Dynamic Location Area Planning in Cellular Network by Virtually Personalize Location Area Management

Ph.D. Synopsis

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1. 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 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 SVR, implemented and results are compared with static method. Amongst these methods, SVR reduce more signaling cost and give better mobility prediction accuracy which is compared with static method.

2. Brief description on the state of the art of the research topic

This section presents the literature review of the LA in GSM network with its importance, work done on LA planning using static methods, pitfalls of static methods, requirement of DLA and various methods used for formulation of DLA based on users' movement in cellular network and mobility (movement) prediction in cellular network.

2.1 Location Area

Cellular networks are a type of networks that support wireless connection to mobile equipment. Cellular networks is rapidly growing network in today's world because of a rapid growth in the population of mobile subscribers, and such growth increases signaling. Increased 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 to achieve this efficiency. Location Management involves two components: Location Update, when MS cross the boundary of Location Area (LA) and entered into new LA, and Paging, when any mobile terminated call is arrived the cellular network page MS in network to elicit a response of MS so call can be routed.

For location management, location area approach has been used by many second generation networks, like GSM. Location area consists of several contiguous cells and whole service area is divided into numbers of LAs. Each LA has its own Location Area Identifier (LAI). LA is important factor in cellular network for Location management. Location management is deals with how to keep track of an active mobile station within the cellular network. Other way, Location management is concerned with the procedure requires to enable the network to maintain location information for each subscriber, or more specially, for each active MS with registered subscriber, and to efficiently handle the establishment of incoming call. When MS is powered on it consider as an active MS.

The size 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 cost.

There are two extreme LA planning approaches; in one approach we make LA size equal to service area of MSC, in this scenario location update cost is minimized but in turn paging cost get increased. And if numbers of LA are equal to number of BS then the location update cost get increased while paging cost gets minimized. We need to balance this pitfall in paging cost and location update cost and hence it is important to better LA management in cellular network.

2.2 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 [1], genetic algorithms [2], simulated annealing [3] and Ant Colony Optimization [4] were employed to derive a proper planning for location areas to minimize the total number of location updates. Greedy Algorithm [2], constrained maximum spanning tree to partition a geographic area into LAs [5], Clustering and Hierarchical location database are also some others methods for LA Planning.

The above static methods have following pitfalls.

1. Location areas 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 location updates leading to higher handoff cost.
3. The location update load of all MUs is concentrated in the boundary cell of LA. The heavy uplink traffic decreases the efficiency of random accessing considerably.

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

2.3 Dynamic Location Area (DLA)

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 methods are classified into State based and Profile 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 [6], the 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 location update/registration cost is reduced and the paging cost (Location Tracking) is increased. For selective-update, LU/ registration can be possible using time-based, distance-based and movement-based method.

In Distance based Methods [6, 7, 8], LU is performed when its distance from cell where it performed last LU exceeds a predefined distance value. Using this method we can create Dynamic LA by taking distance D as a radius and consider all the cells inside the circle as a part of LA. But in this method to find out precise distance D from last LU to current LU is challengeable issue. So this method is difficult to implement. In Time based [6, 7, 8] 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. In this method, unnecessary LU is performed even MU does not change its location which generate huge payload on network. While in movement based [6, 7, 8] method LU is performed after predefined movement across cell boundaries are made. For counting movement across the cells, movement counter, is may be kept at HLR/VLR or at MU level. Here, unnecessary LU is performed when MU movement is zig-zag at cell boundary. Figure 2.1 shows the selective-update (state based) method.

