GSM-INTRODUCTION

Principles of Cellular Telecommunications

- A cellular telephone system links mobile station (MS) subscribers into the public telephone system or to another cellular system's MS subscriber
- Information sent between the MS subscriber and the cellular network uses radio communication. This removes the necessity for the fixed wiring used in a traditional telephone installation.
- The MS subscriber is able to move around and become fully mobile,

WHY GSM?

- The rapid development of analogue cellular networks during the 1980s resulted in many different cellular systems which were incompatible with one another.
- The need for a common standard for mobile telecommunications was therefore obvious, and so an executive body was set up to co-ordinate the complicated task of specifying the new standardized network.

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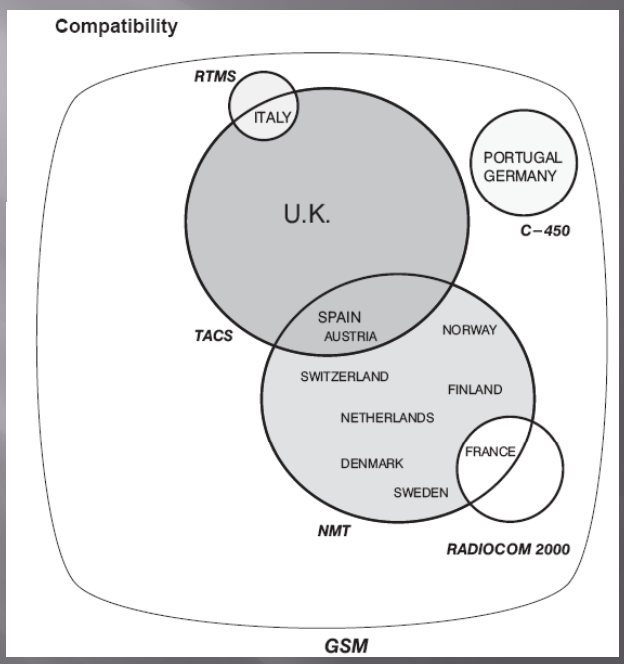
- GSM has been specified and developed by many European countries working in co-operation with each other. The result is a cellular system which has been implemented throughout Europe and many parts of the world.
- An additional advantage resulting from this is that there is a large market for GSM equipment.
- Manufacturers can produce equipment in higher quantities and of better quality, and also, due to the number of manufacturers, a competitive and aggressive pricing structure exists.
- This results in lower costs for the MS subscriber and the network operators.



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- In order to combat the problems caused by noise, GSM uses digital technology instead of analogue.
- By using digital signals, we can manipulate the data and include sophisticated error protection, detection and correction software.
- The overall result is that the signals passed across the GSM air interface withstand more errors
- This leads to better frequency re-use patterns and more capacity.

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- **Sources of Noise**
  - Vehicles ignition system
  - Lightening
  - Co-channel/Adjacent Channel interference
- **GSM Answer**
  - **Digital Interface**
  - **Error Detection/ Error Correction**

GSM Frequency Spectrum

- The frequency spectrum is very congested, with only narrow slots of bandwidth allocated for cellular communications.
- A single Absolute Radio Frequency Channel Number (ARFCN) or RF carrier is actually a pair of frequencies, one used in each direction (transmit and receive)
- For GSM900 and EGSM900 the paired frequencies are separated by 45 MHz
- for DCS1800 the separation is 95 MHz and for PCS1900 separation is 80 MHz

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- For each cell in a GSM network at least one ARFCN must be allocated, and more may be allocated to provide greater capacity
- The RF carrier in GSM can support up to eight Time Division Multiple Access (TDMA) timeslots
- Each RF carrier is capable of supporting up to eight simultaneous telephone calls
- Unlike a PSTN network, where every telephone is linked to the land network by a pair of fixed wires, each MS only connects to the network over the radio interface when required.

