DYNAMIC LOCATION AREA PLANNING IN CELLULAR NETWORK BY VIRTUALLY PERSONALIZE LOCATION AREA MANAGEMENT

A Thesis submitted to Gujarat Technological University

for the Award of

Doctor of Philosophy

in

Computer IT Engineering

by

Nileshkumar Bhailalbhai Prajapati
Enrollment No. 119997107009

under supervision of

Dr. Dhaval R. Kathiriya

GUJARAT TECHNOLOGICAL UNIVERSITY
AHMEDABAD

OCTOBER – 2018

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Abstract

In current scenario mobile users are increasing day by day along with that mobile technologies are also changing rapidly. The main aim of each cellular (mobile) service provider is to provide best quality of services (QoS) using minimum radio bandwidth. QoS is that mobile users (MUs) who get services anytime, anywhere without breaking call link with minimum call blocking and dropping. To provide better QoS we need to find location of MUs in cellular network and for that we must know the current base station of it. Location management is an essential function in cellular networks that allows the network to maintain the position of subscribers, in terms of location areas (LA). In GSM, the whole network divided into different LAs, which are very useful to find current location as well as mobility pattern of the mobile users. LA contain continuous group of cells and hold LA identification number. Size and shape of LA is more important in cellular network.

There are various methods, adopted by cellular companies like static and dynamic, to plan better LA in cellular network. LA planning is very important because location management cost, Location Update (LU) and Paging Cost, is derived based on that. Static LA planning methods form the LA such that total signaling cost will be optimal or minimum. But Static LA is common for all MUs which is not optimal for all MUs. So requirement of dynamic methods are desired to form LA which is optimal for each user. Dynamic methods are better than static one as they depend on the MUs' credential. Most of MUs' movements in cellular network are predefine, which always take same path and probably take same time to reach their workplaces.

This research work is divided into three parts: in first part, MUs' types (Predefine Estimated and Random users) are found out based on user's movement in the cellular network. In second part, dynamic location area (DLA) is created for the users which are regularly visiting some cells in cellular network. These frequently visited cells are assigned to MUs' as an individual LA. Finally in third part, mobility prediction of MU is found out based on the mobility pattern in cellular network which help the network in resource reservation. For creating DLA and finding mobility prediction accuracy in

cellular network three methods, viz Apriori, HMM and proposed SVR, implemented and results are compared with static method. Amongst these methods, proposed SVR reduce more signaling cost (location management cost) and give better mobility prediction accuracy which is also compared with static method.

Acknowledgement

First of all, I would like to express my sincere gratitude to **Lord Swaminarayan, Pramukhswami Maharaj** and **H. H. Mahantswami Maharaj**, who blessed me to conduct and complete this research work.

At this moment of accomplishment, I am also grateful to **Dr. Dhaval R. Kathiriya**, my supervisor for his continuous guidance, precious advice and constant encouragement. His astounding direction, noteworthy contribution in ensuring quality work is highly appreciable. He has always shown readiness to extend support as and when required and whenever I stuck up. He has been a source of inspiration and motivation throughout the course of this research work.

I am very much thankful to **Dr. Arun Somani**, my foreign Co-Supervisor for his remarkable help and support. Valuable suggestions and comments given by him helped me a lot to improve my research work at a great extent. His eagerness to help and motivation will always remember me in my whole life. I would never have possessed the capacity to complete the research work without the directions shown by Doctoral Progress Committee members. I want to express my thanks to my DPC members, **Dr. Apurva Shah** and **Dr. Atul Gonsai** for their helpful suggestions, comments, motivation and proper direction during my DPC review presentations, from beginning of my research work.

I am grateful to **Prof. A. A. Shaikh**, **Prof. M. I. Hasan**, **Dr. N. M. Patel and colleagues** for their valuable inputs, suggestions and motivational support for carried out my research work. I am thankful **to Prof. Nayan Mali**, **Ms. Maitri Patel** and **Prof. Hetal Gaudani** for their valuable inputs and technical support to pursue research work.

I am very thankful to management of **BVM** and **CVM** for giving me permission to do my research work. I am grateful to extend the lexes of admiration in the dignity of **Dr. Akshay Agrawal** (Former VC of GTU), **Dr. Navin Sheth** (Present VC of GTU) and **Dr. Rajul Gajjar** (Dean, PhD Section) of GTU for providing me with all the intellectual needs that have really pushed my work and motivated me all through my work.

I am forever obliged to my parents, **Bhailalbhai Prajapati** and **Kokilaben Prajpati**, and bhai –bhabhi, **Bhavesh Prajapati** and **Kaminiben Prajapati**, for providing me the moral support and encouragement which made me strong enough to achieve every goal in life.

Finally, I am deeply thankful to my wife, **Varsha**, who shared with me good times, and always supported me during bad times with her love, encouragement, patience and sacrifices. Special thank to my son **Mit** and nephews, **Dharm** and **Ankur**, who brought me joy everyday and made even hardships enjoyable.

All might have not been mentioned but none is forgotten.

NILESH B. PRAJAPATI

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List of Abbreviation

Abbreviation	Full form
ANN	Artificial Neural Network
Auc	Authentication Center
BS	Base station
BSC	Base Station Controller
BSIC	Base Station Identity Code
BSS	Base station subsystem
BTS	Base Transceiver Station
CCANN	Cascaded Correlation Artificial Neural Network
CI	Cell Identity
DLA	Dynamic LA
EIR	Equipment Identity Register
ETSI	European Telecommunications Standards Institute
GMSC	Gateway MSC
GSM	Global System for Mobile commutation
HMM	Hidden Markov Model
HLR	Home Location Register
IMEI	International mobile equipment identity
IMSI	International Mobile Subscriber Identity
LAP	LA Planning
LA	Location Area
LAI	Location Area Identifier
LU	Location Update
ME	Mobile Equipment
MSISDN	Mobile Station ISDN number
MSRN	Mobile Station Roaming Number
MSC	Mobile Switching Center
MU	Mobile User
PCS	Personal communication systems
PLMN	Public Land Mobile Network

Abbreviation	Full form
PSTN	Public switched telephone network
RACH	Random Access channel
SS7	Signaling System-7
SIM	Subscriber Identification Module
SVR	Super Vector Regression
TMSI	Temporary Mobile Subscriber Identity
UMB	User Mobility Behavior
UMR	User Mobility Record
VLR	Visiting Location Register

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1. INTRODUCTION

"Stay connected". It's today's way of saying "keep in touch", a language that millions of wireless customers speak, in a world of text messaging and voice mail. Staying connected is what millions of wireless subscribers try to do every day, and keeping them connected is the objective of the wireless providers. Using Cellular networks, wireless connection support is given to mobile equipment (ME). Since last several decades cellular network became the fastest growing wireless network which can be possible due to many reasons like, more and good Quality of location based services, reliable radio signal coverage and reducing price of MEs. One of the example of it is: last year due to Jio telecommunication mobile users (MUs) increase drastically (India's telecom subscriber base grew by 21.02 million at end-November 2016, of which Reliance Jio contributed 16.2 million, according to the Trai report). Radio bandwidth is limited resources so when number of MUs increase in the cellular network it is required to split the cells to make it small to accommodate more number of MUs. Splitting the cells, means reducing the size of cells, creates more challenges especially for location management and frequency distribution. Personal communication systems (PCS) services that are many designed for personal services and user mobility face the same problem like cellular network, due to smaller cell size

As cellular networks administrators implement considerably smaller cells, establishing microcellular and picocellular coverage to increase network capacity, the problem of cost-effective location management will turn out to be more serious because of the extra signaling made by more MUs and more cells. The supplementary signaling incurs additional cost to operators by consuming resources for network control that would otherwise be available to carry revenue generating traffic. The load on other functions of the network such as databases and switching in the fixed network also increases. Radio bandwidth is limited resources of wireless telecommunication network. So it is required to design network that efficiently use the limited radio bandwidth. Effective Location management is one means to achieve such efficiency. Call dropping and blocking are significant facet of telecommunication communications, that have obtained a lot consideration in recent times, which are resolved by proper location area planning, location management.

Location management is concerned about the methodology required to enable keeping location information of every MU, or all the more especially, and to efficiently handling of incoming calls, for every active ME with a registered MU. There is always issue of connectivity of MU, as MU move in network and sometimes in other network while in the telephony system; equipment is fixed to the location. Cellular networks requires information regarding location of MUs, as and when there is an incoming call or message to the MU and that information is specific cell where MUs resides. When incoming call or message arrives station (BS) which gives better radio signal, it perceives paging messages which is for the MU.

MU's mobility and resource managing is the main concern for the cellular network in location management. There are two broad classification of mobility when we are discussing telecommunication network and those are device and personal mobility. Device mobility permits a device to physically move throughout the service area of the cellular network. This is an intrinsic characteristic in all cellular networks. In Personal mobility a MU is allowed to move throughout the service area of the cellular network irrespective of a specific device. This is possible by providing identification number to MU as well as device and keeping track of binding (relationship) between device and MU. For that Smart card concept has been introduced which will be equipped with the compatible device which is called subscriber identification module (SIM). Using SIM, it is possible to deliver and receive calls and messages at particular device, with proper message and call routing. MU is important not the ME, for classified personal mobility category which has to be tracked in the cellular network. Tracking of MU can be done directly or indirectly (by tracking the ME, but using mapping functions of ME and MU identifiers). The smallest unit of location information that cellular networks are concerned regarding is the radio cell, BS. "A cell is the geographical area over which the average signal strength, frequency, from the radio transmitter is transmitted which is varied compared to neighboring cells' frequencies to prevent co-channel interference". The group of frequencies can be used to other cells. Cells are theoretically represented as hexagons but in real environment it might be in different shape. Due to irregular shape and neighboring cell, interference and path losses happens in the cellular network.

Grouping of cells for Location Area (LA) as well as paging area is done while cellular network is concerned about the location management. Design characteristic of LA makes sure that we do not need to update location of MU as far as it is moving in same LA. A LA is the second smallest unit at which the location of the MU is known. By definition paging area "is the set of cells over which a paging message is sent to inform a MU of an incoming call". Obviously, LA and paging areas must be related to be useful. In most of the cellular systems, LA and paging areas are identical. Because of that, LA is identified as group of cells which is required for location management.

Location Management involves two components: Location Update (LU), when MU cross the boundary of LA and entered into new LA, and Paging, when any mobile terminated call is arrived the cellular network page MU in network to elicit a response of MU so call can be routed. LU is initiated by the ME while paging is initiated by the cellular network. The rate of LU and paging messages pertains closely to MU movement and call arrival rates, along with network characteristics such as LA. Total location management cost is depends on the LU and paging cost. The total cost of LU and paging consists three parts [1].

1. The occupied radio link bandwidth.
2. The computational resources required in various network components, such as MSC and BSCs.
3. The network traffic between the network components.

Location management cost can be minimized by minimizing one of the costs. Both costs cannot be minimized at the same time because of tradeoff of between them.

There are two major techniques for location management which is reciprocal to each other in terms of LU and paging. The first technique, called Always Updates [2], keeps track of the location information of the MUs at the individual BS level same as that LA size is equal to one cell. Whenever the MU discovered that it has moved to a new BS a LU is performed. But for highly movable, random user, LU may happen very frequently.

This is clearly very inefficient. However, paging messages need only be sent to one cell, hence the exact location of the MU is known.

At the second extreme approach, called Never Update [2], the LA of the MU consists of all the cells in the network, means size of Mobile Switching Center (MSC). Information of MU's location is available at core part, MSC and HLR, if the cellular network gives information showing that ME is within the network. This means that LUs are not required at all. The cellular network has to broadcast page for every cell in the network when an incoming call is initiated. As this procedure is repeated for every initiated incoming call this is very expensive procedure and hence not satisfactory approach.

In the third approach, called Selective Update [2], location information is stored centrally. LU happens in the cellular network base on threshold values it is also known as dynamics methods. Time, movement and distance threshold are mainly concern for that. These state (threshold) based methods contain some pros and cons which discussed in chapter 3. Other dynamic methods are profile based which uses MUs mobility behavior and pattern for designing LA which are also discussed in chapter 3 with more details.

1.1 Problem Definition

Location management cost, LU and Paging cost, is depended on the LA. The size and shape of LA plays the important role in LU and Paging cost. Like that numbers of LA in cellular network is also affecting the both cost. As discussed above, the size and shape of LA is coverage area of MSC then LU cost is minimized but paging cost is increased. Like that if numbers of LA are equal to number of BS then the LU cost is increased while paging cost is minimized. So it's important to better LA management in cellular network.

The Global System for Mobile commutation (GSM) network use the zone based approach for LU and paging procedure. In zone based approach the boundaries of LA are fixed, called static LA. There are various static LA planning methods are used for obtaining optimal signaling traffic of particular static LA. So, LA planning in cellular network is important factor. Better LA planning gives the better services to MUs in cellular network with minimum location management cost. But static LA has its advantages and disadvantages, like size and shape of static LA is not optimal for all MU reside in that LA, which directed to create dynamic LA for each MUs. Dynamic LA (DLA) is created based on the MUs movement in the GSM network. Majority of MUs have same movement pattern in network which is useful to create individual LA, DLA, for MUs.

In this research work, types of user (Predicted, Estimated and Random) from the cellular networks are obtained. From that for Predicted and Estimated MUs, DLA planning in Cellular network is described and implemented by the use of Apriori, Hidden Markov Model (HMM) and proposed Super Vector Regression (SVR) for finding individual LA in cellular network which uses minimum network resources. Mobility Prediction within DLA is also implemented using above method for finding next movement of MUs in cellular network so MUs get service without breaking call link with minimum call blocking and dropping. So the aim of DLA planning is satisfied. The aim of this work is to minimize the total location management cost, mobility prediction of MUs in cellular network and providing better Quality of Services (QoS) by appropriate DLA planning in the cellular network.

1.2 Motivation

The motivation behind this research work is depended on following reasons. First, the wireless spectrum is a scarce as well as an expensive commodity. In report of wireless spectrum action 2016 [3] demonstrates that overall revenue gained by Indian governments is Rs 65,789.12 Cr just from sold 40% of wireless spectrum. Wireless spectrum is an extremely high priced resource; it is of leading significance to decrease unnecessary network bandwidth use, in this way decreasing the spectrum requirements for a network operator. With the management of MUs' location consuming considerable proportions of the radio spectrum, excellent cost reductions are available through efficient location management implementation. The continuous expansion of wireless communication systems and enlargement of network registration rates, radio signals increased demand for the effective location management. The effective location management is possible through proper LA management.

Second, most of cellular network's users have predefined and same movement in their daily life. For example, student and employee have same movement pattern and take same path to reach school and work place during week days. The movement of these types of users may be changed due to sudden causes but these types of scenarios are rare. In cellular network more than 70% users have same movement pattern and behavior [4]. Based on MU's movement pattern and behavior users are divided into three types of users: predictable, estimated and random. Effective location management for such kind of MUs, predicted and estimated, reduce radio frequency of cellular network.

Third motivation is providing good QoS to MUs. In current scenario of digital world is, every one want good QoS in minimum amount. Also cellular companies are trying their best to provide best QoS to their customers. Rate of call dropping and blocking in the cellular network are increased due to high amount of radio signal used by the MUs. This rate must be kept minimum is the responsibility of the cellular companies. This is possible by proper location management of MUs which leads to effective LA management.

At present carried out location management schemes are entirely static - all MUs in a given region are assigned the same LA regardless of their mobility characteristics. Such an implementation is considerably suboptimal. DLA planning schemes aim to reduce the location management cost of static schemes by assigning appropriately sized and shaped LA depending on individual user mobility behavior and pattern, called individual LA. Using DLA planning both cost, LU and Paging, can be reduced which is not possible in static LA planning methods. Also, Cellular networks are all ready designed and established. Any architectural changes in that use huge amount of money and man power. The present work has not required any changes in current established of cellular network.

1.3 Objective and Scope

The following are the objectives of the research work:

1. To propose new method and its implementation in network without changing existing cellular network architecture for reducing total location management cost which will reduce total radio signaling cost in network.
2. To propose a movement prediction scheme for cellular network so resource management for MUs could be made feasible.
3. To provide good QoS to MUs by implementing proposed method.

The scope of the research work is as follows:

1. To reduce both, LU and Paging, costs are very challenging tasks in static LA based cellular network. The DLA based cellular network helps in reducing both types of cost which reduce total radio signaling cost of cellular network.
2. The DLA based cellular network is formed by few numbers of cells which are frequently visited by MUs. Mobility prediction becomes easy in such kind of LA which provides better QoS to MUs by allocating resources in advance. Call dropping and blocking issues become negligible.

1.4 Organization of Thesis

The thesis describes the research work done to fulfill problem described in Section 1.1. The thesis is organized as follows.

Chapter 2 gives the introduction of the background concepts regarding location management procedure with its types. History and architecture of GSM as well as identification parameter of the cellular network are also discussed. Location management procedures in GSM network are elaborated in detail which leads the importance of LA as well as proper planning LA.

Chapter 3 describes the literature reviews regarding previous work into planning of LA for effective location management through various static and dynamic methods. Various Static LA methods are elaborated with its pros and cons which lead to importance of DLA planning methods. Different DLA planning methods, State based; Profile based and Hybrid methods; and mobility prediction methods for prediction movement of MUs are discussed to find out research gap.

Chapter 4 present the implementation of the research work carried out during research period. Implementation is partitioned in three fold. First types of users, Predictable users, estimated users and random users; are categorized from the Dartmouth dataset which is used for mobility prediction. In second and third phase using dynamic and proposed method DLA formulation and mobility prediction in the cellular network are demonstrated.

Chapter 5 represents the result analysis part of the thesis. In this chapter, results of static, dynamic and proposed methods for LU, paging and mobility prediction accuracy are compared. Also some others results like, minimum, maximum and average used access points are given with detail information.

Chapter 6 describes the conclusion and future work possible in this area. Conclusion shows that proposed SVR method perform better than static and dynamic methods for reducing radio bandwidth, minimizing location management cost, and give more mobility prediction accuracy. Adaptive base methods can be developed for more mobility prediction for predictable and estimated users when movements of them are deviated from regular movement.

2. LOCATION MANAGEMENT

Location management is main concern of this research work. Location management fundamentals, GSM architecture and importance of LA in location management of second generation networks are discussed in this chapter. These details are going to useful for enhancing background knowledge for understanding research work.

There are two broad categories of location management methods which are network generated procedures and mobile equipment generated procedures [5]. If there is an incoming call or message for MU then and then only network generated procedure are called while mobile equipment generated procedures called in every circumstances if MU active or powered on and this is the major difference between these two procedures.

2.1 Network Generated Location Management Procedure

For handling incoming call, set of procedure needs to activated and one of that is Network Generated procedure. Fixed network user or another MU of the cellular network might have initialized incoming call. The purpose of Network Generated location management procedure is to locate the MU for whom the incoming call is proposed.

There are basically two steps while locating the MU; one is interrogation phase in which searching is carried out in location database for LA. For incoming call, Second step is a paging phase, in which all the cells, of the current LA, generates broad cast a paging message.

Interrogation

Location information and other details of the MU is kept into the home network in special database in every cellular network. The MU’s details may be stored at centralized or distributed manner as per the structure of database. This database structure and standard are may be differ as per cellular network or as per implementation of the same. During this phase, an advanced switch in the cellular or fixed network will search in the database for the present location of the MU related with the destination dialed number. An intermediate switch has an access to the location database. Answer of this query may be redirect to another dataset called visiting location register (VLR), dataset, which has information regarding current BS, or LA, of the MU.

Paging

In this phase, Paging includes messages consigned over the radio interface or network to notify the MU that an incoming call is remaining. While the MU responds its specific BS to which it is connected within cellular network, the call setup can proceed. Recall that the cellular network knows the situation of the MU only at the LA level. Since radio spectrum is limited resources so paging messages have to be retained to a minimum in the cellular network for correctly finding location of MU in interrogation phase. The ME has to keep vigil to the paging channel continually as it cannot clearly predict the arrival of paging messages however this scenario consumes battery power of ME.

