Lecture 11
Wireless and Mobile Networks

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11.1 Wireless Basics

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Wireless and Mobile Networks

Background:

- # wireless (mobile) phone subscribers now vastly exceeds # wired phone subscribers
- # wireless Internet-connected devices exceeds # wireline Internet-connected devices

- Two important (but different) challenges
  - *wireless:* communication over wireless link
  - *mobility:* handling the mobile user who changes point of attachment to network

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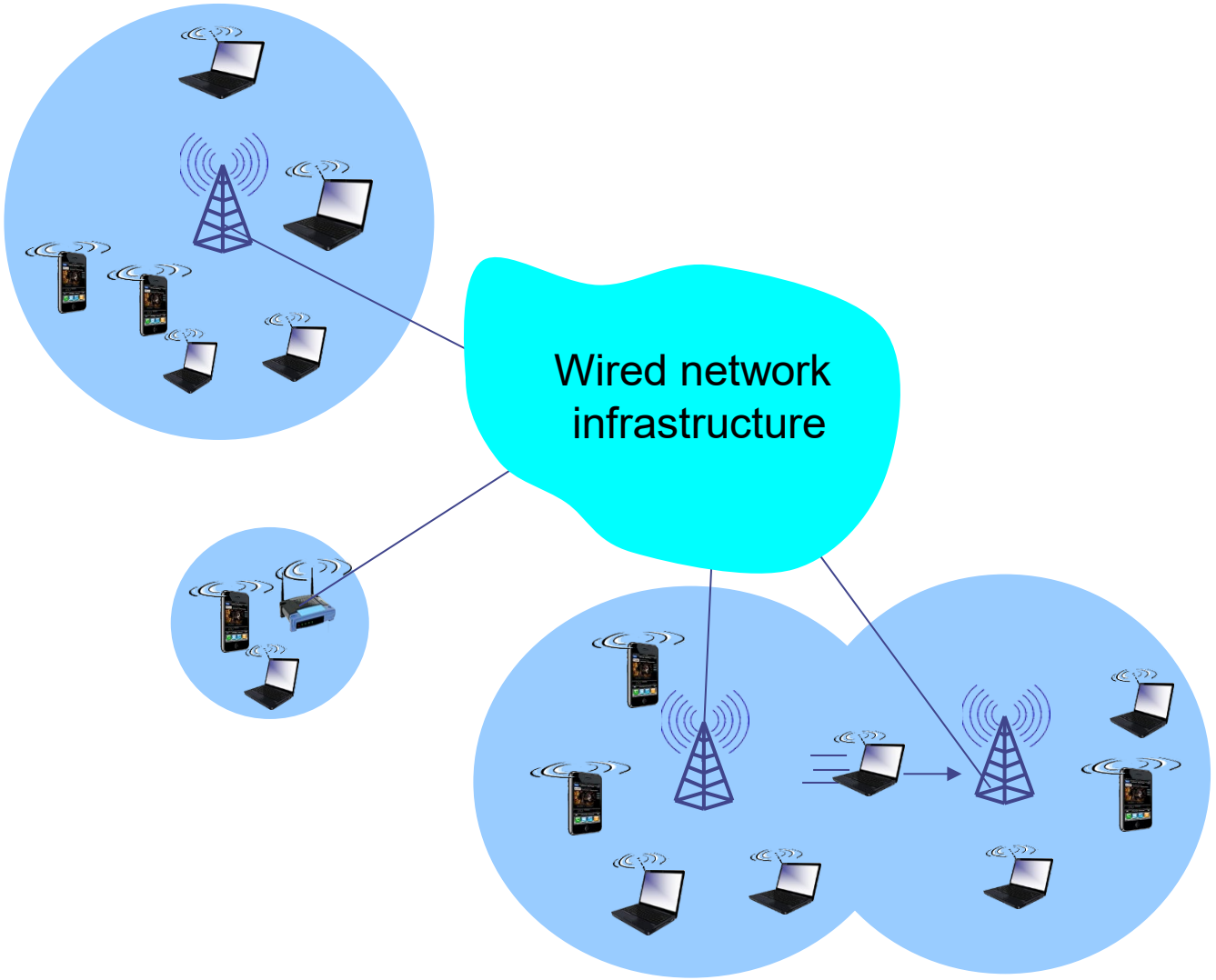
Elements of a wireless network



