First Generation Celluar

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Telcom 2700
Slides 5
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First Generation Systems

• Goal: Provide basic voice service to mobile users over large area
• 1 G Systems developed late 70’s early 80’s, deployed in 80’s
  – Advanced Mobile Phone System (AMPS) - USA
  – Total Access Communications Systems (TACS) - UK
  – Nordic Mobile Telephone (NMT) System – Scandinavian PTTs
  – C450 - W. Germany
  – NTT System - Nippon Telephone & Telegraph (NTT) – Japan
• Incompatible systems using different frequencies!
  – Have similar characteristics though
First Generation Systems

- Characteristics of 1G systems
  - Use Cellular Concept to provide service to a geographic area (i.e. number of small adjacent cells to provide coverage)
    - Frequency Reuse
    - Handoff/Handover
  - FDMA/FDD systems
  - Common Air Interface (CAI) standards only
    - Analog Voice communications using FM
    - Digital Control channels for signalling
  - Adjustable Mobile Power levels
  - Macro Cells: 1-40 km radius
- Focus on AMPS system

AMPS

- Advanced Mobile Phone System is first generation wireless in US
  - Earlier systems used line of sight radio (eg, AT&T’s Improved Mobile Telephone Service in 1960s)
  - AT&T developed cellular concept in 1940s
  - 1971 proposed High Capacity Mobile Phone Service to FCC
  - 1979 FCC standardized it as AMPS in 800-900 MHz range
  - 1983 launched in Chicago
- Licenses for geographic service areas (similar to radio station model) – areas based on commercial trading zones
  - MSA: metro service area, RSA: rural service area
AMPS
Metropolitan Statistical Areas and Rural Service Areas

FCC allocated 2 licenses for each MSA, RSA

One license to local phone company: wireline common carrier (WCC)

Other license given out by lottery: radio common carrier (RCC)

Speculation and fraud in RCC lottery!

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AMPS

• Originally 40 MHz of spectrum separated into two bands of 20 MHz each (A and B band). Later expanded to 25 MHz each
  – A band lower spectrum went to RCC, B band to WCC
• FDD used with 45 MHz separation in uplink and downlink – prevents self interference.
• AMPS uses 30 kHz radio channels between mobile station and base stations (EIA/TIA-533 radio interface)
• Two service providers in area are each allocated 25 MHz => 12.5 MHz for each direction => 416 pairs of channels: split into 395 voice channels + 21 control channels for signaling
• Channels numbered consecutively 1-666, when expanded kept same numbering assuming 30 KHz channels even in places were no spectrum allowed
  - \( f(c)_{\text{uplink}} = 825,000 + 30 \times (c) \text{ KHz} \quad 1 \leq c \leq 799 \)
  - \( f(c)_{\text{uplink}} = 825,000 + 30 \times (c-1023) \text{ KHz} \quad 991 \leq c \leq 1023 \)
  - \( f(c)_{\text{downlink}} = f(c)_{\text{uplink}} + 45,000 \text{ KHz} \)

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### AMPS Frequency Allocation and Channels

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>825</td>
<td>845</td>
<td>MHz</td>
<td>870</td>
</tr>
<tr>
<td>1</td>
<td>666</td>
<td>Ch.</td>
<td>1</td>
</tr>
</tbody>
</table>

a. Original spectrum (666 channels)

<table>
<thead>
<tr>
<th>A</th>
<th>A</th>
<th>B</th>
<th>A</th>
<th>B</th>
<th>A</th>
<th>A</th>
<th>B</th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>824</td>
<td>825</td>
<td>845</td>
<td>849</td>
<td>MHz</td>
<td>869</td>
<td>870</td>
<td>890</td>
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</tr>
<tr>
<td>991</td>
<td>1,023</td>
<td>666</td>
<td>799</td>
<td>Ch.</td>
<td>991</td>
<td>1,023</td>
<td>666</td>
<td>799</td>
<td></td>
</tr>
</tbody>
</table>

b. Expanded spectrum (832 channels)

