Last time

- Ethernet
  - frame structure
  - CSMA/CD algorithm
- Hubs
  - physical-layer repeaters
  - make one large collision domain
- Switches
  - link-layer devices
  - separates collision domains
  - transparent, plug-and-play, self-learning

This time

- Wireless link-layer
  - Introduction
  - Characteristics of wireless links
  - 802.11 wireless LANs
  - 802.15 networking
  - Cellular Internet access

Chapter 6: Wireless and Mobile Networks

Background:

- # wireless (mobile) phone subscribers now exceeds # wired phone subscribers!
- Computer networks: 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

Chapter 6 outline

6.1 Introduction

Wireless

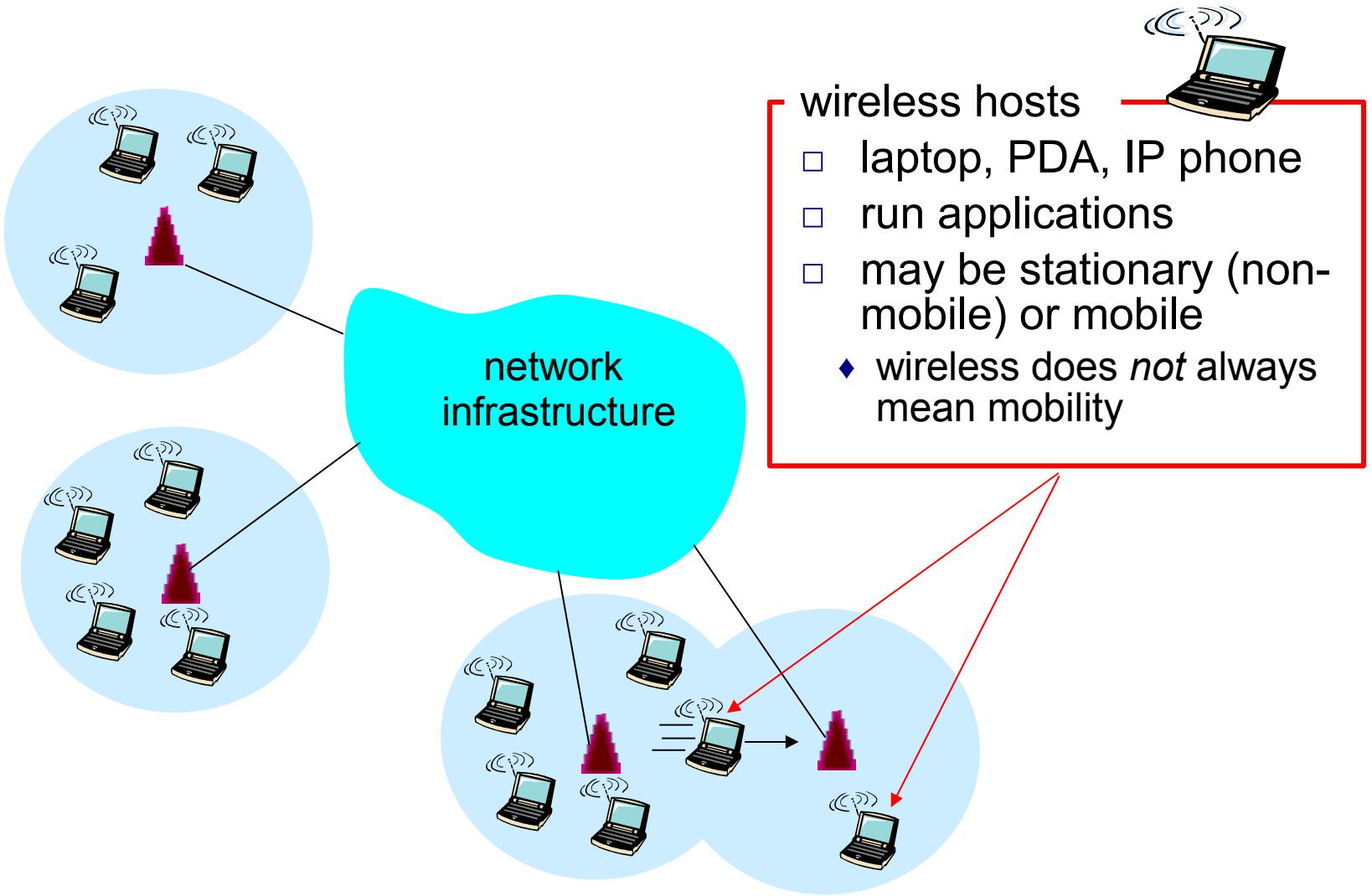
- 6.2 Wireless links, characteristics
  - CDMA
- 6.3 IEEE 802.11 wireless LANs (“wi-fi”)
- 6.4 Cellular Internet Access
  - architecture
  - standards (e.g., GSM)

