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Engineering

22. Wireless Internet

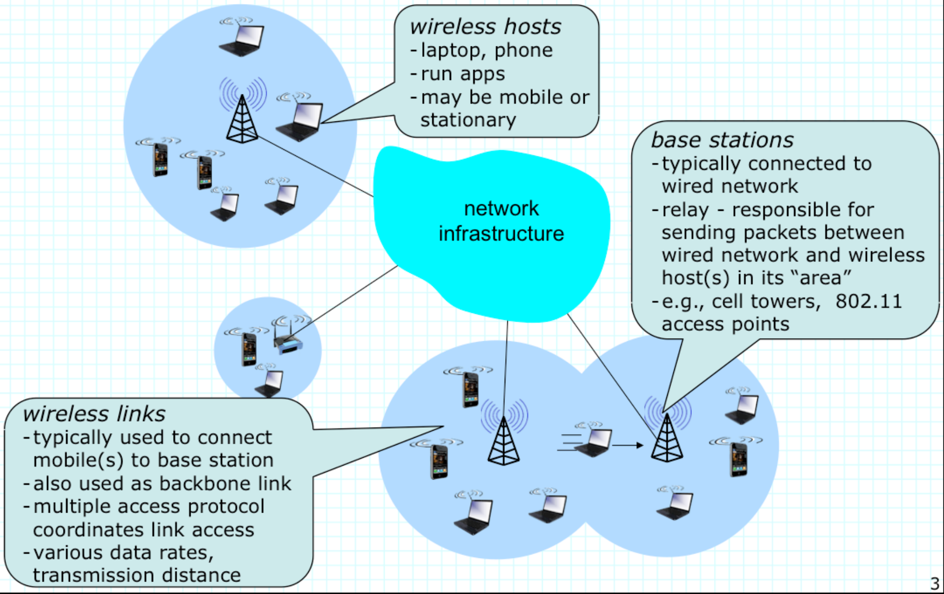
- General wireless network issues
- WiFi
  - » channels and association
  - » CSMA/CA
  - » packet header fields

Jon Turner – based on slides from Kurose & Ross

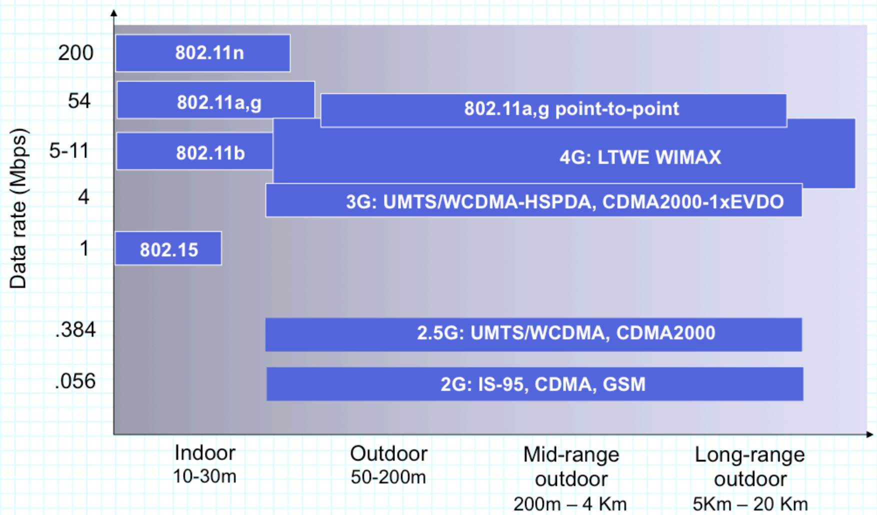
Wireless and Mobile Networks

- 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
- two important (but different) challenges
  - » *wireless:* communication over wireless link
  - » *mobility:* handling the mobile user who changes point of attachment to network

