50.012 Networks

Lecture 20: Wireless Networks

2021 Term 6

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Outline

Wireless and mobile networks overview

Wi-Fi

Read textbook Section 7.1, 7.3

Wireless and Mobile Networks

Background:

- # wireless (mobile) phone subscribers now exceeds # wired phone subscribers (5-to-1)!
- # wireless Internet-connected devices equals # wireline Internet-connected devices
  - laptops, Internet-enabled phones promise anytime untethered Internet access

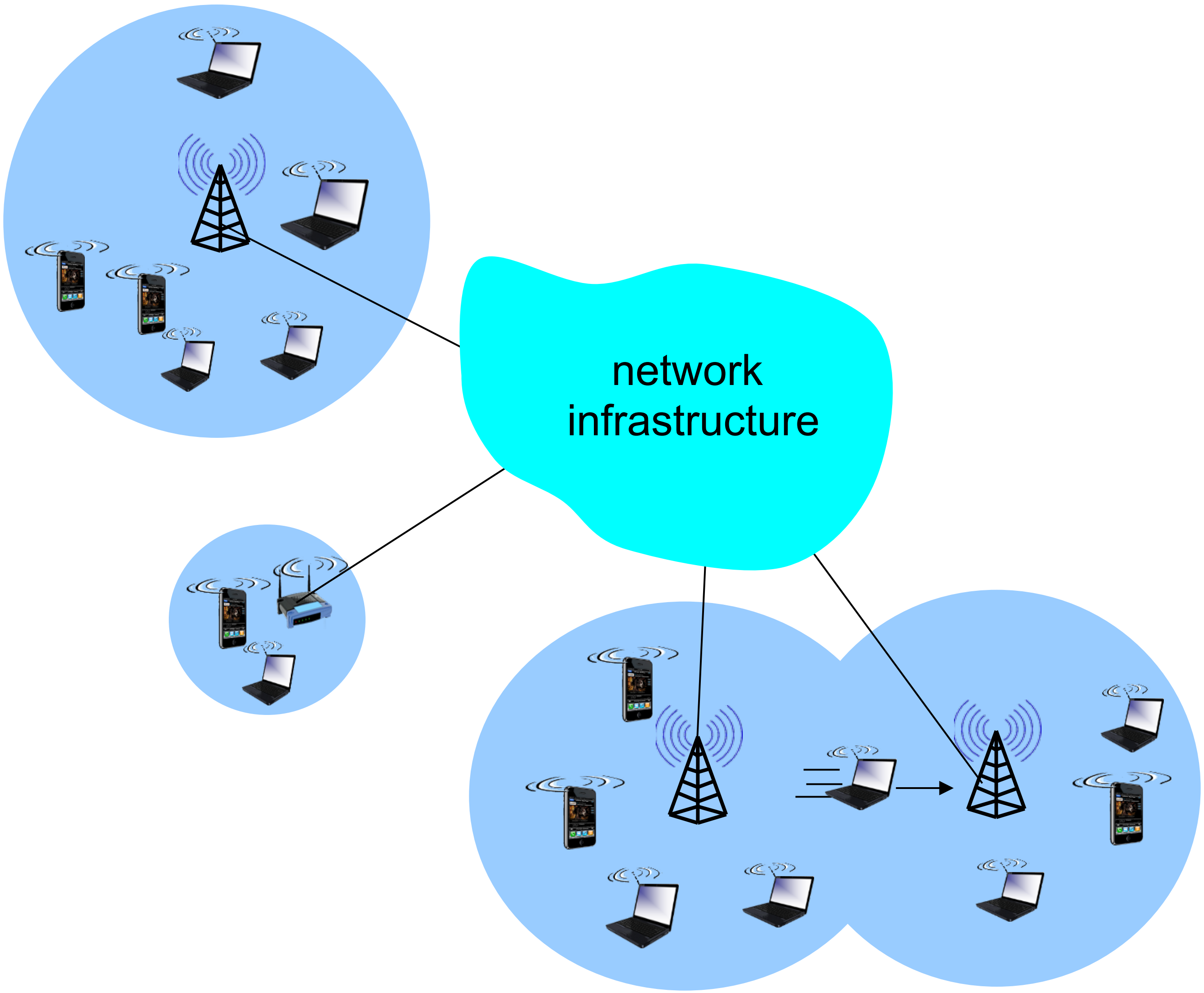
About 8000 Terabytes / day *(src: Nokia)*:

- 2001: global Internet
- 2010: global mobile traffic
- 2018: a country (Finland)'s internet traffic
- 5G and beyond: a single game in our national stadium

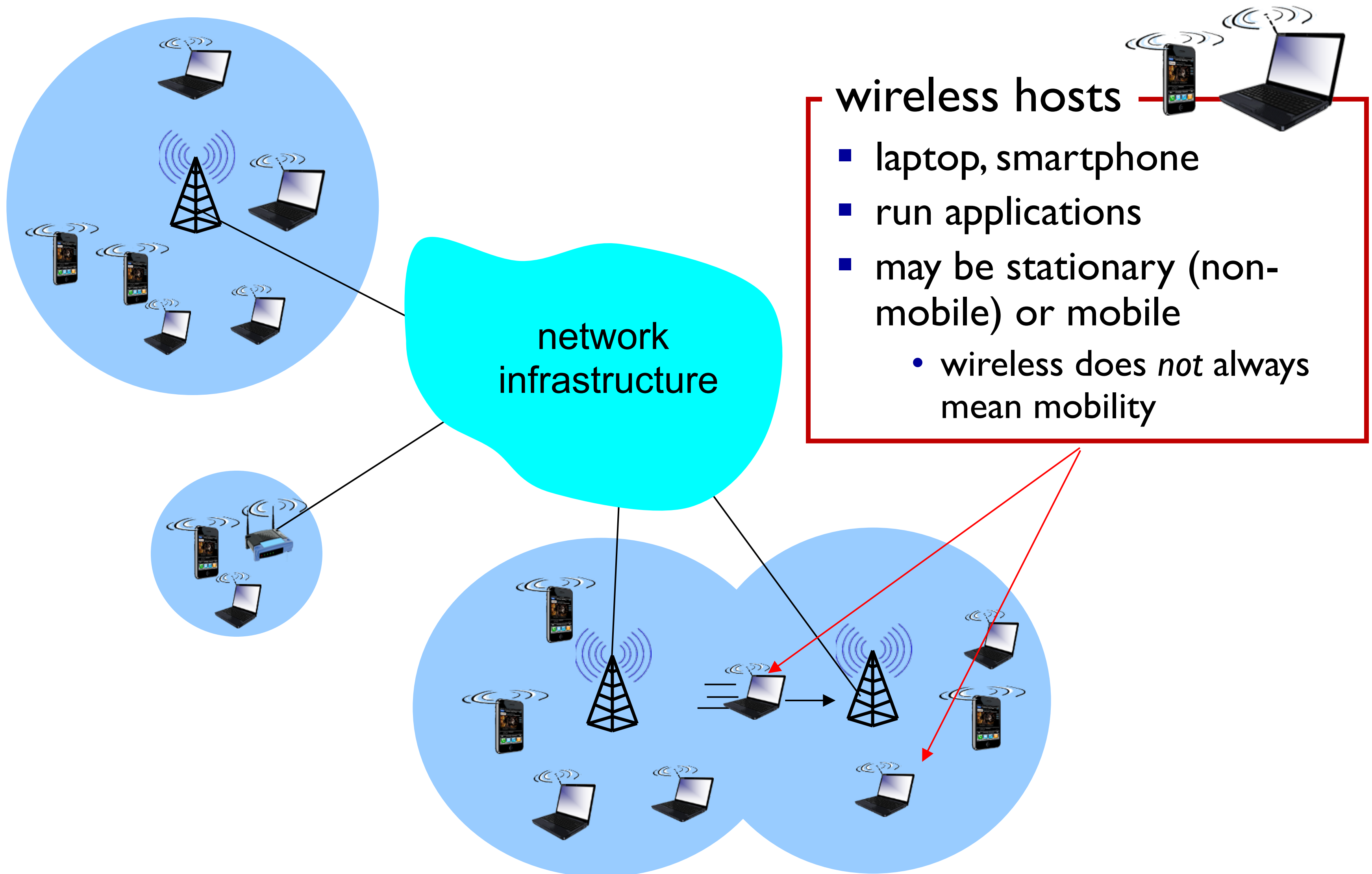
Wireless and Mobile Networks

- two important (but different) challenges
  - *wireless:* communication over wireless link
    - Communication error (due to noise, interference)
    - Energy constraint
  - *mobility:* handling the mobile user who changes point of attachment to network

