Analysis, Design and Comparative study on Location Updating Strategies in Mobile Computing

A Thesis submitted to Gujarat Technological University

for the Award of

Doctor of Philosophy

in

Computer Science

by

Kalpesh Ashokkumar Popat
Enrollment No. : 129990931002

under supervision of

Dr. Priyanka Sharma

GUJARAT TECHNOLOGICAL UNIVERSITY
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DECLARATION

I declare that the thesis entitled **Analysis, Design and Comparative study on Location Updating Strategies in Mobile Computing** submitted by me for the degree of Doctor of Philosophy is the record of research work carried out by me during the period from March 2012 to December 2016 under the supervision of Dr. Priyanka Sharma and this has not formed the basis for the award of any degree, diploma, associateship, fellowship, titles in this or any other University or other institution of higher learning.

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Abstract

In today's fast decision making life it is compulsory for all of us to be in touch with the regular updates in terms of everything like education, technology, office routine, banking, regular transactions of business etc. For this purpose it is also mandatory to be active throughout the day. Now a day each and every one of us need data on our fingertips all the time. Moreover, it is also impossible that a person can sit in front of his/her computer / laptop throughout the day. As he / she has to roam outside the office also for routine work.

In the above situation, now a day's people use to have mobile computing devices which serves as a hand held computing device even when the person is moving from one place to another place. To get updated with the Calls / SMS / Mobile data - the device requires to update its location. Regular updates of location costs bandwidth and battery consumption. Managing location information of mobile devices is a very much important task in mobile computing systems. In cellular network, coverage area is divided into cells. Everyday mobile companies try to accommodate more users by reducing size of cells. Location management is currently one of the most important and fundamental issues in mobile computing. When the user changes location, an update occurs. The main goal of any location management strategy is to provide efficient search-updates.

Location Update Management (LUM) is one of the most important activities in cellular network. LUM should be less costly at the same time highly efficient. In this research work, we have analyzed Time Based Location Update Strategy using Qualnet simulator. At present, Location Update is performed for every node at fixed interval. This interval is fixed and remains same for all the situations. For example, if Location Update is performed every minute instead of every two minutes, the total number of location updates will be doubled. In reality, a location update task consumes resources. If we decrease the interval and set it to a small value then a large number of location update will waste network resources. If we increase the interval and set it to a large value then there is a possibility that location updates are postponed. A perfect value of interval is very difficult to found. At present, fixed values are used for various timers and various thresholds. In this research work, we will try to find most appropriate value of interval dynamically considering various parameters like number of location updates succeed, number of location updates failed, number of location updates actually required etc.

The whole thesis is divided into 6 chapters. Chapter - 1 gives full idea about introductory part and gives detail about questions like what is Mobile and Mobile Computing, History of Mobile Computing, Categories of Mobile Computing, Attributes of Mobile Computing, Dimensions of Mobile Computing and Conditions of mobile users. Chapter -2 is Literature survey which gives detail GSM infrastructure, , Various factors affecting Location Update, Various Location Update Procedures in detail. Chapter - 3 gives detail about various routing protocols and specially Location aware routing protocols. In chapter - 4 various scenarios have been created to perform the simulation task. Chapter - 5 has proposed algorithm and results with observations which has been tested on scenarios given in Chapter - 4. Chapter - 6 gives conclusion, future work for the research and publication details.

Acknowledgement

Research is combination of two words "Re" and "Search". Here, "Re" means "Again" and "Search" means "To Explore". If we combine these two words, it means "To carry out the exploration in intensive way in order to get the desired result"

By keeping this in mind, I carried out research work on "Analysis, design and comparative study on location updating strategies in mobile computing"

One has to accept that it is the almighty who is guiding us every moment in one way or the other. This research work has become possible only because of the blessings and stimulation of the Supreme, the LORD. I bow to the feet of almighty and seek his further grace and guidance.

At the same time it is also true that there are divine souls who uplift your spirit and enrich yourself to fulfill the goal. To make this research fruitful and prosperous, I have also got the help of these divine souls and at this occasion I want to show my respect for their humble and selfless efforts in this Research.

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A quality time is must to carry out research. When a research is conducted along with ongoing responsibility as Professor, it becomes a bit tough to manage the things well. However it becomes easy when an organization, in which you are employed help you in carry out the work and support you for the same. With the blessings of God, I belong to such an institute which admire the research work and value the same in great way. To be a part of Marwadi Education Foundation's Group of Institution (MEFGI) is always a dream come true. I offer my gratitude to the institution and to the following persons to help me in spending quality time to conduct my research work.

(1) Shri Ketanbhai Marwadi - Chairman, MEFGI,
(2) Shri Jitubhai Chandarana - Vice Chairman, MEFGI,
(3) Dr. R. Sridaran - Dean, Faculty of Computer Application, MEFGI,
(4) Dr. Sunil Bajeja - HOD, Faculty of Computer Application, MEFGI
(5) Dr. Divyakant Meva - Coordinator, Faculty of Computer Applications, MEFGI.

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As it is a prolonged journey, maybe I have forgotten few names to consider but nonetheless they remain core part of this mammoth task and I seek forgiveness for the same and offer my kind respect to each and every one of them.

Thanking you.

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List of abbreviations

Abbreviation	Full form
AC	Alternate Current
ACM	Association for Computing Machinery
AODV	Adhoc On Demand Distance Vector
API	Application program interface
AuC	Authentication Centre
BCCH	Broadcast Control Channel
BSC	Base Station Controller
BSS	Base Station Sub System
BTS	Base Transceiver Station
CDMA	Code Division Multiple Access
CID	Cell ID
DECT	Digital European Cordless Telephone
DSDV	Destination Sequenced Distance Vector
DSR	Dynamic Source Routing
EIR	Equipment Identity Register
FR	Failure Ratio
GEDIR	Geographic Distance Routing
GMSC	Gateway Mobile Switching Centre
GPRS	General Packet Radio Service
GPS	Global Positioning System
GPSR	Greedy Perimeter Stateless Routing
GRA	Geographical Routing Algorithm
GSM	Global System for Mobile
HDD	Hard Disk Drive
HiperLAN	High Performance Radio Local Area Network
HLR	Home Location Register
IEEE	Institute of Electrical and Electronics Engineers
ILD	Intermediate Location Database
IMEI	International Mobile Equipment Identity
IMSI	International Mobile Subscribers Identity
IoT	Internet of Things
IP	Internet Protocol
ISDN	Integrated services digital network
KG	KiloGram
LA	Location Area
LAC	Location Area Code
LAI	Location Area Identity
LAN	Local Area Network
LAR	Location Aided Routing
LCD	Liquid Crystal Display
LSTP	Local Signaling Transfer Point
LUA	Location Update Attempts

Abbreviation	Full form
LUF	Location Update Failed
MCC	Mobile Country Code
ME	Mobile Equipment
MHZ	Megahertz
MNC	Mobile Network Code
MS	Mobile Station
MSC	Mobile Switching Centre
MT	Mobile Terminal
NLA	Network Location Awareness
NSS	Network and Switching Sub System
OLSR	Optimized Link State Routing
OMC	Operations and Maintenance Center
OOP	Object Oriented Programming
PA	Paging Area
PC	Personal Computer
PDA	Personal Digital Assistant
PSP	Play Station Portable
PSTN	Public Switched Telephone Network
QC	Quality Control
QoS	Quality of Service
QRY	Query
RA	Registration Area
SIM	Subscriber Identity Module
SMS	Short Message Service
SNT	Scalable Network Technologies
SSD	Solid State Drives
TMSI	Temporary Mobile Subscriber Identity
TORA	Temporally Ordered Routing Algorithm
TRX	Transreceiver
TV	Television
UML	Unified Modelling Language
UMTS	Universal Mobile Telecommunications System
UPD	Update
VHE	Virtual Home Environment
VLR	Visitor Location Register
WRP	Wireless Routing Protocol

Table of Contents

CHAPTER – 1

Introduction

1.1 Introduction to Mobile

The term mobile refers to anything which is in moving condition or in other words anything which is capable of moving from one place to another. Another term which is very much closely connected with mobile is mobile device. In very simple terminology it gives us an idea that we can think of variety of devices that are capable enough to allow people to access their information and data from the place where they are currently located.

1.2 Introduction to Computing

The term Computing refers to any kind of computational work which is to be carried out with the help of machine. it is generally goal-oriented activity which will be carried out with some intention to compute something. For example, the term computing includes development or building of hardware and software systems; It also includes management of various kinds of information, making properly structuring of the collected information, and to make process on collected information to get some fruitful results. The term also includes performing scientific research on and with computers, to make computer systems ready to behave intelligently, creation and usage of communication and entertainment media and so on[1]. Various fields that are connected with the field of computing includes computer engineering, software engineering, computer science, information systems, and information technology.

1.3 Introduction to Mobile Computing

The term mobile computing [4] refers to human-computer interaction in which the computer is expected to give work while in transit also. The term involves mobile communications, mobile hardware and mobile software. Mobile communication includes infrastructure, ad-hoc networks, communication properties, protocols, data transfer, data formats etc. Mobile hardware includes mobile devices and the components which connects the mobile devices. Mobile software includes various applications which runs on the hardware. It also includes Operating system, Kernel and end user applications.

Mobile computing systems are the computing systems which can be easily moved physically and whose computing capabilities can also be used while transit. Laptops, PDAs (Personal Digital Assistant), Cellular phones are the best examples of such devices. The main difference between mobile computing systems and various other computing systems is the design, the working, resources used, applications used and the operations performed on these devices.

A mobile computing device is termed as computer not constrained in its location to a specific place. In last 10-15 years the availability of various mobile computing devices increased a lot. With the help of these devices, in real terms we can think to access our digital content anywhere - anytime.

The term "Mobile computing" [2][3]is widely used because in today's world generally people require to interact with central information system even when they are away from the work place. This technology allows the mobile user to (a) create; (b) access; (c) process; (d) store; and (e) communicate information without any hurdles and from anywhere without the constrain of location. By means of mobile computing the organizational personnel can be connected to organization's fixed information system for any kind of interaction. The concept of mobile computing can be further revised through: (a) examination of the technologies that make mobile computing possible; (b) an analysis of the many benefits of mobile computing; and (c) the presentation of the MOBILE framework, that provides guidance on when mobile computing is best applied to a problem, opportunity, or directive. Fig. 1.1 describes structure of mobile computing devices where fixed connected devices and wireless connected devices are connected with data communication. Fig. 1.2 explains typical mobile computing architecture in which data is available and Application servers will access that data, Computers, laptops, mobiles etc. will access the same data through web servers and internet. There is firewall placed in between web servers and internet which is useful to protect the data.

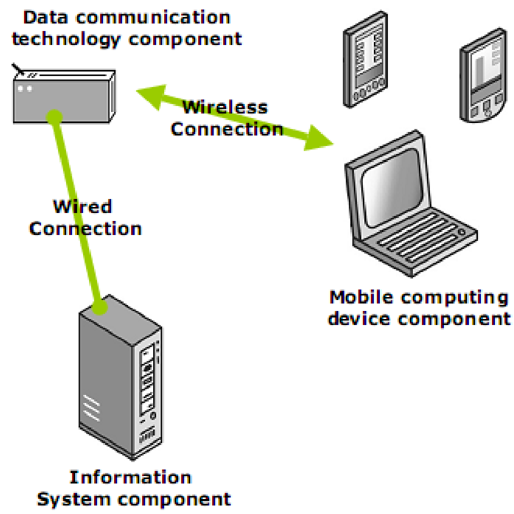

Figure 1.1 : Structure of Mobile Computing Devices [4]

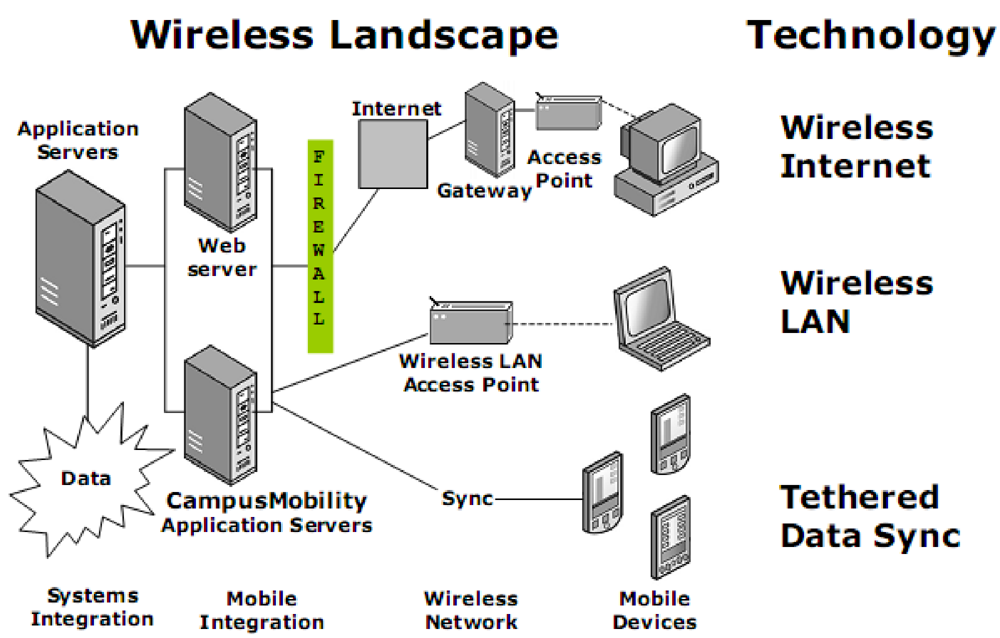

Figure 1.2 : Typical Mobile Computing Architecture [4]

1.4 Definitions

According to the definition given in Wikipedia *"Mobile computing is taking a computer and all necessary files and software out into the field."[5]*

According to the definition given by Uwe Vieille, ACM Organisation *"Mobile computing is the ability to use computing capability without a pre-defined location and/or connection to a network to publish and/or subscribe to information." [6]*

According to the definition given by James Bucki, *" Mobile computing is a generic term used to refer to a variety of devices that allow people to access data and information from where ever they are. Sometimes referred to as "human-computer interaction," mobile computing transports data, voice and video over a network via a mobile device." [7]*

According to the definition given by Paul Cartmell, *"A mobile computing device is described as small, lightweight, portable and containing wireless Internet access by the Public Library Association." [8]*

1.5 History of Mobile Computing

If we go to the history of the mobile computing, it was started in the century when people were used to use light beams for communications. Heliographs (Sun on mirrors), different types of flags etc. have been used in the ancient age for transmitting the messages.

Figure 1.3 : Use of flags and Sun - Mirror for communication

In the above Fig. 1.3, it shows how people were using mirror, sun and flags for their communications in the past age.

Table 1.1 : History of Mobile Computing

Year	Detail
150 B.C.	Smoke signals were used by Polybius, Greece for communication purpose.
1794 A.D.	Optical Telegraph were used by Claude Chappe.
1831 A.D.	Electromagnetic waves were demonstrated by Michael Faraday and Joseph Henry. This waves also makes a significant mark in the history of mobile computing.
1864 A.D.	James Maxwell has given theory of electromagnetic fields.
1886 A.D.	Heinrich Hertz demonstrated the wave character of electrical transmission through space.

1895 A.D.	Guglielmo Marconi has demonstrated wireless telegraphy with digital signals. He has been awarded with noble price in 1909.
1901 A.D.	First transatlantic Connection was developed.
1906 A.D.	First radio broadcast has been done. In the same year Vacuum tubes were invented.
1907 A.D.	Commercial transatlantic connections were came in to the market.
1911 A.D.	First mobile sender on the board of Zeppelin.
1915 A.D.	Wireless voice transmission has been established.
1920 A.D.	First commercial radio station has been established in U.S. In the same year Marconi has discovered short waves with the help of reflection at the ionosphere which he has make possible with the help of vacuum tubes.
1926 A.D.	First car radio service has been designed
1928 A.D.	First TV broadcast started.
1933 A.D.	Edwin H. Armstrong has demonstrated Frequency modulation.
1958 A.D.	German A-Netz has demonstrated Analogue System with 160 MHz, from mobile station with no handover.
1972 A.D.	German B-Netz has demonstrated connection setup from the fixed network with mobile station with the condition that location of the mobile station has to be known.
1979 A.D.	Nordic Mobile Telephone System has been developed.
1982 A.D.	GSM specifications has been developed.
1984 A.D.	Standards are decided for cordless telephones
1986 A.D.	German C-Netz has demonstrated analog voice transmission with 450 MHz and also with hand-over facility. Automatic location of mobile devices were also possible to manage.
1991 A.D.	DECT (Digital European Cordless Telephone) was developed. This was used in more than 40 countries.
1992 A.D.	Start of GSM with 900 MHz and facilities of cellular roaming was also developed.
1994 A.D.	Start of GSM with 1800 MHz with facility of SMS.
1996 A.D.	HiperLAN (High Performance Radio Local Area Network)
1998 A.D.	Wireless LAN with IEEE 802.11. Also start of service for GPRS.

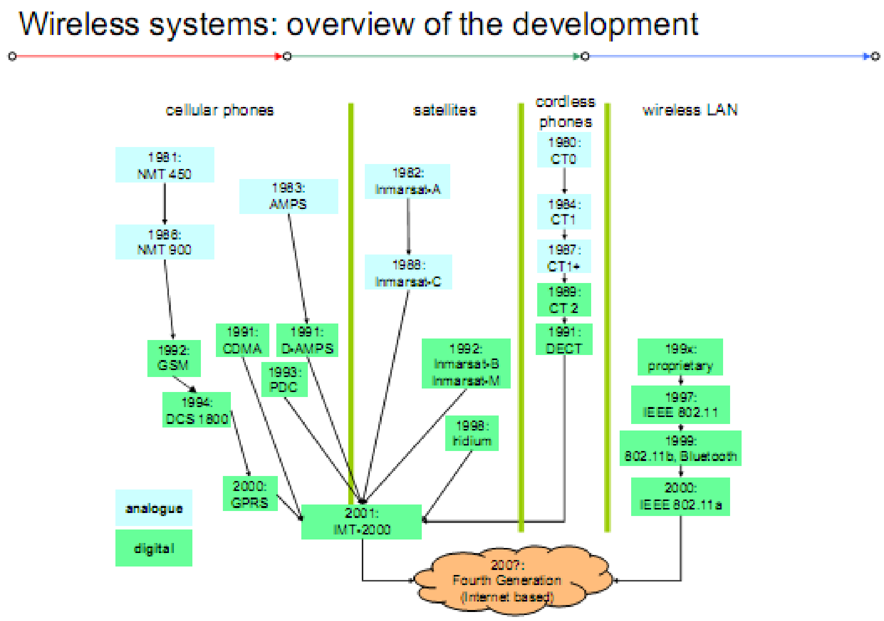

Figure 1.4 : Overview of Wireless Systems

In Fig. 1.4 it displays overview of Wireless Systems and history of mobile computing year wise. In Fig. 1.5 it displays the timeline of evolution of mobile computing. It can be really said from the above figure that the starting of the mobile computing was done with the invention of first computing device i.e. Abacus. Abacus was invented and used back in 500 B.C., people used to have other aspects of computing also i.e. storage of information, sharing of information etc. Abacus was the first device which becomes helping hand for the people wants to perform operations like mentioned above. People think of computing devices for storage of their writings in that early days. The first mobile storage systems was introduced as the innovation of electronics in 1800's.

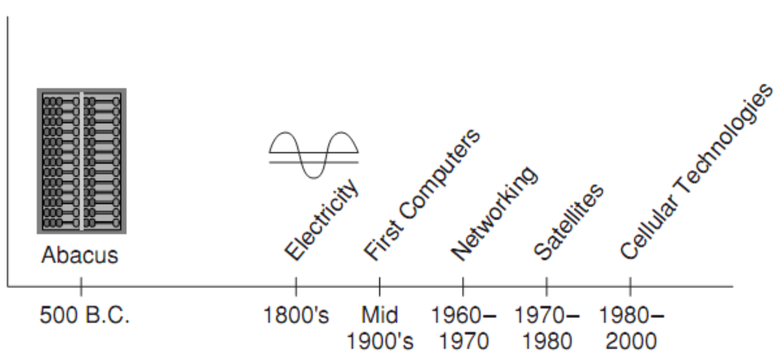

Figure 1.5 : Timeline of Mobile Computing

As we seen earlier that now a day's people wants to be connected with the office even when they are in transit. A mobile computing system itself provides this kind of computing power to the people and it allows them to connect with the network. In the terms of networking when two or more computers needs to transfer information among them at that time some connection medium is needed to pass the signals between them. In general, some wired medium used to connect these computers which wants to transfer information among them. But in case of mobile computing devices this kind of wiring is not possible. In other words in mobile computing we need some wireless communication medium to transfer messages between the computing devices. In this scenario the wireless communication systems are required as shown below.

Figure 1.6 : Wireless Communication System

The commercialization of communication satellites was almost done late by the 1970s. With the help of all new communication satellites the QoS and reliability was improved a lot. But the major problem was the expense on building and launching of satellites. At the same time the maintenance of the satellites was also expensive. Due to all above reasons the bandwidth which was provided by the satellites was very limited. In next 20 years the technological growth was very impressive and the improvement in terms of service was tremendous with financially feasible also.

From 1990 onwards the world of mobile devices was become very powerful and the devices which are developed by various companies of that time have taken over the wireless communication / computing industry. The term mobile computing becomes very powerful and need-of-hour technology which is not physically connected to any kind of static network. Initially the term was used for radio transmitters which were used to operate on a stable base with the help of large antennas. Initially this technology was given to police officers for two way communication in case of emergency situations which in turn converted to a wireless device which can be connected to any network for transmitting data and voice facility almost from anywhere. So many wireless communication devices were introduce to perform above mentioned task i.e. Laptops, PDAs, cellular phones etc.

During 1990s most of the laptops and PDAs carried wireless cards or Bluetooth interface which helps the device to connect with the outside world. In the same era various other tools for communication were introduced i.e. Global Positioning System (GPS) and cellular phones were also introduced. Lots of software development was going on for PDAs because various companies were trying very hard to make this wireless technology available affordably to the general public. During these years even the development of software for PDA and smart phones was more compare to desktop computer software.

In the same era of 1990s another mobile computing device which becomes very popular was Pocket PCs. The major advantage of using Pocket PC is user can access internet on the fly. The pioneers in making pocket PCs was Palm Pilot. Many other companies like Dell, HP and Toshiba were also come to the same market. The major benefit of using it was having Windows interface which makes the usage of the same very easy. People can surf the internet with the help of Internet Explorer, can download useful software, games, eBooks etc. In this way the mobile computing has taken a large step from two-way radios with large antennas to a simple 3 inch personal computing device which can do all the work that a regular computer do.

Newton Message Pad was launched by Apple Corporation in 1993. This is the device which was clearly ahead then all the devices available in the market at that time. Even though the Newton Message Pad was not able to became popular but it has definitely started the market towards the beginning of mobile computing era. By 2009, around 17 million mobile computing devices were sold worldwide annually. By the end of 2010 the mobile computing devices becomes necessity from luxury. Clearly, mobile devices are increasingly very common.

1.6 Categories of Mobile Computing

Mobile computing devices can be broadly divided into various categories as (1) Laptops, (2) Ultrabooks, (3) Netbooks (4) Tablets, (5) E-book readers, (6) Smartphones (7) Media players or Game players.

1.6.1 Laptops

The term "Mobile Computer" is now-a-days only used to refer to very small hand held devices or pocatable devices. In general public's mind a fix picture will come when they think of laptop (or notebook) computer, it is a computer which is not fixed on the desk. Think from technology point of view, laptops are basically a desktop computer reconfigured and packed in a compact way for use its mobility. Laptops are computers with almost same hardware and software configurations means that in laptops we have motherboard, HDD and other hardware devices which are mostly available in most of the desktops and also able to run on operating system like windows and applications like Microsoft Office.

At the starting point of laptops, people use to think that laptops cannot give performance like desktop PCs. But now a day's people directly think of replacement of desktop PC in terms of performance. Laptops have more flexibility that it contains screen, keyboard and mouse (touchpad) in itself. Laptops are capable of connecting with wifi very easily and in today's world wifi hotspots are easily available as a sharing internet. Laptops are easy to carry from one place to another and people can do work during travelling also.

Laptops come in various range of sizes. At highest level laptops come with very large displays (19+ inches) and at the other end devices with less than 12 inches in size. This creates a new category of laptops called net books.

1.6.2 Ultra books

Ultra books are new in the era of laptops. In its starting age laptop models are larger and heavier. Ultra books specification are given by Intel and the laptop which is comply with the standards given by Intel are known as Ultra books. major specification includes the size less than 21mm thickness, provides battery life of at least 5 hours, provides anti-theft technology, faster booting from sleep to resume mode etc. Most of the

Ultra books uses SSD (Solid State Drives) instead of traditional Hard Drives. Weight of the Ultra books is normally not more than one KG.

1.6.3 Net Books

Net books (also known as ultra mobiles) are small, low-powered laptops with less than 12 inch screen size. The first net book was developed by Psion in the year 2000. Wide range of Net books were introduced by ASUS in 2007 and after that only the market of net books became more popular in the market. Initially ASUS has introduced net books with the intention of usage by children but then after it becomes more popular among the persons who wants light weight laptops.

1.6.4 Tablets

Tablets were introduced in early nineties but not got that much success in the market. The main reason behind its failure was expectations from the general people regarding its computation power. In November 2002, Microsoft launched a Tablet PC with windows XP operating System. At the same time Toshiba and Compaq also came into the market. The major change in this market was happen when Apple has launched its most awaited project of iPad in January 2010.

In special terms a tablet is a laptop / ultra book / net book without a keyboard and which can be operated with the help of touch screen. When Microsoft introduce its first tablet it was having capacity of single-touch and it was operated with stylus. On the other hand device like iPad are slimmer, lighter with multi-touch facility which gives user interface like zooming of photographs with multiple fingers. Initially tablets were made to run inbuilt applications only while in today's world tablets are able to connect with internet and can run / download applications from the internet.

1.6.5 EBook Readers

E-Book readers or in other words e-readers were came into market from 2008-09. Main usage of e-book readers are to store and read books, newspapers and magazines. The major difference between tablets and e-readers is in tablets mostly LCD screens are there while in e-readers e-ink display is there. It gives feeling of physical news paper / book. The another major advantage of e-book readers is with a single battery charge it can be used for many days because it supports the technology in which the change frequency of pages will be very less. On the other hand there some drawbacks also i.e. screen refresh rate is very low, e-readers screens are available in black and white only etc.

Various types of e-book readers are available in the market. The most famous among them is Kindle from Amazon. In some of the kindles there is a facility like playing MP3 files, reading a book in audio mode etc.

1.6.6 Media Players and Mobile Game Consoles

Now-a-days it is very difficult categorize every type of mobile computing devices available in the market. In this type of category we can include music and video players that can be carried in the pocket. We can also include mobile games in this category. In some of these devices we also have internet connection facility. Media players includes various models like Apple iPod and devices from creative or Sony also. Now-a-days the most popular game consoles are Play Station Portable or "PSP".

1.6.7 Smartphone

In today's world almost everybody uses Smartphone. Now-a-days Smartphone became hand held computing devices. After invention of android operating systems all Smartphone are capable enough to do all computing tasks. After invention of Smartphone people does not require to carry Pocket PC for their digital work. It provides internet access on the go, it provides facility to make text messages, camera, voice call, movie on demand and so on. Smartphone are made by various companies like Samsung, Apple, Nokia etc. Most of the Smartphone today runs on android operating system. Apple phones runs on i-os operating system.

1.7 Various Attributes of Mobile Computing

The term mobile computing refers to different context used by different people at the time of working with mobile computing paradigm. Following are various context used with mobile computing.

1. Mobile Computing : In this term - the computing environment is mobile and it moves along with the user. It is just like sim card number of GSM mobile phone - when you enter card in any mobile the number transfers.

2. No time and Location barrier : In this generic definition which states that information is available anywhere and all the time as and when needed.
3. Virtual Home Environment : Virtual Home Environment (VHE) is defined as environment where user can operate home devices from remote places This feature is also known as IoT (Internet of Things). For example if a person would like to start Air conditioner of his / her room 15 minutes before reaching to home.
4. Nomadic Computing : The term nomadic computing means the network of mobile computing will moves along with the user of the device.
5. Pervasive Computing : Here the environment is pervasive in nature and it can be available in any environment.
6. Ubiquitous Computing : The term ubiquitous computing means the network used in mobile computing is not seen by anybody in the real world.
7. Global Service Portability : Service of mobile computing can be available globally.
8. Wearable Computers : Wearable computers means the computers which can wear by the user like clothes, hat or any other accessories. [9]

1.8 Applications of Mobile Computing

List of various application areas of mobile computing can be summarized with the following list.

- Vehicles
- Nomadic user
- Smart mobile phone
- Invisible computing
- Wearable computing
- Intelligent house or office
- Meeting room/conference
- Taxi/Police/Fire squad fleet
- Service worker
- Lonely wolf
- Disaster relief and Disaster alarm
- Games
- Military / Security

(1) Vehicles : The application of mobile computing in vehicles can be described with the help of Fig. 1.7 :

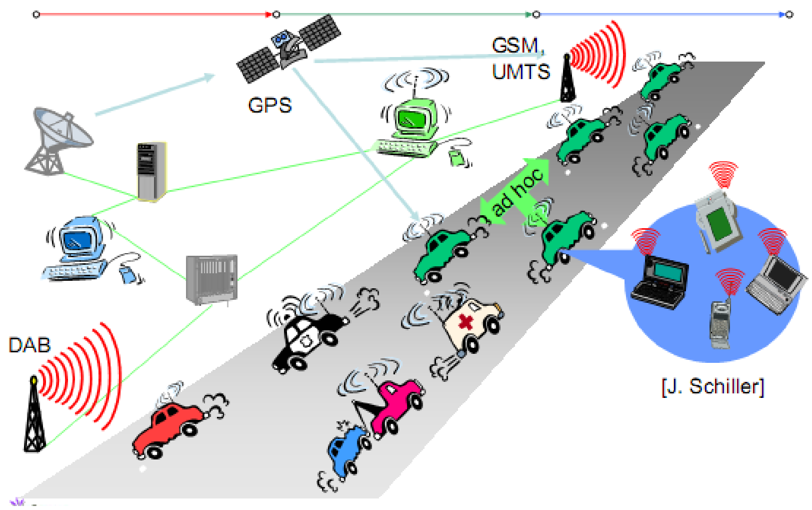

Figure 1.7 : Vehicle Tracking with Mobile Computing

(2) Nomadic user : Nomadic user means the user who uses either laptop / palmtop for his / her computing task. But obvious the application of mobile computing will come into picture because laptop / palmtop is mobile by nature.

(3) Smart mobile phone : With today's smart phones user can do various tasks while on the move. These tasks includes voice calls, video calls, email / instant messaging, play hi-fi games, use of maps, get information regarding weather, sports, stocks etc., online ticket booking, trade of stocks and many more....

(4) Invisible computing and Wearable computing : This includes devices like spy camera / spy recording devices or any other wearable computing devices like user can wear them in their shoes, spectacles etc. [9]

(5) Intelligent house or office : Today's smart mobile computing devices replace cables with Bluetooth devices. With the help of these devices user can convert house to intelligent house. E.g. user can switch on / off any of the electronic device from outside by using application from his mobile device.

(6) Meeting room / Conference : In meeting room or in conference application of mobile computing can be used in various tasks which includes sharing of data among all members instantly, secrete voting on some topic, finding of person with similar interests, broadcasting of last minute changes etc.

(7) Taxi / Police / Fire squad : Mobile computing can be used for connecting all the vehicles with some media, police can have better control with traffic, traffic police can check who has broken the signal, immediate fire service can also be given to victims etc.

(8) Lonely wolf : Mobile computing is useful to a person who is lonely, It helps him to play games, listen music, watch videos etc.

(9) Disaster relief : Disaster relief can be given immediately with the help of mobile computing equipments. Services can be given immediately at the time of earthquake, tsunami, volcano etc., patients can be easily and early transmitted to the

hospitals, with the help of satellites one can search for a person inside the damaged building at earthquake place.

(10) Disaster Alarm : With the help of satellite system govt. can manage alarm system at the time of disaster.

(11) Games : One can play hi-fi games on play stations, mobiles, other game devices by connecting with others with the help of mobile communication.

Various mobile devices can be summarized in Fig. 1.8 according to their performance, features and size.

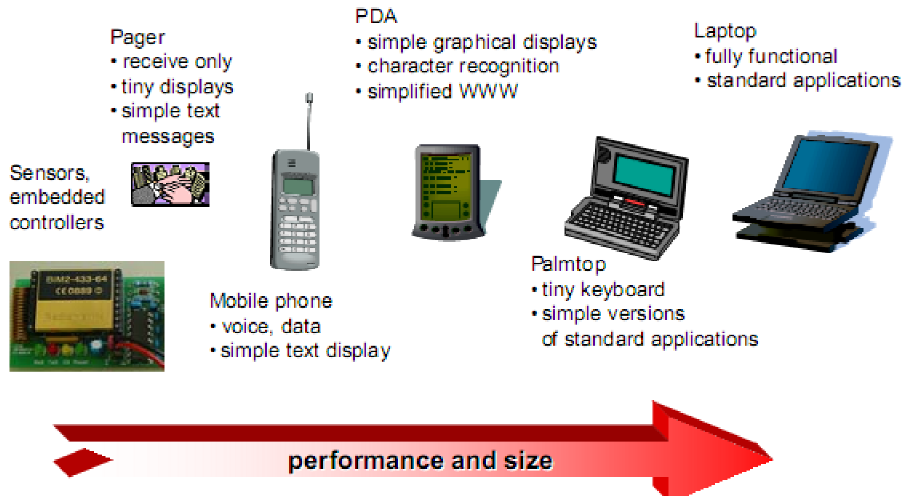

Figure 1.8 : Mobile Devices - performance and size

1.9 Dimensions of Mobile Computing

Sometimes mobile computing devices may also behave like stationary devices. If the device stop its moving condition it becomes stationary. In other words, mobile computing systems are superset of stationary computing systems. The dimensions of mobility will be divided into various parts which allows us to make our problem such that it will be qualified for developing mobile software applications as well as mobile computing systems. Remember that all these dimensions given here are not interconnected with each other and not connected with each other also. While using these dimensions we have to keep in mind their relationship with each other in form of orthogonal as well as in form of mobility. We should also keep in mind limitations with respect to usage. Various dimensions for mobility are given in Fig. 1.9.

