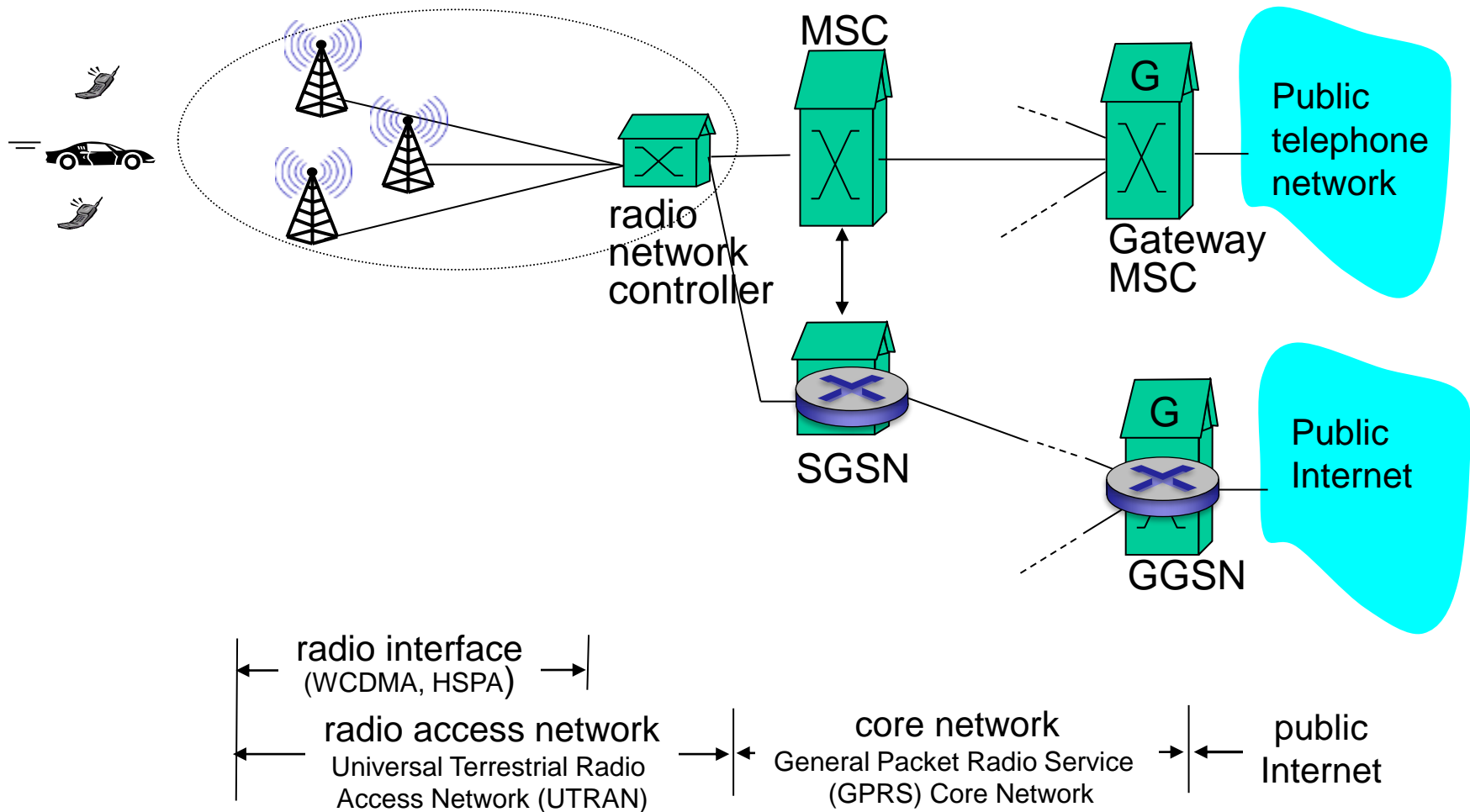
2G (voice) network architecture



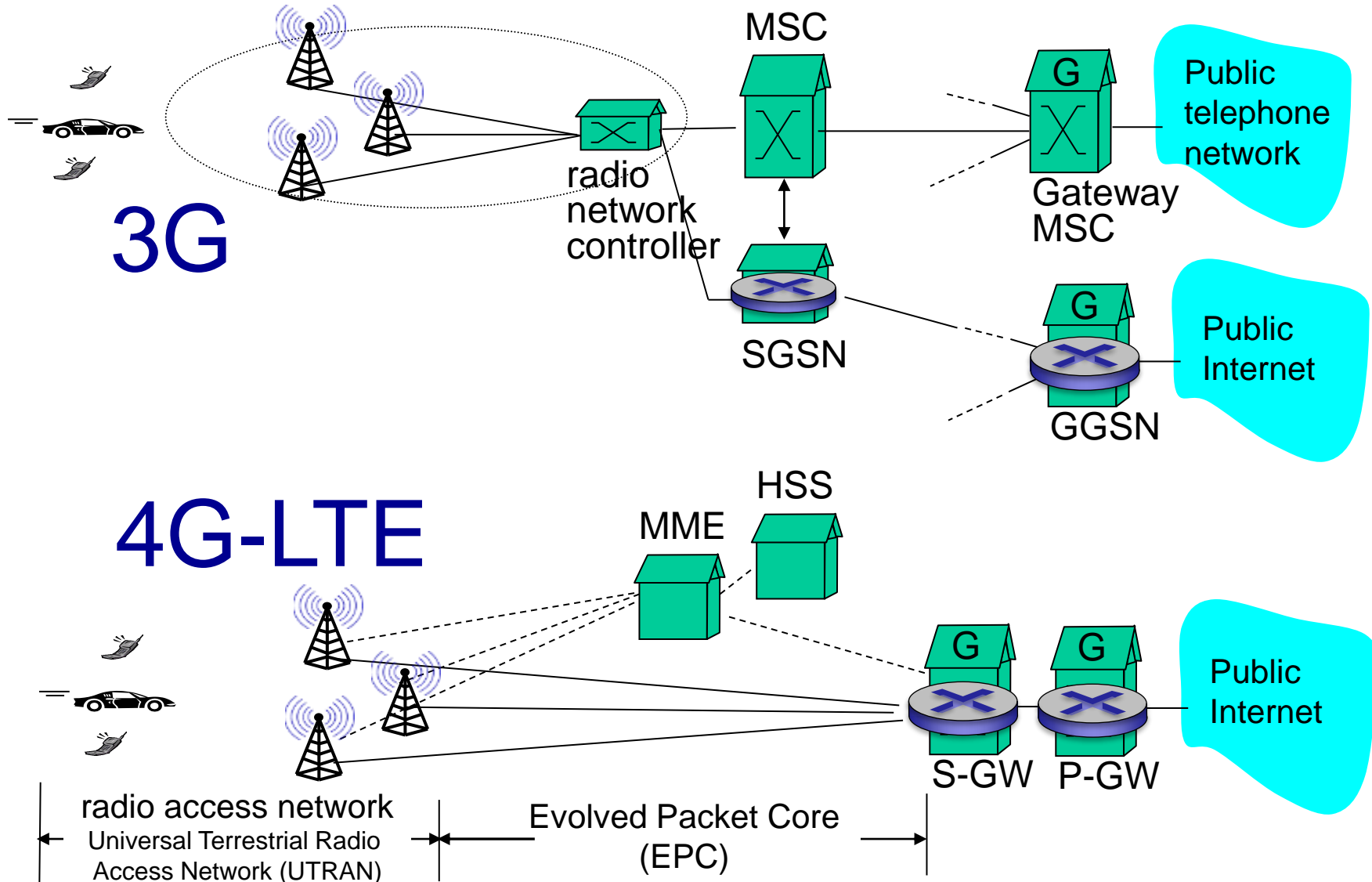
3G (voice+data) network architecture



