Outline

- History of GSM
- Frequency bands of operation around the world
- Physical channels and framing structure
- Logical channels
- Sample call setup and Layer 3 messages
- Coding and modulation
- Crunching the numbers
- Radio network features
- Reading Assignment
What’s in a Name?

GSM

did stand for...

Groupe Spéciale Mobile

…but now stands for...

Global System for Mobile Communications

GSM History

1982  CEPT establishes *Groupe Speciale Mobile* to develop standards for pan-European mobile network
1987  Memorandum of Understanding (MoU) signed by 12 countries
1989  Responsibility transferred to newly formed ETSI. GSM now stands for *Global System for Mobile Communications*
1990  Phase I specs. published & specs. ported to DCS 1800
1992  Official commercial launch of GSM in Europe
1995  GSM specifications ported to PCS 1900
2000  Responsibility for GSM Standard transferred to 3GPP
       AT&T lead TDMA operators in announcing shift to GSM
2001  554 million subscribers in over 171 countries (end of June)

Source: GSM Association Website, July 2001
## GSM Bands Around the World

<table>
<thead>
<tr>
<th>Band</th>
<th>Frequency Bands</th>
<th>Duplex Spacing</th>
<th>Carriers</th>
</tr>
</thead>
<tbody>
<tr>
<td>450</td>
<td>2 x 25 MHz</td>
<td>45 MHz</td>
<td>125</td>
</tr>
<tr>
<td>900</td>
<td>2 x 25 MHz</td>
<td>45 MHz</td>
<td>125</td>
</tr>
<tr>
<td>1250</td>
<td>2 x 75 MHz</td>
<td>95 MHz</td>
<td>375</td>
</tr>
<tr>
<td>1800</td>
<td>2 x 30 MHz</td>
<td>80 MHz</td>
<td>300</td>
</tr>
</tbody>
</table>

Note: GSM in the 1800 band is often called Digital Cellular System (DCS), and GSM in the 1900 band used to be called PCS 1900. GSM is now more simply referred to by the term "GSM" and the band. i.e.: GSM 450, GSM 900, GSM 1800, and GSM 1900

## Duplex and Access Configuration

For GSM 1900:

- **FDMA**
  - 512, 513, 514, 515, ... 808, 809, 810 MHz
- **TDMA**
  - 0, 1, 2, 3, 4, 5, 6, 7

**Frame Train on Frequency Track**

**Burst** - Transmission quantum in GSM
5 Burst Structures in GSM

**Burst - The Transmission Quantum:**

<table>
<thead>
<tr>
<th>Burst Type</th>
<th>Structure</th>
<th>GP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal Burst</td>
<td>3 57 1 26 1 57 3</td>
<td>8.25</td>
</tr>
<tr>
<td>Random Access Burst</td>
<td>8 41 36 3</td>
<td>68.25</td>
</tr>
<tr>
<td>Frequency Correction Burst</td>
<td>3 142</td>
<td>8.25</td>
</tr>
<tr>
<td>Synchronization Burst</td>
<td>3 39 64 39 3</td>
<td>8.25</td>
</tr>
<tr>
<td>Dummy Burst</td>
<td>3 58 26 58 3</td>
<td>8.25</td>
</tr>
</tbody>
</table>

T. Seq. = Training Sequence
T = Tail Bits
GP = Guard Period

“Physical Channel” - The time slot on a certain frequency.

Logical Channel Structure

Speech or Circuit - Switched Data:
- TCH/F
- TCH/H
- BCCH
- SCH
- BCH
- SACCH
- FACCH
- SDCCH
- AGCH
- RACH
- PCH
- PCH

Mobile transmits
Base station transmits
Both transmit

Logical Channel - The packaged freight on the physical channel

See GSM textbook for acronym definitions.
Logical Channel Mapping

- Dedicated Control Channels
- Traffic Channel
- Synchronization Channel
- Frequency Correction Channel
- Normal Burst
- SCH Burst
- FCCH Burst