2.2 Mobile Equipment Generated Location Management Procedure

The main concern of this group of procedure is to transmit location detail pertaining to ME to the cellular network when the ME is powered on. This updating of record is done depending on few scenarios like when the ME powers on or off, or LA is changed when an active ME identifies it.

Location Update

The prime ME generated procedure is the LU. A cellular network consists of several cells, which are usually arranged with each other into LAs. A BS will broadcast a LAI as along with a cell identifier. A ME constantly observes signal power and/or quality from adjacent cells. If a ME determines that coverage is better in another cell, and the LAI of the new cell differs from the LAI of the current cell which is stored in ME, a LU is activated. As due to resource crunch of limited radio spectrum, and limited channel, LU needed the setup of a signaling channel to deliver the location detail which needs to be reduced.

Location registration

In Location registration procedure, data of MU is retrieved from other dataset when not present in the current dataset. It is prime difference between LU and location registration. These types of situation happen when the ME is switched off and power on in another LAs. Location registration is also depends on the LU, as new location of MU is detected.

Attach and Detach

For reducing location management cost, we requires to reduce total number of paging and for that same purpose two opposite functions are used which are attach and detach. The detach function is executed while an active ME powers off due to battery problem or MU's requirement. An incoming call is not completed if ME is power off, unreachable, so radio signals are going to waste while paging this ME. To reduce misuse of radio signal for this kind of situation, ME's last location must be informed to the network for storing details of ME. So when any incoming call for these kinds of MUs are arising that will be rejected at the core level of cellular network. So extra efforts by radio signaling, to elicit response from MU using paging is drastically reduced which save cellular network resources.

The attach function is invoked by ME when it powers on again. When ME is power on then based on its location in cellular network following scenarios are happens. First scenario, when ME is power on in the same LA where it powered off then only attach information given to the cellular network. This information is useful to network for delivering call, messages and network supports to that ME. But instead of same LA if ME power on in another LA then LU will happens. A LU cause due to LAI is differing then the LAI stored in ME where it powered off. This will help the network to get information of ME from the core part of cellular network. Also the current location of ME is known to cellular network which helps for further communication.

2.3 Location Management Procedure in GSM

The location management idea as well as processes will be discussed in detail depending on their execution in the GSM digital cellular standard. GSM is digital cellular network which transmit digital signals for communication between entities of network as well as over the radio interface. It gives ISDN compatibility relating to user services offered and basic protocol structure, although not in terms of data rates, considering the allotted radio spectrum is finite [5].

Following section discussed GSM standard establishment history, including the GSM network architecture and the location management techniques and parameters affecting it. These concepts is going to be required to understand the importance of LA and its proper planning, to reduce radio singling, in cellular network for better location management and mobility management procedure used in GSM.

2.3.1 GSM Network

GSM is a second-generation (2G) digital cellular communication system which is one of the fastest growing mobile networks in the world. GSM is the name of standardization group established in 1982 when frequency bands of 890-915 MHz and 935-960 MHz were allocated for the Pan-European Public Land Mobile Network (PLMN). The main purpose of the group was develop a 2G standard to resolve the roaming problem in the existing different 1G analog cellular system in Europe.

Before a 2G digital cellular networks all the mobile telephone systems were use analog cellular network which is called 1G network. One challenge facing analog system (1G) was the inability to handle the growing capacity needs in a cost-efficient manner. To overcome this problem digital technology was introduced. The advantage of digital (2G) system over analog system include ease of signaling, lower levels of interfacing, integration of transmission and switching, and increased ability to meet capacity demands[6].

From 1982 to 1985 discussions were held to decide by committee to build an analog or digital system. In 1986, the task force was formed, and in 1987 a memorandum of understanding was signed. In 1989, European Telecommunications Standards Institute (ETSI) included GSM in its domain. In 1991, the specification of the standard was completed, and in 1992, the first deployment started. By the year 1993, 22 countries adopted the GSM standard, and by 2001, close to 150 countries had adopted GSM for cellular operation [7]. An outline of GSM landmark is presented in below Table 2.1.

Year	Milestone
1982	GSM formed
1986	Task force was formed
1987	Memorandum of understanding signed
1989	ETSI include GSM
1991	Specification of the standard completed
1992	First deployment started
1993	22 countries adopted the GSM standard

TABLE 2.1 GSM MILESTONES [7]

2.3.2 GSM Architecture

GSM is digital cellular network which transmit digital signals for communication between entities of network as well as over the radio interface. Fundamentally GSM network can be divided into three parts based on their functions: 1. ME 2. Base station subsystem (BSS) 3. Switching subsystem. As shown in Figure 2.1, each of the system is made up of number of functional entities. For transmission of data and communications purpose entities uses different interface making use of specified protocols [7].

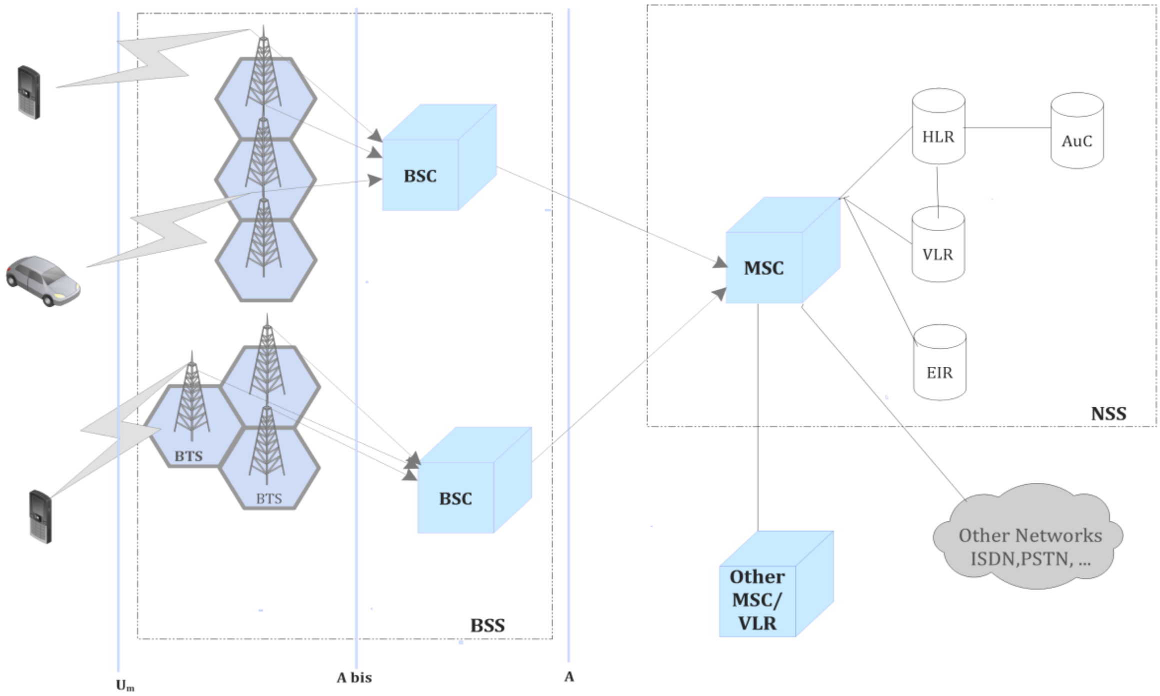

FIGURE 2.1: FUNDAMENTAL ARCHITECTURE OF GSM NETWORK

Mobile Equipment

The ME communicates the information with the user and modifies it to the transmission protocols of the air-interface to communicate with the BSS. The ME has two elements as shown in Figure 2.2. The first element is Mobile device, which is a piece of hardware and second component of the ME in the GSM is a smart card called the Subscriber identity module (SIM). The ME consists of all the elements required for the implementation of protocol to interface with the user and the air-interface to the BSS. The elements consist of speaker, microphone, keypad and the radio modem. The SIM card is an integral part of the GSM design that permits the functioning of personal mobility. Whenever subscriber plug SIM card into ME then they able to receive and make call with proper routing and billing information. SMS are also stored into SIM card. SIM card also stored information of location as well as information of subscriber identity so it's useful for the mobility management functions. SIM card carry the private information of user so SIM card also implemented security related functions such as encryption and authentication.

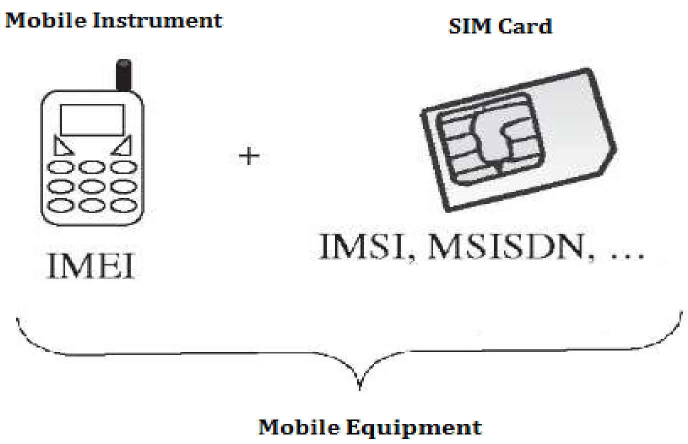

FIGURE 2.2: PARTS OF MOBILE EQUIPMENT

Base Station Subsystem

The BSS communicates with the user through the wireless air-interface while with the wired infrastructure through the wired protocols. All the radio interface related functions for the wireless networks are performed into BSS. The BSS contains following elements:

1. **Base Station Controller (BSC)**

BSC provides physical links between MSC and BTS. BSC is switch inside the BSS which control of radio frequency power level and handover among the BTSs inside a BSS. One MSC contains one or more than one BSC while number of BTS served by a BSC. BSC uses interface A to connect with MSC while BSC uses A_{bis} interface to connect with BTSs. Important functionalities of BSC contains: radio channels (frequencies) reservation for communication and managing handover, allocation and controlling of radio channels for BTSs. Likewise, call maintenance; authentication, encryption and decryption of data; updating location registry for MUs and frequency hopping functionalities are also supported by BSC. BSC also responsible for traffic control by continuously measuring the frequency channels used at given time. For example, when a serving BTS does not receive adequate signaling power from a ME, the BSC will hand over the signal to another BTS to ensure optimal transmission power for the MU(s).

2. **Base Transceiver Station (BTS)**

In cellular network each cell of the network is called BTS, also called Base Station, BS. The BTS is the counterpart of the MU for physical communication over the air-interface. BTS is physically located in the center of the cells where the BSS antenna is installed. BTS contains one or more transceivers (TRX) which are responsible for radio signal transmission and reception. Because of BTS's transmission and receiving capability same as radio equipment we can also say that BTS itself radio equipment. Main functionality of BTS is to amplify the signals up to acceptable strength so signal can be able to transmitted data without loss of information.

Switching Subsystem

The Switching subsystem performs the call related and subscriber related functions. The Switching subsystem is the most elaborate part of GSM network which involved one hardware element while four other software elements which are shortly introduced below.

1. Mobile Switching Center (MSC)

A MSC is hardware part of GSM network that can communicate with other Public switched telephone network (PSTN) switches and other MSCs in the coverage area of a service provider using the signaling system-7 (SS7) protocol. MSC is also called the core switching element of the network because it's performing telephony functions, such as call to and from the user. MSC also contains the functionality need for handling subscriber mobility and security. A GSM network has one or more MSCs. One and more than one BSCs are connected with MSC. MSC also provides registration, authentication, call location, inter-MSC handover and call routing to a MU.

2. Home Location Register (HLR)

HLR is the database software which keeps records of each subscriber of the network. Subscriber of the GSM network is associated with one particular HLR. HLR is the permanent database of user. HLR stores the subscriber's address, service type, authentication keys, current location of mobile station, forwarding address and accounting information. It also plays a major role in the process of calls delivering to the MU.

3. Visiting Location Register (VLR)

VLR is temporary database software which is connected with the area of one MSC. It also works similar to HLR and information which it contains is subset of HLR information. When any ME visits another service area at that times it associated with VLR of that service area, MSC. At that time VLR of that service area needed information of that ME and its get the information about it from its HLR in which it's registered. HLR is responsible for giving information to VLR.

4. Authentication Center (AuC)

A unit called AuC provides different algorithms that are used for authentication and encryption of the subscribers which verify user's identity and make sure the confidentiality of each call.

5. Equipment Identity Register (EIR)

The EIR is database which contains information about identity of ME. It keeps the international mobile equipment identity (IMEI). From IMEI we can know the manufacturer, country of production and type of terminal. This information is used to report stolen phones and checking the specification of phones.

2.3.3 Recognization Parameter in GSM network [8]

The GSM cellular network delights the MU and the ME in several ways. Cell phone numbers, MU and ME identifiers are a portion of the known ones. There are numerous different identifiers which may have been well-defined, that are needed for MU's mobility management as well as for dealing with the remaining cellular network elements. Essential addresses and identifiers that are being used as a part of GSM network are described below:

1. **International Mobile Station Equipment Identity (IMEI):**

From all over the world, we need to identify ME without any duplication and to achieve this special number is given to the ME which is called The International Mobile Station Equipment Identity (IMEI). This number to ME is issued by the manufacturing company of device and network operator will keep records of this number for each ME, EIR is used by the Network operator to store IMEI number. This same number is used to identify device for stolen, obsolete and non-function device. It consists of a maximum of 19 digits, which are divided up into a Type Approval Code (6 digits), Final Assembly Code (6 digits), Serial Number (6 digits) and Spare (1 digit) which is also shown in Figure 2.3. This number can be used to extract the manufacturing date, and manufacturer of the device along with identifying the device itself.

TAC	FAC	SN	Spare
(6 digits)	(6 digits)	(6 digits)	(1 digit)

FIGURE 2.3: IMEI NUMBER FORMULATION

2. **International Mobile Subscriber Identity (IMSI):**

In cellular network, we required to identify MU uniquely and for that IMSI is required. Registered MUs have an IMSI plus IMEI number stored in their SIM. This number has special parts which are shown as follow.

Mobile Network Code: Unique identity of mobile network in county which is of 2 digits

Mobile Country Code: This uniquely identifies country from rest of the world (3 digits like for India 091),

Mobile Subscriber Identification Number (up to 10 digits),

identification number of MU in the home network as shown in below Figure 2.4.

MCC	MNC	MSIN
(3 digits)	(2 digits)	(10 digits)

FIGURE 2.4: IMSI NUMBER FORMULATION

3. **Temporary Mobile Subscriber Identity (TMSI):**

The Temporary Mobile Subscriber Identity is assigned by a VLR to a MU, and is valid only while the MU is registered at that VLR during its mobility within the area handled by that VLR. It is give current location information of MU. The purpose of the TMSI is to reduce radio singling by minimum paging by providing help for locating MU in the cellular network. For identifying MU, a TMSI number alone is not helpful; help of current LA is required. A TMSI is smaller than the IMSI.

4. **Mobile Station ISDN number (MSISDN):**

The MSISDN is called authentic telephone number of the MU which is dialed by a caller to access the MU. The format of MSISDN visually display in Figure 2.5 consists of a Country Code (up to 3 digits), a National Destination Code (2-3 digits) and a Subscriber Number (10 digits). For proper translation of number to SS7 worldwide title address for HLR of the MU, the National Destination Number and Country Code should have enough information. The ME may have more than one SIM and MSISDN number is allocated to SIM respectively. These initial digits of the Subscriber Number can be utilized for further routing.

NDC	SN
(2-3 digits)	(10 digits)

National Mobile Number

CC	NDC	SN
(3 digits)	(2-3 digits)	(10 digits)

International Mobile Subscriber ISDN

FIGURE 2.5: MSISDN NUMBER FORMULATION

5. **Mobile Station Roaming Number (MSRN):**

While MSC uses a special numbering plan for roaming devices, which is similar to local telephone number and that is called Mobile Station Roaming Number. This same is used by VLR to route an incoming call to device using this special number called MSRN. MSRN has the same structure as the MSISDN. The VLR has repository of numbers as pool from which MSRN may allocated to ME for the purpose of incoming call. Incoming calls are channeled to the MU due to MSRN.

6. **Location Area Identifier (LAI):**

The LAI is transmitted by every BS, uniquely determining the LA to which it belongs. The LAI is also stored in SIM of the ME. The Location area Identity (LAI) has three sections in header: Mobile Network Code which is of 2 digits, Location Area Code which is of 16 digits and Mobile County Code which is of 3 digits as described graphically in Figure 2.6. Size of LAC is 16 bits so up to 2^{16} different cells, BTS, can be within one LA.

MCC	MNC	LAC
(3 digits)	(2 digits)	(16 digits)

FIGURE 2.6: LAI NUMBER FORMULATION

7. **Cell Identity:**

2 octet field lengths are given to cell, which is called cell identity. This same is used to identify cell in the LA. For global level, to identify cell it also required LAI and hence it is also appended.

8. **Base Station Identity Code (BSIC):**

The BSIC is a code used in GSM to uniquely identify a base station. The code is needed because it is possible that mobile stations receive the broadcast channel of more than one base station on the same frequency.

Here we discussed in brief foundation of GSM network, architecture and Recognization parameter in GSM. Some of first generation and Most of second generation cellular network use zone based approach for LU. Zone based approach has two scheme

LA and Reporting cells. Now we discuss about reporting cells, LA and LA's importance in cellular network.

2.4 Reporting Cells

One of the location management strategies is reporting cells or reporting centers [9]. In the reporting cells approach, subsets of cells have been determined from all cells. All those determined cells are known as reporting cells, while the other cells are known as non-reporting cells. The BS of every cell broadcasts a signal to reveal whether the cell is a reporting one or non-reporting cells. Because of that a ME knows whether currently it is in a reporting cell or non-reporting cells. Figure 2.7 shows a service area with six reporting cells, marked by black colors. For every reporting cell, its surrounding area is considered the collection of all non-reporting cells which are reachable from cell without crossing another reporting cell. The reporting cell is part of its own surrounding area. For example, the surrounding area of cell 3 includes cells 1, 4, and 6 in below Figure 2.7.

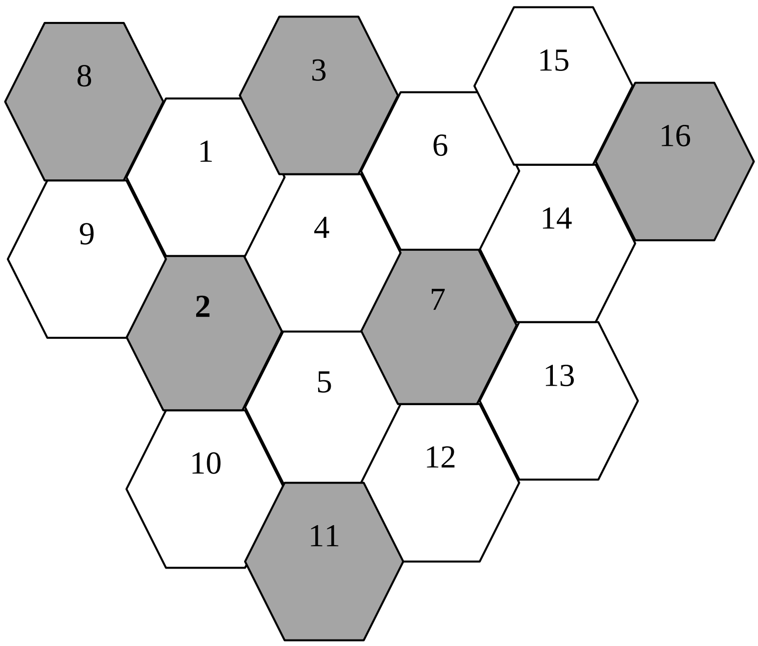

FIGURE 2.7: A SERVICE AREA WITH SIX REPORTING CELLS.

