Location Management Techniques in Cellular Network: A Novel Approach

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Location Management Techniques in Cellular Network: A Novel Approach

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by

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2010-2015

Dedicated

to

The Dreams and Sacrifices

of my Dear Ones
who Love me a Lot.

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Certificate

This is to certify that the thesis entitled **"Location Management Techniques in Cellular Network: A Novel Approach"** *by* **Nilakanth Prajnaranjan Nath***, submitted to the National Institute of Technology, Rourkela for the award of Bachelor of Technology in Electrical Engineering and Master of Technology in Electronic System and Communication Engineering, is a record of bonafide research work carried out by him in the Department of Electrical Engineering, under my supervision. I believe that this thesis fulfills part of the requirements for the award of degree of Master of Technology.The results embodied in the thesis have not been submitted for the award of any other degree elsewhere.*

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Abstract

Communication had become the necessity of our lives. It is no longer just a way to communicate with each other. Its now a part of our life. Most of this changes are the result of the rapid growth in mobile industry. The number of subscribers are increasing in an exponential manner. At current stage the number of mobile devices had already crossed the total human population of our planet. But this high paced increase in number of subscribers had brought in some new and challenging problems into the field also. Particularly the problem of accommodating this huge number of subscribers into the limited amount of spectrum, without compromising the Grade of Service. In this thesis we had tried to address this issue by reducing the spectrum utilization in the location management.

Location management are the set of techniques that are used by the telecom provider to determine the current location of the user (location update) and to inform the user regarding an incoming call (paging). Both of these process consumes a huge portion of the available spectrum. This thesis presents a dynamic profile based location management technique that optimizes both these technology. When simulated using actual user data, the algorithm shows it is 3 times more efficient than the conventional paging and 2 times more efficient compared to other intelligent paging algorithms. Similarly in case of location update, the algorithm shows an improvement of 17% compared to the conventional technique. The thesis also includes a comparison between sequential paging and concurrent paging based on parameters like probability of channel being busy, average waiting time per user etc.

The novelty of this work is that it uses CDR (Call Data Record) to profile the users. And the algorithm is implemented on actual user data rather than any theoretically predicted data. The optimization is done at individual user level. So the optimization achieved through the proposed algorithm is greater compared to other algorithms. The final output shows promising result specifically in terms of bandwidth conservation.

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Definitions

The following terms are used throughout this document and replicated here for reference.

* **Base Station or Base Transceiver System (BTS) :** An antenna situated on a tower that transmits and receives radio signals in a wireless network.
* **Base Station Controller :** A controlling agent for a group of base stations. It manages the allocation of channels, performs paging, controls handover, and interfaces with the MSC and HLR.
* **Cell :** A geographical area covered a BTS in a wireless network. Cells are the building blocks of a cellular network.
* **Global System for Mobile Communication (GSM) :** The standard for second generation mobile phone communication. It is defined on the various protocols for GSM communication.
* **Hand-off :** The technique of transferring a call in-progress from one cell to a neighbouring cell without interruption.
* **Home Location Register (HLR) :** The central database that stores information of all subscribers. This database is specific to the carrier. It also keeps a record of each user's last known location, which assists in routing calls to the correct cell.
* **Location Area (LA) :** A group cells (adjacent of each other) clubbed together to form a larger meta-cell. Location update is triggered when the user changes this meta-cell. A Location Area can be static or dynamic.
* **Spectrum :** It is a portion of the electromagnetic waves within which a mobile device communicate. Allocation of of these frequencies are governed by regulatory bodies. A service provider must purchase a license to use a particular frequency band within this spectrum to broadcast cellular data.
* **Subscriber Identity Module (SIM) :** A small smart card used in mobile phones to identify the subscriber. SIM are kept under the GSM standards.

List of Acronyms

Acronym	Description
3G	Third Generation
A-GPS	Assisted Global Positioning System
BSC	Base Station Controller
BTS	Base Transceiver Station
CDR	Call Data Record
CDMA	Code Division Multiple Access
EDGE	Enhanced Data Rate for GSM Evolution
EOTD	Enhanced Observed Time Difference
GERAN	GSM and EDGE Radio Area Network
GOS	Grade of Service
GPRS	General Packet Radio System
GPS	Global Positioning System
GSM	Global System for Mobile communications
HLR	Home Location Register
LA	Location Area
LAC	Location Area Code
LM	Location Management
LMU	Location Management Unit
LOS	Line-of-Sight
MS	Mobile Station
MSC	Mobile Switching Center
PA	Paging Area
PCMD	Per Call Measurement Data
RAN	Radio Access Network
RSSI	Received Signal Strength Indicator
VLR	Visitor Location Register

Chapter 1

Prologue

This thesis presents a new profile based dynamic location management scheme for cellular networks. The motivation and goals guiding the development of this system are discussed in this chapter. The specific research contributions of this project are outlined, along with an overview of the structure of the remainder of this document.

1.1 Motivation

Day to day increase in mobile subscribers in recent years has resulted in exploitation of wireless network resources, in particular, the bandwidth available. The continuous reduction of cell size to incorporate more number of user had increased the frequency of location management. At a busy hours MSC are getting over flooded with paging request. All of these problems highlight the need for improvement of spectral utilization in mobile communication. As location management is the chief consumer of bandwidth and generates most of the unnecessary spectral overhead it is in a dire need of optimization.
At current scenario most of the implemented location management techniques are purely static i.e. all users in a given region have the same location management characteristics regardless of their movement and call arrival rate. Such an implementation is highly suboptimal. Current dynamic location management proposals, while reducing total location management cost, suffers from some significant weaknesses. Most of them make a number of unrealistic assumptions that are far from actual user data. The result so obtained are purely theoretical. Hence, a profile based dynamic location management scheme, able to be implemented efficiently in cellular networks, would stand to benefit network carriers tremendously.

1.2 Project Goal

The primary aim of this project is simply to reduce the spectrum utilization of cellular network operators in managing the location of users. All developments are proposed in the context of this aim. The location management technique while being spectrum efficient should provide a higher level of performance to be feasible for practical implementation. Underscoring this philosophy, the research presented will take a departure from conventional user profiling methods, with an emphasis on actual user data and dynamic location management in cellular networks. A profile based dynamic location management scheme is presented, adhering to this major objective. The aim of a spectral efficient location management may be realised through the following goals:

* Develop a profile based location management technique, capable of application on a large user database.

* Implementing a spectrum efficient mechanism to optimise the bandwidth utilization of location management

* Formulating a dynamic user profile to adapt to any change user behaviour pattern and optimise the location management to best fit the user behaviour.

