Part 2.1 – Wired and Wireless

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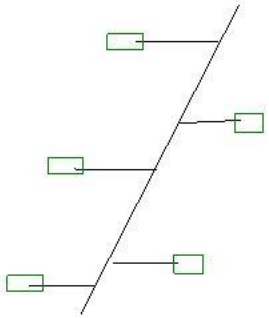
WIRED - ETHERNET

Ethernet

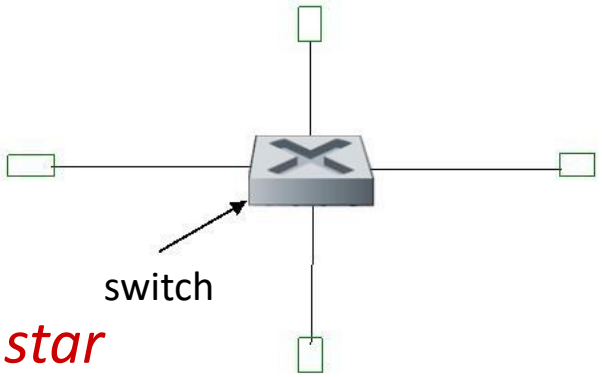
- Invented in 1973, Ethernet is today's most popular LAN standard with over 40,000,000 installed nodes.
- As a shared media technology, Ethernet provides a common 10 Mbit/sec communication channel for all users to share and a protocol for determining how users get access to this channel.
- As networks grow, more users share Ethernet's fixed 10 Mbit/sec of data carrying capacity resulting in less available bandwidth per user
- Fundamentally, there are two ways to increase available network bandwidth per user. Fast Ethernet and Gigabit Ethernet increases Ethernet's bandwidth from 10 Mbit/sec to 100 Gbit/sec improving bandwidth per user by a factor of 10,000. Alternatively, the number of users per Ethernet network can be reduced
- Reducing the number of users per network, a process called segmentation, creates more networks. Users on these different network segments still need to communicate and share resources, so a mechanism is required for providing high speed inter-segment connectivity. This is achieved with an Ethernet bridge / switch

Ethernet: Physical Topology

- *Bus:* Popular through mid 90s
  - all nodes in same collision domain (can collide with each other
- *Star:* Prevails today
  - active *switch* in center
  - each "spoke" runs a (separate) Ethernet protocol (nodes do not collide with each other)



bus: coaxial cable



star

Ethernet Frame Structure

Sending adapter encapsulates IP datagram (or other network layer protocol packet) in Ethernet frame

preamble:

- 7 bytes with pattern 10101010 followed by one byte with pattern 10101011
- Used to synchronize receiver, sender clock rates

Ethernet Frame Structure (ore)

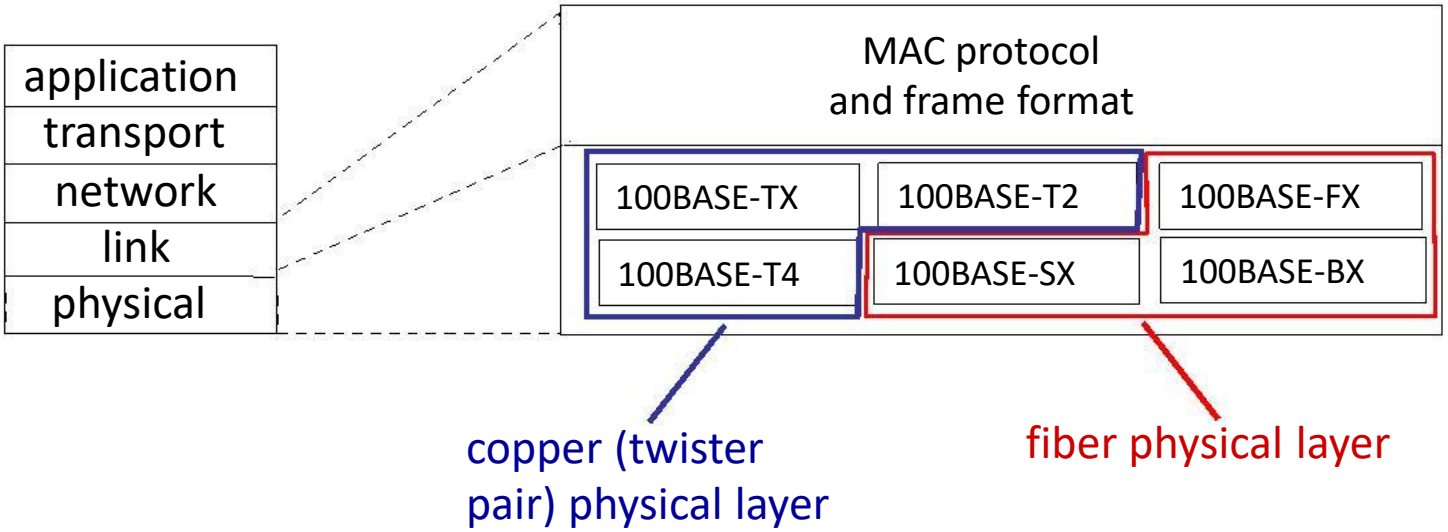
- *Addresses:* 6 byte source, destination MAC addresses
  - if adapter receives frame with matching destination address, or with broadcast address (e.g. ARP packet), it passes data in frame to network layer protocol
  - otherwise, adapter discards frame
- *Type:* indicates higher layer protocol (mostly IP but others possible, e.g., Novell IPX, AppleTalk)
- *CRC:* cyclic redundancy check at receiver
  - error detected: frame is dropped

Ethernet: Unreliable, Connectionless

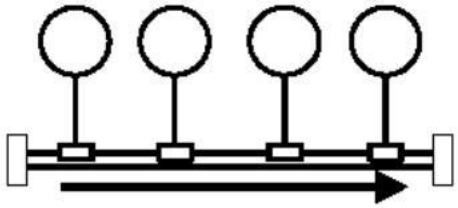
- *Connectionless:* no handshaking between sending and receiving NICs
- *Unreliable:* receiving NIC doesn't send acks or nacks to sending NIC
  - data in dropped frames recovered only if initial sender uses higher layer rdt (e.g., TCP), otherwise dropped data lost
- Ethernet's MAC protocol: unslotted *CSMA/CD with binary backoff*

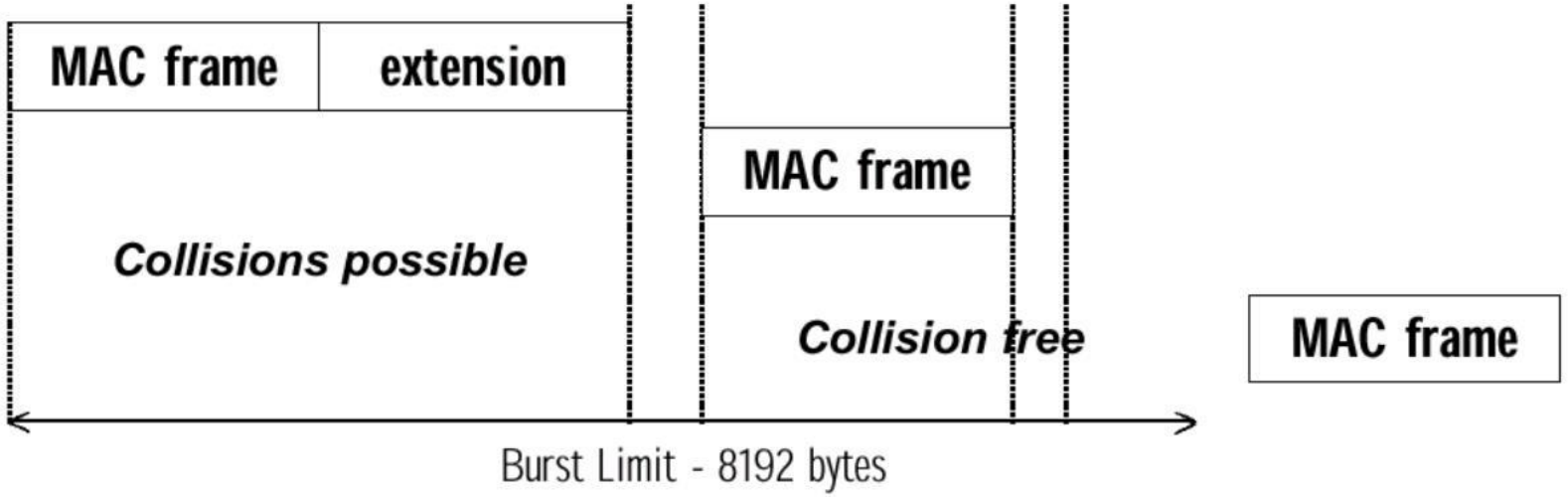
802.3 Ethernet Standards: Link & Physical Layers

- *Many* different Ethernet standards
  - common MAC protocol and frame format
  - different speeds: 2 Mbps, 10 Mbps, 100 Mbps, 1Gbps, 10 Gbps, 40 Gbps
  - different physical layer media: fiber, cable