A ME will update its location (i.e. cell ID) whenever it goes into a new reporting cell. For example, when a ME goes from cell 7 to cell 6, then to cell 3 in figure 2.7, it will report its new location because cell 7 and cell 3 are two different reporting cells. However, when a ME goes from cell 7 to cell 6, and then move back to cell 7, no LU is necessary. Whenever an incoming call comes for a ME, the cellular system will page all cells within the surrounding area of the last reporting cell from which the MU updated their location. The reporting cells method is also global in the sense like all ME transmit their LUs in a similar group of reporting cells, and it is static in the sense like reporting cells are fixed.

The reporting cell topology might be bounded or unbounded. The unbounded strategy needs a lesser number of reporting cells, which is reducing the number of unnecessary LUs. This however needs an intelligent paging approach to manage the unbounded search space. These kinds of strategies require extra overhead due to probability calculation based on pre-established probability matrices. The overall performance gains attainable with a reporting cell topology are somewhat limited. Without direct consideration of the movements of MUs, an optimum arrangement of reporting cells assignment is not possible. Even with information of the cellular network, it is shown in [9] that the choice of an optimum group of reporting centers is an NP-complete problem.

2.5 Location Area (LA)

For location management, LA approach [10] has been used by some first generation cellular networks as well as many second generation networks, like GSM. LA consists of several contiguous cells and whole service area is divided into numbers of LAs. Each LA has its own LAI. The base station, BTS, of each cell broadcast the LAI for uniquely identifying the LA to which it belongs and because of that ME knows which LA it is in. Figure 2.8 shows the service area which is dived into four LA. Where using various colors boundary of the each LA is shown while shape of hexagon inside the LA shows boundary of BS which are within that LA. In GSM network, LA and Paging area is considered similar. Each LA is associated with VLR. VLR has one or more LA within it.

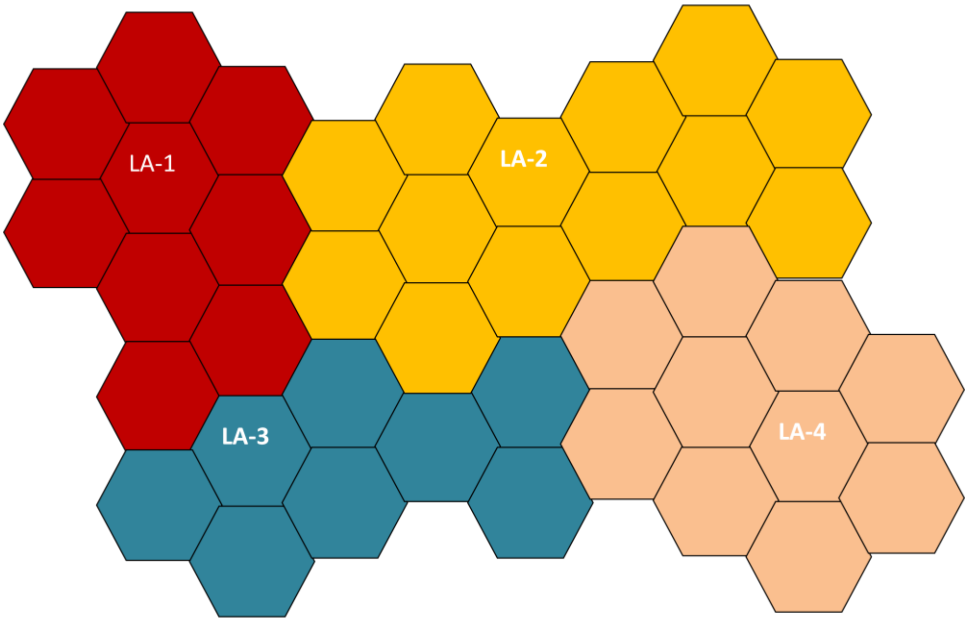

FIGURE 2.8: SERVICE AREA DIVIDED INTO FOUR LOCATION AREAS.

There are two types of LA, Static LA and Dynamic LA; can be possible in the cellular network. Static LA is common for all the MUs which are inside it while dynamic LA is formed as per MU's mobility pattern in the network, also called individual LA of MU. There are many methods for designing static as well as dynamic LA, which are described in chapter 3 with more details. Both types of LA required proper planning for reducing radio bandwidth of cellular network because size and shape of the LA is also important for LU and paging.

2.5.1 Importance of LA

There are different LU schemes which are used for location management in cellular networks. All cellular networks use the zone based approach for location management. In zone base approach the entire cellular network is dived in to LA [11]. So, LA is important factor in cellular network for Location management. Location management is deals with how to keep track of an active ME within the cellular network. Other way, Location management is concerned with the procedure requires to enable the network to maintain location information for each MU, or more specially, for each active ME with registered subscriber, and to efficiently handle the establishment of incoming call. When ME is powered on it consider as an active ME.

Location management involves two basic operations: LU and Paging. In the LU the ME time to time, notifies the cellular network about its new access point, and the network database stores the new position, or LA. When an incoming call arrives for a ME, the cellular network will page the ME in all possible cells to find out the cell in which the ME is located so the incoming call can be routed to the corresponding base station, BTS. This process is called paging, also called Call delivery. LU involves reverse control channels while paging involves forward control channels. LU cost and paging cost gives the total location management cost. There is a trade-off between the LU cost and paging cost. At the same time both cost can’t be minimized. However, the total cost can be minimized or one cost can be minimized by putting a bound on the other cost [12]. How LU and paging performs in the GSM network are described below.

Location Update (LU) in GSM network

The LU procedure can be further decomposed in two steps. In first step from time to time the ME notifies the network of its access point, and in the second step the network database updates/stores the LA according to the LU message received. A LU is always initiated by the ME. It is typically initiated whenever the ME visits a cell which broadcasts a LAI that is different from the one stored in the SIM card (if a previous value exists). In addition, LA updates may be triggered periodically, to let the cellular network know that the ME is still available, or to permit the cellular network to update its location registers in case of failure. LUs are not needed while roaming within the same LA. If the ME registers at a VLR for the first time, no subscriber detail is available there yet, and it must be requested from the HLR. For LU between LAs under the same VLR, the subscriber detail is already exists which is also called intra-VLR LU.

While MU crosses the LA boundary and reaches into another LA which belongs to different VLR then it’s called inter-VLR LU. The procedure for inter-VLR LU is mentioned below Figure 2.9 with execution steps:

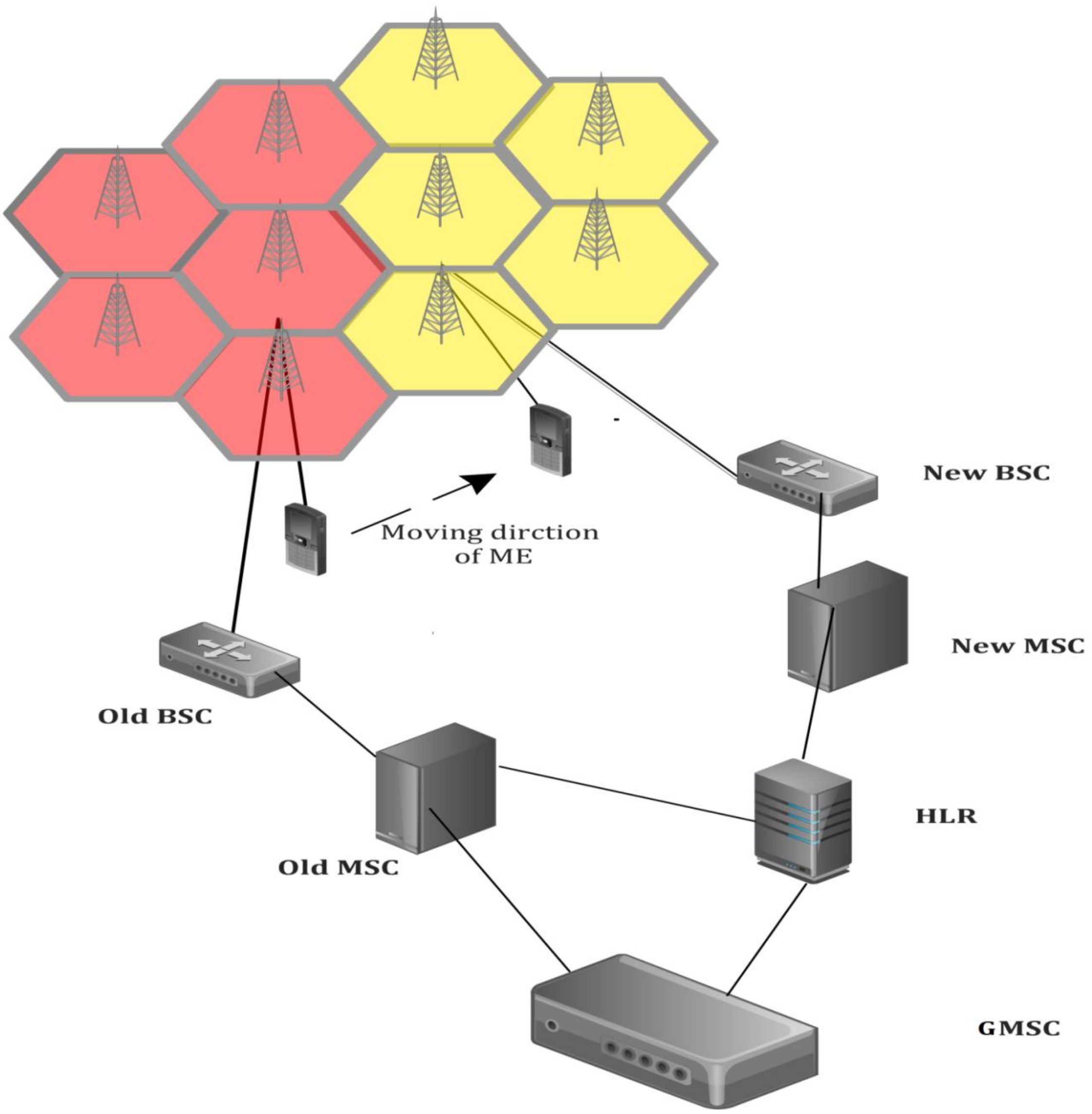

FIGURE 2.9: LOCATION UPDATE PROCEDURES IN GSM.

1. When ME crosses the boundary of servicing LA and enter into new LA than ME send a channel request to Random Access channel (RACH) for LU to the X BS of the new LA. X BS forward this channel request to its BSC. This BSC allocate a radio channel to ME through X BS for further communication to take place.
2. Now ME is set on the assigned radio channel and send a LU request along with the old (Y BS - TMSI+ Y BS- LAI) information to the X BS. X BS forward this message to its BSC and BSC forward this information to its MSC.
3. To complete the procedure, BSC sends and ACK to BS and BS send ACK to ME.

Location Area (LA)

4. Now the new MSC checks the LA and found that it does belong to some other MSC. So it starts searching the TMSI in its own database. After completing the search it finds out that, this is a new visitor and has not been registered before.
5. After that new MSC send a request (TMSI) to old MSC to get IMSI of the ME. As the ME was previously registered with old MSC So old MSC found a valid entry for the corresponding TMSI.
6. Old MSC provide the IMSI to the new MSC for further procedure. The new MSC has the IMSI of the ME but does not have the subscriber information, which is stored in HLR.
7. New MSC send the request to HLR, so HLR can upgrade the MSC pointer (from old MSC to current MSC) and provide the subscriber information.
8. As HLR get request from new MSC, HLR first update the MSC information and provide the subscriber information to the current (new) MSC.
9. Information from the HLR used for authentication process. Now the new MSC creates an entry in the VLR and store the subscriber information.
10. After this entry current MSC give reply to HLR regarding this new entry created in its VLR and waiting for HLR response.
11. The entry of IMSI now exists with two MSCs, so one has to be deleted. HLR send a request to the old MSC to delete the record for the corresponding IMSI. After deleting the entry, the old MSC give that confirmation to HLR while HLR send message back to the new MSC that the entire required database has been updated now.
12. Now the new MSC look forward to authenticate the ME. In authentication procedure MSC throws a RAND (the 128 bit random) challenges to ME.
13. In ME’s SIM card, a secret key (Ki- 128 bit individual subscriber authentication key, shared between ME and HLR) is stored which is used to compute the SRES (the 32 bit Signed Response) and Kc value (the 64 bit ciphering key used as a session key). After receiving RAND, ME runs an internal algorithm to generate SRES and Kc. The generated SRES is send back to the MSC. If MSC found that received SRES matches with its database then authentication procedure is considered to be completed.

14. After authentication procedure, new MSC ask the new BSC to enable a ciphering for further communication. The new BSC send the ciphering mode command to ME to enable the ciphering. At the reception of ciphering mode command, ME sends the ciphering mode complete message. After that new BSC inform the new MSC the ciphering is successfully enable.
15. Now current MSC assign a new TMSI to ME through BSC-BS. TMSI assign after ciphering mode enable so other MU does not get any information about TMSI.
16. As ME gets TMSI from current MSC, it replies back to MSC that TMSI is allocated successfully. Now, this TMSI is used for further communication procedure.

Here, procedure of LU shows that how LU messages are transmitted over the cellular network which generate traffic load onto the cellular network. If more LUs happened in the network more radio signaling are used so it is required to plan LA of the MU such that minimum LU happens in the cellular network.

Paging (Call Delivery) in GSM network

In the cellular network two types of call routings are possible: call originated from MU and call terminated to MU. From these two types, paging is required during call terminated to MU. In both procedures following steps are used: determining the serving VLR of the called MU and locating the visiting cell of the called MU. Locating the serving VLR of the MU involves the following database lookup procedure.

Call terminated to MU required following steps to complete whole procedure which include paging procedure for elicit response of called MU in the LA of the cellular network. Below Figure 2.10 and steps are describe the whole procedure in detail.

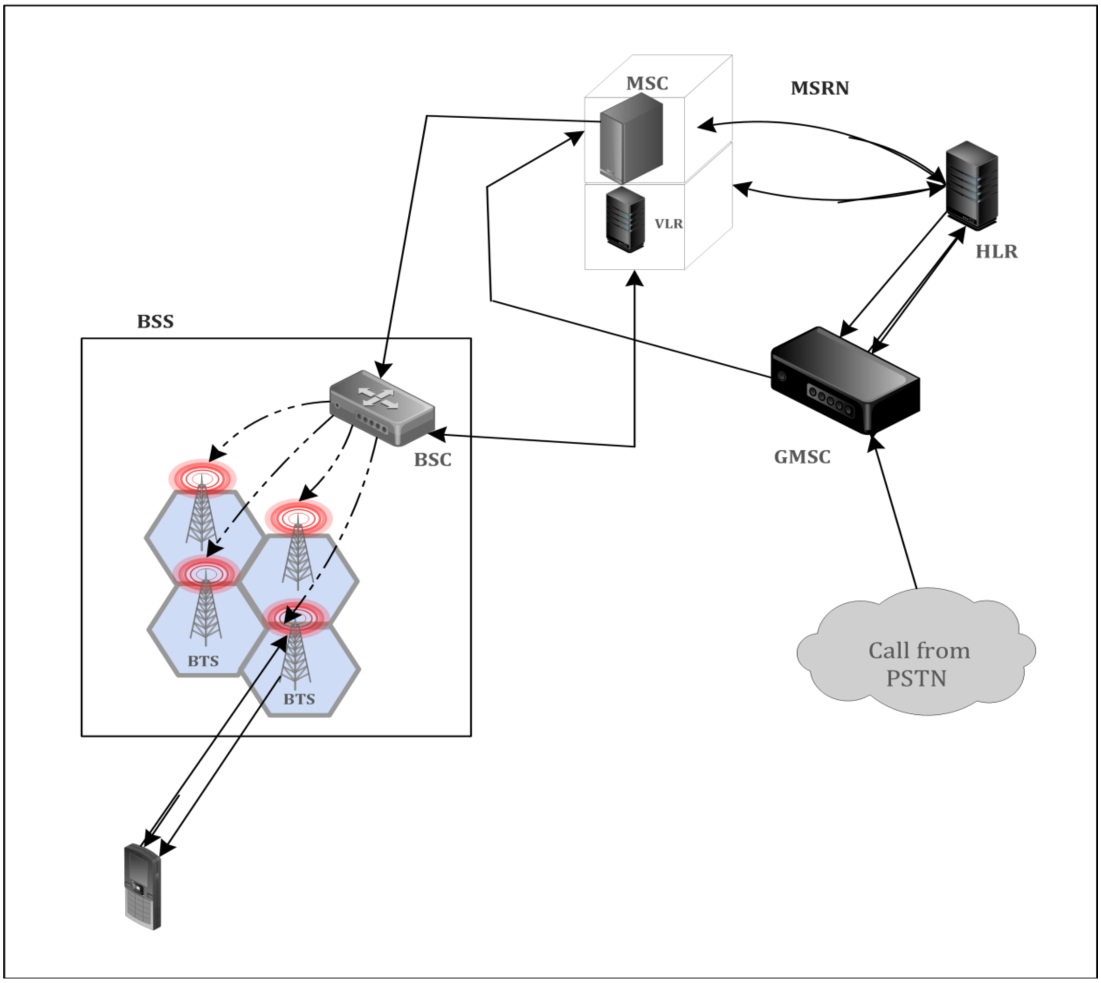

FIGURE 2.10: PAGING PROCEDURES IN GSM DURING CALL TERMINATED TO MU.

1. When a PSTN subscriber call a MU. This call reaches at the PSTN office where it is identified as a GSM call and forwarded it to the gateway MSC (GMSC).
2. The GMSC receive the call and identifies the HLR for the subscriber and signals the call set-up to the HLR (based on the IMSI number of the ME).
3. After that HLR checks if the number is a valid number or not? And whether that MU has subscribed to this particular service? If so then an MSRN is requested from the subscriber’s current VLR.
4. Once MSRN received, the HLR determines the MSC responsible for the ME and sends this information to the GMSC.
5. Now, the GMSC forward the call request to the concern MSC.
6. The concern MSC request the current status, current LA, of the MU from the VLR.

7. After that the MSC reaches to the ME using BSC through broadcast message which is known as paging message. In this procedure, paging is initiated in all the cells of the current LA. This procedure is continued up to find the exact BS of the MU.
8. If any response is found against paging by any BS or ME gives response to the page request, the VLR performs a security check and asks the MSC to connect to the MU.
9. For that, the BSC allocate a traffic channel and send a message to the ME to tune to the channel. After answer of the MU the speech connection can be possible.

The procedure describe above allows the cellular network to setup a connection from the calling PSTN subscriber to the serving BS of the called MU. Since each BS is associated with an LA and there is more than one BS in each LA, a mechanism is therefore necessary to determine the BS, cell, location of the called MU. LU involves the updating of location database when current location information is available or transferred to the network. On the other hand, paging, call delivery, involves the querying of location databases (HLR and VLR) to determine the current location of a called MU. There is a tradeoff between LU and paging. If LU reduce then paging is increase and vice versa. But the rate of LU and paging, both, can be reducing by proper planning of LA which is not fixed but DLA as per individual MU's mobility.

2.5.2 Location Area Planning

The size and shape of an LA or the number of cells in it may vary depending on the rate at which cells receive calls, and on the inter-cell traffic characteristics. In fact, the size of an LA can be optimized to create a balance between the LA update rate and the expected paging rate within an LA. In other words proper planning of LA reduces total location management costs which save the radio signaling of the cellular network. Various static and dynamic methods are available for proper and optimal planning of LA which is described in detail in next chapter.

3. LITERATURE REVIEW

This chapter presents the literature review of the LA planning in GSM cellular network using static methods, pitfalls of static methods, requirement of DLA and various methods used for formulation of DLA planning based on MUs' movement in the cellular network and mobility (movement) prediction methods of the cellular network.