Elements of a Wireless Network



Characteristics of Wireless Links



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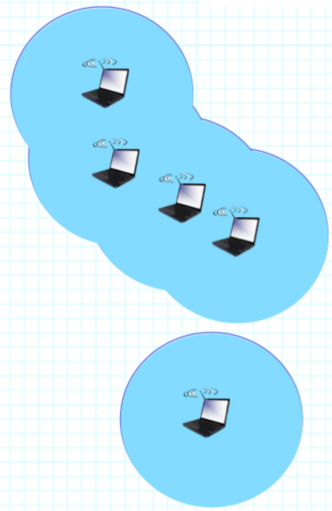
Ad hoc Operation

- No base stations or "infrastructure nodes"
- Nodes can only transmit to others within range
- Nodes organize and among themselves
  - » cooperate to form "network" and forward packets



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Wireless Network Classification

	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 wireless nodes MANET, VANET

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Wireless Link Characteristics

- Differences from wired links
  - *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., wireless phones, electric motors, microwave overs)
  - *multipath propagation:* radio signal reflects off objects and ground, arriving at destination at slightly different times
- Makes communication across (even point-to-point) wireless link more challenging
  - lower achievable bit rates
  - higher error rates
  - limited distances (so limited propagation delay)
  - more vulnerable to snooping

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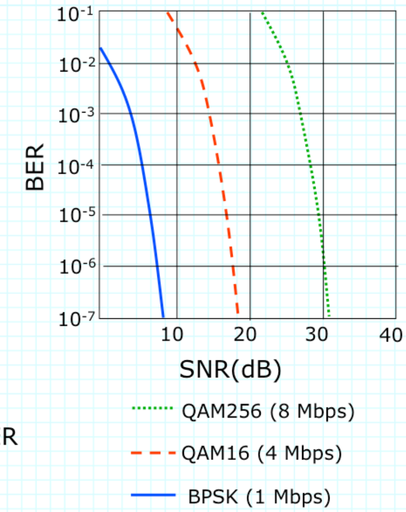
Wireless Link Characteristics

- SNR: signal-to-noise ratio
  - » larger SNR is good
    - easier to separate signal from noise
  - » measured in decibels (db)
    - logarithmic scale – increase of 3 db corresponds to doubling ratio
- SNR versus BER tradeoffs
  - » signal power
    - increased power leads to higher SNR and lower BER
  - » alternate modulation schemes
    - more sophisticated methods yield higher data rate, but also higher BER
    - can sometimes select modulation technique based on conditions



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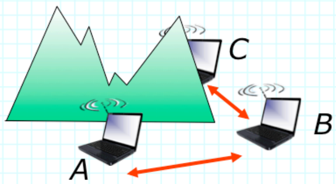
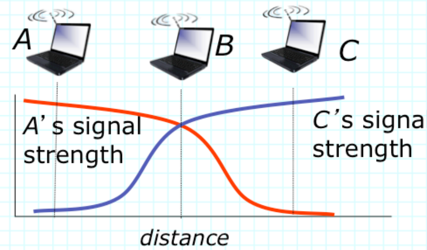
Wireless Network Characteristics

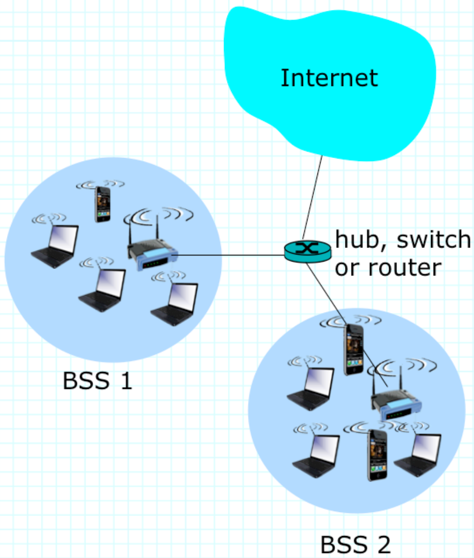
- Multiple wireless senders and receivers create additional problems (beyond multiple access):





- Hidden terminal problem
  - » *A*, *B* hear each other, *B*, *C* hear each other
  - » *A*, *C* cannot hear each other, so may send simultaneously causing interference at *B* – *A, C* cannot detect collision
  - » can be caused by obstacle or signal attenuation over distance

