Chapter – 1

Introduction of Mobile Computing

1.1 Concept Of Mobile Communication

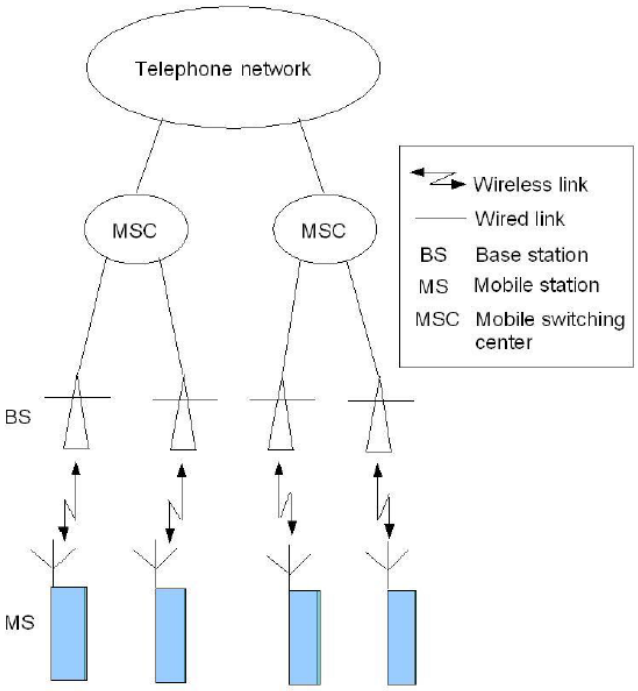
Communication is one of the integral parts of science that has always been a focus point for exchanging information among parties at locations physically apart. After its discovery, telephones have replaced the telegrams and letters. Today, mobile communication has become the backbone of the society. All the mobile system technologies have improved the way of living. It's main plus point is that it has privileged a common mass of society.

1.1.1 Evolution of Mobile Radio Communications

The first wire line telephone system was introduced in the year 1877. Mobile communication systems as early as 1934 were based on Amplitude Modulation (AM) schemes and only certain public organizations maintained such systems. With the demand for newer and better mobile radio communication systems during the World War II and the development of Frequency Modulation (FM) technique by **Edwin Armstrong**, the mobile radio communication systems began to witness many new changes. Mobile telephone was introduced in the year 1946. However, during its initial three and a half decades it found very less market penetration owing to high costs and numerous technological drawbacks. But with the development of the cellular concept in the 1960s at the Bell Laboratories, mobile communications began to be a promising field of expanse which could serve wider populations. Initially, mobile communication was restricted to certain official users and the cellular concept was never even dreamt of being made commercially available. Moreover, even the growth in the cellular networks was very slow. However, with the development of newer and better technologies starting from the 1970s and with the mobile users now connected to the Public Switched Telephone Network (PSTN), there has been an astronomical growth in the cellular radio and the personal communication systems. Advanced Mobile Phone System (AMPS) was the first U.S. cellular telephone system and it was deployed in 1983. Wireless services have since then been experiencing a 50% per year growth rate. The number of cellular telephone users grew from 25000 in 1984 to around 3 billion in the year 2007 and the demand rate is increasing day by day.

1.1.2 Fundamental Techniques

Mobile radio terminal means any radio terminal that could be moved during its operation. Depending on the radio channel, there can be three different types of mobile communication. In general, however, a Mobile Station (MS) or subscriber unit communicates to a fixed Base Station (BS) which in turn communicates to the desired user at the other end. The MS consists of transceiver, control circuitry, duplexer and an antenna while the BS consists of transceiver and channel multiplexer along with antennas mounted on the tower. The BSs are also linked to a power source for the transmission of the radio signals for communication and are connected to a fixed backbone network. Below figure shows a basic mobile communication with low power transmitters/receivers at the BS, the MS and also the Mobile Switching Center (MSC). The MSC is sometimes also called Mobile Telephone Switching office (MTSO). The radio signals emitted by the BS decay as the signals travel away from it. A minimum amount of signal strength is needed in order to be detected by the mobile stations or mobile sets which are the hand-held personal units (portables) or those installed in the vehicles (mobiles). The region over which the signal strength lies above such a threshold value is known as the coverage area of a BS. The fixed backbone network is a wired network that links all the base stations and also the landline and other telephone networks through wires.



[Fig. 1.1: Basic Mobile communication structure]

1.1.2.1 Radio Transmission Techniques

I. Simplex System

For Example: pager

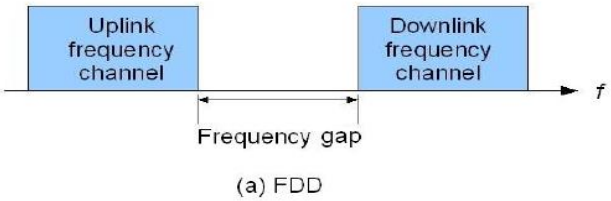
II. Half Duplex System

For Example: walkie-talkie

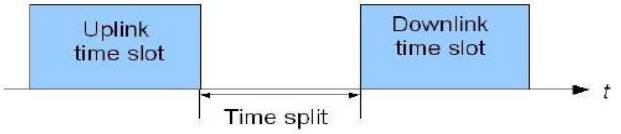
III. Full Duplex System

Both the users can communicate to each other simultaneously. This can be done by providing two simultaneous but separate channels to both the users. This is possible by one of the two following methods.

❖ **Frequency Division Duplexing (FDD):** FDD supports two-way radio communication by using two distinct radio channels. One frequency channel is transmitted downstream from the BS to the MS (forward channel).



(a) FDD

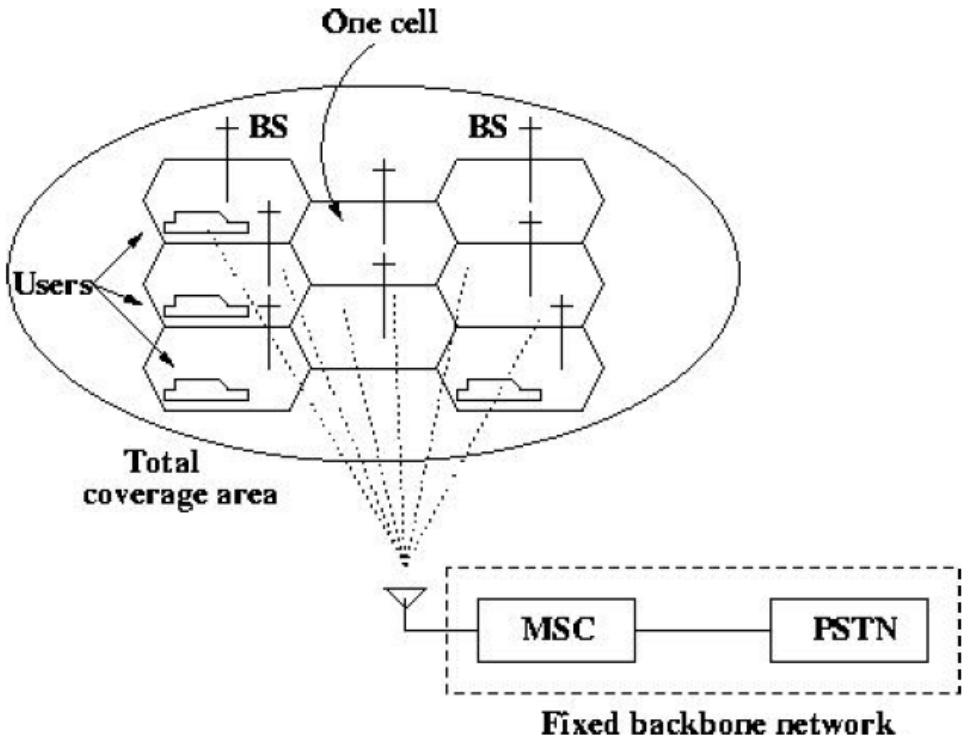


(b) TDD

A second frequency is used in the upstream direction and supports transmission from the MS to the BS (reverse channel). Because of the pairing of frequencies, simultaneous transmission in both directions is possible. To mitigate self-interference between upstream and downstream transmissions, a minimum amount of frequency separation must be maintained between the frequency pair.

- **Time Division Duplexing (TDD):** TDD uses a single frequency band to transmit signals in both the downstream and upstream directions. TDD operates by toggling transmission directions over a time interval. This toggling takes place very rapidly and is imperceptible to the user.

A full duplex mobile system can further be subdivided into two categories: a single MS for a dedicated BS, and many MS for a single BS. Cordless telephone systems are full duplex communication systems that use radio to connect to a portable handset to a single dedicated BS, which is then connected to a dedicated Telephone line with a specific telephone number on the Public Switched Telephone Network (PSTN). A mobile system, in general, on the other hand, is the example of the second category of a full duplex mobile system where many users connect among themselves via a single BS.



[Fig. 1.2: Basic Cell Structure]

1.2 Different Generations of wireless Communication

However, the spread of mobile communication was very fast in the 1990s when the government throughout the world provided radio spectrum licenses for Personal Communication Service (PCS) in 1.8 - 2 GHz frequency band. There are many wireless generations which we are going to discuss.

1.2.1 Evolution of wireless Networks

The first wireless network was commissioned in Germany in1958. It was called A-Netz and used analog technology at 160MHz. Only outgoing calls were possible in this network. That is to say that connection set-up was possible from the mobile station only. This system evolved in B-Netz operating at the same 160MHz. In this new system, it was possible to receive an incoming call from fixed telephone network, provided that location of the mobile station was known. A-Netz was wireless but not a cellular network. Therefore these systems did not have any function, which permitted handover or change of base station.

In 1968, in USA, the FCC reconsidered its position on cellular network concept. FCC agreed to allocate a larger frequency band for more number of mobile phones provided the technology to build a better mobile service is demonstrated. AT&T and Bell Labs proposed a cellular system to the FCC with many small, low powered, broadcast towers each covering a hexagonal 'cell' of a few kilometers in radius. Collectively these cells could cover a very large area. Each tower would use only a few of the total frequencies allocated to the system. As the phones travelled across the area, calls would be passed from tower to tower.

Besides AT&T and Bell Labs, other enterprises were also engaged in research in the wireless domain. In April 1973, Martin Cooper of Motorola invented the first mobile phone handset and made the first call. By 1977, AT&T and Bell Labs constructed a prototype of a public cellular network. In 1978, public trials of the cellular telephony system started in Chicago with over 2000 trial customers. In 1982, FCC finally authorized commercial cellular service for USA. In 1983, the first American commercial analog cellular service AMPS (Advanced Mobile Phone Service) was made commercially available in Chicago. This was the first cellular mobile network in the world.

In 1979, the first commercial cellular telephone system began operations in Tokyo. During the early 1980, cellular phone experienced a very rapid growth in Europe, particularly in Scandinavia and the United Kingdom and after that it was started in other countries too.

To take advantage of this growing market, each country in Europe developed its own analog mobile system and joined the bandwagon. These cellular systems developed by each country in Europe were mutually incompatible. These incompatibilities made the operation of the mobile equipment limited to national boundaries. Also, a mobile sub- scriber of one network cannot use the same device in another network in another country. This became an increasingly unacceptable situation in a unified Europe.

To cope with these problems Europeans decided to evolve a standard for mobile phone technology. In 1982, the Conference of European Posts and Telegraphs (CEPT) formed a study group called the Groupe Spécial Mobile (GSM) to develop a standard for pan-European mobile system. In 1989, GSM responsibility was transferred to the European Telecommunication Standards Institute (ETSI), and GSM became a technical committee within ETSI. In 1990, phase I of the GSM specifications were published. Commercial service of GSM started in mid 1991. Although standardized in Europe, GSM became popular outside Europe as well. Therefore, to give a global flavor, GSM was renamed as 'Global System for Mobile Communications'. In the

beginning of 1994, there were 1.3 million subscribers worldwide. This has grown to more than 1 billion by the end of February 2004 in over 200 countries. In October 2004, number of mobile subscribers in India crossed the number of fixed phones.