3G (voice+data) network architecture

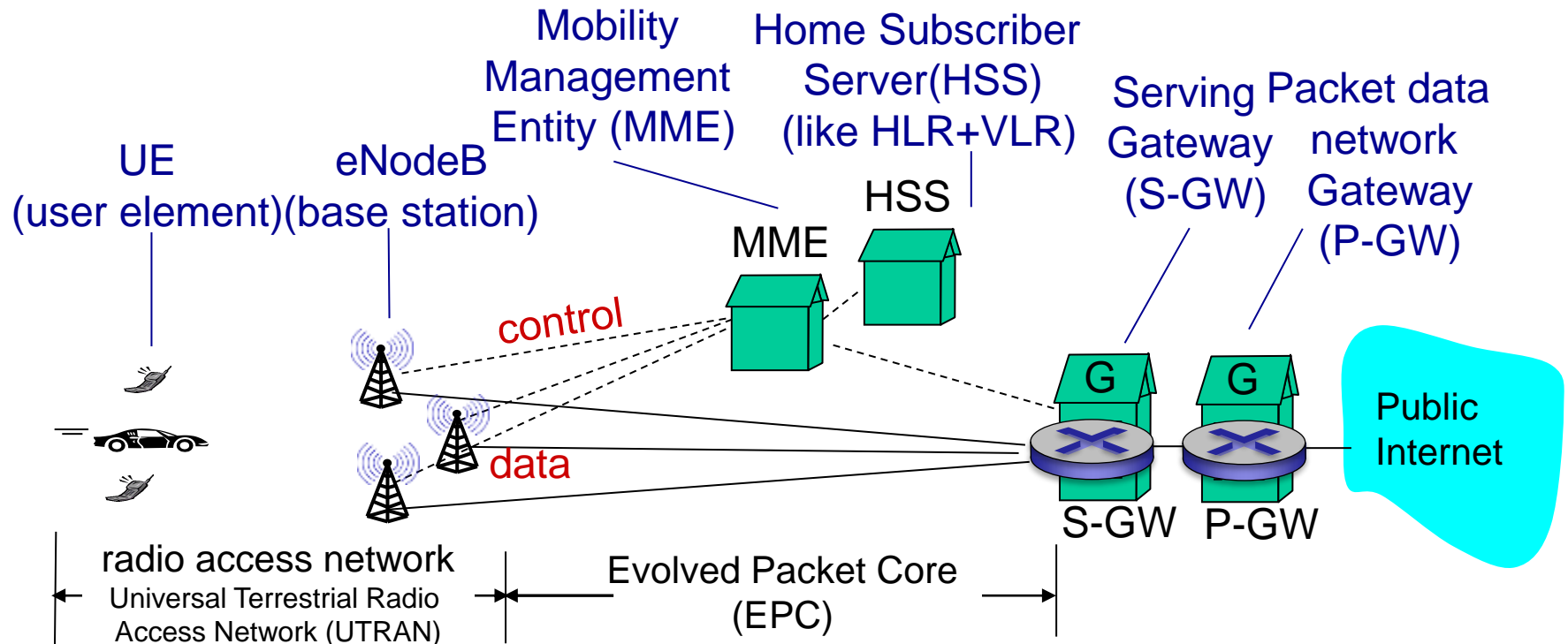


3G versus 4G LTE network architecture



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



