

Computer Networking: A Top-Down Approach 6th Edition
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CHAPTER 6

Wireless and Mobile Networks

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CHAPTER 6

Roadmap:

<p><u>Wireless:</u></p> <ul style="list-style-type: none"> 6.1 Background & Introduction 6.2 Wireless links, characteristics 6.3 IEEE 802.11 wireless LANs (“Wi-Fi”) 6.4 Cellular Internet Access <ul style="list-style-type: none"> ▪ Cellular Architecture 	<p><u>Mobility:</u></p> <ul style="list-style-type: none"> 6.5 Principles: addressing, routing to mobile users <ul style="list-style-type: none"> ▪ Home, Visited networks ▪ <i>Care-of-addresses</i>, foreign agent ▪ Indirect & direct routing
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CHAPTER 6 (6.1) Introduction

Wireless and mobile networks

Background:

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

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CHAPTER 6 Element of a wireless networks

The diagram illustrates the elements of a wireless network. A central cloud labeled 'Network infrastructure' is connected to three circular 'Coverage area' regions. Each coverage area contains one or more 'Wireless access points' (represented by tower icons) which are connected to 'Wireless hosts' (represented by laptop and smartphone icons). Some hosts are shown with motion arrows, indicating they are mobile. A key in the bottom left defines the symbols: a tower for 'Wireless access point', a laptop for 'Wireless host', a laptop with an arrow for 'Wireless host in motion', and a dashed circle for 'Coverage area'. A yellow box on the right states 'Wireless does not always mean mobility'.

Wireless hosts:

- ❖ laptop, smartphone
- ❖ run applications
- ❖ may be stationary (non-mobile) or mobile

Wireless does not always mean mobility

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Element of a wireless networks

Key:

- Wireless access point
- Wireless host
- Wireless host in motion
- Coverage area

Base station:

- typically connected to wired network
- relay - responsible for sending packets between wired network and wireless host(s) in its "area"
 - e.g., cell towers, 802.11 access points

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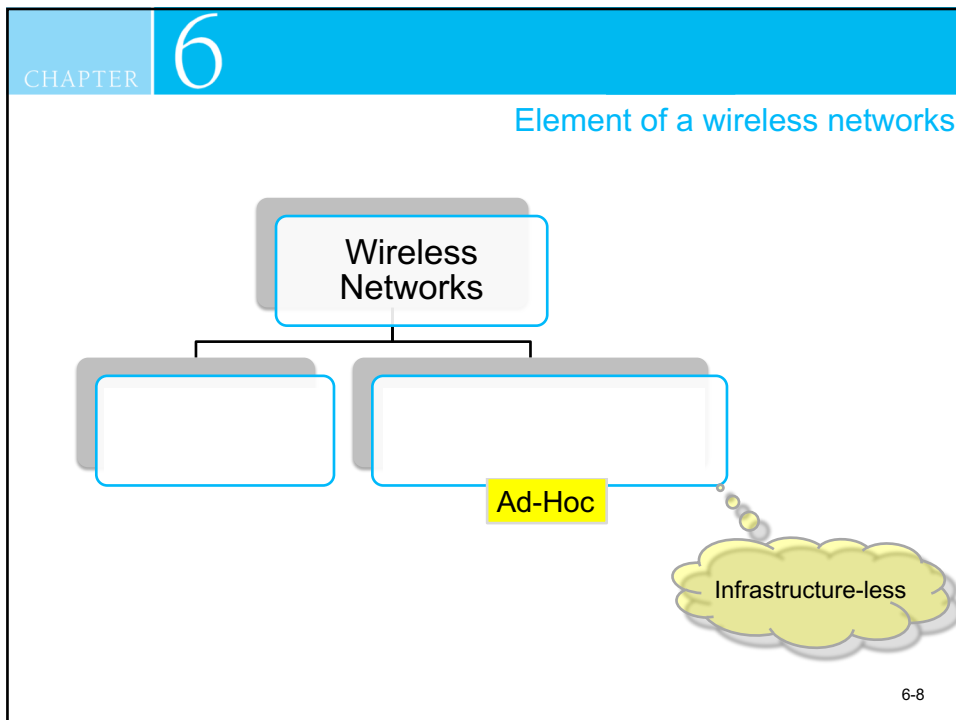
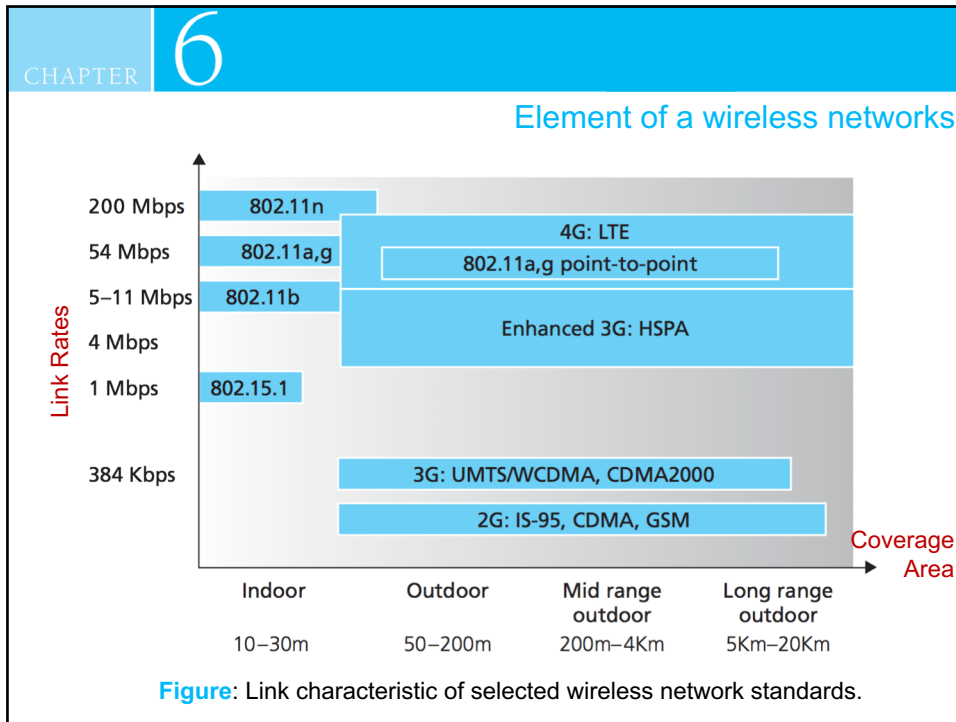
Element of a wireless networks

