MC, 8th ISE

MOBILE COMPUTING

UNIT 1

MOBILE DEVICES AND SYSTEMS, ARCHITECTURES

UNIT 1: SYLLABUS:

MOBILE DEVICES AND SYSTEMS, ARCHITECTURES: Mobile phones, Digital Music Players, Handheld Pocket Computers, Handheld Devices, Operating Systems, Smart Systems, Limitations of Mobile Devices, Automotive Systems.

GSM–Services and System Architectures, Radio Interfaces, Protocols, Localization, Calling, Handover, General Packet Radio Service.

(8 Hours)

1.1MOBILE PHONES

Mobile phones communicate with other phones using cellular services provider network. Mobile phones can synchronise, upload and download data to and from PCs. It provides email and Internet connectivity and can be used to send faxes too. It includes *Personal Information Manager (PIM)*, a handheld computer, and an entertainment device.

1.1.1 Smartphones and Multimedia

Smartphones have the functionalities of mobile phones plus several advanced functions.

FEATURES OF SMARTPHONES:

- A GSM, CDMA, or tri-band wireless radio interface to a cellular network provided by a mobile service provider.
- A smart T9 keypad.
- A small area LCD display.
- Provides applications such as phone diary,address book,task list,calculator,alarm and calendar.
- Ability to send and receive SMS messages of upto 160 characters,MMS.
- WAP wnabled Web pages access, download, and other Web-based applications through a WAP gateway or proxy.
- Provisions for games, e-commerce, and e-ticketing.
- Bluetooth communication with PCs and the neighbouring devices.
- Integration of location information.

1.1.1.1 Multimedia Phones

A multimedia phone (multiphone) offers multimedia functionalities like playing of MP3 format audio and MP4 format video files, Camera and video-recording facilities etc. Another popular application of multimedia phones is mobile gaming. The *Nokia N-Gage* is an example of a gaming-oriented phone. The Nokia N-series phones are designed to perform specific multimedia functions. The N91 belongs to this series and focuses on music and media playing.

FEATURES of N91 :

- GSM/GPRS EDGE 900/1800/1900 MHz connectivity.
- Advanced voice calling functions such as an integrated handsfree speaker, voice dialling, voice recording, and conference calling.
- Up to 4 GB of internal dynamic memory for multimedia functions and an additional 30 MB for storing calendar,contacts, and text messages.
- A music player optimised for listening to music.
- External speakers using a stereo audio jack.
- FM radio and visual radio.
- 2 Megapixel camera for video recording and still pictures.
- PIM for managing features such as calendars, contacts, task lists and PIM printing.
- WLAN 802.11b/g for hotspot connectivity, Bluetooth version 1.2 for wireless connectivity and XHTML browser for Internet browsing.
- Nokia PC suite to synchronise data with the PC using a USB port or Bluetooth.
- Battery with a digital talk time of upto 4 hours and standby time of up to 7.9 days.

1.1.2 Cellular Networks for Mobile Phones

- A mobile service region is divided into *cells*. Each cell has a base station with cell boundaries defined by the coverage area.
- A base station functions as an access point for the mobile services.
- Mobile device within a base station communicates through the base station only.
- Each cell has cells adjoining it in various directions. Adjacent cells have distinct frequencies. This avoids *interference* between the signals transmitted by different cells.
- Interference takes place when the frequencies are equal or integral multiples of each other.
- The base stations connect among themselves through either guided (wire or fibre-based) or wireless networking.
- A station can also connect to a *Public Switching Telephone Network (PSTN).*

- A *multi-cell cellular network* entails that when the transceivers move from place to place, they will also have to switch from cell to cell. When a mobile device moves and reaches a cell boundary, there is *handoff* by a station. Switching on to next cell occurs by *handover* of the device connection to the neighbouring base station.

1.1.3 Apple iPhone

The iPhone was announced in January 2007 by Apple CEO Steve Jobs. The iPhine brings together the features of an iPod, a Smartphone, a digital camera, and a handheld computer. It is a *multimedia and Internet-enabled mobile phone.*

FEATURES:

- It comes in two versions – 4 GB and 8 GB flash memory versions.
- It has wide, touch-sensative.3.5-inch display screen which has a resolution of 320 X 480 pixels at 160 pixels-per-inch display.
- A proximity sensor shuts down the display and touch screen when the phone is held to the ear.
- It incorporates *multi-touch* and a *virtual keypad.*
- The iPhone has only a single physical button, called *'home'*.
- It makes phone call by simply pointing the finger at a name or number in a call log, address book or favorites list. It automatically synchronises all contacts from PC, Mac or Internet service.
- A special phone-call feature automatically adjusts music volume with incoming phone calls.
- Allows conferencing, call holding, call merging and caller ID.
- Supports the Visual Voicemail feature.
- SMS text messaging here is similar to iChat.
- It seamlessly synchronizes data for the Internet HTML web browsing service and e-mail service and it works with any Mac or PC.
- It supports full iTunes integration.
- Supports SMS, calendar, photo, camera, calculator, charts, maps, weather, notepad, clock, settings, phone, mail, Web browsing, multimedia player and iPod.
- It connects to computer via 30-pin iPod dock connector or IEEE 802.11b/g WiFi or Bluetooth 2.0 capabilities.
- It runs on Mac OS X operating system.
- Supports data download upto 220 kbps and deploys quad-band GSM +EDGE phone.
- Supports 3G features.

1.2 Digital Music Players

Digital (mobile) music Players include software that play music files encoded in formats such as MP3, WMA, Realmedia,etc on mobiles, PCs and laptops. Realplayer, Window Media Player, QuickTime player, etc are some example of media-playing software. Some of digital medai file formats are MP3, AAC, WMA and WAV.

1.2.1 Apple iPod

The iPod family of devices includes flash-based players. The iPods have simple user interfaces and are mostly designed around a central scroll wheel.

FEATURES OF iPOD NANO WHITE:

- It stores 240 songs in 1 GB, 500 songs in 2 GB and 1000 songs in 4 GB version.
- It supports Apple audio communication by AAC files betwwen 16 kbps and 320 kbps.
- It has battery life of up to 14 hours for music playback and up to 4 hours for slide shows with music.
- It has a fast charging battery.
- It provides customised main menu to create multiple On-the-Go playlists,rate the songs, shuffle the songs, repeat one or all the songs, sleep timer etc etc.
- It supports MP3, VBR, WAV, and AIFF file formats. It supports JPEG file photo display and download. It syncs iPod-viewable photos in BMP, TIFF, PSD and PNG formats.
- It supports protected AAC files from the iTunes Music store. It supports audible formats.
- It supports Web browsing.
- It supports a calendar and task-to-do lists.
- It supports ear-bud headphones and a speaker phone.
- It has a ports dock connector, a stereo mini jack, a USB through dock connector, and a USB cable.

1.2.2 Popular Audio File Formats

Some popular audio file formats and their characteristics are:

(1) WAVE (Waveform audio) :

- This format is an audio format standard for storing audio.It is one of the methods for storing data in 'chunks'.
- It contains uncompressed audio in the PCM (pulse code modulation) format but they are also capable of holding compressed audio.
- It can be used for maximum audio quality and it can also be manipulated for storing compressed audio.
- It supports a variety of bit resolutions, sample rates and channels of audio.

(2) Real Audio:

- Developed by RealNetworks.
- It uses both low-bitrate formats for use over dialup modems and high fidelity formats for music.
- It can also serve as a streaming audio format which can be played while it is being downloaded.
- It is used by many Internet radio stations to stream their programs in real time.
- The officiall playing software for the realAudio file format is the RealPlayer.

(3) MP3 (MPEG audio layer 3):

- It is the most popular of the digital audio encoding and compression formats available today.
- It is designed to reduce the size of audio files to about 10% of the original uncompressed files without comprimising too much on sound quality. It became an ISO/IEC standard in 1991.
- PCM-encoded audio is represented using the MP3 format.
- It takes less space than straightforward encoding methods because it uses psychoacoustic models.

1.3Handheld Pocket Computers

How is handheld pocket computers different from Smartphone??

Handheld PCs are programmed for the customised applications. Unlike Smartphones, which usually use the text-on-nine keys format, handheld have the full text keypad or a touch screen keypad. A stylus is generally used to enter data into handheld devices such as PDAs and palmtops. Hnadheld computers may include qwerty keyboards.

What are palmtops?

Plamtops are programmable pocket computers. They include word processors and spreadsheet software as well as PIM software.

FEATURES OF HANDHELD PCs:

- Pocket PCs do not have CD drivessss and hard disks. Instead, they use flash memory.
- Clock speeds of pocket computer processors are limited up to 200 MHz due to considerations in battery life.
- They have specially designed operating systems which are scaled to the requirements of the software, hardware and peripherals used in handheld computers.

1.4 Handheld Devices : Operating Systems

These operating systems provide interfaces, perform allocation , and management functions and act as platforms for running the increasingly sophisticated software that are created for mobile computing devices.

1.4.1 Windows CE

Windows CE software is an operating system from *Microsoft.* It is designed to support *multitasking* on handheld devices.

FEATURES:

- High resolution colour/display, touchscreen and the stylus keypad.
- Complex APIs used which gives user a PC-like feel and windows-like GUI.
- PIM, MS Office, Internet explorer features on handheld mobile system.
- The CompactFlash card slots to extend memory and extenson card slots.
- OS memory requirement is large but scales to the requirement of the device peripherals.
- Built-in microphone for voice recording.
- USB port.
- Infrared port to communicate with mobile phones and external modems.
- Digital camera card.
- Games.
- Microsoft Windows media Player and other media players.
- ActiveSync for synchronizing mobile data with PC using a USB, serial port, PC infrared port or Ethernet LAN for interfacing.
- Needs high processor clock speed.

1.4.2 PalmOS

PalmOS is an operating system from palm Inc.

ADVANTAGES:

- It is optimised to support a very specific range of hardware.
- Performance is very finely tuned.

DISADVANTAGES:

- Inability to adapt to different sort of hardware.
- Does not support multitasking.
- Not a great platform for running multimedia applications.

FEATURES:

- Simple APIs compared to Windows CE.
- OS memory requirement is low.
- Needs lesser processor clock speed.

- PIM, address book, memo pad, SMTP email download, Internet browsing functions, Windows organizer etc.
- Allows Wireless communications like email, messaging, browsing etc.
- A cradle connects handheld devices to PCs.
- HotSync for synchronizing with PCs through a serial port or infrared port.
- Infrared port for communication with mobile phones and external modems.
- Extension card slots.
- PalmOS is compatable with Dragonball processor from Motorola.
- PalmOS can be integrated with GSM/CDMA cellular phones.
- Serves third party applications like games, travel and flight planner, calculators, graphic drawings, preparing slide shows etc.

PalmOne Tungsten T5 handheld uses the PalmOS has following features:

- Palm desktop software for both Windows and MAC and other essential software.
- 256 MB internal flash memory.
- Expansion slot that supports MMC, SD memory card, and SDIO (Secure digital input/output) memory card.
- Doubles as a flash drive that enables quick drag and drop of files from a PC to the handheld device.

1.4.3 Symbian OS

ADVANTAGES:

- It offers pre-emptive mutitasking, multithreading, and memory protection.
- It emphasizes on memory conservation.
- It embodies event-based programming.
- It is very useful in conserving battery life.

FEATURES:

- Support for WLAN.
- Improves and speeds up Smartphone performance.
- High-end security enhancement features.
- Graphic support including support 3D rendering.
- Hindi and Vietnamese language support to serve a larger range of consumers.
- Native support for Wi-Fi.
- Support for FOTA(firmware over-the-air).
- Improved memory management.
- Low boot-time.
- Native support for Push-to-talk.
- Provides high-speed datra-connectivity using EGPRS (EDGE).

- It has advanced voice features such as a hands-free speakerphone and conference calling capability.
- It includes the Adobe Acrobat Reader for accessing PDF files.
- It has a large storage memory which includes 80 MB of built-in memory plus multimedia card (MMC) slot.
- It has Internet connectivity for Web browsing.
- It has PC synchronization feature.

1.4.4 Linux for Mobile Devices

The Embedded Linux Consortium (ELC) is an association which promotes Linux and develops standards for Linux in embedded systems. They also develop standards for designing user interfaces, managing power consumption in devices, and real-time operation of embedded Linux. The Motorola ROKR E2 music phone is the best example of a Linux-based phone.

FEATURES:

- USB 2.0 PC networking for the fast 'drag-and-drop' transfer.
- Built-in FM radio.
- Support for Motorola's iRadio service.
- Support for Bluetooth.
- 1.3 Megapixel camera for video capture and playback.
- MMS enabled.
- Opera Web browser.
- 'Airplane mode' for safely listening to music when abroad an aircraft.
- PIM with picture caller ID.

1.5 Smart Systems

Smart systems provide comfort, efficiency, and remote access to devices and appliances. They are used in our day-to-day lives.

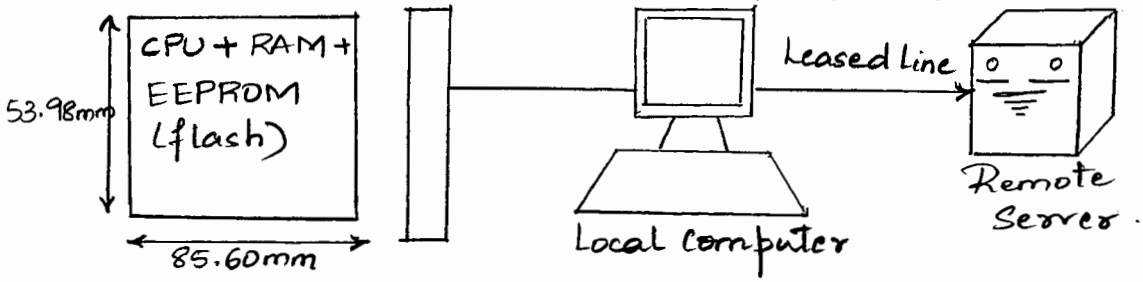
1.5.1 Smartcards

- Smartcards (Integrated Circuits Cards or ICC) are small, pocket-sized cards with electronic processing circuits embedded in them.
- Some smartcards are simply memory cards to store data. These cards functions as rewritable memory devices for storing and updating data.
- Smartcards may bedivided into Contact smartcards and Contact-less smartcards.
- *Contact Smartcard* has gold-coated pins on the chip that provide contact with the electrical circuits of the card reader when the card is inserted in it. Example, telephone cards.

- *Contact-less cards* communicate with card readers using Radio frequency induction technology. These cards have to be held close to reader antenna. Example, ISO/IEC 14443.
- Smartcards have secured hardware.
- JavaCard is used to program smartcards.
- Smartcards do not have batteries and the energy is provided by the card reader.
- A smartcard has a *fabrication key, personalisation key and utilization key.*
  - *Fabrication key* identifies a card uniquely.
  - *Personalization key* that the host machine server inserted is to activate and program the card for enabling future transactions.
  - *Utilization lock* is used by the server to lock or unlock the use of the card.
- Application protocol data unit (APDU) is an accepted standard for card-host communication.

APPLICATIONS OF SMARTCARDS:

- In financial transactions as a credit card or ATM/debit cards.
- To store personal ID and personal information.
- To store the medical records of the holder.
- An employee in an enterprise uses a card to open the security locks at work and log in.
- A student uses a card to get books issued from the college library.