Mobility

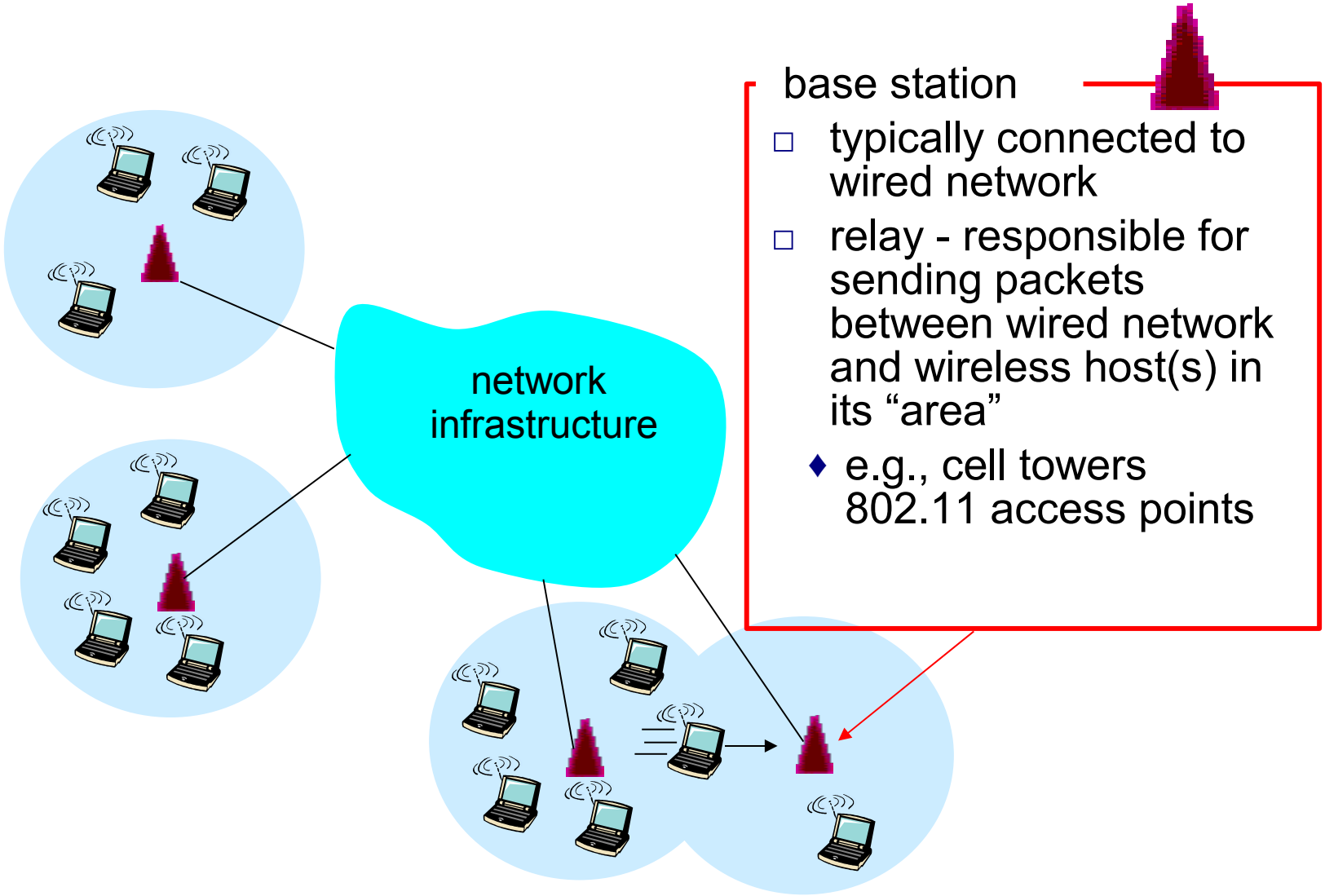
- 6.5 Principles: addressing and routing to mobile users
- 6.6 Mobile IP
- 6.7 Handling mobility in cellular networks
- 6.8 Mobility and higher-layer protocols