Elements of a wireless network



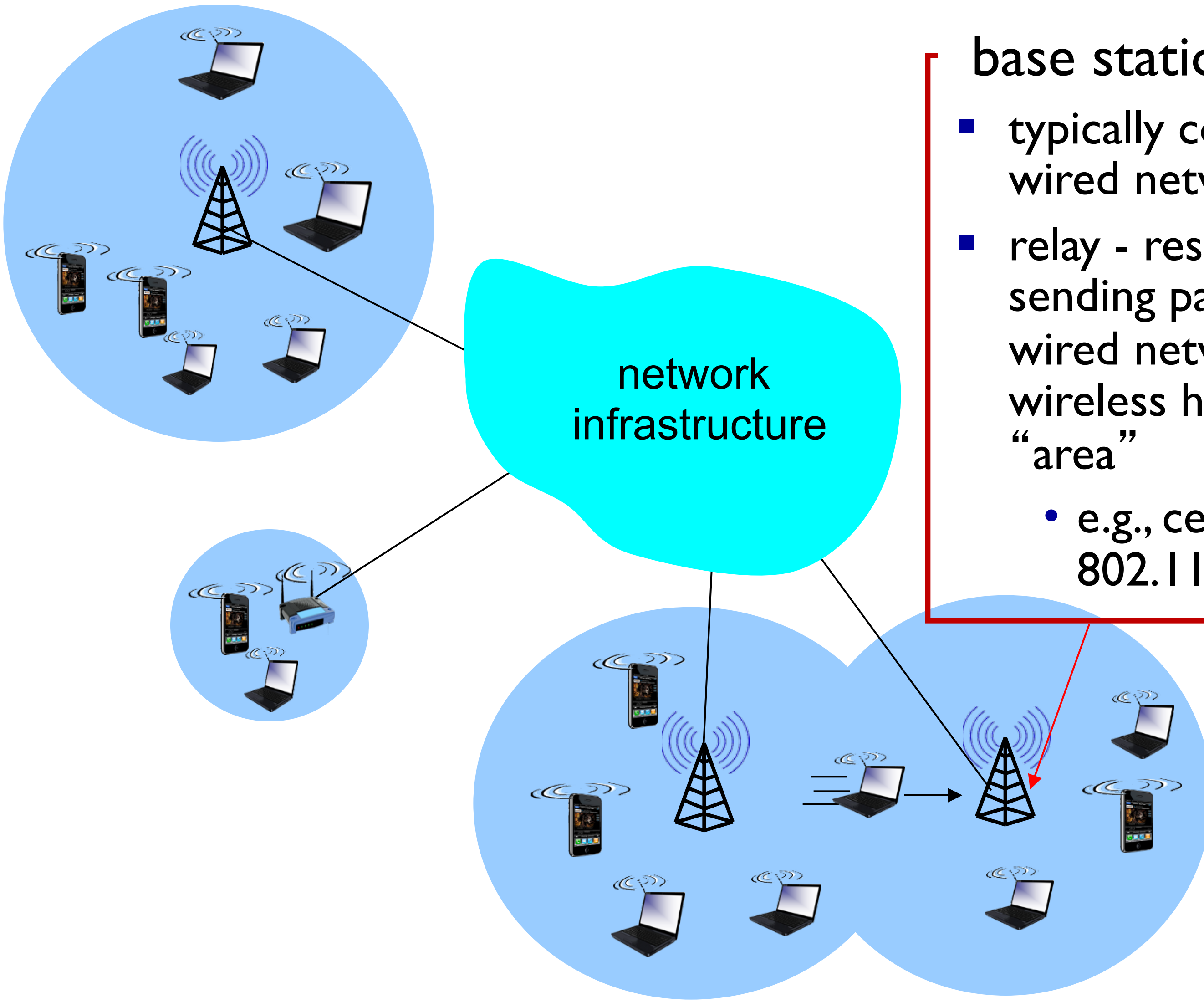
Elements of a wireless network



wireless hosts

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

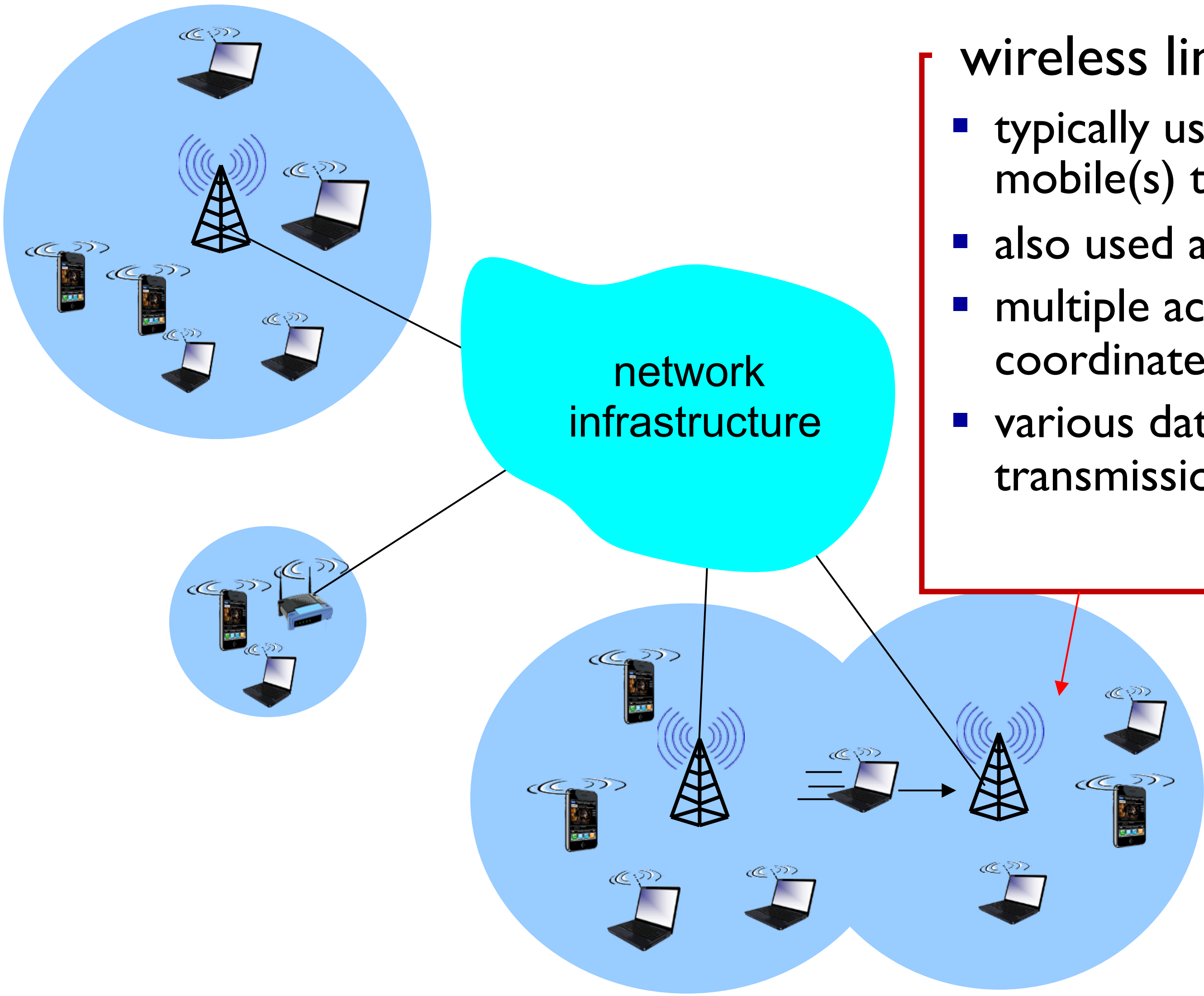
Elements of a wireless network



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