1.2.2 Types of Wireless Network Generations

1) First Generations (1G): First generation of wireless technology uses the analog technology. It uses FDMA(FDMA/FDD) for modulation. In it data is transmitted through circuit switching. It was introduce in around 1990s. It's speed was upto 2.4kbps. First it was available to only country area. It was not globally available. Example of 1G is AMPS, which was first introduce in USA.

Drawback of 1G:

- Poor voice quality
- Poor battery life
- Poor hand off reliability(Hand Off means mobile user goes from one cell to another while he/she is on call)
- Limited capacity
- Large phone size

2) Second Generations (2G):

The second generation or 2G technologies use digitized technology. It uses a Combination of TDMA (Time Division Multiple Access) and FDMA technologies. An example is GSM first used in the early 1990s in Europe. In 2G technology, voice is digitized over a circuit. In 2G networks, data is transacted over circuits, it means before data transmitted on network, their path decided first through which the data will be transmitted. This technology is called Circuit Switched Data or CSD in short. Using modems, a data connection is established between the device and the network. This is similar to what happens in a dial-up network over analog telephones at home.

GSM provides voice and limited data services and uses digital modulation for improved audio quality. Features of it are listed below:

- Voice call
- Text
- Sms
- Fax
- 2 Dimension image view
- It provides better quality and capacity

Drawbacks of 2G Networks:

- The GSM is a circuit switched , connection oriented technology, where the end systems are dedicated for the entire call session
- This causes inefficiency in usage of bandwidth and resources. The GSM enabled systems do not support high data rates. They are unable to handle complex data such as video
- Reduce range of sound.
- Weaker digital signal.

- Costly handoff service in case of roaming of mobile user

3) 2.5 Generations Networks (2.5G):

2.5G describes the state of wireless technology and capability usually associated with General Packet Radio Services (GPRS) - that is, between the second and third generations of wireless technology. Each generation provides a higher data rate and additional capabilities. GPRS offers data speeds at 28 Kbps (and possibly higher) and is expected to be introduced in the 2001 through 2003 timeframe. 2.5G networks also brought into the market some popular application, a few of which are: Wireless Application Protocol (WAP), General Packet Radio Service (GPRS), High Speed Circuit Switched Data (HSCSD), Enhanced Data rates for GSM Evolution (EDGE) etc. 2.5G system may make use of 2G system infrastructure, but it implements a packet-switched network domain in addition to a circuit-switched domain.

Features of 2.5G Networks:

- supporting higher data rate transmission for web browsing
- enabling location-based mobile service
- supporting e-mail traffic
- Enhance multimedia and streaming videos are possible.
- Phone calls/ Fax
- Voice mail
- Supports camera phones
- It is GPRS which is evolution from GSM which could provide data rates from 56kbps up to 115kbps.

4)3rd Generation Networks (3G):

3G is the third generation of mobile phone standards and technology, superseding 2.5G. It is based on the International Telecommunication Union (ITU) family of standards under the International Mobile Telecommunications-2000 (IMT-2000). ITU launched IMT-2000 program, which, together with the main industry and standardization bodies worldwide, targets to implement a global frequency band that would support a single, ubiquitous wireless communication standard for all countries, to provide the framework for the definition of the 3G mobile systems. Several radio access technologies have been accepted by ITU as part of the IMT-2000 framework.

3G networks enable network operators to offer users a wider range of more advanced services while achieving greater network capacity through improved spectral efficiency. Services include wide-area wireless voice telephony, video calls, and broadband wireless data, all in a mobile environment. Additional features also include HSPA data transmission capabilities able to deliver speeds up to 14.4Mbit/s on the down link and 5.8Mbit/s on the uplink.

3G networks are wide area cellular telephone networks which evolved to incorporate high-speed internet access and video telephony. IMT-2000 defines a set of technical requirements for the realization of such targets, which can be summarized as follows (Features of 3G)

- high data rates: 144 kbps in all environments and 2 Mbps in low-mobility and indoor environments
- symmetrical and asymmetrical data transmission
- circuit-switched and packet-switched-based services
- speech quality comparable to wire-line quality
- improved spectral efficiency

- several simultaneous services to end users for multimedia services
- seamless incorporation of second-generation cellular systems
- global roaming
- Open architecture for the rapid introduction of new services and technology, etc.
- Navigation / maps
- Video conferencing
- TV streaming
- Send/receive large email messages

As mentioned before, there are several different radio access technologies defined within ITU, based on either CDMA or TDMA technology. An organization called 3rd Generation Partnership Project (3GPP) has continued that work by defining a mobile system that fulfills the IMT-2000 standard. This system is called Universal Mobile Telecommunications System (UMTS). After trying to establish a single 3G standard, ITU finally approved a family of three 3G standards, which are part of the 3G framework known as IMT-2000:

- W-CDMA
- CDMA2000
- TD-SCDMA

Advantages of 3G:

- New radio spectrum to relieve overcrowding in existing systems.
- More bandwidth, security & reliability.
- Inter-portability between services providers.
- High data rates.
- Rich multimedia services.
- Always online devices.

Disadvantages of 3G

- Expensive input fees for the 3G service licenses.
- Numerous differences in the licensing terms.
- It is a challenge to build the necessary infrastructure for 3G
- Expense of 3G phones.
- Lack of buy-in by 2G mobile users for the new 3G
- Wireless services

1.3 Basic of Cell

- **What is a Cell?**

The power of the radio signals transmitted by the BS decay as the signals travel away from it. A minimum amount of signal strength (let us say, x dB) is needed in order to be detected by the MS or mobile sets which may the hand-held personal units or those installed in the vehicles. The region over which the signal strength lies above this threshold value x dB is known as the coverage area of a BS and it must be a circular region, considering the BS to be isotropic radiator. Such a circle, which gives this actual radio coverage, is called the foot print of a cell. It might so happen that either there may be an overlap between any two such side by side circles or there might be a gap between the coverage areas of two adjacent circles. Such a circular geometry, therefore, cannot serve as a regular shape to describe cells. Along with its regularity, a cell must be designed such that it is most reliable too, i.e., it supports even the

weakest mobile with occurs at the edges of the cell, without any overlap and gap between two cell. For any distance between the center and the farthest point in the cell from it, a regular hexagon covers the maximum area. Hence regular hexagonal geometry is used as the cells in mobile communication.

- **Frequency Reuse:**

Frequency reuse, or, frequency planning, is a technique of reusing frequencies and channels within a communication system to improve capacity and spectral efficiency. The essential characteristics of this reuse are:

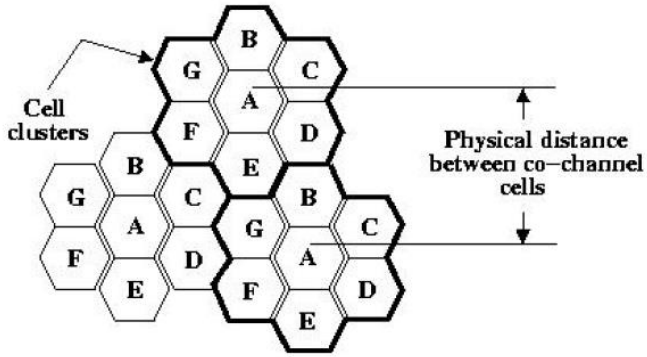
I. The area to be covered is subdivided into radio zones of cells. Though in reality these cells could be of any shape, for convenient modeling purposes these are modeled as hexagonal. Base stations are positioned at the center of these cells.

II. Each cell *i* receives a subset of frequencies fb_i from the total cell assign to the respective mobile network. To avoid any type of co-channel interference, two neighboring cells never use the same frequencies.

III. Only at distance D(frequency reuse distance), the same frequency from the set of fb_i can be reused. Cells with distance D from cell *i*, can be assign one or all the frequencies from the set fb_i belonging to cell *i*.

IV. When moving from one cell to another during an ongoing conversation, an automatic channel change occurs. This phenomenon is called Handover. Handover maintains an active speech and data connection over cell boundaries.

The regular repetition of frequencies in cells result in a Clustering of cells and the group cells which uses allotted unique frequency channel is called **cluster**. Since each cell is designed to use radio frequencies only within its boundaries, the same frequencies can be reused in other cells not far away without interference, in another cluster. Such cells are called `co-channel' cells. The reuse of frequencies enables a cellular system to handle a huge number of calls with a limited number of channels. Consider a cellular system with C duplex channels available for use and let N be the number of cells in a cluster. If each cell is allotted A duplex channels with all being allotted unique and disjoint channel groups we have C = AN under normal circumstances. Now, if the cluster are repeated M times within the total area, the total number of duplex channels, or, the total number of users in the system would be T = MC = AMN.



[Fig. 1.3 Cell clusters in cellular network]

1.4 Noise and its effect on Mobile

Noise is unwanted electrical or electromagnetic energy that degrades the quality of signals and data. Noise occurs in digital and analog systems, and can affect files and communications of all types, including text, programs, images, audio, and telemetry.

In a hard-wired circuit such as a telephone-line-based Internet hookup, *external noise* is picked up from appliances in the vicinity, from electrical transformers, from the atmosphere, and even from outer space. Normally this noise is of little or no consequence. However, during severe thunderstorms, or in locations were many electrical appliances are in use, external noise can affect communications. In an Internet hookup it slows down the data transfer rate, because the system must adjust its speed to match conditions on the line. In a voice telephone conversation, noise rarely sounds like anything other than a faint hissing or rushing.

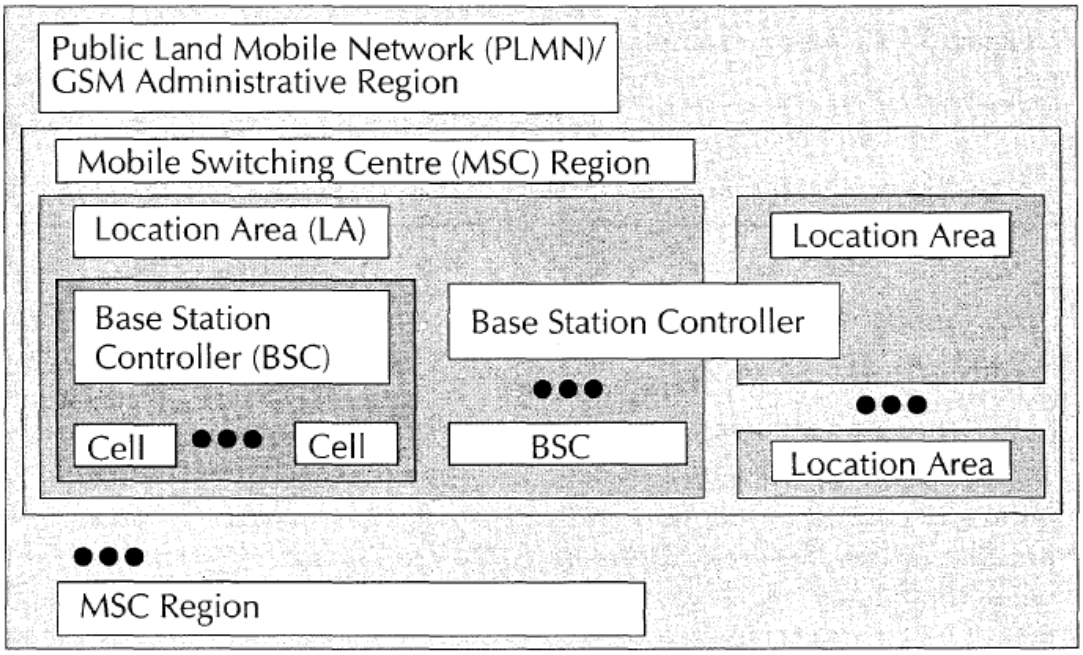
Noise is a more significant problem in wireless systems than in hard-wired systems. In general, noise originating from outside the system is inversely proportional to the frequency, and directly proportional to the wavelength. At a low frequency such as 300kHz, atmospheric and electrical noise are much more severe than at a high frequency like 300 megahertz. Noise generated inside wireless receivers, known as *internal noise*, is less dependent on frequency. Engineers are more concerned about internal noise at high frequencies than at low frequencies, because the less external noise there is, the more significant the internal noise becomes.

