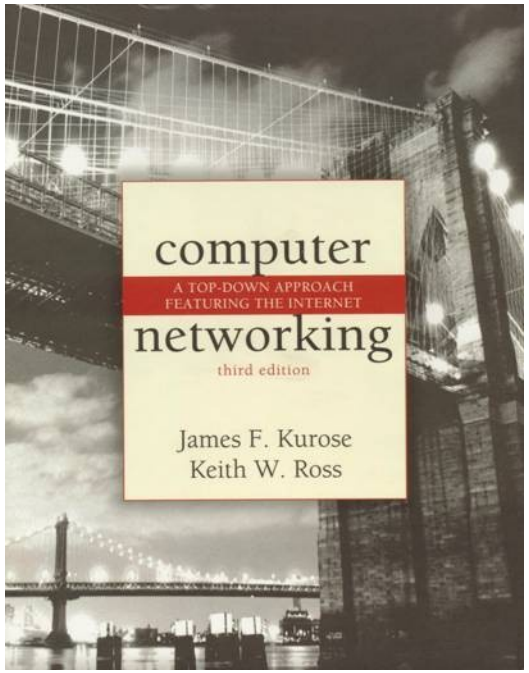
Wireless Networks



Computer Networking: A Top Down Approach Featuring the Internet,

3rd edition.
Jim Kurose, Keith Ross
Addison-Wesley, July 2004.

Wireless Networks

Background:

- # wireless (mobile) phone subscribers now exceeds # wired phone subscribers!
- computer nets: laptops, palmtops, PDAs, Internet-enabled phone promise anytime untethered Internet access
- two important (but different) challenges
  - communication over wireless link
  - handling mobile user who changes point of attachment to network

Outline

Introduction

Wireless

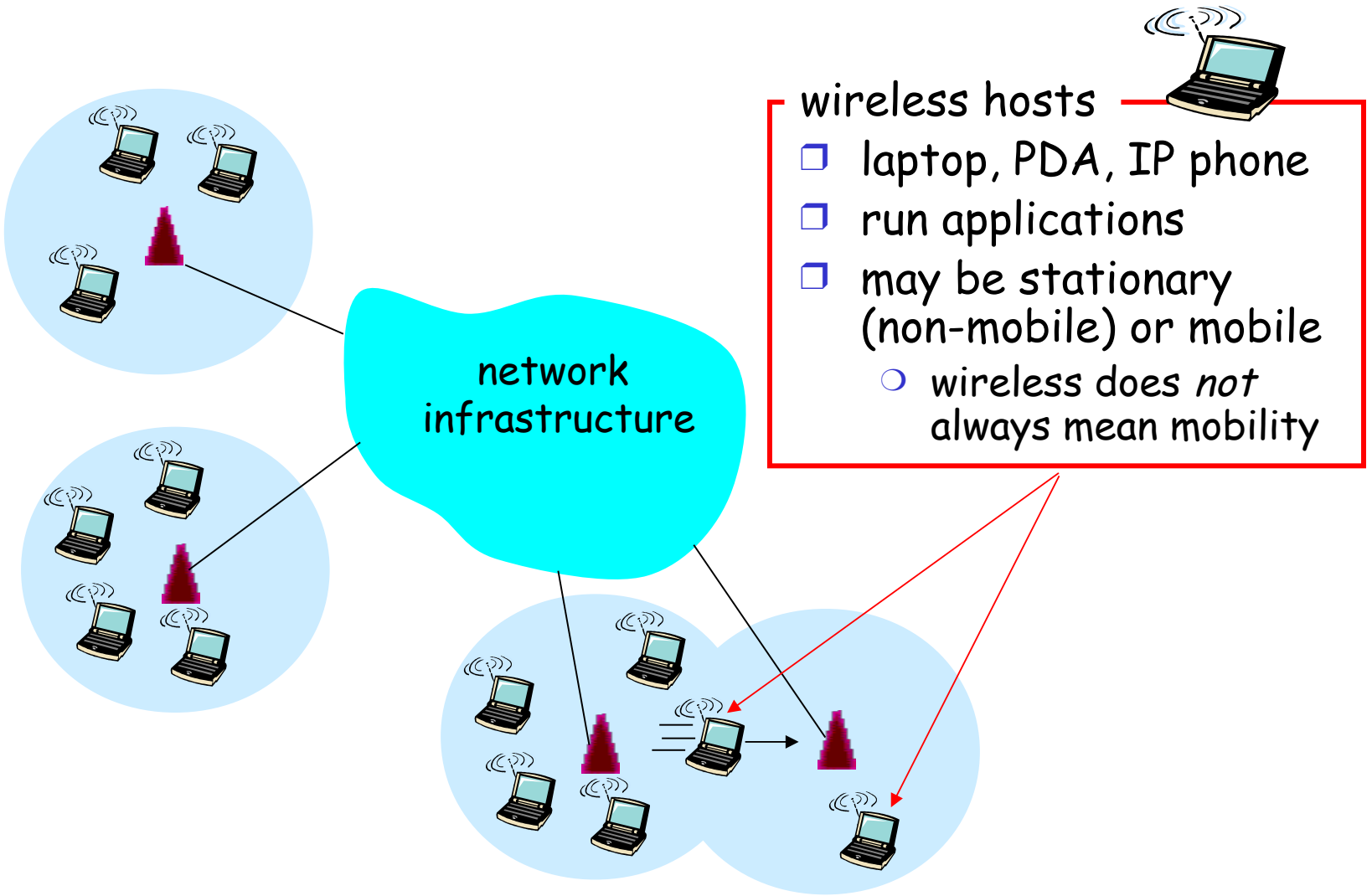
- Wireless links, characteristics
- IEEE 802.11 wireless LANs ("wi-fi")

Mobility

- Principles: addressing and routing to mobile users
- Mobile IP
- Mobility and higher-layer protocols

Summary

Elements of a wireless network



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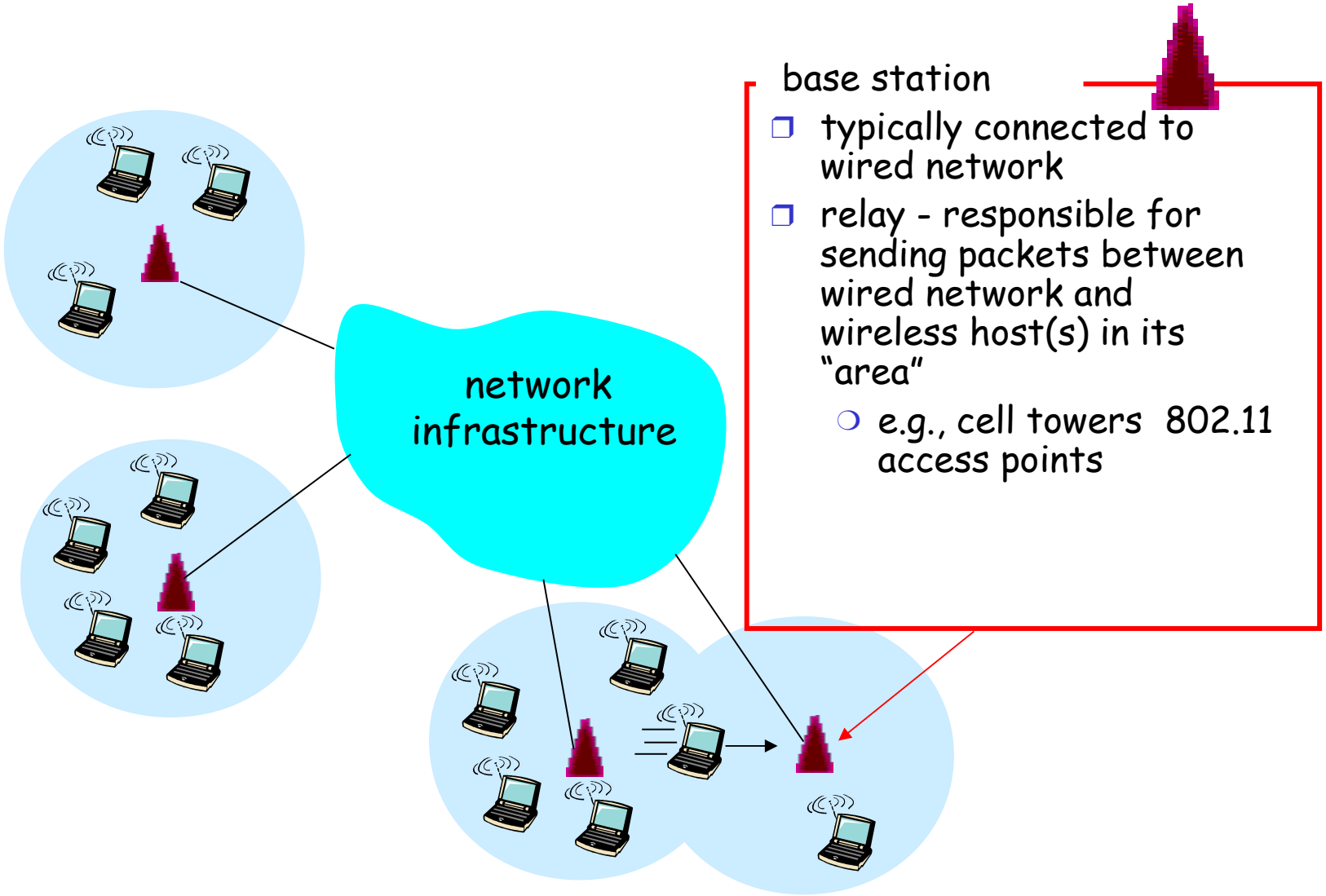