* Incorporating actual user data and avoiding any assumptions on network topology or user behaviour to obtain a result that is similar to the real-time data.

1.3 Contribution

Many individual developments and contributions are required in the satisfaction of the aforementioned project goals. These contributions, in the context of this project, are summarised as follows:

* A comparative study between the existing systems of location management.
* Analysis and incorporation of CDR for location management.
* Designing an algorithm that correlates the periodicity in user's presence over a particular time of a particular day of the week.
* Designing a dynamic profile based location management scheme that utilises the user periodicity to increase the spectral efficiency of location management system.

1.4 Thesis Structure

The thesis is divided into six chapters. The first chapter is the prologue of the thesis. It describes the project goal and motivation for the project along with different contributions of this thesis. The next section highlights the background of the project. It encompasses the different technical areas and literature reviews which had been considered for the development of this thesis. The third section compares the different paging algorithms that are currently in use. It highlights their performance at different Erlang values. In section 4. we had proposed a dynamic profile based paging algorithm that uses the CDR data for creating the profile. The proposed algorithm is compared with another intelligent paging and conventional paging with respect to bandwidth conservation and paging success rate. In section 5. the profile based location update counter part is described. The proposed location update algorithm is compared with the conventional location update characteristics with respect to location update per-user. The final chapter concludes the thesis and gives the future scope of the work.

Chapter 2

Background of the project

In this chapter the background of location management is discussed in brief. This section mainly focuses on topics that are considered in the project like types of location update and paging, the cellular concept of mobile communication, etc.

2.1 The Cellular Concept

Cell and Frequency Reuse

The early mobile systems have large transmitting antenna and tall towers to cover a large geographical area. This type of system only supported a few simultaneous calls over an area of thousand square miles. Hence, with the increase in number of user the system soon faced a shortage of frequency. This problem is solved by a concept call, *frequency reuse*.
Instead of a single tall, high power transmitter several small, low power transmitters were placed to cover the geographical area. The small fragments of area covered by a single transceiver is termed as **cell**. The total available frequency is divided among a small group of cells which are adjacent to each other. The same group of frequency now can be reused in other cells that are not adjacent to the previous cells (to prevent interference). In this way, the same set of frequency can be reused again and again to accommodate the whole geographical region. If the number of subscriber increases then the range of antennas are further reduced and more number of BTS are installed (*cell splitting*) [1].
An example of frequency reuse: Let there be total **S** duplex channels available for use and each cell be given **k** channels such that **(k < S)**. Now, the **S** channels are divided among a group of **N** channels, uniquely and disjointly so that

$$S = kN.$$

This cluster is repeated **M** times to cover the whole geographical area. So the total number of duplex channels available **C**, will be,

$$C = MkN = MS$$

Where **N** can only have values as given by equation,

$$N = i^2 + j^2 + ij$$

.

Where, both i and j are positive real values.

So, the possible values are, N=3 for i=1, j=1, N=7 for i=2, j=1, N=19 for i=3, j=2 etc.

GSM

GSM stands for Global System for Mobile communication. GSM is a communication protocol developed by the European Telecommunications Standards Institute (ETSI) to facilitate the 2G digital communication protocol. It replaced the older analogue counter part 1G system. It operates on the 900 Mhz and 1800 Mhz band [2].
GSM has two major building blocks:

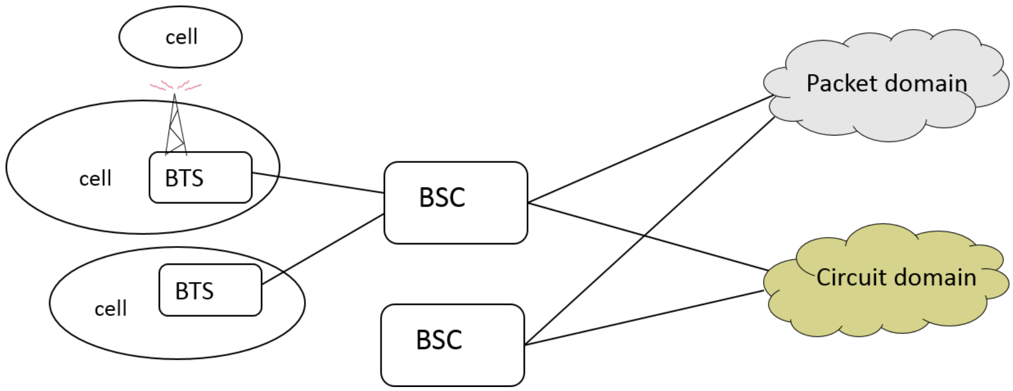


Figure 2.1: gsm architecture

1. **Radio Equipment:** This block provides wireless access to the subscribers and other GSM network structures.

2. **Core Equipment:** This block contains databases that stores and monitors the subscriber data. It also performs important functions like call handling and billing.

A cell which is defined by a base transceiver station (BTS), is the basic building block of GSM architecture. BTS performs the transmission and reception of radio frequency signals within a defined range and hence provides radio coverage to a confined geographical area. Communication between two mobile stations is established via a base station.
A GSM network can be divided into four subsystems :

1. Mobile Station/Terminal (MS/MT)

2. Base Station Subsystem (BSS)

3. Network Switching Subsystem (NSS)

4. Operation and Support Subsystem (OSS)

Mobile Station/Terminal (MS/MT) It is the user terminal in GSM architecture. it consists of a SIM (Subscriber Identification Module) and a mobile equipment. The mobile equipment is identified by its IMEI number (International Mobile Equipment Identity number). It performs tasks like digitizing, encryption, encoding, modulation, paging acknowledgement etc..

Base Station Subsystem (BSS) The BSS consists of base transceiver station (BTS) and base station controller (BSC). A BTS is responsible for radio transmission and reception. It consists of devices like antenna and signal processing instruments. BSC on the other hand is the intelligent unit in BSS. It controls the radio functions of GSM system and communicate with the MSC for a smother operation.

Network Switching Subsystem (NSS) The NSS performs the call switching and mobility management functions. The architecture contains specific features and functions which are needed to assist the mobile nature of the phones. The MSC is the main unit of NSS that handles the routing and call handling. MSC recognises the location areas and gives the paging request when the call arrives. MSC also communicates with other MSC to support inter MSC calls. NSS also holds some of the important registers like Home Location Register (HLR) and Visitor Location Register (VLR). They help in maintaining the user's mobility information and roaming information respectively. AuC is the authentication center that stores the billing information and the subscribers data. EIR is another database that stores the IMEI numbers.