Key:

- Wireless access point
- Wireless host
- Wireless host in motion
- Coverage area

Wireless link:

- typically used to connect mobile(s) to base station
- also used as backbone link
- multiple access protocol coordinates link access
- various data rates, transmission distance



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Element of a wireless networks

Key:

- Wireless access point
- Wireless host
- Wireless host in motion
- Coverage area

Infrastructure mode:

- base station connects mobiles into wired network
- mobile changes base station providing connection into wired network

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Element of a wireless networks

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

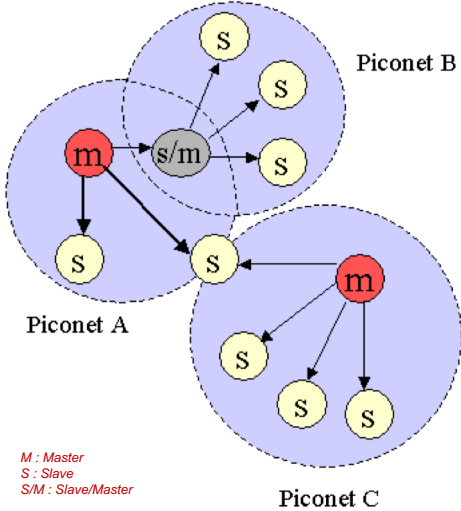
6-10

CHAPTER 6 Wireless network taxonomy

	Single hop	Multiple hops
Infrastructure-based (e.g., APs)	Host connects to base station which connects to larger Internet (<i>WiFi, WiMAX, cellular</i>) 	Host may have to relay through several wireless nodes to connect to larger Internet (<i>mesh network</i>)
No Infrastructure	No base station, no connection to larger Internet (<i>Bluetooth, ad hoc networks</i>) 	No base station, no connection to larger Internet. May have to relay to reach other a given wireless node. (<i>Piconet, MANET, VANET</i>)

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CHAPTER 6 Example: Piconet



- Multiple hops
- No infrastructure

- ❖ Temporary Network
- ❖ Up to 8 Active Devices
- ❖ Master coordinates the Piconet; and Slaves follow the Master
- ❖ Each bluetooth devices may operate as either master or slave

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<http://semiengineering.com/wp-content/uploads/2015/04/Figure-2-scatternet.gif>

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<http://www.intechopen.com/source/html/41429/media/image8.jpeg>
<http://www.intechopen.com/source/html/41429/media/image9.jpeg>

Example: MANET

- Multiple hops
- No infrastructure

- ❖ *Mobile Ad-Hoc Network (MANET)*: e.g for mobile devices.
- ❖ Non-heterogeneous nodes connected wirelessly.
- ❖ Node communicate through WiFi in Ad Hoc mode.

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<https://conceptdraw.com/62471c3/p1/preview/640/pict--vanet-diagram-vehicular-ad-hoc-network>

Example: VANET

- Multiple hops
- No infrastructure

- ❖ *Vehicular Ad-Hoc Network (VANET)*: e.g. for moving car
- ❖ Heterogeneous nodes connected wirelessly.
- ❖ Node communicate through WiFi in Ad Hoc mode automatically.

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CHAPTER 6 (6.2) Wireless Links Characteristic

- ❑ *important* differences from wired link as wireless link can have:
 - *decreased signal strength*: radio signal attenuates as it propagates through matter (_____).
 - *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.
 - *Multi-path 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”

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- ❖ *SNR: Signal-to-Noise Ratio*
 - larger SNR – easier to extract signal from noise (a “good thing”)
- ❖ *SNR versus BER tradeoffs*
 - *Bit Error Rate (BER)* is the number of bit errors divided by the total number of transferred bits
 - *given physical layer*: increase power → **increase SNR → 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)

decreased signal strength

Modulation Techniques

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

QAM (Quadrature Amplitude Modulation)

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Multiple wireless senders and receivers create additional problems (beyond multiple access):

multipath propagation

Interference from other sources

Hidden terminal problem:

- ❖ B, A hear each other
- ❖ B, C hear each other
- ❖ A, C can not hear each other means A, C unaware of their interference at B

Signal attenuation / :

- ❖ B, A hear each other
- ❖ B, C hear each other
- ❖ A, C can not hear each other interfering at B

Wireless, Mobile Networks 6-18

CHAPTER 6 (6.3) WiFi: IEEE 802.11 Wireless LANs

WiFi

802.11b

- ❖ 2.4-5 GHz unlicensed spectrum
- ❖ up to 11 Mbps
- ❖ *Direct Sequence Spread Spectrum* (DSSS) in physical layer
 - all hosts use same chipping code