3.1 Static LA planning Methods

Static LA consist contiguous number of cells which are fixed for all MUs residing in that. Static LA formed by considering call-to mobility ratio, number of users, busy hours call rate, call rate and other important parameters of the cellular network. There are so many techniques for Static LA planning use static geographic strategies to reduce or obtain optimal signaling traffic of particular LA. Followings are the main techniques used for LA Planning (LAP) for minimizing total Location Management cost of static LA. LA planning as a 0–1 linear programming problem, in which searching techniques, such as taboo search [13], genetic algorithms [14], simulated annealing [10] and Ant Colony Optimization [15] were employed to derive a proper planning for LAs, using optimization functions, to minimize the total number of LUs and paging. Greedy Algorithm [14], constrained maximum spanning tree to partition a geographic area into LAs [16] which make balance between LU and paging, Clustering and Hierarchical location database; used for reducing paging cost, are also some others methods for static LA Planning.
The above static methods have following pitfalls.

1. LAs are assigned such that combined control bandwidth usage is minimized globally but the static size of LA is not optimal for all mobile users (MU)s.

2. If MU moves back and forth frequently (Zig-Zag movement) between two LAs. There are excessive LUs leading to higher handoff cost.

3. The LU load of all MUs is concentrated in the boundary cell of LA. The heavy uplink traffic decreases the efficiency of random accessing considerably which affects the QoS.

So, it is required to use Dynamic LA planning methods which is directed to create individuals MUs LAs for reducing signaling cost.

3.2 Dynamic LA planning Methods

In cellular network, number of users uses the same path, and often takes same amount of time, to reach their workplace or study place from their home or residential place. These kinds of users have fix movement pattern which we can utilize to reduce signal and ultimately bandwidth. By the mobility pattern of the users in mobile network we can distribute them in 3 categories: Predictable users, estimated users and random users. If we use the frequently (most visited) cells of MUs as a dynamic LA then LU and Paging cost can be reduced. There are many dynamic methods existing using which we can reduce total location management cost. Dynamic LA planning methods are categorized into

1. State based methods
2. Profile based methods.

3.2.1 State Based Methods

For static LA planning methods two extreme approaches are available never update and Always Update. Third approach Select-update is useful with dynamic methods. In Select- update, the LU, registration, process occurs only when certain conditions are met. In this case, it needs to page the cells where the MU is possibly in to get the MU's current location. Therefore, the LU/registration cost is reduced and the paging cost (Location Tracking) is increased.

For selective-update, also called state based method, LU/ registration can be possible using:

1. Time based method
2. Distance based method
3. Movement based method.

These state based methods are discussed in detail in this section.

1. Time Based Method

In Time based method [2, 17, 18], MU performs LU at a constant regular time interval. Here each MU required internal clock which keep track of time that has passed since its last LU. The time interval could be optimize per MU to minimize redundant LU messages in the cellular network based on the MU mobility behavior and call arrival information. In this method, main drawback, unnecessary LU is performed even MU does not change its location which generate huge payload on network. While paging is become easy as particular time the location of the MU is known to the cellular network.

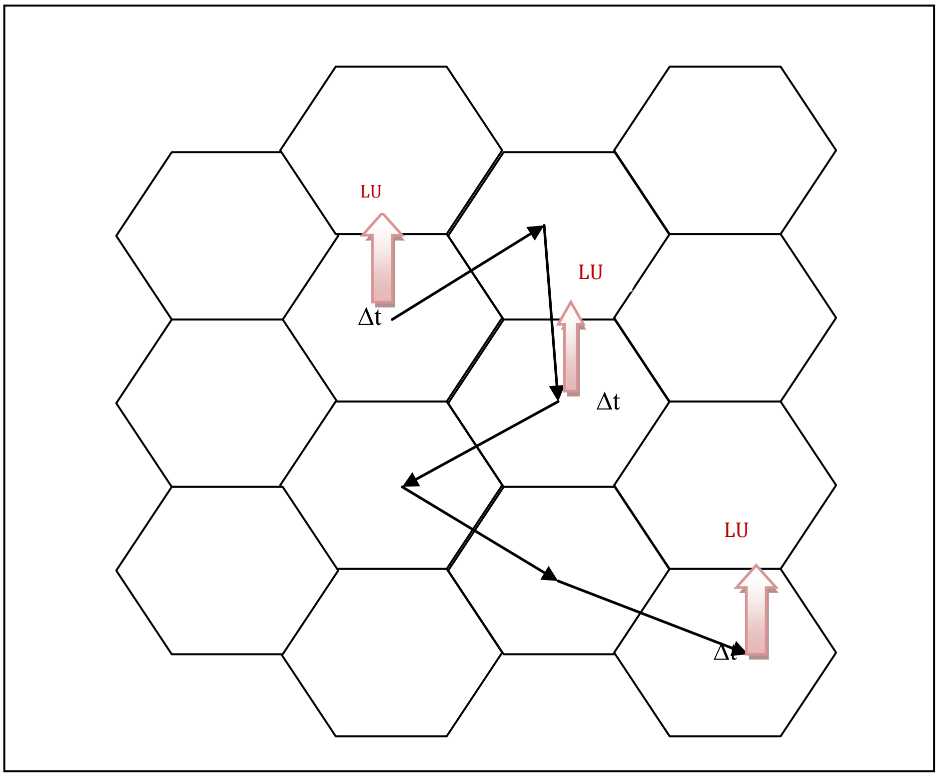

FIGURE 3.1: TIME BASED METHOD

Figure 3.1 shows the time based method with time interval Δt. In the figure LU performs at regular interval Δt without taking consideration of movement of MU. This method has also one another advantage, when ME detached from the cellular network then LU is not performed for it as per scheduled time interval. Also, if the cellular network does not receive any LU message of ME in expected time interval it assume that ME is detached. In both case additional signaling costs might be reduced.

2. Distance Based Method

In Distance based method [2, 17, 18], LU is performed when its distance from cell where it performed last LU exceeds a predefined distance value, called distance threshold. This threshold might be optimizing per MU to reduce frequent LU based on the MU mobility behavior and call arrival information. In this method ME required to keep track about its present location and distance from the last performed LU. The main advantage of this method is LU signaling reduced when MU keeps its mobility within the radius of distance threshold.

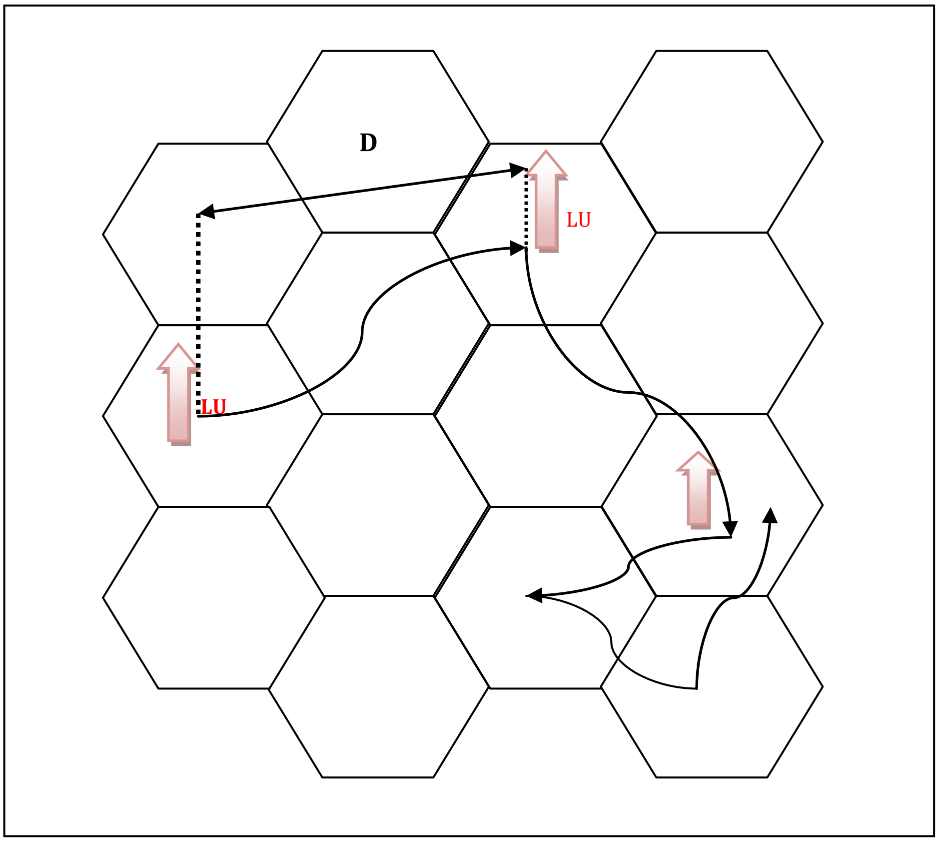

FIGURE 3.2: DISTANCE BASED METHOD

Distance based method is illustrated in Figure 3.2 with distance threshold D. In the figure LU occurs when the MU move beyond the distance threshold. This method somehow difficult to implement because in this method ME required to keep track of its starting point, where LU is performed, and required some mechanism to calculate distance from last LU, for that concept of coordinate system must be known, to compare with distance threshold.

3. Movement Based Method

In movement based method [2, 17, 18], LU is performed after predefined movement across cell boundaries are made, called movement threshold M. Here BS required keeping track of each MU movement in the cellular network for knowing number of cells boundaries crossed by the MU. Movement threshold is also optimizing per MU to reduce frequent LU based on the MU mobility behavior and call arrival information. Figure 3.3 shows the movement based method with movement threshold M = 3.

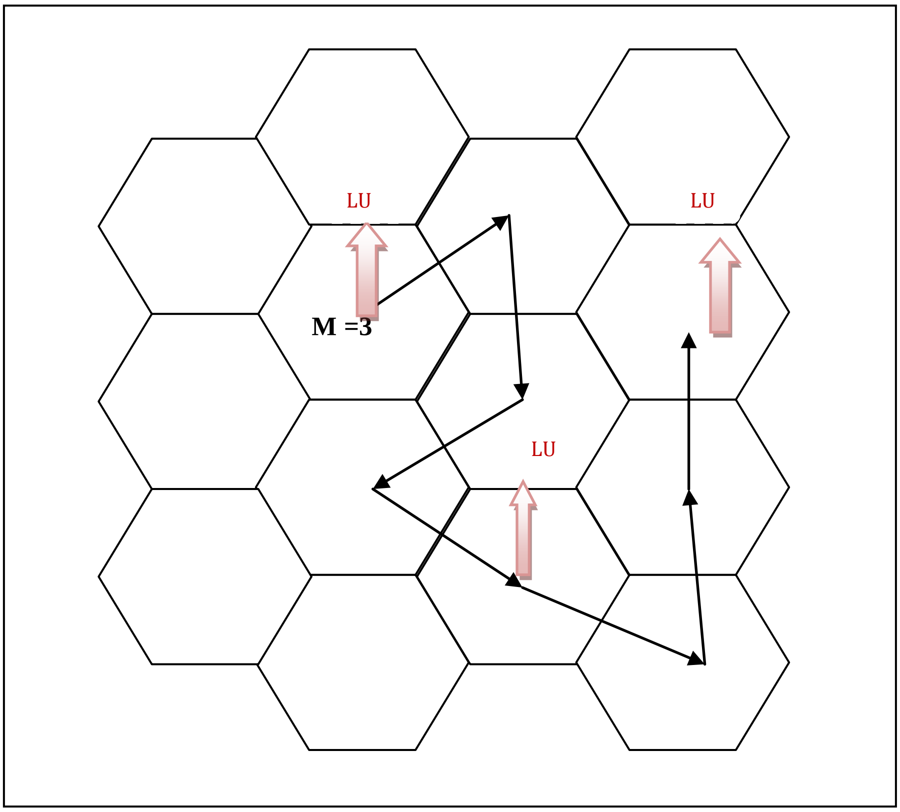

FIGURE 3.3: MOVEMENT BASED METHOD

In the figure, LU performs when MU's movement, number of crossing cells boundaries exceed then the movement threshold. Here when LU performs counter set to zero and increased as per crossing boundary of cells. This method has one major drawback; if any MU has zig-zag, repeating crossing same cell boundary, movement in the cellular network then unnecessary LU happens. From the above mentioned state based methods; Time based and Movement based methods are easily implemented while distance based method is somehow complex in comparison of both.

3.2.2 Profile Based Methods

In Profile based method, the cellular network maintain a profile of every MU based on mobility pattern and behavior of MUs. Profile based methods are assume that majorities of MUs have predefined and regular movement in the cellular network. There are many methods are available which use profile of MU's for reducing total location management cost, radio signaling, in the cellular network. From that some of the profile based methods are listed below:

1. Artificial Neural Network [4, 19, 20, 21, 22, 23]
2. User Mobility Behavior [24]
3. Directed Graph (Search Tree)[25, 26]
4. User Mobility with Simulated Annealing [27] and Heuristic Function [28]
5. Dynamic Distance and User profile based [18]
6. Dynamic and Distributed LA [30]

Above listed profile based methods are discussed in detail in this section. Some other methods are also available which use combination of state and profile based method for reducing total location management cost.

1. Artificial Neural Network (ANN)

In ANN, first learning phase is initiated and then testing phase is performed. Here, in the cellular network learning phase is used to find out the regular movement, routine, of MUs in the network so the appropriate resources and services could be provide to the MUs. In [19, 23] Cascaded Correlation Artificial Neural Network (CCANN) is used to know about user's regular routine. Due to increased mobility, UPH – User Profile History is used to locate MU; to reduce LU cost. User Mobility Profile (UMP) is a combination of historic records and predictive patterns of ME. In UPH – MU position is known in advanced, without explicit registration. Here, Strategy is divided in to two steps: training and application. For training purpose, Artificial Neural Network is used. Back propagation algorithm is used to locate cell. After training, network is ready for application. In CCANN, efficiency is enhanced over time by iteratively updating the weights in the network as compared to traditional ANN algorithms. This strategy associates to each MU, a list of cells where the MU is likely to be there with a given probability in each time interval. Based on that list is prepared which shows rank from the most likely to the least likely place where a MU may be found. When a call arrives for a MU, it is paged sequentially in each location based on rank assigned in list. When a MU moves within LA in the list, no LUs are required. The results obtained from performance evaluation confirm the efficiency and the effectiveness of UPH in comparison with the UMTS standard and other well-known strategy. This implementation shows minimum use of radio signaling by minimizing LU and paging signaling costs.

There are various algorithm; viz genetic, multi layer and etc, used with ANN for formulation of DLA to reduce signaling cost of the cellular network.

2. User Mobility Behavior

In this [24] paper, MU mobility behavior is used for generating LU and paging in cellular network where a database called user mobility Record (UMR) used for maintaining history of MUs. In this scheme from the UMR, behaviors of MUs are deduced which is useful for designing DLA and predicting the MUs movement in the cellular network. This approach reduces the radio signaling traffic because MUs can track every cell that they enter without any need for extra signaling and delivery of call easily done within those cells. Here, Activity-Based mobility model is used for modeling the MU mobility in cells. During LU, an MU derives a User Mobility Behavior (UMB) from its UMR, and registers it to the cellular network. UMBs consist of a number of nodes made up of a cell id and an expected cell entry time. Unless the MU detects that it moves out of the registered UMB, it does not perform another LU.

When a call arrival for the MU, the cells in its last registered UMB are paged sequentially according to the expected cell entry times. If a delay bound is reached before receiving a reply from the MU, all of the unpaged cells are polled simultaneously. Here, analytical, statistical, and simulation based experiments are used to evaluate the performance of the proposed scheme. The performance of the PBS is also compared with the time-based and movement-based location update techniques, and the blanket and selective paging techniques.

Authors of [29] paper have also proposed mobility pattern based location management scheme using the movement profile, User Mobility Behavior. Mobility pattern is learned and system will page only the restricted probable area. They have compared the proposed scheme with distance-based location management schemes. Improved location management cost saving is achieved with proposed method. For mobility model, daily worker mobility pattern is assumed. Also, here proposed method will be able to deal with location noise and time noise both. Selective paging and Block paging in restricted probable area, called paging area; both are described and also tracking protocol flowchart is described.

3. Directed Graph (Search Tree)

Here, authors [25, 26] have suggested directed graph method for creating individual MU's LA, called DLA. In this paper a location management algorithm is suggested which takes the movement history of every MUs to create directed graph which concluded individualized LAs, based on previous mobility from cell to cell. Cells of the cellular network are considered as a node of the tree while transitions between the cells based on the visit of the MUs create edges of the cells. Based on the frequent movement of MU in the nearest cells, the weights of the edges are increased. These edges weights are useful in creation of LA of the MU. All those nearest cells whose edges transition probabilities, weights, are higher than user defined threshold are involved in DLA of the MU. So when user moving within those cells, LU is not performed in this proposed method but if the mobility of the MU is change then LU is performed and create new directed graph for the MU. The average duration spent in each visited cell is also maintained which is used during paging for searching MU easily. An activity-based mobility model [26] was developed to test the proposed algorithm. Overall, the dynamic algorithm incurred significantly lower location management costs, in terms of signaling messages generated, for all parameters examined. Hunt algorithm [25] used by the author for finding DLA of individual MU based on the search tree. First using search tree, DLA is formulated then Hunt algorithm is applied on that to find out DLA which is optimal for the individual MU for reducing location management cost.

4. User Mobility with Simulated Annealing and Heuristic Function

MUs mobility in the cellular network are more important based on that behavior of the MUs can be predicted. Mobility pattern of the MUs are used for the creation of DLA for the MUs. In the [27], personalized location areas (PLA) using a dynamic location management method is presented by the authors. The suggested method considers both the mobility behavior of the individual MUs in the system and the other system parameters. To evaluate the LU and Paging cost, authors model the network after a continuous time Markov chain. Using this model PLA are created and assigned to each MU by taking into account individual MU's mobility pattern in the system. The problem of dynamic planning of PLAs is proved to be NP-complete. Due to the high computational complexity of the problem, authors search for an approximate solution using a simulated annealing (SA) algorithm. SA algorithm used here for giving DLA to user such that which contain optimal number of cells, as well as give optimal location management cost for the same. The author of the [28], use the same concept for formulation of DLA for the MUs but use heuristic function for dynamically define DLA for the MUs. It also uses the same concept for assigning number of cells in the DLA as simulated annealing algorithm. Simulation results show that the proposed dynamic location management scheme always outperforms than always-update mechanism. Also the PLAs formulated by the SA algorithm reduce more location management cost compared to that obtained using the heuristic algorithm.

5. Dynamic Distance and User profile based method

In this [18] a highly dynamic location management approach is proposed using which total location management cost could be reduce. The existing schemes use either always-update, reduce paging, or never-update, excessive LU. Here proposed algorithm reduce the number of LUs by finding out mobility behavior of the MUs and derive dynamic distance within the radius of this MUs can move freely. Profile based techniques exploit the basic fact that often moving objects have some degree of regularity in their motion. In the algorithm, during training phase MU’s mobility history was used to derive dynamic distance. MU's mobility traces were also used to determine the locations of interest, preference and their probable entry and exit times. Based on this the MUs future locations and paths were predicted. When the MU moves along the predicted paths the algorithm produces best results. As call rate is used to fine tune the chosen scheme the required balance between the LU and paging operations could be achieved. Here proposed method could also able to provide good QoS to MU by predicting its movement in the cellular network.

6. Dynamic and Distributed LA

In this [30] author suggested the distributed and dynamic LA management scheme (DD scheme) for PCS is described. This method proposes individual LA of each MU. The size of LA is depends on the movement behavior and call arriving of MU. The LA contains all those cells that MU is visiting or has visited. In LA there is an Agent Cell, which manages the other cells called General Cells, and acts as VLR in GSM. A discrete analytical model is also introduced for the schemes, which describes the LU and paging cost. An analytical result of the scheme shows that this method has better performance than the other GSM scheme. Here, operation protocols for distributed dynamic scheme are presented.