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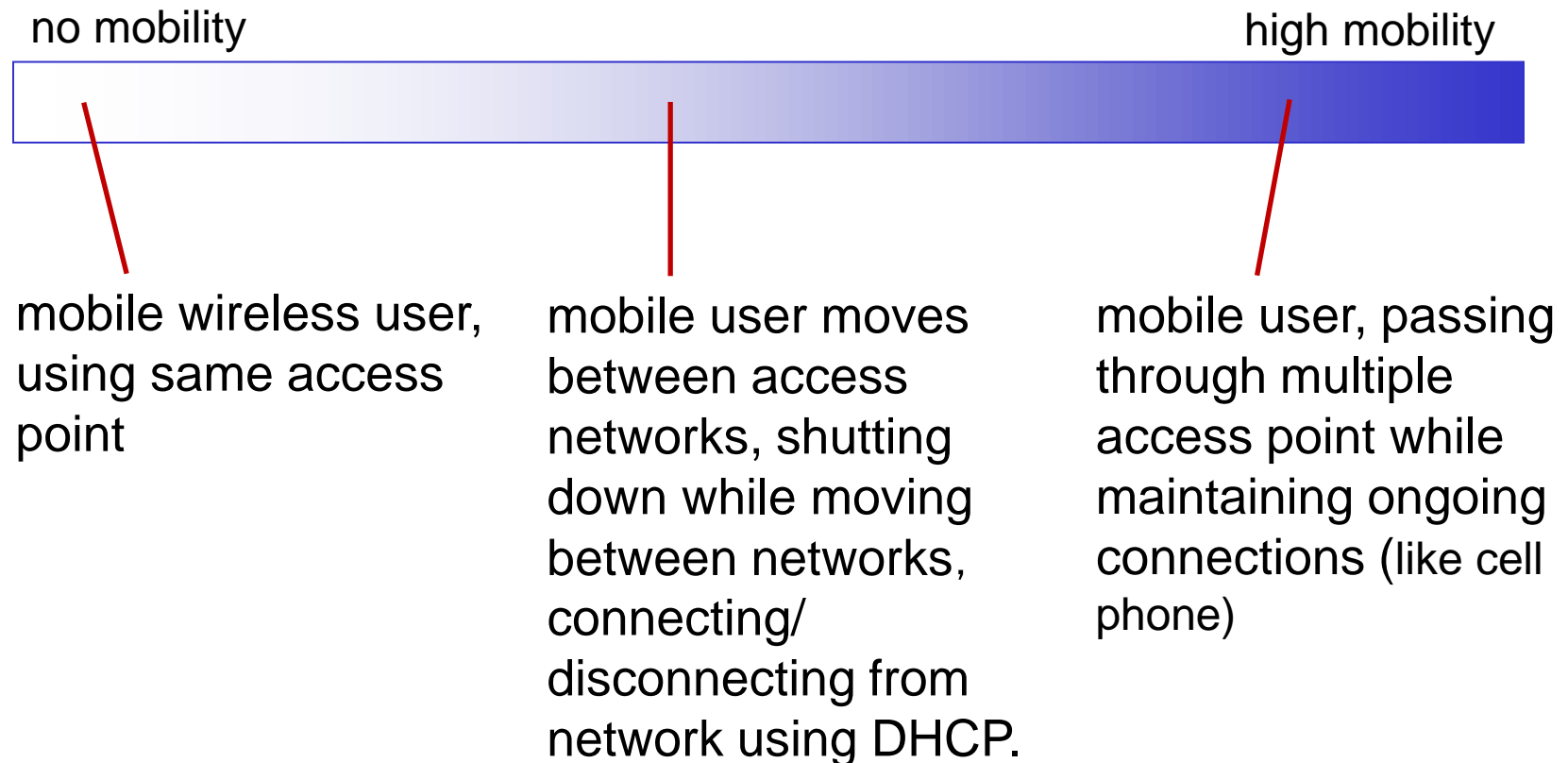
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What is mobility?