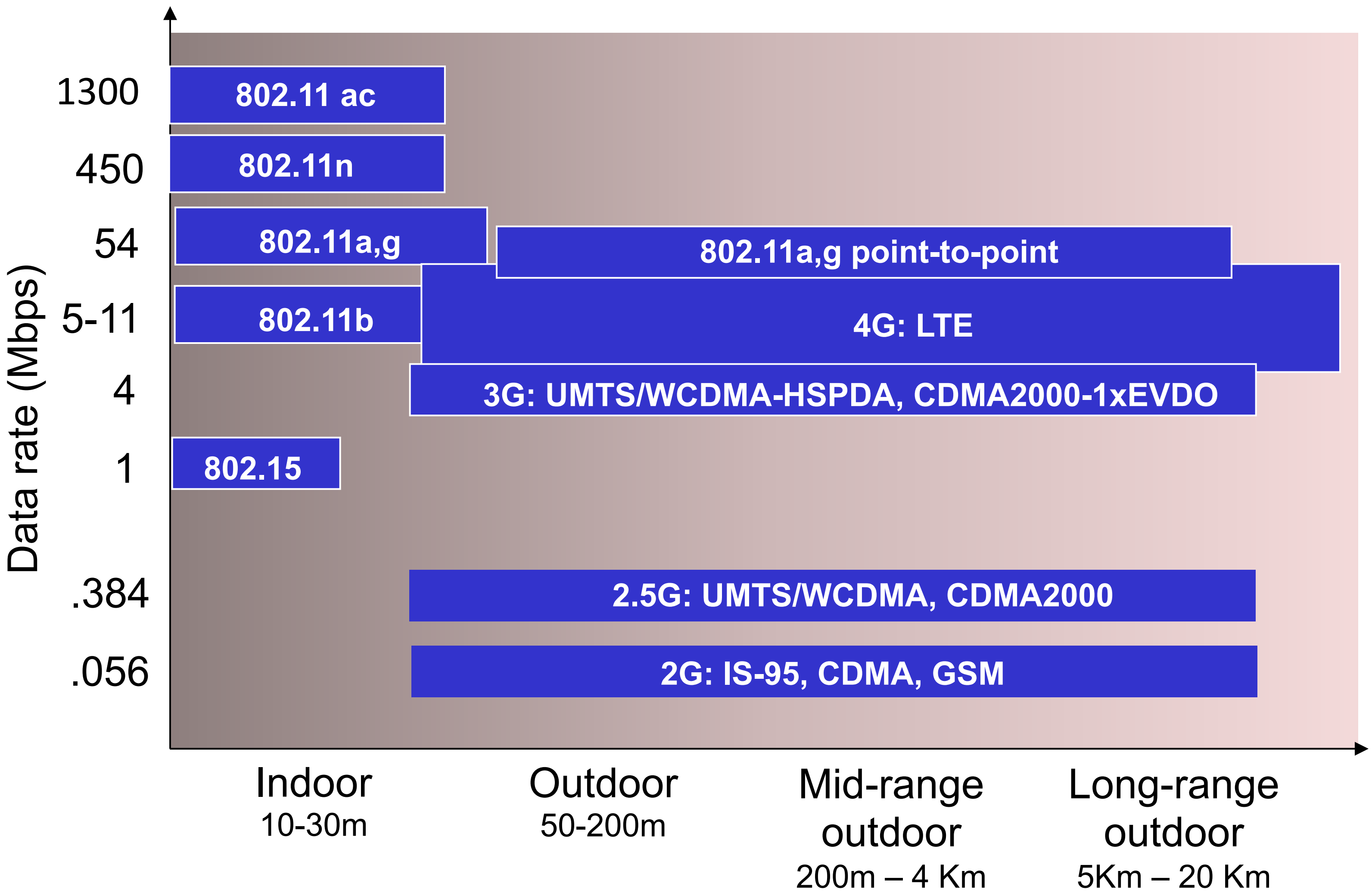
Elements of a wireless network



wireless link

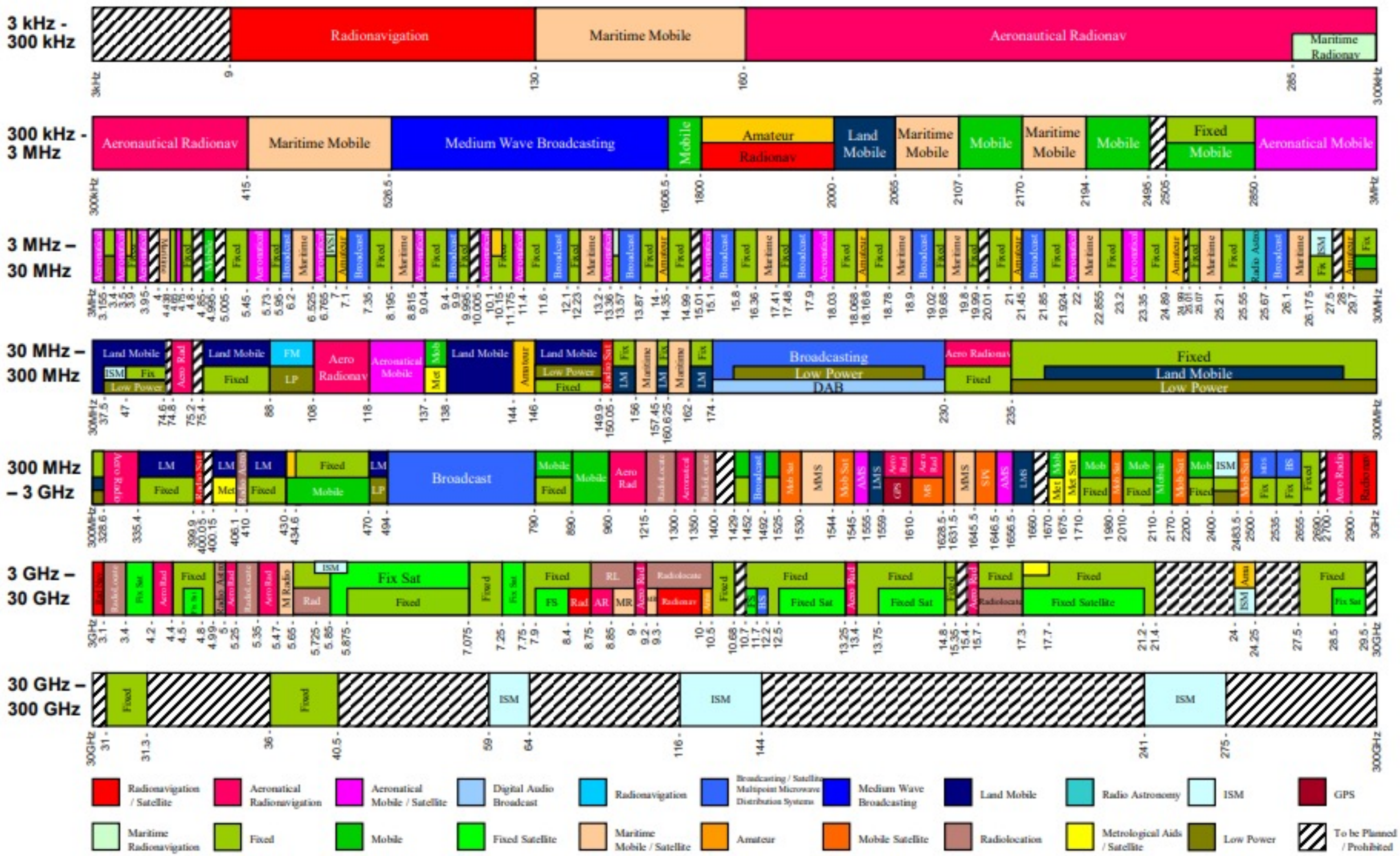
- typically used to connect mobile(s) to base station
- also used as backbone link
- multiple access protocol coordinates link access
- various data rates, transmission distance