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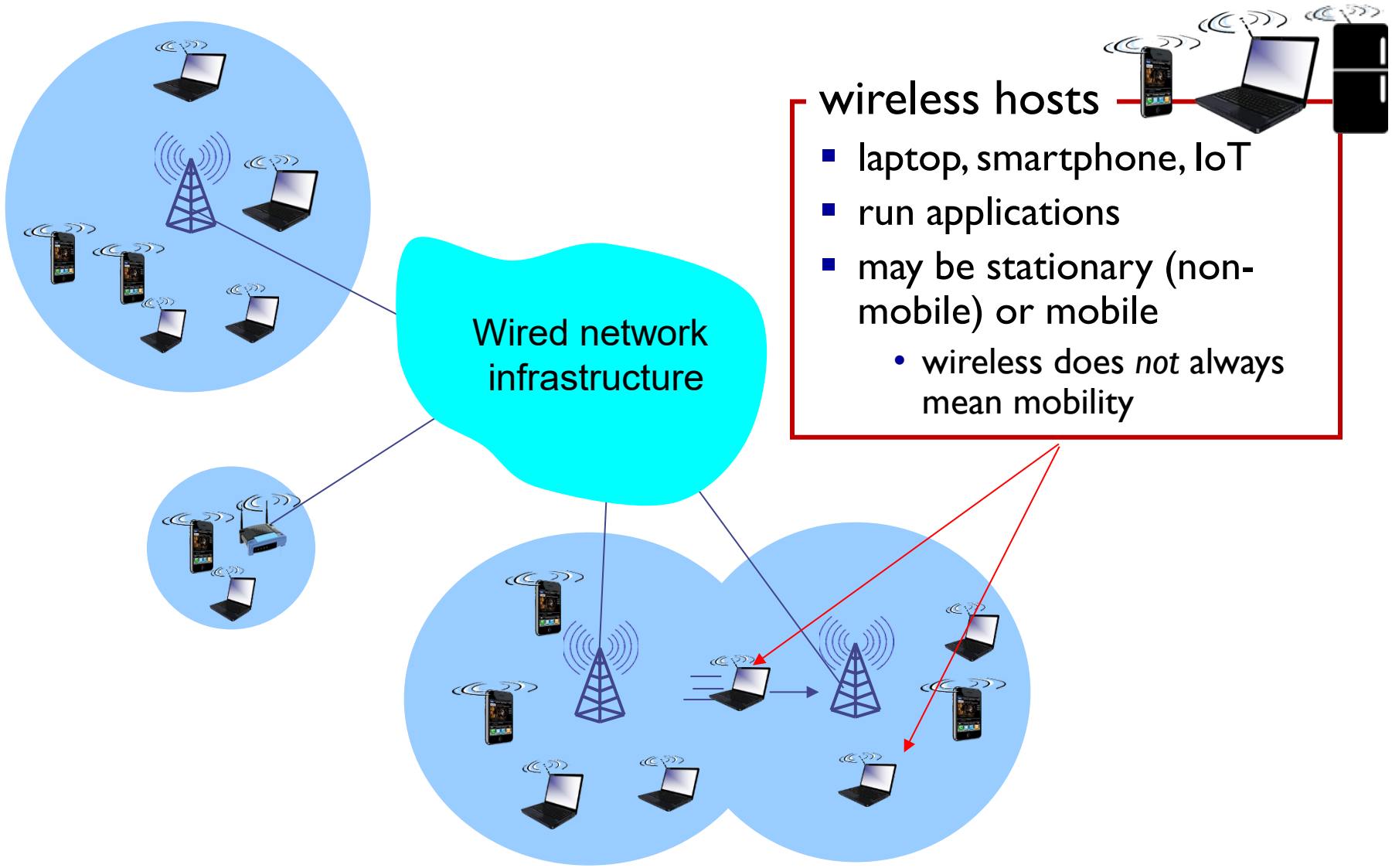
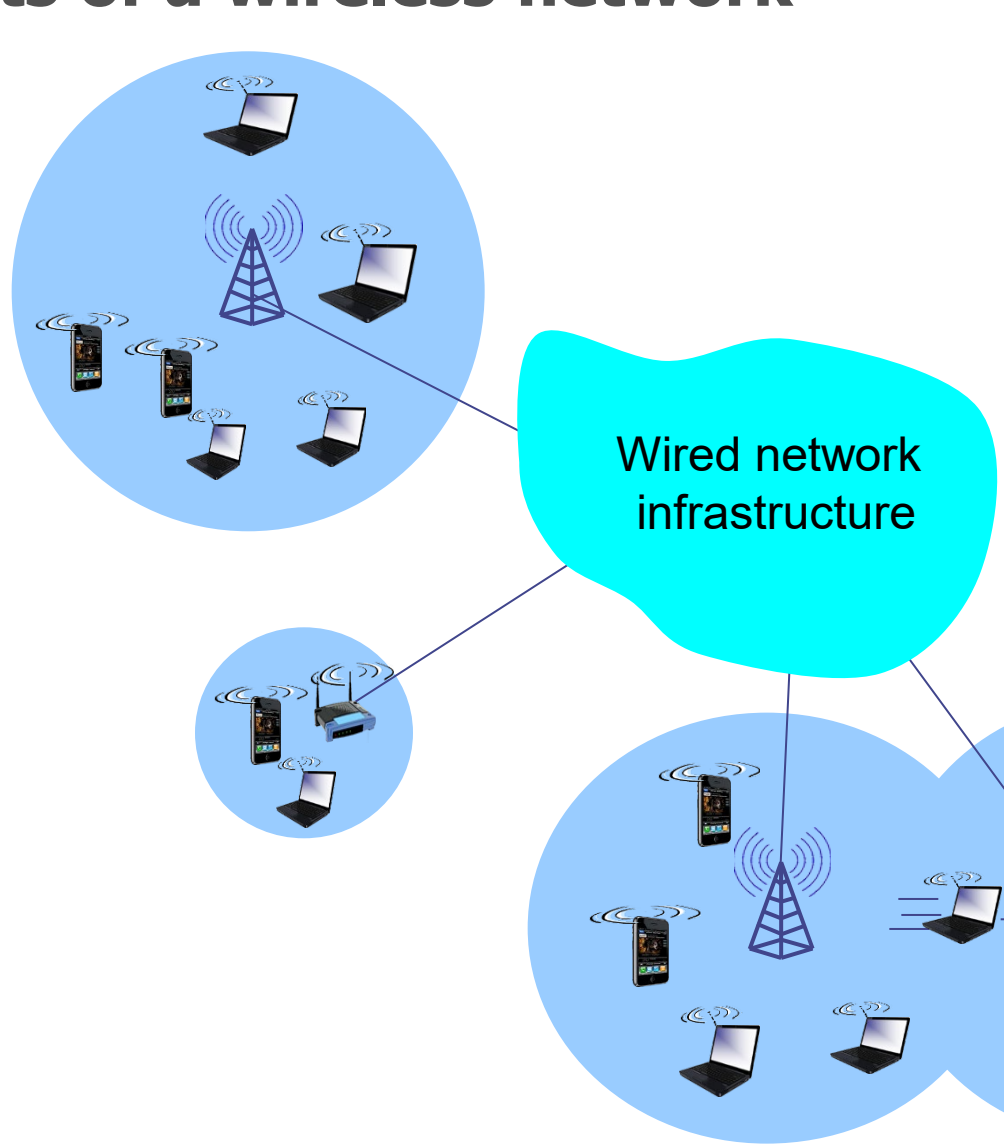
Elements of a wireless network



Elements of a wireless network



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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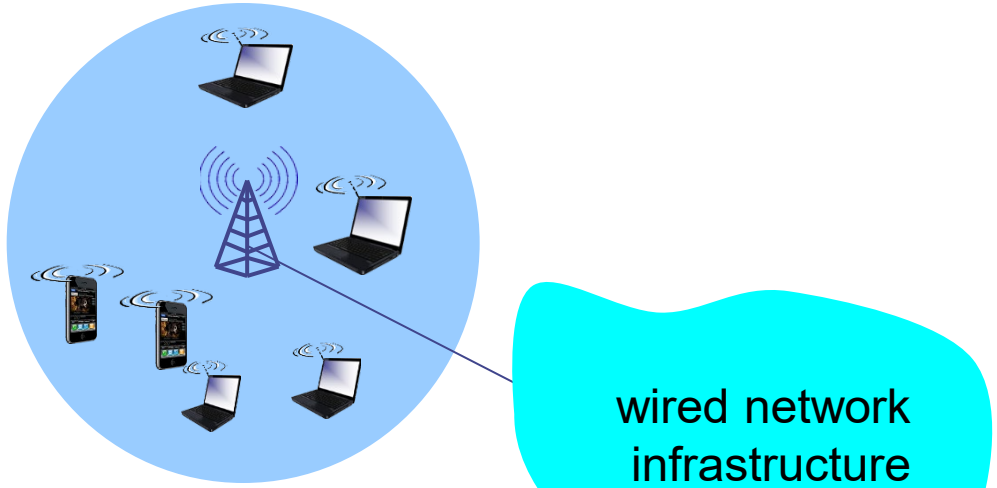
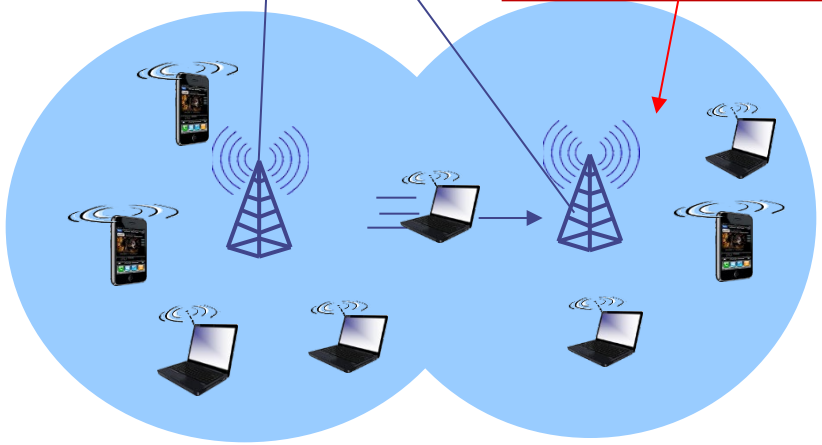
Elements of a wireless network





