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

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

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 spreading 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
  - All use CSMA/CA for multiple access
  - All have base-station and ad-hoc network versions

802.11: Channels, association

- **802.11b**: 2.4 GHz-2.485 GHz 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

Components of cellular network architecture

- **Cell**: covers geographical region
- **Base station (BS)** analogous to 802.11 AP
- **Mobile users**: attach to network through BS
- **Air interface**: physical and link layer protocol between mobile and BS

- **MSC**: connects cells to wide area net
- **Mobile switching center**: manages call setup (more later)
- **Public telephone network, and Internet**: handles mobility (more later)
What is mobility?

- spectrum of mobility, from the network perspective:
  - no mobility
  - high mobility
  - mobile wireless user, using same access point
  - mobile user, connecting/disconnecting from network using DHCP
  - mobile user, passing through multiple access point while maintaining ongoing connections (like cell phone)

Indirect Routing: comments

- Mobile uses two addresses:
  - permanent address: used by correspondent (hence mobile location is transparent to correspondent)
  - care-of-address: used by home agent to forward datagrams to mobile
- Foreign agent functions may be done by mobile itself
- Triangle routing: correspondent-home-network-mobile
  - inefficient when correspondent, mobile are in same network

Mobile IP: indirect routing

- Overcome triangle routing problem
- Non-transparent to correspondent: correspondent must get care-of-address from home agent
  - what if mobile changes visited network?

Direct Routing: comments

- Overcome triangle routing problem
- Non-transparent to correspondent: correspondent must get care-of-address from mobile
  - what if mobile changes visited network?
Components of cellular network architecture

- **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 #, 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

Handling mobility in cellular networks

- **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**

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

1. Old BSS informs MSC of impending handoff, provides list of 1+ 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

GSM: handoff between MSCs

- **Anchor MSC**: first MSC visited during call
- **Call remains routed through anchor MSC**
- **New MSCs add on to end of MSC chain as mobile moves to new MSC**
- **IS-41 allows optional path minimization step to shorten multi-MSC chain**
GSM: handoff between MSCs

- **anchor MSC**: first MSC visited during call
- Call remains routed through anchor MSC
- New MSCs add on to end of MSC chain as mobile moves to new MSC
- IS-41 allows optional path minimization step to shorten multi-MSC chain

**Home network**: PSTN

**Anchor MSC**: first MSC visited during call

**New MSCs**: add on to end of MSC chain as mobile moves to new MSC

**Path minimization**: optional step to shorten multi-MSC chain

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**Mobility: GSM versus Mobile IP**

<table>
<thead>
<tr>
<th>GSM element</th>
<th>Comment on GSM element</th>
<th>Mobile IP element</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home system</td>
<td>Network to which the mobile user’s permanent phone number belongs</td>
<td>Home network</td>
</tr>
<tr>
<td>Gateway Mobile Switching Center or Home Location Register (HLR)</td>
<td>Home MSC: point of contact to obtain routable address of mobile user. HLR: database in home system containing permanent phone number, profile information, current location of mobile user; subscription information</td>
<td>Home agent</td>
</tr>
<tr>
<td>Visited System</td>
<td>Network other than home system where mobile user is currently residing</td>
<td>Visited network</td>
</tr>
<tr>
<td>Visited Mobile services Switching Center, Visitor Location Record (VLR)</td>
<td>Visited MSC: responsible for setting up calls from mobile nodes in cells associated with MSC; VLR: temporary database entry in visited system, containing subscription information for each visiting mobile user</td>
<td>Foreign agent</td>
</tr>
<tr>
<td>Mobile Station Roaming Number (MSRN), or “roaming number”</td>
<td>Routable address for telephone call segment between home MSC and visited MSC, visible to neither the mobile nor the correspondent</td>
<td>Care-of-address</td>
</tr>
</tbody>
</table>

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**Chapter 6 Summary**

**Wireless**
- Wireless links:
  - capacity, distance
  - channel impairments
  - CDMA
- IEEE 802.11 (“wi-fi”)
- CDMA2000 reflects wireless channel characteristics
- cellular access
  - architecture
  - standards (e.g., GSM, CDMA-2000, UMTS)

**Mobility**
- Principles: addressing, routing to mobile users
  - home, visited networks
  - direct, indirect routing
  - care-of-addresses
- Case studies
  - mobile IP
  - mobility in GSM
  - impact on higher-layer protocols

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**Chapter 7: Goals**

**Principles**
- Classify multimedia applications
- Identify the network services the apps need
- Making the best of best effort service
- Mechanisms for providing QoS

**Protocols and Architectures**
- Specific protocols for best-effort
- Architectures for QoS
Chapter 7 outline

- 7.1 Multimedia Networking Applications
- 7.2 Streaming stored audio and video
- 7.3 Real-time Multimedia: Internet Phone study
- 7.4 Protocols for Real-Time Interactive Applications: RTP, RTCP, SIP
- 7.5 Distributing Multimedia: content distribution networks
- 7.6 Beyond Best Effort
- 7.7 Scheduling and Policing Mechanisms
- 7.8 Integrated Services and Differentiated Services
- 7.9 RSVP

Streamed Multimedia

Streaming:
- Media stored at source
- Transmitted to client
- Streaming: client playout begins before all data has arrived
- Timing constraint for still-to-be transmitted data: in time for playout

Streaming Live Multimedia

Examples:
- Internet radio talk show
- Live sporting event

Streaming:
- Playback buffer
- Playback can lag tens of seconds after transmission
- Still have timing constraint

Interactivity:
- Fast forward impossible
- Rewind, pause possible!