Characteristics of selected wireless links



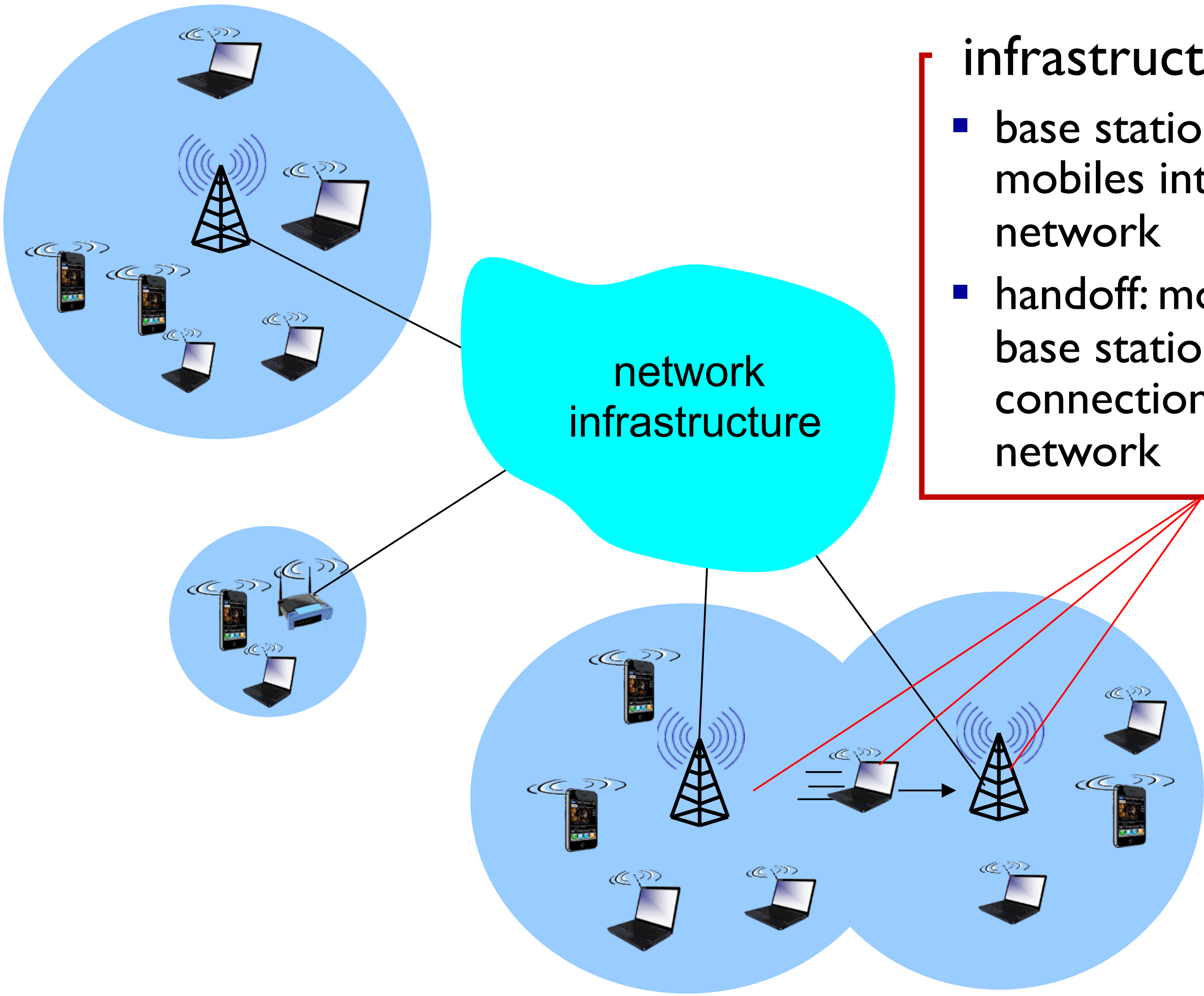
Singapore Spectrum Allocation Chart

•Frequency Spectrum is not drawn to scale.



https://www.imda.gov.sg/-/media/Imda/Files/Regulation-Licensing-and-Consultations/Frameworks-and-Policies/Spectrum-Management-and-Coordination/SpectrumChart.pdf

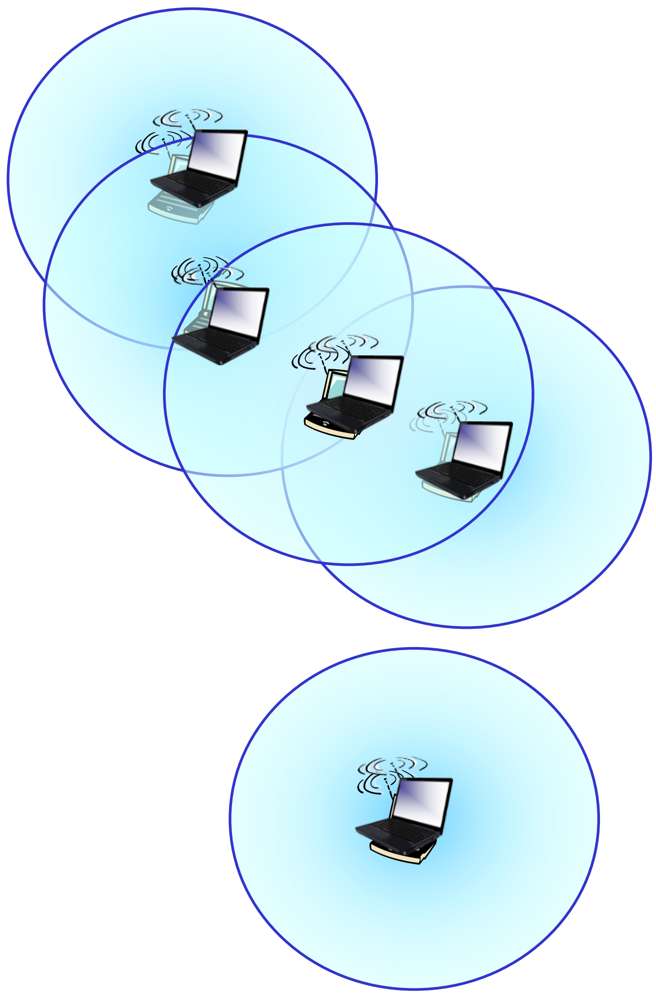
Elements of a wireless network



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 network taxonomy

	single hop	multiple hops
infrastructure (e.g., APs)	host connects to base station (WiFi, cellular) which connects to larger Internet	host may have to relay through several wireless nodes to connect to larger Internet: *mesh net*
no infrastructure	no base station, no connection to larger Internet (Bluetooth)	no base station, no connection to larger Internet. May have to relay to reach other a given wireless node MANET, VANET

Outline

Wireless and mobile networks overview

Wi-Fi

IEEE 802.11 Wireless LAN

802.11b
- 2.4-5 GHz unlicensed spectrum
- up to 11 Mbps

802.11a
- 5-6 GHz range
- up to 54 Mbps

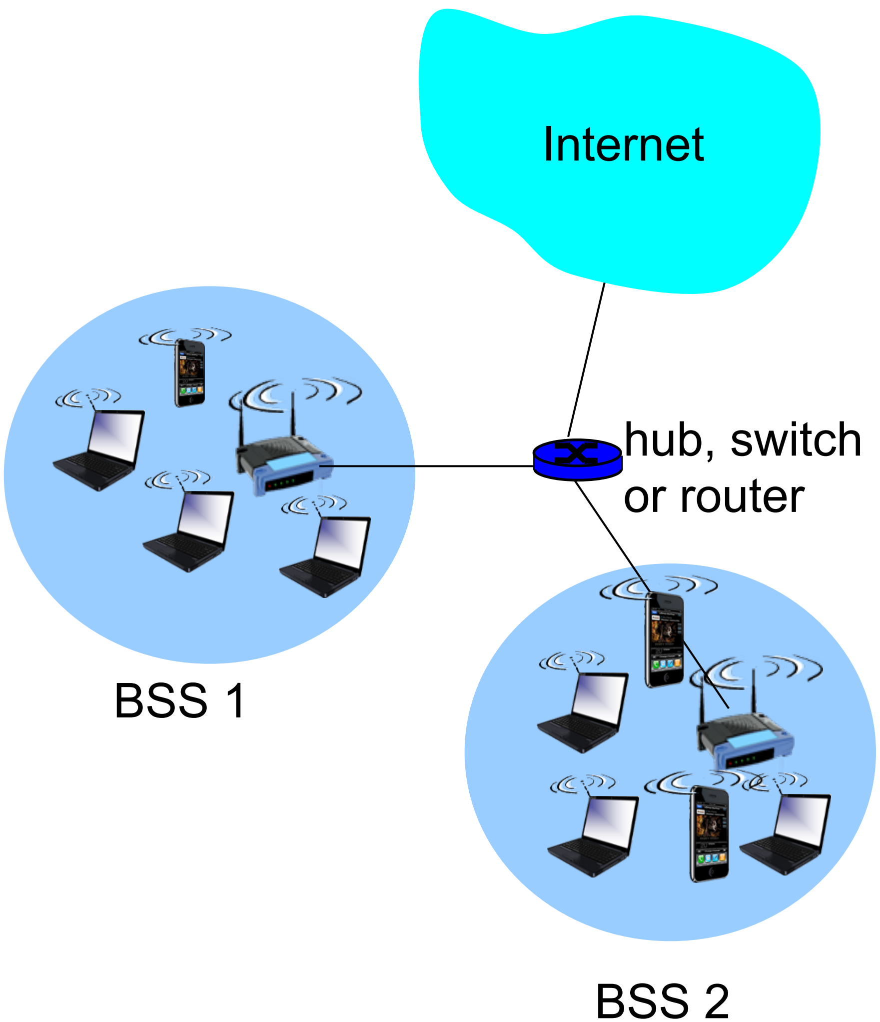
802.11g
- 2.4-5 GHz range
- up to 54 Mbps

802.11n: multiple antennae
- 2.4-5 GHz range
- up to 200 Mbps

802.11ac (Wi-Fi 5), 802.11ax (Wi-Fi 6)….