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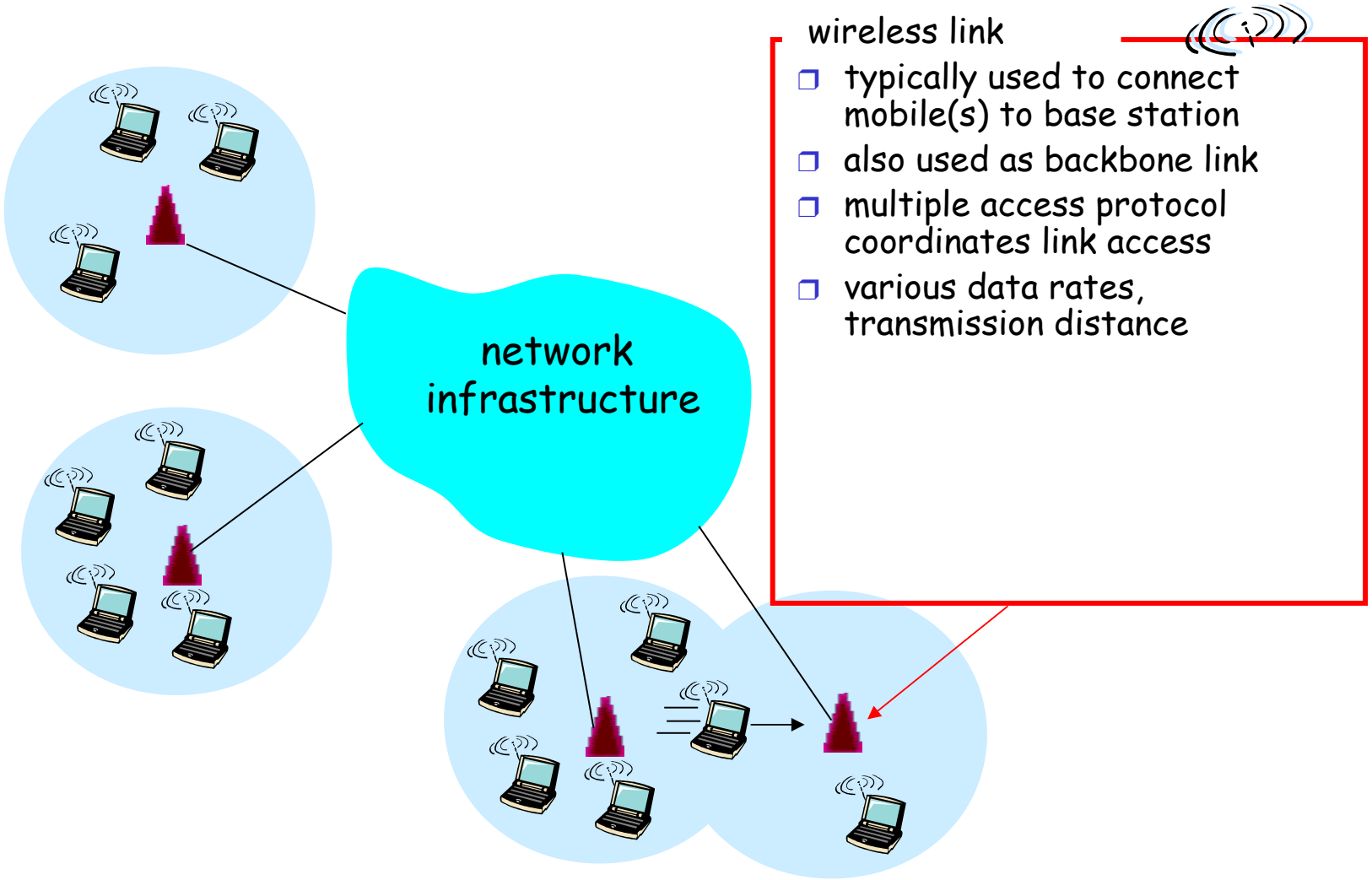
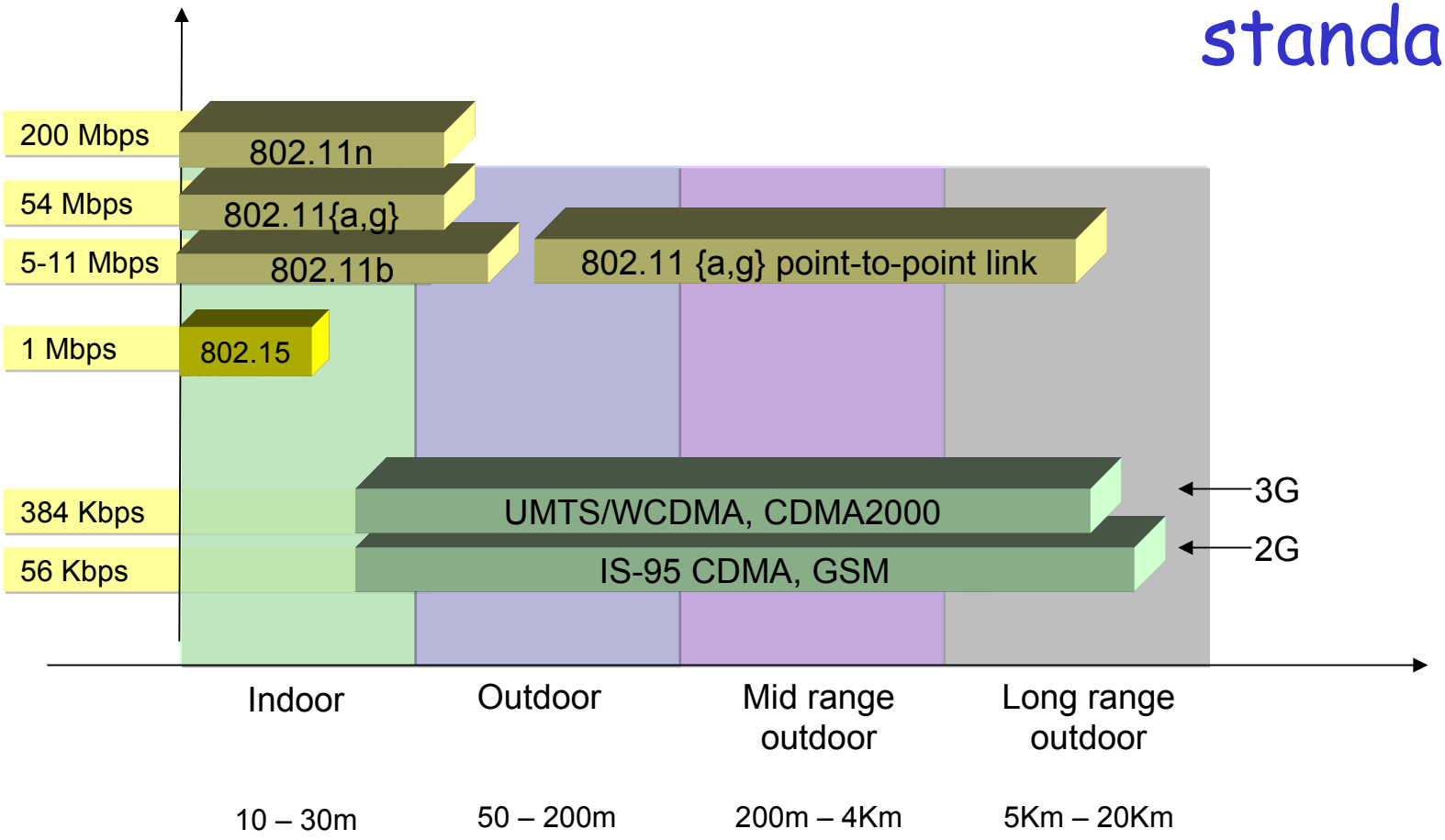


Characteristics of selected wireless link standards



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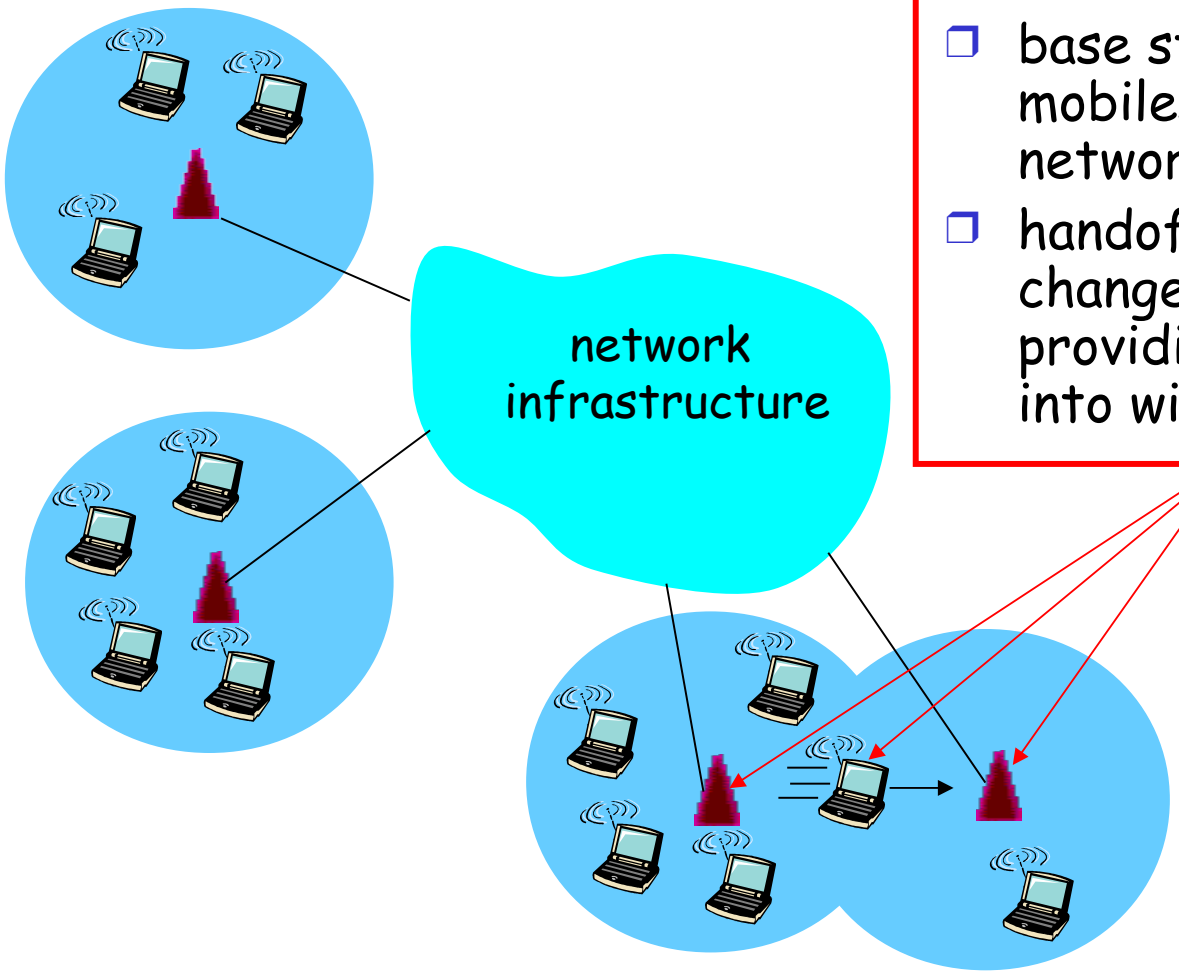
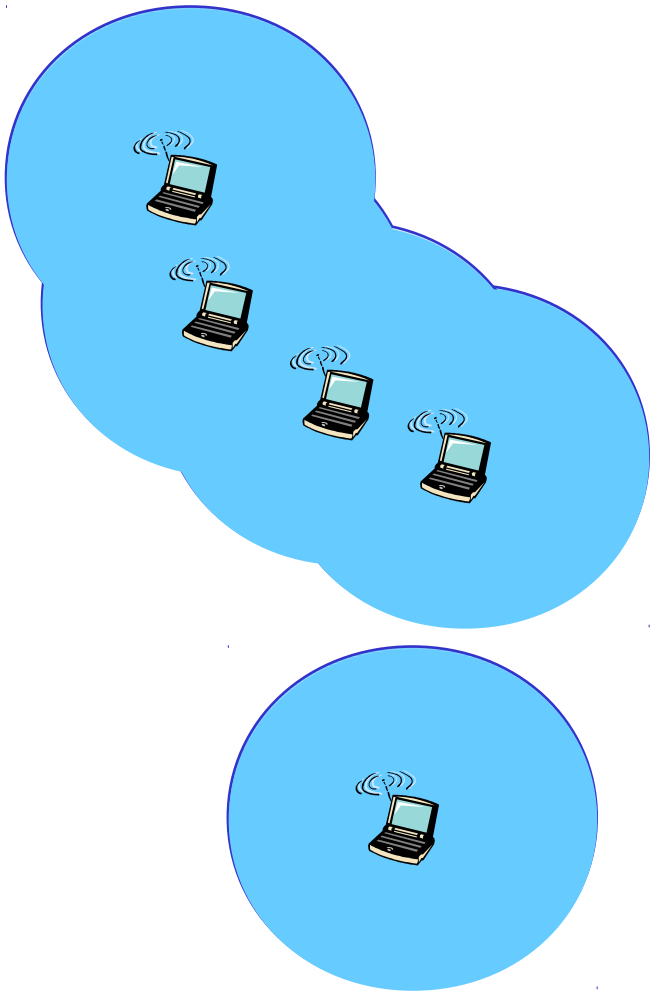