GSM 900/GSM 1800

- GSM- 900
  - Receive (Uplink) 890-915MHz
  - Transmit (Downlink) – 935-960 MHz
  - ARFCN = 124
- GSM- 1800 (DCS-1800)
  - Receive (Uplink) 1710-1785 MHz
  - Transmit (Downlink) 1805 - 1880MHz
  - ARFCN = 374

Cont'd

- ARFCN
  - Bandwidth =200KHz
  - 8 TDMA timeslots

GSM Network Components

- GSM networks are made up of
  - Mobile services Switching Centers (MSC),
  - Base Station Systems (BSS)
  - Mobile Stations (MS).
- With the MSC, BSS and MS we can make calls, receive calls, perform billing etc, as any normal PSTN network would be able to do

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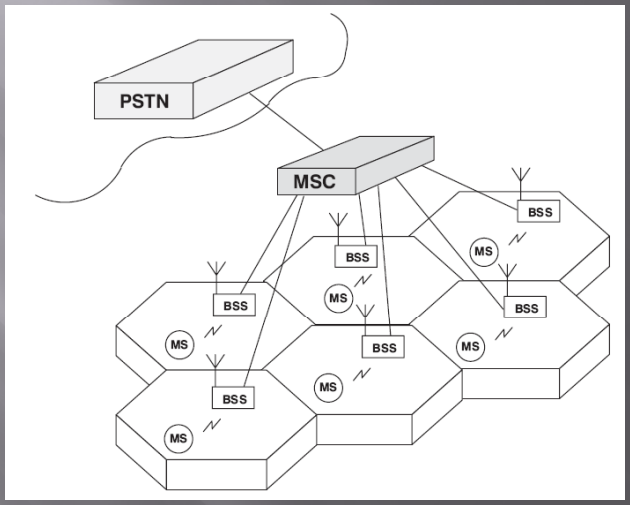
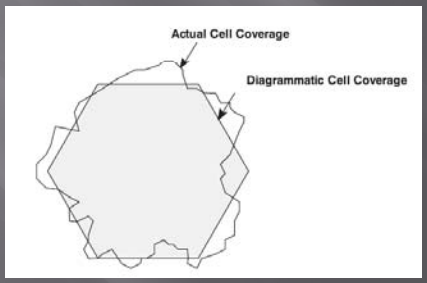


Cell

- Mobile Stations within the cellular network are located in "cells", these cells are provided by the BSSs.
- The cells are normally represented by a hexagon, but in practice they are irregular in shape.



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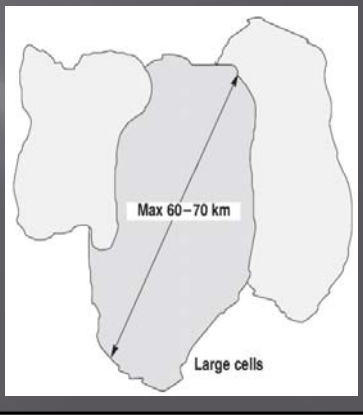
- The number of cells in any geographic area is determined by the number of MS subscribers who will be operating in that area, and the geographic layout of the area(hills, lakes, buildings etc).

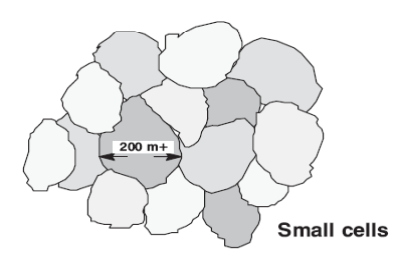
Large Cells

- Large Cells- The maximum cell size for GSM is approximately 70 km in diameter
  - Used in:
    - Remote areas
    - Coastal Areas
    - Areas with few subscribers
    - Large areas needed to be covered with minimum number of cell sites (Motorways… etc)



Small Cells

- Small cells are used where there is a requirement to support a large number of MSs, in a small geographic region or where a low transmission power may be required to reduce the effects of interference.
- Small cells currently cover 200 m and upwards.
  - Used in:
    - Urban Areas
    - Low transmission power required
    - High number of MSs



Frequency Reuse

- Standard GSM has a total of 124 frequencies available for use in a network.
- Network providers are generally allocated a small subset of the 124