Communications engineers are constantly striving to develop better ways to deal with noise. The traditional method has been to minimize the signal bandwidth to the greatest possible extent. The less spectrum space a signal occupies, the less noise is passed through the receiving circuitry. However, reducing the bandwidth limits the maximum speed of the data that can be delivered. Another, more recently developed scheme for minimizing the effects of noise is called digital signal processing (digital signal processing). Using fiber optics, a technology far less susceptible to noise, is another approach.

1.5 Basics Of GSM Architecture

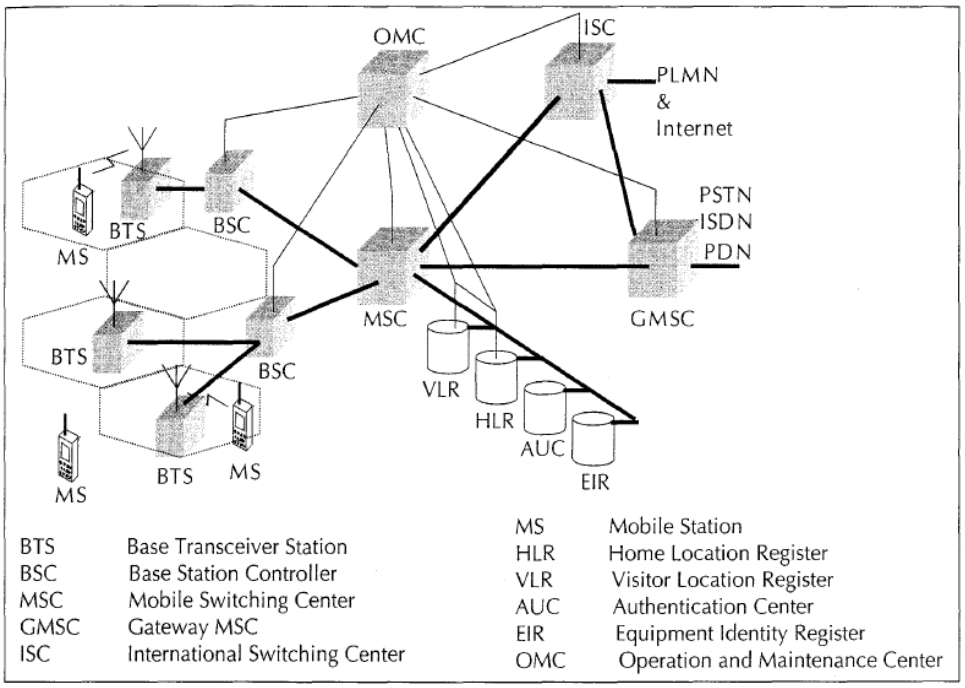
Due to its innovative technologies and strengths, GSM rapidly became truly global. GSM uses a combination of FDMA (Frequency Division Multiple Access) and TDMA (Time Division Multiple Access). The GSM system has an allocation of 50 MHz (890-915 MHz and 935-960 MHz) bandwidth in the 900 MHz frequency band. Using FDMA, this band is divided into 124 (125 channels, 1 not used) channels each with a carrier bandwidth of 200 KHz. Using TDMA, each of these channels is then further divided into 8 time slots. Therefore, with the combination of FDMA and TDMA we can realize a maximum of 992 channels for transmit and receive. In order to be able to serve hundreds of thousands of users, the frequency must be reused. This is done through cells (Cellular Network).

GSM networks are structured in hierarchic fashion (Fig. 1.4). It consists at the minimum one administrative region assigned to one MSC (Mobile Switching Centre). The administrative region is commonly known as PLMN (Public Land Mobile Network). Each administrative region is subdivided into one or many Location Area (LA). One LA consists of many cell groups. Each cell group is assigned to one BSC (Base Station Controller). For each LA there will be at least one BSC. Cells in one BSC can belong to different LAs.

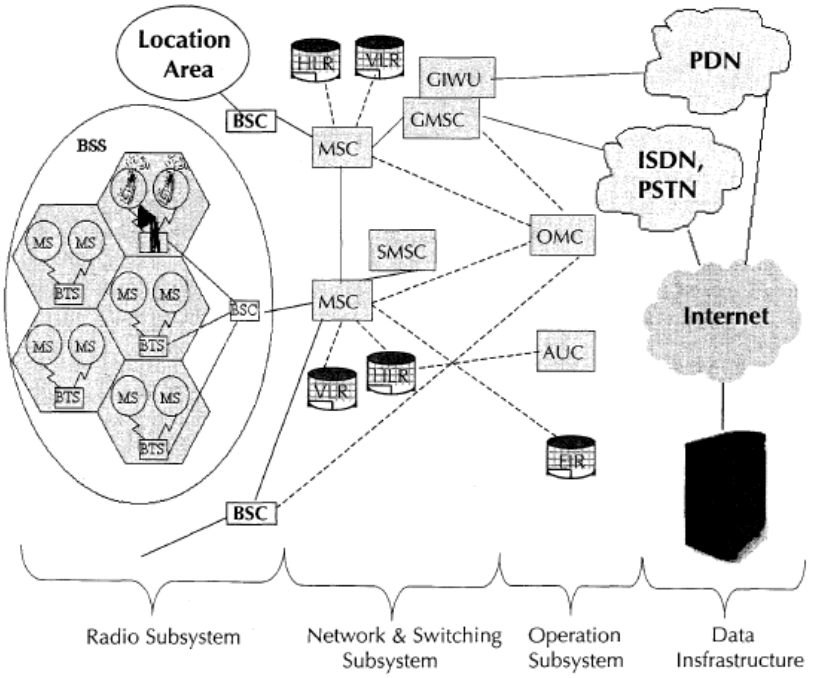


[Fig. 1.4: Hierarchy of GSM Network]

Cells are formed by the radio areas covered by a BTS (Base Transceiver Station) shown in below figure. Several BTSs are controlled by one BSC. Traffic from the MS (Mobile Station) is routed through MSC. Calls originating from or terminating in a fixed network or other mobile networks is handled by the GMSC (Gateway MSC). Fig. 1.5 depicts the architecture of a GSM PLMN from technology point of view, whereas Fig. 1.6 depicts the same architecture from operational point of view. For all subscribers registered with a cellular network operator, permanent data such as the service profile is stored in the Home Location Register (HLR).



[Fig. 1.5: Architecture of GSM]



BTS	Base Transceiver Station	ISDN	Integrated System Digital Network
BSC	Base Station Controller	HLR	Home Location Register
MSC	Mobile Switching Center	VLR	Visitor Location Register
GMSC	Gateway MSC	AUC	Authentication Center
SC	Service Center/SMS Controller	EIR	Equipment Identity Register
GIWU	Gateway Interworking Unit	OMC	Operation and Maintenance Center
PDN	Public Data Network	PSTN	Public Switched Telephone Network
MS	Mobile Station		

[Fig. 1.6: System Architecture of GSM]

1.5.1 GSM Entities:

The GSM technical specifications define different entities that form the GSM network by defining their functions and interface requirements. The GSM network can be divided into four main groups

1) The Mobile Station (MS): This includes the Mobile Equipment (ME) and the Subscriber Identity Module (SIM).
2) The Base Station Subsystem (BSS): This includes the Base Transceiver Station (BTS) and the Base Station Controller (BSC).
3) The Network and Switching Subsystem (NSS): This includes Mobile Switching Center (MSC), Home Location Register (HLR), Visitor Location Register (VLR), Equipment Identity Register (EIR), and the Authentication Center (AUC).
4) The Operation and Support Subsystem (OSS): This includes the Operation and Maintenance Center (OMC). Now let's see each sub group in detail.

1) Mobile Station (MS):

Mobile equipment or mobile station is any handheld cellular device which user can use anywhere in network area. Each mobile station has one unique identifier number called IMEI (International Mobile Equipment Identity) number to uniquely identify the mobile station.

Another part of this subgroup is SIM (Subscriber Identity Module). The SIM is installed in every GSM phone and identifies the terminal (MS). Without the SIM card, the terminal is not

operational. The SIM cards used in GSM phones are smart processor cards. These cards possess a processor and a small memory. By inserting the SIM card into the terminal, the user can have access to all the subscribed services. The SIM card contains the International Mobile Subscriber Identity (IMSI) used to identify the subscriber to the system, a secret key for authentication, and other security information. Another advantage of the SIM card is the mobility of the users. In fact, the only element that personalizes a terminal is the SIM card. Therefore, the user can have access to its subscribed services in any terminal using his or her SIM card. Typically SIM cards contain 32 K bytes of memory. Part of the memory in the SIM card is available to the user for storing address book and SMS messages.

2) Base Station Subsystem:

It connects the Mobile Station and the NSS (Network and Switching Subsystem). It is in charge of the transmission and reception for the last mile. The BSS can be divided into two parts:

a) **The Base Transceiver Station (BTS) or Base Station in short**: The Base Transceiver Station corresponds to the transceivers and antennas used in each cell of the network. In a large urban area, a large number of BTSs are potentially deployed. A BTS is usually placed in the center of a cell. Its transmitting power defines the size of a cell. The BTS houses the radio transmitter and the receivers that define a cell and handles the radio-link protocols with the Mobile Station.

b) **The Base Station Controller (BSC):** Base Station Controller is the connection between the BTS and the Mobile service Switching Center (MSC). The BSC manages the radio resources for one or more BTSs. It handles handovers, radio-channel setup, control of radio frequency power levels of the BTSs, exchange function, and the frequency hopping.

3) Network and Switching Subsystem: The main part of NSS is MSC (Mobile Switching Center). It does following function:

- Switching and Call routing: A MSC controls call set-up, supervision and release and may interact with other nodes to successfully establish a call. This includes routing of calls from MS's to other networks such as a PSTN.
- Charging: An MSC contains functions for charging mobile calls and information about the particular charge rates to apply to a call at any given time or for a given destination. During a call it records this information and stores it after the call, e.g. for output to a billing center.
- Service Provisioning: Supplementary services are provided and managed by a MSC.
- Communication with HLR: The primary occasion on which an MSC and HLR communicate is during the set-up of a call to an MS, when the HLR requests some routing information from the MSC1.
- Communication with VLR: Associated with each MSC is a VLR, with which it communicates for subscription information, especially during call set-up and release.
- Communication with other MSC's: It may be necessary for two MSC's to communicate with each other during call setup or handovers between cells belonging to different MSC's.
- Control of Connected BSCs: The MSC has the function of controlling the primary BSS node: the BSC. Each MSC may control many BSC's, depending on the volume of traffic in a particular MSC service area. An MSC may communicate with its BSC's during, for example, call set-up and handovers between two BSC's
- It acts like a normal switching node for ISDN.