infrastructure mode

- 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

Taxonomy

- Single-hop, infrastructure-based
  - 802.11 infrastructure mode, 802.16 WiMAX
- Single-hop, infrastructure-less
  - 802.11 ad hoc mode, Bluetooth
- Multi-hop, infrastructure-based
  - Some wireless sensor networks
- Multi-hop, infrastructure-less
  - Mobile/vehicular ad hoc networks

Wireless Link Characteristics

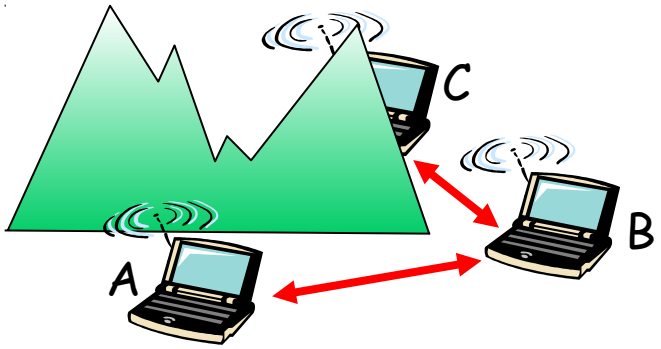
Differences from wired link ….

- 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 for 802.11 {b,g}, Bluetooth, Zigbee) shared by other devices (e.g., US cordless phones, motors, microwaves)
- multipath propagation: radio signal reflects off objects ground, arriving ad destination at slightly different times

…. make communication across (even a point to point) wireless link much more "difficult"

Wireless network characteristics

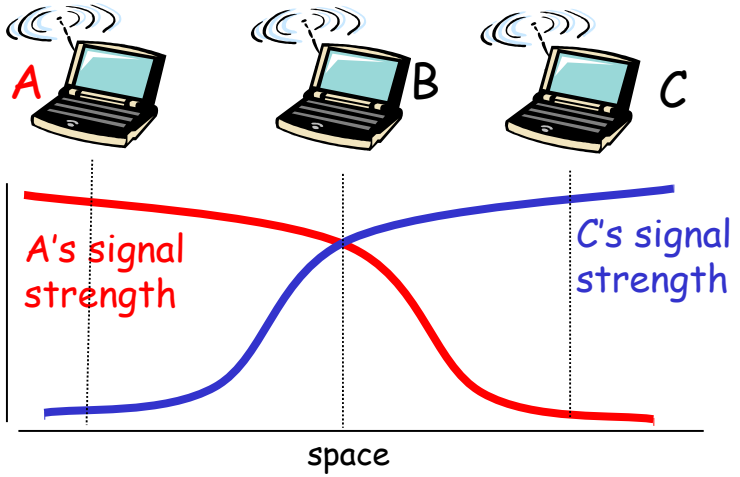
Multiple wireless senders and receivers create undetectable collision problems



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 fading:

- B, A hear each other
- B, C hear each other
- A, C can not hear each other interferring at B

Code Division Multiple Access (CDMA)

- Channel partitioning protocol
- used in several wireless broadcast channels (cellular, satellite, etc) standards
- 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
- *encoded signal* = (original data) X (chipping sequence)
  - $Z_{i,m} = d_i * c_m$
- *decoding:* inner-product of encoded signal and chipping sequence
  - $D_i = 1/M \sum Z_{i,m} * c_m$
- allows multiple users to "coexist" and transmit simultaneously with minimal interference (if codes are "orthogonal")

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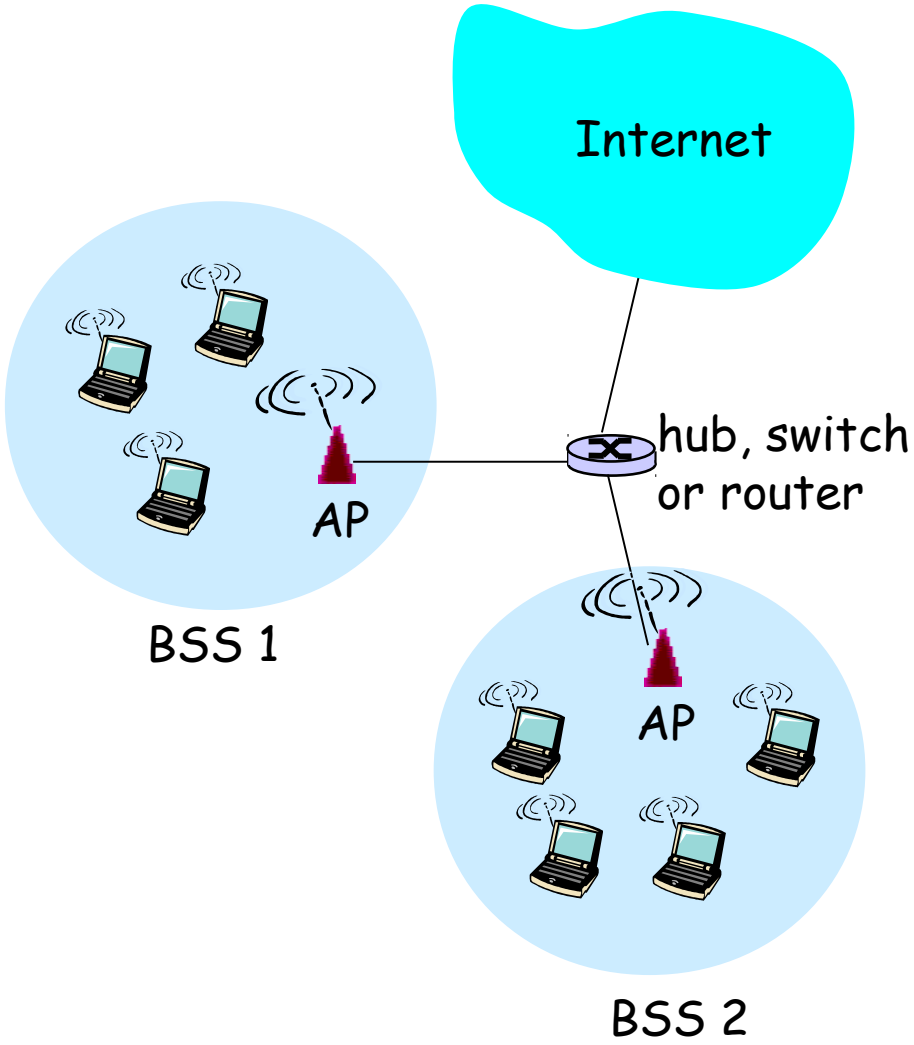
IEEE 802.11 Wireless LAN

- 802.11b
  - 2.4-5 GHz unlicensed radio spectrum
  - up to 11 Mbps
  - direct sequence spread spectrum (DSSS) in physical layer
    - all hosts use same chipping code
  - widely deployed, using base stations
- 802.11a
  - 5-6 GHz range
  - up to 54 Mbps
- 802.11g
  - 2.4-5 GHz range
  - up to 54 Mbps
- All use *Carrier Sense Multiple Access with Collision Avoidance* for multiple access
- All have base-station and ad-hoc network versions

802.11 LAN architecture



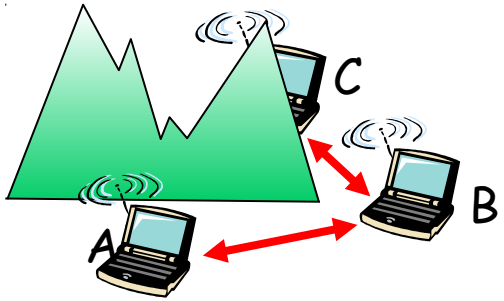
- wireless host communicates with base station
  - base station = access point (AP)
- Basic Service Set (BSS) (aka "cell") in infrastructure mode contains:
  - wireless hosts
  - access point (AP): base station
  - ad hoc mode: hosts only

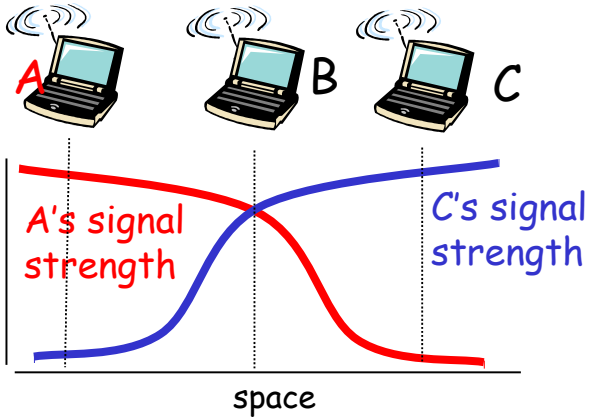
802.11: Channels, association

- 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
    - `iwlist scan`
  - selects AP to associate with
  - may perform authentication
    - `iwconfig`
  - will typically run DHCP to get IP address in AP's subnet
    - `dhclient`

IEEE 802.11: multiple access

- 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/C(ollision)A(voidance)