wired network infrastructure

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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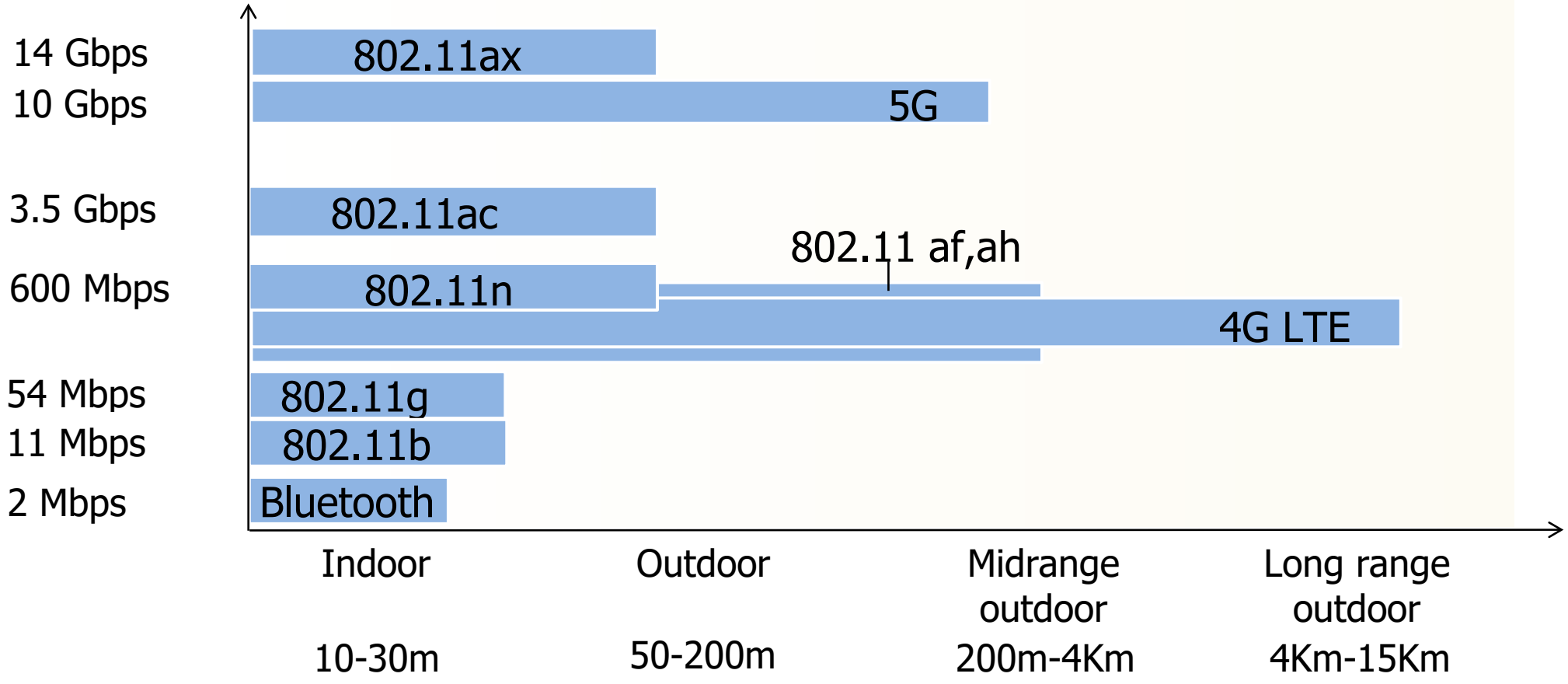
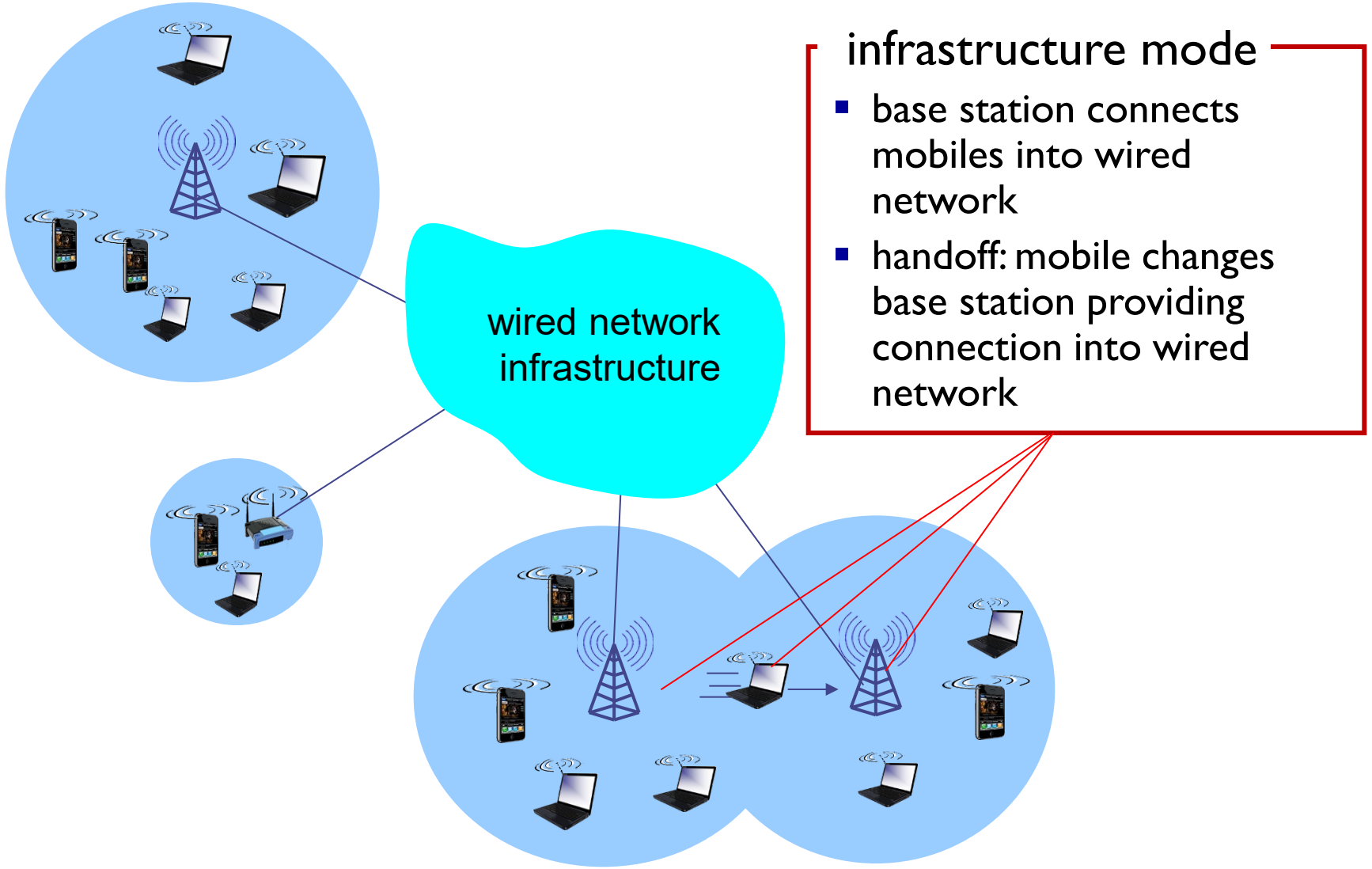
Characteristics of selected wireless links



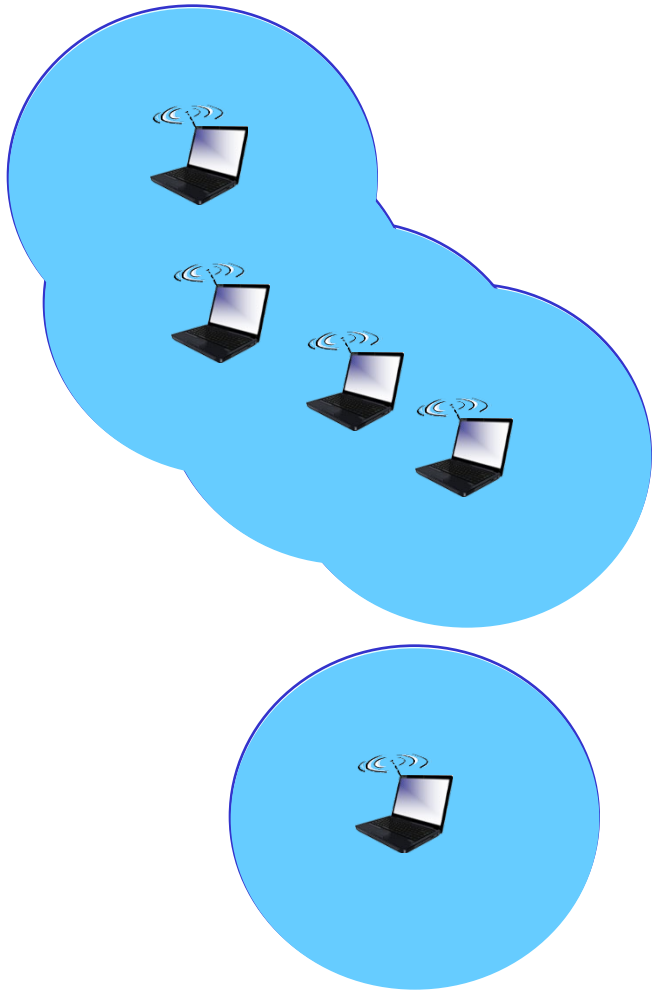
Elements of a wireless network



infrastructure mode

- base station connects mobiles into wired network
- handoff: mobile changes base station providing connection into wired 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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11.2 The 802.11 Wireless LAN

