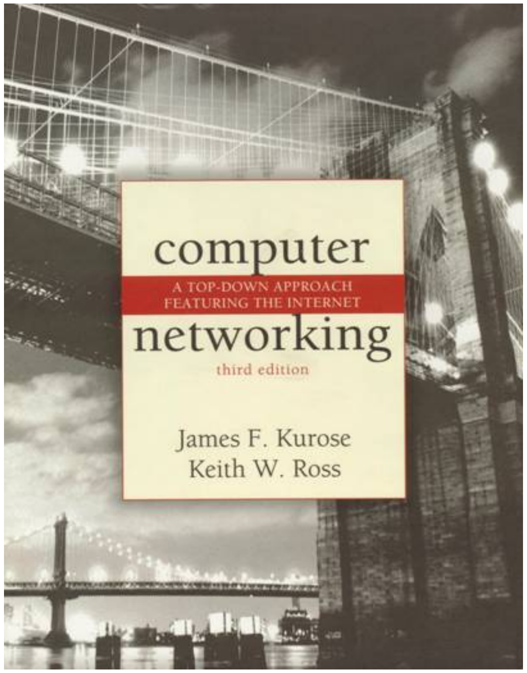
Chapter 6
Wireless and Mobile Networks



Computer Networking: A Top Down Approach Featuring the Internet, 3rd edition.
Jim Kurose, Keith Ross
Addison-Wesley, July 2004.

Chapter 6: Wireless and Mobile 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

Chapter 6 outline

6.1 Introduction

Wireless

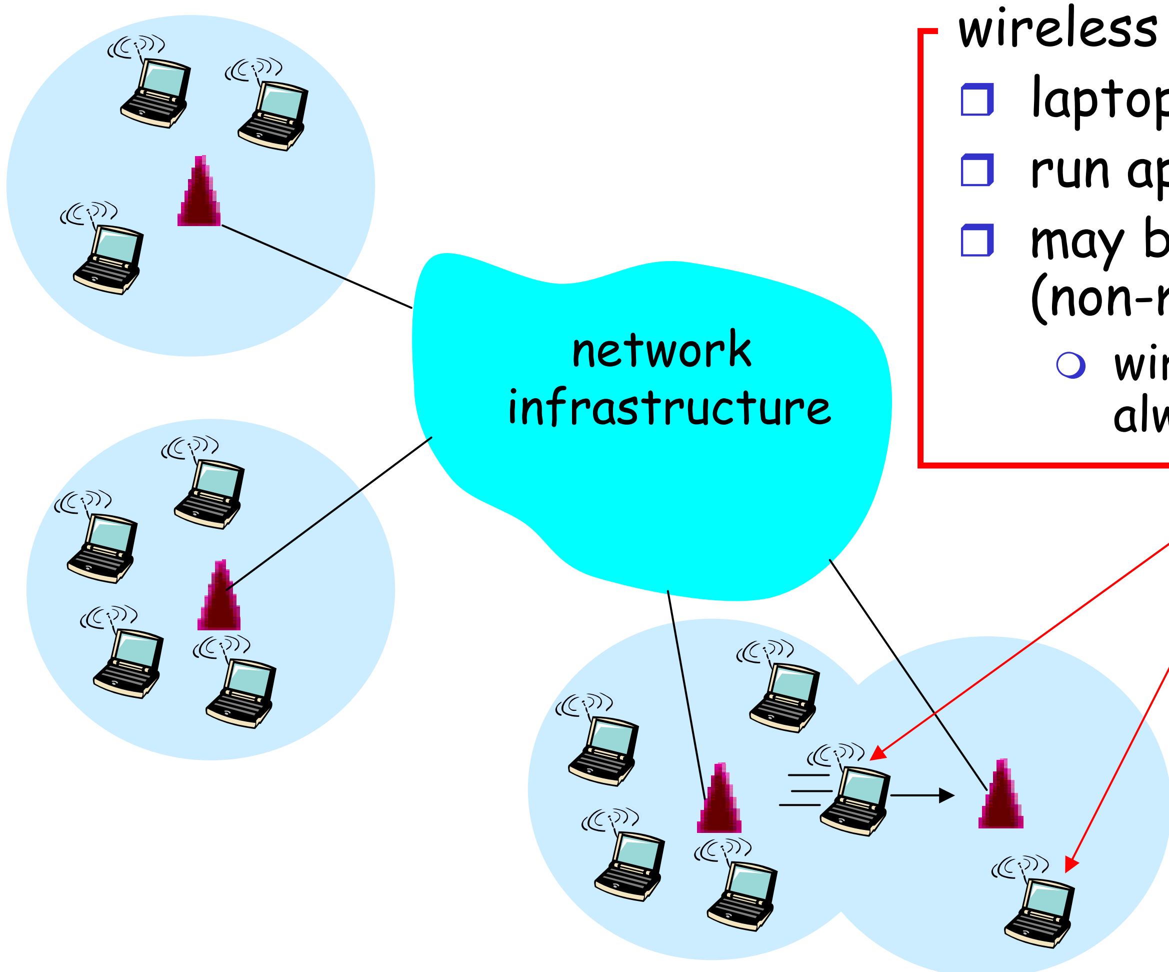
- 6.2 Wireless links, characteristics
  - CDMA
- 6.3 IEEE 802.11 wireless LANs ("wi-fi")
- 6.4 Cellular Internet Access
  - architecture
  - standards (e.g., GSM)

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

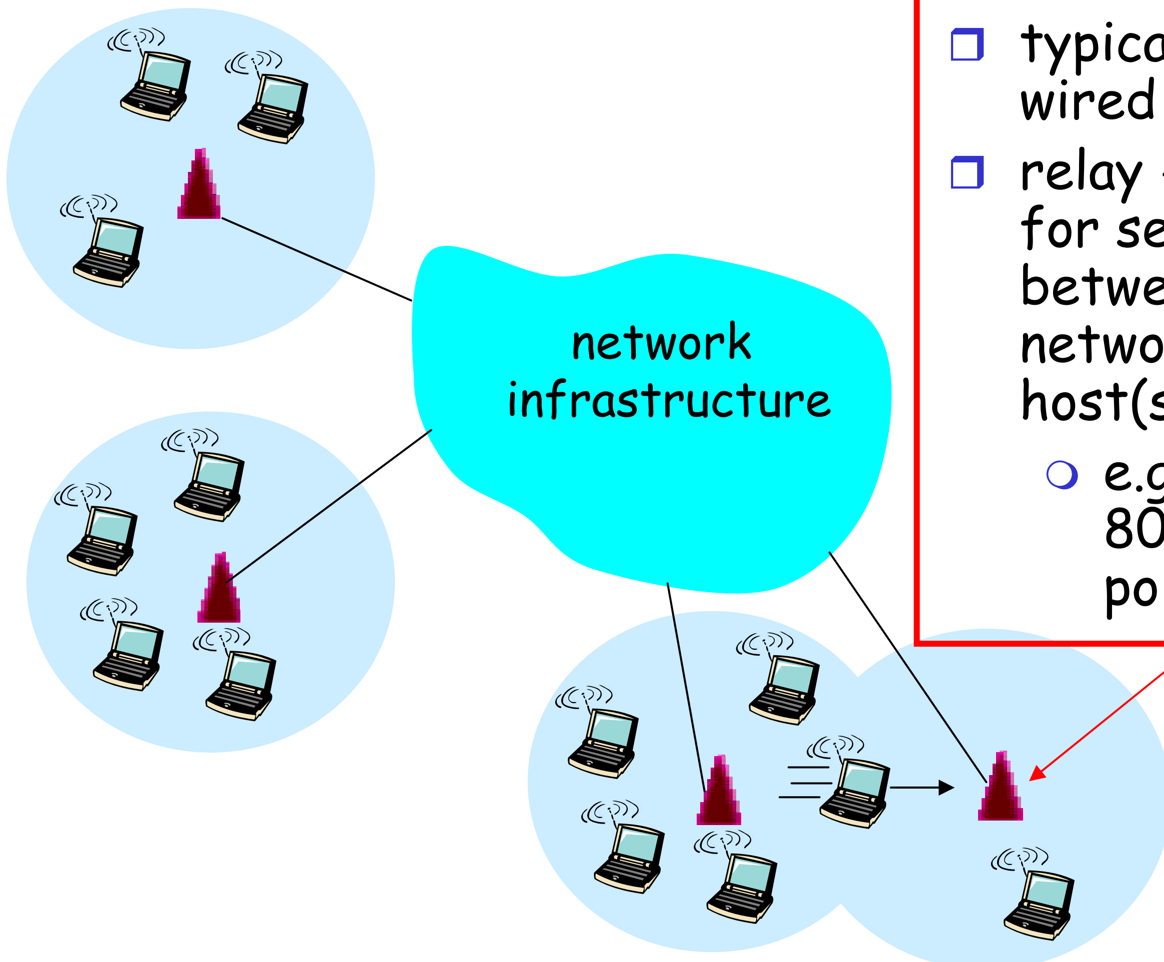
Elements of a wireless network



wireless hosts

- laptop, PDA, IP phone
- run applications
- may be stationary (non-mobile) or mobile
  - wireless does *not* always mean mobility

