

Wireless Networks

Reading: Section 2.8

COS 461: Computer Networks
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<http://www.cs.princeton.edu/courses/archive/spring11/cos461/>

Widespread Deployment

- Worldwide cellular subscribers
 - 1993: 34 million
 - 2005: more than 2 billion
 - 2009: more than 4 billion> landline subscribers

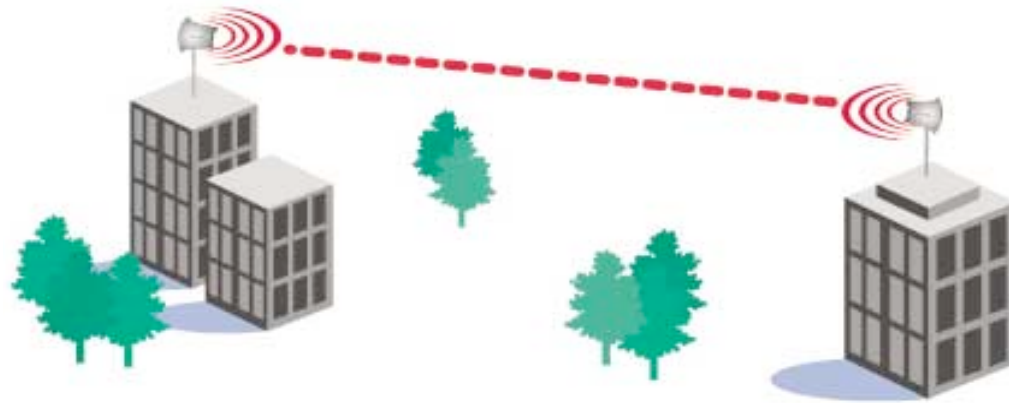


- Wireless local area networks
 - Wireless adapters built in to most laptops, and even PDAs
 - More than 220,000 known WiFi locations in 134 countries
 - Probably many, many more (e.g., home networks, corporate networks, ...)

Wireless Links and Wireless Networks

Wireless Links: High Bit Error Rate

- Decreasing signal strength
 - Disperses as it travels greater distance
 - Attenuates as it passes through matter



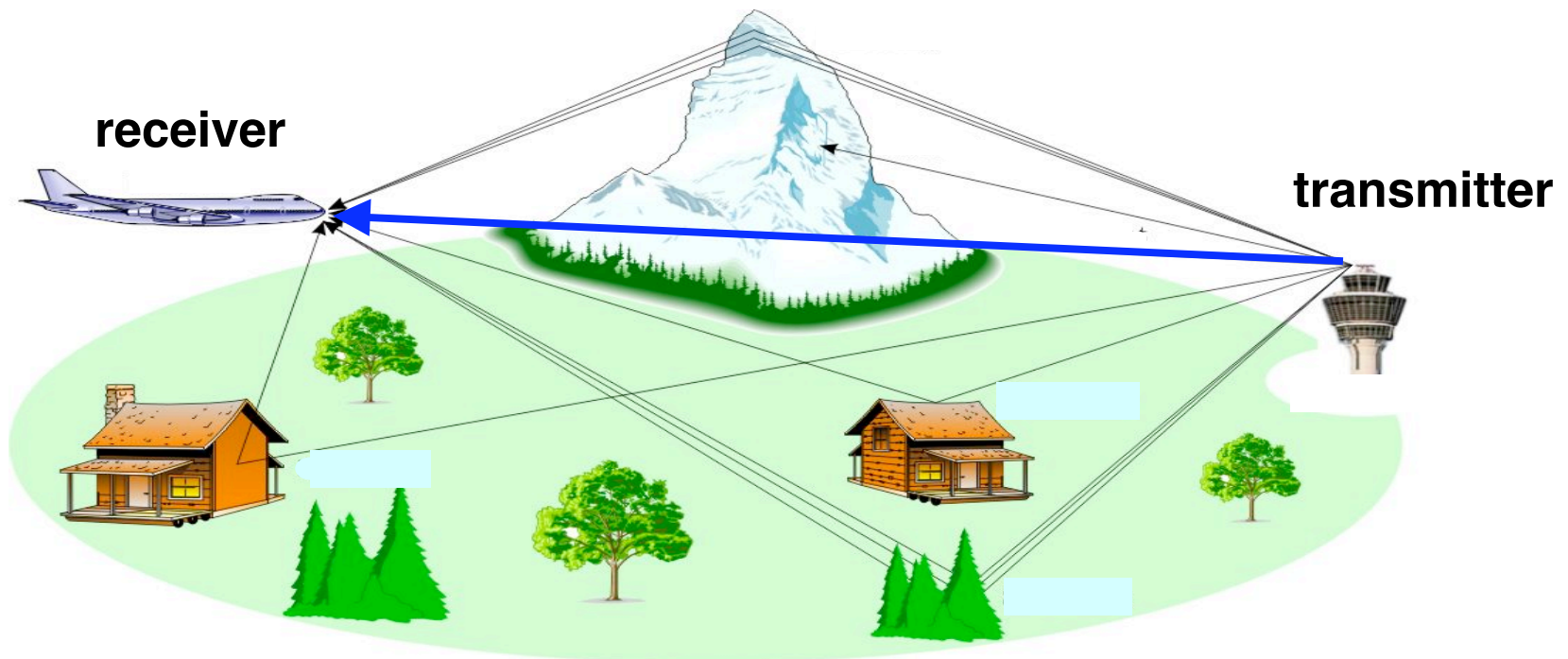
Wireless Links: High Bit Error Rate

- **Interference from other sources**
 - Radio sources in same frequency band
 - E.g., 2.4 GHz wireless phone interferes with 802.11b wireless LAN
 - Electromagnetic noise (e.g., microwave oven)





Wireless Links: High Bit Error Rate


- **Multi-path propagation**
 - Electromagnetic waves reflect off objects
 - Taking many paths of different lengths
 - Causing blurring of signal at the receiver



Dealing With Bit Errors

- **Wireless vs. wired links**
 - Wired: most loss is due to congestion 
 - Wireless: higher, time-varying bit-error rate
- **Dealing with high bit-error rates** 
 - Sender could increase transmission power
 - Requires more 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

Wireless Links: Broadcast Limitations

- **Wired broadcast links**
 - E.g., Ethernet bridging, in wired LANs
 - All nodes receive transmissions from all other nodes
- **Wireless broadcast: hidden terminal problem** 

