EECS 489
Computer Networks

Wireless Networking

Agenda

- Wireless network basics
- 802.11 Wireless LAN

Recap: Point-to-point vs. broadcast medium

- Point-to-point: dedicated pairwise communication
  - E.g., long-distance fiber link
  - E.g., Point-to-point link btw. Ethernet switch and host
- Broadcast: shared wire or medium
  - Traditional Ethernet (pre ~2000)
  - 802.11 wireless LAN

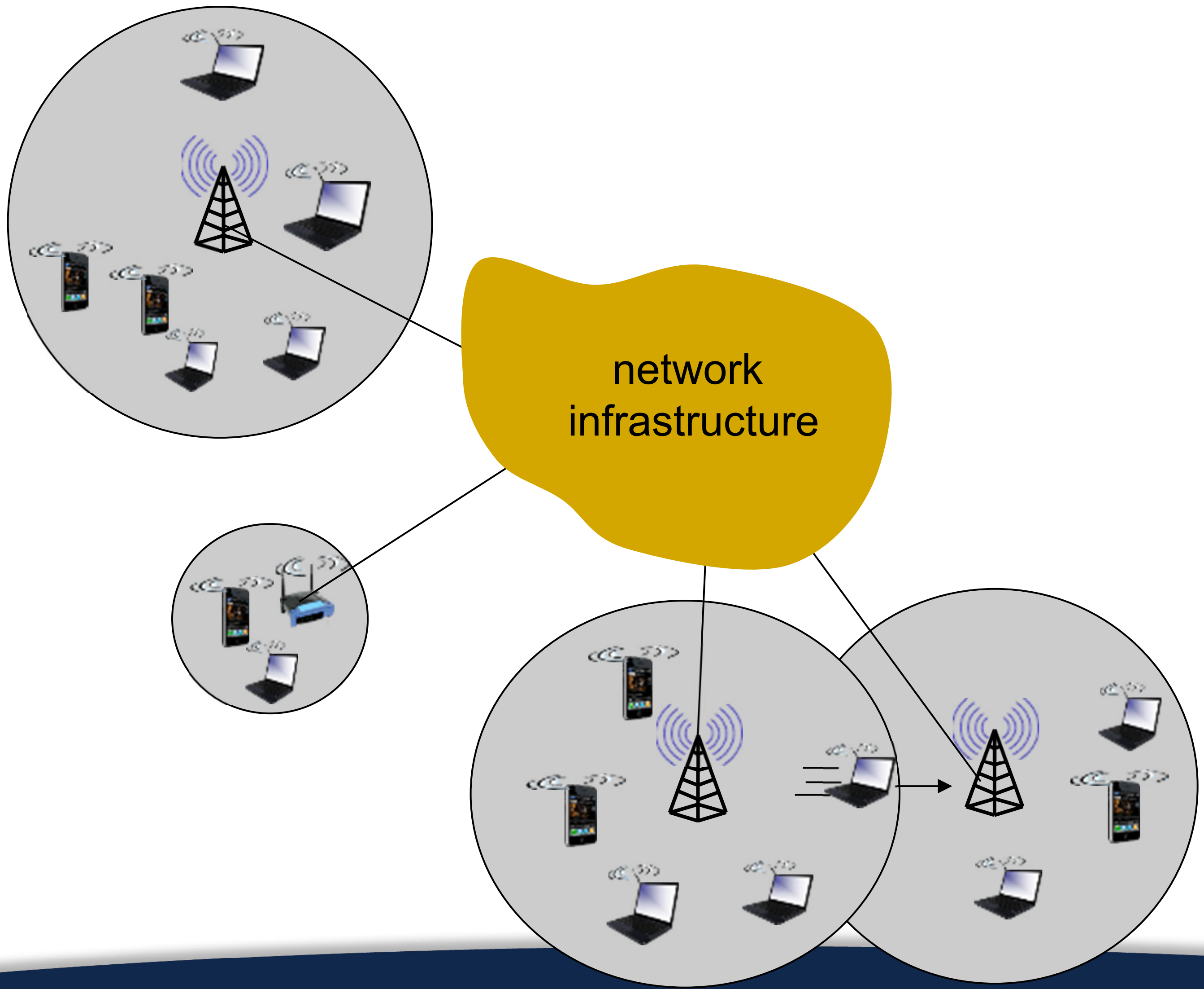
Recap: Multiple access algorithm

- Context: a shared broadcast channel
  - Must avoid having multiple nodes speaking at once
    - Otherwise, collisions lead to garbled data
  - Need distributed algorithm to determine which node can transmit
- Three classes of techniques
  - Channel partitioning: divide channel into pieces
  - Taking turns: scheme for deciding who transmits
  - Random access: allow collisions, and then recover
    - More in the Internet style!

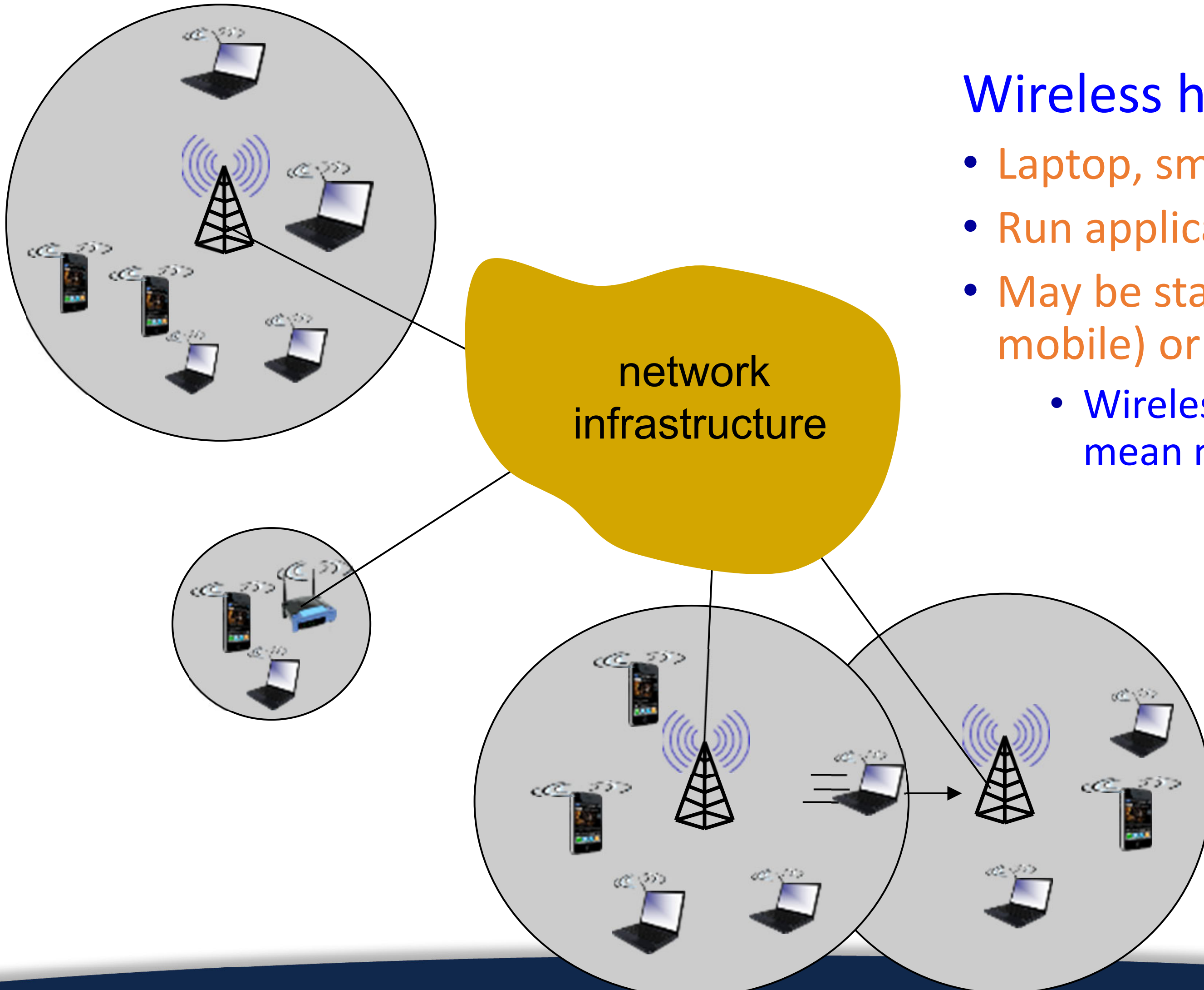
Recap: Random access MAC protocols

- When node has packet to send
  - Transmit at full channel data rate **w/o** coordination
- Two or more transmitting nodes $\Rightarrow$ collision
  - Data lost
- Random access MAC protocol specifies
  - How to detect and recover from collisions
- Examples
  - ALOHA and Slotted ALOHA
  - CSMA, CSMA/CD, CSMA/CA (wireless)

