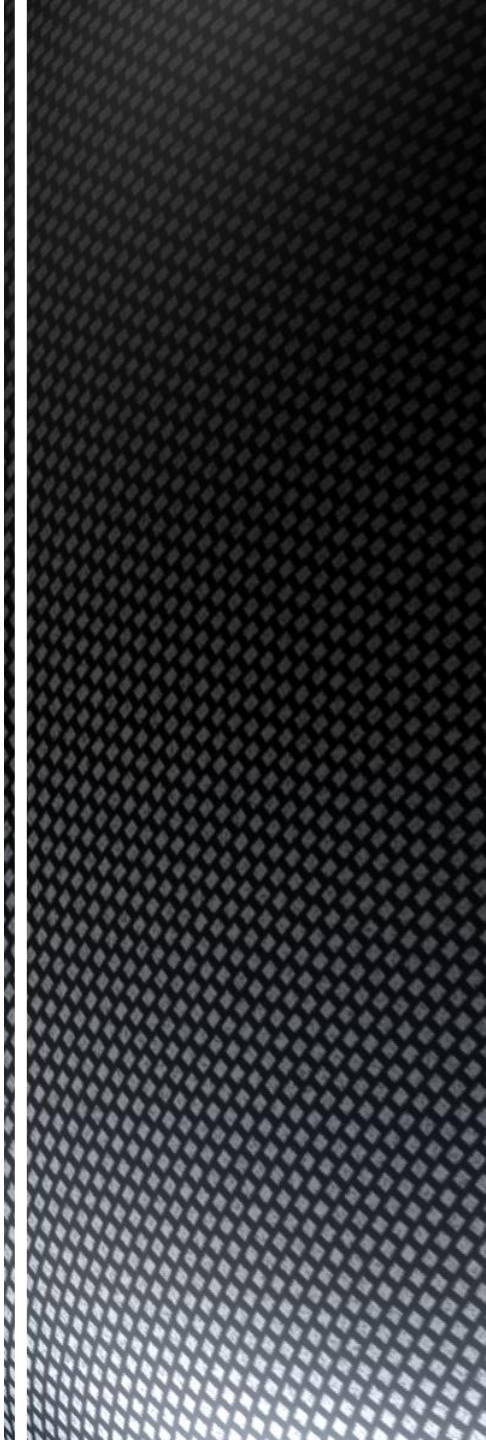
Assignment 4:
Wireless Communication Standards

Topic: GSM (2G Cellular Phone)

Masaru Ho

ELEX 7860



GSM General Information:

GSM (Global System for Mobile Communications, formerly known as Groupe Spécial Mobile)

- Purpose
  - GSM was developed to replace the first generation analog cellular networks
  - In the 1980s the cellular service industry was becoming more international and there was great need develop a standardized cellular communication specification.

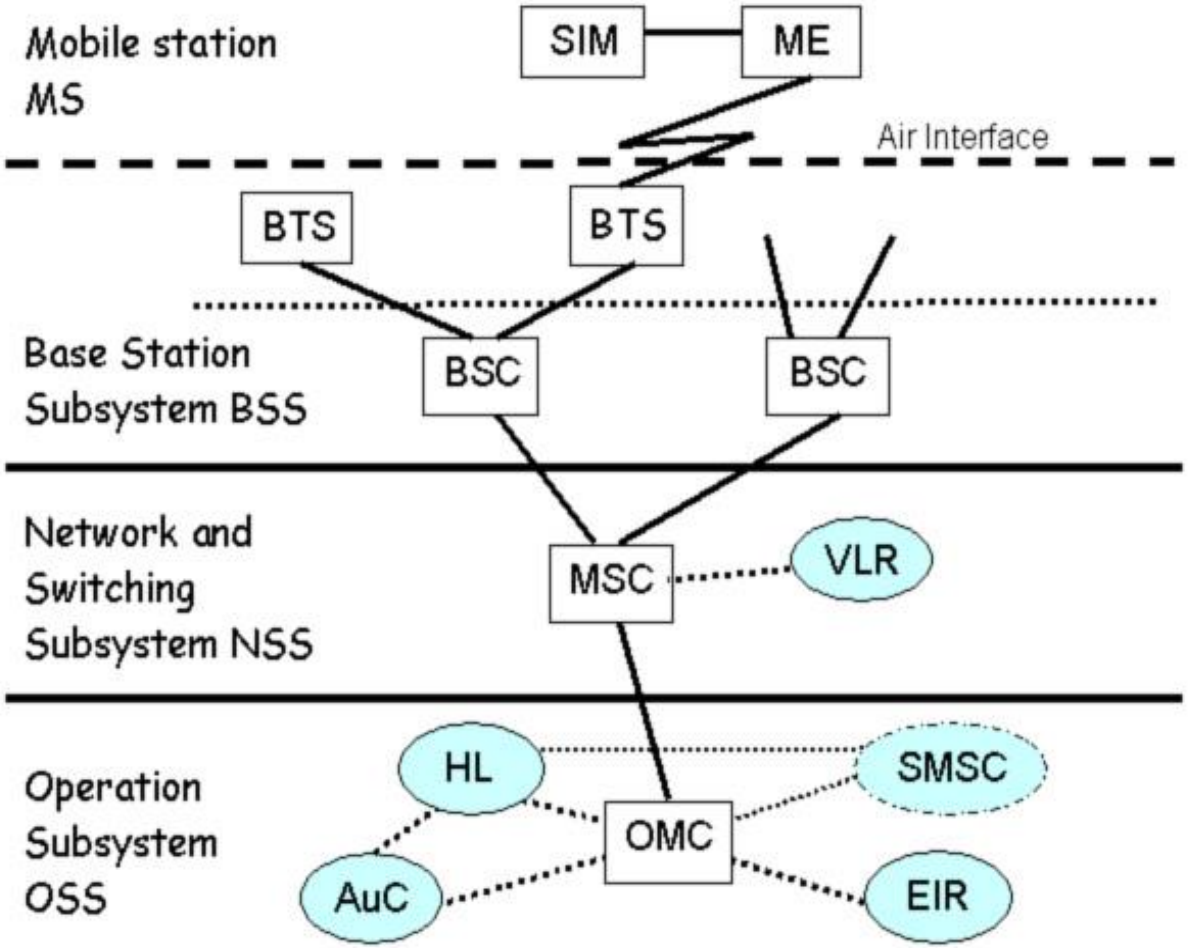
- Typical Devices
  - Most cell phones, (ie. Iphone)