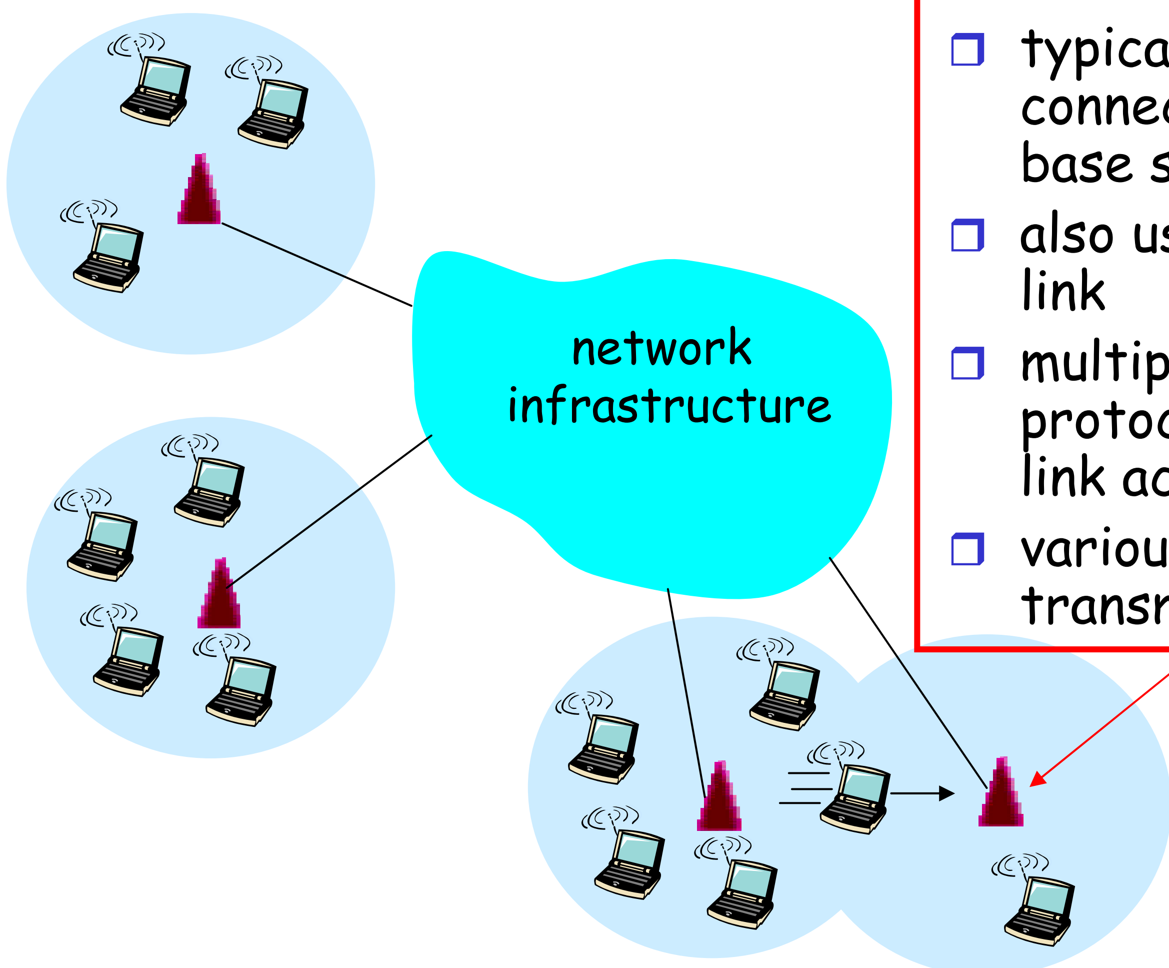
Elements of a wireless network



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

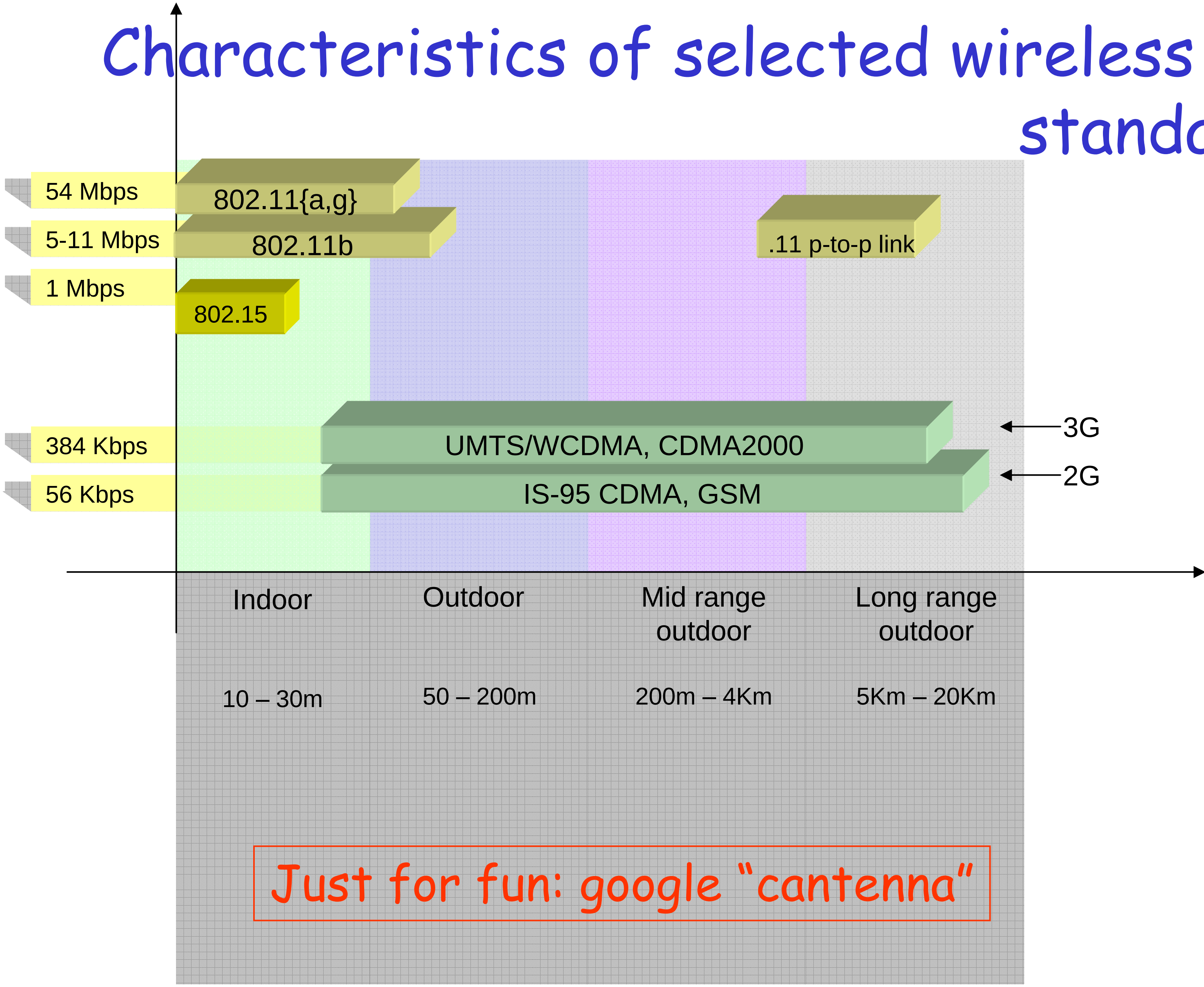
Elements of a wireless network



wireless link

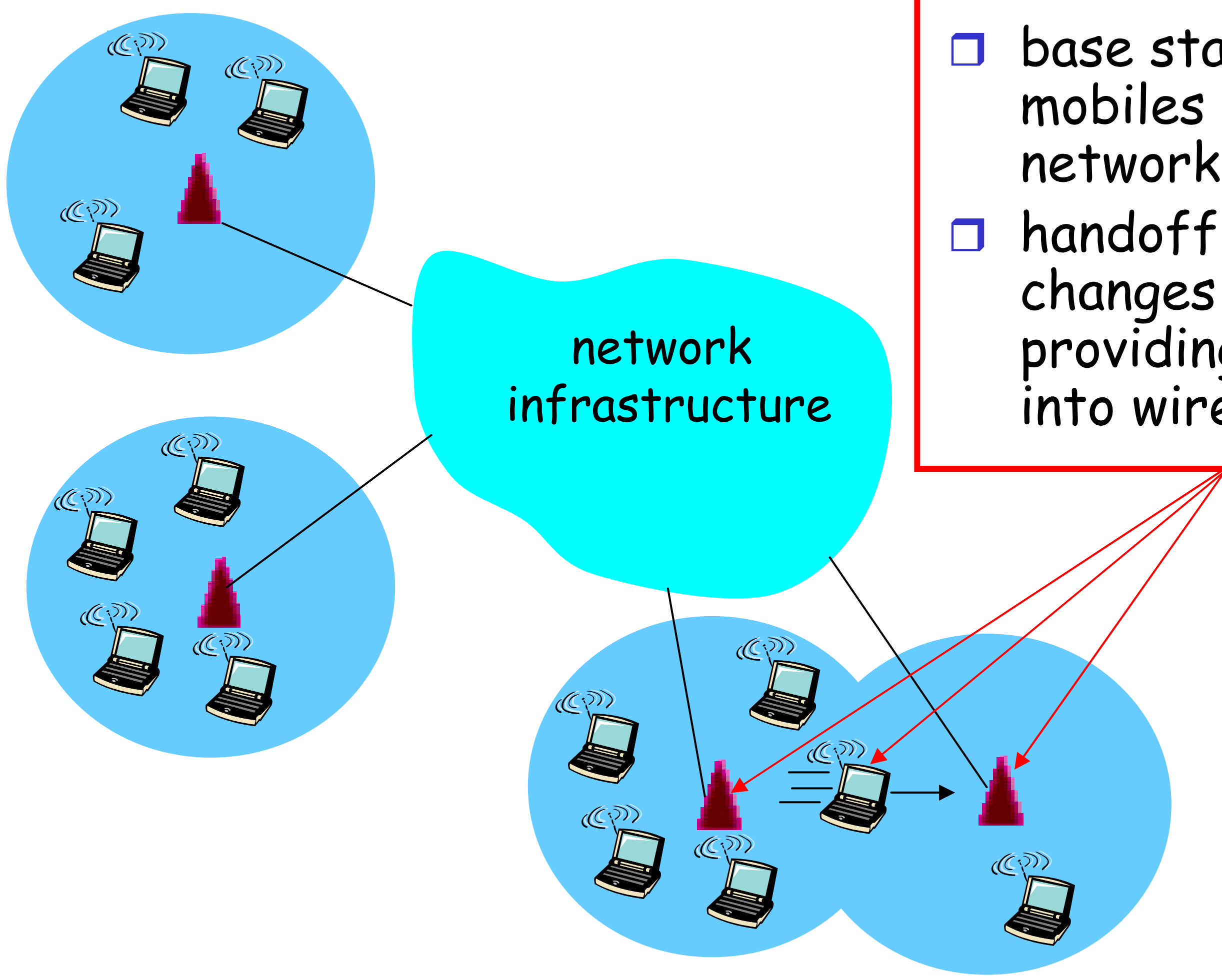
- typically used to connect mobile(s) to base station
- also used as backbone link
- multiple access protocol coordinates link access
- various data rates, transmission distance

