MOBILE COMPUTING

Introduction & Architecture

Mobile Computing

- A computing environment of physical mobility
- User will be able to access data, information, or other logical objects from any device in any network while on the move
- MC system allows user to perform a task from anywhere using a computing device in the public, corporate, and personal information spaces

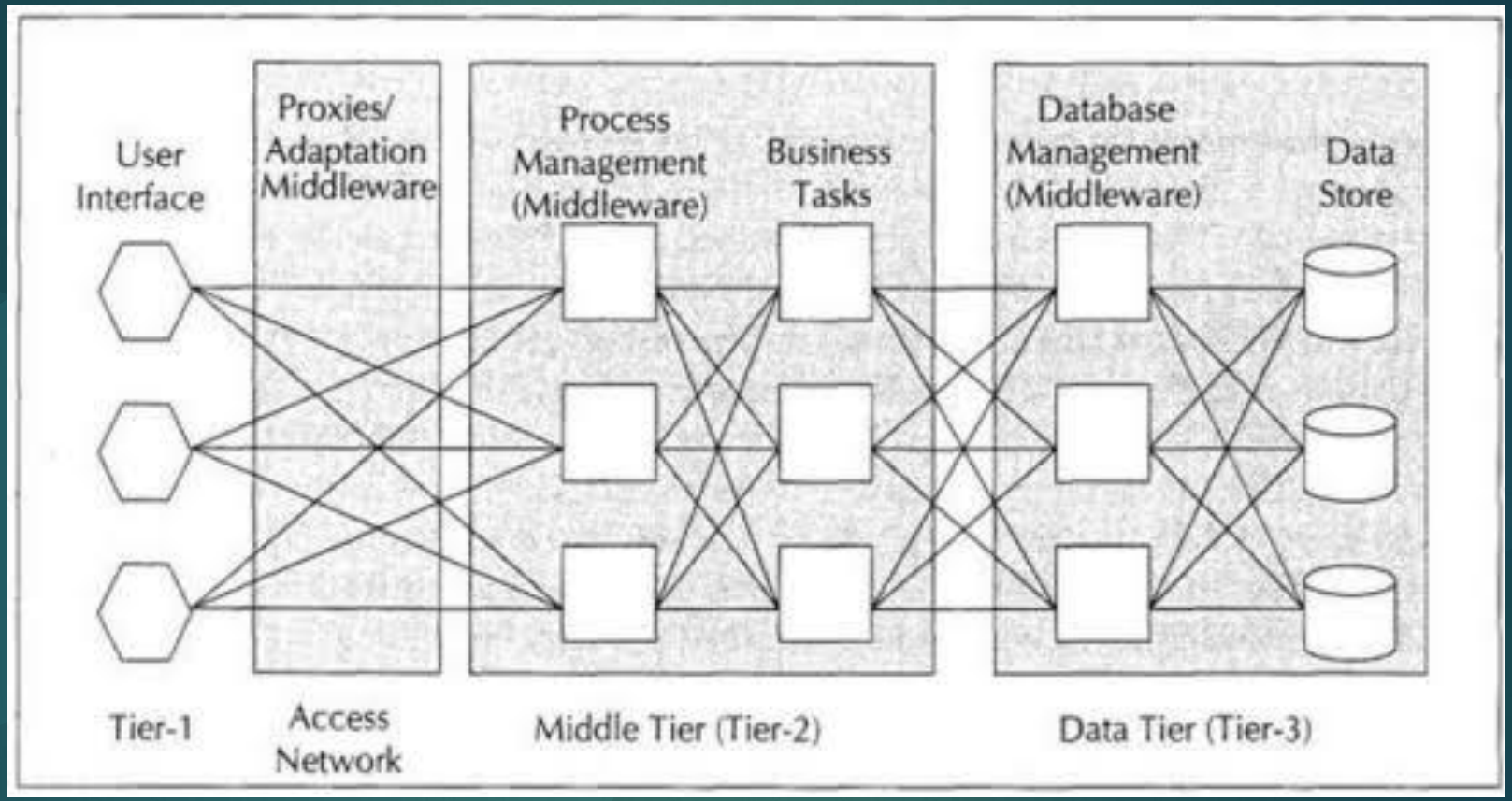
Mobile computing is used in different contexts with different names

- Anywhere, Anytime computing
- Virtual Home Environment
- Nomadic Computing
- Pervasive Computing
- Ubiquitous Computing
- Global Service Portability
- Wearable Computers

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

- User Mobility
- Network Mobility
- Bearer Mobility
- Device Mobility
- Session Mobility
- Host Mobility

Architecture for Mobile Computing



3 tier architecture

User interface/Presentation tier

- Deals with user facing device handling and rendering
- User services (text input, dialog, display management) reside here

- Process management/application tier
- Layer is for application programs or process management where business logic and rules are executed
- Capable of accommodating hundreds of users
- Controls transaction and asynchronous queuing to ensure reliable completion of transactions

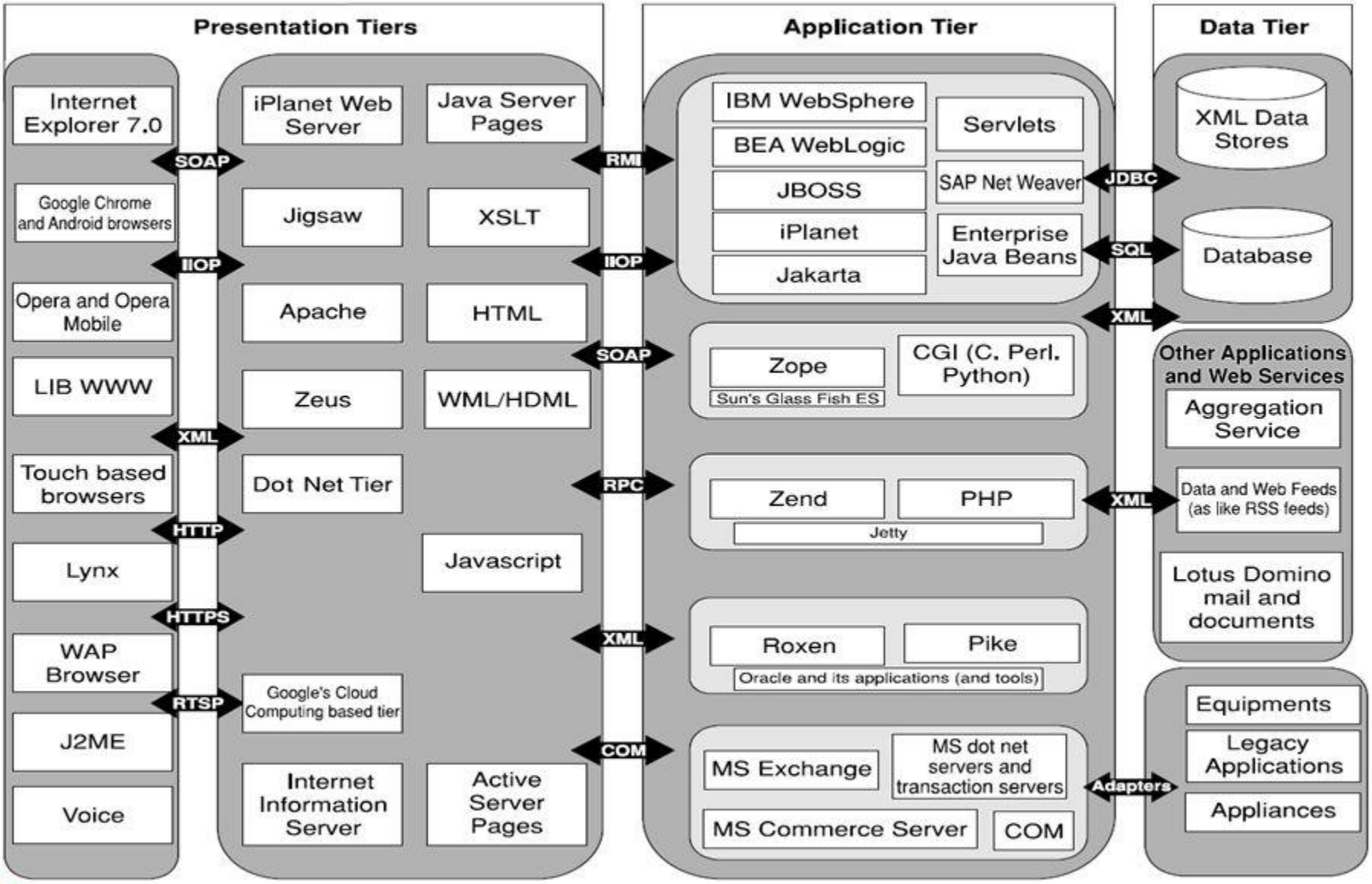
- DB management/ data tier
- For db access and management

- Architecture provides increased performance, flexibility, maintainability, reusability, scalability
- This made this architecture a popular choice of internet applications and net centric information systems

The mobile computing architecture

- While designing mobile computing system, one should keep in mind that,
- It will be used through any network, bearer, agent, device
- Server is connected to network such as internet to have universal access
- A web browser is used to have access from any device
- System is context aware

Mobile Computing Architecture



Presentation Tier

- User facing system
- Layer of agent applications and systems
- These applications run on the client device
- Offer user interfaces
- Responsible for presenting information to the end user
- Keyboard, touchscreen, voice are used to feed data to the system
- Tier includes web browsers, customized client programs
- Agents should be device independent and context aware

- Functions performed by agent systems vary-
- Accessing other application through HTTP API
- Complex applications such as sales and inventory management

- Some agents work as web scrapers
- They embed functionality of browser and functions like automated browser
- Picks up part of data from web page, filters off remaining data according to some predefined templates
- Also there are agent s/w that access remote services through telnet interface

Application Tier

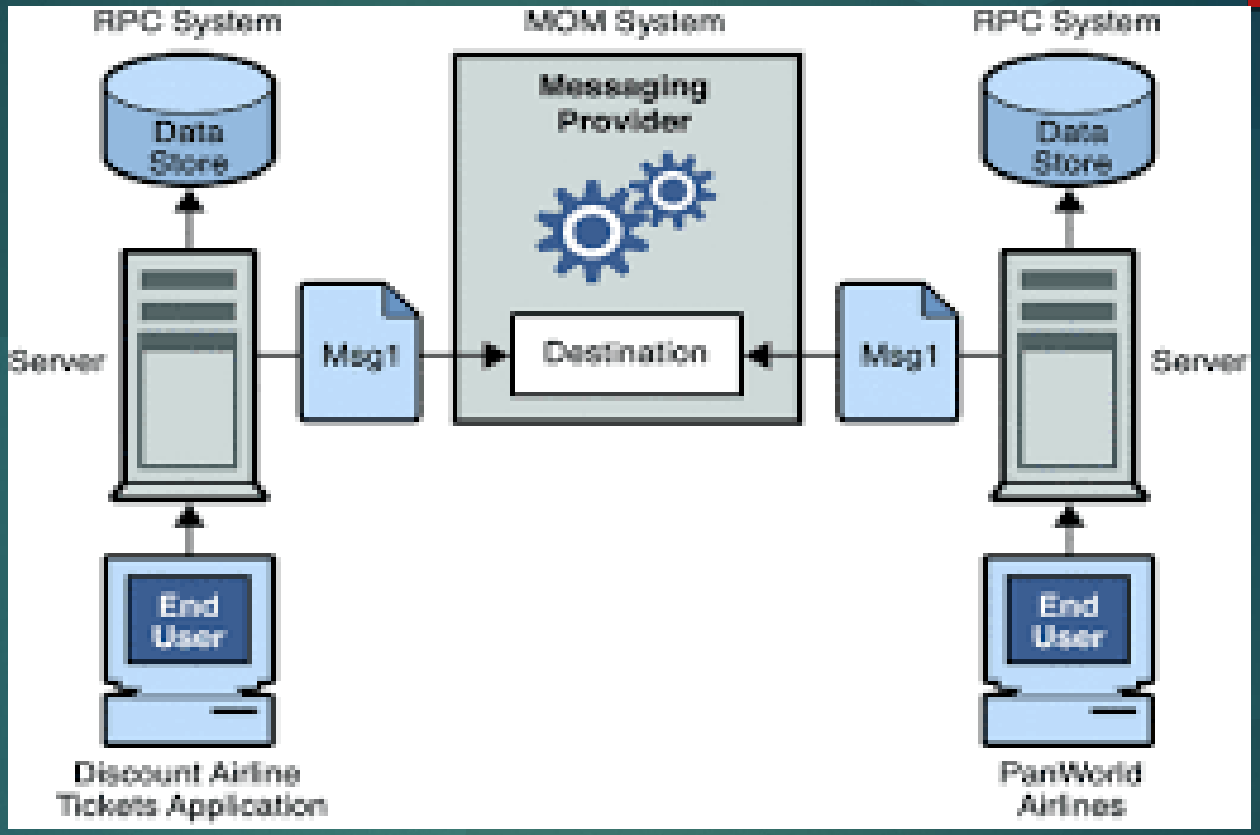
- Engine of ubiquitous application
- Performs business logic of processing input, obtaining data and making decisions
- May include technologies such as Java, .Net services, PHP, JSP, CGI etc which are deployed on Apache, WebSphere etc
- Presentation and data base independent

- In addition to business logic other functions are performed- rendering, n/w management, security etc
- These functions are implemented using middleware s/w
- Sits between agent and business logic
- Can also be considered as s/w gateway connecting two independent objects

