As you can see in picture 4, until the 1990s analog radio equipment was used in civil as well as military radio equipment. However, during the introduction of analog devices into daily service, scientists in Europe worked to develop a very new technology made possible by the digital revolution.

We will now consider:
- what is the Global System of Mobile Communication?
- what are its components and how does it work?
- what are the basics of communication between the Mobile station and Network?

1. Structure and Components of a Mobile Network

Please consider the picture of components and interfaces in a Public Land Mobile Network.

![Components and Interfaces in a Public Land Mobile Network](image)

1.1 The Mobile Station

I shall begin with a description of the element on the far left, the Mobile Station. You must bear in mind that a mobile station represents the latest developments not only in miniaturized electronics but also in:
- compression of speech to minimize bandwidth
- encoding to avoid eavesdropping of speech or data messages
- coding and decoding to detect and correct failures during transmission over the air interface.

There is an interesting difference between the Mobile Equipment and the Mobile Station. The former is the body, you only have the latter once you have added the Subscriber Identity Module (SIM) to the ME.

Let's have a look at the features of the body and brain.
1.1.1 The Mobile Equipment
The ME is a small transmitter–receiver station equipped with large-scale integrated circuits which allow:
- High-level digital filtering to enable a very short changeover time
- Fast signal processing and highly stable oscillators
- High performance signal processing for encoding and decoding of information
- Battery power supply allowing long standby time and a transmitting power of up to 8 watts
- Colour display with high resolution suited to viewing pictures taken by a 1.3 MB Pixel camera
- The body is characterized by an International Mobile Equipment Identity (IMEI). The IMEI consists of 15 digits (60 bits). There is a 6 digit type approval code TAC, a 2 digit Final Assembly Code FAC, 6 digit serial number SNR and a 4 bit space SP.

1.1.2 Subscriber Identity Module
The SIM consists of the mobile’s data bank and free usable memory. The data bank consists of:

Administrating data
- The Personal Identification Number PIN
- The Pin Unblocking Key PUK
- The SIM-Service Table

Authentication and Ciphering
- The Encoding algorithms (A3, A8), identical to the ones held in the network, and the authentication computation
- Ciphering Key Sequence Number (CKSN) (3 bit) identical to the one held in the network
- The strong secret Kc and Ki

Subscriber specific
- International Mobile Subscriber Identity IMSI, consisting of 15 digits or less with a 3 digit mobile country code MCC, a 2 digit mobile network code MNC and an up to 10 digit mobile subscriber identification number MSIN
- Temporary Mobile Subscriber Identity TMSI, given to the mobile by the network during roaming (to hide the IMSI)

Roaming data
- Local Area Identity LAI
- Preferred PLMNs list
- Forbidden PLMNs list
- List of beacon frequencies (ARFCNs of the home PLMN)
- Storage of location information

Personal data of the user
- Directory number of a mobile radio subscriber MSISDN
- Storage of SMS, Telephone Numbers etc.

The most attractive feature of the separation of ME and SIM is that it makes it possible to put the SIM into another ME. In this way I have upgraded my mobile communication from GSM to GPRS to UMTS, in each case using newer Mobile Equipment but the same SIM-Card.
1.2. The Base Station Subsystem BSS

The Base Station Subsystem is coloured green in picture 5. Its main components are:

1.2.1 The Base Transceiver Station (BTS)
The Base Transceiver Station realises the Air-Interface between mobile and network. It consists of:
- the antennas
- output and input filters, which are band-pass filters. While the input filters are broadband and not tuneable, the output filters are wideband and tuneable
- radio transmitter and radio receiver
- the Transmission/Reception-Module TRX which serves: Channel Coding and Decoding, Ciphering, Slow Frequency Hopping, Burst formatting, Gaussian Minimum Shift Keying (GMSK) of all transmitted and received data, the generation and sending of the BCCH on Channel 0, the realisation of the protocol LAPD on the channel to the BSC
- Operation and Maintenance (O&M) Module.

1.2.2 The Base Station Controller (BSC)
The Base Station Controller is the BSS’s centre of intelligence. It consists of:
- a switching array which connects several BTSs to the MSC
- a data bank in which the quality and availability of the radio resources are stored and the status of the BSS-Hardware is dynamically watched
- a central processing unit (CPU) which makes the handover decisions.

1.2.3 The Transcoding Rate and Adaptation Unit (TRAU)
The Transcoding Rate and Adaptation Unit is responsible for compressed data transmission on the air interface. The compression method used is called Regular Pulse Excitation-Long Term Prediction (RPE-LPT). The bit rate of an ISDN channel with 64 kbit/sec is reduced to the bit rate on the air interface of 16 kbit/sec (if the Full Rate Transport Channel is used).

1.3. The Network Switching Subsystem (NSS)

The Network Switching Subsystem is dark yellow in picture 5. It is the central part of any Mobile Radio System and controls several BSSs. Its components are responsible for all the call processing, controlling and data bank functions which are necessary to examine the authentication, to make set-up the call, to encrypt the data and to control roaming. Its components are:

1.3.1 Mobile Services Switching Centre MSC
The MSC is a standard ISDN-switching system adapted to be used in Mobile Radio Networks. It takes over the exchange of channels inside a PLMN or between several PLMNs and controls handover between several MSC areas.
The MSC also adapts protocols between Call Control (ISDN-typical) and ISDN User Part ISUP as used in SS#7
The MSC receives the information necessary for switching a signal processing from the HLR and the VLR (see paragraphs 1.3.3 and 1.3.4).
1.3.2 Gateway Mobile Services Switching Centre GMSC
Only the GMSC is able to create a connection from a PLMN to another network. e.g. There is a subscriber in the fixed network who wishes to call a subscriber of the mobile radio network. The calling information comes from ISDN using the D-Channel, passes the trunk network using the SS#7 and arrives at the GMSC. The GMSC initiates a search for the called subscriber using his Home Location Register. It then switches to the responsible MSC which links the call to the BSC and a BTS where the subscriber is camping. The call is then sent with a PAGING REQUEST to the wanted subscriber.

1.3.3 Home Location Register HLR
Generally one PLMN consists of several HLRs. The first two digits of the mobile directory number (e.g. 0171 2620757) are the number of the HLR where the mobile subscriber is stored. Among other things, the following data from any subscriber is stored:

- Subscriber specific:
  - IMSI
  - Ki
  - Restriction of services
  - Supplementary Services
  - Directory Number (MS ISDN)

- Authentication and Ciphering:
  - Algorithm A3
  - Algorithm A8
  - RAND, SRES, KC

- Seeking for Subscriber/Call Control
  - Information related to the current location of the subscriber e.g. the actual VLR
  - Number of the MSC

1.3.4 Visitor Location Register VLR
A VLR stores subscription data for those subscribers currently situated in the service area of the corresponding MSC. A subscriber who logs into an allowed PLMN is registered by the responsible VLR after the latter has asked for their user data from the responsible HLR. A VLR function is integrated with every MSC. The following information is stored in the VLR

- Subscriber specific:
  - International Mobile Subscriber Identity IMSI
  - Temporary Mobile Subscriber Identity TMSI

1.3.5 Equipment Identity Register EIR
Every MS possesses an International Mobile Equipment Identity IMEI. It is possible to ask for this ID by typing the string *#06# on the Mobile. The IMEI is stored in the EIR in a so-called ‘white-list’. A ‘black-list’ contains a list of defective or stolen MS and this equipment is therefore blocked.