802.11a

- 5-6 GHz range
- up to 54 Mbps

802.11g

- 2.4-5 GHz range
- up to 54 Mbps

802.11n: multiple antennae

- 2.4-5 GHz range
- up to 200 Mbps

802.11ac: multiple antennae

- 5 GHz range
- 500 Mbps – 1Gbps

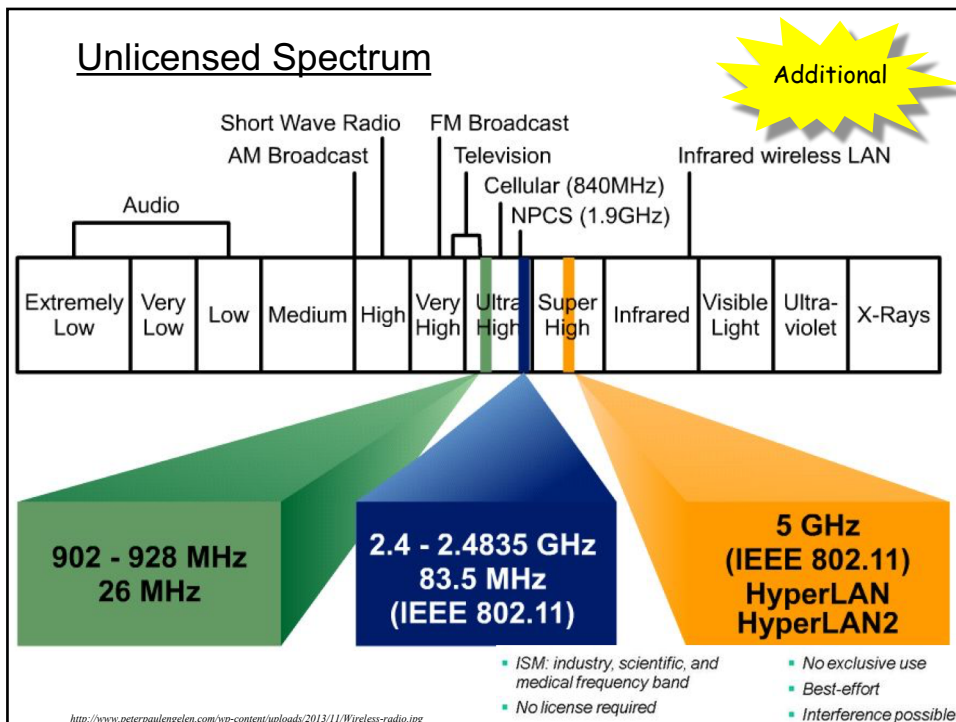
802.11ad: multiple antennae

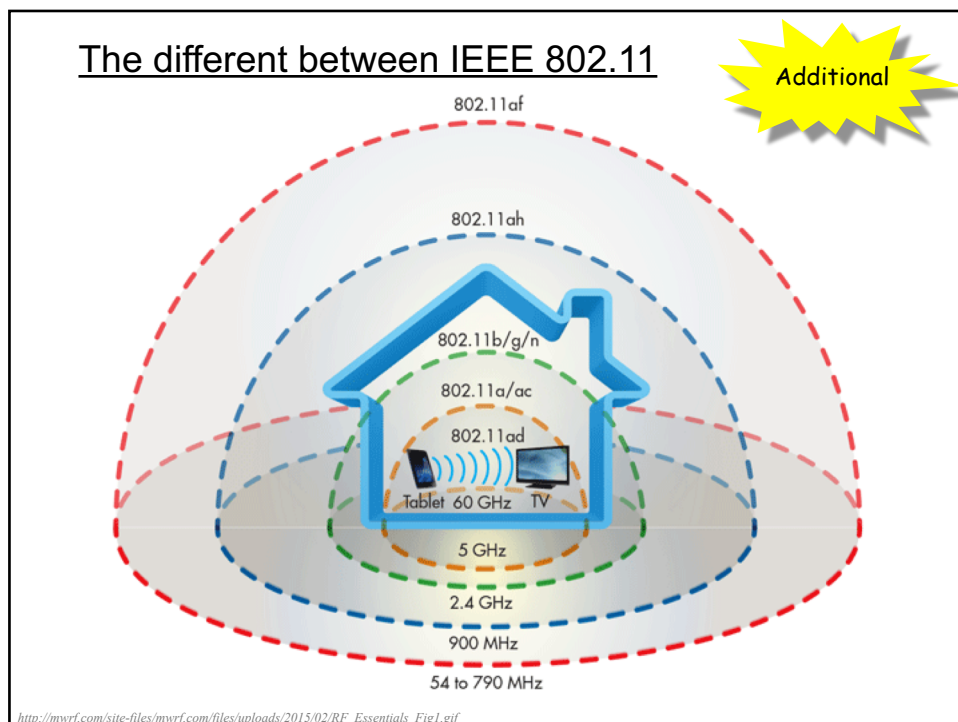
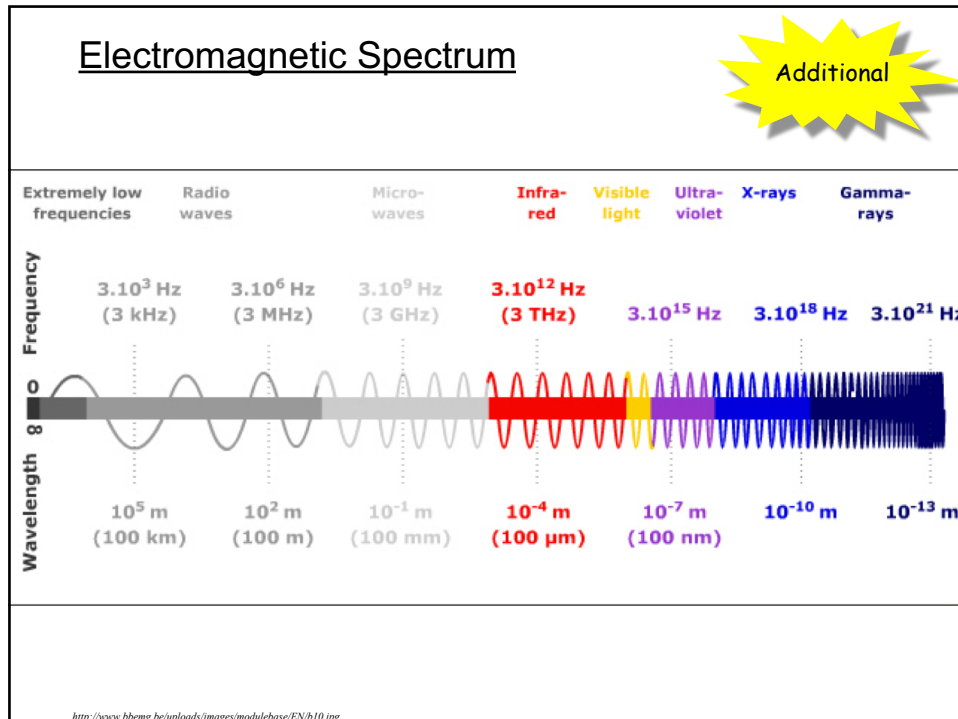
- 60 GHz range
- 4.6Gbps

❖ all use CSMA/CA for multiple access

❖ all have base-station and ad-hoc network versions

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CHAPTER 6 802.11 LAN Architecture

- ❖ wireless host communicates with base station
 - base station =

- ❖ *Basic Service Set (BSS)* (aka “cell”) in infrastructure mode contains:
 - wireless hosts
 - AP: base station
 - ad hoc mode: hosts only

CHAPTER 6 802.11 LAN Architecture

Channels, association (Host-AP)

- ❖ **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!