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802.11: Channels, Association

- Access Points use different frequencies depending on Wifi standard/technology, e.g.:
  - Wifi 3 at 2.4 GHz
  - Wifi 5 at 5 GHz
- Frequency bands are split in channels (commonly11)
  - 2.4 GHz supports 20MHz channels (3 non-overlapping)
    - Crowded frequency band (e.g. bluetooth)
  - 5 GHz supports 20, 40, 80, and even 160 MHz channels (no overlap)
    - Worse attenuation and medium penetration

- 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

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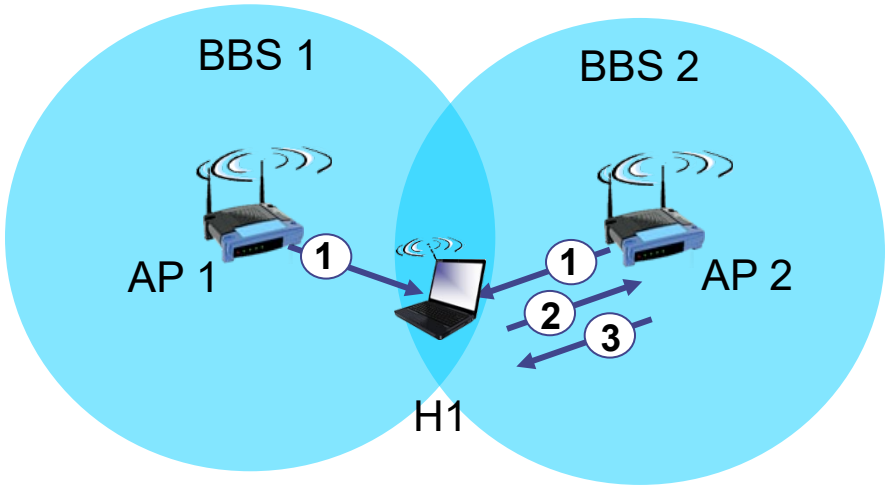
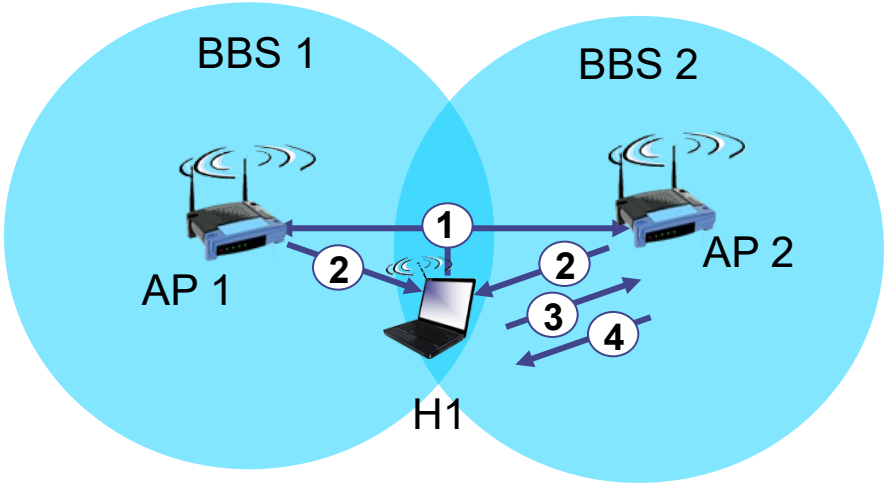
802.11: Passive/Active Scanning





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

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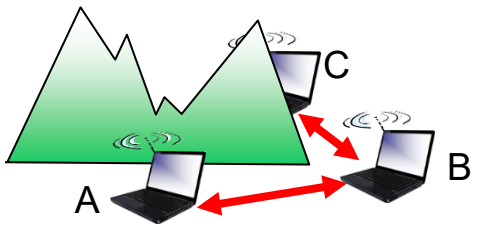
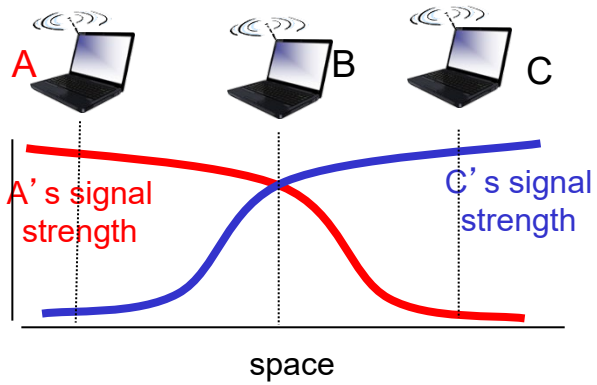
802.11: MAC Protocol

- Uses CSMA/CA - collision avoidance, instead of collision detection
  - Collisions are hard to detect

- Collision avoidance
  1. A device listens to the channel.
  2. If idle, it waits a random backoff time before transmitting (to reduce collision chance).
  3. Optionally uses RTS/CTS (Request to Send / Clear to Send) handshake to reserve the channel

- Uses CRC error detection and forward error correction methods
- Uses ARQ (Automatic Repeat reQuest) - link layer acknowledgement/retransmission scheme





11.3 CDMA and Cellular

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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 orthonogal)
- **Encoding**: inner product: (original data) X (chipping sequence)
- **Decoding:** summed inner-product: (encoded data) X (chipping sequence)