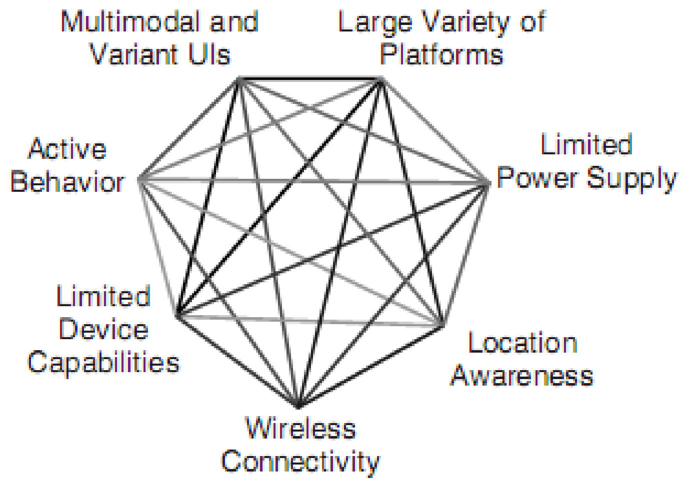

Figure 1.9 : Dimensions of Mobile Computing

From the above Fig. 1.9 we can derive seven different dimensions of mobile computing environment. They are given below list :

1. Location Awareness
2. Wireless Network Connectivity
3. Limited Capabilities of Devices
4. Limited Power Supply
5. Large range of User Interfaces
6. Large variety of Platforms
7. Active behavior

1.9.1 Location Awareness

Location awareness means that device is passively or actively involved in location management process. For vassals and vehicles, navigational instruments provides location coordinates. Network Location Awareness (NLA) describes the location of a node in a network.

The term location awareness applied to real-time position support with respect to global or local scope. It is supported by navigation systems, positioning systems or location services. If location awareness is maintain without the active participation of the device at that time it is known as non-cooperative locating.

When we think of a mobile device, as its name suggest it is normally not stationary means that it is not working from the single place, its location is always changing. This creates a great difficulty for the designers of the device, operating system or application developers. On the other hand it also gives us an opportunity of using the location to enhance the applications. There are so many methods available for collecting the user's as well as device's location and use it at various places.

Sometimes, we can create an application which will ask the user about his / her location, but it creates a problem that the user-friendliness of the application will be gone. Think of a system or application which gives you route for particular destination but only when you tell the system about your present position. Now, sometimes or almost every time it is very much difficult for the user to give exact information about its present position, at that time the application becomes useless.

In today's world the most well known location information system is GPS. With the help of latitude and longitude GPS can give accuracy of 1 to 5 meters. GPS system was initially used only with military and general public was not allowed to use GPS system because of security reasons. But now-a-days military has removed most of the restrictions on usage of GPS. GPS devices uses a special technique called triangulation for converting the entire earth surface into triangle points. If we think about the devices having no GPS connectivity but having Cellular network connectivity at that time with the help of MCC (Mobile Country Code), MNC (Mobile Network Code - it is a unique 2 - digit number which will identify a mobile network), LAC (Location Area Code - Location Areas are always comprised of one or more radio cells. Each Location Area has been given an unique number within network which is known as Location Area Code. This code is useful as an unique reference for the location of mobile subscribers) and CellId (CID) techniques [10] or with the help of any other technique the location information is possible to gather.

We are least concern with how we are able to get the location information. For us it is most important that we are able to distinguish stationary systems and mobile systems. Think of a mobile application which is useful to keep route tracking who is moving from home to working place and working place to home on daily basis. If the application is capable enough to trace the route then it is useful to tell the user about which route is fastest / shortest for the daily routine or sometime it is the requirement of the user to find the route which may not be shortest but without traffic so that fuel consumption can be minimized. Here also if the user needs to enter route manually at that time the application becomes useless. If we think of a person who is a field service worker and he / she has to choose next destination after completing his / her current task. Based on his / her present location if the system is able to give him / her route for the next destination, then it will be very much beneficial for the person who is using it. All these application should be stand-alone. Stand-alone means it should depend on any one mechanism for location i.e. either on GPS or on Cellular network or something else but should not depend on all the things at a time.

1.9.2 Wireless Network Connectivity

In mobile computing we are using wireless communication with mobility. Whenever we use the term mobility it definitely affects the reliability of the service. When the moving object changes its location from one place to another place it always creates physical barriers and with that it has to disconnect for some time from one network to another network or from one area to another area. In Wireless Connectivity, some physical conditions affect the Quality of Service. This physical condition is mostly whether which affects wireless connection quality.

Whether or other climate related changes always affects the Quality of Service for wireless devices. The QC department of wireless devices will always checks the quality of the product for its reliability in different weather conditions. Network signal strength is the most important factor in deciding the quality of wireless devices in terms of reliability. Network operators try to control the physical layer on the network system which is useful to provide various other facilities. Some of the facilities are Internet Protocol (IP), which is useful for software application connectivity.

Mostly when network operators thinks about QoS, various parameters are always taken into consideration which are : (1) bandwidth, (2) connectivity strength (3) data packet loss etc. When it comes to QoS, the device hardware must be capable enough to handle some unavoidable circumstances also through its basic applications. For example, If the user is in moving condition and he gets a call from another mobile user. Now, both are talking to each other but sometimes it happened that the user makes Handoff and he losses the signal at that time call disconnect exception should be generated and the mobile hardware or application should be capable enough to cut the call so that the device will function smoothly. Second and the most important quality measurement is of bandwidth. The device should capable enough either through hardware or through software to handle and provide maximum bandwidth available to the user programs.

1.9.3 Limited Capabilities of Devices

If we think of first computer of the world, it occupies around 2 rooms of space. If we tell a person to handle that computer while moving, the person gone mad. Today we need all computing power through mobile devices which are small in size. On the other hand when we make size of the device small, it affects a lot to its storage, its CPU capabilities, its memory and so on. Other most important factor is the mobile devices are not capable enough that a desktop computer can do. The reason behind the same is again hardware resources provided in desktop computer v/s. hardware resources provided in mobile devices. Today's mobile applications are always resource-starved. Limited memory always creates a problem to the designers of the mobile applications because mobile application developers always try to give same facilities which are available in the desktop computer applications, but the major issue that mobile devices facing today is the limited memory. As mobile users needs devices in small size, the limitation of memory always affects the performance of the mobile devices.

The major benefit of smaller devices is they are easy to carry and consequently, they may become more and more pervasive. This affects a lot to the price of the device. When engineers think of making electronic devices small in size it generally increase the cost because the research behind making them small is much expensive. On the other hand it is also sure that once the technology becomes mature and the process of manufacturing these kind of devices becomes automated the prices will definitely comes down. The best example is, when smart phones came into market, the cost of the same was very high but now-a-days the same phone with better configuration we are getting with less price. So we can also say that there is no direct relationship between size and price. But we have to keep in mind the most important rule i.e. when we talk about mobile devices - small size is always better. On the other hand we also needs to keep in mind about the limitations of transistors in form of the capacity of storage and processing power of the same. At the same time the heat produced by the microchips specially in small devices will also affects a lot. The industry has improved a lot since its starting phase to till date but industry has still lot to travel in this area.

1.9.4 Limited Power Supply

From the above point discussion we have already seen that the mobile devices gives the benefit of small in size and have drawback of limited storage capacity. At the same time we have to keep in mind that the mobility of mobile devices also affects the network connectivity. Because of the same reason wireless connectivity is the primary method for network connectivity in mobile devices. When we think about power for the mobile devices the first and only choice is battery. For mobile devices batteries are the only and primary power source. There are so many researches going on to improve batteries every day and it is tough environments where suitable AC power is not available. Yet, often the user is constantly moving and devices are consuming more and more power with processors that have more and more transistors packed into them.

The desirability of using batteries instead of an AC power source combined with the size constraints creates yet another constraint, namely a limited power supply. This constraint must be balanced with the processing power, storage, and size constraints; the battery is typically the largest single source of weight in the mobile device. At the same time we have to remember that the battery or the power supply has a direct or an indirect effect on everything that we are doing with the help of a mobile device. Consider the example that if the user keeps the display of the mobile device with more brightness, it consume more battery power. So, in other words we can say that user experience for the interface is always connected with battery or power supply it uses.

Generally the functionality for making power management most efficient is always given through the operating system of the devices. So, it becomes the responsibility of the developer of the operating system to make power management of the device such that it gives a balanced power usage in the mobile device. When the device is stationary, it may get power from outside world i.e. by making the device in charging condition. In that case the device will get enough power to run it as well as to store it in battery. But when the device is in moving condition at that time, the battery has to take care for everything i.e. display of the device, network of device, running of all application and so on. So, it is the prime responsibility of the operating system of mobile devices to take care about not a single bit of power should not be wastage. Operating system must give some alert to the user about the battery power available in the device or up to how much time the device will function properly without getting power from outside world. Even operating system should stop some application which are consuming more power compare to other applications by informing the user about the abrupt consumption of the power. Ultimately we can say that the major limitation of any mobile device lies with the battery it contains to get the power. Today, almost all mobile companies are working on giving battery with more and more capacity so that users of devices should not face the problem of power when they are in moving condition and they can perform their task without facing problem of mobile power.

1.9.5 Large range of User Interfaces

When user working on PC, it is known as stationary user. While working with PC or a similar devices the users uses standard PC equipments like Keyboard and mouse for input, and Monitor for output. People used to do work with this kind of stationary devices are always happy with the performance and usefulness of such devices. But when we think of a mobile device, we can't think of standard input and standard output devices like keyboard, mouse and monitor in case of Desktop PC. In mobile devices we can use voice input, smaller touch screen displays which also works as input device, small keyboard available through mobile screen, use of stylus for giving inputs and so on.

For example, think of an application which gives direction to the users while driving a vehicle. Here the user has to enter the destination either by entering the particular address through keyboard or the user can select the destination from the map given by the application. After setting the destination through any of the method described above, the user may get the response from the application either in form graphical map which displays the desired route required by the user or by voice driven data which guides the user throughout the way to take turn left - turn right - go straight etc. Here navigating through the map provided by the application is not that much easy and efficient as compared to navigation provided by the voice system. The main reason behind this situation is entering data on small devices like mobile will be much difficult when the user driving a vehicle but instead of that if speech based application is given at that time it will be much more convenient for the user.

Various user interfaces are very much difficult to design and implement because of the following reasons :

1. Application Designers require to understand all the needs of user's all requirements.
2. All the requirements and also the platforms are different.
3. Developers of the applications must think of giving suitable weightage to various factors like design aspect, standard graphic design, writing technical documents, internationalization, performance of the system, levels of details, various social factors and implementation time while creating mobile applications.
4. Need to learn all the existing theories which is bit difficult.
5. Preparation of interactive design is bit difficult.
6. Handling input events at real-time is difficult.
7. Testing of user interface from user level is difficult
8. Languages are not fully supporting to all types of user interfaces
9. Modularization of user interface software is difficult.

In today's world we have various software design tools and development methodologies available like Object Oriented Programming (OOP) for programming and for designing Unified Modeling Language (UML). There are also various supporting languages and tools available in the market which will solve the above mentioned difficulties. (Specially difficulty no. 1,8 and 9 mentioned above).

1.9.6 Large variety of Platforms

Because mobile devices are small and there is much less hardware in them than in a PC, they are typically less costly to assemble for a manufacturer. This means that more manufacturers can compete in producing these devices. These cheaper, and typically smaller, devices are often used for special purposes. The sum of these and other similar reasons gives rise to proliferation of the types of devices in the marketplace that an application must support.

If any developer wants to create a device specific application then it is absolutely unnecessary because platform dependency of devices. For example, suppose a developer creates a voice based phone book application for the mobile device which is not platform independent at that time it is not a vise decision because it should run on different devices. Of course, it is very true that the manufacturers of mobile devices, platform makers of mobile devices and operating systems developers of mobile devices will always try to create some kind of restrictions on the developer to stop them from writing applications which are platform independent. They all gives that features which are may be possible to be implemented on their platform to catch the developer and to stick the developer to their platform. Remember that the main aim of the developer is to develop user friendly application which meets all the requirements of the user. One more thing that should be keep in mind is that if these user requirements contains one requirement like support for multiple platforms, which is most probably for mobile computing devices at that time platform independence is the top most requirement that developer has to fulfill.

1.9.7 Active Behaviour

If the user is doing his / her work on a desktop PC or on any other stationary device at that time he or she is always knows that he or she is accessing some information from the computing device. Even if the user does not perform any specific task then also he or she knows very well that by using keyboard and mouse in front of monitor means that the user is performing some information processing related task. We can related this with a very well known example : students sitting on their desks with open books at that time anybody can tell by just seeing them that they are studying something. Like that if the person is seating in front of desktop with keyboard, mouse and monitor anybody can tell that the person is doing some information processing task. For example, if the user is performing some task like writing a letter to the client for seeking payment from that client at that time, the possibility of checking his account through some other application software is much high as compared with the person is listening favorite songs on the desktop PC. This kind of internal reminder system helps the user to perform various tasks which are related to the task being performed. For this purpose we are not require to prepare a separate reminder system which gives us reminder to check the person's account while writing a letter for payment to that party.

Meaning of Active transaction is the transactions which are initiated by the system. Active transactions can also be asynchronous or synchronous. All time dependent transactions are known as Synchronous transactions. The word transaction means any activity which is related to data storage and some actions to be performed on the data and may also be roll-baked if it will not executed successfully in some given fixed predefined manner, which is necessary and must condition for the transaction to be complete. Here we use the term transaction means a sequence of interaction of user with computing device which will be end with completion of specific task. Following are the properties which are require to perform a synchronous active transactions :

1. This type of transaction is always initiated by the system.
2. During the completion of whole transaction - the user has been given opportunity to respond the system.
3. Timely response from the user is always needed.
4. The communication between user and the system is always in sequential during this type of transaction.
5. Always between single user and the system.
6. May be replicated by many users but at a time only one user in the system.

Let us take one example to understand the transaction described above : In general when the field staff goes for work at that time it is order from the company that to note down log time of the task but generally the person who is in the field forgets to enter the same in the logging book. Here if there is a mobile device available with the person which is equipped with the application which tell the user that you are require to make log entry in the system through voice driven system then it would be amazing for the person who is using the system. Here, the voice driven system will ask some questions to the employee and if the employee does answer any of the question within some specific time at that time system treats the transaction as failure. But on the other hand if the employee gives answers to the system regarding the work done the system stores the information and consider the transaction as successful. In this application the developer has to take care about some below mentioned points :

1. The call should be system generated
2. There should be proper time for giving answer
3. All questions should not be asked at a time
4. System needs to wait for answer up to specific period of time before asking another question
5. System should not ask the question while user is giving the answer.

In today's world most of the systems are asynchronous. This type of transactions are not time-dependent. Various properties of Asynchronous transactions discussed below :

1. This type of transactions works like messaging systems.
2. Here the user connection may be 1-1 or 1-n
3. There may be 1-n users with 1-m topics
4. They can be established with either 1–n receivers or 1–n topics to which 1–m receivers are subscribed.
5. This type of transactions may be composition of 1-n messages
6. It requires 1-m messages back from the users.
7. If 1-m responses are not received within specific time frame the transaction treated as failure.

Now, let us consider the same example which we have taken in the above transaction model that is of time-logging system application. Here also the system makes a call to the user and waits for user to answer - but no reply from the user's side. Once again the system generates the call - again user is not able to give the answer due to some circumstances. Now, the system consider this transaction as fail and logs it as user's absence in the remarks. On the opposite side, if we take that the user answers the call, the system will reminder the user that the user has to do log entry of today into the system before the day end. After some time user makes necessary entry into the system and system will consider the transaction as either successful or complete. One more situation that if the user does not makes a call back to complete his / her transaction at that time the system continue to call back the user to complete the transactions. The system call back for n times (the limit defined by the system) if that limit has been reached the system will consider the transaction as failed. Once again, there are a variety of reasons for the failure of the transaction that can be recorded by the system. Here the main reason for the example is that the system does not require response in particular time. The system asks the user to perform the task at later time also. The system is flexible in terms of time.

1.10 Conditions of Mobile User

When we talk about computing system it has minimum two participants i.e. user and the computing device. The major difference between stationary applications and mobile applications is the moving condition of the computing device. Now, let us see that how mobile users are different from fixed device users. We will treat this difference as mobile condition. The various elements of mobile condition which are given here are not necessarily complete as the user studies done and the industry experience with mobile applications is in an childhood stage. However, together, they contain all of the major differences between mobile and stationary users.

The mobile user and the stationary user differs in the following ways:

1. Stationary user is fixed while the mobile user is in moving condition.
2. The moving of mobile user may be between known or unknown locations.
3. The main focus of mobile user is not computing.
4. Mobile user needs immediate response from the system.
5. Mobile user may change its task very frequently
6. Mobile user requires the system access anywhere and anytime.

Here we have to consider a special note that the mobile condition is not describes the physical condition of the user but also about the mental position of the user. Some other factors are expectations from the system, state of mind, moving condition, targeted work etc. So the relationship between the mobile condition and the dimensions of mobility is one of cause and effect.

1.10.1 Changing Location

When we talk about mobile users, we always know that mobile user is in moving condition. But, this moving condition gives a new dimension about location information that we can use for some working for the user who is using our application. This is the main reason because of which this two parameters i.e. location information and QoS are part of dimensions for the mobility. When user is in moving condition the location of the user will be always variable. We can also consider some other variables like speed of the user, network connectivity mode of the user, quality of connectivity at given time and place, for how much period the person connected to the network. On the other hand if we take expectations of the mobile user then he or she also wants to have good connectivity from the network. Second requirement of the user would be like system should give proper or fair accurate location information to the application so that the application can work properly or he or she can utilize the system at the most. These are the various aspects which gives opportunities to the developers that they can create the applications with the functionality which is not possible at all for the stationary applications. Therefore, building such applications which takes advantage of information about location are now-a-days must for the commercial mobile applications.

The mobility of the user also restrict the user for usage of power and size of the device, wireless connectivity with the network system and state of the mobile user. No doubt it will create restrictions which are already been discussed. With the help of location information available through the application, we can grab the opportunity to provide some more functionality which stationary applications never able to provide. The moving nature of the mobile user is a physical aspect that gives way to a mental state of lack of focus.

1.10.2 Lack of Focus

The main focus of the every mobile user is mostly not on the computing task (in general definitely there may be exceptions to this, but here we are thinking from majority of the user's point of view and specially when the user using mobile devices.) This is the main reason behind the need for active transactions. For Example when the user is coming from office to home by driving a car the main task of the user is to drive a car properly - in other words the main focus of the user is to drive a car. During the car driving if he or she thinks of some other task in the mind, it may be harmful and may cause accident. Mobile users are so called mobile because they are moving between two points and their primary goal is to reach the destination.

Another major reason behind the lack of focus is multitasking environment of person's life. A common example for the same is a person driving a vehicle as well as talking on the phone also. Another common example is one sales person who is selling some product or services to the customer like Insurance Agent, while doing his or her field work he or she may enter data collected by him or her into the mobile computing devices. As we have seen, most of the time when user using mobile devices mostly they are doing multitasking. This will gives more support to voice driven applications. If the user interface and application designs in such a way that it is very much user friendly and if it uses senses of user for communication with machines then it becomes very easy for the user to use that application. As discussed above, in today's car systems, users while driving car can also get information about the way or path through voice driven system which is very much useful and the main focus of the user i.e. driving a car remains on priority and he or she also gets information i.e. secondary but important task through voice driven system.

1.10.3 Immediacy

Mobile users are often in a situation where they need to quickly perform one or more computing tasks, such as retrieving contact information, sending a voice or e-mail message, or triggering some remote process. They don't have the time to go through a long boot sequence or long application setup times. Mobile users normally have higher expectations of performance from their devices than stationary users do. Performance of mobile applications is not an afterthought as it often is in the development of stationary applications. A short delay in application responsiveness can decrease its usefulness enormously. For example, if the user is trying to search contacts from his or her mobile contacts application but due to some problem in the system, he or she does not able to get proper information at that time frustration will come and he or she may find alternate way to search the number i.e. through directory services. Here we have to keep in mind that there are various types of immediacy.

1.10.4 Rapid Changes in Task

As we have discussed earlier, the mobile user is said to be mobile and the main reason behind the same is main focus of the user is something other than computing task. For example, many a times mobile users may think that they are saving their time while using mobile devices and they can use that time for some other task. This will also affects a lot for the main task to be changed every now and then.

These are the factors that application developer must keep in mind while designing the flow, design and user interface of the application. The mobile users require to be able to stop some computing task unexpectedly, they may start doing something which may be totally unrelated to the task being perform presently, and it may also happen that the user will return to the main application task after some period of time, and, without much efforts to remember what he or she had been doing, continue the previous computing task. Majority of the mobile users always expects mobile applications which flows smoothly and does not require any complex navigation regardless of how many times unexpected changes he or she made in computing task.

1.10.5 Anywhere and Anytime

When we talk about mobile, the words like “Anywhere, Anytime, Everywhere, Everyplace, Anyplace, Pervasive or Ubiquitous" mostly used. On the other hand, it is the most important thing in subject like mobile computing. All mobile users expects the response from the system and do computing task at any given moment of time. Now, this is the main reason for application developers to make their application which supports a variety of platforms and more number of user interfaces because the words anywhere and anytime should be application under any circumstance. Mobile users sometime also expects that the user can start the computing transaction on one device, leave it unfinished and after some time at some place and also with some different device wants to finish that task.

From the above discussion, it is concluded that when we talk about mobile computing and mobile users, its location changing behavior is most important. All the time people needs to access the data while they are on the go. In the whole mobile computing scenario location management is the most important factor. Next chapter will discuss about the GSM architecture and various location update strategies in detail.

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CHAPTER – 2

Literature Survey

2.1 Introduction to Location Management

When we talk about the term mobile devices and mobile computing systems, its location information management is one of the most important task.[1][2] Coverage area in cellular network is always divided into cells. Everyday mobile companies try to accommodate more users by reducing size of cells.[1] Location management is one of the most important and fundamental issue in mobile computing. When the user changes his or her location, an update for the location occurs. The main goal of any location management strategy is to provide efficient search-updates.

Managing Location Information is the most important and fundamental issue in the current as well as next-generation wireless mobile communication networks. When we talk about the term mobile computing, it gives us first impression that we have computing power which is available anytime and anywhere. At the beginning of the 1970s, mobile users could only roam locally or regionally, while international roaming was possible only after the 1990s [1][3]. As with the increase in mobile devices and population (users of mobile devices), it affects the Quality of Service (QoS). In the 3G and 4G wireless communication systems, both voice and data services have been supported [1][4]. The basic mechanisms of these two schemes are very similar. Both of them manage the user mobility by a two-tier hierarchical database system consisting of Home Location Register (HLR) and Visitor Location Register (VLR)[1][5]. A mobile user permanently registers to an HLR with the user profile. The VLR stores user information currently residing in its charge area. When a user enters a new register area (RA) charged by a new VLR, the mobile terminal is required to send an update message to the new VLR. The new VLR will exchange information with user's HLR through a global-title-translation procedure and obtains the user's profile. It is anticipated that the core networks for 4G systems will be all packet switched. In order to deliver packets to the moving users, the system must have an efficient way to locate them when call requests arrive. This concept is known as mobility management for wireless communication system. Generally, in a wireless communication network, the covered service areas are partitioned into cells, and the cells are aggregated into groups geographically, which are called location areas (LAs). To deliver services to a user, all the cells in the LA covering that user will be paged to establish the radio link connection. The smaller LA size can facilitate networks to trace users more efficiently and reduce transmission delay or packet loss significantly [1][4]. When we think about the 3G and 4G data in mobile computing, in next generation the use of mobile network will be more for data transfer as compared to traditional voice communication. In 3G/4G systems, the services would be user oriented, namely, the networks would provide specific services for specific users. In order to provide user-oriented services, the system needs to store the user profile which records the necessary information. We can observe that many users follow some daily routines. If the system knows the routines in advance and uses the information to predict the user's location, then the registration traffic could be reduced. As long as the user follows the pattern, no explicit registration is necessary and the network can organize the system resource more efficiently, thus we can reduce the spectrum consumption caused by the location updates. On the other hand, a user may change his/her fixed route due to traffic or weather reasons.

A GSM network or UMTS network, like all cellular networks, it is a radio network consisting of individual cells, which is known as base stations. Each base station covers a small geographical area. When the integration has been made of each of the base stations, all small areas will able to cover a much wider area. A group of base stations will be termed as location area or routing area.

Location management is a very important and complex problem in mobile computing [6][7][8]. As a mobile user, a person can be anywhere but a network has to keep track of user, in-case if somebody wants to call him, so the transaction that keeps network updated about the subscriber present location is termed as location update. A mobile phone constantly receives information sent by the network, which includes ID of the VLR area in which mobile is currently located & mobile stores that ID. In order to make a mobile terminated call, The GSM network should know the location of the MS (Mobile Station), despite of its movement. For this purpose the MS periodically reports its location to the network using the Location Update procedure. In GSM based cellular network, the paging information is not possible to be sent in the whole network because the paging channel capacity is limited. Therefore the concept of Location Area (LA) has been introduced. Location Area consist of small divisions known as Cells. The base station will carry out the paging in all the cells throughout the LA of MS. Again the size of the Location Area plays an important role in the performance of network design architecture.

Management of LA registration for all LA is important because the paging for the MS will be carried out by paging all the cells within the given LA, which in turn gives us the definition for the Location Update. Location update is divided into major three parts namely : (1) Periodic Location Update (2) Generic Location Update and (3) IMSI attach.

2.2 Introduction to GSM Architecture

A GSM network it is a radio network consisting of individual cells or else known as base stations. all the base stations covers small geographical area. When the integration has been made of each of the base stations, all small areas will able to cover a much wider area. A group of base stations will be termed as location area or routing area.

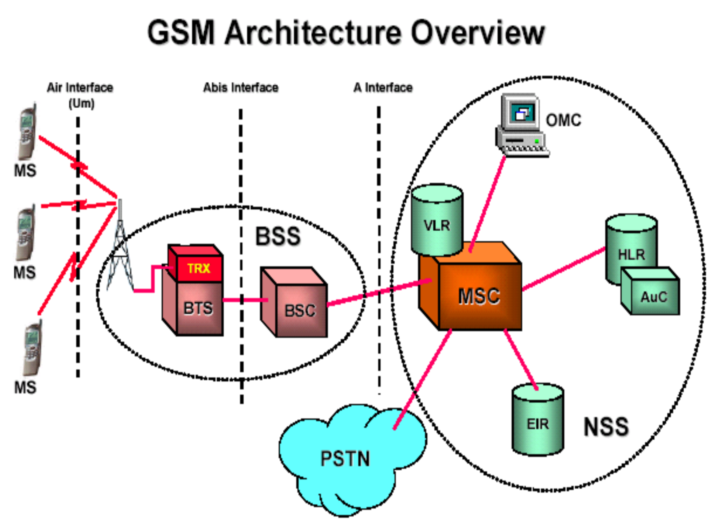

Figure 2.1 : GSM Architecture overview

There are major three subsystems in GSM architecture. As shown in Fig. 2.1 these three subsystems are namely (1) MS (Mobile Station), (2) BSS (Base Station Sub System - consist of BTS and BSC) and (3) NSS (Network and Switching Sub System - consist of MSC and other important registers like VLR, HLR, AuC, EIR, PSTN etc.). To connect all three subsystems there are three interfaces provided. (1) Air interface - Um between MS and BSS, (2) Abis interface between BTS and BSC and (3) A interface between BSS and NSS.

In the above Fig. 2.1 MSC – Mobile Switching Center, BSC – Base Station Controller, BSS – Base Station Sub-system, BTS – Base Transceiver Station, HLR – Home Location Register, VLR – Visitor Location Register, AuC – Authentication Center, TRX – Transceiver, MS – Mobile Station, EIR – Equipment Identity Register, OMC – Operations and Maintenance Center, PSTN – Public Switched Telephone Network.

Here the Mobile Station is the physical instrument or device used by the end user to connect with the system. There are major two components of MS namely Mobile Equipment (ME) and Subscriber Identity Module (SIM) which will be inserted into the ME.

The SIM is useful to store some temporary and permanent data about the mobile device as well as about the network - which includes :

- The International Mobile Subscribers Identity (IMSI)
- MS ISDN number of subscriber
- Authentication key (Ki) and algorithms for authentication check

Each and every mobile equipment contains a unique International Mobile Equipment Identity (IMEI), which is used by the Equipment Identity Register (EIR).

Figure 2.2 : Typical Mobile Station

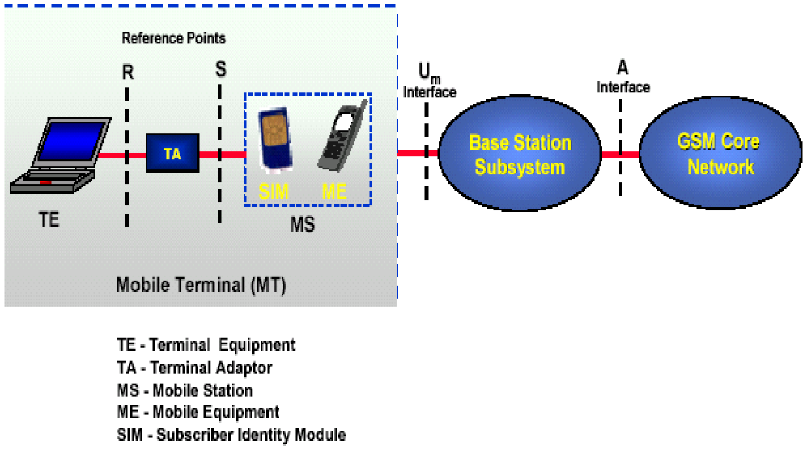

Figure 2.3 : Mobile Terminal

The IMSI (International Mobile Subscriber Identity) is responsible to make identification of the subscriber inside the GSM cellular network while the MS ISDN is the actual telephone number that a caller (Other person who is connected with another network) uses to reach that person.

The system requires to provide security and for that purpose an authentication key and by generating Temporary Mobile Subscriber Identity (TMSI) during the data transfer which gives protection to IMSI.

The IMEI (International Mobile Equipment Identity) is used at MS level to provide authentication as well as security while connecting the instrument to the network and also to find stolen document.

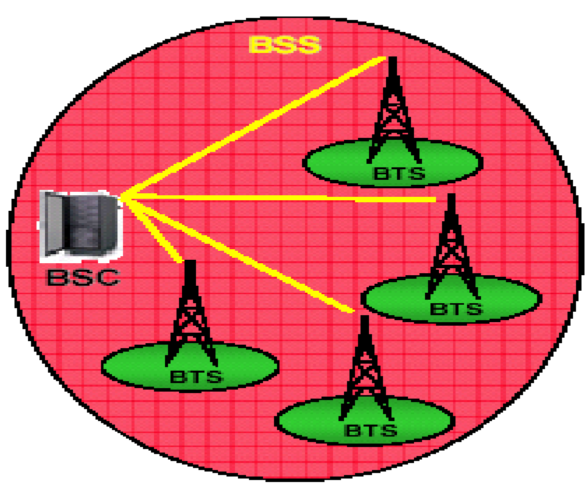

Figure 2.4 : Base Station Subsystem (BSS)

The BSS consist of Base Station Controller (BSC) which is responsible for connecting One or more Base Transceiver Stations (BTSs). The main responsibility of BTS is to provide connectivity through which Mobile Stations can access radio network as well as to manage radio access aspects of the system. BTS contains : Radio Transmitter/Receiver (TRX), signal processing and equipment control, Feeder cables and Antennas.

Major work of BSC consist of allocation of channels for the call, maintenance of the call, monitoring the quality of the call, control of signal transmission between MS and BTS and the most important is to generate handover to another cell whenever required.

Network Switching System (NSS) performs the operation for the call routing switches with the help of MSC and GMSC and also affects the database registers which is needed to track the movements of the subscribers. The most important task that is call routing can be possible between MSCs is taken through PSTN or ISDN networks.

Various functions of MSC can be summarized as : (1) Logging the calls, Controlling the calls and Switching the calls. (2) Interaction with PSTN and ISDN (3) Make the management of mobility over the whole radio network and other connected networks (4) Radio Resource management i.e. handover between connected BSCs (5) Billing Details.

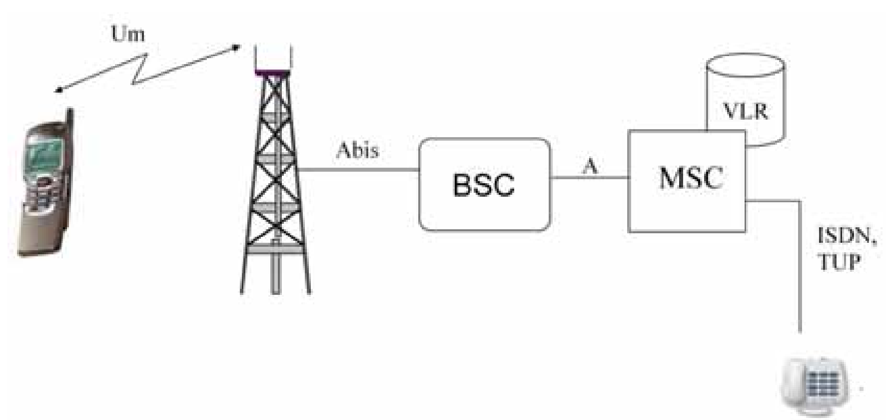

Figure 2.5 : MSC Interface

2.3 GSM Infrastructure

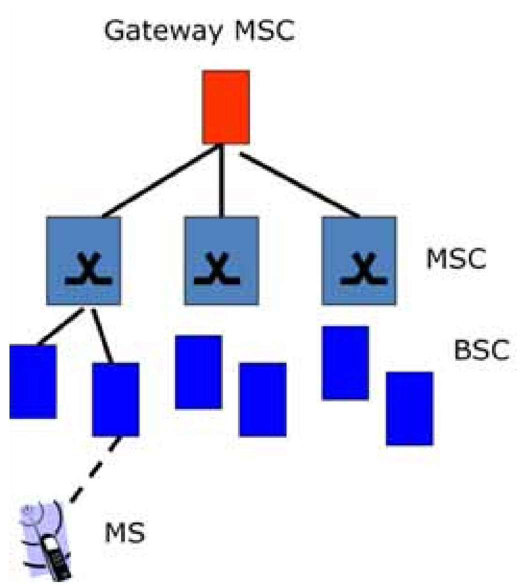

Figure 2.6 : Simple GSM Infrastructure

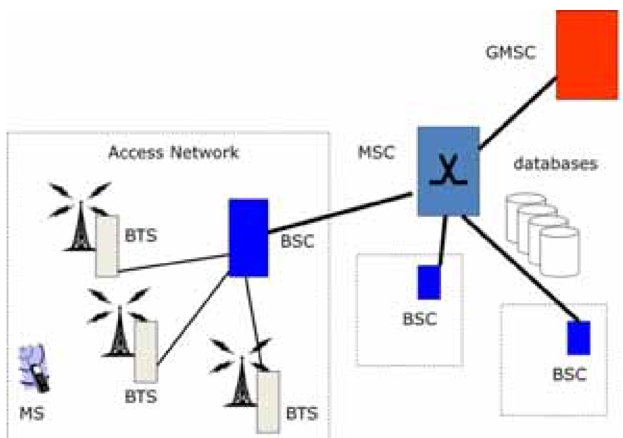

Figure 2.7 : Detail GSM Infrastructure

Here in the above Fig. 2.7 a detail GSM Infrastructure has been given. Here the main thing is the Mobile Station (MS) is directly connected with Base Terminal Station (BTS) i.e. mobile towers. All BTS of the same city will be connected with one Base Switching Center (BSC). Now all the BSC from different cities will be connected with Mobile Switching Center (MSC). The MSC will be connected with General Mobile Switching Center (GMSC) and the Database for Location Management [9]. Fig. 2.8 displays typical mobile tower with 90^0 x 4.