Characteristics of selected wireless link standards



Just for fun: google "cantenna"

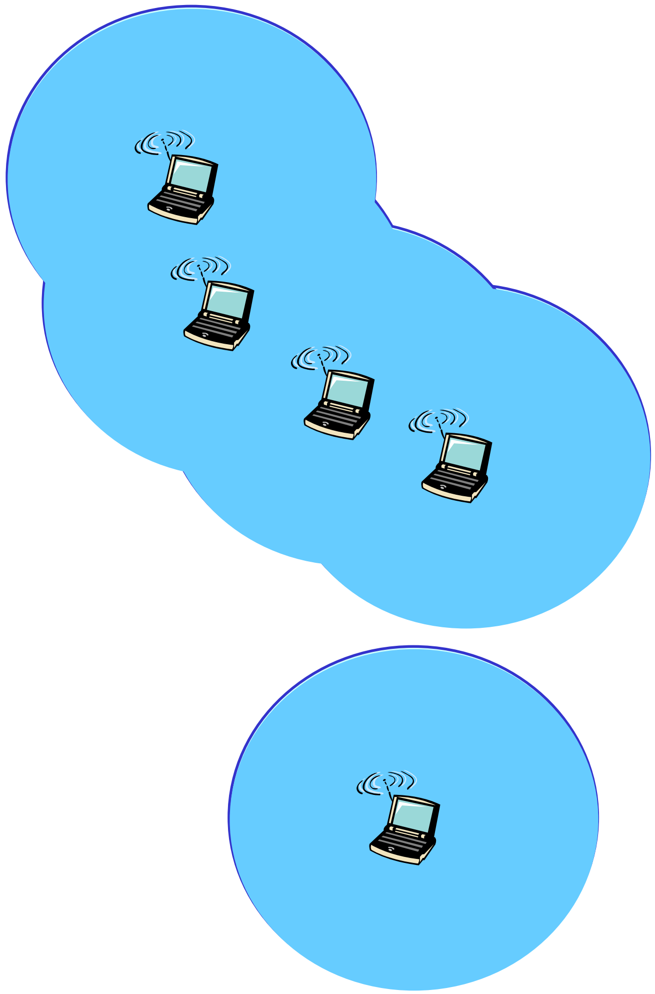
Elements of a wireless network



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

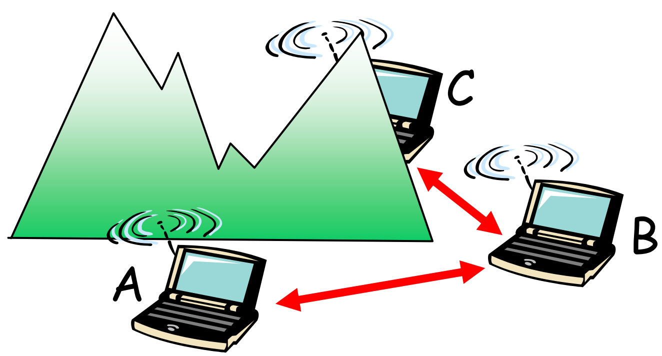
Differences from wired link ….

- 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

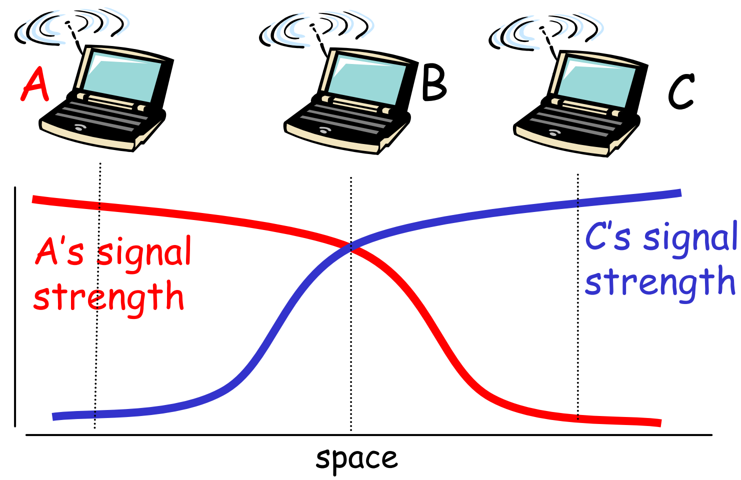
Multiple wireless senders and receivers create additional problems (beyond multiple access):



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



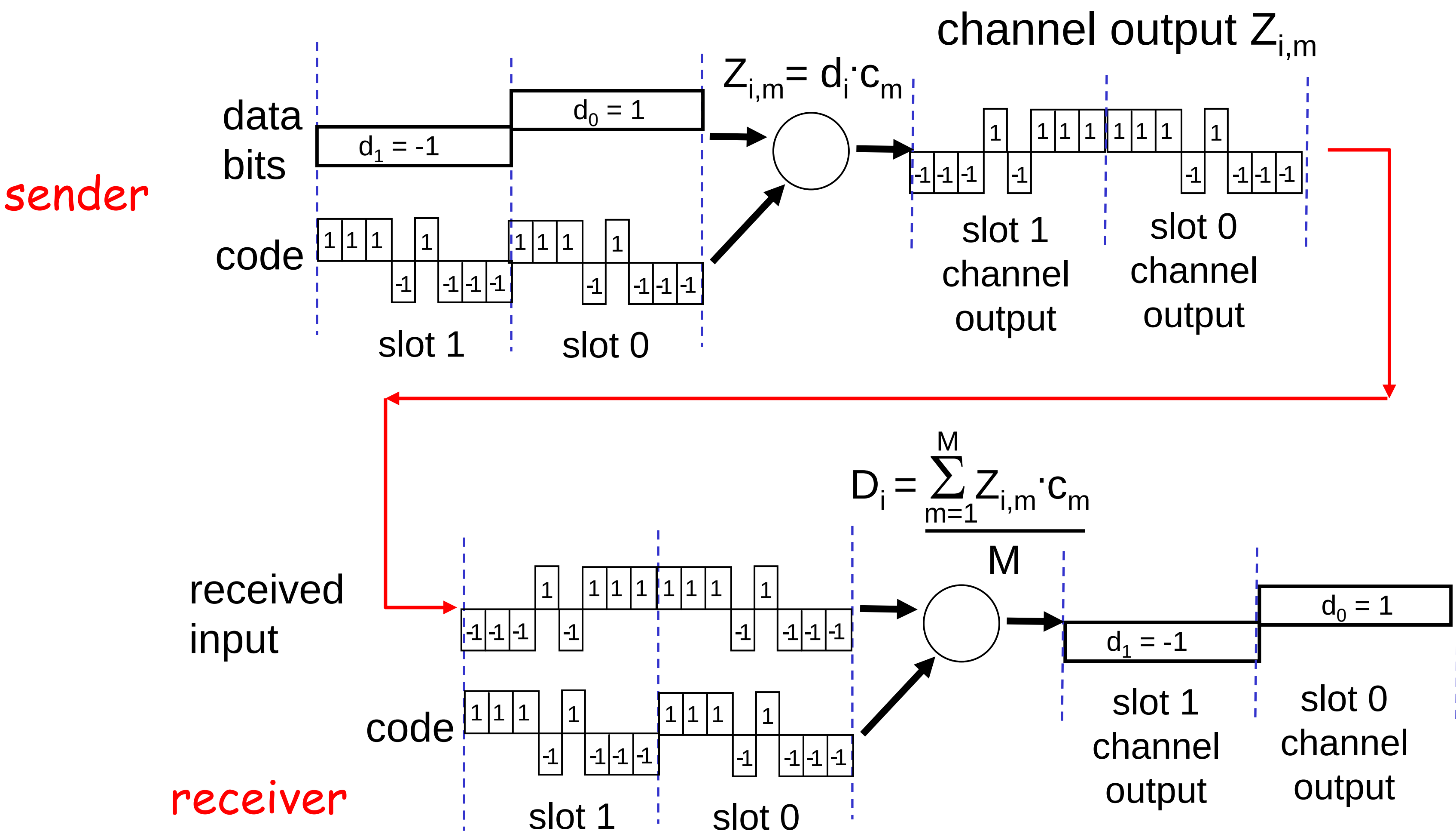
Signal fading:

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

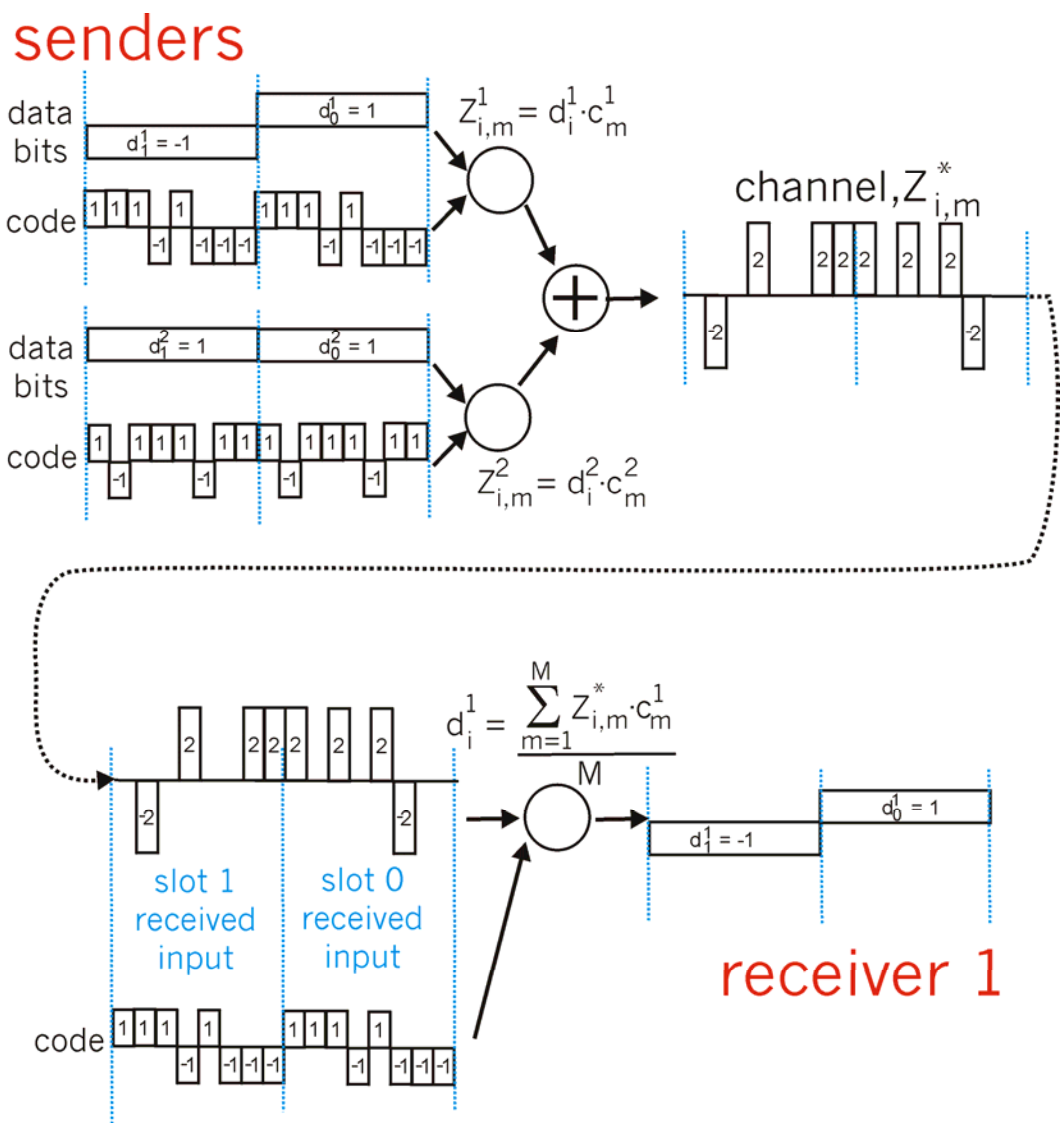
Code Division Multiple Access (CDMA)

- 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")

CDMA Encode/Decode



CDMA: two-sender interference



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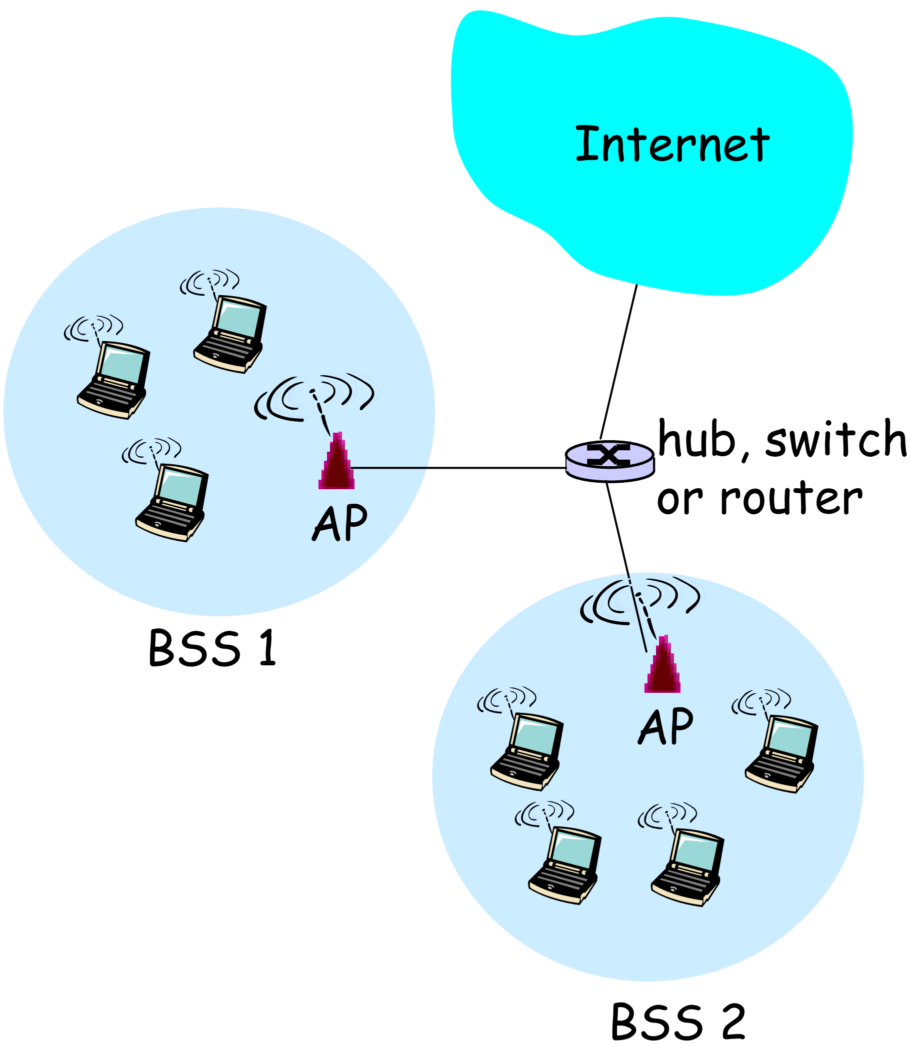
IEEE 802.11 Wireless LAN

- 802.11b
  - 2.4-2.485 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
  - 5.1-5.8 GHz range
  - up to 54 Mbps
- 802.11g
  - 2.4-2.485 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



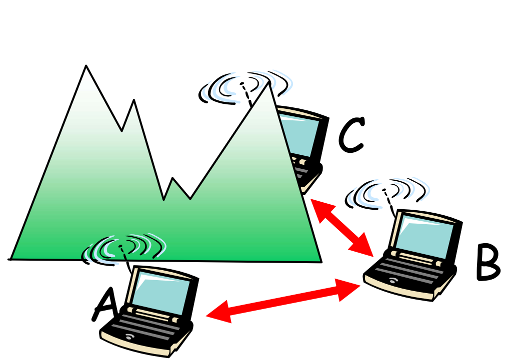
- wireless host communicates with base station
  - base station = access point (AP)
- Basic Service Set (BSS) (aka "cell") in infrastructure mode contains:
  - wireless hosts
  - access point (AP): base station
  - ad hoc mode: hosts only

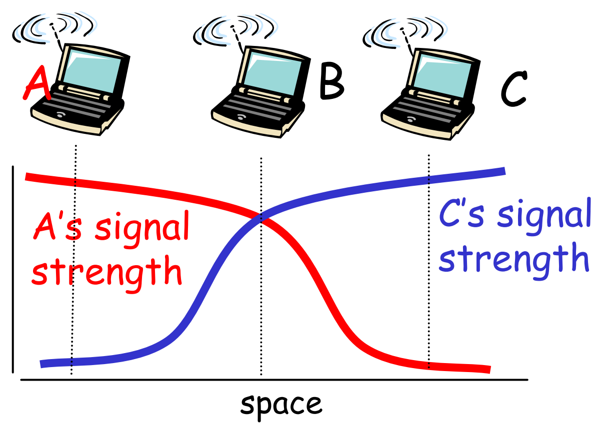
802.11: Channels, association

- 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 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: 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) – hardware expensive!
  - can't sense all collisions in any case: hidden terminal, fading
  - goal: *avoid collisions:* CSMA/C(ollision)A(voidance)