IEEE 802.11 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 backoff time

timer counts down while channel idle

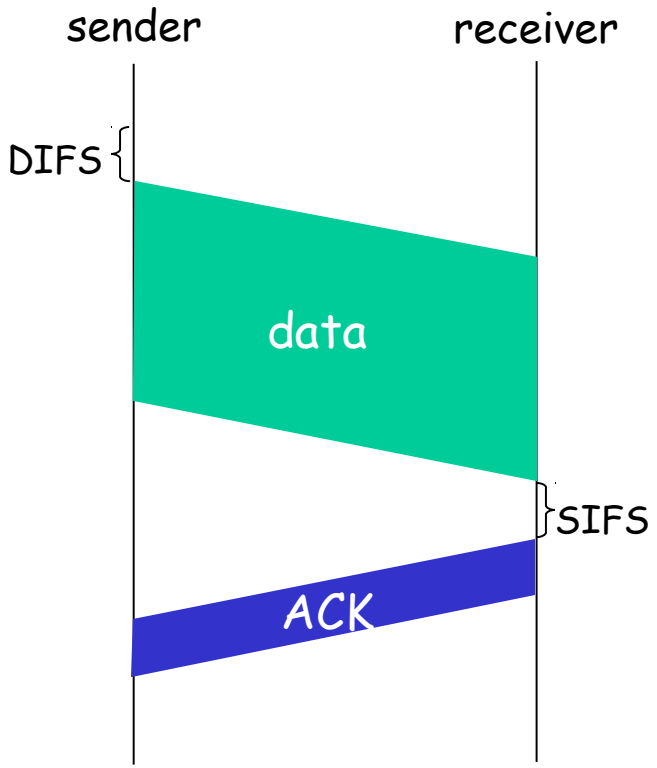
transmit when timer expires

if no ACK, increase random backoff interval, repeat 2

802.11 receiver

- if frame received OK

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



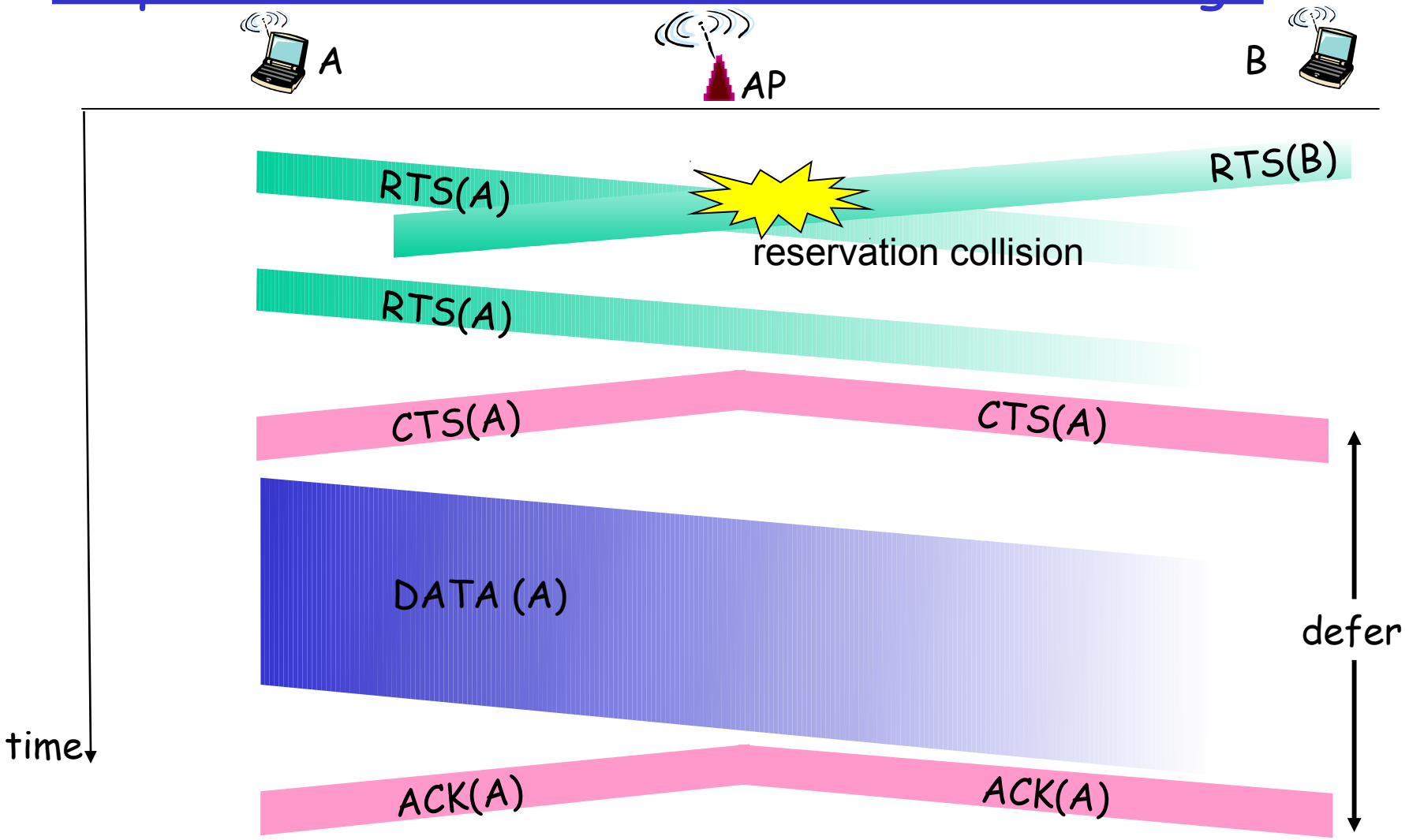
Avoiding collisions (more)

idea: allow sender to "reserve" channel rather than random access of data frames: avoid collisions of long data frames

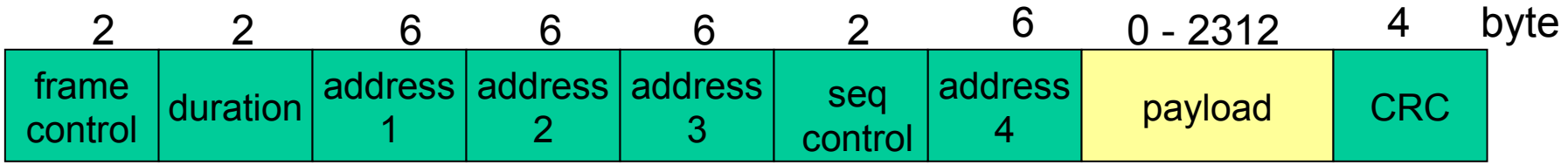
- sender first transmits *small* request-to-send (RTS) packets to BS using CSMA
  - RTSs may still collide with each other (but they're short)
- BS broadcasts clear-to-send CTS in response to RTS
- RTS heard by all nodes
  - sender transmits data frame
  - other stations defer transmissions

Avoid data frame collisions completely using small reservation packets!

Collision Avoidance with hidden terminals: Request-To-Send - Clear-To-Send exchange



802.11 frame: addressing



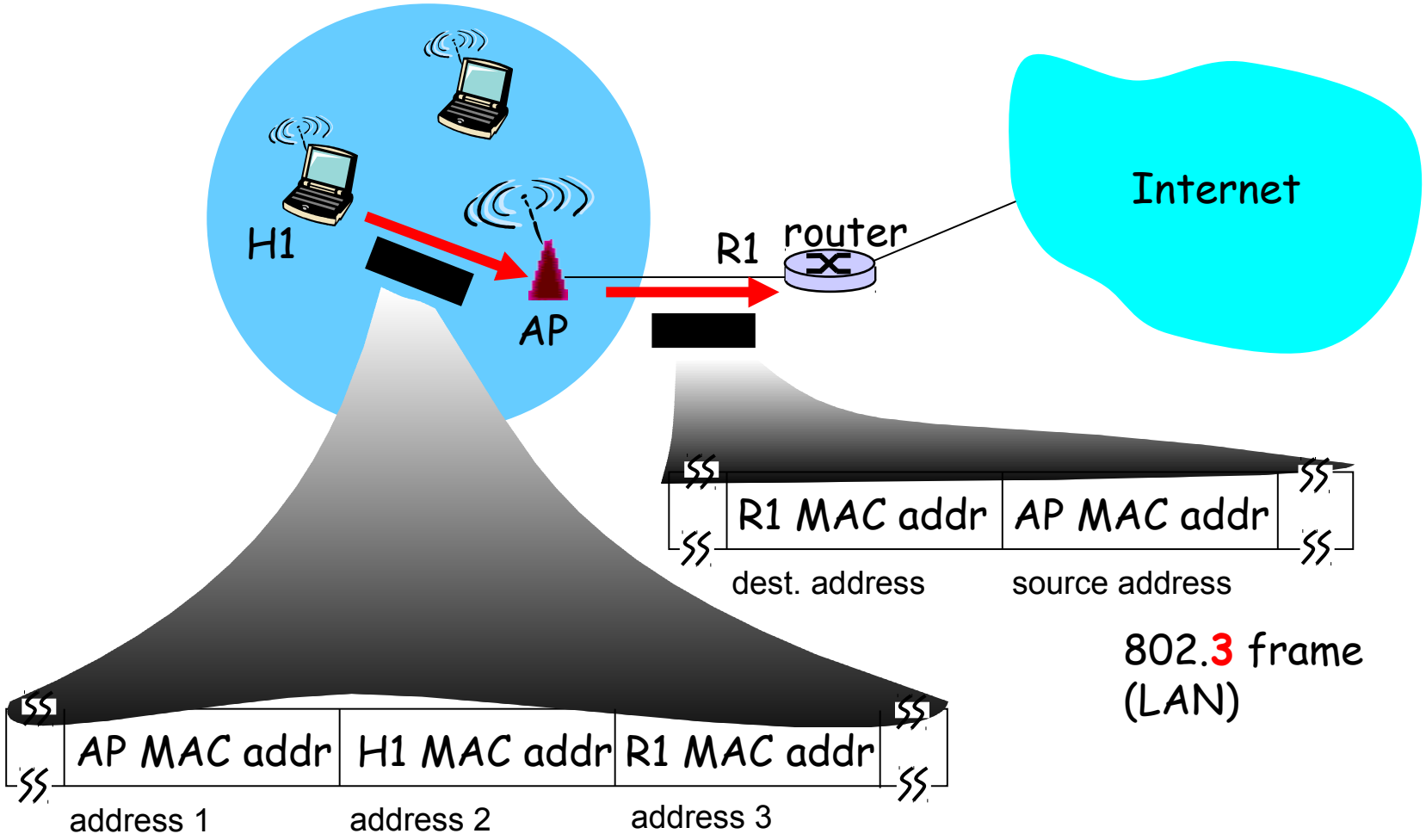
Address 1: MAC address of wireless host or AP to receive this frame