Above mentioned methods are vastly used for formulation of the individual MU’s LA, called DLA. Some other authors have also suggested some other methods for formulation of DLA to reduce radio signaling in the cellular network. In [29], author is suggested pattern-based location management scheme using the MU’s mobility profile. Here, scheme is very efficient for MUs with a steady movement pattern. The LA, registration area, consists of only possible cells where the MU can reside. Therefore, the pattern based scheme is efficient for both high mobility user, as well as user with high incoming call rate which helps to reduce location management cost. In this paper [31], new location methodology is proposed with user mobility pattern and behavior. In new system, size of LA for MU is optimized to reach minimal signaling traffic in LU. Paging of the ME and the optimum size depends on the incoming call arrival rate and mobility of MU. Also there are protocols are proposed for LU and paging. Algorithm keeps track of mobility and call arrival rate. Here, analysis shows that proposed scheme saves signaling bandwidth when call arrival rates are user-variant or time-variant. Proposed scheme allocates signaling burden of LU more evenly than fixed system.

Other profile based method [32] has presented result which shows that individual MU's mobility behavior based schemes performance is better than the static schemes. Analytical solution is proposed by the authors, that shows how to deploy presented method, in which MUs are responsible for performing their LUs, without changing current cellular systems. Authors have also simulated the relative cost savings approach which is compared with existing static methods. The results shows that method given by the authors reduce the radio signaling by minimizing location management cost. Proposed method has two major components: Cost function and co-ordinate system. Also certain assumptions: cost of LU and paging in the cellular network are considered as a factor of 10:1; Network consists of an infinite hexagonal cells; User movement is random. This method has the additional advantage that it is relatively easy to deploy in that it relies on a relatively low complexity cost function, which does not require excessive computations in the network coupled with input parameters that are already known to the terminals. In [17] dynamic approach for location management using Cartesian coordinate is proposed. The scheme delegates the responsibility of performing individual updates to the MU. This method use distance based static method with Cartesian coordinate system for formulation of DLA of the MU, which main aim to reduce total signaling cost of the cellular network.

Other methods are also available which are use state based and profile based method for reducing signaling cost , known as a hybrid method. Such kind of methods use distance, time or movement based method with MU's mobility behavior for reducing location management cost. In these methods, dynamically threshold for state based methods are deduced based on mobility and call arrival pattern of the MUs.

Based on the MUs mobility in the cellular network profile based method is also classified in three main categories. Theoretical, which assume MU follows physical and/or statistical model, Position based, based on position frequencies of MU, and Local movement based, movement indices: location, speed, direction are considered, for better LA planning for MUs.

All the above mentioned methods, state based, profile based and hybrid, formulate DLA for individual MU by using different techniques. Some of the methods reduce LU cost while others are reducing only paging cost. Majorities of the methods apply on the fixed network showing concepts of DLA for MU but not a single method deigns the DLA for individual MU. Here, in the proposed method, DLA is formulated for the individual MU which further used for mobility prediction of the same. Mobility prediction accuracy increased when DLA is created for the individual MU.

3.3 Mobility Prediction Methods

Mobility prediction in the cellular network is one of the important tasks for providing resources for ongoing call or during handoff events of the MUs. Call dropping and blocking issues are resolved by predicting mobility of MUs in cellular network. Mobility prediction is become more easy and accurate when DLA created for MUs. In DLA, every MU most probably follows the same path with same unit of time to reach its destination from home location. Predicting next cell movement of any MUs in DLA became easier using mobility pattern and behavior of them. Using mobility prediction resource allocation during ongoing call or handoff procedure of MUs can be properly possible which reduce call dropping rate

In the real scenario, MUs take their way according to the viability of the streets, roads and highways (also called the transportation facilities) for reaching their working place. These roads are predefined or say fixed for the particular place. When MUs use roads or highways at that time they follow the direction of the roads and highways without random movement which can be helpful for prediction next cell mobility in the cellular network. In [33] proposed method requires that cell must include a place where MUs adopt a regular and deterministic displacement profile, like roads, streets, and highways. This makes it possible to have information which is more appropriate in the cache and thus improve prediction accuracy. Cellular architecture advancement in direction of the utilization of increasingly small cells will reinforce our algorithm efficiency. That allows for correct prediction of movements up to 85% by employing the history of a MU. The prediction accuracy can be improved by refining the cell’s decomposition. Simulations showed that the integration of proposed prediction algorithm in resources reservation protocol considerably reduces the probability of handoff blocking with little effect on probability of new-call blocking.

There are many methods for mobility prediction from that some of methods listed below which are widely used in the cellular network.

1. Artificial Neural Network [4]
2. Clustering Method [34, 35]
3. Knowledge Grid [36]
4. Search Tree [37]

These, all above mentioned, methods are described in detail in this section. Other methods like, machine learning, maximization algorithm, Gaussian mixture model, ant colony optimization and etc are also used for mobility prediction of MUs.

1. Artificial Neural Network

ANN is used for mobility prediction of MUs using different parameters as an input. Number of researches have been used ANN with its different types as per their requirement of prediction. In [4] authors have proposed a prediction-based location management approach for locating a MU, which based on its history of mobility pattern. A multilayer neural network (MNN) model for user mobility prediction is designed to predict the future movement of a MU. The MNNs are trained using the data obtained from the mobility pattern of a MU which can be used for making future predictions. The performance of the method for prediction accuracy has been verified by considering different mobility patterns of a MU. For uniform mobility an average of 93% prediction accuracy is achieved using simulation, 40% to 70% for regular mobility and 2% to 30% for random mobility patterns of a MU. The back propagation algorithm is used by the MNN which is formulated for predicting mobility of MU. Here, the neural networks are trained with respect to mobility pattern for learning optimized functions for predictions. The role of the neural networks in this application is to capture the unknown relation between the past and the future values of the mobility pattern. This helps in predicting the future location of a MU for location management.

In the paper [21], path prediction algorithm is proposed that utilizes human creatures' behavior. A novel hybrid Bayesian neural network model is used for predicting locations of MUs in Cellular Networks. Different parallel implementation techniques on MUs of the proposed approach are explained and compare it to many standard neural network techniques such as: Back-propagation, Elman, Resilient, Levenberg-Marqudat, and One-Step Secant models. In experiments, result comparison of the proposed Bayesian Neural Network with 5 standard neural network techniques in predicting both next location and next service to request are shown. Bayesian learning for Neural Networks predicts both location and service better than standard neural network techniques since it uses well founded probability model to represent uncertainty about the relationships being learned. The result of Bayesian training is a posterior distribution over network weights. We use Markov chain Monte Carlo methods (MCMC) to sample N values from the posterior weights distribution. These N samples vote for the best prediction. Simulations of the algorithm, performed using a Realistic Mobility Patterns, show increased prediction accuracy.

Some other research papers also exist which is used ANN for predicting the next movement of the MU which uses direction, distance and speed of the MU as an input. In [20], hidden genetic layer based neural network method is proposed for mobility prediction. This method divides in two phases, in first phase using mathematical model mobility rules are extracted from user mobility databases which given as an input of second phase which form the class for classification mode. Algorithm layer-GA-SOFM based new neural network classifier is used to find next mobility prediction of MUs.

2. **Clustering Method**

Clustering method is also one of the important methods for predicting next cell movement of the MU in the cellular network. Cluster-Object-based Smart Cluster Affinity Search Technique [35] (CO-Smart-CAST) generates user clusters and similarities between mobile sequences are evaluated by Location-Based Service Alignment (LBS-Alignment). In this method using Genetic algorithm MU's mobility logs are generated for specific time intervals. CTMSP-Mine technique, which creates CTMSPs utilizes Co-Smart-Cast and time intervals results. Using mining techniques, mobility patterns are generated which are useful for predicting next movement and providing location based services. Various prediction strategies for predicting the subsequent MU behaviors using the discovered CTMSPs are introduced. MUs clusters are formed using CO Smart-CAST clustering algorithm using MUs transaction history and location based services similarities. Also best suitable time interval is generated by GetNTSP method. Using MUs' cluster and generated best suitable time intervals prediction become possible as well as enhancement in the results. The cellular network provider uses these kinds of prediction results for enhancing the QoS of location based services.

Statistical and k-means clustering algorithm used in [34] for finding mobility prediction of MUs' in the cellular network. Here, mobility pattern is extracted based on MU's movement pattern and/or calling pattern. In statistical method z-score is calculated for estimating location of MU's in (x, y) position for different time intervals. K-means algorithm uses MU's location at (x, y) for forming the clusters. For updating procedure both ME generated and network generated are considered as well as paging is used to find pattern table of the MU. Various simulations are applied on different strategies' to find out mobility prediction accuracy which shows that k-means based clustering method give higher prediction accuracy then other dynamic and static method.

3. Knowledge Grid

Next possible movement of MU's can be predicted using distributed algorithm. Knowledge grid based mobility pattern mining is one of an algorithm introduced in [36] for mining the next probable movement of MUs based on the user mobility database. From the MU's daily movement which called user actual path, user mobility patterns (UMP) are generated. UMPs are used for calculating mobility rules of the MU. In grid based network databases are stored at each grid node which are used to mine frequent location of the MUs and communicate to all other grid nodes for finding the global frequent location, called mobility rules. Minimum support is calculated using count distribution algorithm. In grid network algorithm is processed parallel so results are passed to other grid node immediately. From the mobility rules and support the next movement(s) of MU in the cellular network is predicted so resource and location based services can be provided to the MUs.

4. Search Tree

Predicting MU's location in the cellular network using mobility behavior and history, by finding mobility patterns, using search tree is proposed in [37]. Search tree is constructed based on the previous movements which are provided by mobility history. Search tree is not a binary search tree. Node of the search tree consist the location visited by the MUs. Each nodes of the search tree is known as decision node. Mobility prediction process is divided in two parts: training process and location prediction. Training process starts with root node and expands by adding training sample. Tree expansion, in training phase takes place due to decision node which is contains sequence of visited cell and predicting value. After training search tree is ready for prediction MU's location in the cellular network. Mobility prediction accuracy of proposed method is good compare to other methods.

Mobility prediction of MUs in the cellular network could be possible by various methods. All the above methods try to predict MUs in the entire cellular network based on the mobility pattern of the MUs. Mobility prediction accuracy can be increased by applying methods in DLA.

In this research, main objective is to formulate DLA for individual MUs based on frequently visited cell in the cellular network. Once DLA of MU's is formulated then total location management cost can be decreased which reduce use of radio bandwidth. Mobility prediction accuracy of any MU in the DLA is also increase due to less number of cells in DLA. In next chapter, dynamic methods and proposed SVR method are implemented for formulation of DLA, for predicted, estimated and random users; and finding mobility accuracy of the MU's, for predicted and estimated users; in the cellular network.

4. IMPLEMENTATION

This chapter presents the implementation of the DLA planning in the GSM cellular network using dynamic methods and proposed SVR method. All the dynamic methods provides only dynamic way by which one of the location management cost, either LU or paging, can be reduce in the cellular network. Here, DLA for individuals MUs are created using dynamic and SVR methods.

4.1 Dataset

For this research work simulation, create cellular network environment, dataset of Dartmouth University is used [38]. This dataset is benchmark dataset and mainly used in research related to mobility. This dataset contain mobility trace (movement) of more than 5000 students (UG & PG) and faculties of Dartmouth University. Dataset contain Access point, timestamp, longitude and latitude of access points and more. This dataset contain more than three years (2001 to 2004) mobility information of each user. Using this dataset, mobility behavior and mobility patterns of the users can easily found out. Also the prediction accuracy of next access point, BS, for MU(s) can be modeled.

4.2 Thread 1: Types of Users

In the first part of research, a module is implemented which derive types of users of the cellular networks which are acquired from above mentioned dataset based on the movement pattern and behavior of the MUs. In the dataset, some of the users visited many APs during the period of data gathering while some other users are visited only few numbers of APs. Majority of the users relatively visit few APs while some of the users visit many APs but only a few visits for each AP. Below Figure 4.1 shows the results of types of users exist, predicted, estimated and random users, in the dataset based on the movement behavior.

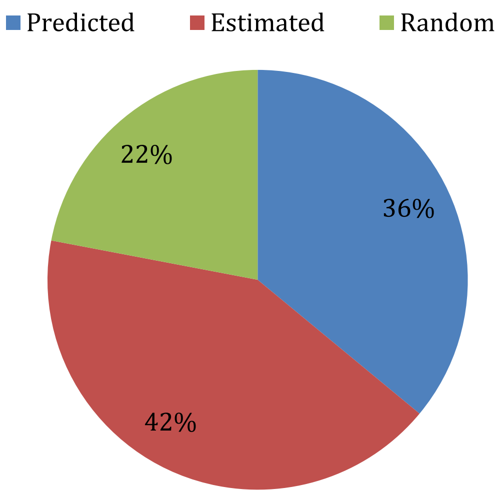

FIGURE 4.1: TYPES OF USERS

From the results we can know that most of the users in the cellular networks are predicted and estimated. Appropriate LA planning of these users reduces the total singling cost which leads to provide good QoS and save radio bandwidth.

4.3 Thread 2 & 3: DLA formulation and Mobility Prediction

DLA formulation and mobility prediction could be possible by various methods by applying different techniques as mentioned in chapter 3. Here in this research, DLA formulated based on users frequent and regular movement in cells of the cellular network as well as mobility prediction accuracy is also deduced from this DLA. There are below mentioned dynamic methods and proposed regression based (SVR) methods are implemented. Basic of each method and use of them in research are discussed in detail.

1. Apriori Algorithm
2. Hidden Markov Model (HMM)
3. Super Vector Regression (SVR)

4.3.1 Apriori Algorithm

Apriori algorithm is used for finding frequent itemset using an Iterative level-wise approach based on candidate generation. Apriori algorithm is also useful to generate association rules which are find interesting relationship between frequent itemset (data).

Basic of Apriori algorithm and how it is implemented for DLA formulation and mobility prediction accuracy finding are discussed below.

Basic of Apriori Algorithm

Apriori is a seminal algorithm proposed by R. Agrawal and R. Srikant in 1994 for mining frequent itemsets for Boolean association rules [39]. The name of the algorithm is based on the fact that the algorithm uses prior knowledge of frequent itemset properties. Apriori employs an iterative approach known as a level-wise search, where k-itemsets are used to explore (k+1)-itemsets. First, the set of frequent 1-itemsets is found by scanning the database to accumulate the count for each item, and collecting those items that satisfy minimum support. The resulting set is denoted L1.Next, L1 is used to find L2, the set of frequent 2-itemsets, which is used to find L3, and so on, until no more frequent k itemsets can be found. The finding of each Lk requires one full scan of the database. How Apriori algorithm [39] is executed stepwise on any transaction database is mentioned below with some of the terminology used in the algorithm for mining the association rules.

- Transaction: It is a set of itemset (collection of huge dataset)
- Confidence: It is useful to measure uncertainty or trust merit associated with each generated pattern.
- Support: It is the measure of how many times an item(s) occurs in the transaction in compare to all the transaction of an itemset as a percentage.
- Frequent itemset: Set of an itemset which satisfies minimum support provided by system.
- Association rules: minimum support and confidence satisfied by the rules are known as strong association rules

For Apriori algorithm transactions are fetched out from the large dataset(s). Relationship between frequent items of the dataset(s) are mined which can be used for further process according to requirement of the system.

Apriori Algorithm*:* Find frequent itemset using an Iterative level-wise approach based on candidate generation

Input:

D, a database of the Transaction

min_sup, the minimum support count Threshold

Output:

L, frequent itemsets in D.

Method:

1. L1 = find_frequent_1-itemsets(D);
2. for(k=2; Lk-1≠∅; k++) {
3. Ck = Apriori_gen(Lk-1);
4. For each transaction t ∈ D { /scan D for counts
5. Ct = subset(Ck, t) ; // get the subsets of t that are candidates
6. For each candidate c ∈ Ct
7. c.count++;
8. }
9. Lk = { c ∈ Ck | c. count >= min_sup}
10. }
11. Return L = ∪kLk

Using above code frequent itemset could be found out from the dataset(s). Once frequent itemset obtained, applying minimum confidence constraint according to application association rules are generated. Formula for calculating support and confidence, which are useful for finding Association rules are as follow:

$$\mathbf{supp}(\mathbf{X}) = \frac{\text{no.of transactions which contain the itemset X in dataset}}{\text{total no.of transactions in the dataset}}$$

and,

$$\boldsymbol{conf}(\boldsymbol{X} \to \boldsymbol{Y}) = \frac{\text{supp(item X} \cup \text{item Y)}}{\text{supp (item X)}}$$

Association Rules are an important class of methods of finding regularities/patterns in data using the criteria support and confidence. Using these functionalities mobility pattern and mobility rules are generated from the dartmouth dataset for formulation of DLA and mobility prediction.

Apriori Algorithm for DLA formulation and Mobility Prediction

In this research work, the functionality of Apriori algorithm to find frequent itemset from the transaction is used to find frequently visited cells by MUs. From the dataset and user mobility most of users have same mobility pattern and use same path. We take Access points (Base station) as an item and considering whole day movement as a one transaction. From the dataset we can create transaction history of each MU so we can apply Apriori algorithm on that. Modified Apriori algorithm pseudo-code for finding DLA and mobility prediction accuracy for individual MU(s) is given below:

DLAMP_Apriori Algorithm*:* Find DLA for individual MU(s) and next movement prediction in the cellular network.

Input:

Dataset (Mobility Traces from Dartmouth),

min_support, min_confidence, matching parameter (m)

Output:

DLA for MUs,

Mobility rules and next movement prediction

Method:

1. Input user Mobility dataset and min_support
2. Generate Candidates using mobility pattern (Which are used for deduce DLA for individual Mobile User)
3. Mobility rules formulation based on mobility patterns (Candidates) and min_confidence
4. Next possible predicted cell(s) for individual Mobile User are deduced from mobility rules and matching parameter (m)
5. Set of predicted Cell(s) for Mobile user(s)

Transaction history and minimum support are given as an input to the algorithm. This gives frequently visited cells which can be used to create DLA of individual MUs. So when MU moves within these cells, no LU is required as well as paging required only for these cells. Table 4.1 and Figure 4.2 are shows the results of DLA creation for types of users using functionality of Apriori algorithm. MUs are cross the total number of cells during their transaction history but some cells are such that which they cross in their daily lives. These cells are used for forming DLA.

Types of user	**Predicted**	**Estimated**	**Random**
No. of Total Cells	10	36	60
No. of Cells in DLA	4	11	3

TABLE 4.1: RESULTS FOR DLA PLANNING USING APRIORI ALGORITHM

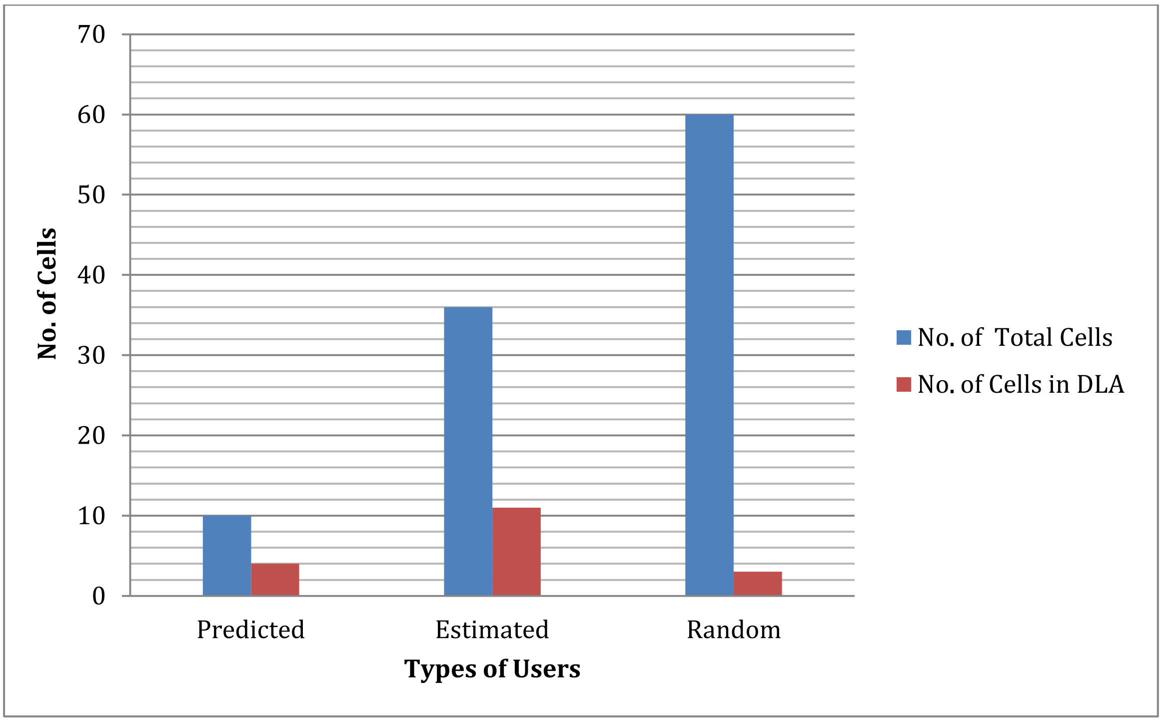

FIGURE 4.2: DLA CREATION USING APRIORI FOR DIFFERENT TYPES OF MUS

Mobility prediction gets straight forward after creating DLA. Association rule mining, for finding regularities/pattern in data using the minimum support and confidence is used in DLA to find out Mobility rules. Here mobility rules are produced based on association of MUs movement in interconnected cells of DLA. Head part, before arrow, of the mobility rules gives the information of current access point while tail, after arrow, part gives information of next cell(s) information which is visited by MUs. Here probability of correct prediction is calculated based on the user movement as per the mobility rules and movement parameter. Random user's movement in cellular network is not predicted as any given time. Only predicted and estimated users' mobility (movement) prediction accuracy is tested in all the, existing and proposed, dynamic methods. Discussion of result for mobility accuracy of predicted and estimated user using mobility rules and mobility parameter are in results analysis section.