Additional

Channels	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13
Frequency (GHz)	2.412	2.417	2.422	2.427	2.432	2.437	2.442	2.447	2.452	2.457	2.462	2.467	2.472

<https://www.researchgate.net/profile/Hanan-Abdullah/publication/237877785/figure/fig?AS=2678565080924626&I440873376957/figure-3-Three-non-overlapping-channels-in-IEEE-80211b-standard.png>

6
802.11 LAN Architecture

Channels, association (Host-AP)

- ❖ **Host:** must *associate* with an **AP**
 - scans channels, listening for _____ containing AP's name 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.

Perimeter of building floor that requires wireless coverage
 Channel A - Operating on 802.11 Channel 1 (2.412 GHz)
 Channel B - Operating on 802.11 Channel 6 (2.437 GHz)
 Channel C - Operating on 802.11 Channel 11 (2.462 GHz)

<https://i-rechnet.sec.s-msft.com/dynimg/IC197487.gif>

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802.11 LAN Architecture

Channels, association (Host-AP)

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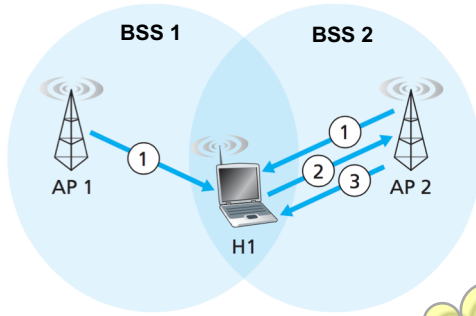
graph TD
    A[Channel Scanning] --> B[ ]
    A --> C[ ]
        