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

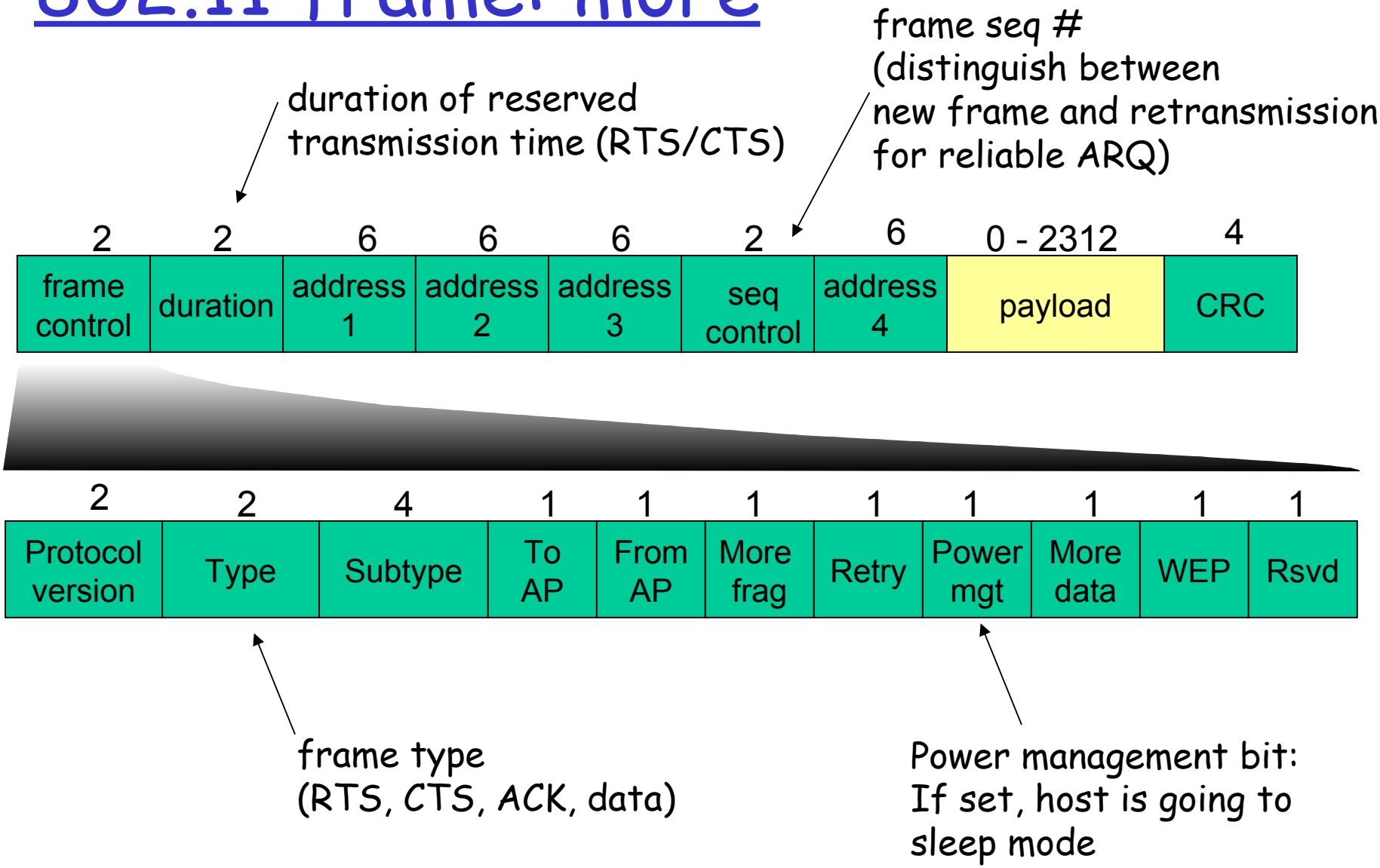
Address 3: MAC address of router interface to which AP is attached

Address 4: used only in ad hoc mode

802.11 frame: addressing

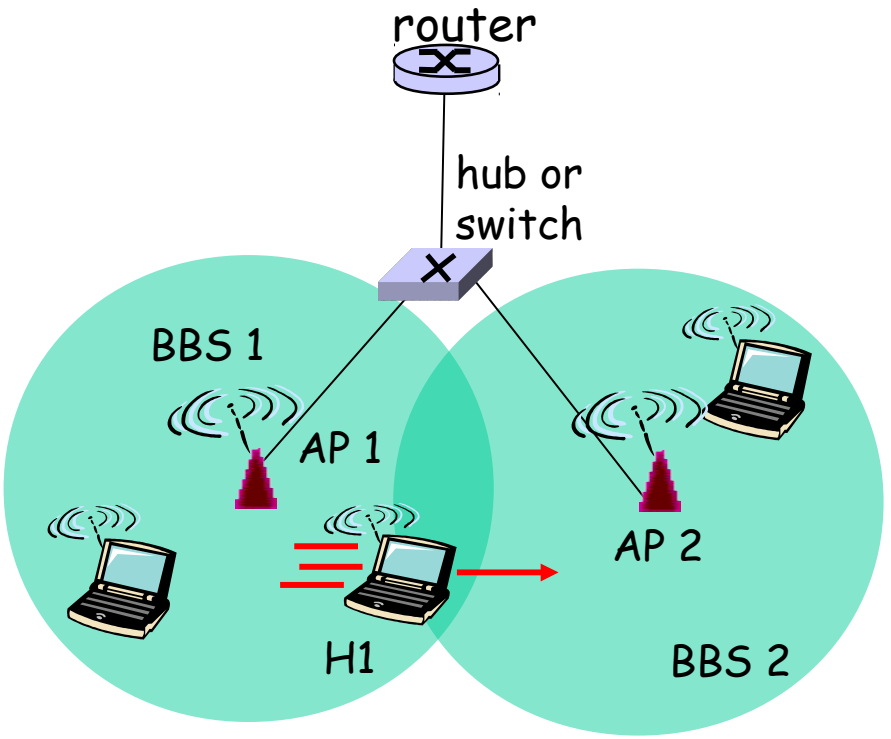


802.11 frame: more



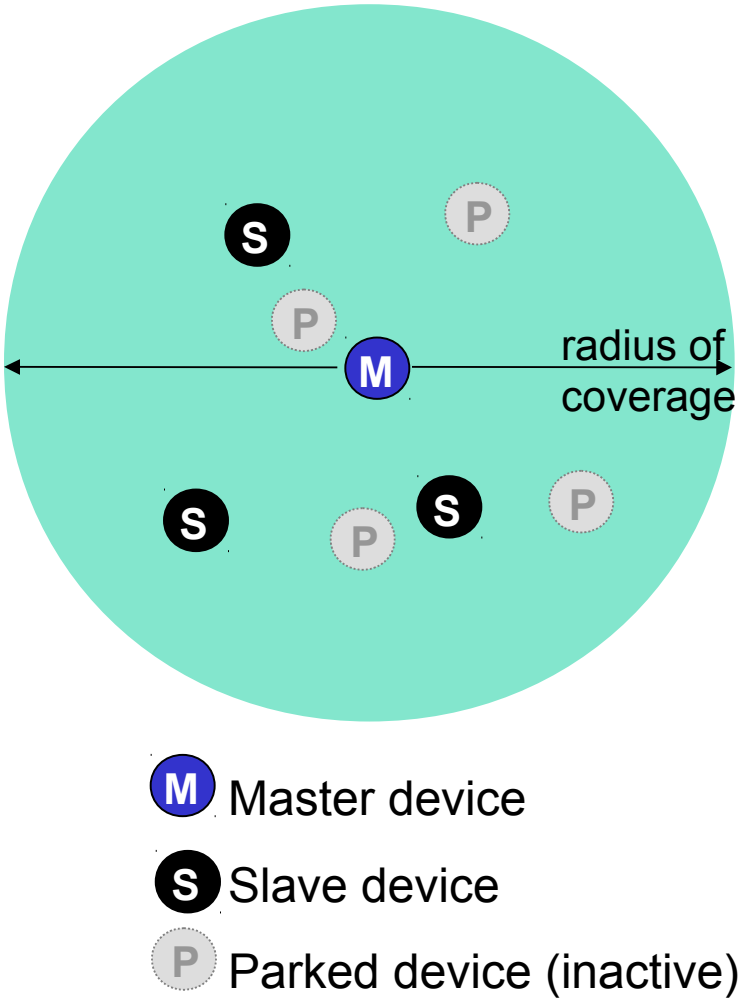
802.11: mobility within same subnet

- H1 remains in same IP subnet: IP address can remain same
- switch: which AP is associated with H1?
  - self-learning: switch will see frame from H1 and "remember" which switch port can be used to reach H1
  - AP1 & AP2 usually share SSID, so H1 handles the handoff easily



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



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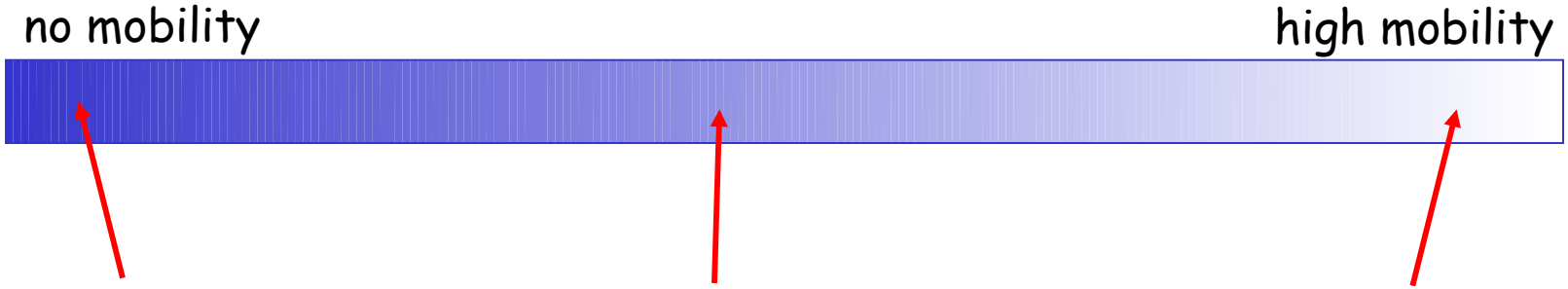
Summary

What is mobility?

