Wireless Networking

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Wireless Networks

Background

- Number of wireless (mobile) phone subscribers now exceeds number wired phone subscribers!

- Computer networks
  - laptops, palmtops, PDAs, Internet-enabled phone promise anytime un-tethered Internet access

- Two important (but different) challenges:
  1. wireless: communication over wireless link
  2. mobility: handling mobile user who changes point of attachment to network
Wireless Networks

Wireless Hosts

- Wireless hosts
  - laptop, PDA, IP phone
  - run applications
  - may be stationary (non-mobile) or mobile
    - wireless does not always mean mobility

Wireless Networks

Base Station

- 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
Wireless Networks

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 Link Standards

<table>
<thead>
<tr>
<th>Data rate (Mbps)</th>
<th>Indoor 10-30m</th>
<th>Outdoor 50-200m</th>
<th>Mid-range outdoor 200m – 4 Km</th>
<th>Long-range outdoor 5 Km – 20 Km</th>
</tr>
</thead>
<tbody>
<tr>
<td>802.15</td>
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<td></td>
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<tr>
<td>802.11a,g</td>
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<tr>
<td>802.11b</td>
<td></td>
<td></td>
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<tr>
<td>802.11a,g point-to-point</td>
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<tr>
<td>802.16 (WiMAX)</td>
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<tr>
<td>UMTS/WCDMA-HSPDA, CDMA2000-1xEVDO</td>
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<tr>
<td>UMTS/WCDMA, CDMA2000</td>
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<tr>
<td>IS-95, CDMA, GSM</td>
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<tr>
<td>802.11n</td>
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<td>802.16</td>
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</tbody>
</table>
Wireless Networks

Infrastructure Mode

- Infrastructure mode
  - Base station connects mobiles into a wired network
  - Handoff: mobile changes base station providing connection into wired network

Wireless Networks

Ad-hoc Mode

- 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>infrastructure (e.g., APs)</th>
<th>single hop</th>
<th>multiple hops</th>
</tr>
</thead>
<tbody>
<tr>
<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>
<td></td>
</tr>
<tr>
<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 MANET, VANET</td>
<td></td>
</tr>
</tbody>
</table>

Wireless Networks

Wireless Link Characteristics

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
  ✦ portions of the radio signal reflect off objects on the ground, arriving at destination at slightly different times

…. make communication across (even a point to point) wireless link much more “difficult”
Wireless Networks
Wireless Link Characteristics

- 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 throughput
    - SNR may change with mobility: dynamically adapt physical layer (modulation technique, rate)

Wireless Networks
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 fading:
- B, A hear each other
- B, C hear each other
- A, C can not hear each other interfering at B
Wireless Networks
Code Division Multiple Access (CDMA)

- Used in several wireless broadcast channels (cellular, satellite, etc) standards
- Unique “code” assigned to each user
  - code set partitioning
- All users share same frequency, but each user has own “chipping” sequence (i.e., code) to encode data
- Encoded signal = (original data) X (chipping sequence)
- Decoding: inner-product of encoded signal and chipping sequence
- Allows multiple users to “coexist” and transmit simultaneously with minimal interference (if codes are “orthogonal”)

IEEE 802.11 Wireless LAN

- 802.11b
  - 2.4-5 GHz unlicensed radio spectrum
  - up to 11 Mbps
  - direct sequence spread spectrum (DSSS) in physical layer
    - all hosts use same chipping code
  - widely deployed, using base stations

- 802.11a
  - 5-6 GHz range
  - up to 54 Mbps

- 802.11g
  - 2.4-5 GHz range
  - up to 54 Mbps

- 802.11n
  - 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
**IEEE 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

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**IEEE 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
  - will typically run DHCP to get IP address in AP’s subnet
IEEE 802.11
Multiple Access

- Avoid collisions: $2^n$ 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

Sender
- If sense channel idle for DIFS then
  » transmit entire frame (no CD)
- 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

Receiver
- If frame received OK
  » return ACK after SIFS (link-layer ACK)
IEEE 802.11 MAC Protocol
Avoiding Collisions

- 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

![Diagram of RTS-CTS exchange](image)
IEEE 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>Address 4</th>
<th>Payload</th>
<th>CRC</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>2</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>2</td>
<td>6</td>
<td>0-2312</td>
</tr>
</tbody>
</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

IEEE 802.11 Frame

Addressing

H1

AP

R1

Internet

802.3 frame

802.11 frame

AP MAC addr | H1 MAC addr | R1 MAC addr
---|---|---
address 1 | address 2 | address 3

R1 MAC addr | AP MAC addr
dest. address | source address
IEEE 802.11 Frame

IEEE 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
IEEE 802.15
Personal Area Network (WPAN)

- 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

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
Wireless and Mobility
Impact on Higher Layer Protocols

- Logically, impact should be minimal …
  - best effort service model remains unchanged
  - TCP and UDP can (and do) run over wireless, mobile

- … but performance-wise:
  - packet loss/delay due to bit-errors (discarded packets, delays for link-layer retransmissions), and handoff
  - TCP interprets loss as congestion, will decrease congestion window unnecessarily
  - delay impairments for real-time traffic
  - limited bandwidth of wireless links