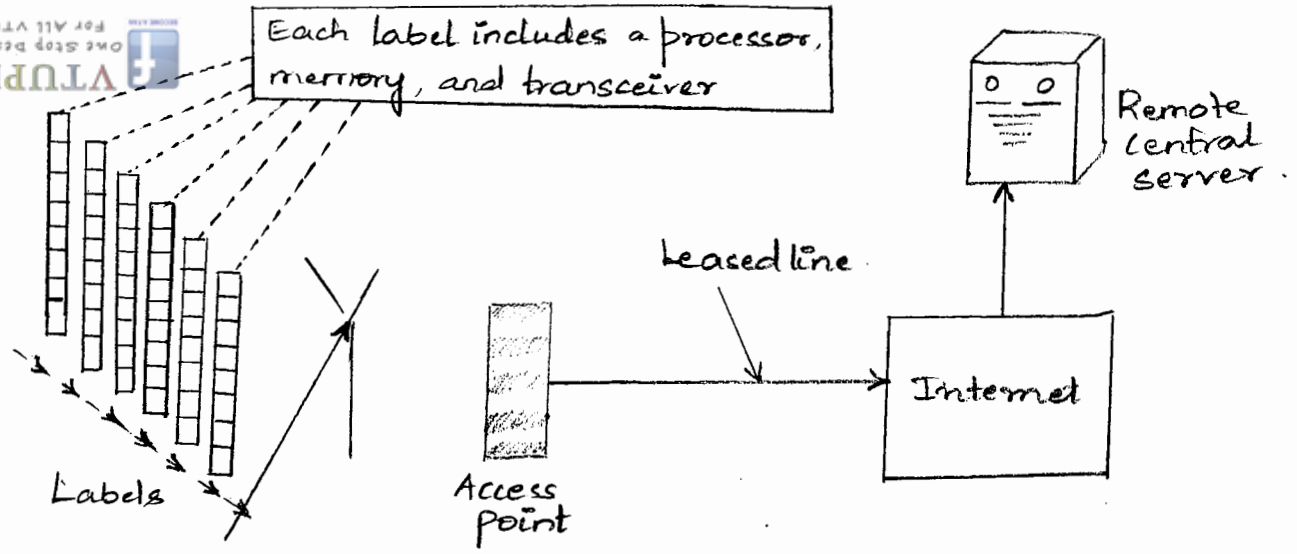


1.5.2 Smart Labels

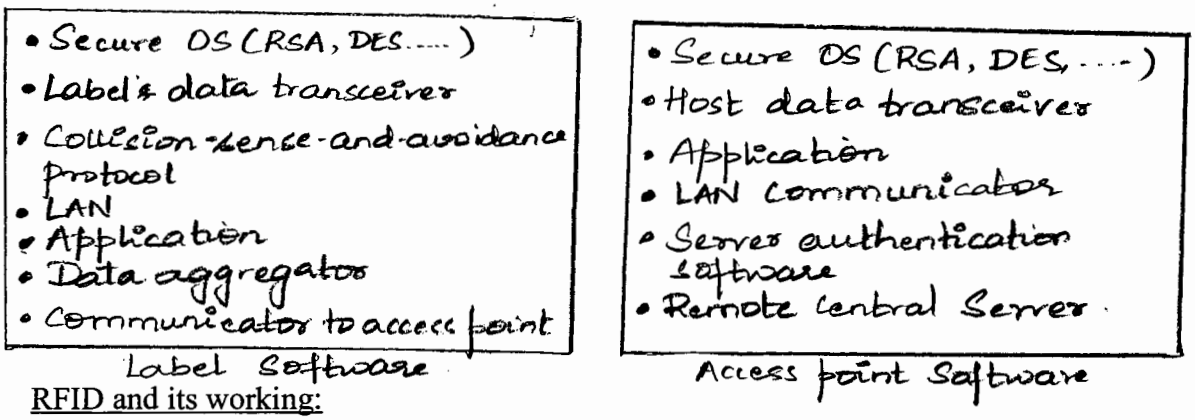
Generally, a label serves the purpose of identifying the contents of a package. For example, a barcode label on a book packs in information about the publisher, title, author, publishing date and reprint edition of a book. A smart label has a processor, memory, transceiver, and antenna similar to a contact-less smart card. They are powered by receiving signals.

The smart labels are networked together using a central reading and host or PC. Cluster of labels form a network similar to a LAN network. A collision-sense-and-avoidance protocol is used so that multiple labels are not allocated the same ID tag and the central server can uniquely identify each one. The central server can also detect the removal of a labelled product or packet from a product-shelf and raises alarm in case the product does not reach the destined point. A label may use secured hardware and server-authentication software. Below fig(a) shows a network of labels and fig(b) shows the software components in a smart label.

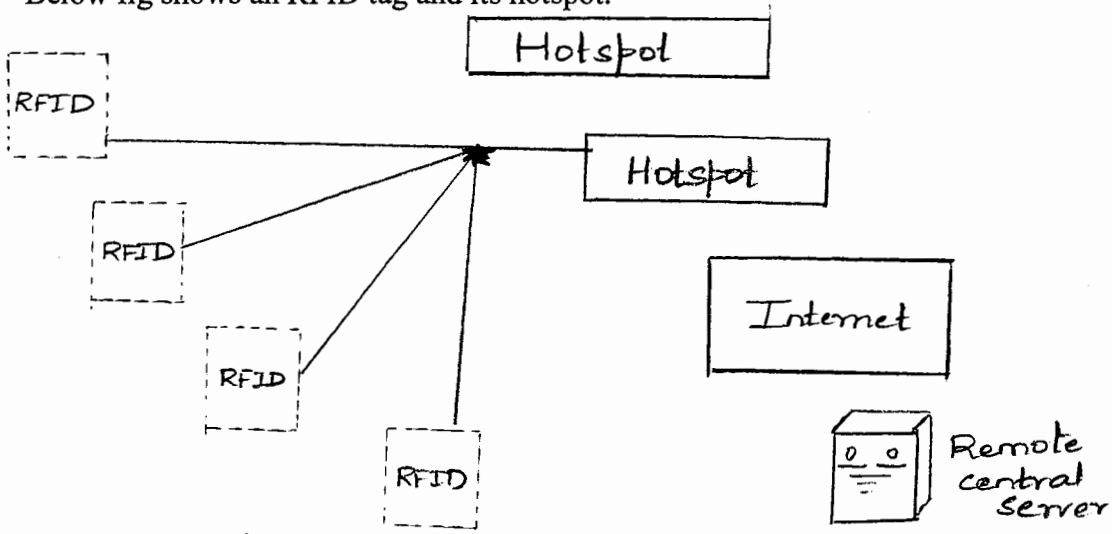
fig(a)



fig(b)



- RFID and its working:
  - ✓ RFID (Radio frequency Identification) is an automatic identification method for remote storage and retrieval of data on RFID tags. RFID tags are attached onto people, products, or animals to enable their identification using radio waves from near by source.
  - ✓ Each RFID tag is monitored by a hotspot which is in the vicinity of the tag and has a line-of-sight access to it.
  - ✓ Each RFID has a processor, memory, and transceiver for backscattering of hotspot RF, a charge pump and an antenna.
  - ✓ The hotspot has a computer and wireless transceivers to transmit and receive signals from the RFID tags. The hotspot connects to the Internet and a mobile device or PC with wireless interface is programmed to function as the hotspot. Below fig shows an RFID tag and its hotspot.



1.5.3 Smart Tokens

A smart Token is an encapsulated chip including an embedded processor and a memory. They are used for authentication purposes before an action. They use either a wire-based protocol and communicate at 16-128 kbps or ASK 13.56 Mbps for contact-less Communication.

Smart tokens are used for granting permission to employess to enter a work place, remotely open car doors, in defence departments to accept only authenticated parcels.

1.5.4 Sensors

- Sensors are electronic devices that sense the physical environment, for example, there are sensors for temperatures, pressure, light, metal, smoke, and proximity to an object. The sender sends the signals to a computer or controller.
- A sensor may be a CCD (Charge-coupled device) camera to identify various objects or a microphone to recognise voices.
- Smart sensors have computational, communication, and networking capabilities.
- A smart sensor consists of the sensing device, processor, memory, analog-to-digital (ADC), signal processing element, wireless or infrared receiver and transmitter.

Some examples for sensors are as follows:

  - Used for Voice amplification during a call.
  - Used to contrl the brightness of LCD screen which reduces power dissipation.
  - Used for measuring the strength of the signal received and controls the amplification of received signals.

1.5.5 Actuators

- An actuator receives the signals from a controller or central computer and accordingly activates a physical device, appliance, or system.
- A smart actuator receives the commands or signals from a network, mobile device, computer, or controller and accordingly activates the physical device or system.
- Sensor-actuator pairs are used in control systems.
- A set of smart sensors and actuators are networked using Control area network bus (CAN bus).

1.5.6 Sensors and Actuators for Robotic Systems

- Robotic systems incorporate a variety of overlapping technologies from the fields of srtificial intelligence and mechanical engineering.
- Robotic systems are essentially programmable devices consisting of mechanical actuators and sensory organs that are linked to a computer embedded in them
- The sensors transmit, through internal wires, the signals to the embedded processors at the central computer chip in the robot.
- The robot wirelessly communicates data to a central server when the actions of a group of robots need to be synchronized.
- Master-slave systems of robots can be used in which master robot sends commands to the slave robots.
- Robot sensors can be programmed using either assembly language or C.

Some examples of sensors used in robotic systems are:

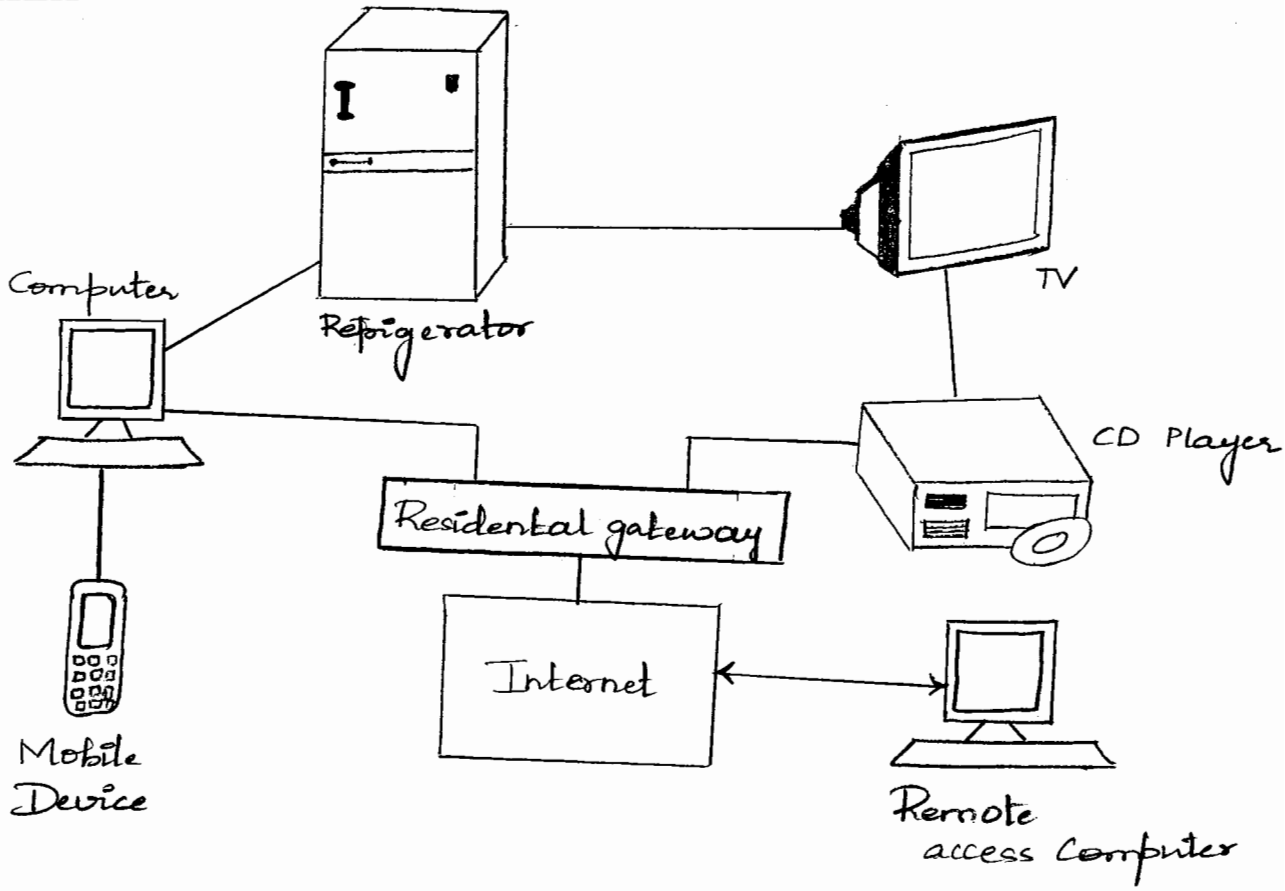
- Acceleration and force sensors in the right and left feet.
- Infrared distance sensors at the head and thumb.
- CCD cameras in eyes, Microphones in the ears etc.

Some of the actuators used in a robot are:

- At the mouth, there can be a speaker to let a robot issue commands to other robots or relay sensed information via spoken message.
- At each moving joint- feet, knee, waist, neck etc, there are actuators and motors.

1.5.7 Smart Appliances

- Home appliances can also be networked using very short-ranged wireless protocols, such as Bluetooth or Zigbee.
- Smart home and office appliances are web-enabled devices. A smart appliance can be allotted a web address.
- The appliance then connects to the Internet through a residential gateway which enables the user to access devices from outside using WLAN.
- An authentication process is first carried out, after which the gateway allows access from outside to the home devices or vice-versa.
- The gateway can also use a service-provider server for the networking functions.
- A smart appliance can also be allotted a number by the mobile service provider. It can be controlled from Smartphone using SMS service. Fig shows a network of appliances.



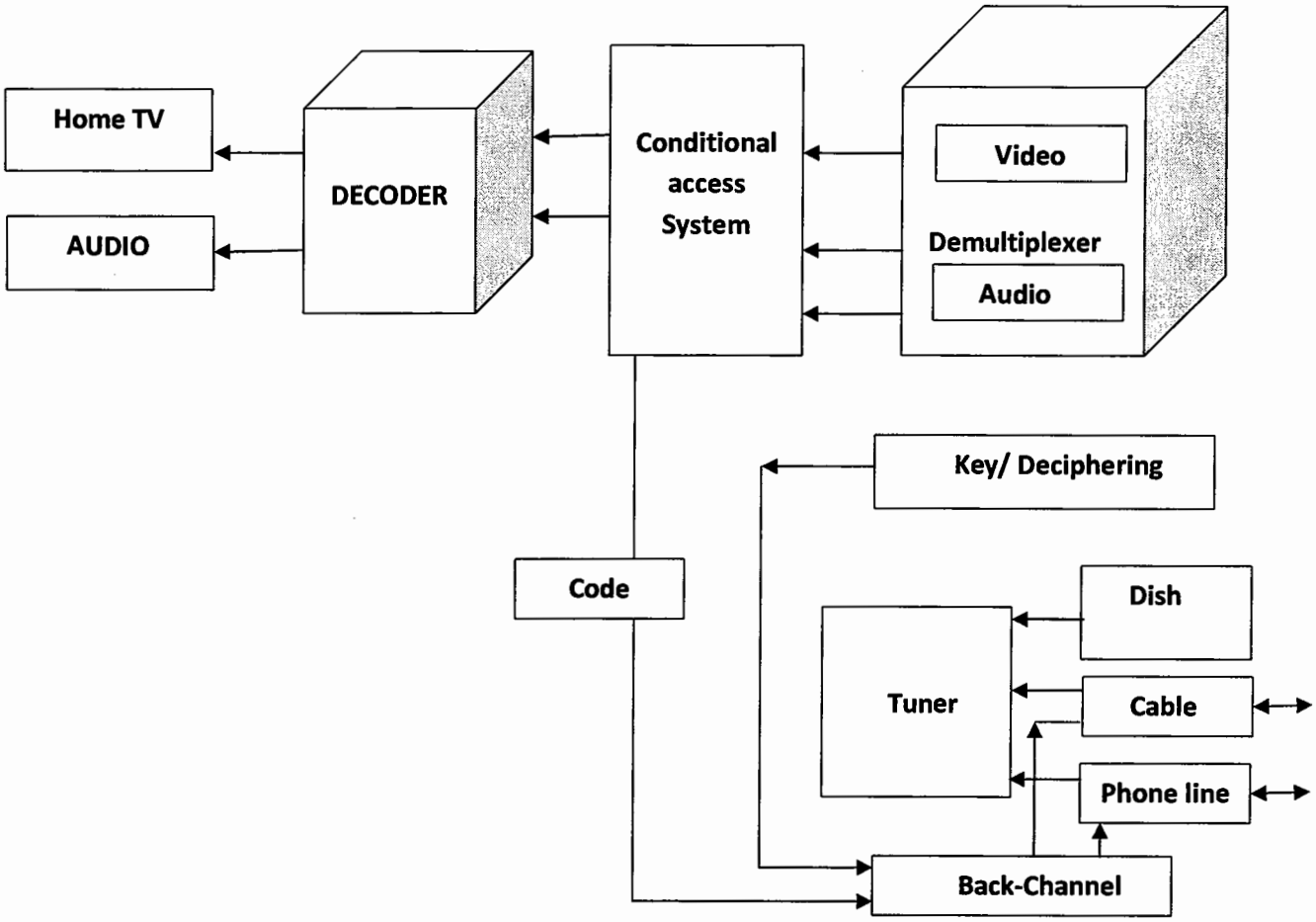
1.5.8 Setup Boxes

- A setup box (set-top box) is a sophisticated-based device which has data, media, and networking processing capabilities. It interconnects the home TV and the broadcasting service network.
- Java is the most commonly used programming language in setup box.
- There is a software component, called a device agent, which administers the device on behalf of the service provider.
- Setup boxes have multi-channel tuners. A demultiplexer separates the channel selected by the user.