- It provides all the functionality needed to handle a mobile subscriber, such as registration, authentication, location updating, handovers and call routing.
- It includes databases needed in order to store information to manage the mobility of a roaming subscriber.

These different services are provided in conjunction with several functional entities, which together form the Network Subsystem. The signaling between functional entities in the Network Subsystem uses Signaling System Number 7 (SS7).

The HLR is considered a very important database that stores information of subscribers belonging to the covering area of a MSC. Although a HLR may be implemented as a distributed database, there is logically only one HLR per GSM network. It stores following information in database:

- Authentication information like International Mobile Subscriber Identity (IMSI)
- Identification information like name, address, etc. of the subscriber
- Identification information like Mobile Station International Subscriber Directory Number (MSISDN) etc.
- Billing information like prepaid or postpaid
- Operator selected denial of service to a subscriber
- Handling of supplementary services like for CFU (Call Forwarding Unconditional), CFB (Call Forwarding Busy), CFNR (Call Forwarding Not Reachable) or CFNA (Call Forwarding Not Answered)
- Provisioning information like whether roaming is enabled or not
- Information related to auxiliary services like Voice mail, data, fax services etc.

The VLR can be considered a temporary copy of some of the important information stored in the HLR. VLR is similar to a cache, whereas HLR is the persistent storage. The VLR contains selected administrative information borrowed from the HLR, necessary for call control and provisioning of the subscribed services. Note that MSC contains no information about a particular mobile station—this information is stored in location registers. When a subscriber enters the covering area of a new MSC, the VLR associated with this MSC will request information about the new subscriber from its corresponding HLR in the home network. For example if a subscriber of a GSM network in Bangalore is roaming in Delhi, the HLR data of the subscriber will remain in Bangalore with the home network, however, the VLR data will be copied to the roaming network in Delhi. The VLR will then have enough information in order to assure the subscribed services without needing to refer to the HLR each time a communication is established. Though the visiting network in Delhi will provide the services, the billing for the services will be done by the home network in Bangalore.

Within the NSS there is a component called Gateway MSC (GMSC) that is associated with the MSC. A gateway is a node interconnecting two networks. The GMSC is the interface between the mobile cellular network and the PSTN. It is in charge of routing calls from the fixed network towards a GSM user and vice versa. The GMSC is often implemented in the same node as the MSC.

4) **Operation and Support Subsystem:** As the name suggests Operations and Support Subsystem (OSS) controls and monitors the GSM system. The OSS is connected to the different components of

the NSS and to the BSC. It is also in charge of controlling the traffic load of the BSS. However, the increasing number of base stations, due to the development of cellular radio networks, has resulted in some of the maintenance tasks being transferred to the BTS. This transfer decreases considerably the cost of the maintenance of the system. Provisioning information for different services is managed in this layer.

Equipment Identity Register (EIR) is a database that contains a list of all valid mobile equipment within the network, where each mobile station is identified by its International Mobile Equipment Identity (IMEI). EIR contains a list of IMEIs of all valid terminals. An IMEI is marked as invalid if it has been reported stolen or is not type approved. The EIR allows the MSC to forbid calls from this stolen or unauthorized terminal.

Authentication Center (AUC) is responsible for the authentication of a subscriber. This is a protected database and stores a copy of the secret key stored in each subscriber's SIM card. These data help to verify the user's identity.

❖ Short Message Services

Like many other eccentric technologies, SMS was also allegedly the right idea at the wrong time. On 3 December 1992, a scientist named Neil Papworth at Sema, a British technology company, sent the first text message 'Merry Christmas' to the GSM operator Vodafone. It was sent to Vodafone director Richard Jarvis in a room at Vodafone's HQ in Newbury in southern England. SMS was almost forgotten and became an unwanted child until seven years later in 1999 when other mobile phone operators started to allow customers to swap SMS. Today SMS is the most popular data bearer/ service within GSM with an average of one billion SMS messages (at the end of 2002) transacted every day around the world, with a growth of on an average half a billion every month. It uses ss#7 signaling channel to transmit the message. Each short message is up to 160 characters in length when 7-bit English characters are used. It is 140 octets when 8-bit characters (some European alphabets) are used, and 70 characters in length when non-Latin alphabets such as Arabic, Chinese or Hindi are used (70 characters of 16 bit Unicode).

Strength of SMS

Following is a list of characteristics of SMS, which make this an attractive bearer for mobile computing.

I. **Omnibus nature of SMS:** SMS uses SS7 signaling channel, which is available throughout the world. SMS is the only bearer that allows a subscriber to send a long distance SMS without having long distance subscription. For example, you cannot make a voice call to a mobile phone in UK unless you have an international calling facility. However, you can send a SMS to a subscriber in UK, without having an international call facility.

II. **Stateless:** SMS is session less and stateless. Every SMS message is unidirectional and independent of any context. This makes SMS the best bearer for notifications, alerts and paging. SMS can be used for proactive information dissemination for 'unsolicited response' and business triggers generated by applications

III. **Asynchronous:** In http, for every command (e.g., GET or POST) there is a request and a response pair making it synchronous at the transaction level. Unlike http, SMS is completely asynchronous. In case of SMS, even if the recipient is out of service, the transmission will not be abandoned. Therefore, SMS can be used as message queues. In essence, SMS can be used as a

transport bearer for both synchronous (transaction oriented) and asynchronous (message queue and notification) information exchange.

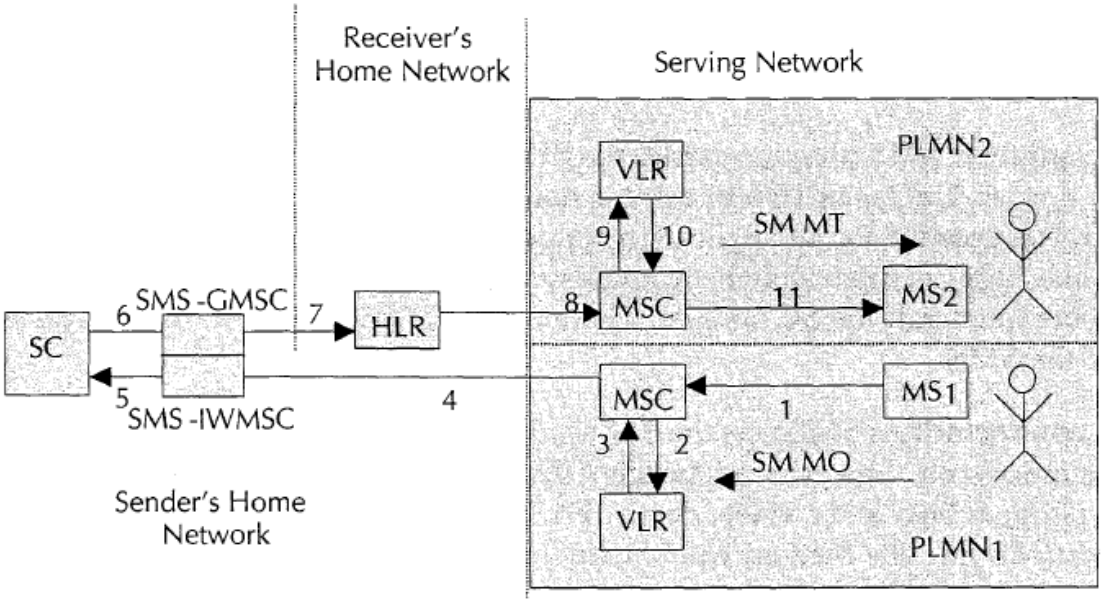
IV. **Self-configurable and last mile problem resistant:** SMS is self-configurable. In the case of Web or WAP, it is no trivial task to connect to a service from a foreign network without any change in the configuration or preference setting. The device needs to be configured interactively by the user or system administrator to access the network. This makes the access dependent on the last mile. SMS has no such constraints. While in a foreign network, one can access the SMS bearer without any change in the phone settings. The subscriber is always connected to the SMS bearer irrespective of the home.

V. **Always connected:** As SMS uses the SS7 signaling channel for its data traffic, the bearer media is always on. User cannot switch OFF, BAR or DIVERT any SMS message. When a phone is busy and a voice, data or FAX call is in progress, SMS message is delivered to the MS (Mobile Station) without any interruption to the call.

SMS Architecture

SMS are basically of two types, SM MT (Short Message Mobile Terminated Point-to-Point), and SM MO (Short Message Mobile Originated Point-to-Point). SM MT is an incoming short message from the network side and is terminated in the MS. SM MO is an outgoing message, originated in the user device (MS), and forwarded to the network for delivery. For outgoing message, the path is from MS to SC via the VLR and the IWMSC function of the serving MSC, whereas for incoming message the path is from SC to the MS via HLR and the GMSC function of the home MSC (Fig. 1.7).

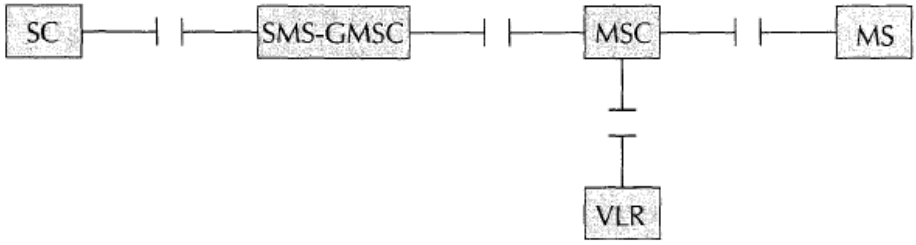
To use SMS as a bearer for Information exchange, the Origin server or the Enterprise server needs to be connected to the SC through a short message entity (SME). The SME in this case works as a SMS gateway, which interacts to the SC in one side, and the enterprise server on the other side.



[Fig. 1.7: The main network structure serving as a basis for the short message transfer]

Short Message Mobile Originated (SM MO)

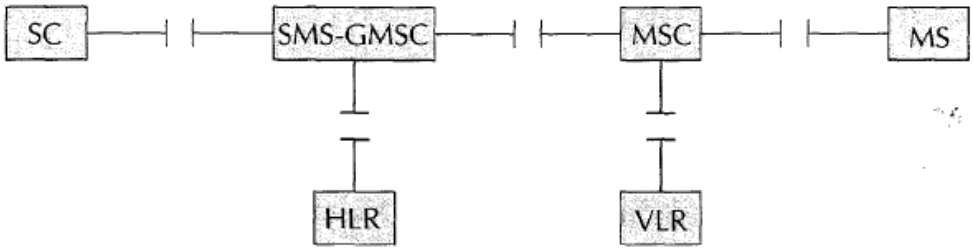
SM MO is an outgoing message originated in the MS where generally the user types in a message and sends it to a MSISDN number. For a MO message, the MSC forwards the message to the home SC. The SC is an independent computer in the network and works as a store and forward node. In SS7 terminology SC is a SCP (Service Control Point) within the SS7 cloud. MO message works in two asynchronous phases. In the first phase, the message is sent from the MS to the home SC as a MO message (Figure 1.8). In the second phase, the message is sent from the home SC to the MS as a MT message (Figure 1.9). It is possible to attempt to send a SMS message to an invalid MSISDN number. In such a case, the message will be sent successfully from the MS to the SC. However, it will fail during the SC to the MS transfer.



[Fig. 1.8: interface involved in the short message mobile originated procedure]

Short Message Mobile Terminated (SM MT)

For a SM MT message, the message is sent from SC to the MS. This whole process is done in one transaction (Figure). For the delivery of MT or incoming SMS messages, the SC of the serving network is never used. This implies that a SMS message can be sent from any SC in any network to a GSM phone anywhere in the world. This makes any SM MT message mobile operator independent.