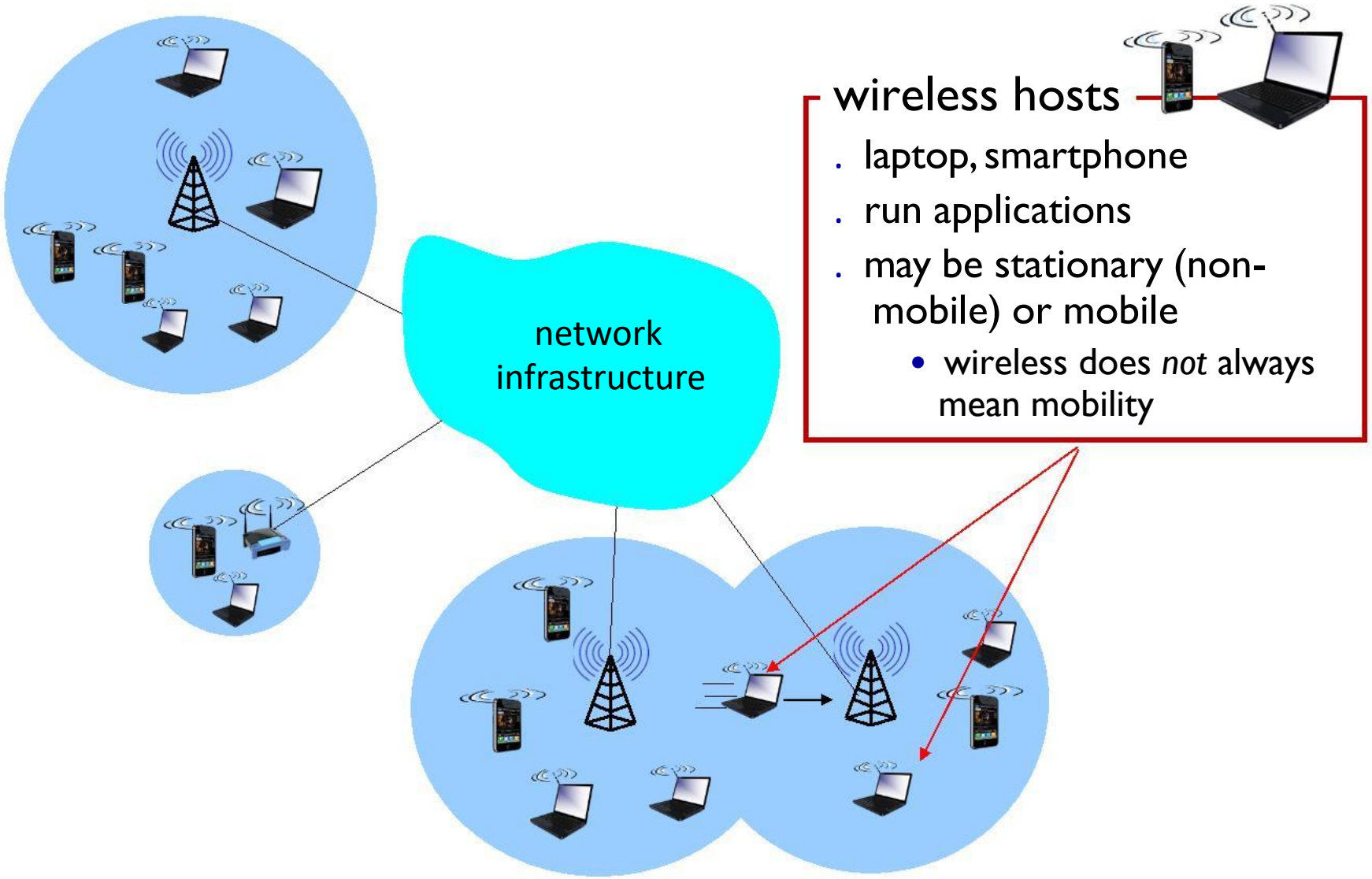
Gigabit Ethernet – Frame Bursting



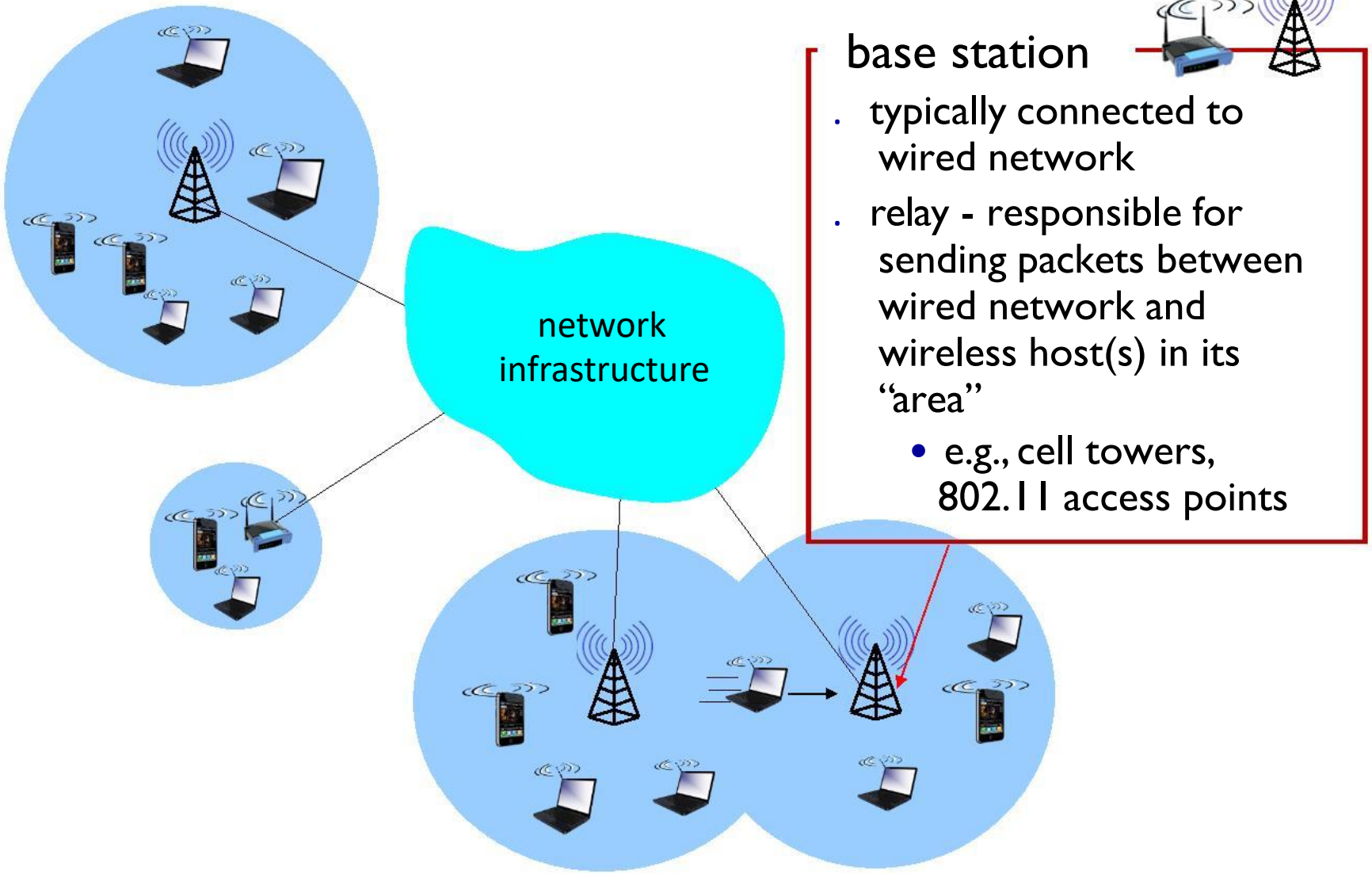


WIRELESS

Elements of a Wireless Network



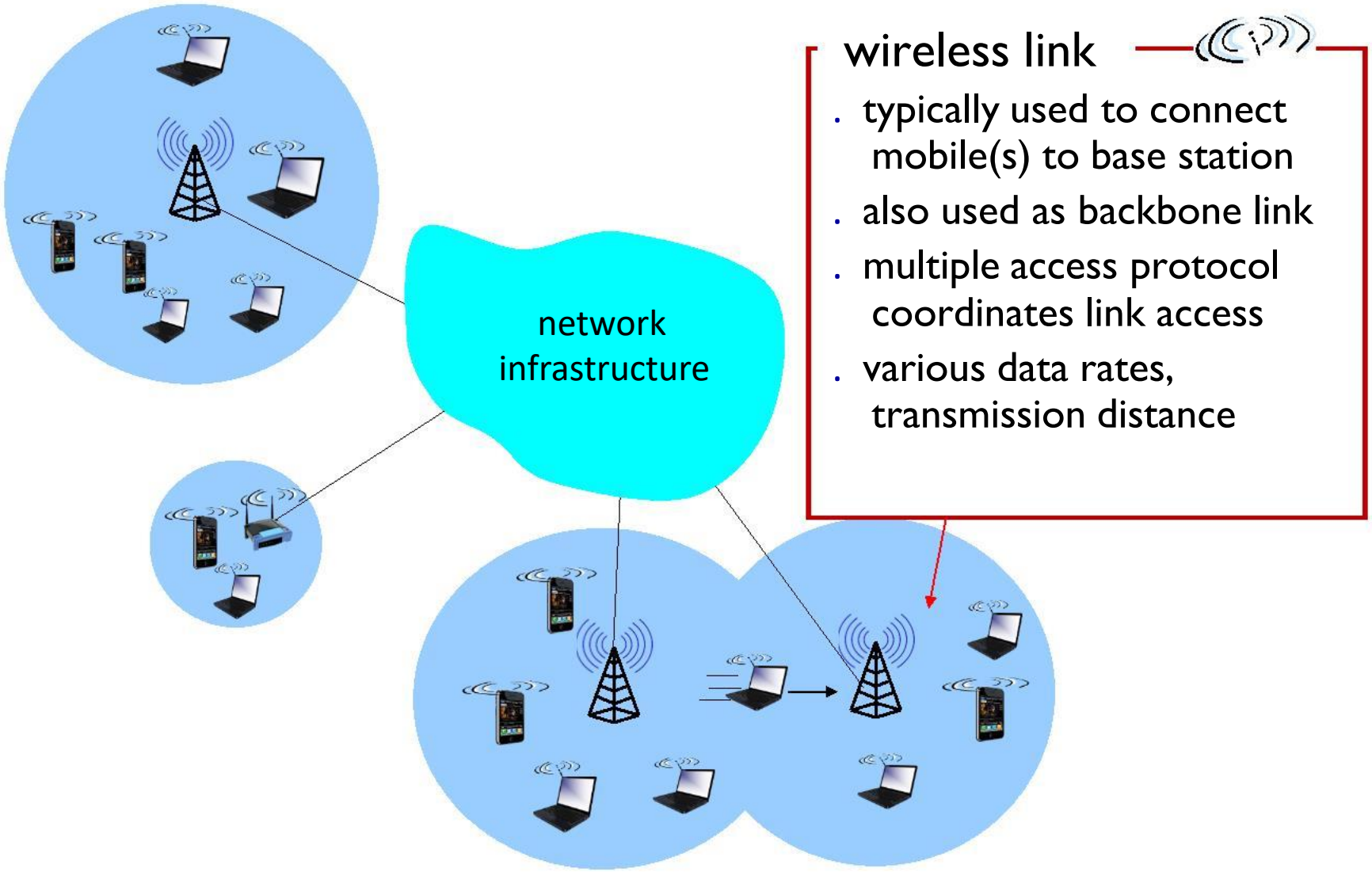
Elements of a Wireless Network



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

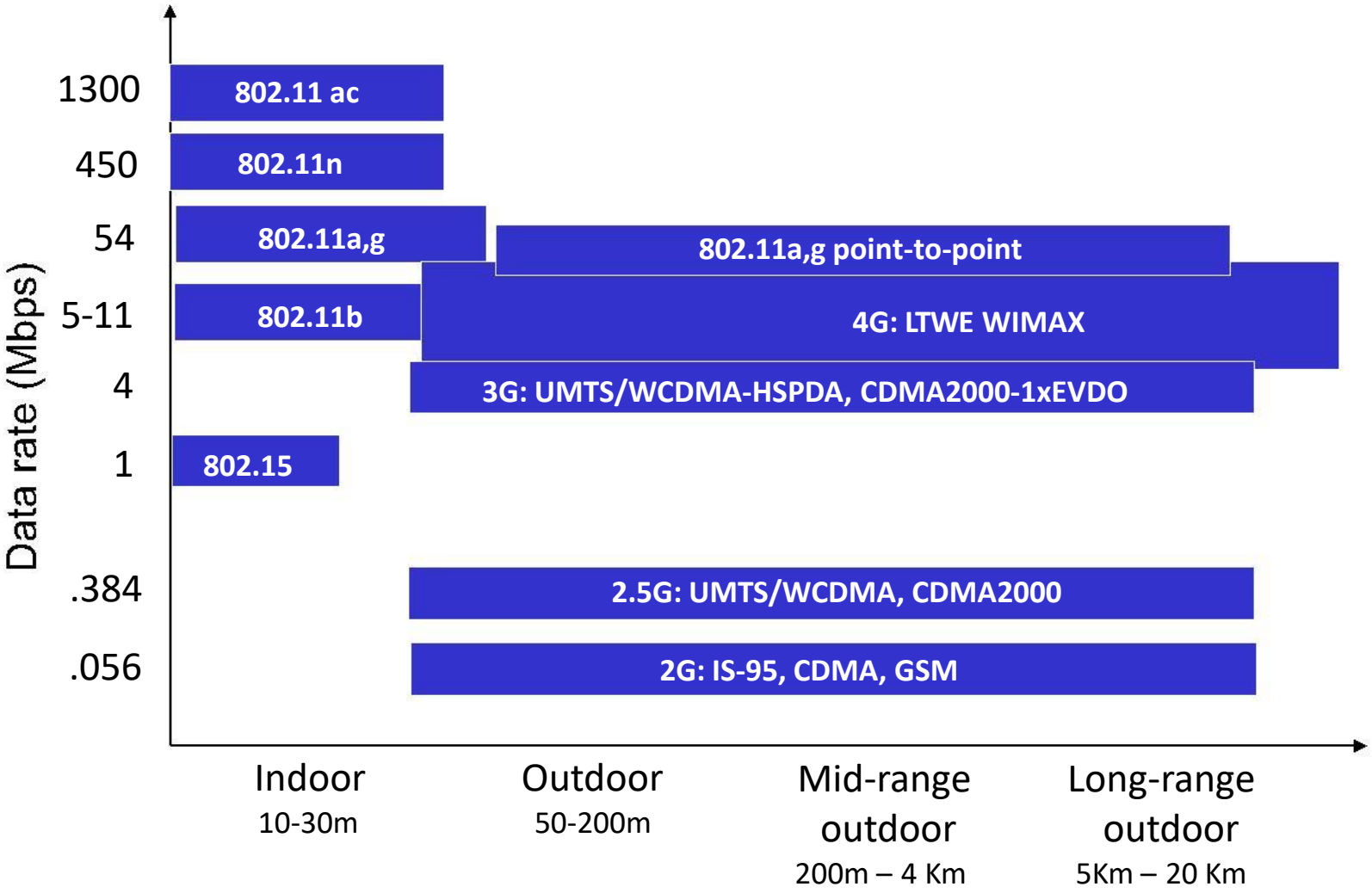
Elements of a Wireless Network



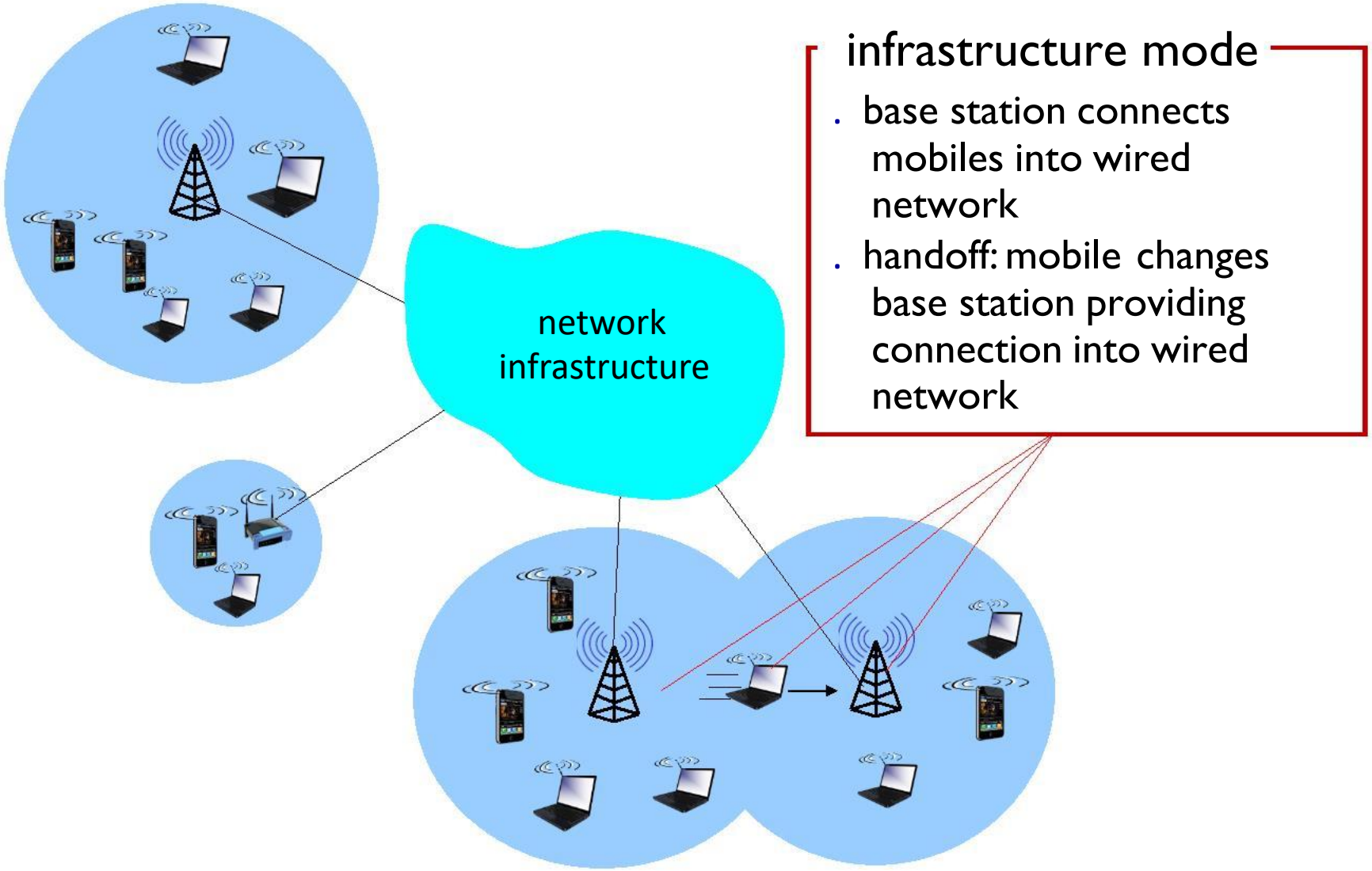
wireless link

- 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



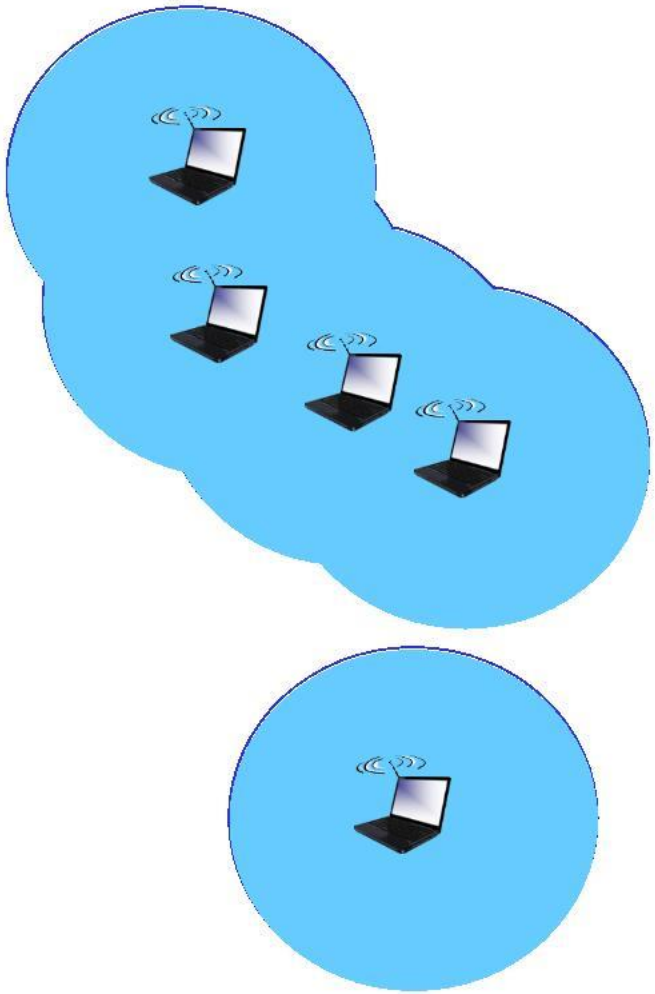
Elements of a Wireless Network