Setup box serves a multitude of functions. Few are listed below.

- Provides a great platform for Java-based multimedia games.
- Includes wireless keypads to interact with the TV for selecting, tuning, adjusting contrast, picture, and sound quality, for playing video games, and for Internet browsing.
- Provides hard disks and a CD-ROM drive.
- A setup box can be connected to a PC or printer via a USB port.

Below fig shows the functions in a setup box.



1.6 Limitations of Mobile Devices.

The primary goals that a mobile device is expected to fulfil are *Efficiency* and *Convenience.* Mobile devices are limited in various ways.

- **Quality and Security of Service**

The greatest challenge facing mobile computing is maintaining QoS along with the provisioning of seamless access to all users.

- ✓ **Accessibility**

  Each mobile device is limited by accessibility constraints. Smart labels on packages have limited access because their transmitted signals are low in power. An RFID access is limited to ranges within line of sight and it also requires hotspots close by due to low transmitted signal strength.

- ✓ **Range**

  Signal strength is inversely propotional to the square of the distance from the transmission source. There is degradation of signal quality due to reflection, scattering, and diffraction. Therefore, the access to a mobile device is limited to the range up to which the signal strength is such that it can be separated from the noise and signal quality can be restored.

✓ **Connectivity**

There may be connectivity loss or intermittent connectivity in certain situations. The atmospheric conditions and changes in environment affect signal strength.

✓ **Security**

Unsolicited advertisements and unwanted messages may be drop-delivered to a device. Virus attacks on mobile devices can cause a software crash or even corrupt the hardware. Hackers may hack into device and render it functionless or threaten integrity and security of the data stored on the device. Repeated transmission of unwanted signals by an attacker can drain the resources of the device.

✓ **Mobility**

Non-availibility of an access point or base station and other infrastructural issues restrict the mobility of a device. The use of different standards in different regions may limit the operability of a device. Also, some service providers may not be able to provide connectivity in all parts of the country or in other continents, etc.

➢ **Energy Constraints in Devices**

All mobile devices have limited energy stored in their battery. Also, battery power is limited due to considerations such as size, weight, and bulk of mobile devices. The devices, therefore, need to be recharged after short periods of time. In this way energy availability also limits device mobility.

✓ **Mobile Computing Strategy**

A processor circuit dissipates higher energy when its clock frequency is higher. Computational speed is higher at higher clock frequency. A device is thus programmed so that only computationsc run at full processor speed. The clock frequency is reduced for the other computations to save power.Many innovative mobile computing strategies are adopted to mitigate the effects of energy constraints. They are as listed below:

- Zigbee protocol has a lesser stack size as compared to bluetooth which reduces the energy requirement.
- A program which adapts itself is made use in host or hotspot so that frequently required data is calculated and stored in buffer fron where it can be sent at slow clock frequencies on demand from the host.
- Communication scheduling strategies are adopted and frequently required data is transmitted as per a schedule thus saving the host energy.

✓ **Processor Design**

Innovative circuits of mobile device processors have been designed and are continuosly improved upon so that the same program instructions process with lesser energy dissipation per unit computational speed. Example, ARM and TigerSharc.

✓ **Transceiver Design and Programming**

Innovative transceiver circuits have been designed such that

(a) Signals of low strength are transmitted to the receiver.

(b) Controls commands from the host are sent at lower signal frequencies and the transceiver transmits the data for operation once the device is ready.

(c) Signal strength reduces according to the inverse square law.

➢ **Hardware Limitations**

✓ **Memory**

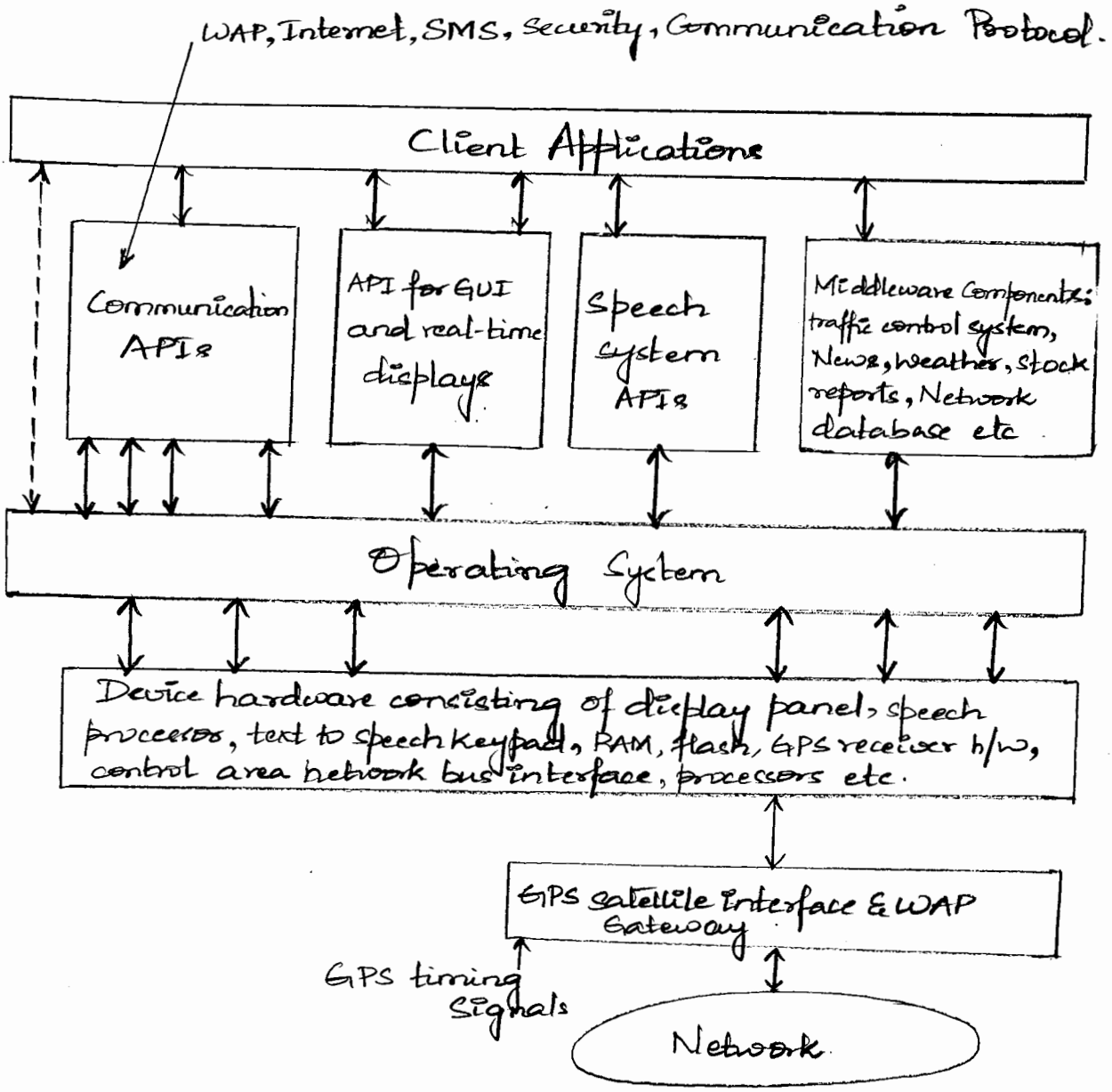
Most mobile devices do not support hard-disk drives and CD drives due to size limitations. Internal flash drives and card slots for external memory are used. Memory stick is used to enhance with memory in the device. Some examples of large memory capacity in mobile devices are Sony Network Walkman.

✓ **Bandwidth**

A service provider is not permitted to air signals at any random frequency and signal strength. The service must use the frequency spectrum allotted to it efficiently. Multiplexing and coding techniques help in achieving an efficient transmission. Limited bandwidth may become an obstacle to seamless connectivity and quality of signals aired when a large number of mobile devices simultaneously demand network connectivity.

1.6 Automotive Systems

Below fig shows the mobile computing architecture in an automobile **(Page no 73)**



1.7.1 Speech Recognition System (SRS)

The automobile can start by the driver's commands after recognizing their voice through SRS. Application software can be programmed such that the driver can command the automobile to hault, maintain the current speed, or stay under a given speed limit. The SRS uses a digital signal processor

1.7.2 Messaging System

A Wireless Application Protocol (WAP) device in an automobile enables it to connect to the Internet. A traffic control service sends traffic reports. The automobile owner can subscribe to a traffic control service provider which provides SMS messages about traffic slowdowns and blockages at various points in the city. The messages are then converted to speech using text-to-speech (TTS) converter software. An anti-collision system can warn the driver if the automobile gets too close to another.

Application programmers can use C in Linux for converting an SMS TTS. Programmers can also use Java, ASP, and JSP for web-based applications and retrieval of data from databases at various portals.

1.7.3 GPS System

An automobile can be fitted with a Global (Geographical) Positiioning System (GPS) receiver. It receives signals transmitting by various GPS satellites orbiting the earth.

Application programmers can use GTK (Graphic tool kit) language or C in Linux for drawing.

1.7.4 Automobile Start and Malfunction Logins

A smartcard or smart token can be used in place of a key to start the automobile. At the service workshops, a card reader attached to a PC reads the card and retrieves the logged data as well as the service history details. The workshop can render a more efficient service using this information. The service provider's PC can then write the details of the service provided onto the card memory for future reference.

1.7.5 Sensor and Actuator Programming

An automobile has a number of sensors and actuators. They connect the enabled systems inside an automobile. The systems connect to the CAN bus.

1.7.6 Entertainment Systems

An automobile can be fitted with a number of entertainment systems, for example, FM radio, media players to play Wave (WAV),RealAudio (RA), and MPEG-1 audio layer 3(MP3) files. A USB port can be used to download files from another system. A Bluetooth device can be used to download data from PDAs, Smartphones, and pocket PCs.

1.7.7 Real-time Applications Programming

A programmer can use the Windows CE OS for running real-time applications on the PC fitted into an automobile. Applications can be coded using any of the programming languages such as Win32 API, Visual C and Visual Basic. The OS provides functions for the multiple threads, networking and communication protocol APIs.

Real-time applications for the Java platform can also be developed using OSEK which is a small OS used for microcontrollers in engine control units of automobiles.

1.8 GSM- Services and system Architecture

The Global System for Mobile computing (GSM) is one of the most popular mobile communication standards. GSM communication uses cellular networks. GSM standards operates in the frequency ranges of 900, 1800, and 1900 MHZ.

1.8.1 Services

GSM provides integrated services for voice and data. GSM has defined three different categories of services: **bearer services, teleservices** and **supplementary services.**

- **TELE SERVICES:**
  - ✓ Teleservices are offered by a mobile service network to a caller (TE). Some teleservices provided by GSM service providers are telephone-voice at full data rate, fax, SMS, emergency number for emergency calls, and MMS.
  - ✓ Teleservices are *point-to-point* which means from TE to another TE. A point-to-point service is implemented using cellular communication
  - ✓ Additional teleservices are *half-data-rate speed* or *enhanced full-rate speech* services and these may or may not be rendered by cellular and point-to-point access systems.

- **SUPPLEMENTARY SERVICES:**
  - ✓ In addition to tele and bearer services, GSM providers can offer supplementary services. These services offer various enhancements for the standard telephony service, and may vary from provider to provider.
  - ✓ Typical services are *user identification*, *call redirection*, or *forwarding of ongoing calls*, *barring of incoming/outgoing calls*, *Advice of Charge (AoC)* etc.
  - ✓ Standard ISDN features such as closed user groups, multiparty communication, call holding, call waiting, and barring calls may be available.

- **BEARER SERVICES:**
  - ✓ Bearer services are responsible for transmission of data(voice signals are also transmitted as data) between two user network interfaces using intermediate interfaces in the mobile network.
  - ✓ Bearer means a set of data which is transmitted from or received by a TE. This data is then transmitted at certain standardized rates through the interfaces.
  - ✓ A bearer services is either
    - (a) Transparent Data Transfer
    - (b) Non-transparent Data Transfer.

(a) Transparent Data Transfer:

- ✓ Transparent data is said to be transparent since the interface for the service uses only physical layer protocol.

- ✓ Physical layer is the layer which transmits or receives data after faomatting or multiplexing using a wired or wireless medium.
- ✓ Physical layer protocol in GSM bearer service also provides for FEC (Forward Error Correction) which entails insertion of redundant bits along with the data. This detects and corrects errors.
- ✓ FEC requires *high bandwidth* but is advantageous in situations where retransmission is not convenient.
- ✓ FEC transmission *reduces data rate*, but helps in broadcasting *without handshaking.*
- ✓ It also enables broadcast to multiple destinations from a single source.

The actual data transmission rate with FEC is given by:

$$\textbf{Actual data rate} = r\,X\,n\,/\,(n+m)$$

where m are redundant bits that are appended in a data stream of n bits.
$(n+m)$ are the total number of data bits transmitted from the sender's end.
At the receiving end, an algorithm is employed to detect and correct transmission errors (error means 0 received as 1 or 1 received as 0). This algorithm extracts the original n-bit streams from the received $(n+m)$ bit sequences. Therefore for every $(n+m)$ bits sent by the sender, the receiver receives only n bits of actual data and the transmission channel offers a data rate r.

(b) Non-transparent Data Transfer:

- ✓ Non-transparent data transfer means that the service interfaces uses physical layer, data link layer and flow control layer protocols.
- ✓ Data link layer is the layer which is responsible for *framing*(i.e., combining and appending additional bits and header and ensures very small error rate).
- ✓ The protocols of data link provide for *error detection and correction* and flow control layers provide for *selecting, rejecting and re-transmitting the data.*
- ✓ Example for non-transparent communication is a special error correction facility called RLP(radio link protocol) used in GSM networks.