[Fig. 1.9: interface involved in the short message mobile terminated procedure]

❖ Multimedia Message Service (MMS)

SMS was launched in 1992 and has become the most successful wireless data service to date. SMS was originally designed to carry text message. Vendors started thinking adding more life to the text message. Result was enhanced SMS EMS offered a combination of text and simple pixel-image (pictures) and melody (ringing tone). SMS was person-to-person, whereas EMS was content-to-person. The popularity of the first and the second generation messaging made device vendors think of next generation messaging. In the third generation of messaging, the message content will be multimedia objects. This is called Multimedia Messaging Service or MMS in short. An MMS message can contain formatted text, graphics, data, animations, images, audio clips, voice transmissions and video sequences.

Though MMS is targeted for the 3G networks, it can work under a 2G or 2.5G network as well. All it needs is a MMS handset and the MMS infrastructure. There are two standards bodies producing

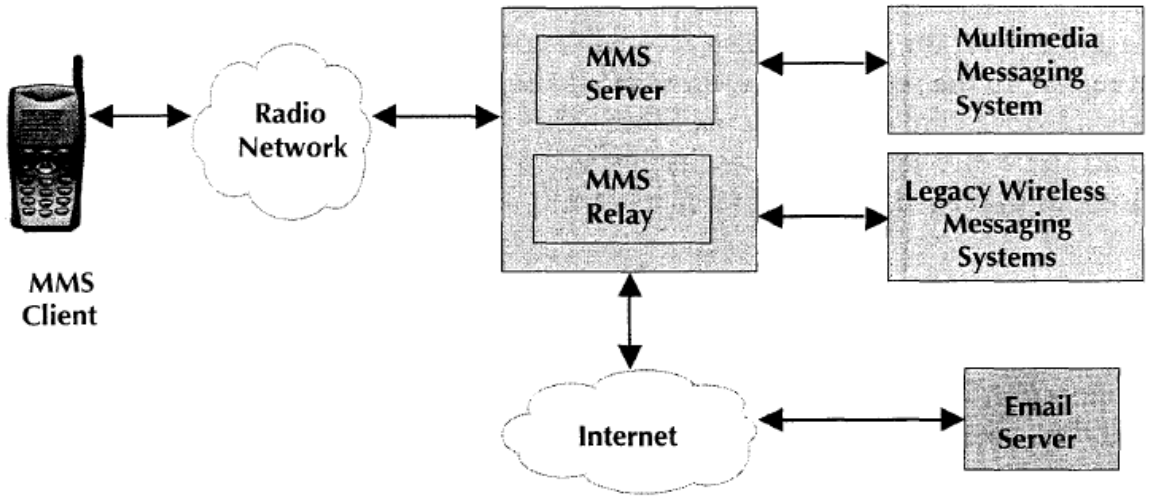
specifications relating to MMS messages. These are WAP Forum and the 3GPP (third Generation Partnership Project). The standards produced by these two bodies in turn use existing specifications from two Internet standards bodies: the W3C (World Wide Web Consortium) and the IETF (Internet Engineering Task Force). The standards from the WAP Forum specify how messages are composed and packaged whereas the standards from the 3GPP specify how messages are sent, routed, and received.

Below Figure shows a generalized view of the Multimedia Message Service architecture for a 3G messaging system. It combines different networks and network types. It integrates existing messaging systems within these networks. A user takes a picture using his mobile phone and sends it to another person using the MMS functionality (person-to-person). The picture can be sent directly as a MMS message or can be sent as an attachment to an email message. MMS messages can also be automatically generated and sent through software (content-to-person). For example, a user could ask for the day's weather forecast to be sent to her phone each morning complete with animated maps and audio of the weatherman.

In the first phase of the MMS, users should be able to create presentation slides through software. The layout and ordering of the slides are specified through a language called SMIL (Synchronization Multimedia Integration Language). This may be a slide show with multiple or even a single slide. In the second phase, users should be able to record their own video content (10 second video clip) and send it via MMS. The maximum size of the entire packaged message that first generation devices can support is 50 kB.

MMS Architecture

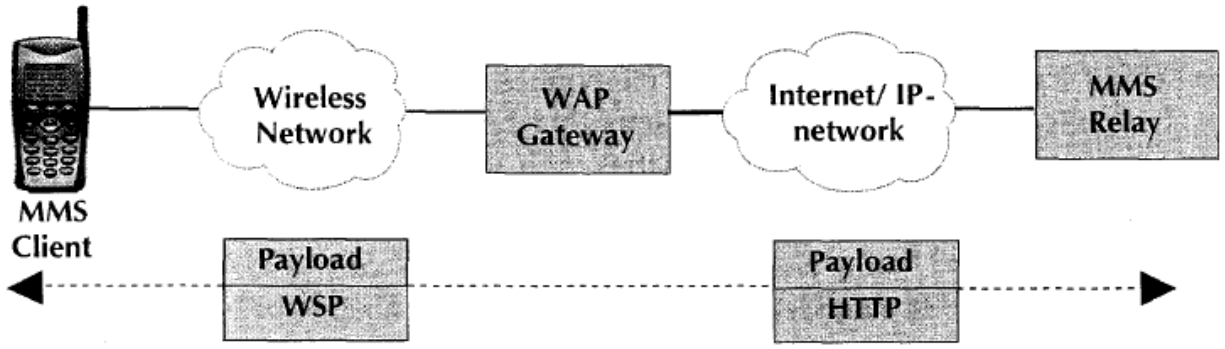
The connection between different networks in Figure 1.10 is provided by the Internet protocol and its associated set of messaging protocols. This approach enables messaging in wireless networks to be compatible with messaging systems found on the Internet. Multimedia Message Service Environment (MMSE) encompasses various elements required to deliver a MMS (Figure 1.11). This includes:



[Fig. 1.10: MMS Network]

- MMS Client: This is the entity that interacts with the user. It is an application on the user's wireless device.

- MMS Relay: This is the system element that the MMS client interacts with. It provides access to the components that provide message storage services. It is responsible for messaging activities with other available messaging systems. The SMS relay along with the MMS content server is referred to as MMSC (MMS Controller).
- WAP Gateway: It provides standard WAP services needed to implement MMS.
- MMS Server: This is the content server, where the MMS content is generated
- Email Server: MMS can integrate seamlessly to the email system of Internet.



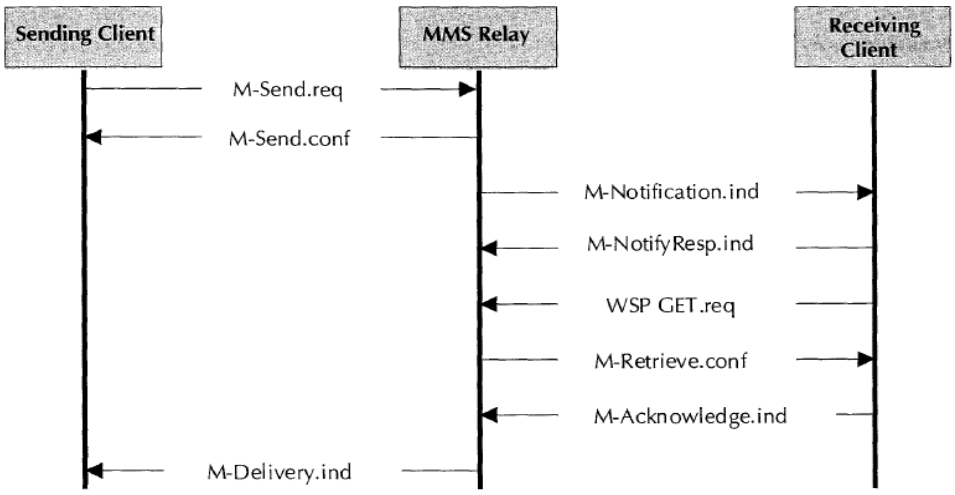
[Fig. 1.11:client to MMS Relay Link]

The messages that transit between the MMS Client and MMS Relay pass through WAP Gateway. Data is transferred between the MMS client and WAP gateway using WAP Session Protocol (WSP). Data is transferred between the WAP gateway and the MMS Relay using HTTP.

MMS Transaction Flows

As mentioned earlier, the MMS service is realized by the invocation of transactions between the MMS Client and the MMS Relay. The general transactions of sending and retrieving messages do not depend on what type of client the message is sent to or received from. The other endpoint for the message may be another MMS Client or a client on a legacy wireless messaging system or it may even be an email server. The above message exchanges can be considered to form the following logically separate transactions (Figure 1.12):

- ✓ MMS Client (sender) sends a message to MMS Relay(M-Send.req, M-Send.conf)
- ✓ MMS Relay notifies MMS Client (recipient) about a new message arrival(M-Notification.ind, M-NotifyResp.ind)
- ✓ MMS Client fetches (recipient) a message from MMS Relay(WSP GETreq, M-Retrieve.conf)
- ✓ MMS Client (recipient) sends a retrieval acknowledgement to MMS Relay(M-Acknowledge.req)
- ✓ MMS Relay sends a delivery report about a sent message to MMS Client (sender)(M-elivery.ind)



[Fig. 1.12: Example of MMS Transaction Flow-Delayed Retrieval]

From this list it is clear that MMS uses 8 types of messages to perform messaging transactions. The M-Notification.ind function is generally done through SMS. This is a special type of SMS. This SMS is not forwarded to the SMS inbox; it is forwarded to the MMS client. Client notifies the user about the arrival of a MMS message. The user then fetches the message from the relay. Some terminals allow the facility to configure the MMS client so that the message is fetched automatically. The multimedia messaging PDUs (Protocol Data Units) consist of MMS headers and a message body. The message body may contain any content type such as text, image, audio, and video. The message body is used only when the multimedia message is sent or retrieved. All other PDUs contain only the MMS-headers part.

1.7 Different Modes used for Mobile Communication

There are many types of mobile communication modes all are divided in to two categories.

1) In which form the communication takes place
    a. Voice
    b. Web
    c. Text/Multimedia
    d. Data
    e. Using Smartphone
2) Using which transmission medium communication takes place
    a. Broadcast radio
    b. Microwave radio signals
    c. Communication satellite

1) In which form the communication takes place

a. Voice: Basic cell phones provide their subscribers with domestic and international wireless voice communication. Service providers offer a range of domestic tariffs to subscribers to make calls between cell phones on the same mobile network, between cell phones on different mobile networks, or between cell phones and landlines. You can also make international calls when you are outside your own country; however, international calls are subject to high tariffs known as roaming charges.

b. **Web**: Cell phones with Internet capability allow subscribers to surf the Web and use email. One third party website has reported that within five years, mobile Web is likely to overtake PC-based Web as the most popular way to access the Internet. The growing popularity of mobile Web is due partly to improvements in cell phone screens and partly to the wider availability and lower cost of high-speed mobile broadband.

c. **Text/Multimedia**: A popular alternative to mobile voice communication is text messaging, using the Short Messaging Service (SMS). Costs are lower than voice calls, and most service providers offer tariffs that include a number of free text messages. Another alternative which allows sending images and small animation pictures is MMS (Multimedia Message Service).