Elements of a wireless network



Elements of a wireless network



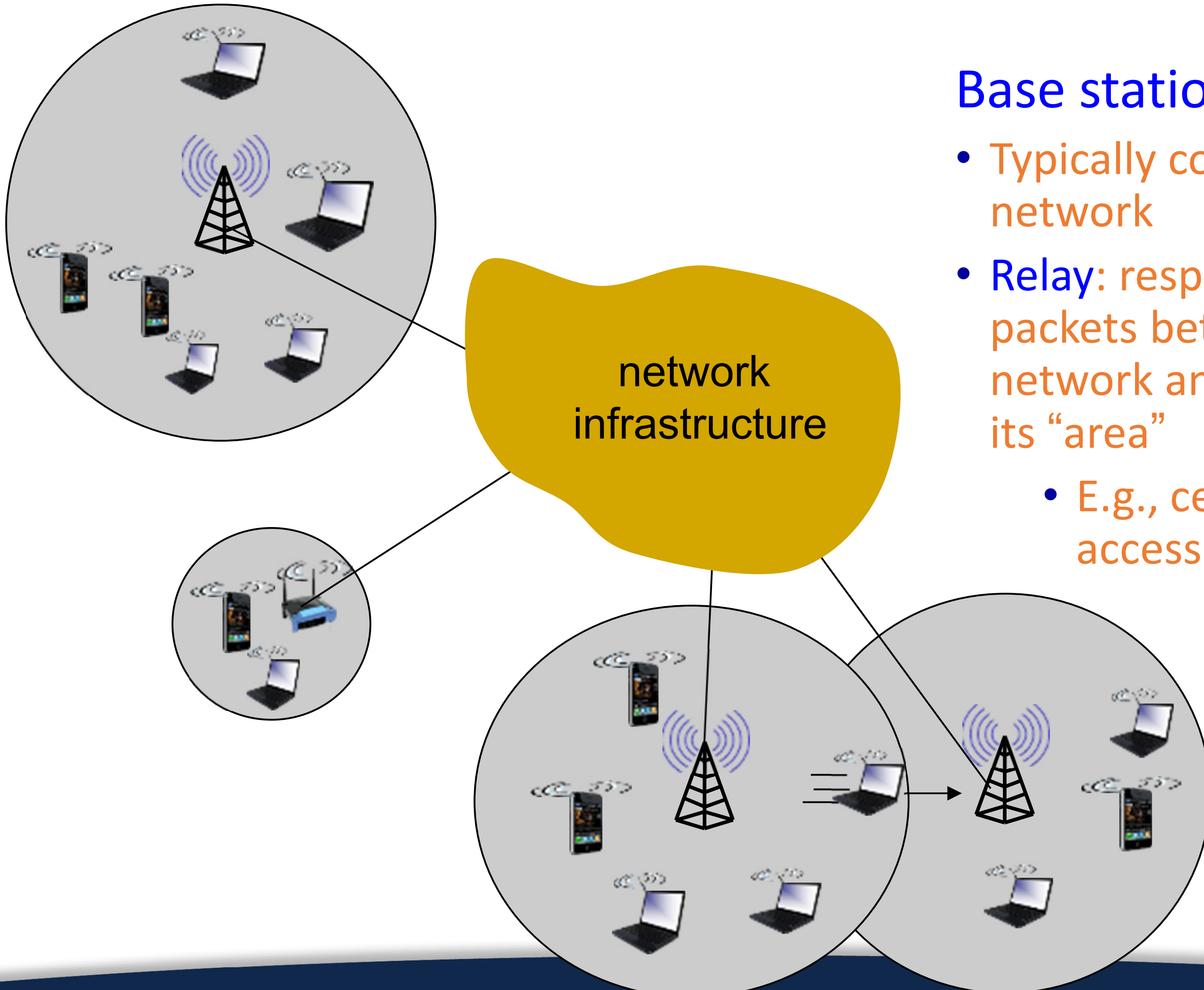
Wireless hosts

- Laptop, smartphone
- Run applications
- May be stationary (non-mobile) or mobile
  - Wireless does *not* always mean mobility

Wireless vs. mobile

- Wireless networks deal with communication over wireless links
- Mobility deals with handling mobile users that change point of attachment to network
  - Non-wireless networks may also have to deal with mobility issues
  - Handoff: Mobile changes base station providing connection into wired network

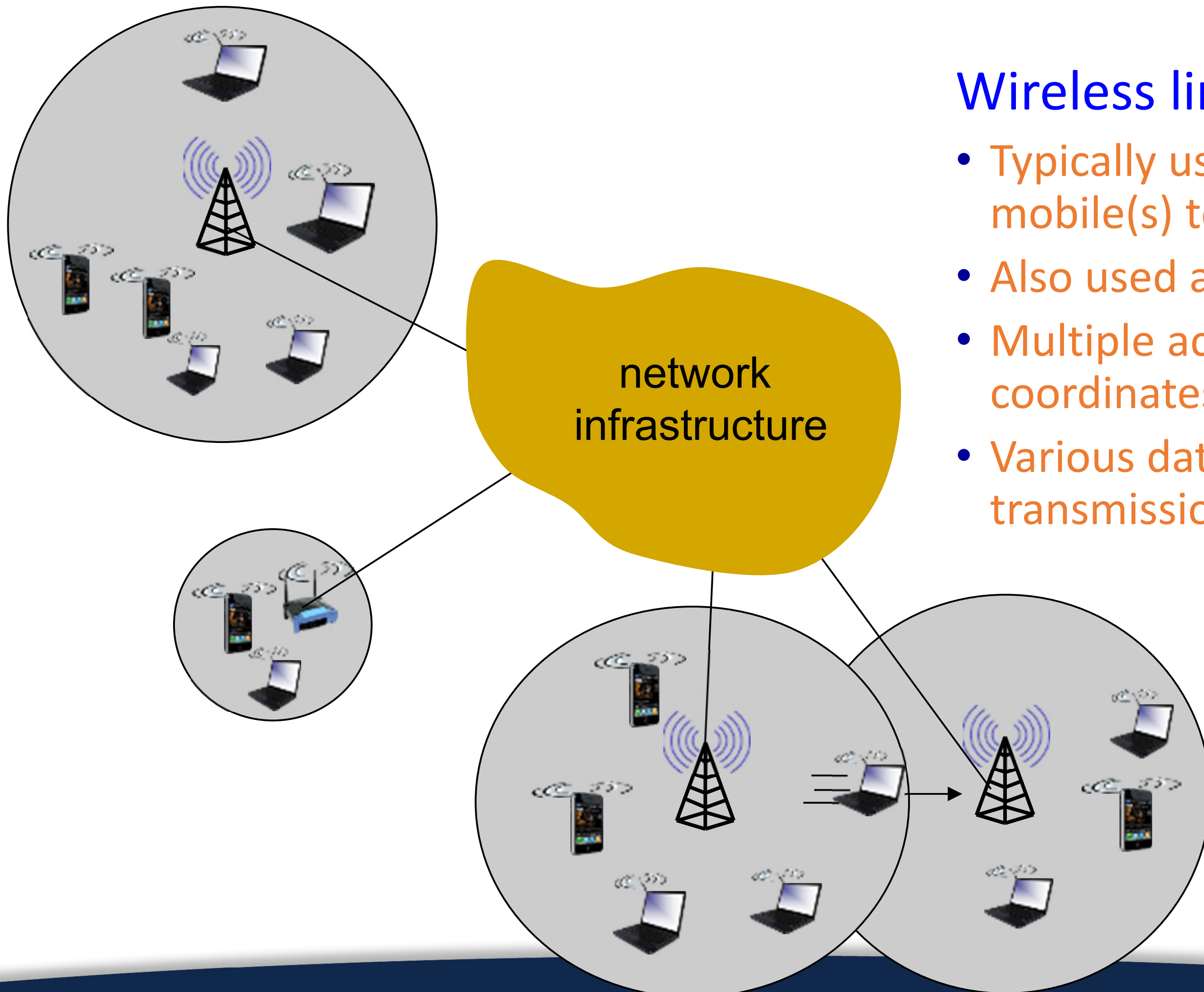
Elements of a wireless network



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 (AP)