Refer Fig 3.1 (Page No. 80)

1.8.2 Synchronous, Asynchronous, and Synchronous packed Data Transmissions:

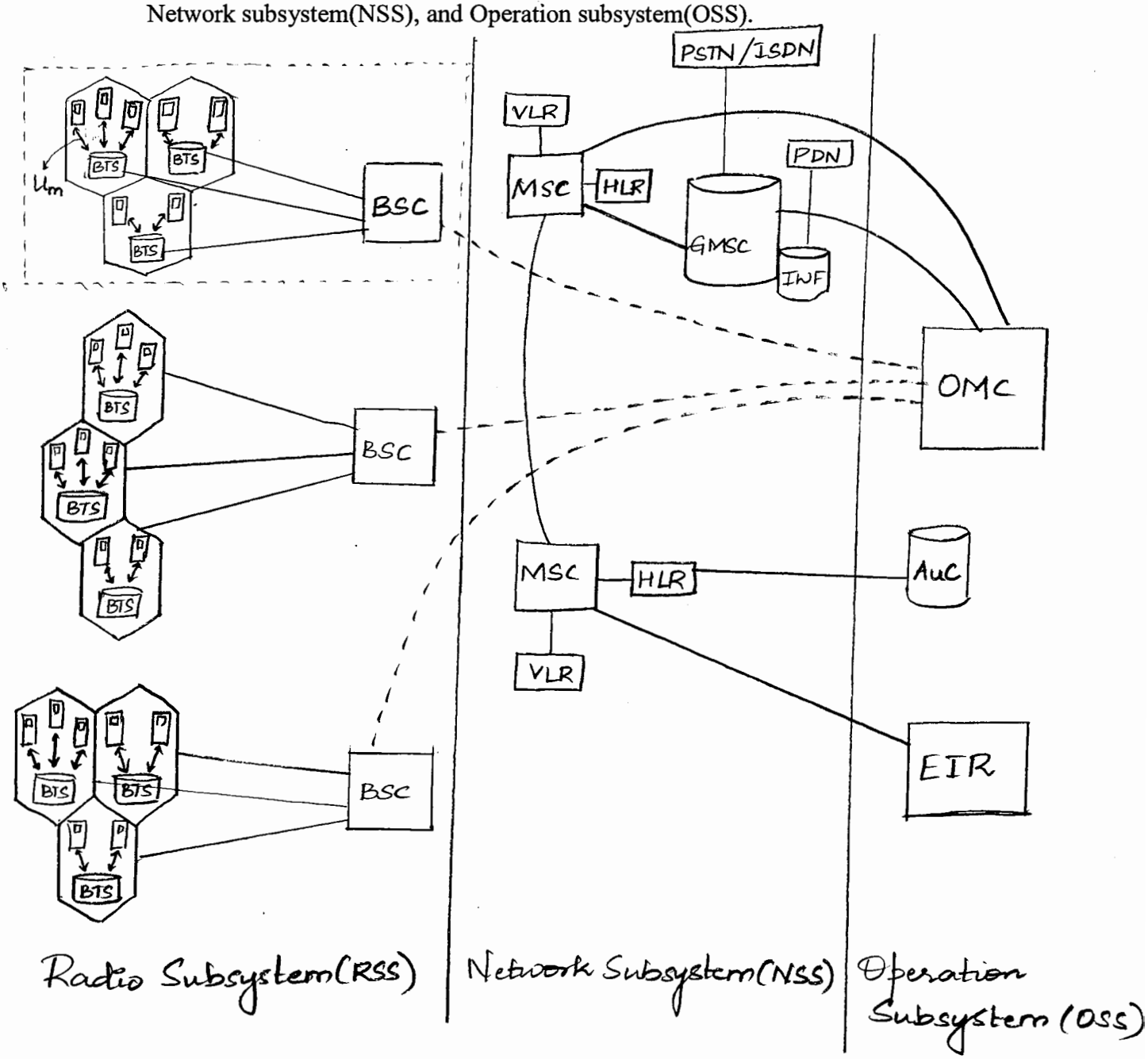
- ***Synchronous data transmissions:*** It means that data is transmitted from a transceiver at a fixed rate, as a result constant phase differences are maintained between data bursts or frames. Handshaking is not required. The receiver must also synchronize clock rate according to the incoming data bits. Synchronous data transmission is fast because there is no waiting period during data transfer.
- ***Asynchronous data transmission:*** It means the data is transmitted by the transceiver at variables rate, as a result constant time intervals are not maintained between consecutive bursts or frames. There is handshaking or acknowledgement of data in

asynchronous data transfer. Even there is no acknowledgement, data flow maintained by using the FEC and buffers can still be asynchronous.

- ***Synchronous packet transmission:*** It takes place after formation of packets. There is no handshaking and acknowledgement of data during the flow of packets. Different packets are transmitted through different interfaces, routes, channels, or time-slots to reach a common destination. At the destination, various packets are arranged in their order sequence. A sequence number transmitted along with each packet helps in sequential arrangement of packets at the receiver. Each packet flow is transmitted as synchronous data.

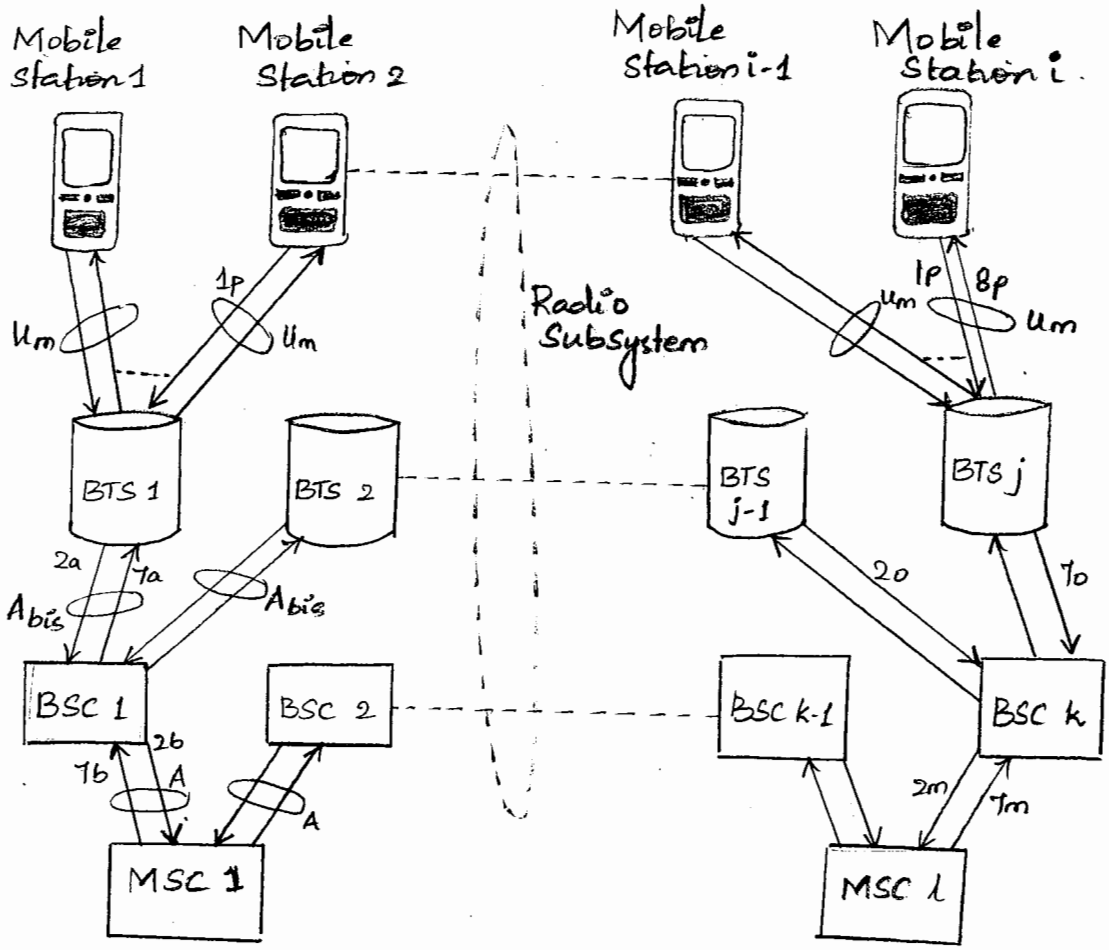
1.9 GSM System Architecture

GSM network is divided into three subsystem namely, Radio subsystem(RSS), Network subsystem(NSS), and Operation subsystem(OSS).



1.9.1 Radio Subsystem (RSS)

The radio subsystem (RSS) comprises all radio specific entities, i.e., the mobile stations (MS). The RSS consists of a number of base station controllers (BSC) which connects to a number of Base transceiver systems (BTS) and each BTS connects to a number of MS. A BSC along with the BTSs connected to it together form a Base station system (BSS) The figure shows the connection between the RSS architecture and interfacing to NSS.



(a) Mobile Station (MS): A MS is a mobile device or phone which connects to the GSM network. It consists of a Mobile terminal (MT) that transmits through the interface U_m. [Refer fig (1)]

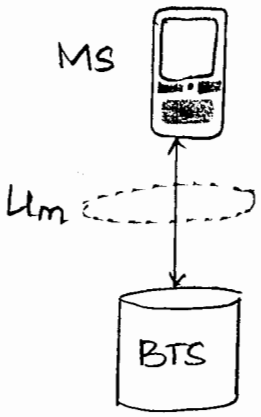


fig 1: MS to BTS interface

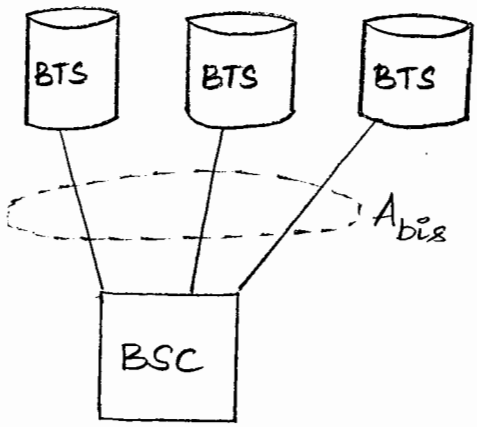


fig 2: BTS-to-BSC interface in GSM n/w

Each MS has a Subscriber Identity Module (SIM). SIM is a card inserted into MS. Some of functions of SIM are:

- SIM stores the temporary mobile cipher key for encryption, temporary mobile subscriber identity (TMSI) and location Area Identification (LAI).
- SIM contains information which doesn't change when MS moves into another location—(i) International Mobile Subscriber identity (IMSI), (ii) card serial number and type.
- It stores PUK (PIN unblocking Key) which enables subscriber to unlock the SIM.
- It stores 128-bit authenticated key provided by the service provider.
- It stores IMSI, a unique 15 digit number. It has three parts—a three digit Mobile country code (MCC), two digits Mobile network code (MNC), 10 digits Mobile Subscriber Identity Number (MSIN).

(b) Base Transceiver Station (BTS) : It performs the following functions.

- Formation of cells using appropriately directed antennae.
- Processing of signals.
- Amplification of signals so that there is no loss of data.
- Channel coding and decoding.
- Frequency hopping so that multiple channels for various mobile stations can operate simultaneously using different channels band frequencies.
- Encryption and decryption of data.
- Adapting to the rate of data.
- Paging. [Refer fig(2)]

(c)Base Station Controller (BSC) : It performs the following functions.

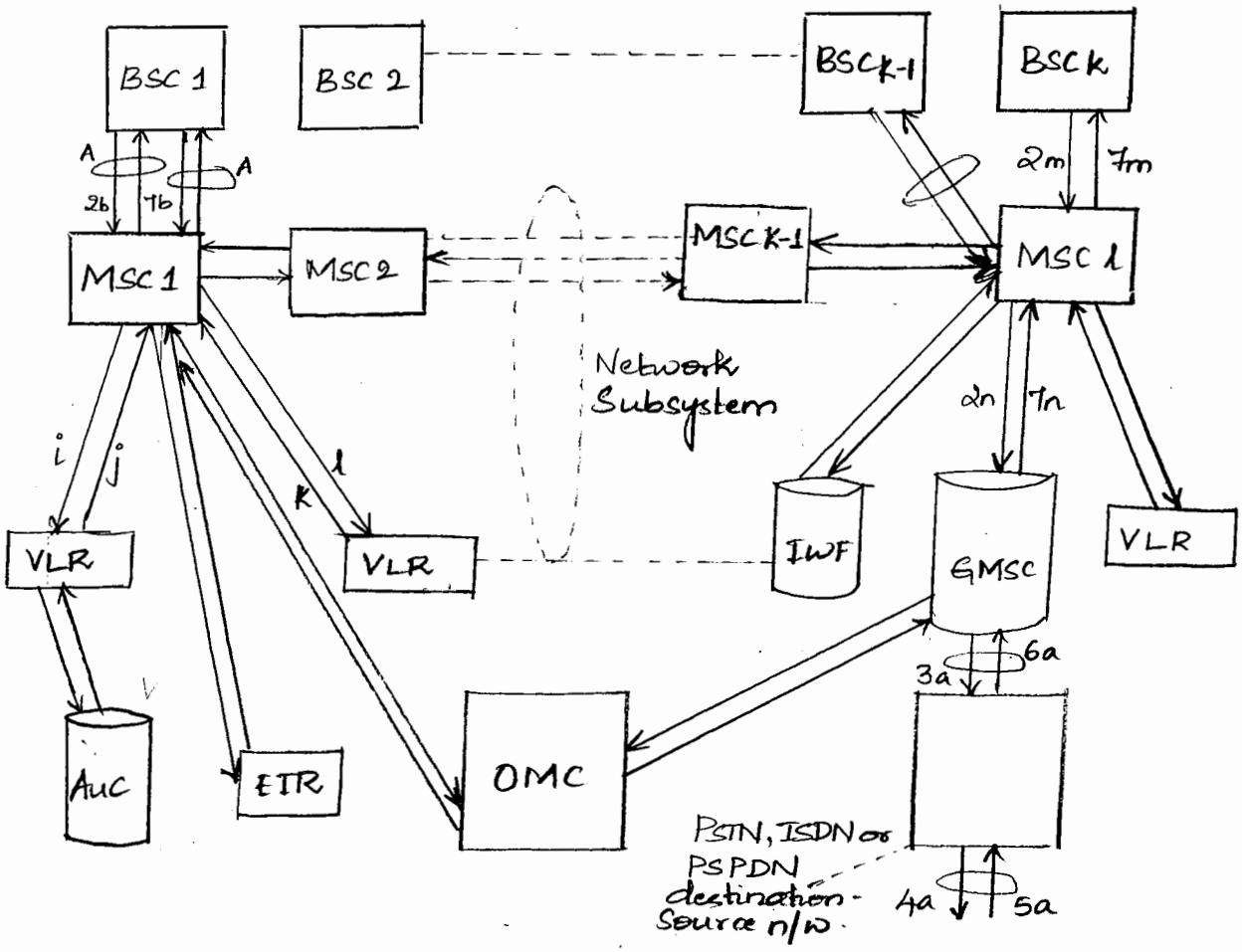
- Processing of signals.
- Controlling signals to the connected BTS and control of handover of signals from the BTS to another with a BSS.
- Control and handover of the signals from BSC to MSC
- Mapping the signals of a channel.
- Reserving radio frequency.
- Frequency Hopping.
- Traffic control by continuous measurement of the frequency channel spectrum being used at the given instance.
- Authentication, encryption and decryption of data.
- Updating location registry for the MSs.
- Paging.

1.9.2 Network Subsystem (NSS)

It acts as an interface between wireless and fixed networks. It mainly consists of switches and databases and manages functions such as handovers between BSSs, worldwide user localization, maintenance of user accounts and call charges, and management of roaming.

The NSS consists of *l* mobile services switching centres(MSC), *m* and *n* home and Visitor location registers, gateway MSCs(GMSC), and inter-working functions(IWF) with the mobile switching centres. The connections and components in the NSS can be summed up as follows:

- Every MSC in the NSS can manage several base station systems.
- Every MSC has a home location register(HLR) and Visitor location register(VLR). An MSC can connect to another MSC, GMSC, and IWF.
- An HLR connects to an AuC in the OSS.
- A GMSC can connect to an OMC in the OSS.
- GMSCs are also used to connect to a PSTN, ISDN, or PSPDN network.



(a) Mobile Services Switching Centre (MSC) : It performs the following functions:

- Processing of signals.
- Establishing and terminating the connection between various MS via BSCs.
- Establishing and terminating the connection between various MS and a fixed line phone via a GMSC or IWF.

- Monitoring of calls made to and from an MS.
- Call charging, multi-way calling, call forwarding, and other supplementary services.

