2

Telecommunication Networks

2. Global System for Mobile Communications

A digital cellular phone technology is based on TDMA. GSM was first deployed in seven European countries 1992.

It operates in the 900 MHz and 1.8 GHz bands in Europe and the 1.9 GHz PCS band in the U.S. Based on a circuit switched system that divides each 200 KHz channel into eight 25 kHz time slots, GSM defines the entire cellular system, not just the TDMA air interface. Its ubiquity makes international roaming very common between mobile phone operators, enabling subscribers to use their phones in many parts of the world GSM also pioneered (initiated) a low cost alternative to voice calls, the SMS, which is now supported on other mobile standards on others mobile standard as well. Another advantage is that the standard includes one worldwide Emergency telephone number, 112.

Newer versions of the standard were backward- compatible with the original GSM phones .Eg. The standard added packet (mail boat) data capabilities, by means of GPRS and Higher speed data transmission using Enhanced data Rate for GSM Evolution (EDGE)

2.1 GSM

Goal: The goal of GSM is to provide a mobile phone system that allows users to roam throughout Europe and provide voice services compatible to ISDN and PSTN.

Generation:

- GSM is in second generation
- Replacing first generation analog systems doesn"t offer the data rates as that of third generation systems.

Version:

(1) GSM 900: Initially deployed in Europe. Frequency offered is

1. Uplink →890 to 915 MHz
2. Dwonlink →935 to 960 MHz

(2) GSM 1800: otherwise called as Digital Cellular System DCS 1800

1. Uplink -> 1710 to 1785 MHz
2. Downlink → 1805 to 1880 MHz

(3) GSM 1900: Otherwise called as personal communication service PLS 1990

1. Uplink -> 1850 to 1910 MHz
2. Downlink → 1930 to 1990 MHz

(4) GSM 400:

1. Uplink -> 450.4 to 478 MHz
2. Downlink → 460 to 496 MHz

(5) GSM Rail:

1. Used in European countries.
2. Used for railroad system.

Features of GSM Rail:

(1) Offers 19 exclusive channels for voice and data traffic.
(2) Special features like emergency calls, voice group call service etc. are available.
(3) Calls are prioritized (Assign a priority).
(4) Used to control the trains, switches, signals, gates.

2.2 Services Offered By GSM

- GSM allows the integration of voice and data services and also the internet working with the existing networks.
- Three types of services are offered by GSM viz.
  (1) Bearer (holder) Services, (2) Tele services (3) Supplementary services

Reference Model for GSM Services:

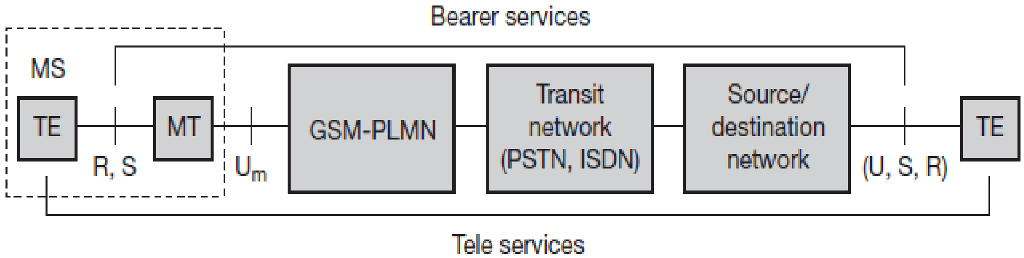

Fig 2.1: Bearer and Tele services reference Model

Explanation:

A mobile station MS is connected to the GSM public land mobile network PLMN via u_m interface.

PLMN is the infrastructure (basic structure) needed for the GSM networks.

- This network is connected to transit network. (eg.) PSTN, ISDN, etc.
- There will be additional network the Source/Destinations network before another TE is connected.

2.2.1 Bearer Services

- Bearer services comprises of all services that enable the transparent transmission of data between the interfaces to the network.
- Bearer services permit transparent (Easily understood) /non transparent, synchronous (Occurring at the same time) and asynchronous data transmission.

Transparent Bearer Services:

- This services uses the function of physical layer to transmit data.
- Data transmission has a constant delay and throughput if no error occurs but not in real time.
- FEC is used increase the transmission quality.
- Does not try to recover the lost data in case of hand over etc.

Non- Transparent Bearer Services:

- Uses the protocol of layers data link and network to transmit data.
- These services uses transparent bearer services radio link protocol (RLP).
- RLP has mechanisms of high level data link control HDLC.
- Allows retransmission of erroneous data by using selective reject mechanisms.

2.2.2 Tele Services

- Tele services are application specific and need all the 7 layers of ISO/OSI reference model.
- Services are specified end to end.
- These tele services are voice oriented tele services.
- They are encrypted voice transmission, messages services , and data communication with terminals (depots) from PSTN/ISDN.

Some of the important services are as follows,

(1) Telephony services, to have high digital voice transmission.

(2) Emergency Number:

- The same number can be used throughout Europe.
- Mandatory (compulsory)services for all services providers.
- Free of change.
- This connection has the highest priority with pre-emption.

(3) Short Message Services:

- Used for simple message transfer introduced by GSM.
- Max of 160 char.
- SMS does not use the standard data channels of GSM uses the Signaling channels.
- Sending and receiving of SMS is possible during data /voice transmission.

(4) Enhanced Message Services:

- used for large message size.
- 760 char, animated picture small images can be transmitted.

(5) Multimedia Message Services:

- Used to transmit large picture of GIF, JIFG, video clips.

(6) Group 3 Fax:

- Fax data is transmitted as digital data over analog telephone network using modem.
- Transparent fax service is used.

2.2.3 Supplementary Services:

GSM offers supplementary services. They are,

(1) User Identification.
(2) Call Redirection/Forwarding.

(3) Closed User Group.
(4) Multiparty Communication.

2.3 GSM ARICHITECTURE

The architecture of GSM comes in hierarchy, consisting of many entities , interface and subsystem.

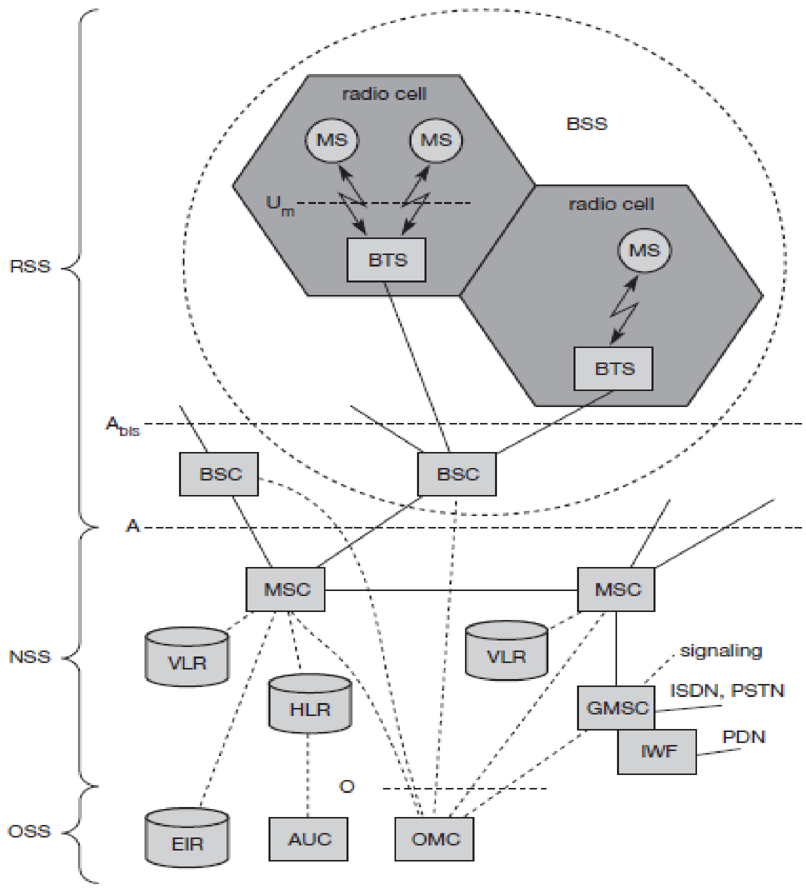

Fig 2.2: Functional architecture of GSM system.

- The GSM system consist of three subsystem.
  (1) The radio Subsystem (RSS)
  (2) Network and Switching Subsystem (NSS)
  (3) Operation Subsystem (OSS)

- The customer is able to notice few components of the network viz. Mobile Station (MS) and antenna of the Base Transceiver Station (BTS).
- Remaining entities are not visible.

2.3.1 Radio Subsystem:

- The Radio Subsystem consists of all radio specific entities. The mobile station and base station subsystems.
- As they are in the same radio frequency they from a cell.

Component of RSS:

i. Mobile Station
ii. Base Transceiver Station
iii. Base Station Subsystem
iv. Base Station Controller.

Mobile Station:

- MS has all user equipment and software needed for mobile communication
- MS has user independent hardware and software.

- **Subscriber Identity Module (SIM):** It stores all user specific data.

- **International Module Equipment Identity:** Mobile station can be identified with IMEI.

- **Constituents of Simcard:**
  - Has identifiers and tables
  - Personal identity number (PIN)
  - PIN un looking key (PUK)
  - Authentication key k_i
  - International mobile subscriber Identity (IMSI).

- **Temporary Mobile Subscribe Identity:** The current location of the MS is found using TMSI.

- **Location Area Identification (LAI):** With the TMSI and LAI the current location can be identified.

Base Station Subsystem (BSS)

The Base Station Subsystem (BSS) is the section of traditional cellular telephone network which is responsible for handling traffic and signaling between a mobile phone and the Network Switching Subsystem. The BSS carries out transcoding of speech channels, allocation of radio channels to mobile phones, paging (The system of numbering pages), quality management of transmission and reception over the Air interface and many other tasks related to the radio network.

Base Transceiver Station (BTS)

The Base Transceiver Station, or BTS, contains the equipment for transmitting and receiving of radio signals (transceiver), antennas, and equipment for encrypting and decrypting communication with the Base Station Controller (BSS). Typically a BTS for anything other than a picocell will have several transceivers (TRXs) which allow it to serve several different frequencies and different sectors of the cell (in the case of sectorised base station). A BTS is controlled by a parent BSC via the Base Station Control Function (BCF). The BCF is implemented as a discrete unit or even incorporated in a TRX, as well as software handling and alarm collection.

The function of a BTS vary depending on the cellular technology used and the cellular telephone provider. There are vendors in which the BTS is a plain transceiver which receives information from the MS (mobile station) through the UM (Air interface) and then converts it to a TDM ("PCM") based interface, the Abis, and sends it towards the BSC. There are vendors which build their BTS so the information is preprocessed, target cell lists are generated and even intracell handover (HO) can be handed. The advantage in this case is less load on the expansive Abis interface.

The BTS are equipped with radio that are able to modulate layer 1 of interface UM; for GSM 2G+ the modulation type in GMSK, which for EDGE-enable network it is GMSK and 8-PSK.

Antenna combiners are implemented to use the same antenna for several TRXs (carriers), the more TRXs are combined the greater the combiner loss bill be . Up to 8:1 combiners are found in micro and pico cells only.

Frequency hopping is used to increase overall BTS performance; this involves the rapid switching of voice traffic between TRXs in sector. A hooping sequence is followed by the TRXs and handsets using the sector. Several hopping sequence are available, and the sequence in use for a particular cell is continually broadcast by the cell so that it is known to handsets.

A TRX transmits and receives according to the GSM standards, which specify eight TDMA timeslots per radio frequency. A TRX may lose some of this capacity as some information is required to be broadcast to handsets in the area that the BTS serves. This information allows the handsets to identify the network and gain access to it. This signaling makes use of channel knows as the BCCH (Broadcast Control Channel).

Base Station Controller (BSC)

The Base Station Controller (BSC) provides, classically, the intelligent behind the BTSs. Typically a BSC has 10s even 100s of BTSs under its control. The BSC handles allocation of radio channels, receive measurement from the mobile phones, control handovers from BTS to BTS (except in the case of an inter-BSC handover in which case control is in part the responsibility of the anchor MSC).

A key function of the BSC is to act as concentrator where many different low capacity connections to BTSs (with relatively low utilization) become reduced to a smaller number of connections towards the Mobile Switching Center (MSC) (with high level of utilization). Overall, this means that networks are often structured to have many BSCs distributed into region near their BTSs which are the connected to large centralized MSC sites.

The BSC is undoubtedly the most robust element in the BSC as it is not only a BTS controller but, for some vendors, a full switching (act of changing) center, as well as an SS7 node with connections to the MSC and SGSN (when using GPRS). It also provides all the required data to the Operation Support Subsystem (OSS) as well as to the performance measuring centers.

A BSC is often based on a distributed computing architecture, with redundancy applied to critical function units to ensure availability in the event of fault condition. Redundancy often extends beyond the BSC equipment providing the A-ter interface to PCU.

The database for all the sites, including information such as carrier frequency, frequency hopping lists, power reduction levels, receiving levels for cell border calculation are stored in the BSC. This data is obtained directly from radio planning engineering which involves modeling of the signal propagation as well as traffic projections.

BSS Interfaces

- Um-The air interface between the Ms(Mobile Station)and the BTS. This interface uses LAPD Protocol for signaling, to conduct call control, measurement reporting, Handover, Power control, Authentication, Authorization, Location Update and so on. traffic and signaling are sent in bursts of 0.577ms at intervals of 4.615ms, to form data blocks each 20ms.

- Abis -The interface between the Base Transceiver station and Base Station Controller. Generally carried by DS-1,ES-1 or E1 TDM circuit. Uses TDM sub channels for traffic (TCH), LAPD protocol for BTS supervision and telecom signaling, and carries synchronization from the BSC to the BTS and MS.

- A-The interface between the BSC and Mobile Switching Center. It is used for carrying Traffic channels and the BSSAP user part of the SS7 stack. Although there are usually transcoding units between BSC and MSC, the signaling communication takes place between these two ending points and the transcoder unit doesn"t touch the SS7 information, only the voice or CS data are transcoded or rate adapted.

- Ater-The interface between the Base Station Controller and Transcoder.It is a proprietary interface whose name depends on the vendor (for example Ater by Nokia),it carries the A interface information from the BSC leaving it untouched.

- Gb-Connects the BSS to the Serving GPRS Support Node(SGSN)in the GPRS Core Network.

2.3.2 Network and Switching Subsystem

This subsystem is the heart of GSM.

Functions:

- Connects wireless network with standard public network.
- Performs handover between different BSS.
- Localization (To locate the mobile station)
- Charging, accounting and roaming of users.

Components:

The NSS contains the following switches and database.

(i) Mobile Services Switching Center (MSSC)

- They are digital ISDN switches.
- Establish connections with other MSC and BSC via A interface.
- Gateway MSC connects to fixed networks (eg) PSTN, ISDN.
- With Internet Working Functions, MSC can connect to publish data Network PDN.
- Handles all signaling needed for connection setup, connection release and handover.
- (e.g.)Standard signaling system number 7 SS7.

(ii) Home Location Register HLR:

- Important data base.
- Stores user relevant information.
- Has static information and dynamic information

Static Information:

- Mobile subscriber ISDN Number.
- Subscribed services for that number.
- International mobile subscriber identity.

Dynamic Information:

- Current location Area (LA) of MS.
- Mobile subscriber roaming number (MSRN).
- VLR,MSC
- When MS leaves the current LA, the information is updated in HLR.
- Usage of the information is to locate the user.

(iii) Visitor Location Resister:

- VLR is associated to each MSC.
- Dynamic data base.
- Stores all the information needed for the MS currently in LA.
- If new MS comes to LA, the VLR is responsible/copies the info needed from HLR.

2.3.3 Operation Subsystem:

- This subsystem contains the function needed for network operation and maintenance.
- The network entities present are

(1) Operation Maintenance Center:

- The OMS monitors and controls all other network entities via 0 interface.

Functions

- Traffic monitoring.
- Status reporting of network entities.
- Security management.

- OMC uses the concept of telecommunication management and network.

(2) Authentication Center:

- The Radio interface is vulnerable (Susceptible to attack) to attacks.
- AUC is to protect the user identity and data transmission.
- Aus has the algorithms for authentication, encryption.

(3) Equipment Identity Register:

- Stores the device identification.
- EIR has a data base of stolen devices
- As the mobile stations can be stolen, this EIR is used to trace the MS.

2.3.4 Radio Interface U_m

- This interface is the interesting interface.
- This is interesting because it does multiplexing and media access.
- Media access is TDMA and FDMA.
- In GSM 900,124 channels each 200Khz wide are used for FDMA.
- Of 124 channels 32 is reserved for organizational data and 90 for customers.

Burst:

- Data is transmitted is small portion called bursts.
- The guard space is used to avoid overlapping with other bursts due to different delay.

The TDMA Frame:

- In the Fig2.3 the burst in 546.5µs.
- Contains 148 bit data.30.5 µs is used as guard space to avoid overlapping.