### FDD/FDMA - AMPS (B block)

- $f(c)_{\text{uplink}} = 825,000 + 30 \times \text{(channel number)} \text{ KHz}$
- $f(c)_{\text{downlink}} = f(c)_{\text{uplink}} + 45,000 \text{ KHz}$
### Initial AMPS System Operators

<table>
<thead>
<tr>
<th>Market No.</th>
<th>Area</th>
<th>System Operator</th>
<th>No. of Cells</th>
<th>Switching Equipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>New York</td>
<td>W (B-Side) - Nynex Mobile (6/15/84) NW-Metro One (B-Side) (4/5/86)</td>
<td>56</td>
<td>AT&amp;T Motorola</td>
</tr>
<tr>
<td>2</td>
<td>LA</td>
<td>W-PacTel Cellular (6/13/84) NW-LA Cellular (3/27/87)</td>
<td>81</td>
<td>AT&amp;T Ericsson</td>
</tr>
<tr>
<td>3</td>
<td>Chicago</td>
<td>W-Ameritech Mobile (10/13/83) NW-Cellular One (1/3/85)</td>
<td>73</td>
<td>AT&amp;T Motorola</td>
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<tr>
<td>4</td>
<td>Philadelphia</td>
<td>W-Bell Atlantic Mobile (7/12/84) NW-Metrophone (2/12/86)</td>
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<td>AT&amp;T Ericsson</td>
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<tr>
<td>5</td>
<td>Detriot</td>
<td>W-Ameritech Mobile (9/21/84) NW-Cellular One (7/30/85)</td>
<td>37</td>
<td>AT&amp;T Motorola</td>
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<tr>
<td>6</td>
<td>Boston</td>
<td>W-Nynex Mobile (1/1/85) NW-Cellular One (1/1/85)</td>
<td>30</td>
<td>AT&amp;T Motorola</td>
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<tr>
<td>7</td>
<td>San Francisco</td>
<td>W-GTE Mobilnet (4/2/85) NW-Cellular One (9/26/86)</td>
<td>28</td>
<td>Motorola Ericsson</td>
</tr>
<tr>
<td>8</td>
<td>Washington</td>
<td>W-Bell Atlantic Mobile (4/2/84) NW-Cellular One (12/16/83)</td>
<td>46</td>
<td>AT&amp;T Motorola</td>
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<tr>
<td>9</td>
<td>Dallas</td>
<td>W-SW Bell Mobile (7/31/84) NW-MetroCel (1/1/86)</td>
<td>41</td>
<td>AT&amp;T Motorola</td>
</tr>
</tbody>
</table>

### Sectored Frequency Planning

- AMPS operators typically used either clusters of size 21 with no sectoring or clusters of 7 in cell frequency reuse pattern with 3 sectors per cell
- Use a Frequency Chart to plan cells: groups frequencies into 21 categories Cells 1-7 and sectors A, B, C in each cell

*Module numbers indicate 21 unique channels for Block A and Block B respectively.
### Sectored Frequency Planning

Notice 21 control channels for each provider in center of AMPS band:
- A provider has 312-333
- B provider has 334–354

#### Table 5.1 New Frequency Management (Full Spectrum) - Block A

<table>
<thead>
<tr>
<th>1A</th>
<th>2A</th>
<th>3A</th>
<th>4A</th>
<th>5A</th>
<th>6A</th>
<th>7A</th>
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<th>4B</th>
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<th>1C</th>
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<th>3C</th>
<th>4C</th>
<th>5C</th>
<th>6C</th>
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<tbody>
<tr>
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</table>