Operation and Support Subsystem (OSS) They support management functions such as network inventory, service provisioning, network configuration and fault management. The OSS interlinks all the BSCs and MSCs in the network. OMC (Operation and Maintenance Centre) is established through OSS, and it monitors the network round the clock. OSS provides fault management system.

2.2 User Location Prediction

User location prediction is a set of technology that are used to predict the location of user where predicting the location means pinpointing the geographical location of the mobile with minimum error possible without compromising with the performance. This information is then used for various services like emergency response, radio resource management like handoffs or mobile traffic management, etc. This sector got the largest push when USA Telecom authority made it mandatory for mobile service provider to provide the location data of the user for faster E-911 response [3].
There are various technology that are used for determining the user's location. It can be broadly classified into two groups,

1. Handset based
2. Network based

These are further divided into various parts based on different technology. These technologies are implemented either combined with other technology for better precision or implemented alone to save cost with the sacrifice of accuracy. The handset-based technology uses the forward DATA channel to give the mobile station the required data (often from more than one base station). Then the mobile station do the necessary calculation. This method suffer from a significant challenge that is the power available is limited. So this method often compromise with accuracy. The other method uses the backward DATA channel to get the required information from the MS via more than one BS and then relay this information to MSC where the user location is estimated with precision. As this method uses more than one BS, this method is not appropriate for rural areas where the BS are far apart. Generally the location of the user is decided in comparison to the BSs because the BSs are equipped with GPS, which provide them with absolute geographical location. And the MS location is provided in relative to that.

2.2.1 Handset based location update techniques

Cell ID

The mobile station needs to identify itself over the BS to get the required information to initiate a call or data transfer. So the MS sends its MPIN over to BS after a fixed time interval in idle mode. This information is transmitted to MSC and MSC stores that location of the MS in Home Location Register (HLR) for paging when the call comes. This update happens continuously when the user is on call, so this information was initially being used by the service provider to get the location data. It was then used to provide roaming services and handoff initiation. This is the cheapest possible way of getting the location information. Also, it does not utilise much of the provided resources, and it also does not need any modification in the MS or BSC. But the biggest problem with this technique is its inaccuracy. It only provides the information that in which cell the MS is present, or the MS is near to which BS. So its accuracy is based on the size of the cell and in remote places the cell size are significant and so is the error in location prediction. It also requires an active voice call to locate the MS or else it shows the past location of MS. Hence generally it is used with other location determining techniques to get a better accuracy [4].

Timing Advance (TA) + Cell ID

The radio resources are divided into various time slots for multiple access so that each user is provided with a particular time slot, and the transmission signal have to reach the MS at that particular time slot. So the transmission burst takes into account the MS distance from the BS and coordinates its signal transmission with it. Hence, this sense of time management can be used to estimate the distance of MS from BS. It provides a slight increase in accuracy but this accuracy comes in multiples of 550 meters because the adjustment or advancement of the signal burst is made as a multiple of 550 meters.

Signal Strength + Cell ID

This is another method which is used with Cell ID to determine the user location. The transmission power of the mobile and BS is controlled by the BS depending upon its distance from BS to prevent the near far problem and also to prevent unnecessary drainage of power from the handset. So by measuring the Rx signal strength at the MS and by measuring the change of its strength with direction of movement of MS, we can estimate the approximate distance of BS from MS and can predict the user location. This method is useful in case of village areas because of less obstruction and more availability of line-of-sight path. But in urban areas there is no clear line of sight path hence the signal undergoes many reflections before reaching the MS (multipath) and hence this method is prone to error for urban areas [5].

Enhanced Observed Time Difference (EOTD)

This method is similar to Timing Advance in some extent. Here the MS listens to the synchronization burst sent by neighbouring BSs (a mechanism to pseudo-synchronise the network) and technique to find the timing delay between the received signals of various BSs. The MS then uses Multilateration technique to find out its position. In this method the 2D accuracy is good but it fails to provide any altitude information. As 3G networks does not need to synchronise, hence more data is required to locate the user i.e. the time offset between the transmission of two signals. To get this information allocation measurement unit (LMU) is used on BSs, which is expensive. Also, it requires a software modification in MS to carry out the operation hence it is soon replaced by its counterpart Uplink-Time Difference of Arrival which uses MSC resources to carry out the computation.

Global Positioning System (GPS)

GPS is a space-based location or position determining system. It uses low earth orbiting satellites to determine the position of any device which is fitted with a GPS receiver. And with increase in number of mobile phones having a GPS receiver incorporated with them finding their location had become very efficient and easy. It uses minimum 4 satellites to pinpoint a user's location with an accuracy of few meters and good altitude prediction. The GPS satellite communicates with the GPS receiver in the mobile and uses triangulation to find the user location. It is non-commercial service hence the user don't have to pay for accessing the satellite. Adding to that, this system works everywhere and also is not affected by weather condition. But it has one problem that is in indoor environments due to poor signal strength the accuracy decreases and in some case the mobile becomes unable to access the GPS service.

2.2.2 Network-Based Location Technique

Network-based techniques use the available resources of MSC to compute the location of user. This involves more than one BS and the data received are then sent to MSC for calculation. The MSC then use triangulation or other methods to pinpoint the location. This method is more efficient than the previous methods and is widely used considering the present scenario.

Uplink-Time Difference of Arrival (U-TDOA)

It is similar to EOTD except for the fact that the location computation is done in MSC. The transmission signal from MS reaches LMUs placed on different BSs at different time depending upon its distance from BSs. This timing difference from various LMUs are then used to compute the location of MS. This method is quite efficient, and it produces result within 50 meters of error. Also as this method is network based, so no software or hardware modification of any kind have to be implemented on MS. But this method fails to provide any altitude measurement and like EOTD, requires LMUs for accurate measurement.