Field Structure:

Tail: The 3 bits are set to „0"when the data is of normal burst. The first and last 3 bits are tail bits.

Flag S: The flag S indicates whether the data field contains user data or network control data.

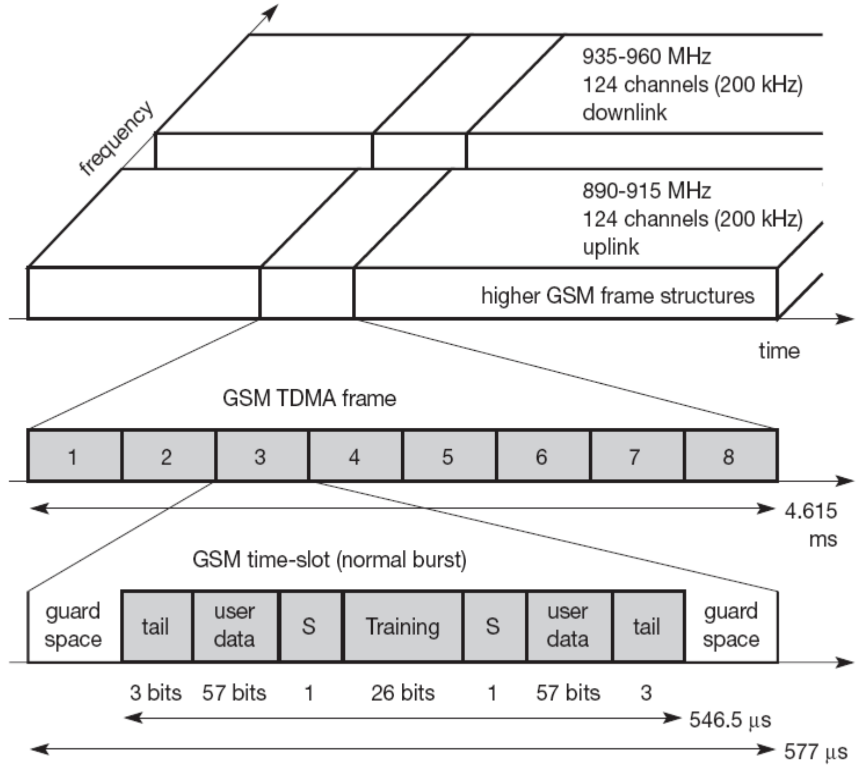

Fig 2.3: GSM TDMA frame, slots, and burst

Each slot has

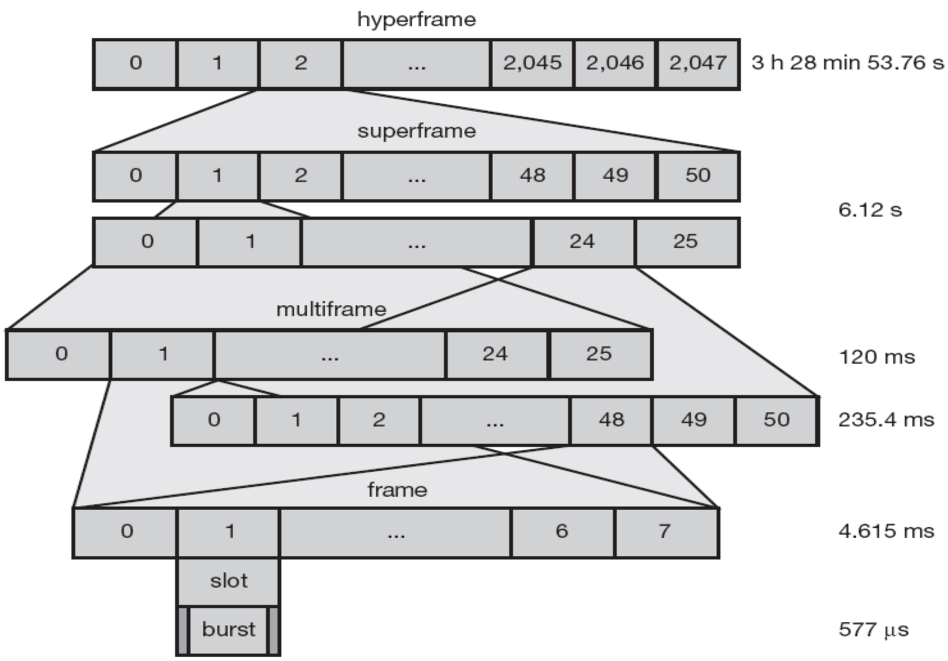

Fig 2.4:GSM structuring of time using a frame hierarchy

Training:

- The training sequence is used to adapt the parameters of the receiver to the current path propagation characteristic. It is used to select the strongest signal for multipath propagation.

Bursts

Burst is the transmission of data in small portions.

Types of Bursts:

(1) **Frequency Correction Burst:** This allows the MS to correct the local oscillator to avoid interference with neighboring channel.
(2) **Synchronization Burst:** This allows the synchronization of MS with BTS in time.
(3) **Access Burst:** This is used for initial connection setup.
(4) **Dummy Burst:** This is used when no data is available for the slot.

2.3.5 Logical Channels and Frame Hierarchy:

GSM specifies two groups of logical channels.

- Traffic Channels
- Control Channels.

2.3.5.1 Traffic Channels (TCH)

GSM uses this Traffic Channels to transmit user data.

- Two types of TCH are there
  (i) Full rate TCH (TCH/F)-data rate=22.8 kBPs
  (ii) Half-rate TCH (TCH/H)-data rate=11.4 kBps
- Speech quality decreases when TCH/H is used. The Standard codec is 5.6 kBPs.
- For Full the codec is 13 kBPs and for Half the codec is 5.6 kBPs.
- The voice codec uses 13 Kbps, remaining used for error correction of 22.8 kBPs.
- To improve the above TFO mode is used. TFO stands for tandem free Operation.
- The TFD mode is used to exchange voice data between two MS.
- Rates example are
  TCH/F 4.8 for 4.8 kBPs, TCH/F 9.6 for 9.6 kBPs

2.3.5.2 Control Channels

Many control channels are used to control the medium access, allocate traffic channels, mobility management. Three control channels are available. Each has its own subchannels.

(i) Broadcast Control Channel:

This channel is used to broadcast information to all the MS with in a cell. The sub channels available are,

(a) FCCH: Frequency Correction Channel

- This channel is used for sending about frequency correction (i.e.) Handover.

(b) SCH: Synchronization Channel

- This channel is used for sending information about time synchronization.

(ii) Common Control Channel: CCCH

This channel is used for transmitting information related to establishment of a channel between MS and BS.

Sub channels are

(a) Paging Channel:

When there is a call to the MS, the BTS uses paging channel for paging the correct MS.

(b) Random Access Channel (RACH)

If the MS wants to setup a call this channel is used to send data to BTS.

(c) Access Great Channel: AGCH

This channel is used to signal an MS that it can use the TCH or SDCCH for further connection setup.

(iii) Dedicated Control Channel: DCCH

This channel is alone bi-directional and it is used to send control related information. The Sub channels are,

(a) Stand alone dedicated control channel: SDCCH

- Until the MS has not established a TCH with BTS the SDCCH is used for low data rate for signaling.

(b) Slow associated dedicated control channel: SACCH

- Each TCH and SDCCH has SACCH. This is used to exchange system information.

(c) Fax associated dedicated control channel: FACCH

- When more signaling information needs to be transmitted this channel is used.This channel uses time slots.

2.3.6 GSM Protocol Suites

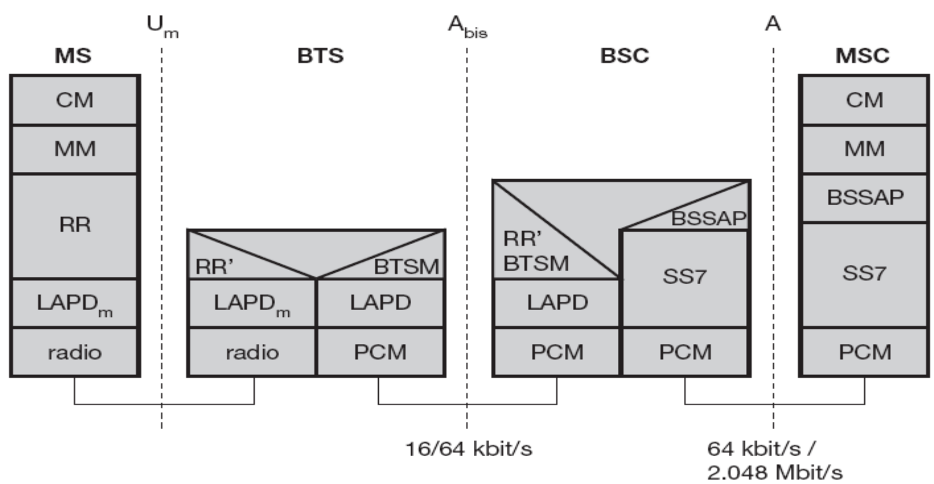

Fig 2.5:Protocol architecture for signaling

- The above figure shows the protocol architecture of GSM. The layers are,

Layer 1: Physical Layer:

- The physical layer handles all radio specific functions.

Functions:

1) Creation of burst in any one of 5 formats.
2) Multiplexing burst into a TDMA frame.

3) Synchronization with BTS.
4) Detection of idle channel.
5) Channel quality measurement.
6) Channel coding and Error detection and correction.

- The Um interface uses GMSK for modulation and performs encryption and decryption.

Layer 2:

- For signaling between entities in a GSM network this layer is used. The protocol used is LAPDM. LAPD stands for link access procedure for D channel. LAPDM has no buffers has to follow Um interface patterns.
- Functions are
    1) Reliable data transfer
    2) Resequencing of data
    3) Flow control.

Layer 3: Network Layer

- The Network layer has sublayers. They are

(i) Radio Resource Management:

- This is the lowest sublayer. A part of RR" is implemented in BTS, remaining is implemented by BSC.
- Function of RR
    1) Setup
    2) Maintenance
    3) Release of Radio Channels.
- RR directly access the physical layer.The function of RR" are supported by the BSC via this BTS management (BTSM)

(ii) Mobility Management:
Functions:

1) Registration
2) Authentication
3) Identification
4) Location updating
5) Providing TMSI, IMSI

Layer 4: Call Management

This layer contains 3 entities.

1) Call control
2) SMS
3) Supplementary services.

Call Control:

- Provides point to point connection between two terminals.
- Used for call clearance, change of call parameters.

- **Short Message Services:** Allows message transfer using control channels.
- **Supplementary Services:** The supplementary services discussed already are to be reproduced here.
- **Functions:** To send in band tone called dual tone multiple frequency over GSM.

2.3.7 Localization and calling

- The important feature of GSM in worldwide localization of users.
- The system always knows where the user is currently and the same phone number is valid worldwide.
- To provide this service the GSM periodically updates even if the user does not use the mobile station.
- The HLR contains the information about the current location.
- The VLR is responsible to inform the HLR about the location change.
- As soon as the MS moves to new region, the HLR sends all the necessary data to the new VLR.
- Changing VLr with uninterrupted availability of all services is called Roaming.
- The Roaming can take place within inter-provider
- .For the localization of the MS the following numbers are needed.

(1) Mobile Station International ISDN Number

- The GSM user should remember the phone number.
- The phone number is associated with the SIM.
- The constituents of the number are
  a. Country code
  b. National Destination code: Address of the service provider.
  c. Subscriber Number

(2) International Mobile Subscriber Identity:

- This is used to uniquely identify the subscriber.
- IMSI consists of
  a. Mobile Country Code
  b. Mobile Network Code
  c. Mobile Subscriber Identification Number.

(3)Temporary Mobile Subscriber Identity (TMSI)

- To hide the IMSI, GSM uses 4 byte TMSI for local subscriber identification.
- TMSI is selected by current VLR.
- The VLR changes the TMSI periodically.

Mobile Station Roaming Number:

- This is another temporary address.
- This is used to hide identity and location of a subscriber.
- The VLR generates this address on request from MSC and the address is stored in HLR.
- MSRN contains current visitor country code and visitor national destination code.

- This is used to help the HLR to find a subscriber for an incoming call.

Calling Functions

The calling function is used to make a call to a mobile (or) a landline.

Mobile Terminated Case:

- Here the end receiver is a mobile station.
- The steps needed to establish a call is as follows:

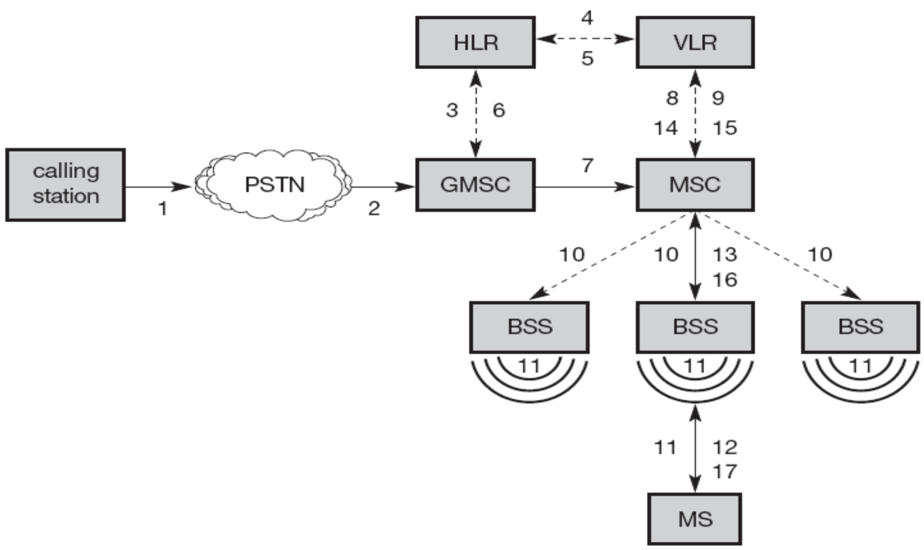

Fig 2.6:Mobile Terminated Call

Step 1: The user dials a GSM subscriber phone number.
Step 2: The PSTN identifies that the number dialed number belongs to GSM network and forwards the call to Gateway MSC.
Step 3: The gateway MSC identifies the HLR of the subscriber and signals the call setup to the HLR.
Step 4: The HLR checks whether the number exists and the services are permitted services and requests MSRN from the current VLR.
Step 5: The HLR receives the MSRN.
Step 6: The HLR determines the MSC responsible for the MS forwards the information to the GMSC.
Step 7: The GMSC forwards the call setup request to the MSC indicated.
Step 8: The MSC is responsible for the steps from here after.
Step 9: The MSC requests the VLR to provide the current status of the MS. The MSC resends the request.
Step 10: If the MS is available the MSC initiates paging in all cells responsible for.
Step 11: The BTS of all the BSS transmit the paging signal.
Step 12 & 13: If the MS answers the VLR performs security check.
Step 14: The MSC response is transmitted to VLR.
Step 15 to 17: The VLR asks the MSC to setup a connection to communicate.

Mobile Originated Call:

Step 1: The MS transmits a request for a connection.
Step 2: The BSS forwards the request to MSC.
Step 3: The MSC checks if the user is allowed to setup a call with the requested service and checks the availability of resources.

If all the resources are available MSC sets up a connection between MS and fixed network.