Sample Call Setup

- **PCH** (Paging of the mobile station)
- **RACH** (Channel request)
- **AGCH** (Channel assignment)
- **SDCCH** (Reply to the paging from network)
- **SDCCH** (Authentication request)
- **SDCCH** (Authentication response)
- **SDCCH** (Request to transmit)
- **SDCCH** (Acknowledgment of request)
- **SDCCH** (Setup message for incoming call)
- **SDCCH** (Confirmation)
- **SDCCH** (Assignment of a traffic channel)
- **FACCH** (Acknowledgment of traffic channel)
- **FACCH** (Alerting)
- **FACCH** (Connect when mobile 'answers')
- **FACCH** (Acceptance of connect message)
- **TCH** (Exchange of user data - Call in Progress)
Layer 3 Message Example

Mobile Originating Call
Assignment Command on the downlink contains the most critical setup information.

Layer 3 Messages
- UL: CHANNEL REQUEST
- UL: IMMEDIATE ASSIGNMENT
- UL: CM SERVICE REQUEST
- UL: CIPHERING MODE COMMAND
- UL: CIPHERING MODE COMPLETE
- UL: SETUP
- DL: CALL PROCEEDING
- DL: ASSIGNMENT COMMAND
- UL: ASSIGNMENT COMPLETE
- DL: PROGRESS
- DL: CONNECT
- UL: CONNECT ACKNOWLEDGE
- UL: DISCONNECT
- DL: RELEASE
- UL: RELEASE COMPLETE
- DL: CHANNEL RELEASE

GSM Speech Coding
- Original vocoder (below) used RPE-LTP, producing blocks of 260 bits at 13 kb/s
- Most common vocoder today is the Enhanced Full Rate (EFR) vocoder, producing 244 bits at 12.2 kb/s
- Future Adaptive Multi-Rate Vocoder will support variable rates, 12.2 kb/s to 4.75 kb/s

GSM Speech Coding Diagram:
- Voice (300-3,400Hz)
- BandPass Filter
- A/D (8kHz, 13-bit)
- 104kbps
- RPE-LTP Speech Encoder (13kbps)
- Channel Coding
- VAD

Note:
- Decoder includes interpolation, a lowpass filter, 13-8 bit converter, and does not include VAD.
- RPE - Regular Pulse Excitation
- LTP - Long Term Prediction
- VAD - Voice Activity Detection
Channel Coding Process

- GSM (like most standards) uses a combination of Block and Convolutional Coding
- Note the 456 bits output = 4 x 114 = data in 4 bursts
  - The EFR vocoder delivers 244 bits, thereby freeing 16 bits for additional channel coding (channel coder output is still 456 bits)

Modulation

- GMSK = Gaussian Minimum-Shift Keying
  - BT = 0.3 (defined by specs.)
    - (BW\_Filter)(Bit Period)
  - Rate = 270,833 bps
    - Bit Period = 3.69\( \mu \)s
    - BW\_Filter = 81.3kHz

MSK Truth Table

<table>
<thead>
<tr>
<th>Digital Input</th>
<th>MSK Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Odd Even</td>
<td>H/L Sense</td>
</tr>
<tr>
<td>1 1</td>
<td>High +</td>
</tr>
<tr>
<td>-1 1</td>
<td>Low -</td>
</tr>
<tr>
<td>1 -1</td>
<td>Low +</td>
</tr>
<tr>
<td>-1 -1</td>
<td>High -</td>
</tr>
</tbody>
</table>
Crunching the Numbers

1  - 120ms
- 26 Frames - 4.615.. ms per frame
- 8 Timeslots - 0.577.. ms per slot
- 156.25 Bits - 3.692..

\[
\frac{1}{3.692} = 270.833.. \text{ kb/s}
\]

Bandwidth Efficiency = 1.35

Modulating signals are coherently orthogonal if:

\[
\int_0^{T_{\text{bit}}} (\sin \omega_{\text{LOW}} t) (\sin \omega_{\text{HIGH}} t) = 0
\]

Modulation Index = 0.5 allows this.