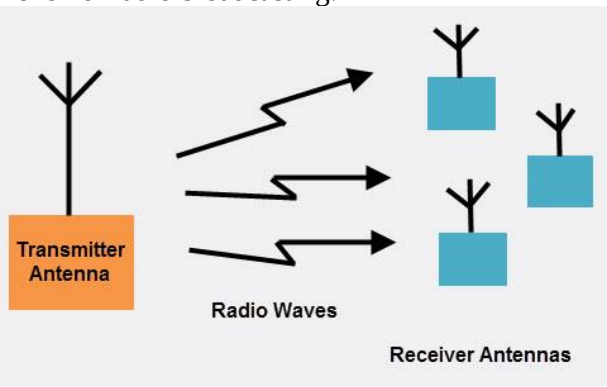
d. **Data**: Mobile access to internet allows downloading video content and participating in conferences featuring video content. Text messaging uses a cell phone's data communication capability. Service providers build on that data capability to offer subscribers a range of functionality using mobile applications, or apps.

e. **Using Smartphone**: Smart phones combine all cell phone capabilities and add computing power to create a powerful business tool. Organizations are using this capability to develop business applications that improve the productivity of their employees. For example, field service engineers can download data on equipment they are about to repair, and then send reports to headquarters on completion.

2) Using which transmission medium communication takes place

a. **Broadcast Radio**: Radio is the radiation (wireless transmission) of electromagnetic signals through the atmosphere or free space.[n 1] Information, such as sound, is carried by systematically changing (modulating) some property of the radiated waves, such as their amplitude, frequency, phase, or pulse width. When radio waves strike an electrical conductor, the oscillating fields induce an alternating current in the conductor. The information in the waves can be extracted and transformed back into its original form.

Radio broadcasting is a one-way wireless transmission over radio waves intended to reach a wide audience. Stations can be linked in radio networks to broadcast a common radio format, either in broadcast syndication or simulcast or both. Audio broadcasting also can be done via cable radio, local wire television networks, satellite radio, and internet radio via streaming media on the Internet. The signal types can be either analog audio or digital audio. Below figure define the phenomenon of radio broadcasting.

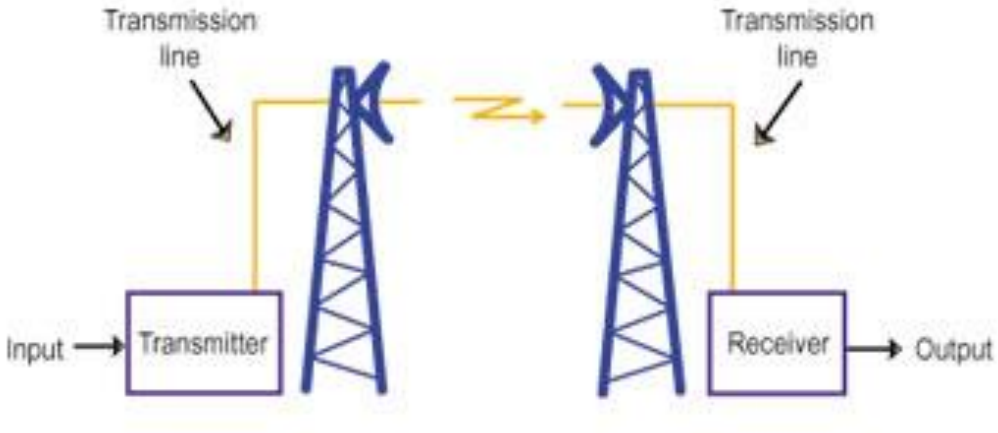


[Fig. 1.13: Example of Broadcast Radio Network]

b. Microwave Radio Signals: Microwaves signals are in the form of electromagnetic radiation with wavelengths ranging from as long as one meter to as short as one millimeter; with frequencies between 300 MHz (0.3 GHz) and 300 GHz. Antennas used in microwave transmission are of convenient sizes and shapes. Microwave transmission depends on line-of-sight in order to work properly.

The distance covered by microwave signals relies on the height of the antenna. Each antenna is built with a fitted repeater to regenerate the signal before passing it on to the next antenna in the line. The ideal distance between each antenna is approximately 25 miles.

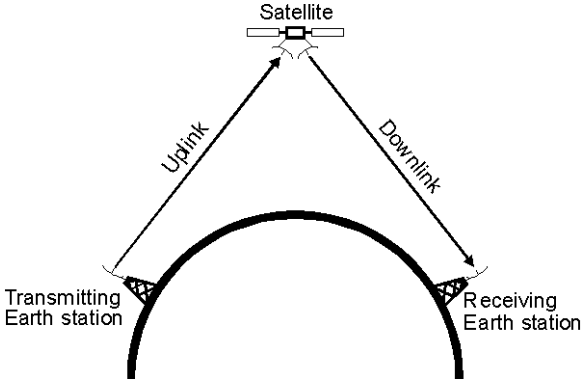
The main drawback of microwave signals is that they can be affected by bad weather, especially rain. Below figure define the phenomenon of microwave radio signal.



[Fig. 1.14: Example of Microwave Radio Signals]

c. Communication satellite: A communication satellite is an artificial satellite used specially as a communication transmitter/receiver in orbit. It behaves like a radio relay station above the earth to receiver, amplify, and redirect analog and digital signals carried on a specific radio frequency.

Data is passed though a satellite using a transponder which is a signal path. Most satellites have between 24 to 72 transponders, with a single transponder capable of transmitting and receiving 155 million bits of information per second. This huge capability makes communication satellites an ideal medium for transmitting and receiving all kinds of content, including audios and videos.



[Fig. 1.15: Example of Satellite Transmission]

Application of satellite communication:

- Telephone
- Television
- Digital cinema
- Radio
- Internet access
- Military

1.8 Architecture of Mobile Computing

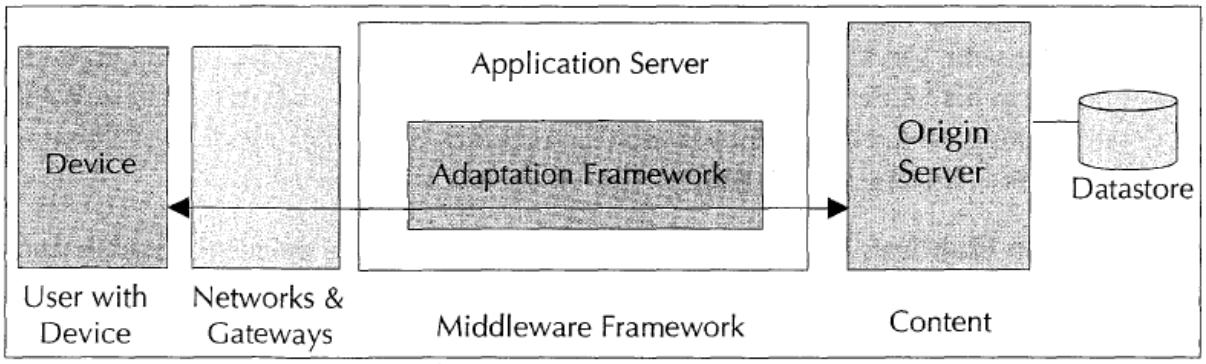
❖ Mobile Computing

Mobile computing can be defined as a computing environment over physical mobility. The user of a mobile computing environment will be able to access data, information or other logical objects from any device in any network while on the move. Mobile computing system allows a user to perform a task from anywhere using a computing device in the public (the Web), corporate (business information) and personal information spaces (medical record, address book). While on the move, the preferred device will be a mobile device, while back at home or in the office the device could be a desktop computer. To make the mobile computing environment ubiquitous, it is necessary that the communication bearer is spread over both wired and wireless media. Be it for the mobile workforce, holidaymakers, enterprises, or rural population, the access to information and virtual objects through mobile computing are absolutely necessary for optimal use of resource and increased productivity.

- Mobile Computing Function

The function of mobile computing is divided into following major segments.

1) Mobile Device: The user device, this could be a fixed device like desktop computer in office or a portable device like mobile phone. Example: laptop computers, desktop computers, fixed telephone, mobile phones, digital TV with set-top box, palmtop computers, pocket PCs, two way pagers, handheld terminals, etc.
2) Network: Whenever a user is mobile, he will be using different networks at different places at different time. Example: GSM, CDMA, iMode, Ethernet, Wireless LAN, Bluetooth etc.



[Fig. 1.16: Mobile Computing Functions]

3) Gateway: This is required to interface different transport bearers. These gateways convert one specific transport bearer to another transport bearer. Example: From a fixed phone (with voice interface) we access a service by pressing different keys on the telephone. These keys generate

DTMF (Dual Tone Multi Frequency) signals. These analog signals are converted into digital data by the IVR (Interactive Voice Response) gateway to interface with a computer application. Other examples will be WAP gateway, SMS gateway etc.

4) Middleware: This is more of a function rather than a separate visible node. In the present context, middleware handles the presentation and rendering of the content on a particular device. It will also handle the security and personalization for different users.
5) Content: This is the domain where the origin server and content is. This could be an application, system, or even an aggregation of systems. The content can be mass market, personal or corporate content. Origin server will have some means to accessing the database and the storage devices.

❖ Architecture:

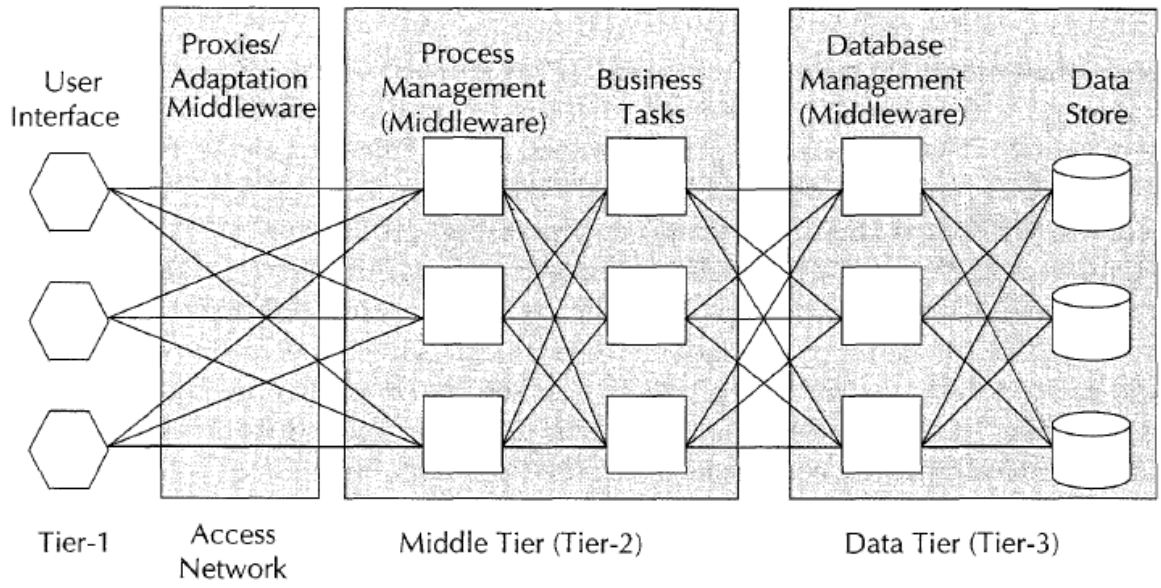
Three-tier architecture is a client-server architecture in which the functional process logic, data access, computer data storage and user interface are developed and maintained as independent modules on separate platforms.

Presentation Tier: Occupies the top level and displays information related to services available on a website. This tier communicates with other tiers by sending results to the browser and other tiers in the network.

Application Tier: Also called the middle tier, logic tier, business logic, this tier is pulled from the presentation tier. It controls application functionality by performing detailed processing.

Data Tier: Houses database servers where information is stored and retrieved. Data in this tier is kept independent of application servers or business logic. For example: In the web development field, three-tier is often used to refer to websites, commonly electronic commerce websites, which are built using three tiers: A front-end web server serving static content, and potentially some cached dynamic content. In web based application, Front End is the content rendered by the browser. The content may be static or generated dynamically. A middle tier does dynamic content processing. The data tier comprising both data sets and the database management system software that manages and provides access to the data.