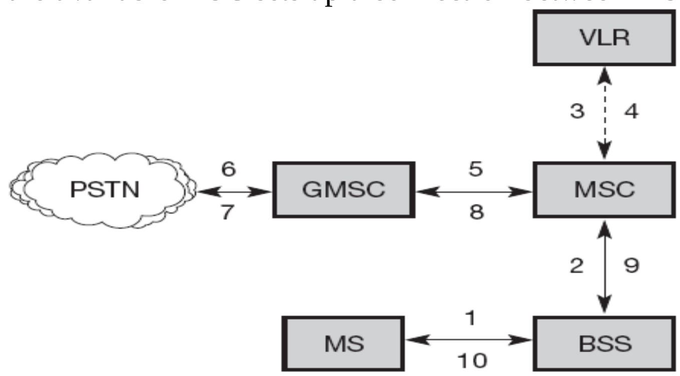

Fig 2.7: Mobile Originated Call

Message Exchanges for MTC and MOC

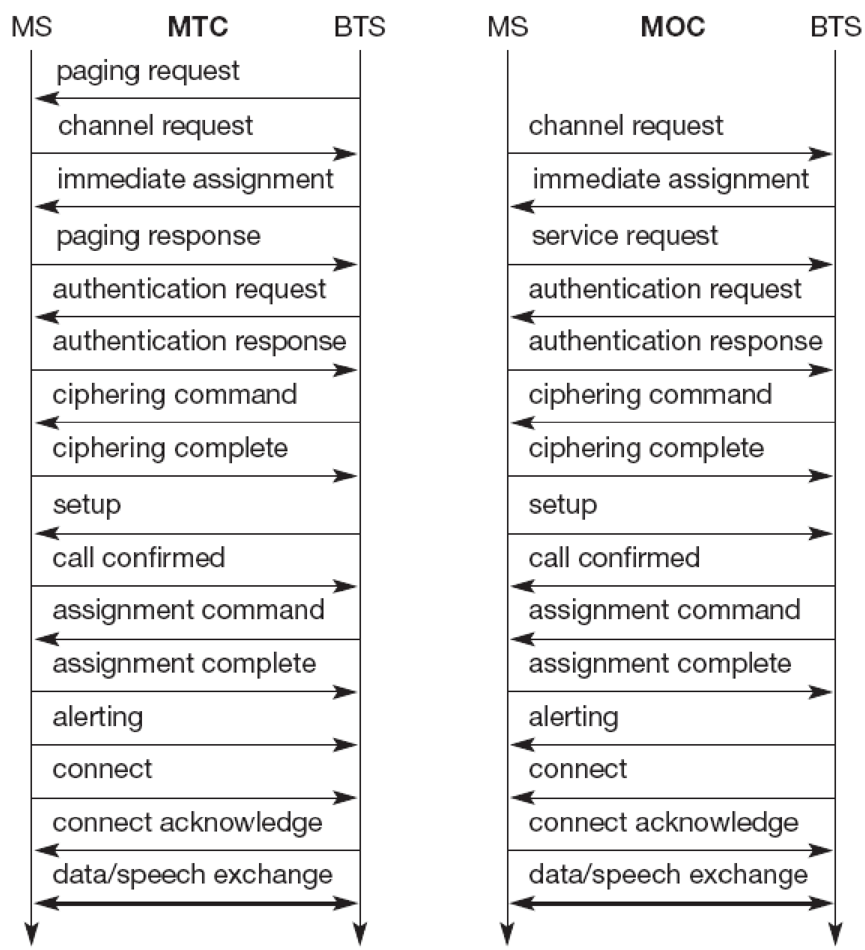

Fig 2.8: Message flow for MTC and MOC

2.3.8 Handover

- Handover means handing over the mobile from one cell to another cell.
- Two reasons for handover

(i) When a mobile station moves out of the range of BTS the signal level decreases continuously and falls below the minimal requirements for communication. The error rate increases due to interference. The quality of radio link decreases.

(ii) The Traffic in one cell is too high, shifting of some MS to other cells with lower load. This is called as load balancing. The number of handover will be more when the cell size is small. Due to handover the calls should not get to cutoff which is called as call drop.

Types of Handover in GSM

(1) Intra cell handover

- With in a cell, narrow band interference can cause transmission at a certain frequency impossible.
- The BSC decides to change the carrier frequency.

(2) Inter cell, Intra BSC handover

- The mobile station moves from one cell to another but remains with in the same BSC.
- The BSC performs a handover, assigns a new radio channel in the new cell and releases the old one.

(3) Inter BSC, Intra MSC handover:

- The BSC controls only limited cells.
- Handover needs to be done between different BSC.
- This is controlled by MSC.

(4) Inter MSC handover

- A handover is needed between 2 cells which belong to difference MSC.
- Both MSC performs the handover together.

Messages involved when Intra MSC handover takes place

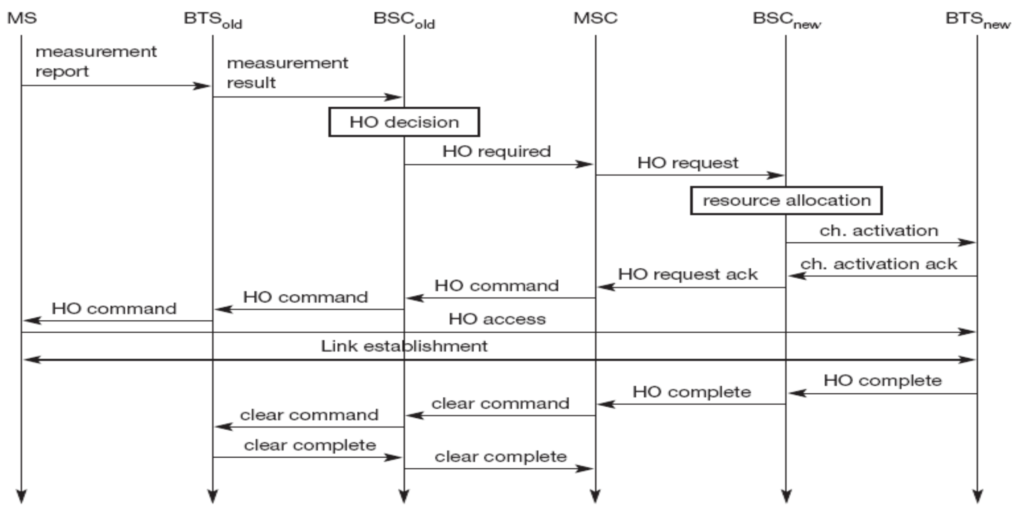

Fig 2.9:Intra-MSC handover

Explanation

- The MS sends the measurement report to the BTSold.
- The BTSold forwards to BTSold.
- Based on these values, the BTSold may decide to perform a handover and sends HO-required to MSC.
- The MSC has the HO-request, transmits to BTSnew
- This BTSnew checks if the necessary resources requested can be allocated.
- If yes then activates the Physical channel at BTSnew to prepare for the arrival of MS.
- The BTSnew acknowledges the successful channel activation, BTSnew acknowledges the handover request.
- MSC issues handover command which is forwarded to MS.
- The MS access the new BTS.
- The link is established between BTSnew and MS.
- Handover is finished and the resources needs to be released at BTSold to BTSold.
- Finally clear complete message is forwarded from BTSold to MSC to release the resources.

2.3.9 Security

- GSM offers security services with the confidential information stored in AUC and in the SIM.
- The SIM stores the secret data and is protected with PIN.
- The security services offered by GSM are

(i) Access Control and Authentication

- The authentication of the valid user for the SIM.
- The user needs a PIN to access sim.
- The Subscriber authentication is done based on challenge response scheme.

(ii) Confidentially:

- User related data are encrypted.
- After authentication the BTS and MS apply encryption on to the data.
- Confidentially exist between MS and BTS only.
- Hence no end to end security.

(iii) Anonymity

- To provide user anonymity the data is encrypted and transmitted.
- User ID is not transmitted.
- The GSM provides the TMSI which varies at any time is transmitted.
- The algorithms to provide security in GSM are
    1. A3-Authentication
    2. A5-Encryption
    3. A8-Generation of Cipher Key

Authentication

- To use a GSM service the user should be authenticated.
- Authentication is based on SIM.

- Sim stores the individual Authentication key the user identification IMSI, algorithm for authentication A3.
- Authentication uses **Challenge response method**

The Method

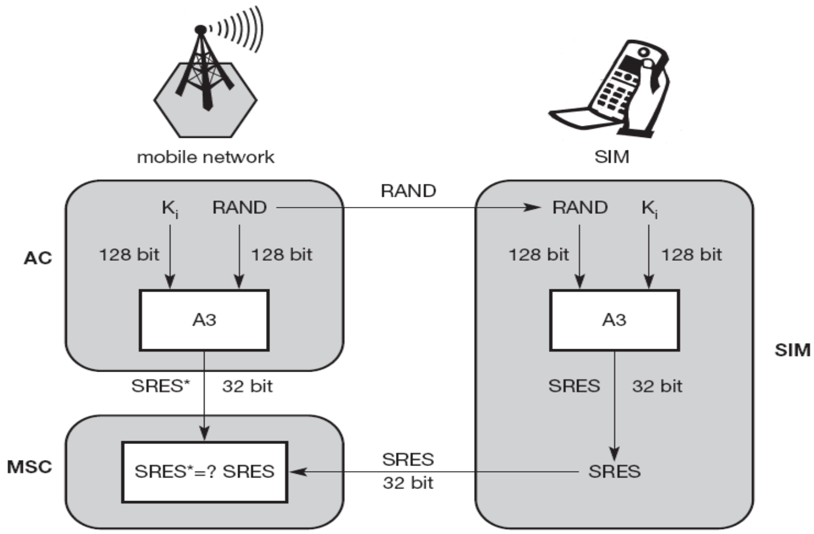

Fig 2.10: Subscriber authentication

- The Access control AC generates a random number RAND as Challenge.
- The SIM in the MS answers with SRES (Signed response) as response.The AUC performs the generation of RAND, SRES, and KC for each IMSI and forwards to HLR.
- The current VLR, requests the appropriate values from HLR. For authentication VLR sends RAND to SIM.
- The mobile network and SIM perform the A3 algorithm with RAND and Kj. The MS sends the SRES generated by the SIM to VLR. The VLR compares the both. If same subscriber is accepted else rejected.

Encryption:

- To have privacy all the user related information messages are encrypted.
- After authentication MS and BSS encrypt using Kc. Kc is generated using Kj and a random value using A8.
- The Kc is not transmitted. Hence the SIM and the network calculate Kc, Using RAND.
- MS and BTS encrypt and decrypt using A5 and Kc. Kc is 64 bit length.
- Encryption is not strong because of 64 bits; 16 bits are always 0 in kc.

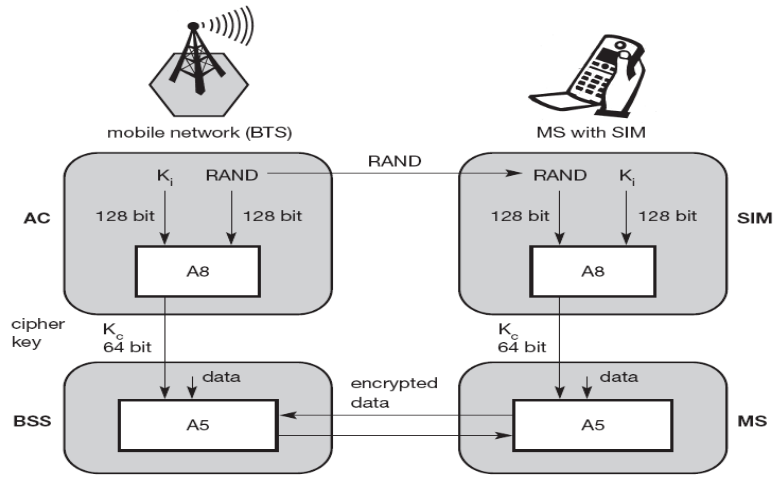

Fig 2.11:Data encryption

2.3.10 GSM Summary

This Page discusses the GSM mobile telephony system, which is increasingly popular and established throughout the world. The term GSM usually means the GSM standard and protocols in the frequency spectrum around 900MHz.There is also DCS 1800-GSM protocols but at different air frequencies around 1800MHz-and in the United States, where spectrum for Personal Communication Services(PCS)was auctioned at around 1900MHz,operators using the aptly-named GSM 1900 are completing against a plethora of other standards. As a result of this, the original and most widely-used GSM frequency implementation is also becoming known as GSM900,and DCS1800 is also known as GSM1800.However,although the physical frequencies used differ, the protocols and architecture remain the same.

The following sections summarize the functional entities, the radio interface signaling protocol, the logical and physical channel structure and the TDMA structure based on GSM.

Multiple Access Method	TDMA / FDMA
Base station to Mobile frequencies (MHz)	935-960(basic GSM)
Mobile to Base station frequencies (MHz)	890-915(basic GSM)
Duplexing	FDD
Channel spacing, KHz	200
Modulation	GMSK
Portable TX power, Maximum/average (mW)	1000/125
Power control, handset and BSS	yes
Speech coding and rate (kbps)	RPE-LTP / 13
Speech channels per RF channel:	8
Channel rate (kbps)	270.833
Channel coding Rate	½ convolutional
Frame duration (ms)	4.615

System Architecture

Refer the Architecture Figure. The Functional entities are briefed as follows,

MS: Mobile Station. The MS is the physical equipment used by a subscriber, most often a normal hand-held cellular telephone.

BTS: Base Transceiver Station. The BTS comprises the radio transmission and reception devices, and also manages the signal processing related to the air interface.

TRAU: The Transcoder Rate Adaptor Unit. The TRAU (not shown in the above figure) functionally belongs to the BTS. The TRAU enables the use of lower rates.(32,16 or 8 kbps) over the A-bits interface instead of the 64 kbps ISDN rate for which the MSC is designed. The TRAU can be located at the BTS, the BSC, or (immediately in front of) the MSC.

BSC: Base Station Controller The BSC manages the radio interface, mainly through the allocation, release and handover of radio channels.

BSS: Base System Station. The BSS consists of a BSC and one or more BTSs.

MSC: Mobile switching Center. The MSC is basically an ISDN-switch, coordinating and setting up calls to and from MSs.An Inter-Working Function (IWF) may be required to adapt GSM specific rates to that used in a particular PSTN/PLMN.

VLR: Visitor Location Register. The VLR contains all the subscriber data, both permanent and temporary, which are necessary to control a MS in the MSCs Coverage area. The VLR is commonly realized as an integral part of the MSC, rather than a separate entity.

AuC: Authentication Center. The AuC database contains the subscriber authentication keys and the algorithm required to calculate the authentication parameters to be transferred to the HLR.

HLR: Home Location Register. The HLR database is used to store permanent and semi permanent subscriber data; as such, the HLR will always know in which location area the MS is (assuming the MS is in coverage area), and this data is used to locate an MS in the event of a MS terminating call set-up..

EIR: Equipment Identity Register. The EIR database contains information on the MS and its capabilities. The IMEI (International Mobile Subscriber Identity) is used to interrogate the EIR.

GMSC: Gateway Mobile Switching Center. The6 GMSC is the point to which a MS terminating call is initially routed, without any knowledge of the MS"s location. The GMSC is thus in charge of obtaining the MSRN (Mobile Station Roaming Number) from the HLR based on the MSISDN (Mobile Station ISDN Number, the “directory number” of a MS)and routing the call to correct visited MSC. The “MSC” part of the term GMSC is misleading, since the gateway operation does not require any linking to a MSC.

SMS-G: This is the term used to collectively describe the two Short Message Services Gateways described in the GSM recommendations. The SMS-GMSC (Short Message Service gateway Gateway Mobile Switching Center) is for mobile terminating short messages and SMS-IWMSC (Short Message Service Inter-Working Mobile Switching Centre) for mobile originating short messages. The SMS-GMSC role is similar to that of the GMSC, whereas the SMS-IWMSC provides a fixed access point to the Short Message Service Centre

Interfaces
Um: The air interface is used for exchanges between a MS and a BSS. LAPDm, a modified version of the ISDN LAPD, is used for signaling.

Abis: This is a BSS internal interface linking the BSC and a BTS, and it has not been standardized. The Abis interface allows control of the radio equipment and radio frequency allocation in the BTS.

A: The A interface is between the BSS and the MSC.The A interface manages the allocation of suitable radio resources to the MSs and mobility management.

B: The B interface between the MSC and the VLR uses the MAP/B protocol. Most MSCs are associated with a VLR, making the B interface “internal”. Whenever the MSC needs access to data regarding a MS located in its area. it interrogates the VLR using the MAP/B protocol over the B interface.

C: The C interface is between the HLR and a GMSC or a SMS-G.Each call originating outside of GSM (i.e., a MS terminating call from the PSTN) has to go through a Gateway to obtain the routing information required to complete the call, and the MAP/C protocol over the C interface is used for this purpose. Also, the MSC may optionally forward billing information to the HLR after call clearing.

D: The D interface is between the VLR and HLR, and uses the MAP/D protocol to exchange the data related to the location of the MS and to the management of the subscriber.

E: The E interface interconnects two MSCs. The E interface exchanges data related to handover between the anchor and relay MSCs using the Map/E protocol.

F: The F interface connects the MSC to the EIR, and uses the Map/F protocol to verify the status of the IMEI that the MSC has retrieved from the MS.

G: The G interface interconnects two VLRs of different MSCs and uses the MAP/G protocol to transfer subscriber information, during e.g. a location update procedure.

H: The H interface is between the MSC and the SMS-G, and uses the MAP/H protocol to support the transfer of short messages.

I: The interface (not shown in figure1) is the interface between the MSC and the MS. Messages exchanged over the I interface are relayed transparently through the BSS.

Protocols over the A, A-Bis and Um interfaces

Refer Protocol stack of GSM. The CM, MM and RR layers together correspond to layer three in the ISO OSI protocol suite, and layer two is composed of LAPD and LAPDm. Customarily, the lower three layers terminate in the same node. Not so in GSM, where the functionality is spread over distinct functional entities with standardized interfaces between them. for instance, the RR part of layer three is spread over the MS,BTS,BSC. and MSC.

CM: The communication management (CM) layer consists of setting up calls at the users" request. Its functions are divided in three: Call control, which manages the circuit oriented services; Supplementary services management, which allows modifications and checking of point short message services.

MM: The Mobility management (MM) layer is in change of maintaining the location data, in addition to the authentication and ciphering procedures.