| 127 | 128 | 129 | 130 | 131 | 132 | 133 | 134 | 135 | 136 | 137 | 138 | 139 | 140 | 141 | 142 | 143 | 144 | 145 | 146 | 147 |
| 148 | 149 | 150 | 151 | 152 | 153 | 154 | 155 | 156 | 157 | 158 | 159 | 160 | 161 | 162 | 163 | 164 | 165 | 166 | 167 | 168 |
| 169 | 170 | 171 | 172 | 173 | 174 | 175 | 176 | 177 | 178 | 179 | 180 | 181 | 182 | 183 | 184 | 185 | 186 | 187 | 188 | 189 |
| 190 | 191 | 192 | 193 | 194 | 195 | 196 | 197 | 198 | 199 | 200 | 201 | 202 | 203 | 204 | 205 | 206 | 207 | 208 | 209 | 210 |

#### Cell Design - Reuse Pattern

- AMPS equipment usually requires C/I = 18 dB => frequency reuse cluster size K= 21 or K = 7 (usually having 3 sectors per cell).
- For K=7 case and 395 traffic channels have 4 cells in a cluster with 56 channels, 3 cell with 57.
- Traffic load in Erlangs

<table>
<thead>
<tr>
<th>Cell</th>
<th>Channel s</th>
<th>Erlangs (2% blocking)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>56</td>
<td>47.7</td>
</tr>
<tr>
<td>B</td>
<td>56</td>
<td>47.7</td>
</tr>
<tr>
<td>C</td>
<td>56</td>
<td>47.7</td>
</tr>
<tr>
<td>D</td>
<td>56</td>
<td>47.7</td>
</tr>
<tr>
<td>E</td>
<td>57</td>
<td>48.7</td>
</tr>
<tr>
<td>F</td>
<td>57</td>
<td>48.7</td>
</tr>
<tr>
<td>G</td>
<td>57</td>
<td>48.7</td>
</tr>
</tbody>
</table>
First Generation Systems

- Basic Architecture AMPS, NMT, etc. similar
- Mobile telephone switching office (MisTO) connects base stations to PSTN, location and equipment databases were local to each geographical service area

AMPS (cont)

- Identification numbers:
  - Mobile station’s 32-bit binary ESN (electronic serial number) stored in ROM at time of manufacture
    - 8-bit manufacturer code + 6-bit reserved (unused) + 18-bit manufacturer assigned serial number
  - Service provider’s 15-bit binary SID (system identification number) assigned by FCC license – one for each service provider in an area
    - Transmitted to identify service provider’s system
  - Mobile station’s 34-bit MIN (mobile identification number) = 10-digit telephone number
  - Station Class Mark (SCM): type of mobile, e.g., 1 – vehicle mount, 4 handheld
  - Supervisory Auditory Tone (SAT): tone to identify base station assigned to a call: pure tone at 5970, 6000, or 6030 Hz. Transmitted by both mobile and base station to distinguishes between frequency reuse clusters
  - Signaling Tone (ST): 10 KHz tone for on/off hook signalling
### AMPS System Identifiers

<table>
<thead>
<tr>
<th>Notation</th>
<th>Name</th>
<th>Size (bits)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MIN</td>
<td>Mobile Identifier</td>
<td>34</td>
<td>Directory number assigned by operating company to a subscriber</td>
</tr>
<tr>
<td>ESN</td>
<td>Electronic serial number</td>
<td>32</td>
<td>Assigned by manufacturer to a mobile station</td>
</tr>
<tr>
<td>SID</td>
<td>System identifier</td>
<td>15</td>
<td>Assigned by regulators to a geographical service area</td>
</tr>
<tr>
<td>SCC</td>
<td>Station class mark</td>
<td>4</td>
<td>Indicates capabilities of a mobile station</td>
</tr>
<tr>
<td>SAT</td>
<td>Supervisory audio tone</td>
<td>One of three sine wave signals</td>
<td>Assigned by operating company to each base station</td>
</tr>
<tr>
<td>DCC</td>
<td>Digital color code</td>
<td>2</td>
<td>Assigned by operating company to each base station</td>
</tr>
</tbody>
</table>