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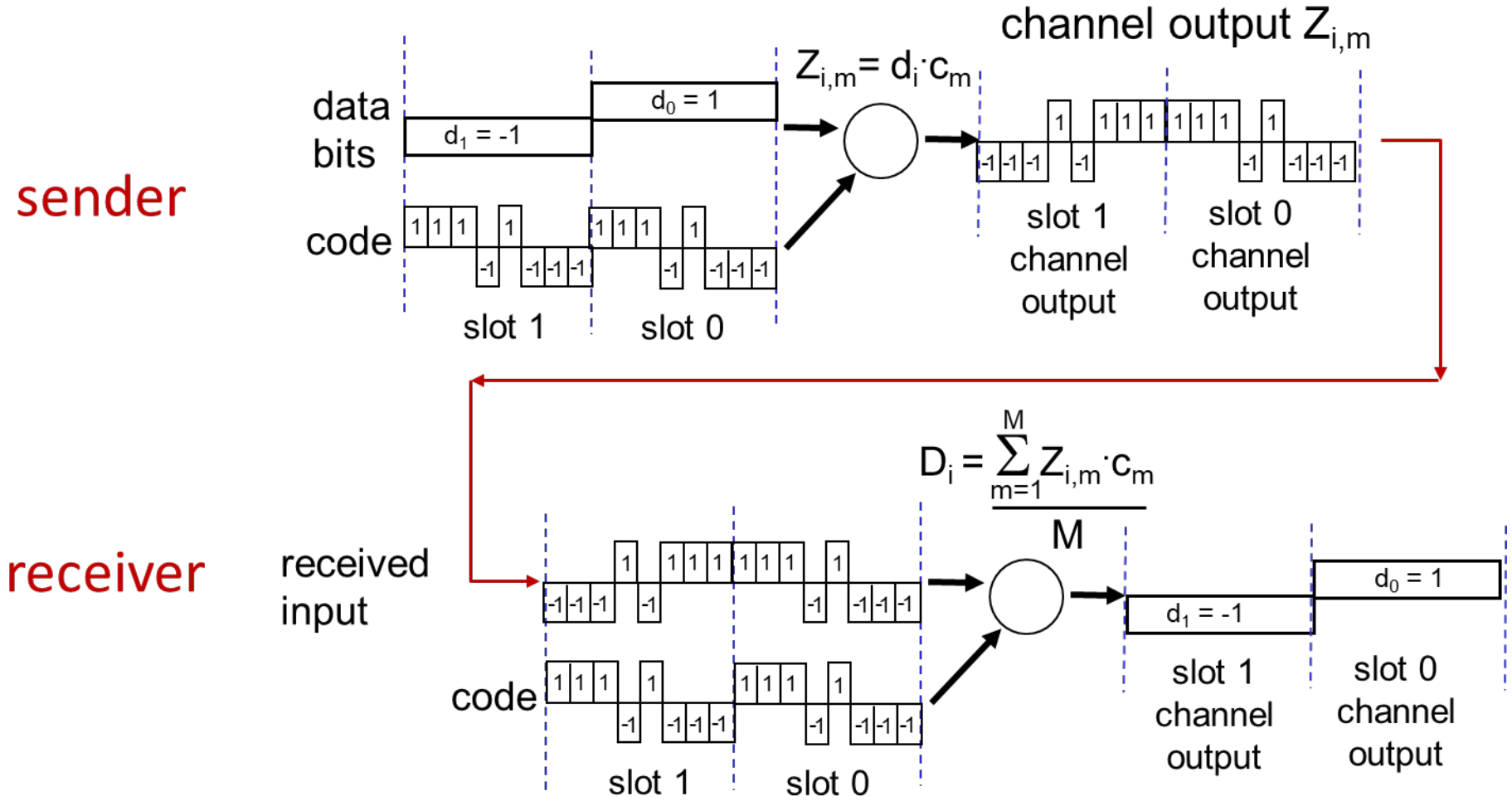
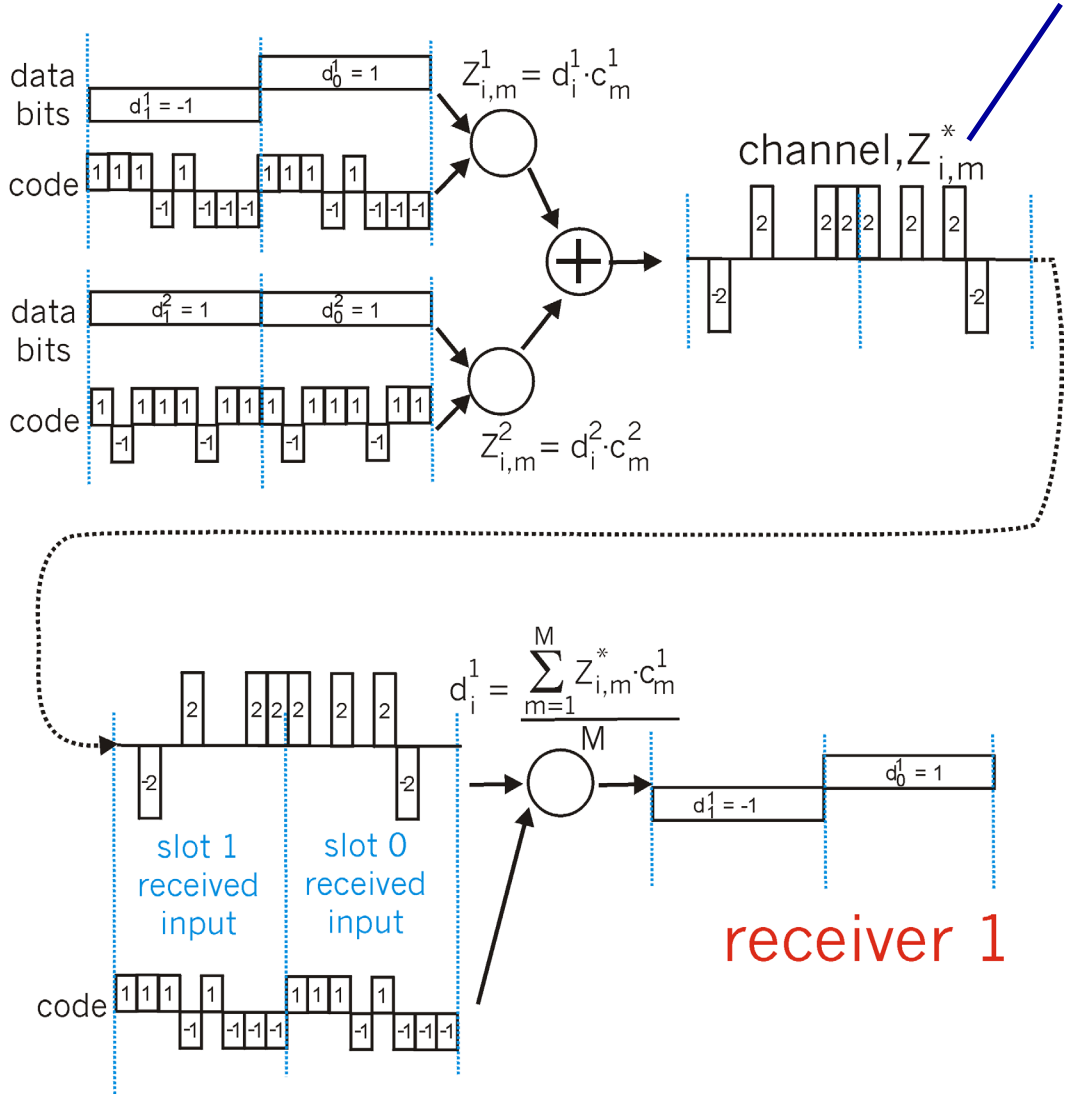
CDMA encode/decode



CDMA: Two-sender interference

Sender 1

Sender 2



channel sums together transmissions by sender 1 and 2

using same code as sender 1, receiver recovers sender 1's original data from summed channel data!

4G/5G Cellular Networks

Similarities to wired Internet

- Edge/core distinction, but both belong to same carrier
- Global cellular network: a network of networks
- Widespread use of protocols we've studied: HTTP, DNS, TCP, UDP, IP, NAT, separation of data/control planes, SDN, Ethernet, tunneling
- Interconnected to wired Internet