RR: The Radio Resource (RR) Management layer is in charge of establishing and maintaining a stable uninterrupted communications path between the MSC and MS over which signaling and user data can be conveyed. Handovers are part of the RR layers responsibility. Most of the functions are controlled by the BSC, BTS, and MS, though some are performed by the MSC (in particular for inter-MSC handovers.)

RR': The RR" layer is the part of the RR functionality which is managed by the BTS.

LAPDm: The layer two protocol is provided for by LAPDm over the air-interface. This protocol is a modified version of the LAPD (Link Access Protocol for the ISDN D-Channel) protocol. The main modifications are due to the tight synchronization required in TDMA and bit error protection mechanism required over the air-interface(and in GSM handled by layer 1),making the corresponding functionality of the LAPD protocol redundant(and thus wasteful over the air-interface).The LAPD frame flags are replaced by a length indicator, and the FEC field is removed.

BTSM: The Base Transceiver Station Management (BTSM) is responsible for transferring the RR information (not provided for in the BTS by the RR" protocol) to the BSC.

LAPD: This is the ISDN LAPD protocol (Link Access Protocol for the ISDN D-channel) providing error-free transmission between the BSC and MSC.

BSSAP: The Base Station System Application Part(BSSAP) is split into two parts, the BSSMAP and the DTAP(not shown In the above figure). The message exchanges are handled by SS7. Messages which are not transparent to the BSC are carried by the Base procedures between the MSC and the BSS that require interpretation and processing of information related to single calls, and resource management. The messages between the MSC and MS which are transparent to the BSC (MM and CM messages) are catered for by Direct Transfer Application Part(DTAP)

SCCP: The signaling Connection Control Part (SCCP) from SS7.

MTP: The message Transport Part (MTP) of SS7.

Logical and Physical Channels

GSM distinguishes between physical channels (the timeslot) and logical channels(the information carried by the physical channels, which are used by different logical channels to transfer information-both user data and signaling.

Common Channels

The forward common channels are used for broadcasting bulletin board information, paging and response to channel requests. The return common channel is a slotted Aloha type random access channel used by the MS to request channel resources before timing information is conveyed by the BSS, and uses a burst with an extended guard period.

Dedicated Point-to-Point Channels

The dedicated point-to-point channels are divided into two main groups, the dedicated signaling channels and the traffic channels. The dedicated signaling channels are used to set-up the connection, and the traffic channel of a variety of rates is used to convey the user for e.g. link monitoring, and FACCH for time-critical signaling during e.g. a handover. The FACCH ”steals” the entire traffic burst for signaling.

These logical channels are defined in GSM:

TCHf	Full rate traffic channel
TCH h	Half rate traffic channel
BCCH	Broadcast Network information, e.g. for describing the current control channel structure. The BCCH is a point-to-multipoint channel (BSS-to MS).
SCH	Synchronization of the MSs.
FCH	MS frequency correction.
AGCH	Acknowledge channel requests from MS and allocate a SDCCH.
PCH	MS terminating call announcement.
RACH	MS access requests, response to call announcement, location update, etc.
FACCHt	For time critical signaling over the TCH (e.g. for handover signaling).Traffic burst is stolen for a full signaling burst.
SACCHt	TCH in-band signaling, e.g for link monitoring.
SDCCH	For signaling exchanges, e.g during call setup, registration/location updates.
FACCHs	FACCH for the SDCCH. The SDCCH burst is stolen for a full signaling burst. Function not clear in the present version of GSM (could be used for e.g. handover of an eight-rate channel, i.e using a “SDCCH-like” channel for other purposes than signaling).
SACCHs	SDCCH in-band signaling, e.g .for link monitoring.

The normal burst has a throughput after coding of 22.8 kbps, and offers full rate voice at a net bit rate of 13kbps and data at up to 9.6 kbps.GSM has also specified a half-rate service by time-multiplexing two users onto the TDMA structure. This service offers a gross bitrate of 11.4 kbps, and data at 4.8 kbps.

2.4 GPRS

- GPRS stands for General Packet Radio Services.
- This mechanism is flexible and powerful.
- This method provides packet mode for data transfer for small volumes of data,to increase the data transfer.

Expectations:

(1) Should use the existing network resources efficiently.
(2) Should provide the selection of QoS parameters.
(3) Should provide unicast, broadcast, multicast services.
(4) Should provide cheaper, more efficient, Packet transfer for IP applications.

GPRS Platform

GPRS (General Packet Radio Service) is the world‟s most ubiquitous wireless data service, available now with almost every GSM network. GPRS is a connectivity solution based on Internet Protocols that supports a wide range of enterprise and consumer applications. With throughput rates of up to 40 kbit/s, users have a similar access speed to a dial up modem, but with the convenience of being able to connect from anywhere. GPRS customers enjoy advanced, feature-rich data services such as colour Internet browsing-mail on the move, powerful visual communications such as video streaming, multimedia messages and location-based services.

For operators, the adoption of GPRS is a fast and cost-effective strategy that not only supports the real first wave of mobile Internet services, but also represents a big step towards 3GSM (or wideband-CDMA) networks and services.

The General Packet Radio Services (GPRS) is a new no voice value added service that allows information to be sent and received across a mobile telephone network. It supplements today‟s Circuit Switched Data and Short Message Service. GPRS is NOT related to GPS (the Global Positioning System), a similar acronym that is often used in mobile contexts.

2.4.1 Concepts of GPR's

- The GSM can allocate between 1 to 8 slots in a TDMA frame for the new GPRS radio channels.
- Time slots are not allocated in a fixed, predetermined manner.
- The time slots are shared by the active users.
- Uplink and Downlink are allocated separately.
- Allocation of slots depends upon the current load and operator preferences.
- GPRS is independent of channel characteristic and the type of channel does not limit the maximum transfer rate.
- GPRS services can be used in parallel.
- The real available data rate depends on the current load of the cell as the GPRS uses idle time slots.
- The transfer rate depends upon the capabilities of MS.

- Types of packet transfer services are,
    - Point to point packet transfer services
    - Point to multipoint service.

Point to Point Packet Transfer Service:

Classification under this Scheme
(i) PTP connection oriented network service.

- The GPRS maintains a virtual circuit upon change of the cell with in a GSM network.
- Available in X.25.

(ii) PTP connection less network service.

- Here no connections are maintained suitable for IP.
- The users can specify the QoS profile.
- The QoS decides the Service precedence, Reliability, Delay and Throughput.
- Delay in the network is due to the channel access delay, coding for error correction and transfer delay in fixed and wireless.
- No buffering of packets is done in GPRS.
- Instead GPRS tries to forward the packet as fast as possible.
- GPRS provides security services such as authentication, access control, confidentiality of user and data. Anonymous services is also feasible with GPRS.

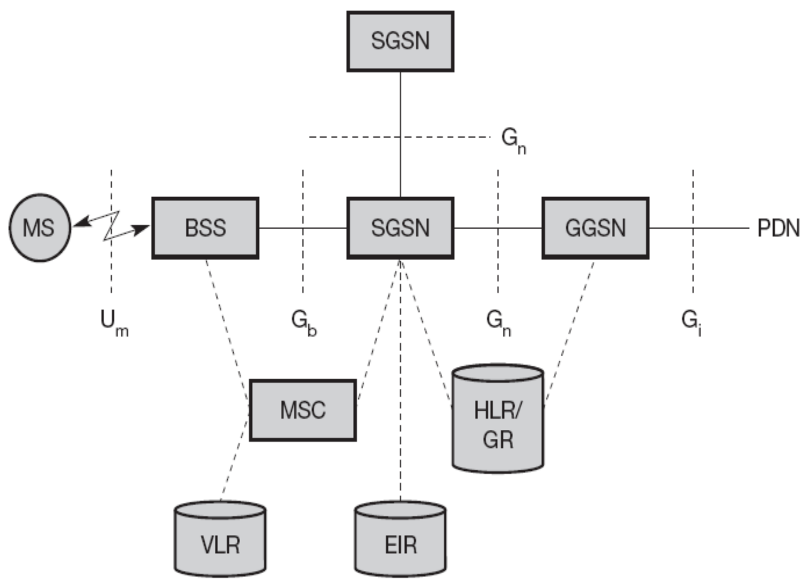

Fig 2.12: GPRS Architecture Reference Model

2.4.2 Reference Model for GPRS Architecture:

The GPRS architecture introduces new network elements via Gateway GPRS support nodes (GGSN) and servicing GPRS support node SGSN.

GSN:

- The GSN are routers.
- The GSN are integrated into the GSM architecture.

- **GGSN**
  - The GGSN are the internetworking unit present between GPRS Network and packet Data Networks.
  - The GGSN contains routing information and does address conversions and tunneling.
  - The GGSN is connected to the external network via a G_i interface and transfers packet to SGSN via G_n interface.

- **Serving GPRS support node SGSN:**
  - This node support MS via G_b interface.
  - The SGSN requests the user address from GPRS (GR) and keeps track of individual MS location. SGSN is connected to the BSC via frame relay.
  - This node is responsible for billing and security related functions.
  - The GR is in HLR and stores GPRS relevance –data.

2.4.3 Packet Transmission:

- Consider the previous packet is transmitted from a PDN via GGSN, SGSN, and BSS to the MS.
- The MSC is responsible from transport in circuit switched GSM.
- Before sending the data, MS must attach to the procedures of mobility management. They are,
  - Assigning a temporary identifier called as temporary logical link identify.
  - Encrypting using a ciphering (Convert ordinary language into code) key sequence number (CKSN).
  - After attachment for each MS, CKSN flag indicates if compression is done and routing data.
  - This context tells the status of MS, CKSN flag indicates if compression is done and routing data.
- The above four are called as attachment procedures.
- In addition to the above the functions of mobility management are
  - Authentication
  - Location management
  - Ciphering

Modes of MS:

The MS can be in the following:

- **Idle Mode:** In this mode the MS is not reachable and context is deleted.
- **Standby Mode:** In this mode movement across the routing area is updated to SGSN but not changes of the cell.
- **Ready:** Every movement of the MS is indicated to the SGSN.

Protocol Reference Model:

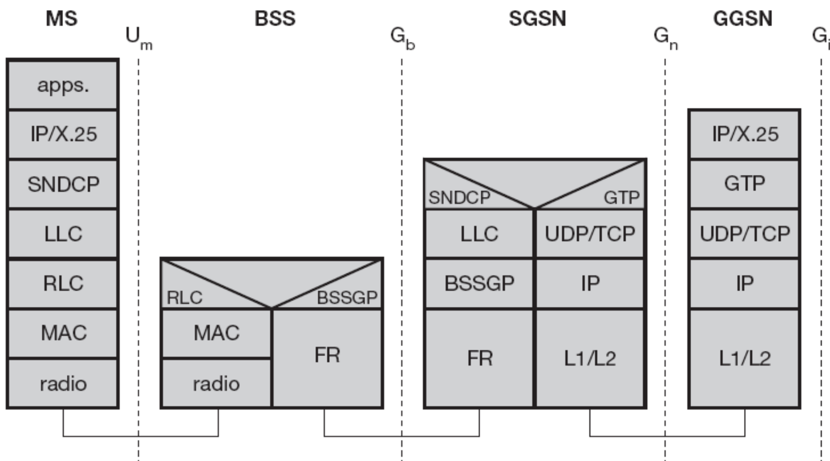

Fig 2.13:GPRS transmission plane protocol reference model

- The above figure shows the protocol architecture of the transmission plane for GPRS.

MS:

- all the data within the GPRS back bone (i.e.)between GSN is transferred using GPRS Tunneling Protocol(GTP)
- GTP uses 2 different transport layer protocols
  - **(a)**TCP
  - **(b)**UDP
- The network layer protocol is IP.
- As the protocols are different to adapt to the different characteristics Sub network Dependent Convergence protocol (SNDCP) is used between SGSN and MS.
- On the top of SNDCP and GTP user data is tunneled from MS to the GGSN.
- To achieve high reliability, LLC is used .LLC has ARQ and FEC.

BSS:

- The Base Station Subsystem GPRS protocol is based (BSSGP) Specify Routing and QoS related information between BSS and SGSN.
- The BSSGP does not perform error correction and works on top of frames relay.
- The Radio link dependent protocols needed to transfer data over U_m interface.
- The RLC provides reliable, MAC controls the access with signaling procedure and mapping of LLC frames on to GSM physical channels.
- The Radio interfaces at U_m do not need any changes.
- New logical channels and mapping to the physical resources have been defined (e.g.) Packet Data Traffic channels.
- Capacity allocation is a demand and shared between circuit switched channels.
- The important factor needed is that for any application working should not notice any details from GPRS infrastructure.
- Tunneling takes place to keep them not informed about the hops.

- Due to tunneling all the MS are given with private IP address and translated to global address. The advantage is that security.

The disadvantage is that if an MS wants to provide a service using fixed, IP address, and it is not feasible with IPV_4 but feasible with IPV_6.

2.4.4 GPRS Summary:

GPRS is an enhancement over the GSM and adds some nodes in the network to provide the packets switched services. These network nodes are called GSNs (GPRS Support Nodes) and are responsible for the routing and delivery of the data packets to and from the MS and external packet data networks (PDN).

Network Architecture:

Addition of two network elements:

- Serving GPRS Support Node (SGSN)
- Gateway GPRS Support Node (GGSN)

GPRS Subscriber Terminals:

- Only GPRS terminals (TEs) can access GPRS servers.
- GPRS enabled phones, PDAs with embedded GSM, PC cards for laptops
- These terminals will be backward compatible with GSM for voice calls, because existing **GSM phones:**
  - Cannot handle the enhanced air interface.
  - Cannot packetize data directly.

GPRS BSS:

- A software upgrade is required in the existing Base Transceiver Sit (BTS).
- The Base Station Controller (BSC) also requires software upgraded, and the installation of a new piece of hardware called a **packet control unit** (PCU).
- The PCU direct the data traffic to the GPRS network and can be a separate hardware element associated with BSC. The PCU provides a physical and logical data interface out of BSS for packet data traffic GPRS network.

GPRS Support Node (SGSN):

Gateway GPRS:

Sup GPRS can be thought of as an overlay network onto the GSM network.

- The data overlay network provides packet data transport from 9.6 to 171 kbps.
- Multiple users can share the same air-interface resources.
- GPRS uses most of existing GSM network elements, plus new network elements, interface, and protocols for building a packet-based mobile cellular network port Node (GGSN).

Databases (VLR and HLR):

All the databases involved in the network require software upgrades to handle the new call models and functions introduced by GPRS.The Home Location Register (HLR) and Visitor Location Register (VLR) especially require upgrades to functionally service GPRS. A main issues in the GPRS network is the network is the routing of data packets to/from a mobile user, which is divided into two areas: Data packets routing Mobility management

Data packet routing:

- GGSN,Handles interaction with the external data network.
- Routes external data packets to the SGSN, There is the use of the various tools in a GPRS network,
- Three different routing schemes are possible:
  - Mobile –originated message.
  - Network-initiated messages when the MS is in its home network.
  - Network-initiated messages when the MS has roamed to another BPRS Operator"s network.

GPRS operators will allow roaming through an inter operator backbone network. GPRS operators connect to the inter operator network by a border gateway (BG).

The main benefits the architecture are its flexibility, scalability, interoperability and roaming.

- The GPRS network encapsulates all data network protocols into its own encapsulation protocol, called the GPRS Tunning Protocol (GTP).

Network architecture –new interfaces:

- Gb : between the PCUSN and SGSN, using Frame relay.
- Gr : between SGSN and HLR, extension of the mobile application part (MAP).
- Gn : between SGSN and GGSN, using the GTP (tunneling) protocol.
- Gi : between GGSN and PDNs (x.25 and internet protocol IP).
- Gs : between SGSN and MSC/VLR, for some simultaneous GPRS and GSM operations.
- Gd : delivers SMS messages via GPRS.
- Gc : between GGSN and HLR.

GPRS Logical Channels:

A logical channel refers to a flow of information between entities for a particular purpose.

- Logical channels are carried within the physical channels.
- Packet Broadcast Control Channel(PBCCH)
- A downlink function used for broadcast of system information to the mobile station in a cell.
- Packet Common Control Channel(PCCCH)
- A control channel service for signaling for the packet data
- Packet Random Access Channel(PRACCH)
- Packet Paging channel(PPCH)
- Packet Access Grant Channel(PAGCH)
- Packet Notification Channel(PNCH)
- Packet Data Traffic Channel(PDTCH)
- The traffic channel is an up and downlink function used for user data traffic transfer.
- PDTCH is temporarily dedicated to a user or group of users.

- PDTCH for uplink and PDTCH for downlink are unidirectional and assigned separately to support asymmetric user traffic flow.

Packet –dedicated control channel (PDCCH)

- Packet associated control channel(PACCH)
- An uplink and downlink function used to carry signaling information to and from the mobile station.
- Packet timing advance control channel /uplink (PTCCH/DL)
- Used for estimation of timing advance of one mobile station.
- Packet timing advance control channel /downlink (PTCCH/DL)
- Used to transmit timing advance information to several mobile stations.