```

Figure: The process of scanning channels and listening for access points.

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802.11 LAN Architecture

Channels, association (Host-AP)



Beacon frame:

- contains all information about the network
- transmitted periodically to announce the presence of a wireless LAN
- transmitted by APs in an infrastructure *Basic Service Set* (BSS)

(A) Passive scanning:

- Beacon frames** sent from APs
- Association Request frame sent: H1 to selected AP2
- Association Response frame sent from selected AP2 to H1

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6
802.11 LAN Architecture

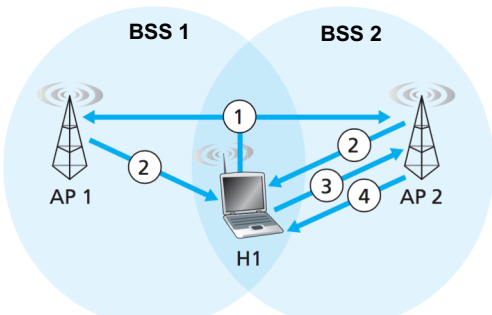
Channels, association (Host-AP)

Probe Request frame:

- sends to APs to obtain information about the network


Probe Response frame:

- Contains all information about the network from APs



(B) Active scanning:

- Probe Request frame** broadcast from H1
- Probe Response frames** sent from APs
- Association Request frame sent: H1 to selected AP2
- Association Response frame sent from selected AP2 to H1



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802.11 LAN Architecture

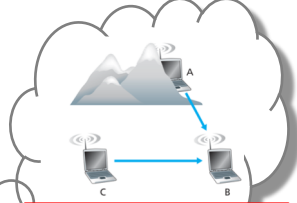
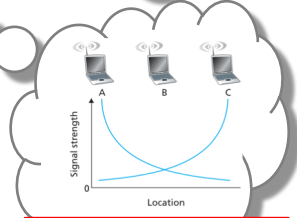
Multiple access protocol


Avoid collisions: 2+ nodes transmitting at same time

- ❖ 802.11: CSMA - sense before transmitting
 - don't collide with ongoing transmission by other node

- ❖ 802.11: *no* collision detection!
 - difficult to receive (sense collisions) when transmitting due to weak received signals (fading)
 - can't sense all collisions in any case: **hidden terminal, fading**

- goal: **avoid collisions**: CSMA/CA (Collision Avoidance)



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802.11 LAN Architecture

MAC protocol: CSMA/CA

802.11 sender


- 1 if sense channel idle for **DIFS** then