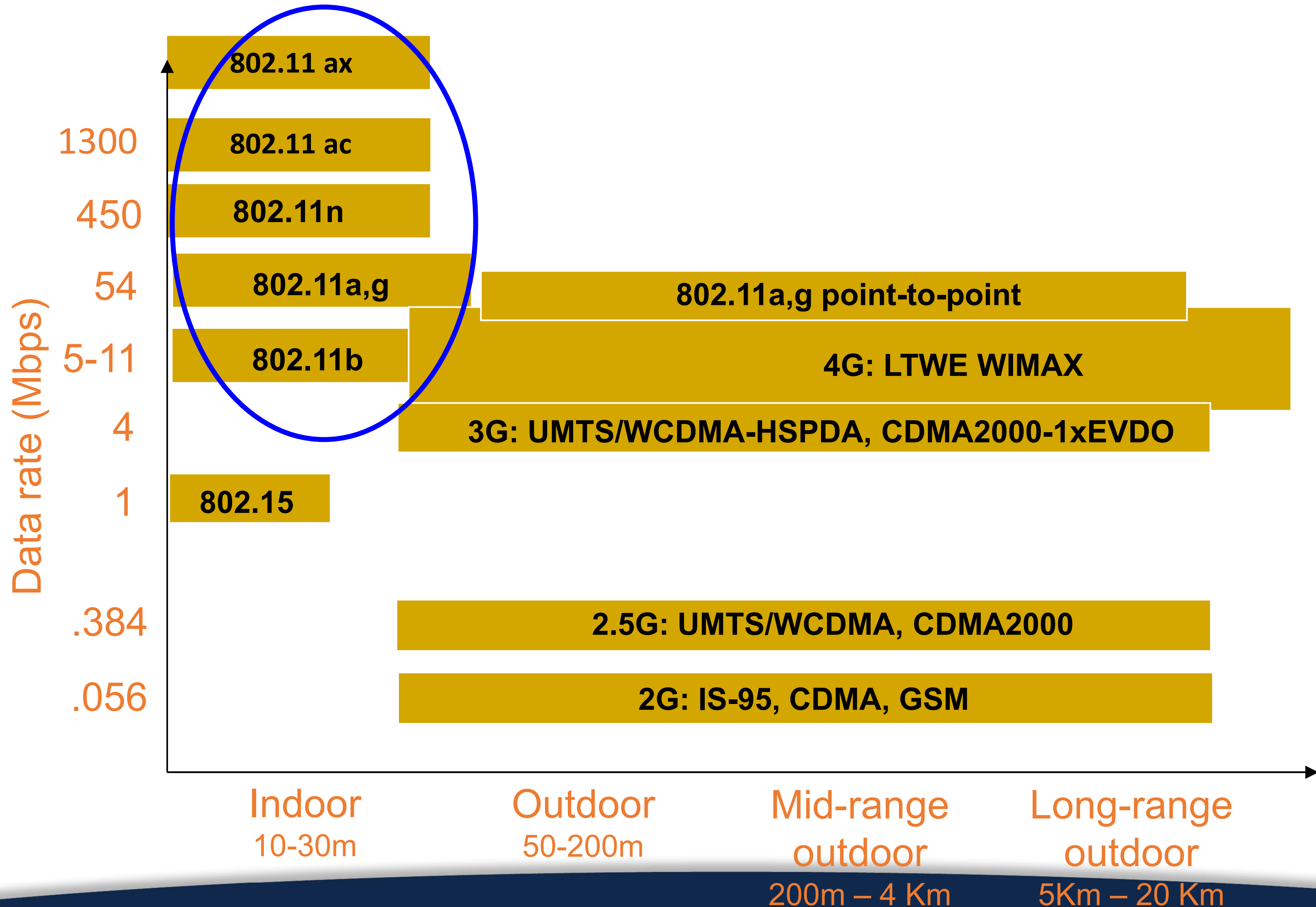
Elements of a wireless network



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

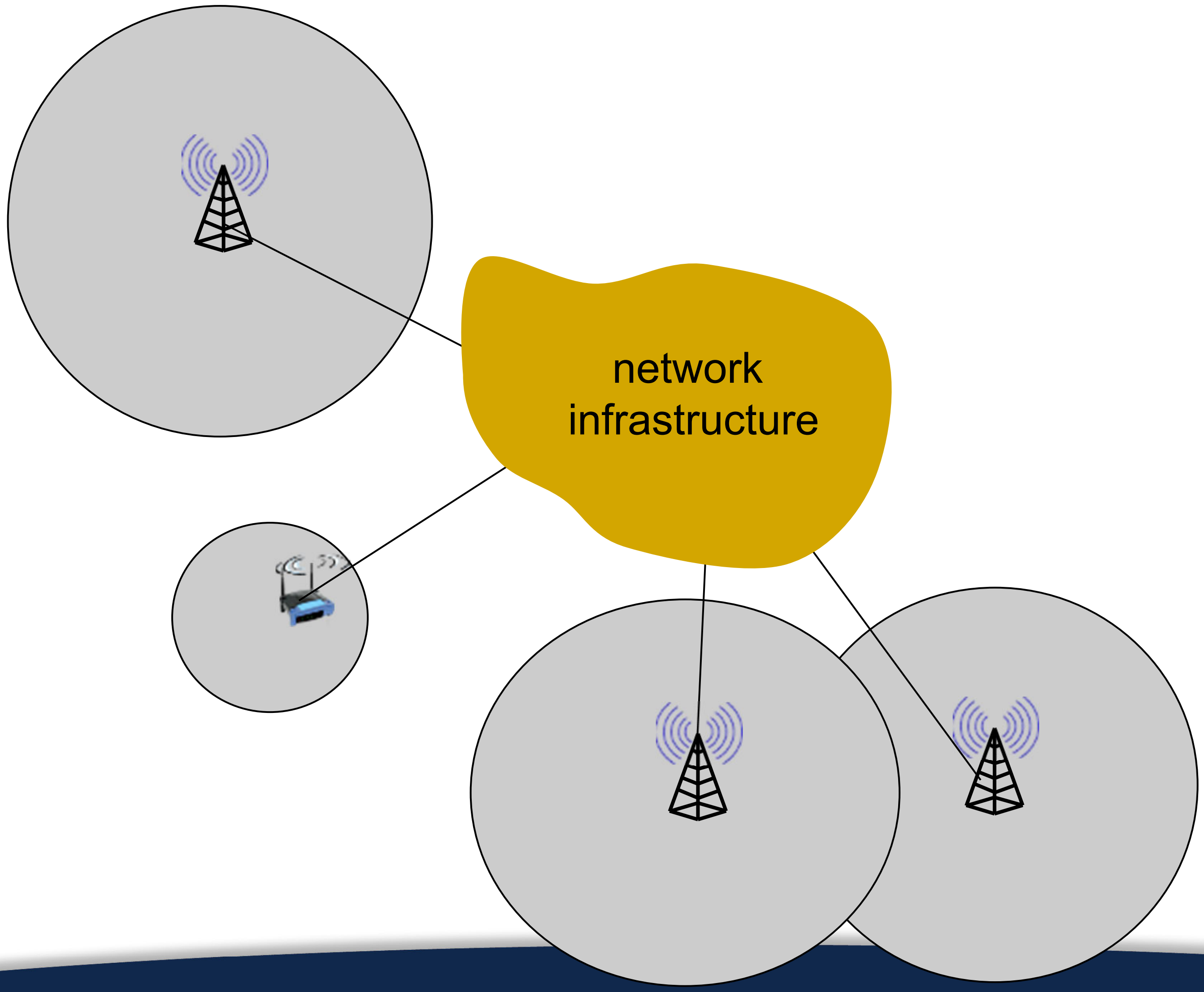
Characteristics of selected wireless links



Two modes of operation

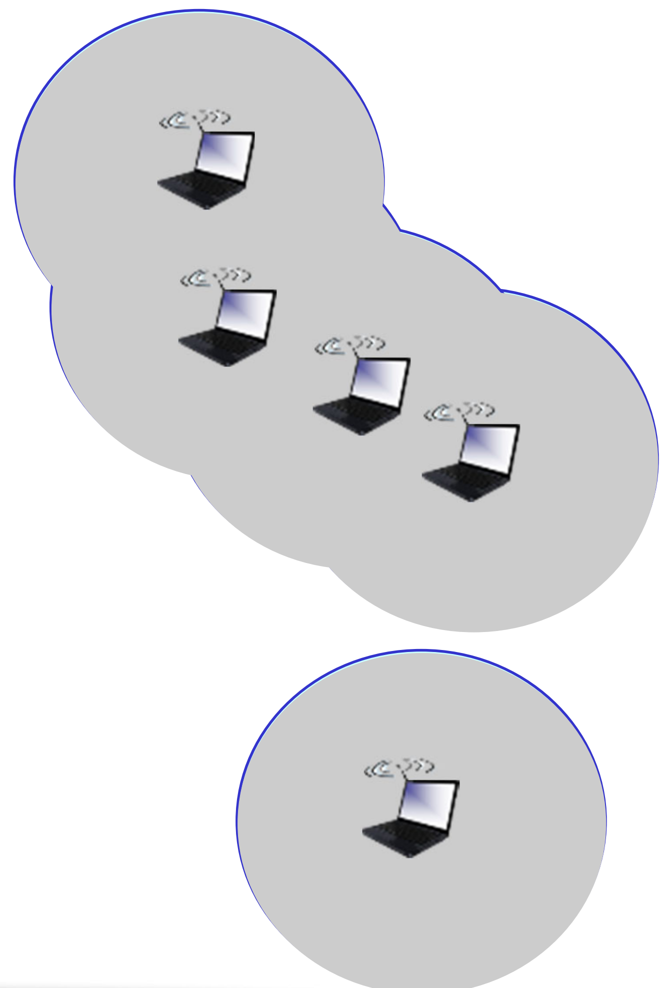
- Infrastructure mode: Base stations connect mobiles to wired network
- Ad-hoc mode: Wireless hosts organize themselves to communicate