GSM System Architecture:

- Main Architecture layers
  - The Mobile Station(MS)
    - Consists of the physical equipment, ie phone, SIM cards
  - The Base Station Subsystem (BSS)
    - Consists of the Base Transceiver Station (BTS) and Base Station Controller (BSC)
  - The Network Switching Subsystem (NSS)
    - Handles various functions from authentication to managing switching calls between mobiles
  - The Operation Support Subsystem(OSS)
    - Entity where network operator monitors and controls the system

- Architecture Components
  - **ME** = Mobile Equipment
  - **BTS** = Base Receiving Station
  - **BSC** = Base Station Controller
  - **MSC** = Mobile Switching Center
  - **VLR** = Visitor Location Register
  - **OMC** = Operation and Maintenance Center
  - **AuC** = Authentication Center
  - **HLR** = Home Location Register
  - **EIR** = Equipment Identity Register
  - **SMSC** = Short Message Service Centre

GSM System Architecture:



GSM Standardization:

- 1982 – Development started in Europe for a digital cellular voice telephony standard by the European Conference of Postal and Telecommunications Administrations (CEPT)
- 1989 – responsibility for specification development passed to the newly created European Telecommunications Standards Institute (ETSI)
- 1991 – Commercial Launch of GSM service

GSM Market:

- Roughly 6 billion subscribers (2012)
- Equipment sales: total mobile sales 1.75 billion handsets in 2012
  - $1.75\ billion * \$500 = \$875\ billion$
- Service revenue
  - $6\ billion * \$40 = \$240\ billion$

GSM Frequency Bands and Channelization:

- Frequency Bands
  - GSM900
    - Uplink: 890-915 MHz (mobile station to base station)
    - Downlink: 935-960 MHz (base station to mobile station)
  - GSM1800
    - Uplink: 1710-1785 MHz
    - Downlink: 1805-1880 MHz
  - GSM1900
    - Uplink: 1850-1910 MHz
    - Downlink: 1930-1990 MHz
- Channelization
  - Channel spacing of 200 kHz

GSM

Data Rates, Modulation, Coding, Multiple Access Techniques and Speech Coding:

Data Rates

- Over the air bit rate of 270 kbps

Modulation

- Gaussian Minimum Shift Keying (GMSK)

Coding

- Digital Encoding

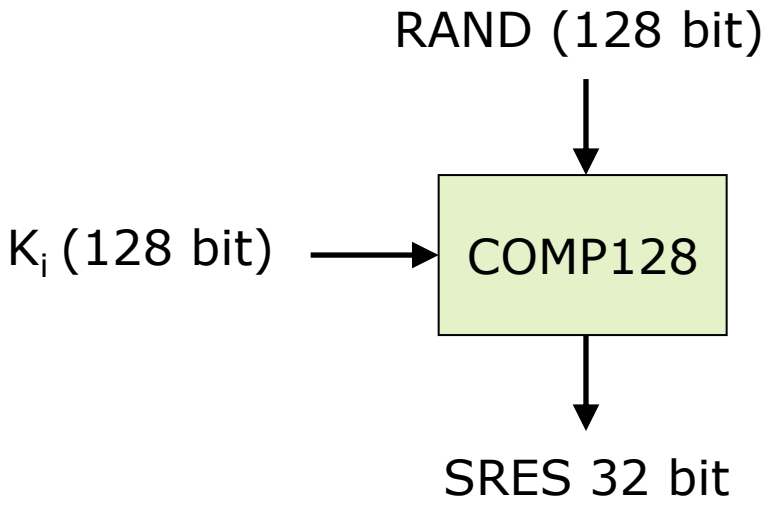
Multiple Access Techniques:

- TDMA and FDMA combination
  - 25 MHz bandwidth divided into 124 carrier frequencies of 200 kHz bandwidth. One or more carriers are then assigned to each Base station. These carriers are then divided by time using TDMA (8 slots). 1 slot for transmission, 1 slot for reception.