 - transmit entire frame (no CD)
- 2 if sense channel busy then
 - start random [] time
 - timer counts down while channel idle
 - transmit when timer expires
 - if no ACK, increase random [] interval, repeat 2

802.11 receiver


if frame received OK

- return ACK after **SIFS** (ACK needed due to **hidden terminal problem**)


Source




Destination




DIFS




data



SIFS



ack



DIFS (Distributed Inter-Frame Spacing)
 SIFS (Short Inter-Frame Spacing)
 CD (Collision Detection)

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[Optional]

802.11 LAN Architecture

Collision Avoidance: RTS-CTS exchange

Idea → The 802.11 MAC protocol also allow sender to “reserve” channel rather than random access of data frames to **avoid collisions / reduce frame collisions** of long data frames introduced by the **hidden terminal** problem.

Figure: Hidden terminal example: H1 is hidden from H2, and vice versa.

RTS (Request To Send)
CTS (Clear To Send)

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Collision Avoidance: RTS-CTS exchange

- ❖ sender first transmits *small Request-To-Send* (RTS) packets to AP using CSMA
 - RTSs may still collide with each other (but they're short)
- ❖ AP broadcasts **Clear-To-Send** (CTS) in response to RTS
- ❖ CTS heard by all nodes
 - sender transmits data frame
 - other stations defer transmissions

Avoid data frame collisions completely using small reservation packets!

CHAPTER 6 (6.4) Cellular Network Architecture Overview

- ❖ This section will adopt the terminology of the *Global System for Mobile* (GSM) standards.
- ❖ GSM describes the protocols for a *cellular* technology that often classify as belonging to one of several “generation”.
- ❖ The term cellular refers to the region covered by a cellular network → *cell*.