Angle of Arrival (AOA)

It is one of the classic radio detection technique and is still in use and had gone through various improvement to provide better accuracy. This uses Directional Antenna Array to pinpoint the angle of arrival. The angle of arrival can be calculated in two ways. One way by calculating the time delay between the signal reaching different elements of the antenna array or by measuring the phase difference. In either way, the result is very accurate. This result can be accompanied by results from other BSs to triangulate the position of the MS or

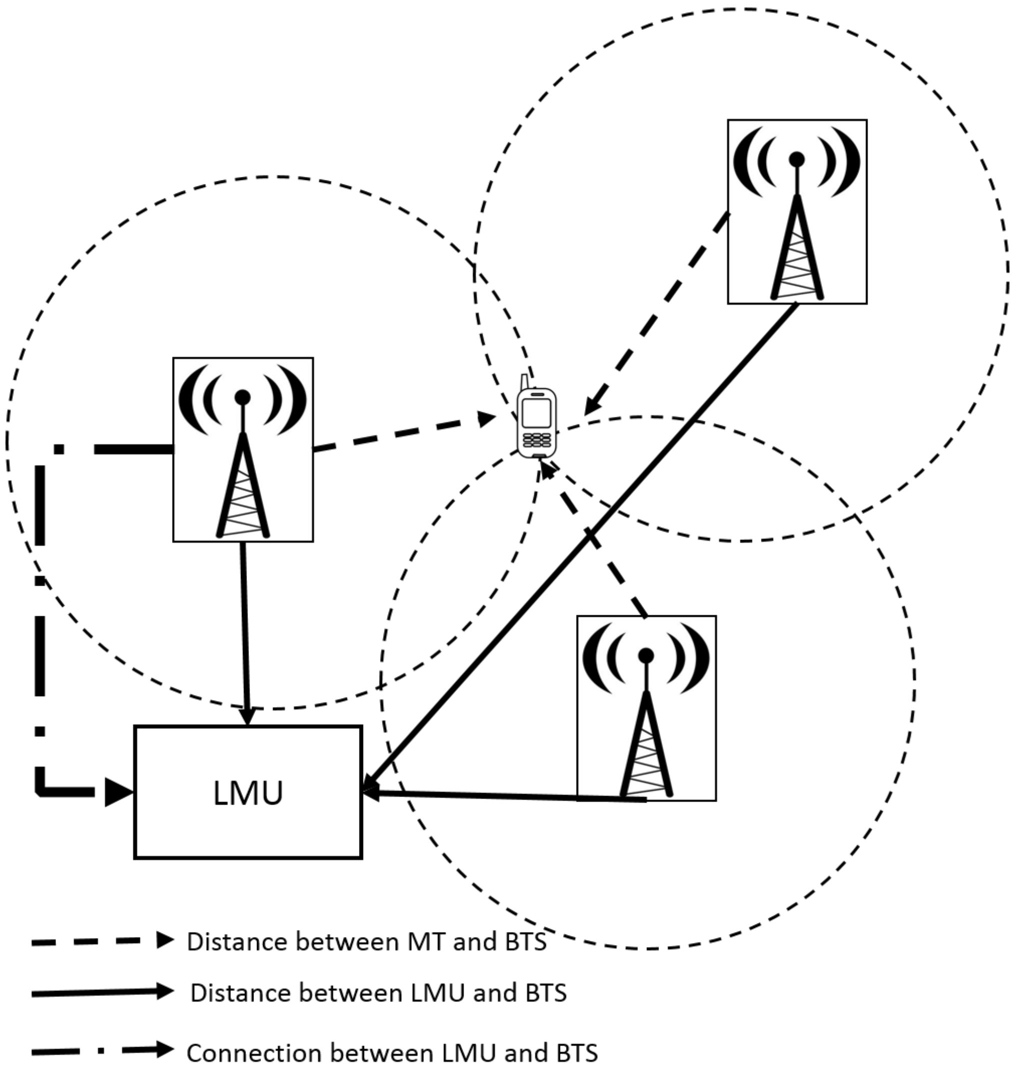


Figure 2.2: EOTD: Enhanced Observed Time Difference

this can be accompanied with the power distribution profile to directly calculate the MS location. While the firstLEO satellite thi method is fast and easy the second method is more accurate. This system is the oldest method and is widely used in military application. But its use in finding user location in case of CDMA or other cellular services had decreased with time because it requires a line of sight (LOS) path for its accurate measurement and with the ever increasing number of cell phones LOS path is nearly impossible to find hence it is used in some village areas or areas with less population density [6].

Assisted Global Positioning System (A-GPS)

It stands for Assisted-GPS which is similar to GPS but with few improvements. When a GPS device is turned on it takes some time to find the orbit and clock data of the LEO satellite, this is called Time To First Fix or TTFF in short. This time varies somewhere between 30 seconds to few minutes. This delay is more in urban areas than in villages or planes. But with A-GPS this time is reduced. As the name suggest in A-GPS the GPS receiver is generally assisted to find out the location. This assistance comes from structures like cellular towers that has GPS receiver built into them and they constantly pull the satellite information hence they provide the required data to the mobile so that the TTFF is reduced. Also the mobile can send its location data directly to the cellular network via the control channels [7].