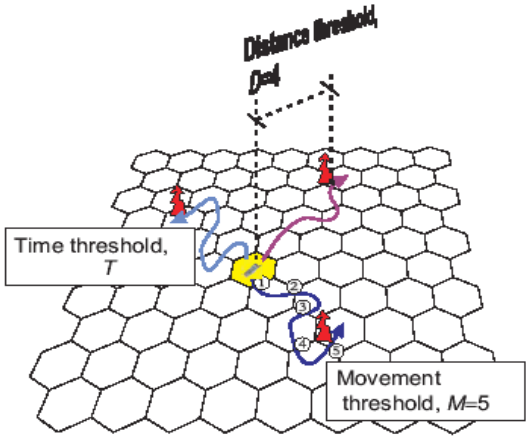

Fig: 2.1. Selective Update Methods[5]

Other methods are also available which are known as Profile based methods: Artificial Neural Network [9, 10, 11, 12, 13, 14] : in this method users mobility history is given for train the network and based on that dynamic LA (DLA) is formed as well as the mobility prediction can performed. User Mobility Behavior [15]: based on the user mobility in cellular network user mobility behavior (UMB) is deduced and store in user mobility record (UMR). This UMB is work as LA for that user so when call come for that user based on the behavior and residential time of user call is established. This save the paging cost and when behavior of user is changed from stored UMB then LU is performed. Other method is Directed Graph [16, 17]: in this method graph edges shows the transition probabilities between nearest cells and node shows the cells. When MU visit same cells the weight of that edges are increase. All those edges which have weight above the user defined threshold then all those cells which are connected with this edged are used to create DLA. There are two others methods in which user mobility are used to find out dynamic LA; User Mobility with Simulated Annealing [18] and Heuristic Function [19]. In these methods based on mobility pattern, DLA is formed and after that using simulating algorithm and heuristic method optimal LA is formed which reduce LU in the cellular network. Dynamic Distance and User profile based [8] method also used to create DLA, which use mobility pattern and based on that dynamic distance threshold is created. When MU within the radius of dynamic distance threshold no LU is performed. While another approach is Dynamic and Distributed LA [20], which create agent cell (AC) and general cell (GC). Based on user movement in cellular network AC is home cell which contain number of visited cells as a GC. That information is given to HLR. AC works as a VLR and maintains GC. When user movement is changed new AC is created that time LU is performed. Here work of VLR is distributed and when new AC

creates that information is given to HLR. All these methods give various ways to create DLA but some methods force to reduce paging cost while some are force to reduce LU cost.

2.4 Mobility Prediction

Mobility prediction in 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 possible when DLA created for MUs. In DLA, every user most probably follows the same path with same unit of time to reach its destination from home location. It is easy to predict next cell movement of any MUs in DLA using mobility pattern and behavior. Using mobility prediction resource allocation during ongoing call or handoff procedure of MUs can be properly possible which reduce call dropping rate. There are many methods for mobility prediction in cellular network like Artificial Neural Network [10], Clustering [23], Directed graph [16] and Knowledge Grid [25], etc. These methods use direction, time and behavior of MUs for mobility prediction. All these methods use whole network while predicting Mobility of MUs, so performance or accuracy is not achieved considerable.

3. Objectives and Scope of work

The following are the objectives:

1. To propose new method and its implementation in network without changing existing cellular network architecture for reducing total location management cost, sum of LU and paging cost, which will reduce total signaling cost in network.
2. To propose a mobility prediction scheme for network so resource management for MUs could be made feasible.
3. To provide good Quality of Services (QoS) to MUs by implementing proposed method.

The scope of the 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 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.

4. Original Contribution by the Thesis

The entire work in this synopsis, as well as thesis is the original work, with the copyright and the research papers as the back bone. The proposed framework and the algorithms have been visualized as a collection of various modules, each of which are supported with relevant publications. The contributions of this research work in the support of the above said discussions are as follows: The work in thesis is divided into three threads: First is finding types of users, second is creating DLA using functionalities of Apriori, HMM and SVR methods and third is finding mobility prediction accuracy of MUs in cellular network by above mentioned methods.

1. A method is proposed which finds out types of mobile users as discussed above based on the movement of MUs in the cellular network.
2. Dynamic methods are proposed which find out and create DLA for predictable, estimated and random users based on the frequently visited cells by them in the cellular network. DLA used to reduce singling cost, LU + paging cost, in the cellular network by performing LU and paging within cells under DLA.
3. In the third part of this thesis, methods are proposed which find out mobility prediction for predictable and estimated users in the cellular network as the mobility of such users are regular and follow same pattern. Random user's predictability in the network is not possible as its mobility is not predefined. Mobility prediction accuracy of each method is obtained and compared with proposed SVR method.