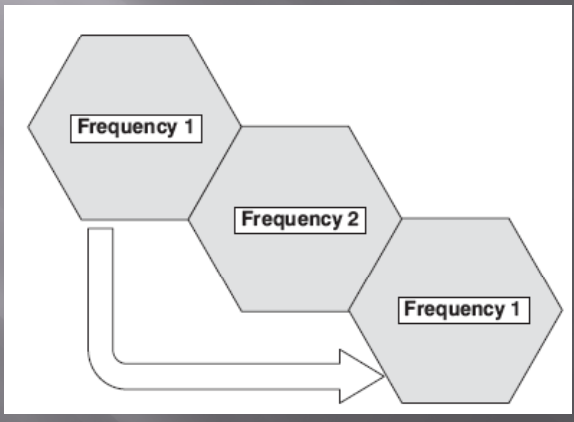
EXAMPLE

- A network provider has been allocated 48 frequencies to provide coverage over a large area, let us take for example Great Britain. As we have already seen, the maximum cell size is approximately 70 km in diameter, thus our 48 frequencies would not be able to cover the whole of Britain.

Frequency Re-use Pattern

- To overcome this limitation the network provider must re-use the same frequencies over and over again, in what is termed a "frequency re-use pattern".
- When planning the frequency re-use pattern the network planner must take into account how often to use the same frequencies and determine how close together the cells are, otherwise co-channel and/or adjacent channel interference may occur

Frequency Re-use



Sectorization

- In Omni-directional cells each site has a single cell and that cell has a single transmit antenna which radiates the radio waves to 360 degrees.
- The problem with employing omni-directional cells is that as the number of MSs increases in the same geographical region, we have to increase the number of cells to meet the demand.
- To do this, we have to decrease the size of the cell and fit more cells into this geographical area.
- Using omni-directional cells we can only go so far before we start introducing co-channel and adjacent channel interference, both of which degrade the cellular network's performance.

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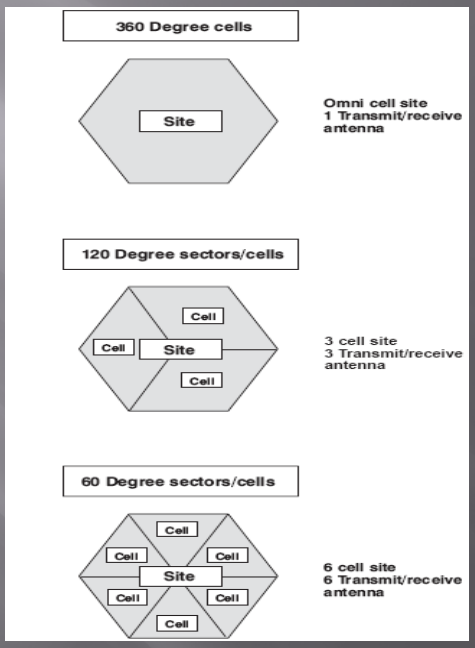
- Sectorization splits a single site into a number of cells, each cell has transmit and receive antennas and behaves as an independent cell.
- Each cell uses special directional antennas to ensure that the radio propagation from one cell is concentrated in a particular direction.

ADVANTAGES OF SECTORIZATION

- We are now concentrating all the energy from the cell in a smaller area 60, 120, 180 degrees instead of 360 degrees, we get a much stronger signal, which is beneficial in locations such as "in-building coverage".
- We can now use the same frequencies in a much closer re-use pattern, thus allowing more cells in our geographic region which allows us to support more MSs.

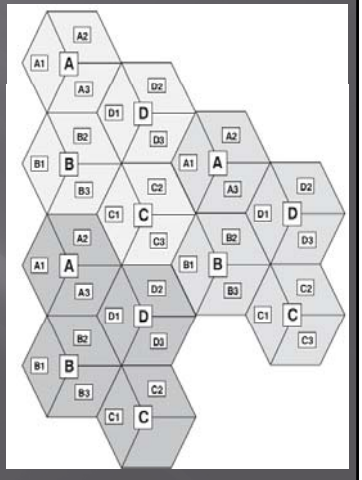


Example: 4 Site-3 Cell

A typical re-use pattern used in GSM planning is the 4 site/3 cell.