\[
\text{Mod. Index} = 0.5 = \frac{\Delta f}{R_b} = 135.4\text{kHz}
\]

\[
R_b = 270.8\text{kbps}
\]

Many Radio Network Features in GSM

- Hierarchical Cell Structures
- Dynamic Overlaid/Underlaid
- Combined Control Channels
- Adaptive Configuration of SDCCH
- Frequency Allocation Support
- Efficient Priority Handling
- Immediate Assignment on TCH
- Discontinuous Transmission
- Differential Channel Allocation
- Directed Retry
- Idle Channel Measurements
- Frequency Hopping
- Power Control
- Dynamic HR Allocation
- Software Power Boost
- Double BA Lists
- Handover on SDCCH
- Intracell Handover
- Handover Power Boost
- Neighbor Cell Support
- Cell Load Sharing
- Channel Administration

- Some of the key features are on the following slides
Frequency Hopping

- Important feature for interference averaging in high capacity networks and frequency diversity
- Random and cyclic sequences supported

Power Control

- Regulates the transmit power, in steps of 2 dB to give a fixed (optimal) receive power at the receiver
- Implemented in both the BTS and MS
- Considers both signal strength and quality
- Reduces risk of receiver saturation
- Conserves battery power
- Reduces Interference
**Discontinuous Transmission (DTX)**

- Stops transmitting during periods of silence (approximately 50% of the time)
  - Voice Activity Detector (VAD) determines if voice is present
  - VAD uses complex adaptive algorithm
- Implemented in both the BTS and MS
- Silence Descriptor (SID) frames are sent periodically to generate “Comfort Noise” in the receiver
- Reduces intermodulation at the BTS
- Conserves battery power
- Reduces interference

**Hierarchical Cell Structures (HCS)**

- HCS allows traffic to be directed to a preferred cell
- Each cell is defined in a particular layer
- The lower the layer, the higher the priority
  - Mobiles will select a cell on the lowest layer as long as it has “sufficient” signal strength, even if higher layer cells are stronger
Overlaid/Underlaid Cells

- Increases traffic capacity without adding new sites
- Overlaid cells are smaller, with lower power
- Load is balanced by handing over between overlaid and underlaid cells
- Tighter frequency reuse in overlaid cells can be supported

Cell Load Sharing

- Distributes traffic load between neighboring cells during heavy load
- Handover hysteresis borders are shifted
- Network can be dimensioned for a higher load
Intracell Handover

- Handover within a cell, either on the same frequency (different timeslot) or a different frequency
- Solves temporary co-channel and adjacent channel interference problems, in addition to avoiding intermodulation

Networking Points About GSM

- Global roaming supported by GSM
  - Including roaming between all frequency bands
  - Most operators support roaming with more than 50 countries
- Mobile Application Part (MAP) is the primary networking protocol in GSM, based on SS7 protocol
  - Used to transfer all service information from HLR to VLRs
- IN services commonly used
  - Soon to be provisioned across networks with “Customized Applications for Mobile network Enhanced Logic (CAMEL)”
- GAIT standard to be introduced soon
  - See TDMA lecture
Wireless Data Over GSM

- Rates of 9.6 kb/s and 14.4 kb/s have been available for a long time
- Short Message Service (SMS) very popular, particularly in Europe
- High Speed Circuit Switched Data (HSCSD) available from some vendors/operators
  - 38.4kb/s and 57.6 kb/s by combining 4 timeslots
  - Timeslots can be dynamically assigned asymmetrically
- General Packet Radio Service (GPRS) launching now
  - Packet data using up to 8 timeslots to provide 115.2 kb/s
  - Suitable for bursty data such as web browsing

Reading Assignment

- GSM Switching, Services, and Protocols
  - Chapter 5 Air Interface - Physical Layer (P. 57-93)
  - Section 6.3 Security-Related Network Functions and Encryption (P. 118-124)
  - Sections 8.4.1-8.4.3 Handover Info. (P. 194-204)
  - Section 12.3.1 Improved Codecs for Speech Services (P. 273-276)