Infrastructure mode



Ad-hoc mode

- No base station
- 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

- Three important differences from wired link …
  - Decreased signal strength: Radio signal attenuates as it propagates through matter (path loss)

Path loss/path attenuation

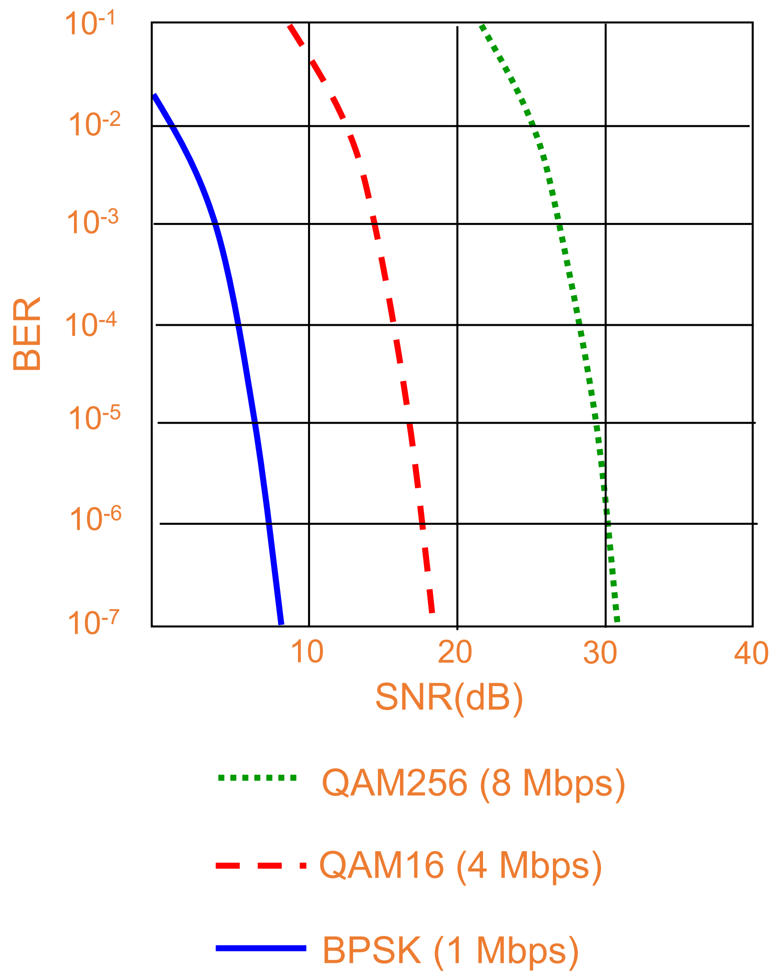
- Free Space Path Loss (FSPL):

$$FSPL = \left(\frac{4\pi df}{c}\right)^2$$

  - d = distance
  - λ = wave length (c/f)
  - f = frequency
  - c = speed of light
- Due to
  - Reflection, diffraction, absorption, terrain contours (urban, rural, vegetation), humidity

SNR and BER

- SNR: Signal-to-noise ratio
  - Larger SNR makes it easier to extract signal from noise (good)
- BER: Bit error rate
- SNR vs. BER tradeoffs
  - Given physical layer: Increase power → increase SNR → decrease BER
  - Given SNR: Choose physical layer that meets BER requirement, giving highest throughput
  - SNR may change with mobility: Dynamically adapt physical layer



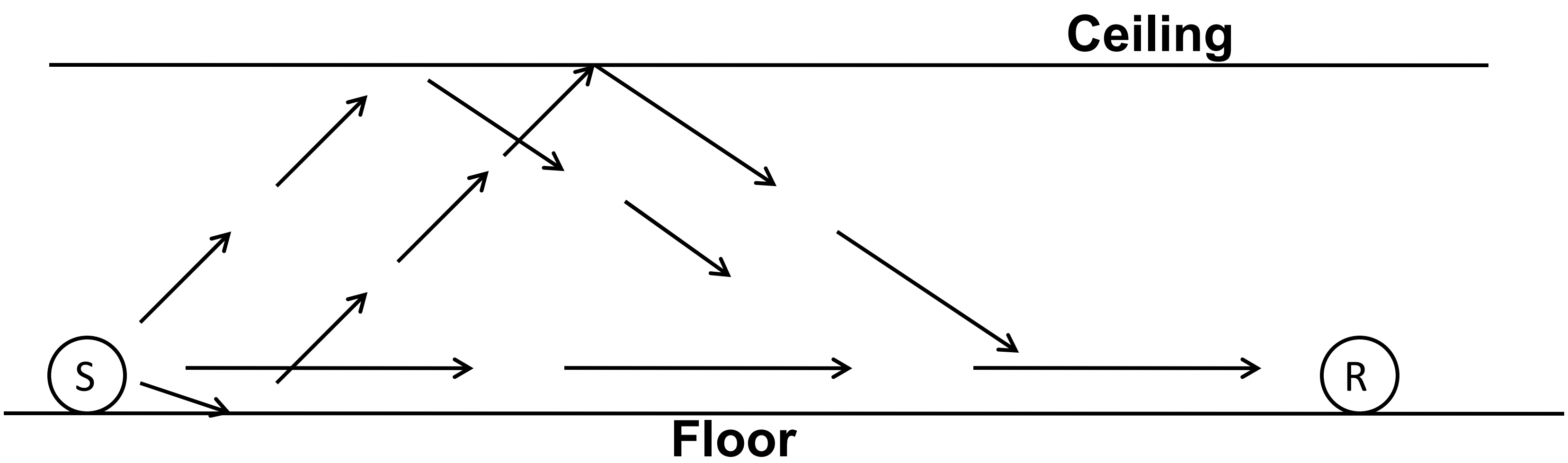
Dealing with bit errors

- Wired vs. wireless links: most loss due to congestion vs. higher, time-varying BER
- Dealing with high wireless bit-error rates
  - Sender could increase transmission power
    - Needs hi energy (bad for battery-powered hosts)
    - Creates more interference with other senders
  - Stronger error detection and recovery
    - More powerful error detection/correction codes
    - Link-layer retransmission of corrupted frames
  - Many TCP alternatives/extensions for wireless
    - TCP Westwood uses Explicit Loss Notification (ELN)

Wireless link characteristics

- Three important differences from wired link …
  - Decreased signal strength: Radio signal attenuates as it propagates through matter (path loss)
  - Multipath propagation: Radio signal reflects off objects ground, arriving at destination at slightly different times

Multipath effects



- Signals bounce off surface and interfere with one another
- Self-interference

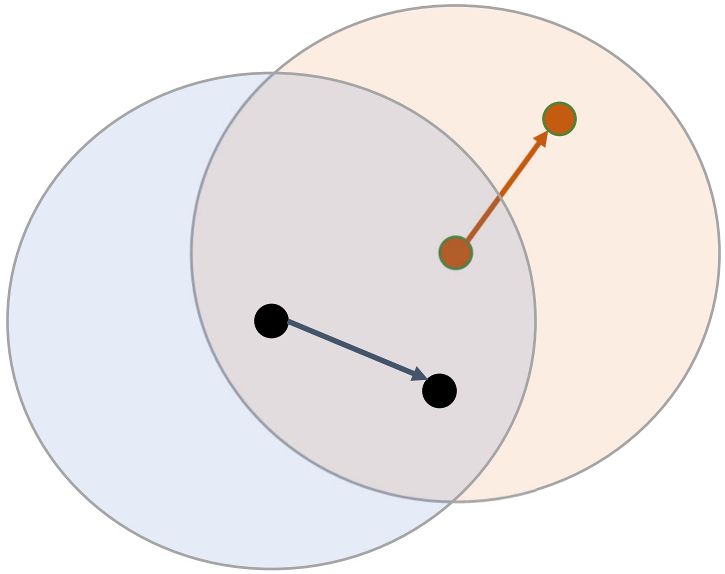
Wireless link characteristics

- Three important differences from wired link …
  - Decreased signal strength: Radio signal attenuates as it propagates through matter (path loss)
  - Multipath propagation: Radio signal reflects off objects ground, arriving ad destination at slightly different times
  - 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
- … make communication across (even a point-to-point) wireless link much more "difficult"