6.9 Summary

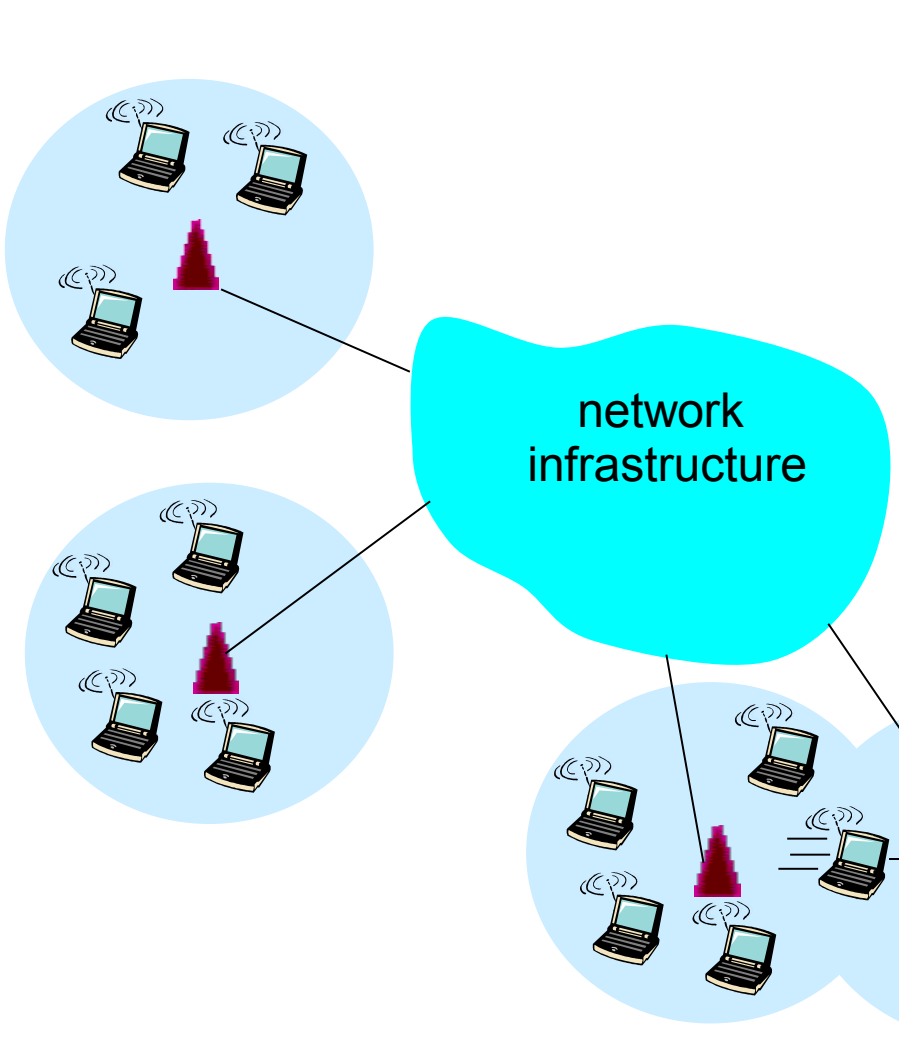
Elements of a wireless network



Elements of a wireless network



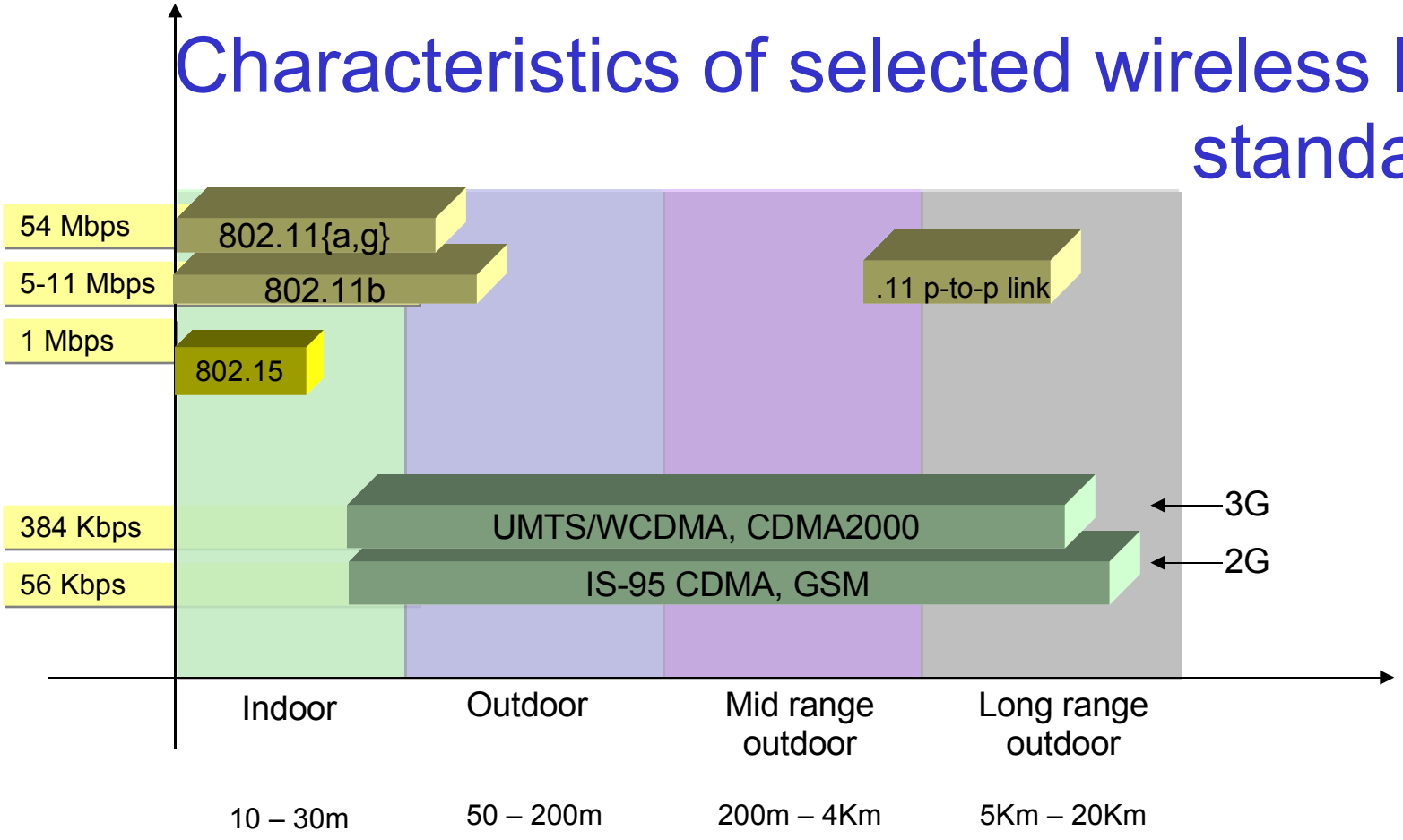
Elements of a wireless network



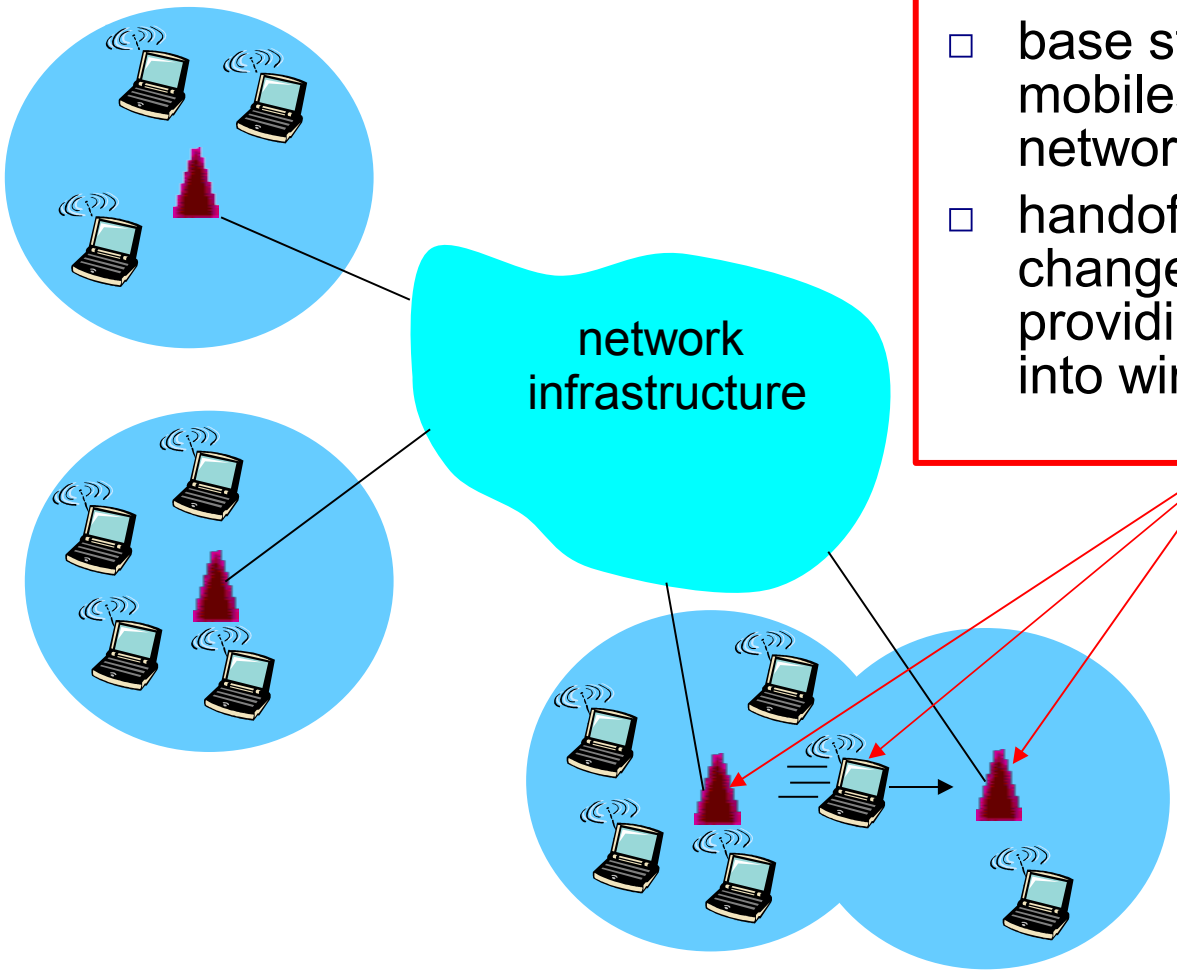
wireless link

- 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

Characteristics of selected wireless link standards



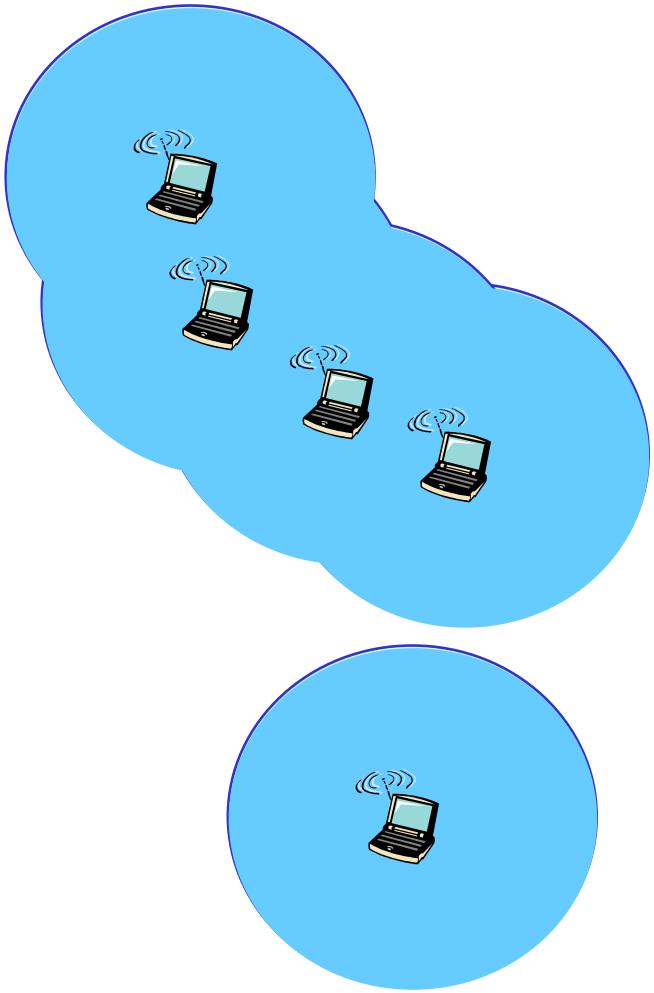
Elements of a wireless network



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

Wireless Link Characteristics

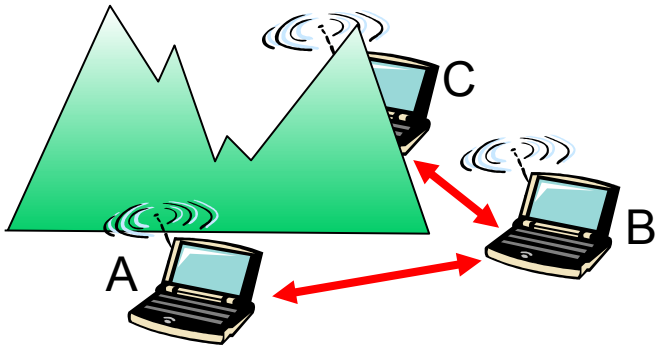
Differences from wired link …