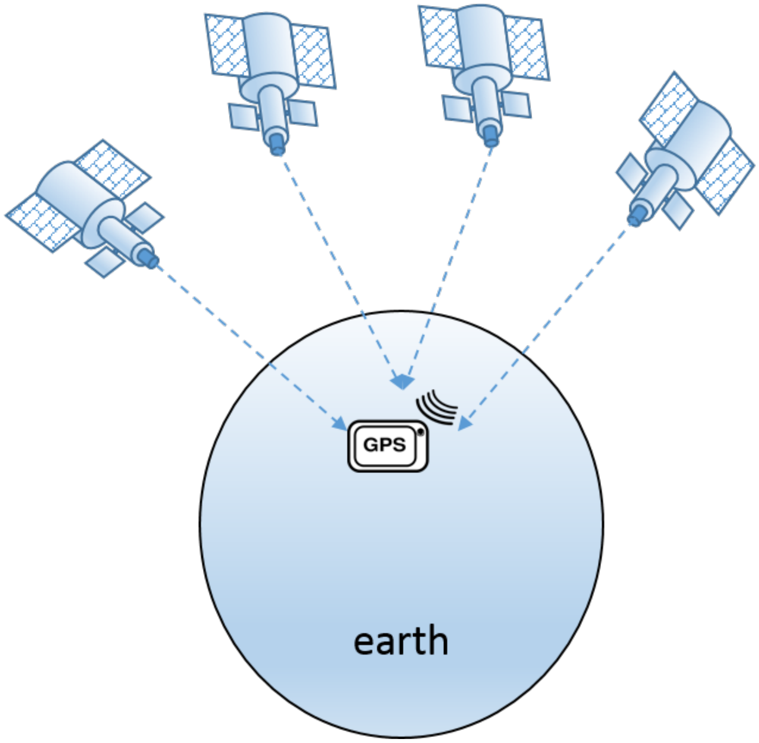


Figure 2.3: Global Positioning System

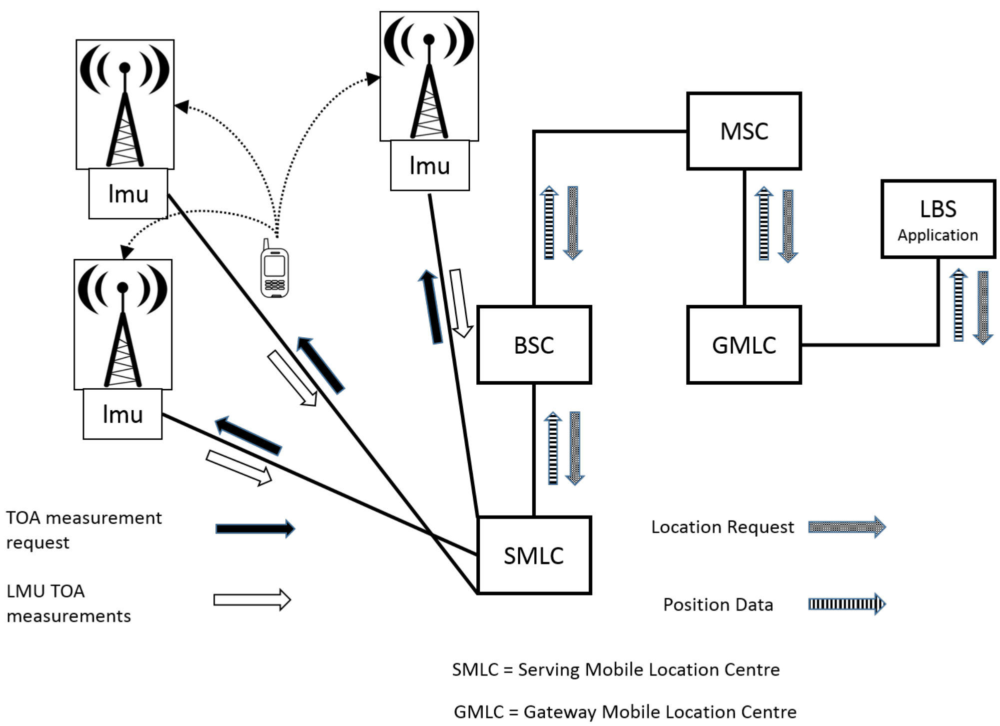


Figure 2.4: UTDOA: Uplink Time Difference of Arrival

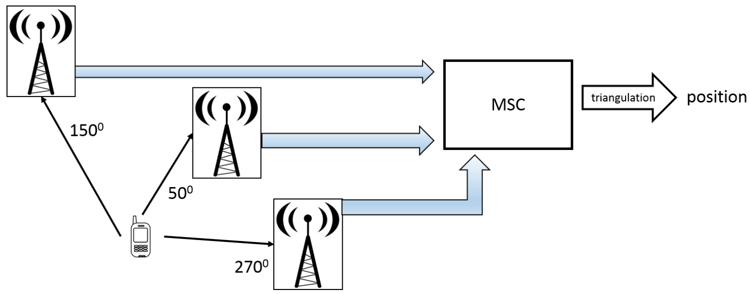


Figure 2.5: AOA: Angle of Arrival

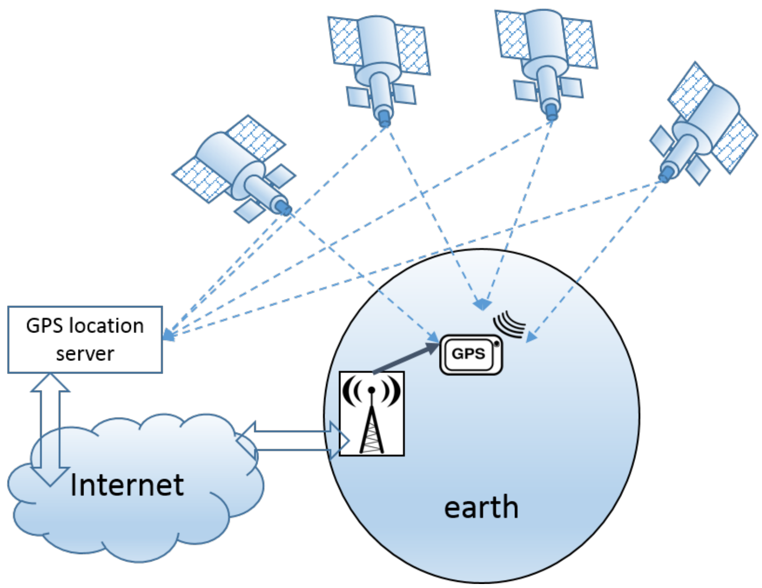


Figure 2.6: Assisted Global Positioning System

2.3 Location Update

The mobile stations are not static and hence, they change their position from time to time. Location update is the technique that informs the MSC regarding the current location of the user. So that the transfer of controls and call requests to that particular cell can be facilitated. But location update needs to utilize the available resources, namely, spectrum and computational ability so that the continuous update will not only result in unnecessary use of these resources resulting in extra cost but will also hamper the user experience as there will be less resource to be utilised by the user. Also, if the user location is not updated then the paging cost will be very high, and the user has to wait for a longer time to get the call connected. With the reduction of cell size to accommodate more number of subscribers, the frequency of location update is quite high. Particularly in an urban area the location update rate of user is very high. Hence, there is an urgent need to optimize the location update process so that it will be less resource intensive. And to do so we have to upgrade the location of user or the MS based upon certain criteria and depending upon these criteria the location update can be broadly classified into two categories:

1. Static Location Update
2. Dynamic Location Update

2.3.1 Static Location Update Schemes

In this scheme, the location update is done based upon certain factors that is independent of the user i.e. the update rules are same for all users irrespective of their movement profile. As this scheme does not require specific user tracking so the computational requirement is very small and hence, it is very cheap to implement. But it is not efficient as the other schemes. It is further divided into subsections depending upon the parameter used [8].

Always Update

The MS location is always known to the MSC in real time and hence, it does not require any paging cost, as a result it is useful for users with less movement rate and more call arrival rate. But if the case is the reversed then it results in unnecessary location update and hence, proves costly. Therefore, this system is not used for any practical purposes but in AMPS system once the call gets connected the updating scheme used throughout the call is always update type. And this system also forms the base for other update system.

Never Update

This is exactly the opposite of the previous scheme. Here, the MS location is never updated. Hence, the updating cost is zero but if the MS changes its location frequently then the paging cost is very huge so it is seldom used when the subscriber unit is not mobile. Therefore, there is no need to update the location and in those cases this works fine.

