Elements of a wireless network

- **Network Infrastructure**
- **Wireless Hosts**
  - Laptop, PDA, IP phone
  - 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 a 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

Network infrastructure
Some wireless link standards

- **802.11n**
- **802.11a,g**
- **802.11b**
- **802.16 (WiMAX)**

Data rates (Mbps):
- 200
- 54
- 5-11
- 4
- 1
- 0.384
- 0.056

Distance ranges:
- **Indoor** 10-30m
- **Outdoor** 50-200m
- **Mid-range outdoor** 200m – 4 Km
- **Long-range outdoor** 5Km – 20 Km

Technology:
- UMTS/WCDMA, CDMA2000
- IS-95, CDMA, GSM

3G and 2G cellular enhancement.
Elements of a wireless network

- **Infrastructure mode**
  - base station connects mobiles into wired network
  - handoff: mobile changes base station providing connection into wired network

Network infrastructure
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

<table>
<thead>
<tr>
<th></th>
<th>single hop</th>
<th>multiple hops</th>
</tr>
</thead>
<tbody>
<tr>
<td>infrastructure (e.g., APs)</td>
<td>host connects to base station (WiFi, WiMAX, cellular) which connects to larger Internet</td>
<td>host may have to relay through several wireless nodes to connect to larger Internet: <em>mesh net</em></td>
</tr>
<tr>
<td>no infrastructure</td>
<td>no base station, no connection to larger Internet (Bluetooth, ad hoc nets)</td>
<td>no base station, no connection to larger Internet. May have to relay to reach other a given wireless node <em>MANET, VANET</em></td>
</tr>
</tbody>
</table>
Wireless Link Characteristics (1)

Differences from wired link ....

- **decreased signal strength**: radio signal attenuates fast
- **interference from other sources**: 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 to a destination at slightly different times
Wireless Link Characteristics (2)

- SNR: signal-to-noise ratio
  - larger SNR is good!
- SNR versus BER (Bit Error Rate) tradeoffs
  - given physical layer: increase power \(\rightarrow\) increase SNR \(\rightarrow\) decrease BER
  - given SNR: choose physical layer that meets BER requirement, giving highest throughput
    - SNR may change with mobility: dynamically adapt physical layer (modulation technique, rate)
Wireless network characteristics

Additional problems:

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
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

- 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
802.11: Channels, association

- 802.11b: 2.4GHz-2.485GHz
  - 11 channels
  - AP admin chooses frequency for AP
  - 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
**Passive Scanning:**
(1) beacon frames sent from APs
(2) association Request frame sent: H1 to selected AP
(3) association Response frame sent: H1 to selected AP

**Active Scanning:**
(1) Probe Request frame broadcast from H1
(2) Probes response frame sent from APs
(3) Association Request frame sent: H1 to selected AP
(4) Association Response frame sent: H1 to selected AP
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)
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

A

AP

B

RTS(A)

reservation collision

RTS(B)

CTS(A)

DATA (A)

ACK(A)

defer
# 802.11 frame: addressing

<table>
<thead>
<tr>
<th>Frame Control</th>
<th>Duration</th>
<th>Address 1</th>
<th>Address 2</th>
<th>Address 3</th>
<th>Seq Control</th>
<th>Address 4</th>
<th>Payload</th>
<th>CRC</th>
</tr>
</thead>
</table>

**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

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802.11 frame: addressing

![Diagram showing 802.11 frame addressing with nodes H1, AP, and router connected to the Internet, with MAC addresses R1 MAC addr and H1 MAC addr for the 802.3 frame, and AP MAC addr, H1 MAC addr, and R1 MAC addr for the 802.11 frame.](image-url)
802.11 frame: more

<table>
<thead>
<tr>
<th>Frame Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protocol version</td>
</tr>
<tr>
<td>------------------</td>
</tr>
<tr>
<td>frame control</td>
</tr>
</tbody>
</table>

The diagram illustrates the structure of an 802.11 frame, including:
- **Frame Control**: 2 bits for protocol version, 2 bits for type, 4 bits for subtype, 1 bit for to AP, 1 bit for from AP, 1 bit for more fragment, 1 bit for retry, 1 bit for power management, 1 bit for more data, 1 bit for WEP, and 1 bit reserved.
- **Duration**: Represents the duration of transmission time (RTS/CTS).
- **Frame Sequence Number**: Represents the frame sequence number (for RDT).
- **Payload**: Holds the actual data.
- **CRC**: Cyclic Redundancy Check for error detection.

Frame type includes:
- RTS
- CTS
- ACK
- Data
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

Diagram:
- M: Master device
- S: Slave device
- P: Parked device (inactive)

radius of coverage
802.16: WiMAX

- like 802.11 & cellular:
  - base station model
    - transmissions to/from base station by hosts with omnidirectional antenna
    - base station-to-base station backhaul with point-to-point antenna
- unlike 802.11:
  - range ~ 6 miles ("city rather than coffee shop")
  - ~14 Mbps
802.16: WiMAX: downlink, uplink scheduling

- transmission frame
  - down-link subframe: base station to node
  - uplink subframe: node to base station

- WiMAX standard provide mechanism for scheduling, but not scheduling algorithm