802.11 MAC : CSMA/CA -- overview

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

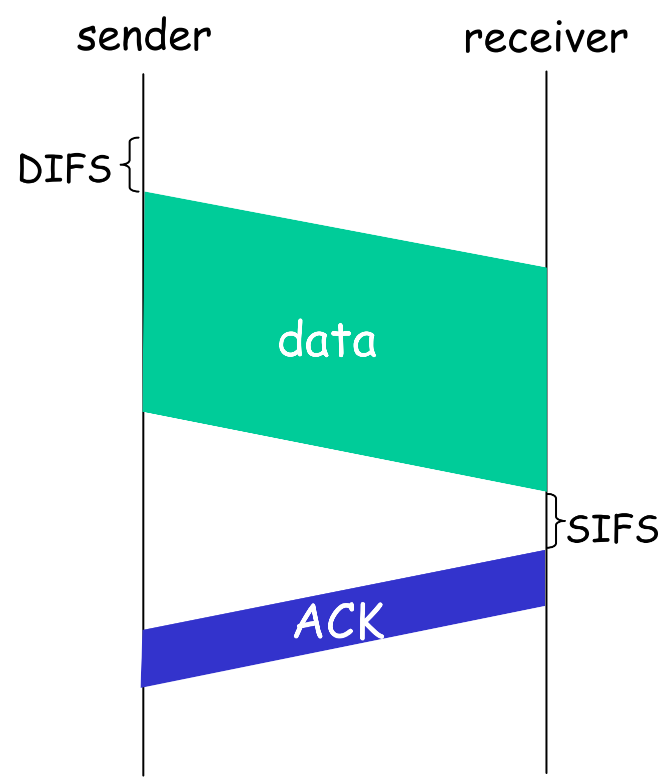
transmit when timer expires

if no ACK, increases random backoff interval, repeat 2

802.11 receiver

- if frame received OK

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



802.11: Carrier-sensing functions

- Physical carrier-sensing:
  difficult (or expensive), and not comprehensive (due to fading, hidden terminal, etc), as discussed before
- Virtual carrier-sensing: network allocation vector (NAV):
  most 802.11 frames have a field to reserve the medium for some time period
  - Sending station set NAV (e.g. 10)
  - Other stations count down from NAV (=10) to 0
    - If NAV > 0, medium busy
    - If NAV = 0, medium idle
- Either physical or virtual carrier-sensing indicates medium busy ➔ MAC report busy to higher layer

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

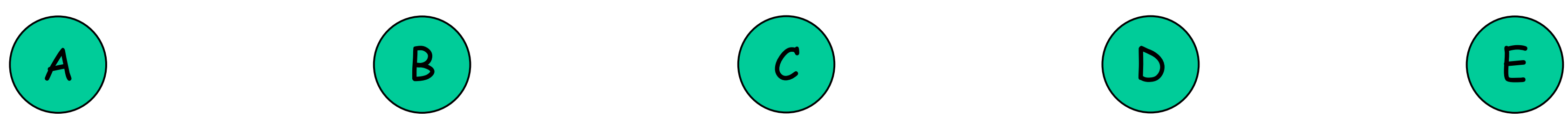
Avoid data frame collisions
using small reservation packets!

Infrastructure of RTS/CTS

- RTS announces the intent to send a pkt; it includes:
  - Sender/Receiver's MAC address
  - Duration of reservation (ms)
- CTS indicates that medium is available; includes:
  - Sender/Receiver's MAC address
  - Duration of reservation remaining (ms)

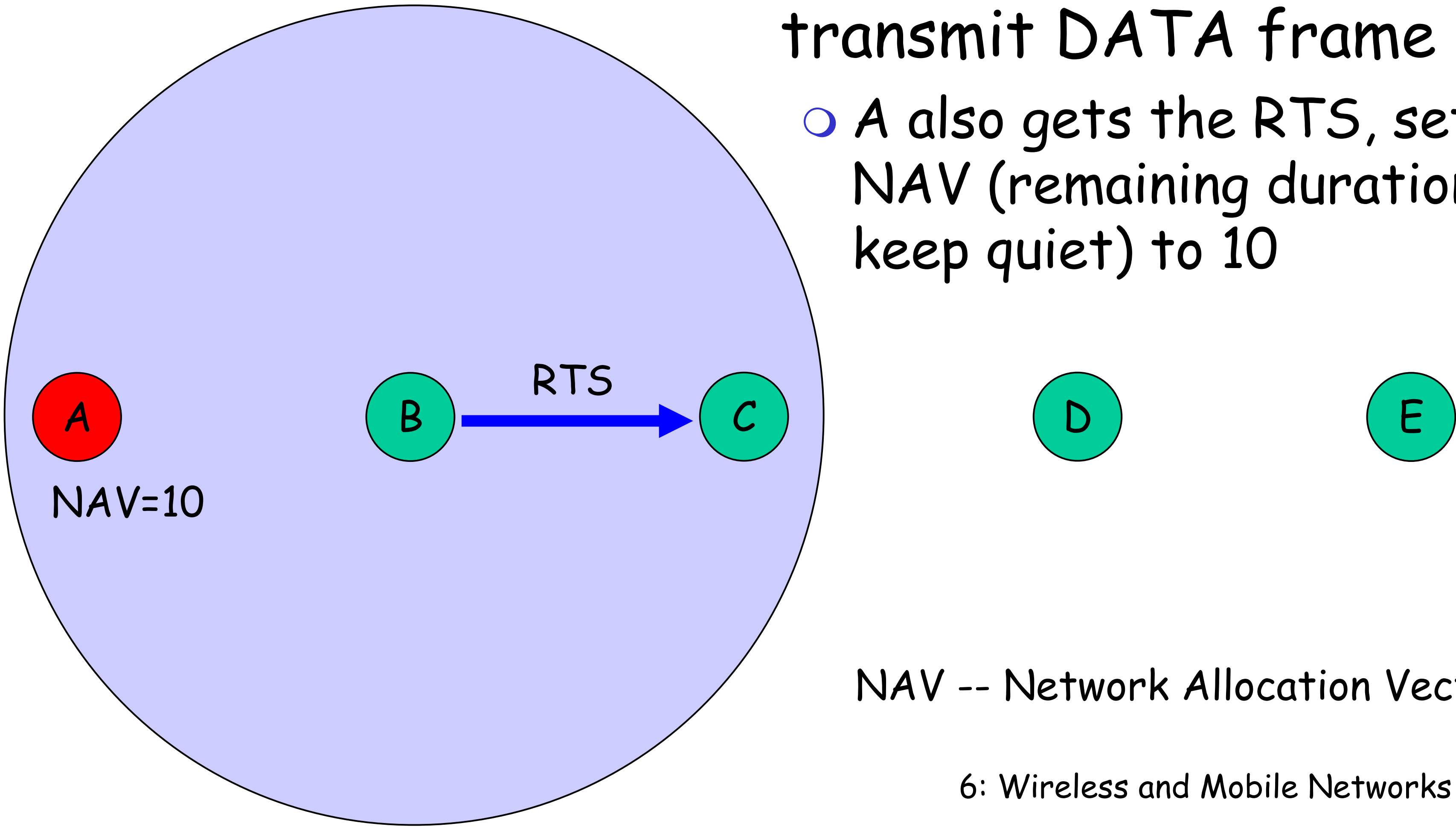
RTS-CTS example

- B wants to send a DATA frame to C
- D cannot hear from B, B cannot hear from D: hidden terminals



RTS-CTS example (continue)

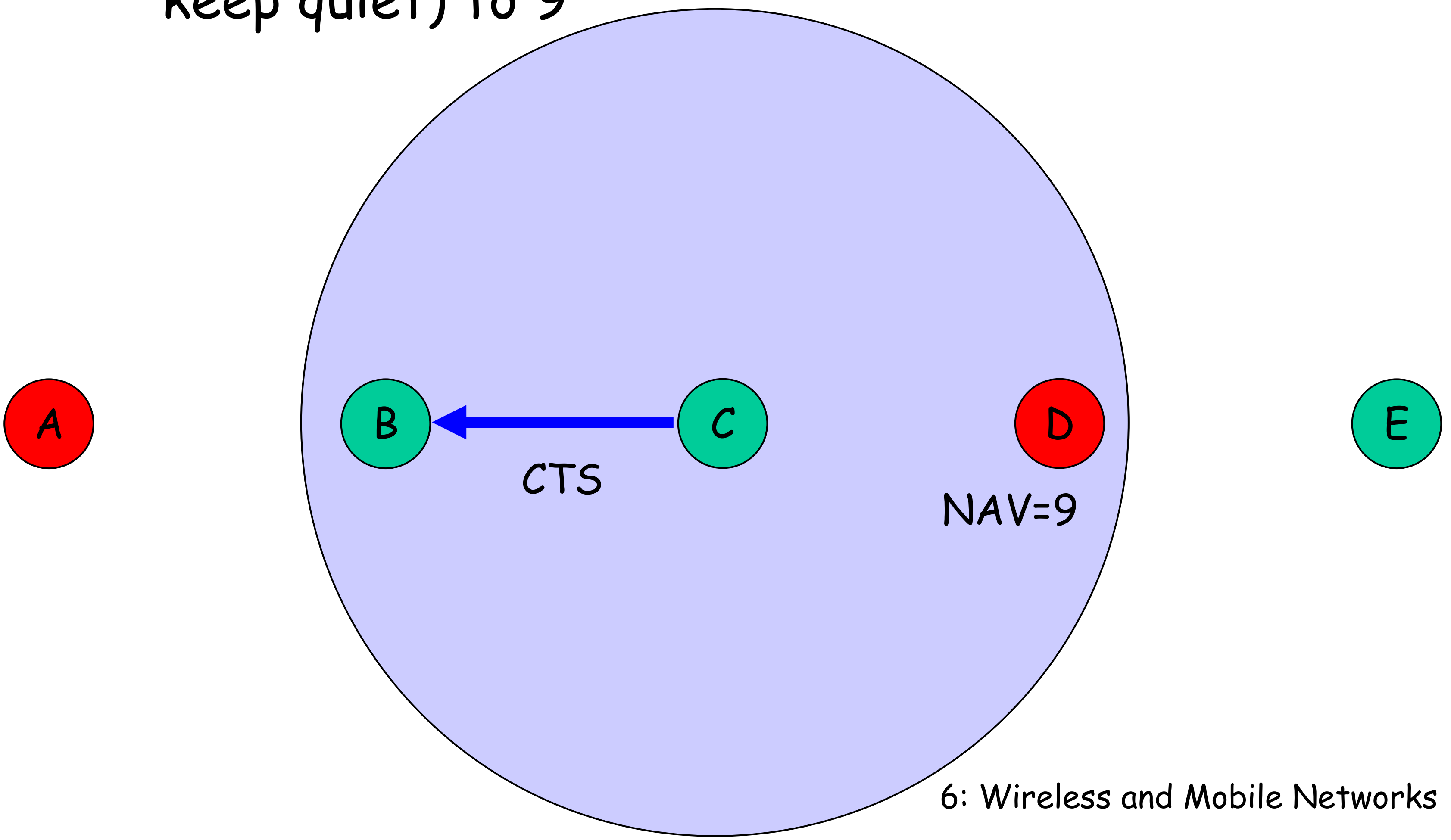
- Step 1: B broadcasts a RTS (request to send) to C to reserve 10 time slots to transmit DATA frame
  - A also gets the RTS, set NAV (remaining duration to keep quiet) to 10