The Reporting Cell Concept

The two previous schemes discussed were the extreme ends of location update and so they are not at all optimized. To get an optimized location update this scheme is developed. And this scheme later paved the path for other advanced update schemes. In this system, some of the cells are made reporting cells and by making them reporting cell the MS is instructed to update its location when it enters the reporting cell. This ensures that the MS is most likely to be in the vicinity of the last reporting cell and thus, those cells are paged first and as a result the updating as well as the paging costs are reduced. The reporting cell can be of two types, namely, bounded and unbounded. The bounded reporting cell makes sure that a mobile phone will cross a given reporting cell before going N cells away from last reporting cell. Whereas, the unbounded reporting cells reduce the number of redundant location updates. However, there is a chance that the user may be far away from the last reporting cell without going through any of the reporting cells. So in that case the paging cost will be high to locate the user. Hence, the MSC have to use an intelligent algorithm to make sure that the user does not go far away from the reporting cell without reporting its location. Also, the reporting cells should be wisely distributed considering the traffic routes and population densities [9], [10].

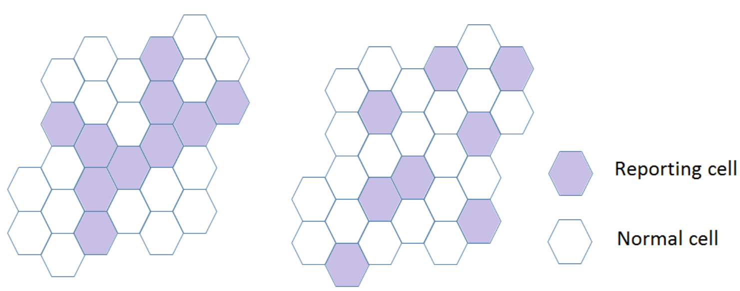


Figure 2.7: Bounded and Unbounded Reporting Cell Arrangement

Location Area

This concept groups few cells together to create a location area. Thus, the entire geographical area is divided into a number of location areas. Then the update may be done periodically or based on location area boundary crossing i.e., the MS have to update its location when it leaves its current location area. The periodical location update makes the mobile station to update its location at a particular frequency. And when the call comes, the cells of the last known location area are paged. This system does not take into account the MS's speed so if the MS moves very fast and crosses the location area before reaching its updating time then in that case the MSC have to page more than one location area so the paging cost goes high. So, the location area boundary crossing scheme provides a more useful aspect in a sense that a mobile station has to update its location every time it crosses the location area so it's sure that the MS will be confined to a particular location area. But it is not devoid of all adversities as there is something called Ping-Pong effect that occurs when a user travels between the cells of neighbouring location area, it creates unnecessary location update and hence, costs more money and resources. Though, to overcome this problem many proposals had been put forward but none of them are used widely in particular [11], [12].

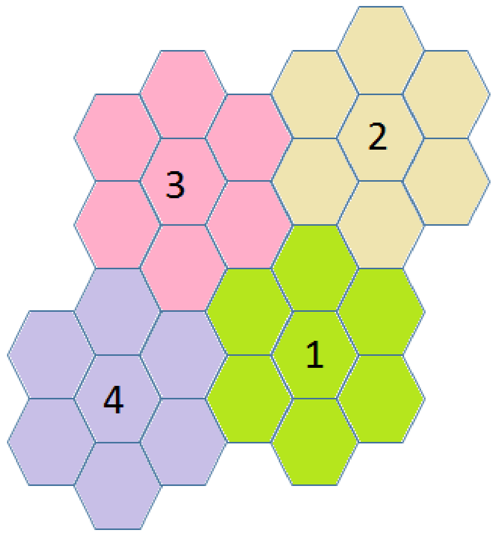


Figure 2.8: The location area concept

2.3.2 Dynamic Location Update

This location update takes into account the movement and call arrival rate of each user and on that basis sets the threshold of the parameter. The parameter can be distance, time or movement based. This helps in optimizing the location update and paging cost per user. Also, in this scheme, each cell can act as a reporting unit and the location update is independent of cell. This scheme needs special algorithms to decide the location update criteria. Therefore, it needs huge computational power and the installation cost is high too. But the advantages of this system easily outweigh the cost concern. Currently, this area is the hottest topic of research. Considering the parameters, this location update scheme can be divided into various subsections as well [11, 13].

Threshold Based

In this a certain parameter is monitored and the threshold value is set depending upon the user's activity. The most commonly used parameters are time, distance and movement.

a. **Time based update:** It is the most widely used threshold. The MS have to update its location after the pre-set amount of time. This pre-set or threshold time is user specific. It requires less computational overhead as it requires the mobile device to only maintain a simple timer. This is very useful for user with high mobility and low call rate as it eliminates large part of the overhead that is generated in other two cases.

b. **Movement based:** In this method, the MS updates its location after crossing some predefined number of cells. So in that way the area to be paged is reduced by n-1 number of cells around the last updated cell. Hence, for user with high call arrival rate n is kept small and vice versa. This method outweighs the time based method for users with high call arrival rate and less movement. But this scheme generates large overhead if the user moves continuously in and out of the cell.

c. **Distance based:** This takes into account the distance from its last updated location. Therefore, if it crosses the threshold radius then it updates its location. This frees us from the problem of high overhead that occur in movement based update as instead of cell crossing it takes into account of the actual distance travelled. But on the flip side, this system requires high computational ability as it deals with the actual distance parameters and this makes it less widely used option.

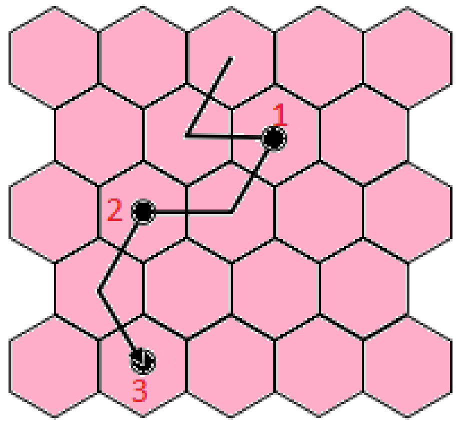


Figure 2.9: Distance-Base location update
(location is updated after crossing two cell boundaries)

