Chapter 6 outline

6.1 Introduction
Wireless
6.2 Wireless links, characteristics
- CDMA
6.3 IEEE 802.11 wireless LANs ("Wi-Fi")
6.4 Cellular Internet Access
- architecture
- standards (e.g., GSM)
6.5 Principles: addressing and routing to mobile users
6.6 Mobile IP
6.7 Handling mobility in cellular networks
6.8 Mobility and higher-layer protocols
6.9 Summary

What is mobility?

- spectrum of mobility, from the network perspective:

  no mobility  high mobility
  mobile wireless user, using same access point  mobile user, passing through multiple access point while maintaining ongoing connections (like cell phone)

Mobility: vocabulary

- permanent address: remains constant (e.g., 128.119.40.186)
- care-of-address: address in visited network (e.g., 79.129.13.2)
- visited network: network in which mobile currently resides (e.g., 79.129.13.24)
- home network: permanent "home" of mobile (e.g., 128.119.40.24)
- visited network: network in which mobile currently resides (e.g., 79.129.13.24)
- permanent address: address in home network, can always be used to reach mobile (e.g., 128.119.40.186)
- home agent: entity that will perform mobility functions on behalf of mobile, when mobile is remote
- foreign agent: entity in visited network that performs mobility functions on behalf of mobile
- correspondent: wants to communicate with mobile
- wide area network

How do you contact a mobile friend?

Consider friend frequently changing addresses, how do you find her?

- search all phone books?
- call her parents?
- expect her to let you know where he/she is?

I wonder where Alice moved to?
Mobility: how to handle it?

- **let routing handle it**: routers advertise permanent address of mobile-nodes-in-residence via usual routing table exchange.
  - routing tables indicate where each mobile located
  - no changes to end-systems
- **let end-systems handle it**:
  - **indirect routing**: communication from correspondent to mobile goes through home agent, then forwarded to remote
  - **direct routing**: correspondent gets foreign address of mobile, sends directly to mobile

**Mobility: approaches**

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**Mobility: registration**

- Mobile contacts foreign agent on entering visited network
- Home agent intercepts packets, forwards to foreign agent
- Foreign agent receives packets, forwards to mobile
- Mobile replies directly to correspondent

**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 or close to each other.

**Indirect routing: moving between networks**

- Suppose mobile user moves to another network
  - registers with new foreign agent
  - new foreign agent registers with home agent
  - home agent update care-of-address for mobile
  - packets continue to be forwarded to mobile (but with new care-of-address)
- Mobility, changing foreign networks transparent: **ongoing connections can be maintained!**
Mobility via direct routing

1. Correspondent requests, receives foreign address of mobile
2. Correspondent forwards packets, forwards to mobile
3. Mobile replies directly to correspondent

Mobility via direct routing: comments

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

Accommodating mobility with direct routing

- anchor foreign agent: FA in first visited network
- data always routed first to anchor FA
- when mobile moves: new FA arranges to have data forwarded from old FA (chaining)

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Mobile IP

- Specified in RFC 3344 (2002)
- has many features we've seen:
  - home agents, foreign agents, foreign-agent registration, care-of-addresses, encapsulation (packet-within-a-packet)
- three components to standard:
  - indirect routing of datagrams
  - agent discovery
  - registration with home agent

Mobile IP: indirect routing

- Packet sent by home agent to foreign agent: a packet within a packet
  - Dest: 128.119.40.186
  - Dest: 79.129.13.2
- Packet sent by correspondent: 79.129.13.2
  - Dest: 128.119.40.186
  - Dest: 128.119.40.186
IP and ICMP

Mobile IP uses ICMP for router management (advertising home/mobile agents)

<table>
<thead>
<tr>
<th>Protocol</th>
<th>Type of service (Tos)</th>
<th>Total length (in bytes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification</td>
<td>Flags</td>
<td>Fragmentation offset</td>
</tr>
<tr>
<td>Time to live (TTL)</td>
<td>Protocol</td>
<td>Header checksum</td>
</tr>
<tr>
<td>Source IP address</td>
<td>Destination IP address</td>
<td>Option (if any)</td>
</tr>
<tr>
<td>Data</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


When "Protocol" equals 0x01, the IP packet carries an ICMP as its payload (data).

ICMP: Internet Control Message Protocol review

A combination of "type of message" and "code" specifies the meaning of this ICMP packet. Among others:
- Type 9 is for "route advertising".
- Run IP packet analysis lab solution (no pcap) using "icmp-etherreal-trace-1" as data to see Type 8 and Type 0 ICMP messages (Echo request and Echo reply).

ICMP Type 9 message (route discovery)


Mobile IP: agent discovery

- agent advertisement: foreign/home agents advertise service by broadcasting ICMP messages (typefield = 9).


Flags in ICMP mobile extension

- H: home agent bit
- F: foreign agent bit
- R: registration required bit
- M,G: encapsulation bits (minimal or GRE encapsulation)
- B: busy
- r: reserved
- T: reverse tunneling

Other ICMP Messages Used by Mobile IP

- Type 10: agent solicitation, mobile agent is looking for COA without advertisement
- Type 35: mobile registration request
- Type 36: mobile registration reply
Mobile IP: registration example

- **home agent (HA):** 128.119.40.7
- **foreign agent (COA):** 79.129.13.2
- **registration req.:**
  - COA: 79.129.13.2
  - HA: 128.119.40.7
  - MA: 128.119.40.186
  - Lifetime: 9999
  - identification: 714
- **registration reply:**
  - HA: 128.119.40.7
  - MA: 128.119.40.186
  - Lifetime: 4999
  - Identification: 714

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 ID, 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. **call routed to home network**
2. **home MSC consults HLR,** gets roaming number of mobile in visited 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 BS (continuing connectivity, less battery drain)
  - load balance: free up channel in current BS
- **GSM doesn’t mandate why to perform handoff (policy), only how (mechanism)**
- **handoff initiated by old BS**

GSM: handoff with common MSC

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

(a) before handoff

- **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
- optional path minimization step to shorten multi-MSC chain

(b) after handoff

- **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
- optional path minimization 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 mobile user’s permanent phone number belongs</td>
<td>Home network</td>
</tr>
<tr>
<td>Gateway Mobile Switching Center, or &quot;Home MSC&quot;</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 Switching Center, Visitor Location Record (VLR)</td>
<td>Visited MSC: responsible for setting up calls to/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>Care-of-address</td>
</tr>
<tr>
<td>Mobile Station Roaming Number (MSRN), or &quot;roaming number&quot;</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")
    - CSMA/CA reflects wireless channel characteristics
  - cellular access
    - architecture
    - standards (e.g., GSM, 3G, 4G LTE)

**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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**Wireless, 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 un-necessarily
  - delay impairments for real-time traffic
  - limited bandwidth of wireless links