2.5 DECT:

- DECT stands for Digital Enhanced Cordless Telecommunication.
- DECT is used in offices, trade shows, home etc.
- Access points to PSTN are established with in.
- Digital Cellular networking specialized by ESTI in 2002.

Difference between DECT and GSM:

- The difference lies in cell diameter and cell capacity.
- GSM is designed for outdoor ,cell diameter of 70 km
- DECT is designed for indoor, cell diameter of 30 mm from the base station.
- DECT can offer service to 10,000 people within one km^2.
- DECT works at a frequency range of 1880-1990 MHz offering QD Full duplex channels.
- TDD is used using 10ms frames
- Frequency range is subdivided into 10 carries frequency using FDMA, each frames are divided into 24 slots using TDMA.
- 12 slots are used for uplink and another 12 slots for downlink.

DECT:

DECT is based on time division duplex (TDD) and time division multiple access (TDMA) with 10 carriers in the 1880-1900MHz band. It has a TDD/TDMA frame structure. The complete frame is 10ms in duration with 24 time slots. The first 12 slots are allocated for the transmission from base station to handsets, and other 12 slots are for the transmission from handsets to base station. A connection always uses a pair of time slots separated by one half TDMA frame.

DECT uses Dynamic Channel Allocation (DCA).

This means that slots and frequencies are not pre assigned, but each connection automatically selects the channel with the best quality. Since this can change over time, connections may be transferred o another channel which may or may not be with the same base station (handover).

A normal DECT slot is 417 microseconds long and contains 420 bits. It is made up of the following fields:

- 16 bits preamble (yellow)

- 16 synchronization word(blue)
- 64 bit A field. It specifies what the content of the B field is (red).
- 324 bits B field. This contains the actual information: voice of data (green).

Modulation Scheme:

Most of the DECT product on the market today use Gaussian filtered FSK (GFSK) as their modulation scheme.

The advantages of GFSK can be summarized as follows.

- **Constant envelop nature:** this allows GFSK modulated signal to be operated with class-C power amplifier without introducing spectrum regeneration. Therefore, lower power consumption and higher power efficiency can be achieved.

- **Narrow power spectrum:** narrow main lobe and low spectral tails keep the adjacent channel interference to low levels and achieve higher spectral (being a phantom) efficiency.

- **Non-coherent detection:** GFSK modulated signal can be demodulated by the limiter/ discriminator receiver.

In addition to GFSK, the DECT specification allows three other modulation schemes: p/ 2DBPSK, p/4-DQPSK and p/8-D8PSK. While the first of these modulation schemes is compatible with GFSK, the last two provide 2 and 4 times the data rate as GFSK. This means that combined with the high speed data profile, data rates of up to 2Mbps can be achieved using DECT.

DECT was not designed with a training sequence, thus enabling cheaper terminals that do not have to offer equalization. However, equalization can significantly improve DECTs performance over relatively long links in multipath environments.

2.5.1 System Architecture

- A DECT system can use different physical implementation depending upon the actual use. Different entities can be integrated into one physical unit.

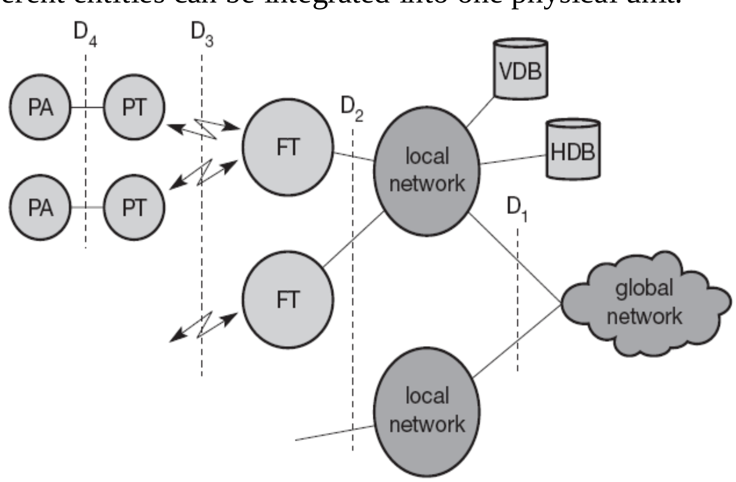

Fig 2.14: DECT system architecture reference model

- **Global Networks:** connects the local structure to the outside world, offer services via interface D_1, External Network.
- Global Network can be ISDN/PSTN/PLMN or PSPDN.
- The services offered can be transportation of date, translation of address and routing of data between networks.

Local Network:

- The local networks in DECT offer local Communication Services (e.g.) call forwarding, address translation. This is the core of the DECT system.
- All the network functions needs to be integrated in with local or global network.
- The local network has Home Data Base (HDB) and Visitor Data Base (VDB).
- These data bases support mobility. They are similar to HLR and VLR.
- Incoming calls are automatically forwarded to the current subsystem responsible for the DECT user and the VDB informs the HDB about change in location.

Fixed Radio Termination and Portable Radio Termination

- They form the (FT & PT) core of DECT network.
- They provide multiplexing.
- They form layer 1 to 3 in both fixed network and mobile network.

2.5.2 Protocol Architecture

- The protocol architecture follows the OSI` reference model.
- The layers are physical Layer, Medium access control and Data Link control for control plane. (C-Plane) and user plane (U-Plane).
- For the C-Plane there is an additional network layer, the user data from layer 2 is directly forwarded to the U-plane.
- A management plane vertically covers all lower layer of a DECT system.

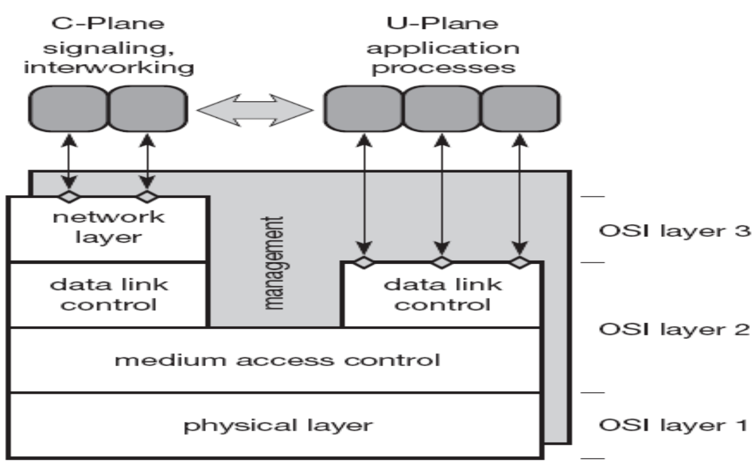

Fig. 2.15: DECT protocol Layers

2.5.3 Physical Layer

The functions are

(1) Modulation/demodulation.

(2) Incoming signal detection.

(3) Sender/receiver Synchronization.
(4) Collection of status information for the management plane.

- This layer generates the physical channel structure.
- On request from the MAC layer the physical layer assigns a channel for data transmission.

2.5.3.1 DECT Frame structure

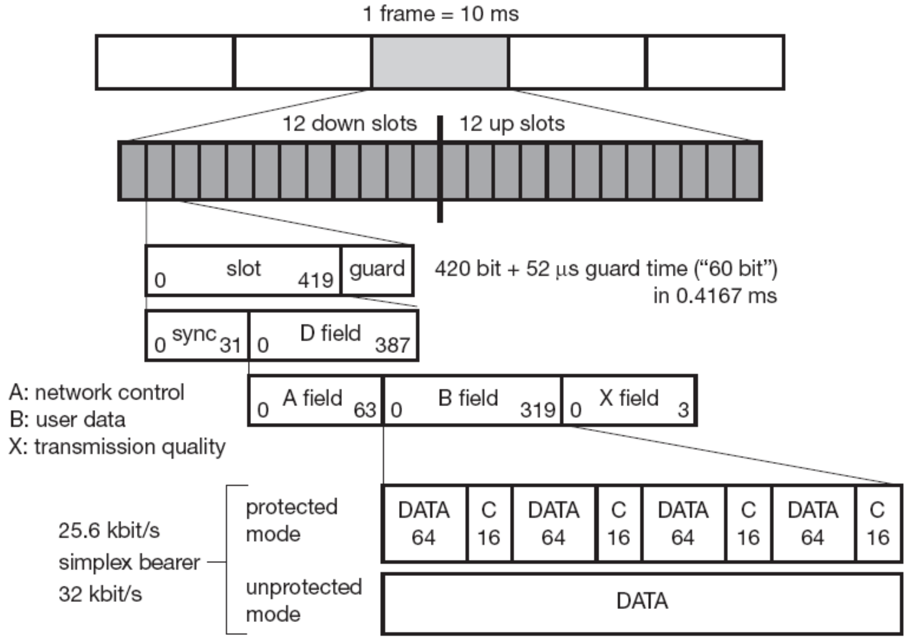

Fig.2.16: DECT multiplex and frame structure

- The above figure shows TDMA frame structure.
- The duration is 10 ms and contains 12 slots for downlink and 12 slots for uplink in basic connection mode.
- If the mobile node receives data in slot S, it returns data in slot S + 12.
- An advanced connection mode allows different allocation scheme.
- Each slot has duration of 0.4167 ms and contain several different physical packets.
- 420 bits are used for data, 52 µS are used as guard space.
- The 420 data bits are divided into 32 bit synchronization pattern, followed by the data field D.
- The fields for data transmission use the 388 bits for network control A field
- User data B field
- Transmission Quality-X field.
- Network control is transmitted at 6.4 kBPs.
  User data depends upon error correction mechanisms.

Modes:

(1) Unprotected Mode:
Simpler bearer service at 32 kBk

(2) Protected Mode:
64 bit data, 16 bit CRC
Data rate: 25.6 kBPs.

- **Duplex Bearer service**
  Combines 2 simplex bearer services.
  80 kBPs.

- **Increases Throughput.**

2.5.3.2 Medium Access Control Layer

Functions

1. Establish, maintain, release channel for higher layer by activating and de-activating physical channels.
2. Multiplex several logical channels to physical channel.
3. Logical channels are used for signaling network control, user data transmission, paging broadcast messages.
4. Services are segmentation and reassembly.
5. Error control and correction.

2.5.3.3 Data Link Control Layer: DLC

Functions:

- Creates and maintains reliable connections between mobile and base station.

Services for C-Plane

1. Connection less broadcast for paging called LB.
2. Point to point protocol.

Services for U-Plane:

1. Transparent, unprotected service, FEC, Rate adaptation.

2.5.3.4 Network Layer

- The network layer exists only for C-plane.
- Functions are to request, check, reserve control and release resource at the fixed
- station and mobile terminal.
- The **mobility management** is responsible for identity management, authentication
- and to manage local data bases.
- The **call control** handles connection setup, release and negotiation.

The message services are

1. Connection oriented massage service (COMS).
2. Connection less message service (CLMS).

They are responsible for data transfer to from the Internetworking unit that connects the DECT system to the outside world.

2.6 UNIT AND IMT-2000

IMT- International Mobile telecommunications-2000.

- International Telecommunication Union ITU made a request for proposals for radio transmission technologies for IMT.
- IMT allowed user mobility, supporting the idea of universal personal telecommunication UPT.
- The WRC 1992 identified 1885-2025 and 2110-2200 MHz as the frequency band for IMT-2000 systems.
- The ITU Frequency allocated is 1885-2025 for uplink and 2110-2200 for downlink.

2.6.1 UMTS

UMTS (Universal Mobile Telecommunications Service) is a third-generation (3G) broadband, Packet-based transmission of text, digitized voice, video, and multimedia at data rates up to 2 megabits per second (Mbps). UMTS offers a consistent set of services to mobile computer and phone users, no matter where they are located in the world. UMTS is based on Global System for Mobile (GSM) communication standard.

It is also endorsed by major standards bodies and manufacturers s the planned standard for mobile users around the world. Once UMTS is fully available, computer and phone users can be constantly attached to the Internet wherever they travel and, as they roam, will have the same set of capabilities. User will have access through a combination of terrestrial wireless and satellite transmissions. Until UMTS is fully implemented, users can use multi-mode devices that switch to the currently available technology (such as GSM 900 and 1800) where UMTS is not yet available.

Previous cellular telephone systems were mainly circuit-switched, meaning connections were always dependent on circuit availability. A packet-switched connection uses the Internet Protocol (IP), meaning that a virtual connection is always available to any other end point in the network. UMTS also makes it possible to provide new services like alternative billing methods or calling plans.

For instance, users can choose to pay-per-bit, pay-per-session, flat rate, or asymmetric bandwidth options. The higher band width of UMTS also enables other new services like video conferencing or IPTV. UMTS may allow the virtual Home Environment (VHE) to fully develop, where a roaming user can have the same services to either at home, in the office or in the field through a combination of transparent terrestrial and satellite connections.

2.6.2 Family of IMT-2000

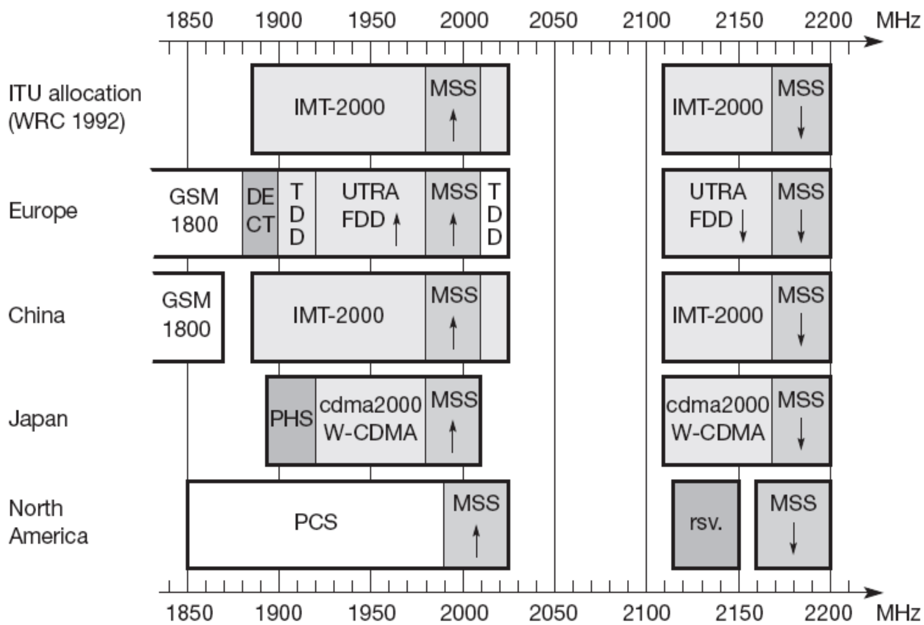

Fig. 2.17 IMT-2000 frequencies

The ITU standardized the 5 groups of 3G radio access technologies as

IMT-DS:

- DS-Direct spread technology has wide band CDMA (W-CDMA) systems.
- This is the technology specified for ULTRA-FDD and used by Europe and Japan.

IMT-TC:

- TC stands for Time Code.
- This family member is called time code contained the UTRA-TDD system.
- Uses TD-CDMA.
- The Chinese proposal TD synchronous CDMA (TD-SCDMA) was added.

IMT-MC:

- CDMA -2000 is a multicarrier technology standardized by 3 GPP ^{2}.
- Third generation partnership project 2, 3 GPP ^{2} 2002 was formed.
- Version CDMA-2000 EV-DO has been accepted as 3G standard.

IMT-SC:

- SC – Single Carrier.
- This is the enhancement of US TDMA system systems UWC-136. This is a single carrier technology originally promoted by UWCC.

IMT-FT

- Frequency time technology an enhanced version of cordless telephone standard DECT has been selected for application that does not require high mobility.

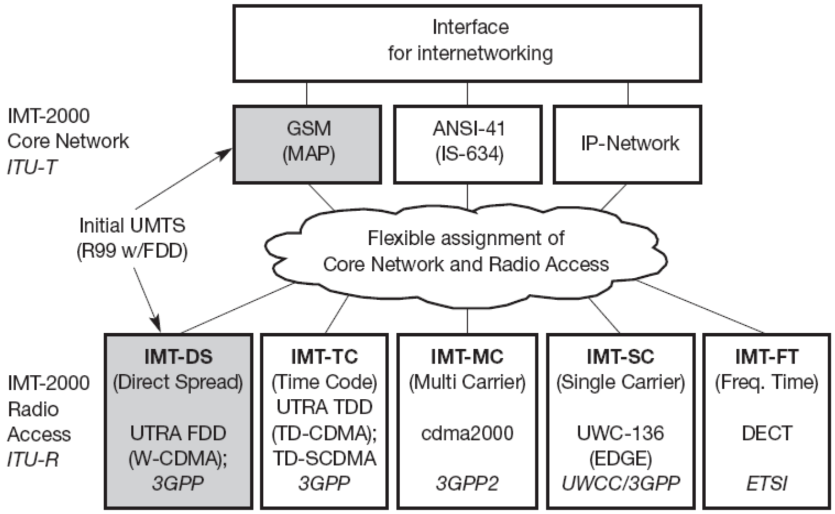

Fig.2.18 the IMT-2000 family

2.6.3 UMTS System Architecture

Simplified UMTS Architecture

Fig. 2.19: main components of the UMTS reference architecture

- The above figure shows the simplified UMTS reference architecture.
- This is applied to UTRA,3 GPS 2000
- The UTRA network UTRAN handles cell level mobility and has Radio Network Subsystem(RNS)

Functions of RNS:

1) Channel ciphering and deciphering
2) Handover control
3) Radio Resource Management

- The UTRAN is connected to the user equipment UE via radio interface U_u which is similar to U_m in GSM.
- The UTRAN is connected to core network CN via I_u interface which is similar to A in GSM

Functions of CN (core network):

1) Inter system handover
2) Gateways to other network handover
3) Location management

- UMTS subdivides the simplified architecture into domains.