Message oriented middleware

- Loosely connects different applications through asynchronous exchange of messages
- Works over networked environment without having to know what platform or processor the other application is resident on
- Message can contain formatted data, requests for action or unsolicited response
- If the destination process is out of service or busy, message is held in temporary storage until it can be processed

- Works in publish/subscribe fashion
- One/many objects subscribe to an event
- As the event occurs, it will be published by the loosely coupled asynchronous objects
- MOM notify subscribers about event
- Example: Message queue from IBM – MQ Series, Java Messgae Service(JMS)


RPC System
MOM System
RPC System
Data Store
Messaging Provider
Data Store
Server
Msg1
Destination
Msg1
Server
End User
End User
Discount Airline Tickets Application
PanWorld Airlines

Transaction Processing(TP) Middleware

- Provides tools and environment for developing transaction based applications
- TP is used in delivery order processing, customer service, airline reservation, data management, network access, security system etc
- TP systems are capable of providing services to thousands of clients in a distributed client/server environment

- TP middleware maps numerous client requests to application tasks through application service routines
- Also includes numerous management features –restoring failed processes, ensuring consistency of distributed data
- Independent of db architecture

- Optimizes the use of resources by multiplexing many client functions onto a much smaller set of application service routines
- Hepls in reducing response time
- Highly active system that includes services for order processing, data management, network access, authorization, security etc
- E.g: transaction processing done through J2EE application server

Transaction processing middleware

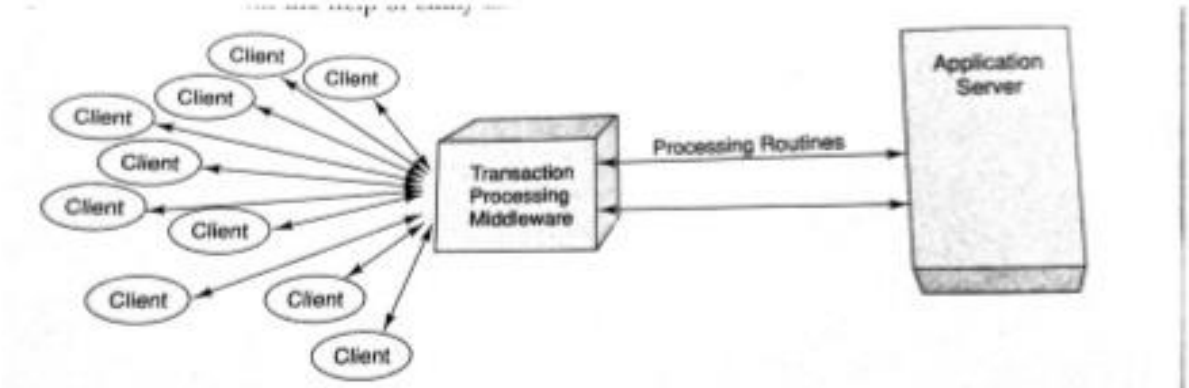


Figure 2.3 Transaction Processing Middleware

Communication Middleware

- Used to connect one application to another through applications such as telnet
- Useful in telecom world
- Many elements in telecom network have user interface through telnet

Distributed object and components

- E.g: CORBA- Common Object Request Broker Architecture
- Simplifies many common network programming tasks
- Object registration, object location and activation, request demultiplexing, error handling etc

- Vendor independent infrastructure
- CORBA based program from any vendor can interoperate with CORBA based program same/another vendor on almost any computer, OS, programming language, network

- It integrates machines from so many vendors with systems of varied sizes

Transcoding middleware

- Used to transcode one format of data to another to suit the needs of client
- E.g: transcoding of HTML to WML page
- Accessing map from PDA
- Used for content adaption to fit the need of the device, to meet network bandwidth needs
- Protocol: ICAP (Internet Content Adaption Protocol)

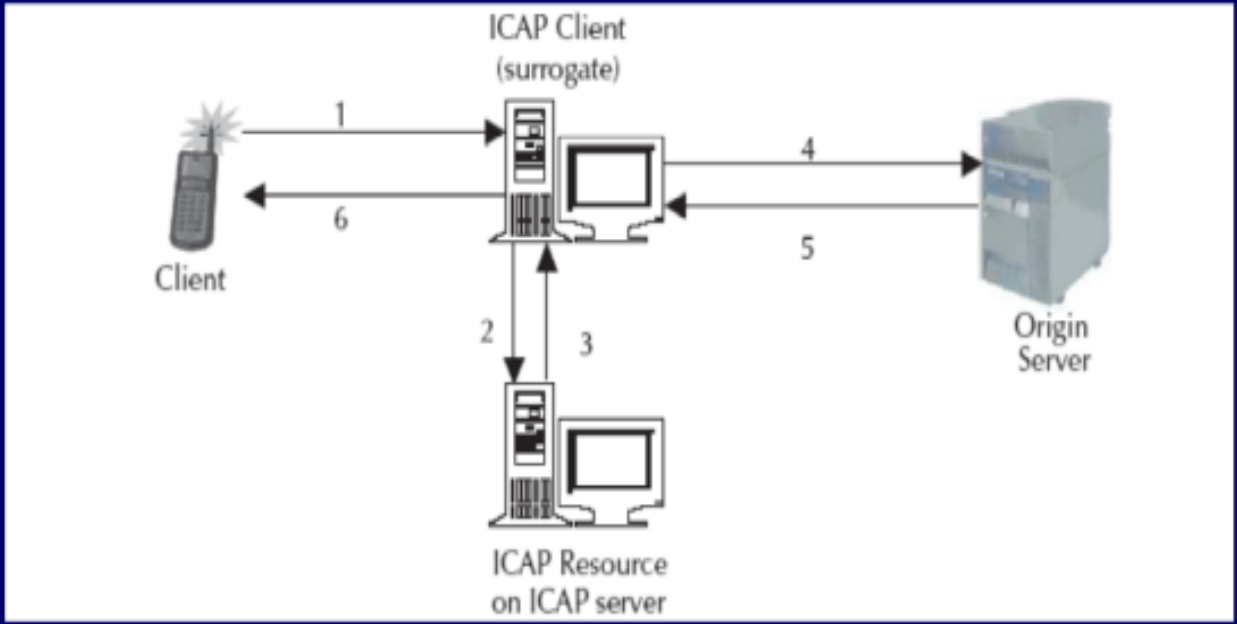
ICAP (Internet Content Adaption Protocol)

- Aimed at providing simple object based content vectoring for HTTP services
- Lightweight protocol to do transcoding on HTTP messages
- Similar to executing a remote procedure call on HTTP request
- Protocol allows ICAP clients to pass HTTP messages to ICAP servers for some sort of transformation
- Server executes its transformation service on messages and sends back responses to the client, usually with modified messages
- Adapted messages may be either HTTP requests or HTTP responses

ICAP (Internet Content Adaption Protocol)

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

Data flow in an ICAP environment



Data tier

- Used to store data needed by the applications
- Acts as a repository for both temporary and permanent data
- Data can be stored in any form of data base
- Relational db, hierarchical db, text files
- Data can be stored in XML format for interoperability with other systems and data stores

Database middleware

- Business logic should be independent of the db
- Helps in maintenance of the system better
- DB middleware allows business logic to be independent and transparent of database technology and vendors

- Also called as connectors
- Examples: ODBC, JDBC
- Using these middlewares, application will be able to access data from any data source
- (text files, flat files, spreadsheets, relational, networked, hierarchical, XML, indexed, object databases)

SyncML

- SyncML protocol is standard for synchronization of data access from different nodes
- Industry initiative to develop and promote single, common data synchronization protocol that can be used industry-wide
- Supports naming and identification of records and common protocol commands to synchronize local and network data
- Supports identification and resolution of synchronization conflicts

SyncML

- Protocol works over all networks used by mobile devices- both wireless and wireline
- Since wireless networks employ different transport protocols and media, a syncML will work smoothly over: HTTP, SMTP, POP3, IMAP, Pure TCP/IP networks etc

Global System for Mobile Communication

- Extremely successful technology and bearer for mobile communication system
- Covers major part of digital wireless network
- Second generation cellular standard developed to cater voice services and data delivery using digital modulation

- Developed by Group Spéciale Mobile (founded 1982) which was an initiative of CEPT (Conference of European Post and Telegraphs)
- Aim : to replace the incompatible analog system
- Presently the responsibility of GSM standardization resides with special mobile group under ETSI (European telecommunication Standards Institute)
- Under ETSI, GSM was named as "**G**lobal **S**ystem for **M**obile communication"
- 1991: first GSM network launched

Objectives

- Support for international roaming
- Good speech quality
- Low terminal and service cost
- Spectral efficiency
- Support for a range of new services and facilities
- ISDN compatibility

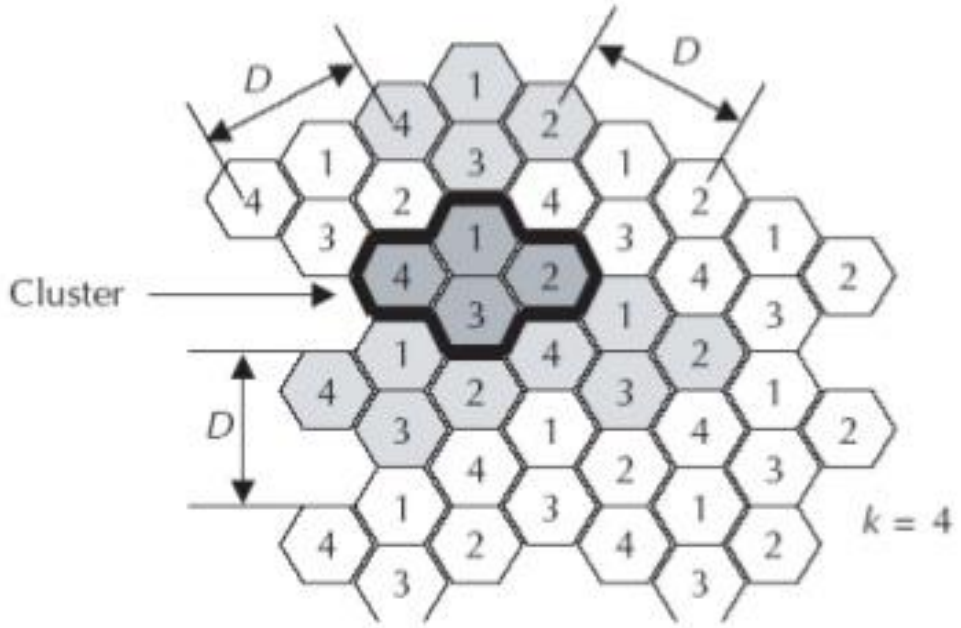
- Uses combination of FDMA (Frequency Division Multiple Access) and TDMA(Time Division Multiple Access)
- In order to be able to serve thousands of users, the frequency must be reused

Essential characteristics of frequency reuse

- The area to be covered is subdivided into cells
  - Base stations are positioned at the center of these cells
- Each cell i receives a subset of frequencies (fbi) from the total set assigned to the respective mobile network
- Only at a distance D(frequency reuse distance), the same frequency from the set fbi can be reused
- When moving from one cell to another during an ongoing conversation, an automatic channel change occurs(handover).
  - Handover maintains an active speech and data connection over cell boundaries

- The regular repetition of frequencies in cells results in a clustering of cells
- Clusters can consume whole frequency band
- Size of cluster is defined by k, the number of cells in the cluster
- This also defines frequency reuse distance