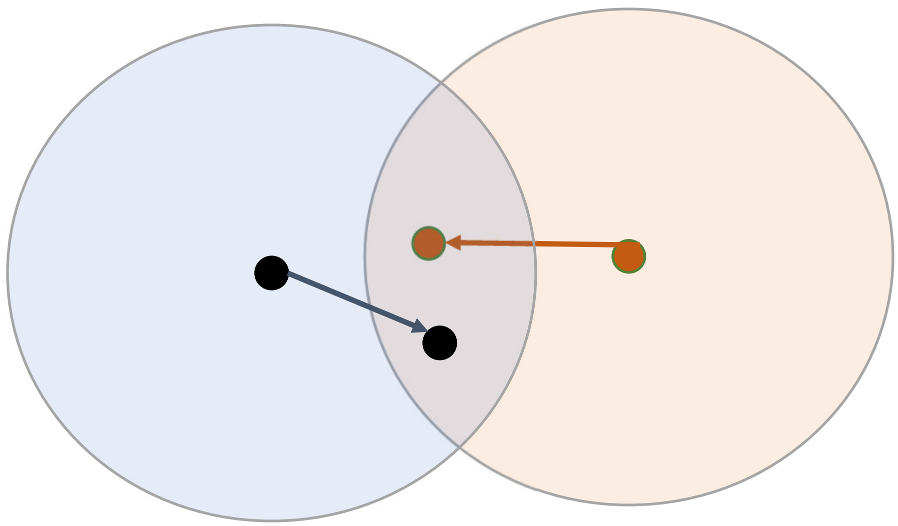
Wireless network characteristics

- Broadcast medium
  - Anybody in proximity can hear and interfere
- Cannot receive while transmitting
  - Our own (or nearby) transmission is deafening our receiver ⇒ Half-duplex
  - Recent work has shown that full duplex is possible
- Signals sent by sender don't always end up at receiver intact

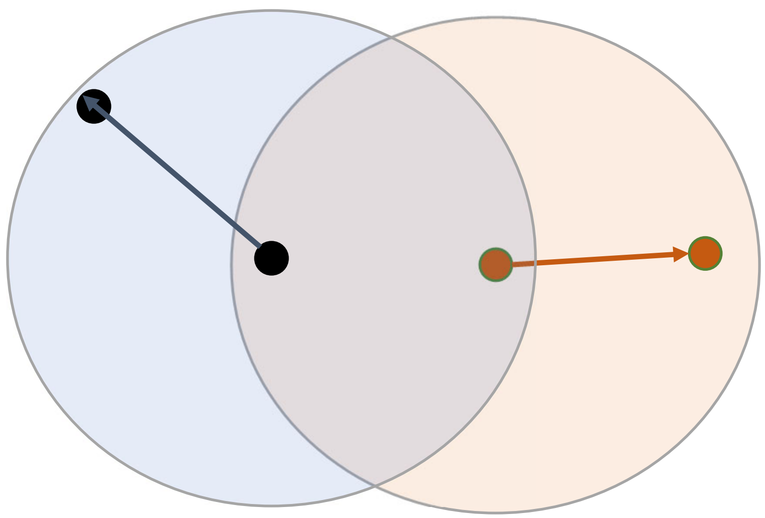
Design this protocol



Does your protocol work?



How about now?

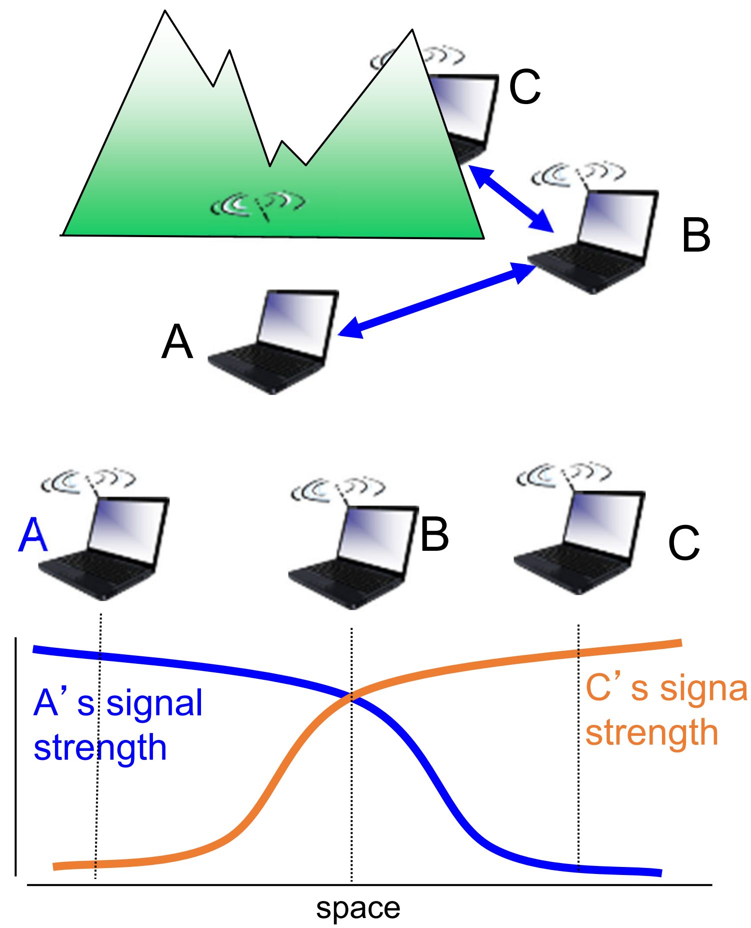


Wireless network characteristics

- Multiple wireless senders and receivers create many problems
  - Multiple access issues (we’ve seen this before)
  - Hidden terminal problem

Hidden terminal problem

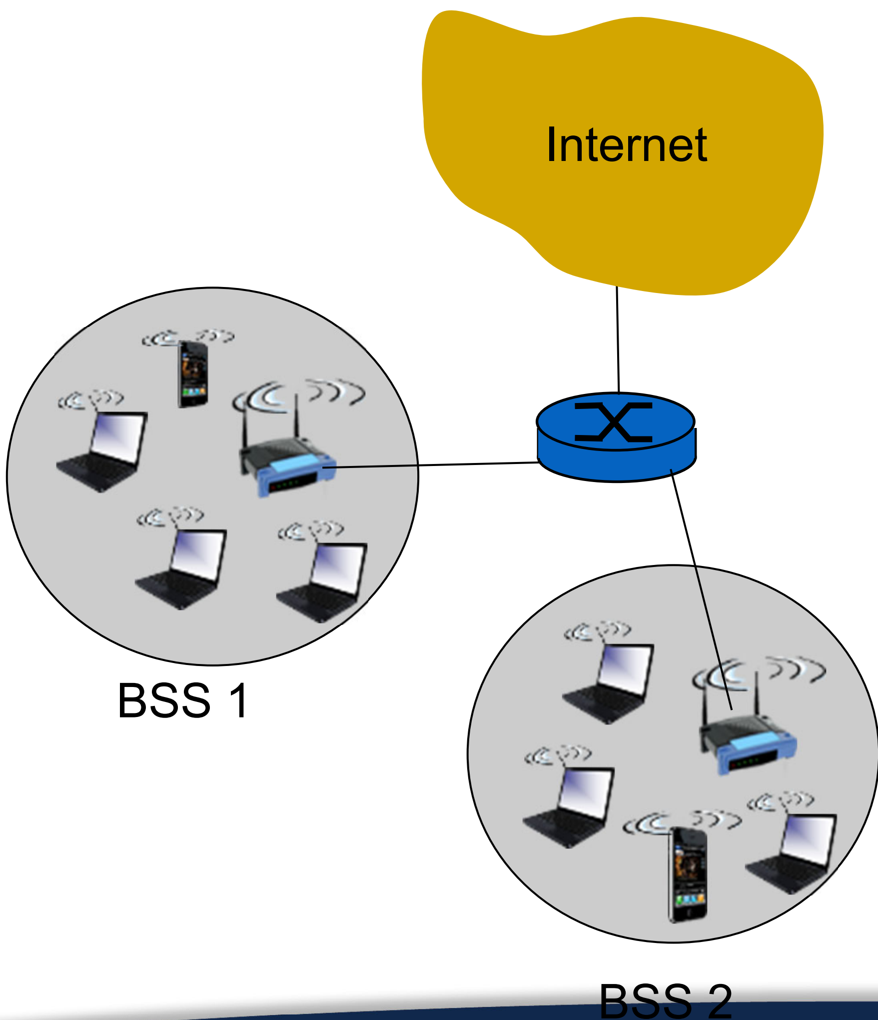
- B, A hear each other
- B, C hear each other
- A, C can not hear each other
- Hence, A, C are unaware of their interference at B



802.11 wireless LAN (aka WiFi)