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, WiMAX, 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, ad hoc nets)	no base station, no connection to larger Internet. May have to relay to reach other a given wireless node MANET, VANET

Wireless Link Characteristics (1)

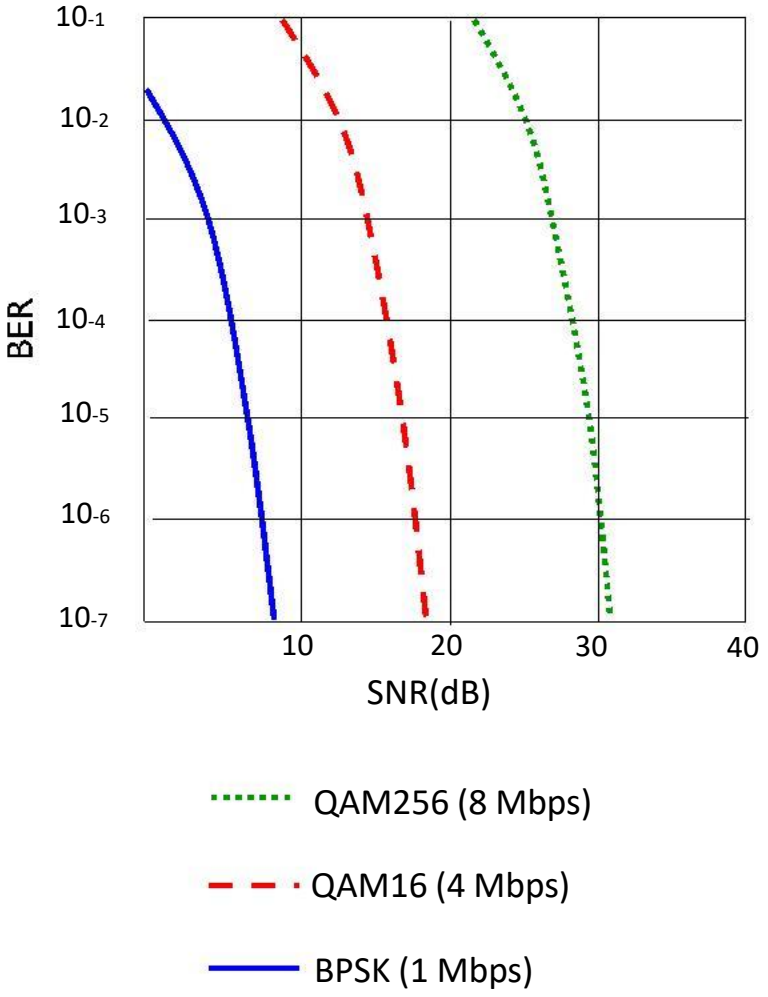
Important differences from wired link …

- *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 ad destination at slightly different times

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

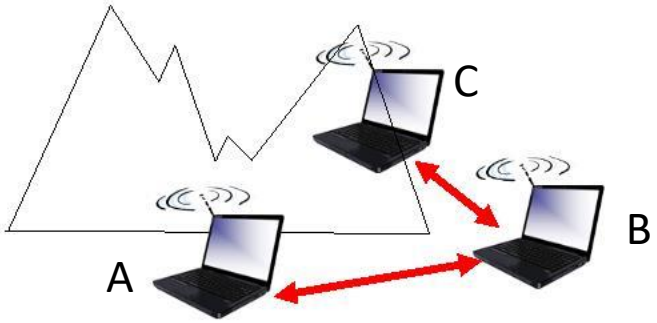
Wireless Link Characteristics (2)

- SNR: signal-to-noise ratio
  - larger SNR – easier to extract signal from noise (a "good thing")
- *SNR versus BER tradeoffs*