### AMPS Logical Channels

<table>
<thead>
<tr>
<th>Name</th>
<th>Notation</th>
<th>Use</th>
<th>Topology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reverse Control Channel</td>
<td>RECC</td>
<td>Signalling</td>
<td>(Random Access) Many-to-one</td>
</tr>
<tr>
<td>(1 per sector per cell)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reverse Voice Channel</td>
<td>RVC</td>
<td>Traffic</td>
<td>Dedicated One-to-One</td>
</tr>
<tr>
<td>(Associated Control Channel)</td>
<td></td>
<td>(Signalling)</td>
<td></td>
</tr>
<tr>
<td>Forward Control Channel</td>
<td>FOCC</td>
<td>Signalling</td>
<td>Broadcast One-to-Many</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Forward Voice Channel</td>
<td>FVC</td>
<td>Traffic</td>
<td>Dedicated One-to-One</td>
</tr>
<tr>
<td>(Associated Control Channel)</td>
<td></td>
<td>(Signalling)</td>
<td></td>
</tr>
</tbody>
</table>
AMPS FM modulator

- Audio input
- Compress
- Pre-Emphasize
- Limit
- Low Pass Filter
- Frequency Modulator
- Supervisory audio tone
- Amplify & transmit

μ-law compandor

Companding

Analog Compander emphasizes small values, de-emphasizes large values
Reverse the mapping at the receiver with an expander

\[ F(s) = \text{sgn}(s) \frac{\ln(1 + \mu|s|)}{\ln(1 + \mu)} \]
Modulation Techniques

- Frequency Modulation for voice: change frequency with information $s(t)$
  
  
  \[ m(t) = V \cos(\varphi(t)) \] where
  
  \[ \frac{d\varphi(t)}{dt} = \omega + \kappa s(t) \]

  Bandwidth of FM signal is approximately $2(MI + 1) f_{\text{max}}$
  
  \[ = 2(3+1)4 \text{ KHz} = 32 \text{ KHz} \]

- For digital control info use same modulator in Frequency Shift Keying (FSK) mode:
  - change frequency with each symbol
  - Manchester format for digital data feed to modulator
  - 10 Kbps channel rate

Channel Coding in AMPS

(n channel bits, k information bits; $d_{\text{min}}$, minimum distance)

Code rate $r = k/n$

<table>
<thead>
<tr>
<th>Channel</th>
<th>$n$</th>
<th>$k$</th>
<th>$m$</th>
<th>$b/s$</th>
</tr>
</thead>
<tbody>
<tr>
<td>RVC</td>
<td>48</td>
<td>36</td>
<td>5</td>
<td>662-703</td>
</tr>
<tr>
<td>FVC</td>
<td>40</td>
<td>28</td>
<td>11</td>
<td>271</td>
</tr>
<tr>
<td>RECC</td>
<td>48</td>
<td>36</td>
<td>5</td>
<td>1,250-1,442</td>
</tr>
<tr>
<td>FOCC</td>
<td>40</td>
<td>28</td>
<td>5</td>
<td>1,215</td>
</tr>
</tbody>
</table>
**AMPS FOCC: Structure**

Word sync 11100010010

Bit sync 1010101010 indicator

Word A(1), wordA(2)… wordA(5) are identical with 28 bits information in a (40,28;5) BCH code

Word B(i) has same format as Word A(i)

Word A bit rate = 28/463 X 10kbps = 604.75 bps

(463=(40x10)+10+11+42 busy/idle bits))

**AMPS: RECC Structure**

Digital Color Code

Word sync 11100010010

Bit sync 101010…

Data(1)…Data(5) are identical with 36 information bits encoded with BCH (48,36;5) block code

With 1 word per frame 5X48 + 30 + 11 + 7 = 288 bits => data rate = 36/288 X 10kbps = 1250bps

With 5 words per frame = 1248 bits => data rate = 5 x 36/1,248 x 10Kbps = 1442 bps
Reverse control channel access protocol