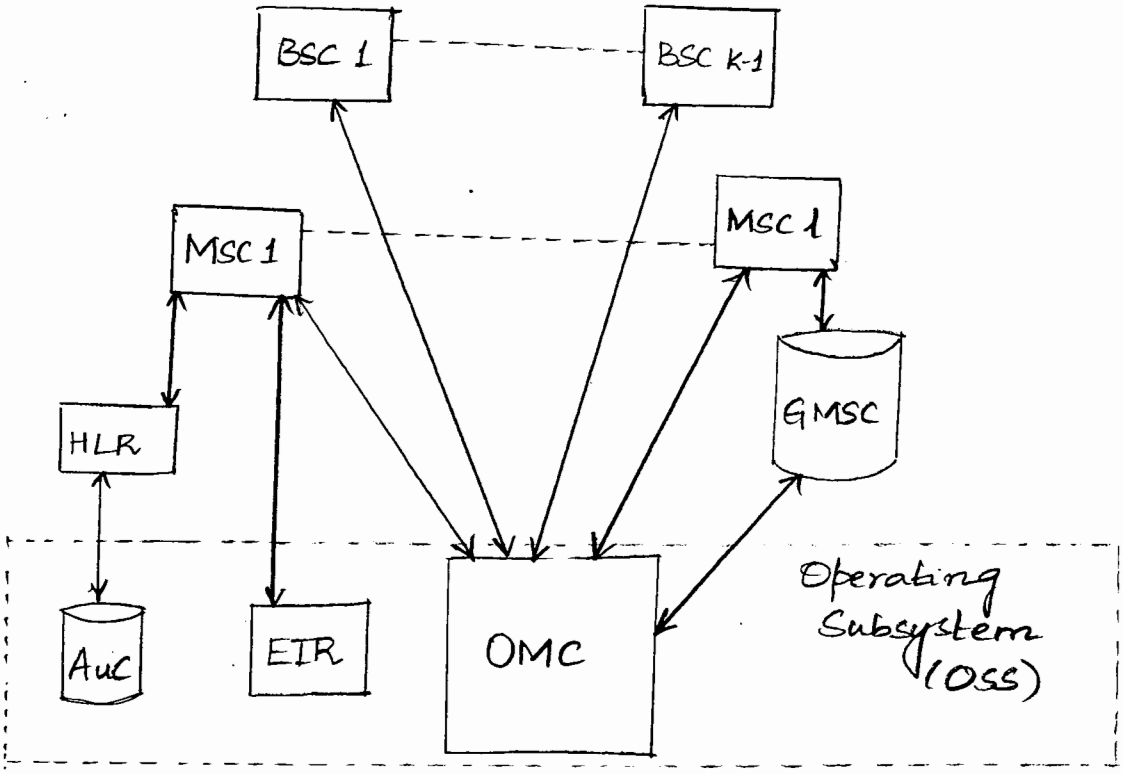
(b) Gateway Mobile Services Switching Centre (GMSC): It is a special node which handles connections to other fixed networks. These other networks may be ISDN, PSTN, PSPDN or other PLMN networks. Special IWF may be used by a GMSC to connect to public data networks.

(c) Visitor Location Register (VLR) : Each MSC has VLR. A VLR is a dynamic real-time database that stores both permanent and temporary subscriber data which is required for communication between the MSs in the coverage area of the MSC associated with that VLR. The VLR is an integral part of the MSC.

(d) Home Location Register (HLR) : The HLR has the MT databases in a GSM network. It stores all the relevant subscriber data including mobile subscriber ISDN number (MSISDN), details of subscription permissions such as call forwarding, roaming etc., subscriber's ISMI, user's location area, user's current VLR and MSC status. HLR contacts AuC in the OSS for authentication. Each HLR is associated to an MSC so that when an MS registered at a certain HLR moves to another location area (LA).

1.9.3 Operation Subsystem (OSS)

OSS administers the operation and maintenance of the entire network. It contains the following components which is explained with the below OSS architecture.



(a) Operation and Maintenance Centre (OMC) : It monitors and controls all other network entities through *O* interface. The OMCs tasks include management of status report, traffic monitoring, subscriber security management, and accounting and billing.

(b) Authentication Centre (AuC) : It is used by the HLR to authenticate a user. The AuC may also be a secured partitioned part of the HLR itself. GSM standard specifies the algorithm for key generation that should be separated out as an OSS network entity called AuC in order to prevent attacks. AuC database stores subscriber authentication keys. AuC also performs the calculation of authentication parameters and then conveying these to the HLR.

(c) Equipment Identity Register (EIR) : It stores the International Mobile Equipment Identity (IMEI) numbers for the entire network. The IMEI enables the MSC in identifying the type of terminal, mobile equipment manufacturer, model etc which helps in locating the device in case of stolen or misplaced. The EIR contains three different types of lists:

- A *black list* includes MS which have been reported stolen or currently locked due to some reason.
- A *white list* which records all MSs that are valid and operating.
- A *grey list* including all those MSs that may not be functioning properly.

1.10 Radio Interfaces

The U_m interface is a radio interface between MS and the BTS. It describes the space, frequency, and time division multiple access techniques. The BTS and MS communicate across the U_m interface for managing tasks such as call setup and voice and data traffic.

1.10.1 Space Division Multiple Access (SDMA) :

SDMA means division of the available space so that multiple sources can access the medium at the same time. A BTS with *n* directed antennae covers MSs in *n* cells. Each cell defines a space. A given BTS_j covers the i_{th} cell and the cell is presently covering *k* mobile stations, MS_1, MS_2,.....MS_k. There is no space division multiplexing of the signals from the MSs. Uplink and downlink capacities can be enhanced using SDMA.

1.10.2 Time Division Multiple Access (TDMA) :

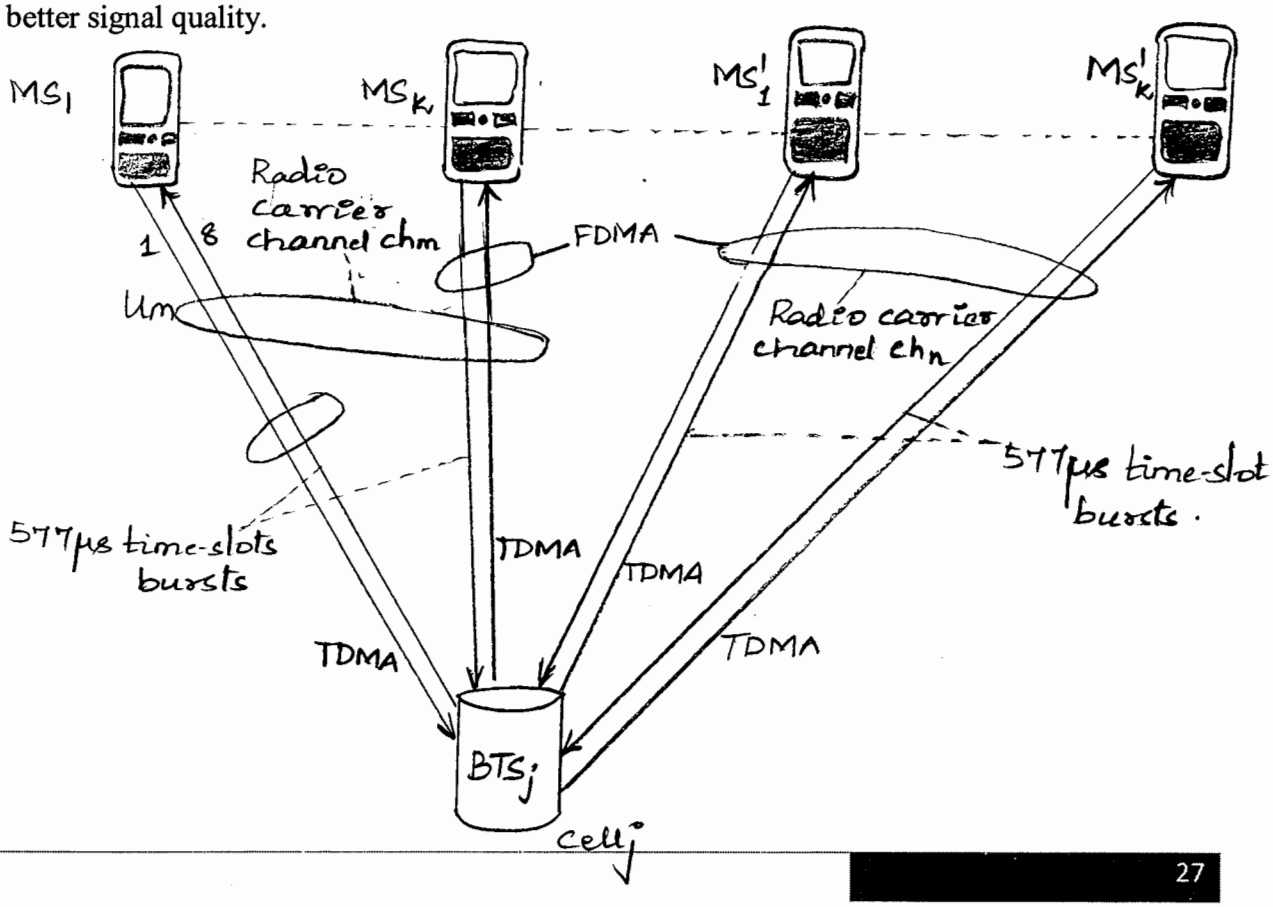
TDMA entails different sources using different time-slices for transmission of signals. The available time-slice is divided among multiple modulated-signal sources. These sources use the same medium, the same set of frequencies, and the same channel for transmission of data. A set of maximum eight MSs out of *l* MSs can be assigned a radio-carrier channel by a BTS_j using FDMA. An MS uses that radio-carrier channel and communicates with BTS_j using the user interface U_m. The U_m access is such that each MS in the set uses a distinct time-slot. An MS can use one of the eight slots, SL_0, SL_1.....SL_7, each of 577µs. A set of data bits in an SL is known as a *burst.* A set of eight data bursts defines a *data frame.*

Half-duplex Transmission: The transceiver of a mobile device can function in half-duplex mode when the uplink time slot, t_u and the download link slot, t_d, are assigned separately by a BTS and t_u - t_d is constant at 577µs.

1.10.3 Frequency Division Multiple Access (FDMA):

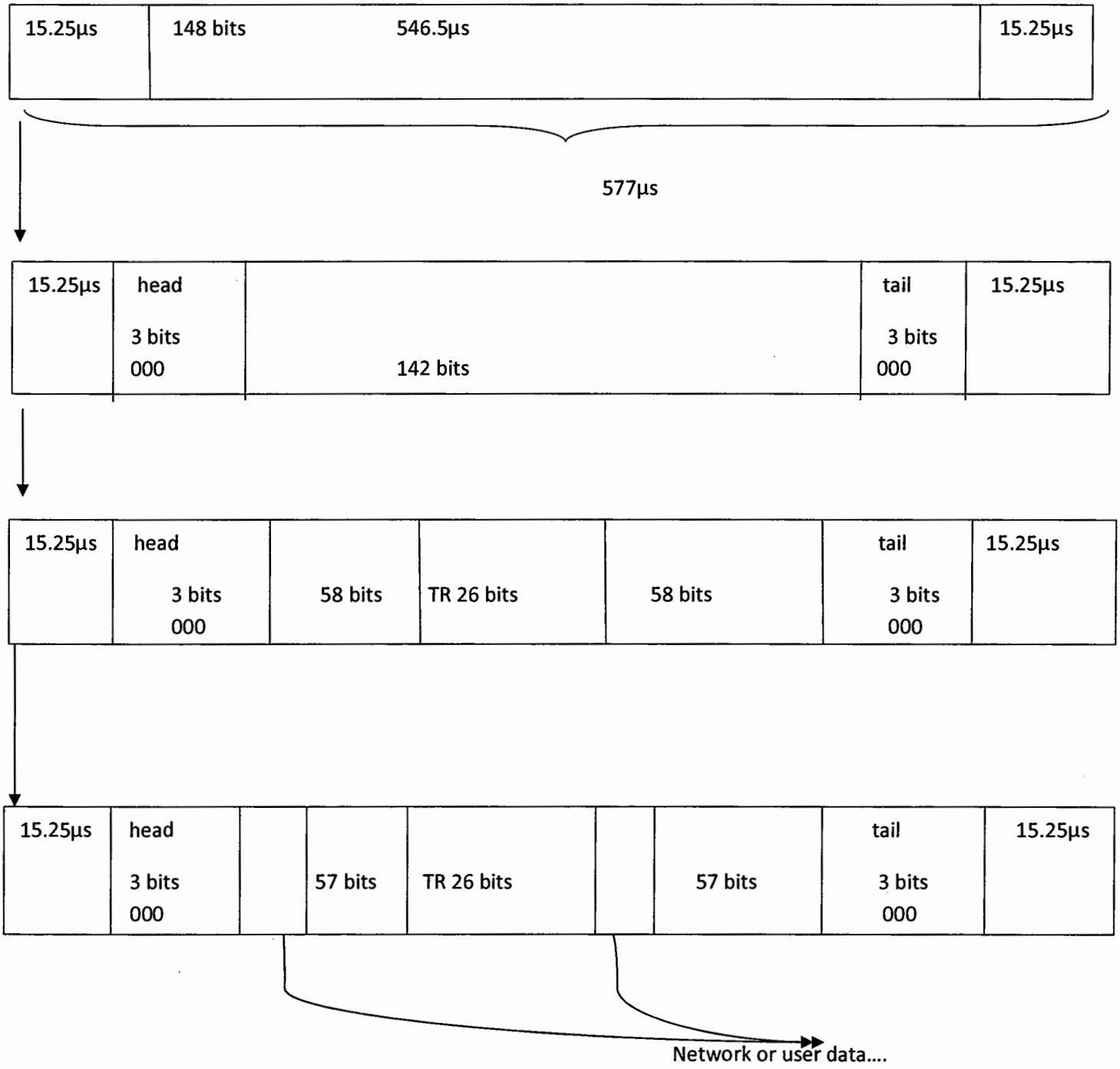
FDMA means dividing the allotted or available bandwidth into different frequency channels for communication by multiple sources. Various channels are allotted distinct frequency band for transmission. FDMA is an access method which entails assignment of different frequency-slices to different users for accessing the same carrier.

Frequency Hopping in Data Frames: There may be some specific frequency values that result in signal fading and do not provide expected signal strengths during transmission. A data frame frequency channel assigned to an MS by the BTS can be changed (hop) to select frequencies at a certain rate according to a predetermined sequence. This helps in ensuring better signal quality.



1.10.4 Format of Data Burst

1 data burst



- ✓ At the beginning and end of the data burst of 577µs, guard spaces of 15.25µs each are reserved to account for delays in the reflected signal and computational time.
- ✓ The effective transmission time for the data bits is, 577-(2*15.25)=546.5µs. 148 bits are transmitted in 546.5µs.
- ✓ Six bits, 3 at the head(H) and three at the tail(T) of the 148-bit burst are 000. Now 142 bits are left in the middle.

- ✓ 26-bits in the middle of the burst are transmitted as training bits(TR). The TR bits enable the receiver to
  a) Synchronize using H, TR, and T bits
  b) Select the strong components of the signals.
- ✓ Now (142-26)/2=58 bits each are left after H and before T.
- ✓ Data in the burst can be of two kinds MS data or mobile-service NSS data. On either side of the TR bits, an S bit can be placed to specify whether the source is the MS or NSS control data.

Now 58-1=57 bits each remain after the H bits and before the T bits for transmitting user data. The useful data bits are 57 after H and 57 before T.

- ➢ **Interleaving in a traffic multiframe:** Interleaving means inserting in-between. The packets interleave in a traffic multiframe for voice traffic. Interleaving distributes the effects of channel characteristics variation with time on multiple MSs.
- ➢ **Four Types of Control Data bursts:** Different types of control data bursts are:
  - ✓ *Access Burst:* Using this burst, the call setup takes place while setting the initial connection. The channel in which this burst is sent is called AGCH (access grant channel). It is a part of common control channel (CCCH).
  - ✓ *Synchronisation Burst:* It helps in synchronizing the transmitter and receiver time-slots and in timing advance. The channel in which this burst is sent is called SCH (Synchronisation channel). It is part of the broadcasting control channel (BCCH).
  - ✓ *Frequency correction Bursts:* It helps in correcting the carrier frequency. The channel in which this burst is sent is called frequency correction channel (FCCH). It is also part of BCCH.
  - ✓ *Dummy Burst:* When no useful burst is transmitted from an MS or a BTS after a connection setup, then a dummy burst is transmitted.

- ➢ **Traffic and Control Data Channels (Logical Channels):**

GSM voice and control data channels are called logical channels. One characteristic is if the data is not correctable at the receiver, it is blocked for further processing. It includes Traffic Data Channels and Control Data Channels.

i)Traffic Data Channels: Voice is coded using *codec*. Codec is short for coder-decoder which is a circuit that codes analog signals into digital signals and decodes digital signals into analog signal according to various coding and decoding algorithms. The error correction bits [cyclic redundancy check (CRC) and redundant bits] are then appended and data interleaving is performed.

There are 3 types of voice traffics are voice at *full 13kbps*, *half data-rate* speech and *enhanced full rate* speech.

User data or subscriber data is also called traffic data. The different types of voice traffic are as follows.

a) TCH/FS (traffic channel /full rate set for transmission): Voice is coded with a coder at 13kbps. As the additional bits are appended after coding, the data rate is enhanced to 22.8kbps when transmitting at full speed.

b) TCH/HS (traffic channel /half rate set for transmission): Voice is coded with a coder at 5.6kbps and after the error correction bit is added the data rate is enhanced to 11.4kbps and transmission takes place at half speed but the available rate is 22.8kbps.