NAV -- Network Allocation Vector

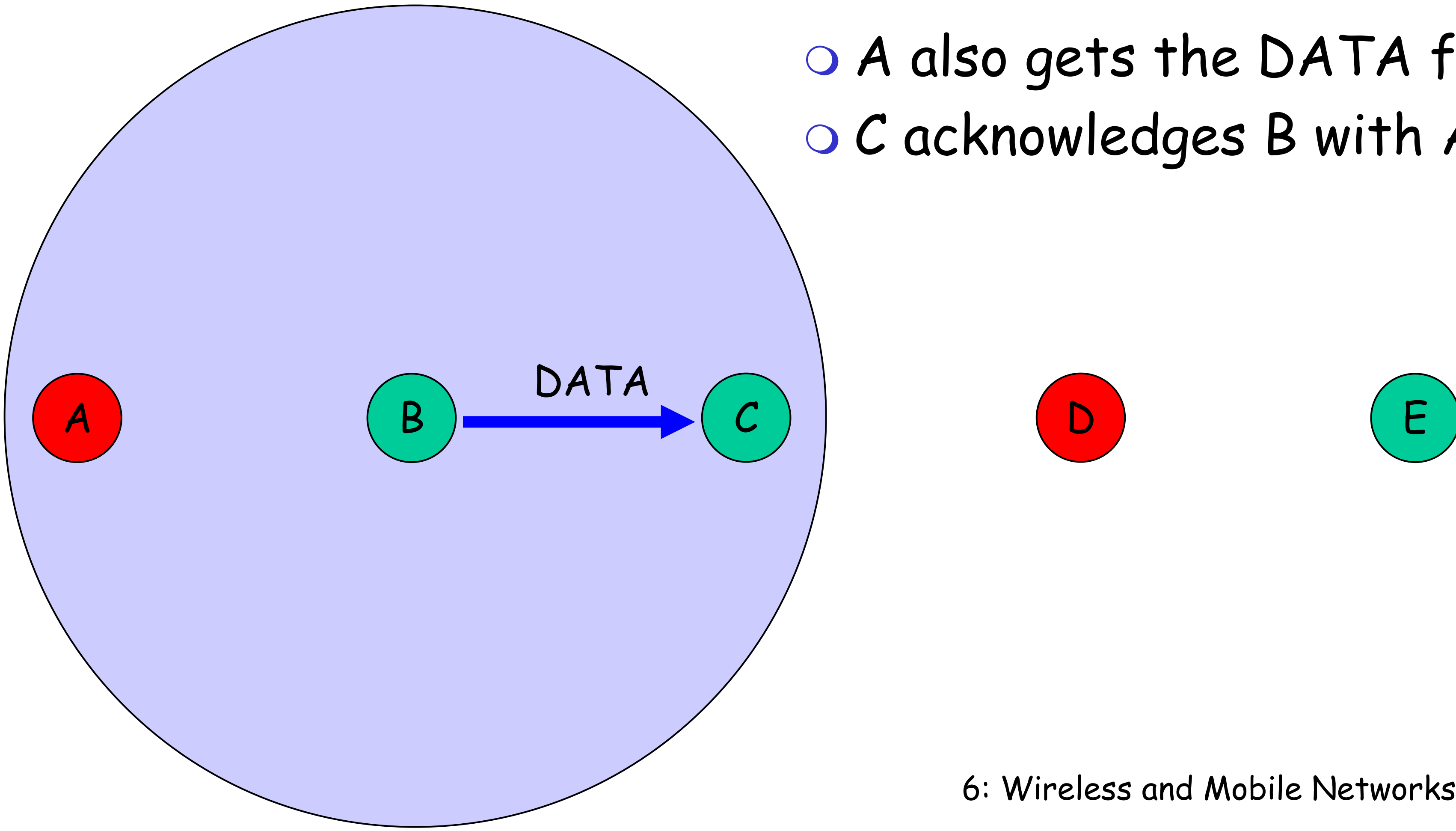
RTS-CTS example (continue)

- Step 2: C broadcasts a CTS (clear to send) to B
  - D also gets the CTS, set NAV (remaining duration to keep quiet) to 9



RTS-CTS example (continue)

- Step 3: B send DATA frame to C
  - A also gets the DATA frame
  - C acknowledges B with ACK



Collision Avoidance w/ RTS and CTS

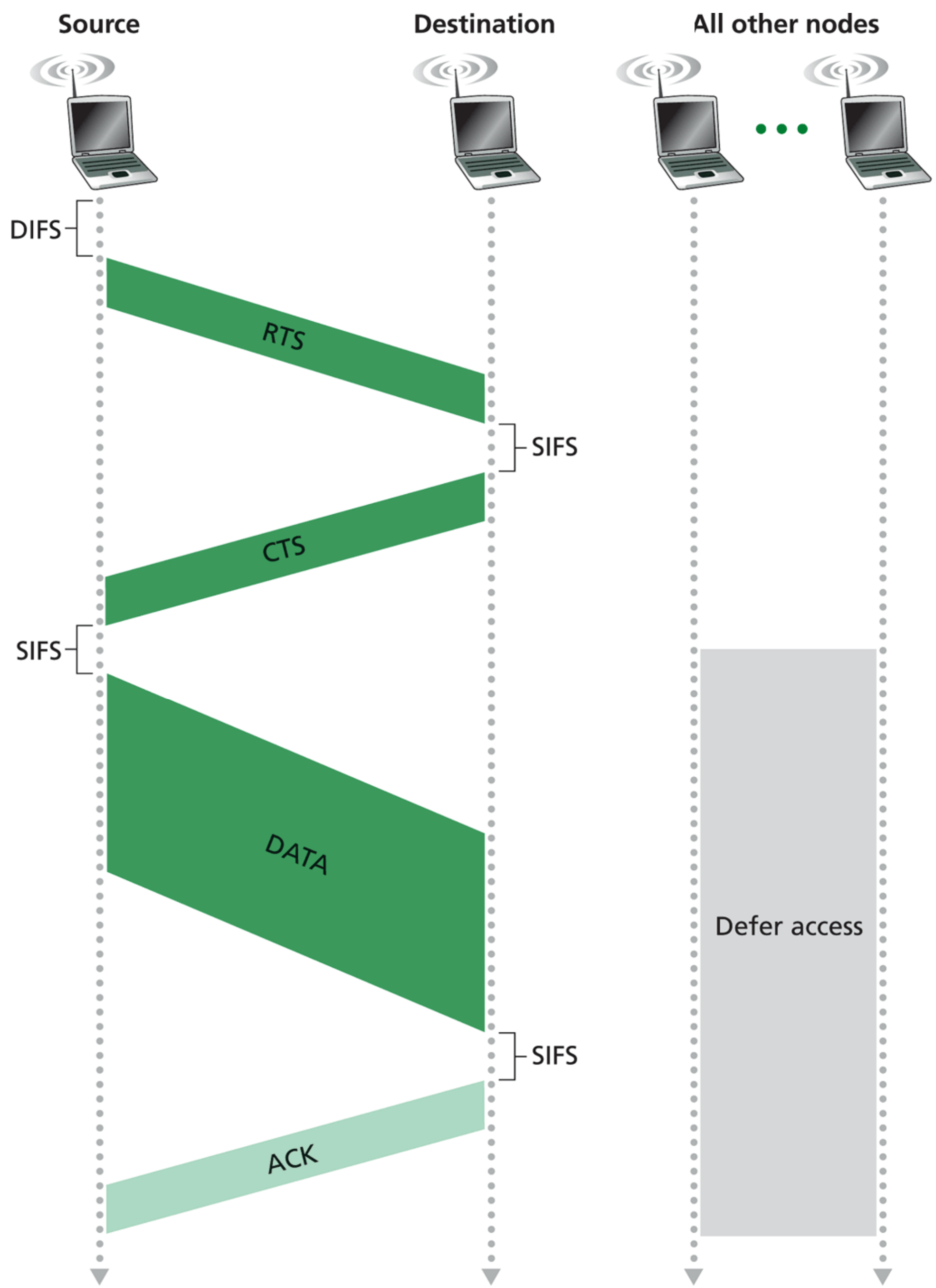


Figure 6.10 ♦ Collision avoidance using the RTS and CTS frames

802.11 MAC: inter-frame spacing

- Distributed inter-frame space (**DIFS)**: If **channel is sensed idle** for DIFS, a station can transmit.
- Short inter-frame space (SIFS): used for the highest-priority transmissions such as RTS/CST frames and ACKs.
  - Example: When receiving station has correctly & completely received a frame, it waits a **SIFS** and then **sends an ACK**
- **DIFS > SIFS**