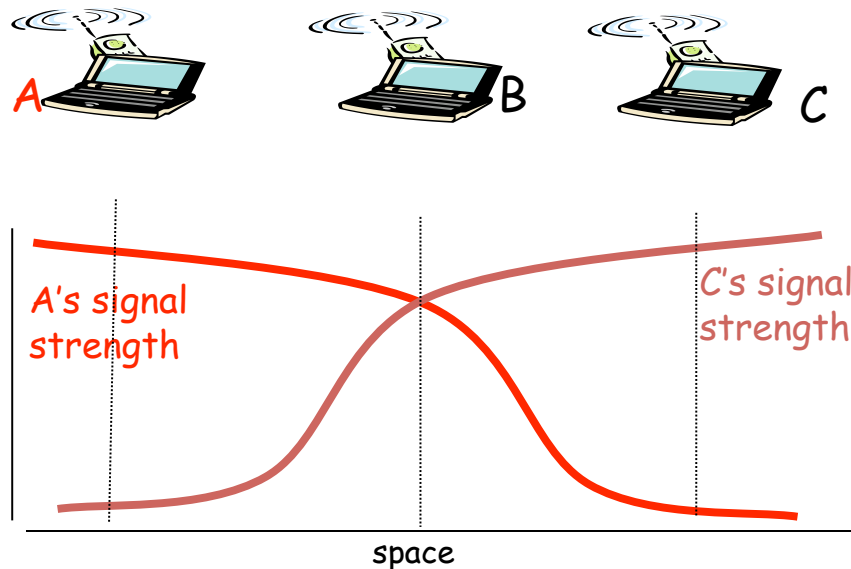


- A and B hear each other
- B and C hear each other
- **But, A and C do not**

So, A and C are unaware of their interference at B

Wireless Links: Broadcast Limitations

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- **Wireless broadcast: fading over distance**



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Example Wireless Link Technologies

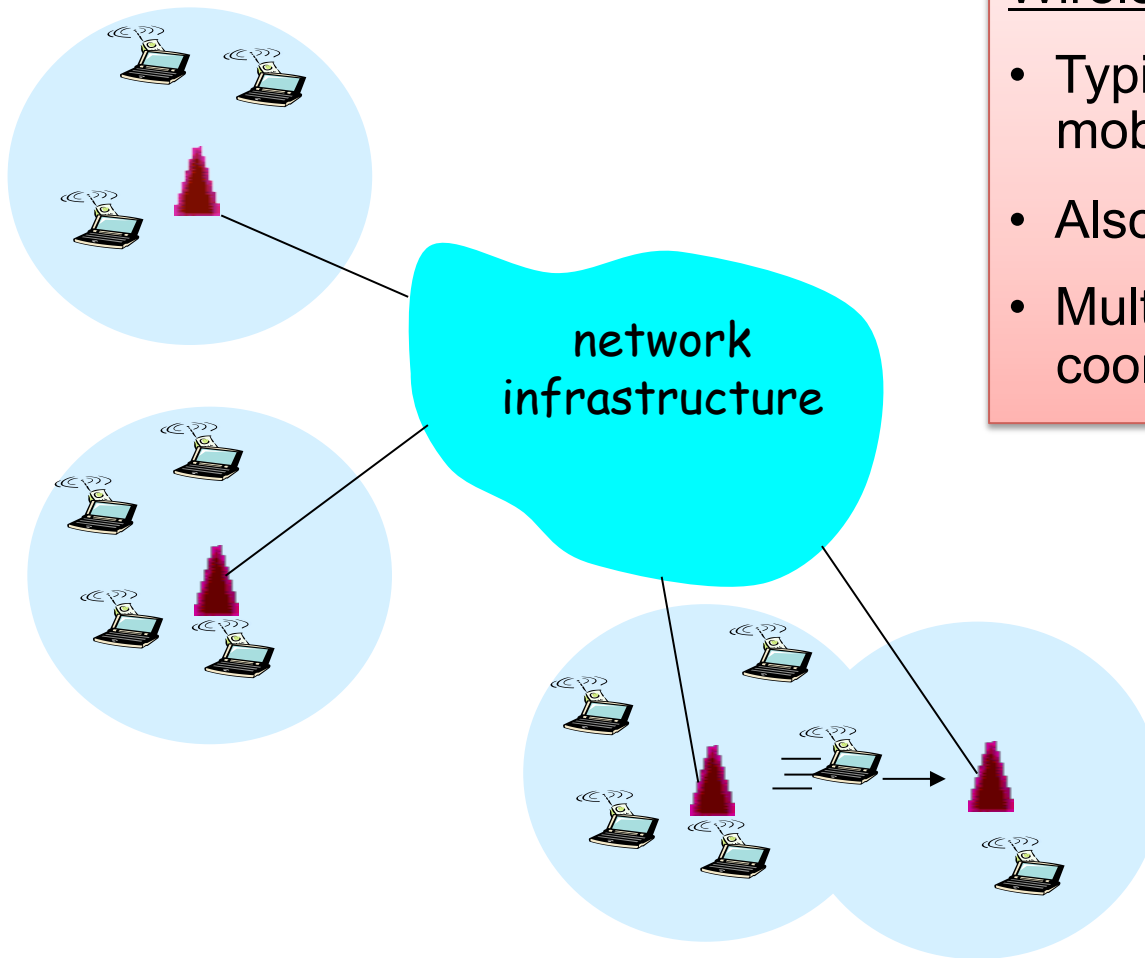
- Data networks

- 802.15.1 (Bluetooth): 2.1 Mbps – 10 m
- 802.11b (WiFi): 5-11 Mbps – 100 m
- 802.11a and g (WiFi): 54 Mbps – 100 m
- 802.11n (WiFi): 200 Mbps – 100 m
- 802.16 (WiMax): 70 Mbps – 10 km