For example, the network provider has 36 frequencies available, and wishes to use the 4 site/3 cell re-use pattern he may split the frequencies up as follows:

Cell A1	Cell A2	Cell A3	Cell B1	Cell B2	Cell B3	Cell C1	Cell C2	Cell C3	Cell D1	Cell D2	Cell D3
1	2	3	4	5	6	7	8	9	10	11	12
13	14	15	16	17	18	19	20	21	22	23	24
25	26	27	28	29	30	31	32	33	34	35	36

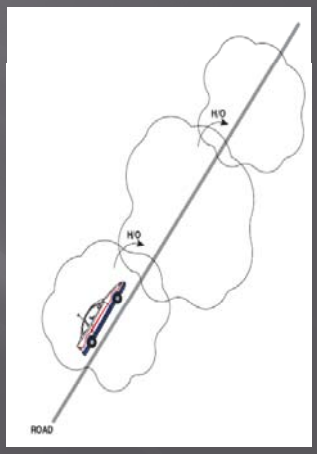


Handover Processes

- The transfer of a cellular phone transmission from one radio frequency within a cell to another radio frequency in an adjacent cell
- Handovers take place as the MS moves between cells, gradually losing the RF signal of one and gaining that of the other.
- The MS switches from channel to channel and cell to cell as it moves to maintain call continuity.

Handovers

- GSM provides Handover processes for the following:
  - Quality(Uplink/Downlink)
  - Interference (Uplink/Downlink)
  - RF level (uplink. Downlink)
  - MS distance
  - Power Budget



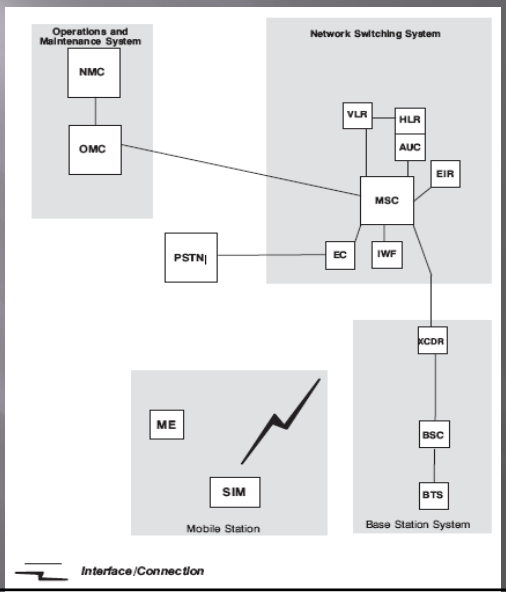
HARD/SOFT HANDOVER

- A **hard handover** is one in which the channel in the source cell is released and only then the channel in the target cell is engaged
- A soft handover is one in which the channel in the source cell is retained and used for a while in parallel with the channel in the target cell. In this case the connection to the target is established before the connection to the source is broken

Supplementary Services

- A supplementary service is a modification of, or a supplement to, a basic telecommunication service.
- The network provider will probably charge extra for these services or use them as an incentive to join their network.
  - Call Blocking
  - Call Forwarding
  - Charging
  - Conference Calling

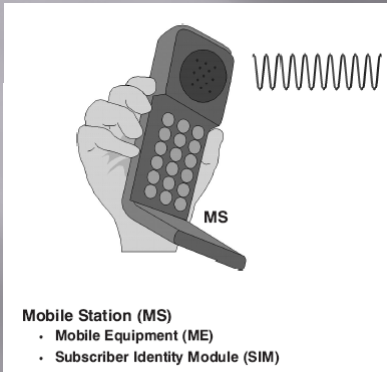
GSM NETWORK COMPONENTS



Mobile Station (MS)

- The MS consists of two parts, the **Mobile Equipment (ME)** and an electronic 'smart card' called a **Subscriber Identity module (SIM)**.
- The ME is the hardware used by the subscriber to access the network.
- The hardware has an identity number associated with it, which is unique for that particular device and permanently stored in it.
- This identity number is called the **International Mobile Equipment Identity (IMEI)**

MS (Mobile Station)



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- The ME is therefore identified by means of a classmark.
- The classmark is sent by the ME in its initial message.
- The following pieces of information are held in the classmark:
  - RF Power Capability (The maximum power the MS is able to transmit, used for power control and handover preparation. This information is held in the mobile power class number)
  - Frequency Capability (Indicates the frequency bands the MS can receive and transmit on).
  - Short Message Capability (Indicates whether the MS is able to receive short messages)