  - *given physical layer:* increase power -> increase SNR->decrease BER
  - *given SNR:* choose physical layer that meets BER requirement, giving highest thruput
    - SNR may change with mobility: dynamically adapt physical layer (modulation technique, rate)



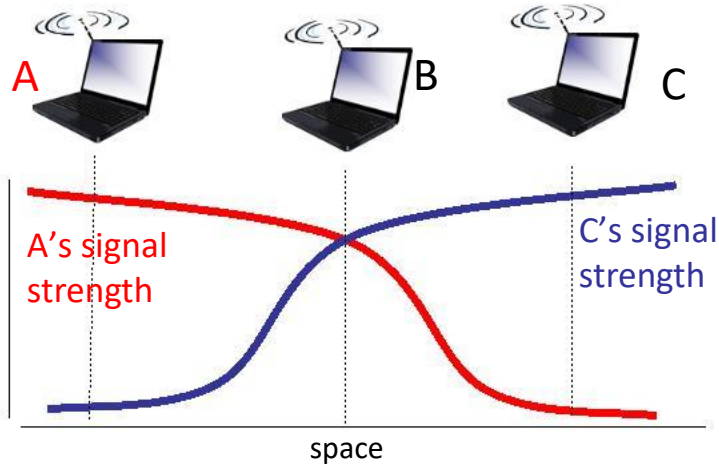
Wireless Network Characteristics

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 attenuation:

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

WIRELESS LAN - WIFI

IEEE 802.11 Wireless LAN

802.11b

- 2.4-5 GHz unlicensed spectrum
- up to 11 Mbps
- Direct sequence spread spectrum (DSSS) in physical layer
  - all hosts use same chipping code