- Cellular networks, outdoors

- 2G: 56 Kbps
- 3G: 384 Kbps
- 3G enhanced: 4 Mbps

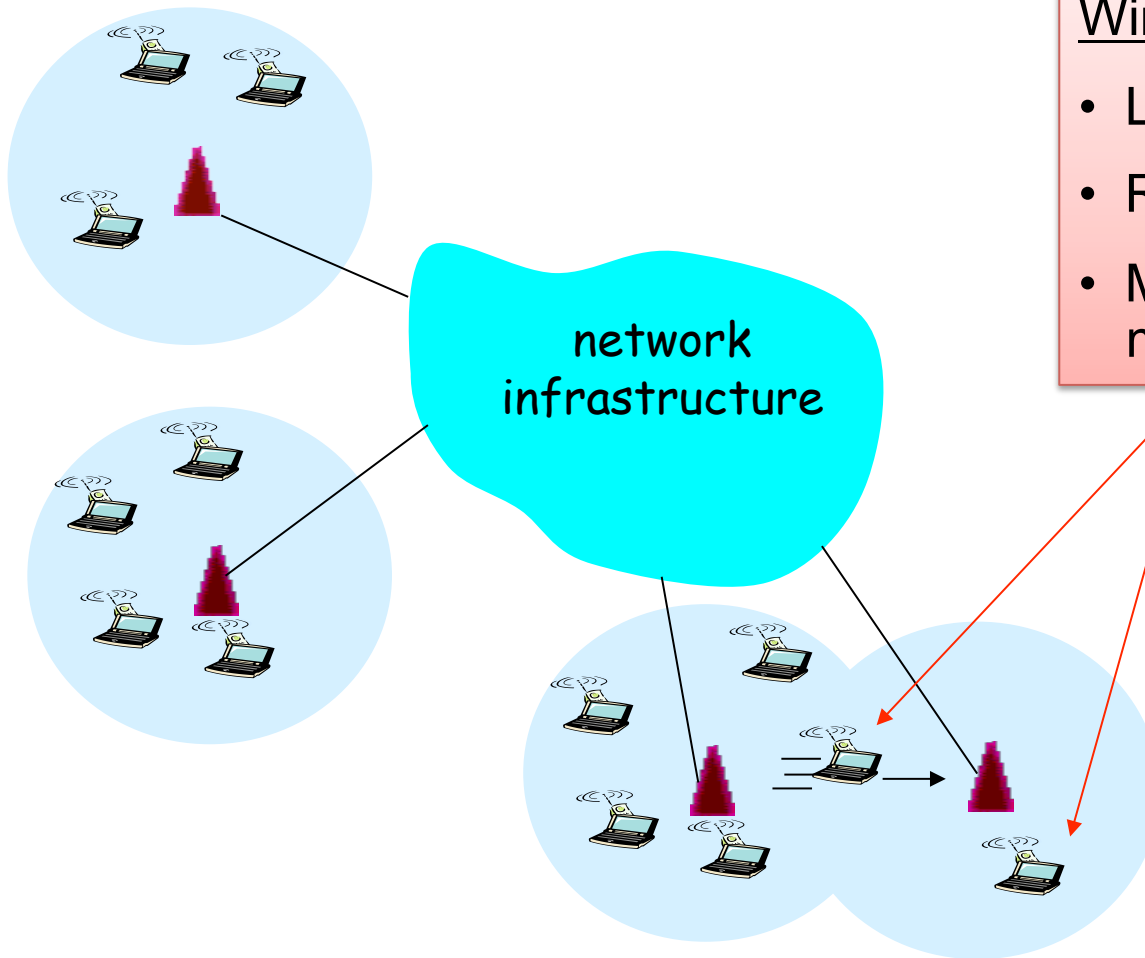
Wireless Network: Wireless Link



Wireless link

- Typically used to connect mobile(s) to base station
- Also used as backbone link
- Multiple access protocol coordinates link access