5. Methodology of Research, Result and Discussions

The following subsection discusses the proposed dynamic methods in cellular network for reducing singling cost and increasing mobility prediction accuracy by forming DLA for individuals MUs.

For this research work simulation dataset of Dartmouth University is used. 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 mobility information of each user.

5.1 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. Below figure 5.1 shows the results of types of users in the dataset. 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.

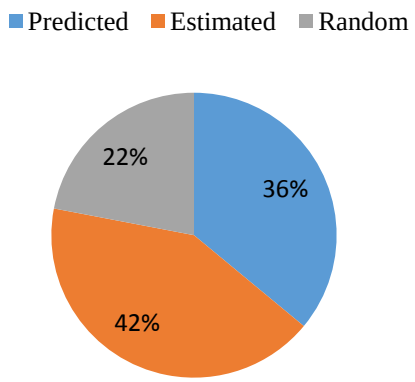

Fig: 5.1. Types of Users

5.2 Thread 2 & 3 : DLA creation and Mobility Prediction

Here, using dynamic methods DLA is created and mobility of users are predicted. These methods are discussed in the following section.

5.2.1. Apriori Algorithm for DLA formulation and Mobility Prediction

In this research work, Apriori algorithm is implemented which used for finding frequent itemset using an Iterative level-wise approach based on candidate generation. The functionality of Apriori algorithm to find frequent itemset from the transaction is used in this research work 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. Transaction history and minimum support are given as an input of the algorithm which gives frequently visited cells which we can use 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 5.1 and figure 5.2 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	03

Table: 5.1. Results for DLA planning using Apriori Algorithm

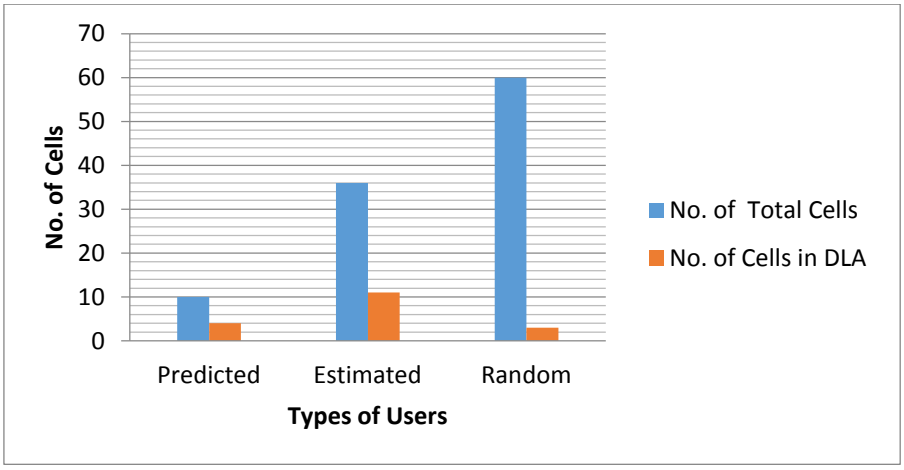

Fig:5.2. DLA creation using Apriori for different types of MUs

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 so 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.

5.2.2 Hidden Markov Model 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. For finding DLA using HMM functionality, first HMM model is initialized with dataset. Transition probabilities of MUs each route to reach at his/her destination from source are calculated. 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. Figure 5.3 shows the results of DLA created using HMM mechanism.