Figure 2.8 : Typical Mobile Tower with 90^0 x 4

2.4 Location Update Procedure

As discussed earlier Location update is divided into major three parts namely : (1) Periodic Location Update (2) Generic Location Update and (3) IMSI attach. In normal or generic location update procedure MS has to do a location update in new location area when it crosses a LAC border. In periodic location update procedure the network has to do a periodic location updates to update the subscribers in each location area. This is also known as T3212 timer location update.

In IMSI attach location update When mobile switch ON it has to do a location update or when moving from non coverage area to a coverage area MS has to do a location update if LAC is different from stored LA or when mobile switch OFF it has to detached from the network.

2.4.1 Generic Location Update

Generic Location Update will be performed when the MS leaves one LA and moves into another LA. After this situation registration is needed. Consider the situation in which the LA of the current cell is different as compared with the LA which is already stored in the MS, it is the responsibility of the MS to inform the network about the change in the location information that it possess. This procedure is called generic location update. In a general and normal condition, if the MS moves from one cell to another cell which is also in nearby area, in this situation MS will change the cell number, perform the location update and does not inform the network immediately. Consider another situation in which MS moved from one LA to another LA in that situation Location Update is must. The main steps involved in the whole process are as follows:

1. Intra VLR Location Update : Intra VLR is very simple location update procedure. This procedure does not require International Mobile Subscriber Identity (IMSI). It will work only in current Visitor Location Register (VLR) without informing the Home Location Register (HLR). As this is the starting point of whole update process, so a new message will be carried by SABM frame, the access cause is MM LOCATION UPDATING REQUEST which carries the MS TMSI and LAI. Now, MSC will receive the same message and it will be forwarded to VLR. Now, VLR will update the information of location of MS and stores it to the new LAI. It is also responsibility of VLR to send a new Temporary Mobile Subscriber Identity (TMSI) to MS if needed (MS continue uses the previous TMSI if no TMSI is available in the TMSI re-allocation command). After receiving the message of TMSI re-allocation, MSC will send location update accept message and channel release happened. After receiving the TMSI re-allocation complete message, MSC will send location update accept message and release the channel. Location Update Complete.
2. Inter-VLR Location Update, Sending TMSI : Consider a situation in which MS enters into a cell and the current LAI is different from the LAI stored in the MS so now it is responsibility of MS to send new LAI and TMSI to VLR with the help of MSC as Location Update request. VLR check the previous VLR which is based on the LAI and TMSI it has received and send a MAP_SEND_IDENTIFICATION to the previous VLR by asking information for IMSI and authentication parameter. The previous VLR will send the IMSI and authentication parameters to the present VLR. If the situation happen that current VLR is not able to obtain the IMSI, it sends MS message for identity request to ask for the IMSI. After receiving the IMSI, now, it is responsibility of VLR to send location update message to HLR which contains the identity information of MS which is useful for the path and data query of HLR. Now, As HLR has received the message, it stores the number of

present VLR and sends MAP/D_CANCEL_LOCATION to the previous VLR if the current MSC/VLR has the normal service rights. Now, as the previous VLR has received the message, it will delete the information about the given MS and send MAP/D_CANCEL_LOCATION_RESULT message to HRL for confirmation of the delete. Now HLR will send MAP_INSERT_SUBSCRIBER_DATA message which will provide the information about the current VLR with additional information which is also needed. It also includes authentication parameters after the procedure of authentication, encryption, and TMSI reallocation is complete. After that it will confirm the location update when it gets the response from the VLR.

3. Inter-VLR Location Update, Sending IMSI : This procedure is very much similar with the above mentioned procedure but it is easy compare to above one because here it request the HLR for authentication parameter through IMSI directly.

2.4.2 Periodic Location Update

The network and the MS loose contact when: (1) The MS is switched on but moves out of the network coverage area i.e. dead zone. (2) The MS sends IMSI detach message and the uplink quality is not proper due to nosiness, the network may not be able to decode the sent message suitably. (3) In third situation we consider that the MS is power off. So it is not possible to it to inform the network about its status and the connectivity is totally lost. Now, if the network makes paging for that MS because the connectivity has been lost. Now, the system will send paging information in the given LA where the system has already found the MS registered at the time of its last call. As the MS is off so, the network will not receive any response from the MS and the resources of the network system has been wasted. To resolve this situation and problem, the implicit detach timer has been introduced in the VLR for the IMSI status management. In addition to this, other measures are also taken in BSS which will force the MS to report its location after particular period of time. Therefore, the network is informed of the status of MS. This kind of mechanism is known as periodic location update. Here it is the responsibility of the network to send a periodic location updating timer T3212 to all the users available in the network cell through the help of Broadcast Control Channel (BCCH) which will force the MS to send its location update request with the cause of periodic location update after T3212 has been timed out. Consider a situation in which before the T3212 timer times out, and if the timeout value has been changed (this situation happen when the service cell has been changed and the T3212 timeout value is broadcast in the network), after that MS will consider the time when the change happens as the its initial value and keep that timing stored. Here total four status have been given by MS namely : LIMITED SERVICE, NO CELL AVAILABLE, PLMN SEARCH, or PLMN SEARCH-NORMAL SERVICE status. Next Location Update will be initiated only after the MS is out of all these service status.

Periodic location update will ensure the whole system to provide proper contact between mobile users and the network. If this period timer is set to minimum at that time it gives improvement in the network performance but on the other hand frequent location updates increases the signal flow and reduce the radio resource utilization and also affects the processing of BTS, BSC and MSC. This will also increase the power consumption of MS and reduce its standby time. So, the setting of T3212 should be done in such a way that it should balance the usage of network resources. The periodic location update procedure is same as generic location updating.

2.4.3 IMSI Attach and Detach

Meaning of IMSI attach and detach is to attach a special binary mark to the subscriber's record in MSC/VLR. The first one is treated as access granted and second one is treated as access denied. When the MS is switched on, it will inform the same to the network by sending an IMSI ATTACH status message. When the network receives this message from MS, the network marks the entry of MS in the current user status database so that in future paging can be done on this MS. If the stored LAI of MS and current LAI are same, the IMSI attach process will be initiated. This procedure is very much similar to the procedure that we have discussed earlier i.e. intra VLR location update with only one change that is the location update request message will be marked with special note IMSI attach and the initial message also contains the IMSI of the MS. After the above process generic location update is initiated. When the MS is switched off, the IMSI detach is triggered by a key-press. Now, Only one command is sent by MS to MSC/VLR. This command is known as unacknowledged message. When MSC receives this message, it will inform VLR to remove the mark from the IMSI while the HLR will be informed about no-radio signal for the user. Now, when the network will do paging for the given user, HLR requests for the MSRN from the

VLR and is informed of the no-radio of this user by this time. Therefore, the paging step has been stopped. Now the paging procedure will be handled directly by making the remark as "The subscriber is powered off."

The procedure that has been discussed above is known as explicit IMSI detach. There is a another procedure also which is known as implicit detach. The implicit detach happens before the implicit detach timer has been timed out. Consider a situation when it is not possible to establish the contact between the network and the MS, the VLR will set the status of IMSI as IMSI detach. The solution to this situation is by making implicit detach timer to set longer period as compared to periodic location updating timer T3212 which will avoid "abnormal" implicit detach. The implicit detach will not allowed during the establishment of radio connection. This timer will be reset after it will release the radio connection. Implicit detach timer is also known as IMSI delete time. Now, VLR will delete the IMSI which was marked as detach periodically (The period which is adjustable) and it will report to HLR for the final status of the user.

2.4.4 Exceptional Situation

Location update can be done in some Exceptional Situations also. These are the situations which are beyond the above given situations. These exceptional situations are as follows:

1. MS Access denied because it reach to access level limit : Sometimes it may happen that MS stays in the same service cell and also performs the normal cell re-selection procedure without triggering location update. Consider a situation when the current cell allows access or other cell is selected, the MS require to initiate location update on immediate basis. IMMEDIATE ASSIGNMENT REJECT is the message received during random access and MS stays in the service cell and starts T3122 based on the value in the immediate assignment reject message. Now, the normal cell selection and re-selection procedure has been performed by the MS. Now if the situation occurs in which either the cell in which MS stays get changed or T3122 timed out, the MS require to initiate location update.
2. Random access failure: Another timer T3213 will be started if the random access get failed. Once the T3213 timed out, the random access procedure has been

started. But if two continuous random access also gets failure message at that time the whole Location update procedure is terminated. All the above four main Location Update Procedures can be summarized in following Fig. 2.9.

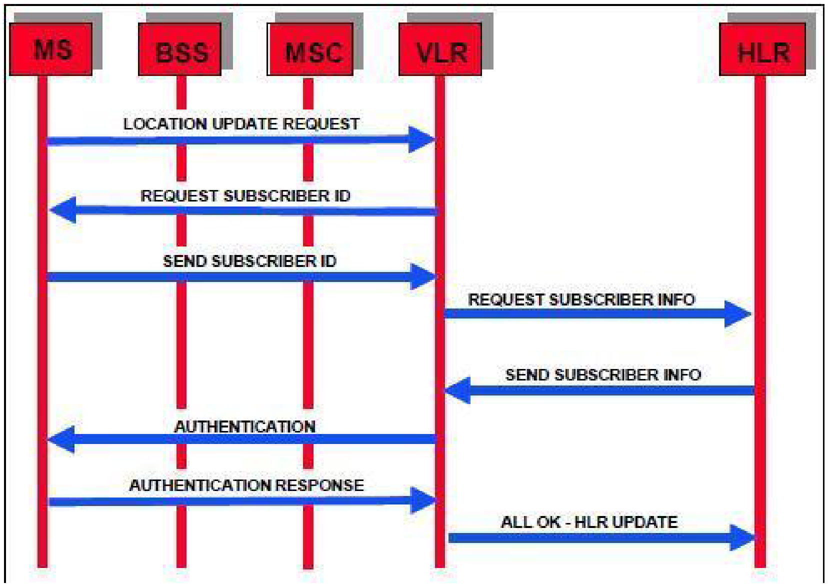

Figure 2.9 : Location Update Procedure

Here, as per above Fig. 2.9 following steps are involved in Location Update Procedure

1. MS sends request to VLR for Location Update and also ask for a separate channel to send and receive further information.
2. VLR accepts the request and request for Subscriber ID from the MS
3. Now MS will send Subscriber ID to the VLR
4. After receiving Subscriber ID from MS, VLR will send that Subscriber ID to HLR.
5. Now HLR will send Subscribers info available in the database of the company to VLR
6. Now VLR send Authentication request to MS.
7. MS will send Authentication Response to the VLR.
8. If everything is fine, VLR sends the request to HLR for Location Update.

Following Fig. 2.10 explains the above mentioned 8 steps in very simple way.

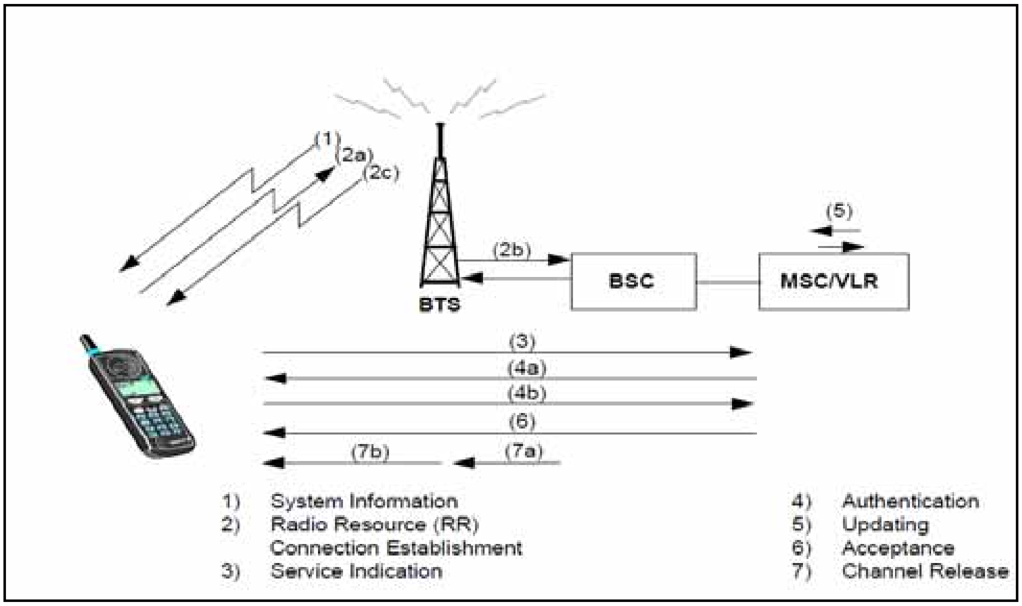

Figure 2.10 : Location Update in Simplified way

2.5 Factors affecting Location Update

In following subsections we discuss about the various factors which will affect Location Update procedure as a whole. It includes Mobility pattern and Call arrival pattern.

2.5.1 Mobility Pattern

User's mobility pattern is most important factor for determining location update cost. In general, user will change its location more during the regular working hours if the user doing business. On the other hand if the user is doing a job then during working hours change of location is minimal. Some models are described by various authors which are as follows.

2.5.1.1 Memory less (Random Walk) Movement Model

In this Memory less (Random Walk) Movement Model, the mobile user's next cell location will not at all depend on the user's present cell location. Which means that, all the cell have equal probability for selection from the neighboring cells. Purely Random Walk Model is generally used to model walking traffic. Here the movements are totally irregular and it may contains various stops and direction changes also [10].

2.5.1.2 Markovian Movement Model

The major difference between Memory Less Movement Model which is described above and Markovian model is, here the Markovian Movement Model uses memory and the mobile user's next movement are always dependent on user's previous movements. The memory that is used by the model includes history of recently visited cells (cell history) and it also includes memory for directions of previous movements (i.e. directional history) [10].

2.5.1.3 Shortest Distance Model

In this model[11], it is assumed that users will first calculate the shortest path from source to destination and then follow that shortest path to reach to the destination. At each and every node or at the time of cell selection or at the time of movement, it selects the path which maintains shortest distance. This model is mostly useful for vehicle based traffic in which user has a fixed source and a fixed destination. In this type of situations this model is very much useful.

2.5.1.4 Gauss Markov Model

Here in this model described in [12][13] will uses some of the important characteristics of real world mobile user's behavior. This includes the relationship between user's movements and user's speed during particular period of time. During a specific period of time, a mobile user's speed (velocity) represented by v_n at particular time slot n which can be represented using following formula :

$$v_n = \propto v_{n-1} + (1-\propto)\mu + \sqrt{1 - \propto^2}\, x_{n-1} \quad \text{......(1)}$$

where , $\alpha \in [0, 1]$, μ is the asymptotic mean of v_n when n tends to infinity, and x_n is an autonomous, stationary and uncorrelated Gaussian process. x_n has zero mean and standard deviation equals to the asymptotic standard deviation of v_n when n approaches infinity.

In the extreme level of cases, this model is a simplified model of Memory less Movement Model (discussed above in 2.5.1.1) and Fluid-Flow Model (discussed below in 2.5.1.7).

Table 2.1 : Activity based Probabilities for Transition of a Mobile User

Time	Current Activity	Next Activity	Probability
...	...	...	...
2	2	6	0.15
4	2	8	0.25
...	...	...	...

2.5.1.5 Activity Based Model

The main concept behind an activity-based model is the activity performed by the user. Here the connection between the trip i.e. mobility and the activity is to be found out. New activities will be decided based on factors like previous activity was happen on which day and at which time.

Based on the previous activity data, various activity-based mobility models can be prepared. Implementation for the model has been described in [14], here each and every activity has been given various parameters like day (on which activity happen), time (at which activity happen), duration (for how much period of time activity was happen) and location (where activity was happen) of the activity. New activities are created based on the data collected in previous step. Based on the collected data a path which was taken to reach from origin to destination as well as time to cross the cell will also be used for simulation purpose. To create this kind of activity based modeling data can be collected from various surveys.

This model collects the above said data for movement behaviors of real world mobile users. The activity-based mobility model has been discussed and implemented in [14, 15, 16].

2.5.1.6 Mobility Trace

In cellular network, the actual mobility of the users i.e. actual movement based behavior of the users in a particular geographical area can be used for simulation purpose. Such data is more realistic and accurate as compared to other mathematical models because it is a real data. But the major problem is this data is not available readily specially not large enough with the size which is needed for simulation network. In addition to this, it may also happen that the movement directions and velocity of users in one network may not be same for other network. It may depend on various other things like network size, geographical area covered by network and so on.

2.5.1.7 Fluid-Flow Model

All the models described above are based on individual user's mobility. There are some models which describes movements for the whole system also. The Fluid-Flow Model is one of that kind of model. Here in this model, the traffic flow of mobile users will be modeled as fluid flow and all the movement pattern of the system will be described In this model, each and every mobile user is assumed to have movement at average speed of v and it is not connected or dependent on the movement of other users. Additionally, each mobile user's direction is homogeneously distributed in the range of {0, 2π}. For a region with length and population density ρ, the average number of users moving out of the area per unit of time is given by :

$$N = \frac{\rho v L}{\pi} \qquad \text{.............................} (2)$$

The Fluid-Flow Model is very much suitable for traffic based on vehicles. Generally when the user is in mobile condition and on vehicle at that time the direction may get changed based on the traffic as well the user may make irregular stops.

2.5.2 Call Arrival Pattern

The rate at which mobile user will receive the calls in a real time cellular network is always varies with time. Consider a situation, A user will get more number of calls if it is regular working hours as compare to non-working hours.

2.5.2.1 Poisson Model

In this model, it assumes the Poisson probability distribution to trace the call arrival pattern at particular mobile station. This will result in exponentially distributed (continuous time) or geometrically distributed (discrete time slot) call interval time.

Data collected by various researchers suggests that the call arrival rate in this model gives more accurate data for real time cellular network. However, for an individual mobile user it may happen that the user will not get calls at Poisson call arrival rate because various factors which affects this rate is time of the day (i.e. working hour or non-working hour) as well as this also affected by holidays (i.e. if Sunday or holiday is there then user will not get that much calls even during working hours).

2.5.2.2 Call Arrival Trace

In Call Arrival Trace model the call distribution will be based on time. Here it will generates the call event based on time of the whole day. As shown in Fig. 2.11, a normal working user will get more calls during working hours as compared to off hours. This distribution can easily be traced out from the mobile call records of individual users.

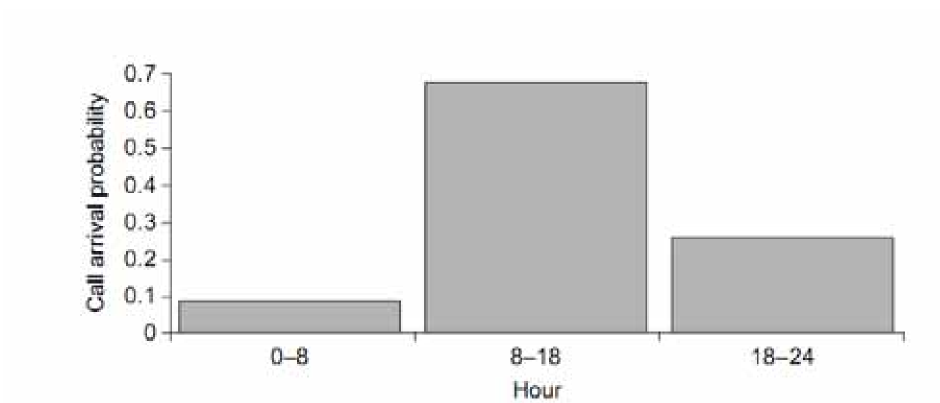

Figure 2.11 : Call Arrival Probability based on time

The available call arrival trace of existing cellular network is useful for simulation purpose. Such real world data is more accurate and more useful for research work as compared to data collected through other mathematical model like Poisson Model. Here the main benefit is this type of data is available through individual user's call records or can be obtained through simple surveys. The model described above is more powerful and useful to represent call arrival patterns of actual users.

A trace generator discussed in [17] which has used real-world data to make simulations. This data includes call information and movement information of the mobile users.

2.6 Various Location Update Strategies

Various location update strategies are available in the mobile computing. Mainly these strategies are divided into two i.e. (1) Always Update Strategy and (2) Never Update Strategy. Further they are divided into specific strategies like (1) Distance Based Location

Update (2) Time Based Location Update (3) Movement Based Location Update (4) Hybrid Strategies and (5) Profile Based Location Update. To understand these strategies we need to work on wireless mobile networks. The Fig. 2.12 below shows Appropriate wireless mobile network architecture.

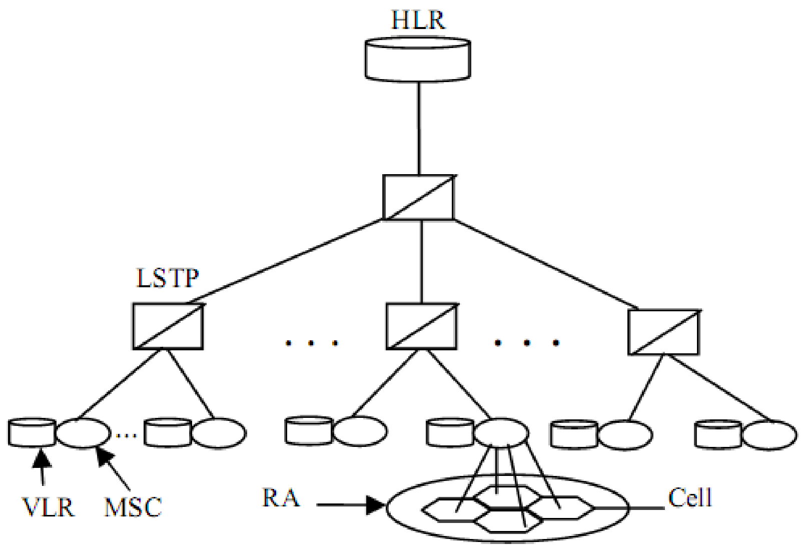

Figure 2.12 : Wireless mobile networks architecture

Various components of Wireless mobile network architecture are (1) HLR – Home Location Register (2) LSTP - Local Signaling Transfer Point (3) VLR – Visitor Location Register (4) MSC – Mobile Switching Center (5) RA – Registration Area. Here the smallest component is Cell. RA can become from combination of various nearby cells. RA is connected with MSC and MSC maintains the VLR. MSC is also connected with LSTP and finally LSTP is connected with the HLR. When we talk about Mobile Computing we need to consider Cellular network as our base. Various components and its details are given in Fig. 2.13 below :

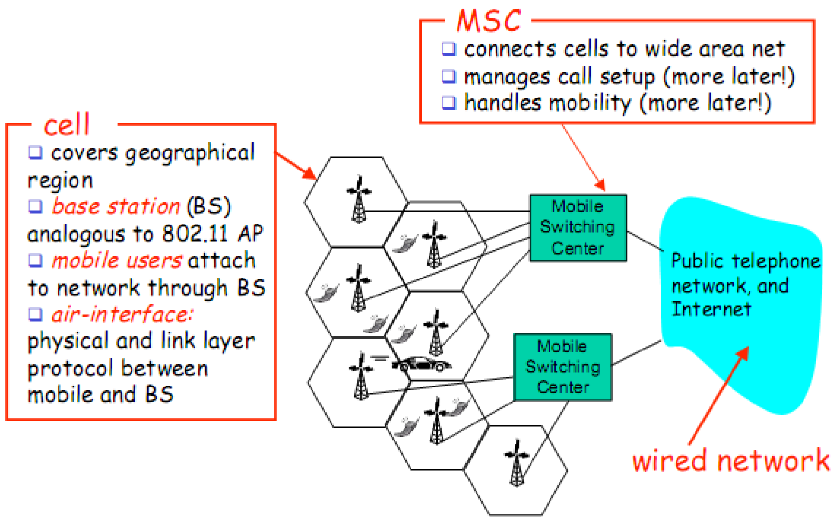

Figure 2.13 : Components of Cellular Network

Whenever we talk about location update strategies, we need to consider the cost factor for update. Cost factor is again divided into mainly two parts (1) Location Inquiry (Paging cost) and (2) Location Update Cost. Different strategies have different cost factors. Sometimes paging cost goes down while sometimes the cost goes down with location update . Location management cost could be divided into following factors.

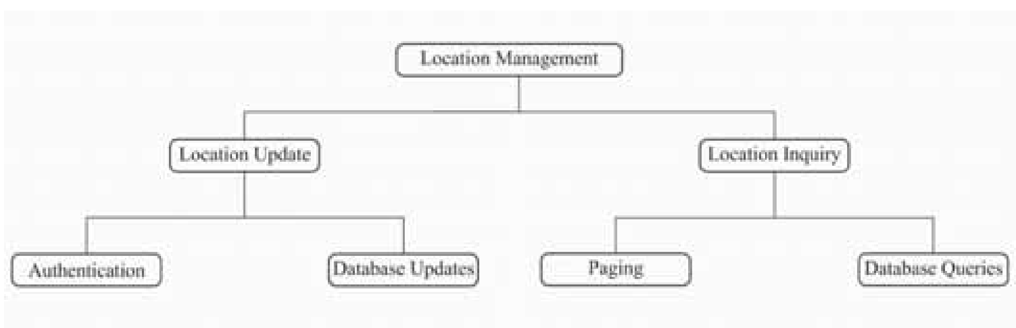

Figure 2.14 : Cost Components of Location Management

The total cost for the location update consist of major two cost components i.e. Location Inquiry and Location Update. Further the Location Inquiry will be divided into two i.e. paging and Database Queries. Location Update is also divided into two parts i.e. Authentication and Actual Database Updates. If we consider particular period of time T, then following equation is useful to calculate the total cost for the Location Management [10].

$$\text{Total cost} = C * N_{LU} + N_P \qquad \text{.............................. (3)}$$

Here, N_{LU} represents total number of Location Update happen during a given period of time i.e. T and N_P represents total number of paging happen during the given period of time T. C represents the constant value which may be any cost factor for the calculation purpose. Now we will discuss above mentioned strategies in detail. Starting with two divisions i.e. (1) Always Update Strategy and Never Update Strategy, we will also discuss all the other strategies.

2.6.1 Always Update Strategy

In this type of strategy each mobile terminal's location would be updated whenever it enters to a new cell. The main benefit of this strategy would be that the current location of each user would always be known. Therefore, search operation would not be required whenever there is a call . This would be a benefit on one hand whereas on the other hand it would create a problem on other side i.e. it would require more resources because it would update the location at each and every cell movement. Here the paging cost would be zero but location update cost would be very high. This kind of strategy would be very much valuable when user's mobility is very less or when the cell size is comparatively very large.

2.6.2 Never Update Strategy

This strategy is totally opposite to the above mentioned strategy i.e. Always update strategy. Here, the location update would never be performed. The main benefit of this strategy would be that since location would never be updated so the location update cost would be zero. This is benefit on one side, but the problem on other side would be that the overhead cost of paging would be more. This kind of strategy would be very much valuable when user's mobility is very high or when the cell size is comparatively very small.

2.7 Distance Based Location Update Strategy

It is a simple strategy for location update. Here the mobile base station would keep track of each mobile terminal for distance (in number of cells) it has travelled since its last update[1][18]. Whenever the terminal travels number of cells from predefined cell size say for example D, at that time location update would occur. When this policy is used, the management is needed to be done per user basis. Here initially the counter would be set to 0 in the initial cell. Now, when the mobile unit would move and cross the cell boundary that counter would increase by 1. When that counter would cross a value greater than D, location update would be done. This strategy would be better for the users who generally move less and move within specific distance i.e. < D. In that case few updates would occur and we would get exact location of the user. Here the paging cost would also be low, because the latest location would be recorded as and when needed. Fig. 2.14 shows Distance based location update with D=2. [10]

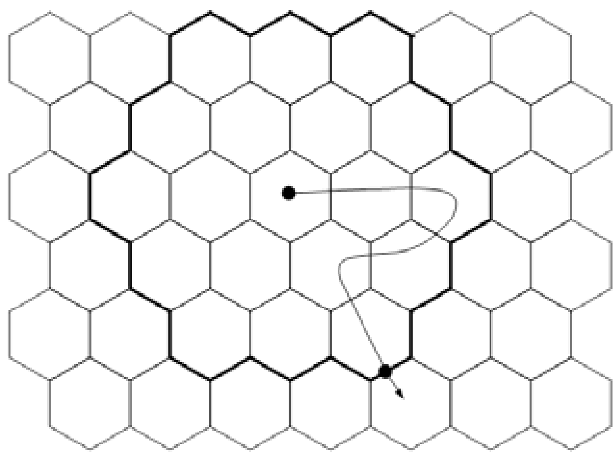

Figure 2.15 : Distance Based Location update with D=2

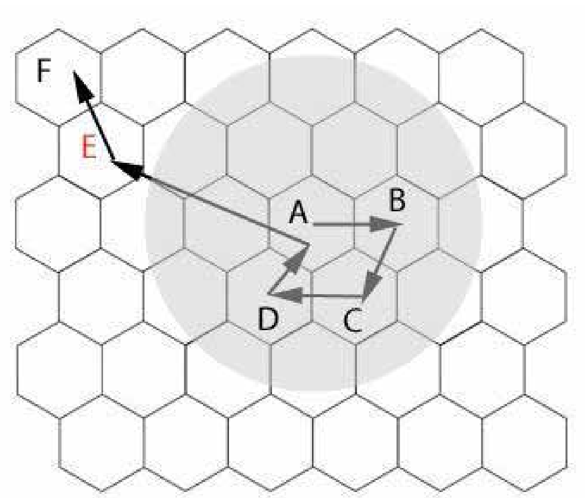

Figure 2.16 : Example of Distance Based Location update with D=2

Here A is the starting point and user moves from A -> B -> C -> D -> E -> F direction. Here the location update would be performed when the user reaches to E. The main drawback here would be that if the user crosses the boundary very frequently, unnecessary location updates would occur.

2.8 Time Based Location Update Strategy

This is also a simple strategy for location update. Here the mobile base station would update the location of user after a particular time period say T.[1] This strategy is comparatively easy to manage because each base station requires maintaining its internal clock only. The other benefit is the value of T could be set different for each user according to each user's mobility pattern or call arrival pattern. There would be one more benefit due to the nature of periodic signaling. The network would know that the mobile terminal is powered-off or outside the coverage area if it does not perform a location update as per the scheduled time. The main drawback would be even though the user is stationary (non-moving) the location update would occur and it would increase the location update cost. Furthermore, mobile users' location uncertainty cannot be bounded: when a call arrives, the search operation cannot be limited to a set of cells. Similar discussion can be found in [19].

The main advantage of this type of strategy would be that it is not dependant on Location Areas (LA). Another advantage would be lower paging cost because at time t location would definitely update. The main drawback here would be sometimes if the user is stationary at that time unnecessary updates would be performed.[1]

2.9 Movement Based Location Update Strategy

In this strategy the base station needs to keep track of the mobile user for number of cell movements or the number of cell boundary crossing[1]. Here, one counter is managed, it will be set to zero initially, and incremented with 1 each and every time the user crosses the boundary. Now, when the counter becomes>M at that time update is done. Fig. 2.17 shows Movement based location update with M=2. [10] and Fig. 2.18 is an example of the same.

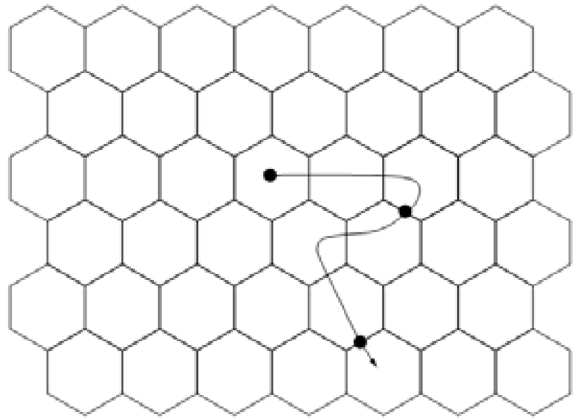

Figure 2.17 : Movement Based Location Update with M=2

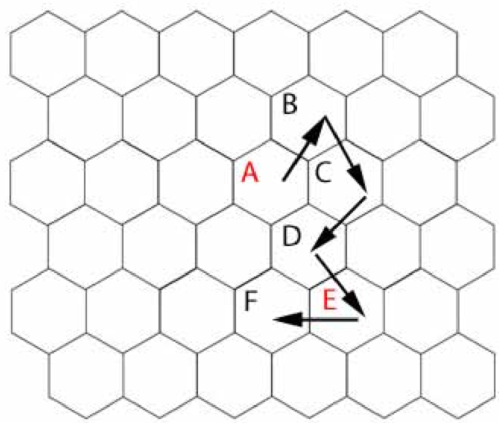

Figure 2.18 : Movement Based Location Update with M=4

Here A is the starting point and counter is zero. Now user moves from A -> B -> C -> D -> E -> F direction. Counter at E is 4 thus, at E the location update would be performed when the user crosses the boundary from D to E. The main drawback of this kind of strategy is when user travels around the boundary at that time unnecessary updates may happen. Fig. 2.19 illustrates the same.

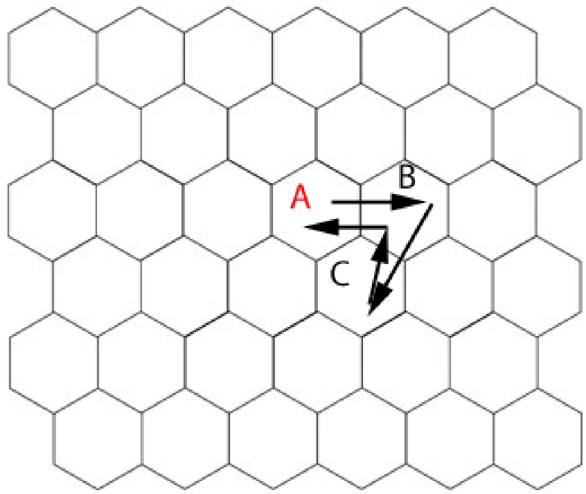

Figure 2.19 : Problem with Movement Based Location Update

Here A is the starting point and counter is zero. Now user moves from A -> B -> C -> A direction. Counter at A is 4 thus, at A the location would be updated which would be an unnecessary update.