- **Advantage:** Double voice signals can be transmitted.
- **Disadvantage:** Degradation in voice quality.

c) TCH/EFR (traffic channel /enhanced full rate set for transmission): Voice is coded using another enhanced coding technique. EFR gives an enhanced voice quality but has limited error correction bits because the data rate is limited to 12.8kbps. Here the codec may function in automatic mode and code the voice as TCH/FS or TCH/EFR depending on the transmission error rate depending on the burst.

- **Advantage:** Voice quality is upgraded, transmission error rate is small.

d) TCH/F14.4, TCH/F9.6 and TCH/F4.8 (traffic channel/full rate at 14.4, 9.6 and 4.8kbps): Due to large number of subscribers at a base station GSM specification provide for the traffic rates of 14.4, 9.6 and 4.8kbps.

ii) Control Data Channels: The various types of control channels are.

a) **DCCH (dedicated control channel):** MS sends TCH traffic only after a call setup. A bidirectional communication channel is present in between BTS and MS before the TCH traffic starts. This is called standalone DCCH.

b) **BCCH (broadcast control channel):** BTS needs to broadcast the frequency and cell identity so BCCH is used. This enables MS to get an available radio carrier frequency channel and transmit with different frequencies and different hops and synchronization with the BTS

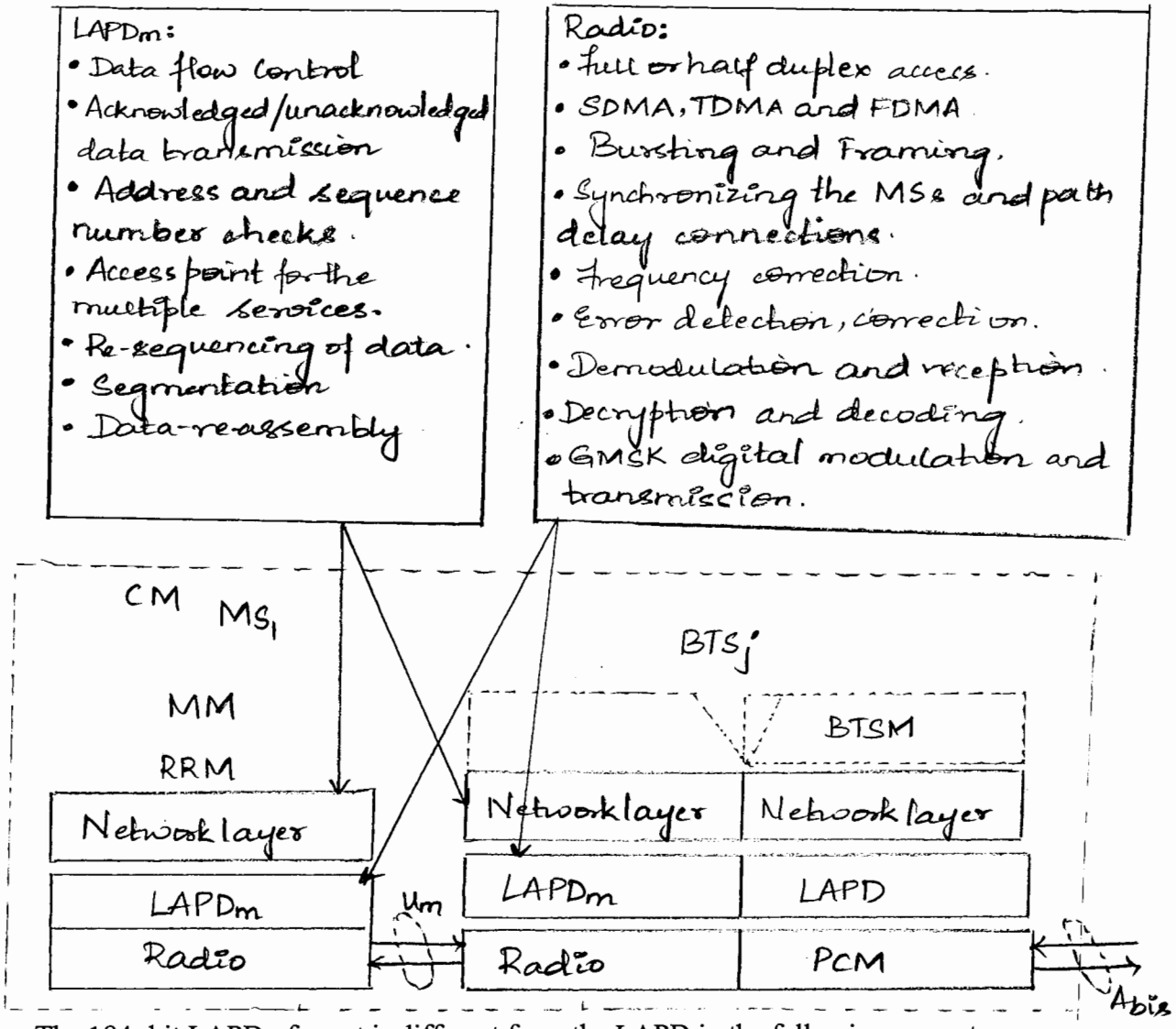
c) **CCCH (common control channel):** BTS uses a channel called AGCH (access grant channel). After access is granted, call setup or call forwarding can take place. The control channel used for such purpose is called CCCH.

1.11 Protocols

Various protocols are used at different layers in a communication network. They are as listed below:

1.11.1 Mobile Station- Base Transceiver Signalling Protocols

The physical layer between the MS and the BTS is called *radio*. The data link layer controls the flow of packets to and from the network layer. The data link layer a protocol between an MS and a BTS is $LAPD_m$ (Link access protocol for D-channel modified) for U_m. The below figure shows the functions and all protocol layers between BTS and MS.



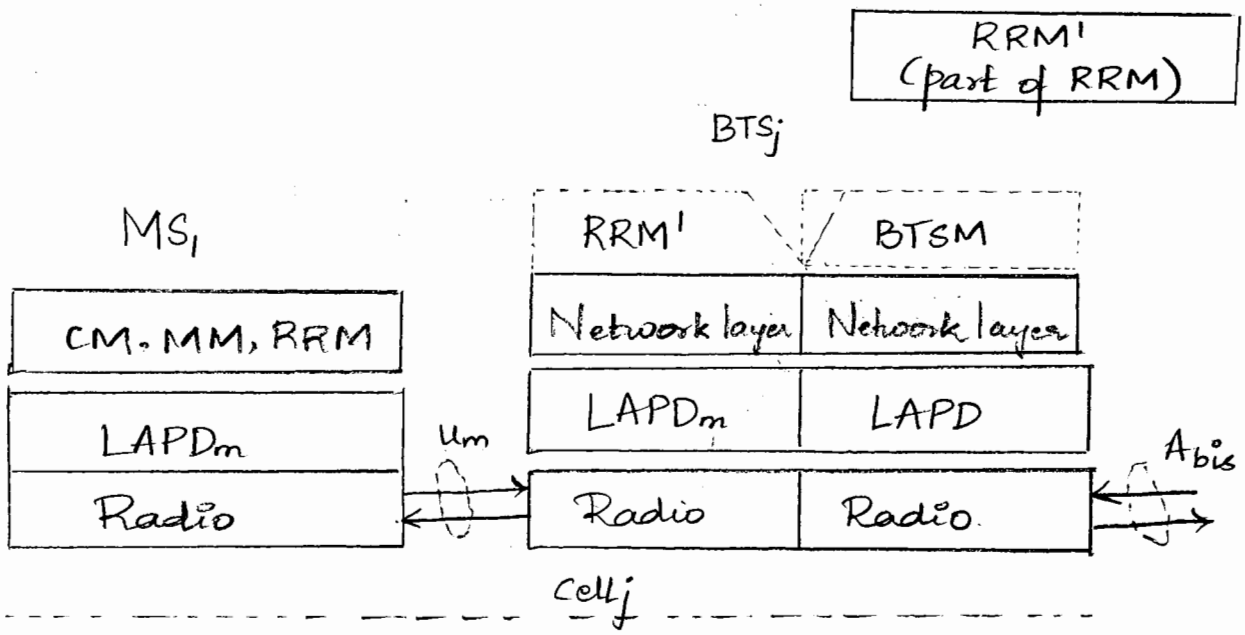
The 184- bit $LAPD_m$ format is different from the LAPD in the following respects:

- 8- bit address field.
- 8- bit control field.
- Information bits of variable length.
- Remaining bits as 1s (filler bits).

The network layer has three sublayers---

- Call (connection) management (CM) – Supports call establishment, maintenance and termination etc.
- Mobility management (MM) – Controls issues regarding mobility management when MS moves to another cell (location area).
- Radio resource management (RRM) (functions refer page no. 104 - fig(a))

fig: Interfaces of the network sublayers.



The network layer performs the following function:

- Defines protocols for implementation of addressed messages received from the data link layer.
- Defines addresses of the messages.
- Transmits the logical channel's data and information bits to the data link layer from an address.
- Receives the logical channel's data and information bits from data link layer for the addressed SAP.

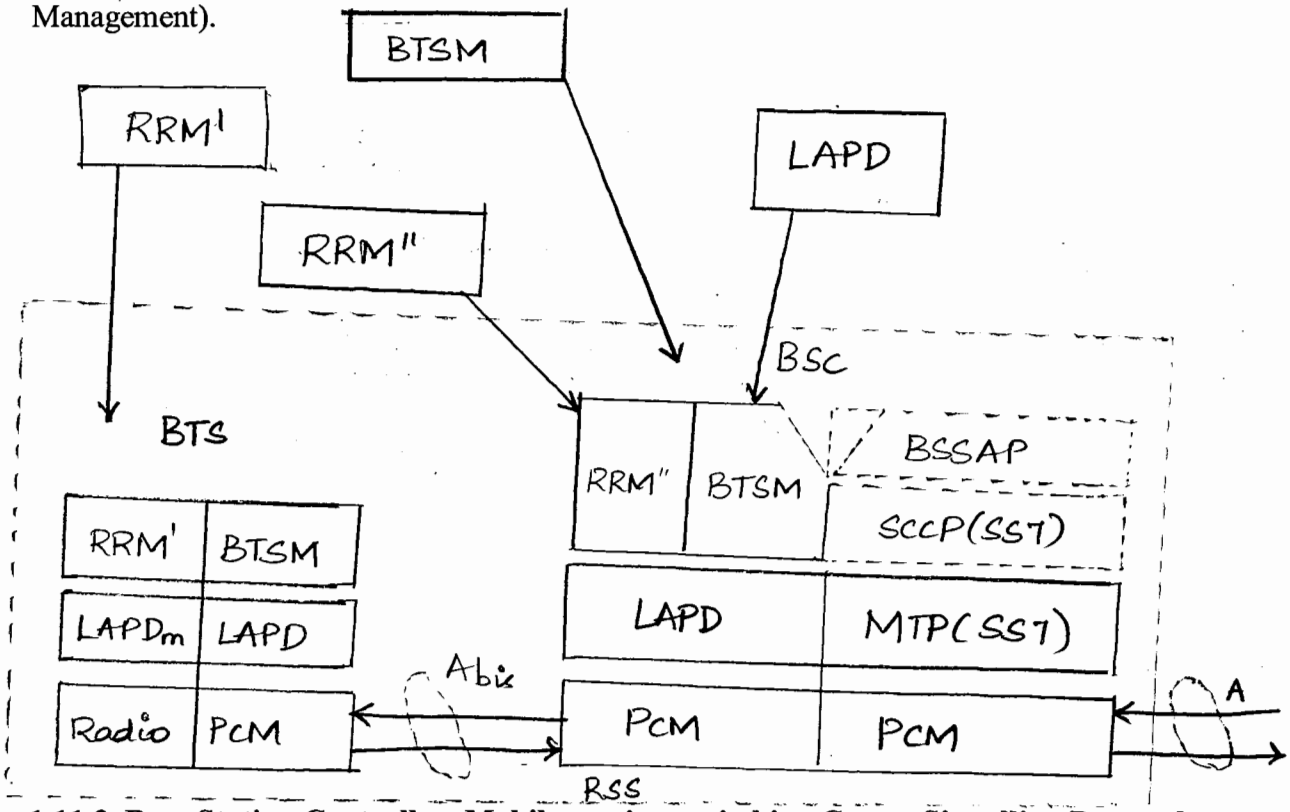
The network layer message format is as follows:

- TI (Transaction Identifier) field so that the protocol to send sequence of messages is identified.
- 8-bit control field
- PD (Protocol Discriminator) field to identify the protocol operation.
- MT (Message Type) field to identify the type of message for protocol operation.
- IE (Information element) field for providing optional information for the operation.
- IEI (Information Element Identifier) field to identify the IE field information.

1.11.2 Base transceiver – Base Station Controller Signalling Protocols

The physical layer between the BTS and the BSC is the A_{bis} interface and the connection is wired. Voice is coded in the 64 kbps PCM format in a PSTN network. The A_{bis} interface between a BTS and a BSC, therefore uses the 64 kbps PCM format. Since PCM uses different coding techniques, translation and retranslation between different formats is performed which may affect voice quality. Therefore a procedure called TFO (Tandem free operation) can be adopted which operates without translation and retranslation.

The data link layer protocol between BTS and BSC is LAPD (link access protocol D-channel) for A_{bis}. The network layer between BTS and BSC is called BTSM (BTS Management).

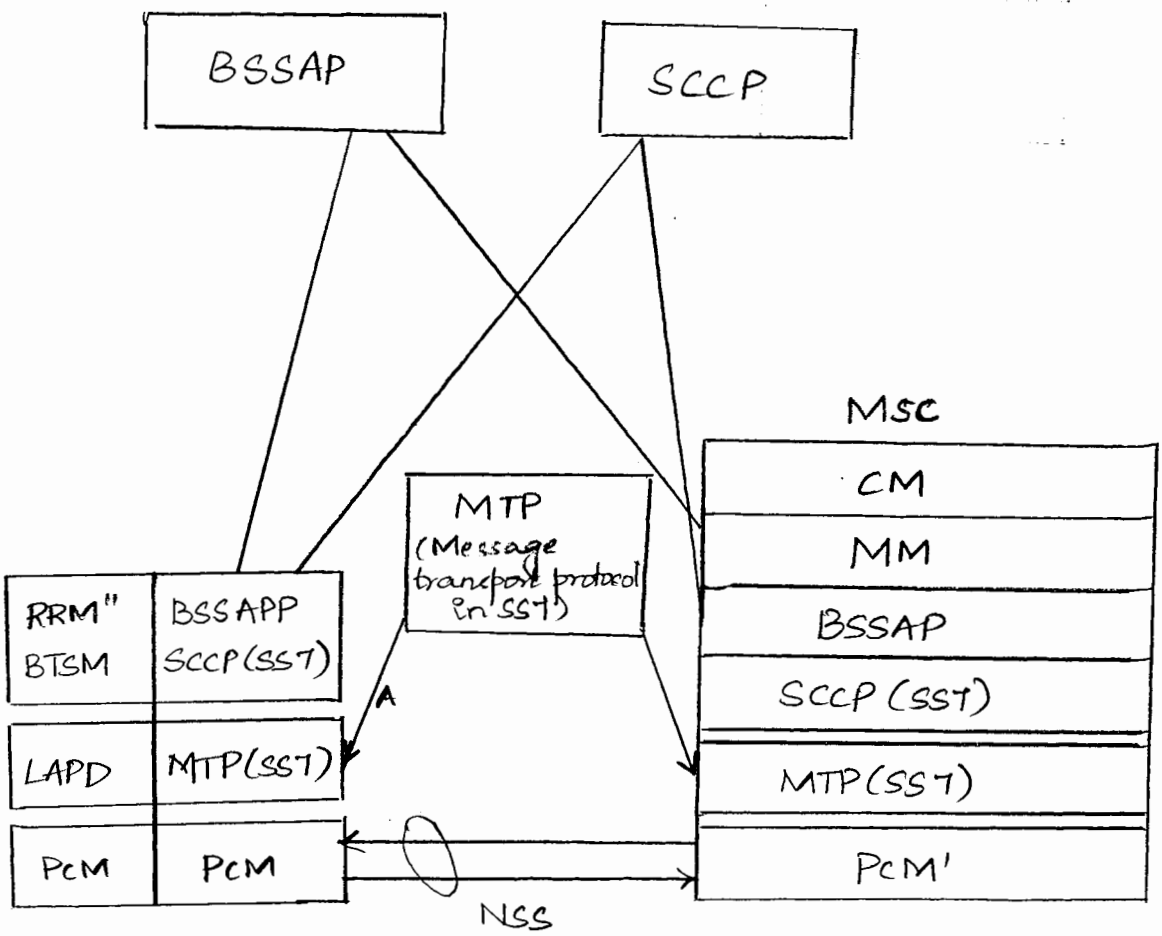


1.11.3 Base Station Controller- Mobile services switching Centre Signalling Protocols

The physical layer between BSC and MSC is PCM` (PCM multiplexed). The MSC connects to PSTN, ISDN, and PSPDN networks which employ the 64 kbps PCM or 2.048 Mbps CCITT (International telegraph and telephone consultative committee) which carries 32 PCM channels. The *A* interface between BSC and MSC uses these networks in place of GSM PLMN (public land mobile network).