In [14], the authors laid a location management technique that satisfies predefined delay requirements and incorporates the distance. The proposed location update scheme with the selective paging mechanism. When an incoming call arrives, all the cells within a distance of D (D is the distance threshold) from the last reported cell, are paged first within one polling cycle. If the system is allowed to have more than one polling cycle to find the called mobile station, the authors proposes to apply a selective paging scheme. Under this scheme, the system partitions the residing area into a number of subareas, and then polls each subarea one by one until Paging is successful. Their result shows a significant reduction in total cost of location management even for a maximum paging delay of 2 polling cycles. They also show that the average total costs are very close to the minimum with a maximum paging delay of 3 polling cycles. The authors also have derived the average total location update and paging cost under given distance threshold and maximum delay constraint. In [15] , the authors have proposed an analytical model which formulates the costs of location update and paging taking into account the movement based location update scheme. Paging is done in 1 polling cycle. The authors prove that the location update cost is a decreasing and convex function with respect to the movement threshold, while paging cost is an increasing and convex function with respect to the threshold. Hence, the total costs of location update and paging is a convex function. It has been observed that the optimal threshold reduces as the call-to-mobility ratio increases, an increase in update cost (or a decrease in polling cost) results in an increase in the optimal threshold. The residence time variance has nearly no significant effect on the optimal threshold.

Profile Based Location Update

In profile based location update, the user's behaviour is monitored by the MSC and a profile is created (hence, the name profile based). The profile holds the information regarding user's mobility, call arrival rate, most visited cells etc. These information are used to reduce the cost and resource utilization of the user. The principle behind this scheme is dictated by the fact that mobility pattern of a majority of the subscribers can be foretold by looking at their past behaviour.
Profile based location update can be of two types static or dynamic. In static the profile is created observing the user for a long duration of time. And the profile once created stays in place for a long time. It generally compromises with the optimization of the system to some extent to give an overall good performance. The implementation cost is less. Whereas in case of dynamic location update, the profile created are dynamic that is the profile keeps changing frequently, generally once to more than once per day. This requires higher

processing speed and more storage. The result so obtained is highly optimised. The dynamic nature of the profile takes care of any change in user behaviour pattern or change in radio arrangement like cell splitting or sectoring etc.. This added advantage makes it a better choice than the static counterpart.
There had been a lot of research in this area. In [16] the author had proposed an algorithm that tracks the user activity over a span of time $[t_i tot_n]$ and then arranges them into an array of the form $[(A_1, P_1), (A_2, P_2), (A_3, P_3).....(A_n, P_n)]$. Where, A_i is the $i^t h$ location area who have the probability of P_i of holding the user. The array is stored and sorted such that $P_1 > P_2 > P_3..... > P_n$. And when the user moves in the list of location area there will be no location update and in case the user go out of these area the location update will be according to the conventional location update. When a paging request comes between $[t_i tot_n]$ the paging is done starting with P_1 first then P_2 etc..
Another profile based location management is described in [17], the proposed work uses directed graph to create a dynamic profile for the user. The profile calculates the number of time the user visited a cell and the average time the user had spent in the cell. Then these data are stored in the form of a directed graph where the weight of the node is the average time the user spends in the node. When the user moves into a new cell apart from that present in the profile the location update is triggered and the weights of the graph are recalculated. On arrival of a call the nodes having the highest weights are paged first and then others subsequently.
The authors in [18] also discussed some location area planning based on the mobility of individual mobile user or a group of user. Another per-user dynamic location area strategy is proposed in [19] . Their paper uses incoming call arrival rate of user along with mobility to dynamically determine the size of a user's location area. Their results show that, their strategy is better than static ones when call arrival rates are subscriber time-dependent.

2.4 Paging

Paging utilizes the common control channels. Paging channel is the link that exists between a mobile and BTS when the mobile doesn't have any dedicated channel assigned. It is used by the BTS to inform MS about the arrival of a call. Paging is very important as it provides all the necessary information that is required for the call to continue. Paging can be done based on IMEI, MIN or ESN. With the arrival of a call, the MSC sends instructions to a set of BTSs to page and look for a particular mobile. The set of BTSs varies according to the type of paging and location update scheme being used. Different user-specific factors are also taken into account to determine the BTS. Only a few BTSs are paged to save bandwidth and also to avoid network congestion. Another system that works in sync with paging is location update; location update is the technique used to inform the MSC about the location of MS. This is done in a timely manner or dynamically based on user's movement. Location update is not done continuously as it will consume a lot of bandwidths and will also burden the MSC [20]. These two techniques together form the location management system [13]. The aim of this system is to pinpoint the location of the mobile station with minimum error possible without compromising the system performance. So the location management system has to be both accurate and less resource-intensive [21, 22, 23].
The Performance of paging is characterised chiefly by,

a. **Paging Cost & Location Update Cost** Location update and paging are closely related to one another. There exists a trade-off between the two i.e. as we increase the location update frequency the uncertainty in user location decreases and hence the number of BTS to be paged decreases and thus it leads to the reduction in paging cost (at the expense of increase in location update cost). And if we reduce the number of location updates the location update cost will decrease but then there will be an increase in paging cost and paging delay. So the technique that has the lowest location management cost is the best algorithm. This cost also includes the cost associated with the use of bandwidth.

b. **Paging Success Rate** Paging Success rate is defined as the ratio between the paging success and the total number of pages. So if n users are paged and n users are found in the same attempt then the paging success rate is 100%. In actual cases however the paging success rate is below 100%. The desired value is more than 90%. But this is achieved in subsequent paging attempt. That is the failed pages of the first attempt are again paged (in a wider area or a different area) and the resultant paging success rate is sum of the two paging success rates. So a higher paging success rate is essential for the system, both for conserving the bandwidth and for better user experience.

c. **Paging Delay** The paging as discussed above happens in more than one step. And each step takes some time to execute. The conventional paging on an average takes around 1 sec. This value depends upon the type of paging, Load on MSC, and number of paging attempt. The paging delay should not be too high as this will both hamper user experience and will increase the holding time and decrease the GOS. So, the paging delay need to be as small as possible [24].(chapter 3)

Paging can be categorised into four categories:

1. Blanket Paging.
2. Sequential paging.
3. Concurrent Paging.
4. profile based paging.

2.4.1 Blanket Paging

Blanket paging is the most primitive type of paging. In blanket paging the whole location area is paged. So the bandwidth consumed is too high for this process. On an average it pages 200 to 400 cells to locate a single user. Which increases the cost and also deteriorates the GOS of the system. The only advantage it offers is the simplicity of implementation. At the present situation where bandwidth conservation has the chief priority this system is seldom used [22].