- 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) 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”

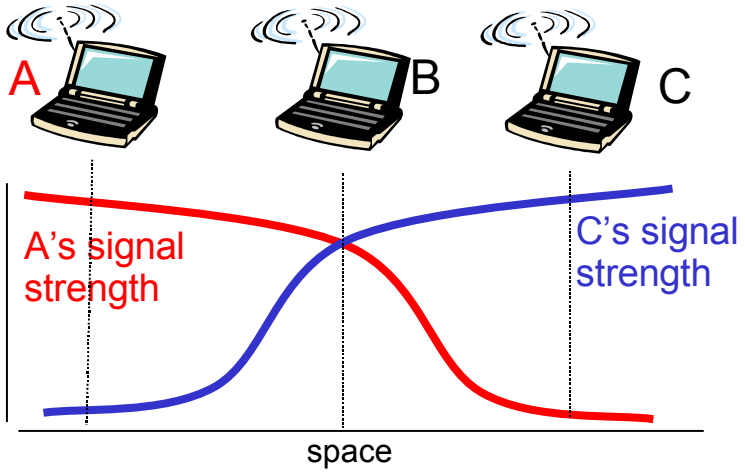
Wireless network characteristics

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



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 interfering at B

Code Division Multiple Access (CDMA)

- 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)
- *Decoding:* inner-product of encoded signal and chipping sequence
- Allows multiple users to "coexist" and transmit simultaneously with minimal interference (if codes are "orthogonal")