802.11a

- 5-6 GHz range
- up to 54 Mbps

802.11g

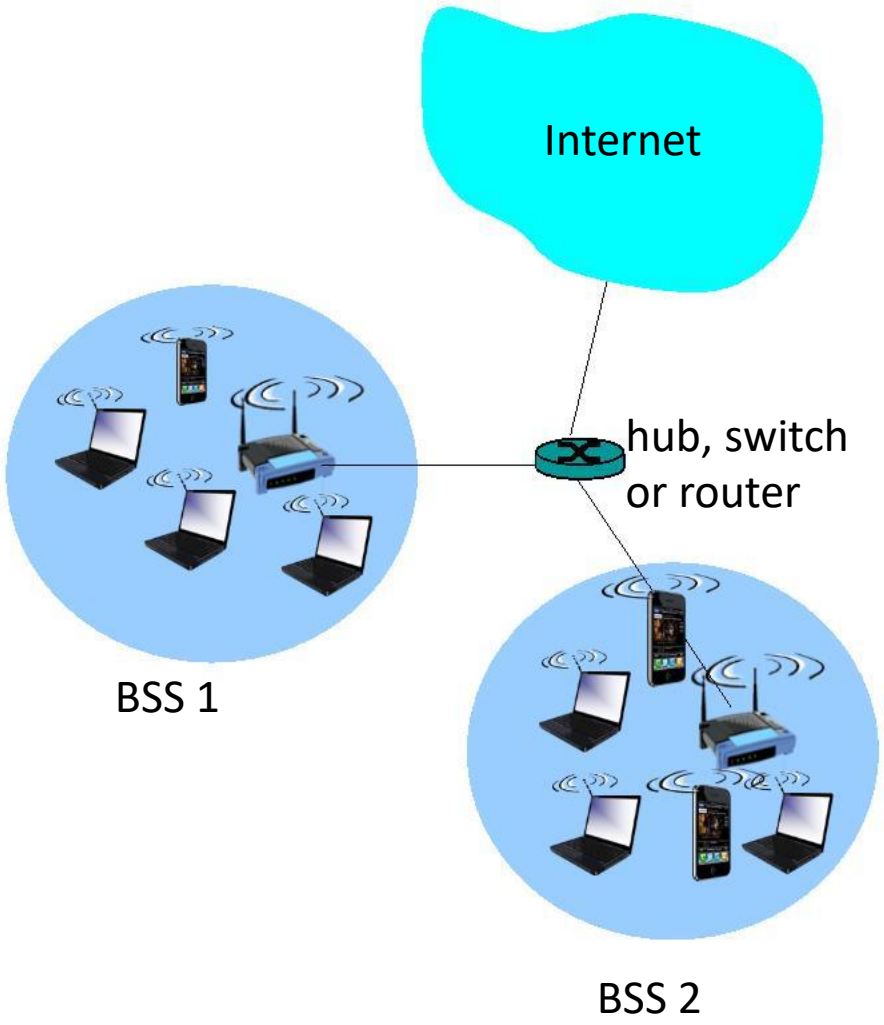
- 2.4-5 GHz range
- up to 54 Mbps

802.11n: multiple antennae

- 2.4-5 GHz range
- up to 200 Mbps

- All use CSMA/CA for multiple access
- All have base-station and ad-hoc network versions

802.11 LAN Architecture

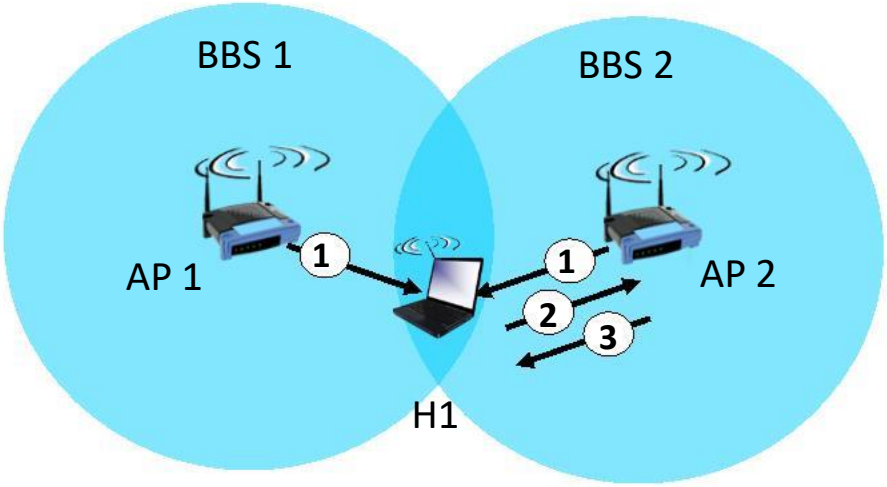


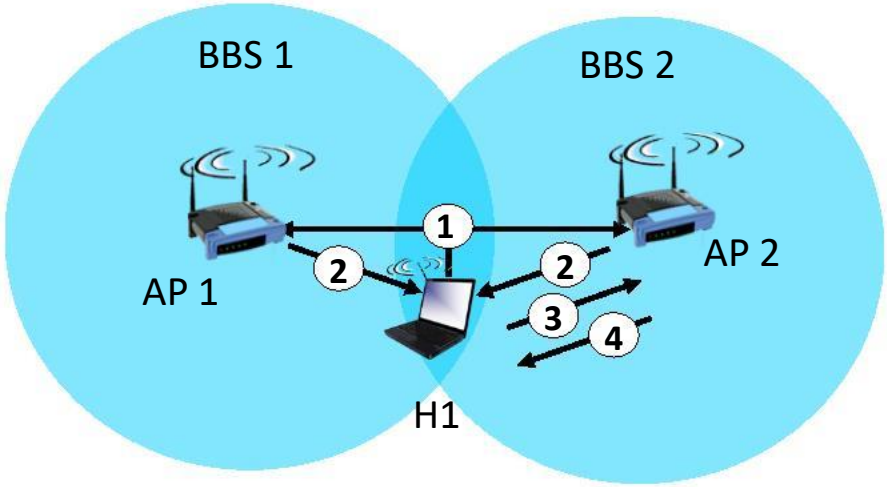
- Wireless host communicates with base station
  - base station = access point (AP)
- Basic Service Set (BSS) (aka "cell") in infrastructure mode contains:
  - wireless hosts
  - access point (AP): base station
  - ad hoc mode: hosts only

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: Passive/Active Scanning





Passive scanning:

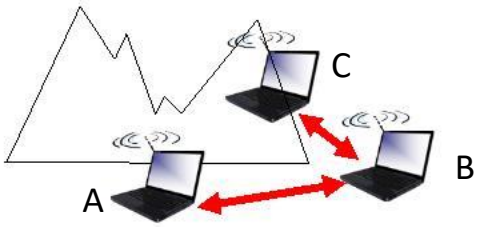
(1) beacon frames sent from APs
(2) association Request frame sent: H1 to selected AP
(3) association Response frame sent from selected AP to H1

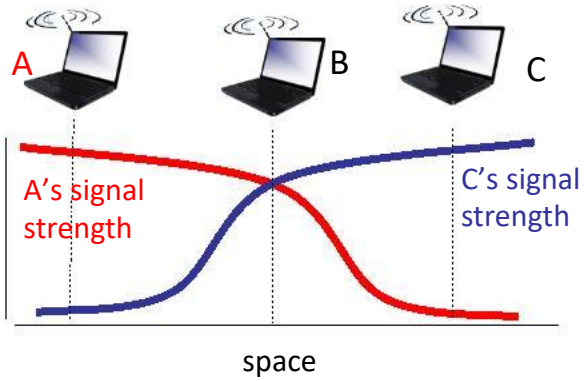
Active scanning:

(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

IEEE 802.11: Multiple Access

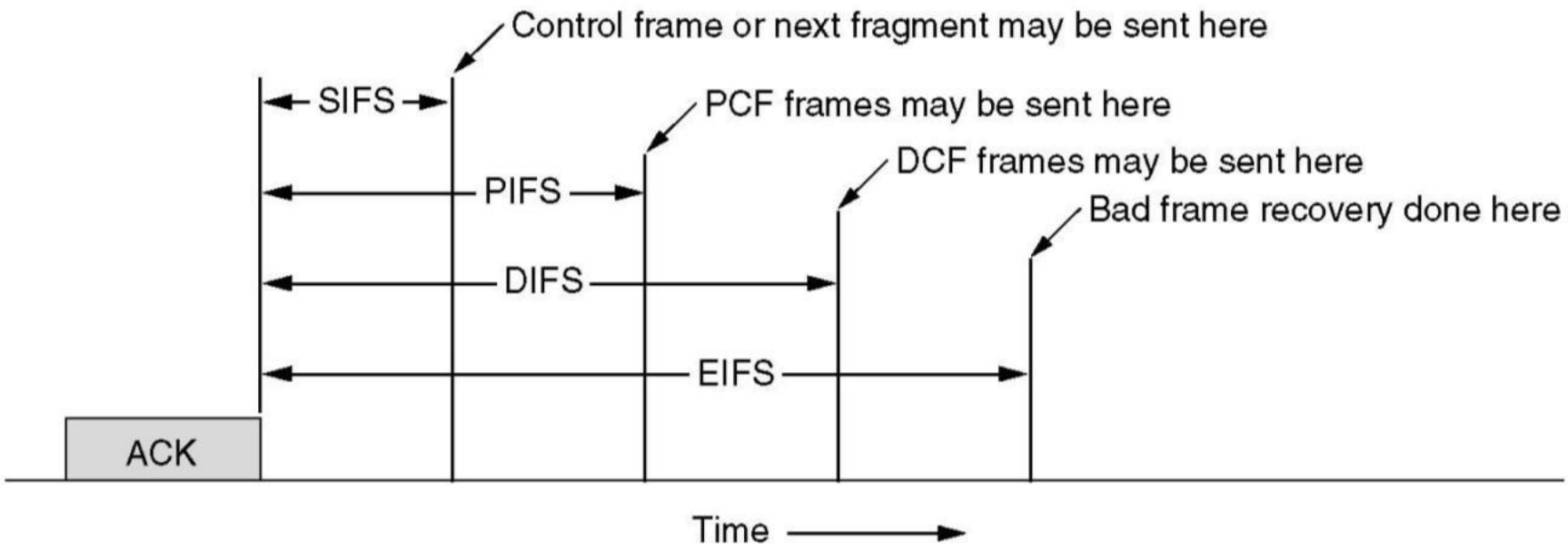
- Avoid collisions: 2+nodes transmitting at same time
- 802.11: CSMA - sense before transmitting
  - don't collide with ongoing transmission by other node
- 802.11: *no* collision detection!
  - difficult to receive (sense collisions) when transmitting due to weak received signals (fading)
  - can't sense all collisions in any case: hidden terminal, fading
  - goal: *avoid collisions:* CSMA/C(ollision)A(voidance)





Interframe Spacing

Interframe spacing in 802.11.