- all use CSMA/CA (will be explained soon) for multiple access
- all have base-station and ad-hoc network versions

802.11 LAN architecture

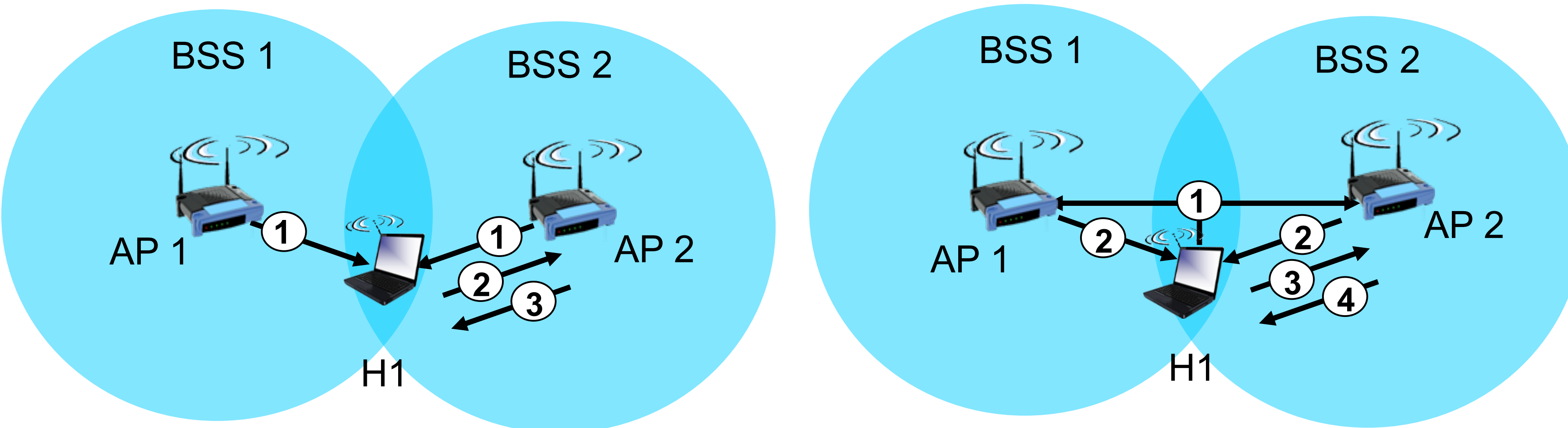


- wireless host communicates with base station
  - base station = access point (AP)
- Basic Service Set (BSS) (aka "cell") in infrastructure mode contains:
  - wireless hosts
  - access point (AP): base station

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
  - will typically run DHCP to get IP address in AP's subnet

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

Multiple access protocols (review)

- distributed algorithm that determines how nodes share channel, i.e., determine when node can transmit

given: broadcast channel of rate R bps
desiderata:

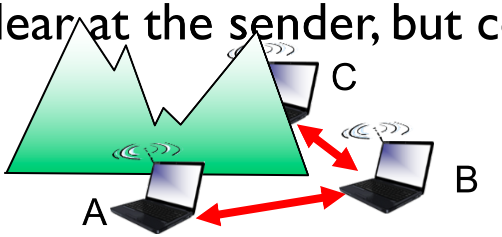
1. when one node wants to transmit, it can send at rate R.
2. when M nodes want to transmit, each can send at average rate R/M
3. fully decentralized:
   - no special node to coordinate transmissions
   - no synchronization of clocks, slots
4. Simple

802.11's solution: DCF (Distributed Coordination Function)

IEEE 802.11: multiple access

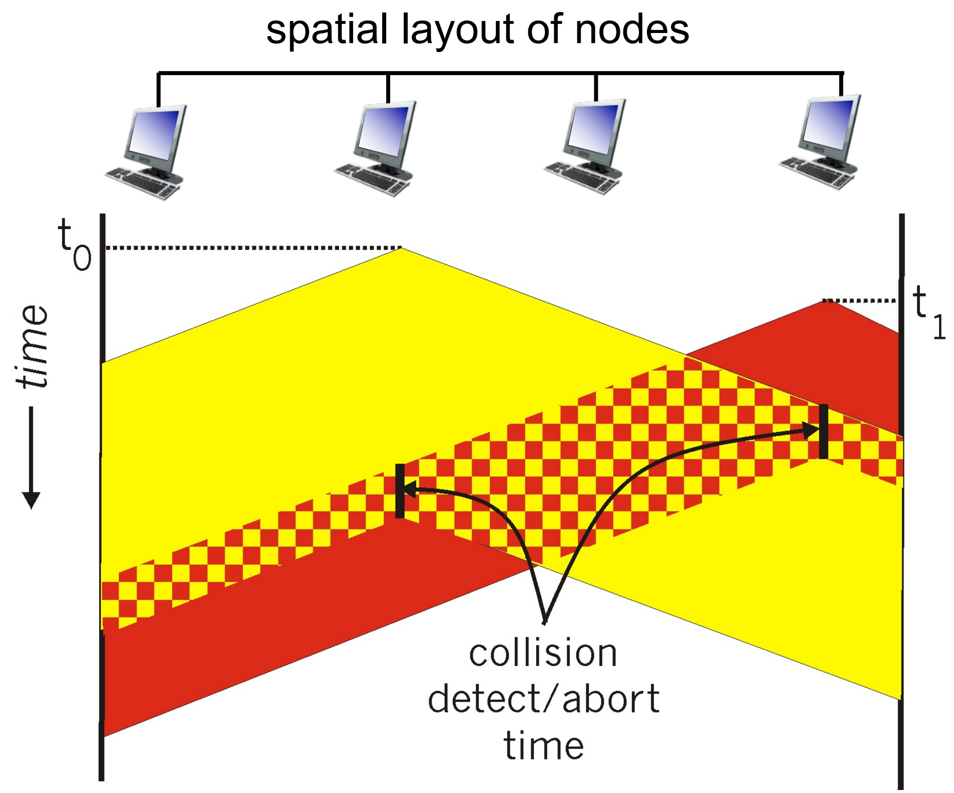
- avoid collisions: 2^+ nodes transmitting at same time
- 802.11: CSMA (carrier sense multiple access) - sense before transmitting
  - if channel sensed busy, defer transmission
  - if channel sensed idle: transmit entire frame
  - Goal: don't collide with ongoing transmission by other node
  - human analogy: don't interrupt others!

- However, CSMA cannot eliminate all collisions
  - Two senders may sense an idle channel together, then decide to send at the same time (collision!)
  - Hidden terminal: Clear at the sender, but collision at the receiver



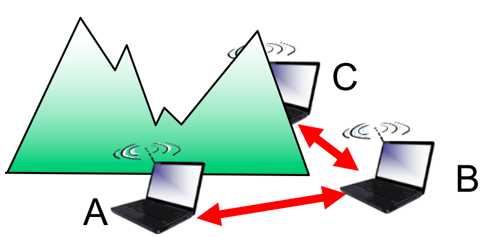
Background: CSMA/CD (collision detection) for wired link

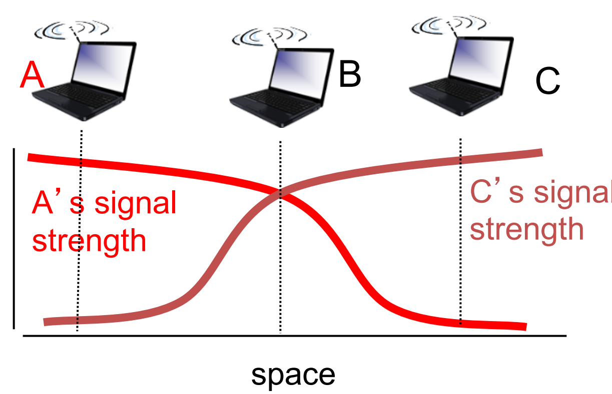
- collisions *detected* within short time
  - colliding transmissions aborted, reducing channel wastage
- collision detection:
  - easy in wired LANs: measure signal strengths, compare transmitted, received signals
  - difficult in wireless LANs: received signal strength overwhelmed by local transmission strength



IEEE 802.11: multiple access

- 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 (**DCF Inter-frame space) then

transmit entire frame (no Collision Detection)