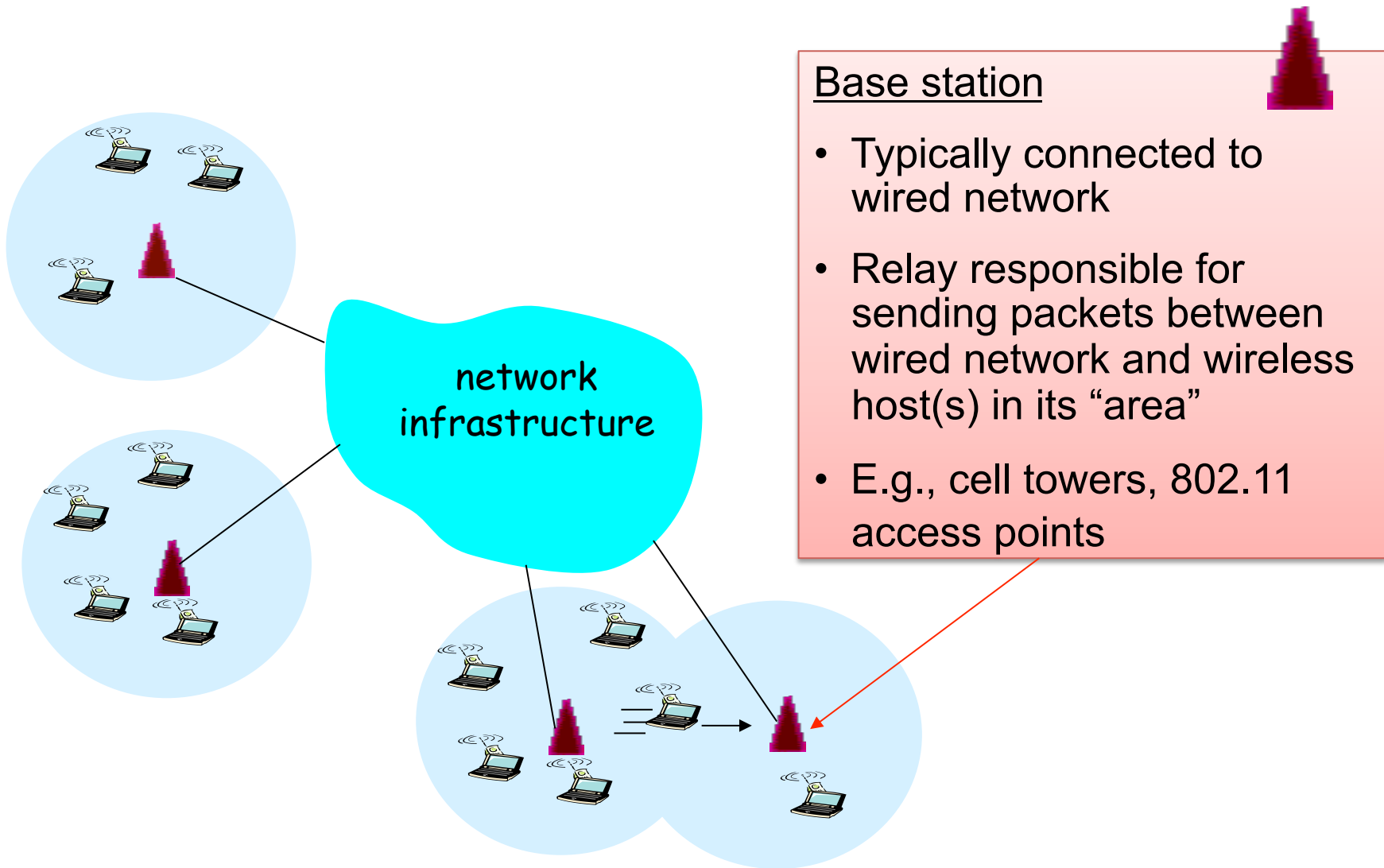
Wireless Network: Wireless Hosts



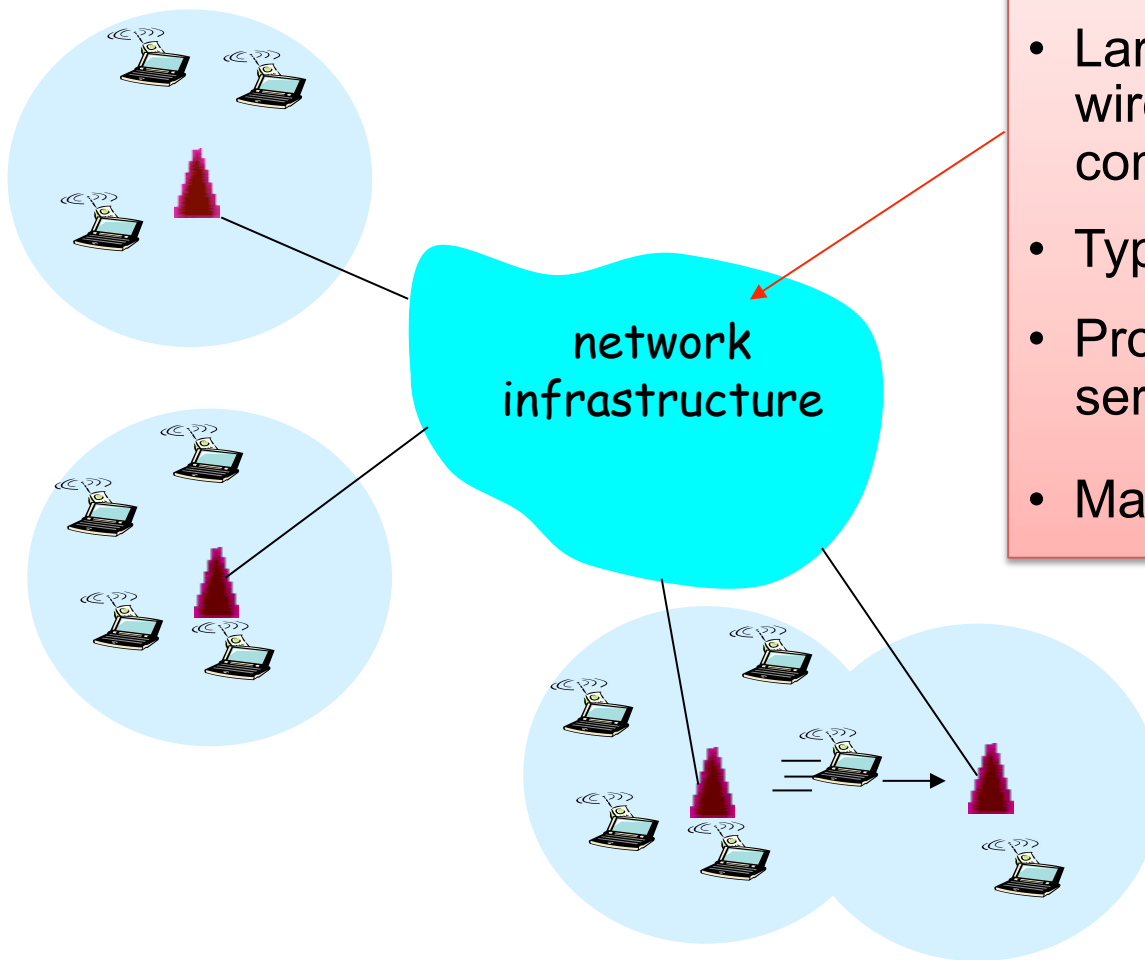
Wireless host

- Laptop, PDA, IP phone
- Run applications
- May be stationary (non-mobile) or mobile

Wireless Network: Base Station



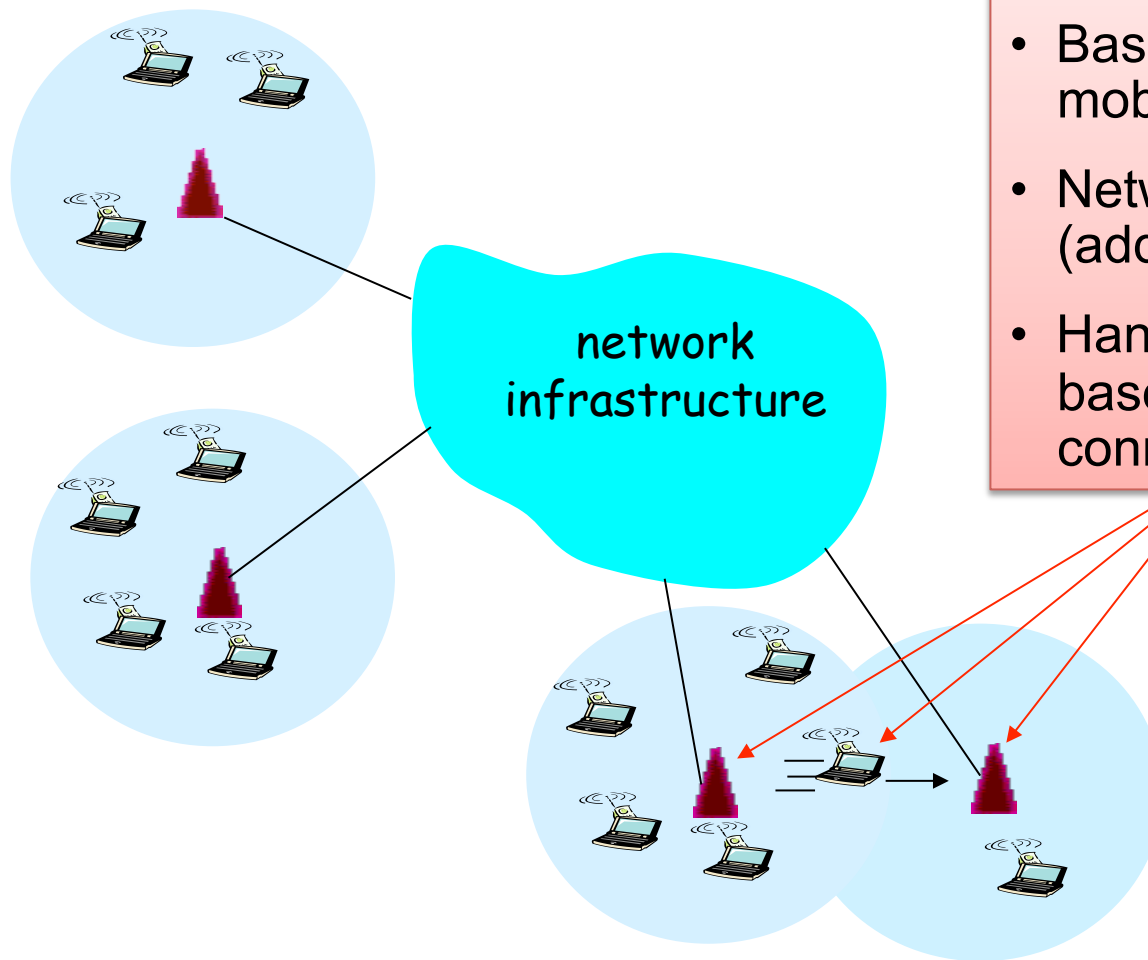
Wireless Network: Infrastructure



Network infrastructure

- Larger network with which a wireless host wants to communicate
- Typically a wired network
- Provides traditional network services
- May not always exist