SIFS – Short InterFrame Spacing
PIFS – PCF InterFrame Spacing
DIFS – DCF InterFrame Spacing
EIFS – Extended InterFrame Spacing

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

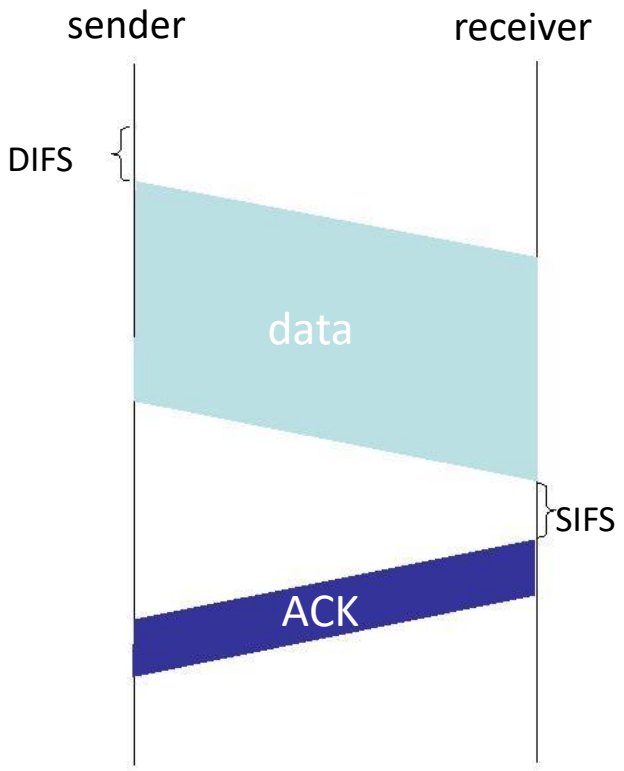
transmit when timer expires

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)



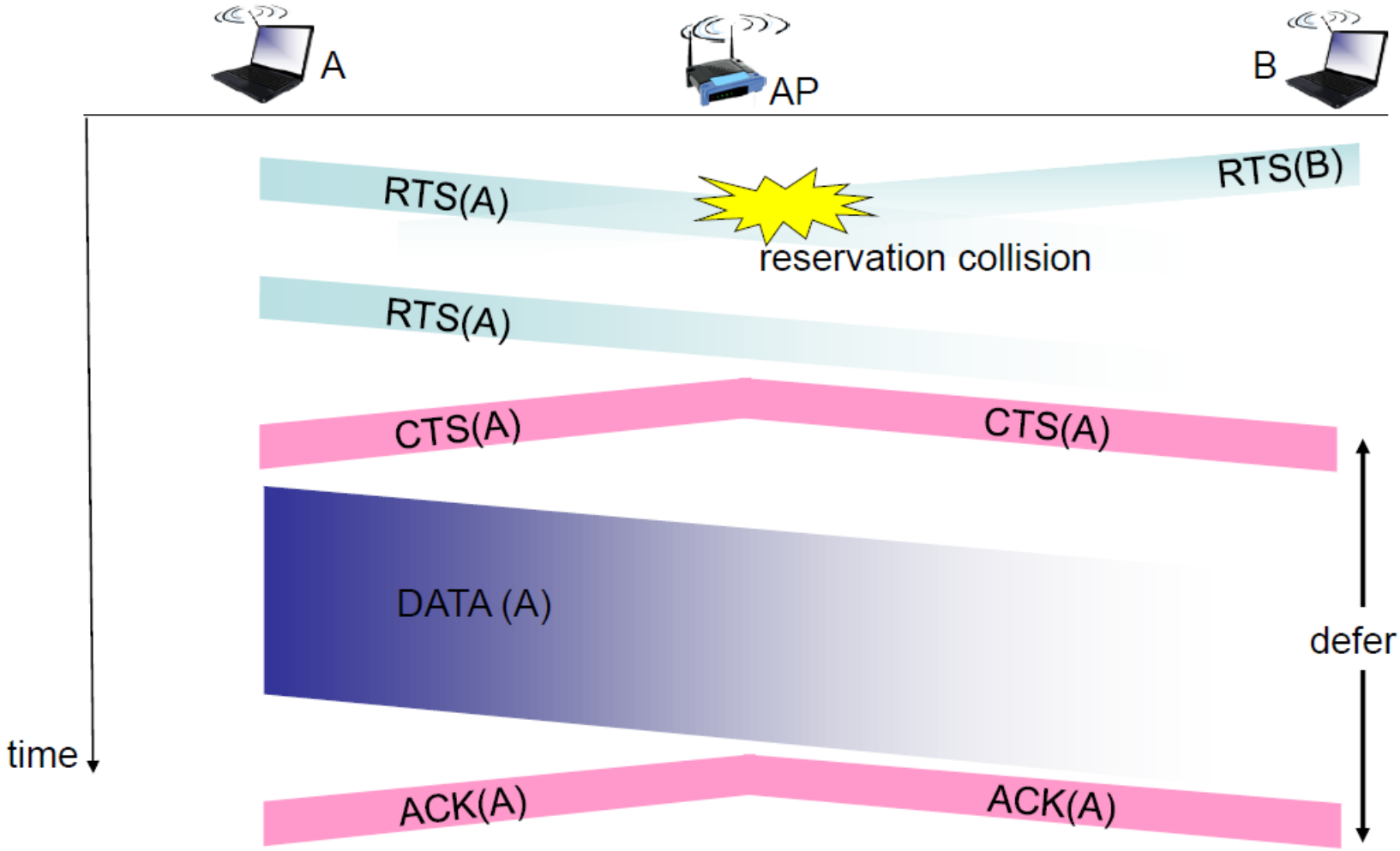
Avoiding Collisions (more)

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

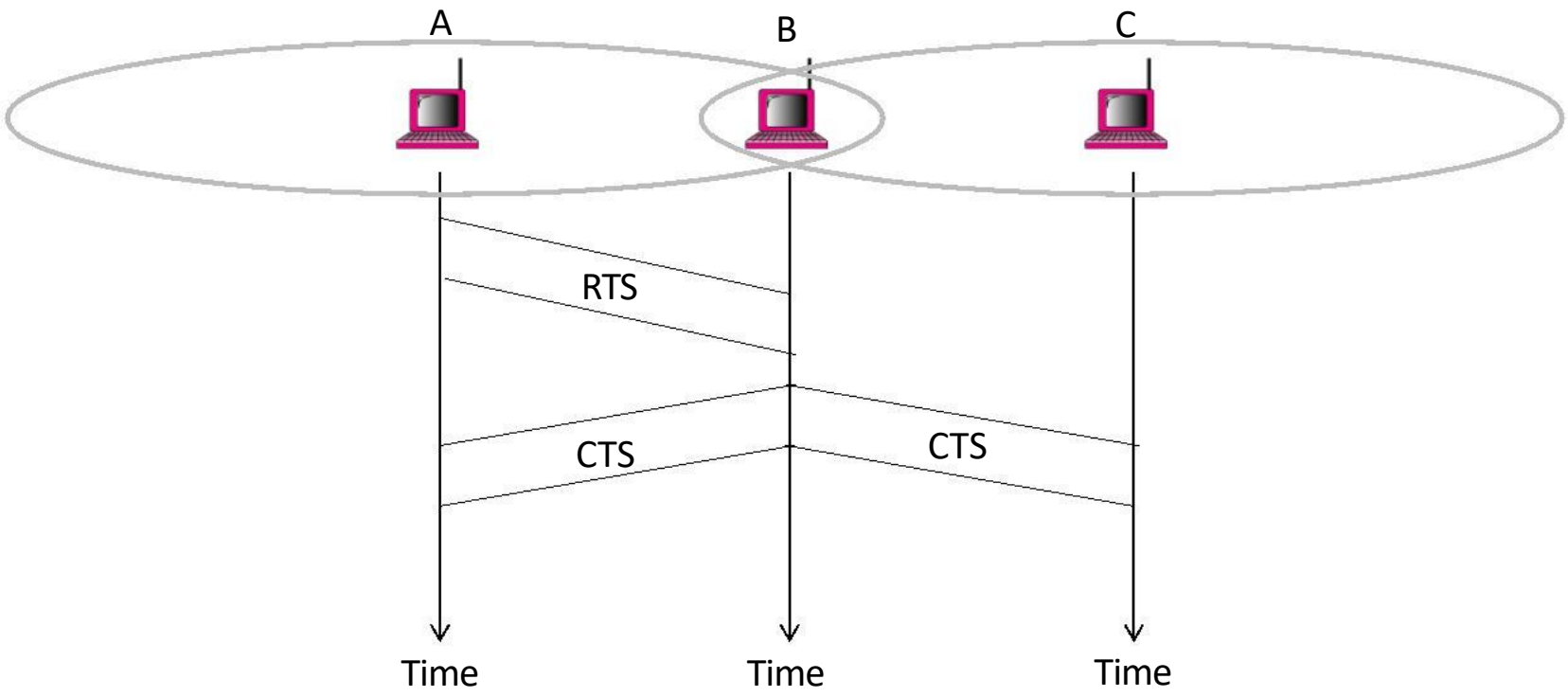
- Sender first transmits *small* request-to-send (RTS) packets to BS using CSMA
  - RTSs may still collide with each other (but they're short)
- BS broadcasts clear-to-send CTS in response to RTS
- CTS heard by all nodes
  - sender transmits data frame
  - other stations defer transmissions

avoid data frame collisions completely using small reservation packets!