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



mobile wireless user, using same access point, not mobile from the network perspective

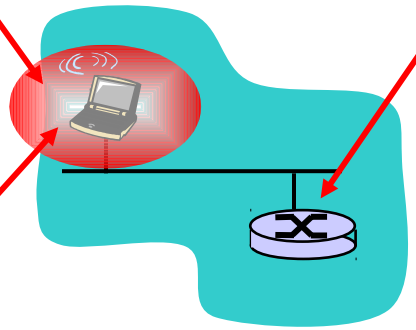
mobile user, connecting/ disconnecting from network using DHCP.

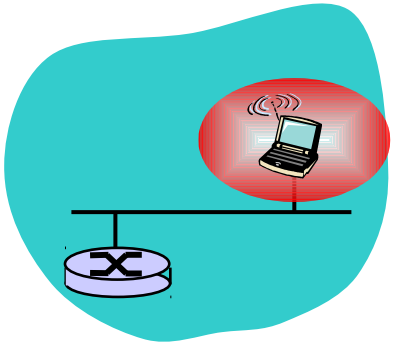
mobile user, passing through multiple access point while maintaining ongoing connections (like cell phone)

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

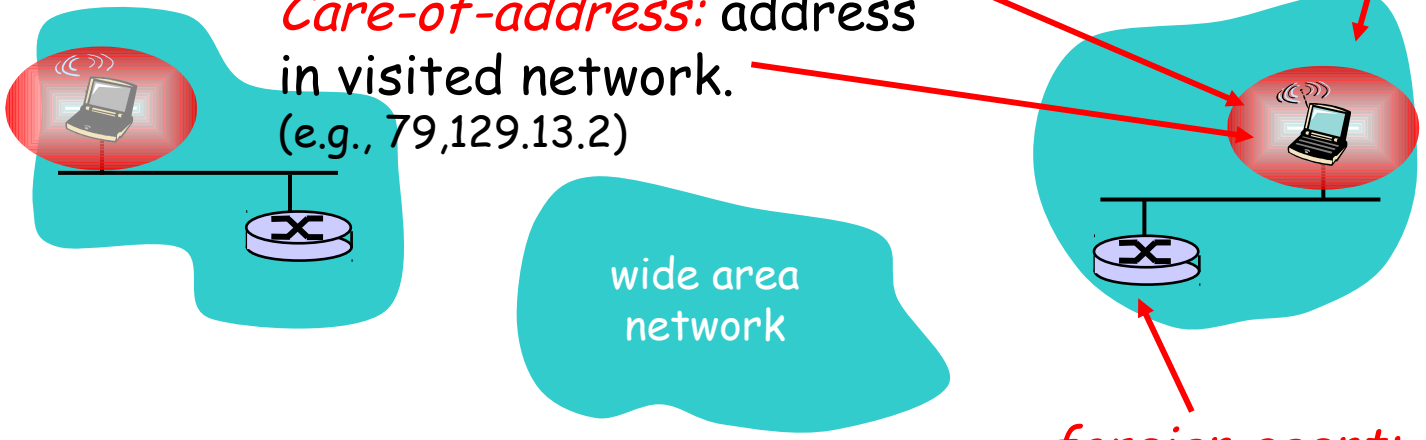
correspondent

Mobility: 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)



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

correspondent: *wants to communicate with mobile*

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 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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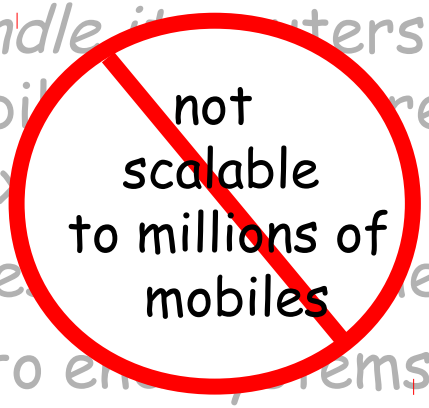

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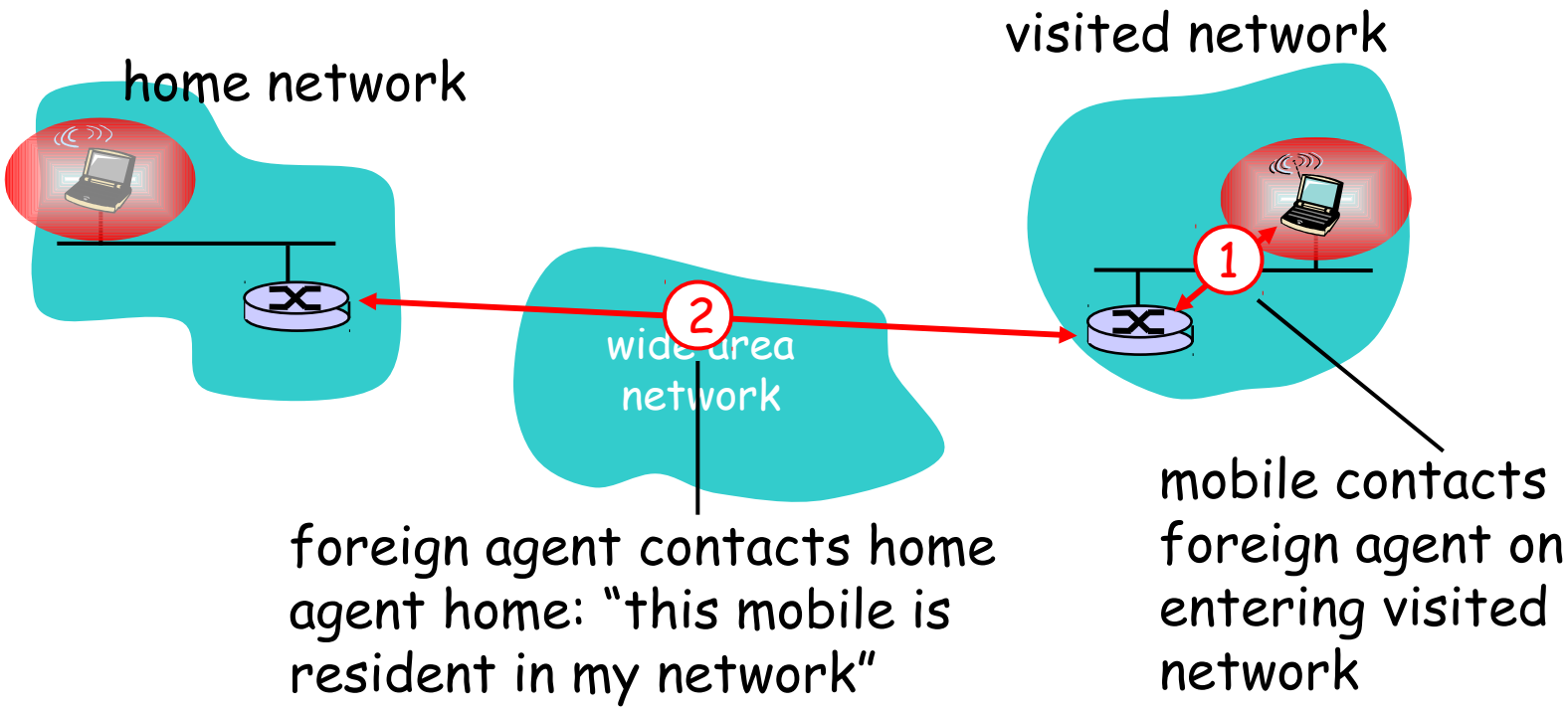
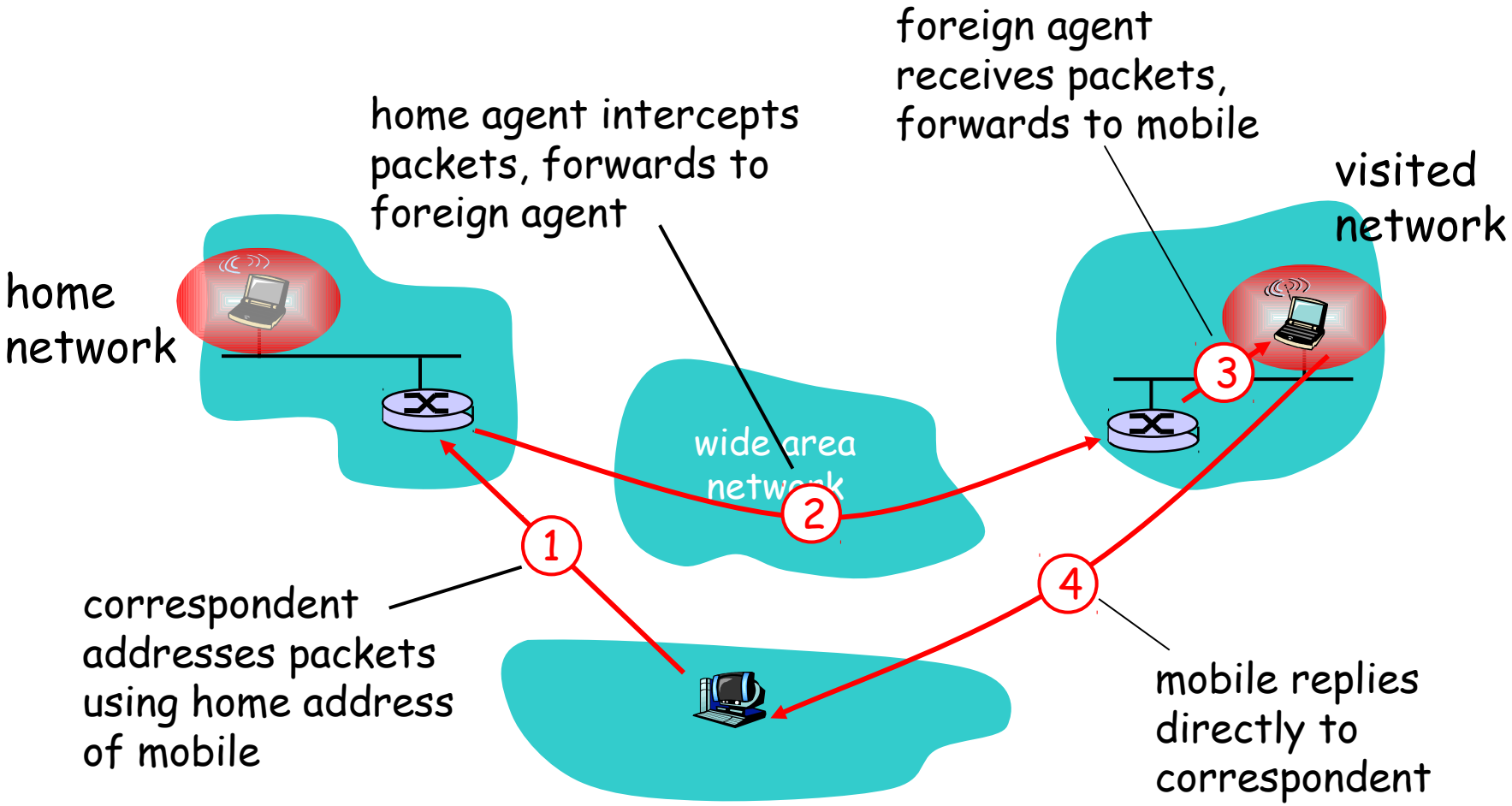
Mobility: registration