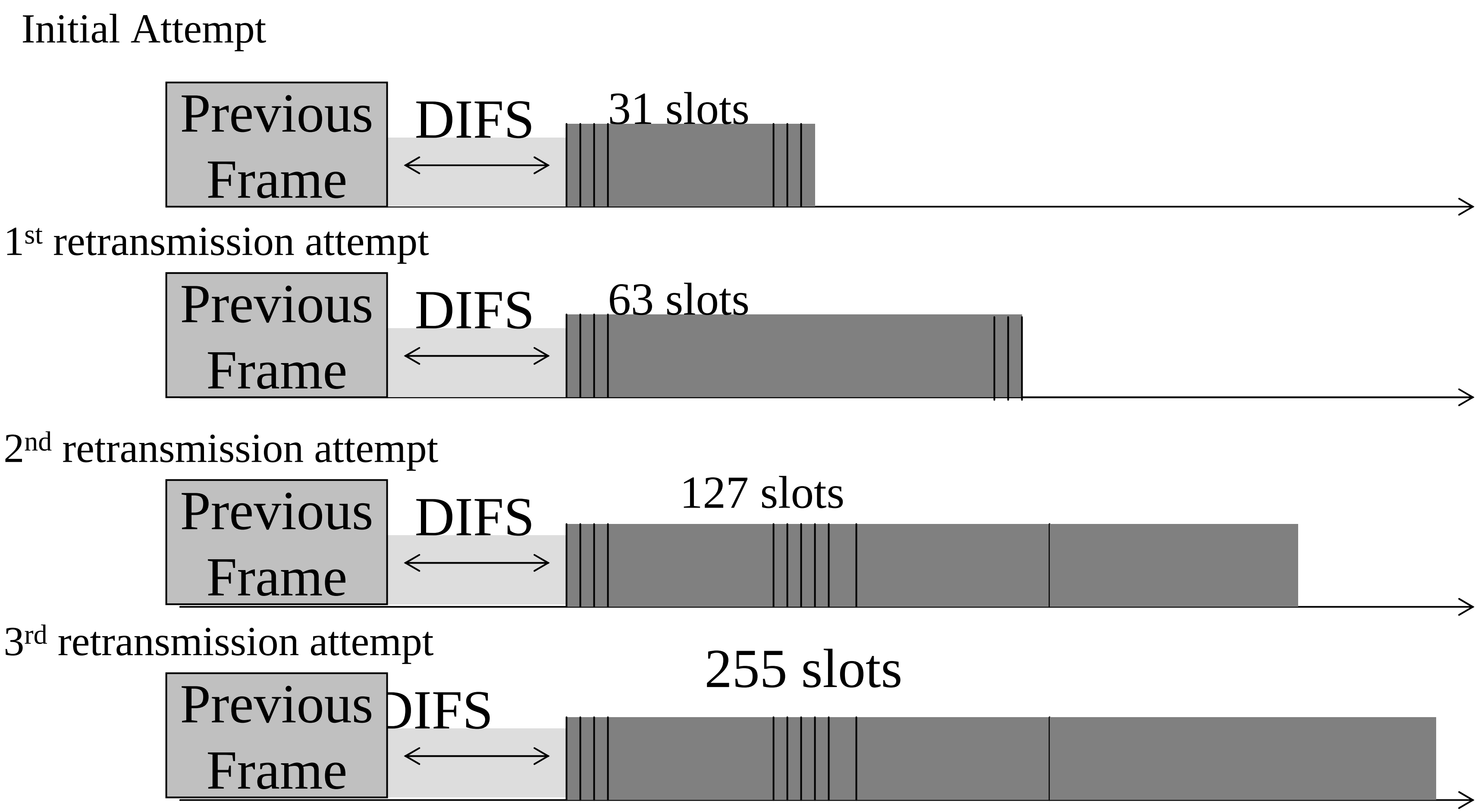
802.11 MAC: Random Backoff

- If channel is sensed busy **will defer its access** until the channel is later sensed to be idle
- Once the channel is sensed to be **idle for time DIFS**, the station computes an **additional random backoff time** and counts down this time as the channel is sensed idle. When the random backoff timer reaches zero, the station transmits its frame
- If in the middle of counting down, the channel is sensed busy: freeze counter. When channel is idle again, wait DIFS, then continue counting down.
- Backoff process to avoid having multiple stations immediately begin transmission and thus collide

802.11 MAC: Random Backoff (more)

- Contention (or backoff) window follows the DIFS
- Window is divided in time slots
- Hosts **randomly pick a** slot and **start counting down.**
- Host that picks the first slot (smallest number) wins
- Each time the retry counter increases, the contention window doubles
- contention window is reset to its minimum size when frames are transmitted successfully, or the associated maximum retry counter is reached and the frame is discarded

Example of random backoff



MAC: Ethernet and 802.11

- Discussion
  - Similarity
    - Random access
    - Carrier sensing
    - Exponential backoff
    - ….
  - Difference
    - Physical carrier sensing and virtual carrier sensing
    - Collision detection and collision avoidance
    - Details of the exponential backoff procedure is different. When does a node enter exponential backoff?
    - Link-layer ack

802.11 frame: addressing

2	2	6	6	6	2	6	0 - 2312	4
frame control	duration	address 1	address 2	address 3	seq control	address 4	payload	CRC

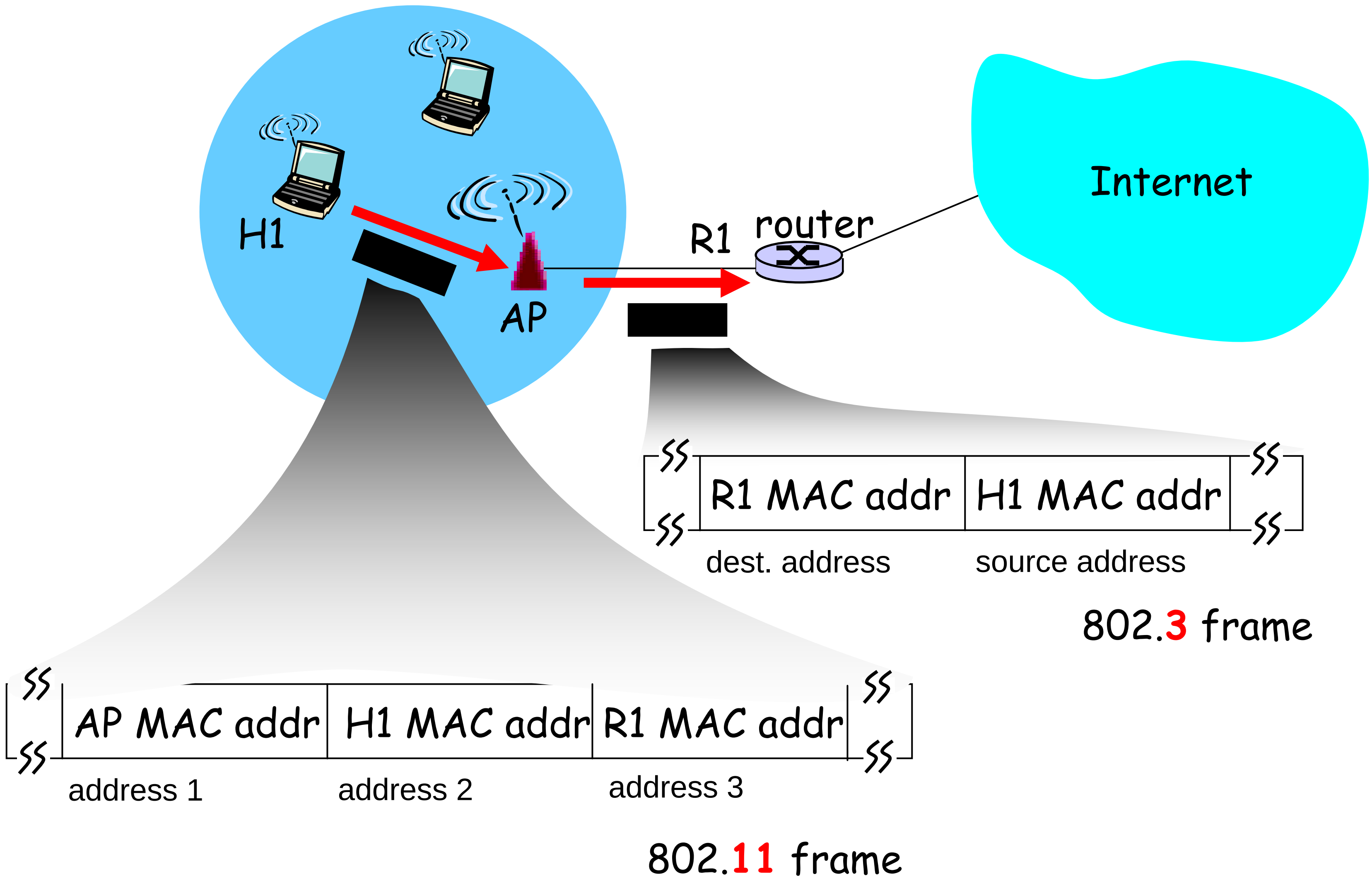
Address 1: MAC address of wireless host or AP to receive this frame