802.11 LAN Architecture



- Wireless host communicates with access point (AP)
- Wireless subnet called Basic Service Set (BSS)
  - » in infrastructure mode contains wireless hosts and access point (AP)
  - » in ad hoc mode, just hosts

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802.11: Channels, Association

- 802.11b: 2.4GHz-2.5 GHz spectrum (unlicensed) divided into 11 channels with overlapping frequencies
  - » AP administrator chooses frequency for AP
    - interference possible: channel can be same as that chosen by neighboring AP (or may overlap)
- 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

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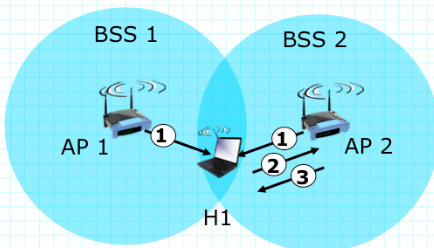
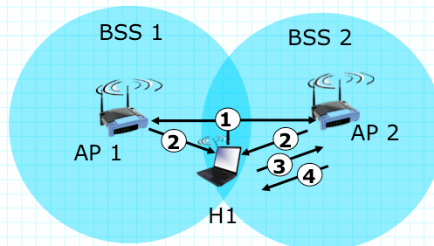
802.11: Passive/Active Scanning





passive scanning:

(1) beacon frames sent from APs
- periodically, every 100 ms

(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

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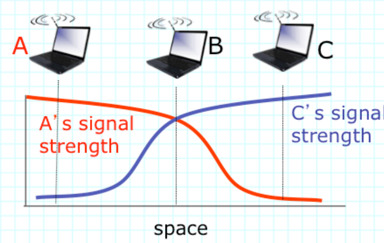
IEEE 802.11: Multiple Access

- Avoid collisions: 2+ nodes transmitting at same time
- CSMA - sense before transmitting
  - » don't collide with ongoing transmission by another node
- *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/CA (collision avoidance)



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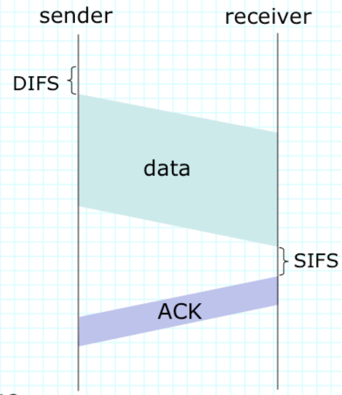
IEEE 802.11 MAC Protocol: CSMA/CA

802.11 sender

- if sense channel idle for *DIFS* then
  - » transmit entire frame (no CD)
- if sense channel busy then
  - » start random backoff timer
    - • timer counts down while channel idle (may start/stop multiple times)
    - • transmit when timer expires
  - » if no ACK, increase random backoff interval, and try again



802.11 receiver

- » if frame received OK
- » return ACK after *SIFS* (ACK needed due to hidden terminal problem)

Timing – 11 Mb/s is 11 bits/μs, propagation time <1 μs

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Avoiding Collisions

- Allow sender to “reserve” channel rather than random access of data frames
  - avoid collisions of long data frames
  - optional feature
- Sender first transmits *small* request-to-send (RTS) packets to Access Point using CSMA
  - RTSs may still collide with each other (but they’re short)
    - less than 50 bytes, vs 1500 bytes for largest Ethernet frame
- AP broadcasts clear-to-send CTS in response to RTS
- CTS heard by all nodes
  - sender transmits data frame
  - other stations defer transmissions