End result:

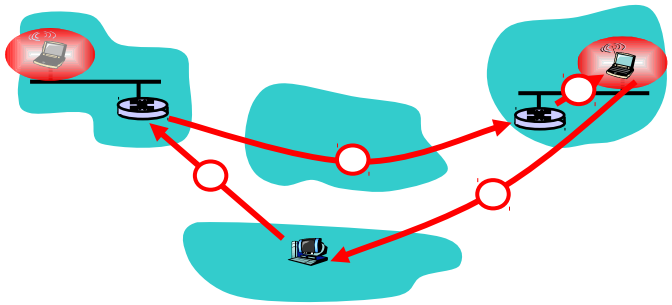
- Foreign agent knows about mobile
- Home agent knows location of mobile

Mobility via Indirect Routing



Indirect Routing: comments

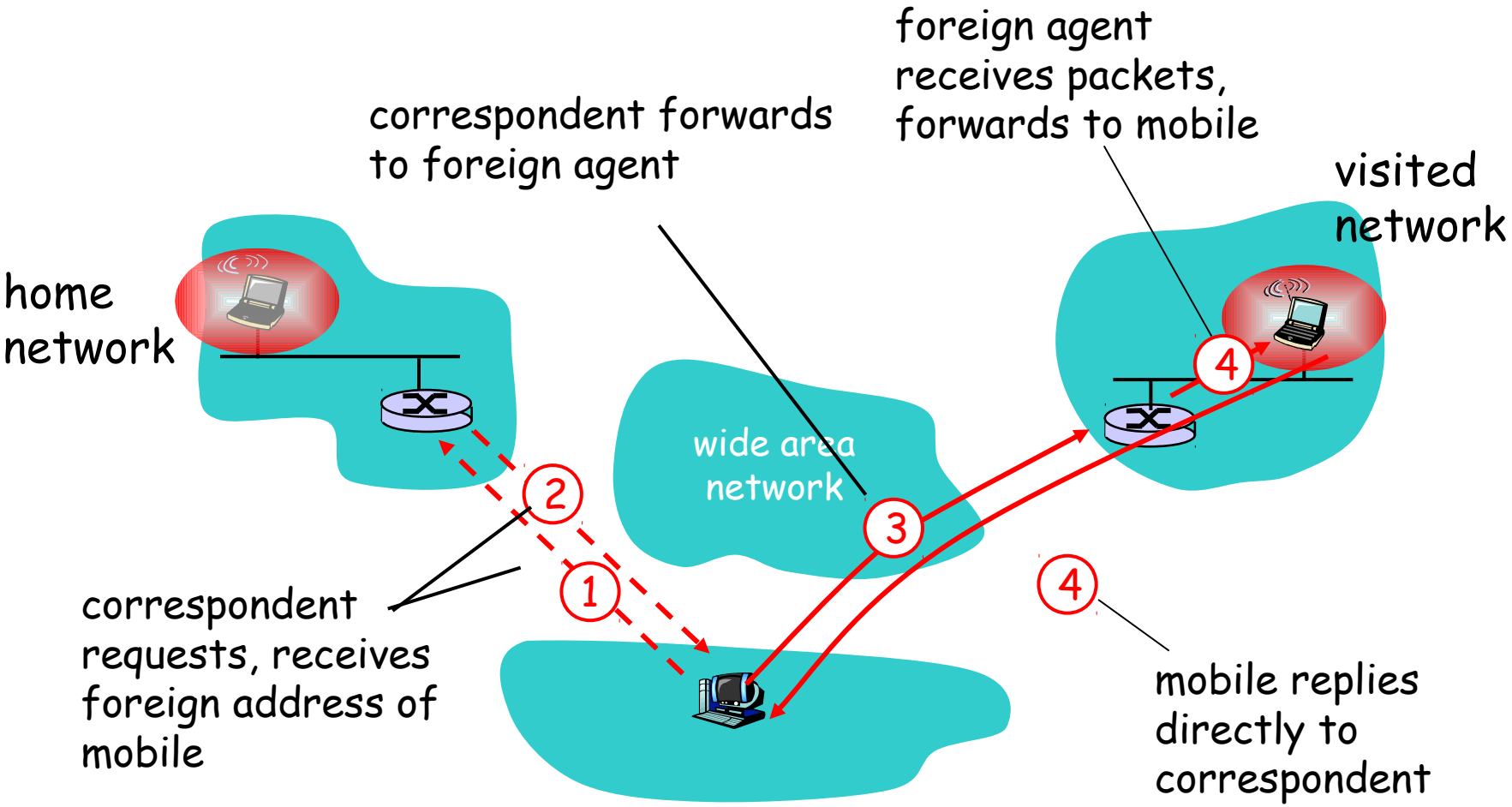
- Mobile uses two addresses:
  - permanent address: used by correspondent (hence mobile location is *transparent* to correspondent)
  - care-of-address: used by home agent to forward datagrams to mobile
- foreign agent functions may be done by mobile itself
- triangle routing: correspondent-home-network-mobile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



Indirect Routing: moving between networks

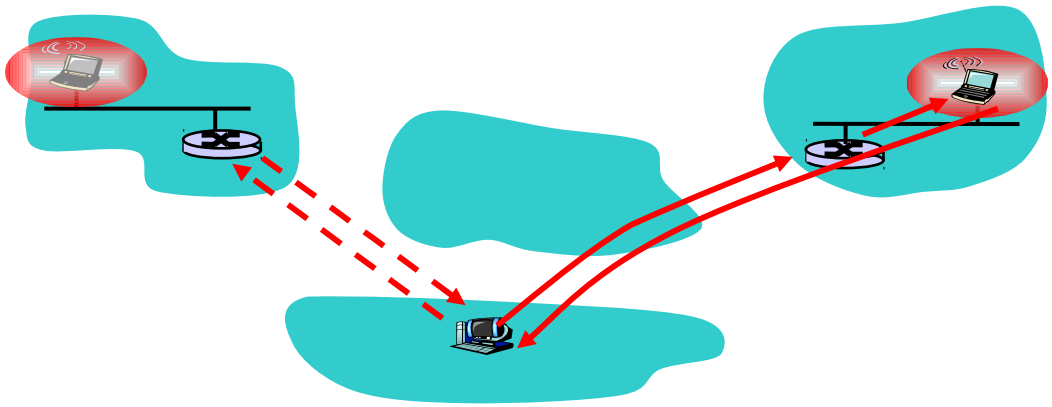
- suppose mobile user moves to another network
  - registers with new foreign agent
  - new foreign agent registers with home agent
  - home agent update care-of-address for mobile
  - packets continue to be forwarded to mobile (but with new care-of-address)
- mobility, changing foreign networks transparent: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

Mobility via Direct Routing



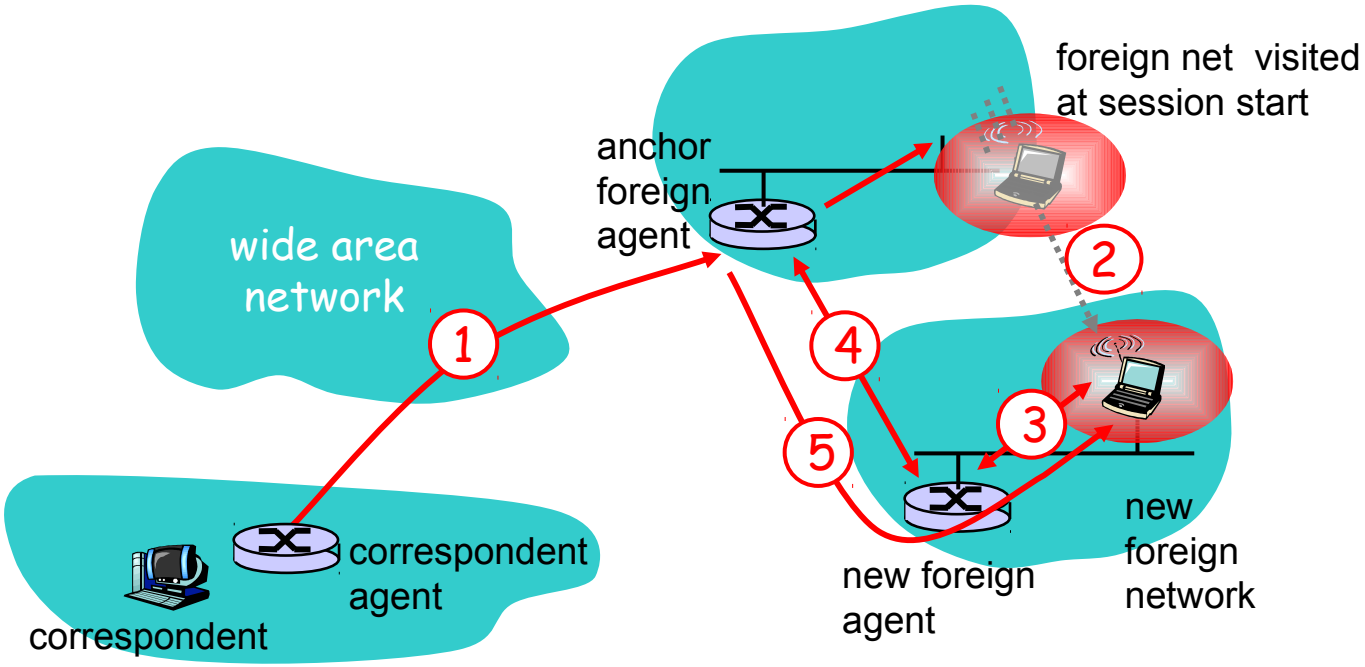
Mobility via Direct Routing: comments

- 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)