2.10 Profile Based Location Update Strategy

The Profile Based Location Update scheme has been proposed in [20] and [21]. In this scheme each user's profile would be maintained and from that profile the location of the user would be traced out. The main idea behind this strategy is that the mobility pattern of majority of subscribers could be easily predicted. This type of strategy would be useful when the user is working in same geographical area for maximum hours of his / her daily routines. To find out the probability of the user's profile location long term statistical data would be useful. To create the profile of each user the following operations could be performed: For each time period (ti, tj), the system maintains a list of location areas, [(a1, p1), (a2, p2), ……., (ak, pk)] here Af is the location area, and Pf is the probability that the subscriber is located in Af. It is assumed that the location areas are ordered by the probability from the highest to the lowest, that is, p1 > p2 > …… > pk. If the subscriber moves within the recorded location areas, a1, a2, … ak, during the corresponding period (ti, tj), the subscriber does not need to perform location update, otherwise the subscriber reports its current location, and the system will track the subscriber as in the classical location area strategy. Therefore location updates could be significantly reduced. Here in this type of scheme the main benefit would be that if we know the user's location based on its profile and if the user is in that location area only at that time no location update would be required. Sometimes it may happen that user changes his / her daily routine due to some circumstances, at that time we would need to do paging to search the latest location of the user.

The main objective behind using this kind of strategy is to use of the strategy given behind the work behavior of the humans. In this approach we will learn the process to derive a list from which we can find the places (exact cells) in which the Mobile Terminal (MT) resides the most of the time of any day. This learning process is able to derive such list after learning the behavior of a particular user by viewing the activity for a certain period of time.

For this purpose we associate a pattern learning process. So that when the learning process gets complete, we are able to decide the mobile user's behavior with possible location of LAs. We can built a table based on profile that we have collected based on his / her day to day activity (as shown in Table - 2.2) When a call arrives for a mobile, we can page it sequentially in each location within the profile. The major benefit here is when the user moves between the LAs available within the given table no location update is required. This profile table is stored at the HLR as well as in the user’s MT.

Table 2.2 : An example of a user’s LA profile

Sr. No.	Profile Number	LSTP ID	LA ID	Number of Visits
1	0	1	6	20
2	0	1	12	40
3	0	1	9	15
4	0	3	6	22
5	0	1	12	20
6	1	1	9	19
7	1	2	20	8
8	1	1	22	7
9	2	3	10	1

In Profile Based System, if the position of the user is always known in advance then the major benefit is registration is necessary and the optimum LA is a single cell that minimizes the paging cost. [21]. This scheme is most useful when most of the users are stationary for a particular period of time in their day to day routine. It is also possible to divide the people group into various categories based on their daily routine. Fix users who have a very high probability of being in an area known in advance by the system. Some users with a probability that he / she will be available at given location is high but low compare to above type of users and at last the random users whose position at a given movement is unpredictable. [21].

Here the cost reduction is totally depends on the behavior of each class of user and the probability that the user found in a given list of probable LAs. It is also expected that when the user follows its fix routine behavior, location update cost will be definitely reduced. In this scheme we can define the local list as the set of LAs that are all under the coverage of one Local Signal Transfer point (LSTP). The prepared list is to be stored at the Intermediate Location Database (ILD) which is directly associated with the LSTP. For further improvement we can also define the global list as a set of LAs which belongs to different LSTPs and that list can be stored in HLR. The LA where the called mobile is roaming is stored at the ILD, while the HLR stores the list of ILDs. Each MSC is assigned to one ILD.[2]

2.10.1 Some assumptions while using Profile Based Location Update

For the above mentioned procedure to work smoothly we need to assume that the link costs and database access costs are not taken into consideration. We also need to consider the cost for list update and maintenance while comparing the strategy with other strategy because we have consider only the following maintenance cost.

1. Processing the billing information of the user to create the list.
2. Transfer of the list to the place where it will be stored
3. Notification of the modifications in the list to the MT.

The system should have two kinds of information, as stated in [20]:

1. The system will store long-term information in a relatively static list. This list must be updated with new updated movement patterns detected by the system for proper output.
2. The system also needs to store short-term information changes depends on the recent behavior of the user which is done by the user in last few hours of the day.

2.11 Hybrid Location Update

Hybrid Location updates strategy discussed in [22]. In this paper authors have suggested combination of two strategies to reduce the cost. Here they have combined two types of strategies i.e. Time Based and Distance Based. In that they have first used Time Based Location Update and then Distance Based Location Update Separately. After that they have proposed a new scheme i.e. TAN (First T then N) and NAT (First N then T). Through hybrid location update strategy, Location update cost can be saved. TAN means first application of time based and after that application of distance based while in NAT first application of distance based and after that time based.

Another type of Hybrid Location Update discussed in [25]. In this paper authors have suggested combination of two strategies. Here they have combined two type of strategies i.e. Time Based and Movement Based. Through the combination of both the strategies authors have found out optimal sequential paging scheme which will ultimately reduce the location update cost.

2.12 Analytical Modelling

Analytical modeling is a way of finding complexity of any methods in terms of space and time requirements. Analytical modeling can be done to find efficiency of a method mathematically. Here we have evaluated all the four Location Update Strategies with reference to analytical modeling [23].

2.12.1 Distance Based Location Update Strategy

Any method which needs linear time and linear space bound can be considered at best. The complexity is bounded by the parameter Threshold value D. lets analyze the best case where the MS is stationary. In this case the cost is $\Omega(1)$ which is the initial location update when the MS was switched on. Lets describe the worst case where the MS is continuously moving. The cost depends upon how fast a MS moving and the direction in which it is moving. Let's say in n seconds, a MS move across m cells, than $m >> D$ is the worst scenario.

The worst case cost can be calculated as,

Cost = $O(m/D)$ if we include the processing cost, it becomes

$O((m/D)+m+D)$ including processing at MS as well as BTS.

So conclusively we can say that the cost will be $O(m)$.

On an average, the complexity can be measured with amortized analysis which is near to $\theta(D)$.

The success complexities are always same as the method works only when location change was occurred [23].

2.12.2 Time Based Location Update Strategy

As the location update is done periodically without depending upon the location or of the mobility. The method gives best, worst and average complexities to (n/T). Where n is the amount of time and T is the time interval. More specifically we can analyze this method.

Best case occurs where the T is equal to the MS's life time. And in that case the complexity will be $\Omega(1)$.

Worst case occurs where the $T \lll n$. the case where the interval is extremely small as compared to the total duration. Here is the total duration has high impact on overall complexity and so the complexity will be $O(n/T)$. Using Akra-Bazzi's theorem we can redefine it as $O(n)$.

Average case occurs where there is perfect balance of T and n. it is always difficult to define perfect balance mathematically. Let's say when the positive waive factor β can be found which is $n = \beta * T$ the complexity will be $\theta(T)$

This method may have lower success complexities specially when the MS is not mobile and the policy updates location without actually of need. Let's say in a duration of n seconds, a MS changes its location C times and location updates was performed T times. The best case occurs when for every T duration, MS is in one unique cell out of the C. in such case $C=n/T$. but in general, it is not expected. Some MS remain paused or some MS might be having irregular mobility pattern with irregular mobility speed. This is the time we can use amortized analysis to define the overall cost. The overall cost can be defined as below. If K time location updates where triggered which is obviously equal to the T. and out of which U times we have found unique updates then the success complexity can be considered as (T/U).

So the worst case is where a MS in one cell only. No mobility at all throughout the duration and so complexity is O(T) which is Ω(T). the best case is where the Ω(T/U), logically it is not 1 but can be considered as Ω(T) or Ω(U). on an average we can define as θ(T/U) [23].

In [26] authors have presented a model in which they have compare three major strategies distance-based, movement-based and time-based using seven state Markovian mobility model. In this paper authors concluded that performance of time based location update strategy is best.

2.12.3 Movement Based Location Update Strategy

In this method, the complexities cannot be easily measured. There are no predefined thresholds or duration available. Every location update depends upon the direction by which a MS takes turns. The best case can be defined as a straight movement where there is no location update at all. In such case the complexity becomes Ω(1). To detect such situation, after a time out, location update is performed – just to identify straight movements.

The worst case occurs when every single move makes a corner and changes the cell at a time. In this case the complexity is O(n). where n is equal to number of angles as well as number of cells changed. On an average complexity can be described as θ(n) where n is the number of angles which changed cells[23].

2.12.4 Profile Based Location Update Strategy

In Profile Based Location Update scheme individual user's routine locations are recorded on timely basis. Best case occurs when a MS is used inside an organization where there is no need of mobility initiated location management. The system periodically performs location management to refresh the results. Here the complexity is Ω(1). The worst case occurs when the MS is highly mobile. The average occurs when the MS is less mobile. Let's say for a MS, the time is divided into T slots and each slot Ti has a duration di. It means in Time slot T1, Location update will be suspended for di duration. The worst case occurs if in every Ti location update performs. Here the complexity becomes O(T). the average case is difficult to estimate it all depends upon the mobility pattern inside time intervals. Amortized analysis says it is near to θ(T/2). [23].

2.13 Location Inquiry Strategies

In 2.7 to 2.10 we have seen various location update strategies. All these strategies are specific to location updates. Now, in this section, various general strategies for location inquiry (paging) will be discussed. These general strategies are applicable to most of the location update strategies discussed above.

2.13.1 Simultaneous Network wide Search

While locating the mobile terminal, simultaneously paging to all the cells within the network is the simplest and easiest technique. The major benefit here is 100% surety that the mobile object will be located if it is present in the given paging area. But on the other hand the major drawback of the same is enormous signaling traffic which is very costly for a large network.

From the above situation it is desirable that to make a limit on location inquiry (search operation) to a limited set of cells or region (i.e. Location Area - LA). At the time of Location Inquiry if a cell is paged and if it does not give any response at that time major two possibilities are there namely : (1) The mobile station is not available in the cell which was paged and (2) The mobile station is available in the paged cell but not able to receive paging signal.

If the first possibility happen at that time the base station will page the next cell in the network for searching. But if the second possibility happen at that time cells in the network must need to be paged again. Now, if the LA is fixed at that time location paging will be limited to the same LA only.

Sometimes sequential paging (or multistep paging) is more useful as compared with simultaneous paging to all the cells where the user is in. In sequential paging mechanism all the cells of the network area will be paged one after another until and unless the requires MS found. There was a problem with sequential paging that it requires more time delay in locating the MS which in turn results in degradation of QoS. Simultaneous search is required when user changes its location very frequently and the situation may arise that the MS has moved from the cell currently paging to a cell which was already paged. This creates a situation where some of the cells paged twice. However, the possibility of such situation is very rare and at that time double paging is needed.

2.13.2 Paging Area

Paging Area is a simple improvement over the strategy discussed above i.e. simultaneously paging. Here the whole network divided into various Paging Areas (PAs). Here the main benefit is Cells within each PA are paged simultaneously. Each PA can then be polled sequentially, until and unless the required mobile station is found [24]. Network operators can define the size and number of PAs that can be adjusted to accommodate any delay constraint and QoS requirements of the network.

In this Paging Area technique, various cells in the network are require to be grouped into PAs. After the grouping has been done the order of PAs query needs to be fixed. Such order deciding is time-consuming and expensive from network operator point of view. From this perspective some random assignment to PA query will be best solution for this situation. Here also one can use the probability with of user's location with the help of various models discussed above.

2.13.3 Expanding Ring Paging

Here in this technique, we assume that the mobile user will be in nearby cell of the cell in which it was found during last update procedure. In this technique, rings are created from the core part i.e. the cell in which the user found. Outside the ring 0, by covering all the surrounding to that cell a new ring created which is known as ring 1,2, and so on. Creation of this kind of "ring of cell" will continue until the required MS is found. This ring of cells can be illustrated for a typical hexagonal configuration network in below Fig. 2.20.

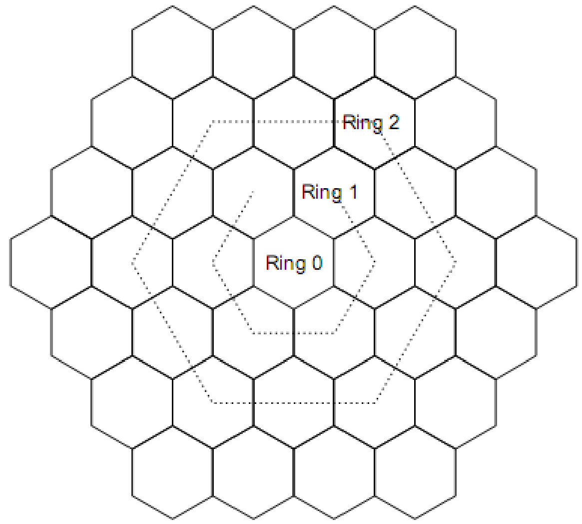

Figure 2.20 : Ring Paging Network

This technique seen as an improved version of PA scheme which we have discussed in 2.13.2. With the help of this technique Page Area planning which consumes a lot of time can be avoided. The major drawback for this technique is the ring creation is totally based on the complexity and the size of the network because number of rings to be created are always depend on size of network as well as the movement of the MS.

Again we can use network wide search technique if the user was not found within the range defined by maximum paging rings.

2.13.4 Intelligent Paging

Intelligent paging is a technique where we use some intelligence in terms of how we do paging. Generally our main goal is to find the MS with less number of paging operations. For this purpose normally we page the cells in the order of location probability (the cells with highest probability will be paged first) For intelligent paging process we can consider various factors like below given list.

1. Attraction point of the user i.e. shopping centers, work place of the user or something other like this.
2. Road condition i.e. user on highway, street traffics etc.
3. Mobility pattern of the user.
4. Velocity of the user's mobility.

5. Time of the day i.e. working hour (peak hour) or off hours.
6. Day of week i.e. weekday or weekend or holiday.

Above mentioned factors are some of the examples of factors which affect the decision while using intelligent paging. These are not limited to the list given above. There may be some more factors also which affect the decision of intelligent paging.

Here, in this chapter we have discussed GSM architecture, GSM infrastructure, Location Update cost factors, Various Mobility models, Various Location Update Strategies in detail. In next chapter we will see various routing protocols in which some of them are Location Aware Routing protocols.

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CHAPTER – 3

Various Routing Protocols

3.1 Introduction to Routing Protocols

In general the routing protocols are divided into major two parts namely (1) Proactive Routing Protocols and (2) Reactive Routing Protocols. Further hybrid protocols can also build by combining both the types of protocols i.e. Hybrid Routing Protocols. The same can be summarize through following Fig. 3.1

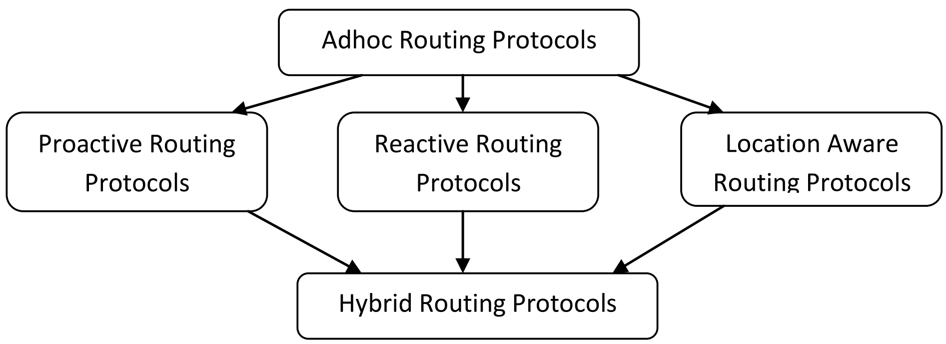


Figure 3.1 : Types of Routing Protocols

Proactive Routing protocols, Reactive Routing Protocols and Location Aware Routing Protocols both can be further divided into following which creates a family tree as shown in below Fig. 3.2.

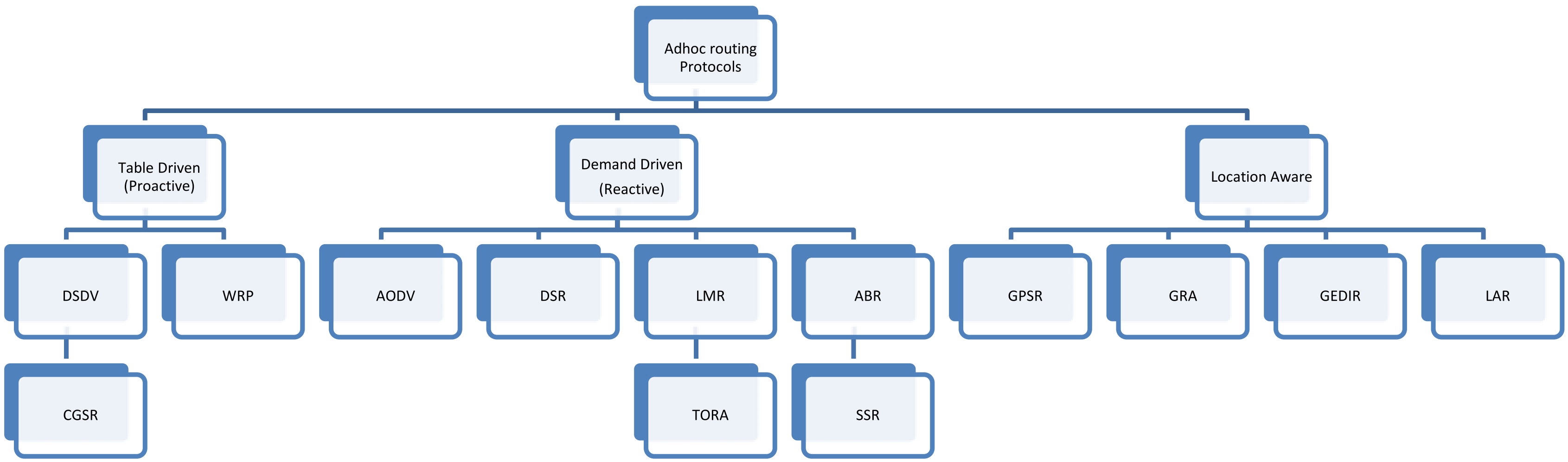


Figure 3.2 : A Family tree of routing protocols

3.1.1 Table Driven (Proactive) Routing Protocols

In Table-driven (or proactive) routing protocols each and every node has to maintain one or more number of tables which contains the routing information of all the other available nodes in the whole network. [1] Each and every node updates the table regularly so that up-to-date view of the network can be available at any time. Mostly routing tables are updated periodically when the network topology has been changed. These types of protocols are not suitable when the network size is large because they need to maintain the entry of each and every node in the routing table. [2] There are some of the well-known Table Driven Routing Protocols are there i.e. DSDV, OLSR, WRP etc.

3.1.2 Demand Driven (Reactive) Routing Protocols

In Demand Driven (or reactive) routing protocols, it takes a lazy approach for routing. The major difference between Table-driven routing protocols and Demand-driven protocols is all maintenance of up-to-date routes by all nodes is not happening. Instead of that the routes will be created as and when needed. When it is required by the source to send some information to the destination, it will apply the route discovery mechanism and find the path to the destination. The route which was decided will be valid until the destination is reachable or the route is not at all needed.

3.1.3 Location Aware Routing Protocols

GPS (Global Positioning System) is the tool which is most widely used to find out location of any mobile device. GPS is a satellite based navigation system which is available worldwide. The whole GPS system consists of total 24 satellites which are responsible for transmitting navigation messages time to time. This message consist of orbit element, status and clock from satellite. When the satellite receives a message for location, A GPS receiver can determine its roaming velocity and position. To find out receiver's longitude and latitude, it needs at least three satellites. If the user also needs to determine altitude one more satellite needed. As the number of satellites increase, it will increase the accuracy also. The GPS gives accuracy which ranges from 1 meter to tens of meters. GPS receivers can be used almost anywhere near the surface of the Earth. The major use of GPS is to find out the present physical location of the user / mobile host. The physical location of the mobile host is very much useful while improving the performance in MANETs and that is the reason that many researchers have used GPS system in MANETs. [3]

3.2 Dynamic Destination-Sequenced Distance-Vector Routing Protocol (DSDV)

DSDV[4][11] is developed by taking a base of very well known Bellman–Ford routing [5] algorithm by making some modifications. Here, every mobile station is require to maintain a routing table which has list of all the available destinations. It also maintains the number of hops which is required to reach to particular destination and also a sequence number which is assigned by the destination node. These sequence numbers are useful to differentiate various nodes so that formation of loop can be avoided. While working with network, all the stations pass its routing tables to all their neighbors. It also require to send the routing table if the change has been occurred in its table as compared to last update send. So, here the update occurs two ways (1) Time driven (After a particular period of time) and (2) Event driven (After the particular event occurrence. While sending the routing table update - the process can be carried out using two different ways i.e. (1) A full dump send - it will send the full routing table to the neighbors or (2) An incremental update - which sends only those entries from the table that has a change since last update. [6] Generally when the network becomes almost stable at that time incremental updates are sent so that extra traffic can be avoided. On the other hand if the network is a fast-changing network at that time incremental update sending becomes more so, in that case full dump is also very useful. Here, each route update packet contains a unique sequence number which is assigned by the transmitter along with routing table information. Node will select the route having label with the highest (most recent) sequence number is used. If two routes have the same sequence number at that time best route (shortest route) will be used. According to past history, all the stations will estimate the settling time of routes and find the best route for sending information.

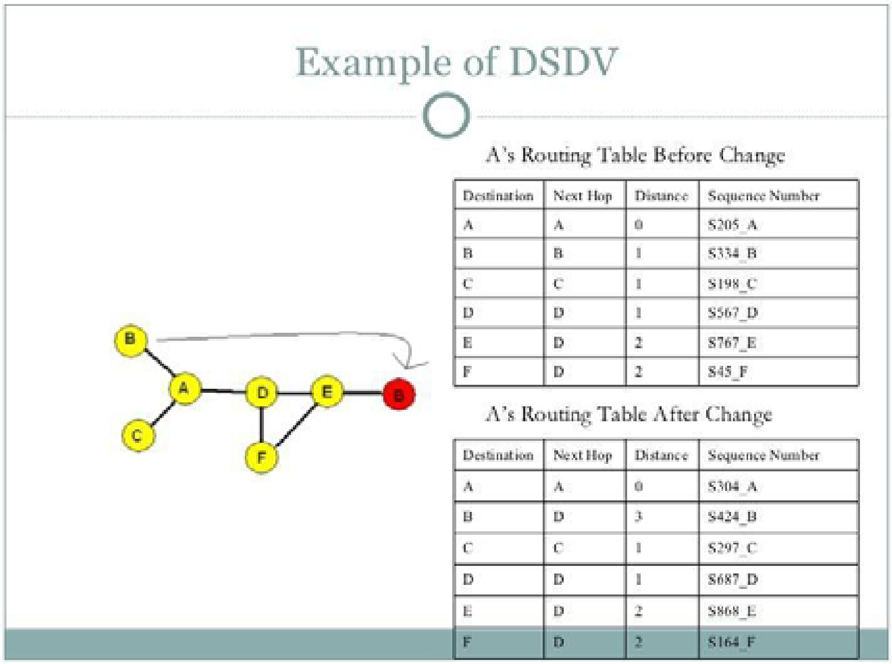


Figure 3.3 : Example of DSDV

3.3 Dynamic Source Routing Protocol (DSR)

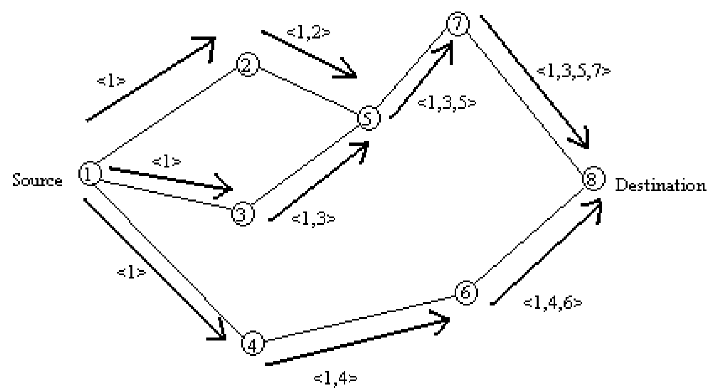
Dynamic Source Routing (DSR) is a reactive protocol which is taking source route approach as base[7][11]. Here in this Routing scheme node always maintain a route cache which contains the source routes that it is aware of. It is the routine for the node to update entries in the route cache when a new route has been found.

Here the protocol works on two major phases namely : route discovery and route maintenance. When the source wants send data to destination at that time the source will check for route cache to find out whether it contains any specific route available from source to destination, if yes then it will use that route to send the required information. On the other hand if the source node does not find any such route at that time it will start the route discovery process by sending a route request packet. This packet contains address of both source and destination and a unique identification number. Now, all the intermediate node will check for available route to destination. If that node does not find any information about that route it will add its own address and forward the same to its neighbors. Counter check has been kept here in form of a flag like if the node found its address in the packet, it will not add its own address in the packet.

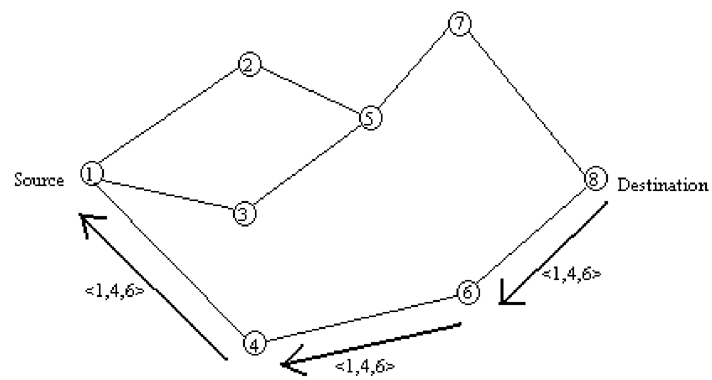
A reply will be generated when either a destination itself or any other intermediate node having information about the destination will be received in the route request packet. When the route request packet will reach to such a node, the sequence of hops will be taken from the source to this node.

Now the route request packet has collected the information through the whole network and the route record has been formed which is shown in Fig. 3.4(a). Here, if the reply has been generated from the destination itself at that time it places the route record from request packet to reply packet. But if any other node is generating the route reply through intermediate node at that time it will add its cached route to the destination in the route reply packet. In Fig. 3.4(b) it shows the route reply packet which has been sent by the destination itself.

DSR Protocol mainly maintains two types of packets namely (1) Route Error packet and (2) Acknowledgement packet. When a node found a problem of fatal transmission at a data link layer, it will generate Route Error Packet. When this situation happens it will remove the hop in error from its route cache. Acknowledge packets are useful to verify whether the correct operation has been carried out or not.



(a) Building Record Route during Route Discovery



(b) Propogation of Route Reply with the Route Record

Figure 3.4 : Example of DSR

3.4 Adhoc On Demand Distance Vector (AODV)

Adhoc On Demand Distance Vector (AODV) [8][11] is similar to DSR and an improvement of DSDV. The major difference is AODV is reactive instead of proactive. Here the major benefit in AODV is it will minimizes the number of broadcasts by creating routes as and when needed which is totally opposed to DSDV which maintains the list of all routes.

Here in this protocol, When source needs to send data to destination, for that purpose it need to find path from source to destination. For this purpose it broadcasts a route request packet. The neighbors to the source will send the same packet to all their neighbors until the packet reaches to the node which knows about route of destination or to the node which works as a destination (as shown in Fig. 3.5(a)). Here also the counter check has been maintain to make the routes loop free by using a sequence numbers for all nodes.

When a node transfer a route request packet to its neighbors, it notes one most important information i.e. node from which the first copy of the request came. This information will be useful when it needs to create a reverse path for the route reply. When the route reply packet transfer back to the source (as shown in Fig. 3.5 (b)), all the nodes which forms the path will forward the route into their tables.

Now, the situation arise when source moves from its original location to some new location at that time it will initiate the route discovery process for the destination. In another situation when any intermediate node moves from its position at that time it will send a link failure notification to all its neighbors and so on until the whole network gets settle and the destination path finalize.

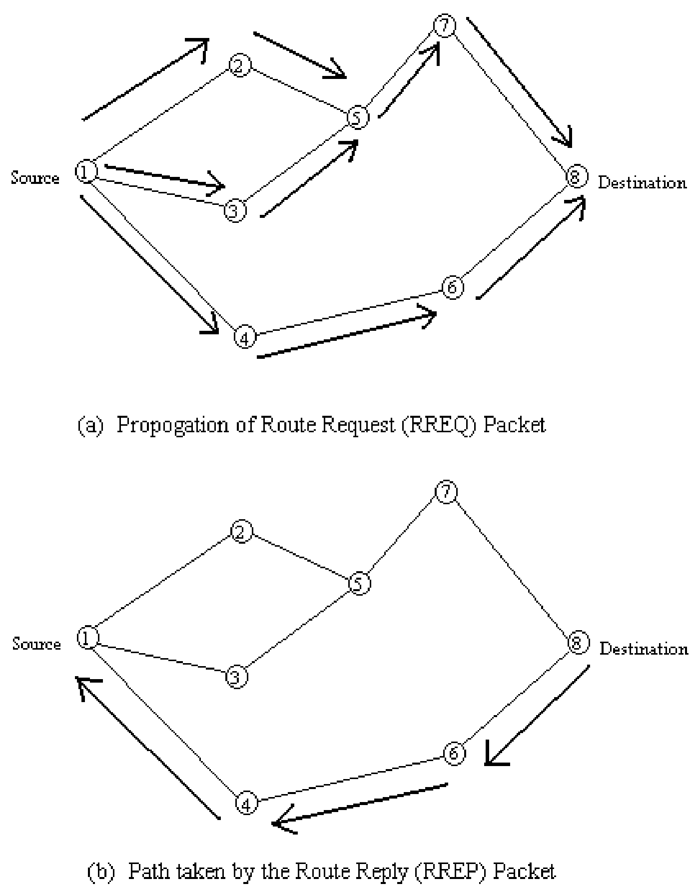


Figure 3.5 : Route Discovery in AODV

3.5 Temporally Ordered Routing Algorithm (TORA)

Temporally Ordered Routing Algorithm (TORA) [11] is an adaptive, infinite loop-free and distributed routing scheme for wireless networks where multi-hop communication is needed. TORA is based on decoupling of control messages communication from the dynamic topology of the network. TORA is specially proposed for Highly dynamic, highly mobile and multi-hop wireless networks. It is a source-initiated on-demand routing protocol. During the process, it finds various routes from the source to destination node. The most important feature of TORA is localization of the control messages to a very small set of mobile station nodes which are very nearer to the occurrence of topological change. To achieve this feature, all the nodes require to maintain routing information about all the adjacent nodes. The protocol has define three basic and most important functions which are as under :

1. Route Creation
2. Route Maintenance and
3. Route Erasure.

In this protocol route creation has been done in two steps i.e. using QRY (Query) and UPD (Update) packets. In first step the route creation algorithm will start with the height (propagation ordering parameter in the quintuple) through destination which sets to 0 at initial level and all other node's height will be set to NULL or undefined. Now, the source node will broadcast a QRY packet by mentioning destination node's ID in it. A node with non-NULL value as height will responds with UPD packet and with its height. A node which receives a UPD packet will set its height to one value plus then that of node which has generated the UPD. The whole process will continue and a node with higher height will be considered to be upstream and node with lower height will be considered downstream. Through this process a directed acyclic graph has been constructed from source to destination. Figure 6 illustrates a route creation process in TORA. As shown in figure 6, node 5 does not propagate QRY from node 3 as it has already seen and propagated QRY message from node 2.

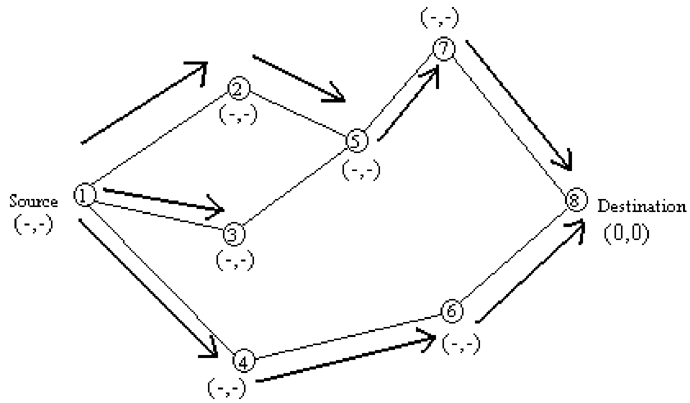


Figure 3.6 : Propagation of QRY

3.6 Greedy Perimeter Stateless Routing (GPSR)

The Greedy Perimeter Stateless Routing (GPSR) protocol having main feature is it assumes that each mobile host knows all its neighbors' locations (with direct links). The location of the destination host is also assumed to be known in advance. When the sender wants to send data to destination, in GPSR protocol it does not require to discover a route prior to sending the packets. The sender can directly forward a packet based on the location information already available. GPSR uses two forwarding methods namely : Greedy Forwarding and Perimeter Forwarding. [9][10]

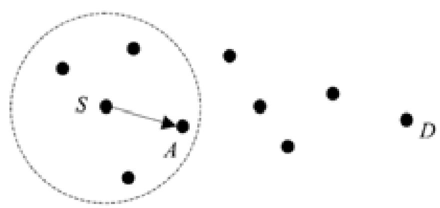


Figure 3.7 : Greedy Approach

Fig 3.7 Shows an example of greedy forwarding. When host S needs to send a packet to host D, it picks from its neighbors one host that is closest to the destination host and then forwards the packet to it. In this example, host A is the closest one. After receiving the packet, host A follows the same greedy forwarding procedure to find the next hop. This is repeatedly used until host D or a local maximum host is reached.

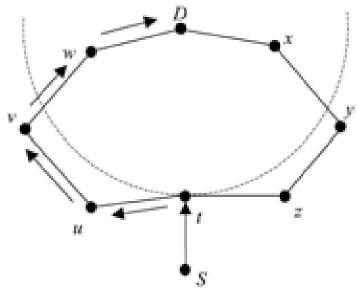


Figure 3.8 : Perimeter forwarding approach

A local maximum host is one that finds no other hosts that are closer to D than itself. In the example in Fig. 4, host t is a local maximum because all its neighbors are farther from D than itself. Therefore, the greedy forwarding method will not work here. When this happens, the perimeter forwarding method is used to forward the packet. The perimeter forwarding method works as follows. The local maximum host first "planarizes" the graph representing the network topology. A graph is said to be planar if no two edges cross. The graph may be transformed into a relative neighborhood graph (RNG) or a Gabriel graph (GG). Both RNG and GG are planar graphs. After the graph is planarized, the local maximum host can forward the packet according to a right-hand rule to guide the packet along the perimeter of a plane counter clockwise. For example, in Fig. 8 at t , we can forward the packet along the perimeter of the plane dxyztuvw counterclockwise. As the packet is forwarded to host w, we know that we are closer to D (as opposed to the location of host t). Then the greedy forwarding method can be applied again, and the packet will reach destination D. Overall, these two methods are used interchangeably until the destination is reached. The GPSR is a stateless routing protocol since it does not need to maintain any routing table.