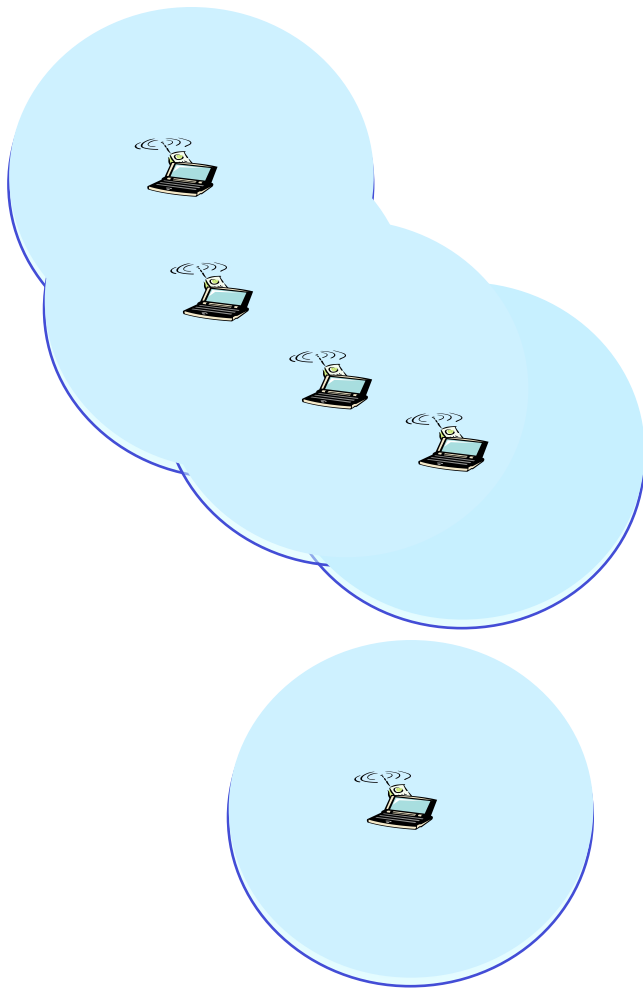
Scenario #1: Infrastructure Mode



Infrastructure mode

- Base station connects mobiles into wired network
- Network provides services (addressing, routing, DNS)
- Handoff: mobile changes base station providing connection to wired network

Scenario #2: Ad-Hoc Networks



Ad hoc mode

- No base stations
- Nodes can only transmit to other nodes within link coverage
- Nodes self-organize and route among themselves

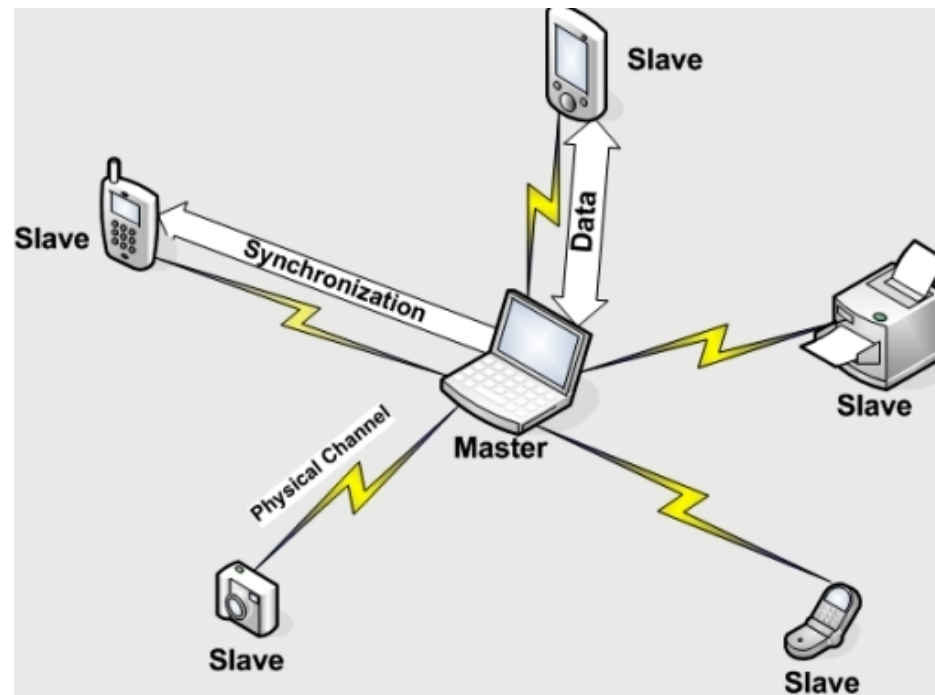



Infrastructure vs. Ad Hoc

- **Infrastructure mode**
 - Wireless hosts are associated with a base station
 - Traditional services provided by the connected network
 - E.g., address assignment, routing, and DNS resolution
- **Ad hoc networks**
 - Wireless hosts have no infrastructure to connect to
 - Hosts themselves must provide network services
- **Similar in spirit to the difference between**
 - Client-server communication
 - Peer-to-peer communication



Bluetooth: 802.15.1
“personal-area-networks”

Bluetooth piconets



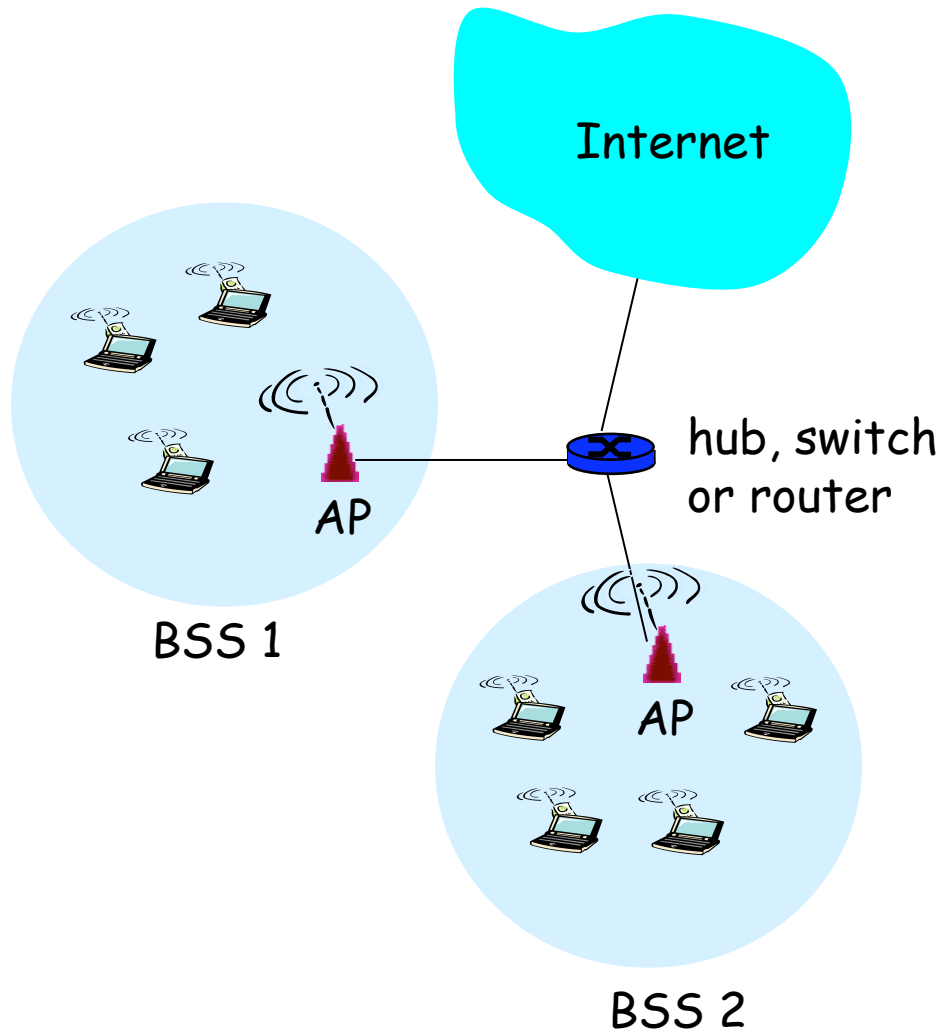
- Up to 7 “slave” devices and 225 “parked” devices
- Operates on unlicensed wireless spectrum 
 - How to prevent interference?

