Ch. 6: 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

Chapter 6 outline

**Introduction**

**Wireless**
- Wireless links, characteristics
- IEEE 802.11 wireless LANs ("Wi-Fi")

**Cellular Internet Access**
- architecture
- standards (e.g., GSM)
- cellular mobility

Elements of a wireless network

- wireless hosts
  - laptop, smartphone
  - 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 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 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

- **Indoor**
  - 10-30m
  - Data rate (Mbps)
  - 200
  - 54
  - 5-11
  - 4
  - 1
  - 1
  - 0.56

- **Outdoor**
  - 50-200m
  - Mid-range outdoor 200m – 4 Km
  - Long-range outdoor 5Km – 20 Km

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  - Architecture
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**Mobility**
- Principles: addressing and routing to mobile users
- Mobile IP
- Handling mobility in cellular networks
- Mobility and higher-layer protocols
Wireless Link Characteristics

*important* 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**: radio signal reflects off objects ground, arriving ad destination at slightly different times

…. make communication across (even a point to point) wireless link much more "difficult"

Wireless network 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 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
- direct sequence spread spectrum (DSSS) in physical layer
  - all hosts use same chipping code

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 points (AP): base station
  - ad hoc mode: hosts only
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 [Chapter 8]
  - will typically run DHCP to get IP address in AP’s subnet

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(llision)/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**

- RTS(A)
- RTS(B)
- RTS(A)
- CTS(A)
- DATA (A)
- ACK(A)
- ACK(A)
- reservation collision
- defer
- time

**802.11 frame: addressing**

<table>
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<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>
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<td>6</td>
<td>6</td>
<td>2</td>
<td>2-2312</td>
<td>4</td>
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</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

**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
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Components of cellular network architecture

Wireless, Mobile Networks 6-21

Cellular networks: the first hop

Two techniques for sharing mobile-to-BS radio spectrum
- combined FDMA/TDMA: divide spectrum in frequency channels, divide each channel into time slots
- CDMA: code division multiple access

Wireless, Mobile Networks 6-22

2G (voice) network architecture

Wireless, Mobile Networks 6-23

Legend

Wireless, Mobile Networks 6-24
**Key insight:** new cellular data network operates in parallel (except at edge) with existing cellular voice network

- voice network unchanged in core
- data network operates in parallel

**Components of cellular network architecture**

Recall:

- Correspondent
- Home network
- Different cellular networks, operated by different providers

**Handling mobility in cellular networks**

- **Home network:** network of cellular provider you subscribe to (e.g., Sprint PCS, Verizon)
  - Home location register (HLR): database in home network containing permanent cell phone number, profile information (services, preferences, billing), information about current location (could be in another network)
- **Visited network:** network in which mobile currently resides
  - Visitor location register (VLR): database with entry for each user currently in network
  - Could be home network
GSM: indirect routing to mobile

1. home MSC consults HLR, gets roaming number of mobile in visited network.
2. call routed to home network.
3. home MSC sets up 2nd leg of call to MSC in visited network.
4. MSC in visited network completes call through base station to mobile.

GSM: handoff with common MSC

- **handoff goal**: route call via new base station (without interruption)
- **reasons for handoff**:
  - stronger signal to/from new BSS (continuing connectivity, less battery drain)
  - load balance: free up channel in current BSS
  - GSM doesn’t mandate why to perform handoff (policy), only how (mechanism)
- **handoff initiated by old BSS**

1. old BSS informs MSC of impending handoff, provides list of 1’s new BSSs.
2. MSC sets up path (allocates resources) to new BSS.
3. new BSS allocates radio channel for use by mobile.
4. new BSS signals MSC, old BSS: ready.
5. old BSS tells mobile: perform handoff to new BSS.
6. mobile, new BSS signal to activate new channel.
7. mobile signals via new BSS to MSC: handoff complete. MSC reroutes call.
8. MSC-old-BSS resources released.

NSA, mobility tracking

- Dec. 4, 2013: NSA tracking cellphone locations worldwide, Snowden documents show

The Washington Post

NSA, mobility tracking

Course Summary

What have we learned: a huge amount!
- principles
- practice
- policy, social
- business

What did we do?
- Introduction to networking
- network structure, who controls the Internet (ICANN, domain names)
- application layer, including HTTP
- 3rd party cookies, ad networks
- dealing with scale: DNS
- CDNs, Netflix case study
- reliable data transfer
- congestion control
- TCP, UDP, IP protocols
- what’s inside a router?
- addressing, DHCP, IPv6
- Dijkstra’s link state, distance vector algorithms
- P2P forensics: illegal content
- Snowden and NSA: privacy
- network neutrality
- local area networks
- multiple access networks
- wireless networks: WiFi, cellular

Whither goest networking?
(some big-picture thoughts)
Q: Whither goest networking?

A: nobody knows! General trends:

- ubiquity of communications
  - IP dialtone, IP-like electricity: it’s everywhere!
  - network-capable appliances (e.g., smart homes)
  - issues of scale important: 100s of millions of network-connected devices

- mobility important:
  - people move, need to communicate

- multimedia important:
  - it is how people communicate

- application-layer networking: p2p, skype – services at the edge (at the application layer)

- increasing link rates, but bandwidth not free
  - increased bandwidth requirements of enabled apps (video to become 90% of backbone traffic?)

- cyber-physical systems: embedded networked devices “everywhere”

- security, management, robustness: critical concerns

- agents: processing “in” or “on” the network in support of end users

- regulation, privacy, business models
  - net neutrality
  - comcast vs level-3/Netflix: a glimpse of things to come?
  - NSA

Our Very Last Note Page!

- networking: will play a central role in computing, information processing

- this course:
  - Internet architecture, protocols
  - fundamental issues: reliable data transfer, flow/congestion control, routing, multiple access, switching
  - business: ad networks, CDNs,
  - policy: privacy, network neutrality

- remember: you learned it HERE!

- Thanks!