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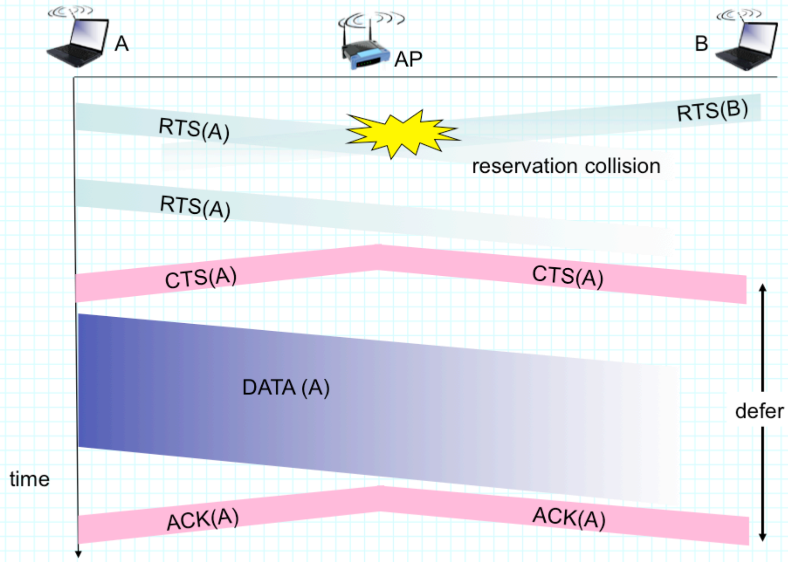
Collision Avoidance: RTS-CTS Exchange



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Exercises

1. Suppose nodes *A, B* and *C* are in an 802.11 network with access point *X* and assume that *A* and *B* can hear each other, *A* and *C* can hear each other, but *B* and *C* cannot hear each other. Assume RTS/CTS is not turned on. Suppose that at time 0, *X* is sending a packet and it continues to send for 500 μs. At time 100, *A* gets a packet to send and initializes its backoff timer to 400 μs. At time 200, *B* gets a packet to send initializes its backoff timer to 300 μs. At time 400, *C* gets a packet to send and initializes its backoff timer to 100 μs. Assume that it takes 200 μs to send each of the packets from *A*, *B* and *C*. When do each of the hosts start sending their packets. Which of them is delivered successfully?
2. Repeat the last problem assuming RTS/CTS is turned on. Assume that it takes just 20 μs to send an RTS or a CTS.

802.11 Frame: Addressing

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

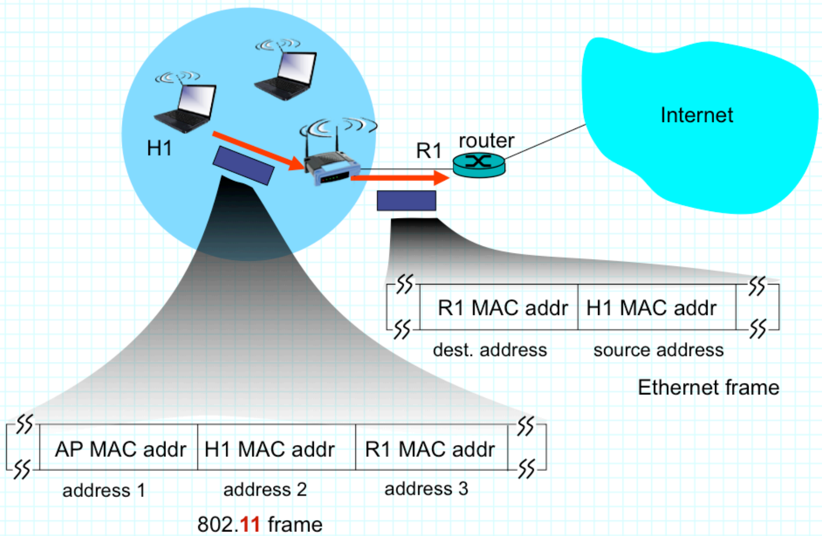
Address 1: MAC address of wireless host or AP to receive this frame

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

Address 3: MAC address of router in switched subnet to which AP is attached

Address 4: used only in ad hoc mode (to support per-hop addresses)