4.3.2 Hidden Markov Model (HMM)

HMM is one of the algorithms by which can predict next probable things based on the previous history or states. Using the MU(s) past mobility in the cellular network or based on the behavior HMM can be useful to finding out DLA of the MU(s) as well as the next cell(s) movement in the cellular network.

Basic of HMM

In cellular network number of users use the same path to reach their workplace or study place from their home or residential place. These kinds of users have fix movement pattern which we can utilize to reduce signaling and ultimately bandwidth. Using MUs mobility in nearest cells or in regular cells we can calculate their transition probabilities. As we have mobility history and behavior HMM can be used to predict current location of MUs in mobile network.

A Hidden Markov Model has two random processes. The first process is a Markov chain that is described by states and transition probabilities within the given network. The second process produces emissions observable at each moment, depending on a state-dependent probability distribution [40]. So, we have used HMM to obtain objective of the research using campus wireless trace dataset.

From the dataset, we can find out current Access Point (AP), last AP and APs used by the MUs in their daily movement. Using mobility history, it is easy to calculate transition probabilities of every MUs. By the transition probability of MU, system can predict transition of MU from one AP to some other nearest AP. Sometime MU take several paths to reach their destination. But these scenarios happen in rare case like, traffic problem and etc. Transition probabilities of such a path are different than regular path.

Each Hidden Markov Model has five key elements: States, Observation Sequence, State transition probabilities, Observation State probabilities and initial state probabilities which are useful to define an HMM completely. [40]. Figure 4.3 shows the model of HMM which consist five elements: State (S), Observation sequence (O), initial state probability (π) , state transition probability (A) and observation state transition probability (B).

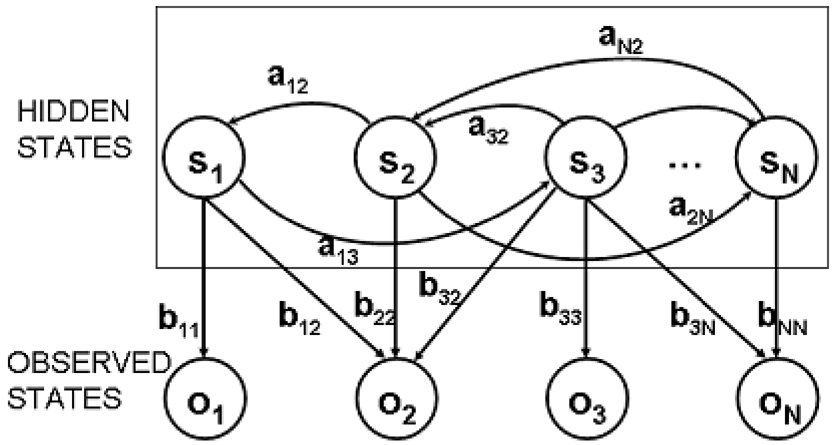

FIGURE 4.3: Hidden Markov Model [40]

In the System,

- $\{S_1, S_2, \ldots, S_N\}$ are the N State of any given system.
- $\{O_1, O_2, \ldots, O_N\}$ are the value of the observation sequence of the system.
- $\{\pi\}$ is the initial state probabilities so $\{ \pi_i)$ shows the probability of starting in state i.
- $\{a_{ij}\}$ are the state transition probabilities where a_{ij} denotes the probability of moving from state i to j.
- $\{b_{ik}\}$ are the observation state probabilities where b_{ik} is the probability of emitting symbol k at state i.

The notation $\lambda= (A, B, \pi)$ is often used to denote a HMM, that means discrete probability distributions of MUs in the cellular network. Using these parameters, if system wishes to predict location of any MU within the cellular network then HMM is built for that. But it is possible when mobility history data of MU's within the system. HMM is also used for creating DLA for MU's based on the transition probabilities between the cells visited by MU.

HMM for DLA formulation and Mobility Prediction

MUs movement in network from one cell to another cells are used to find out transition probability between them. HMM algorithm is used to find out observation probability for hidden state. In this research work HMM characteristic transition probability and observation probability are used to find DLA and mobility accuracy. Here each access points are considered as a state of HMM and movement between each access point is considered as a transition probability. HMM algorithm pseudo-code for finding DLA and mobility prediction for this research work is as follow:

DLAMP_HMM Algorithm*:* Find DLA for individual MU(s) and next movement prediction in the cellular network.

Input:

Dataset (Mobility Traces from Dartmouth),

Number of Previous States

Output:

DLA for MUs,

Mobility Prediction Probabilities

Method:

1. Initialize HMM model.
2. Load the Dataset to train (learn) the HMM Model.
3. Calculate transition probabilities of states.
4. Load another (same) Dataset for testing the HMM model.
5. Give different previous state (s) to predict next (cell) movement of Mobile user (Observing state probabilities).
6. Next Movement (cell) prediction probabilities.

For finding DLA using HMM functionality, first HMM model is initialized with mobility dataset as discussed above. Transition probabilities of MUs each route to reach at his/her destination from source are calculated using equation 1. Path which has highest transition probability, path maximum followed, is used to for DLA creation. All the cells of such path are form the DLA in which user can move without LU and minimum paging rate.

$$P(S_{t+1}|S_0, S_1, S_2, \ldots S_t) = P(S_{t+1}|S_t) \text{ where St is the state at time t } \text{------------------ } (1)$$

Table 4.2 and Figure 4.4 shows the results of DLA created using HMM algorithm for all three types of MUs.

Types of user	**Predicted**	**Estimated**	**Random**
No. of Total Cells	10	36	60
No. of Cells in DLA	5	11	3

TABLE 4.2: RESULTS FOR DLA PLANNING USING HMM

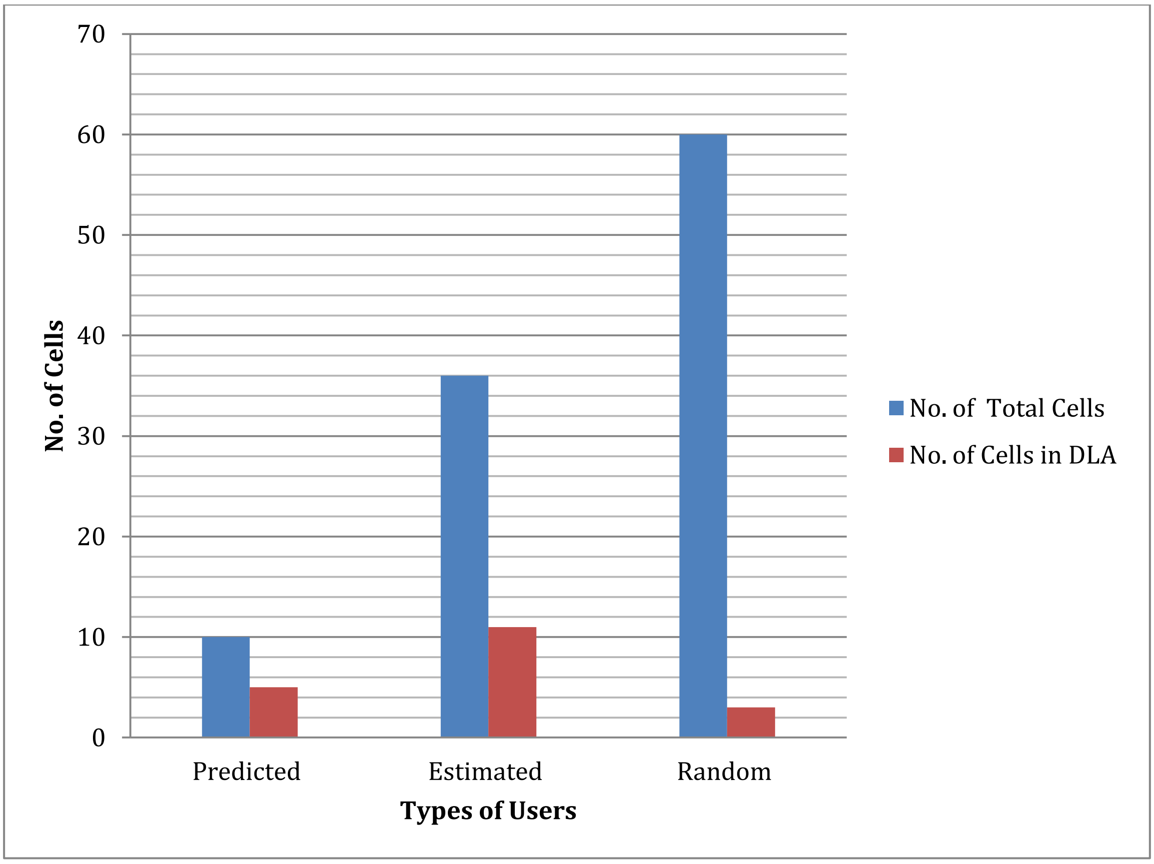

FIGURE 4.4: DLA CREATION USING HMM FOR DIFFERENT TYPES OF MUs

There are several steps which required for predicting MUs location in the cellular network. After HMM is initialized by providing training using dataset it is used to find out mobility prediction of MUs. MU's availability in current access point depends on the previous access points. Based on the previous access points' information, next movement of MUs in cellular network are easily predictable. Here network is trained by giving previous states (access points) information to get next movement information of the MUs. After training, test samples are tested on the model to check correctly indentifying the next mobility movement of the MUs. Using this information, average probability of correctly indentified next movement in cellular network is obtained whose results are shown in result section.

4.3.3 Super Vector Regression Method (SVR Proposed)

SVM is used for regression method which is known as Super Vector Regression (SVR) [41]. The SVR uses the same principles of SVM with minor differences. SVR method used for prediction and approximation based on the previous values. SVR use various kernel functions to predict values in higher dimension. Using MU's timestamp, which shows the attachment of MU's current AP, in the cellular network is used for finding regression probabilities for finding DLA for MU(s).

Basic of SVR

In SVR during training phase input dataset is given, which contain pair of values, like $(x_1, y_1),\ldots, (x_n, y_n)$. From that our goal is to find out the function f(x) that has at most ε deviation from the obtained target form training sets. To obtain proper function various values of epsilon ε and cost (C) are tested with input datasets. Parameter C determines the tradeoff between the model complexity (flatness) and the degree to which deviations larger than ε are tolerated in optimization formulation then the objective is to minimize the empirical risk only, without regard to model complexity part in the optimization formulation. Parameter ε controls the width of the ε -insensitive zone, used to fit the training data. Using SVR, linear and non linear regression can be possible. In Linear regression, linear function is developed which show the dot product of the input values while upper and lower limit are shown by the $\pm\varepsilon$. Non-linear regression is happen when there is a relation between the inputs and outputs is non-linear. In Non-linear regression various kernel functions are used to map the data into a high dimensional feature space where linear regression is performed. Formula of the linear kernel function of the SVR is givenbelow:

$$K(X_i, X_j) = X_i^d X_j$$ ------- Linear Kernel Function

For performing non-linear regression, most commonly used kernel functions are polynomial and radial basis function (RBF). Formulas of both kernel functions are as follow:

$$K(X_i, X_j) = (X_i \cdot X_j)^d$$ ------- Polynomial Kernel Function

and

$$K(X_i, X_j) = \exp\left(-\frac{\|Xi - Xj\|^2}{2\sigma^2}\right)$$ ------- RBF Kernel Function

Using SVR method and above kernel functions future prediction, using time series analysis, and approximation of the linear and nonlinear data can be possible.

SVR for DLA formulation and Mobility Prediction

In SVR method training data is given based on that after applying regression on that future prediction can be done. MUs use the same path with same time for attaching and detaching to any APs based on that timestamp of the MUs with APs are saved which further used by proposed method for calculating regression probability and prediction. So, Like HMM method here regression probability of MUs are used to create DLA. First of all SVR is initialized by loading the dataset which calculate the regression probability for movement path of MUs. DLA contains those cells in its list whose regression probabilities are higher than other cells in the cellular network. Proposed SVR method's implementation pseudo- code is detailed below.

***DLAMP_SVR Algorithm**:* Find DLA for individual MU(s) and next movement prediction in the cellular network.

Input:

Dataset (Mobility Traces from Dartmouth),

Parameters: c and epsilon

Output:

DLA for MUs,

Mobility Prediction Probabilities

Method:

1. Initialize SVR model.
2. Load the Dataset to train (learn) the SVR Model.
3. Calculate the regression probability of input data.
4. Use SVR with kernel function for predication.
5. To improve the performance of the SVR need to select the best parameters for the model.
6. To train a lot of models for the different couples of epsilon and c (cost), and choose the best one.
7. Print the mobility prediction probabilities.

Table 4.3 and Figure 4.5 shows the results of DLA created for different types of users using proposed SVR methods functionality.

Types of user	**Predicted**	**Estimated**	**Random**
No. of Total Cells	10	36	60
No. of Cells in DLA	6	13	5

TABLE 4.3: RESULTS FOR DLA PLANNING USING SVR

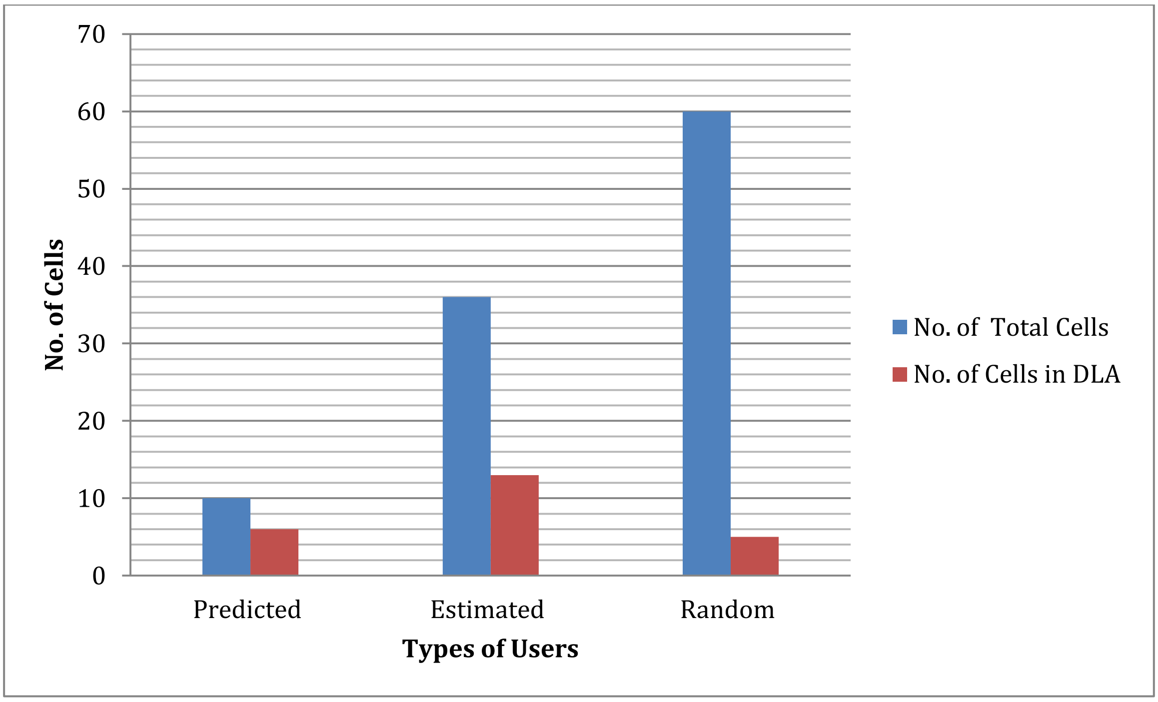

FIGURE 4.5: DLA CREATION USING SVR (PROPOSED) FOR DIFFERENT TYPES OF MUs

In SVR several kernel functions are used for prediction. Linear and non- Linear SVR are main types of the SVR. The kernel functions transform the data into a higher dimensional feature space to make it possible to perform the linear separation. In this work RBF kernel function is used for prediction which gives higher prediction probability then polynomial kernel function. Here SVR model is trained by applying different values of cost and epsilon parameter and best values of both are selected to obtain mobility prediction probability in cellular network. Here, based on regression probability and time series concept, next mobility location is predicted and based on that mobility prediction accuracy of proposed methods is calculated for predicted and estimated users which are shown and discussed in next chapter.

5. RESULT ANALYSIS

In this chapter, results of proposed method and dynamic methods which are obtained using implementation are shown and compare. The main objectives of this research are reducing total location management cost, LU and paging cost, and providing good QoS by mobility prediction. In this chapter, LU and paging cost for predicted, estimated and random user are calculated and compared which are obtained from static, dynamic and proposed methods. Likewise, mobility prediction accuracy computed using dynamic and proposed method for predicted and estimated users are compared.

5.1 LU and Paging cost comparison

LU cost for single estimated user is derived out by dynamic methods, always updates (static method) and proposed SVR method. Table 5.1 and Figure 5.1, shows the result of that. In the Figure 5.1 X-axis contains the various methods name while Y-axis contains the percentage (%) average of LU cost obtained by applying methods stated above.

Methods	Estimated User
Apriori	69.93%
HMM	69.93%
SVR (Proposed)	68.84%
Always Update	71.00%

TABLE 5.1: PERCENTAGE AVERAGE LU COST OF ESTIMATED USER

In above Table 5.1 LU cost of estimated user is shown like that LU cost of predicted and random users can be obtained. This result shows that proposed SVR method give minimum LU cost in comparison of static and dynamic methods.