The data link layer protocols between the BSC and MSC are MTP (Message transfer protocol) and SSCP (Signalling connection control protocol). MTP and SSCP are parts of the SS7 (Signalling system No 7) used by interface *A*.

The Network layer protocol at the BSC is BSSAP (Base system application part). It is as shown in below figure.



1.12 Localization

Localization is a process by which a mobile station is identified, authenticated, and provided service by a mobile switching centre through the base station controller and base transceiver either at the home location of the MS or at a visiting location. The fundamental feature of the GSM system is the automatic, worldwide localization of users for which, the system performs periodic location updates. The HLR always contains information about the current location and the VLR currently responsible for the MS informs the HLR about the location changes. Changing VLRs with uninterrupted availability is called roaming. Roaming can take place within a network of one provider, between two providers in a country and also between different providers in different countries.

The main functions of HLR are as follows:

- Registration of information regarding IMSI, MSISDN, roaming restrictions, call forwarding, mobile subscriber roaming number(MSRN), present VLR, and present MSC.

- Registration if information regarding all associated MSs which have the given MSC as their home location area. There is no de-registration of the information when an MS moves from its home location area into another location area. It connects to the AuC for authenticating an MS and granting service permissions.

The VLR stores the information regarding an MS currently in its area, which helps in saving time taken for searching and fetching the information of that MS from a remote home location register (HLR) at which MS is registered. The main functions of VLR are as follows:

- Registration of information pertaining to currently associated MSs.
- Storing information of the MSs which are in its location area and to which the MSC is currently providing network services.
- Registration of any new MS that moves into the VLR's location area.
- De-registration of an MS, if the MS dissociates from the MSC associated with the given VLR and moves out to another location area.

1.13 Calling

Calling means establishment of communication between a mobile station TE and another TE or the other TE could be a mobile station TE. The various types of calls and their respective procedures are as discussed below:

➢ **Mobile → PSTN Calls**

- These calls are originating from a mobile terminal and ending at a PSTN destination. When a mobile station MS_j, calls and communicates with a PSTN phone, TE_j, the communication is established through switching centres, MSC_i and MSC_j. MS_i establishes a connection between MS_i and TE_j in the following manner:
  - ✓ MS_i connects to BTS_i, then to BSC_i and then to MSC_i.
  - ✓ MSC_i verifies and authenticates MS_i using the VLR. It also discovers available paths to the PSTN phone TE*j* through MSC_j and $GMSC_j$.
  - ✓ MSC_i switches to MSC_j, then to $GMSC_j$, then to TE_j.
  - ✓ TE_j transmits back to $GMSC_j$ and MSC_j.
  - ✓ MSC_j switches to MSC_i , which transmits back to BSC_i, BTS_i and MS_i.

➢ **Mobile → Mobile calls**

- These calls are originating from a mobile terminal and ending at a mobile destination. When a mobile station MS_i, calls and communicates with another mobile phone, MS_j, the communication between them is routed through switching centres, MSC_i and MSC_j. MS_i establishes a connection between MS_i and MS_j in the following manner:
  - ✓ MS_i connects to BTS_i, then to BSC_j , and then to MSC_i.

- ✓ MSC_i verifies and authenticates MS_i using VLR. It also discovers available paths to mobile station MSj through MSC_j.
- ✓ MSC_i switches to MSC_j, and verifies and authenticates MS_j using VLR.
- ✓ MSC_j connects to BSC_j, BTS_j and MS_j.
- ✓ MS_j transmits back to MSC_j.
- ✓ MSC_j switches to MSC_i , which transmits back to BSC_i, BTS_i and MS_i.

➢ **PSTN → Mobile Calls**

These are the calls originating from a PSTN phone and terminating in a mobile destination employ the GMSC. When making a call to a mobile terminal MS_j, a PSTN terminal TE_j connects to $GMSC_i$ which in turn requests HLR_i to discover MSC_j . MSC_j uses VLR_j to verify and authenticate the MS_j and then MSC_j directs the call to MS_j through BSC_j and BTS_j.

➢ **Mobile Station ↔ Base Transceiver Message Exchanges**

If MS_i is setting up a call to another terminal TE_j then following message sequences are exchanged between BTS_i and MS_i before voice or data exchange.

- ✓ The MS requests the BTS to grant it a channel for communication and the BTS responds immediately by assigning channel to MS.
- ✓ The MS sends a request to the BTS for service and the BTS replies with the authentication to the MS.
- ✓ BTS transmits its response for authenticating the MS along with a command by generating the ciphering number.
- ✓ MS runs the algorithm on the ciphering number thus generating the encryption key.
- ✓ The call is setup using the call management (CM) protocol but the MS and the BTS management (BTSM) protocol by the BTS.
- ✓ Call setup is confirmed by the BTS to the MS.
- ✓ Assignment commands are sent by the BTS to the MS and assignment completion messages are sent by the MS to the BTS.
- ✓ An alert message is sent from the BTS to the MS before connection.
- ✓ A connection established message is sent from the BTS to the MS and connection established acknowledgement message is sent from MS to BTS.
- ✓ Voice or data interchange starts.

When a MS_i is setting up a call from TE_j, following message exchanges take place between BTS_i and MS_j before the voice and data exchange begins:

- ✓ BTS sends a request for paging to the MS and MS requests the BTS for channel allocation.
- ✓ A channel is assigned by the BTS to the MS and the MS responds to the page by the BTS.

- ✓ A request for authenticating the MS is sent by the BTS and a response for authentication is sent by the MS to the BTS.
- ✓ BTS sends a command for cipherimg to the MS and the MS replies with message to BTS.
- ✓ Call is set up employing the CM protocol at the MS and the BTSM protocol at the BTS and the call is confirmed by the MS to the BTS.
- ✓ Assignment commands are sent by BTS to the MS and assignment completion message are sent by MS to BTS.
- ✓ Before the connection established, an alert message is sent by the BTS to the MS.
- ✓ Connection established message is sent by the BTS to the MS and connection acknowledgment message is sent by the MS to the BTS.
- ✓ Voice or data interchange begins.

1.14 Handover

- Handover to the neighbouring cell, is defined as a mechanism to handover the control of a mobile device to the neighbouring cell.
- Handover is technically the process of transferring a call (or data transfer) in progress from one channel to another.
- The core network may perform handovers at various levels of the system architecture or it may handover the call to another network altogether.
- There are 2 main **reasons** for handover in cellular networks
    a) If the mobile device moves out of the range of one cell (base station) and a different base station can provide it with a stronger signal.
    b) If channels of one base station are busy, then a nearby base station can provide service to the device.

Types of handover:

Different cellular systems follow different regulations for handover processes.

a) Hard handover:

- ✓ It's one where existing radio link must be dropped for a small period of time before it can be taken over by another base station.
- ✓ A call in progress is redirected not only from a base station to another base station, but also from its current transmit-receive frequency pair to another frequency pair.
- ✓ An ongoing call cannot exchange data or voice for this duration. This break in call is called call drop or call cut-off.
- ✓ Handover to another cell is required when the signal strength is low and error rate is high.

b) Soft handover:

- ✓ An MS at the boundary of two adjacent cells does not suffer call drops due to handover in the boundary region.

- ✓ It does not require breaking of the radio link for cell-to-cell transfer of a call.
- ✓ A mobile device can be connected to several base stations simultaneously.

➢ **Handovers in GSM:** The different types of handovers in GSM networks are:

a) Inter-cell handover:
- ✓ When the signal strength goes weak due to several reasons, (example an MS moving away from the cell in which it is presently localized to the boundary region of another cell), there is handover from a cell to another. This process is called inter-cell handover.
- ✓ The signal strength changes inversely with the square of the distance from the transmitter.

b) Inter-MSC handover:
- ✓ Handover also takes place for load balancing when the traffic from the cells and BSC's is high.
- ✓ An ongoing call, which is being handled by a cell, may be handled over to another MSC.
- ✓ 2 MSC's are interfaced through PCM and the handover is performed over a wired line.

c) Inter-BSC handover:
- ✓ Handover also takes place for load balancing when the traffic from the cells and BTSs is high.
- ✓ A call, which is ongoing in a cell through a BTS, may be handed over to another BSC connected to the same MSC.
- ✓ Since the BSCs connect to MS interfaces by PCM, the handover is over a wired line.

d) Inter-BSC, Inter-MSC handover:
- ✓ Handover also takes place for load balancing when the traffic from the cells and BTSs as well as the BSCs is high.
- ✓ The BTSs connect to a BSC and BSCs connect to an MSC.
- ✓ A call, being handled by a cell through a BTS, may be handed over to another BSC connected to a different MSC.

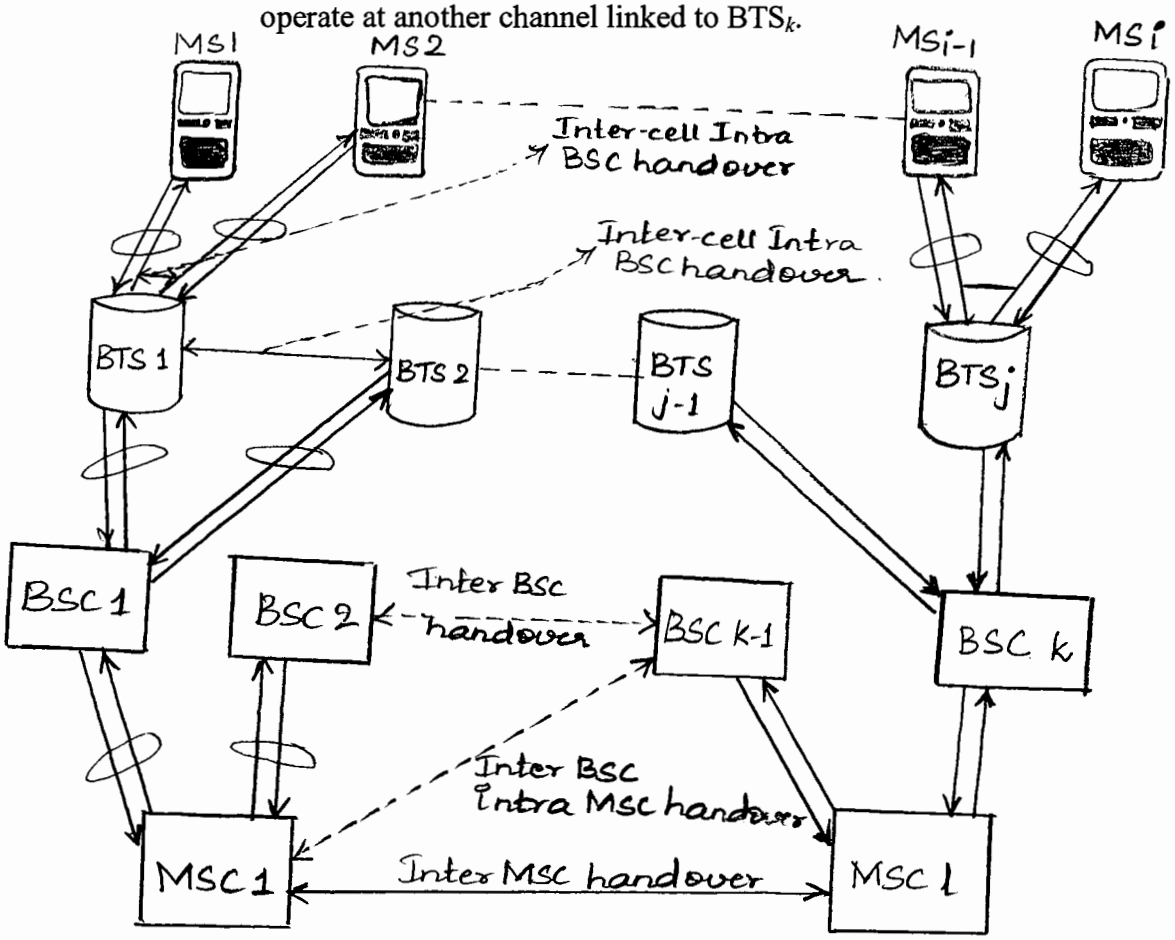
e) Intra-cell handover:
- ✓ Due to interference at certain frequencies, the signal quality becomes poor.
- ✓ The BSC can handover the call to another frequency of the cell in such cases.

f) Inter-cell, Intra-BSC handover:

- ✓ When an MS moves to the neighbouring cell and suffers poor signal quality, the BSC can handover the call to a different BTS channel of the same BSC.
- ✓ Since the BTSs connect to the BSC interfaced by PCM, the handover within the BTSs is over a wire but each BTS has different radio channels.

g) Inter-cell, Intra-MSC handover:

- ✓ The RRM sub layer transmits a signal report from MS*i* to BTS_i, and from BTS_i to BSC_i. Incase a handover is necessary, BSC_i signals the handover requirement to MSC_i.
- ✓ MSC_i signals the handover requirement to another BSC_j and BSC_j allocates radio resources and transmits the activated channel to another BTS_k.
- ✓ BTS_k sends acknowledgement of the channel to BSC_j and BSC_j acknowledges the handover request grant via a message to MSC_i.
- ✓ MSC_i transmits handover command to BSC_i, in turn, BSC_i to BTS_i, and BTS_i to MS_i's RRM layer. The RRM directs the MS radio interface to operate at another channel linked to BTS_k.



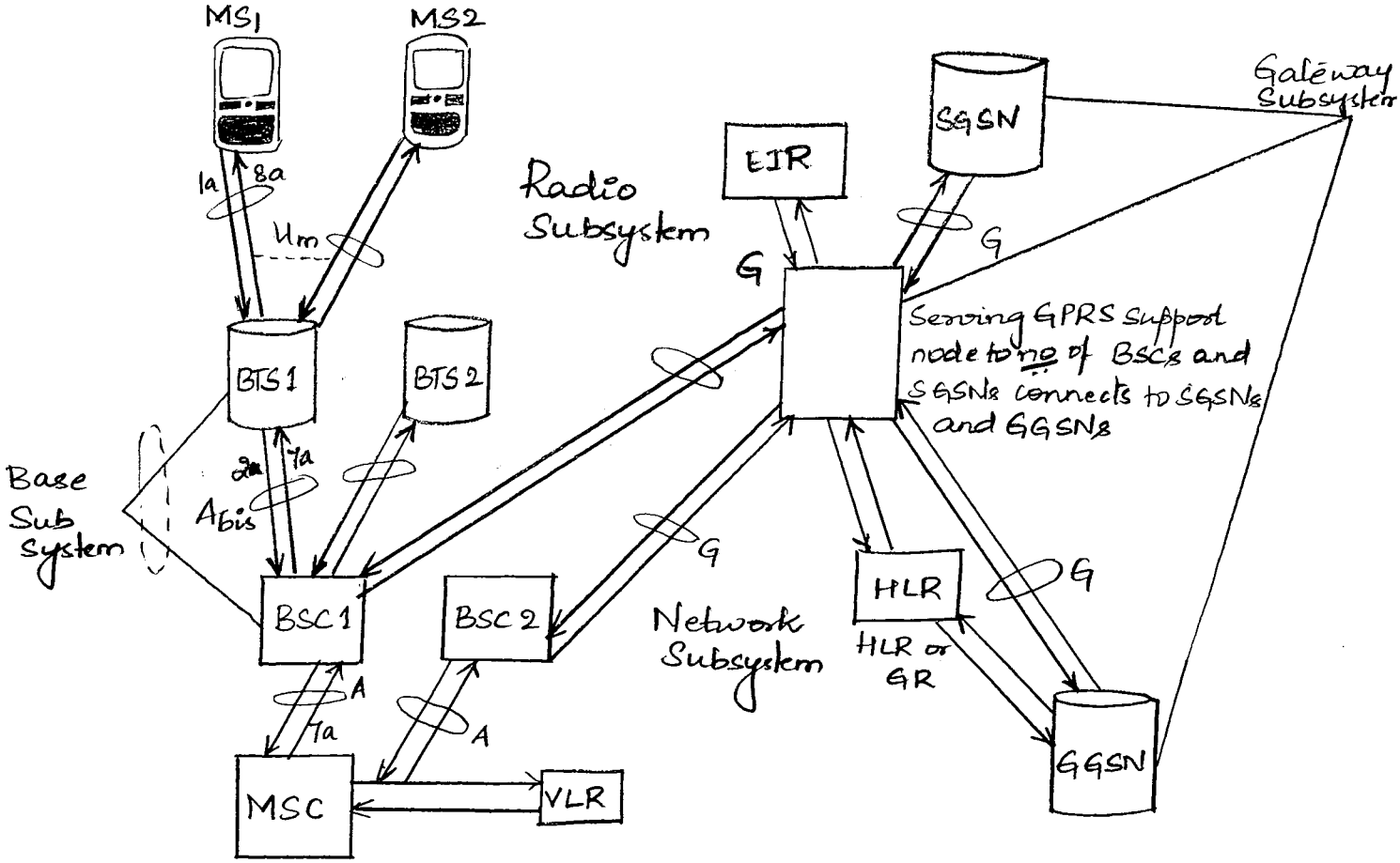
1.15 General Packet Radio Service (GPRS)

GPRS is a speed enhanced data transmission service designed for GSM systems. Speed enhanced data transmission takes place by packetizing of data and simultaneous transmission of packets over different channels.