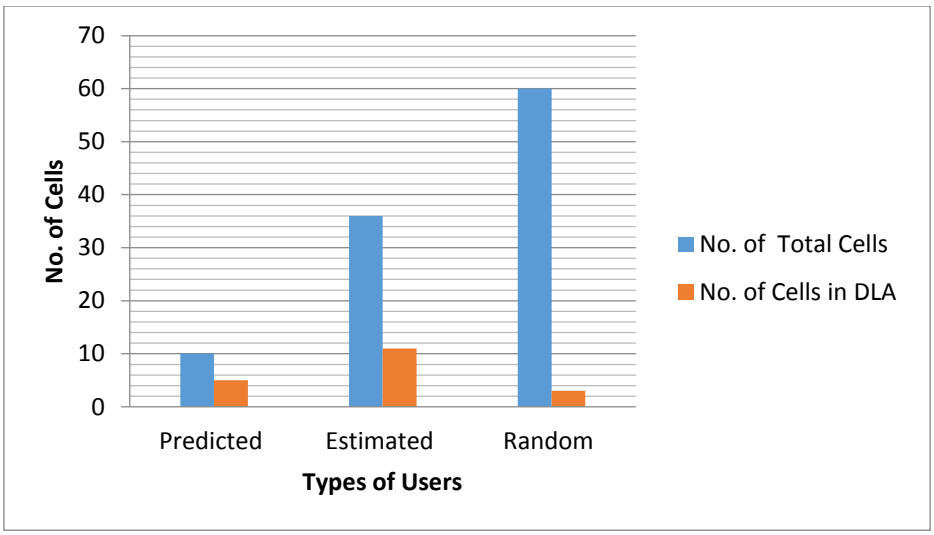

Fig:5.3. DLA creation using HMM for different types of MUs

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 is 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.

5.2.3. Super Vector Regression for DLA formulation and Mobility Prediction

SVM is used for regression method which is known as Super Vector Regression (SVR). The SVR uses the same principles of SVM with minor differences. In SVR method

training data is given based on that after applying regression on that future prediction can be done. 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 network. Figure 5.4 shows the results of DLA created for different types of users using SVR methods functionality.

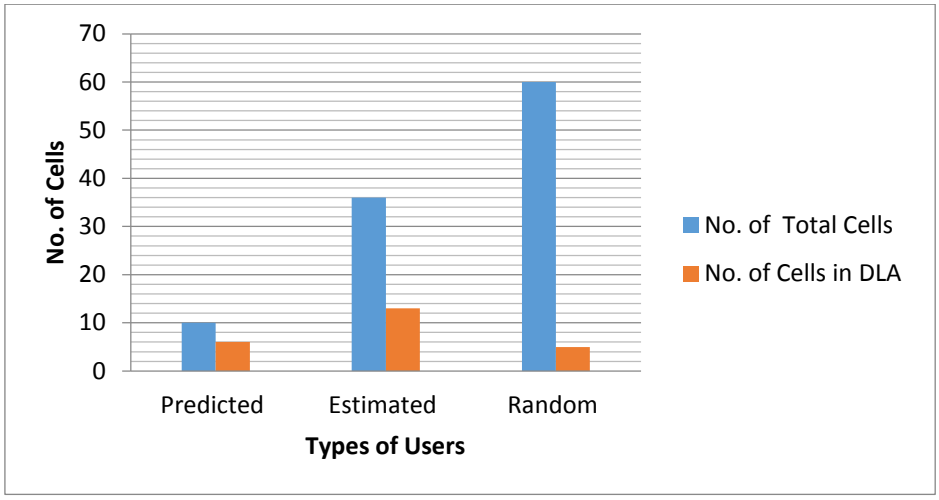

Fig: 5.4. DLA creation using SVR for different types of MUs

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 prediction accuracy of methods is calculated for predicted and estimated users which are shown in next section.

5.3 Results

In this section results regarding reducing LU and Paging cost as well as mobility prediction accuracy of dynamic methods are display. To obtained result for comparison of proposed method with dynamic and static methods different datasets are created.

Table 5.2 and figure 5.5 shows the percentage average of LU cost of various datasets, which contain multiple users, and comparisons of static method and dynamic methods.