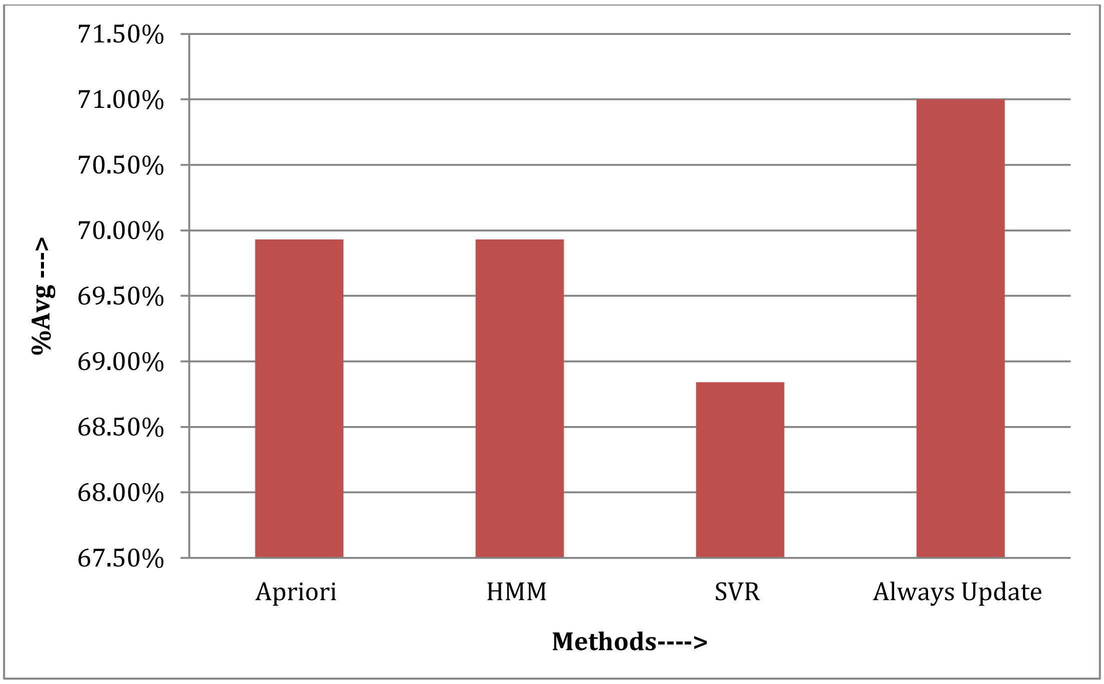

FIGURE 5.1: COMPARISON OF PROPOSED AND VARIOUS METHODS USING PERCENTAGE AVERAGE LU COST OF ESTIMATED USER

Like above results, LU cost is also calculated for group of same kind of user and compare with all the method stated above. Here group of 10 predicted users are created and collective percentage average LU cost of them are calculated which shown in Table 5.2 and visually in Figure 5.2.

Methods	Predicted Users
Apriori	22.44%
HMM	20.81%
SVR (Proposed)	16.90%
Always Update	25.06%

TABLE 5.2: PERCENTAGE AVERAGE LU COST OF PREDICTED USERS

From the result shown in Table 5.2 concluded that proposed SVR method give minimum LU cost in comparison of static and dynamic methods when applying on group of same kind of MUs.

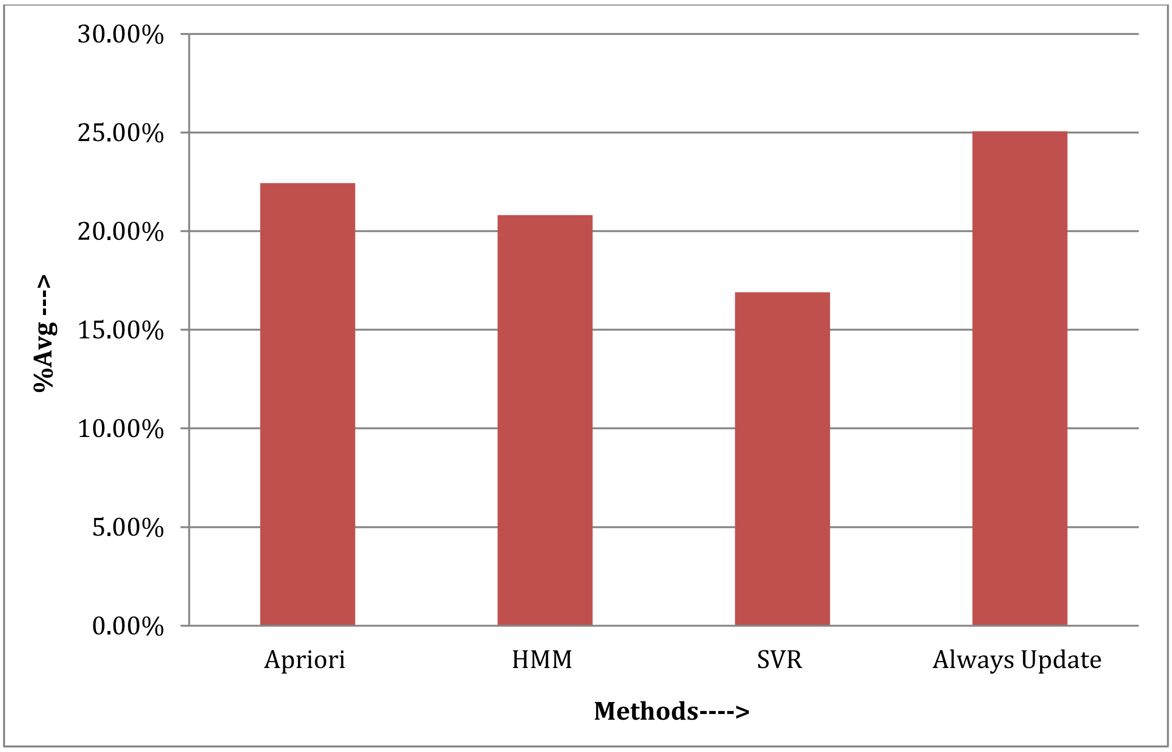

FIGURE 5.2: COMPARISON OF PROPOSED AND VARIOUS METHODS USING PERCENTAGE AVERAGE LU COST OF PREDICTED USERS

Not only for single user or group of same kind of user, proposed method is also tested for on other datasets. Here set of datasets are created which contain same kind of MUs as well as different kind of MUs, which have different mobility behavior, for testing and comparison of proposed method. Table 5.3 shows the results obtained for various dataset using static, dynamic methods and proposed method while Figure 5.3 shows the graphical representation of the results.

Dataset	Apriori	HMM	SVR (Proposed)	Always Update
Dataset_P1	42.36	34.83	32.86	69.38
Dataset_E1	52.25	49.82	48.92	72.57
Dataset_R1	95.24	93.71	92.63	98.99
Dataset_PE	41.19	40.30	39.13	62.08
Dataset_PR	62.92	57.67	52.86	69.54

TABLE 5.3: PERCENTAGE AVERAGE LU COST OF DIFFERENT DATASETS

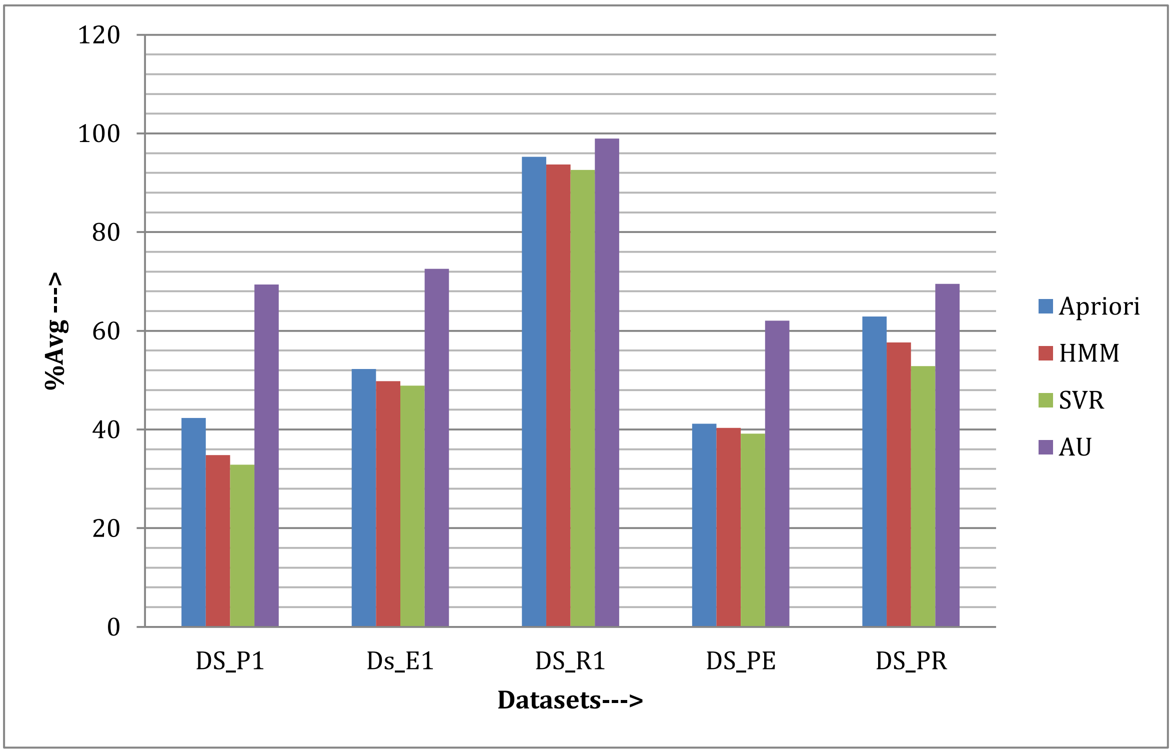

FIGURE 5.3: COMPARISON OF PROPOSED AND VARIOUS METHODS USING PERCENTAGE AVERAGE LU COST OF DIFFERENT DATASETS

All the above results shows that proposed method gives minimum LU cost which save the radio bandwidth of the cellular network. Paging cost is also one of the important parameter for total location management cost. There are tradeoff between LU and paging cost but by creating DLA both cost can be reduced. So paging cost is also remaining minimum in DLA. The results related to paging cost which is obtained by all the methods and proposed methods are now discussed.

Like LU cost, paging cost is also calculated for single user, group of same kind of users (predicted user) and for different kinds of datasets. X-axis of the each figure contains proposed and various methods while Y-axis contains the percentage average of paging cost.

Table 5.4 and Figure 5.4 shows the percentage average of paging cost for single estimated user and comparisons of static method, dynamic methods and proposed method

Methods	Estimated
Apriori	23.30%
HMM	23.30%
SVR (Proposed)	22.00%
Never Update	30.66%

TABLE 5.4: PERCENTAGE AVERAGE PAGING COST OF ESTIMATED USER

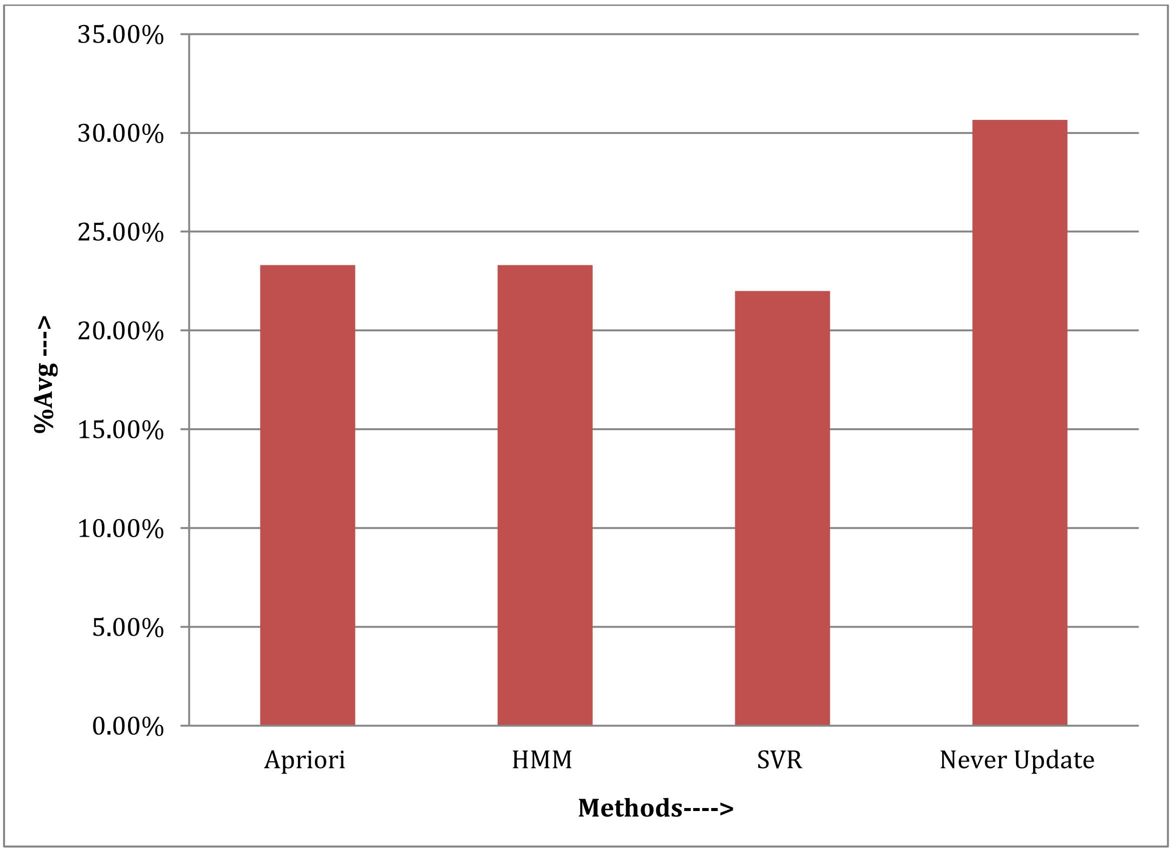

FIGURE 5.4: COMPARISON OF PROPOSED AND VARIOUS METHODS USING PERCENTAGE AVERAGE PAGING COST OF ESTIMATED USER

From the above figure clearly state that paging cost of proposed method is minimum then other methods. Table 5.5 and Figure 5.5 show the percentage average paging cost for group of predicted users. Same 10 predicted users group (used to find LU cost) is used to obtain results.

Methods	Predicted Users
Apriori	8.81%
HMM	8.09%
SVR (Proposed)	6.35%
Never Update	16.80%

TABLE 5.5: PERCENTAGE AVERAGE PAGING COST OF PREDICTED USERS

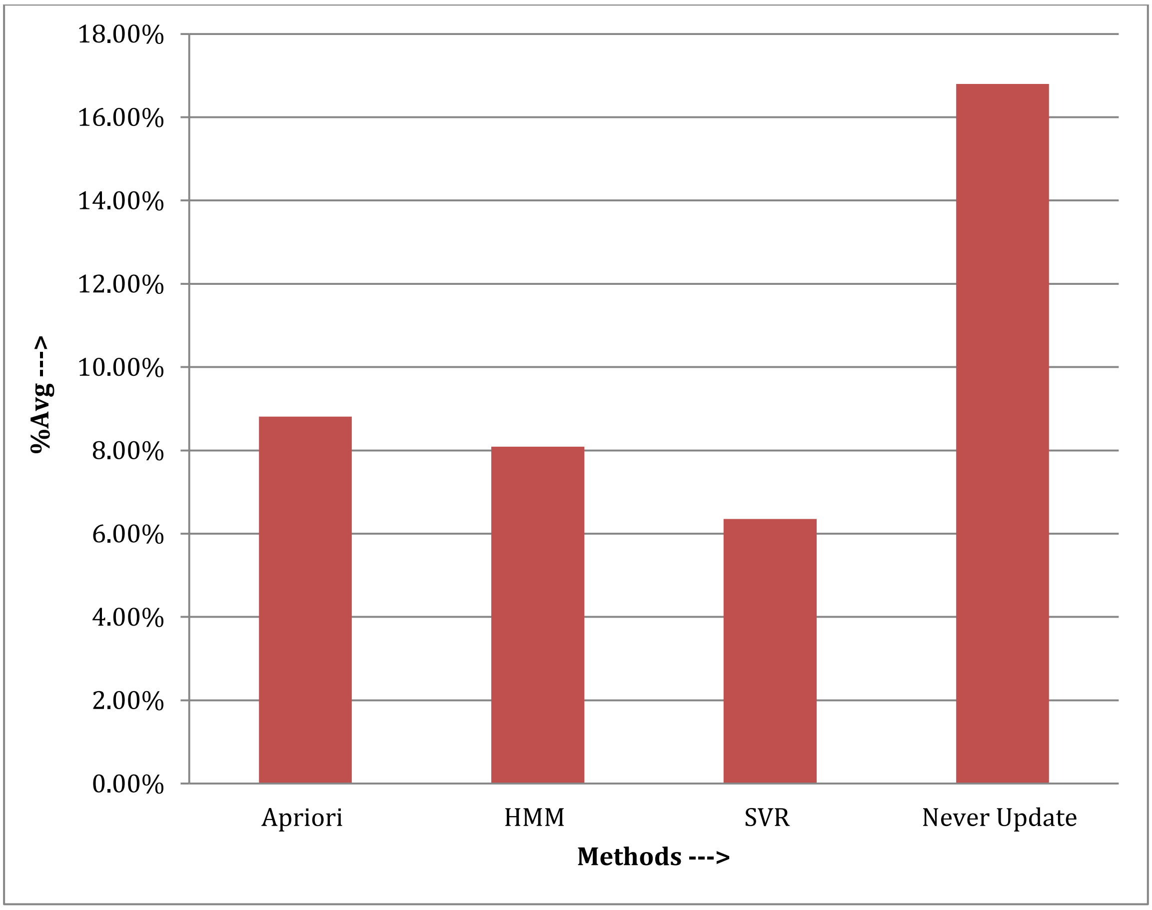

FIGURE 5.5: COMPARISON OF PROPOSED AND VARIOUS METHODS USING PERCENTAGE AVERAGE PAGING COST OF PREDICTED USERS

Paging cost of proposed method is minimum for single user as well as for group of same kind of MUs. Below Table 5.6 and figure 5.6 shows the percentage average paging cost of various datasets and comparisons of static, dynamic methods and proposed SVR method.

Dataset	Apriori	HMM	SVR (Proposed)	Never Update
Dataset_P1	16.64	16.47	15.35	38.36
Dataset_E1	15.56	14.67	13.86	56.74
Dataset_R1	38.45	35.97	34.82	75.11
Dataset_PE	32.13	28.27	25.58	44.58
Dataset_PR	26.45	25.02	21.73	46.21

TABLE 5.6: PERCENTAGE AVERAGE PAGING COST OF DIFFERENT DATASETS

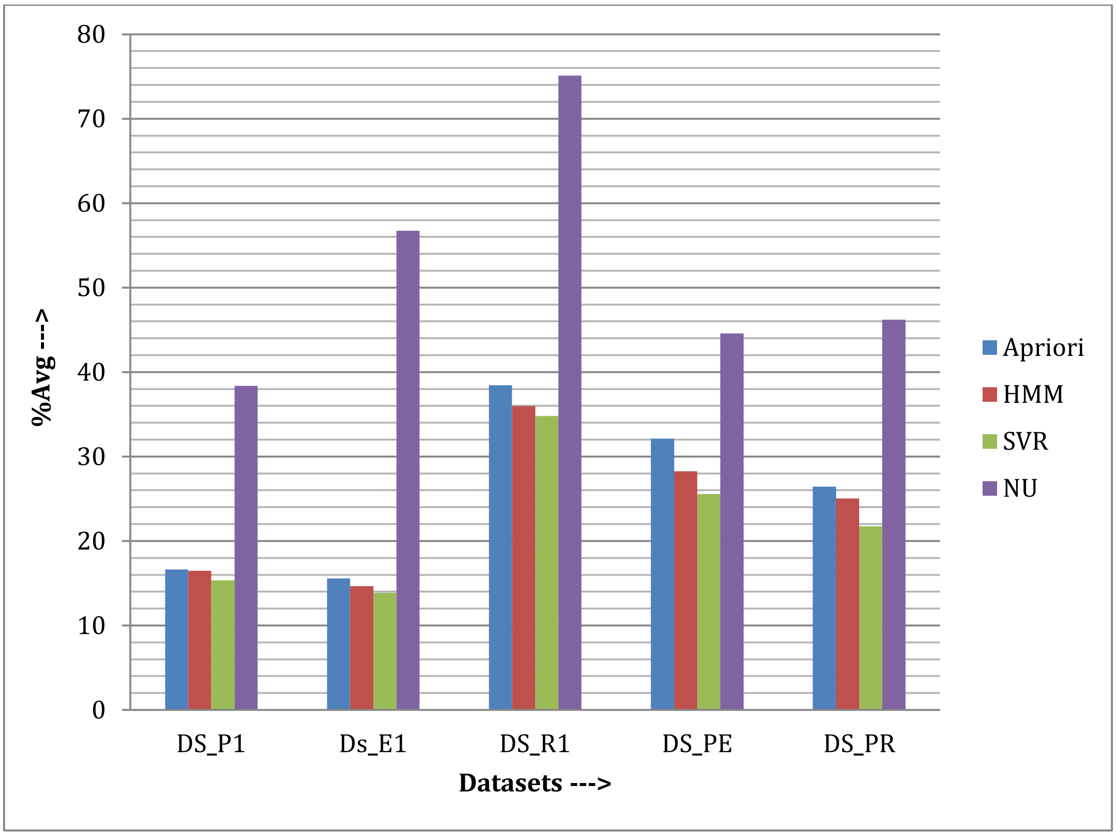

FIGURE 5.6: COMPARISON OF PROPOSED AND VARIOUS METHODS USING PERCENTAGE AVERAGE PAGING COST OF DIFFERENT DATASETS

Above results give the conclusion that paging cost is also reduced in DLA. All the results give information that dynamic methods reduce the paging cost higher than static method. Proposed SVR method gives minimum paging cost than all other methods. DLA formulation saves more radio bandwidth by reducing LU and Paging cost of the MUs.