1.15.1 GPRS System Architecture

It shows four subsystems—RSS (Radio subsystem), BSS (Base subsystem), NSS (Network subsystem), and GSS (Gateway subsystem) consisting of BSCs, MSCs, SGSNs, and GGSNs (Gateway GPRS support nodes). The architectural elements are explained as shown below:

- The RSS consists of number of MSs, BTSs and BSCs.
- An MS having GPRS capability stores a CKSN (Cipher key Sequence Number). It also stores a TLLI (Temporary logical link identity).
- The NSS consists of a number of serving GPRS support nodes (SGSNs)
- The GPRS system creates a GPRS context which is stored in the MS as well as in the SGSN.
- An EIR (GPRS Equipment identity register) stores the equipment data through the SGSN. EIR helps in the authentication, operation, and maintenance subsystems.
- Each SGSN and MSC in the NSS layer is connected to a number of BSCs at the RSS layer.
- There are *m* home location-cum-GPRS registers(HLR/GRs) and *n* (VLRs). The GPRS register (GR) part in a HLR/GR stores the GPRS data and HLR part stores the information of the mobile stations.
- The GSS consists of the SGSNs and GGSNs and provides GPRS connections to the Internet and other PDNs(Public data networks).



1.15.2 GPRS Protocol Layers

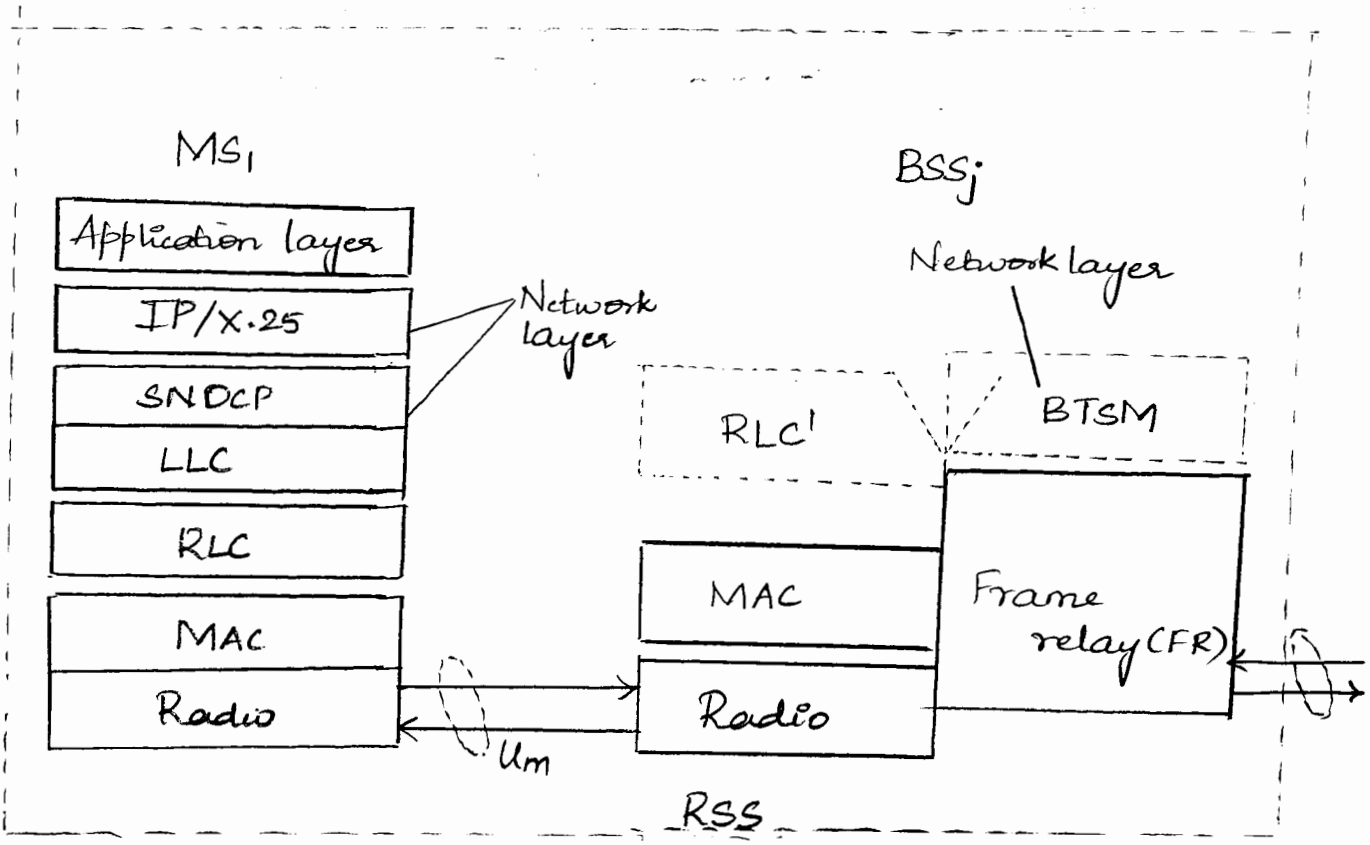
The GPRS protocol layers are similar to the GSM protocol layers as shown below:

- ✓ The MS has 4 layers—physical, data link, network and application. Session presentation and transport layer issues are taken care of by the lower layers.
- ✓ The BSS has just 3 layers – physical, data link, and network. Transport and session layer functions are taken care by network layer protocols.
- ✓ The SGSN and GGSN have 4 layers – physical, data link, network and transport.

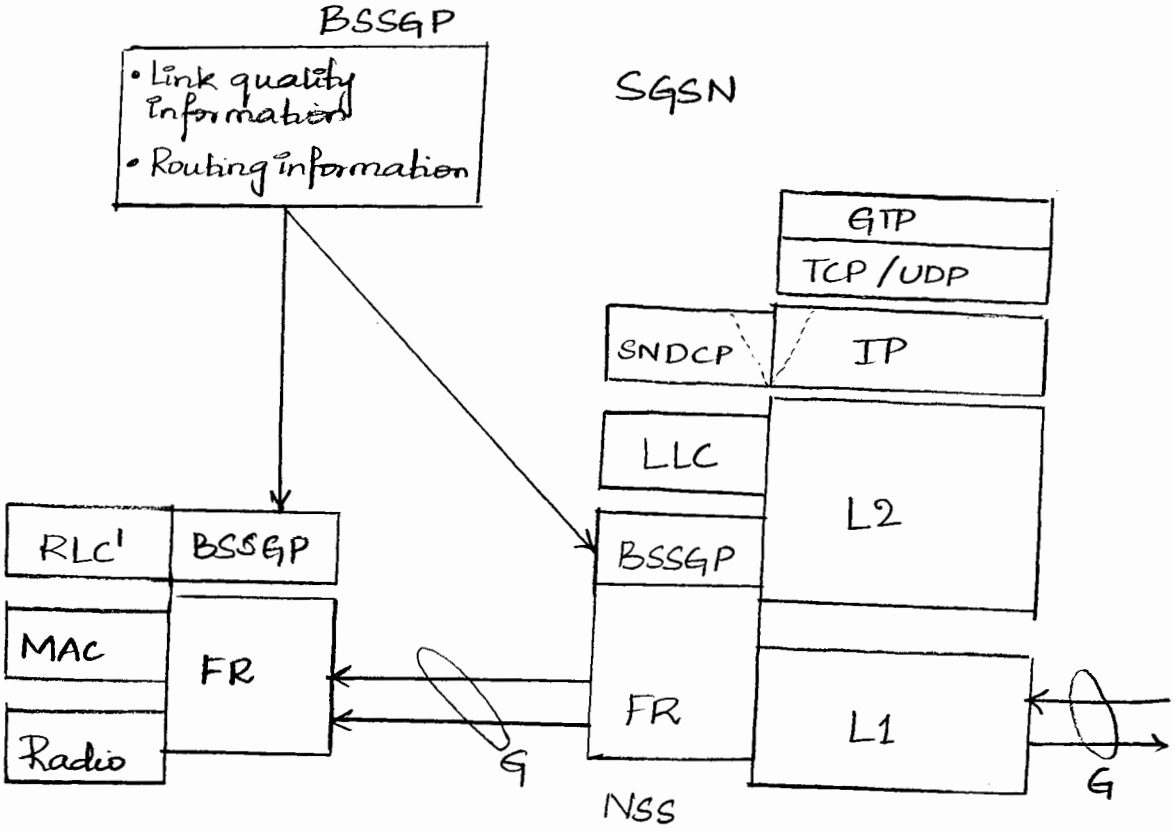
The following describes the signalling protocols:

➢ **Mobile Station and Base Station Subsystem Signalling Protocols**

- ✓ The physical layer between MS and BTS is called *radio* like in the GSM and has similar functions.
- ✓ The data link layer protocols between MS and BSS link through the physical layer which has the interface U_m as in case of GSM. The data link layer of GPRS has 3 sublayers.
  - MAC (media Access Control)
  - RLC (Radio Link Control)
  - LLC (Logical Link Control)
- ✓ The data link at BSS has two sublayers MAC and RLC2.
- ✓ Network layer at the MS has 2 sublayers – IP/X.25 and SNDCP(Sub- network dependent convergence protocol).
- ✓ The application layer at the MS provides end-to-end applications like voice and Internet.



- **Base Station Subsystem and Serving GPRS Support System Signalling Protocols**
  - ✓ The physical layer for transmission and reception of data and network information between the BSS and SGSN is FR (Frame Relay). FR implements several functions of data logical link.
  - ✓ Data Link sublayer at the BSS and the SGSN transmit and receive using BSSGP (base station subsystem GPRS protocol). The data link sublayer at the SGSN is LLC.
  - ✓ The network layer at the SGSN transmits and receive using SNDCP.



- **Serving GPRS Support node and Gateway GPRS Support Node Signalling Protocols.**
  - ✓ Physical layers between the SGSN and GGSN are layer 1 (L1) protocols of the Internet or other PDN (PSDN,ISDN, and PSPDN).
  - ✓ Data link layer protocol layers between SGSN and GGSN are layer 2 (L2) protocols of the internet.
  - ✓ Network layer protocol layers between SGSN and GGSN are IP layer 3 (L3) protocols of the Internet.
  - ✓ Two transport layer protocol layers at the SGSN are TCP (or UDP) and GTP (GPRS tunnelling protocol). TCP is for X.25 protocol at layer 3 and UDP is for IP protocol at layer 3. GTP uses TCP and IP or UDP and IP and it also facilitates flow of packets from multiple protocols.

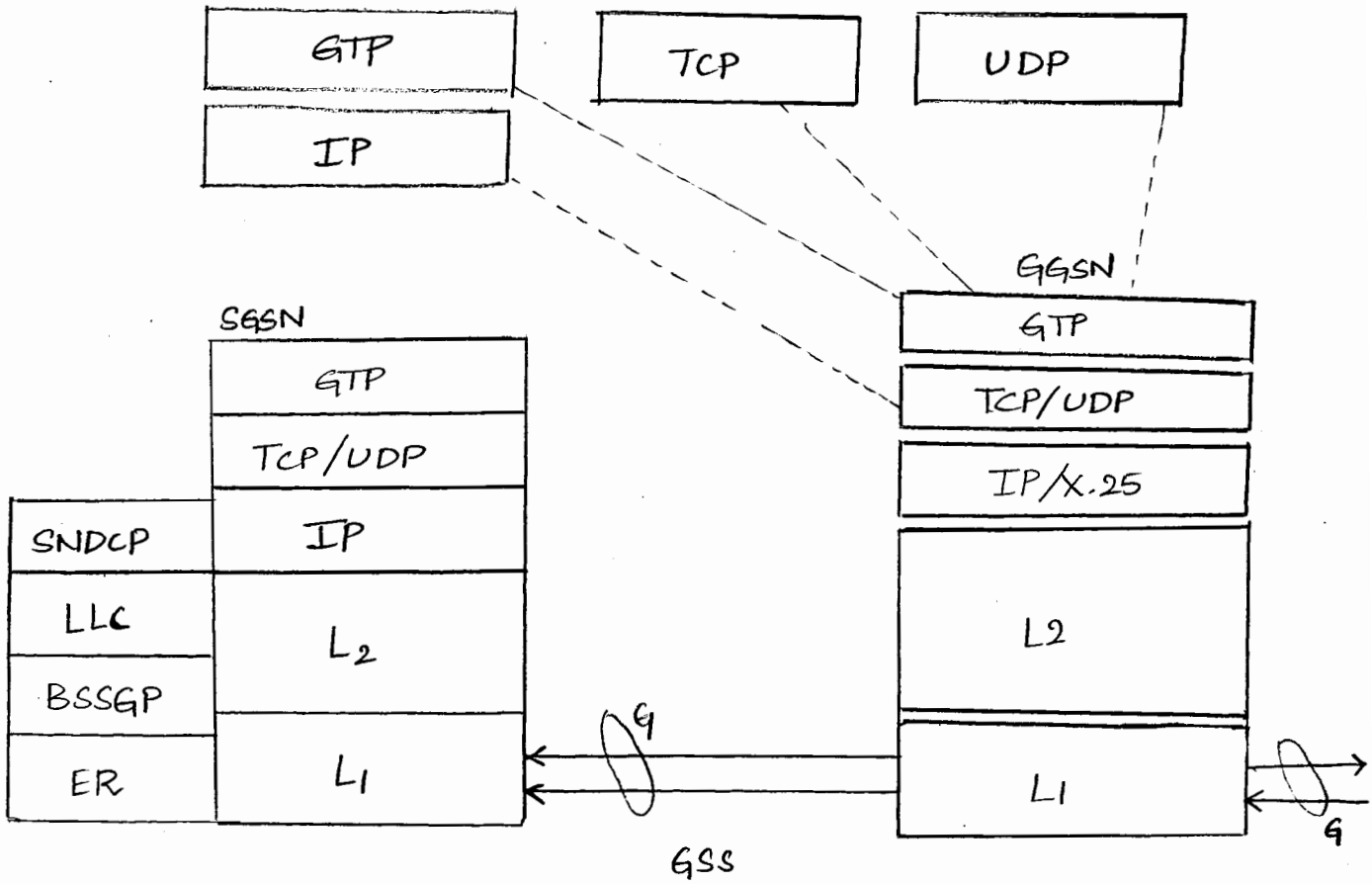


Fig: All protocol layers between the SGSN and the GGSN.