They are,

i. User equipment domain
ii. Infrastructure domain
iii. Core network domain

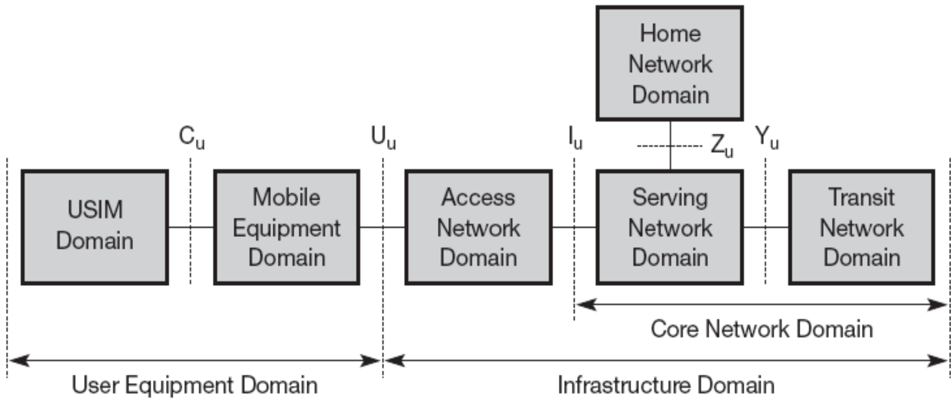

Fig. 2.20: UMTS domains and interfaces

(i) User equipment domain:

- The user equipment U_E domain is assigned to a single user and has all the functions that are needed to access the UMTS services.
- The user equipment domain has (A) USIM domain (B) mobile equipment domain.

USIM Domain:

- The USIM domain contains the SIM for UMTS, performs encryption, authentication, store user related data for UMTS.
- USIM belongs to service provider and contains micro processors for enhanced program execution.

Mobile Equipment Domain:

- The end device is in the mobile equipment domain functions of Radio Transmission, interfaces are located in Mobile equipment domain.

(ii) Infrastructure Domain:

- This domain is shared among all users and offers UMTS services.
- The domain consist of

Access network domain:

- This consist the access to network independent functions.

(iii) Core network Domain:

The core network domains have 3 sub domains with specific task.

1. Servicing network domain: Has all functions currently used by the user for accessing the UMTS services.

2. Home network Domain: All functions related to home network of a user is present.

3. Transmit network Domain: This domain is used when the servicing network cannot directly contact the home network.

2.6.4 UMTS Radio Interface:

- The difference between UMTS and GSM comes with radio interface (U_u).
- The duplex mechanism is used from that of GSM and TDD.
- UMTS uses a chipping rate of 3.8M chips/sec.

2.6.5 UTRA Mode:

1. UTRA - FDD(W-CDMA)
2. UTRA – TDD (TD-CDMA).

2.6.5.1 UTRA-FDD (W-CDMA)

- The FDD mode for UTRA uses wide band CDMA (W-CDMA) with direct sequence spreading.
- The figure shows the radio frame comprising 15 time slots.
- This slot is not used for user separation but it is used for support periodic function.
- Each frame has got logical and physical channels and their mapping.
- The above figure shows three physical channels as they are used for data transmission.
- Of the three two is used for uplink.

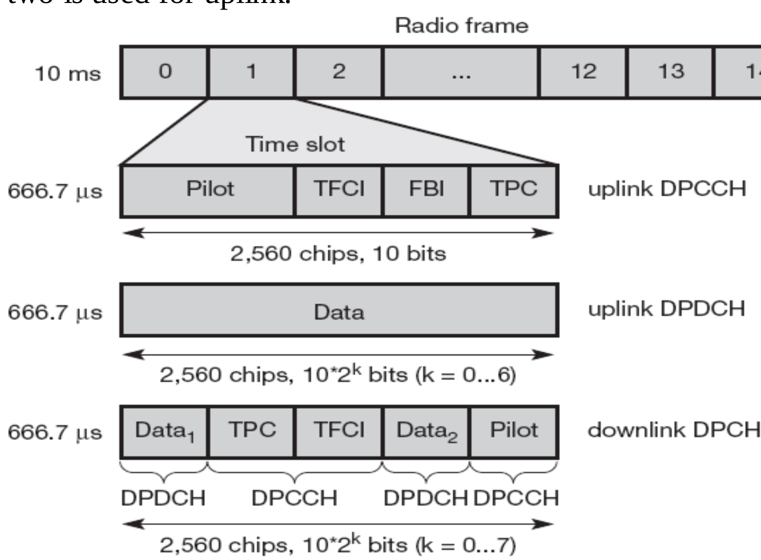

Fig. 2.21: UTRA FDD (W-CDMA) frame structure

Uplink Channels:

1) Dedicated Physical Data Channel:(DPDC)

- This channel conveys user/signaling data.
- The spreading facture is between 4&256.

2) Dedicated Physical control channel (DPCCH)

- In each connection layer 1 needs exactly one DPCCH.
- This channel conveys control data for the physical layer only.
- Spreading is constant at 256.
- The pilot is user for channel estimation.
- The transfer format combination identifies (TFCI) specifies the channels transported with in DPDCH.

- Signaling for the soft hand over is supported by the feedback information field (FBI).
- The last field transmit power control is used for controlling the transmission power of a sender.
- Power control is performed in each slot.

Downlink Channel:

Dedicated physical channel (DPCH):

- The down link time multiplexes control data and user data.
- Spreading factor is between 4&512.
- When no collision occurs on the down links, medium access on the uplink needs to be co-ordinate.
- Physical random access channel PRACH is used for this.
- User equipment UE starts with lowest available transmission power to avoid interfaces with other stations.
- If no positive acknowledgement is received UE tries with other slot.
- The number of available access slots can be defined per cell and is transmitted is a broadcast channel to UE.
- The UE has to perform the following steps during the search for a sale after power on.

1) Primary synchronization:

- The UE has to synchronize with the help of 256 primary synchronization codes.
- This code is same for all cells and helps to synchronize with the time slow structure.

2) Secondary synchronization:

- The UE receives a secondary synchronization code which defines the group of scrambling codes used in the cell. The UE is synchronized with the frame structure.

3) Identification of the scrambling code:

- The UE tries all scrambling codes within the group of codes to find the right code with help of correlate.
- Finally the UE can receive the data over broad cast channel.

2.6.5.2 UTRA-TDD (TD-CDMA)

- This mode UTRA-TDD separates up and downlink using a radio frame.
- 1 slot with 2560 chips per slot form a radio frame with duration of 10ms.
- Chipping rate is 3.84 M Chips/sec.

- **Types of frame**
  - Symmetrical
  - Asymmetrical.

Symmetrical (similarity in size, shape, etc):

- The frame contains same no of uplink and downlink slots.

Asymmetrical:

The frames can be in arbitrary combination. The frame can have only one switching point from uplink to down link.

Frame Structure:

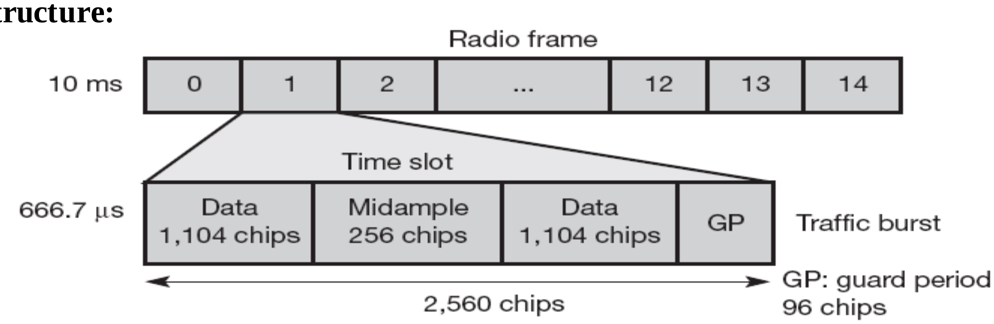

Fig 2.22: UTRA TDD (TD-CDMA) frame structure

Data rates can be 6,624/3,312/1,656/828/414kBPs.The above figure shows type 2 burst.

Explanation:

Data:

1. 2 data fields 1,104 Chips each.
2. Spreading is applied to the data fields only.

Midample:

This field is used for training and channel estimation.

GP: Guard Period.

The stations must be tightly synchronized and the spreading are available once per slot as it uses TDD and same scrambling code for all station. The GP is used to loosen the synchronization.

2.6.6 UTRAN

The following figure shows the architecture of UTRAN.IT consists of

(1) Radio Subsystems RNS:

- RNS is controlled by RNC (Radio Network Controller).
- The RNS has many components called node B.
- RNC is equivalent to BSC, node B is that of BTS.
- RNC is connected to the Core Network (CN) is I_u.

(2) Node B

The node B controls several antennas which make a radio cell via FDD/TDD. The Mobile device UE can be connected to one or more antenna.

- Node B is connected to RNC via Iub.
- Task of node B is the inner loop power control to mitigate near and far effects.

- Node B supports a special handover called softer handover.

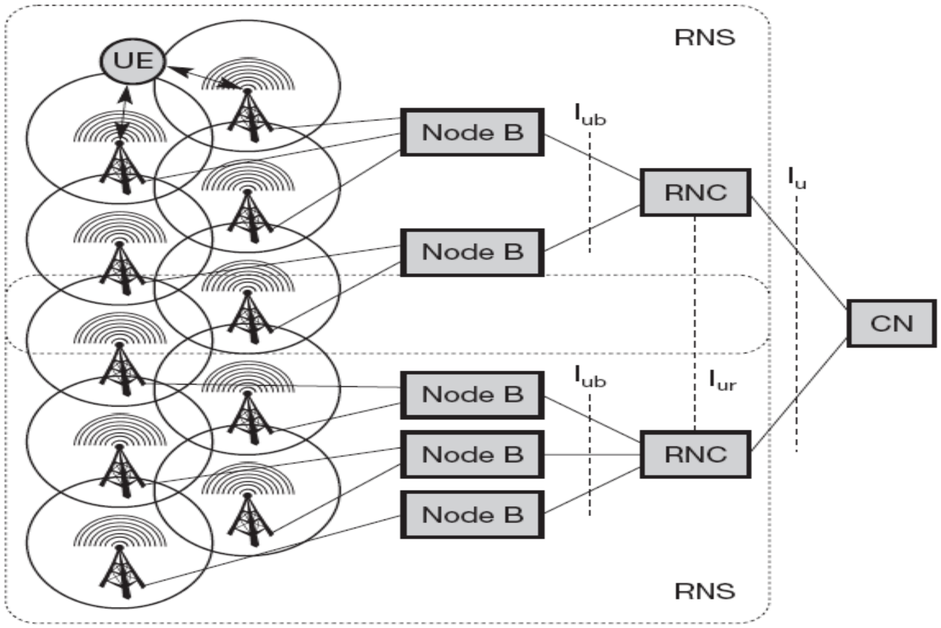

Fig. 2.23: Basic architecture of the UTRA network

(3) User Equipment:
UE is the nodes.

Functions

i. Perform signal quality measurement.
ii. UE has to co-operate during handover and cell selection, encryption/decryption, resource allocation process
iii. Implements mobility management, bearer negotiation function.

Functions of RNC:
(1) Call Admission Control:

RNC calculates the traffic within each cell and decides if additional traffic is acceptable or not.

(2) Congestion Control:

RNS allocates bandwidth to each station in a cyclic fashion and considers QoS.

(3) Encryption and Decryption:

RNC encrypts all data arriving the PSTN before transmission on Wireless Network.

(4) ATM Switching and Multiplexing, Protocol Conversion:

- The Connection are based on ATM.
- RNC has to switch the connections to multiplex the data.

(5) Radio Resource Control:

RNC control a radio resources connected to the cells in a node B.

(6) Radio Bearer Setup and Release:

RNC has to setup, maintain, and release logical data connection to UE.

(7) Code Allocation:

CDMA codes used by UE are selected by RNC.

(8) Power Control:

RNC performs a loose power control

(9) Handover Control and RNS Relocation:

- Depending on the signal strength, on UE, node B, the RNC decides if handover is needed or not.
- If the UE moves out of range of one RNC, a new RNC is needed. This is called RNS Relocation.

(10) Management:

The RNC assesses the current load, current traffic, error state to manage the network.

The UTMS Network can operate in

(i) Circuit Switched Domain (CSD)- has the Classical Circuit Switching Services.

(ii) Packet Switched Domain (PSD)- Packet Switching services.

2.6.7. Protocol Stack for CSD and PSD

CSD Protocol Stack:

- This uses the ATM adaptation layers AAL2 for user data transmission.
- RNC implements the RLC and MAC layer.
- Physical layer is located in node B.
- SAR- Segmentation and reassembly layer SAR is used to segment and reassemble.

PSD Protocol Stack:

- Here more protocols are needed.
- Data transport is performed by lower layer.
- All the packets destined for UE are encapsulated using GPRS tunneling protocol.
- RNC performs protocol conversion from GTP/UDP/IP to packet data convergence protocol PDCP.
- The radio layer is the physical layer depends on UTRA mode.
- MAC layer co-ordinates medium access and multiplex the logical channel on to transport channel.
- The MAC layer does encryption.

Radio Link Control RLC:

Offers three different transport mode viz.

(1) Acknowledged Mode:

- Transfers data using ARQ for error detection.

- Guarantee one time, in order delivery.

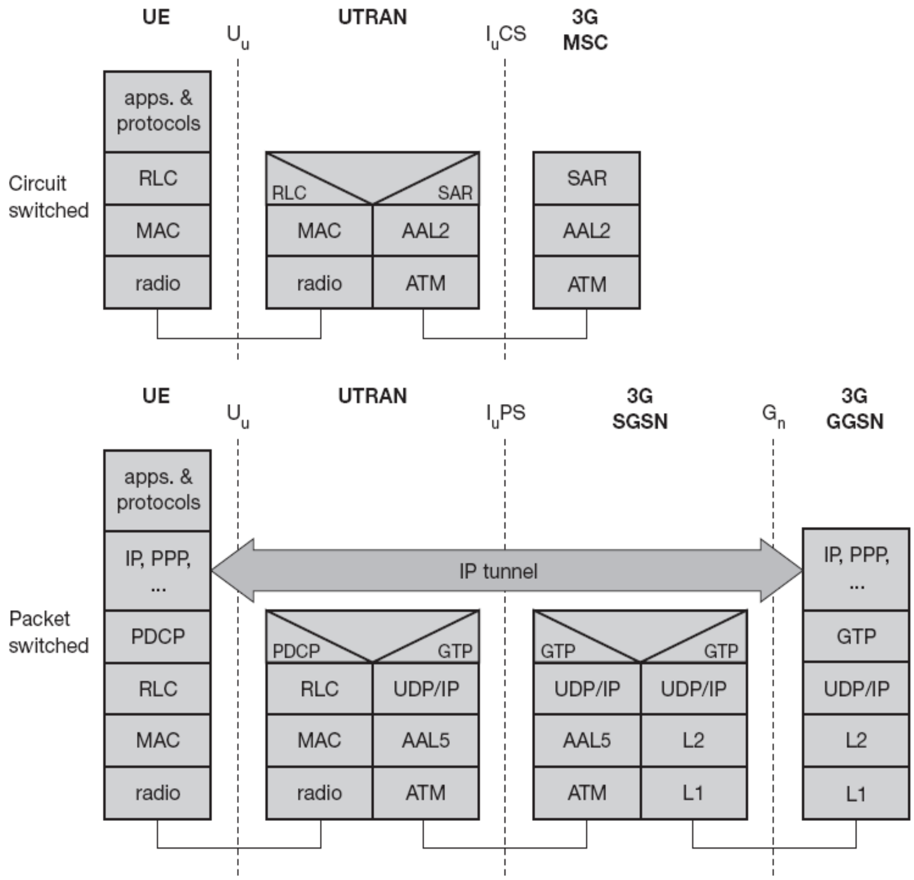

Fig. 2.24: Protocol stack

(2) Unacknowledge Mode:
- Transfers data without ARQ.
- Guarantees atleast one time delivery with the help of sequence nos.