5.2 Mobility Prediction Accuracy comparison

For providing good QoS, next cell(s) mobility prediction is also important so using dynamic methods and proposed method mobility prediction accuracy of MUs are found. Prediction accuracy of predicted and estimated MUs are calculated and compared in this section. As random users' mobility are not predicted because of not getting same mobility pattern and behavior.

Mobility prediction accuracy using dynamic methods and proposed method is calculated for predicted users which are shown in below Table 5.7 and in Figure 5.7 comparison of dynamic methods and proposed method is figure out.

Dynamic Methods	Predicted Users
Apriori	65.53%
HMM	69.09%
SVR	71.23%

TABLE 5.7: PERCENTAGE AVERAGE MOBILITY PREDICTION ACCURACY OF PREDICTED USERS

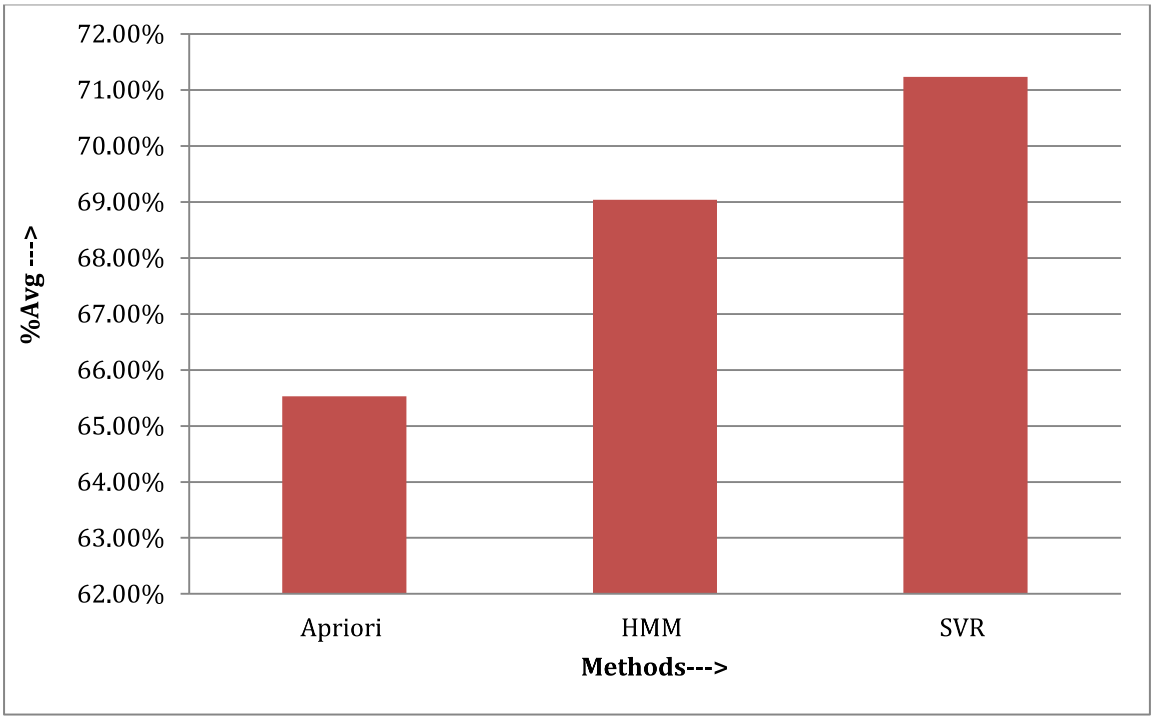

FIGURE 5.7: COMPARISON OF PROPOSED AND VARIOUS METHODS USING PERCENTAGE AVERAGE MOBILITY PREDICTION ACCURACY OF PREDICTED USERS

Likewise mobility prediction accuracy of group of predicted and estimated users' dataset using dynamic methods and proposed method are shown in tabular form in Table 5.8 and graphically comparison in Figure 5.8.

Dataset	Apriori	HMM	SVR
Dataset_P1	16.68	17.59	25.89
Dataset_E1	8.16	9.65	12.24
Dataset_PE	16.29	17.47	19.83

TABLE 5.8: PERCENTAGE AVERAGE MOBILITY PREDICTION ACCURACY OF DIFFERENT DATASETS.

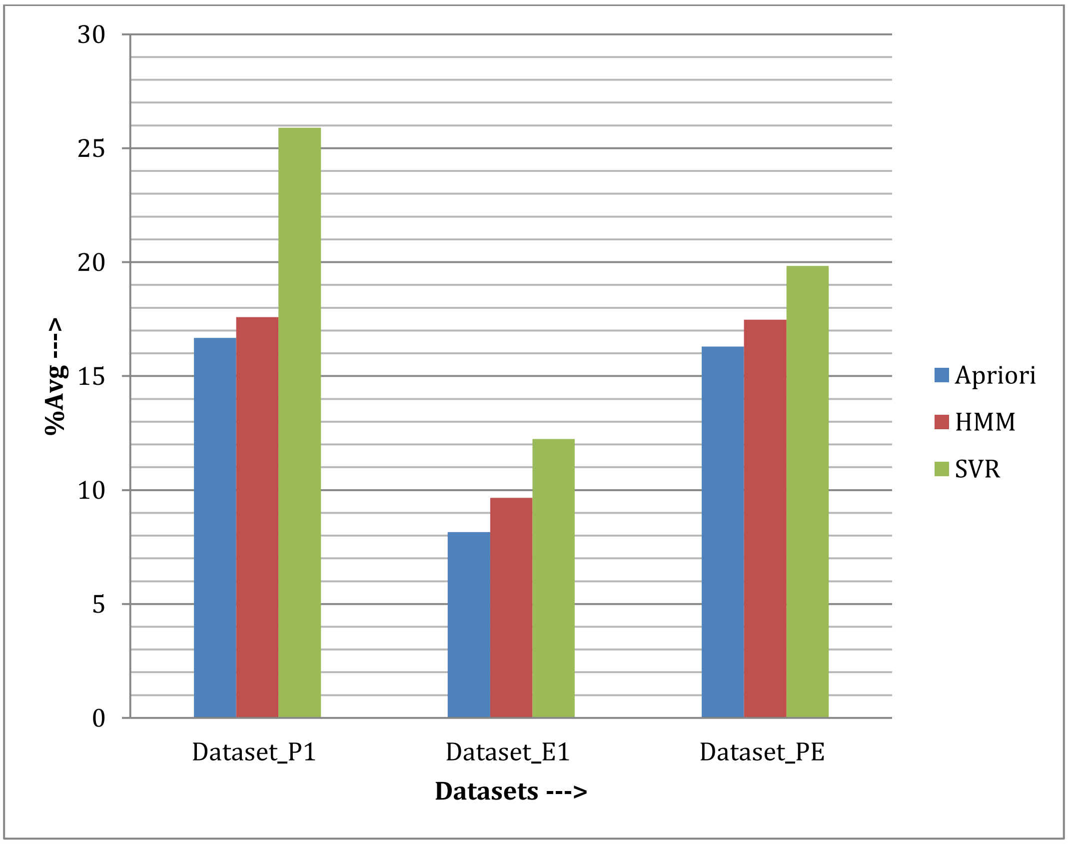

FIGURE 5.8: COMPARISON OF PROPOSED AND VARIOUS METHODS USING PERCENTAGE AVERAGE MOBILITY PREDICTION ACCURACY OF DIFFERENT DATASETS

Mobility prediction is important as discussed above for providing good QoS in wireless and cellular network. Above result shows that proposed SVR method gives more and better prediction accuracy, for predicted and estimated users, then dynamic methods (HMM, Apriori).

5.3 Group Mobility Results

In this research work, some important results are also found which shows group behavior or mobility. Based on that maximum, average and minimum used APs were elicited from the dataset and shown in the Figure 5.9, 5.10 and 5.11 respectively. Maximum visited APs also deduce the information about mobility of the MUs which shows the path which is highly preferable by the number of MUs in the dataset. Likewise same for the minimum and average visited APs.

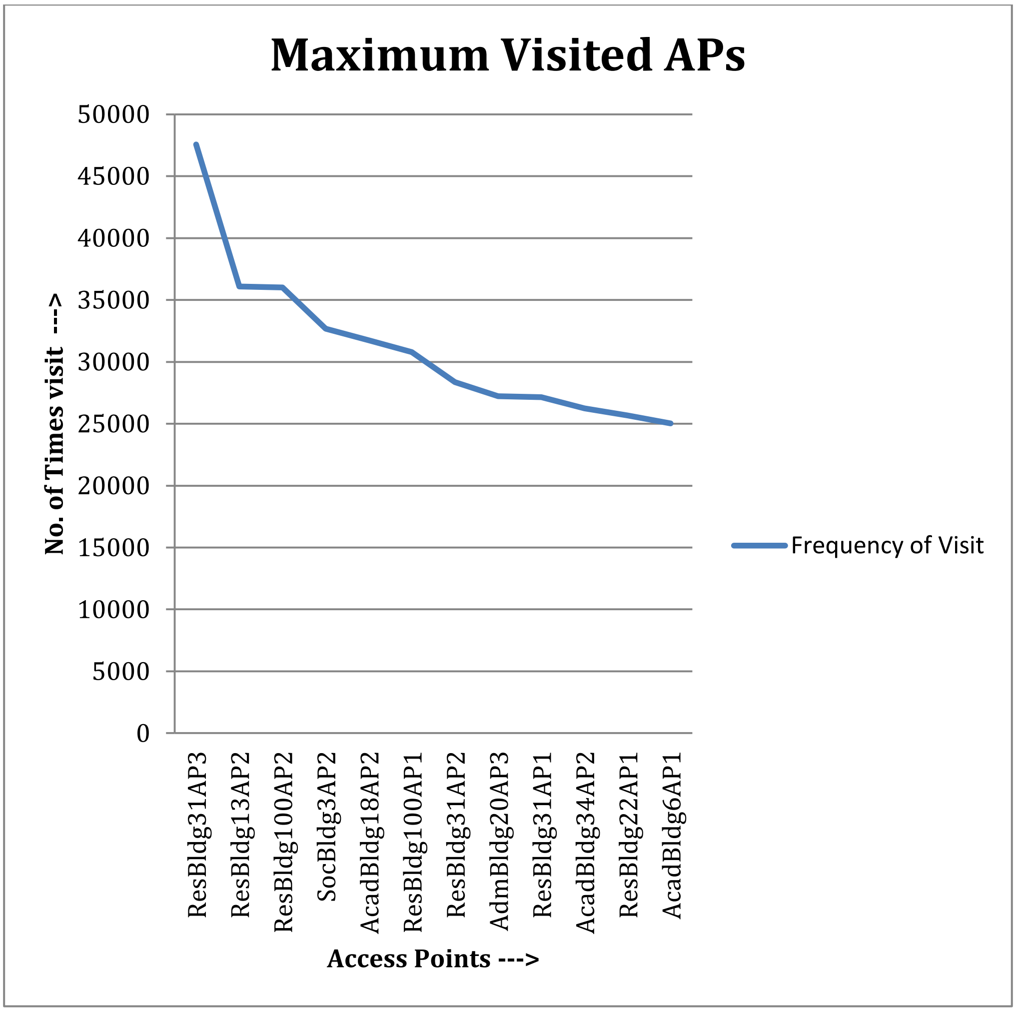

FIGURE 5.9: MAXIMUM VISITED APs BY MUs IN THE DATASET

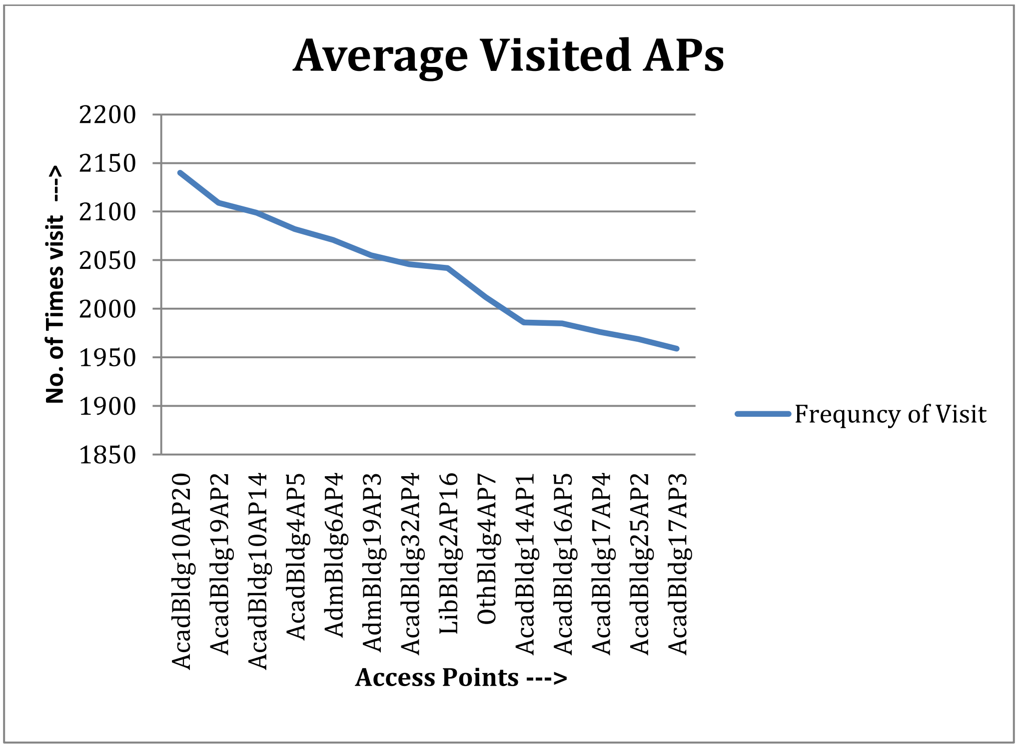

FIGURE 5.10: AVERAGE VISITED APs BY MUs IN THE DATASET

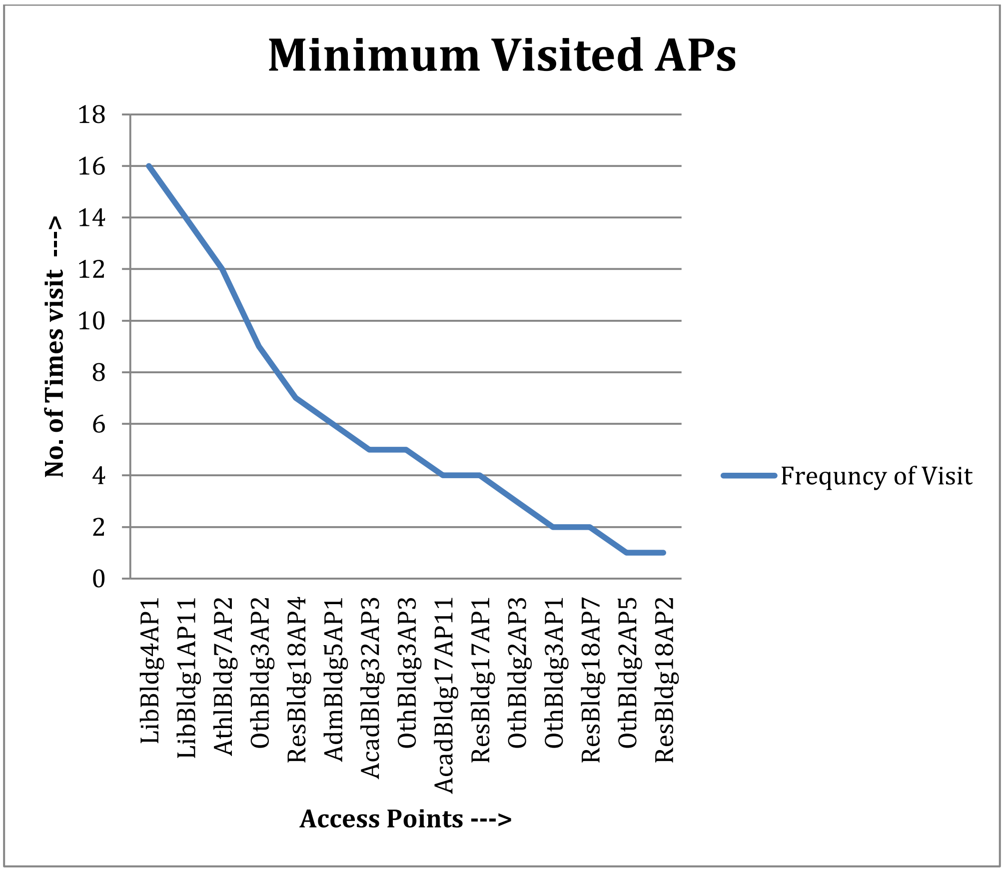

FIGURE 5.11: MINIMUM VISITED APs BY MUs IN THE DATASET

Implementation and result analysis shows that, proposed regression based SVR method is better than static and dynamic methods. Location management cost, summation of Paging and LU cost, and mobility prediction accuracy of proposed method is better which reduce radio signaling bandwidth in the cellular network.

6. CONCLUSION AND FUTURE WORK

6.1 Conclusion

Location Management is important task for the cellular network which is possible by proper planning of LA. Location management cost consist cost of LU and paging which increase signaling cost in the cellular network. To reduce location management cost and providing QoS to MUs, formulation of the proper LA is necessary. Various static and dynamic methods are available for formulation of LA but user based LA gives more advantage over static LA. There are three types, predicted, estimated and random, of MUs are reside in the cellular network based on the mobility behavior of them. QoS is possible in the cellular network if the location of the MU's predicted in advance based on the movement history or behavior.

In this research work, a new regression based dynamic method SVR is proposed for reducing signaling cost (location management cost), by creating DLA for each MUs, and mobility prediction in the cellular network without making any changing in the existing architecture. All dynamics methods reduce more signaling cost as compared to static methods by creating DLA for individual MUs. Proposed SVR method also reduces total Location management cost higher than other dynamic methods and static method. Mobility prediction becomes easy and fast in DLA as compared to static LA. SVR method uses RBF kernel function for predict mobility of MUs in the cellular network. SVR method's mobility prediction accuracy in DLA is higher than other dynamic methods which leads to better QoS provided to MUs using limited radio bandwidth.

6.2 Future Work

It has been observed during research that, if any deviation in the regular movement of the MU(s) occurs in the cellular network then to provide QoS by finding MU(s) in the cellular network become difficult using dynamic methods. When this kind of situation arises then more radio bandwidth is used to find MU(s) in the cellular network. If any adaptive method will be developed which store deviated movement of the MU(s) which can be used in future when MU(s) take same path (deviated path) again for movement prediction of the MU(s). So total location management cost, radio bandwidth, can be reduced.

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