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

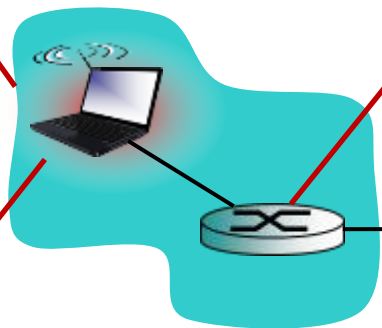


Mobility: vocabulary

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



wide area
network



Mobility: more vocabulary

permanent address: remains constant (e.g., 128.119.40.186)

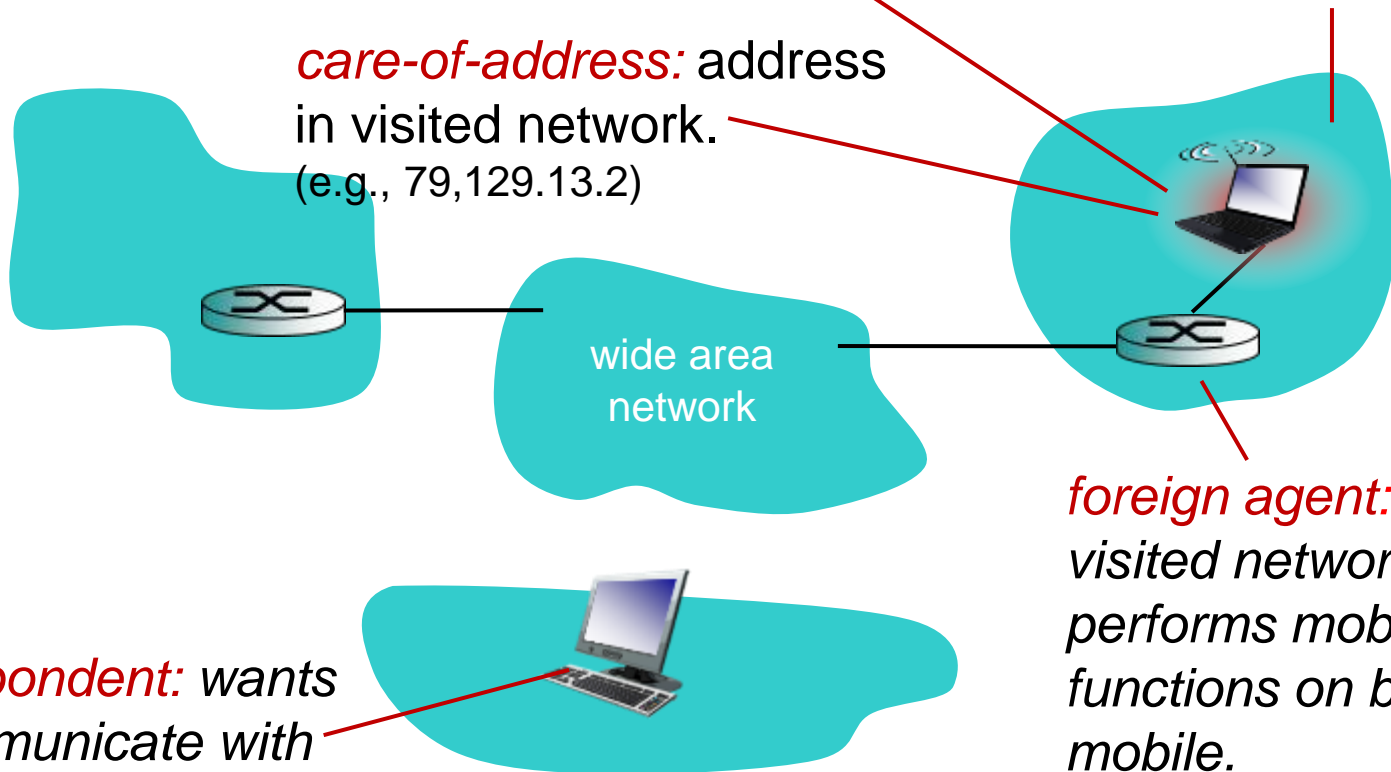
visited network: network in which mobile currently resides (e.g., 79.129.13/24)