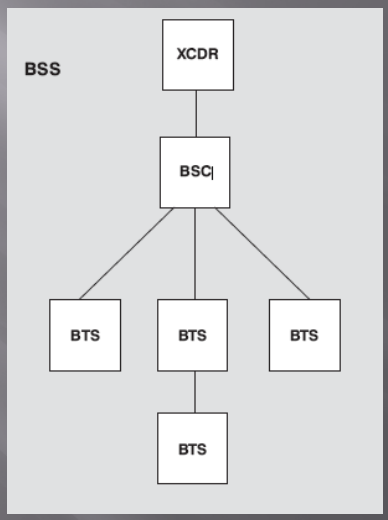
SIM (Subscriber Identity Module)

- The SIM contains several pieces of information:
  - **International Mobile Subscriber Identity (IMSI)**
  - **Temporary Mobile Subscriber Identity (TMSI)**
  - **Location Area Identity (LAI)**
  - **Subscriber Authentication Key (Ki)**
  - **Mobile Station International Services Digital Network (MSISDN)-** This is the telephone number of the mobile subscriber.
    - It is comprised of a country code, a network code and a subscriber number.

Base Station System (BSS)

- The GSM Base Station System is the equipment located at a cell site. It comprises a combination of digital and RF equipment.
- The BSS provides the link between the MS and the MSC.
- The BSS consists of three major hardware components:
  - **The Base Transceiver Station – BTS**
  - The BTS contains the RF components that provide the air interface for a particular cell. This is the part of the GSM network which communicates with the MS.
  - The antenna is included as part of the BTS.

- **The Base Station Controller – BSC**
  - The BSC as its name implies provides the control for the BSS. The BSC communicates directly with the MSC. The BSC may control single or multiple BTSs.
- **The Transcoder – XCDR**
  - The Transcoder **is used to compact the signals from the MS so that they are** more efficiently sent over the terrestrial interfaces.
  - Although the transcoder is considered to be a part of the BSS, it is very often located closer to the MSC



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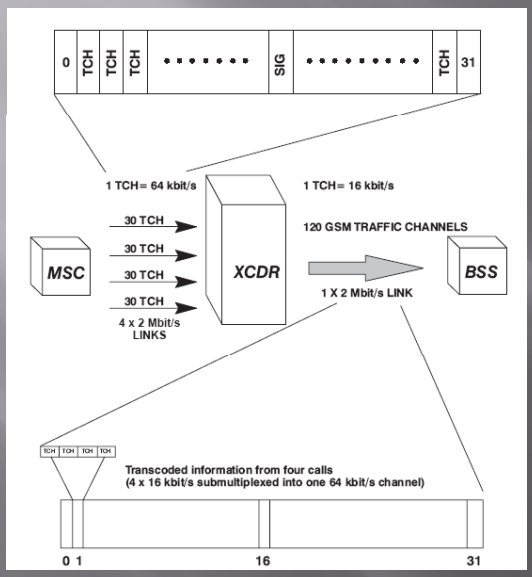


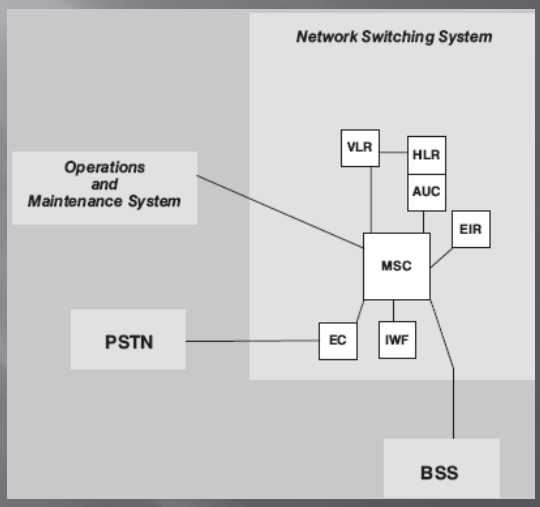
NSS (The Network Switching System)

- The Network Switching System includes the main switching functions of the GSM network.
- It also contains the databases required for subscriber data and mobility management.
- Its main function is to manage communications between the GSM network and other telecommunications networks.