AMPS - Initialization

Base station  Mobile station
Power up and tune to provider A or B
Scan and tune to strongest control channel
Update operating parameters and SID
Control message
Verify initialization parameters; idle state

Control channels
System parameter message
Receive MIN, ESN, SID; registers user
Control message
### Associated Signalling FVC: Structure

<table>
<thead>
<tr>
<th>101</th>
<th>11</th>
<th>40</th>
<th>37</th>
<th>40</th>
<th>37</th>
<th>40</th>
<th>37</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data(1)</td>
<td>Data(2)</td>
<td>Data(3)</td>
<td>Data(11)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Word sync**: 11 bits 1110001010
- **Bit sync**: 101010...
- Data(1)…Data(11) identical with BCH (40,28;5) block code
- Bit rate = 28/1032 × 10kbps = 271bps

Permits signalling while a call is in progress. Uses Blank and Burst mode—interrupts voice and replaces it with control information. For example, increase/decrease power level of mobile. Handoff order.

### Associated Signalling RVC Structure

**Word 1**

<table>
<thead>
<tr>
<th>101</th>
<th>11</th>
<th>48</th>
<th>37</th>
<th>48</th>
<th>37</th>
<th>48</th>
<th>37</th>
<th>48</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data(1)</td>
<td>Data(2)</td>
<td>Data(3)</td>
<td>Data(5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Word 2**

<table>
<thead>
<tr>
<th>37</th>
<th>48</th>
<th>37</th>
<th>48</th>
<th>37</th>
<th>48</th>
<th>37</th>
<th>48</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data(1)</td>
<td>Data(2)</td>
<td>Data(3)</td>
<td>Data(5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Word sync**: 11 bits 1110001010
- **Bit sync**: 101010...
- Data(1)…Data(11) identical with BCH (40,36;5) block code
- One per frame: 544 bits, with 2 per frame 1024 bits

As in FVC works in Blank and Burst mode. Effective bit rate is 662b/s or 703b/s at 10 Kbps channel speed.
AMPS Transmission Formatting

Network Control Messages
1-5 Codewords

28-Bit Words
FVCC and FVC

12 Parity Bits
(BCH Code)

Repeat
11 Times
FVC

Repeat
5 Times
FVCC

FSK +- 8 kHz
10 kb/s Manchester Code

Analog User Signal
+ SAT + ST

36-Bit Words
RECC and RVC

12 Parity Bits
(BCH Code)

Repeat
5 Times
RECC and RVC

12 Parity Bits
(BCH Code)

Repeat
5 Times
FOCC

30 kHz Channel
Frequency Modulation
Max. Deviation 12 kHz

AMPS Messages

<table>
<thead>
<tr>
<th>Message</th>
<th>Network Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>SYSTEM PARAMETER</td>
<td>Call/Radio Resources Management</td>
</tr>
<tr>
<td>GLOBAL ACTION</td>
<td>Radio Resources Management</td>
</tr>
<tr>
<td>REGISTRATION IDENT</td>
<td>Mobility Management</td>
</tr>
<tr>
<td>CONTROL-FILLER</td>
<td>Radio Resources Management</td>
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<tr>
<td>PAGE</td>
<td>Call Management</td>
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<tr>
<td>INITIAL VOICE CHANNEL</td>
<td>Radio Resources Management</td>
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<td>REORDER</td>
<td>Call Management</td>
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<td>INTERCEPT</td>
<td>Call Management</td>
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<tr>
<td>SEND CALLED-ADDRESS</td>
<td>Call Management</td>
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<tr>
<td>DIRECTED RETRY</td>
<td>Radio Resources Management</td>
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<tr>
<td>RELEASE</td>
<td>Call Management</td>
</tr>
<tr>
<td>CONFIRM REGISTRATION</td>
<td>Mobility Management</td>
</tr>
</tbody>
</table>