Cell clusters in GSM



GSM architecture

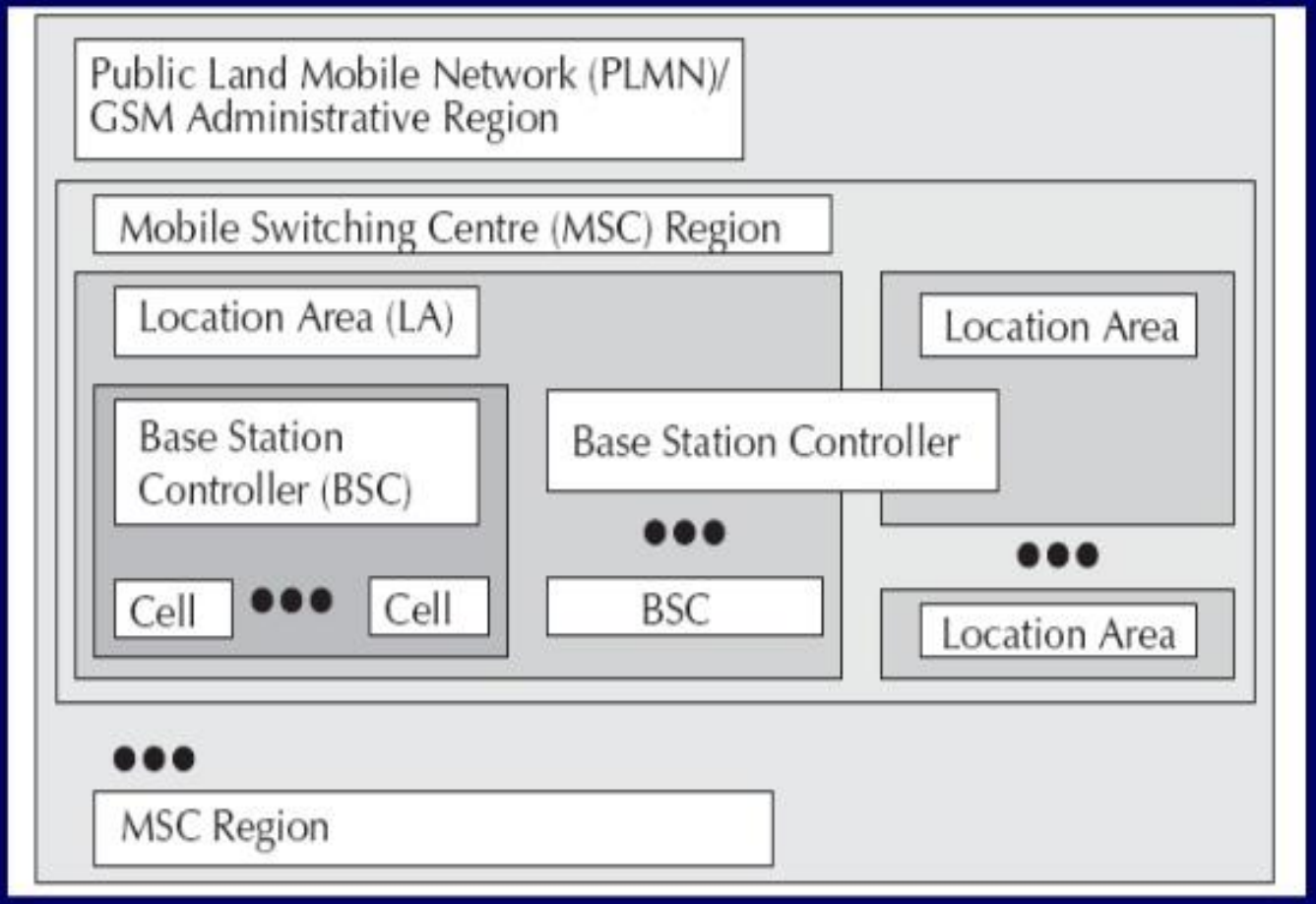
- GSM networks are structured in hierarchic fashion

GSM System Hierarchy

- Consists at the minimum one administrative region assigned to one MSC (Mobile Switching Centre)
- 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 and each cell group is assigned to one BSC (Base Station Controller)
- For each LA, there will be at least one BSC while cells in one BSC can belong to different LAs

- Cells are formed by the radio areas covered by BTS(Base Transceiver Station)
- Several BTSs are controlled by one BSC
- Traffic from the MS(Mobile Station) is routed though MSC
- Calls originating from or terminating in a fixed network or other mobile networks is handled by GMSC(Gateway MSC)

GSM System Hierarchy

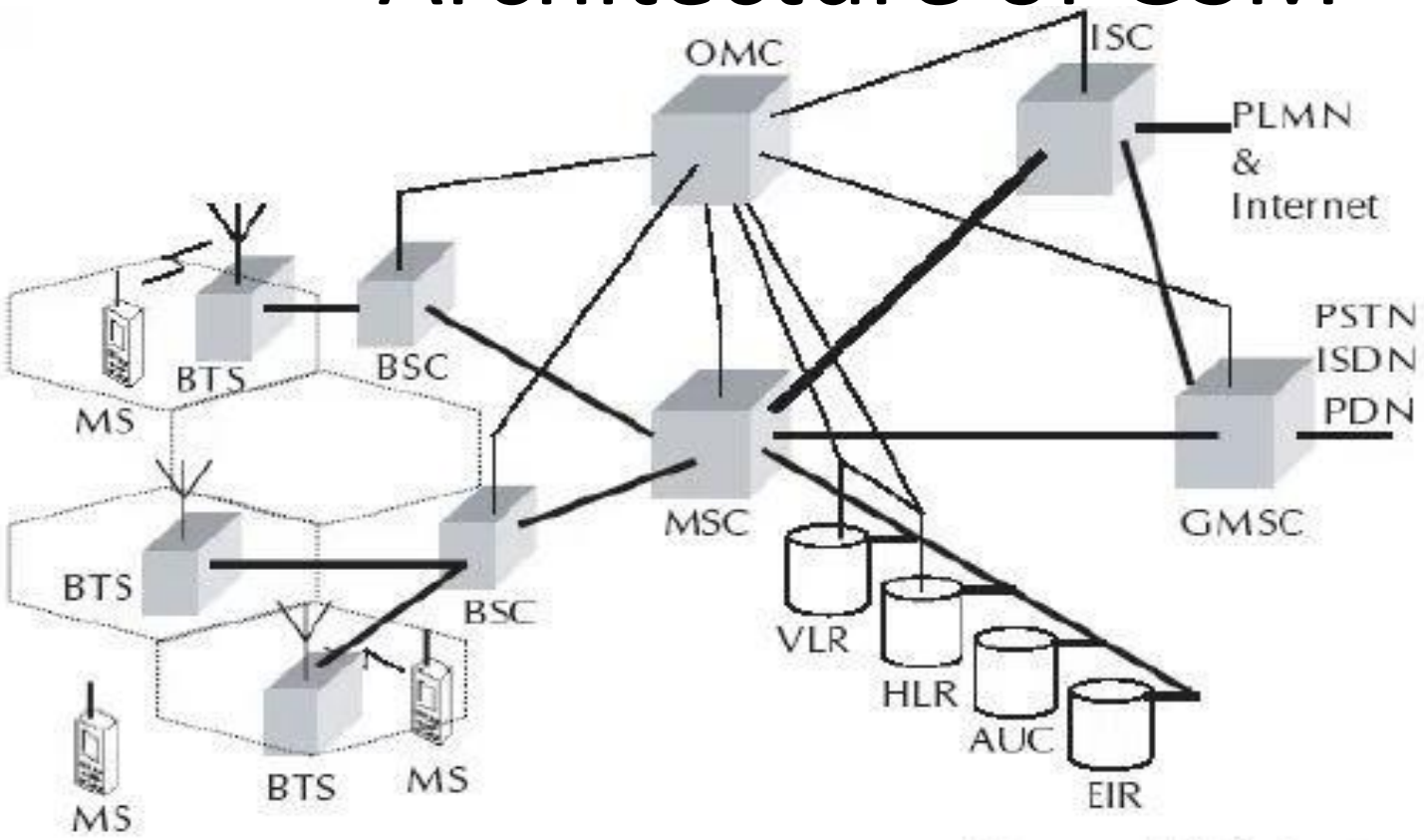


- For all subscribers registered with cellular network operator, permanent data is stored in Home Location Register(HLR)
- Data relate to following information
- Authentication information like IMSI (International Mobile Subscriber Identity)
- Identification information like name, address of subscriber
- Identification information like Mobile Subscriber ISDN
- Billing information like prepaid or postpaid customer

- Operator selected deniel of service to a subscriber
- Handling of supplementary services –CFU(call Forwarding Unconditional), CFB (Call Forwarding Busy), CFNR(Call Forwarding Not Reachable), CFNA(Call Forwarding Not Answered)
- Storage of SMS Service Center number in case of mobile is not connectable so that whenever the mobile is connectable, a paging signal is sent to the SC
- Provisioning information- whether long distance and international calls are allowed or not
- Provisioning information- whether roaming is enabled or not

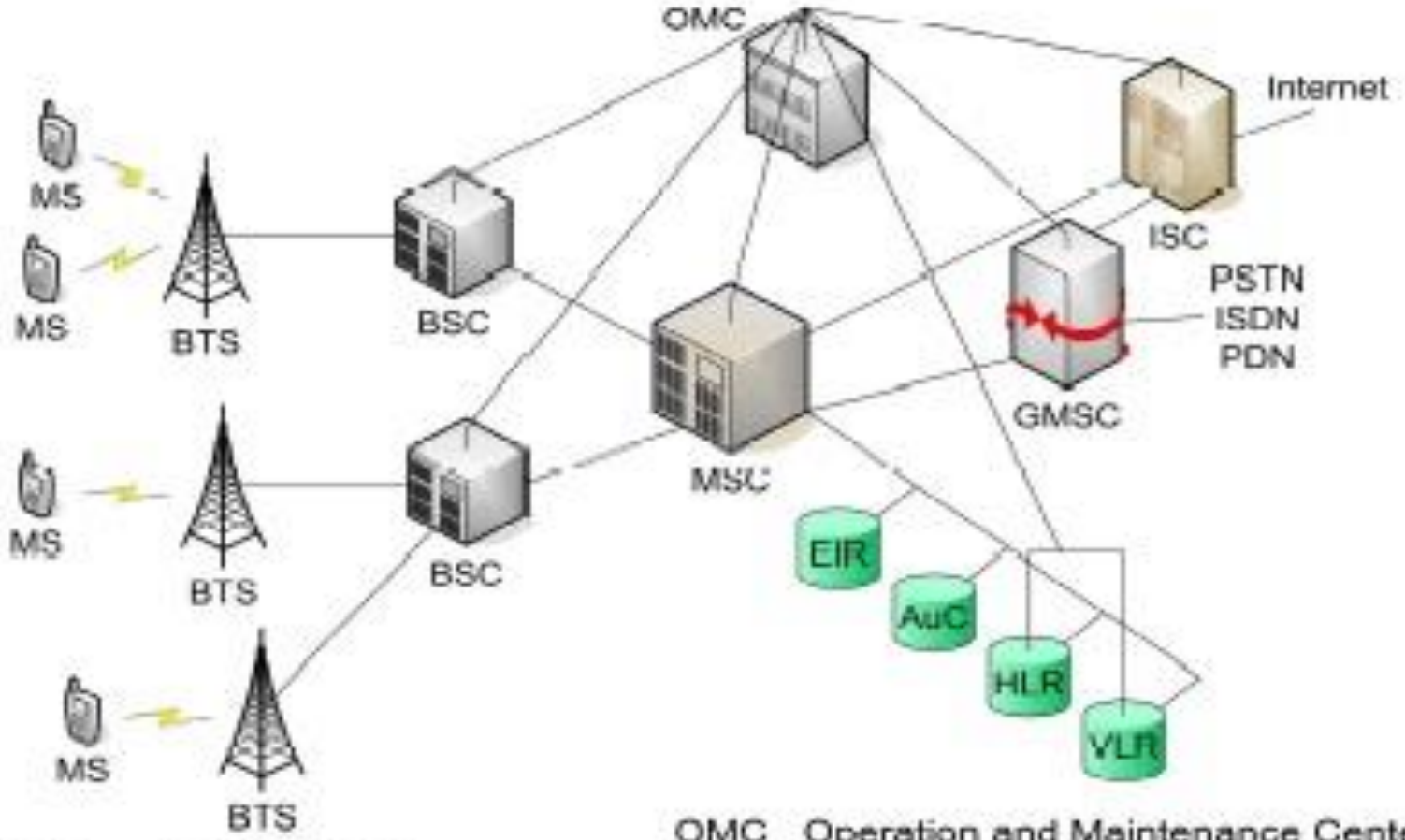
- Information related to auxiliary services like voice mail, data, fax services etc
- Information related to auxiliary services like CLI(Caller Line Identification)
- Information related to supplementary services for call routing(barring of incoming calls while roaming-customization personal profile)
- Variable information-pointer to VLR, location area of subscriber, power off status of handset etc

Architecture of GSM



BTS	Base Transceiver Station
BSC	Base Station Controller
MSC	Mobile Switching Center
GMSC	Gateway MSC
ISC	International Switching Center