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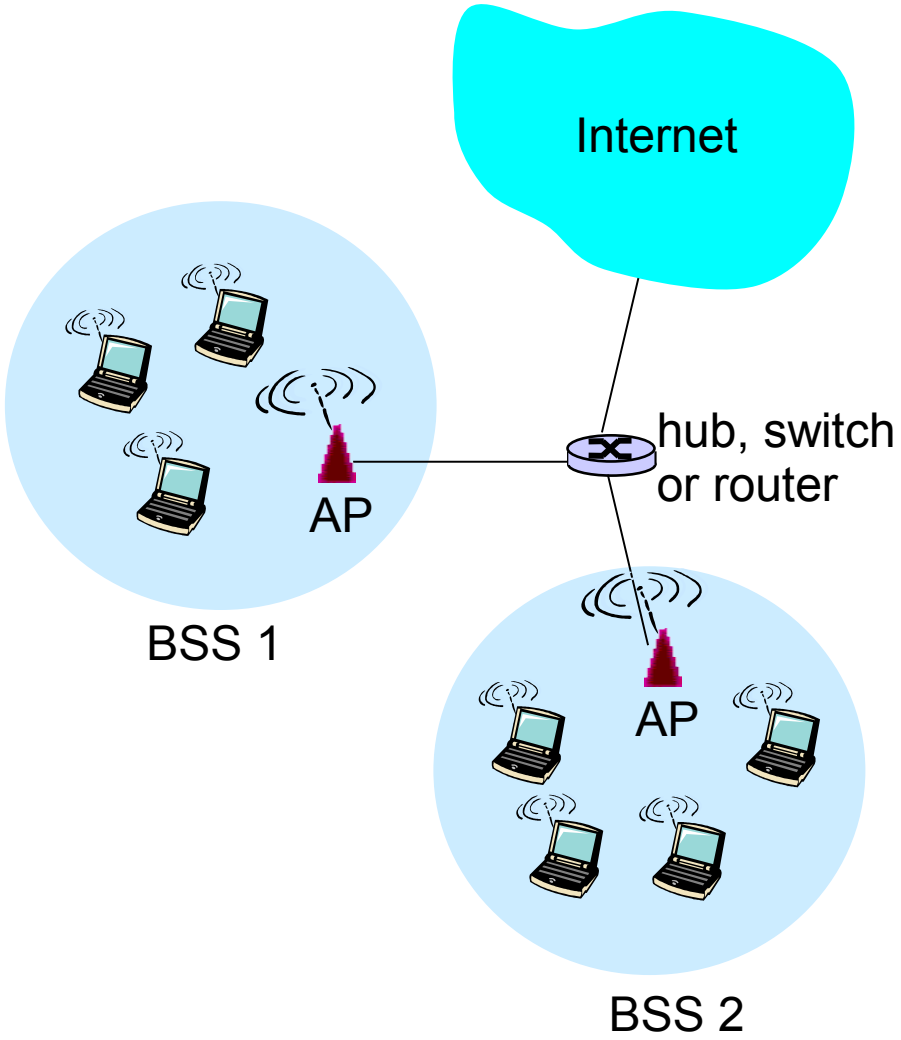
IEEE 802.11 Wireless LAN

- 802.11b
  - 2.4 GHz unlicensed radio spectrum
  - Up to 11 Mbps
  - Widely deployed, using base stations
- 802.11a
  - 5.8 GHz range
  - Up to 54 Mbps
- 802.11g
  - 2.4 GHz range
  - Up to 54 Mbps
- All use CSMA/CA 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

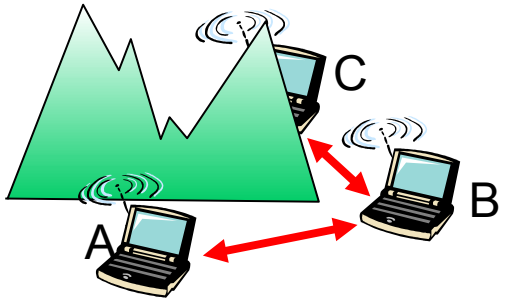
802.11: Channels, association

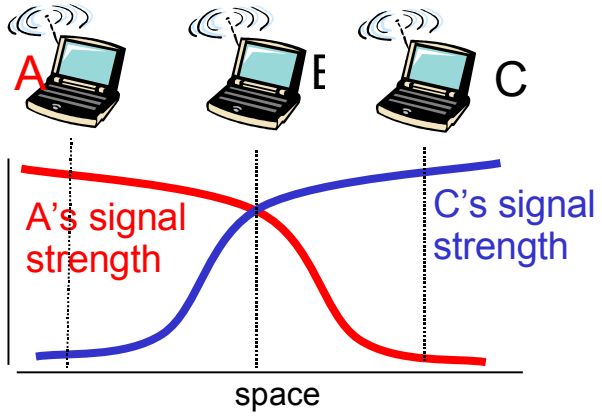
- 802.11b: 2.4GHz-2.485GHz spectrum divided into 11 channels at different frequencies
  - AP admin chooses frequency for AP
  - interference possible: channel can be same as that chosen by neighbouring AP!

- Hosts 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

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

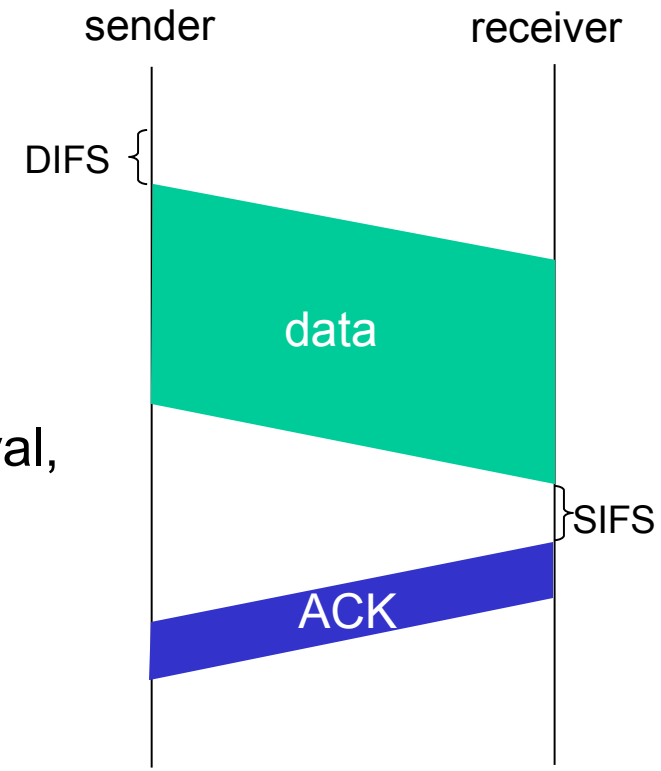
transmit when timer expires

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)