care-of-address: address in visited network. (e.g., 79.129.13.2)

wide area network

foreign agent: entity in visited network that performs mobility functions on behalf of mobile.

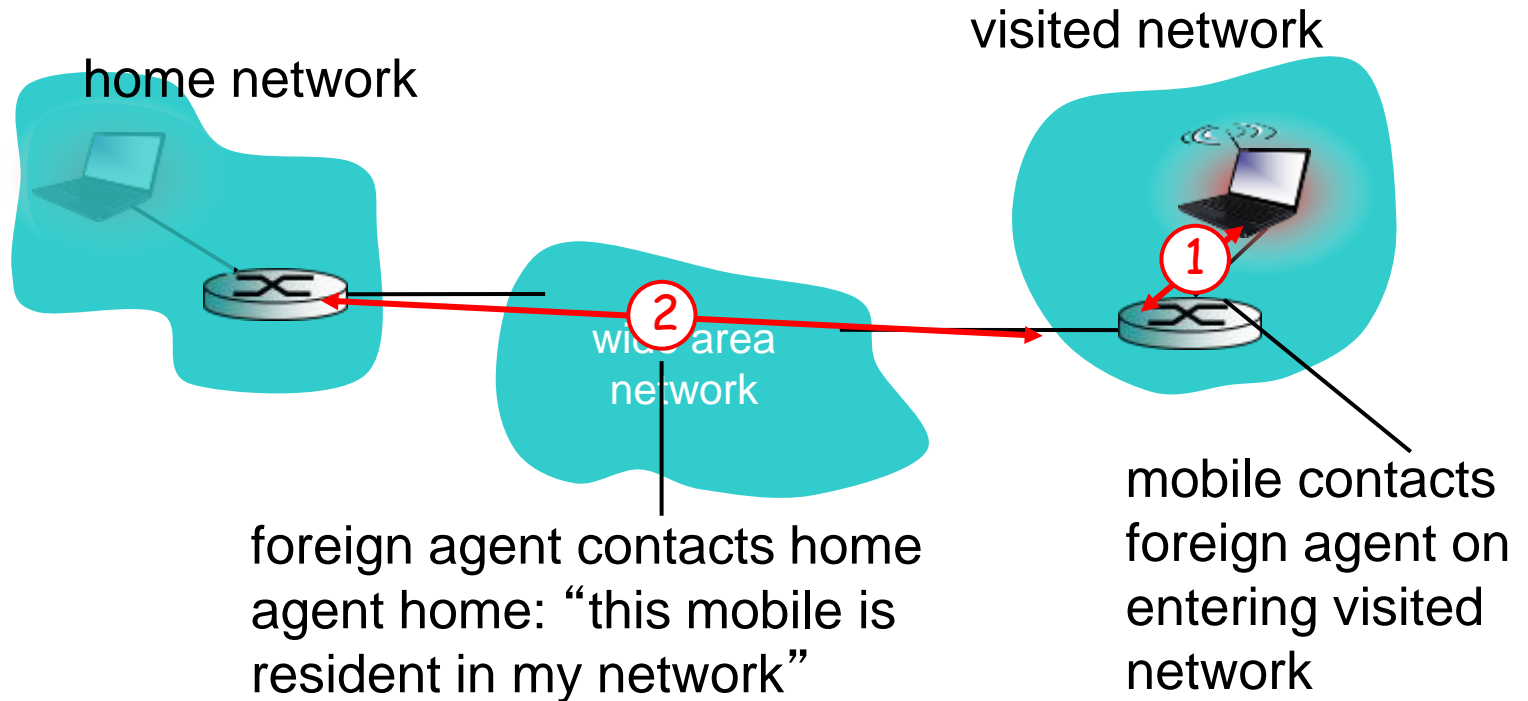
correspondent: wants to communicate with mobile