Collision Avoidance: RTS-CTS exchange

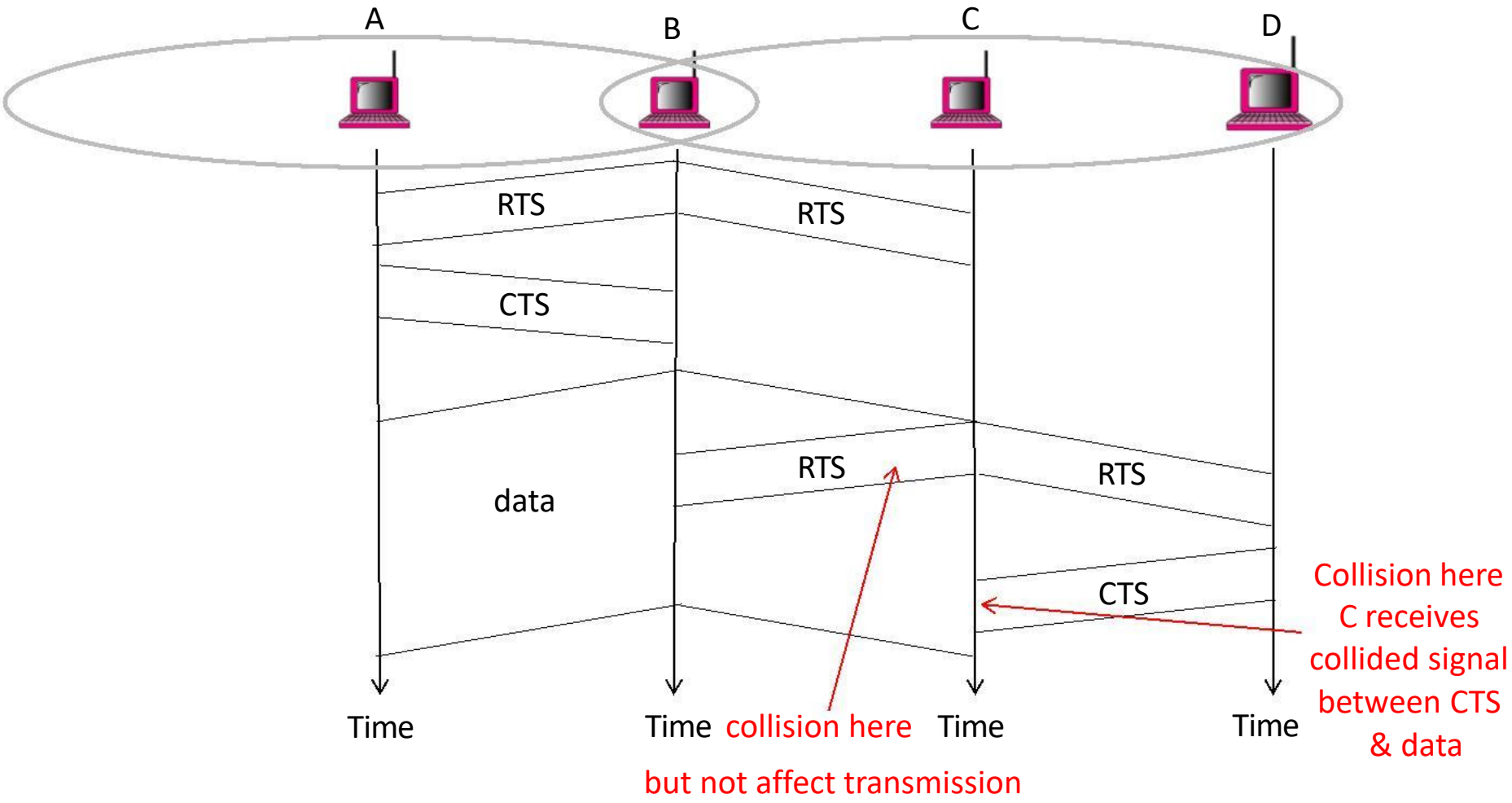


Handshake Preventing Hidden Station Problem



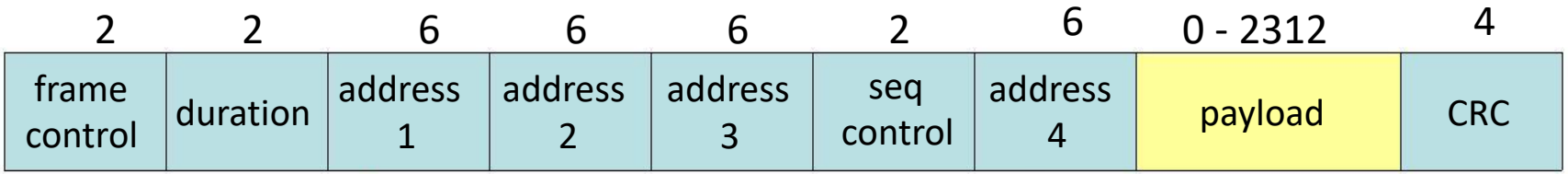
The CTS frame in CSMA/CA handshake can prevent collision from a hidden station

Handshaking in Exposed Station Problem



The handshaking can not help with the exposed station problem.

802.11 Frame: Addressing



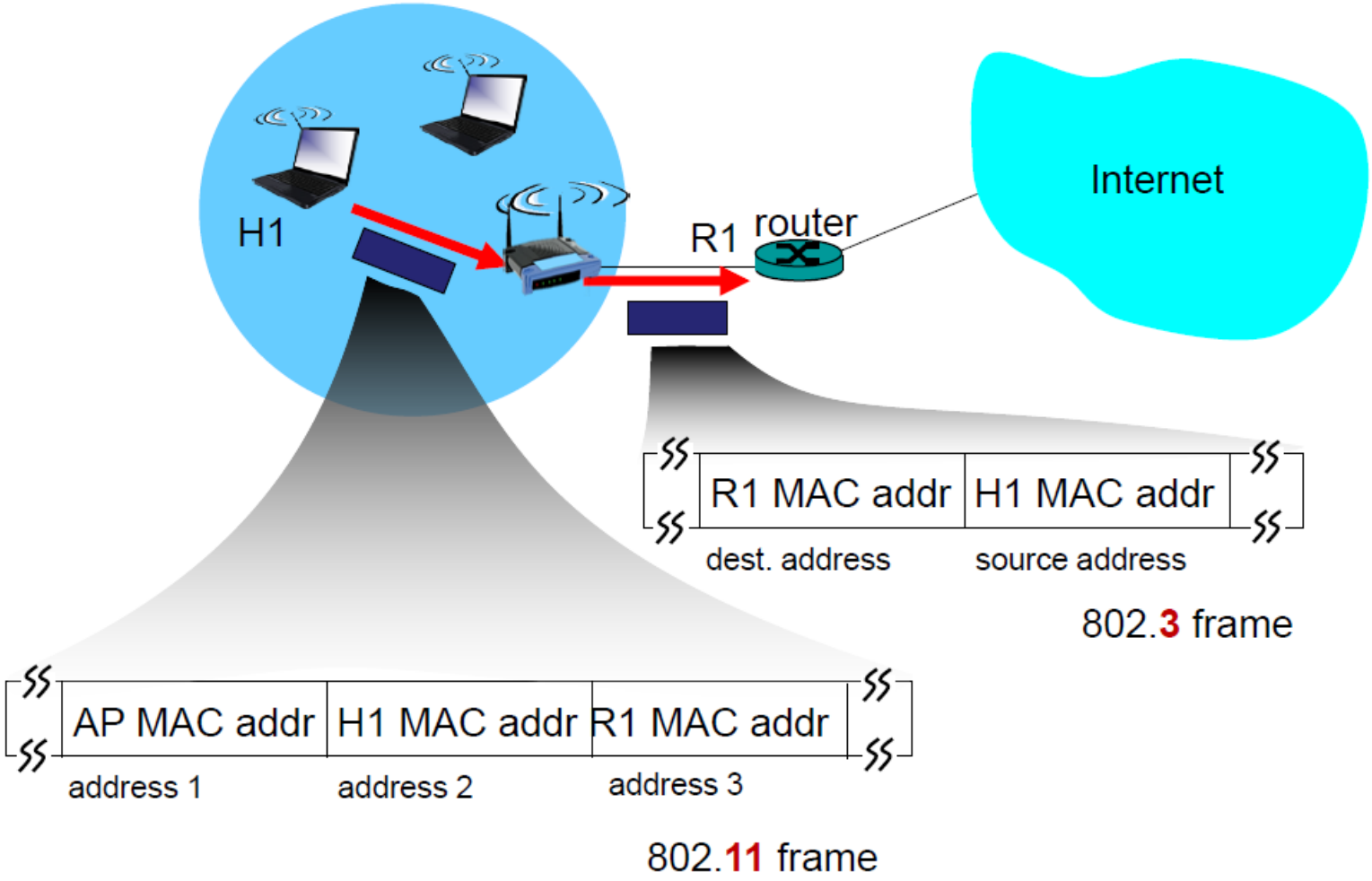
Address 1: MAC address of wireless host or AP to receive this frame