- Multiple Access Techniques:
  - Code-excited linear prediction (CELP)

GSM Security - Authentication:

- Challenge-Response Authentication (CRA) is used for Authentication
  - Subscriber verifies identity by sending information to the MS through a "one-way hash"
  - the information is used conjunction with a 128 Authentication key that is stored on the SIM card
  - MS computes a 32-bit signed response (SRES) and uses it to check authentication with the GSM network



GSM Security - Encryption:

- COMP128 encryption first broken April 1999
  - The Smartcard Developer Association (SDA) together with U.C. Berkeley researches cracked the COMP128 algorithm stored in SIM and succeeded to get K_i within several hours.
- May 2002
  - The IBM Research group discovered a new way to quickly extract the COMP128 keys using side channels

GSM Link Budget Example

EXAMPLE LINK BUDGET SPREADSHEET

(blue indicates user definable parameters)

INITIAL PARAMETERS

System:	GSM900
Frequency:	1800MHz
Channel Bandwidth	200kHz
Coverage Probability - Cell edge:	85%
Cell loading:	80%

LINK BUDGET (Uplink)

Label		Urban Microcell	Urban Macrocell	Suburban	Rural
a	Tx Power (dBm)	21.00	21.00	21.00	21.00
b	Tx Antenna Gain (dBi)	0.00	0.00	0.00	0.00
c	Cable and combiner losses (dB)	0.00	0.00	0.00	0.00
d = a + b + c	EIRP Tx Power (dBm)	21.00	21.00	21.00	21.00
j	Thermal Noise density (dBm/Hz)	-174.00	-174.00	-174.00	-174.00
q	Bandwidth factor	53.01	53.01	53.01	53.01
k	Noise Figure (dB)	4.00	4.00	4.00	4.00
m	Interference to thermal noise (dB)	6.99	6.99	6.99	6.99
n = j + k + m + q	Interference Noise density N (dBm/Hz)	-110.00	-110.00	-110.00	-110.00
r	Average Eb/No (dB)	2.20	3.80	3.80	3.80
t = n + r	Rx Sensitivity (dBm)	-107.80	-106.20	-106.20	-106.20
e	Rx Antenna Gain (dBi)	10.00	17.00	17.00	17.00
f	Cable/Feeder Loss (dB)	-2.00	-2.00	-2.00	-2.00
g	Diversity Gain (dB)	0.00	0.00	0.00	0.00
u	Fading Margin - cell edge (dB)	-1.04	-1.04	-1.04	-1.04
v	Soft Handover Gain (dB)	2.00	5.00	5.00	5.00
w	Building/Car Penetration Loss (dB)	-15.00	-15.00	-12.00	-6.00
x = d+t+e+f+g+u+v+w	Max Path Loss (dB)	122.76	131.16	134.16	140.16
y = Prop(x)	COST 231 Cell Radius (km)	0.39	1.45	6.39	9.41

SHADOW FADING MARGIN (calculation)

		Urban Microcell	Urban Macrocell	Suburban	Rural
	Decay Law (n)	3.57	3.57	3.57	3.57
	Std dev of Fading Margin (dB)	1.00	1.00	1.00	1.00
	Std Dev / n	0.28	0.28	0.28	0.28
	Coverage Probability - cell edge	85.00%			
u	Fading Margin - cell edge (dB)	1.04	1.04	1.04	1.04
	Coverage Probability - whole cell	1.00	1.00	1.00	1.00
	Fade Margin - whole cell (dB)	14.46dB	14.46	14.46	14.46

CELL RADIUS FROM COST 231 FORMULA (calculation)

UE Height:	1.5m
Antenna Correction factor	0.04dB
Urban Correction	0.00dB
Suburban correction	11.94dB
Open Country Correction	31.92dB

	Urban Microcell	Urban Macrocell	Suburban	Rural
BS Height (m)	25.00	25.00	25.00	25.00
Path Loss (dB)	122.76	131.16	134.16	140.16
Distance (km)	0.39	1.45	6.39	9.41

Reference: http://cgi.di.uoa.gr/~pms526/RH_Mobile/GSM/GSM_LinkBudget_ORIGINAL.xls