Lecture 22: Cellular Standards

GSM Standard (You are responsible only for UNDERLINED items)

GSM (Initially was Group Special Mobile, then changed to Global System for Mobile Communications)

- GSM is the first second-generation standard to use digital modulation and was developed in Europe to unify the many first generation standards that existed in different regions of Europe.
- GSM is the most popular 2G system and most widely used cellular system. Almost all countries use GSM to provide full cellular service or at least partially to some of its customers (According to Wikipedia.com: More than 80% or 3 bullion users use GSM)
- GSM was designed to provide a wide range of network services through the use of Integrated Services Digital Network (ISDN) standard.
- GSM standards were set by the European Technical Standards Institute (ETSI) in the second half of the 1980's decade
- GSM started in 1991. By 1993, several countries in South America, Asia, and Australia adopted the GSM standard and the equivalent DCS 1800 which works in the 1.8 – 2.0 GHz.

GSM Features

- GSM supports voice and data services.
- It supports emergency calling, fax transmissions, and videotext
- Supports packet switched protocols with rates from 300 – 9600 bps
- Supports ISDN services such as call diversion, conference calling, caller ID, SMS, Cell broadcasts (transmission of short messages to all mobile phone around a tower)
- Release '97 of the GSM standard added packet data capabilities, by means of General Packet Radio Service (GPRS). (wikipedia.com)
- Release '99 of the GSM standard introduced higher speed data transmission using Enhanced Data Rates for GSM Evolution (EDGE). (wikipedia.com)
- One of the most important features is the Subscriber Identity Module (SIM) card:
    - Stores subscriber ID number
    - Stores subscriber Phone number
    - Stores network ID and Country of network
    - Stores privacy keys
    - Stores other user specific information (phone directory, …)
    - Can be accessed using a pin code so it can be moved to any phone.
- System provides high privacy for the radio transmission through the use of encryption techniques based on an encryption key that is known only to the service provider. The key changes regularly with time.

GSM System Architecture

- There are three subsystems in the GSM network

- BSS (Base Station Subsystem or Radio Subsystem):
  - Most consider Mobile Stations (MS) as part of this subsystem
  - Provides and manages radio communication with mobiles and links the mobiles to the Mobile Switching Center (MSC)
  - Several BSS units connect to a single MSC.
  - Each BSS consists of many Base Station Controllers (BSC) which communicate with MS and connect them to the MSC.
    - Each BSC controls hundreds of Base Transceiver Stations (BTS).
    - Some BTS may be physically located at the same place as the BSC.
    - BTS located far away may be linked to the BSC by microwave links or dedicated leased lines
    - Handoffs between two BTS controlled by different BSC units are handled by the MSC
    - Handoffs between two BTS controlled by a single BSC are handled by the BSC (to reduce load on MSC)
    - Interface which connects a BTS to a BSC is called the Abis interface (standardized interface for all manufactures). In practice, the Abis interface is different for different manufacturers forcing service providers to use the same manufacturer for the BTS and BSC equipment.
  - Interface between BSC and MSC is called the A interface (standardized interface for all manufacturers). Truly standardized allowing service providers to get base stations switching equipment from different manufacturers.
- NSS (Network and Switching Subsystem: Manages switching functions of the system and connects MSC to other external networks such as PSTN and ISDN
  - NSS also manages and provides external access to several customer databases.
  - MSC is central unit of the NSS
  - Each user is assigned a unique International Mobile Subscriber Identity (IMSI)
  - There are three important databases kept by the NSS:
    - HLR (Home Locator Register): this is a database that contains subscriber information and location information for each user who resides in the same region as the MSC using IMSI.
    - VLR (Visitor Locator Register): this database temporarily stores the IMSI and customer information for each roaming subscriber who is visiting the coverage area of a particular MSC
      - VLR is shared by several MSC in a particular market or geographical region and contains subscription information for every visiting user in the area.
      - Once a roaming mobile is logged in the VLR, the MSC sends necessary information to the visiting subscriber's HLR so that calls to the roaming mobile can be appropriately routed over the PSTN by the roaming user's HLR.

- AUC (Authentication Center): This is a strongly guarded database which handles the authentication and encryption keys for every single subscriber in the HLR and VLR.
    - AUC contains a register called Equipment Identity Register (EIR) which identifies stolen or fraudulently altered phones that transmit identity data that does not match with information contained in either the HLR or VLR.