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CHAPTER 6 (6.4) Cellular Network Architecture Components

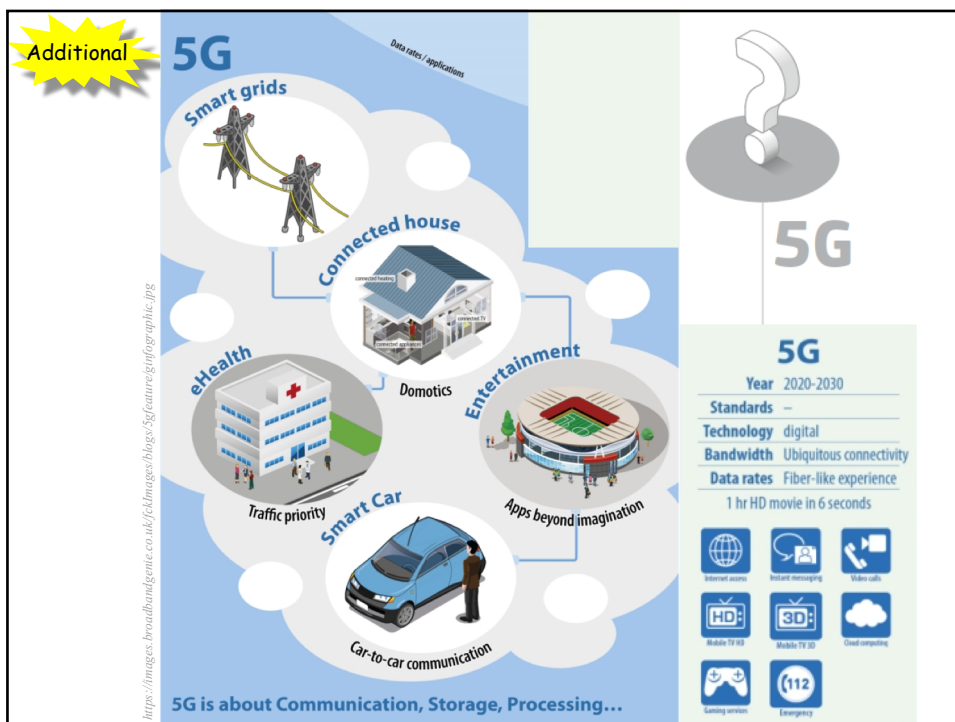
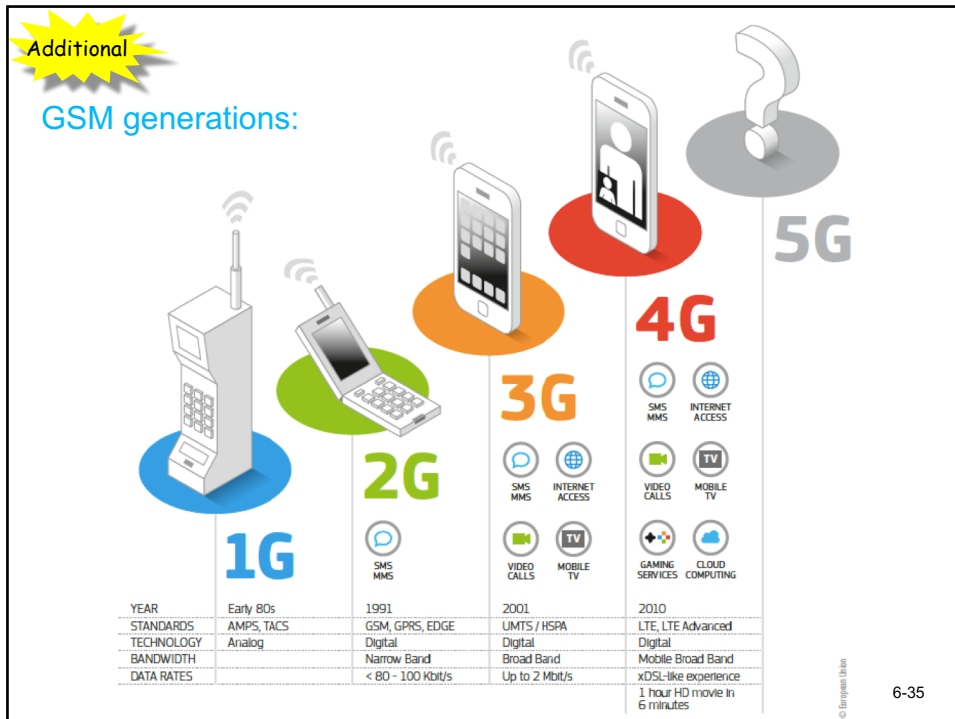
Cell

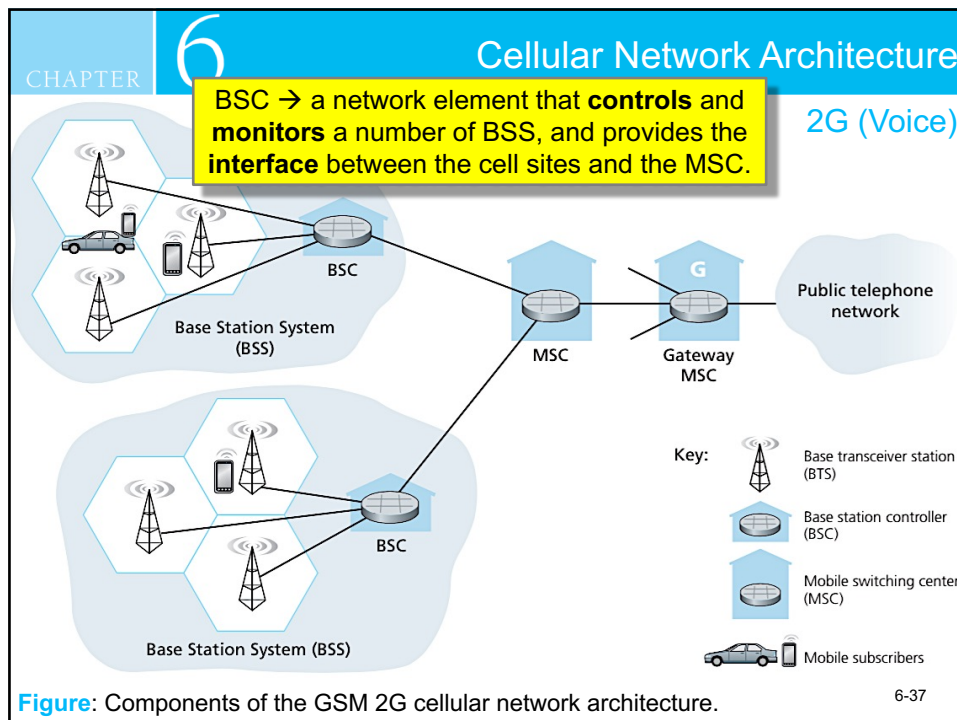
- ❖ covers geographical region
- ❖ *base station* (BS) analogous to 802.11 AP
- ❖ *mobile users* attach to network through BS
- ❖ *air-interface*: physical and link layer protocol between mobile and BS

MSC

- ❖ connects cells to wired telephone network
- ❖ manages call setup
- ❖ handles mobility

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CHAPTER 6 Cellular Network Architecture

3G (Voice + Data)

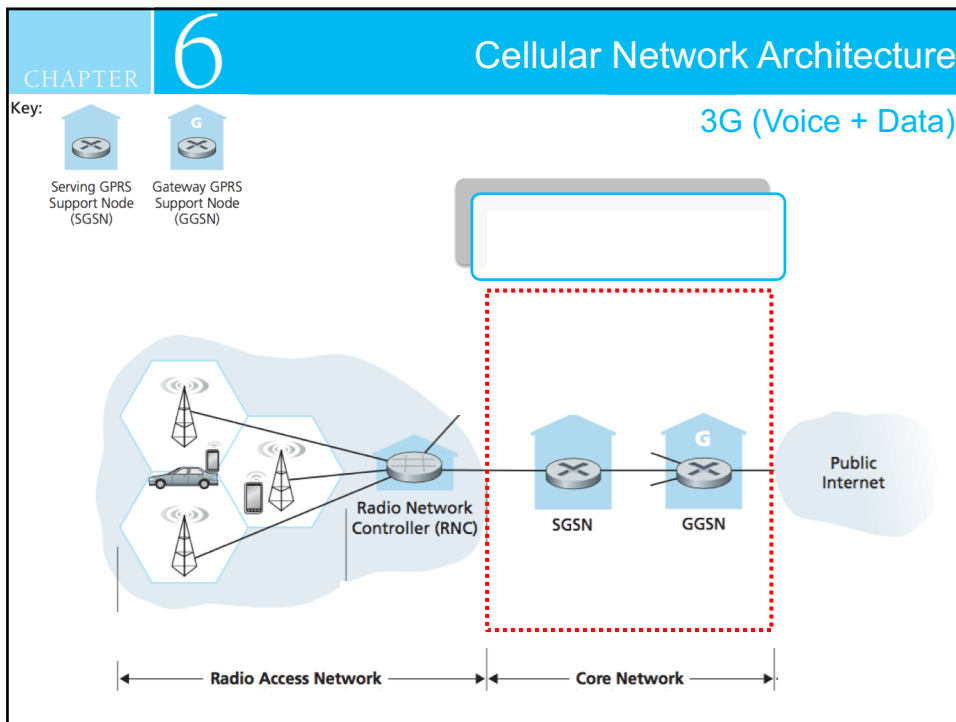
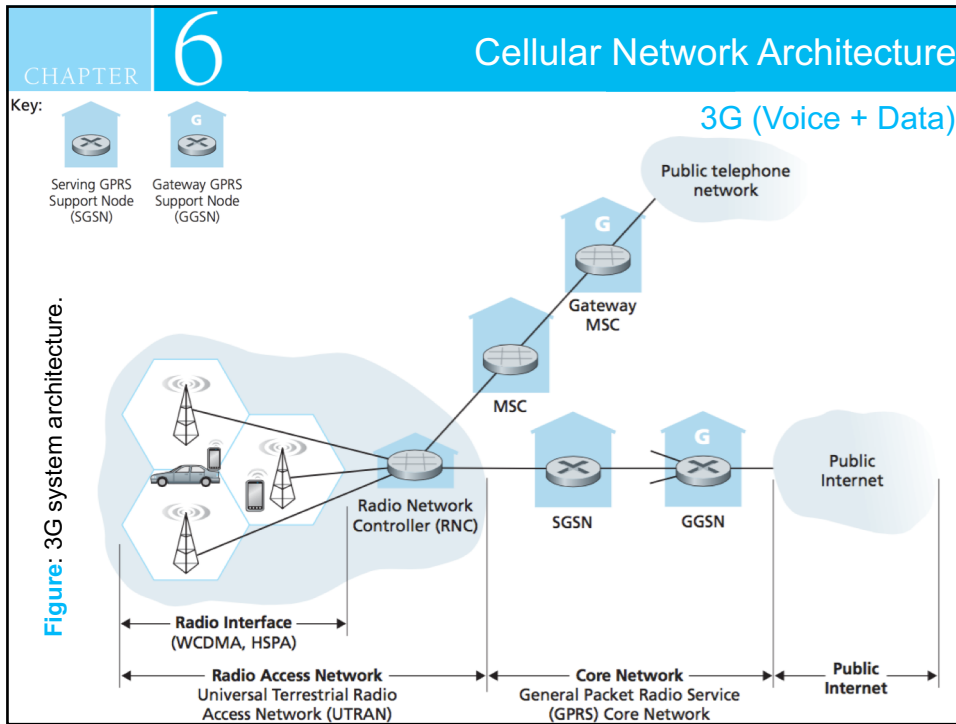
Overview

- ❖ To enable users access to the Internet requires technology beyond 2G.
 - read email, access the Web, and watch streaming video
 - required a full TCP/IP protocol stack and connect into the Internet via the cellular data network.
- ❖ focus on the UMTS (*Universal Mobile Telecommunications Service*) 3G standards

Key insight: new cellular data network operates *in parallel* (except at edge) with existing cellular voice network

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

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CHAPTER 6 Cellular Network Architecture

3G (Voice + Data)

Serving GPRS Support Nodes (SGSNs):

- responsible for delivering to/from the mobile nodes in the **Radio Access Network** to which the **SGSN** is attached.
- performing forwarding between mobile nodes in the **Radio Access Network** and a **GGSN**.

Radio Access Network | Core Network

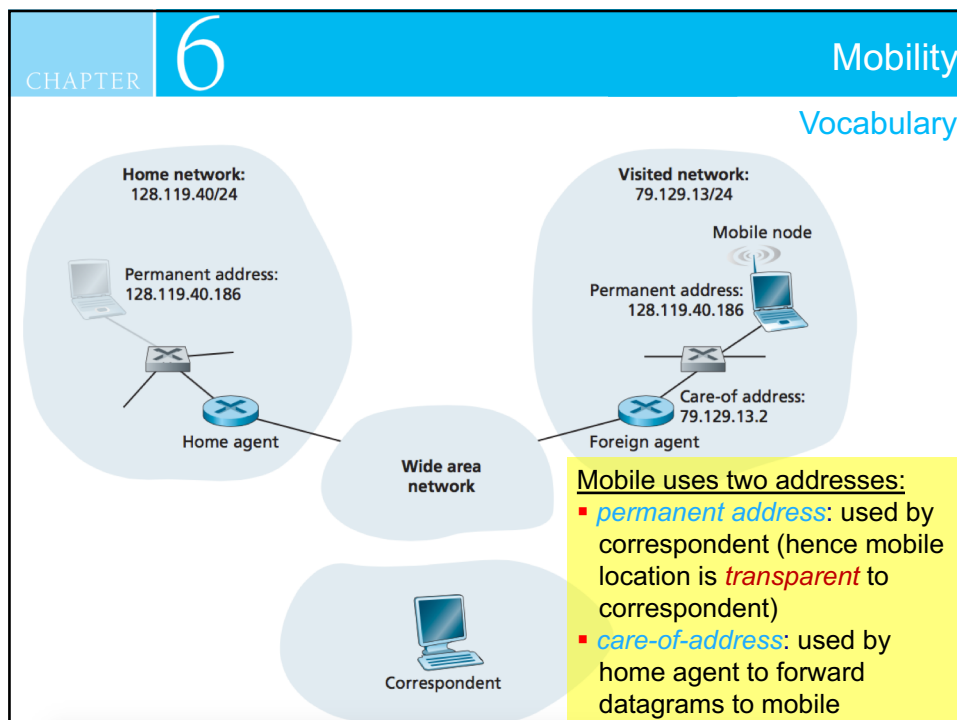
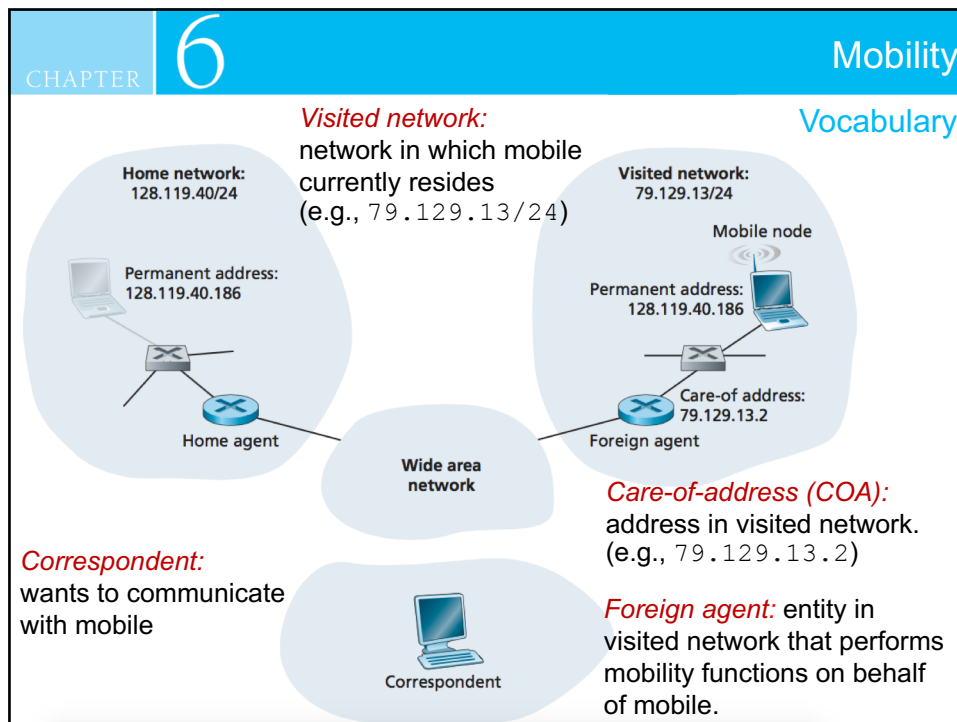
CHAPTER 6 Cellular Network Architecture

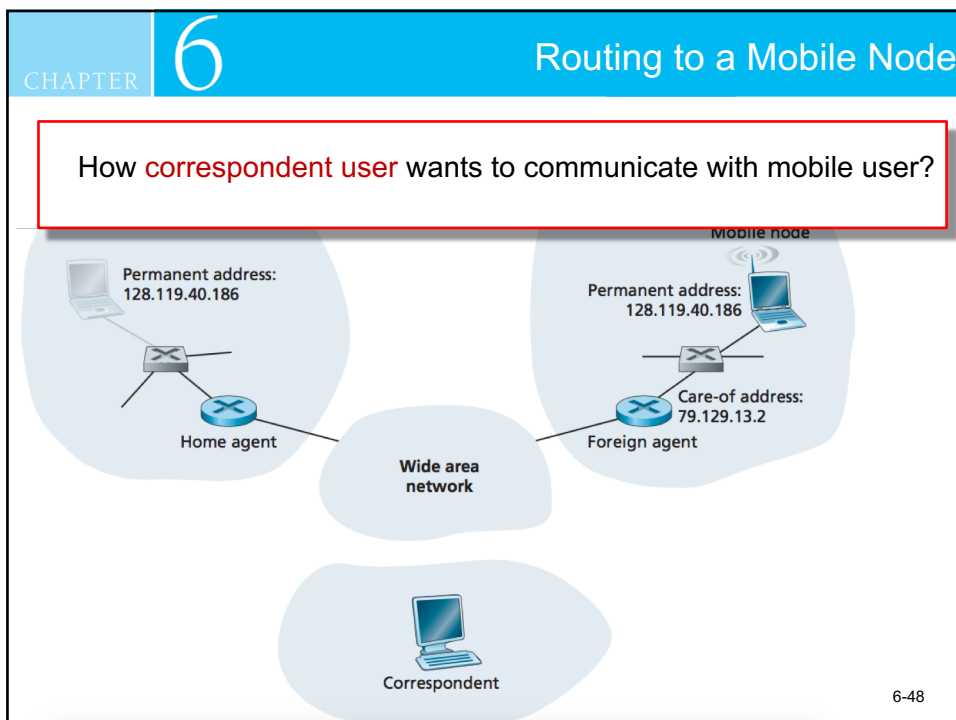
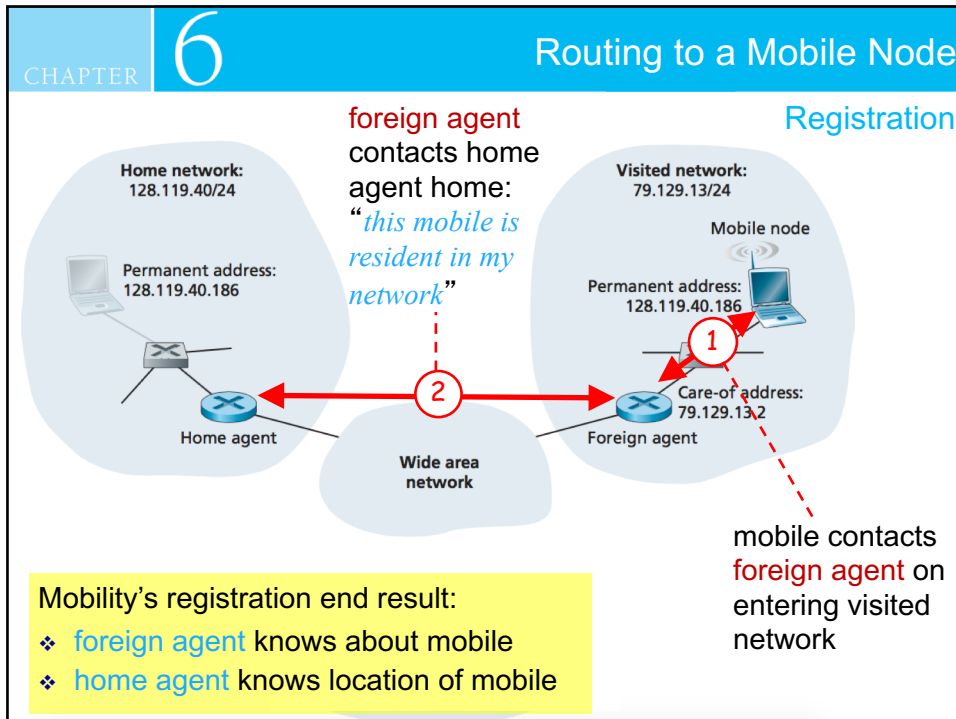
3G (Voice + Data)

Gateway GPRS Support Nodes (GGSNs):