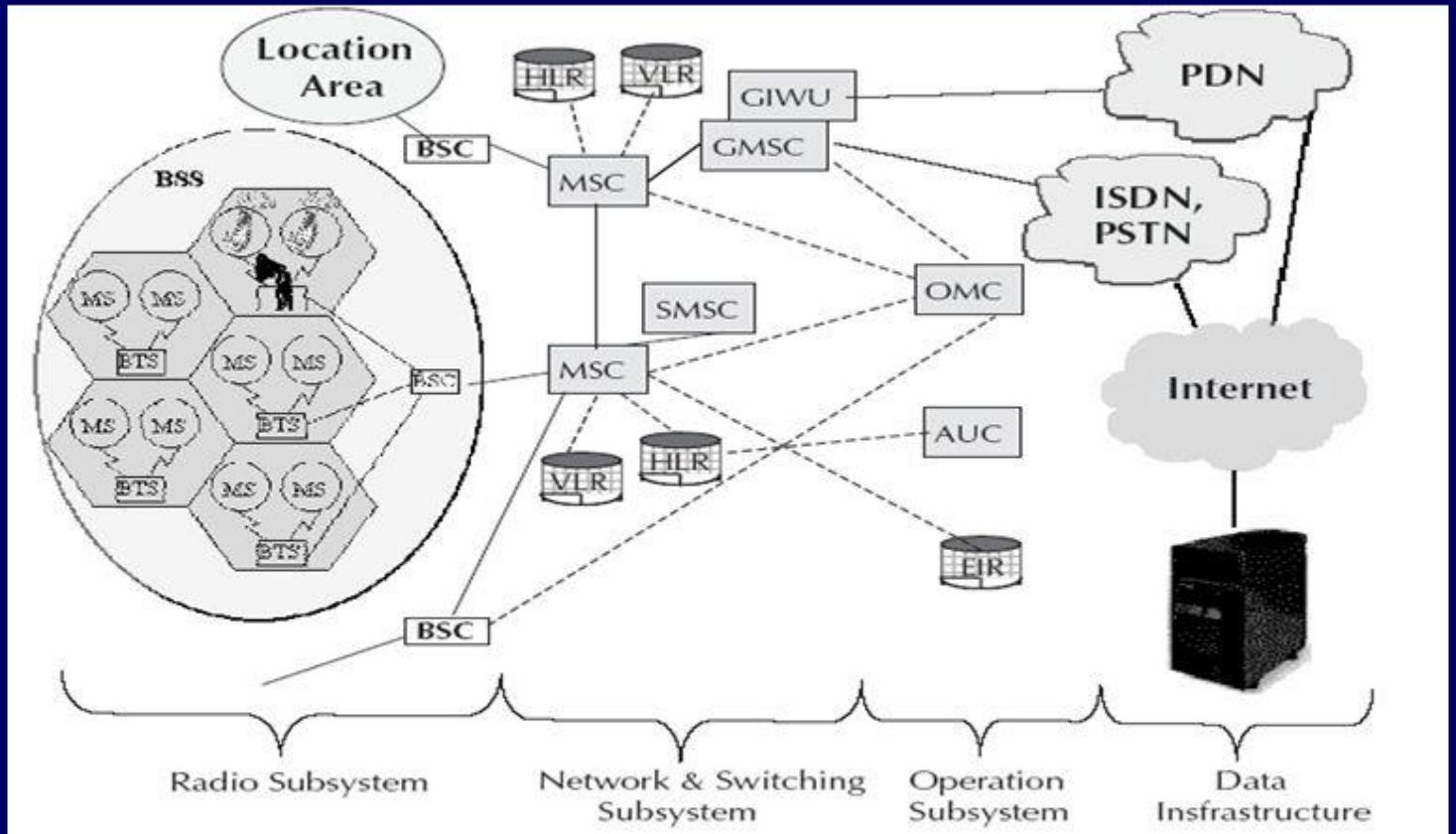
MS	Mobile Station
HLR	Home Location Register
VLR	Visitor Location Register
AUC	Authentication Center
EIR	Equipment Identity Register
OMC	Operation and Maintenance Center



MS	Mobile Station	OMC	Operation and Maintenance Center
BTS	Base Transceiver Station	HLR	Home Location Register
BSC	Base Station Controller	VLR	Visited Location Register
MSC	Mobile Switching Center	AuC	Authentication Center
GMSC	Gateway MSC	EIR	Equipment Identity Register
		ISC	International Switching Center

Figure 1. GSM Architecture

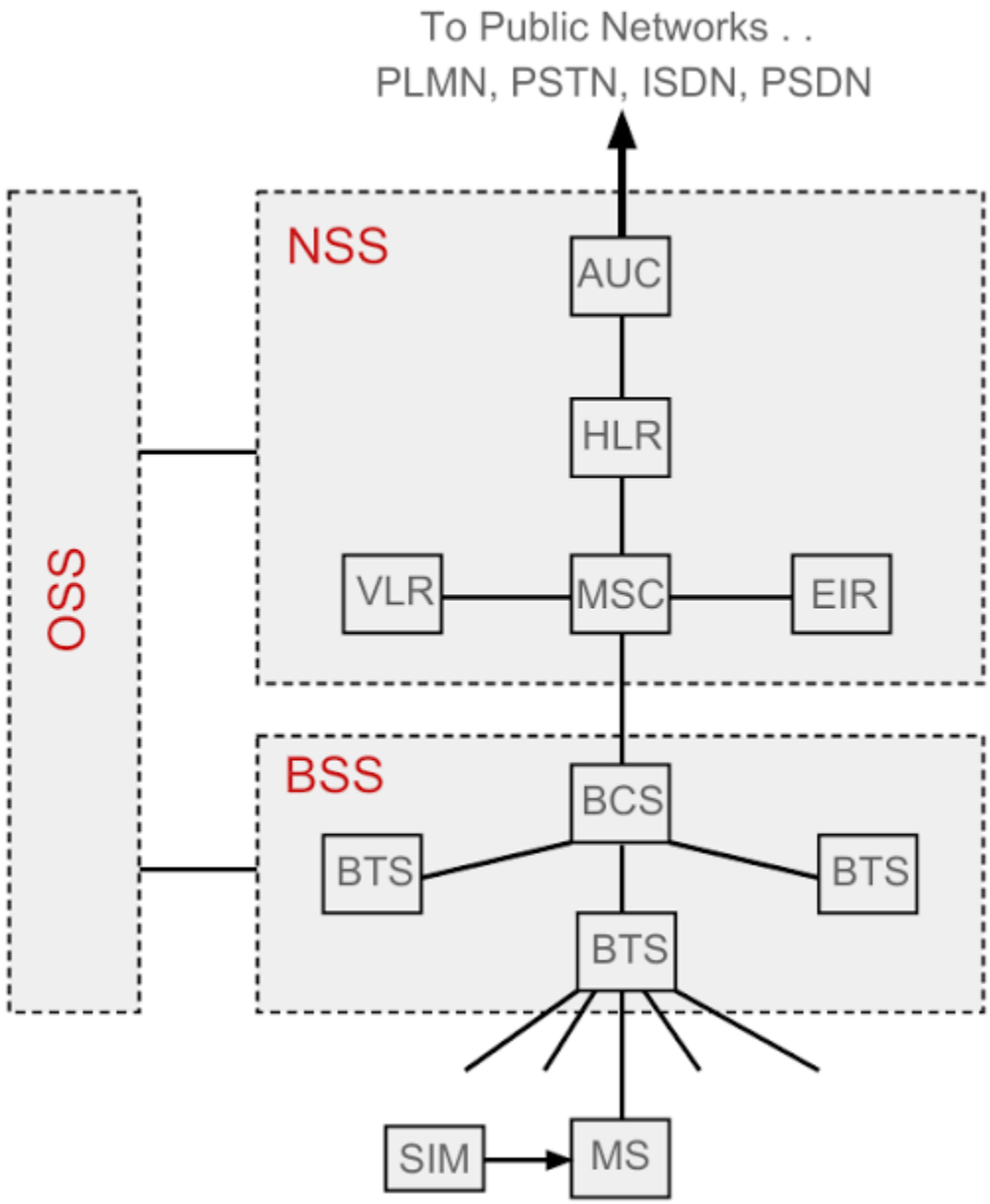
Operational Architecture of GSM



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		

GSM Entities

- Different entities form the GSM network by defining their functions and interface requirements
  - Mobile Station
  - Base Station Subsystem
  - Network and Switching subsystem
  - Operation and Support Subsystem(OSS)
  - Message Centre


To Public Networks . .
PLMN, PSTN, ISDN, PSDN
NSS
AUC
HLR
VLR
MSC
EIR
OSS
BSS
BCS
BTS
BTS
BTS
SIM
MS

Mobile Station

- Technical name of mobile/cellular phone
- Mobile phones were bulky

- MS consists of:
  - Mobile equipment (without SIM card)
  - Subscribe Identity Module(SIM)

- Terminals have experienced highest evolution
  - Weight and volume decreased
  - Battery life increased

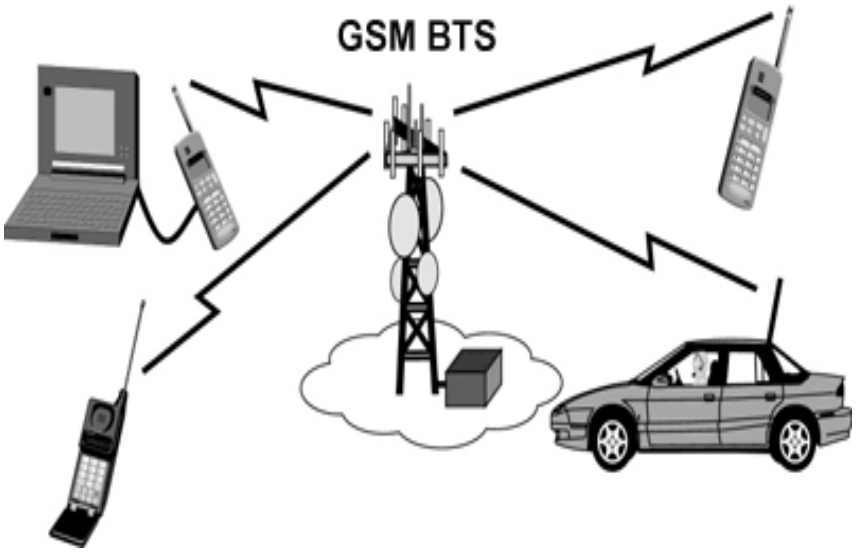
- SIM is installed in every GSM phone; SIM card makes it operational
- Identifies the terminal
- Smart processor cards with processor and a small memory
- Contains:
  - International Mobile Subscriber Identity(IMSI) used to identify the subscriber to the system
  - Secrete key for authentication
  - Other security information

- User can have access to subscribed services in any terminal using SIM card
- Can be protected against unauthorized access by password or personal identity number
- Contain 32K memory-user can use it for address book and SMS
- Applications are developed and stored in SIM cards using SAT(SIM Application Toolkit)
  - Proprietary to the SIM vendor

Base Station Subsystem

- Connects Mobile Station and NSS
- It is in charge of transmission and reception of radio signals
- Composed of two parts:
  - Base Transceiver Station(BTS)
  - Base Station Controller(BSC)

- BTS:
- Corresponds to the transceivers and antennas used in each cell



- In large urban area, large number of BTSs deployed
- Usually placed in the center of a cell
- Size of a cell is decided by transmitting power of BTS
- Houses radio transmitter and receivers that define a cell and handles radio link protocol with Mobile station
- Each BTS has between 1 and 16 transceivers, depending on the density of users in the cell

- BSC:
- Connection between BTS and Mobile Service Switching Center(MSC)
- Manages radio resources for one or more BTSs
- Handles handovers, redio channel setup, control of radio frequency power levels of the BTSs, exchange function, frequency hopping

The Network and Switching Subsystem(NSS)

- Includes:
  - Mobile Switching Center(MSC)
  - Home Location Register(HLR)
  - Visitor Location Register(VLR)
  - Equipment Identity Register(EIR)
  - Authentication Center(AUC)

Mobile Switching Center(MSC)

- Central component of the Network Subsystem
- MSC together with Home Location Register (HLR) and Visitor Location Register (VLR) databases, provide the call-routing and roaming capabilities of GSM

- MSC does the following functions:
- It acts like a normal switching node for mobile subscribers of the same network (connection between mobile phone to mobile phone within the same network)
- It acts like a normal switching node for the PSTN fixed telephone (connection between mobile phone to fixed phone)

- 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

- HLR contains all the administrative information of each subscriber registered in the corresponding GSM network
- Current location of the mobile, service provisioning information, authentication data
- Location of the mobile is typically in the form of the signalling address of the VLR associated with the mobile station

- HLR is always fixed and stored in the home network, where as the VLR logically moves with the subscriber
- VLR is similar to a cache, whereas HLR is the persistent storage
- VLR contains selected administrative information borrowed from the HLR, necessary for call control and provisioning of the subscribed Services
- When a subscriber enters the covering area of a new MSC, the VLR associated with this MSC can request information about the new subscriber from its corresponding HLR in the home network

- There is a component called Gateway MSC (GMSC) that is associated with the MSC
- GMSC is the interface between the mobile cellular network and the PSTN and also is in charge of routing calls from the fixed network towards a GSM user and vice versa
- GMSC is often implemented in the same node as the MSC
- GIWU (GSM Inter Working Unit) corresponds to an interface to various networks for data communications

Operation and Support Subsystem(OSS)

- Controls and monitors the GSM system
- Connected to the different components of the NSS and to the BSC
- In charge of controlling the traffic load of the BSS
- Some of the maintenance tasks are transferred to the BTS
- Provisioning information for different services is managed in this subsystem

- 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 terminals

- Authentication Center (AUC) is responsible for the authentication of a subscriber
- AUC 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

Message Center

- Short Message Service is one of the most popular services within GSM
- A data service and allows a user to enter text message up to 160 characters in length when 7 bit English characters are used
- A proactive bearer and is an ‘always on’ network
- Message center is referred to as Service Centre (SC) or SMS Controller (SMSC)
- SMSC is a system within the core GSM network which works as the store and forward system for SMS messages

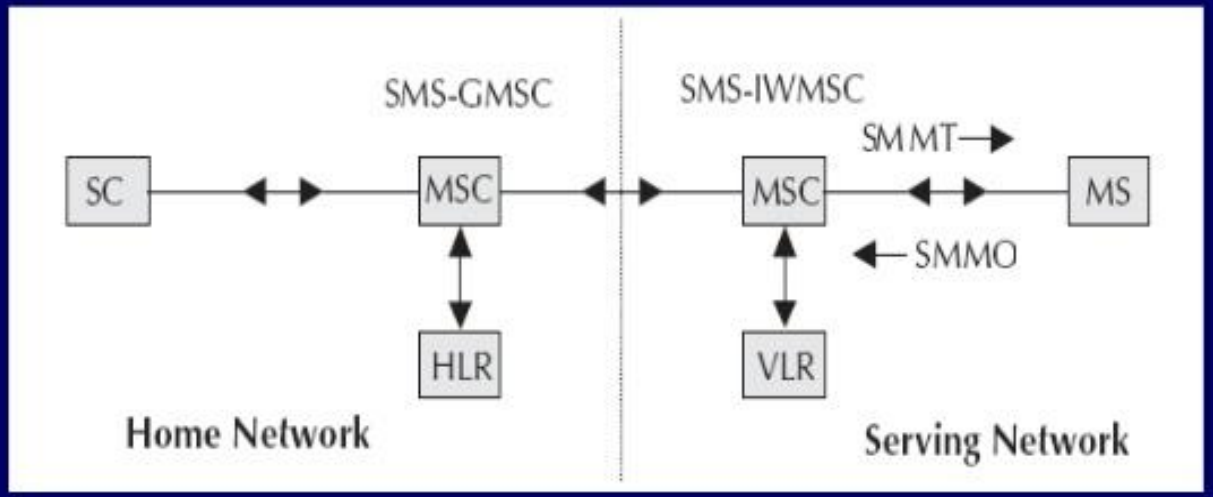
- Two types of SMS:

- SMMT (Short Message Mobile Terminated Point-to-Point)
  - An incoming short message from the network and is terminated in the MS
  - For incoming message, the path is from SC to the MS via the HLR and the Gateway MSC (GMSC)

- Two types of SMS:

- SMMO (Short Message Mobile OriginatedPoint-to-Point)
  - an outgoing message originated in the MS, and forwarded to the network for delivery
  - For an outgoing message, the SMS is sent from the phone to SC via the VLR and the Inter Working MSC (IWMSC)

SMS Transfer



Call Routing-MT call

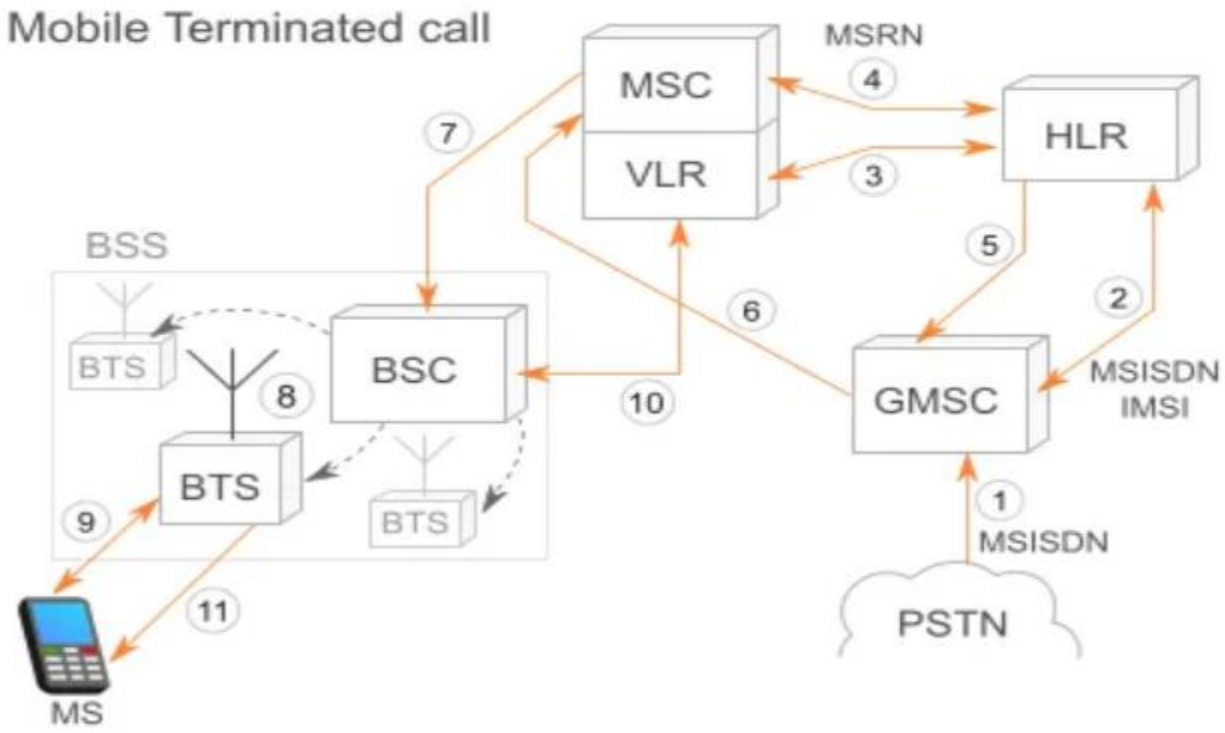
- The call first goes to the local PSTN exchange where PSTN exchange looks at the routing table and determines that it is a call to a mobile network
- PSTN forwards the call to the Gateway MSC (GMSC) of the mobile network
- MSC enquires the HLR to determine the status of the subscriber. It will decide whether the call is to be routed or not. If MSC finds that the call can be processed, it will find out the address of the VLR where the mobile is expected to be present.

- If VLR is that of a different PLMN, it will forward the call to the foreign PLMN through the Gateway MSC. If the VLR is in the home network, it will determine the Location Area(LA)

- Within the LA, it will page and locate the phone and connect the call

- A terminated call in the GSM network is a call received on a mobile device

- For an MT to be placed, it is necessary to locate the network to which the called subscriber is currently connected, and, once this is done, to route the call towards the destination MS



1. When a call is placed from the PSTN towards a given phone number, the PSTN uses the information in the phone number (country and if available, operator) to locate gateway MSC leading to the MSC where the subscriber is registered

2. The GMSC can request information about the subscriber's core network and current location by interrogating the HLR (Home Location Register)

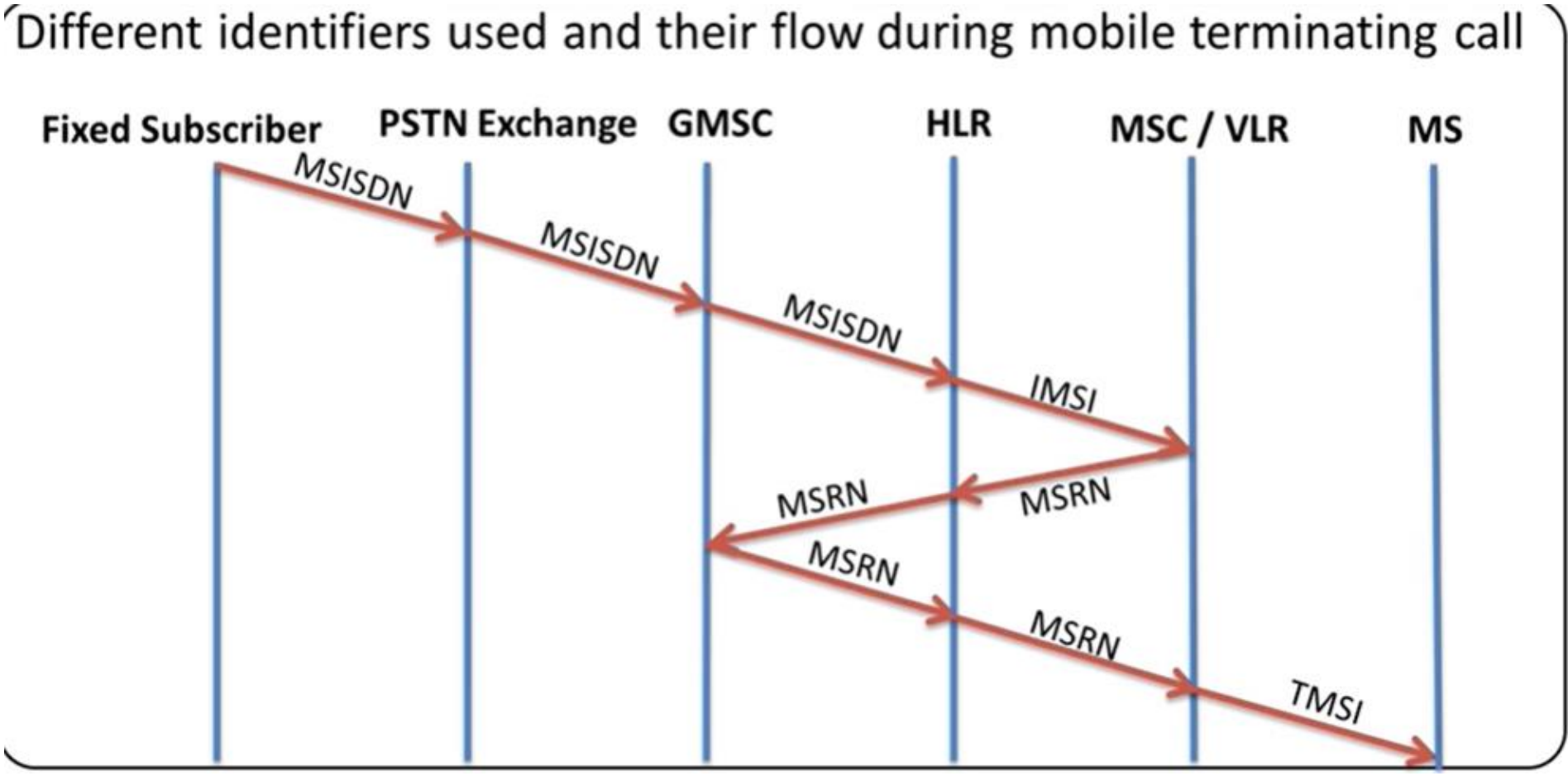
3. The HLR constantly updates locations of the MS stored in the VLRs of the networks the MS visits. In the HLR, the subscriber MSISDN (phone number) is associated with the IMSI number of the SIM card, which was used to authenticate the subscriber in the visited network as they registered. Since authentication is communicated to the MSC, the HLR is aware of the visited MSC/VLR of the MS at a given time

4. In order for the GMSC to pass the call to the MSC, the HLR asks a temporary roaming phone number from the MSC (Mobile Station Roaming Number – MSRN)

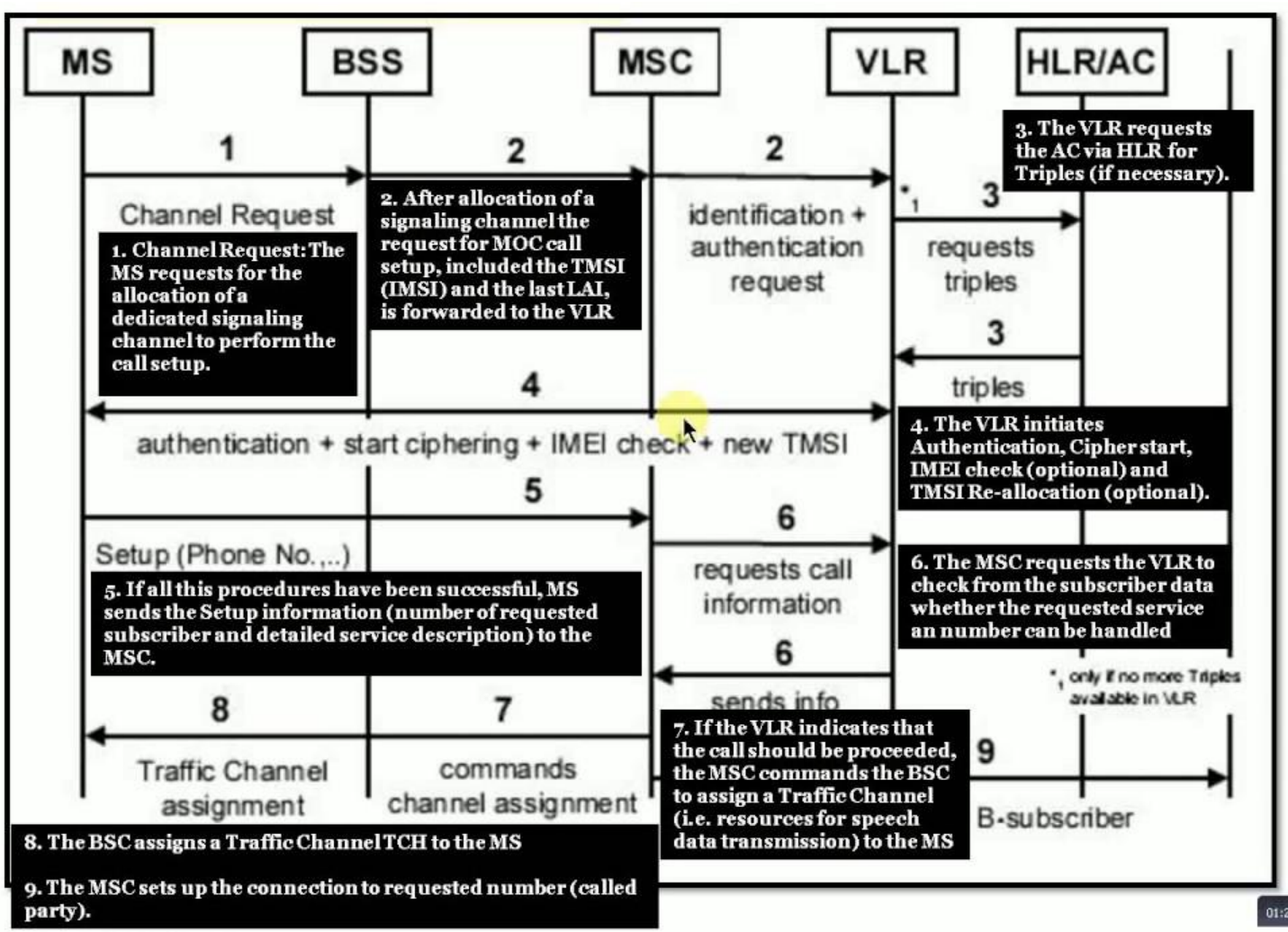
5. The MSRN is sent back from the HLR to the GMSC
6. The GMSC forward the call to the MSC using the assigned MSRN
7. Having received the call, the MSC pages all the BSCs in the area that it serves.
8. The BSC, in turn, page the BTSs assigned to them
9. The called MS responds to the paging from the BTS, asking to establish a radio channel to the BTS.
10. The response is forwarded to the MSC, which, once notified, authenticates the MS and initiates the ciphering of the call using the same procedure as in MO calls.
11. When the MSC sends back to the radio network the call confirmation message, the called MS starts to ring.