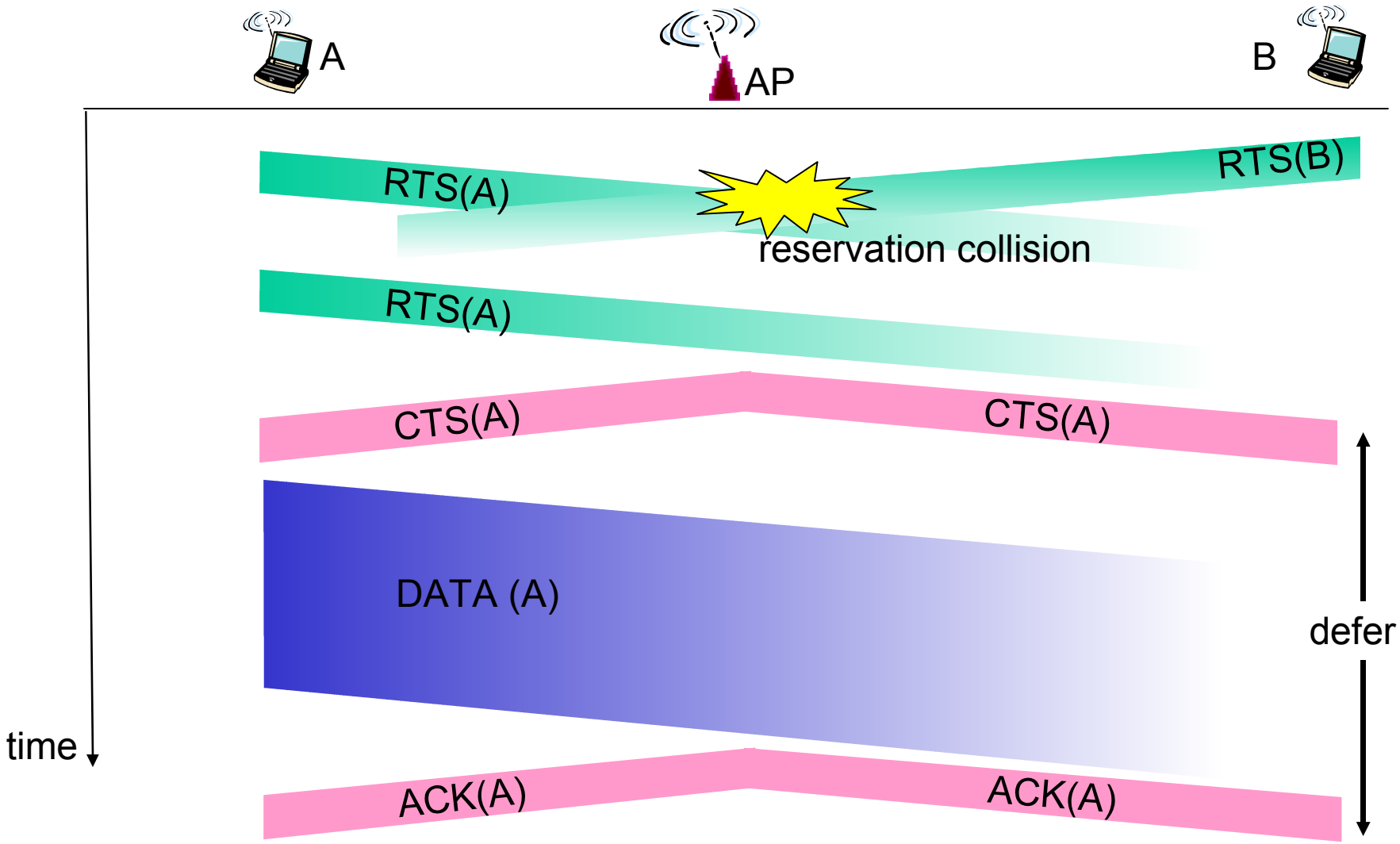
Idea: allow sender to "reserve" channel rather than random access of data frames: avoid collisions of long data frames

- 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
- CTS heard by all nodes
  - sender transmits data frame
  - other stations defer transmissions

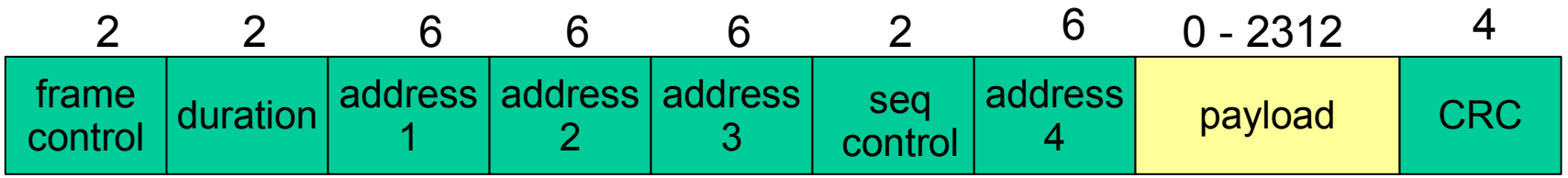
Avoid data frame collisions completely using small reservation packets!