PHY: Spread Spectrum – Frequency Hopping

- Nodes rapidly jump between frequencies
- Sender and receiver coordinated in jumps
 - How coordinate? Pseudorandom number generator, with shared input known to sender/receiver 
- If randomly collide with other transmitted, only for short period before jump again
- Bluetooth
 - 79 frequencies, on each frequency for just 625 us
 - Each channel also uses TDMA, with each frame taking 1/3/5 consecutive slots. 
 - Only master can start in odd slot, slave only in response

WiFi: 802.11 Wireless LANs


802.11 LAN Architecture

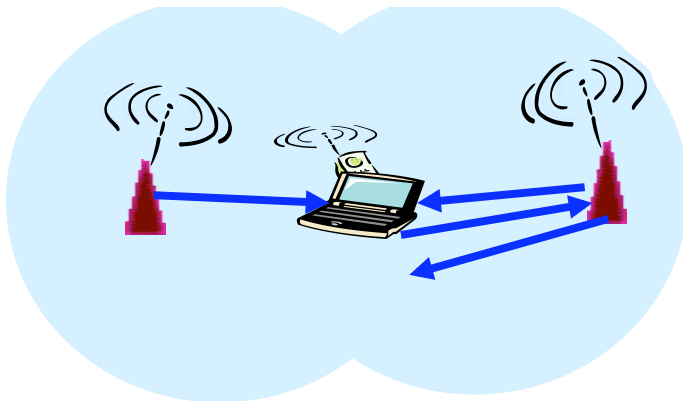
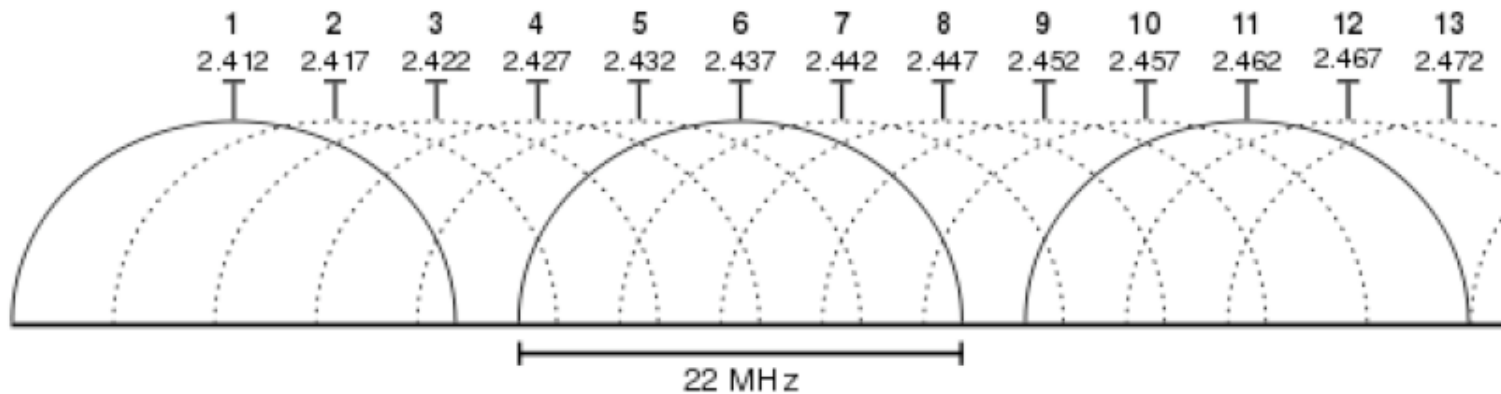


- Access Point (AP)
 - Base station that communicates with the wireless hosts
- Basic Service Set (BSS)
 - Coverage of one AP
 - AP acts as the master
 - Identified by an “network name” known as an SSID

SSID: Service Set Identifier


Channels and Association

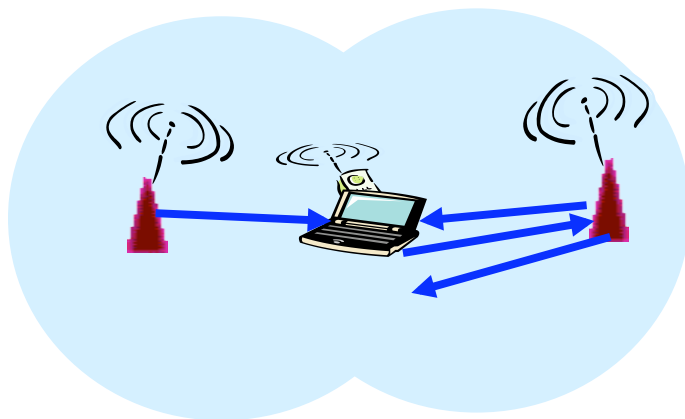
- Multiple channels at different frequencies
 - Network administrator chooses frequency for AP 
 - Interference if channel is same as neighboring AP



- Beacon frames from APs
- Associate request from host
- Association response from AP