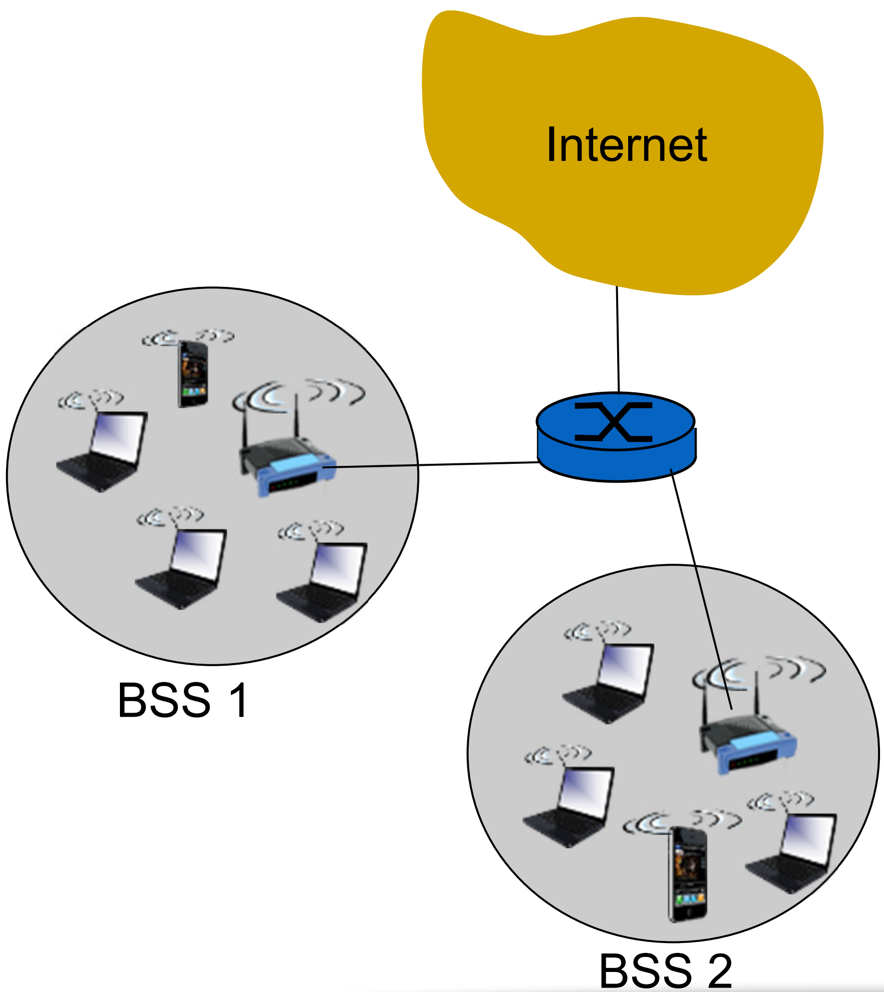
- Many variations
  - 802.11b, 802.11a, 802.11g, 802.11n, 802.11a*
- All use CSMA/CA for multiple access
- All have infrastructure and ad-hoc modes

802.11 LAN architecture



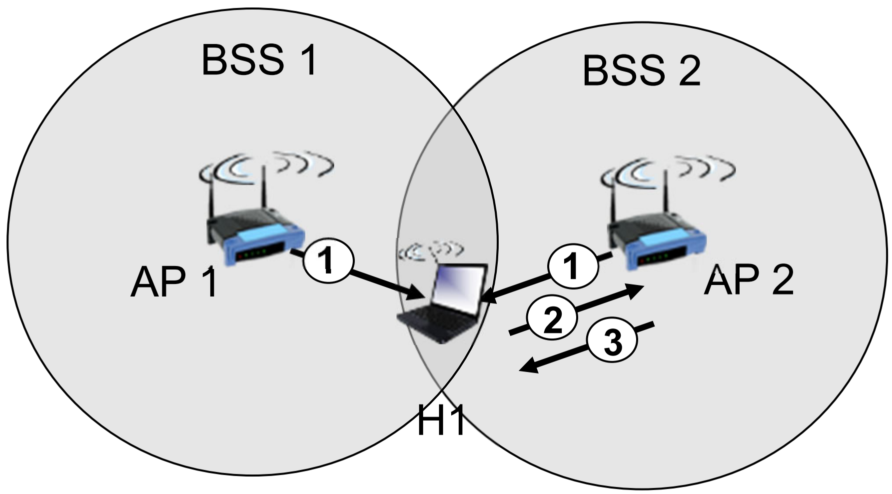
- Wireless host communicates with base station
  - Base station = access point (AP)
- Basic Service Set (BSS) (aka "cell") in infrastructure mode contains
  - Wireless hosts
  - Access point (AP): base station
- Ad-hoc mode: hosts only

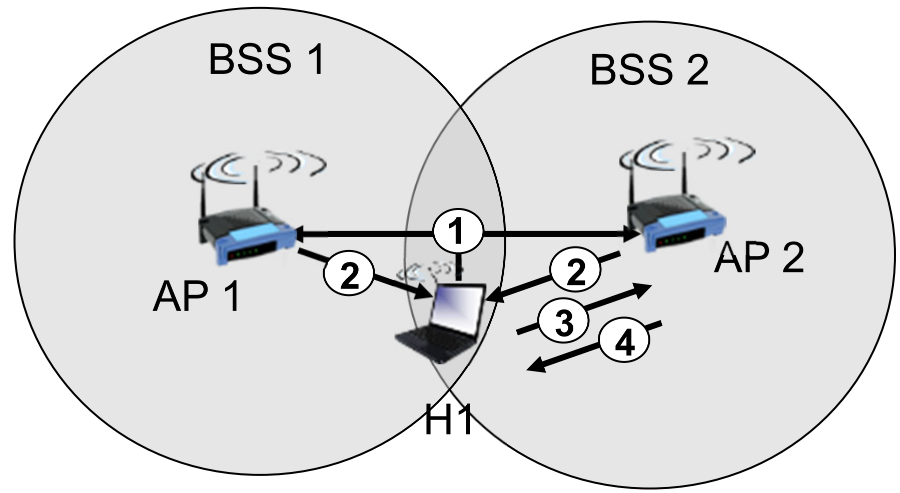
802.11 LAN architecture



- Designed for limited area
- AP is set to specific channel
  - Broadcast beacon messages with SSID (Service Set Identifier) and MAC Address periodically
- Hosts scan all the channels to discover the AP's
  - Host associates with AP

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 from H1 to selected AP
4. Association Response frame sent from selected AP to H1

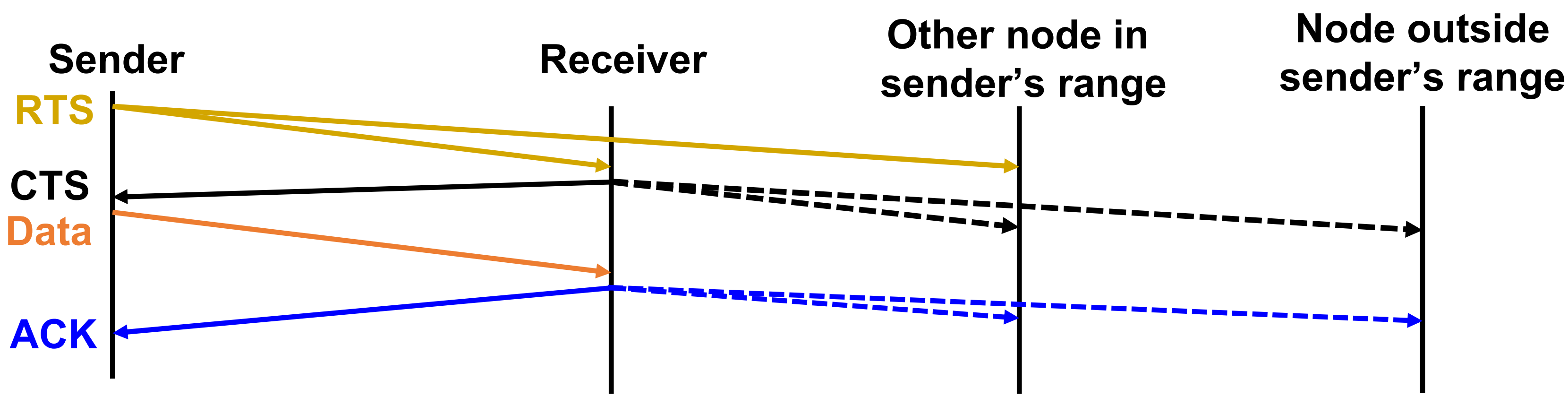
802.11 multiple access

- 802.11 CSMA: sense before transmitting
  - Don't collide with ongoing transmissions by others
- 802.11 has 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
- Avoid collisions: CSMA/CA
  - CA: Collision Avoidance

Basic collision avoidance

- Carrier sense:
  - When medium busy, choose random interval
  - Wait that many idle timeslots to pass before sending
- When a collision is inferred, retransmit with binary exponential backoff (like Ethernet)
  - Use ACK from receiver to infer "no collision"
  - Use exponential backoff to adapt contention window