See the applets on UW-ACE

Collision Avoidance: RTS-CTS exchange



802.11 frame: addressing



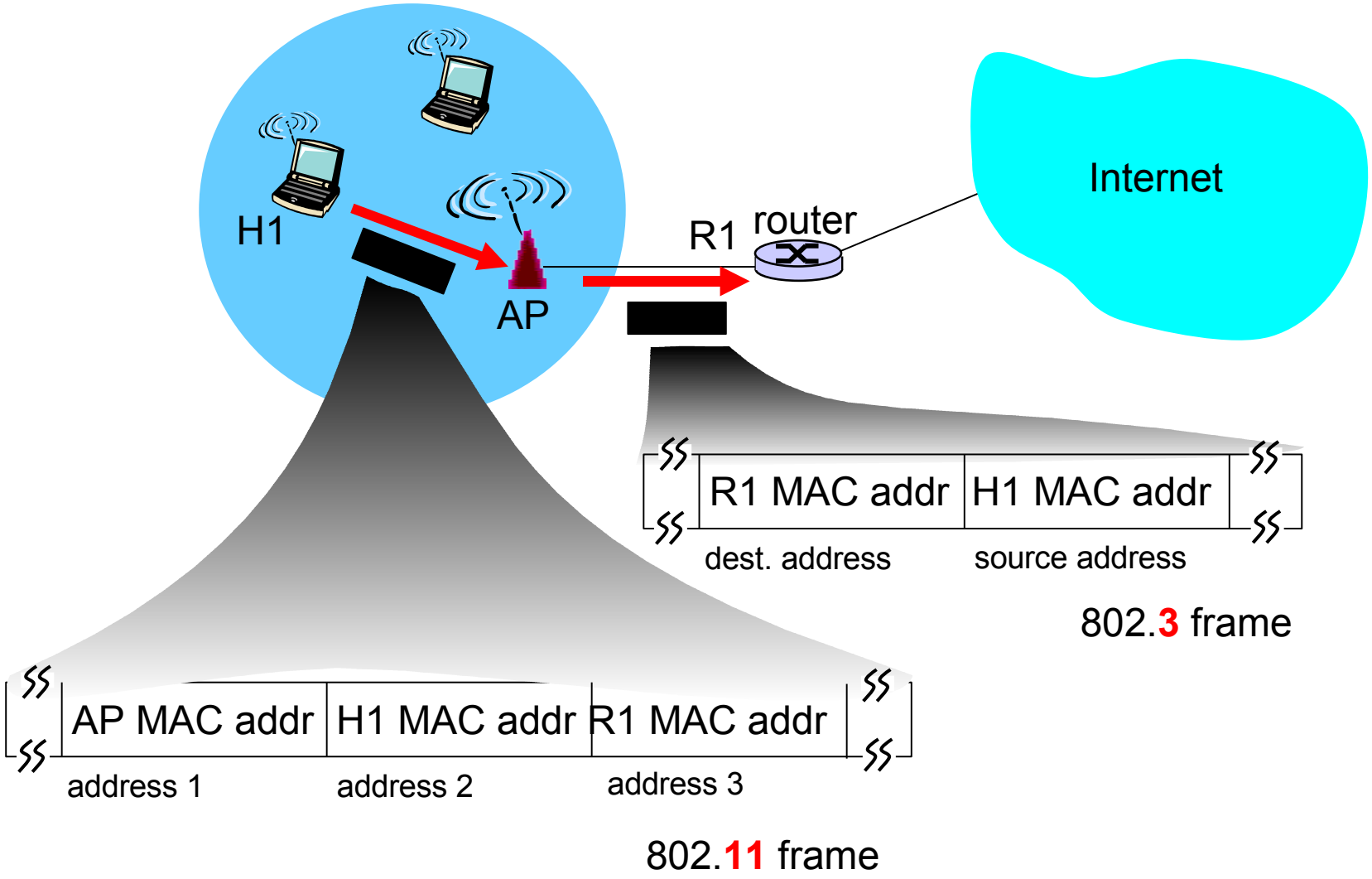
Address 1: MAC address of wireless host or AP to receive this frame

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

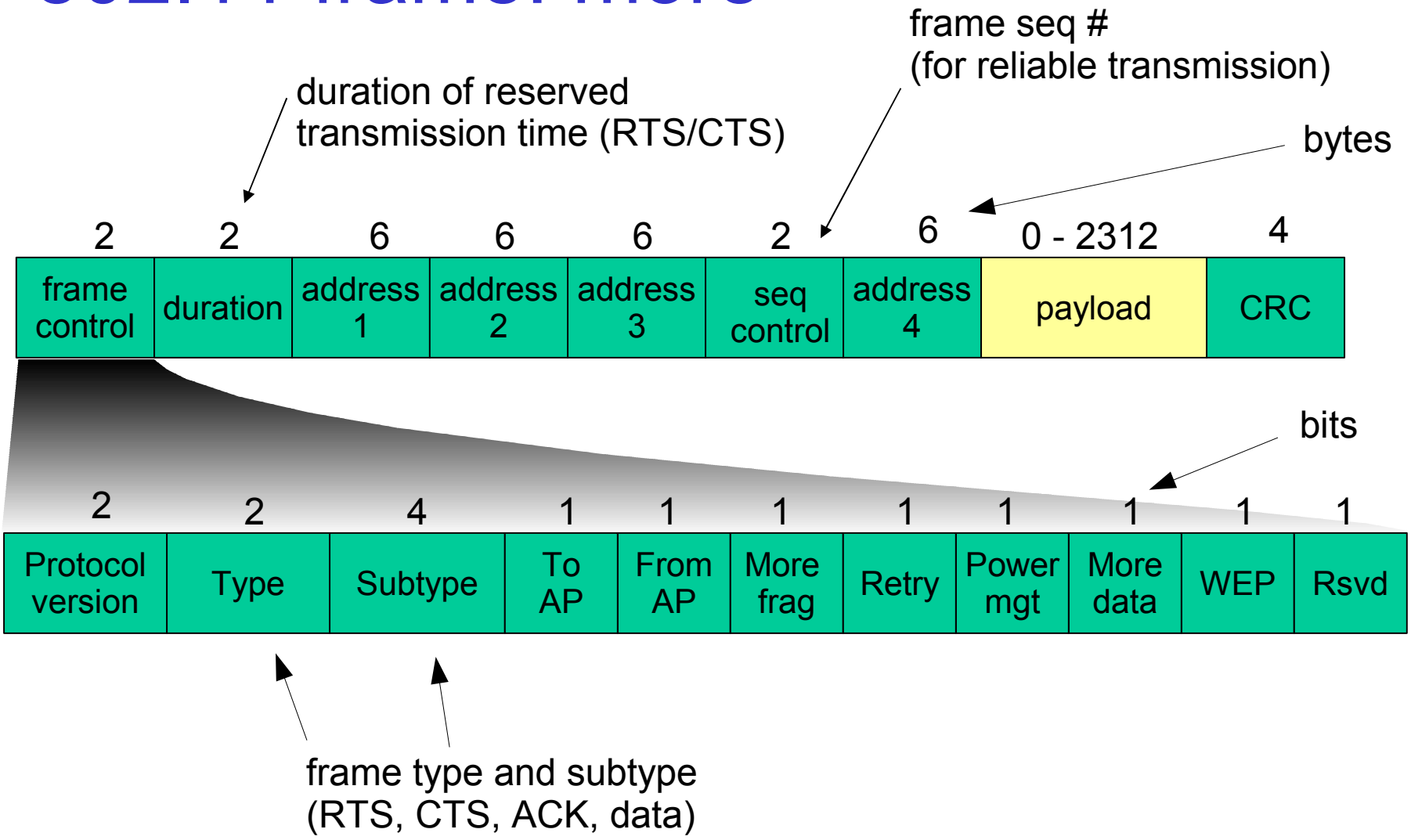
Address 3: MAC address of router interface to which AP is attached