Dataset	Apriori	HMM	SVR	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: 5.2. Percentage average of LU cost of different datasets

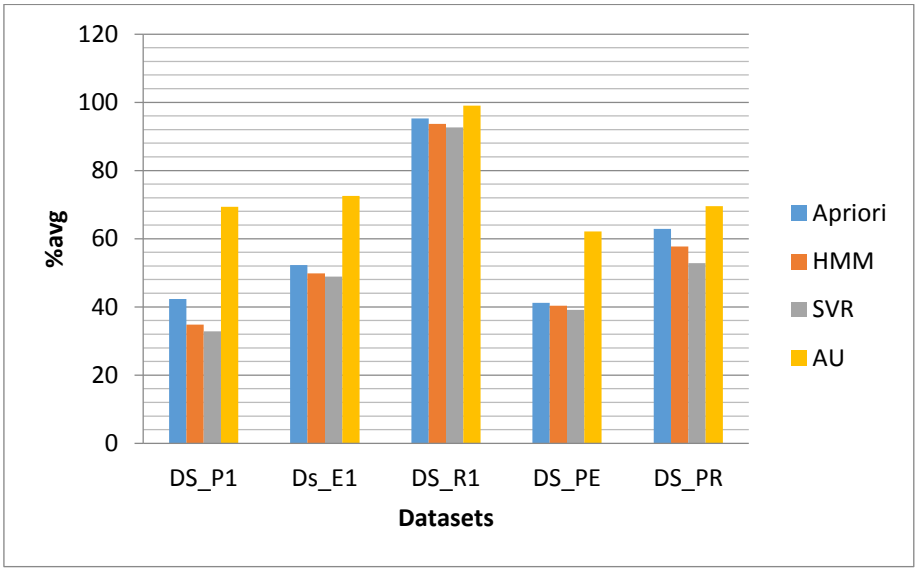

Fig: 5.5.Comparison of various methods using percentage average of LU cost

Table 5.3 and figure 5.6 shows the percentage average of paging cost of various datasets and comparisons of static method and dynamic methods.

Dataset	Apriori	HMM	SVR	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: 5.3. Percentage average of Paging cost of different datasets

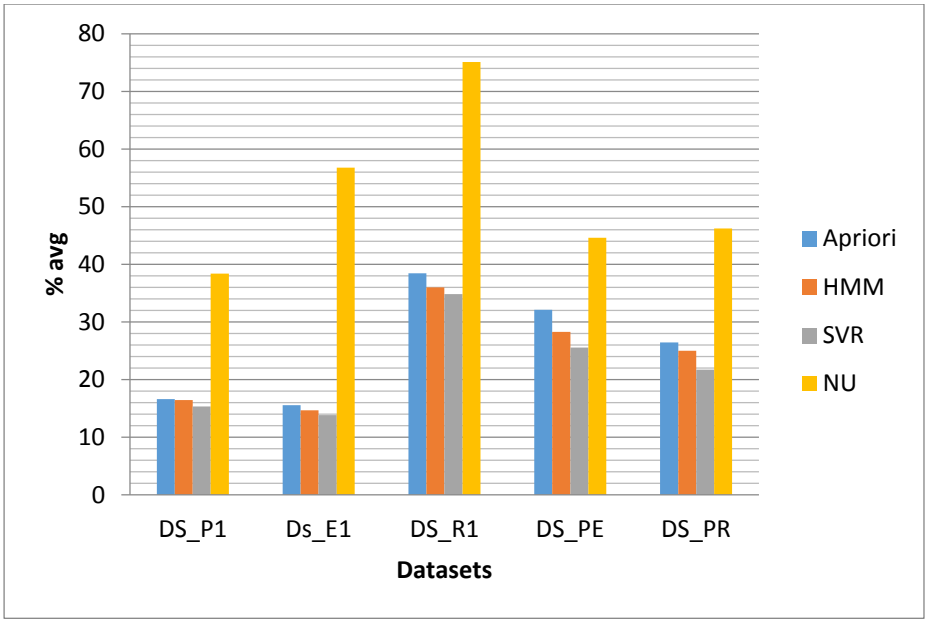

Fig: 5.6. Comparison of various methods using percentage average of Paging cost

Likewise mobility prediction accuracy results of predicted and estimated users using dynamic methods are shown below in table 5.4 and figure 5.7.