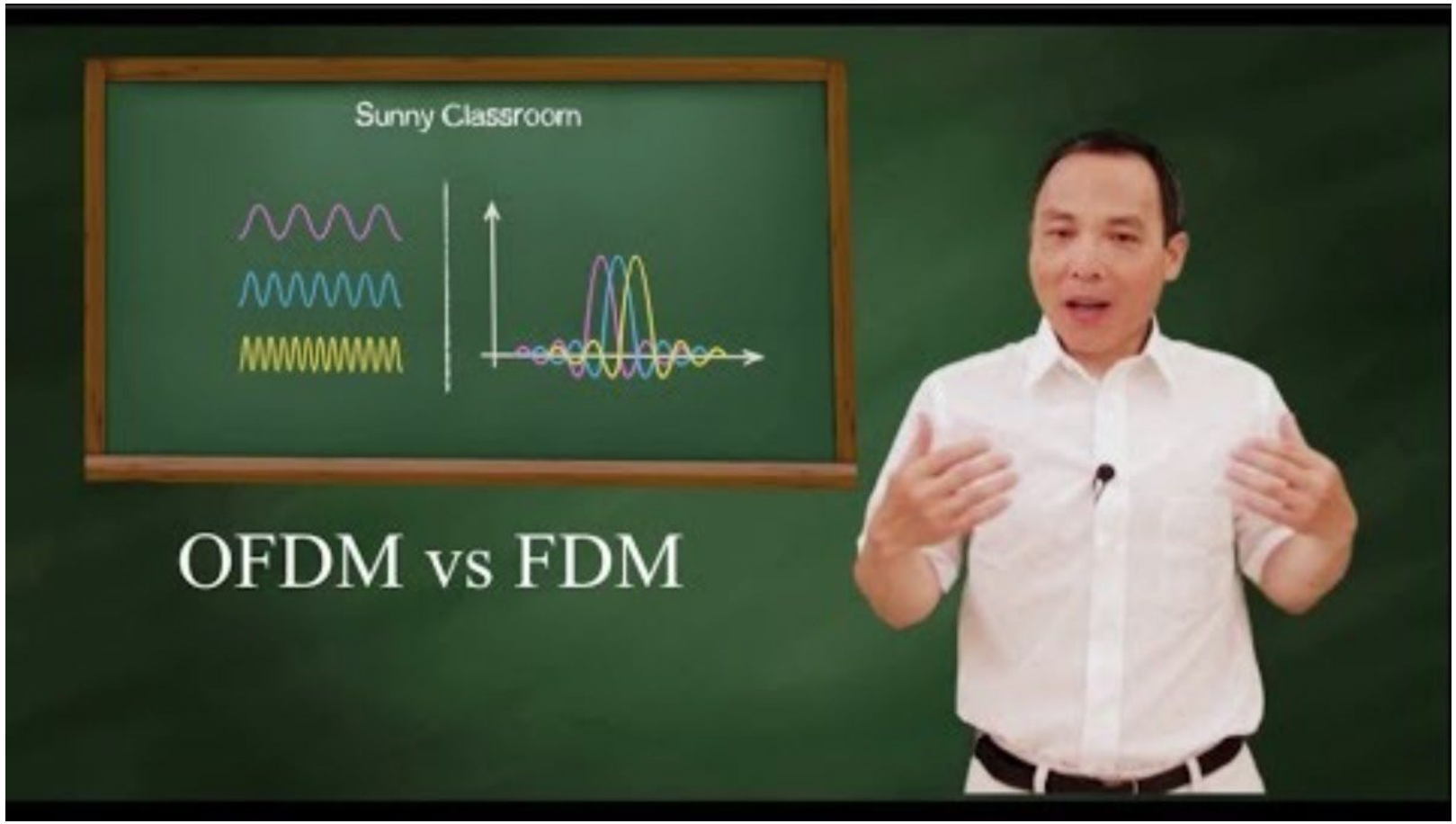
Differences from wired Internet

- Different wireless link layer
- **Mobility as a 1st class service**
- User "identity" (via SIM card)
- Business model: users subscribe to a cellular provider
  - strong notion of "home network" versus roaming
  - global access, with authentication infrastructure, and inter-carrier settlements

Check out:

- https://mobil-daekning.dk/mobilantenner/
- Table 7.2 at page 597

4G's Orthogonal Frequency Division Multiplexing



https://youtu.be/KCHO7zlU25Q?si=funmIqrjSZA2AzIC

11.4 Mobility

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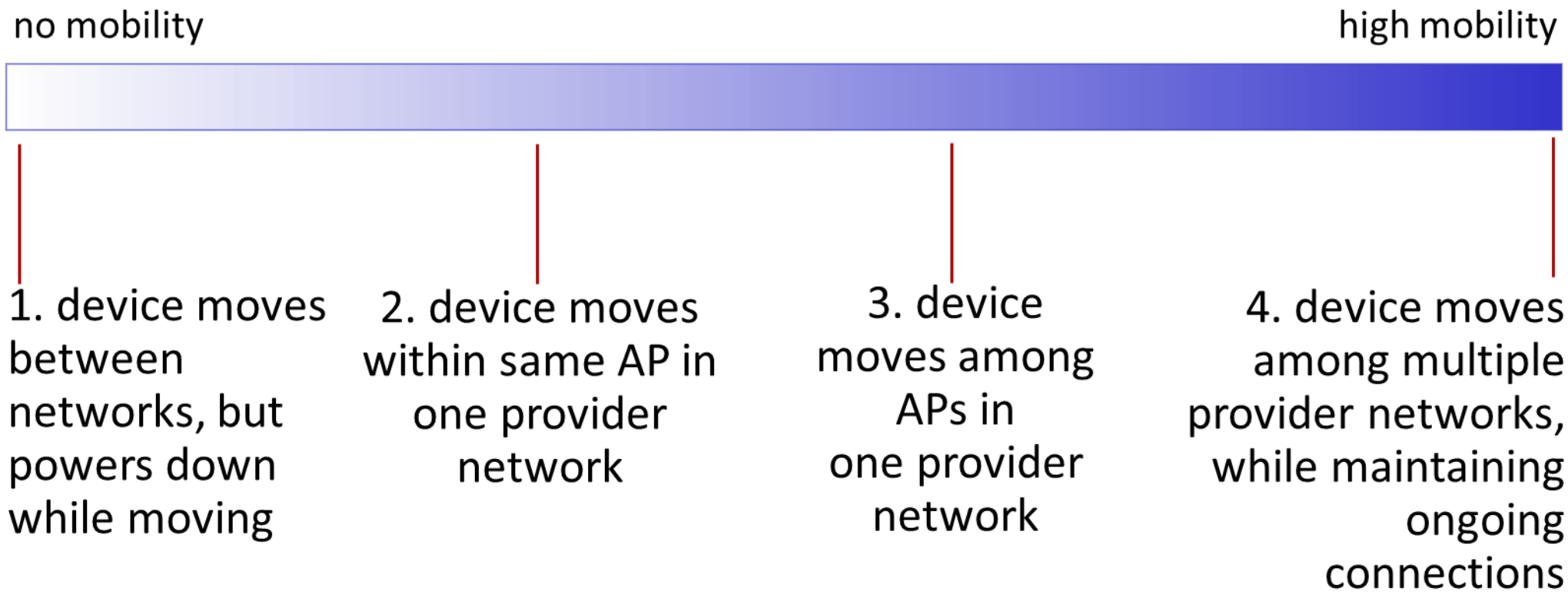
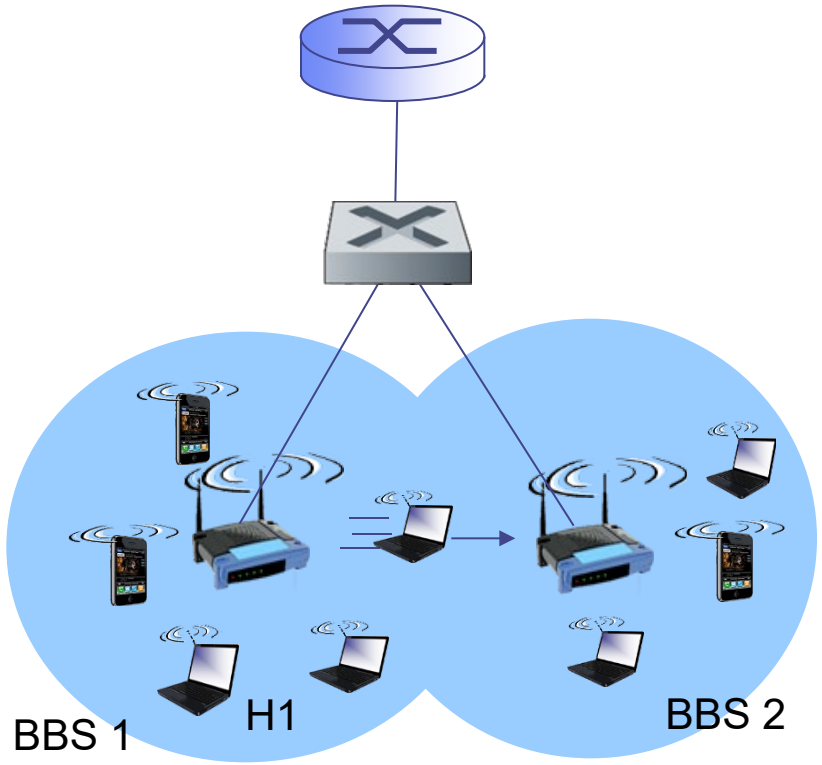
What is mobility?