802.11 Addressing



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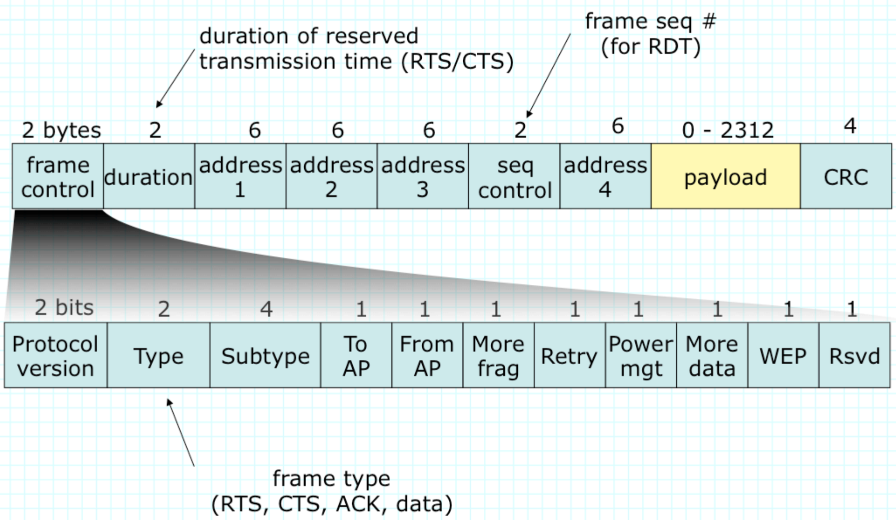
More Details



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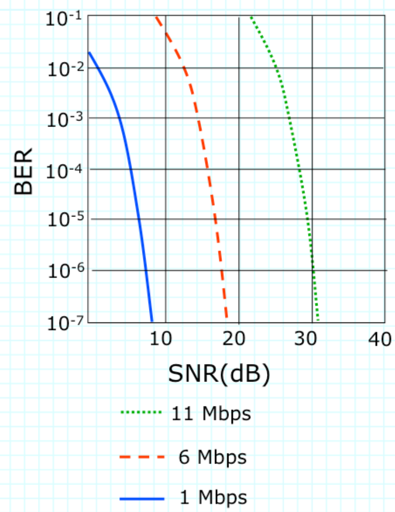
802.11 Rate Adaptation (experimental)

- Dynamically change modulation technique in response to changes in SNR
  - » SNR decreases, BER increases as node moves away from base station
  - » when BER becomes too high, switch to lower transmission rate but with lower BER
- Simple adaptation method
  - » if two consecutive frame transmissions fail (no ack after several retries)"down-shift"
  - » if ten consecutive frame transmissions succeed, "up-shift"



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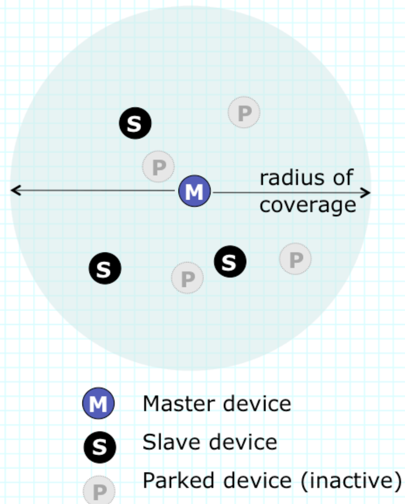
802.11 Power Management

- 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, up to 4 Mb/s
  - » TDM with 79 channels
    - uses "channel hopping"
  - » up to 721 kbps



Exercises

1. Consider a packet going from a host *A* on a wireless network with access point *X* through an Ethernet switch to a router *R*. From there, it goes back to the switch to another access point *Y*, which delivers it to a host *B*. What MAC addresses appear in the three address fields of the 802.11 packet sent over *A*'s wireless network. What MAC addresses appear in the two address fields of the Ethernet packet sent to the router? What MAC addresses appear in the three address fields of the 802.11 packet sent over *B*'s wireless network?
2. Consider a host *A* in an 802.11 network that is using power management. Suppose that some remote host is sending an average of 20 packets per second to *A* and the packets have an average length of 1000 bytes. Approximately what fraction of the time can *A* sleep? Assume no other activity in the network.
3. If frames are 10,000 bits long and an 802.11 network uses the simple rate adjustment scheme described on slide 25, using three modulation schemes with the BER characteristics shown in the figure on slide 24. How big must the SNR be to allow us to switch from low rate modulation scheme to the middle? How big must it be to allow us to switch from the middle rate scheme to the high rate scheme?