CSMA/CA

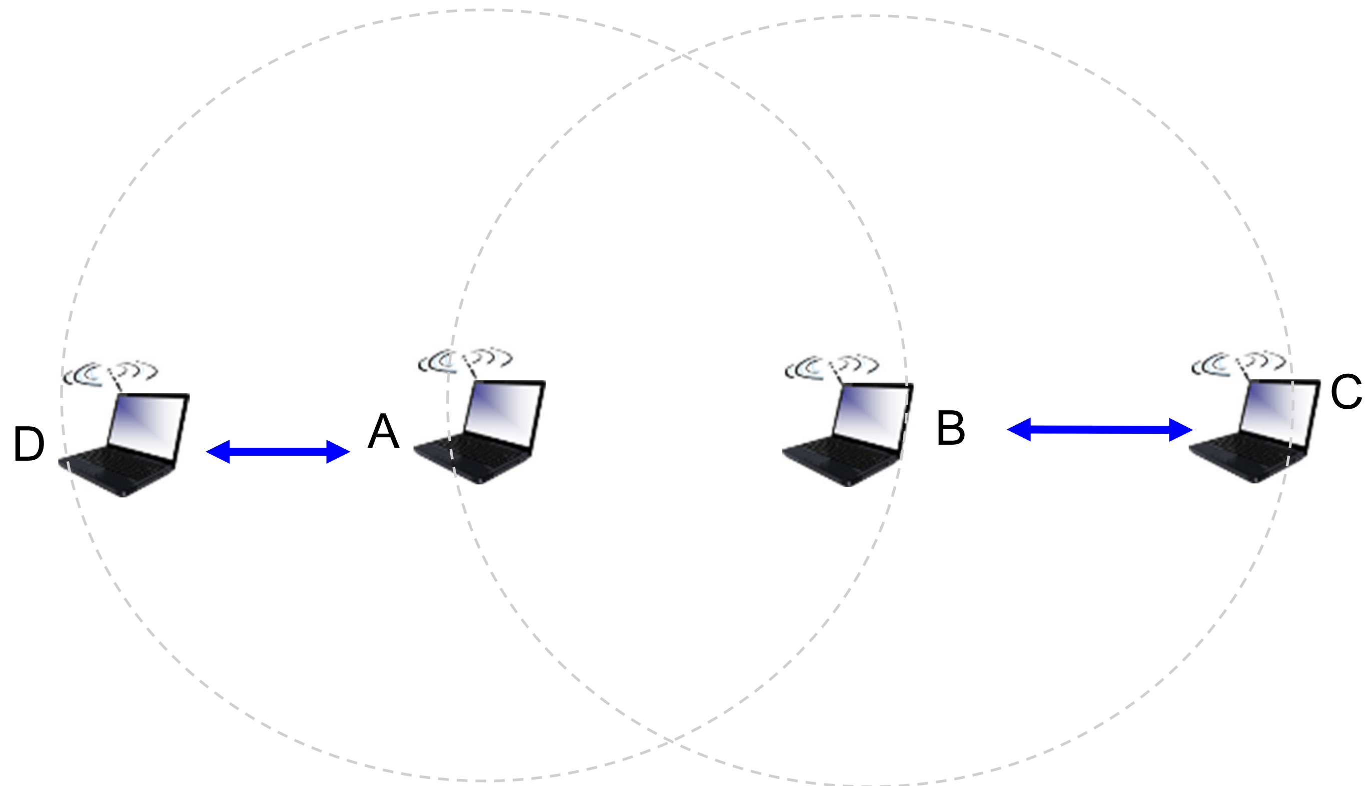


- Before every data transmission
  - Sender sends a Request to Send (RTS) frame with the length of transmission and the destination
  - Receiver respond with a Clear to Send (CTS) frame
  - Sender sends data
  - Receiver sends an ACK
- If sender doesn't get a CTS back, it assumes collision

RTS/CTS

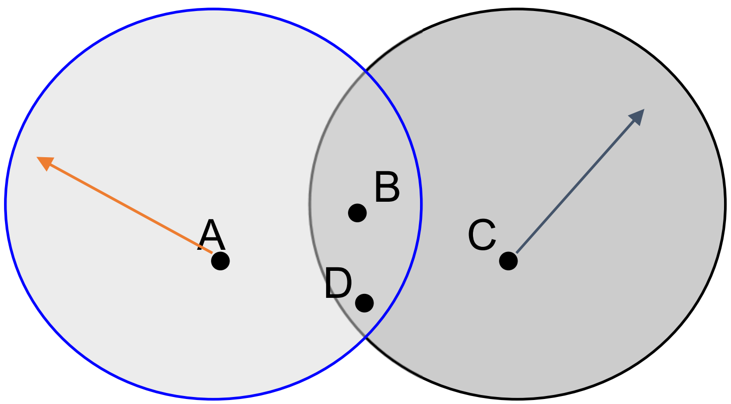
- Works by reserving the channel using short frames before transferring much longer DATA frame
  - Explicitly reserving the channel enables avoidance
- Required to avoid hidden terminals
  - Hidden terminals will hear CTS from the receiver

Exposed Node Problem



Preventing collisions altogether

- Frequency Spectrum partitioned into several channels
  - Nodes within interference range can use separate channels



  - Now A and C can send without any interference!
  - Aggregate Network throughput doubles

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

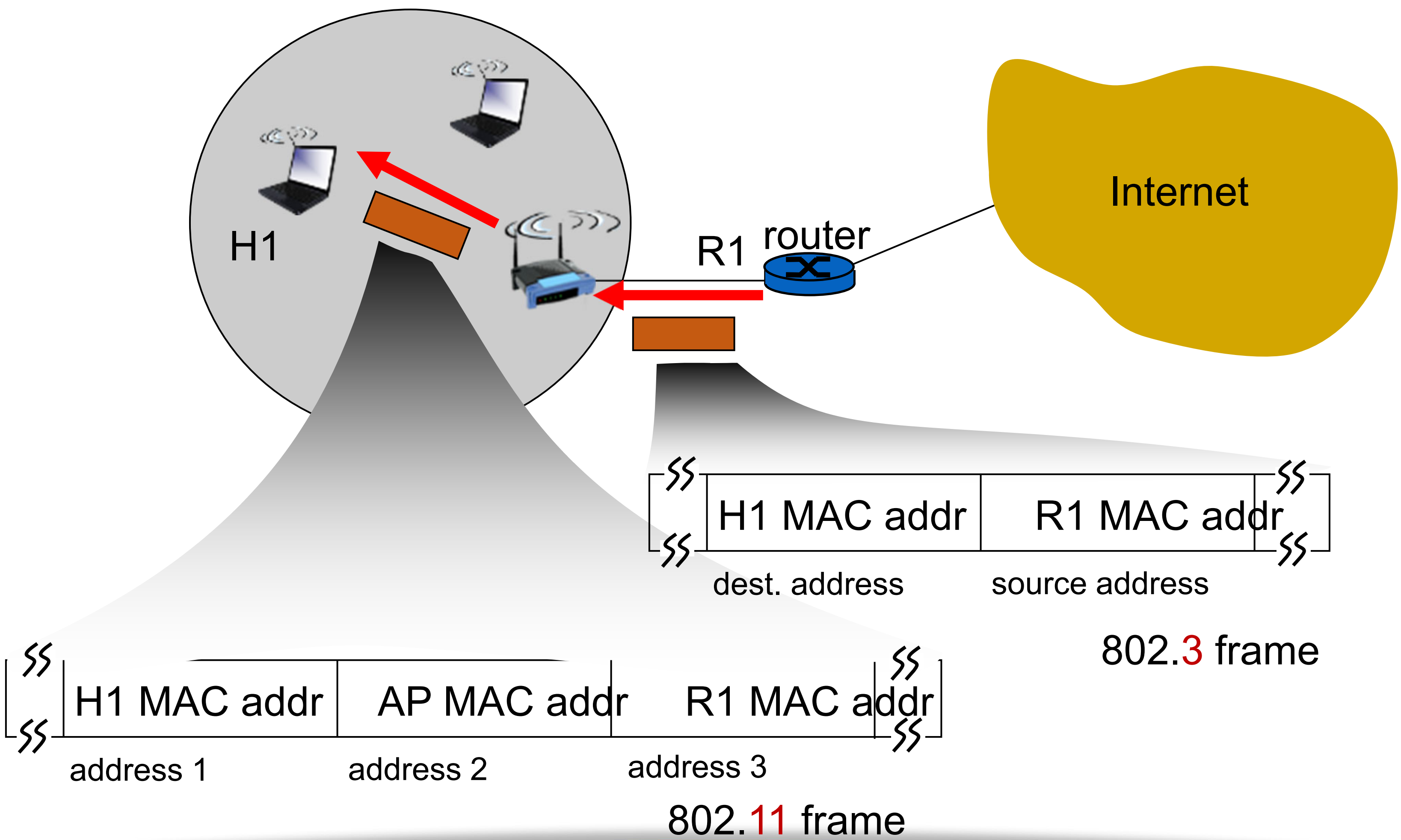
Address 1: MAC address of wireless host or AP to receive this frame

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

Why do we need Address 3?