NSS

- The components of the Network Switching System are listed below:
  - Mobile Services Switching Centre – MSC
  - Home Location Register – HLR
  - Visitor Location Register – VLR
  - Equipment Identity Register – EIR
  - Authentication Centre – AUC
  - InterWorking Function – IWF
  - Echo Canceller – EC

NSS (Cont'd)



Mobile Services Switching Centre (MSC)

- The MSC is included in the GSM system for call-switching. Its overall purpose is the same as that of any telephone exchange.
- One MSC is capable of supporting a regional capital with approximately one million inhabitants
- The functions carried out by the MSC are listed below:
  - **Call Processing-** Includes control of data/voice call setup, inter-BSS and inter-MSC handovers

MSC (Cont'd)

- **Operations and Maintenance Support -** traffic metering and measurement
- **Internetwork Interworking -** Manages the interface between the GSM network and the PSTN.
- **Billing-** Collects call billing data.

HLR (Home Location Register)

- The HLR is the reference database for subscriber parameters.
- This information is entered into the database by the network provider when a new subscriber is added to the system.
- The HLR database contains the master database of all the subscribers
- The data it contains is remotely accessed by all the MSCs and the VLRs in the network

HLR- Information

- Subscriber Number (IMSI and MSISDN)
- Current subscriber VLR (Current Location)
- Supplementary services subscribed to
- Authentication Key
- Subscriber Status

VLR (Visitor Location Register)

- The VLR contains a copy of most of the data stored at the HLR
- It contains temporary data which exists for only as long as the subscriber is "active" in the particular area covered by the VLR.
- The additional data stored in the VLR is listed below:
  - Mobile status (busy/free/no answer etc.).
  - Location Area Identity (LAI).
  - Temporary Mobile Subscriber Identity (TMSI).

VLR

- TMSI:
  - The VLR controls the allocation of new Temporary Mobile Subscriber Identity (TMSI) numbers and notifies them to the HLR.
  - The TMSI will be updated frequently, this makes it very difficult for the call to be traced and therefore provides a high degree of security for the subscriber, The TMSI may be updated in any of the following situation
    - Call setup
    - On entry to new LAI
    - On entry to new VLR
- LAI (LOCATION AREA IDENTITY)
  - Each area is assigned a Location Area Identity (LAI), a location area may typically contain 30 cells.
  - Each VLR controls several LAIs and as a subscriber moves from one LAI to another, the LAI is updated in the VLR. As the subscriber moves from one VLR to another, the VLR address is updated at the HLR.

Equipment Identity Register (EIR)

- The EIR contains a centralized database for validating the International Mobile Equipment Identity (IMEI).
- IMEI is a number, usually unique, to identify GSM, WCDMA mobile phones
- The IMEI number is used by the GSM network to identify valid devices and therefore can be used for stopping a stolen phone from accessing the network

Authentication Centre (AUC)

- The AUC is a processor system, it performs the "authentication" function.
- It will normally be co-located with the Home Location Register (HLR)
- The authentication process will usually take place each time the subscriber "initializes" on the system.

Authentication Process

- Triples (Kc, SRES and RAND) are stored at the VLR.
- The VLR sends RAND via the MSC and BSS, to the MS (unencrypted).
- Ms, with the received RAND from the VLR, calculates the values of SRES and Kc.
- The MS sends SRES unencrypted to the VLR
- Within the VLR the value of SRES is compared with the SRES received from the mobile. If the two values match, then the authentication is successful.

Interworking Function (IWF)

- The IWF provides the function to enable the GSM system to interface with the various forms of public and private data networks currently available.
- The basic features of the IWF are listed below.
  - Data Rate Adaption
  - Protocol Conversion
- ECHO CANCELLER (EC)
  - GSM Network is connected to PSTN via EC.

Operations and Maintenance System

- **The Network Management Centre** (NMC**) has a view of the entire PLMN and is** responsible for the management of the network as a whole. The NMC resides at the top of the hierarchy and provides global network management.
- **The Operations and Maintenance Centre** (OMC) is a centralized facility that supports the day to day management of a cellular network as well as providing a database for long term network engineering and planning tools