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

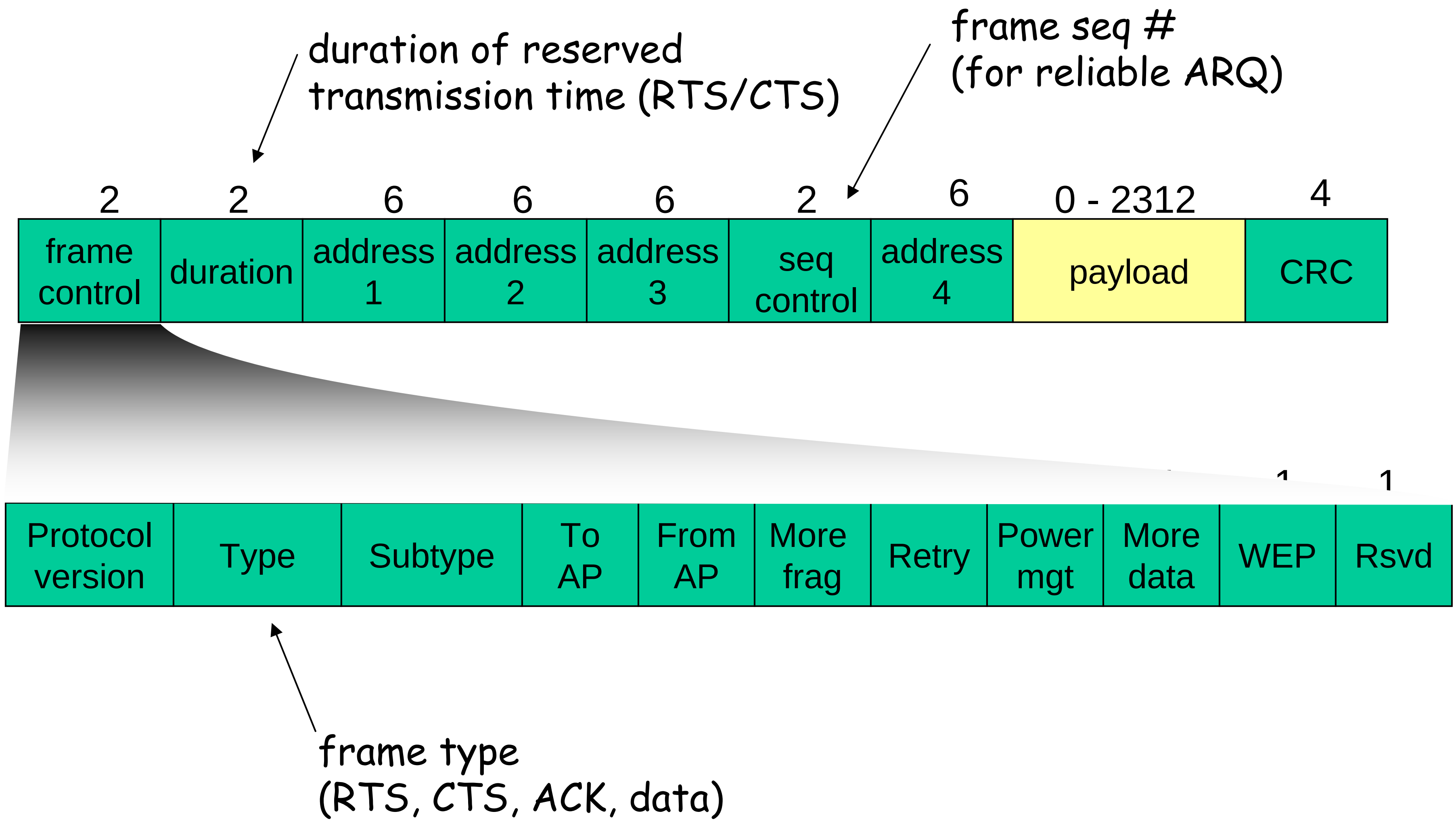
Address 3: MAC address of router interface to which AP is attached

Address 4: used only in ad hoc mode

802.11 frame: addressing

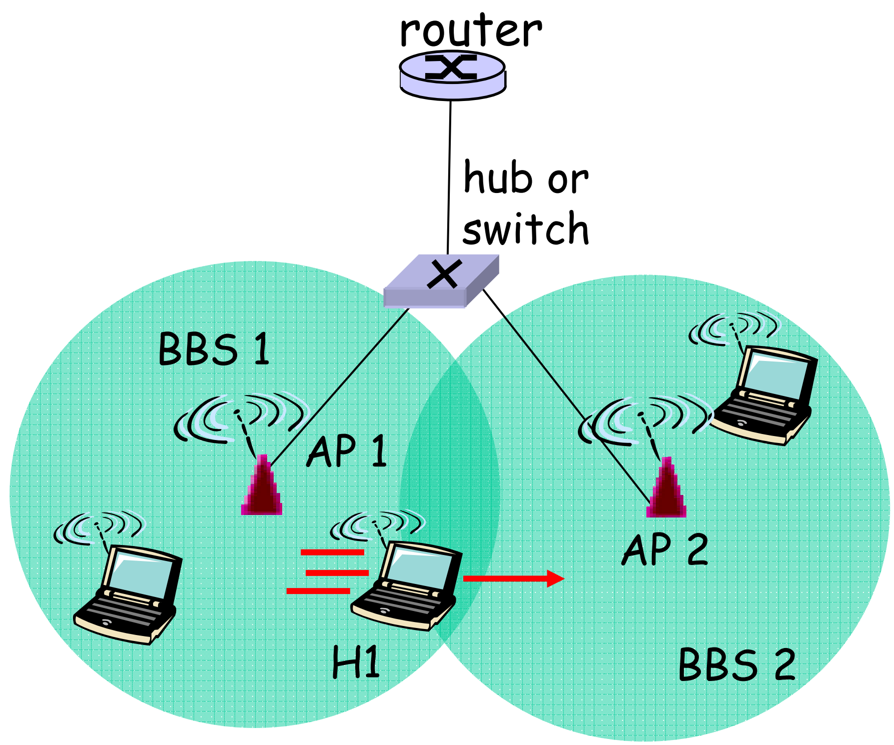


802.11 frame: more



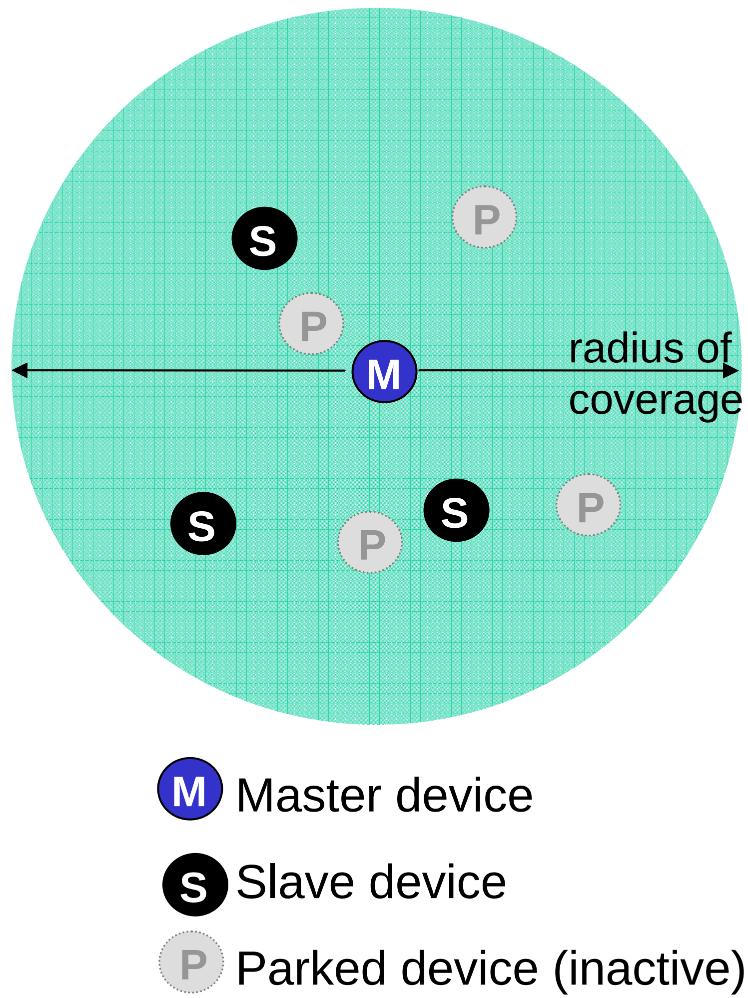
802.11: mobility within same subnet

- H1 remains in same IP subnet: IP address can remain same
- switch: which AP is associated with H1?
  - self-learning (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
- Bluetooth chip < $3 today!



The wireless world ....

- 802.11 (Wi-Fi)
- Bluetooth and 802.15
- Ultra-Wideband (UWB)
- Certified Wireless USB
- WiMAX (Worldwide Interoperability for Microwave Access and IEEE 802.16)
- WiBro (Wireless Broadband)
- Infrared (IrDA)
- Radio Frequency Identification (RFID)
- Near Field Communication (NFC)
- Near-Field Magnetic Communication
- HiperLAN
- HIPERMAN
- 802.20
- ZigBee (IEEE 802.15.4)