3.7 Geographical Routing Algorithm (GRA)

The Geographical Routing Algorithm (GRA)[10] is also derived based on location information. To send or forward a packet, a host first checks route entries in its routing table. If there is one, the packet is forwarded according to the entry. Otherwise, a greedy approach is taken, which will try to send the packet to the host closest to the destination. If the packet runs in to a local maximum host, GRA will initiate a route discovery procedure to discover a route from the host to the destination. This is done by flooding. After the route reply comes back, the route entry will be stored in the host's routing table to use in future.

3.8 Geographic Distance Routing (GEDIR)

The geographic distance routing (GEDIR) [10] protocol assumes that each host has the locations of its direct neighbors. Similar to GPSR, the GEDIR protocol also directly forwards packets to next hops without establishing routes in advance. There are two packet-forwarding policies: distance approach and direction approach. In the distance approach, the packet is forwarded to the neighbor whose distance is nearest to the destination. However, in the direction approach, the packet is forwarded to the neighbor whose direction is closest to the destination's direction. The latter can be formulated by the angle formed by the vector from the current host to the destination and to the next hop.

3.9 Location Aided Routing (LAR)

The location-aided routing (LAR) [10] protocol assumes that the source host (denoted as S) knows the recent location and roaming speed of the destination host (denoted as D). Suppose that S obtains D's location, denoted as (Xd, Yd), and speed, denoted as v, at time t0 and that the current time is t1 . We can define the expected zone in which host D may be located at time t1 (refer to the circle in Fig. 3.9). The radius of the expected zone is R = v(t1 – t0). From the expected zone, we can define the request zone to be the shaded rectangle as shown in Fig. 9 (surrounded by corners S, A, B, and C). The LAR protocol basically uses restricted flooding to discover routes. That is, only hosts in the request zone will help forward route-searching packets. Thus, the searching cost can be decreased. When S initiates the route-searching packet, it should include the coordinates of the request zone in the packet. A receiving host simply needs to compare its own location to the request zone to decide whether or not to rebroadcast the route-searching packet. After D receives the route-searching packet, it sends a route reply packet to S. When S receives the reply, the route is established. If the route cannot be discovered in a suitable timeout period, S can initiate a new route disco very with an expanded request zone. The expanded request zone should be larger than the previous request zone. In the extreme case, it can be set as the entire network. Since the expanded request zone is larger, the probability of discovering a route is increased with a gradually increasing cost.

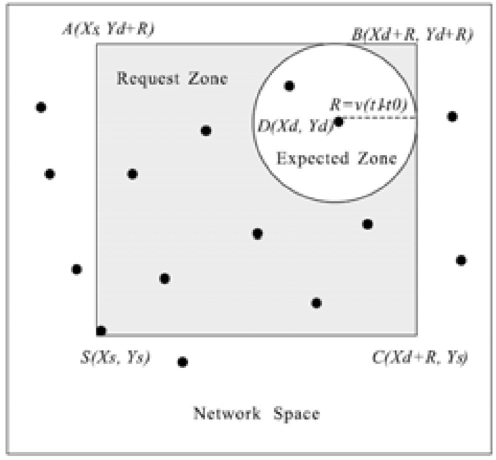


Figure 3.9 : LAR

Here in this chapter we have studied various routing algorithms, specially routing algorithms related to Location Awareness. The following chapter is based on selection of Simulation tool and various scenarios created in the tool.

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CHAPTER – 4

Scenarios

4.1 Introduction

This research work has been carried out using simulation approach. Various networking simulators are available like NS2, NS3, Opnet, Omnet++, NetSim, Jsim, Qualnet etc. Every simulator provides facilities to implement specific types of computer networks. This research work requires implementation of location management in cellular network. Qualnet provides best support as far as implementation of location management in cellular networks is concerned. Qualnet is more realistic in cellular networks with provision to modify API of GSM Architecture. Various location update strategies are also analyzed through analytical modelling to identify the best method complexity wise. Various network simulators are compared as below.

Table 4.1 : Comparison between various network simulators

Features	NS2	NS3	JSIM	OMnet++	OPNET	Qualnet
Language	C++ / OTCL	C++ / Python	Java, TCL	C++	C / C++	C++
GUI Support	Poor	Good	Good	Good	Excellent	Excellent
Learning Period	Long	Moderate	Moderate	Moderate	Long	Very Easy
Download and installation time	Moderate	Long time to download	Easy to download and install	Very Easy	Moderate Time	Very Easy
Platform	Unix / Linux / Windows	Unix / Linux / Windows	Linux / Windows	Linux / Windows / MAC	Linux / Windows / Solaris	Linux / Windows
Supports Network Visualization tool	Yes	Yes	Yes	Yes	Yes	Yes
Availability of analysis tool	Yes	Yes	Yes	Yes	Yes	Yes
Creates trace file	Yes	Yes	Yes	Yes	Yes	Yes
Possibility to create and modify network scenarios	Yes	Yes	Yes	Yes	Yes	Yes
Design and Implementation of Protocols	Yes	Yes	Yes	Yes	Yes	Yes

Interaction with real time system	Possible	Possible	Possible	Possible	Possible	Possible
Fast simulation capabilities	Moderate	Moderate	Poor	Moderate	Excellent	Excellent
Merits	- Easy to add new protocols. - A large number of protocols available publicly.	- NS-3 is not an extension of NS-2 - it is a new simulator. - NS-3 is open-source - Support for virtualization	-Provides support for energy modelling, with the exception of radio energy consumption - Support mobile wireless networks and sensor networks. - Component oriented architecture	- Powerful graphical User Interface (making tracing and bugging easier) - Simulate power Consumption problem	- Possible to communicates with other simulators - Fast discrete event simulation engine - Scalable wireless simulation support	- Powerful graphical User Interface - It shows a very good scalability, simulation time being reasonable. - Qualnet can support real-time speed to enable software-in-the loop, network emulation, and hardware-in-the-loop modelling

Demerits	- Supports only two wireless MAC protocols, 802.11, and a single-hop TDMA protocol. - Need to familiar with writing scripting language	- Python bindings do not work on Cygwin. - Only IPv4 is supported.	- Low efficiency of simulation. - The only MAC protocol provided for wireless networks is 802.11. - Unnecessary run-time overhead	- Number of protocol is not large enough. - Compatibility problem (not portable) - OMNeT++ is a bit slow due to its long simulation run and high memory consumption	- It is commercial product - Memory consuming models - Insufficient tutorials	- Qualnet is a Commercial Product - Difficult installation on Linux.

4.2 Introduction to Qualnet®

Scalable Network Technologies (SNT) have developed a communication simulation platform (QualNet®) which is useful tool for planning, testing and training the behaviour of a real life communication networks. In real world simulation tools are cost effective method for developing, deploying and managing the systems. Mostly in networking world it is quite difficult to test each and everything at real level. Here, the simulations gives facilitates user to evaluate basic behaviour of the network and also allows to test combinations of various features of network. Qualnet® gives us facility to design protocol, create scenarios and also allows to analyze the performance of the network.

This research work uses QualNet®'s built in mechanisms to simulate cellular networks – To establish scenarios with MS, BTS, BSC and MSC. Qualnet® has C++ based API to implement GSM architecture and related mechanisms. Location update strategies implemented with this API is used to achieve other objectives.

The QualNet® analyzes various parameters and represents in graphical forms. Here in this research work, number of location updates made at MS, BTS, BSC are important. The built-in graphical analyzer is used to evaluate various parameters.

Currently following companies are using Qualnet® for their Commercial purpose :

Figure 4.1 : Companies using Qualnet® worldwide

4.3 Features of Qualnet®

Various features of Qualent® includes the following :

- It is based on very well known language C++
- Provides very good help - online as well as offline
- Available in commercial / educational license mode
- Simulation possible for large scale networks also
- Simulation learning is very easy and less time consuming
- It is an improved version of Glomosim which was initially developed by the same company in the year 2000.
- Excellent mobility support
- Excellent GUI compared to all other simulators

4.4 Cellular Library models available in Qualnet® 7.4

4.4.1 Abstract Cellular Model

In the Abstract Cellular Model, a single base station serves a circular service area that is divided into multiple sectors, each of which is allocated with a certain amount of bandwidth. For each base station, several control channels are defined. A large number of base stations cover the simulated area and they are connected to a hub, the switch centre, with wired links. The hub routes the control and data messages to/from the base stations. An aggregated node emulates the services originated or destined to nodes outside the simulated area. A gateway connects to all the BSs and the aggregated node. With help from HLR, the gateway routes the information flows between MSs or between MS and the aggregated node.

4.4.2 Global System for Mobile Communication (GSM) Model :

The GSM model in QualNet® models the behaviour of Mobile Stations (MSs), Base Stations (BSs), and Mobile Switching Centres (MSCs), and the “Um” (BS-to-MS) and “A” (BS-to-MSC) interfaces. The MSs can be located anywhere and can be mobile. The BSs and MSC are stationary. The GSM model allows multiple MSs, multiple BSs, and a single MSC in any scenario. Each BS is connected to the MSC by a wired point-to-point link.

Various features for GSM model in qualnet are as follows :

- Configuration of MSC, multiple Base Stations, and multiple Mobile Stations
- Standard band is supported (900 MHz Mobile Stations and Base Stations)
- Cell selection and re-selection
- Dynamic channel assignment and release
- Location update
- Call setup and tear-down
- Handover (intra-MSC and inter-cell/Base Station).

Configuration Steps :

1. Configuration of UM Interface (MS-BS)
   a. To configure the Um Interface, define the radio channels and channel allocation used in the simulation and specify the GSM-related Physical layer properties.
   b. uplink channels (MS transmitting, BS receiving) should be in the frequency range 890 - 915 MHz and downlink channels (BS transmitting, MS receiving) should be in the frequency range 935 - 960 MHz. Each uplink/downlink channel pair is assigned frequencies as follows:-
      i. Downlink Frequency = (890 + 0.2 n) MHz, $0 < n < 124$
      ii. Uplink Frequency = Downlink Frequency + 45 MHz
2. Configuring the A interface (BS-MSC)
   a. Each BS is connected to the MSC by a wired point-to-point link. In a GSM scenario, routing should be configured to allow packets to be transferred between a BS and MSC over the point-to-point link connecting them. This can be done by means of static routes or any suitable wired routing protocol (such as Bellman Ford).
3. Topology Configuration :
   a. The details of the scenario topology need to be specified. This is done in the GSM Configuration file. For each BS, the GSM Configuration file specifies its Location Area Code (LAC), the channels assigned to it, the ID of the MSC, and information about the neighbour BSs. For each MSC, the GSM Configuration file specifies the BSs connected to it.

4. Enabling GSM model :
    a. To enable the GSM model at a node, include the following parameter in the scenario configuration (.config) file:
    b. [<Qualifier>] NETWORK-PROTOCOL GSM-LAYER3
5. Format of GSM node configuration file :
    a. Defines properties of mobile stations, base stations, and mobile switching centres.
    b. The GSM node configuration file can have three types of entries: -
        i. GSM Mobile Station Specification
        ii. GSM Base Station Specification
        iii. GSM Mobile Switching Center
    c. GSM Mobile Station Specification
        i. GSM-MS <NodeId>
    d. GSM Base Station Specification
        i. GSM-BS <Node ID> <LAC> <Cell ID> <Channel Range> <MSC Node ID> <Neighbor BS Info>
    e. GSM Mobile Switching Center Specification
        i. GSM-MSC <Node ID> <Linked BS Info>

Table 4.2 : Various Parameters related to GSM

Parameter	Value	Description
GSM-NODE-TYPE *Required* *Scope:* All	List: • GSM-MS • GSM-BS • GSM-MSC	GSM node type. GSM-MS: Mobile Station (MS) GSM-BS: Base Station (BS) GSM-MSC: Mobile Switching Center (MSC)
GSM-HANDOVER-MARGIN *Optional* *Scope:* All	Real *Unit:* dBm *Default:* 0.0	Handover margin. This handover margin is used for selecting the target BS to perform handover. When selecting the neighbor BS to perform handover, a BS considers only those neighbor BSs with RSS larger than both the handover margin and the RSS of the current serving BS. **Note:** This parameter is used only if GSM NODE- TYPEis set to GSM-BS.

GSM-CONTROL-CHANNEL *Optional* *Scope:* All	String (see note)	Downlink control channel (broadcast channel;) assigned to a BS. This parameter is specified as a channel index or channel name enclosed in [and]. *Example*: [2] GSM-CONTROL-CHANNEL [0] **Note:** This parameter is required if GSM-NODE- TYPEis set to GSM-BS.
GSM-CONTROL-CHANNEL-LIST Optional Scope: All	String (see note)	Control channels used by MSs. This parameter is specified as a space-separated list of channel indices or channel names enclosed in [and]. Example: [3] GSM-CONTROL-CHANNEL-LIST [0 4] This list consists of all broadcast channels (because each MS can potentially listen to all broadcast channels). **Note:** This parameter is required if GSM-NODE- TYPE is set to GSM-MS.
MAC-PROTOCOL Optional Scope: All	List: • GSM	MAC protocol used at the interface. **Note:** This parameter must be specified for each Um interface.
PHY-MODEL Optional Scope: All	List: • PHY-GSM	Radio model used at the interface. **Note:** This parameter must be specified for each Um interface.
PHY-GSM-DATA-RATE Optional Scope: All	Integer Unit: bps Default: 270833	Data transmission rate. **Note:** This parameter is applicable only to each Um interface.
PHY-GSM-TX-POWER Optional Scope: All	Real Unit: dBm Default: 15.0	Radio's transmission power. **Note:** This parameter is applicable only to each Um interface.
PHY-GSM-RX-SENSITIVITY Optional Scope: All	Real Unit: dBm Default: -91.0	Reception sensitivity for the radio. **Note:** This parameter is applicable only to each Um interface.

PHY-GSM-RX-THRESHOLD Optional Scope: All	Real Unit: dBm Default: -92.0	Minimum reception threshold to accept a packet. **Note:** This parameter is applicable only to each Um interface.
PHY-RX-MODEL Required Scope: All	List: • BER-BASED	Packet reception model. Refer to Wireless Model Library for details of the BER-based reception model. **Note:** This parameter must be specified for each BS and MS.
GSM-NODE-CONFIG-FILE Required Scope: Global	Filename	Name of the GSM Configuration file. The GSM Configuration file describes the GSM configuration parameters for each node. The format of the GSM Configuration file is described in Section 3.4.1.1.
GSM-STATISTICS Optional Scope: Global, Node	List: • YES • NO Default: NO	Enables GSM statistics.

Table 4.3 : GSM Call Parameters

Parameter	Value	Description
<Source> *Required*	Integer *Range:* ≥ 0	Node ID of the calling node. The calling node should be a mobile station.
<Destination> *Required*	Integer *Range:* ≥ 0	Node ID of the called node. The called node should be a mobile station.
<Start Time> *Required*	Time *Range:* > 0S	Start time of the call.
<Duration> *Required*	Time *Range:* > 0S	Duration of the call.

Table 4.4 : GSM Call Scenario Configuration File Parameters

Parameter	Value	Description
APPLICATION-STATISTICS *Optional* *Scope:* Global, Node	List: • YES • NO *Default:* YES	Indicates whether statistics collection is enabled for applications (including the GSM Call application). **Note:** To collect statistics for the GSM Call application set either APPLICATION- STATISTICS or CELLULAR-STATISTICS or both to YES.
CELLULAR-STATISTICS *Optional* *Scope:* Global, Node	List: • YES • NO *Default:* YES	Indicates whether statistics collection is enabled for abstract cellular models including the GSM Call application). **Note:** To collect statistics for the GSM Call application set either APPLICATION- STATISTICS or CELLULAR-STATISTICS or both to YES.

4.4.3 Statistics available for GSM Layer - 3 :

Following tables from 4.5 to 4.9 defines various statistics available while running the scenario using GSM Layer - 3. These all statistics given here are specially useful for calculating various parameters related to location updates. From these statistics Qualnet® analyzer creates graphs.

Table 4.5 : GSM Layer 3 Statistics - Mobile Station (MS)

Statistic	Description
Traffic Packets Sent	Total number of traffic packets sent to BS.
Traffic Packets Received	Total number of traffic packets received from BS.
Channel Request Sent	Total number of times channel requests sent to BS.
Channel Request Attempts Failed	Total number of times channel requests attempts failed.

Channel Assignments Received	Total number of times channel assignments received from BS.
Channel Release Received	Total number of times channel release packets received from BS.
Location Update Request Sent	Total number of times location updates request packets sent to BS.
Location Update Accept Received	Total number of times location updates accept packets received from BS.
Calls Initiated	Total number of calls initiated on MS.
Calls Received	Total number of calls received from other MS.
Calls Connected	Total number of calls connected on MS.
Calls Completed	Total number of calls completed on MS.
Handovers Performed	Total number of times handovers performed on MS.

Table 4.6 : GSM Layer 3 Statistics - Base Station (BS)

Statistic	Description
Traffic packets (On Air) Sent	Total number of traffic packets sent to air interference.
Traffic packets (On Air) Received	Total number of traffic packets received from air interference
Channel Requests Received	Total number of times channel requests received form MSs.
Channel Assignment Attempts Failed	Total number of times channel assignment attempts failed.
Channels Assigned	Total number of times channel assigned to MSs.
Channels Released	Total number of times channel released on BS.

Channels Not Seized (T3101 Expirations)	Total number of times channel seized due to timer T3101 expiration.
Paging Request Sent	Total number of paging requests sent on air interference.
Location Update Received	Total number of times location updated packets received from MSs.
Measurement Report Received	Total number of times channel measurement reports received from MSs.
Handovers Completed (Incoming MS).	Total number of times handover completed on incoming MSs.
Handovers Attempted (Outgoing MS)	Total number of times handover attempts packets received from MSs.
Handovers Completed (Outgoing MS)	Total number of handover completed on MSs.
Handovers Failed (Outgoing MS)	Total number of times handover requests failed.

Table 4.7 : GSM Layer 3 Statistics - Mobile Switching Center (MSC)

Statistic	Description
Location Update Request Received	Total number of times location update requests received from BSs.
Calls Requested	Total number of times calls initiation requests received.
Calls Connected	Total number of calls connected.
Calls Completed	Total number of calls completed successfully.
Handover Required Received	Total number of handover required messages received from BSs.
Handovers Completed	Total number of handover completed successfully.

Handovers Failed	Total number of times handover requests failed
Traffic Packets Transferred	Total number of traffic packets transferred.

Table 4.8 : MAC Layer Statistics - Mobile Station (MS)

Statistic	Description
Cell Selections	Total number of times MS selected cell.
Cell Selection Failures	Total number of times MS failed to select any cell.
Cell Reselection Attempts	Total number of times MS tried to reselect another cell.

Table 4.9 : Physical Layer Statistics

Statistic	Description
Signals transmitted	Total number of signals transmitted on physical layer.
Signals received and forwarded to MAC	Total number of signals received from the physical layer and forwarded to the MAC layer.

4.5 Various Scenarios Created using Qualnet® :

To implement two algorithms proposed in following chapter we have created various scenarios using Qualnet®.

4.5.1 Scenario - 1 (Walking Mobility) :

In this first and basic scenario - I have taken walking mobility of the user. Here in below given scenario there is one MSC (node no. 16), 6 BSC (node nos. 1 to 6) and 9 MS (node nos. 7 to 15). Total duration for the scenario is 315 seconds.

There is GSM call between node 7 to node 11. The call has been started after 10 seconds and the call duration is 300 seconds. Here I have assumed that person who is carrying MS7 is moving straight direction for 500 meters. The location distance parameters for node 7 has been shown in following table :

Table 4.10 : Scenario - 1 Mobility table for Node - 7

Sr. No.	Simulation Time	X	Y
1	0 Seconds	728.51351350777	1290.46778408764
2	300 Seconds	728.51351350777	790.46778408764

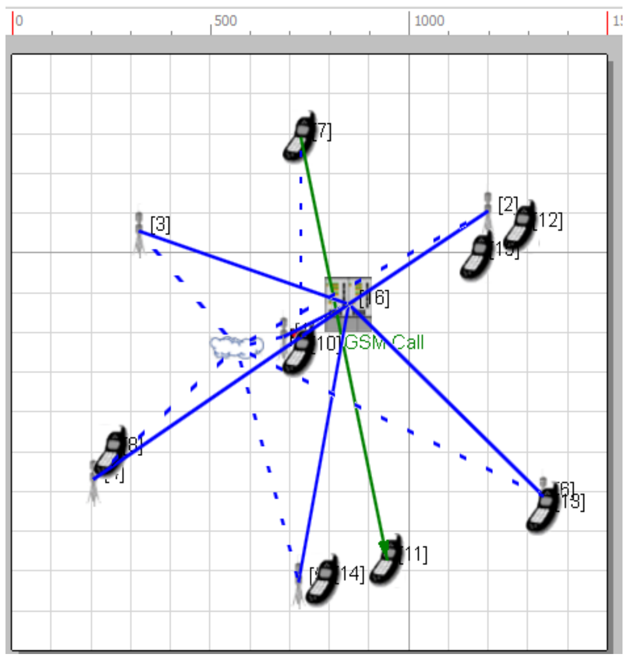

Figure 4.2 : Scenario - 1

4.5.2 Scenario - 2 (Walking Mobility) :

In this second scenario - I have taken walking mobility of the user. Here in below given scenario there is one MSC (node no. 16), 6 BSC (node nos. 1 to 6) and 9 MS (node nos. 7 to 15). Total duration for the scenario is 315 seconds.

There is GSM call between node 7 to node 11. The call has been started after 10 seconds and the call duration is 300 seconds. Here I have assumed that person who is carrying MS7 is moving first right and then down to MS11 direction for total 1088 meters. The location distance parameters for node 7 has been shown in following table :

Table 4.11 : Scenario - 2 Mobility table for Node - 7

Sr. No.	Simulation Time	X	Y
1	0 Seconds	728.51351350777	1290.46778408764
2	150 Seconds	1279.37403663235	1294.6563570842
3	300 Seconds	1293.28122311169	757.838924825534

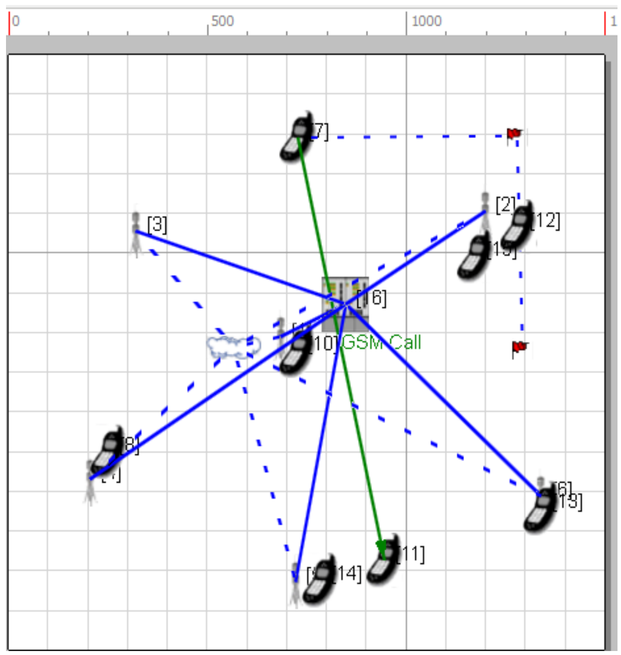

Figure 4.3 : Scenario - 2

4.5.3 Scenario - 3 (Walking Mobility) :

In this third scenario - I have taken walking mobility of the user. Here in below given scenario there is one MSC (node no. 16), 6 BSC (node nos. 1 to 6) and 9 MS (node nos. 7 to 15). Total duration for the scenario is 315 seconds.

There is GSM call between node 7 to node 11. The call has been started after 10 seconds and the call duration is 300 seconds. Here I have assumed that person who is carrying MS7 is moving first left and then down to MS11 direction for total 1101 meters. The location distance parameters for node 7 has been shown in following table :

Table 4.12 : Scenario - 3 Mobility table for Node - 7

Sr. No.	Simulation Time	X	Y
1	0 Seconds	728.51351350777	1290.46778408764
2	150 Seconds	238.886621248788	1293.93860714477
3	300 Seconds	234.642413383839	682.77272992836

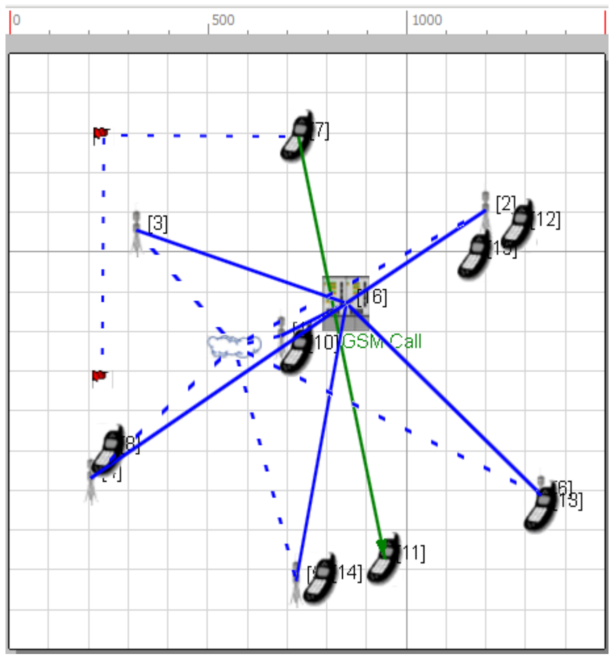

Figure 4.4 : Scenario - 3

4.5.4 Scenario - 4 (Driving Mobility) :

In this forth scenario - I have taken Driving mobility of the user. Here in below given scenario there is one MSC (node no. 16), 6 BSC (node nos. 1 to 6) and 9 MS (node nos. 7 to 15). Total duration for the scenario is 315 seconds.

There is GSM call between node 7 to node 11. The call has been started after 10 seconds and the call duration is 300 seconds. Here I have assumed that person who is carrying MS7 is moving straight to MS11 direction for total 1001 meters. The location distance parameters for node 7 has been shown in following table :

Table 4.13 : Scenario - 4 Mobility table for Node - 7

Sr. No.	Simulation Time	X	Y
1	0 Seconds	728.51351350777	1290.46778408764
2	300 Seconds	969.82329606951	318.617456737387

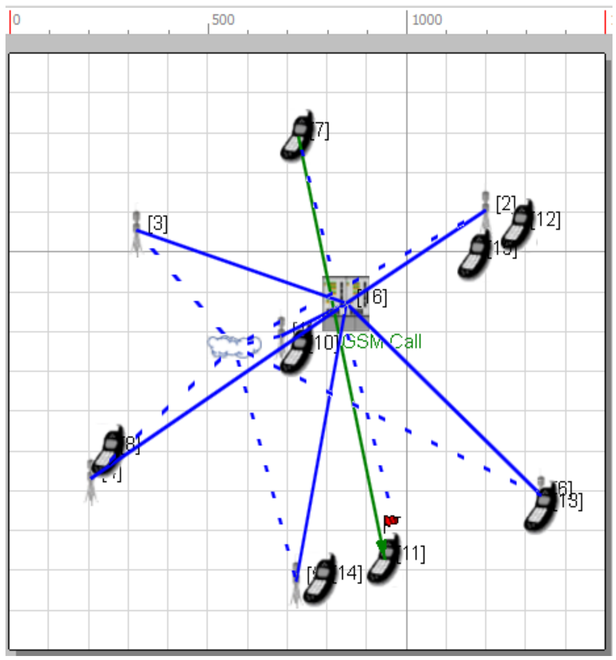

Figure 4.5 : Scenario - 4

4.5.5 Scenario - 5 (Driving Mobility) :

In this fifth scenario - I have taken Driving mobility of the user. Here in below given scenario there is one MSC (node no. 16), 6 BSC (node nos. 1 to 6) and 9 MS (node nos. 7 to 15). Total duration for the scenario is 315 seconds.

There is GSM call between node 7 to node 11. The call has been started after 10 seconds and the call duration is 300 seconds. Here I have assumed that person who is carrying MS7 is moving right side then down side and then towards MS11 direction for total 2039 meters. The location distance parameters for node 7 has been shown in following table :

Table 4.14 : Scenario - 5 Mobility table for Node - 7

Sr. No.	Simulation Time	X	Y
1	0 Seconds	728.51351350777	1290.46778408764
2	100 Seconds	1359.88568608759	1300.38462416264
3	200 Seconds	1383.02498041069	209.532215912358
4	300 Seconds	1068.99170031139	176.476082329016

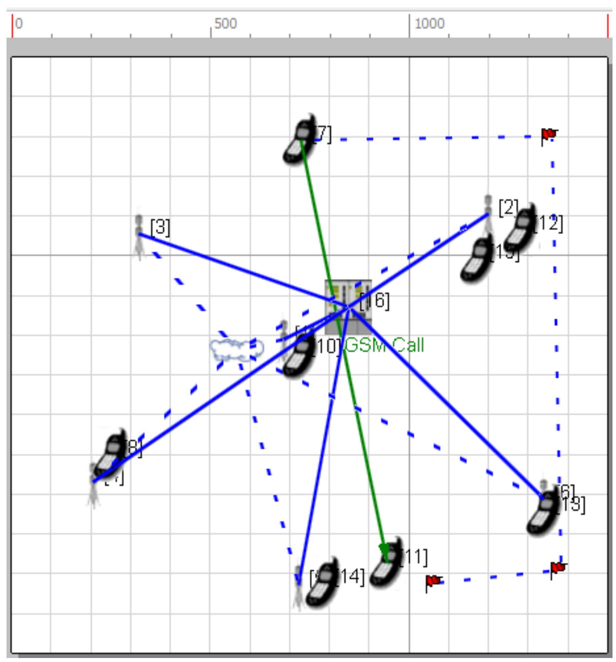

Figure 4.6 : Scenario - 5

4.5.6 Scenario - 6 (Driving Mobility) :

In this sixth scenario - I have taken Driving mobility of the user. Here in below given scenario there is one MSC (node no. 16), 6 BSC (node nos. 1 to 6) and 9 MS (node nos. 7 to 15). Total duration for the scenario is 315 seconds.

There is GSM call between node 7 to node 11. The call has been started after 10 seconds and the call duration is 300 seconds. Here I have assumed that person who is carrying MS7 is moving left side then down side and then towards MS11 direction for total 2581 meters. The location distance parameters for node 7 has been shown in following table :

Table 4.15 : Scenario - 6 Mobility table for Node - 7

Sr. No.	Simulation Time	X	Y
1	0 Seconds	728.51351350777	1290.46778408764
2	100 Seconds	159.947994760788	1283.85655737097
3	200 Seconds	163.253608235518	176.476082329016
4	300 Seconds	1068.99170031139	176.476082329016

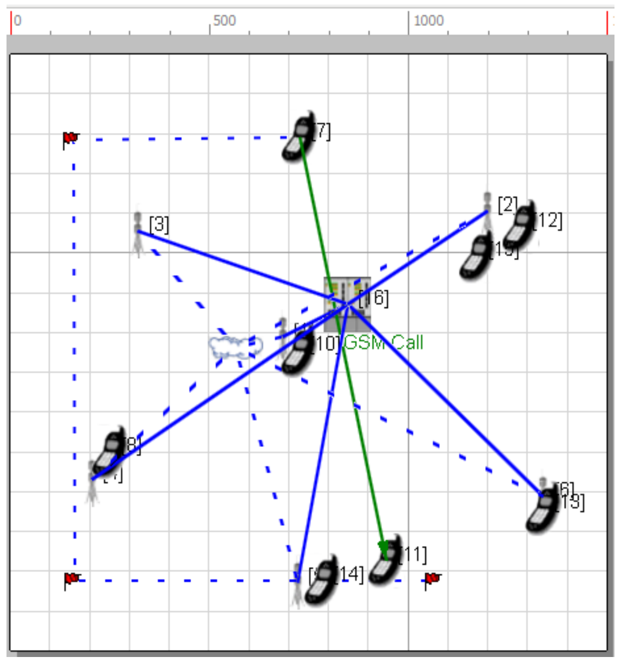

Figure 4.7 : Scenario - 6

4.5.7 Scenario - 7 (No Congestion - Low Mobility) :

In this scenario - I have taken No Congestion - Low Mobility. Here in below given scenario there is one MSC (node no. 16), 6 BSC (node nos. 1 to 6) and 9 MS (node nos. 7 to 15). Total duration for the scenario is 315 seconds.

There is GSM call between node 7 to node 11. The call has been started after 10 seconds and the call duration is 300 seconds. Here only two MS are busy i.e. MS-7 and MS-11. MS-7 moves 2898 meters in 300 seconds while MS-11 moves 3019 meters in 300 seconds. The location distance parameters for node 7 and node 11 has been shown in following two tables i.e. 4.16 and 4.17 respectively :

Table 4.16 : Scenario - 7 Mobility table for Node - 7

Sr. No.	Simulation Time	X	Y
1	0 Seconds	605.9062500912	1286.6250085586
2	100 Seconds	1334.65624962991	1230.31250766046
3	200 Seconds	1291.59374965717	143.812490331977
4	300 Seconds	211.718750340737	137.187490226315

Table 4.17 : Scenario - 7 Mobility table for Node - 11

Sr. No.	Simulation Time	X	Y
1	0 Seconds	1092.843749783	292.8749927094
2	100 Seconds	178.593750361705	246.499991969729
3	200 Seconds	145.468750382673	1240.25000781895
4	300 Seconds	1255.15624968023	1270.06250829442

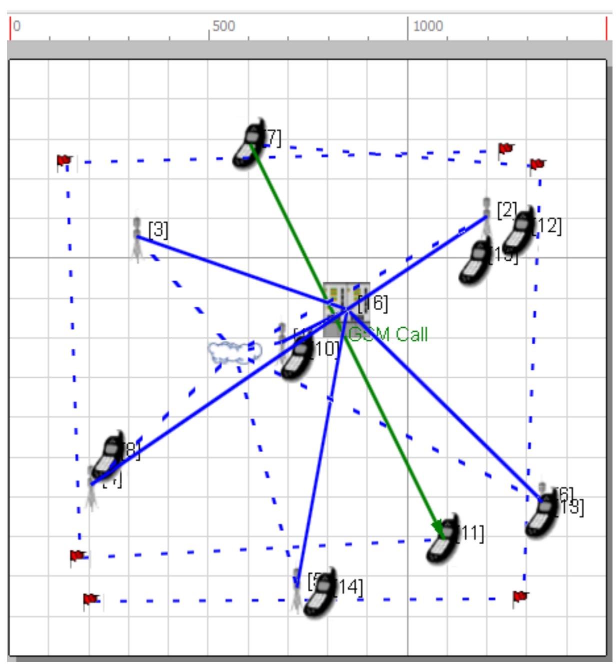

Figure 4.8 : Scenario - 7

4.5.8 Scenario - 8 (No Congestion - Moderate Mobility) :

In this scenario - I have taken No Congestion - Moderate Mobility. Here in below given scenario there is one MSC (node no. 16), 6 BSC (node nos. 1 to 6) and 9 MS (node nos. 7 to 15). Total duration for the scenario is 315 seconds.