- acts as a gateway, connecting multiple SGSNs into the larger Internet

Radio Access Network | Core Network





CHAPTER 6 Routing to a Mobile Node

How correspondent user wants to communicate with mobile user?

Figure: Two approaches of routing to a mobile node.

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CHAPTER 6 Routing to a Mobile Node

(a) Indirect routing

Home network: 128.119.40/24
Permanent address: 128.119.40.186
Home agent

Visited network: 79.129.13/24
Mobile node
Permanent address: 128.119.40.186
Care-of address: 79.129.13.2
Foreign agent

Wide area network

Correspondent

(1) correspondent addresses packets using home address of mobile

(2) home agent intercepts packets, forwards to foreign agent

(3) foreign agent receives packets, forwards to mobile

(4) mobile replies directly to correspondent

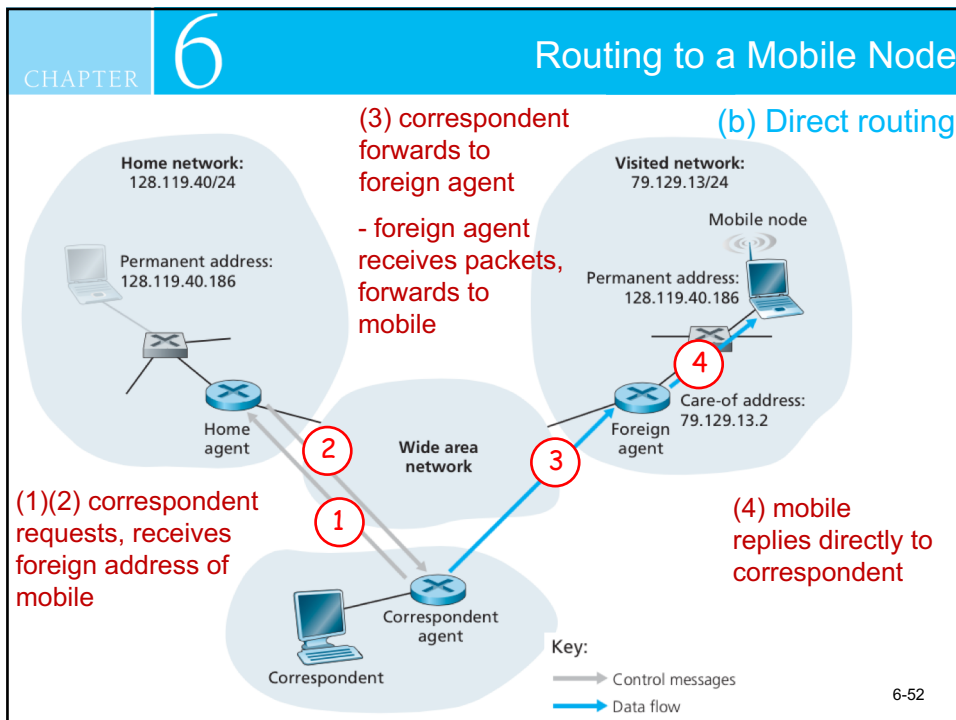
CHAPTER 6 Routing to a Mobile Node

(a) Indirect routing

- ❖ 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!*

Indirect routing introduce → problem

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CHAPTER 6 Routing to a Mobile Node

(b) Direct routing

Comments:

- ❖ overcome triangle routing problem !
- ❖ *non-transparent to correspondent*: correspondent must get *care-of-address* from *home agent*
- ❖ packets continue to be forwarded to mobile (with new *care-of-address*)

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CHAPTER 6 Summary

Wireless

- 6.1 Background & Introduction
- 6.2 Wireless links, characteristics
- 6.3 IEEE 802.11 wireless LANs (“Wi-Fi”)
- 6.4 Cellular Internet Access
 - Cellular Architecture

Mobility

- 6.5 Principles: addressing, routing to mobile users
 - Home, Visited networks
 - *Care-of-addresses*, foreign agent
 - Indirect & direct routing

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