Telcom 2700
### AMPS Messages

<table>
<thead>
<tr>
<th>Message</th>
<th>Network Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Forward Voice Channel Messages</strong></td>
<td></td>
</tr>
<tr>
<td>ALERT</td>
<td>Call Management</td>
</tr>
<tr>
<td>STOP ALERT</td>
<td>Call Management</td>
</tr>
<tr>
<td>MAINTENANCE</td>
<td>Operations admin. and maintenance</td>
</tr>
<tr>
<td>RELEASE</td>
<td>Call Management</td>
</tr>
<tr>
<td>SEND CALLED-ADDRESS</td>
<td>Call Management</td>
</tr>
<tr>
<td>HANDOFF</td>
<td>Radio Resources Management</td>
</tr>
<tr>
<td>CHANGE POWER LEVEL</td>
<td>Radio Resources Management</td>
</tr>
</tbody>
</table>

### Sample AMPS Messages

**HANDOFF** message on FVC

<table>
<thead>
<tr>
<th>Bit Position</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>10 a preamble indicates start of message</td>
</tr>
<tr>
<td>3-4</td>
<td>SAT of new channel (00, 01 or 10)</td>
</tr>
<tr>
<td>5-6</td>
<td>SAT of present channel (00, 01 or 10)</td>
</tr>
<tr>
<td>7-14</td>
<td>Not Used</td>
</tr>
<tr>
<td>15-17</td>
<td>Power level of new AMPS frequency channel</td>
</tr>
<tr>
<td>18-28</td>
<td>New AMPS channel number</td>
</tr>
</tbody>
</table>

**CHANGE POWER LEVEL** message on FVC

<table>
<thead>
<tr>
<th>Bit Position</th>
<th>Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-2</td>
<td>10 a preamble indicates start of message</td>
</tr>
<tr>
<td>3-4</td>
<td>11 indicates not a handoff message</td>
</tr>
<tr>
<td>5-6</td>
<td>SAT of present channel (00, 01 or 10)</td>
</tr>
<tr>
<td>7-14</td>
<td>Not Used</td>
</tr>
<tr>
<td>15-17</td>
<td>New power level</td>
</tr>
<tr>
<td>18-28</td>
<td>01011 indicates power control message</td>
</tr>
</tbody>
</table>
**AMPS Messages**

<table>
<thead>
<tr>
<th>Message</th>
<th>Network Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reverse Control Channel Messages</strong></td>
<td></td>
</tr>
<tr>
<td>ORIGINATION</td>
<td>Call Management, Authentication</td>
</tr>
<tr>
<td>PAGE RESPONSE</td>
<td>Call Management, Authentication</td>
</tr>
<tr>
<td>REGISTRATION</td>
<td>Mobility Management</td>
</tr>
<tr>
<td><strong>Reverse Voice Channel Messages</strong></td>
<td></td>
</tr>
<tr>
<td>CALLED-STATION ADDRESS</td>
<td>Call Management</td>
</tr>
<tr>
<td>ORDER CONFIRMATION</td>
<td></td>
</tr>
</tbody>
</table>

**AMPS - Mobile Originates Call**

- **Base station**
  - Pass to PSTN
  - Control message
  - Send supervisory signal to confirm forward channel
  - Answers and starts conversation

- **Mobile station**
  - Origination message (MIN, ESN, called party)
  - Tune to voice channel
  - Send supervisory signal to confirm reverse channel
### AMPS - Mobile Originates Call

**MTSO** | **Base Station** | **Terminal**
---|---|---

- **Initialize FOCC**
  - overhead message train
  - scan control channels, lock on FOCC, record system parameters, display roaming status

- **Idle FOCC**
  - access channel info
  - record access channel info
  - PAGE messages
  - press SEND button
  - service request

- **access RECC and FOCC**
  - Select voice channel
  - Voice channel indication
  - INITIAL VOICE CHANNEL
  - transmit SAT