There is GSM call between node 7 to node 11. The call has been started after 10 seconds and the call duration is 300 seconds. Here only two MS are busy i.e. MS-7 and MS-11. MS-7 moves 5439 meters in 300 seconds while MS-11 moves 5296 meters in 300 seconds. The location distance parameters for node 7 and node 11 has been shown in following two tables i.e. 4.18 and 4.19 respectively :

Table 4.18 : Scenario - 8 Mobility table for Node - 7

Sr. No.	Simulation Time	X	Y
1	0 Seconds	605.9062500912	1286.6250085586
2	60 Seconds	1334.65624962991	1230.31250766046
3	120 Seconds	1291.59374965717	143.812490331977
4	180 Seconds	211.718750340737	137.187490226315
5	240 Seconds	31.029105836911	1353.27443789599
6	300 Seconds	1343.3575885162	1349.96882453766

Table 4.19 : Scenario - 8 Mobility table for Node - 11

Sr. No.	Simulation Time	X	Y
1	0 Seconds	1092.843749783	292.8749927094
2	60 Seconds	178.593750361705	246.499991969729
3	120 Seconds	145.468750382673	1240.25000781895
4	180 Seconds	1255.15624968023	1270.06250829442
5	240 Seconds	1429.30353448513	202.92098919569
6	300 Seconds	242.588357452716	57.4740014289852

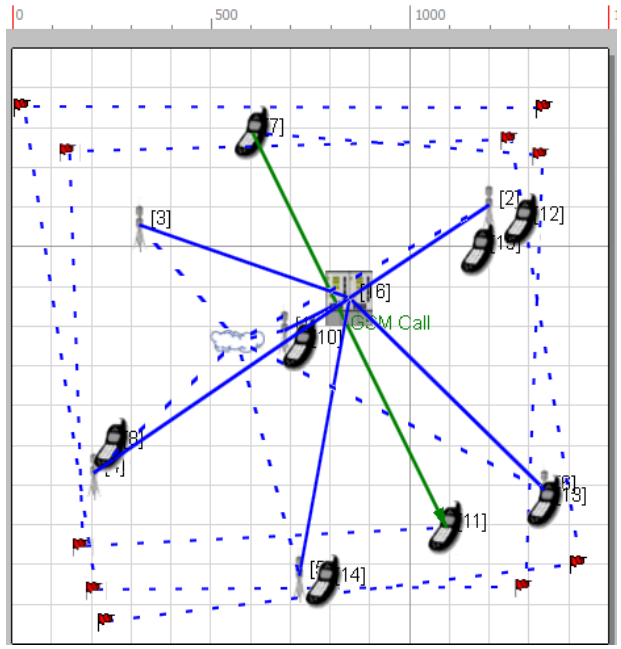

Figure 4.9 : Scenario - 8

4.5.9 Scenario - 9 (No Congestion - High Mobility) :

In this scenario - I have taken No Congestion - High Mobility. Here in below given scenario there is one MSC (node no. 16), 6 BSC (node nos. 1 to 6) and 9 MS (node nos. 7 to 15). Total duration for the scenario is 315 seconds.

There is GSM call between node 7 to node 11. The call has been started after 10 seconds and the call duration is 300 seconds. Here only two MS are busy i.e. MS-7 and MS-11. MS-7 moves 9051 meters in 300 seconds while MS-11 moves 8778 meters in 300 seconds. The location distance parameters for node 7 and node 11 has been shown in following two tables i.e. 4.20 and 4.21 respectively :

Table 4.20 : Scenario - 9 Mobility table for Node - 7

Sr. No.	Simulation Time	X	Y
1	0 Seconds	605.9062500912	1286.6250085586
2	43 Seconds	1334.65624962991	1230.31250766046
3	86 Seconds	1291.59374965717	143.812490331977
4	129 Seconds	211.718750340737	137.187490226315

5	172 Seconds	31.029105836911	1353.27443789599
6	215 Seconds	1343.3575885162	1349.96882453766
7	258 Seconds	109.720495577489	103.136635645974
8	300 Seconds	1439.65838651165	1400.15528987237

Table 4.21 : Scenario - 9 Mobility table for Node - 11

Sr. No.	Simulation Time	X	Y
1	0 Seconds	1092.843749783	292.8749927094
2	43 Seconds	178.593750361705	246.499991969729
3	86 Seconds	145.468750382673	1240.25000781895
4	129 Seconds	1255.15624968023	1270.06250829442
5	172 Seconds	1429.30353448513	202.92098919569
6	215 Seconds	242.588357452716	57.4740014289852
7	258 Seconds	1452.82608840209	1301.39752432213
8	300 Seconds	80.0931663240048	221.645954306254

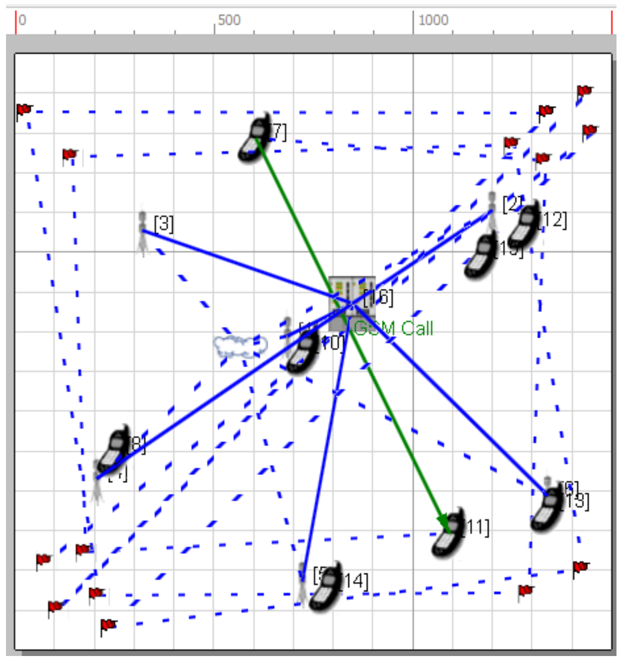

Figure 4.10 : Scenario - 9

4.5.10 Scenario - 10 (Moderate Congestion - Low Mobility) :

In this scenario - I have taken Moderate Congestion - Low Mobility. Here in below given scenario there is one MSC (node no. 16), 6 BSC (node nos. 1 to 6) and 9 MS (node nos. 7 to 15). Total duration for the scenario is 315 seconds.

There are two GSM calls between node 7 to node 11 and node 14 to node 15 respectively. Both the call has been started after 10 seconds and the call duration is 300 seconds. Here total four MSs are busy i.e. MS-7, MS-11, MS-14 and MS-15. MS-7 moves 2898 meters in 300 seconds. MS-11 moves 3019 meters in 300 seconds. MS-14 moves 2774 meters in 300 seconds. MS-15 moves 2403 meters in 300 seconds. The location distance parameters for node 7, node 11, node 14 and node 15 has been shown in following four tables i.e. 4.22, 4.23, 4.24 and 4.25 respectively :

Table 4.22 : Scenario - 10 Mobility table for Node - 7

Sr. No.	Simulation Time	X	Y
1	0 Seconds	605.9062500912	1286.6250085586
2	100 Seconds	1334.65624962991	1230.31250766046
3	200 Seconds	1291.59374965717	143.812490331977

4	300 Seconds	211.718750340737	137.187490226315

Table 4.23 : Scenario - 10 Mobility table for Node - 11

Sr. No.	Simulation Time	X	Y
1	0 Seconds	1092.843749783	292.8749927094
2	100 Seconds	178.593750361705	246.499991969729
3	200 Seconds	145.468750382673	1240.25000781895
4	300 Seconds	1255.15624968023	1270.06250829442

Table 4.24 : Scenario - 10 Mobility table for Node - 14

Sr. No.	Simulation Time	X	Y
1	0 Second	791.3201663312	146.725562104
2	100 Seconds	93.8357586603532	844.209980712525
3	200 Seconds	827.681912702679	1419.38670506268
4	300 Seconds	1445.83160101761	827.681913920854

Table 4.25 : Scenario - 10 Mobility table for Node - 15

Sr. No.	Simulation Time	X	Y
1	0 Second	1174.7713098849	946.6839948209
2	100 Seconds	526.871101811455	1429.30354513768
3	200 Seconds	60.7796255953837	718.596673095825
4	300 Seconds	440.925155842534	77.3076815789904

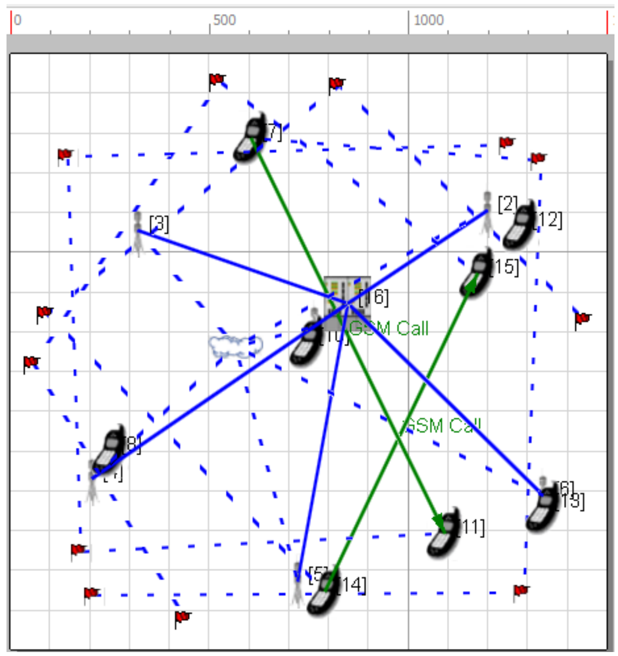

Figure 4.11 : Scenario - 10

4.5.11 Scenario - 11 (Moderate Congestion - Moderate Mobility) :

In this scenario - I have taken Moderate Congestion - Moderate Mobility. Here in below given scenario there is one MSC (node no. 16), 6 BSC (node nos. 1 to 6) and 9 MS (node nos. 7 to 15). Total duration for the scenario is 315 seconds.

There are two GSM calls between node 7 to node 11 and node 14 to node 15 respectively. Both the call has been started after 10 seconds and the call duration is 300 seconds. Here total four MSs are busy i.e. MS-7, MS-11, MS-14 and MS-15. MS-7 moves 5439 meters in 300 seconds. MS-11 moves 5296 meters in 300 seconds. MS-14 moves 4887 meters in 300 seconds. MS-15 moves 5270 meters in 300 seconds. The location distance parameters for node 7, node 11, node 14 and node 15 has been shown in following four tables i.e. 4.26, 4.27, 4.28 and 4.29 respectively :

Table 4.26 : Scenario - 11 Mobility table for Node - 7

Sr. No.	Simulation Time	X	Y
1	0 Seconds	605.9062500912	1286.6250085586
2	60 Seconds	1334.65624962991	1230.31250766046
3	120 Seconds	1291.59374965717	143.812490331977

4	180 Seconds	211.718750340737	137.187490226315
5	240 Seconds	31.029105836911	1353.27443789599
6	300 Seconds	1343.3575885162	1349.96882453766

Table 4.27 : Scenario - 11 Mobility table for Node - 11

Sr. No.	Simulation Time	X	Y
1	0 Seconds	1092.843749783	292.8749927094
2	60 Seconds	178.593750361705	246.499991969729
3	120 Seconds	145.468750382673	1240.25000781895
4	180 Seconds	1255.15624968023	1270.06250829442
5	240 Seconds	1429.30353448513	202.92098919569
6	300 Seconds	242.588357452716	57.4740014289852

Table 4.28 : Scenario - 11 Mobility table for Node - 14

Sr. No.	Simulation Time	X	Y
1	0 Seconds	791.3201663312	146.725562104
2	60 Seconds	93.8357586603532	844.209980712525
3	120 Seconds	827.681912702679	1419.38670506268
4	180 Seconds	1445.83160101761	827.681913920854
5	240 Seconds	1419.38669456563	54.168388070651
6	300 Seconds	80.6133054343654	70.696454862322

Table 4.29 : Scenario - 11 Mobility table for Node - 15

Sr. No.	Simulation Time	X	Y
1	0 Seconds	1174.7713098849	946.6839948209
2	60 Seconds	526.871101811455	1429.30354513768

3	120 Seconds	60.7796255953837	718.596673095825
4	180 Seconds	440.925155842534	77.3076815789904
5	240 Seconds	1409.46985464614	1442.52599857101
6	300 Seconds	216.143451000741	1442.52599857101

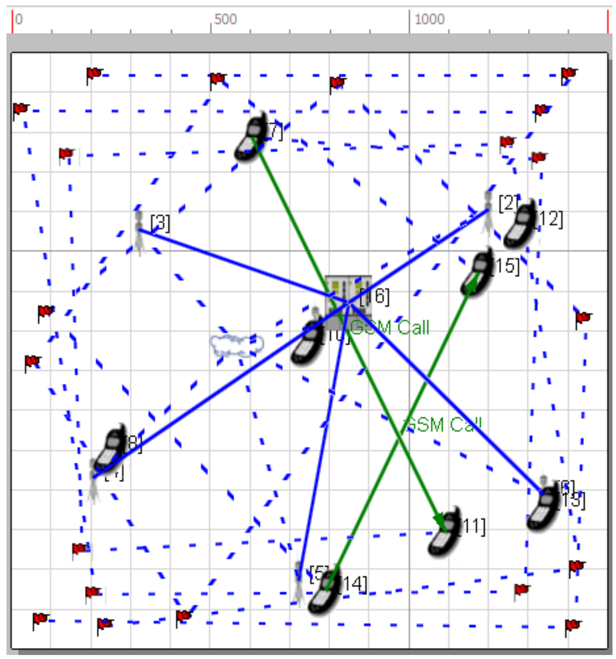

Figure 4.12 : Scenario - 11

4.5.12 Scenario - 12 (Moderate Congestion - High Mobility) :

In this scenario - I have taken Moderate Congestion - High Mobility. Here in below given scenario there is one MSC (node no. 16), 6 BSC (node nos. 1 to 6) and 9 MS (node nos. 7 to 15). Total duration for the scenario is 315 seconds.

There are two GSM calls between node 7 to node 11 and node 14 to node 15 respectively. Both the call has been started after 10 seconds and the call duration is 300 seconds. Here total four MSs are busy i.e. MS-7, MS-11, MS-14 and MS-15. MS-7 moves 9051 meters in 300 seconds. MS-11 moves 8778 meters in 300 seconds. MS-14 moves 7713 meters in 300 seconds. MS-15 moves 7753 meters in 300 seconds. The location distance parameters for node 7, node 11, node 14 and node 15 has been shown in following four tables i.e. 4.30, 4.31, 4.32 and 4.33 respectively :

Table 4.30 : Scenario - 12 Mobility table for Node - 7

Sr. No.	Simulation Time	X	Y
1	0 Seconds	605.9062500912	1286.6250085586
2	43 Seconds	1334.65624962991	1230.31250766046
3	86 Seconds	1291.59374965717	143.812490331977
4	129 Seconds	211.718750340737	137.187490226315
5	172 Seconds	31.029105836911	1353.27443789599
6	215 Seconds	1343.3575885162	1349.96882453766
7	258 Seconds	109.720495577489	103.136635645974
8	300 Seconds	1439.65838651165	1400.15528987237

Table 4.31 : Scenario - 12 Mobility table for Node - 11

Sr. No.	Simulation Time	X	Y
1	0 Seconds	1092.843749783	292.8749927094
2	43 Seconds	178.593750361705	246.499991969729
3	86 Seconds	145.468750382673	1240.25000781895
4	129 Seconds	1255.15624968023	1270.06250829442
5	172 Seconds	1429.30353448513	202.92098919569
6	215 Seconds	242.588357452716	57.4740014289852
7	258 Seconds	1452.82608840209	1301.39752432213
8	300 Seconds	80.0931663240048	221.645954306254

Table 4.32 : Scenario - 12 Mobility table for Node - 14

Sr. No.	Simulation Time	X	Y
1	0 Seconds	791.3201663312	146.725562104
2	43 Seconds	93.8357586603532	844.209980712525

3	86 Seconds	827.681912702679	1419.38670506268
4	129 Seconds	1445.83160101761	827.681913920854
5	172 Seconds	1419.38669456563	54.168388070651
6	215 Seconds	80.6133054343654	70.696454862322
7	258 Seconds	62.4324181590798	1462.35967872102
8	300 Seconds	1467.31810220904	1171.46570318761

Table 4.33 : Scenario - 12 Mobility table for Node - 15

Sr. No.	Simulation Time	X	Y
1	0 Seconds	1174.7713098849	946.6839948209
2	43 Seconds	526.871101811455	1429.30354513768
3	86 Seconds	60.7796255953837	718.596673095825
4	129 Seconds	440.925155842534	77.3076815789904
5	172 Seconds	1409.46985464614	1442.52599857101
6	215 Seconds	216.143451000741	1442.52599857101
7	258 Seconds	1450.79003533786	1049.15800892925
8	300 Seconds	624.386691779063	196.309762479022

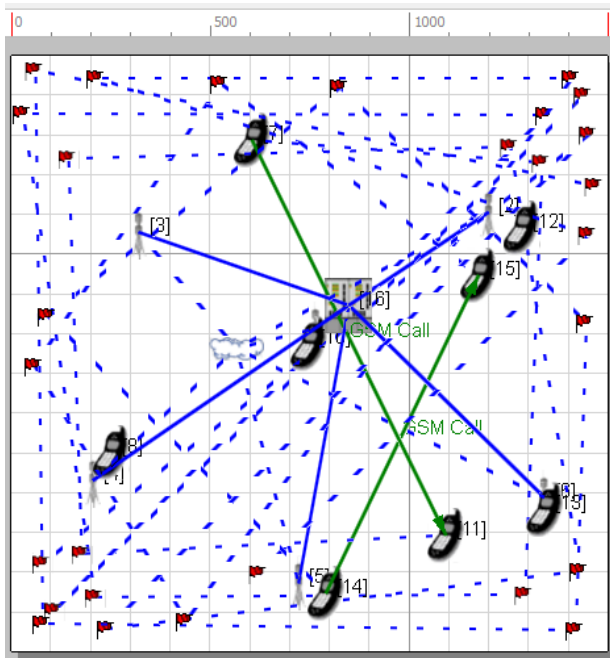

Figure 4.13: Scenario - 12

4.5.13 Scenario - 13 (High Congestion - Low Mobility) :

In this scenario - I have taken High Congestion - Low Mobility. Here in below given scenario there is one MSC (node no. 16), 6 BSC (node nos. 1 to 6) and 9 MS (node nos. 7 to 15). Total duration for the scenario is 315 seconds.

There are three GSM calls between node 7 to node 11, node 14 to node 15 and node 8 to node 12 respectively. All the three calls have been started after 10 seconds and the call duration is 300 seconds. Here total six MSs are busy i.e. MS-7, MS-11, MS-14,MS-15, MS-8 and MS-12. MS-7 moves 2898 meters in 300 seconds. MS-11 moves 3019 meters in 300 seconds. MS-14 moves 2774 meters in 300 seconds. MS-15 moves 2403 meters in 300 seconds. MS-8 moves 2799 meters in 300 seconds. MS-12 moves 2438 meters in 300 seconds. The location distance parameters for node 7, node 11, node 14, node 15, node 8 and node 12 has been shown in following six tables i.e. 4.34, 4.35, 4.36, 4.37, 4.38 and 4.39 respectively :

Table 4.34 : Scenario - 13 Mobility table for Node - 7

Sr. No.	Simulation Time	X	Y
1	0 Seconds	605.9062500912	1286.6250085586
2	100 Seconds	1334.65624962991	1230.31250766046
3	200 Seconds	1291.59374965717	143.812490331977
4	300 Seconds	211.718750340737	137.187490226315

Table 4.35 : Scenario - 13 Mobility table for Node - 11

Sr. No.	Simulation Time	X	Y
1	0 Seconds	1092.843749783	292.8749927094
2	100 Seconds	178.593750361705	246.499991969729
3	200 Seconds	145.468750382673	1240.25000781895
4	300 Seconds	1255.15624968023	1270.06250829442

Table 4.36 : Scenario - 13 Mobility table for Node - 14

Sr. No.	Simulation Time	X	Y
1	0 Second	791.3201663312	146.725562104
2	100 Seconds	93.8357586603532	844.209980712525
3	200 Seconds	827.681912702679	1419.38670506268
4	300 Seconds	1445.83160101761	827.681913920854

Table 4.37 : Scenario - 13 Mobility table for Node - 15

Sr. No.	Simulation Time	X	Y
1	0 Second	1174.7713098849	946.6839948209
2	100 Seconds	526.871101811455	1429.30354513768
3	200 Seconds	60.7796255953837	718.596673095825

4	300 Seconds	440.925155842534	77.3076815789904

Table 4.38 : Scenario - 13 Mobility table for Node - 8

Sr. No.	Simulation Time	X	Y
1	0 Second	251.4687503156	501.5624960377
2	100 Seconds	953.295218349563	1449.13722528768
3	200 Seconds	1439.22037440462	748.347193320833
4	300 Seconds	1072.29729738345	74.0020682206562

Table 4.39 : Scenario - 13 Mobility table for Node - 12

Sr. No.	Simulation Time	X	Y
1	0 Second	1282.22	1066.89
2	100 Seconds	424.397089310049	1432.60915849601
3	200 Seconds	57.4740122888867	622.733885704133
4	300 Seconds	262.422037291698	40.9459346373142

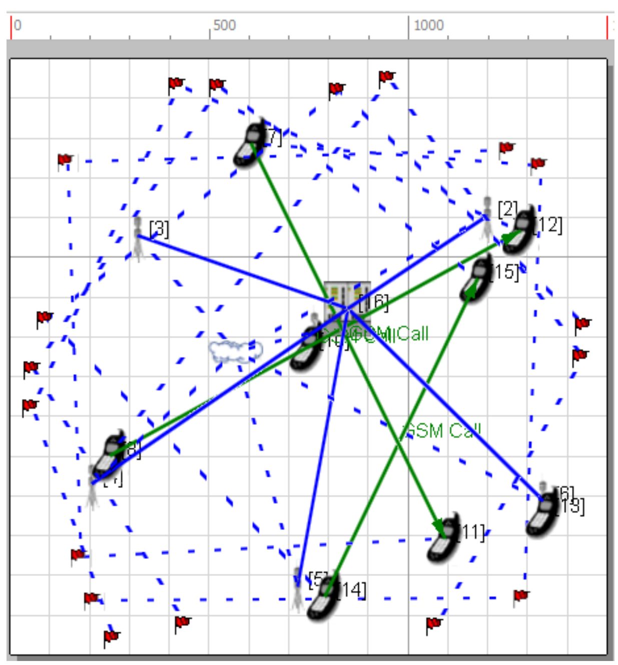

Figure 4.14 : Scenario - 13

4.5.14 Scenario - 14 (High Congestion - Moderate Mobility) :

In this scenario - I have taken High Congestion - Moderate Mobility. Here in below given scenario there is one MSC (node no. 16), 6 BSC (node nos. 1 to 6) and 9 MS (node nos. 7 to 15). Total duration for the scenario is 315 seconds.

There are three GSM calls between node 7 to node 11, node 14 to node 15 and node 8 to node 12 respectively. All the three calls have been started after 10 seconds and the call duration is 300 seconds. Here total six MSs are busy i.e. MS-7, MS-11, MS-14,MS-15, MS-8 and MS-12. MS-7 moves 5439 meters in 300 seconds. MS-11 moves 5296 meters in 300 seconds. MS-14 moves 4887 meters in 300 seconds. MS-15 moves 5270 meters in 300 seconds. MS-8 moves 4920 meters in 300 seconds. MS-12 moves 4712 meters in 300 seconds. The location distance parameters for node 7, node 11, node 14, node 15, node 8 and node 12 has been shown in following six tables i.e. 4.40, 4.41, 4.42, 4.43, 4.44 and 4.45 respectively :

Table 4.40 : Scenario - 14 Mobility table for Node - 7

Sr. No.	Simulation Time	X	Y
1	0 Seconds	605.9062500912	1286.6250085586
2	60 Seconds	1334.65624962991	1230.31250766046
3	120 Seconds	1291.59374965717	143.812490331977
4	180 Seconds	211.718750340737	137.187490226315
5	240 Seconds	31.029105836911	1353.27443789599
6	300 Seconds	1343.3575885162	1349.96882453766

Table 4.41 : Scenario - 14 Mobility table for Node - 11

Sr. No.	Simulation Time	X	Y
1	0 Seconds	1092.843749783	292.8749927094
2	60 Seconds	178.593750361705	246.499991969729
3	120 Seconds	145.468750382673	1240.25000781895
4	180 Seconds	1255.15624968023	1270.06250829442

5	240 Seconds	1429.30353448513	202.92098919569
6	300 Seconds	242.588357452716	57.4740014289852

Table 4.42 : Scenario - 14 Mobility table for Node - 14

Sr. No.	Simulation Time	X	Y
1	0 Seconds	791.3201663312	146.725562104
2	60 Seconds	93.8357586603532	844.209980712525
3	120 Seconds	827.681912702679	1419.38670506268
4	180 Seconds	1445.83160101761	827.681913920854
5	240 Seconds	1419.38669456563	54.168388070651
6	300 Seconds	80.6133054343654	70.696454862322

Table 4.43 : Scenario - 14 Mobility table for Node - 15

Sr. No.	Simulation Time	X	Y
1	0 Seconds	1174.7713098849	946.6839948209
2	60 Seconds	526.871101811455	1429.30354513768
3	120 Seconds	60.7796255953837	718.596673095825
4	180 Seconds	440.925155842534	77.3076815789904
5	240 Seconds	1409.46985464614	1442.52599857101
6	300 Seconds	216.143451000741	1442.52599857101

Table 4.44 : Scenario - 14 Mobility table for Node - 8

Sr. No.	Simulation Time	X	Y
1	0 Second	251.4687503156	501.5624960377
2	60 Seconds	953.295218349563	1449.13722528768
3	120 Seconds	1439.22037440462	748.347193320833

4	180 Seconds	1072.29729738345	74.0020682206562
5	240 Seconds	82.2661564774596	354.979203679063
6	300 Seconds	125.239126605148	1445.83161192935

Table 4.45 : Scenario - 14 Mobility table for Node - 12

Sr. No.	Simulation Time	X	Y
1	0 Second	1282.22	1066.89
2	60 Seconds	424.397089310049	1432.60915849601
3	120 Seconds	57.4740122888867	622.733885704133
4	180 Seconds	262.422037291698	40.9459346373142
5	240 Seconds	42.5987994365167	1095.43659594592
6	300 Seconds	1199.56337979735	1402.858638271

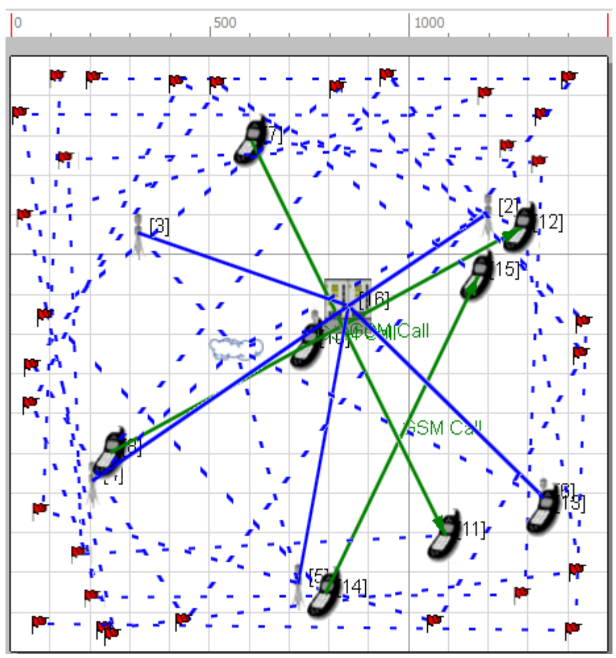

Figure 4.15 : Scenario - 14

4.5.15 Scenario - 15 (High Congestion - High Mobility) :

In this scenario - I have taken High Congestion - High Mobility. Here in below given scenario there is one MSC (node no. 16), 6 BSC (node nos. 1 to 6) and 9 MS (node nos. 7 to 15). Total duration for the scenario is 315 seconds.

There are three GSM calls between node 7 to node 11, node 14 to node 15 and node 8 to node 12 respectively. All the three calls have been started after 10 seconds and the call duration is 300 seconds. Here total six MSs are busy i.e. MS-7, MS-11, MS-14,MS-15, MS-8 and MS-12. MS-7 moves 9071 meters in 300 seconds. MS-11 moves 8778 meters in 300 seconds. MS-14 moves 7713 meters in 300 seconds. MS-15 moves 7753 meters in 300 seconds. MS-8 moves 7375 meters in 300 seconds. MS-12 moves 7213 meters in 300 seconds. The location distance parameters for node 7, node 11, node 14, node 15, node 8 and node 12 has been shown in following six tables i.e. 4.46, 4.47, 4.48, 4.49, 4.50 and 4.51 respectively :

Table 4.46 : Scenario - 15 Mobility table for Node - 7

Sr. No.	Simulation Time	X	Y
1	0 Seconds	605.9062500912	1286.6250085586
2	43 Seconds	1334.65624962991	1230.31250766046
3	86 Seconds	1291.59374965717	143.812490331977
4	129 Seconds	211.718750340737	137.187490226315
5	172 Seconds	31.029105836911	1353.27443789599
6	215 Seconds	1343.3575885162	1349.96882453766
7	258 Seconds	109.720495577489	103.136635645974
8	300 Seconds	1439.65838651165	1400.15528987237

Table 4.47 : Scenario - 15 Mobility table for Node - 11

Sr. No.	Simulation Time	X	Y
1	0 Seconds	1092.843749783	292.8749927094
2	43 Seconds	178.593750361705	246.499991969729

3	86 Seconds	145.468750382673	1240.25000781895
4	129 Seconds	1255.15624968023	1270.06250829442
5	172 Seconds	1429.30353448513	202.92098919569
6	215 Seconds	242.588357452716	57.4740014289852
7	258 Seconds	1452.82608840209	1301.39752432213
8	300 Seconds	80.0931663240048	221.645954306254

Table 4.48 : Scenario - 15 Mobility table for Node - 14

Sr. No.	Simulation Time	X	Y
1	0 Seconds	791.3201663312	146.725562104
2	43 Seconds	93.8357586603532	844.209980712525
3	86 Seconds	827.681912702679	1419.38670506268
4	129 Seconds	1445.83160101761	827.681913920854
5	172 Seconds	1419.38669456563	54.168388070651
6	215 Seconds	80.6133054343654	70.696454862322
7	258 Seconds	62.4324181590798	1462.35967872102
8	300 Seconds	1467.31810220904	1171.46570318761

Table 4.49 : Scenario - 15 Mobility table for Node - 15

Sr. No.	Simulation Time	X	Y
1	0 Seconds	1174.7713098849	946.6839948209
2	43 Seconds	526.871101811455	1429.30354513768
3	86 Seconds	60.7796255953837	718.596673095825
4	129 Seconds	440.925155842534	77.3076815789904
5	172 Seconds	1409.46985464614	1442.52599857101
6	215 Seconds	216.143451000741	1442.52599857101

7	258 Seconds	1450.79003533786	1049.15800892925
8	300 Seconds	624.386691779063	196.309762479022

Table 4.50 : Scenario - 15 Mobility table for Node - 8

Sr. No.	Simulation Time	X	Y
1	0 Seconds	251.4687503156	501.5624960377
2	43 Seconds	953.295218349563	1449.13722528768
3	86 Seconds	1439.22037440462	748.347193320833
4	129 Seconds	1072.29729738345	74.0020682206562
5	172 Seconds	82.2661564774596	354.979203679063
6	215 Seconds	125.239126605148	1445.83161192935
7	258 Seconds	1282.20370696599	1409.46986498767
8	300 Seconds	1354.92719487438	113.669428520667

Table 4.51 : Scenario - 15 Mobility table for Node - 12

Sr. No.	Simulation Time	X	Y
1	0 Seconds	1282.22	1066.89
2	43 Seconds	424.397089310049	1432.60915849601
3	86 Seconds	57.4740122888867	622.733885704133
4	129 Seconds	262.422037291698	40.9459346373142
5	172 Seconds	42.5987994365167	1095.43659594592
6	215 Seconds	1199.56337979735	1402.858638271
7	258 Seconds	1232.61951066481	90.5301350123272
8	300 Seconds	45.9044125232621	140.11433538734

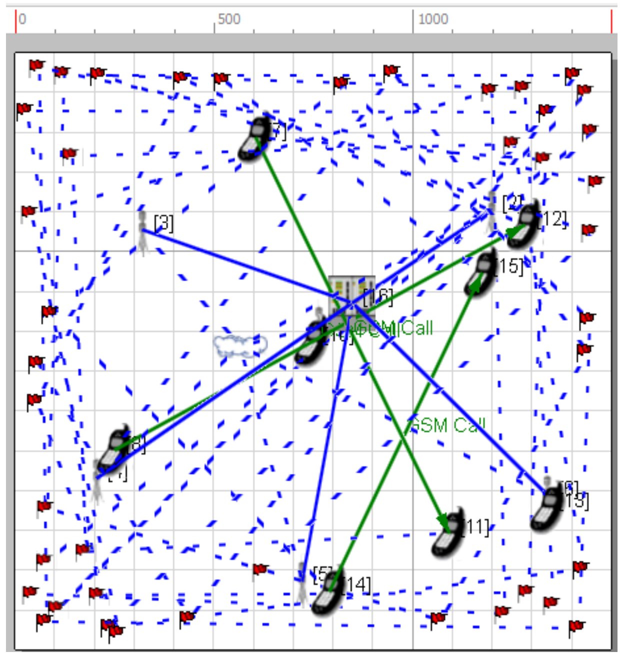

Figure 4.16 : Scenario - 15

Table 4.52 : Summary for Scenario no. 7 to 15

Scenario No.	Congestion	Mobility
7	**No congestion** 2 MS are busy. 1 call between MS 7 and MS 11	**Low Mobility** MS 7 moves 2898 meters in 300 seconds MS 11 moves 3019 meters in 300 seconds
8	**No congestion** 2 MS are busy. 1 call between MS 7 and MS 11	**Moderate Mobility** MS 7 moves 5439 meters in 300 seconds MS 11 moves 5296 meters in 300 seconds
9	**No congestion** 2 MS are busy. 1 call between MS 7 and MS 11	**High Mobility** MS 7 moves 9051 meters in 300 seconds MS 11 moves 8778 meters in 300 seconds
10	**Moderate congestion** 4 MS are busy. 1 call between MS 7 and MS 11 1 call between MS 14 and MS 15	**Low Mobility** MS 7 moves 2898 meters in 300 seconds MS 11 moves 3019 meters in 300 seconds MS 14 moves 2774 meters in 300 seconds MS 15 moves 2403 meters in 300 seconds

Scenario - 15 (High Congestion - High Mobility) :

11	**Moderate congestion** 4 MS are busy. 1 call between MS 7 and MS 11 1 call between MS 14 and MS 15	**Moderate Mobility** MS 7 moves 5439 meters in 300 seconds MS 11 moves 5296 meters in 300 seconds MS 14 moves 4887 meters in 300 seconds MS 15 moves 5270 meters in 300 seconds
12	**Moderate congestion** 4 MS are busy. 1 call between MS 7 and MS 11 1 call between MS 14 and MS 15	**High Mobility** MS 7 moves 9051 meters in 300 seconds MS 11 moves 8778 meters in 300 seconds MS 14 moves 7713 meters in 300 seconds MS 15 moves 7753 meters in 300 seconds
13	**High Congestion** 6 MS are busy. 1 call between MS 7 and MS 11 1 call between MS 14 and MS 15 1 call between MS 8 and MS 12	**Low Mobility** MS 7 moves 2898 meters in 300 seconds MS 11 moves 3019 meters in 300 seconds MS 14 moves 2774 meters in 300 seconds MS 15 moves 2403 meters in 300 seconds MS 8 moves 2799 meters in 300 seconds MS 12 moves 2438 meters in 300 seconds
14	**High Congestion** 6 MS are busy. 1 call between MS 7 and MS 11 1 call between MS 14 and MS 15 1 call between MS 8 and MS 12	**Moderate Mobility** MS 7 moves 5439 meters in 300 seconds MS 11 moves 5296 meters in 300 seconds MS 14 moves 4887 meters in 300 seconds MS 15 moves 5270 meters in 300 seconds MS 8 moves 4920 meters in 300 seconds MS 12 moves 4712 meters in 300 seconds
15	**High Congestion** 6 MS are busy. 1 call between MS 7 and MS 11 1 call between MS 14 and MS 15 1 call between MS 8 and MS 12	**High Mobility** MS 7 moves 9051 meters in 300 seconds MS 11 moves 8778 meters in 300 seconds MS 14 moves 7713 meters in 300 seconds MS 15 moves 7753 meters in 300 seconds MS 8 moves 7375 meters in 300 seconds MS 12 moves 7213 meters in 300 seconds

Here in this chapter we have selected Qualnet® as a simulation tool after making comparison between various tools available in the market. Various features related to GSL layer - 3 and other statistical data has been available through simulation work. We have also selected 15 scenarios based on real life situations for our research work. The next chapter will describe the proposed work.