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



802.11: Mobility Within Same Subnet

- BSS (Basic Service Set)
- H1 remains in same IP subnet: IP address can remain same
- Switch: Which AP is associated with H1?
  - Self-learning (Ch. 6): switch will see frame from H1 and "remember" which switch port can be used to reach H1
- Router: New IP and broken connection



Normally same SSID and password

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?

Mobility: approaches

- *Let routing handle it:* routers advertise address of mobile-nodes-in-residence via usual routing table exchange.
  - routing tables indicate where each mobile located
  - no changes to end-systems (IPv6)
- *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 a ent address of mobile-nodes-in-residence via usual routin
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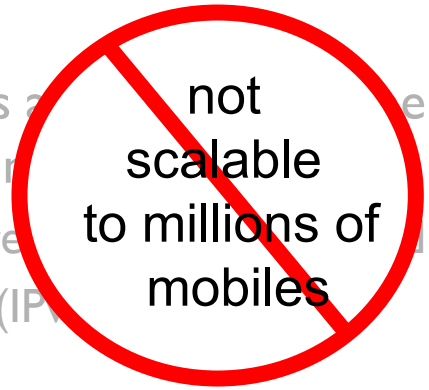

- *Let end-systems handle it:*
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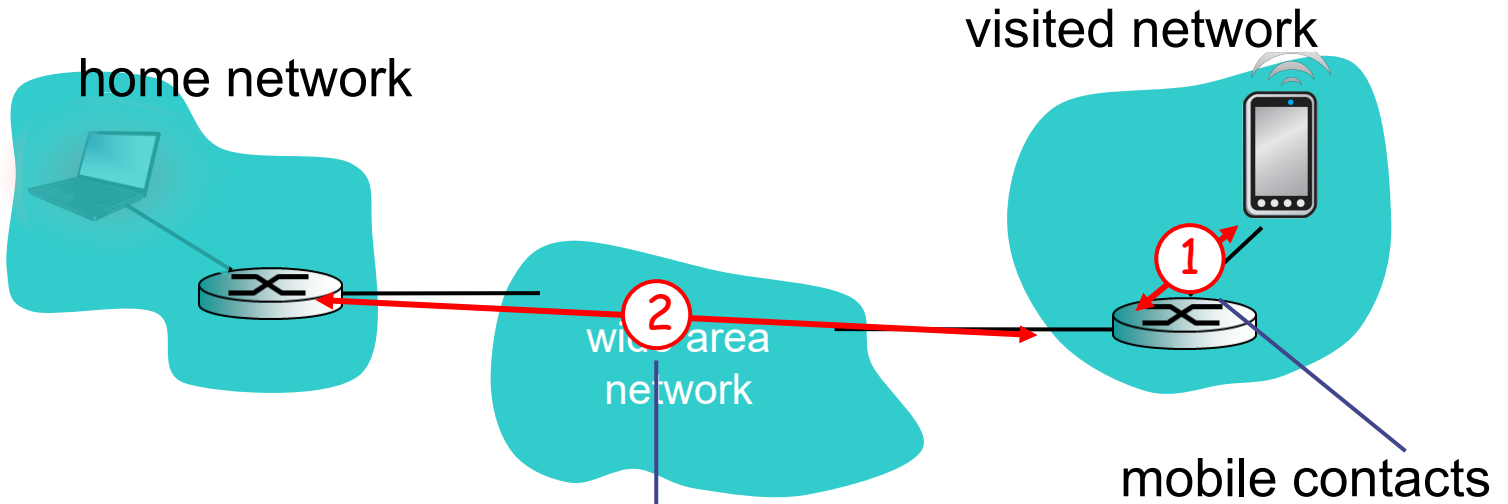
  - *direct routing:* correspondent gets foreign address of mobile, sends directly to mobile

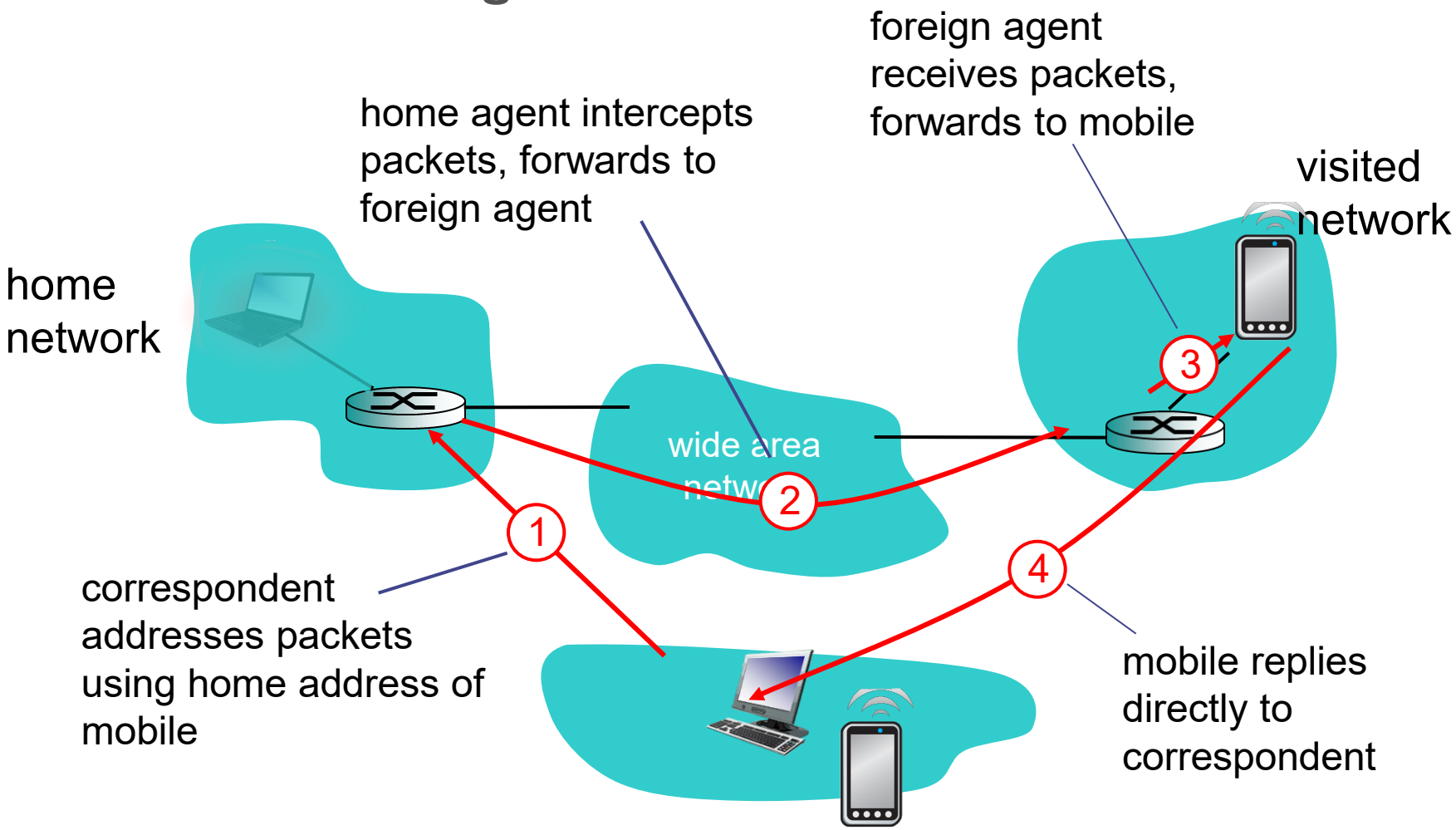
Mobility: Registration



End result:

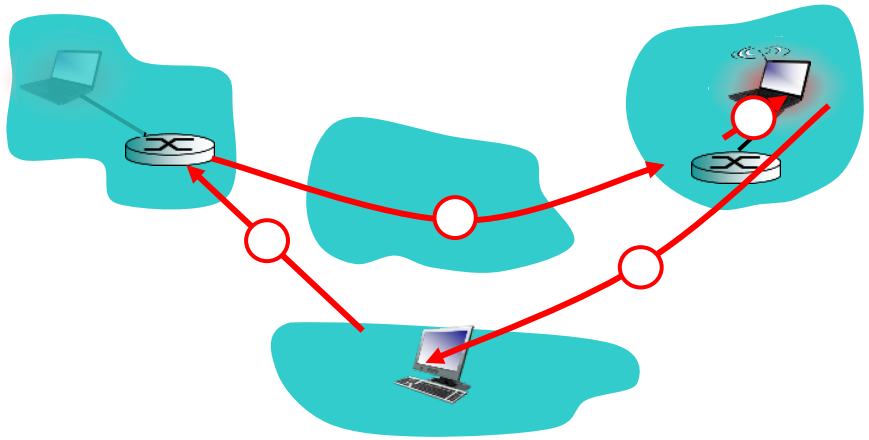
- Foreign agent knows about mobile
- Home agent knows location/address of mobile

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
- Triangle routing: correspondent-home-network-mobile
  - inefficient when correspondent, mobile are in same network



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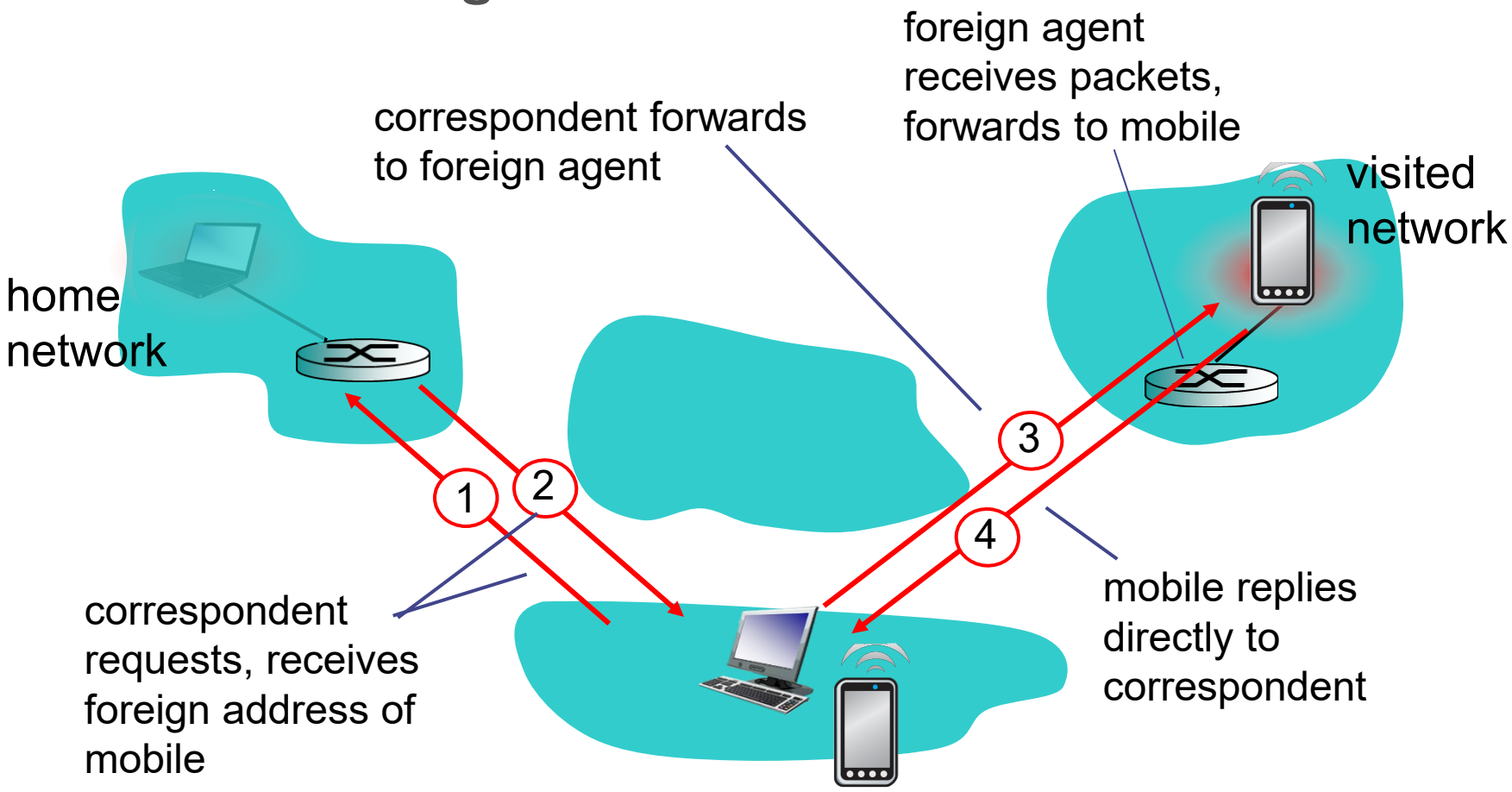
Indirect routing: moving between networks

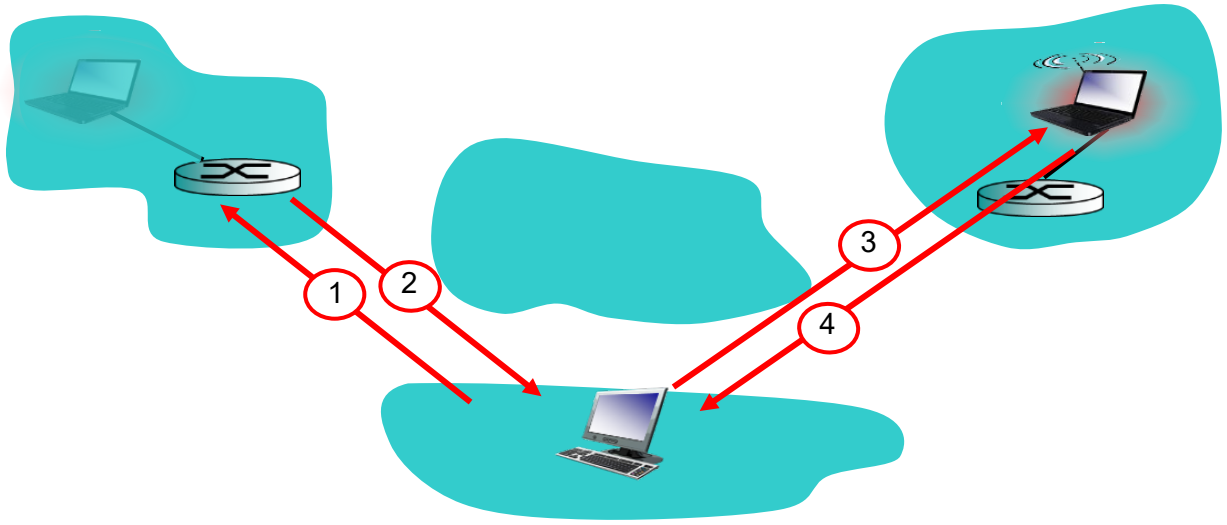
- Suppose mobile user moves to another network
  - Registers with new foreign agent
  - New foreign agent registers with home agent
  - Home agent update care-of-address for mobile
  - Packets continue to be forwarded to mobile (but with new care-of-address)
- Mobility, changing foreign networks transparent: *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?



Final Notes

Book covers many details we did not talk about here. These are not expected knowledge for the exam.

- The course will therefore only cover:
  - 7.1-7.2
  - 7.3
    - 7.3.1-2
    - 7.3.4
  - 7.4.1
  - 7.5

- I think Bluetooth is highly relevant 7.3.6, but not part of this course.

- Suggested Exercises:
  - CDMA - https://gaia.cs.umass.edu/kurose_ross/interactive/
  - Wireshark Lab on itsLearning

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