Fundamental characteristics:
- Typically delay sensitive
- End-to-end delay
- Delay jitter
- But loss tolerant: infrequent losses cause minor glitches
- Antithesis of data, which are loss intolerant but delay tolerant.
**Interactive, Real-Time Multimedia**
- **Applications:** IP telephony, video conference, distributed interactive worlds
- **End-end delay requirements:**
  - Audio: < 150 msec good, < 400 msec OK
  - Includes application-level (packetization) and network delays
  - Higher delays noticeable, impair interactivity
- **Session initialization**
  - How does callee advertise its IP address, port number, encoding algorithms?

**Multimedia Over Today’s Internet**
- **TCP/UDP/IP:** "best-effort service"
  - No guarantees on delay, loss
    - But you said multimedia apps require QoS and level of performance to be effective?

**How should the Internet evolve to better support multimedia?**
- **Integrated services philosophy:**
  - Fundamental changes in Internet so that apps can reserve end-to-end bandwidth
  - Requires new, complex software in hosts & routers
  - Laissez-faire
  - No major changes
  - More bandwidth when needed
  - Content distribution, application-layer multicast
  - Application layer

**A few words about audio compression**
- Analog signal sampled at constant rate:
  - Telephone: 8,000 samples/sec
  - CD music: 44,100 samples/sec
- Each sample quantized, i.e., rounded:
  - E.g., $2^n$, 256 possible quantized values
  - Each quantized value represented by bits:
    - 8 bits for 256 values
- Example rates:
  - CD: 1.411 Mbps
  - MP3: 96, 128, 160 kbps
  - Internet telephony: 5.3 - 13 kbps

**A few words about video compression**
- Video is sequence of images displayed at constant rate:
  - E.g., 24 images/sec
- Digital image is array of pixels
- Each pixel represented by bits
- Redundancy:
  - Spatial
  - Temporal

**Chapter 7 outline**
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Streaming Stored Multimedia

Application-level streaming techniques for making the best out of best effort service:
- client side buffering
- use of UDP versus TCP
- multiple encodings of multimedia

Internet multimedia: simplest approach

- audio or video stored in file
- files transferred as HTTP object
- received in entirety at client
- then passed to player

audio, video not streamed:
- no, "pipelining," long delays until playout!

Internet multimedia: streaming approach

- browser GETs metafile
- browser launches player, passing metafile
- player contacts server
- server streams audio/video to player

Streaming from a streaming server

- This architecture allows for non-HTTP protocol between server and media player
- Can also use UDP instead of TCP.

Streaming Multimedia: Client Buffering

- Client-side buffering, playout delay compensate for network-added delay, delay jitter
Streaming Multimedia: UDP or TCP?

**UDP**
- Server sends at rate appropriate for client (oblivious to network congestion)
- Often send rate = encoding rate = constant rate
- Then, fill rate = constant rate - packet loss
- Short playout delay (2-5 seconds) to compensate for network delay jitter
- Error recovery: time permitting

**TCP**
- Send at maximum possible rate under TCP
- Fill rate fluctuates due to TCP congestion control
- Larger playout delay: smooth TCP delivery rate
- HTTP/TCP passes more easily through firewalls

User Control of Streaming Media: RTSP

**HTTP**
- Does not target multimedia content
- No commands for fast forward, etc.

**RTSP: RFC 2326**
- Client-server application layer protocol
- For user to control display: rewind, fast forward, pause, resume, repositioning, etc.

What it doesn’t do:
- Does not define how audio/video is encapsulated for streaming over network
- Does not restrict how streamed media is transported; it can be transmitted over UDP or TCP
- Does not specify how the media player buffers audio/video

RTSP Example

**Scenario:**
- Metafile communicated to web browser
- Browser launches player
- Player sets up an RTSP control connection, data connection to streaming server

RTSP: out of band control

**FTP** uses an “out-of-band” control channel:
- A file is transferred over one TCP connection.
- Control information (directory changes, file deletion, file renaming, etc.) is sent over a separate TCP connection.
- The “out-of-band” and “in-band” channels use different port numbers.

**RTSP** messages are also sent out-of-band:
- RTSP control messages use different port numbers than the media stream: out-of-band.
- Port 554
- The media stream is considered “in-band”.

Metafile Example

```xml
<title>Twister</title>
<session>
  <group language=en lipsync>
    <switch>
      <track type=audio
        e="PCMU/8000/1"
        src="/http://audio.example.com/twister/audio.en/soft/">
        src="/http://audio.example.com/twister/audio.en/hifi/">
      </switch>
      <track type=audio
        e="DVI4/16000/2" pt="90 DVI4/8000/1"
        src="/http://audio.example.com/twister/audio.en/soft/">
        src="/http://audio.example.com/twister/audio.en/hifi/">
      </switch>
      <track type=video/width src="/http://video.example.com/twister/video/smart">
        src="/http://video.example.com/twister/video/">
    </group>
  </session>
```