CHAPTER – 5

Implementation & Results

5.1 Introduction

This research work has been carried out in two parts. 1st part of the research work is about the literature survey of cellular networks and location update mechanisms. 2nd part of the research work is about enhancing overall performance by introducing a novel approach of location update mechanism. 2nd part of the research has been carried out in two parts: selection of best location update strategy so far and modifying it for performance improvement. This chapter focuses on 2nd part of our research. Section 5.2 shows an algorithm to select best location update strategy from the existing location update strategies. Section 5.3 shows an algorithm to introduce dynamic time based location update strategy.

5.2 Selection of Best Location Update Strategy

Various existing location update strategies are evaluated with rank based algorithm. Every scenario of a cellular network is evaluated across five parameters: Routing protocol, Number of infrastructure stations, Congestion of Cell, Mobility, Energy and memory saving. Every parameter is a goal and every goal has a support associated with it. If value of a parameter is improved, it can be said that the goal is achieved better. Based on this, all parameters of all scenarios are evaluated for all location update strategies. The location update strategy which has best value of the total goal achievement is ranked 1st. in our results, we have noticed that time based location update strategy performs best as compared to other location update strategies.

5.2.1 Parameters for Algorithm

Various parameters which are required to calculate Best Location Update Strategy are given in Table 5.1. These parameters are taken based on the importance of the goal. Each goal has support.

Table 5.1 : Algorithm Parameters

Id	Support	Goal	Parameters
G1	1	Location updates with reference of routing protocol	Throughput Per Min
G2	2	Location updates with reference of Number of infrastructure stations	total_ms / total_bs Fixed in Network
G3	4	Location updates with reference of Congestion of Cell	Total_calls / Cell Per Min
G4	5	Location updates with reference of Mobility	Average_speed Per Min
G5	3	Location updates with reference of energy and memory saving	1 / Average_energy_consumed_station Per Min

5.2.2 Algorithm

Various notations used in proposed algorithm for finding out best Location Update Strategy are given in Table 5.2

Table 5.2 : Notations used in Algorithm

Parameter	Detail
N	Total number of Scenarios
M	Total number of Location Update Strategies
P	Total number of goals per location update strategy
Support (Gi)	The Importance of Goal Gi while evaluating a location update strategy
Value (Gi)	Value of Goal Gi
Value (LiSj)	Sum value of Li with reference of all goals for a scenario Sj
Value (Li)	Sum value of Li with reference of all goals for all scenarios
Rank (Li)	Rank of Li location update strategy

For each location update strategy L1 to LM with index i

Value(Li) = 0

For each scenario S1 to SN with index j

Value(LiSj) = 0

For each goal G1 to GP with index k

Value(LiSj) = Value(LiSj)+(Support (Gk)* Value(Gk))

End

Value(Li) = Value(Li) + Value(LiSj)

End

End

Note:- Here the location update Strategy L, with highest value of Value(L) can be considered as the best location update strategy which has Rank(L) to 1.

5.2.3 Results

The results based on above algorithm are given in Table 5.3

Table 5.3 : Results

Scenario id Sj	Policy Li	G1	S1	G2	S2	G3	S3	G4	S4	G5	S5	SjLi
1	Time based	345	1	10	2	5	4	10	5	0.453	3	436.359
2		343	1	20	2	7	4	20	5	0.234	3	511.702
3		278	1	30	2	10	4	30	5	0.123	3	528.369
4		225	1	40	2	18	4	40	5	0.563	3	578.689
5		187	1	50	2	20	4	50	5	0.267	3	617.801
6	Distance based	235	1	10	2	5	4	10	5	0.254	3	325.762
7		233	1	20	2	7	4	20	5	0.111	3	401.333
8		232	1	30	2	10	4	30	5	0.985	3	484.955
9		123	1	40	2	18	4	40	5	0.223	3	475.669
10		232	1	50	2	20	4	50	5	0.137	3	662.411
11	Movement based	234	1	10	2	5	4	10	5	0.647	3	325.941
12		321	1	20	2	7	4	20	5	0.237	3	489.711
13		321	1	30	2	10	4	30	5	0.167	3	571.501
14		126	1	40	2	18	4	40	5	0.753	3	480.259
15		256	1	50	2	20	4	50	5	0.869	3	688.607

From the above calculation, final results are as follows :

Value (Time Based) 2672.92

Value (Distance Based) 2350.13

Value (Movement Based) 2556.01

From the above values it is easily seen that Value(Time Based Policy) is highest, so we can consider it as best location update strategy in general case. We have tested this algorithm for different 100 scenarios. For simplicity, only 15 different scenarios are considered here. The overall observation has been described in Table 5.4

Table 5.4 : Observations

Sr.	Scenario Type	Time Based	Distance Based	Movement Based
1	High Mobility of MS	Poor performance. Least Expensive.	Average performance. Moderate Expensive.	Best performance. Heavily Expensive.
2	Average Mobility of MS	Average performance. Least Expensive.	Average performance. Moderate Expensive.	Best performance. Heavily Expensive.
3	Low Mobility of MS	Average performance. Least Expensive.	Average performance. Moderate Expensive.	Average performance. Heavily Expensive.

5.3 Dynamic Time-Based Location Update Strategy

GSM architecture has various timers to repeat certain events at regular intervals. So far most of the timers have fixed values which don’t change our time as per cellular network situations.

We have set dynamic calculation for following timers.

Default value of T3210 Timer (DefaultGsmLocationUpdateRequestTimer) is 10 Seconds

Default value of T3211 Timer (DefaultGsmLocationUpdateFailureTimer) is 10 Seconds

Default value of T3212 Timer (DefaultGsmPeriodicLocationUpdateTimer) is 360 Seconds

These timers are having static values and they don't change as per cellular network's situations. We are proposing a Dynamic Time-Based Location Update Strategy by calculating values of these timers with reference of the network performance. The main two parameters are used as a part of dynamic timers calculation are, Total No. of Location Updates Attempts– LUA and Total No. of Location Updates Failed – LUF. Based on the Failure Ratio calculated as below various values of Timers are set.

5.3.1 Algorithm

To implement dynamic Time Based Location Update Strategy, we have calculated values for the all the three timers dynamically. The proposed algorithm is as follows :

Failure Ratio -FR = (LUF*100)/LUA

T3210 = (FR * 10)/100

T3211 = (FR * 10)/100

T3212 = (FR * 360)/100

5.3.2 Example of Calculation

Following Table 5.5 explain the calculation for all the above three timers.

Table 5.5 : Calculations

LUA	LUF	FR	T3210 Value Seconds	T3211 Value Seconds	T3212 Value Seconds
50	10	20	2	2	72
50	20	40	4	4	144
50	30	60	6	6	216
50	40	80	8	8	288
50	50	100	10	10	360

With all above results we can say that Dynamic Time Based Location Update strategy gives best result and save the network resources. Following chapter includes Graphs for the results.

5.4 Results

This section shows location update statistics with reference of Time Based Location Update strategy and Dynamic Time Based Location Update strategy for each of the scenarios discussed in Chapter 4.