Address 4: used only for "mesh" networks

802.11 frame: addressing

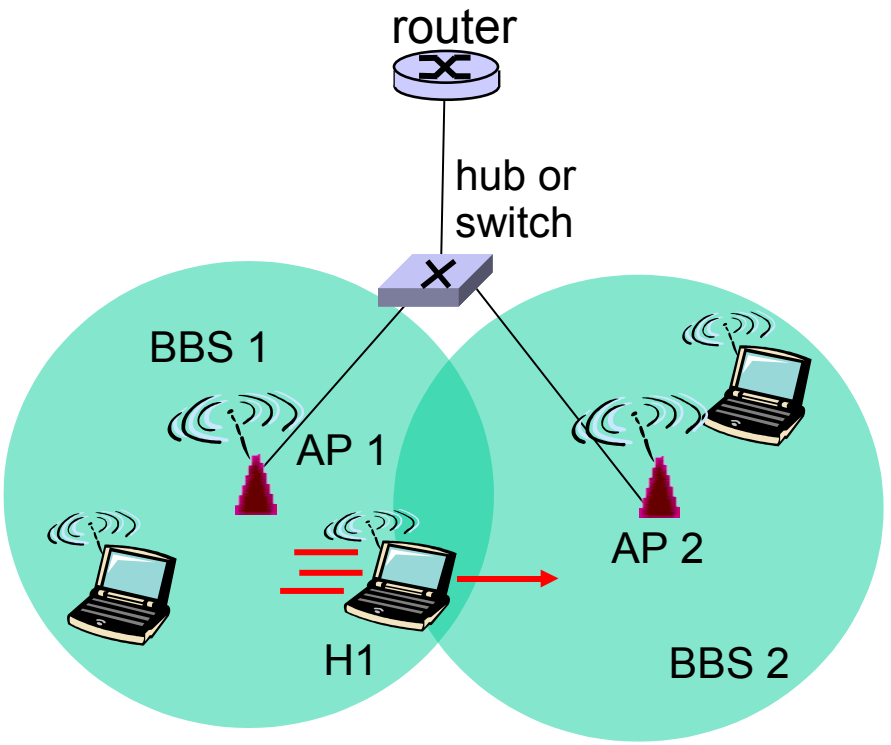


802.11 frame: more



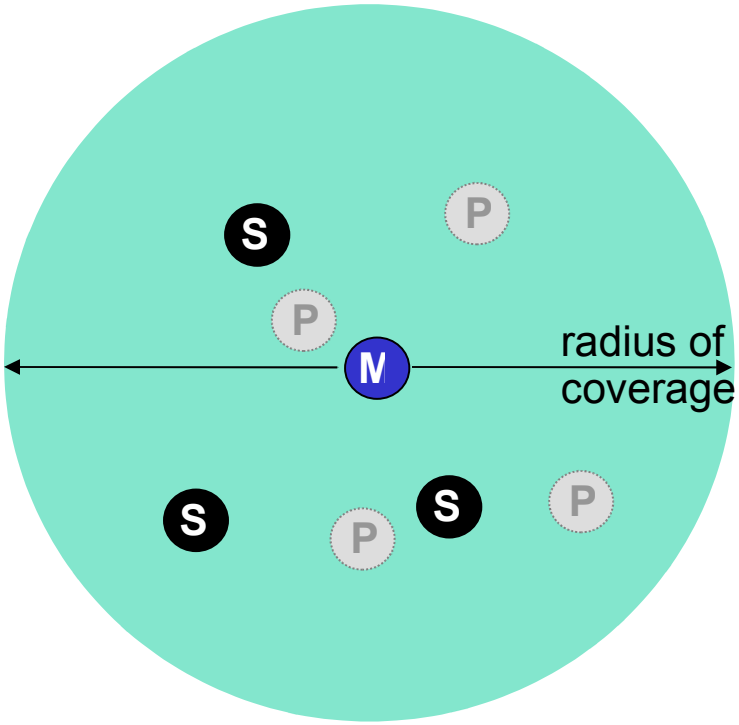
802.11: mobility within same subnet

- H1 remains in same IP subnet: IP address can remain same
- switch: which AP is associated with H1?
  - self-learning (Ch. 5): switch will see frame from H1 and "remember" which switch port can be used to reach H1



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)

Cellular Internet Access

- Cellular Phone Networks
  - complex, but highly engineered
  - high reliability
  - licensed radio spectrum
- Packet service / Internet access possible
- Wide-area coverage
- Expensive and low bitrate
  - compared to Wireless LAN

Recap

- Wireless link-layer
  - Introduction
    - Wireless hosts, base stations, wireless links
  - Characteristics of wireless links
    - Signal strength, interference, multipath propagation
    - Hidden terminal, signal fading problems
  - 802.11 wireless LANs
    - CSMA/CA
    - Frame structure
  - 802.15 networking
  - Cellular Internet access

Next time

- Start on the Network layer
  - Introduction
  - Virtual circuit vs. datagram details
  - IP: the Internet Protocol