### AMPS - Mobile Originates Call continued

**MTSO** | **Base Station** | **Terminal**
---|---|---

- **conversation RVC and FVC**
  - Tune to voice channel, detect SAT
  - Transmit SAT

- Detect SAT
- Confirm voice channel connection

- Complete call through network
- Conversation
  - press END button
  - Transmit ST (10 kHz)

- Call release indication
  - Release call in network
  - Turn off transmitter

ends when the user presses the END button
AMPS - Mobile Receives Call

Base station ➔ Mobile station

Mobile ID from PSTN; page control message ➔ Receives page

Mobile ID from PSTN; page control message ➔ Page response message (MIN, ESN)

Control message; tune to voice channel ➔ Tune to voice channel

Send supervisory signal to confirm forward channel ➔ Send supervisory signal to confirm reverse channel

AMPS - Mobile Terminated Call

<table>
<thead>
<tr>
<th>MTSO</th>
<th>Base Station</th>
<th>Terminal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Idle FOCC</td>
<td>Access channel info</td>
<td>Record access channel info</td>
</tr>
<tr>
<td>Call arrives from network</td>
<td>Send ringing tone to caller</td>
<td>PAGE</td>
</tr>
<tr>
<td>page commands to cells</td>
<td></td>
<td>Detect users MIN</td>
</tr>
<tr>
<td>access RECC and FOCC</td>
<td>service request</td>
<td>PAGE RESPONSE</td>
</tr>
<tr>
<td>Select voice channel</td>
<td>Voice channel indication</td>
<td>INITIAL VOICE CHANNEL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>transmit SAT</td>
</tr>
</tbody>
</table>
### AMPS - Handoff

- **Handoff initiation:**
  - Base station 1 notices mobile station’s signal is weakening (when the received signal strength goes below a certain threshold value)
  - Base station 1 sends a handoff measurement request message to its MSC
  - MSC requests neighbor base stations to report their reception of mobile’s signal strength
  - MSC pick neighbor base station with highest received signal strength
Handoff decision

![Diagram showing received signal strength at BS1 and BS2, with HO_MARGIN and MS indicating handoff decision points.]

AMPS Handoff

<table>
<thead>
<tr>
<th>MTSO</th>
<th>Original Base Station</th>
<th>New Base Station</th>
<th>Terminal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>conversation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>RVC and FVC</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>conversation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Detect weak signal</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Handoff request</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Measurement request</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Measurement request at many cells</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Measurement report</td>
<td>Measure signal strength</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Measurement report</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Handoff command</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Handoff indication</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Telcom 2700
AMPS - Handoff

<table>
<thead>
<tr>
<th>MTSO</th>
<th>Original Base Station</th>
<th>New Base Station</th>
<th>Terminal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>HANDOFF</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Send ST for 50 ms</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Turn off transmitter</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Tune to new voice channel</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Turn on transmitter</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Transmit new SAT</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Detect new SAT</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Confirm voice channel connection</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Transfer conversation to new base station</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>conversation</td>
</tr>
</tbody>
</table>

First Generation Systems (cont)

<table>
<thead>
<tr>
<th>System</th>
<th>Japan</th>
<th>North America</th>
<th>England</th>
<th>Scandinavia</th>
<th>Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NTT</td>
<td>AMPS</td>
<td>TACS</td>
<td>NMT</td>
<td>C450</td>
</tr>
<tr>
<td>Transmission Freq: (MHz)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Base station</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mobile station</td>
<td>870-885</td>
<td>869-894</td>
<td>917-950</td>
<td>463-467.5</td>
<td>461.3-465.74</td>
</tr>
<tr>
<td></td>
<td>925-940</td>
<td>824-849</td>
<td>872-905</td>
<td>453-457.5</td>
<td>451.3-455.74</td>
</tr>
<tr>
<td>Spacing between Tx and Rx Freq: (MHz)</td>
<td>55</td>
<td>45</td>
<td>45</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Spacing between channels (kHz)</td>
<td>25, 12.5</td>
<td>30</td>
<td>25</td>
<td>25</td>
<td>20</td>
</tr>
<tr>
<td>No. channels</td>
<td>600</td>
<td>832 (control ch.21x2)</td>
<td>1320 (control ch.21x2)</td>
<td>180</td>
<td>222</td>
</tr>
</tbody>
</table>
First Generation Systems (cont)