2 if sense channel busy then

start random backoff time

timer counts down while channel idle

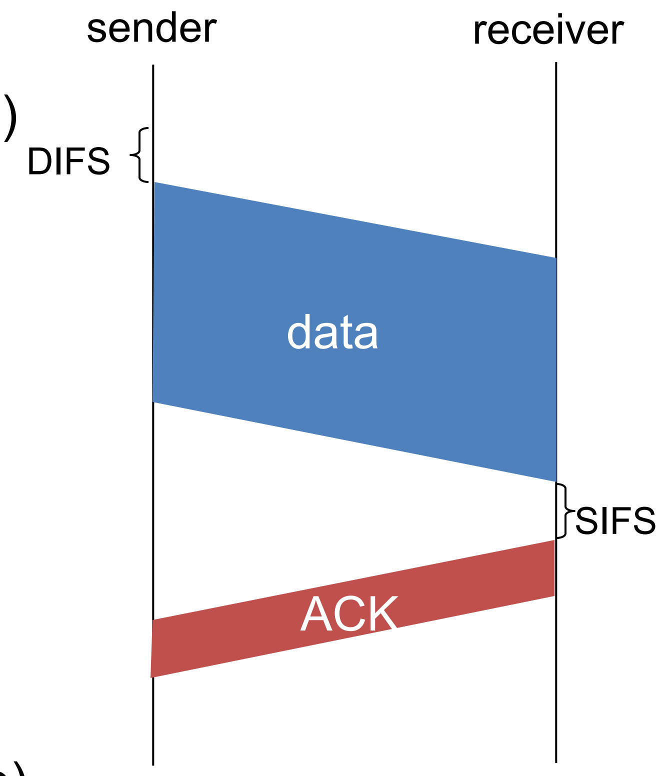
transmit when timer expires

if no ACK, increase random backoff interval (*exponential increase* here), repeat 2

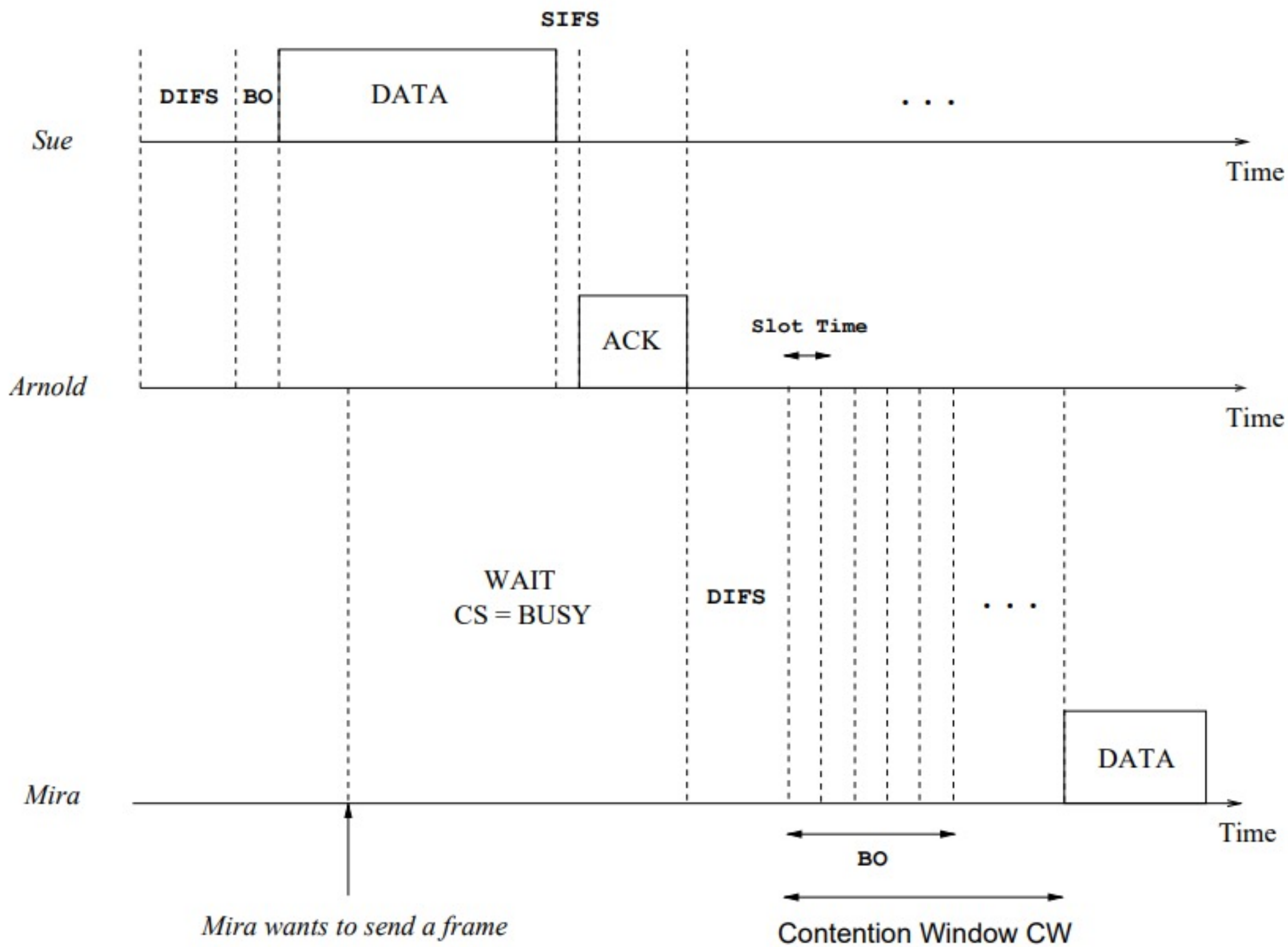
802.11 receiver

- if frame received OK

return ACK after **SIFS** (Short inter-frame space)