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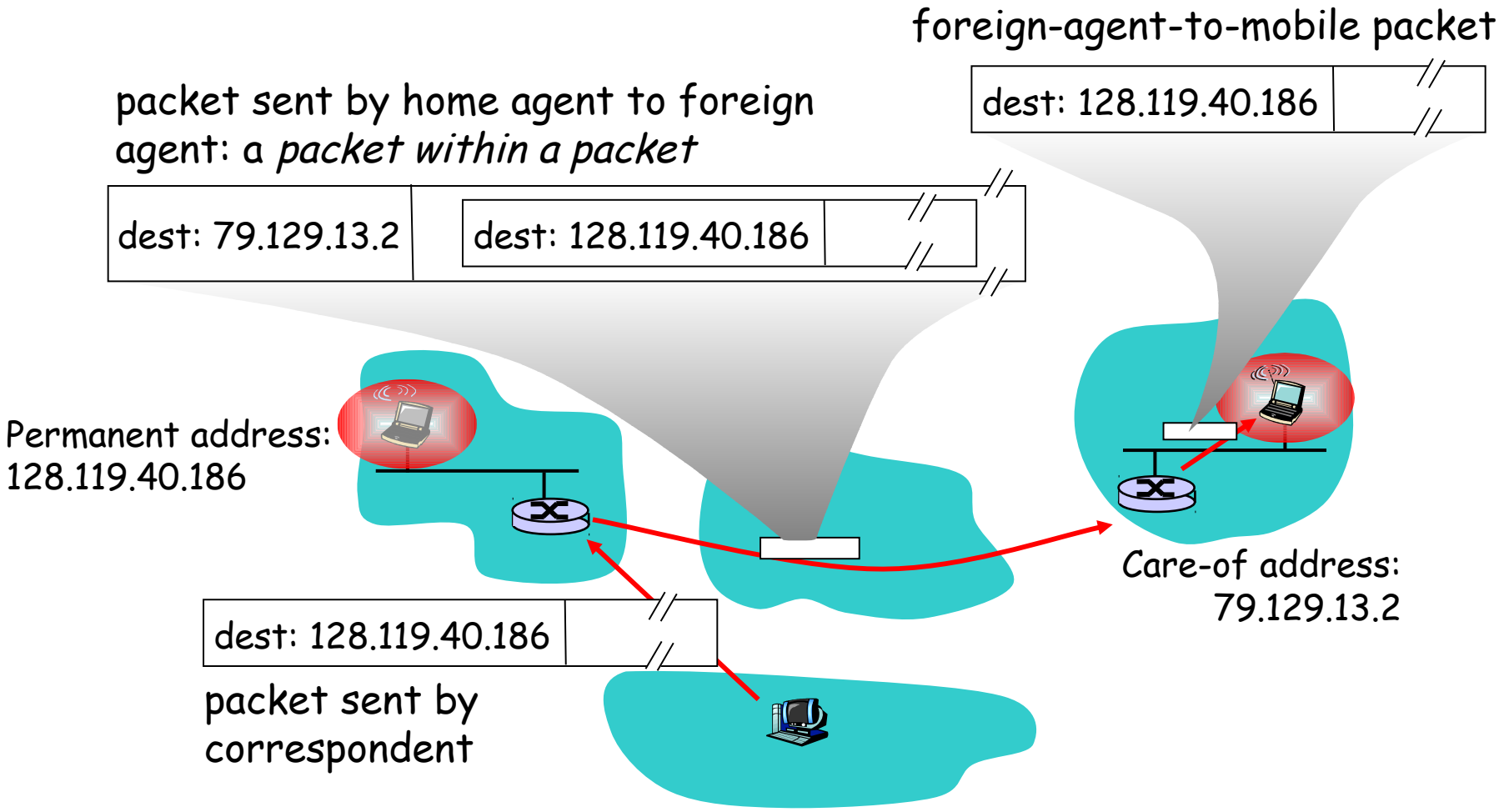
Mobile IP

- RFC 3344 for IPv4
- 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
- major security considerations

Mobile IP: indirect routing

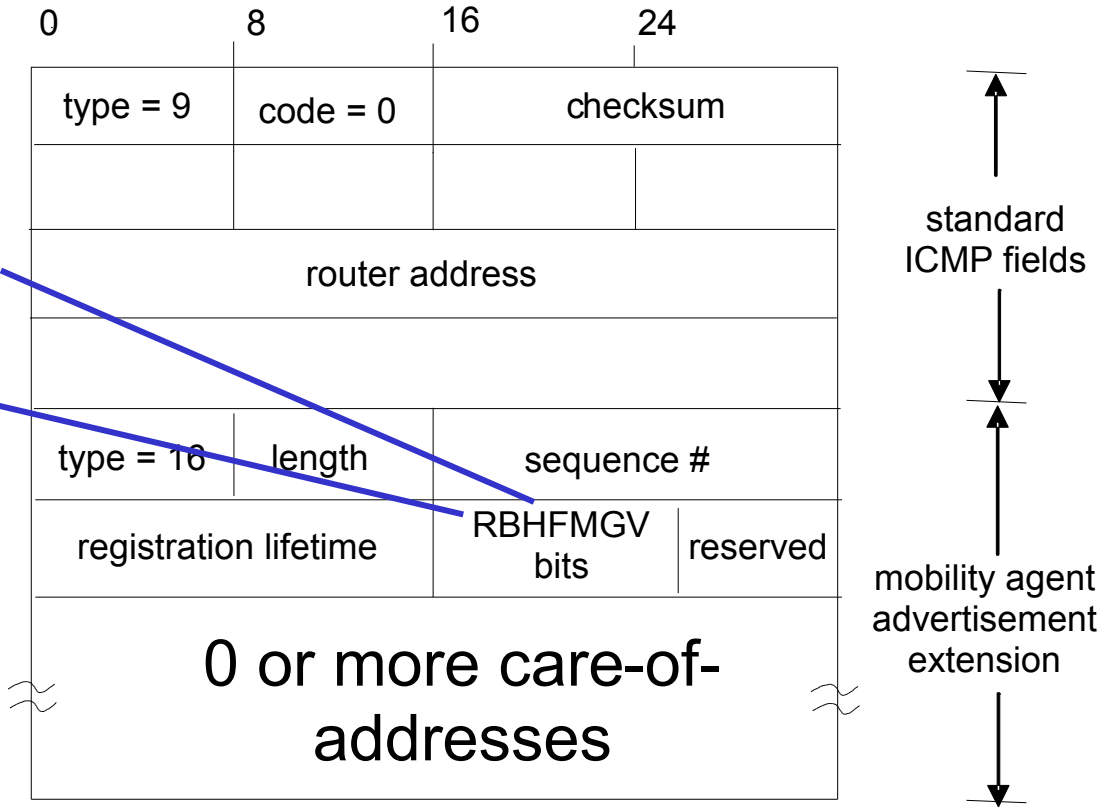


Mobile IP: agent discovery

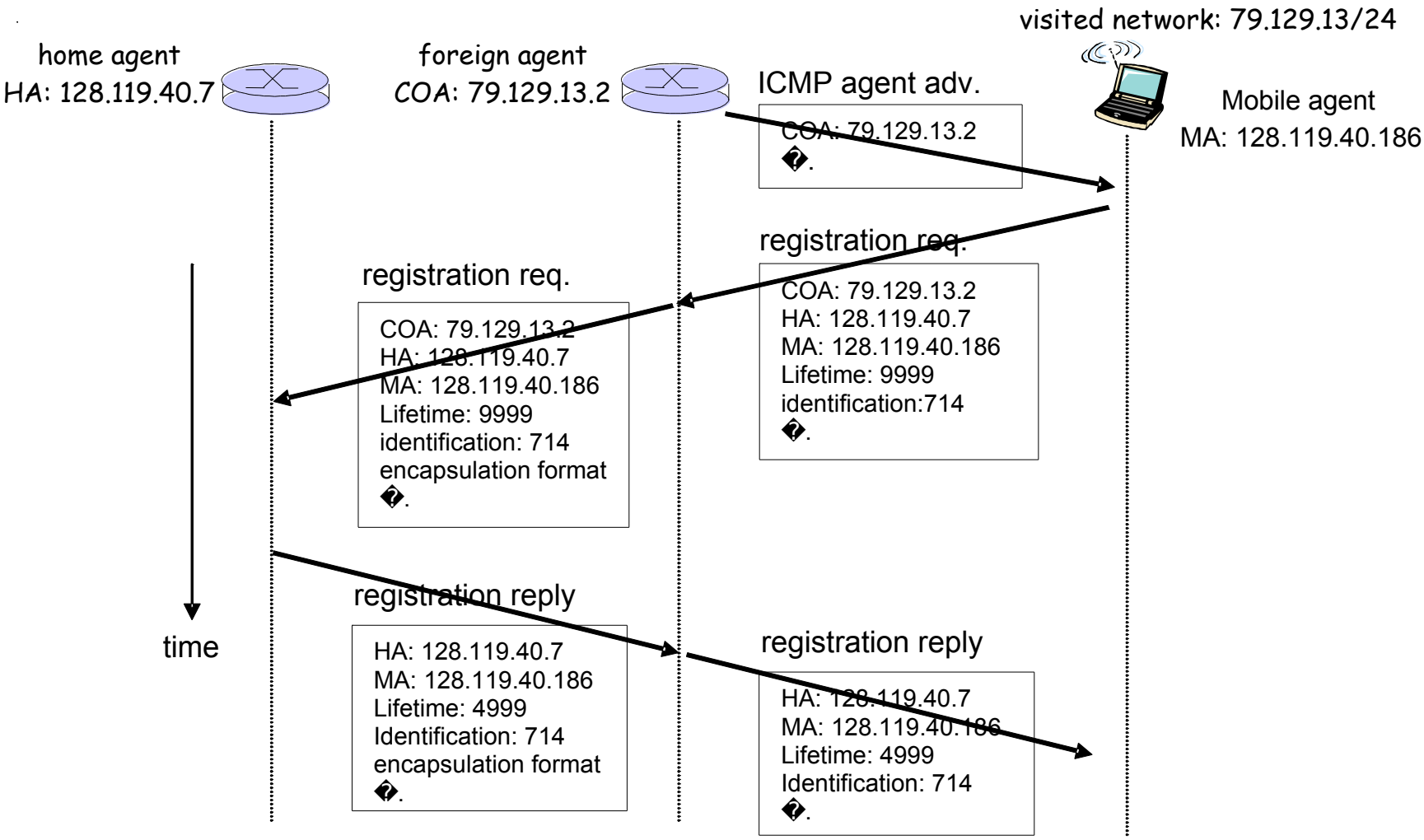
- agent advertisement: foreign/home agents advertise service by broadcasting ICMP control messages (typefield = 9, router discovery)

H,F bits: home and/or foreign agent

R bit: registration required (host cannot act as foreign agents for themselves in this network)



Mobile IP: registration example



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

Summary

Wireless

- wireless links:
  - capacity, distance
  - channel impairments
  - CDMA
- IEEE 802.11 ("wi-fi")
  - CSMA/CA reflects wireless channel characteristics

Mobility

- principles: addressing, routing to mobile users
  - home, visited networks
  - direct, indirect routing
  - care-of-addresses
- case study
  - mobile IP
- impact on higher-layer protocols