The three-tier architecture is better suited for an effective networked client/ server design. It provides increased performance, flexibility, maintainability, reusability, and scalability, while hiding the complexity of distributed processing from the user. All these characteristics have made three-tier architectures a popular choice for Internet applications and net-centric information systems. Centralized process logic makes administration and change management easier by localizing changes in a central place and using it throughout the systems. Below figure shows 3-tier architecture of mobile computing.



[Fig. 1.17: Three Tier Architecture for Mobile Computing]

1) **Tier-1**: The first layer is the User Interface or Presentation Tier. This layer deals with user facing device handling and rendering. This tier includes a user system interface where user services (such as session, text input, and dialog and display management) reside. This is the layer of agent applications and systems. These applications run on the client device and offer all the user interfaces. This tier is responsible for presenting the information to the end user. Humans generally use Visual and audio means to receive information from machines. Humans also use keyboard (laptop computers, cell phones), pen (tablet PC, palmtops), touch screen ,or voice (telephone) to feed the data to the system. In the case of the visual, the presentation of information will be through a screen. Therefore, the visual presentation will relate to rendering on a screen. 'Presentation Tier' includes web browsers (like Mozila, lynx, Internet Explorer and Netscape Navigator), WAP browsers and customized client programs. A mobile computing agent needs to be context-aware and device-independent.
2) **Tier-2:** The second tier is the Process Management or Application Tier. This layer is for application programs or process management where business logic and rules are executed. This layer is capable of accommodating hundreds of users. The application tier or middle tier is the 'engine' of a ubiquitous application. It performs the business logic of processing user input, obtaining data, and making decisions. In certain cases, this layer will do the transcoding of data for appropriate rendering in the Presentation Tier. The Application Tier may include technology like CGI's, Java, JSP, NET services, PHP or ColdFusion, deployed in products like Apache, WebSphere, WebLogic, iPlanet, Pramati, JBOSS or ZEN D. The application tier is presentation and database-independent.
3) **Tier-3:** The third and final tier is the Database Management or Data Tier. This layer is for database access and management. The Data Tier is used to store data needed by the application and acts as a repository for both temporary and permanent data. The data could be stored in any form of data store or database. These can range from sophisticated relational database, legacy hierarchical

database, to even simple text files. The data can also be stored in XML format for interoperability with other system and data sources.

❖ **Advantages of 3-tier Architecture:**

- Having separate functionality servers allows for parallel development of individual tiers by application specialists.
- Provides more flexible resource allocation. Can reduce the network traffic by having the functionality servers strip data to the precise structure needed before sending it to the clients.
- Reusability of the business logic component results in quick development
- Provides higher security because user don't have direct interface to database which resides in data-tier.

1.9 Design Consideration for Mobile Computing

The mobile computing environment needs to be context-independent as well as context-sensitive. Context information is the information related to the surrounding environment of an actor in that environment. The term 'context' means, all the information that help determine the state of an object (or actor). This Object can be a person, a device, a place, a physical or computational Object, the surrounding environment or any other entity being tracked by the system. In a mobile computing environment, context data is captured so that decisions can be made about how to adapt content or behavior to suit this context. Mobility implies that attributes associated with devices and users will change constantly. These changes mean that content and behavior of applications should be adapted to suit the current situation. There are many ways in which content and behavior can be adapted. Following are some examples:

1. **Content with context awareness:** Build each application with context awareness. There are different services for different client context (devices). For example a bank decides to offer mobile banking application through Internet, PDA and mobile phone using WAP. These services are different and are http://www.mybank.com/inet.html, http://www.mybank.com/palm.html and http://www.mybank.com/Wap.wml, respectively. The service http://www.mybank.com/inet.html assumes that the user will use computers to access this service. Therefore it is safe to offer big pages with text box, drop down menu. Also, it is fine to add a few animated pictures for the new product the bank is launching. We know that http://www.mybank.com/palm.html is a service for a PalmOS PDA. As the display size is small, we design the screen to be compact for the PDA and do not offer the same product animation. For the WAP service at http://www.mybank.com/wap.wml, we do a completely different user interface; we make all drops down options available through the option button in the mobile phone and remove all the graphics and animations.
2. **Content switch on context:** Another way is to provide intelligence for the adaptation of content within the service. This adaptation happens transparent to the client. In this case the service is the same for Internet, PDA and WAP. All access the bank's service through http://www.mybank.com/. A intelligent piece of code identifies the agent to decide what type of device or context it is. This intelligent code does the adaptation at run time based upon the agent in hand. The simplest way to do this is to look at the User-Agent value at the HTTP header and decide whether to route the request to http://mybank.com/inet.html or http://www.mybank.com/palm.html or http://www.mybank.com/wap.wml.
3. **Content transcoding on context:** Another way is to provide an underlying middleware platform that performs the adaptation of the content based on the context and behavior of the device. This

adaptation happens transparent to the client and the application. The middleware platform is intelligent enough to identify the context either from the http parameters or additional customized parameters. In this case the service may be in html or XML, the middleware platform transcode the code from html (or XML) to html, and wml on the fly. It can also do the trasncoding based on policy so that the html generated for a computer is different from a PDA.

1.10 Characteristics of Mobile Communication

We can define a computing environment as mobile if it supports one or more of the following characteristics:

- **User Mobility**: User should be able to move from one physical location to another location and use the same service. The service could be in the home network or a remote network. Example could be a user moves from London to New York and uses Internet to access the corporate application the same way the user uses in the home office.
- **Network Mobility**: User should be able to move from one network to another network and use the same service. Example could be a user moves from Hong Kong to New Delhi and uses the same GSM phone to access the corporate application through WAP (Wireless Application Protocol). In home network he uses this service over GPRS (General Packet Radio Service) whereas in Delhi he accesses it over the GSM network.
- **Bearer Mobility:** User should be able to move from one bearer to another and use the same service. Example could be a user was using a service through WAP bearer in his home network in Bangalore. He moves to Coimbatore, where WAP is not supported, he switch over to voice or SMS (Short Message Service) bearer to access the same application.
- **Device Mobility:** User should be able to move from one device to another and use the same service. Example could be sales representatives using their desktop computer in home office. During the day while they are on the street they would like to use their Palmtop to access the application.
- **Session Mobility**: A user session should be able to move from one user-agent environment to another. Example could be a user was using his service through a CDMA (Code Division Multiple Access) 1X network. The user entered into the basement to park the car and got disconnected from his CDMA network. User goes to home office and starts using the desktop. The unfinished session in the CDMA device moves from the mobile device to the desktop computer.
- **Service Mobility:** User should be able to move from one service to another. Example could be a user is writing a mail. To complete the mail user needs to refer to some other information. In a desktop PC, user simply opens another service (browser) and moves between them using the task bar. User should be able to switch amongst services in small footprint wireless devices like in the desktop.
- **Host Mobility**: The user device can be either a client or server. When it is a server or host, some of the complexities change. In case of host mobility the mobility of IP needs to be taken care of.

1.11 Application of Mobile Communication

The importance of Mobile Computers has been highlighted in many fields of which a few are described below:

- For Estate Agents: Estate agents can work either at home or out in the field. With mobile computers they can be more productive. They can obtain current real estate information by accessing multiple listing services, which they can do from home, office or car when out with clients. They can provide clients with immediate feedback regarding specific homes or neighborhoods, and with faster loan approvals, since applications can be submitted on the spot. Therefore, mobile computers allow them to devote more time to clients.
- Emergency Services: Ability to receive information on the move is vital where the emergency services are involved. Information regarding the address, type and other details of an incident can be dispatched quickly, via a CDPD (Cellular Digital Packet Data) system using mobile computers, to one or several appropriate mobile units which are in the vicinity of the incident.
- In courts: Defense counsels can take mobile computers in court. When the opposing counsel references a case which they are not familiar, they can use the computer to get direct, real-time access to online legal database services, where they can gather information on the case and related precedents. Therefore mobile computers allow immediate access to a wealth of information, making people better informed and prepared.
- Credit Card Verification: At Point of Sale (POS) terminals in shops and supermarkets, when customers use credit cards for transactions, the intercommunication required between the bank central computer and the POS terminal, in order to effect verification of the card usage, can take place quickly and securely over cellular channels using a mobile computer unit. This can speed up the transaction process and relieve congestion at the POS terminals.
- Electronic Mail: Usage of a mobile unit to send and read emails is a very useful asset for any business individual, as it allows him/her to keep in touch with any colleagues as well as any urgent developments that may affect their work which can be access anywhere.
- Web Access: User can visit any desired website anywhere.
- Location awareness services: Location based services like to find services in the local environment, track location of any object, sharing of location on social media etc.
- Entertainment: Online games, movies or music.
- Stock Information Collation/Control: In environments where access to stock is very limited ie: factory warehouses. The use of small portable electronic databases accessed via a mobile computer would be ideal.
- In companies: Managers can use mobile computers in, say, and critical presentations to major customers. They can access the latest market share information. At a small recess, they can revise the presentation to take advantage of this information. They can communicate with the office about possible new offers and call meetings for discussing responds to the new proposals. Therefore, mobile computers can leverage competitive advantages.

1.12 Security Concern Related To Mobile Computing

The security issues in mobile computing environment pose a special challenge. This is because we have to offer services over the air using networks over which we do not have any control. All the

infrastructure and technology designed by GSM and other forums are primarily to increase the revenue of network operator. For example, the SMS technology is operator centric; WAP requires WAP gateway. These gateways are installed in the operator's network and managed by the operator. The security policy implemented by the network operator depends on operator's priority and revenue generation potential and not on the need of the content provider or customer.

In a mobile computing environment user can move from one network to another, one device to another, and one bearer to another. Therefore, theoretically the security implementation need to be device independent, network independent, bearer independent etc. The requirement is to arrive at a security model, which can offer a homogenous end-to-end security.

1.13 Middleware and Gateway Required For Mobile Computing

- **Middleware:** In a mobile computing environment, in addition to the business logic there are quite a few additional management functions that need to be performed. These functions relate to decisions on rendering, network management, security, data-store access etc. Most of these functions are implemented using different middleware software. A middleware framework is defined as a layer of software, which sits in the middle between the operating system and the user facing software. Middleware used in the context of mobile-computing devices. Mobile middleware offers various transparencies that hide the complexities of mobile environments. For instance, location transparency allows applications to exchange data with other applications without any regard for their location. In case of a net centric architecture, a middle-ware framework sits between an agent and the business logic.

  Middleware covers a wide range of software systems, including distributed objects and components, message-oriented communication, database connectors, mobile application support, transaction drivers, etc. Middleware can also be considered as a software gateway connecting two independent open objects.