Channels and Association

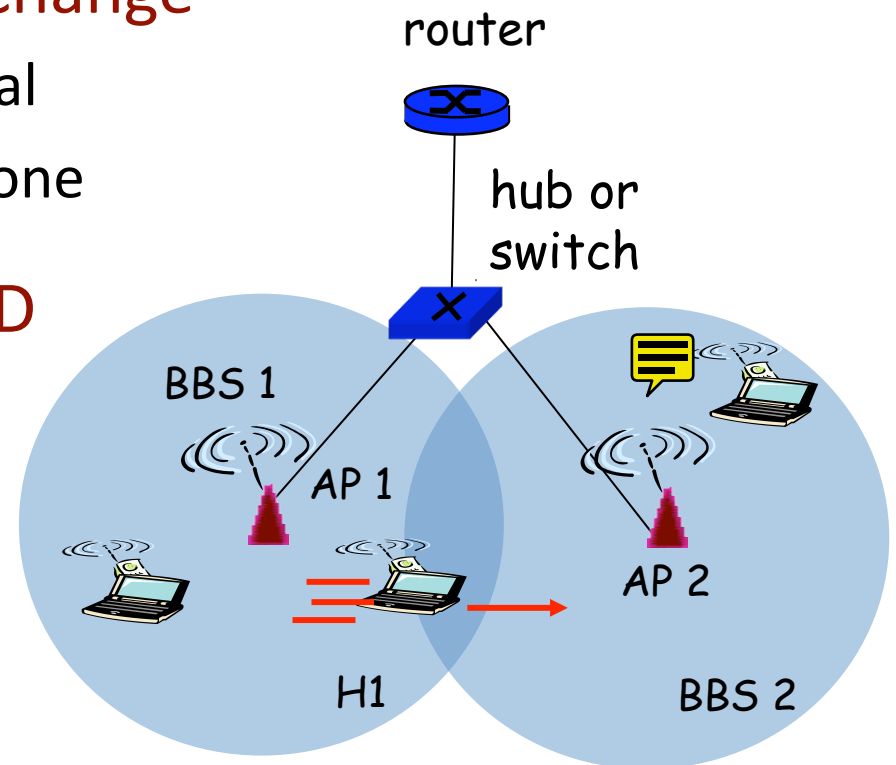
- Multiple channels at different frequencies
 - Network administrator chooses frequency for AP
 - Interference if channel is same as neighboring AP
- Access points send periodic beacon frames
 - Containing AP's name (SSID) and MAC address 
 - Host scans channels, listening for beacon frames
 - Host selects an access point to associate with



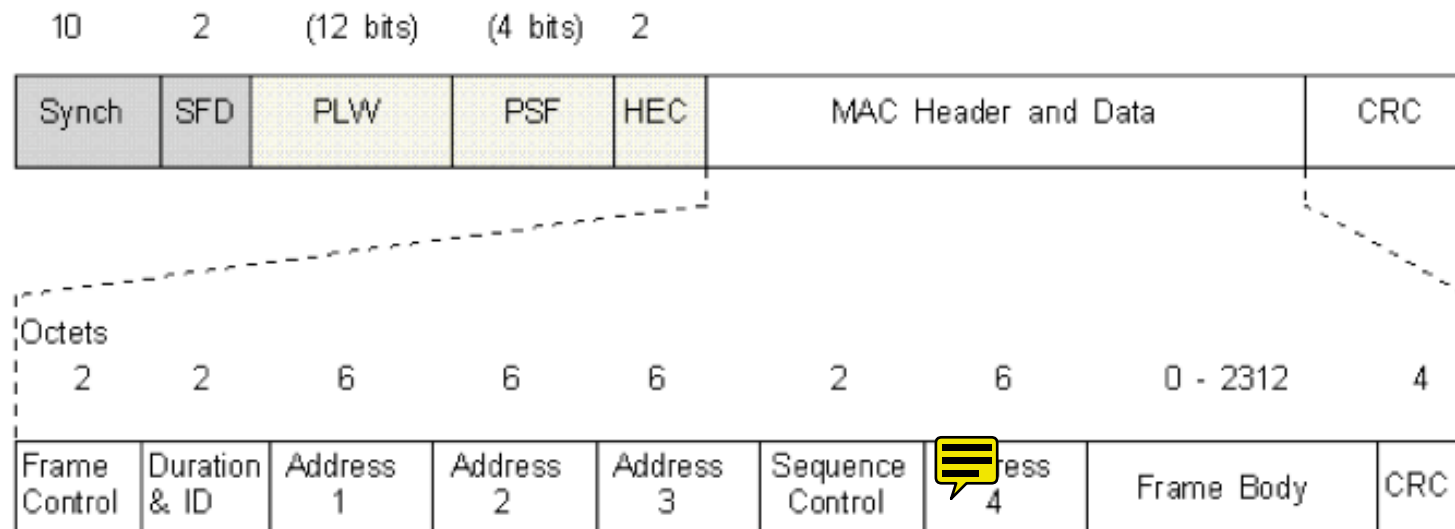
- Beacon frames from APs
- Associate request from host
- Association response from AP

Mobility Within the Same Subnet

- **H1 remains in same IP subnet**
 - IP address of the host can remain same
 - Ongoing data transfers can continue uninterrupted
- **H1 recognizes the need to change**
 - H1 detects a weakening signal
 - Starts scanning for stronger one
- **Changes APs with same SSID**
 - H1 disassociates from one
 - And associates with other
- **Switch learns new location**
 - Self-learning mechanism



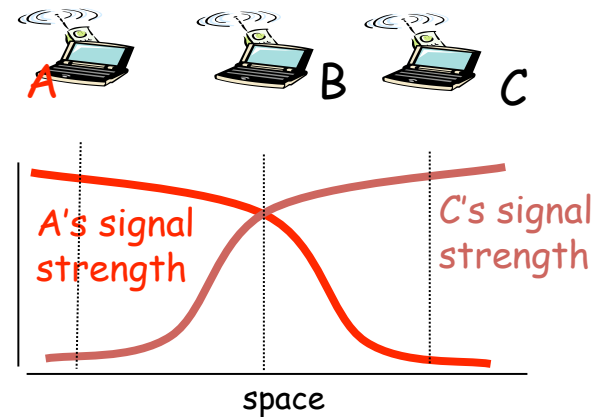
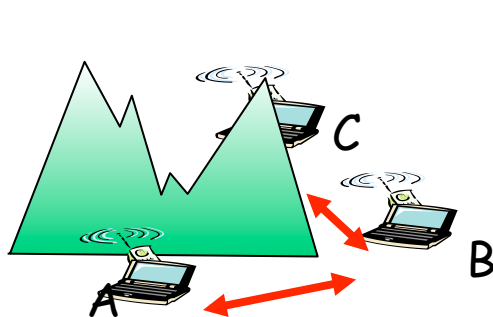
Wireless LAN addressing and bridging



Function	Addr 1 (Receiver)	Addr 2 (Transmitter)	Addr 3	Addr 4
Intra-BSS	Dest	Source		
To AP	BSS ID	Source	Dest	
From AP	Dest	BSS ID	Source	
Bridged APs	Receiver	Transmitter	Dest	Source