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

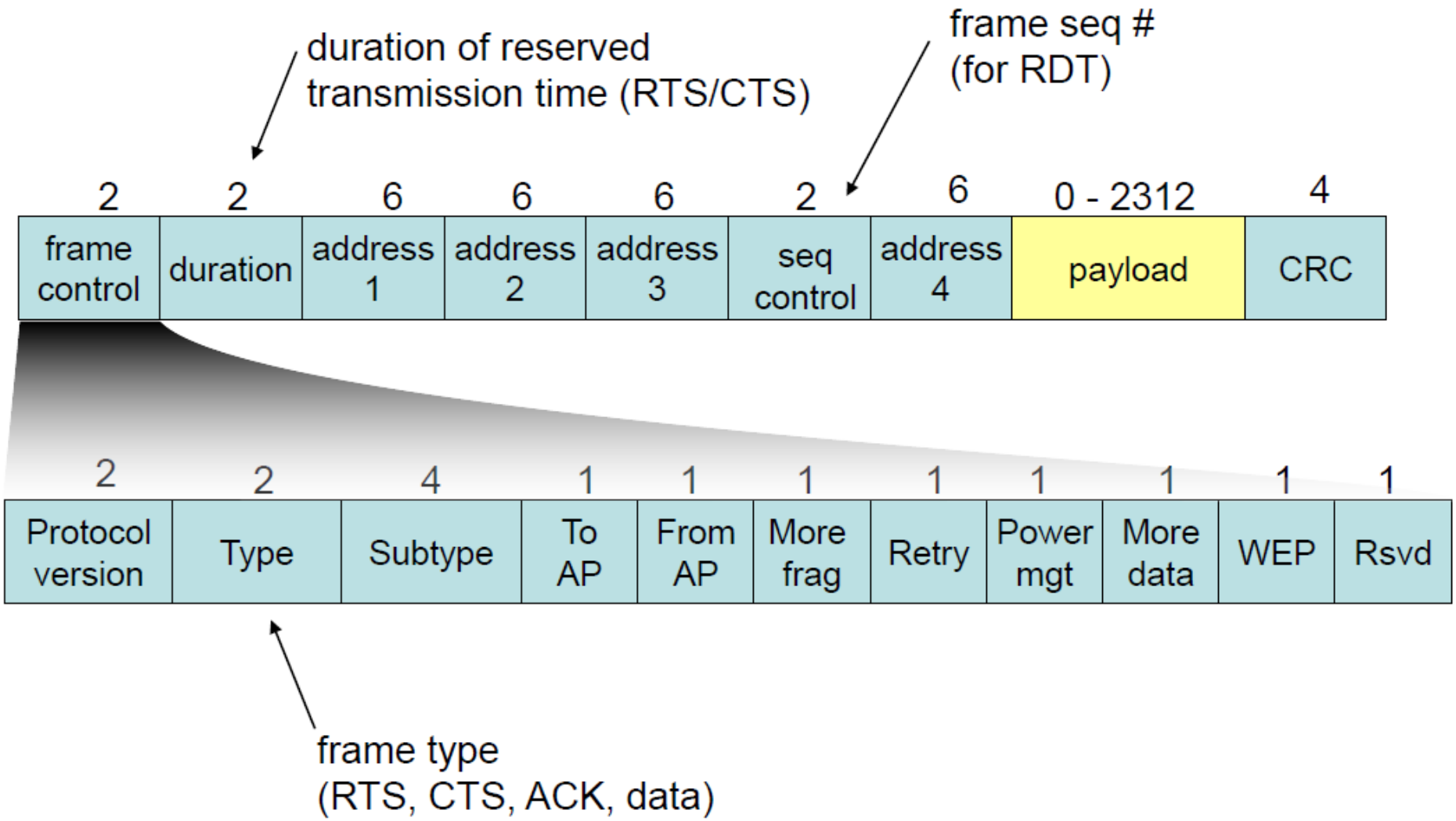
Address 3: MAC address of router interface to which AP is attached

Address 4: used only in ad hoc mode

802.11 Frame: Addressing

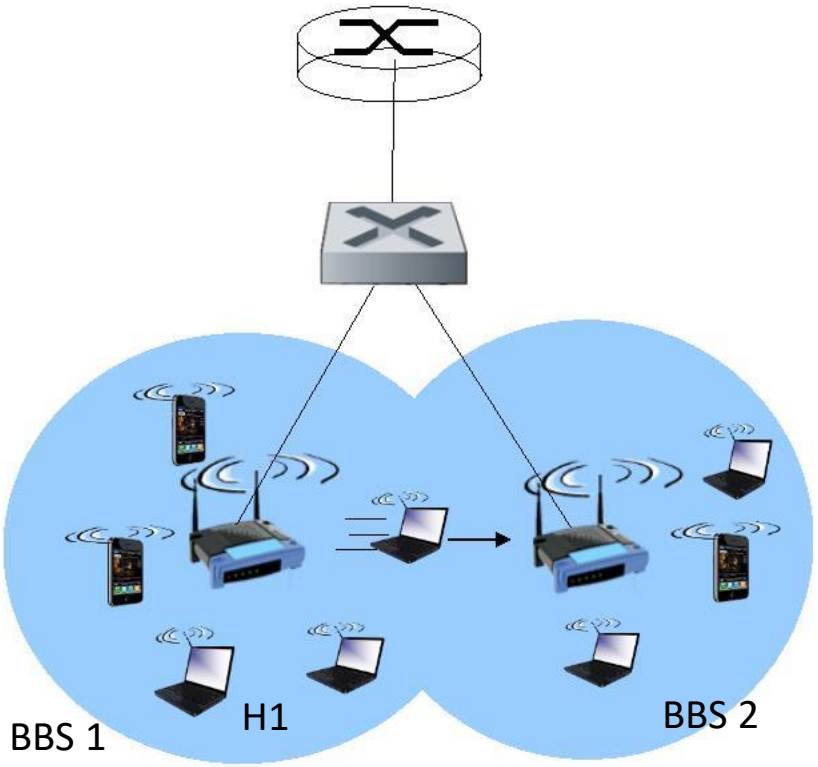


802.11 Frame: More



802.11: Mobility Within Same Subnet

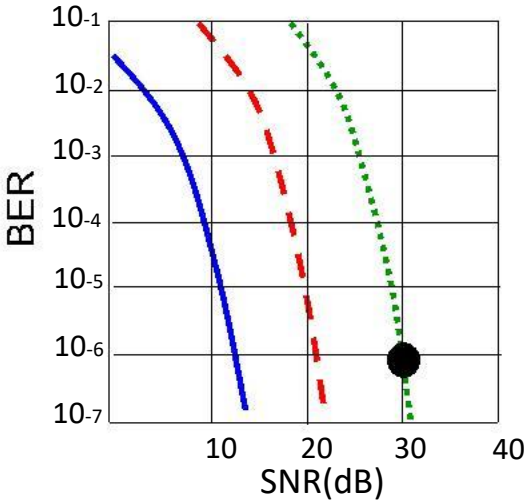
- H1 remains in same IP subnet: IP address can remain same
- Switch: which AP is associated with H1?
  - self-learning (Ch. 5): switch will see frame from H1 and "remember" which switch port can be used to reach H1

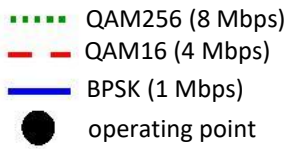


802.11: Advanced Capabilities

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

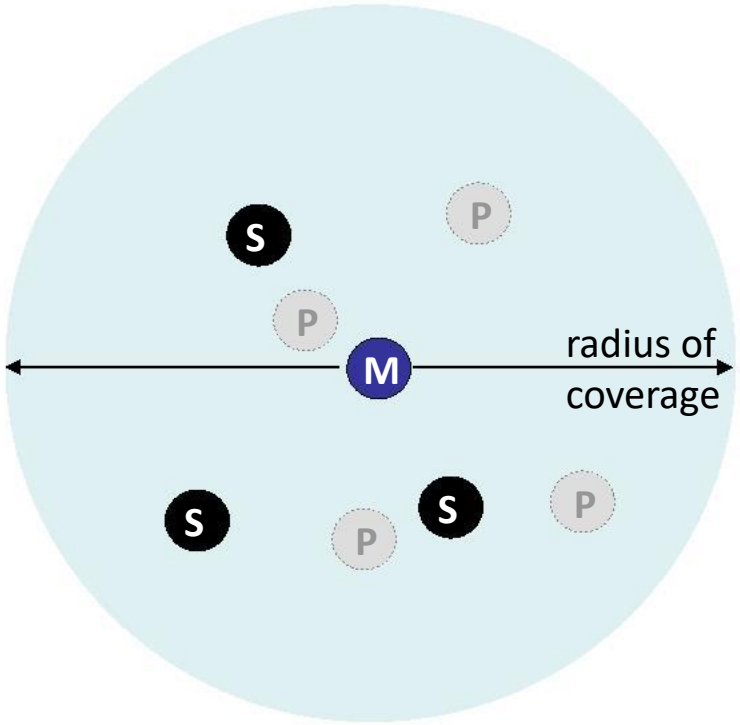
802.11: Advanced Capabilities

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

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



Drawbacks on the conventional MAC protocols

- **Collisions**
  - Two or more nodes simultaneously transmit on a shared medium.
- **Overhearing**
  - Node drains energy receiving irrelevant packets e.g. unicast packets or redundant broadcast packets.
- **Overhead**
  - Useless data that results energy waste when transmitting or receiving.
  - Some control packets (RTS or CTS) do not carry any useful data to application.
- **Idle listening**
  - Node keeps turn on the radio while waiting for the receiving data.