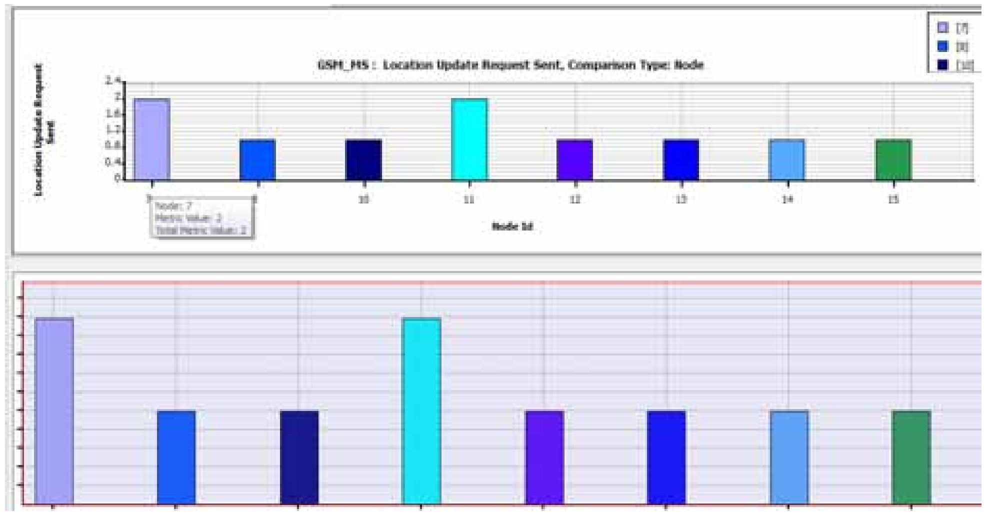

Figure 5.1 : S1 - Time Based Location Update

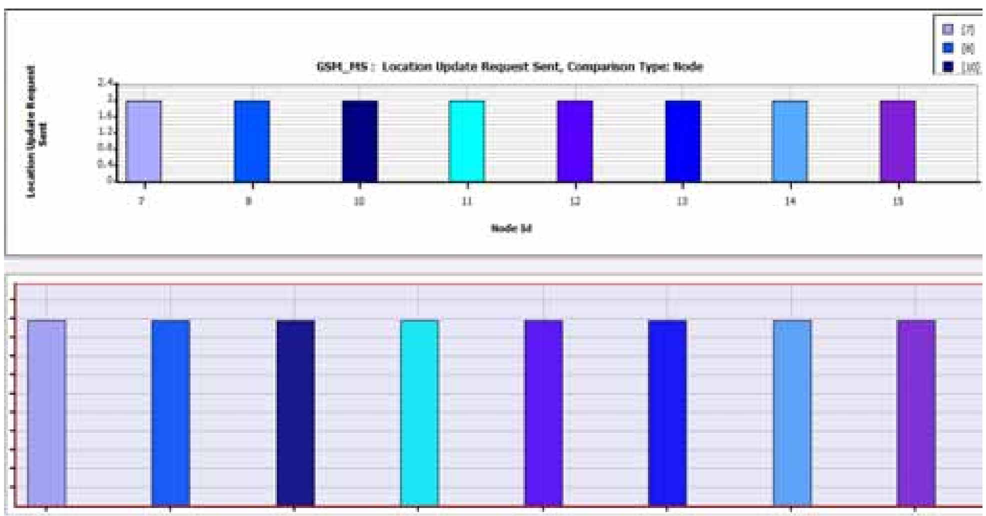

Figure 5.2 : S1 - Dynamic Time Based Location Update

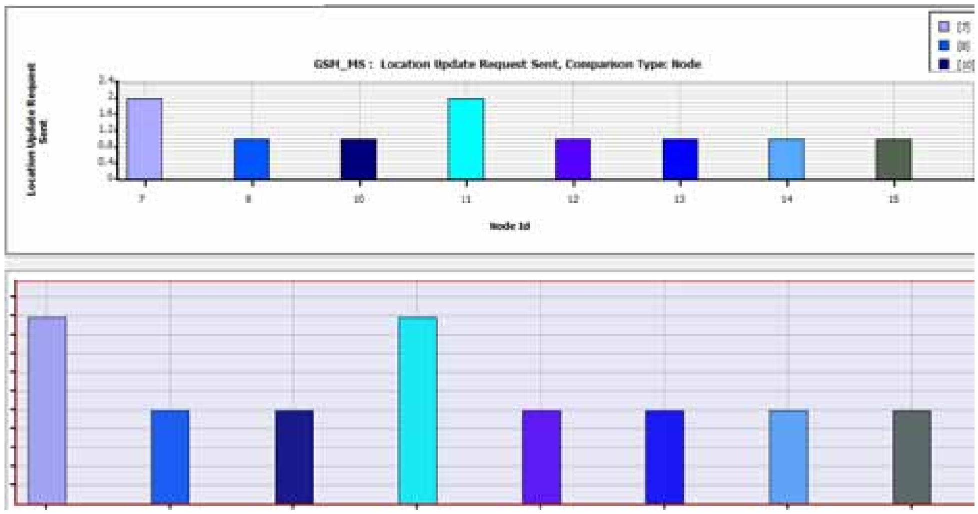

Figure 5.3 : S2 - Time Based Location Update

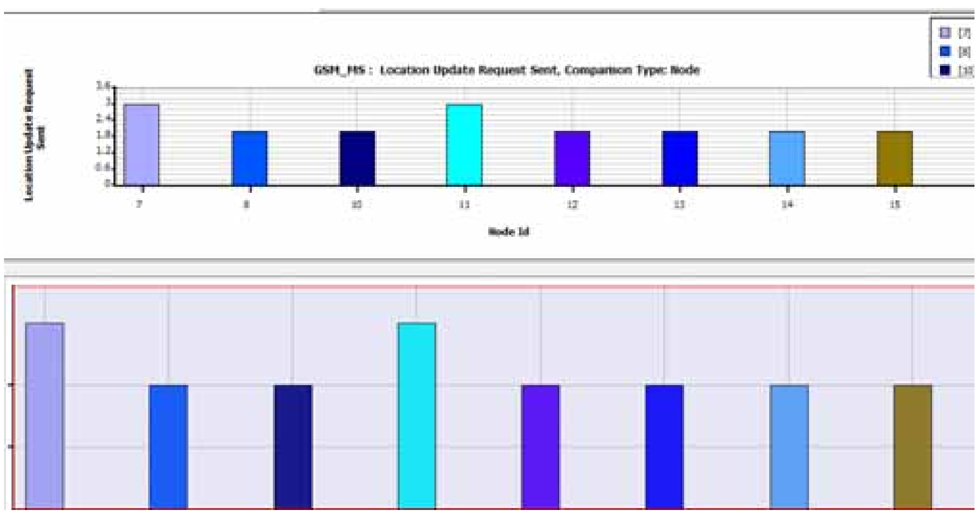

Figure 5.4 : S2 - Dynamic Time Based Location Update

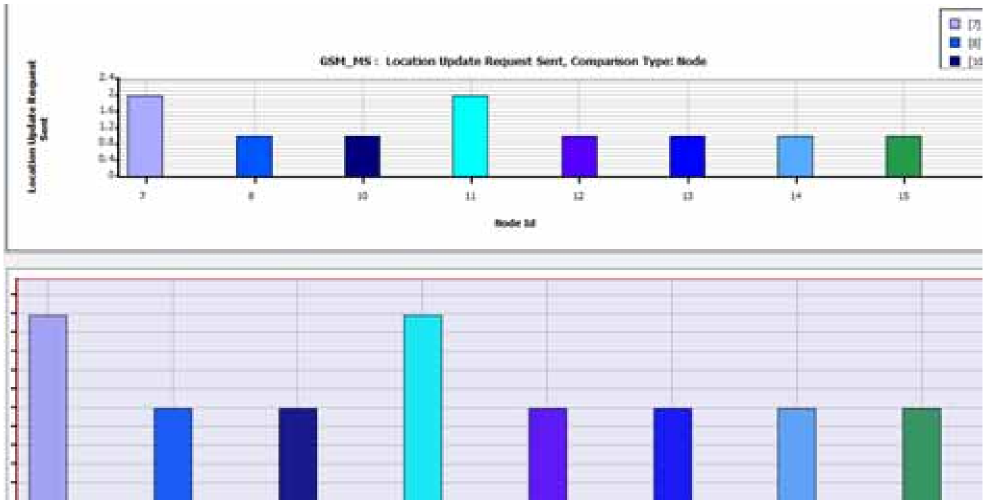

Figure 5.5 : S3 - Time Based Location Update

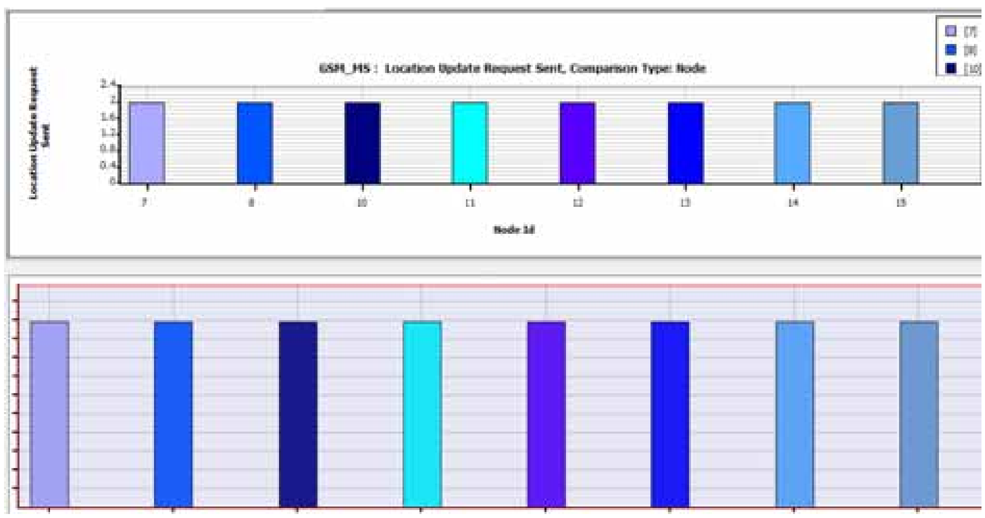

Figure 5.6 : S3 - Dynamic Time Based Location Update

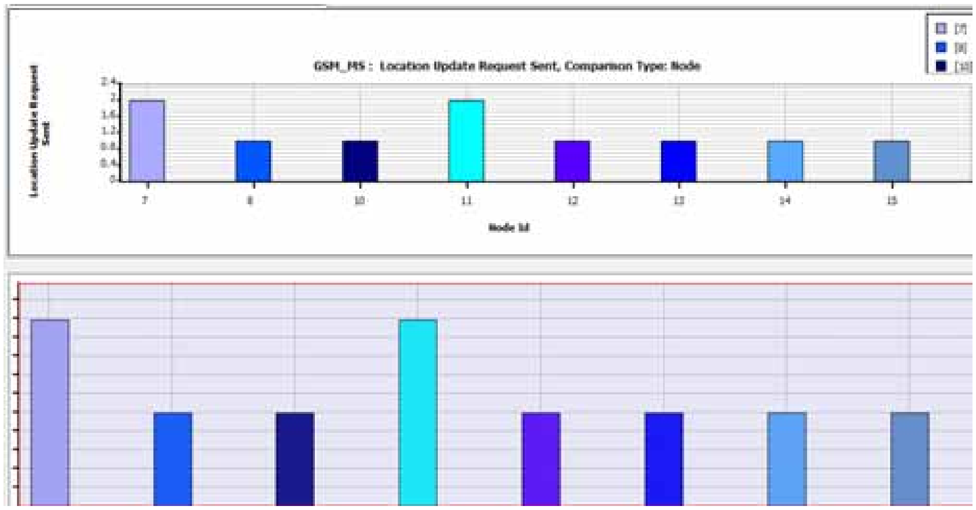

Figure 5.7 : S4 - Time Based Location Update

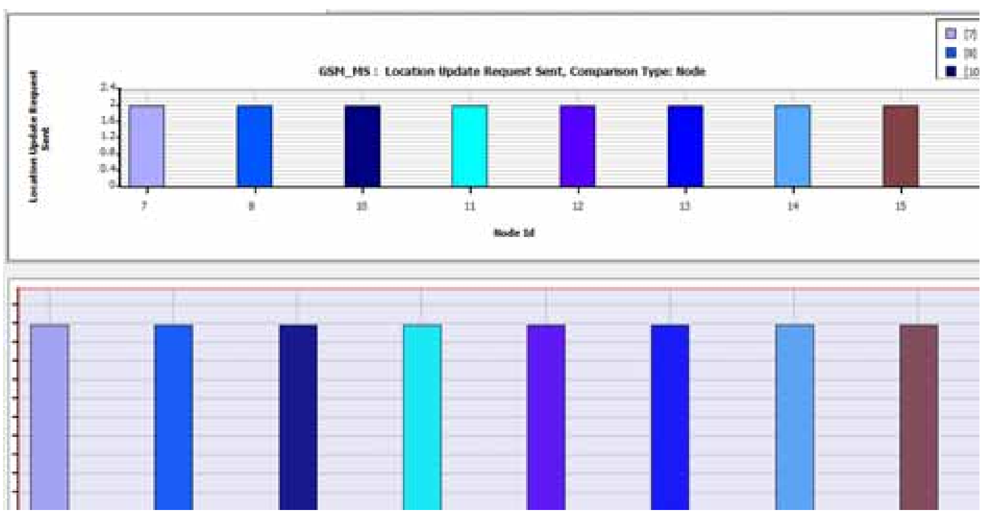

Figure 5.8 : S4 - Dynamic Time Based Location Update

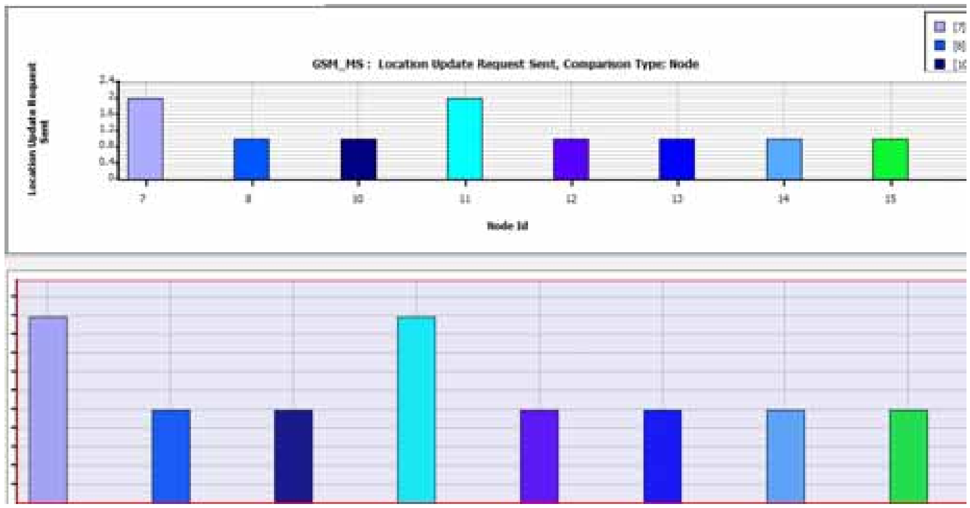

Figure 5.9 : S5 - Time Based Location Update

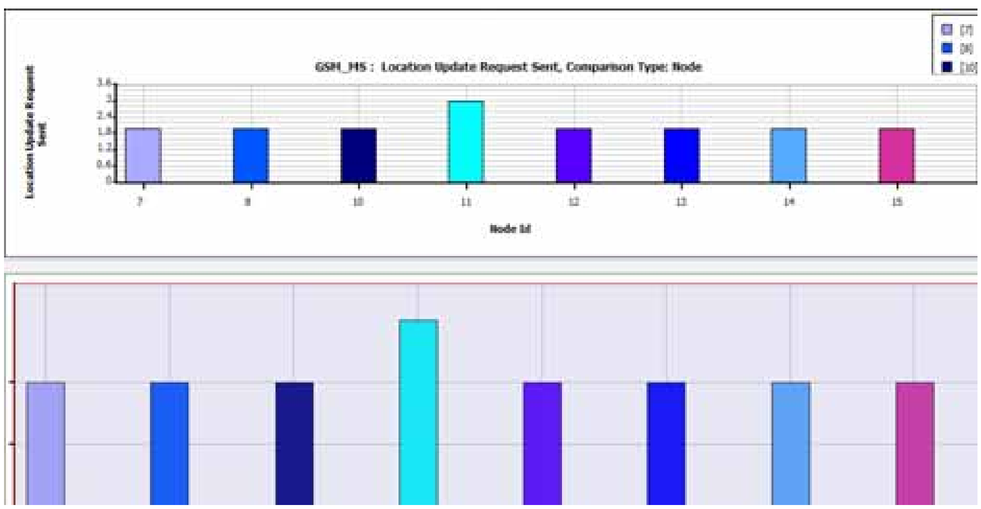

Figure 5.10 : S5 - Dynamic Time Based Location Update

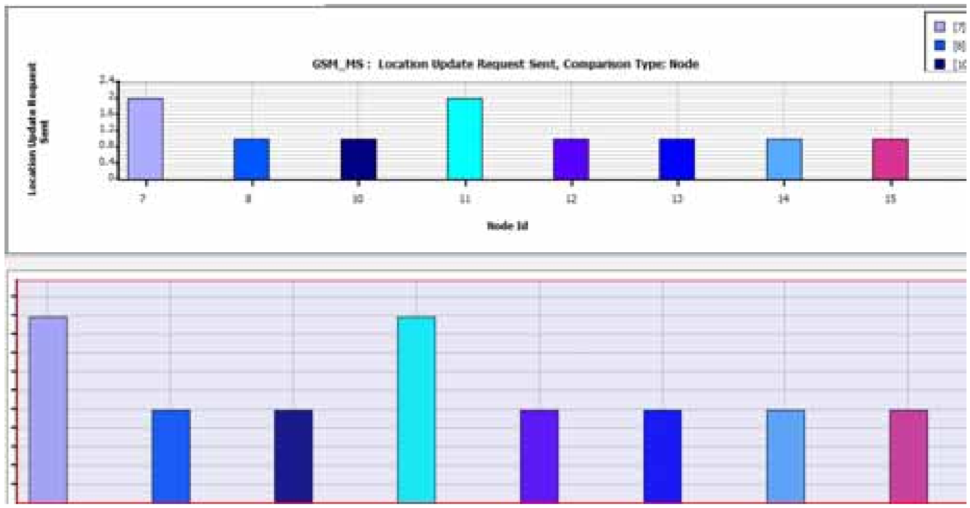

Figure 5.11 : S6 - Time Based Location Update

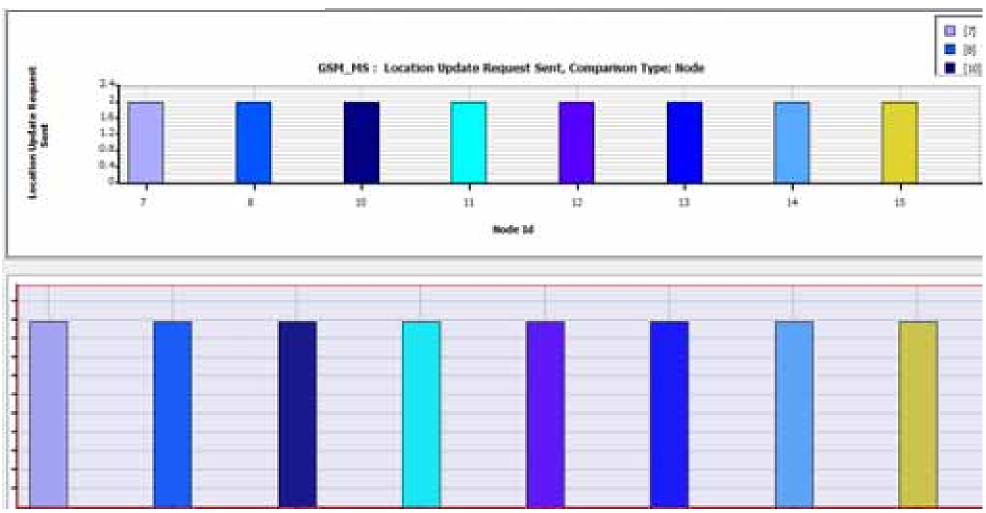

Figure 5.12 : S6 - Dynamic Time Based Location Update

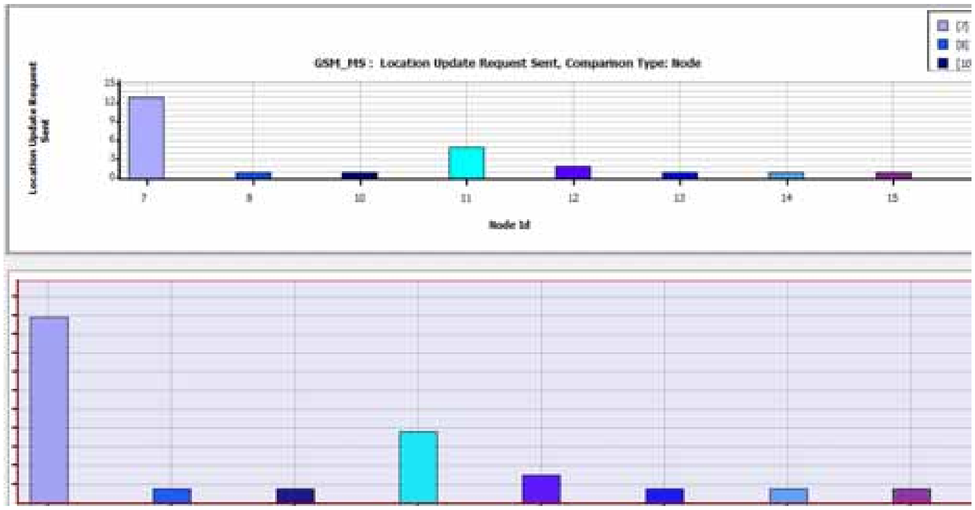

Figure 5.13 : S7 - Time Based Location Update

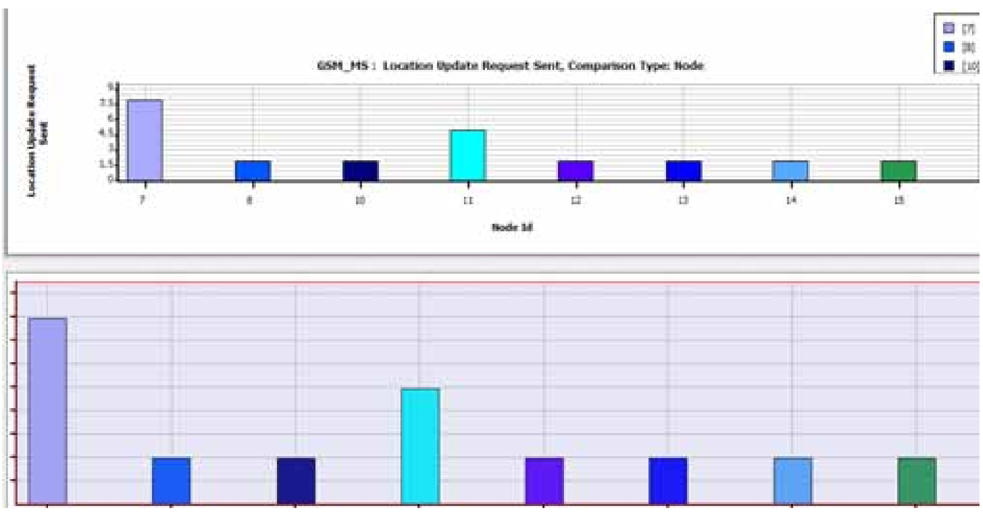

Figure 5.14 : S7 - Dynamic Time Based Location Update

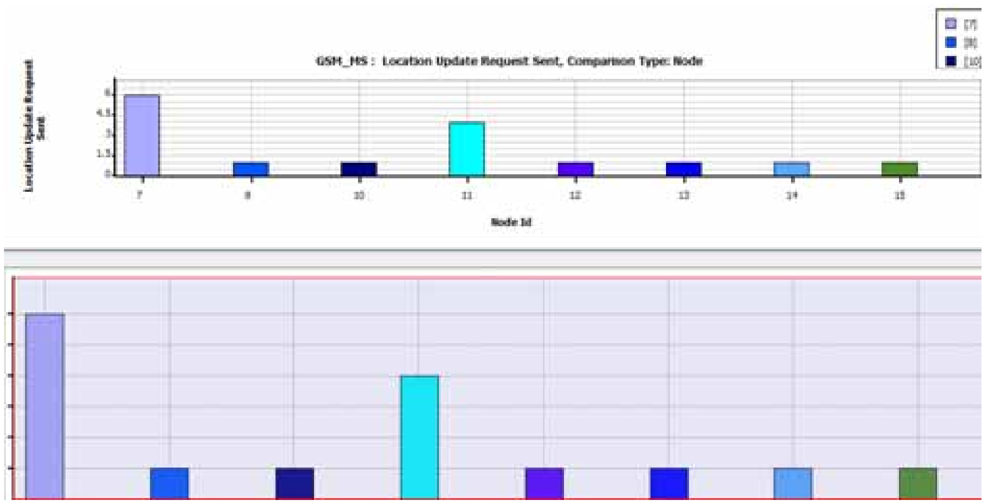

Figure 5.15 : S8 - Time Based Location Update

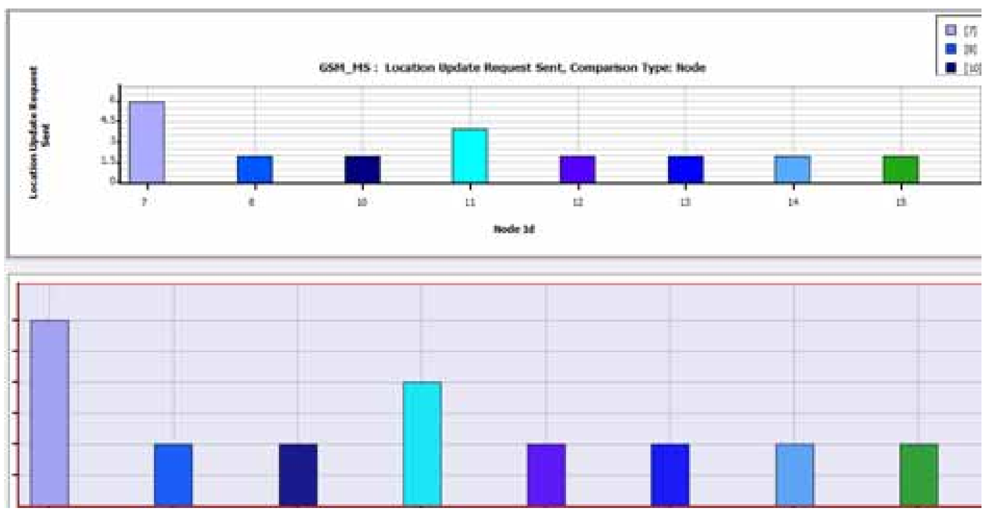

Figure 5.16 : S8 - Dynamic Time Based Location Update

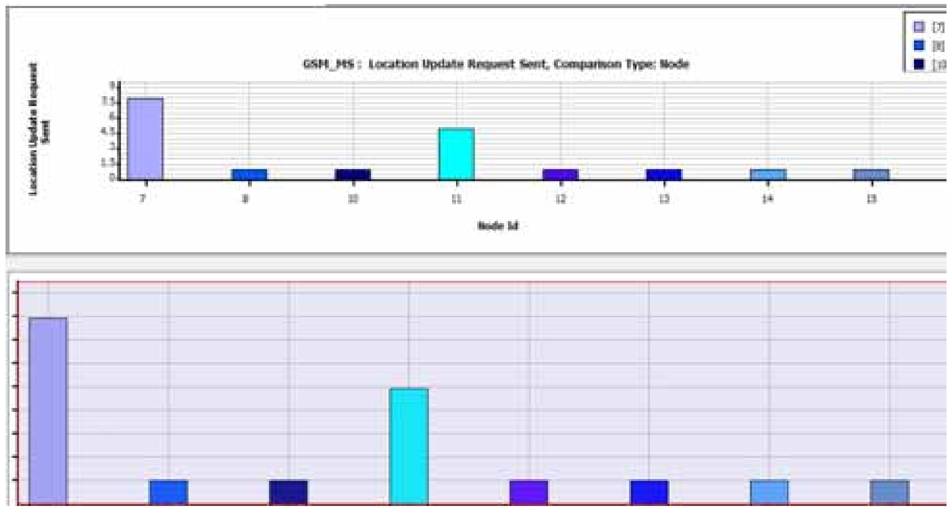

Figure 5.17 : S9 - Time Based Location Update

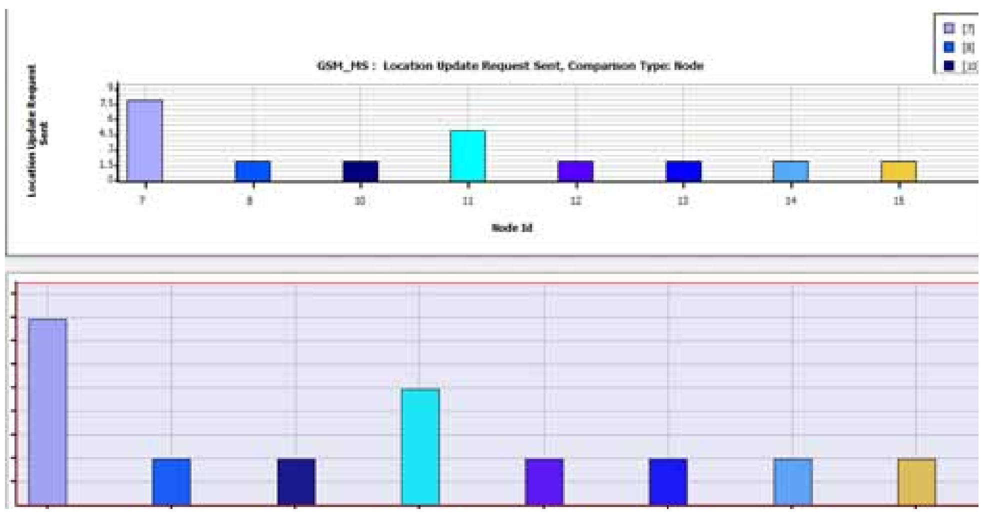

Figure 5.18 : S9 - Dynamic Time Based Location Update

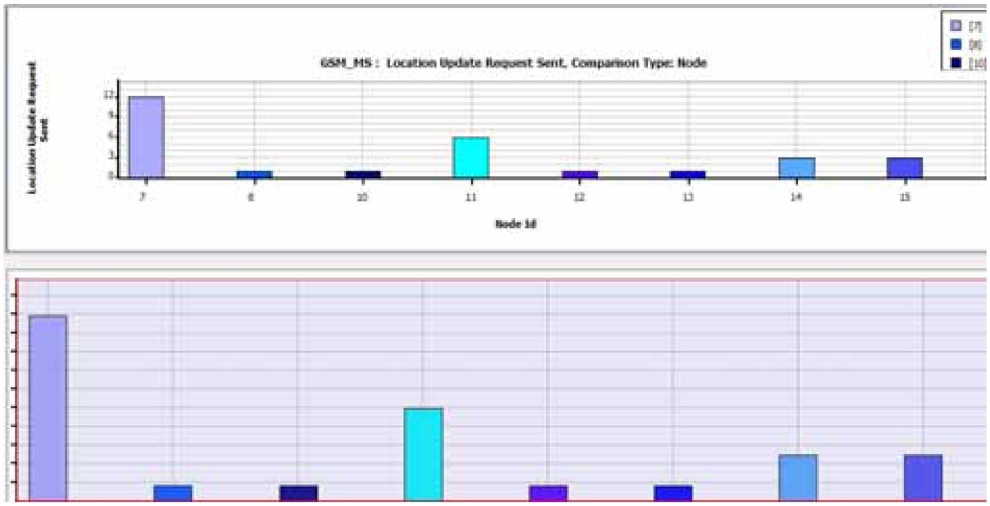

Figure 5.19 : S10 - Time Based Location Update

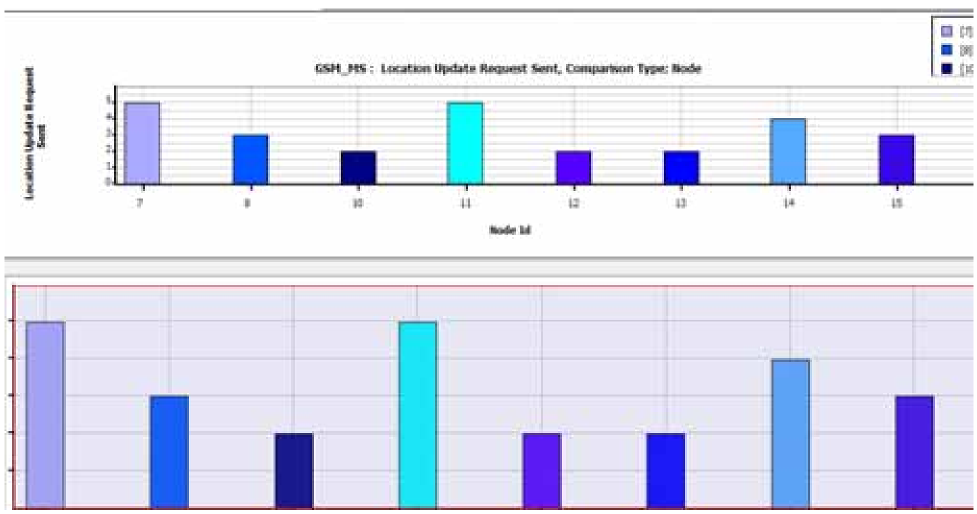

Figure `5.20 : S10 - Dynamic Time Based Location Update

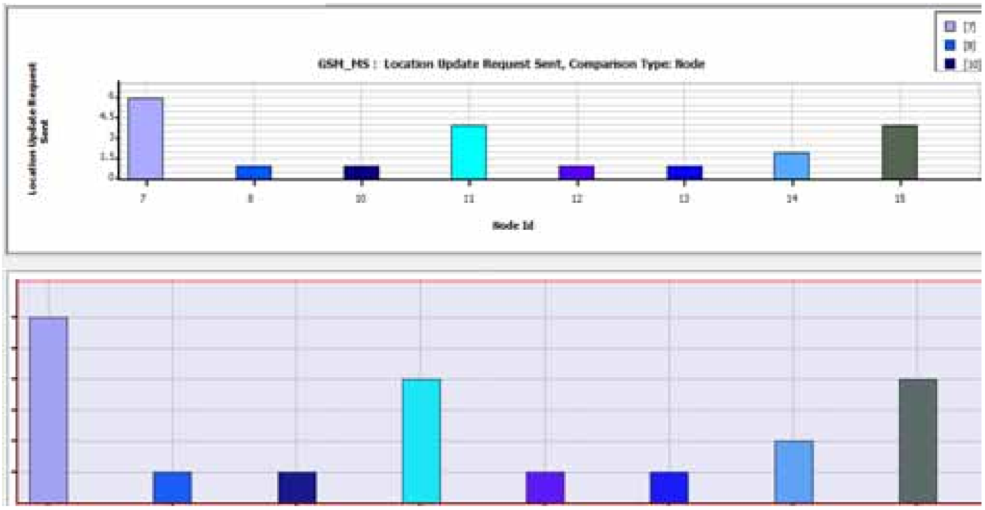

Figure 5.21 : S11 - Time Based Location Update

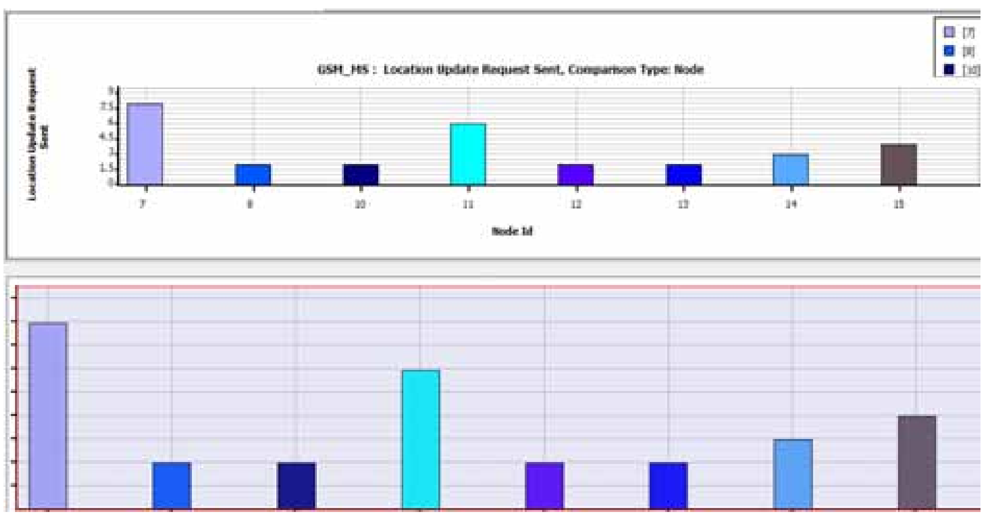

Figure 5.22 : S11 - Dynamic Time Based Location Update

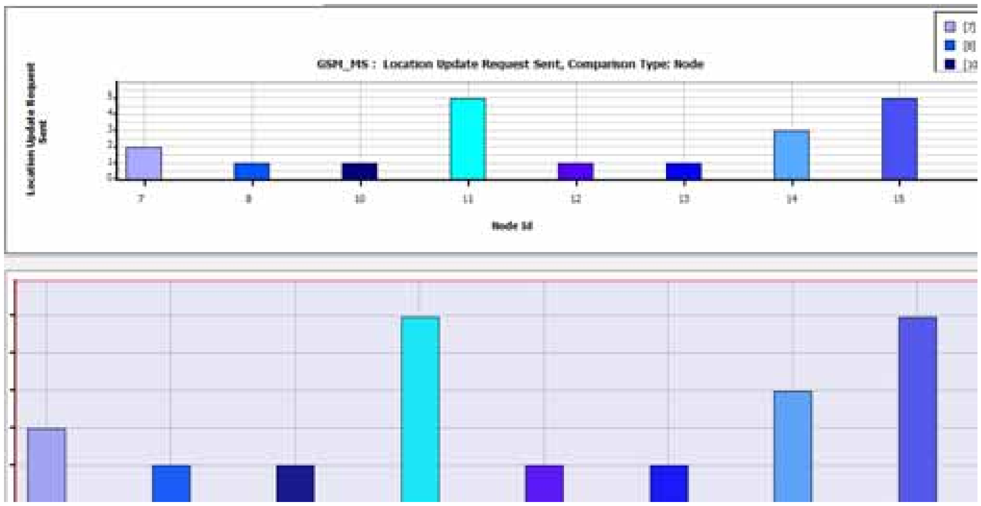

Figure 5.23 : S12 - Time Based Location Update

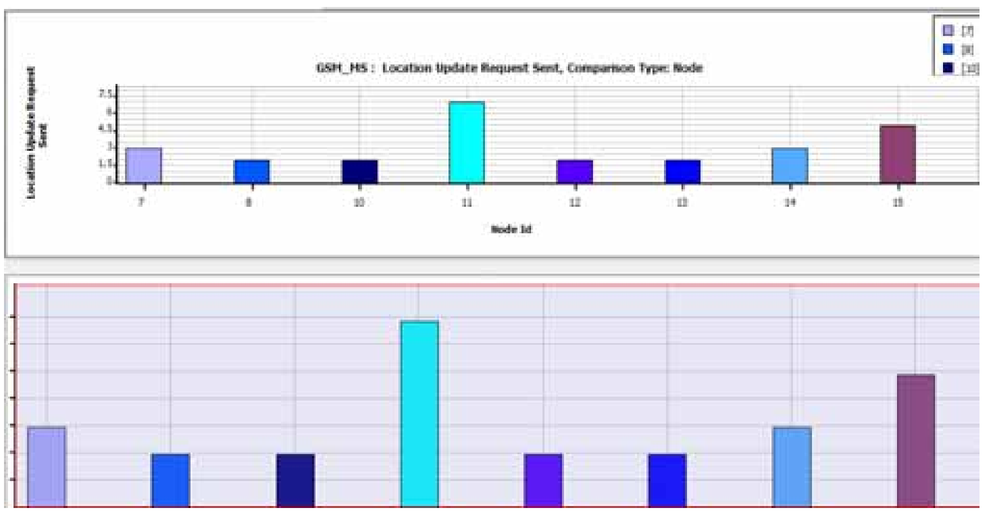

Figure 5.24 : S12 - Dynamic Time Based Location Update

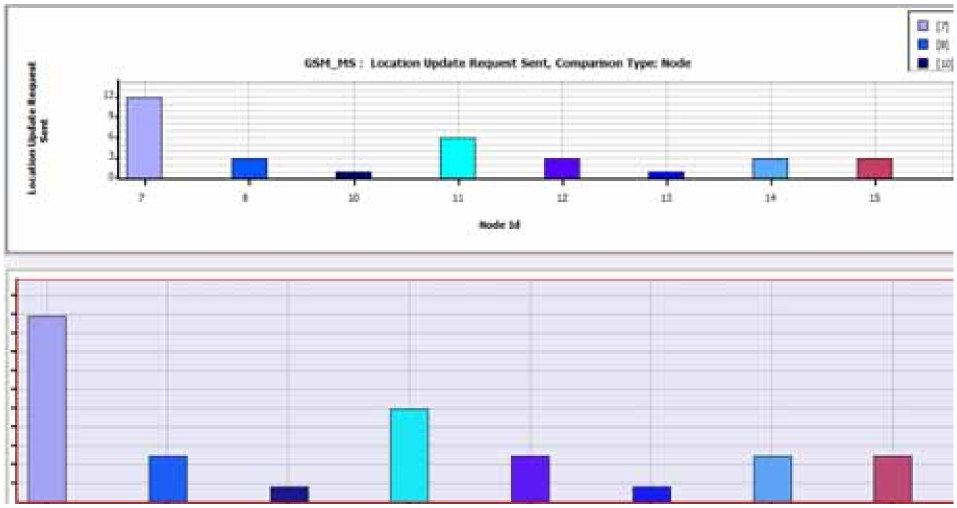

Figure 5.25 : S13 - Time Based Location Update

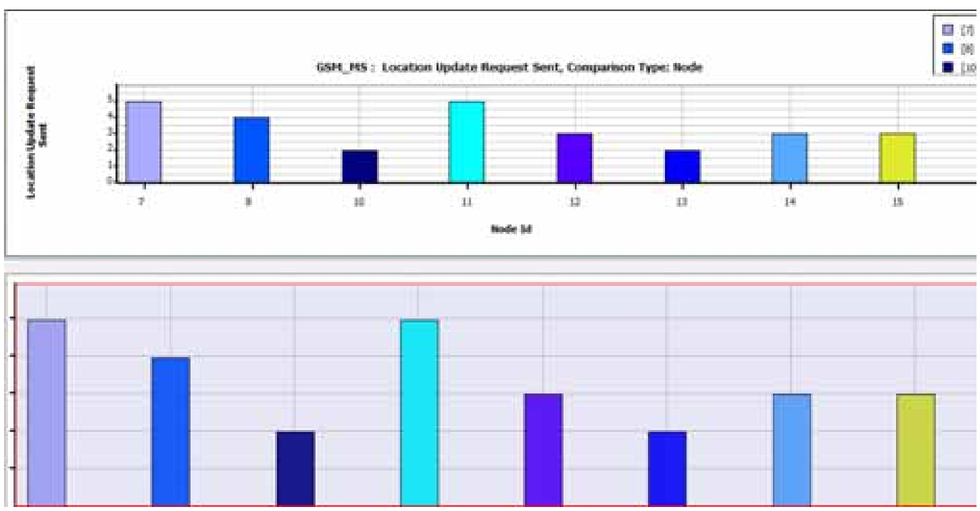

Figure 5.26 : S13 - Dynamic Time Based Location Update

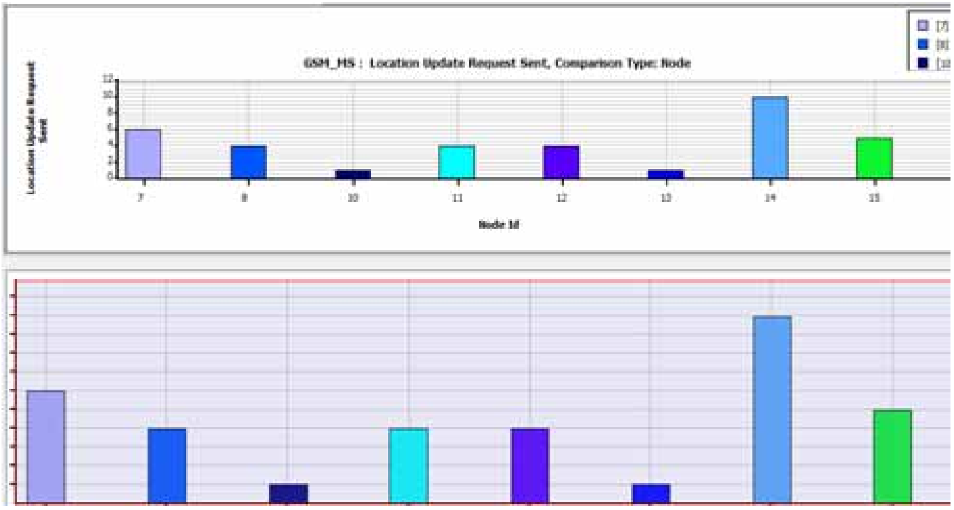

Figure 5.27 : S14 - Time Based Location Update

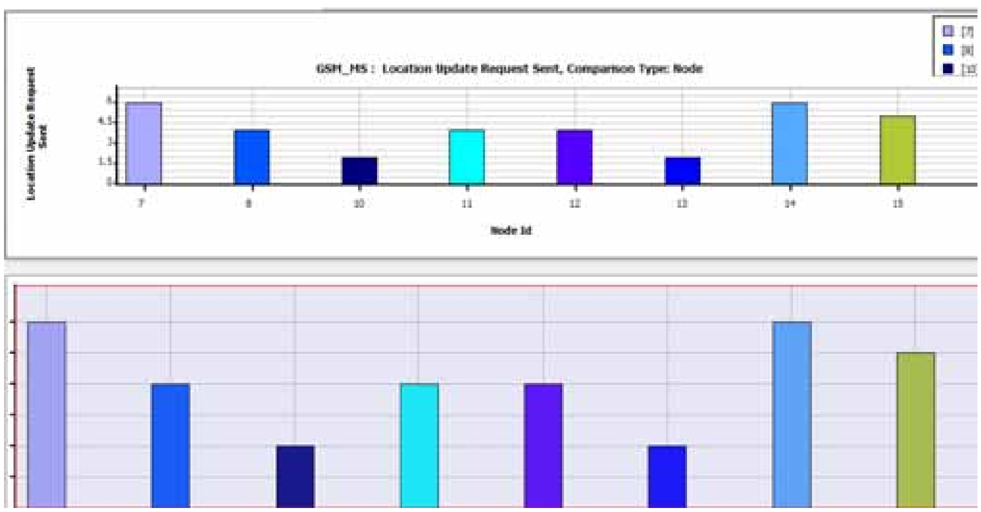

Figure 5.28 : S14 - Dynamic Time Based Location Update

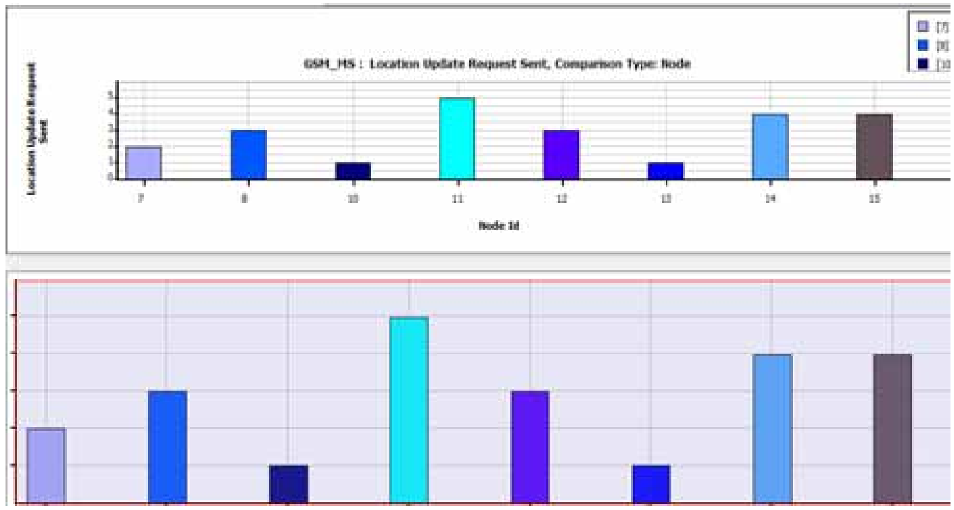

Figure 5.29 : S15 - Time Based Location Update

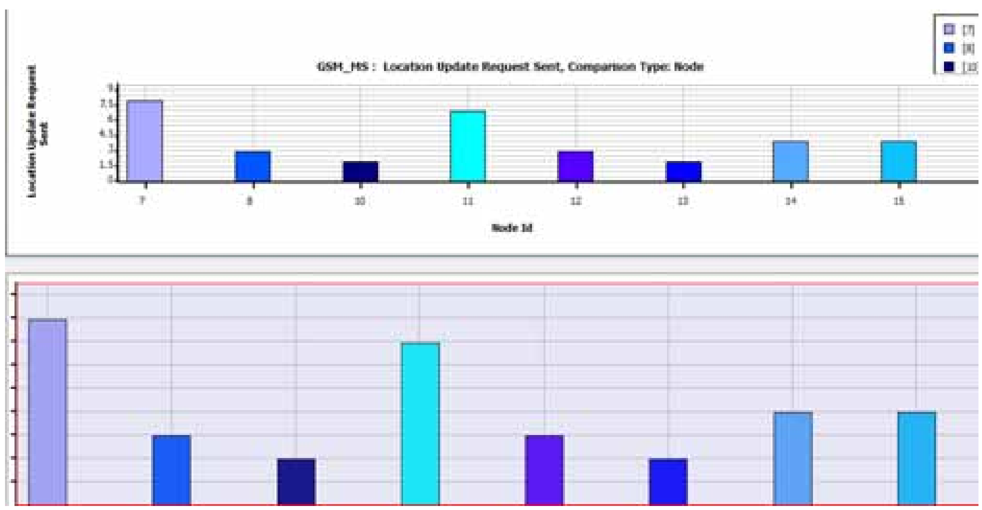

Figure 5.30 : S15 - Dynamic Time Based Location Update

Table 5.6 : Observations

Scenario ID	Caller1	Caller2	Time Based Location Update		Dynamic Time Based Location Update	
			No. of Location Update : Caller1	No. of Location Update : Caller2	No. of Location Update : Caller1	No. of Location Update : Caller2
1	7	11	2	2	2	2
2	7	11	2	2	2	3
3	7	11	2	2	2	2
4	7	11	2	2	2	2
5	7	11	2	2	3	3
6	7	11	2	2	2	2
7	7	11	12	5	8	5
8	7	11	6	5	6	5
9	7	11	8	5	8	5
10	7	11	12	6	5	5
	14	15	3	3	4	3
11	7	11	6	4	8	6
	14	15	2	4	3	4
12	7	11	2	5	3	7
	14	15	3	5	3	5

Scenario ID	Caller1	Caller2	Time Based Location Update		Dynamic Time Based Location Update	
			No. of Location Update : Caller1	No. of Location Update : Caller2	No. of Location Update : Caller1	No. of Location Update : Caller2
13	7	11	12	6	5	5
	14	15	4	4	3	3
	8	12	3	3	4	3
14	7	11	6	4	6	4
	14	15	10	5	6	5
	8	12	4	4	8	4
15	7	11	2	5	8	7
	14	15	4	4	4	4
	8	12	3	3	3	3

5.5 Observations

There are the cases where dynamic time based location update scheme performs more location updates than the traditional time based location update scheme. The reason is that in case of good past record of location updates, timers are set to small intervals which facilitate more location updates. Here good past record indicates the cellular network is stable as far as congestion is concerned. This way, we can conclude that dynamic time based location update doesn’t postpone important location updates.

There are the cases where dynamic time based location update scheme performs less location updates than the traditional time based location update scheme. The reason is that in case of poor past record of location updates, timers are set to large intervals which facilitate less location updates. Here poor past record indicates the cellular network is not stable as far as congestion is concerned. This way, we can conclude that dynamic time based location update doesn’t increase congestion by sending frequent location updates.

CHAPTER – 6

Conclusion, Future Work and Publications

6.1 Conclusion

Cellular phones are becoming more and more popular throughout the world. Due to wide acceptance, cellular networks have grown their geographical area in recent years. cellular networks are wireless networks as far as connectivity with the cellular phones are concerned. Wireless networks have their own disadvantages like limited bandwidth, poor signal strengths, signal drops, noise etc. at the same time, cellular phones are allowed to change their locations from one place to another place. GSM and GPRS architectures are the most widely accepted base of cellular network above which 3G and 4G are developed. The base of GSM is kept intact with the advance cellular network architecture. Here a set of cellular devices are controlled by a base station. Whenever a cellular device goes out of the range of a base station, it needs to be connected with an another base station to continue being a part of the cellular network. Such task is called handover. Handover should be sufficiently smooth that there is no disconnection while moving from one base station to another base station. Every cellular network needs to be identified whenever cellular network needs to reach to it. Location management is very crucial task in any cellular network. If locations of all the cellular devices are not maintained properly then voice / data calls may get disturbed / damaged / cancelled. This research work focuses on improving overall performance by enhancing location update scheme.

This research work started with studying the basis of GSM architecture and various associated issues. Various location update schemes like time based location update, movement based location update, distance based location update and profile based location update schemes are studied. Qualnet® simulator is used to simulate GSM scenarios. To identify the best location update strategy so far, research paper and suggestion from the cellular industry is studied. All location update strategies are tested with different scenarios as explained in Chapter 4. An algorithm is developed to select best out of all the tested location update strategies. Every scenario of a cellular network is evaluated across five parameters: Routing protocol, Number of infrastructure stations, Congestion of Cell, Mobility, Energy and memory saving. This algorithm shows that in most of the cases, time based location update performs better than rest of the location update schemes. The focus is given to enhance time based location update strategy.

Dynamic time based location update strategy is introduced. GSM architecture has various timers to repeat certain events at regular intervals. So far most of the timers have fixed values which don't change our time as per cellular network situations. In existing location update strategy, these timers are having static values and they don't change as per cellular network's situations. Dynamic time based location update strategy sets the values of these times as per cellular network's status. The information about past failures and acceptance of location updates are considered to decide how frequently new location updates should be initiated. There are two main observations are noticed as below.

There are the cases where dynamic time based location update scheme performs more location updates than the traditional time based location update scheme. The reason is that in case of good past record of location updates, timers are set to small intervals which facilitate more location updates. Here good past record indicates the cellular network is stable as far as congestion is concerned. This way, we can conclude that dynamic time based location update doesn't postpone important location updates.

There are the cases where dynamic time based location update scheme performs less location updates than the traditional time based location update scheme. The reason is that in case of poor past record of location updates, timers are set to large intervals which facilitate less location updates. Here poor past record indicates the cellular network is not stable as far as congestion is concerned. . This way, we can conclude that dynamic time based location update doesn't increase congestion by sending frequent location updates.

The main reason of this research work is to improve overall performance in cellular network by enhancing location update mechanism. The goal is to ensure that only required number of location updates should be done. Very Large number of location updates simply waste network resources and very small numbers of location updates simply skip some important location updates. Dynamic time based location update strategy balances between these two issues.

To efficient testing of this scheme, various real life scenarios are generated as explained in Chapter 4. Scenarios are classified with reference of mobility, congestion and handover. To implement channel limitation, Qualnet®'s built-in channel assignment process is modified so that real life situation can be simulated. Overall it is found that dynamic time based location update strategy is comparatively efficient that the traditional time based location update strategy.

6.2 Future Work

This research work tests dynamic time based location update strategy by generating real life scenarios in Qualnet® simulator. Though Qualnet® is one of the best simulators specially for the cellular networks, this scheme should be tested in real cellular networks. Advances to this scheme, further improvement can be done by incorporating location aware routing algorithms with cellular networks. It is also possible to set various parameters of time based location update schemes dynamically. A hybrid location update strategy can be implemented which supports all location update strategies. A specific location update strategy is selected as per user's mobility pattern and network situation.

6.3 Publications

1) A paper on "Wearable Computer Applications A Future Perspective" has been published in International Journal of Engineering & Innovative Technology, Volume 3, Issue 1 ISSN : 2277:3754 of July 2013.

2) A Paper on "Various Location Update Strategies in Mobile Computing" presented in National Conference on Emerging Trends in Information & Communication Technology (NCETICT-2013) held on 12th October, 2013 at Marwadi Education Foundation's Group of Institutions, Rajkot, followed by publication in conference proceedings in International Journal of Computer Applications with ISSN No. : 0975-8887 in March, 2014.

3) A Paper on "Importance of Paging Cost Reduction for Location Management in Mobile Computing" presented in National Conference on Emerging Trends in Engineering, Technology and Management (NCEETM) held on 31st January, 2014 at Indus University, Ahmedabad, followed by publication in conference proceedings with ISBN No. : 978-81-923049-9-1.

4) A Paper on "Profile Based Location Update Strategy in Mobile Computing" presented in National Conference on Emerging Trends in Information & Communication Technology (NCETICT-2014) held on 5th November, 2014 at Marwadi Education Foundation’s Group of Institutions, Rajkot, followed by publication in conference proceedings in International Journal of Advance Networking Applications (IJANA) with ISSN No. : 0975-0290 in November 2014.

5) A Paper on "Location update procedure in mobile computing" has been published in International Journal of Sciences and Applied Research (IJSAR), Volume 1, December 2014 edition ISSN (Online) : 2394-2401 and ISSN (Print) : 2394-384x.

6) A Paper on "Location Aware routing Schemes for Mobile Adhoc Networks" presented in International Conference on Recent Trends in Engineering Science and Management (ISBN : 978-81-931093-2-0) (ICRTESM-15) held on 15th March, 2015 at Jawaharlal Nehru University, New Delhi, followed by publication in conference proceedings in International Journal of Advance Research in Science and Engineering (IJARSE) with ISSN No. : 2319-8354 in March 2015 Special Issue.

7) A Paper on "A Study of Routing Protocols for MANETs" presented in International Congress on Information and Communication Technology (ICICT-2015) held on 9th and 10th October, 2015 at Hotel Golden Tulip, Udaipur, followed by publication in conference proceedings through Springer.

8) A Paper on "Opportunistic Location Update – A Novel Cost Efficient Reactive Approach to Remove Pauses in Cellular Networks" presented in International Conference on Communication and Networks (COMNET 2016) held on 20th and 21st February, 2016 at Ahmedabad Management Association Hall, Ahmedabad under CSI Ahmedabad Chapter and ACM Ahmedabad Chapter, followed by publication in conference proceedings through Springer.

9) A Paper on "Simulation based analysis of Location Update Strategies in mobile computing with Analytical Model" presented in International Conference on

Computing for Sustainable Global Development (IndiaCom 2016) held on 16th to 18th March 2016 at New Delhi followed by publication in conference proceedings through IEEE.

10) A Paper on "Simulation based analysis for effects of GSM Call during mobility and Location Update" presented in International Conference on Computing for Sustainable Global Development (IndiaCom 2017) held on 1st to 3rd March 2017 at New Delhi followed by publication in conference proceedings through IEEE.