CSMA: Carrier Sense, Multiple Access


- **Multiple access: channel is shared medium**
 - Station: wireless host or access point
 - Multiple stations may want to transmit at same time
- **Carrier sense: sense channel before sending**
 - Station doesn't send when channel is busy
 - To prevent collisions with ongoing transfers
 - But, detecting ongoing transfers isn't always possible



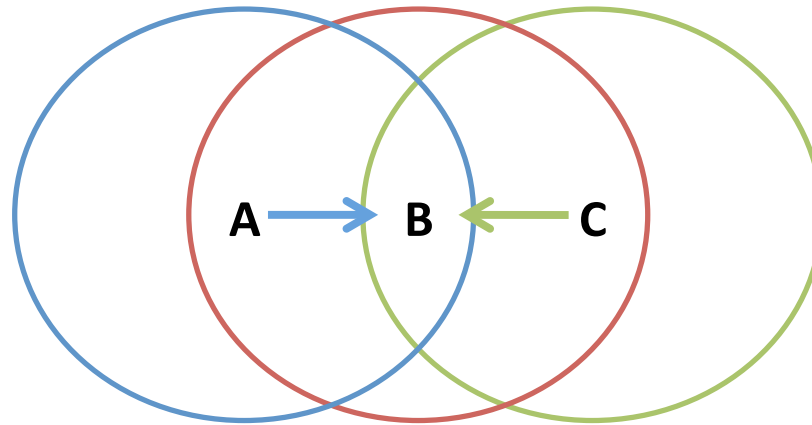
CA: Collision Avoidance, Not Detection

- Collision detection in wired Ethernet
 - Station listens while transmitting
 - Detects collision with other transmission
 - Aborts transmission and tries sending again
- Problem #1: cannot detect all collisions
 - Hidden terminal problem
 - Fading

CA: Collision Avoidance, Not Detection


- Collision detection in wired Ethernet
 - Station listens while transmitting
 - Detects collision with other transmission
 - Aborts transmission and tries sending again
- Problem #1: cannot detect all collisions
 - Hidden terminal problem
 - Fading
- Problem #2: listening while sending
 - Strength of received signal is much smaller
 - Expensive to build hardware that detects collisions 
- So, 802.11 does collision avoidance, not detection

Hidden Terminal Problem

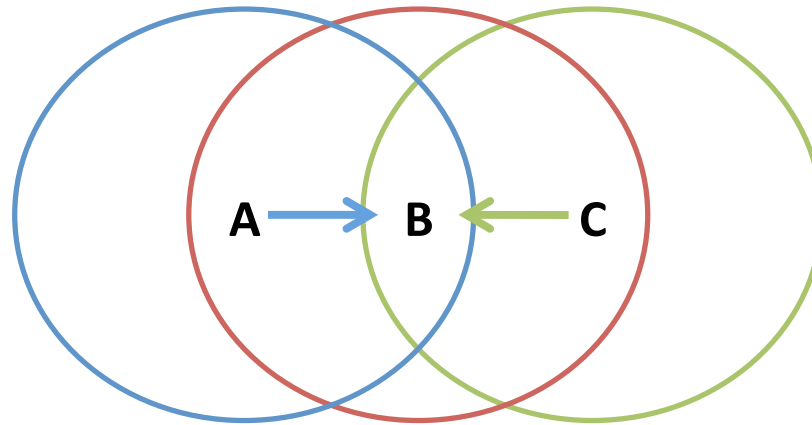


- A and C can't see each other, both send to B
- Occurs b/c 802.11 relies on physical carrier sensing, which is susceptible to hidden terminal problem

Virtual carrier sensing

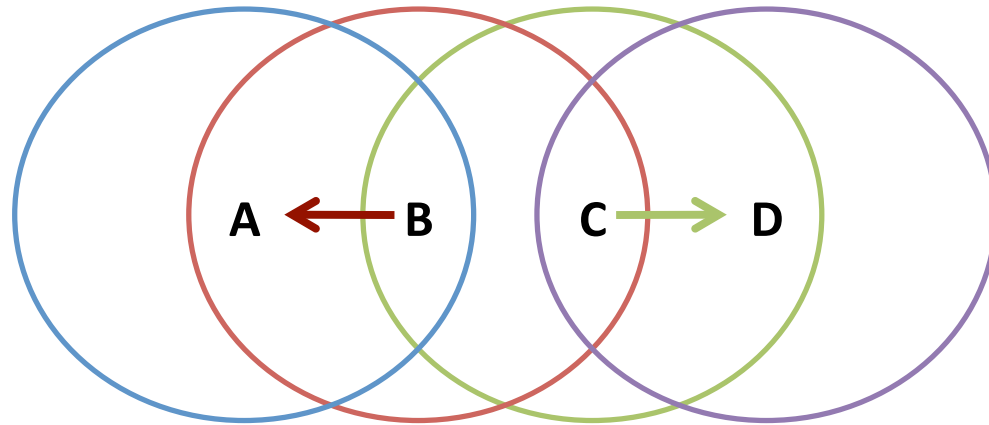
- First exchange control frames before transmitting data
 - Sender issues “Request to Send” (RTS), incl. length of data
 - Receiver responds with “Clear to Send” (CTS) 
- If sender sees CTS, transmits data (of specified length)
- If other node sees CTS, will idle for specified period
- If other node sees RTS but not CTS, free to send

Hidden Terminal Problem



- A and C can't see each other, both send to B
- RTS/CTS can help
 - Both A and C would send RTS that B would see first
 - B only responds with one CTS (say, echo'ing A's RTS)
 - C detects that CTS doesn't match and won't send

Exposed Terminal Problem



- B sending to A, C wants to send to D
- As C receives B's packets, carrier sense would prevent it from sending to D, even though wouldn't interfere
- RTS/CTS can help
 - C hears RTS from B, but not CTS from A
 - C knows it's transmission will not interfere with A
 - C is safe to transmit to D

Impact on Higher-Layer Protocols

- **Wireless and mobility change path properties**
 - Wireless: higher packet loss, not from congestion
 - Mobility: transient disruptions, and changes in RTT
- **Logically, impact should be minimal ...**
 - Best-effort service model remains unchanged
 - TCP and UDP can (and do) run over wireless, mobile
- **But, performance definitely *is* affected**
 - TCP treats packet loss as a sign of congestion
 - TCP tries to estimate the RTT to drive retransmissions
 - TCP does not perform well under out-of-order packets
- **Internet not designed with these issues in mind**

Conclusions

- **Wireless**
 - Already a major way people connect to the Internet
 - Gradually becoming more than just an access network
- **Mobility (not discussed)**
 - Today's users tolerate disruptions as they move
 - ... and applications try to hide the effects
 - Tomorrow's users expect seamless mobility
- **Challenges the design of network protocols**
 - Wireless breaks the abstraction of a link, and the assumption that packet loss implies congestion
 - Mobility breaks association of address and location
 - Higher-layer protocols don't perform as well