- At the other end, the MSC notifies the GMSC, which notifies the PSTN that the destination number is being alerted.

Different identifiers used and their flow during mobile terminating call



Call Routing-MO call



GSM Addresses and Identifiers

- International Mobile Station Equipment Identity (IMEI)
  - Every mobile equipment in this world has a unique identifier which is called IMEI
  - IMEI is allocated by the equipment manufacturer and registered by the network operator in the Equipment Identity Register (EIR)

- International Mobile Subscriber Identity (IMSI):
- When registered with a GSM operator, each subscriber is assigned a unique identifier called IMSI which is stored in the SIM card and secured by the operator
- IMSI consists of several parts:
  - 3 decimal digits of Mobile Country Code (MCC),
  - 2 decimal digits of Mobile Network Code (MNC)
  - maximum of 10 decimal digits of Mobile Subscriber Identification Number (MSIN) which is a unique number of the subscriber within the home network

- Mobile Station International Subscriber Directory Number(MSISDN):
- The MSISDN number is the real telephone number as is known to the external world
- MSISDN number is public information whereas IMSI is private to the operator.
- MS can have multiple MSISDN numbers

- MSISDN follows the international ISDN (Integrated Systems Data Network) numbering plan
- ISDN has Country Code (CC) of 1 to 3 decimal digits, National Destination Code (NDC) of 2 to 3 decimal digits and Subscriber Number (SN) of maximum 10 decimal digits.

- Location Area Identity: Each LA in a PLMN has its own identifier called Location Area Identifier (LAI) which is structured hierarchically and unique. LAI consists of 3 digits of CC, 2 digits of Mobile Network Code and maximum of 5 digits of Location Area Code.
- Mobile Station Roaming Number (MSRN): When a subscriber is roaming in another network, a temporary ISDN number is assigned to the subscriber called MSRN. MSRN is assigned by the local VLR in charge of the mobile station and follows the structure of MSISDN.

- Temporary Mobile Subscriber Identity (TMSI): TMSI is a temporary identifier assigned by the serving VLR used in place of the IMSI for identification and addressing of the mobile station. Together with the current location area, a TMSI allows a subscriber to be identified uniquely.

- Local Mobile Subscriber Identity (LMSI): LMSI is assigned by the VLR and stored in the HLR and is used as a searching key for faster database access within the VLR.

Cell Identifier: Within a LA, every cell has a unique Cell Identifier (CI) and together with a LAI, a cell can be identified uniquely through Global Cell Identity (LAI & CI).

MSCs and Location Registers (HLR & VLR) are addressed with ISDN numbers while they may use a Signaling Point Code (SPC) within a PLMN.

MOBILITY MANAGEMENT

- In a mobile environment, the point of attachment constantly changes making old routing table invalid
- Establishing and maintaining a connection is complex
- MM function handles all functions that arise from the mobility of the subscriber allowing calls, SMS and other services to be delivered to them

Paging

- For MT call, the MS needs to traced, located, and then the call connected
- MS is traced through the Paging Process
- Using the BSS signaling channel the paging message for an MS is sent
- It includes the IMSI as the identifier of the MS
- MS listens on downlink channel if any alert for it is found on the downlink

Paging-Where to start?

- A cellular network may be spread over thousands of sq.km with thousands of cells
- If we cannot locate the mobile quickly, the call cannot be connected

Start from center of network and search each and every cell	Start from the location where mobile station was last present
• Is very expensive in terms of response time as well as signaling cost	• The probability of finding the phone is maximum there; optimized for response time

Location Update

- Concerned with procedures that enable network to know the current location of a powered-on MS
- Location information is regularly updated within the network (VLR and HLR)
- MS must be powered on and attached to network
- It must be located through paging before a successful communication can take place for MT calls and SMS
- A location update message is sent to the new MSC/VLR which records the location area information and then sends the location information to the subscriber's HLR.
- If the mobile station is authenticated and authorized in the new MSC/VLR, the subscriber's HLR cancels the registration of the mobile station with the old MSC/VLR.

Location Update

- IMSI detaches- Types
- Explicit IMSI detach:
- When an MS is powered off, the HLR is updated with an explicit IMSI detach-IMSI being unavailable-MS is not available and a connection cannot be established

- Implicit IMSI detach:
- MS is powered on but not successfully connected to the network due to MS being out of coverage area

Location Update

- To complete a call, IMSI must stay attached with VLR and HLR
- IMSI attach is accomplished through location updates
- Location update can be initiated by either MS or the network
- Frequent location update costs in terms of power in MS and signalling traffic

Location Update

- Location update is restricted to the following conditions:
- When there is a MO call, location information is updated in VLR and HLR
- When MS moves from one LA to another
- MS updates location information when its location is more than k cells away in distance from the location information of the last update
- MS updates location information when it crosses exactly k cell boundaries
- Explicit periodic location update by MS- defined by the GSM network operator- range of 1 decihour(6 min) to 240 decihours(24 hrs)

Handover

- The relationship between radio signals and the user is dynamic while a call is in progress
- There may be need of changing the association of resources to another channel within the same cell or a different cell
- Handover- procedure of changing the resources
- Needs to be very fast without causing any disruption to the service
- Can be initiated by MS(RF level, quality of radio signal, distance from tower) or the network(current traffic loading per cell, maintenance requests)

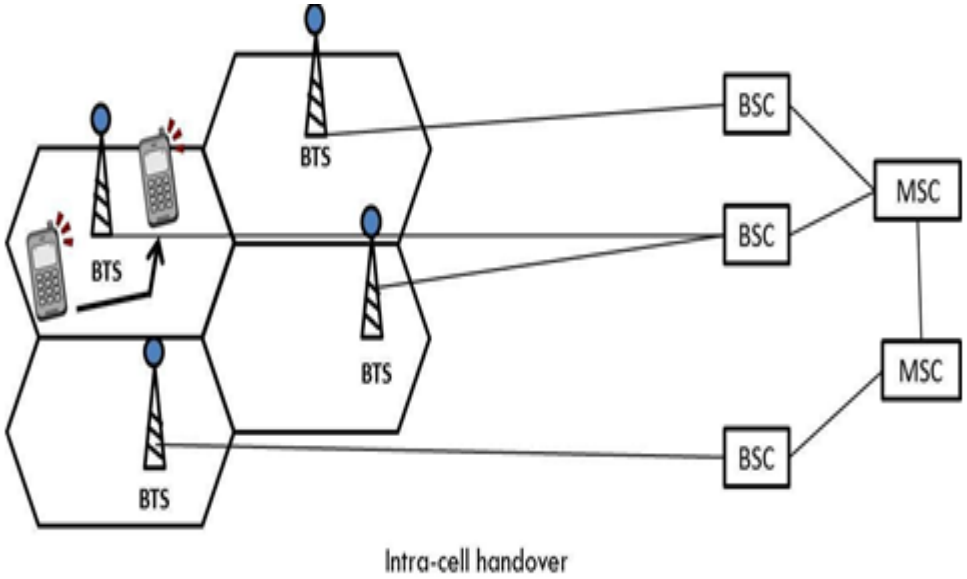
Handover-Types

- 4 types which involve transferring a call between:
- Internal handovers- involve only one BSC without involving MSC except to notify it at the completion of the handover
- Channels in the same cell
- Cells(BTS) under the control of the same BSC

- External handovers-handled by the MSC
- Cells under the control of different BSCs, but belonging to the same MSC
- Cells under the control of different MSCs

Handover-Types

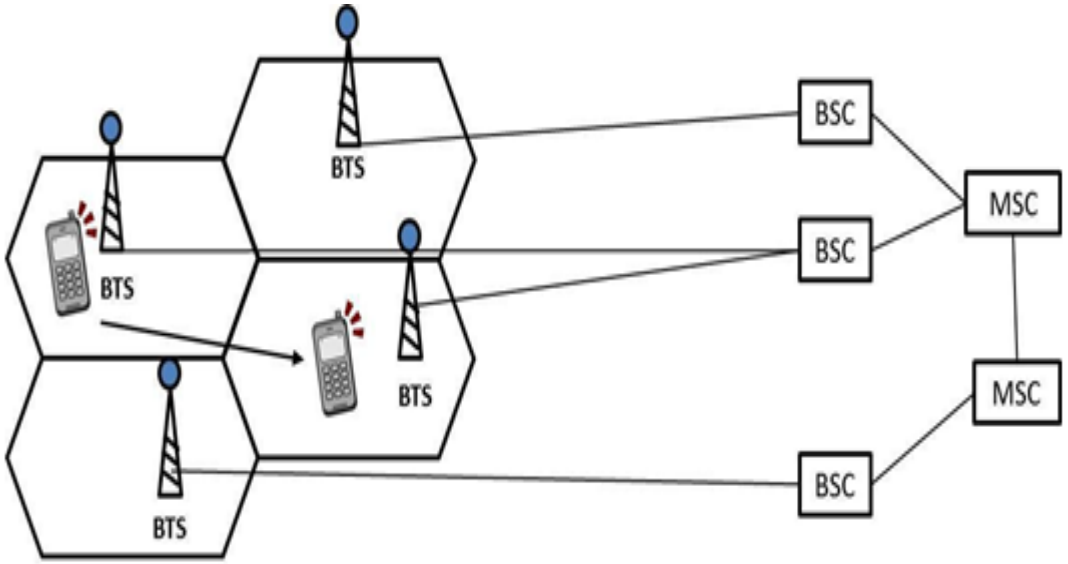
- 4 types which involve transferring a call between:
- Channels in the same cell



Intra-cell handover

Handover-Types

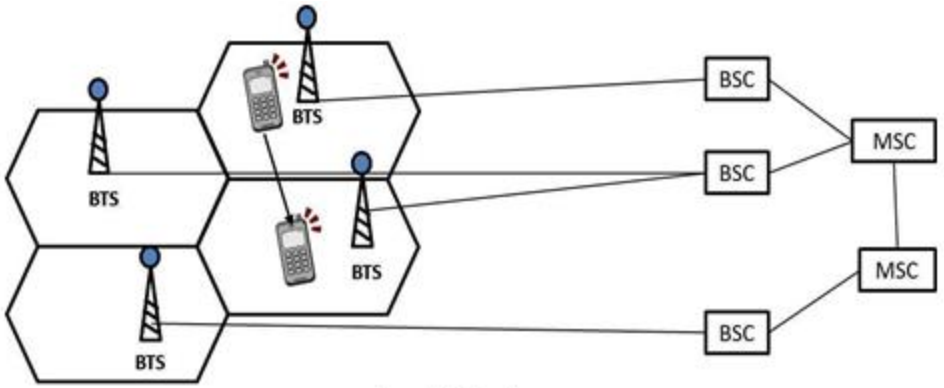
- 4 types which involve transferring a call between:
- Cells(BTS) under the control of the same BSC



Intra-BSC handover

Handover-Types

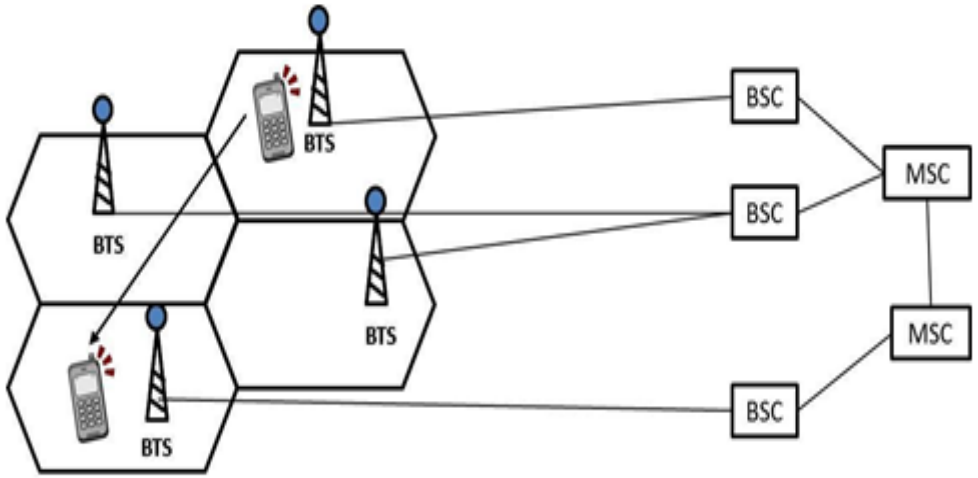
- 4 types which involve transferring a call between:
- Cells under the control of different BSCs, but belonging to the same MSC