Mobility: approaches

- *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

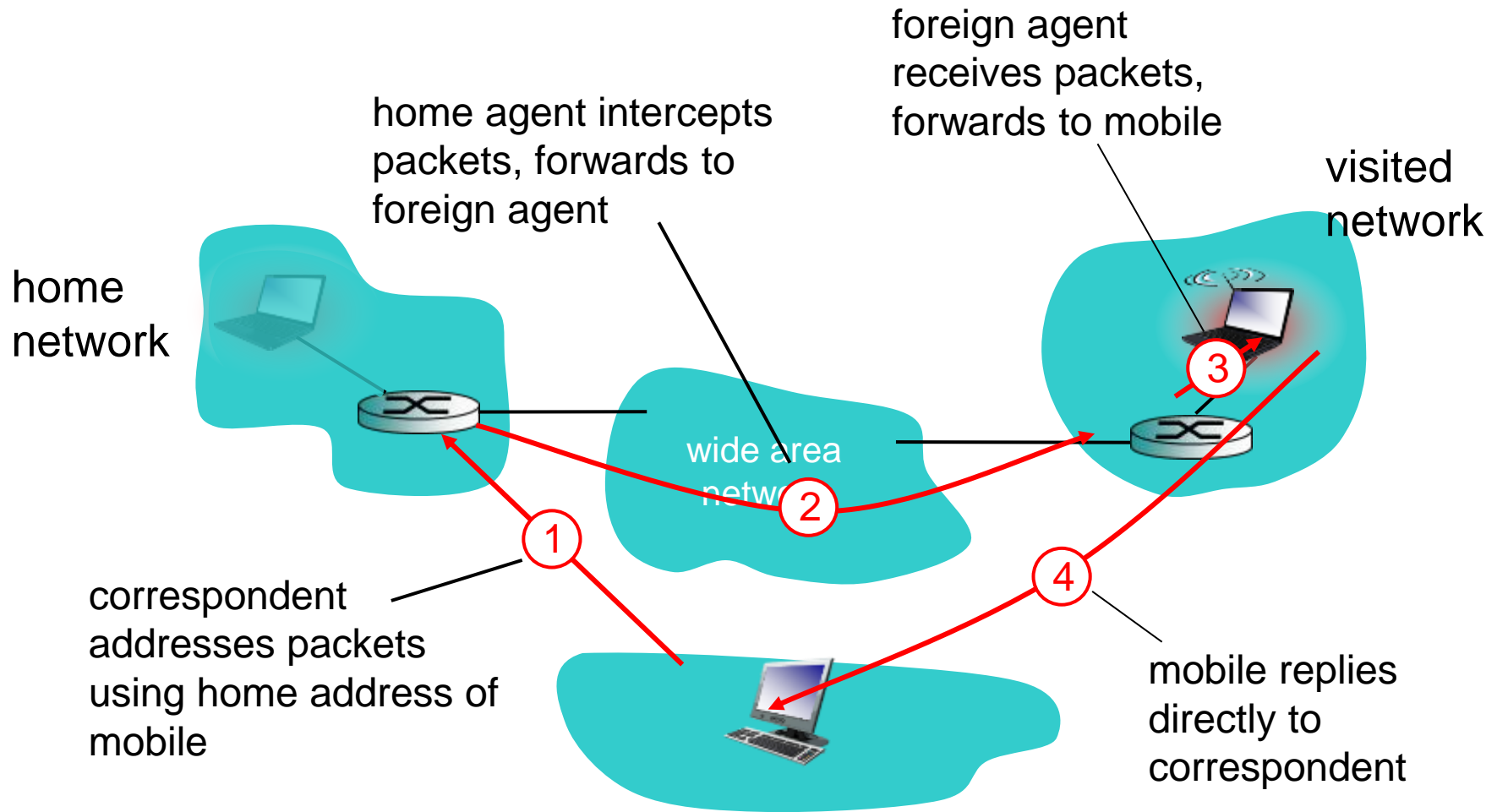
Mobility: registration



end result:

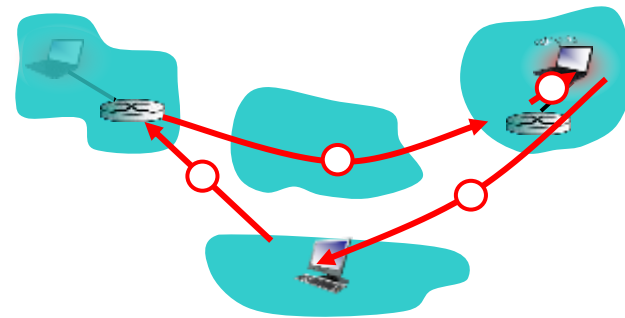
- foreign agent knows about mobile
- home agent knows location of mobile