(3) Transparent Mode:
- Transfers the data without processing.
- Relies upon FEC used in radio layer.

2.6.8 Handover
UMTS has 2 classes of handover

(1) Hard Handover:
- Switching between different antenna/system is performed at a certain point of time.
- UTRA supports this type only.
- Inter frequency handover, Inter System, Inter satellite handover are hard handover.

InterFrequency Handover:
- Change the carrier frequency.

Intersystem Handover:

- Handover from one GSM system to other system.

Intersegment Handover:

- Satellite handover is called Inter Segment handover.

(2) Soft Handover: Here the nodes receive the signals from many stations whereby making the handover soft.

- This Mechanism is present only in FDD mode and only in UMTS.
- Soft handovers use macro diversity a property of CDMA.

Micro Diversity:

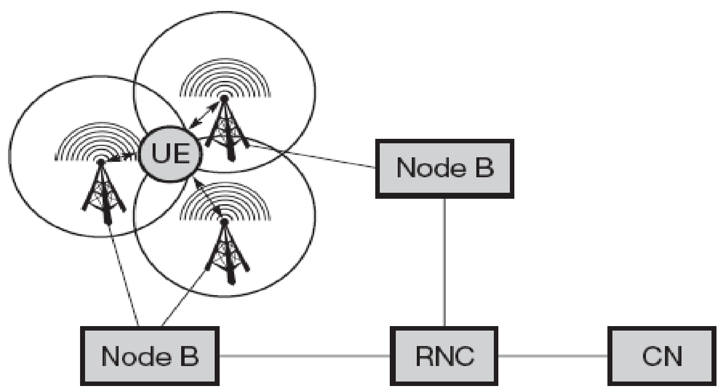

Fig. 2.25: Macro-diversity supporting soft handovers

- UE can receive signals from upto three antennas which may belong to different node 3.
- The UE combines the received data.
- In other direction UE sends the Data which is received by all node B involved.
- RNC combines the data stream received from node B.
- UE receives data from different antenna at the same time makes a handover soft.
- Moving from one cell to another is smooth.

2.6.9 Handover Types in UMTS

1) Intra Node B, Intra RNC:

- UE1 moves from one antenna of node B1 to another antenna.
- This handover is called soft handover.

2) Inter Node B, Intra RNC:

- UE2 moves from node B1 to node B2.
- RNC1 supports the soft handover by combining and splitting data.

3) Inter-RNC

When UE3 moves from node B2 to node B3 Two types of handover can take place

(i) Internal Inter RNC Handover:

- This is not visible for CN.
- RNC1 can act as SRNC , RNC2 will be DRNC.
- CN communicate via I_u.

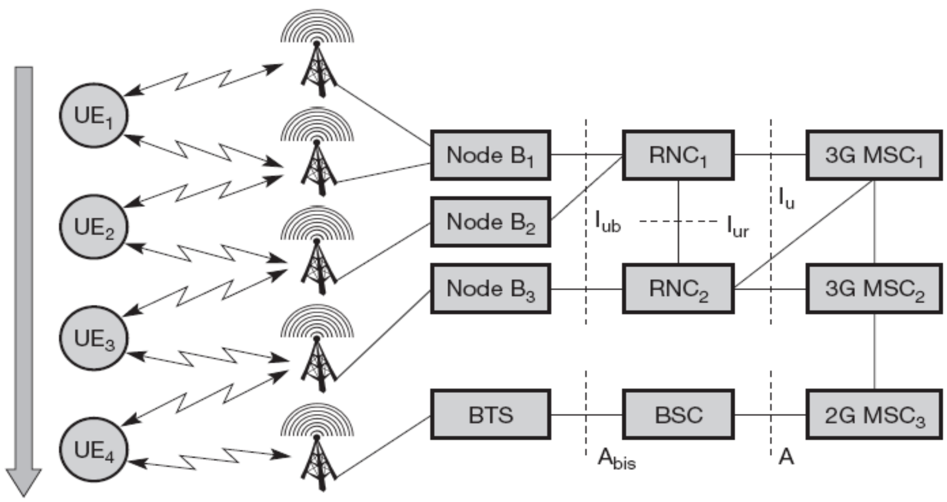

Fig. 2.26: Overview of different handover types

(ii) External Inter RNC Handover:

- As soon as the relocation of the interface Iu takes place the handover is called external Inter RNC handover.
- Communication is by the same MSC1 but handover is hard handover.
- UE4 moves from a 3G UMTS to a 2G GSM network.
- The handover is hard hand over.
- Real time usability.

2.7 SATELLITE COMMUNICATIONS

2.7.1 Satellite-Related Terms

- Earth Stations –antenna systems on or near earth
- Uplink-transmission from an earth station to a satellite
- Downlink-transmission from a satellite to an earth station.
- Transponder-electronics in the satellite that convert uplink signals to downlink signals.

2.7.2 Ways to Categorize Communications satellites

- Coverage area
  - Global, regional, national
- Service Type
  - Fixed service satellite (FSS)
  - Broadcast service satellite (BSS)
  - Mobile service satellite (MSS)
- General usage
- Commercial,military,amateur,experimental

2.7.3 Classification of Satellites

- Circular or elliptical orbit
    - Circular with center at earth‟s center
    - Elliptical with one foci at earth‟s
- Orbit around earth in different planes
    - Equatorial orbit above earth‟s equator.
    - Polar orbit passes over both poles.
    - Other orbits referred to as inclined orbits.
- Altitude of satellites
    - Geostationary orbit (GEO)
    - Medium earth orbit (MEO)
    - Low earth orbit (LEO)

2.7.4 Geometry (pure mathematics) Terms

- Elevation angle-the angle from the horizontal to the point on the center of the main beam of the antenna when the antenna is pointed directly at the satellite.
- Minimum elevation angle.
- Coverage angle-the measure of the portion of the earth‟s surface visible to the satellite

2.7.5 Minimum Elevation Angle

- Reasons affecting minimum elevation angle of earth station‟s antenna(>0^0).
    - Buildings, trees, and other terrestrial objects block the line of sight.
    - Atmospheric attenuation is greater at low elevation angles.
    - Electrical noise generated by the earth‟s heat near its surface adversely affects reception.

2.7.6 GEO Orbit

- Advantages of the GEO orbit
    - No problem with frequency changes
    - Tracking of the satellite is simplified
    - High coverage area.
- Disadvantages of the GEO orbit
    - Weak signal after traveling over 35,000km
    - Polar regions are poorly served
    - Signal sending delay is substantial.

2.7.7 LEO Satellite Characteristics

- Circular/slightly elliptical orbit under 2000km
- Orbit period ranges from 1.5 to 2 hours.
- Diameter of coverage is about 8000 km
- Round-trip signal propagation delay less than 20 ms
- Maximum satellite visible time up to 20 min
- System must cope with large Doppler shifts
- Atmospheric drag results in orbital deterioration.

2.7.8 Little LEOs and Big LEOs

Little LEOs

- Frequencies below 1 GHz
- 5MHz of bandwidth
- Data rates up to 10 kbps.
- Aimed at paging, tracking, and low-rate messaging

Big LEOs

- Frequencies above 1 GHz
- Support data rates up to a few megabits per sec
- Offer same services as little LEOs in addition to voice and positioning services

2.7.9 MEO Satellite Characteristic

- Circular orbit at an altitude in the range of 5000 to 12,000 km
- Orbit period of 6 hours
- Diameter of coverage is 10,000 to 15,000 km
- Round trip signal propagation delay less than 50 ms
- Maximum satellite visible time is few hours

2.7.10 Frequency Bands Available for Satellite Communications

Band	Frequency Range	Total Bandwidth	General Application
L	1 to 2 GHz	1 GHz	Mobile satellite service(MSS)
S	2 to 4 GHz	2 GHz	MSS, NASA, deep space research
C	4 to 8 GHz	4 GHz	Fixed satellite services(FSS)
X	8 to 12.5 GHz	4.5 GHz	FSS military, terrestrial earth exploration, and meteorological satellites
Ku	12.3 to 18 GHz	5.5 GHz	FSS. Broadcast satellite service (BSS)
K	18 to 26.5 GHz	8.5 GHz	BSS, FSS
Ka	26.5 to 40 GHz	13.5 GHz	FSS

2.7.11 Satellite Link Performance Factors

- Distance between earth station antenna and satellite antenna.
- For downlink, terrestrial distance between earth station antenna and "aim point" of satellite.
- Displayed as a satellite footprint(figure2.27)
- Atmospheric attenuation
- Affected by oxygen, water, angle of elevation, and higher frequencies

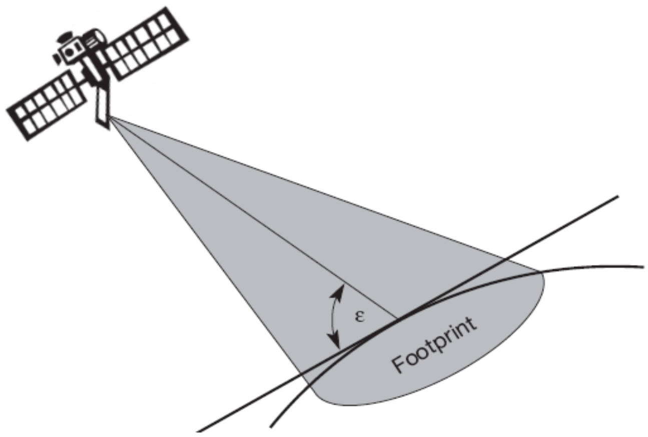

Fig. 2.27: Typical satellite footprint

2.7.12 Capacity Allocation Strategies

- Frequency Division Multiple Access (FDMA)
- Time Division Multiple Access (TDMA)
- Code Division Multiple Access (CDMA)

2.7.13 Frequency-Division Multiplexing

- Alternative uses of channels in point to point configuration
  - 1200 voice-frequency(VF) voice channels
  - One 50-Mbps data stream
  - 16 channels of 1.544 Mbps each
  - 400 channels of 64 kbps each
  - 600 channels of 40 kbps each
  - One analog video signal
  - Six to nine digital video signals.

2.7.14 Frequency Division Multiple Access

- Factors which limit the number of subchannles provided within a satellite channel via FDMA
  - Thermal noise
  - Intermodulation noise
  - Crosstalk

2.7.15 Forms of FDMA

- Fixed- assignment multiple access (FAMA)
  - The assignment of capacity is distributed in a fixed manner among multiple stations
  - Demand may fluctuate
  - Results in the significant underuse of capacity
- Demand Assignment Multiple Access (DAMA)

- Capacity assignment is changed as needed to respond optimally to demand changes among the multiple stations.

2.7.16 FAMA-FDMA

- FAMA-multiple stations access the satellite by using different frequency bands
- Uses considerable bandwidth

2.7.17 DAMA-FDMA

- Single channel per carrier (SCPC)-bandwidth divided into individual VF channels
  - Attractive for remote areas with few-user stations near each site
  - Suffers from inefficiency of fixed assignment
- DAMA-set of sub channels in a channel is treated as a pool of available links
  - For full-duplex between two earth stations, a pair of sub channels is dynamically assigned of demand
  - Demand assignment performed in a distributed fashion by earth station using CSC

2.7.18 Reasons for Increasing Use of TDM Techniques

- Cost of digital components continues to drop
- Advantages of digital components
  - Use of error correction
- Increased efficiency of TDM
  - Lack of inter modulation noise

2.7.19 FAMA-TDMA Operation

- Transmission in the form of repetitive sequence of frames
  - Each frames is divided into a number of time slots
  - Each slot is dedicated to a particular transmitter
- Earth stations take turns using uplink channel
  - Sends data in assigned times slot
- Satellite repeats incoming transmission
  - Broadcast to all stations
- Stations must know which slot to use for transmission and which to use for reception

2.7.20 General Application of satellites

1. Weather Forecasting,
2. Radio and TV Broadcast Satellites
3. Military Satellites,
4. Satellite for Navigation

Applications related to mobile communication

1. **Global Telephone Backbones international:** The satellites are used for telephonic communication.

2. **Connections for Remote or Developing Areas:** Due to their geographical locations many places do not have direct wired connection to the telephone network. Satellites offer a simple and quick connection to the network.

3. **Global mobile communication:** satellites support global mobile data communication.
   The reason for the usage of satellites is to extend the coverage area. The towers cannot be set up in all parts of the country due to cost. Hence when satellites are used the mobile phones can switch to satellites.

   Satellites system for global mobile telecommunication system.

   Every satellite has its own coverage area called footprint. Within the coverage area the satellite can do communication. For the mobile they communicate via Mobile uses Link (MUL). The gateway is connected to the satellite via Gateway Link (GWL).
   The satellites can communicate among themselves via Inter Satellite Link (ISL).

2.7.21 Classification of satellites Orbits:

(1) Geo stationary or Geosynchronous Earth Orbit (GEO).
Distance covered: 36,000 km to earth.
Used in TV Broadcast, weather, radio satellites.

(2) Medium Earth Orbit (MEO).
Distance covered: 5000-12,000 km.

(3) Low Earth Orbit (LEO).
Distance covered: 500 to 1500 km.
Used in espionage.

(4) Highly Elliptical Orbit (HEO).
This class has all the satellite which does not take circular orbits.
Used to improve communication quality.

2.7.22 GEO

Distance = 35,786 km. **Example:** Inmarsat

Advantages:

- Can cover any on the earth.
- Senders and receivers use fixed antenna positions. Hence no adjusting is needed.
- Lifetime is about 15 years.
- Does not need handover due to large footprint.
- Does not exhibit Doppler shift because relative movement is zero.

Disadvantages:

- Northern or southern regions have problems in receiving due to low elevation above the latitude of 60o.
- Transmit power needed is high. Hence cannot be used for low/battery powered devices.

- High latency needed.
- The frequency cannot be reused due to large footprint.
- Transferring GEO into orbit is expensive.

2.7.23 LEO

- Circulate on a lower orbit.
- Duration is 95 to 120 minutes.
- High elevation for every spot hence high quality communication link.
- Visible on earth for 10 minutes only

Classification

(1) Little Leo: Has low bandwidth 100 b/s.
(2) Big Leo: 1,000 bits/sec.
(3) Broadband: Some MBPs.

Advantages

- Transmission rate 2400 bits/sec.
- Low transmit power (1 W).
- Delay for packet delivery is low i.e., 10 ms.
- Smaller footprint hence frequency reuse is possible.
- Higher elevation to polar regions, hence better global coverage.

Disadvantages

- Needs many satellites to cover the earth.
- Due to short time visibility with high elevation needs additional mechanism for handover between satellites.
- Lifetime is 5 to 8 years.
- Low latency.
- Factors are needed for inter-satellite routing. Example: Global star, Iridium.

2.7.24 MEO:

Positioned between LEO and GEO.

Advantages:

- As the orbit is 10,000km needs a dozen satellite to cover the earth.
- Movement is relatively low (6 hours).
- Coverage is high, hence few handover.

Disadvantages:

- Due to larger distance delay is 70-80ms.
- Satellites need high transmit power.

2.7.25 Routing

The figure has satellite system with gate ways and fixed terrestrial networks. The system has to route data from one user to another user.

Routing on earth is done as usual. Routing on satellite has two alternatives:

Alternate 1: If the satellites offer ISL then the traffic can be routed between satellites.

One user sends data up to a satellite and the satellite forwards it to another satellite which has the receiver. Here there is only one uplink and one downlink.

Advantages: Reduce the no. of gateways needed on earth.

Disadvantages: High complexity due to additional antenna.

Alternate 2: If the ISL is not offered then the traffic is routed to earth and delayed back to satellite.

The user sends data to a satellite but this satellite does not offer ISL hence forwards the data to the gateway on earth. Routing is done as usual on the fixed network.

Now the data is send up to the satellites which forwards to the receiver.

- Needs two uplinks and two downlinks.

2.7.26 Handover:

There are four types of handover in satellite system.

(1) Intra Satellite Handover:

The user moves from one spot beam to another spot beam of the same satellite.

The spot beam can be created by using special antenna. When the satellite moves the same effect is caused.

(2) Inter Satellite Handover:

When a user leaves the footprint of a satellite (or) when the satellite moves away, this type of handover takes place. Inter satellite handover takes place if they support ISL.

(3) Gateway Handover:

When the mobile and satellite have contact, but the satellites moves away from the current gateway, this type of handover takes place.

(4) Inter System Handover:

This type of handover takes place between different systems. Switching between satellite system and cellular system.