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: 5.4. Percentage average of mobility prediction accuracy of different dataset

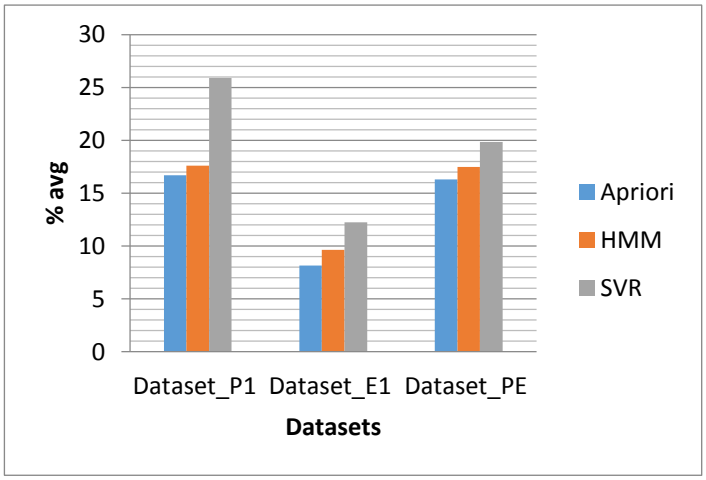

Fig: 5.7. Comparison of various methods using percentage average of mobility prediction accuracy

Results shows that by using DLA we can reduce LU and paging cost which is not possible in static method and other dynamic methods which are applied on whole network.

Mobility prediction accuracy is also increased due to DLA formation. Other results are also achieved like minimum, maximum and average used access points and accessed paths by users from given dataset.

6. Achievements with Respect to Objectives

The objectives were to propose the efficient dynamic method for cellular network to improve the mobility prediction accuracy, reducing singling cost and providing good QoS, using limited radio bandwidth than the existing dynamic and static schemes.

The results demonstrated that the regression based dynamic method, SVR, proposed for the LA based cellular network achieved the higher mobility prediction accuracy and reduced signaling overhead by reducing LU and paging cost then the existing dynamic and static schemes. Also, dynamic methods can be incorporated in existing cellular network without making many changes in the infrastructure and architecture.

7. Conclusions

Location Management is important task for cellular network which is possible by proper planning of LA. In this work, we have proposed a new regression based dynamic method SVR for reducing signaling cost and mobility prediction in Cellular network without making any changing in the existing architecture. All dynamics methods reduce more signaling cost as compared to static methods. Proposed SVR method also reduces total Location management cost higher than other dynamic methods. Mobility prediction becomes easy and fast in DLA as compared to static methods. 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.

8. List of Publications arising from the thesis

1. N. B. Prajapati, D. R. Kathiriya, "Comparative Study of Dynamic Location Area Planning Methods", International Journal of Advanced Research in Computer Science and Software Engineering, Volume 3 , Issue 10, October 2013.
2. N. B. Prajapati, D. R. Kathiriya, "Dynamic Location Area Planning in Cellular Network using Apriori Algorithm", International Conference on Industrial Instrumentation and Control (ICIC 2015), 28th -30th May, 2015, Pune.

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- https://www.ieee.org/conferences_events/conferences/conferencedetails/index.html?Conf_ID=34660

3. N. B. Prajapati, D. R. Kathiriya, "Mobility Prediction in Dynamic Location Area in Cellular Network using Association Rule Mining", IRACST - International Journal of Computer Science and Information Technology & Security (IJCSITS), Volume 5, Issue 6, PP no. 406- 409, December 2015.
4. N. B. Prajapati, D. R. Kathiriya, "Mobility Prediction for Dynamic Location Area in Cellular Network using HMM", International Conference on Industry Interactive Innovations in Science, Engineering and Technology (I3SET), 25th-26th October, 2016, JIS Engineering College, Kalyani, West Bengal.
    - I3SET 2016 Proceedings is to be published in Springer series of Lecture Notes in Networks and Systems (LNNS).

Paper Submitted:

5. N. B. Prajapati, D. R. Kathiriya "Dynamic Location Area Planning and Mobility Predication in Cellular Network Using Super Vector Regression", 2nd International Conference on Advanced Computing and Intelligent Engineering (ICACIE 2017), 23-25 November, 2017, Central University of Rajasthan, Ajmer, India.

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