Mobility via indirect routing



Indirect Routing: comments

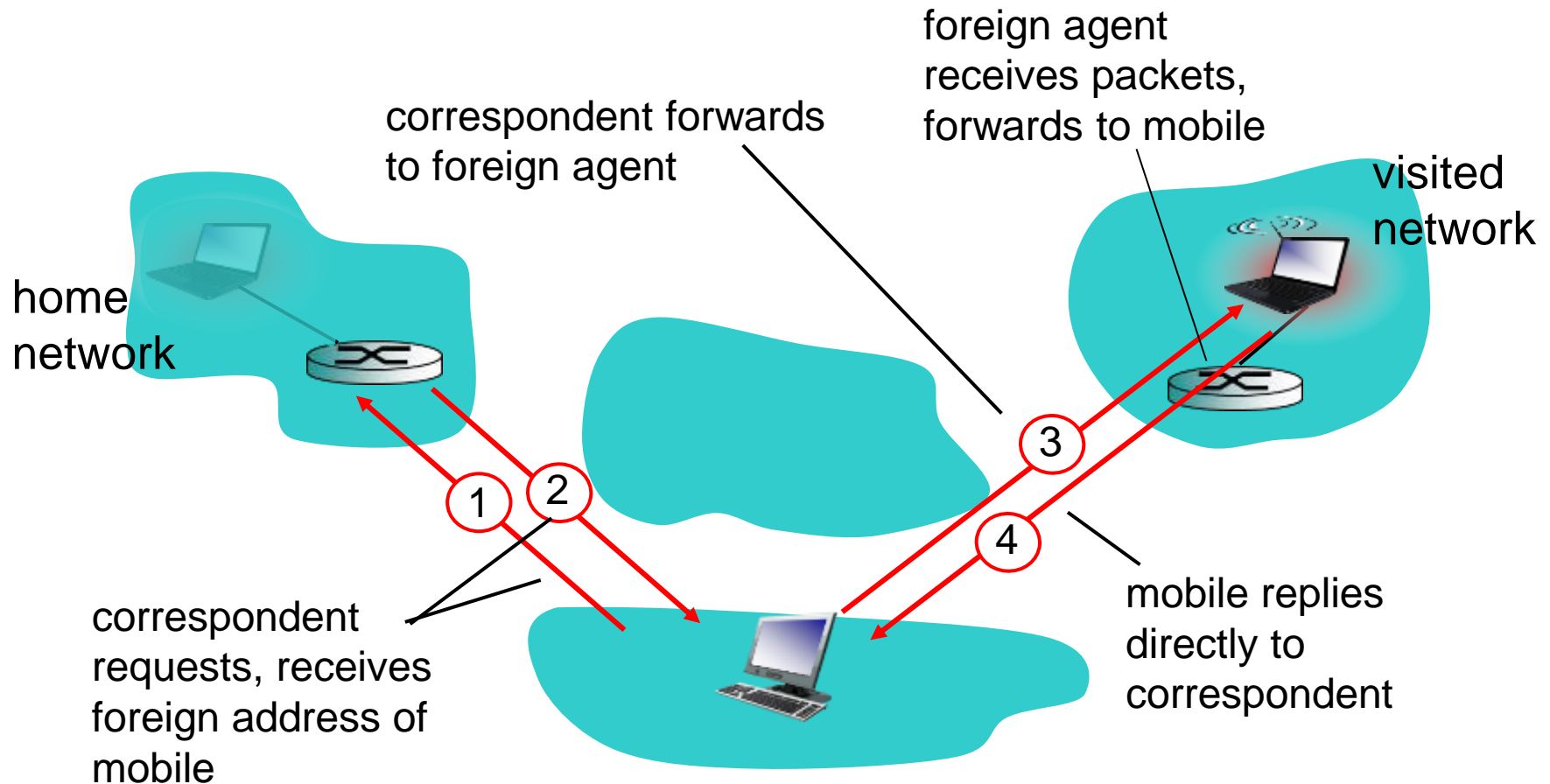
- mobile uses two addresses:
 - **permanent address**: used by correspondent (hence mobile location is *transparent* to correspondent)
 - **care-of-address**: used by home agent to forward datagrams to mobile
- foreign agent functions may be done by mobile itself
- **triangle routing**: correspondent-home-network-mobile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