2.7.27 Comparison of Satellites

	Irdium (orbiting)	Globalstar (orbiting)	ICO (planned)	Teledesic (planned)
No. of satellites	66 + 7	48 + 4	10(?) + 2	288(?)
Altitude [km] coverage	780 global	1,414 ±70° latitude	10,390 global	Approx. 700 global
No. of planes	6	8	2	12
Inclination	86°	52°	45°	40°
Minimum elevation	8°	20°	20°	40°
Frequencies [GHz (circa)]	1.6 MS 29.2 ↗ 19.5 ↙ 23.3 ISL	1.6 MS ↗ 2.5 MS ↙ 5.1 ↗ 6.9 ↙	2 MS ↗ 2.2 MS ↙ 5.2 ↗ 7 ↙	19 ↙ 28.8 ↗ 62 ISL
Access method	FDMA/TDMA	CDMA	FDMA/TDMA	FDMA/TDMA
ISL	Yes	No	No	Yes
Bit rate	2.4 kbit/s	9.6 kbit/s	4.8 kbit/s (144 kbit/s planned)	64 Mbit/s ↙ 2/64 Mbit/s ↗
No. of channels	4,000	2,700	4,500	2,500
Lifetime [years]	5–8	7.5	12	10
Initial cost estimate	$4.4 bn	$2.9 bn	$4.5 bn	$9 bn

Fig. 2.28: Comparison of Satellites

2.8 Overview Of Communication Systems

The communication systems are of two kinds

(1) Symmetric.
(2) Asymmetric.

Symmetric Communication System:

- The symmetric communication systems are those which offer same transmission capabilities in both directions.
- The symmetry is needed in telephone services.

Asymmetric Communication System:

- The asymmetric system is those which do not offer same transmission capabilities in both directions.
- Special one is unidirectional broadcast system.
- Example client server environment, television, radio, pagers.

2.8.1 Broadcast Transmission:

- All the scenario packets are transmitted via broadcast to all receivers.
- The receivers need to pick up the needed packets and discard the unwanted.
- Hence the additional function needed is to personalize the distribution depending upon the individual requirement and application.

Example:

- A radio in a car should present the traffic scenario and filter the unwanted information.
- The same user prefers films songs in the night.
- Hence the sender faces the problems of which information to send at what time.
- The solutions to the above said problems are

2.8.2 Cyclical Repetition of Data:

- A broadcast sender does not know when a receiver will start to listen the transmission.
- In the case of radio/TV the transmission has to be repeated giving a chance for the receivers to receive the information.
- The cylindrical repetition of data block sent via broadcast is called broadcast disks.
- This can be explained with an example. The sender repeats 3 data blocks A,B,C in a cycle.

There are different broadcast patterns.

(i) Flat Disk:

- Here all the blocks are repeated in order.
- Every block is transmitted for equal amount of time.
- The average waiting time for receiving the block is same.

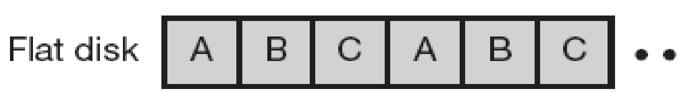

Fig. 2.29: Different broadcast patterns

(ii) Skewed (Turn at an angle)Disks:

- This method favour or more data block.
- Thus repeating them once or several times.
- The probability of all the three blocks is not the same.

Fig. 2.30: Skewed Disks

(iii) Multi Disks:

- Distribute the blocks that are repeated more often than others evenly over cyclic pattern.

Fig.2.31: Multi Disk

- In all the above three methods it is possible to optimize the pattern if the sender knows the content of the data block and the access patterns of the users.
- The receiver should cache the data block in order to minimize the delay.
- To do so the receiver needs to know the content of the data block.
- The receiver should know the access pattern of the user which is difficult.

2.8.3 Digital Audio Broadcasting: DAB

- DAB systems use single frequency networks (SFN). (i.e.) all the senders transmitting the same radio program operate at the same frequency.
- SFN is frequency efficient because single station needs one frequency throughout the country.
- But DAB systems are prone to interference and multipath propagation effects.
- DAB uses DQPSK modulation scheme.
- DAB uses COFDM, for error control FEC is used and guard spaces are there between blocks.
- Transport mechanisms used are

(1) Main Service Channel:

- The MSC carries all user data. (i.e.) audio, multimedia data etc.
- MSC has common interleaved frame (CIF), data fields of 55,296 bits are sent at 24ms.Hence the data rate is 2.3MB/sec.
- CIF has capacity units which has 64 bits, which forms the smallest addressable unit in DAB.

(2) Fast Information Channel:

- FIC has FIB (Fast Information Blocks).
- Each block is 256 bits with 16 bit checksum.
- FIC is used to carry control information.

Modes of Transfer:

- There are two transport modes for data transmission. They are

(1) Stream Mode:

- This mode offers transparent data transmission from source to destination.
- The transfer rate is fixed in the multiples of 8 in sub channels.
- The sub channels have many CU and a CIF.

(2) Packet Mode:

- This mode transfers data in addressable blocks.

- These blocks are used to convey MSC data within a sub channel.

Services:

- DAB offers many services.
- The services are the information which comes along with audio stream.
- The services are stored in program associated data. The PAD has the program information control information etc.

Frame Structure of DAB

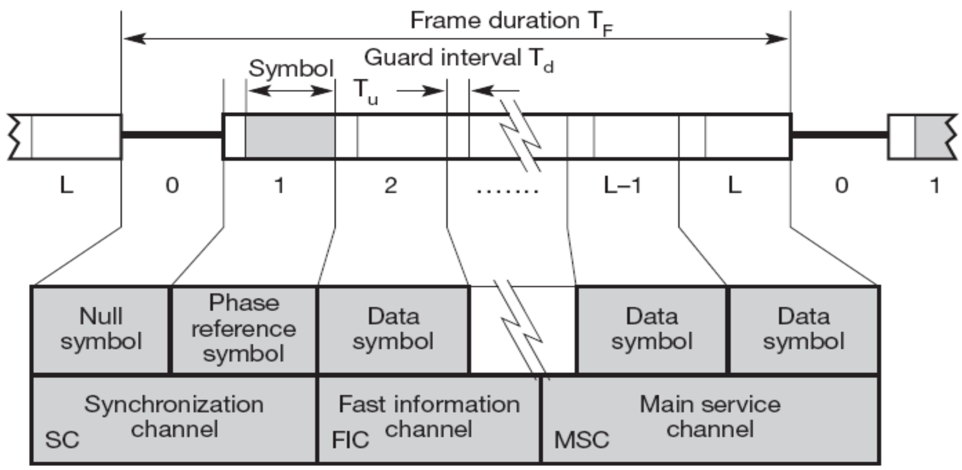

Fig. 2.32: DAB frame structure

- The duration of frame can be 24/48/96 ms.
- DAB has 4 transmission modes.
- within each frame 76/156 symbols are transmitted using carriers of 192/384/768/1536 for COFDM.
- The guard intervals can be 31/62/123/246 microseconds.
- The frame has 3 parts

  (i) Synchronization channel.
  - Marks the star of the frame.
  - Used for synchronization

  ii) Fast Information Channel.
  - Contain the control data.

  iii) Main Service Channel.
  - Contains the audio and data service components.

2.8.3.1 DAB Sender

- Audio is encoded using MPEG compression and coded for transmission. (FEC)
- The data services are multiplexed and coded with redundancy.

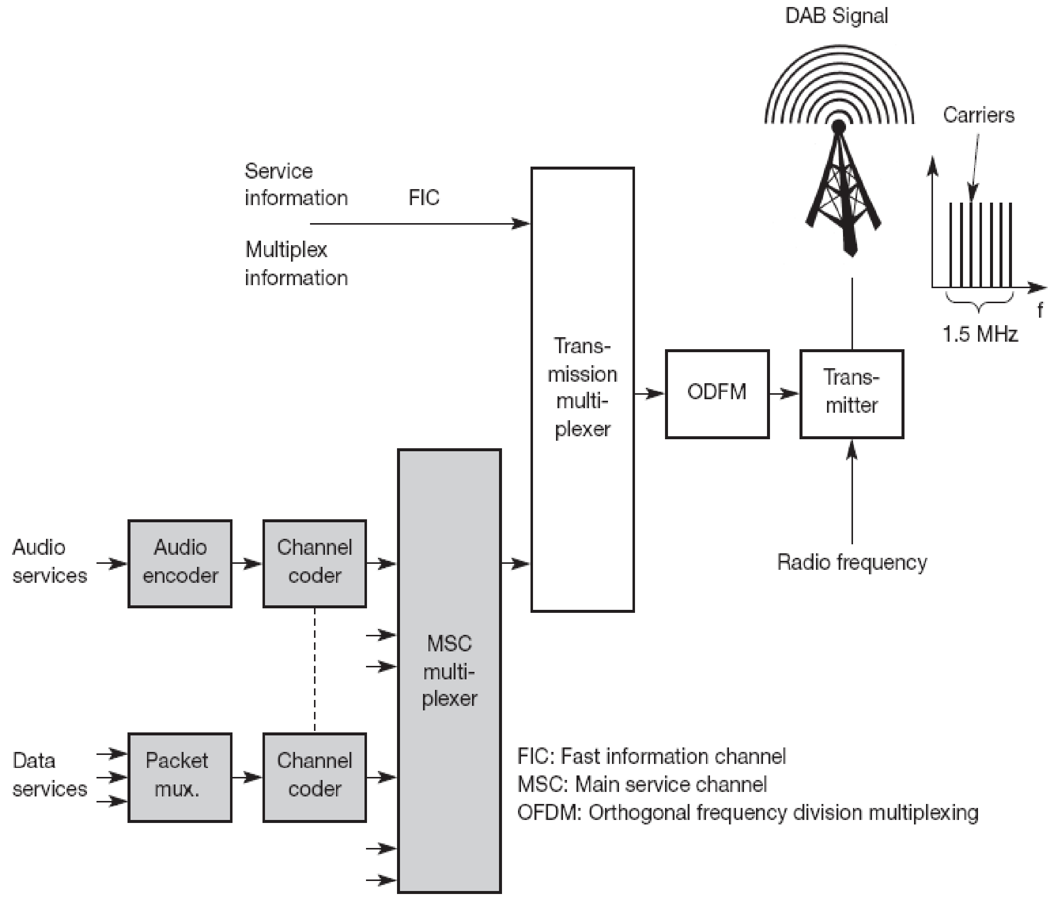

Fig. 2.33: Components of a DAB sender (simplified)

- The MSC multiplexer combines the above 2 and forwards to the transmission multiplexer.
- The transmission multiplexer creates the frame by interleaving FIC.
- Finally OFDM coding is applied and the output is DAB which is transmitted.

2.8.3.2 Allocation of Channels

- The DAB does not need fixed allocation of the channel.
- It can be dynamic.
- In the following figure there are 6 programs
- Each program has its PAD.
- 1, 2, 3 have high quality, 4, 5, lower and 6 the least quality.
- The DAB multiplexer dynamically interleaves the data from all different sources.
- This needs to be informed to the receiver. The FIC sends multiplexer configuration information MCI to the receiver.
- In reality the receivers will have different receiver capabilities.
- This is a problem for DAB.

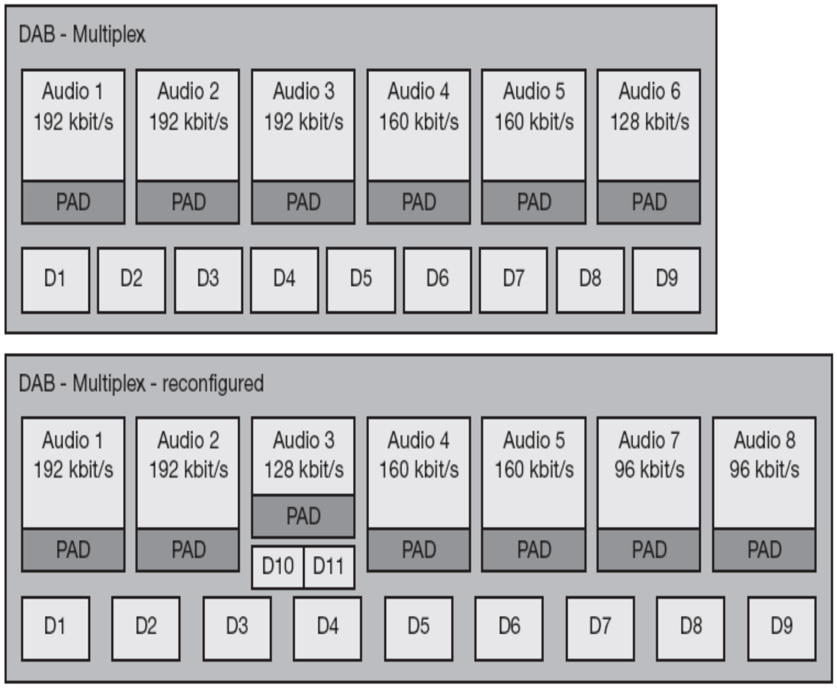

Fig.3.34: Dynamic reconfiguration of the DAB multiplexer

- To solve the above problem a protocol is defined which is called as multimedia object transfer protocol.
- The goal of the protocol is to support data formats used in multimedia systems.
- MOT data is transferred in MOT object is the format for MOT data.

Fig.2.35: Format of MOT

Header Core:

- This is 7 byte information.
- This contains the size of the header, body and the type of the object.
- Based upon this information the receiver will decide the necessary resources to process the object

Header Extension:

- This field is variable in size.
- This contains additional information needed to handle the object. (e.g.) Reception, caching etc.

Body:

- Arbitrary data can be transferred in the body.
- This field is of variable in length.

  When the objects are larger they are segmented. To each segment the DAB can apply different interleaving and reception schemes.

Reception Schemes:

There are 4 reception schemes.

(i) Object Reception:

- Here the object is repeated several times.
- If the object A has 4 segment A_1, A_2, A_3, A_4 they are repeated as A_1, A_2, A_3, A_4, A_1, A_2, A_3, A_4, ...

(ii) Interleaved Objects:

- This is used to avoid burst error problems.
- Here segments of different objects are interleaved test A_1 B_1 C_1 A_2 B_2 C_3 C_2 A_3 B_3 C_3.

(iii) Segment Repetition:

- The important segments are repeated.
  (e.g.) A_1 A_1 A_2 A_2 A_3 A_3 A_4 A_4, ...

(iv) Header Repetition:

- Here the header is repeated if the receiver cannot receive the header of MOT.
  (e.g.) HA_1 A_2 HA_3 A_4 HA_5 A_6, …. .

2.8.4 Digital Video Broadcasting:

The goal of DVB is to broadcast digital television using satellite.
The main component needed for DVB are shown in figure

(1) The integrated receiver codes

This is the center point. This is connected to the high resolution monitor.
This can receive the dVB signals via satellites, etc.

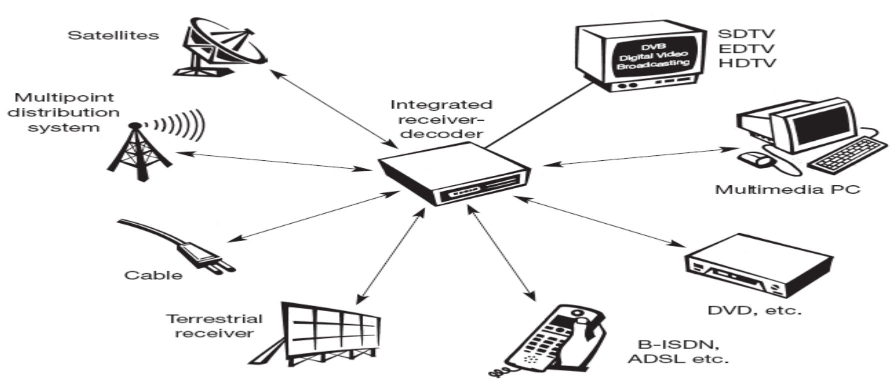

Fig.2.36: Digital Video Broadcasting Scenario

- The DVB transmits data using flexible containers.
- The information is not restricted.
- The contents, can be

(1) Network Information Table:
This table has the list of services of a provider and additional information for set top boxes.

(2) Service Description Table:
This table has names and parameters for each service.

(3) Event Information Table:
This table contains status information about the current transmission and additional information for set top boxes.

(4) Time and Date Table:
Contains update information for set top boxes.

2.8.4.1 DVB Data Broadcasting

ETSI defines several profiles for data broadcasting. They are:

(1) Data pipe:
Simple, asynchronous, end to end delivery of data. Data is directly inserted to pay load of MPEG2 packets.

(2) Data streaming:
Stream oriented, asynchronous synchronized with other stream end to end delivery of data.

(3) Multiprotocol Encapsulation:
Transport arbitrary data on top of MPEG2.

(4) Data Carousels:
Periodic transmission of data.

Object Carousels:

- Periodic transmission of objects.
- Platform independent.
- Compatible with other object broker.

2.8.4.2 DVB Uses

- DVB can be used for high speed, bandwidth, a symmetrical-internet access.
- The main advantage is that
  Information transmitted along with TV programs using free space in the transmitted data. Hence additional lines are not needed.
- The disadvantage is that shared medium satellite.
- Bandwidth is shared.
- Compromise on QoS.