- OSS (Operation Support Subsystem): Supports one or more Operation Maintenance Centers (OMC) of GSM to allow billing, monitoring, diagnoses, and troubleshooting all aspects of the GSM system including MS, BS, BSC, and MSC (For use by staff of GSM provider and is not accessible to users). The OSS has three main functions (one OMC is dedicated to each of these functions in each GSM system):
    - Maintain all telecommunication hardware and network operations in addition to adjusting all base station parameters
    - Manage and adjust all charging and billing procedures
    - Manage all mobile equipment in the system and determine their performance and integrity

GSM Radio Subsystem

- GSM originally was allocated two 25 MHz bands for forward and reverse channels using Frequency Division Duplexing (FDD)
    - 935 – 960 MHz band for forward link channels
    - 890 – 915 MHz band for reverse link channels (separation of forward and reverse bands is 45 MHz)
    - GSM uses TDMA over FDM (each group of users is assigned two channels for the forward and reverse links (FDM) but they are assigned different time slots for transmission (TDMA)).
    - Each channel has a bandwidth of 200 kHz (a total of 125 forward channels and 125 reverse channels).
    - Each channel is shared by 8 users giving a total number of users per cell of 125 * 8 = 1000 users.
    - Each pair of channels in the forward and reverse links that are separated by 45 MHz are assigned an Absolute Radio Frequency Channel Number (ARFCN)
    - Each channel is shared in time by 8 users who all use the same ARFCN but each has his own Time Slots (TS) per frame for transmission/reception.
    - Data is transmitted over the forward and reverse channels at a bit rate of 270.833 kbps using Gaussian Minimum Shift Keying (GMSK) modulation (each bit duration is 3.692 µs)
    - Each user effectively transmits a bit rate of 270.833 kbps/8 users = 33.854 kbps.
    - Nearly one quarter of transmission is overhead data. Actual user data (voice or data bits) is transmitted at a rate of 24.7 kbps
    - Each Time Slot (TS) has the duration of 156.25 bits (576.92 µs)
    - Each frame (with 8 time slots) spans 4.615 ms

- In practice, 100 kHz of guard band is left at the two edges of the transmission band making the total number of channels be 124 channels.
- The combination of a time slot (TS0 – TS7) and an ARFCN form a physical channel. A physical channel can be mapped to different logical channels in different time slots for transmitting different types of information [traffic data (voice, data, fax, …), signaling data (required for the operation of the GSM system, or control data (requests by base stations/mobile phones to initiate/terminate calls, …)]

GSM Channel Types

There are two types of GSM Logical Channels

- Traffic Channels (TCH): carry digitally encoded user speech or user data. TCHs have identical formats for the forward and reverse links. There are 6 types of TCH channels in GSM.
- Control Channels (CCH): carry signaling and synchronization commands between the base station and the mobile station. Specific types of control channels are defined only for the forward link or only the reverse link. There is a large number of CCH types in GSM
  - The first time slot (TS0) is reserved in some ARFCN channels for control information broadcasts by different cells. Over such channels, control channel bursts are transmitted in almost every frame

GSM Control Channel Types

There are 3 main types of control channels in GSM

- Broadcast Channel (BCH): operates on only the forward link of a specific ARFCN in each cell over the first time slot TS0 of certain GSM frames. This logical channel represents a beacon to allow mobile phones in the vicinity of the tower to monitor and lock on to it. This is monitored by mobile phone in the same cell and mobile phones in nearby cells to assist in the MAHO decisions. There are three BCH channel which are given access over different TS0 slots over a sequence of 51 frames.
  - Broadcast Control Channel (BCCH): Used to broadcast information such as cell and network identity, operating characteristics of the cell (channel availability and congestion). This control channel is transmitted in frames 2 – 5 (total of 4 frames) of a 51 frame sequence.
  - Frequency Correction Channel (FCCH): Allows each mobile phone to synchronize its local oscillator frequency to the exact frequency of the base station. This is transmitted on the TS0 over frames 0 and is repeated every 10 frames.
  - Synchronization Channel (SCH): Since mobile phones may be far away from a base station, they use this channel to frame synchronize with the base station. This is transmitted over the TS0 following the FCCH.

- Common Control Channels (CCCH):

- Dedicated Control Channels (DCCH):

Error protection for speech signals

Speech data is divided into 260 bits for each 20 ms of speech (resulting in an effective bit rate of 13 kbps)

Voice activity detector (people speak less than 40% of the time)

A comfort noise subsystem introduces acoustic background noise during silence