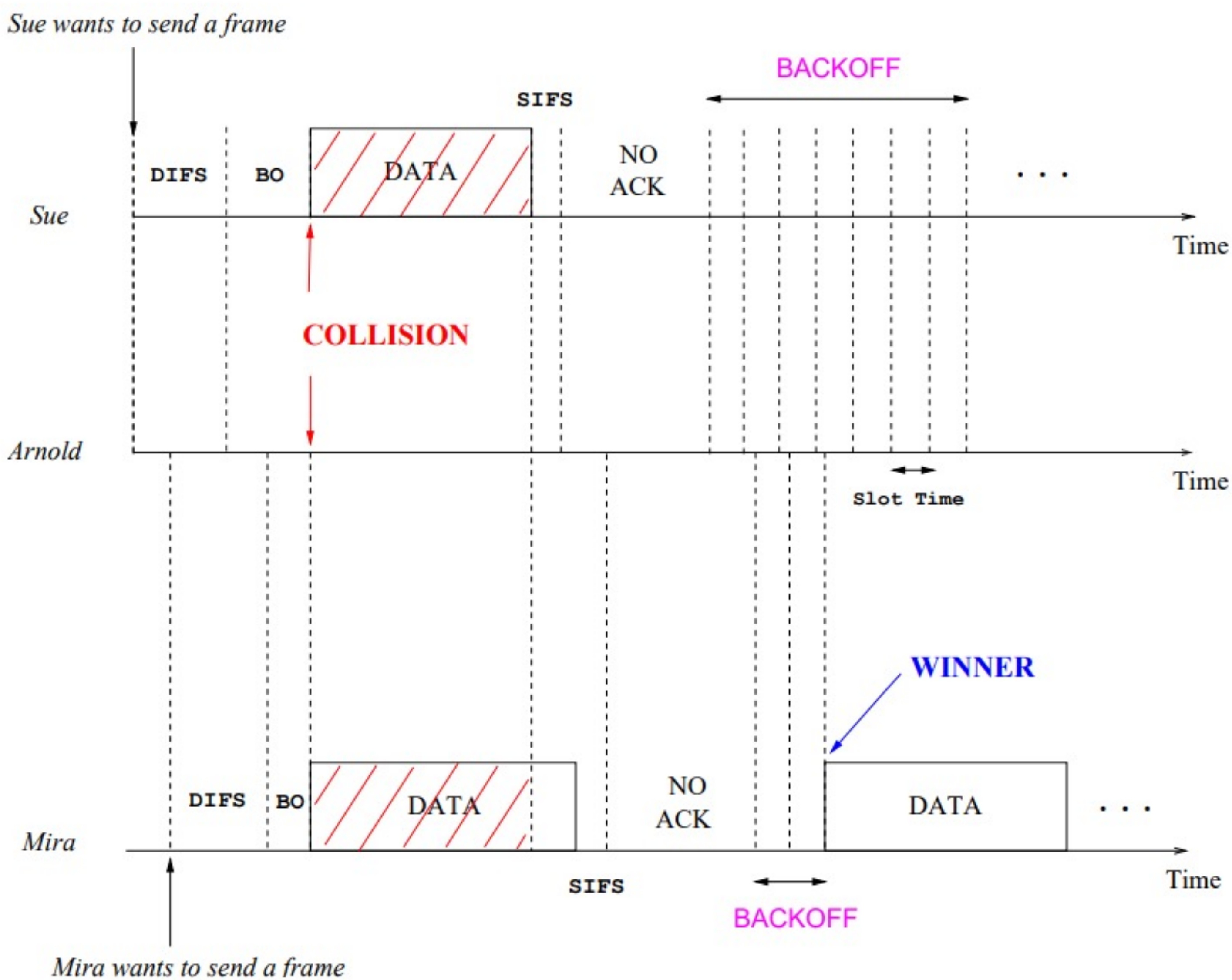


Example 1: without collision



From: https://www.cs.purdue.edu/homes/park/cs422-wireless-2-06s.pdf

Example 2: With collision



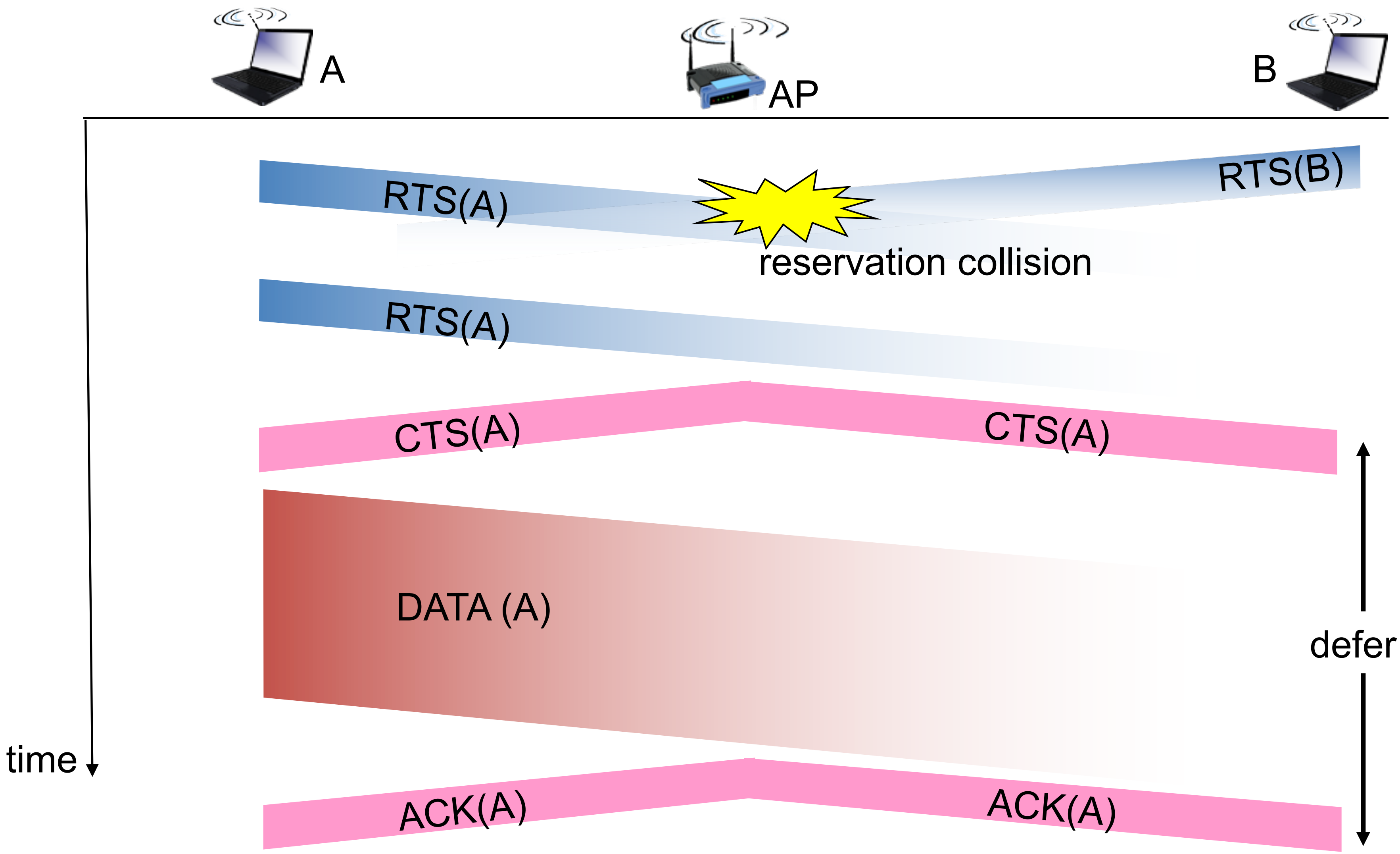
Avoiding collisions (more)

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!

Collision Avoidance: RTS-CTS exchange



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

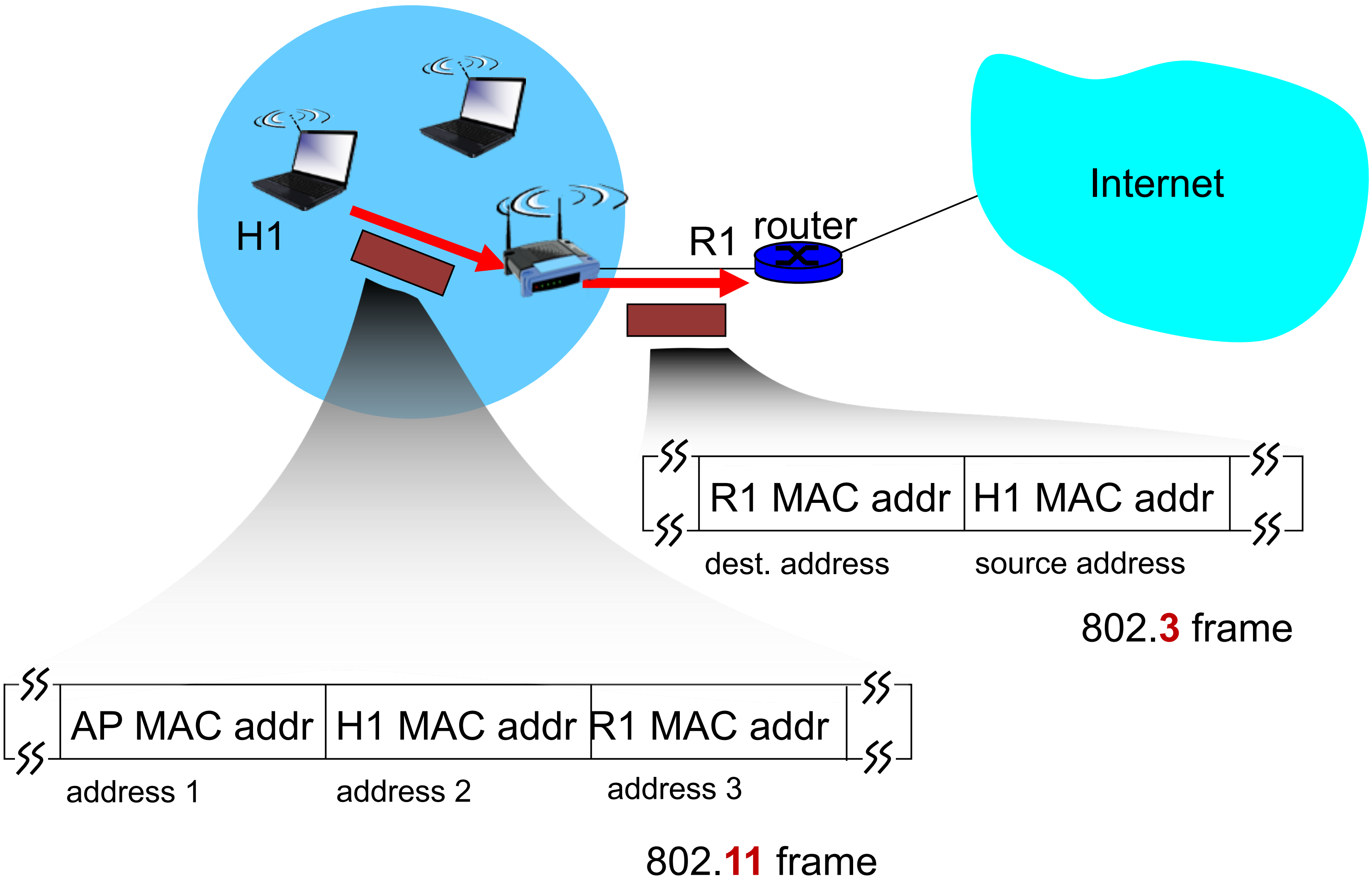
Address 1: MAC address of wireless host or AP to receive this frame