<table>
<thead>
<tr>
<th>System</th>
<th>Japan</th>
<th>North America</th>
<th>England</th>
<th>Scandinavia</th>
<th>Germany</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coverage radius (km)</td>
<td>NTT</td>
<td>AMPS</td>
<td>TACS</td>
<td>NMT</td>
<td>C450</td>
</tr>
<tr>
<td>5 (urban)</td>
<td>2-20</td>
<td>10 (suburbs)</td>
<td>1.8-40</td>
<td>5-30</td>
<td></td>
</tr>
<tr>
<td>Audio signal: Modulation</td>
<td>FM</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency deviation (kHz)</td>
<td>±5</td>
<td>±12</td>
<td>±9.5</td>
<td>±5</td>
<td>±4</td>
</tr>
<tr>
<td>Control signal: Modulation</td>
<td>FSK</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency deviation (kHz)</td>
<td>±4.5</td>
<td>±8</td>
<td>±6.4</td>
<td>±3.5</td>
<td>±2.5</td>
</tr>
<tr>
<td>Data Tx. Rate (kb/s)</td>
<td>0.3</td>
<td>10</td>
<td>8</td>
<td>1.2</td>
<td>5.28</td>
</tr>
<tr>
<td>Message Protection</td>
<td>Transmitted signal is checked when sent back to the transmitter by the receiver. Principle of majority decision Principle of majority decision Receiving steps predetermined according to the message content. Message sent again when an error is detected.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

First Generation Systems (cont)

- First generation systems targeted to few subscribers with car phones
  - Rapid growth in demand for cellular services
  - Availability of low cost, lightweight, portable handsets
    → Growing demand for system capacity
- Capacity can be increased by smaller cells but:
  - More difficult to place base stations at locations for necessary radio coverage
- Increased signaling for handoffs, and more frequent handoffs
  - Base stations handle more access requests and registrations
  - Analog technology has limited options to combat interference effects from smaller cells
- Demand for second generation, digital cellular
  - Also, incompatible first generation (analog) standards in Europe motivated new pan-European digital standard
### Generations of mobile communications

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Generation</strong></td>
<td>First</td>
<td>Second</td>
<td>2.5G</td>
<td>Third</td>
<td>Fourth/Fifth</td>
</tr>
<tr>
<td><strong>Keywords</strong></td>
<td>Analog</td>
<td>Digital Personal</td>
<td>Wireless Data</td>
<td>High speed wireless data</td>
<td>High Data rate, IP-based, high mobility</td>
</tr>
<tr>
<td><strong>Multiaccess</strong></td>
<td>FDMA</td>
<td>TDMA, CDMA</td>
<td>TDMA, CDMA</td>
<td>CDMA</td>
<td>Mixed</td>
</tr>
<tr>
<td><strong>Systems</strong></td>
<td>Analog Cellular</td>
<td>Digital Cellular</td>
<td>HSCSD, GPRS, EDGE, cdma 2000</td>
<td>WCDMA, EVDO</td>
<td>4G-Cellular, Hybrid networks</td>
</tr>
<tr>
<td></td>
<td>Analog Cordless</td>
<td>Digital Cordless</td>
<td>Max Data rate 150kbps</td>
<td>Data rate 2-11 Mbps?</td>
<td>Data rate 2-54 Mbps?</td>
</tr>
<tr>
<td></td>
<td>Mobile Data</td>
<td>Mobile Data</td>
<td>Satellite</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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