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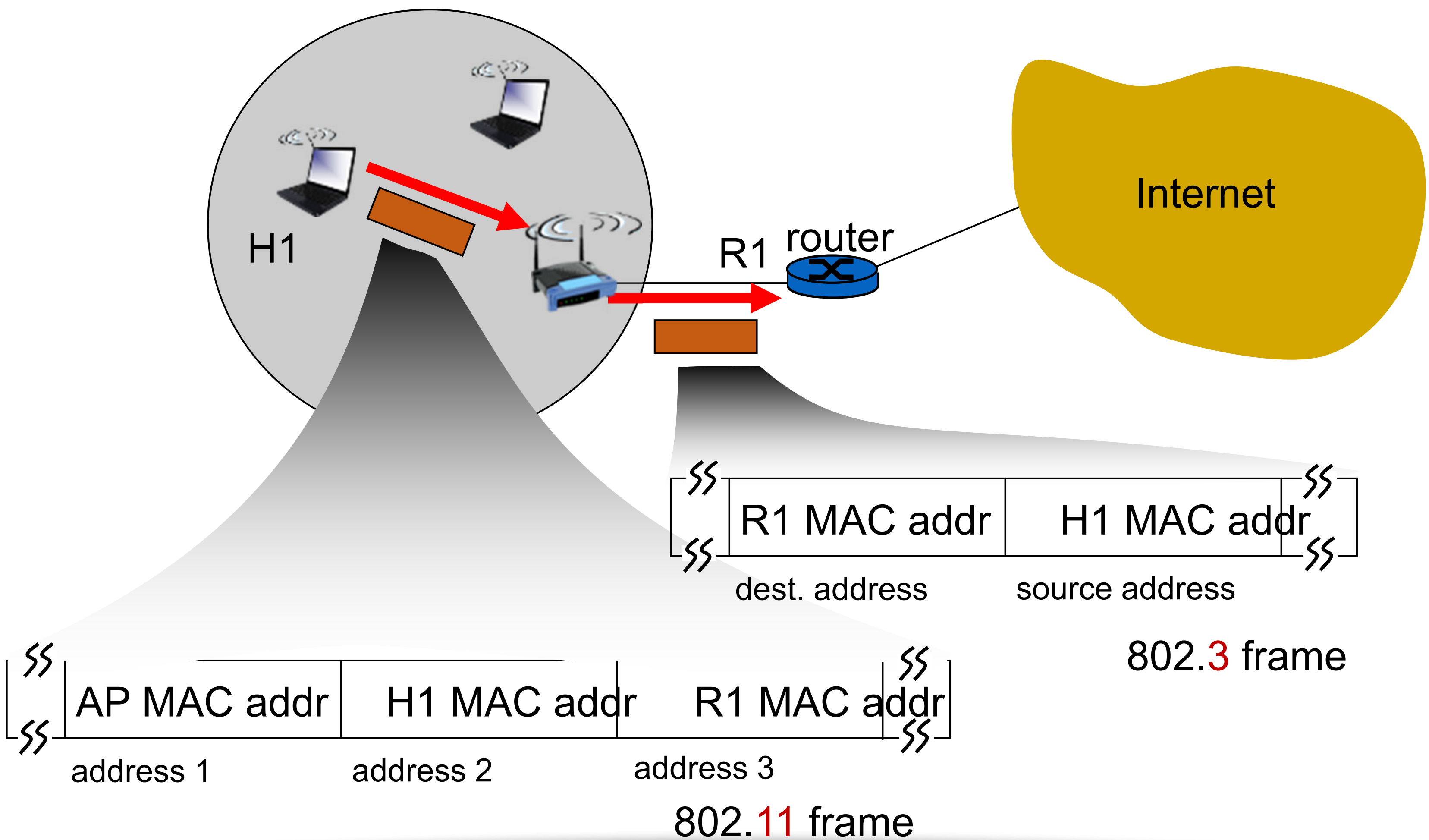
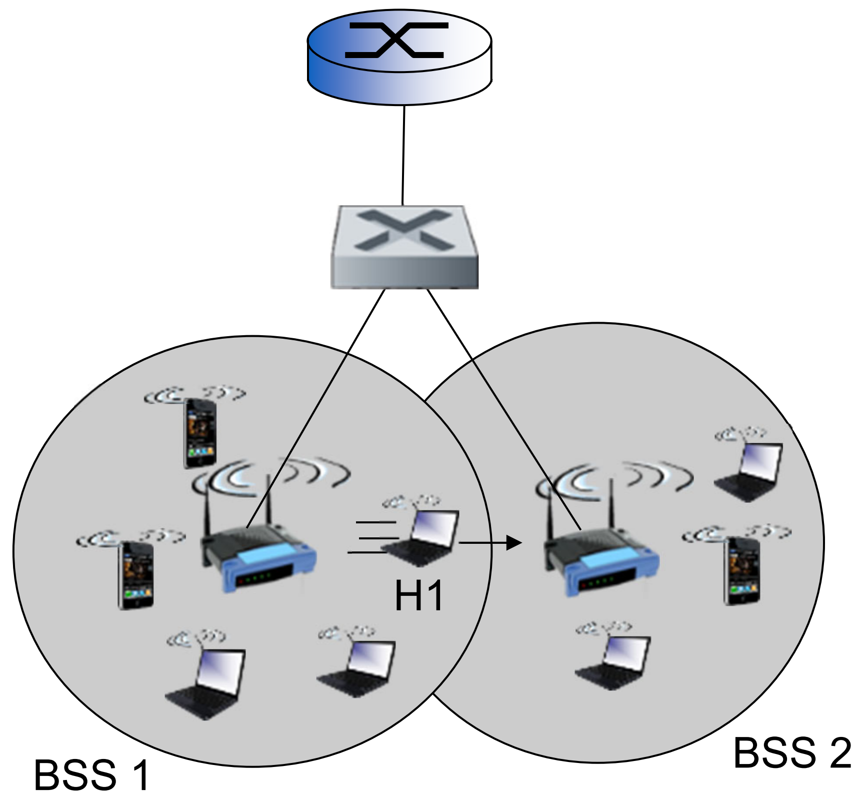


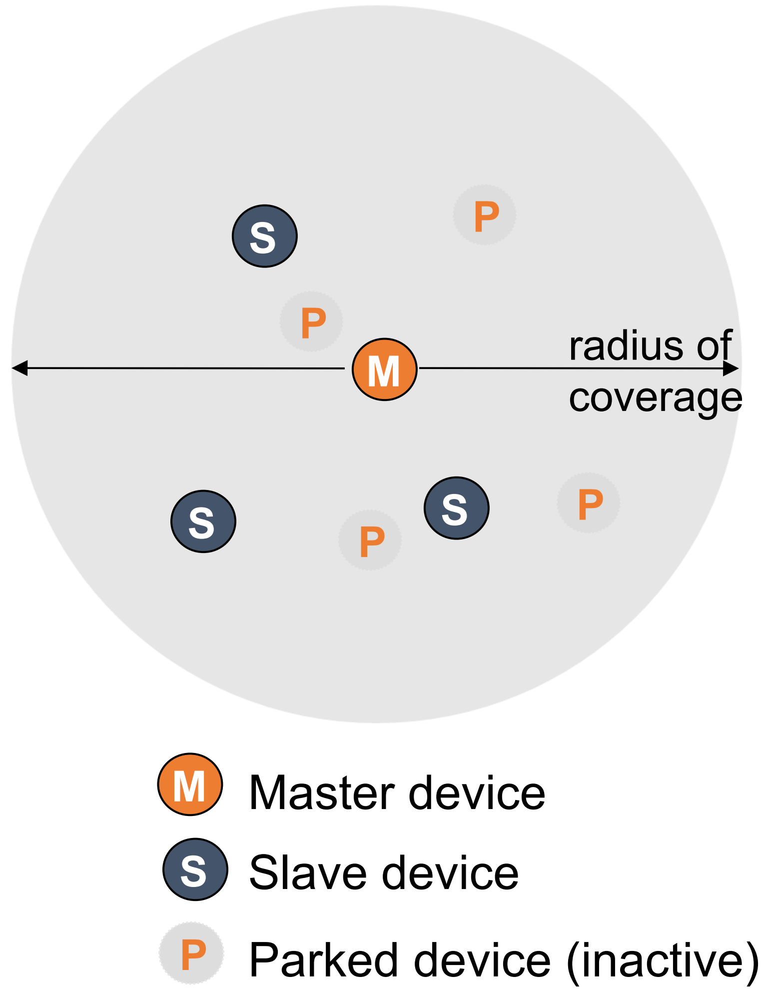
802.11: Mobility within same subnet

- 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



802.15: Personal area network

- 802.15: evolved from Bluetooth specification
- 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



Lecture Quiz on Wireless Networking Due – Wednesday (Nov 20) midnight

https://forms.gle/7h4NVgtAGoUfFZya9

Summary

- Wireless networking introduces more challenges than wired networks
  - Interference, attenuation, multipath, hidden terminals, etc.
- CSMA/CD doesn't work because collision detection is difficult
  - Instead, CSMA/CA is used that avoid collisions by reserving the channel a priori