Indirect routing: moving between networks

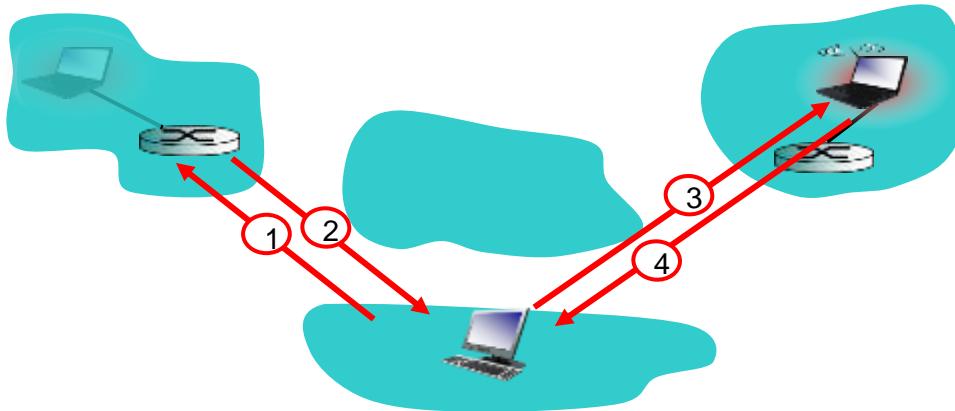
- suppose mobile user moves to another network
 - registers with new foreign agent
 - new foreign agent registers with home agent
 - home agent update care-of-address for mobile
 - packets continue to be forwarded to mobile (but with new care-of-address)
- mobility, changing foreign networks transparent: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

Mobility via direct routing



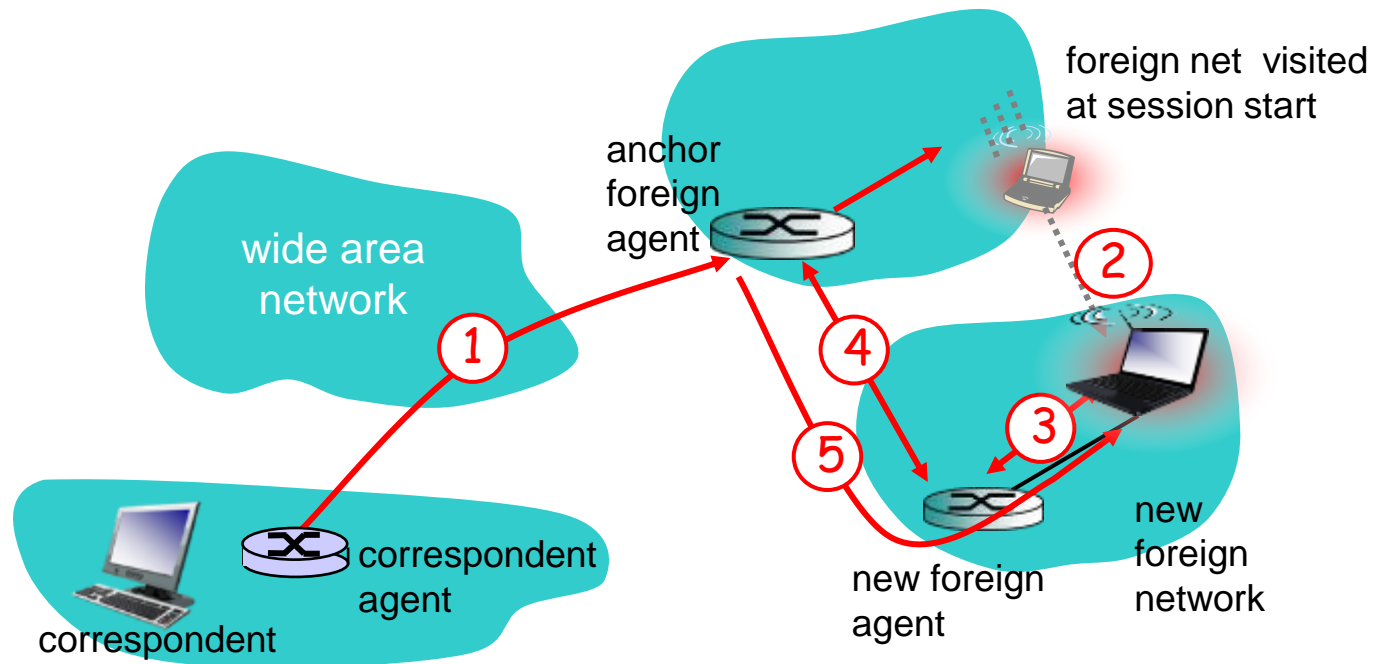
Mobility via direct routing: comments

- 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)



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

Chapter 7 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., 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, LTE
- impact on higher-layer protocols