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

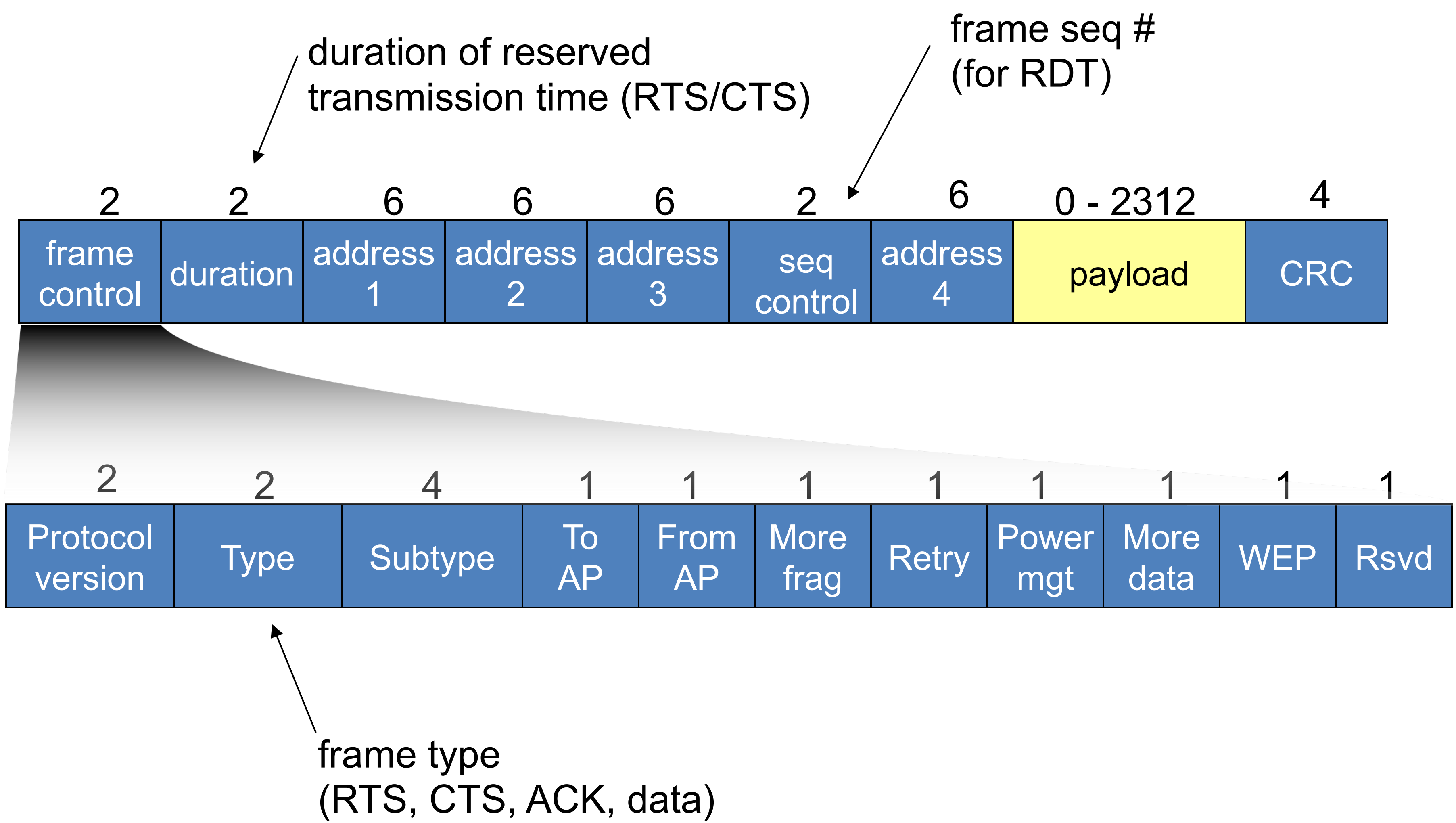
Address 3: MAC address of router interface to which AP is attached

Address 4: used only in ad hoc mode

802.11 frame: addressing

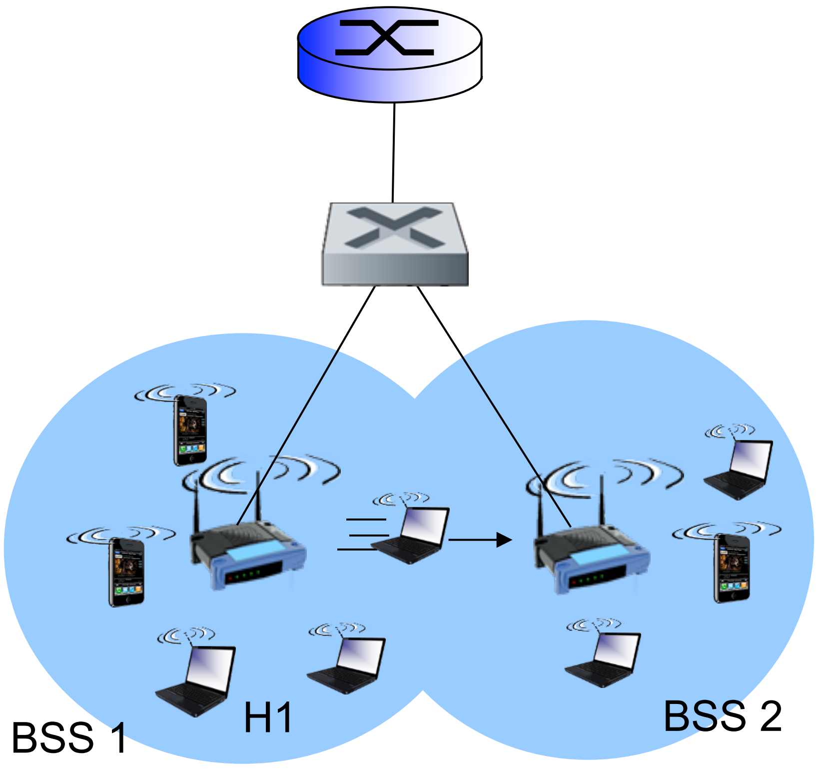


802.11 frame: more



802.11: mobility within same subnet

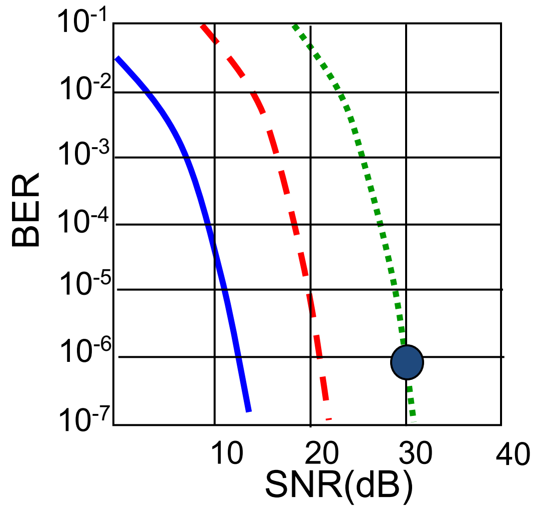
- H1 remains in same IP subnet: IP address can remain same
- switch: which AP is associated with H1?
  - self-learning : switch will see frame from H1 and "remember" which switch port can be used to reach H1

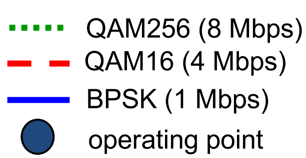


802.11: advanced capabilities

Rate adaptation

- base station, mobile dynamically change transmission rate (physical layer modulation technique) as mobile moves, SNR varies





1. SNR decreases, BER increase as node moves away from base station

2. When BER becomes too high, switch to lower transmission rate but with lower BER

802.11: advanced capabilities

power management

- node-to-AP: "I am going to sleep until next beacon frame"
  - AP knows not to transmit frames to this node
  - node wakes up before next beacon frame
- beacon frame: contains list of mobiles with AP-to-mobile frames waiting to be sent
  - node will stay awake if AP-to-mobile frames to be sent; otherwise sleep again until next beacon frame