Inter-BSC handover

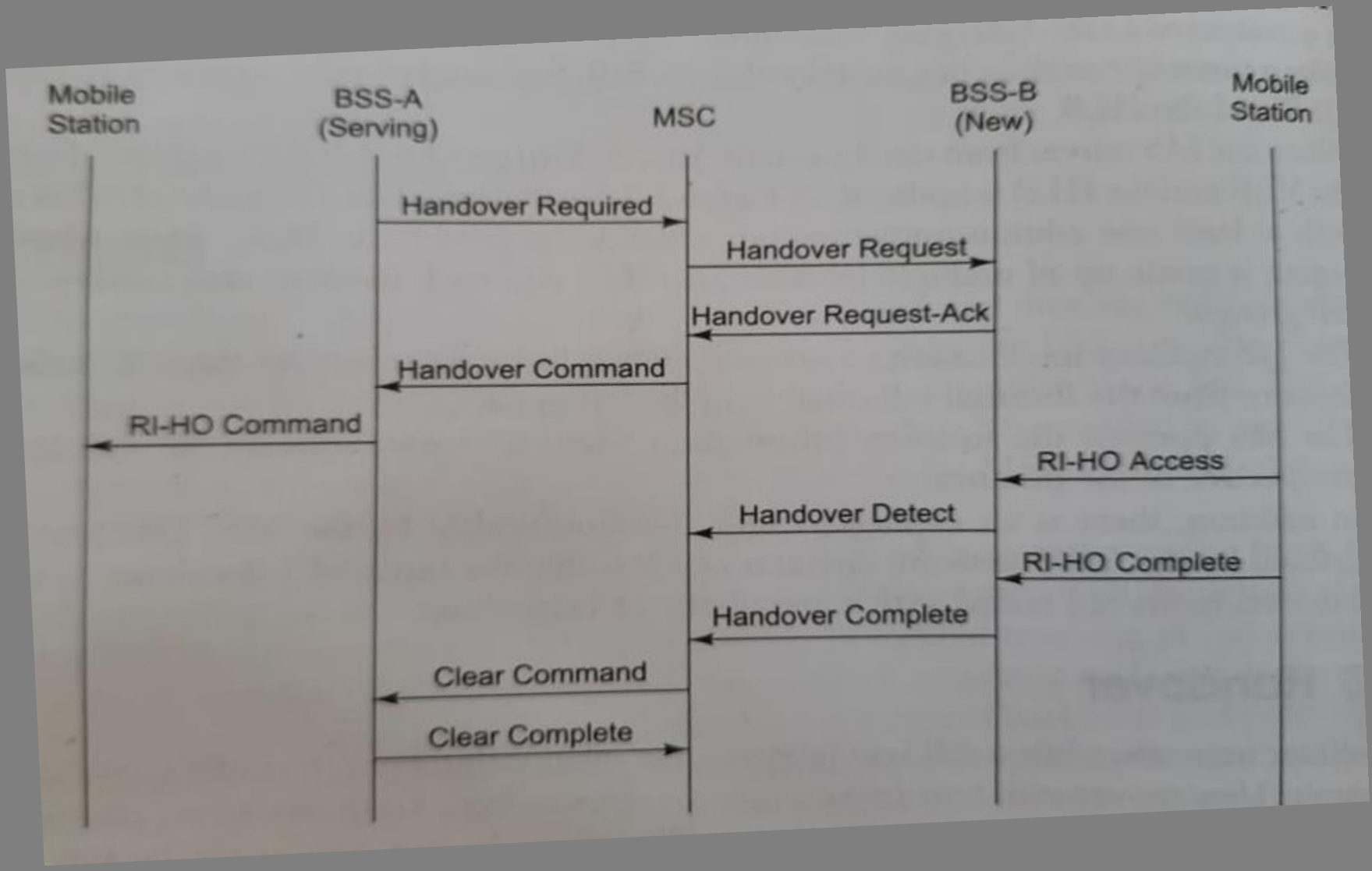
Handover-Types

- 4 types which involve transferring a call between:
- Cells under the control of different MSCs



Inter-MSC handover

Handover Procedure



Handover Procedure

- The current serving BSS sends a Handover_Required message to the MSC
- The MSC sends a Handover_Request message to the new BSS from which it requires radio resources
- This message contains details of the resource that it required; it also specifies the channel in use
- On receipt of the message, the new BSS shall choose suitable idle radio resource
- This information is passed by the new BSS to the MS through MSC and old BSS using Handover_Request_Acknowledgement, Handover_Command, and Radio_interface_Handover_Command respectively
- The MS changes its association from the old BSS to the new BSS with a Handover_Access burst which contains the received handover reference number

Handover Procedure

- The new BSS checks the handover reference number to ensure that it is same as expected, and that there is high probability that the correct MS has been captured
- When the MS is successfully in communication with the network, i.e. Handover_Complete has been received from the MS, then the new BSS will immediately send a message Handover_Complete to the MSC and terminate the procedure
- The MSC in this case will terminate the procedure with the old BSS by sending a Clear_Command with cause “Handover successful”

Roaming

- Roaming: ability for a customer of mobile communications to automatically make and receive telephone calls, send and receive data, or access other services while travelling outside the geographical coverage area of the home network, by means of using a network of another operator
- When the subscriber moves to a different operator's PLMN, he should register with new network to indicate current location
- First location update procedure is called the IMSI attach procedure where MS indicates its IMSI to the new network

Roaming

- A location update message is sent to the new MSC/VLR which records the LA information, and then sends it to the subscriber's HLR
- If MS is authenticated and authorized in new MSC/VLR, subscriber's HLR cancels the registration of the MS with old MSC/VLR

Roaming

- Roaming allows users to seamlessly move around nationally and internationally and remain connected.
- MSRN is a temporary location dependent MSISDN number
- It is assigned by the serving VLR for each MS in its area
- MSRNs are numbers reserved by a PLMN only for roaming use

Roaming-types

- Horizontal Roaming: between two networks from same family(GSM to GSM, GSM to UMTS)
- Vertical roaming: between two networks from different families(GSM to CDMA or GPRS to Wi-Fi)
- When vertical roaming happens without any disruption of session or service it is called Seamless Roaming

Short Message Service (SMS)

- Most popular data bearer/service within GSM
- More than one billion SMS messages interchanged everyday with a growth of more than half a billion every month on an average
- Runs on SS7 signaling channels, which are always present but mostly unused, be it during an active user connection or in the idle state
- Each short message is up to 160 characters in length when 7-bit English characters are used and 140 octets when 8-bit characters are used

Strengths of SMS

- Omnibus nature of SMS: SMS uses SS7 signaling channel which is available throughout the world.
- Stateless: SMS is session-less and stateless as every SMS message is unidirectional and independent of any context. This makes SMS the best bearer for notifications, alerts and paging.
- Asynchronous: SMS is completely asynchronous. In case of SMS, even if the recipient is out of service, the transmission will not be abandoned and hence, SMS can be used as message queues. SMS can be used as a transport bearer for both synchronous (transaction oriented) and asynchronous (message queue and notification) information exchange.

Strengths of SMS

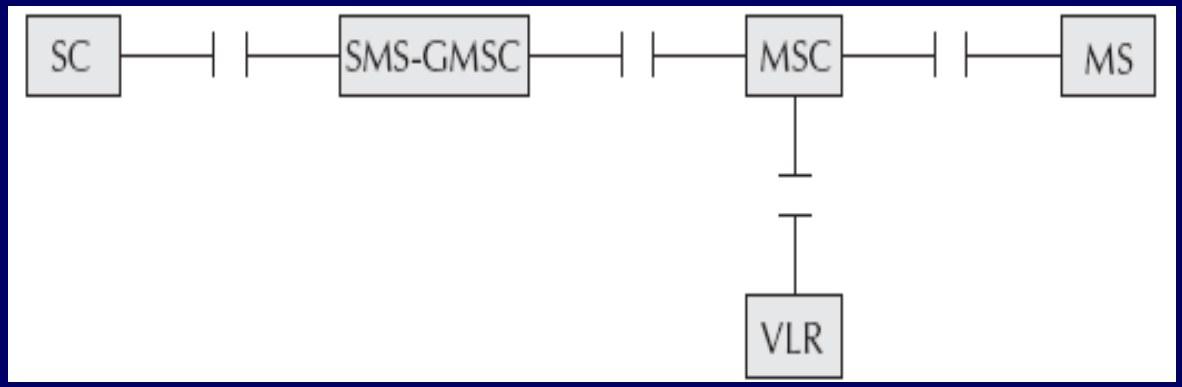
- Self-configurable and last mile problem resistant: SMS is self-configurable and subscriber is always connected to the SMS bearer irrespective of the home and visiting network configurations.
- Non-repudiable: SMS message carries the Service Center (SC) and the source MSISDN as a part of the message header through which any SMS can prove beyond doubt its origin.
- Always connected: As SMS uses the SS7 signaling channel for its data traffic, the bearer media is always on. Users cannot switch OFF, BAR or DIVERT any SMS message. SMS message is delivered to the Mobile Station (MS) without any interruption to the ongoing call.

SMS Architecture

- Two types of SMS - **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 and is terminated in the MS
- SM MO is an outgoing message originated in the MS and forwarded to the network for delivery
- For an outgoing message, the path is from MS to SC via the VLR and the IWMSC (Inter Working MSC) function of the serving MSC whereas for an incoming message the path is from SC to the MS via HLR and the GMSC (Gateway MSC) function of the home MSC

Short Message Mobile Terminated (SMMT)

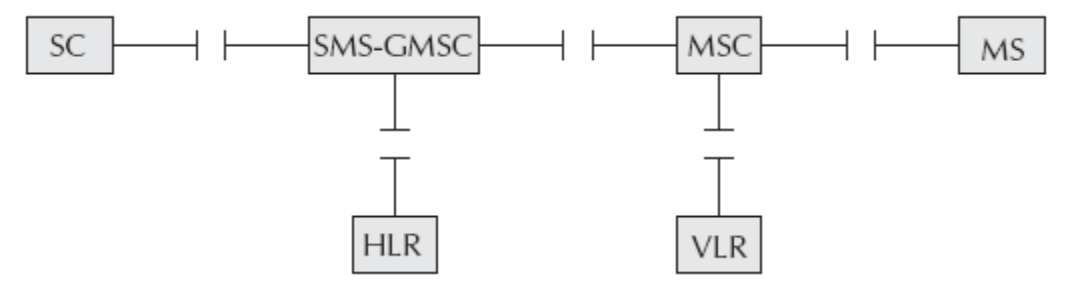
- Message is sent from SC to the MS.
- For the delivery of MT or incoming SMS messages, the SC of the serving network is never used which implies that a SMS message can be sent from any SC in any network to a GSM phone anywhere in the world.



Interfaces in SMMT

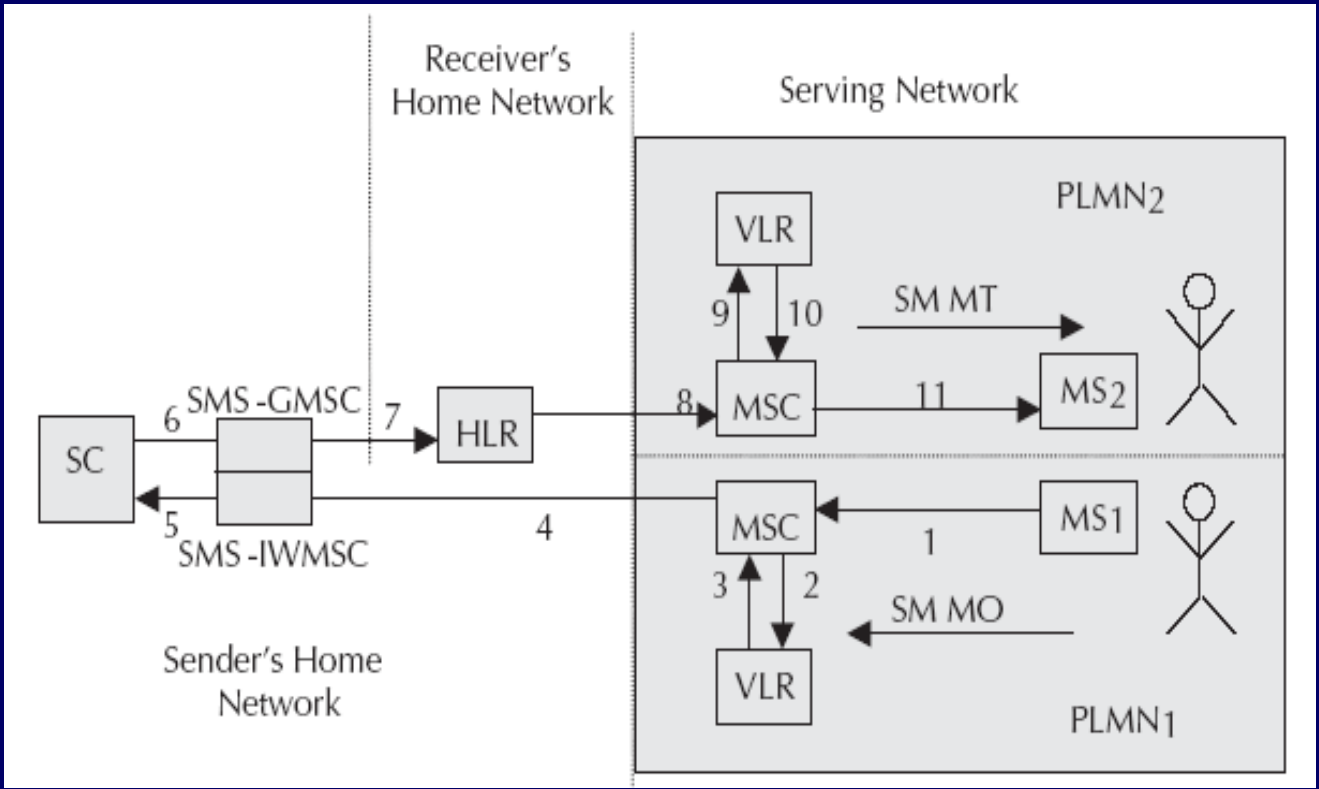
Short Message Mobile Originated

- For a MO message, the MSC forwards the message to the home SC.
- 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. In the second phase, the message is sent from the home SC to the MS as a MT message.