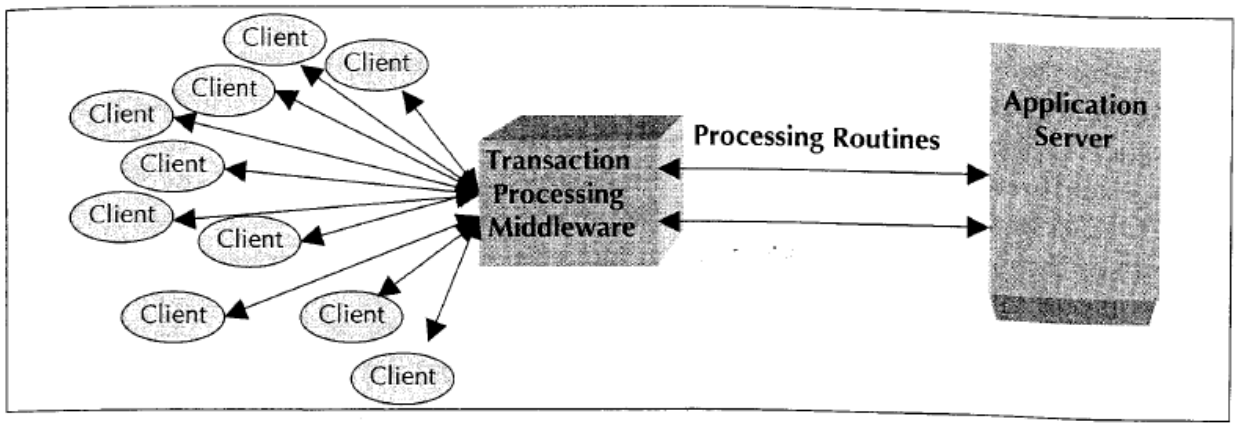
a) **Message Oriented Middleware:** Message-oriented Middleware is a middleware framework that loosely connects different applications through asynchronous exchange of messages. A MOM works over a networked environment without having to know what platform or processor the other application is resident on. The message can contain formatted data, requests for action, or unsolicited response. The MOM system provides a message queue between any two interoperating applications. If the destination process is out of service or busy, the message is held in a temporary storage location until it can be processed. MOM is generally asynchronous, peer-to-peer, and works in publish/ subscribe fashion. In publish/subscriber model one or many objects subscribe to an event. As the event occurs, it will be published by the asynchronous loosely coupled object. The MOM will notify the subscribers about this event. However, most implementations of MOM support synchronous (request/response) message passing as well. MOM is most appropriate for event-driven applications. When an event occurs, the publisher application hands off to the messaging middleware application the responsibility of notifying subscribers that the event has happened. In a net centric environment, MOM can work as the integration platform for different applications. Example of MOM is Message Queue from IBM known as MQ Series. The equivalent from java is JMS (Java Message Service).

Advantages:

- Asynchronous interaction
- Client and server are loosely coupled
- Messages are queued
- Support for reliable delivery service
- May do filtering, transforming, logging, etc.

b) Transaction processing middleware: In many cases a service will offer session oriented dialogue (SOD). For a session we need to maintain a state over the stateless Internet. This is done through an application server. The user may be using a device, which demands a short transaction whereas the service at the backend offers a SoD. In such cases a separate middleware component will be required to convert a SoD to a short transaction. Management of the Web components will be handled by this middleware as well.

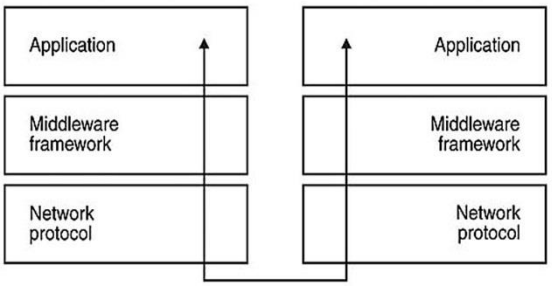
Transaction Processing Middleware provides tools and an environment for developing transaction-based distributed applications. An ideal TP system will be able to input data into the system at the point of information source and the output of the system is delivered at the point of information sink. In an ideal TP system, the device for input and output can potentially be different (Figure 1.18). Also, the output can be an unsolicited message for a device. TP is used in data management, network access, security systems, delivery order processing, airline reservations, customer service, etc. TP systems are generally capable of providing services to thousands of clients in a distributed client/ server environment.



[Fig. 1.18: Transaction Processing Middleware]

TP middleware maps numerous client requests through application-service routines to different application tasks. In addition to these processing tasks, TP middleware includes numerous management features, such as restarting failed processes, dynamic load balancing and enforcing consistency of distributed data. TP middleware optimizes the use of resources by multiplexing many client functions onto a much smaller set of application-service routines. This also helps in reducing the response time. TP middleware provides a highly active system that includes services for delivery-order processing, terminal and forms management, data management, network access, authorization, and security.

c) **Communication Middleware:** A communication middleware framework provides an environment that enables two applications to set up a conversation and exchange data. Typically, this exchange of data will involve the triggering of one or more transactions along the way. It is used by application developers in distributed network environment. Before any middleware developers have to work in network specific environment i.e. application developed for one network cannot be successfully operated in other network because their topology and devices may be different.



Communication middleware framework isolates the application developers from the details of the network protocol. Communication infrastructures encapsulated the technical complexity of such low-level communication mechanisms by insulating the application developer from the details of the technical base of the communication. A communication middleware framework enables you to access a remote application without knowledge of technical details such as operating systems, lower-level information of the network protocol, and the physical network address.

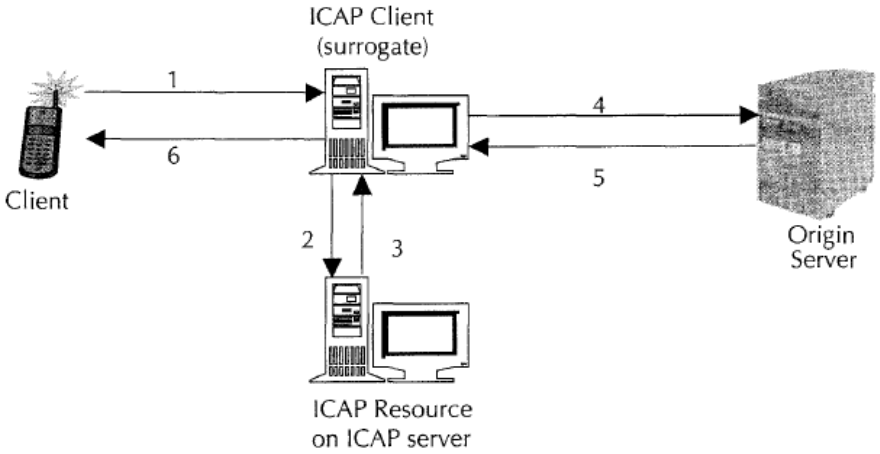
The purpose of communication middleware is to simplify the designing, programming and managing of software application by streamlining the way these applications receive and process the data. Consider a cell phone and PC. They both functions in vastly different capacities, but with communication middleware they are able to 'talk' and 'work' with each other. This can hold true for devices similar capacities with different operating system as well.

Using a communication middleware; reduces system complexity, provides application portability across different operating system and hardware, simplifies the resulting application code.

d) **Distributed Object and Component:** An example of distributed objects and components is CORBA (Common Object Request Broker Architecture). CORBA is an open distributed object computing infrastructure being standardized by the Object Management Group (http://www.omg.org). CORBA simplifies many common network programming tasks used in a net centric application environment. These are object registration, object location, and activation; request de-multiplexing; framing and error-handling; parameter marshalling and de-marshalling; and operation dispatching. CORBA is vendor-independent infrastructure. A CORBA-based program from any vendor on almost any computer, operating system, programming language and network, can interoperate with a CORBA-based program from the same or another vendor, on almost any other computer, operating system, programming language and network. CORBA is useful in many situations because of the easy way that CORBA integrates machines from so many vendors, with sizes ranging from mainframes through minis and desktops to hand-helds and embedded systems. One of its most important, as well as the most frequent, uses is in servers that must handle a large number of clients, at high hit rates, with high reliability.

e) **Transcoding Middleware:** Transcoding Middleware is used to transcode one format of data to another format to suit the need of the client. For example, if we want to access a web site

through a mobile Phone supporting WAP, we need to transcode the HTML page to WML page so that the mobile phone can access it. Another example could be accessing a map from a PDA. The same map, which can be shown in a computer, needs to be reduced in size to fit the PDA screen. Technically transcoding is used for content adaptation to fit the need of the device. Content adaptation is also required to meet the network bandwidth needs. For example, some frames in a video clip need to be dropped for a low bandwidth network. Content adaptation used to be done through proprietary protocols. To allow interoperability, IETF has accepted the Internet Content Adaptation Protocol (ICAP). ICAP is now standardized and described in RFC3507. Typical data flow in ICAP environment is shown in below figure:



[Fig. 1.19: Typical data flow in an ICAP environment]

1) A user agent makes a request to an ICAP client for an object on origin server.
2) The surrogate sends the request to ICAP server
3) The ICAP server executes the ICAP resource's service on the request and sends the possible modified request, or a response to the request back to ICAP client.
4) The surrogate sends the request, possibly different from original client request, to the origin server.
5) The origin server responds to the request.
6) The surrogate sends the reply to client.

f) Database Middleware: We have discussed that for a mobile computing environment, the business logic should be independent of the device capability. Likewise, though not essential, it is advised that business logic should be independent of the database. Database independence helps the maintenance of the system better. Database middleware allows the business logic to be independent and transparent of the database technology and the database vendor. Database middleware runs between the application program and the database. These are sometimes called database connectors as well. Example of such middleware will be ODBCJDBC, etc. Using these middleware, the application will be able to access data from any data source. Data sources can be text files, flat file, spreadsheets, or a network, relational, indexed, hierarchical, XML database, object database, etc. from vendors like Oracle, SQL, Sybase, etc.

❖ **Gateway:** Between the device and the middleware there will be network of networks. Gateways are deployed when there are different transport bearers or networks with dissimilar protocols. For example, we need an IVR gateway to interface voice with a computer, or a WAP gateway to access

internet over a mobile phone. A gateway serves as the entry and exit point of a network; all data routed inward and outward must first pass through and communicates with the gateway in order to use routing paths. Generally, a router is configured to work as a gateway. Such kind of gateway sometimes called as networking gateway. It contains devices such as protocol translators, impedance matching devices, rate converters, fault isolators or signal translators as necessary to provide system interoperability.

1.14 Making Existing Application Mobile Enable

There are many applications that are now being used within the intranet or the corporate network that need to be made ubiquitous. These are different productivity tools like e-mail or messaging applications, workflow systems etc. Information systems for partners and vendors and employees like sales force automation etc. will also fall within this category. These applications need to be made ubiquitous and mobile-computing capable. There are many ways by which this can be achieved.

1. **Enhance existing application:** Take the current application. Enhance the application to support mobile computing.
2. **Rent an application from an ASP:** There are many organizations that develop ubiquitous application and rent the same at a fee.
3. **Write a new application:** Develop a new application to meet the new business requirement of the mobile computing.
4. **Buy a packaged solution:** There are many companies who are offering packaged solutions for various business areas starting from manufacturing to sales and marketing. Buy and install one of these which will also address the mobile computing needs of the enterprise.
5. **Bridge the gap through middleware:** Use different middleware techniques to face-lift and mobile-computing-enable the existing application.

One of these techniques or any combinations can be used to make an application ubiquitous. If the enterprise has a source code for the application, enhancement of the existing application may be a choice. Writing a new application by taking care of all the aspects described above may also be a possibility. Buying a package or renting a solution from an ASP can also be a preferred path for some business situations.

Many of these applications might have been developed in-house, but may not be in a position to be enhanced. Some might have been purchased as products. A product developed by outside agency cannot be enhanced or changed as desired. In many of such situations, mobile computing enabling can be done through middleware. The combination of communication middleware and application middleware can be used to make an application mobile. Let us assume that the enterprise has its sales and distribution application running in SAP in IBM AS/400 system. The enterprise wants this system to be wireless-enabled for its mobile sales force. Using TN5250 communication middleware, the application can be abstracted as an object. Through a transaction processing middleware and APIs, the SAP application can be used as a document. By using a transcoding middleware, the application can be wireless-enabled and used through WAP, J2ME or even SMS (Short Message Service). Through middleware, some additional security features can be added.