Chapter 6 outline

6.1 Introduction

Wireless
- 6.2 Wireless links, characteristics
- 6.3 IEEE 802.11 wireless LANs ("wi-fi")
- 6.4 Cellular Internet Access
  - architecture
  - standards (e.g., GSM)

Mobility
- 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
Components of cellular network architecture

- **MSC**
  - connects cells to wide area net
  - manages call setup (more later!)
  - handles mobility (more later!)

- **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

- **Public telephone network, and Internet**
- **wired network**
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
Cellular standards: brief survey

2G systems: voice channels
- IS-136 TDMA: combined FDMA/TDMA (north america)
- GSM (global system for mobile communications): combined FDMA/TDMA
  - most widely deployed
- IS-95 CDMA: code division multiple access

Don’t drown in a bowl of alphabet soup: use this for reference only
Cellular standards: brief survey

2.5 G systems: voice and data channels

- for those who can’t wait for 3G service: 2G extensions
- general packet radio service (GPRS)
  - evolved from GSM
  - data sent on multiple channels (if available)
- enhanced data rates for global evolution (EDGE)
  - also evolved from GSM, using enhanced modulation
  - data rates up to 384K
- CDMA-2000 (phase 1)
  - data rates up to 144K
  - evolved from IS-95
Cellular standards: brief survey

3G systems: voice/data
- Universal Mobile Telecommunications Service (UMTS)
- CDMA-2000: CDMA in TDMA slots
  - data service: 1xEvolution Data Optimized (1xEVDO) up to 14 Mbps

..... more (and more interesting) cellular topics due to mobility (stay tuned for details)
2G (voice) network architecture

Base station system (BSS)
- BTS
- BSC

MSC

Public telephone network
- Gateway MSC

Legend
- Base transceiver station (BTS)
- Base station controller (BSC)
- Mobile Switching Center (MSC)
- Mobile subscribers

6: Wireless and Mobile Networks  6-8
2.5G (voice+data) network architecture

**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
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6.9 Summary
What is mobility?

- spectrum of mobility, from the network perspective:

  - no mobility
    - mobile wireless user, using same access point
  - high mobility
    - mobile user, connecting/disconnecting from network using DHCP.
    - mobile user, passing through multiple access point while maintaining ongoing connections (like cell phone).
**Mobility: Vocabulary**

- **home network**: permanent “home” of mobile (e.g., 128.119.40/24)
- **home agent**: entity that will perform mobility functions on behalf of mobile, when mobile is remote
- **Permanent address**: address in home network, *can always* be used to reach mobile e.g., 128.119.40.186

**Diagram:**
- Home network
- Home agent
- Wide area network
- Correspondent
Mobility: more 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)

**wide area network**

**foreign agent**: entity in visited network that performs mobility functions on behalf of mobile.

**correspondent**: wants to communicate with mobile

6: Wireless and Mobile Networks  6-13
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: approaches

- *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

- 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
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- 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

not scalable to millions of mobiles
Mobility: registration

End result:
- Foreign agent knows about mobile
- Home agent knows location of mobile
Mobility via Indirect Routing

Step 2: datagram transmitted by sources is encapsulated in a datagram transmitted by the home agent to the COA
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
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: on going connections can be maintained!
Mobility via Direct Routing

1. Correspondent requests, receives foreign address of mobile
2. Correspondent forwards to foreign agent
3. Foreign agent receives packets, forwards to mobile
4. Mobile replies directly to correspondent
Mobility via Direct Routing

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

Mobile can act as foreign agent.
Correspondent can act as corresponding agent.
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

- RFC 3344
- 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

- Permanent address: 128.119.40.186
  - packet sent by correspondent
  - destination: 128.119.40.186

- Care-of address: 79.129.13.2
  - packet sent by home agent to foreign agent: a packet within a packet
  - destination: 79.129.13.2

- foreign-agent-to-mobile packet
  - destination: 128.119.40.186
Mobile IP: agent discovery

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

![Diagram of ICMP fields]

- **R bit:** registration required
- **H,F bits:** home and/or foreign agent

**ICMP fields:**
- **type = 9**
  - code = 0
  - checksum
- **router address**
- **type = 16**
  - length
  - sequence #
  - registration lifetime
  - RBHFMGV bits
  - reserved
  - 0 or more care-of-addresses

6: Wireless and Mobile Networks 6-28
Mobile IP: registration example

- Home agent (HA): 128.119.40.7
  - CoA: 79.129.13.2
- Foreign agent (COA): 79.129.13.2
- ICMP agent adv.
  - CoA: 79.129.13.2
- Mobile agent (MA): 128.119.40.186
- Visited network: 79.129.13/24

Registration request:
- CoA: 79.129.13.2
- HA: 128.119.40.7
- MA: 128.119.40.186
- Lifetime: 9999
- Identification: 714
- Encapsulation format

Registration reply:
- HA: 128.119.40.7
- MA: 128.119.40.186
- Lifetime: 4999
- Identification: 714
- Encapsulation format

In datagramma UDP, porta 434
HA= home agent
MA= mobile address
Components of cellular network architecture

call:

wired public telephone 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 #, 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

**Steps:**

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: indirect routing to mobile

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When MU switches on cell in the new network must register with VLR which communicates affiliation to HLR
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
GSM: handoff with common MSC

1. old BSS informs MSC of impending handoff, provides list of $1^\text{st}$ 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

(a) before handoff
**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

![Diagram of GSM handoff between MSCs](image-url)
## 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><strong>Home system</strong></td>
<td>Network to which mobile user’s permanent phone number belongs</td>
<td><strong>Home network</strong></td>
</tr>
<tr>
<td><strong>Gateway Mobile Switching Center, or “home MSC”. Home Location Register (HLR)</strong></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><strong>Home agent</strong></td>
</tr>
<tr>
<td><strong>Visited System</strong></td>
<td>Network other than home system where mobile user is currently residing</td>
<td><strong>Visited network</strong></td>
</tr>
<tr>
<td><strong>Visited Mobile services Switching Center. Visitor Location Record (VLR)</strong></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><strong>Foreign agent</strong></td>
</tr>
<tr>
<td><strong>Mobile Station Roaming Number (MSRN), or “roaming number”</strong></td>
<td>Routable address for telephone call segment between home MSC and visited MSC, visible to neither the mobile nor the correspondent.</td>
<td><strong>Care-of-address</strong></td>
</tr>
</tbody>
</table>
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
    - ARQ based solutions
    - splitting of transport session (wired section/wireless section)
    - transparent approaches (e.g. TCP Westwood)
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, 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