Interfaces in SMMO

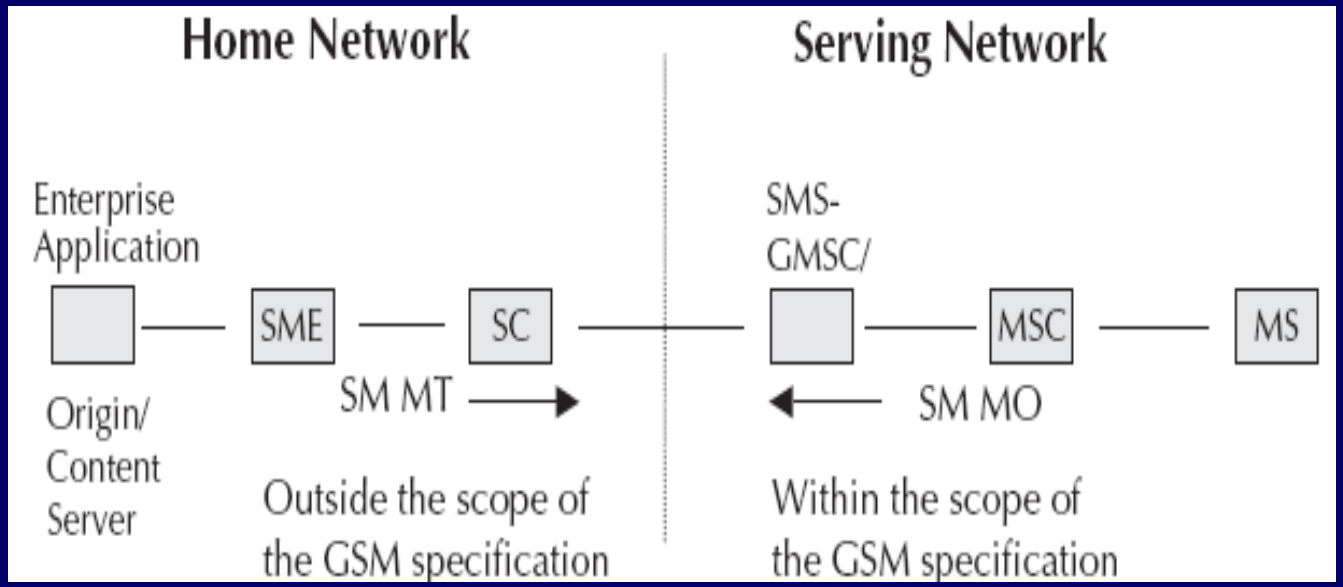
SMS Transfer



SMS as an Information Bearer

- For using SMS as an information bearer, we need to connect the services running on the Enterprise Origin server to the SC through an SME (Short Message Entity) or ESME (External Short Message Entity).
- SME in any network is generally a SMS gateway.
- With respect to SMS, a GSM subscriber is always in control of the SC in the home network irrespective of the serving network.
- If there is any SMS-based data service in the home network, it will be available in any foreign network.

SMS as an Information Bearer



Operator Centric Pull

- Operators offer different information on demand and entertainment services through connecting an Origin server to the SC via a SMS gateway.
- Such service providers are known as Mobile Virtual Network Operator(s) (MVNO).
- MVNOs develop different systems, services and applications to offer data services using SMS.
- Many enterprises use MVNOs to make their services available to mobile phone users.

Example of MVNO

- Let's say few banks offer balance enquiry and other low security banking services over SMS and customers need to register for the service.
- During the registration, the customer needs to mention the MSISDN of the phone which will be used for a banking service.
- Once a user is registered for the service, he enters 'BAL' and sends the message to a service number (like 333) as a MO message and then SC delivers this MO message to the SMS gateway (known as SME-Short Message Entity) connected to this service number.

Example of MVNO

- SMS gateway then forwards this message to the enterprise application and response from the enterprise application is delivered to the MS as a MT message from the SME.
- Even if the subscriber is in some remote region of a foreign network within GSM coverage, he can send the same SMS to the same service number in his home network and this makes the home services available in the foreign network. Hence, operator-centric SMS pull service is completely ubiquitous.

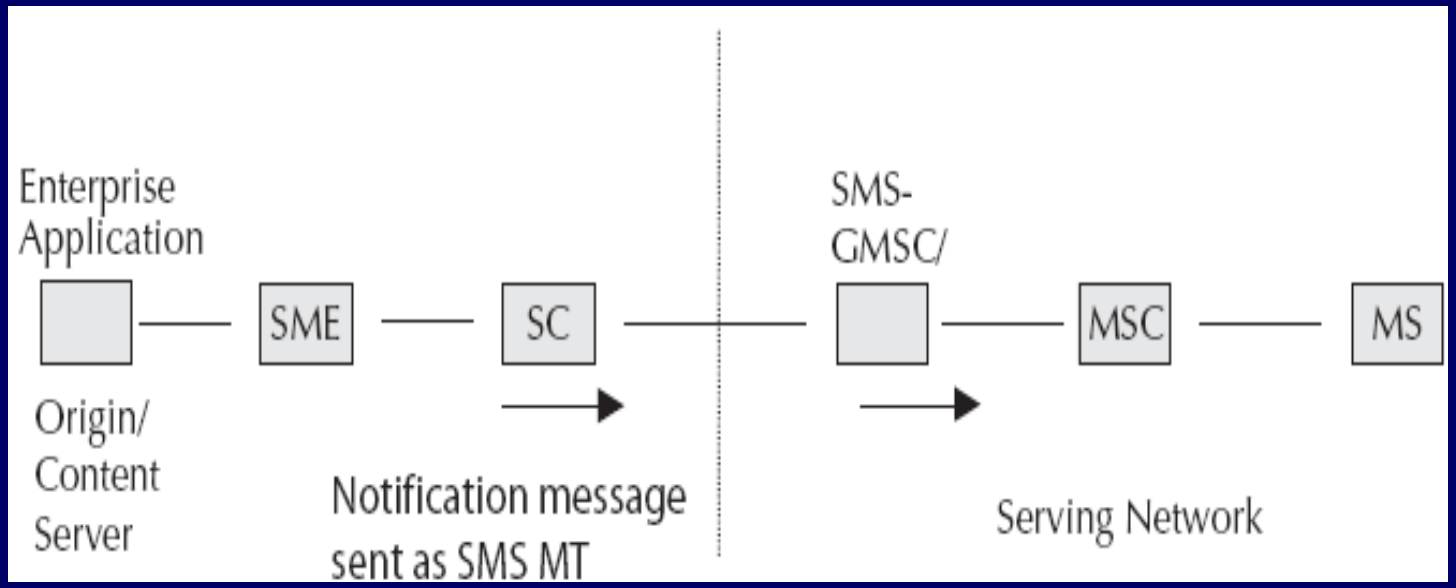
Operator Centric Pull

- Connectivity between SME and Origin server could be anything like SOAP (Simple Object Access Protocol), direct connection through TCP socket or through HTTP.
- There are applications where SMS is used in session oriented transactions as ‘SMS chat’ and ‘SMS contests’ need to remember the user context over multiple transactions.

Operator Independent Push

- Any push, which may be an alert, notification or even response from a pull message generated by an application, can be serviced by any network and delivered to any GSM phone in any network without any difficulty.
- If appropriate roaming tie-ups are in place, an enterprise can use SMS to send business alerts or proactive notifications to its customer anywhere, anytime on his phone.

Operator Independent Push



Value Added Services through SMS

- Value Added Services (VAS) can be defined as services, which share one or more of the following characteristics:

1. Supplementary service (not a part of basic service) but adds value to total service offering
2. Stimulates incremental demand for core services offering
3. Stands alone in terms of profitability and revenue generation potential
4. Can sometimes stand-alone operationally
5. Does not cannibalize basic service unless clearly favorable

Value Added Services through SMS

6. Can be an add-on to basic service, and as such, may be sold at a premium price
7. May provide operational and/or administrative synergy between or among other services and not merely for diversification

Value Added Services through SMS

- VAS over SMS are entertainment and information on demand which is further categorized into:

1. Static information which does not change frequently
2. Dynamic information which changes in days
3. Real-time information which changes continually

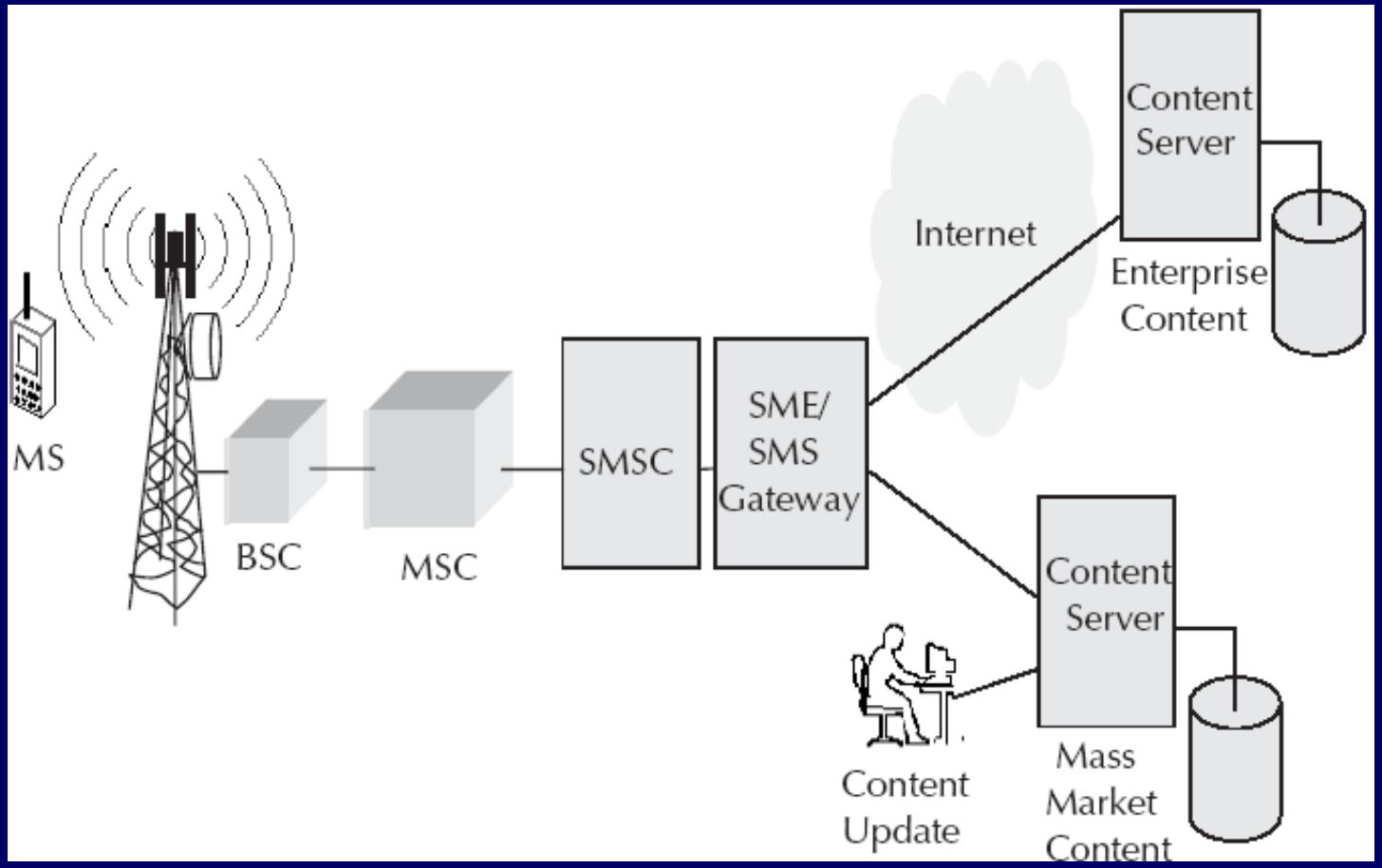
- Some of the common VAS examples are:

1. News/Stock Quotes Service
2. Session-based Chat Application
3. Email through SMS
4. Health Care Services
5. Micro-Payment Services

Alert services through VAS

- Proactive alert services can be of the two kinds – Time based and Watermark based
- Time based proactive alerts are sent to the mobile phone at a pre-assigned time of the day
- Watermark based proactive alerts are sent when some event occurs

VAS Architecture



Location based services through SMS

- Location based services could be road direction, restaurant guide, shopping alerts, etc.
- In location based services, only the information relevant to the current location of the mobile phone (or the subscriber) is provided.
- The location of a mobile phone can be determined either from the network or from the device.
- To find out the location from the device either of the following technologies are used - Cell ID (CID) based system and Global Positioning System (GPS) based system.