2.4.2 Sequential Paging

In sequential paging, the user locating probability is taken into consideration and hence rather than paging the whole location area simultaneously we do it group by group (or in sequential manner). This is the direct improvement over blanket paging. The paging is done based upon the decreasing user probability i.e. the group of cells having highest probability of locating the user based on its last known location is paged first and then the next group with slightly lower probability and so on. As it can be inferred, this takes time if the number of groups are large and if the probability of user being present in a group is small. To overcome this, generally the number of groups are limited to 2 or maximum to 3 and the first group is constituted in such a manner that it contains 90% (or higher) probability of locating the user. In this way the paging delay is kept in check. The performance i.e. paging cost reduction varies depending on the number of groups made and also on the type of user. Typically this gives 25% performance improvement when the LA is divided into two groups and the first group contains user locating probability 90%, as compared to broadcast paging. But its efficiency decreases when the probability of locating the user becomes uniform over the number of cells [3] .

2.4.3 Concurrent Paging

Concurrent by itself means existing, happening, or done at the same time i.e. several processes are carried out during overlapping time periods concurrently instead of sequentially (one completing before the next starts). On that basis we can say Concurrent paging is a modified version of sequential paging. Instead of a sequential search in the selected group of cells, it performs concurrent search. In this technique, instead of searching for a particular user in all the cells and then searching for the other user in all the cells, the users are searched in an alternate basis i.e. user one is searched in cell one and user 2 is searched in cell two at a time and then these positions are interchanged. This is particularly helpful during peak hours when the users to be paged in a particular area are too large which will be discussed below.(chapter 3)

2.4.4 Profile Based Paging

Much of the research work is now based on profile based paging. This is so because it offers a greater spectral efficiency along with flexibility to be operated along with the conventional system. The Profile can be dynamic in which case the algorithm takes care of the changes in the user movement.

In profile based paging, first the user behaviour is monitored the various parameters like call arrival rate, Type of call, Call Duration etc. are the main characteristic monitored in profile based paging. The final profile is created based on these parameters. The profile is stored in MSC and then the paging rate is determined based on the profile. The main objective of the algorithm remains to optimise the paging resource utilization without affecting the grade of service [25].

2.5 Call Data Record (CDR)

CDR or Call Data Record (also known as PCMD, Per Call Measurement Data) is a data generated in MSC for each and every call generated or received by a user through the BTS covered by it. These are generally stored in the MSC (Mobile Switching Center). They are generated for individual user and contain a lot of information regarding the call placed. In this work we used those parameters to profile user. Some of the parameters that are used from CDR are:

1. Date of call
2. call starting time
3. call ending time
4. initial cell identifier and location area
5. final cell identifier and location area
6. type of call

apart from this there are a lot of other fields in CDR also like MSISDN, Account balance etc., but those parameters are not used in this paper.

2.6 Hypo-LA paging

Hypo-LA stands for Hyper LA proposed in [26]. In this paging scheme the location area (LA) is divided into smaller areas called Paging Area (PA). When a mobile enters into a location area it triggers a location update. The location update contains the Cell ID. This is used to identify the cell. In Hypo-LA paging, When A call arrives instead of paging the whole location area, the PA containing the reported cell is paged first. In case of paging failure other PAs are paged one after the other starting from the nearest one. In this way the bandwidth utilization is less if the user is found in the first few attempt. But also on the other hand paging delay increases. So to optimise The PA size is kept equal to the BSC size. The algorithm when implemented on GERAN (GSM EDGE Radio Area Network) [27, 28] some significant bandwidth improvements are observed in terms of bandwidth conservation [29]. The results of this algorithm is used in chapter 4 for comparison with the proposed paging algorithm.

Chapter 3

Paging Techniques

In this section a comparative study is done between the two most widely used paging techniques, sequential paging and concurrent paging. While sequential paging had been around for quite a long time, many service providers are now adopting concurrent paging because it offers a greater GOS (Grade of Service). In this section both the paging techniques are discussed and then their performance is evaluated taking an Erlang C channel [30].

3.1 Introduction

Sequential Paging: In sequential paging, the different location areas (or different parts of a location area) are paged one after other, in the decreasing order of probability (i.e. the group having the highest probability is paged first). Mostly, the probability is calculated based on the user's last known location and the time difference between the location update and paging. Hence, this type of paging does not require much storage and computation resources apart from HLR and VLR [31]. (subsection 2.4.2)

Concurrent Paging: In concurrent paging however, instead of waiting for the search completion (paging) of one user, different users are paged in different groups simultaneously to reduce both the load and waiting time. In concurrent paging, all the users probability are calculated in each group hence, computational needs are slightly higher compared to sequential paging. Further comparison of the two techniques are given bellow which emphasizes more on bandwidth conservation and Grade of Services (GOS)[32, 33]. (subsection 2.4.3)

3.2 Sequential Vs. Concurrent paging

Let us take an example, user A and user B are to be paged in a location area having two cells, cell A and cell B (CA and CB). So if we follow sequential algorithm then first we page both CA and CB for user A with probability of success being 0.5 in each of the paging (considering initial conditions are unknown). And then we again page both CA and CB for user B with 0.5 probability of success. So total it will require two pages in CA and two pages in CB. Hence total four pages to locate two users.
But if we follow sequential paging then first user A will be searched in CA and user B will be searched in CB again with a probability of 0.5. But the difference is that if any one of the users is to be paged for the next then instead of two we have to page a single cell only. So in this case the total no of paging required is $2 + 1 = 3$. Here the no of pages per user decreases to 1.5 pages per user. The initial conditions are unknown here, but in actual conditions cells are graded based on the last known location for efficient paging. Hence, the probability of paging success in sequential paging further increases.
In this paper we have shown that compared to the normal sequential paging, concurrent paging takes less bandwidth and also takes less waiting period for called party. We used Erlang C formula and designed the system with block calls delayed.
Erlang C formula,

$$Pr[Cchannelsarebusy] = \frac{A^c}{A^c + C!(1 - \frac{A}{C})\sum_{k=0}^{C-1}(\frac{A^k}{k!})} \tag{3.1}$$

Where A is the total offered traffic in Erlang and C is the number of trunked channels.

Average delay D for all the user is

$$D = Pr[delay > 0]\frac{H}{C - A} \tag{3.2}$$

H is the holding time i.e. the duration of call.

Average wait for delayed users is,

$$AWD = \frac{1}{\mu \times (C - A)} \tag{3.3}$$

Average time in system is,

$$T = AWD + \frac{1}{\mu} \tag{3.4}$$

$$\frac{1}{\mu} = H \tag{3.5}$$

3.2.1 Algorithm

For total n number of users to be paged in N number of cells within the location area, these are steps followed by the two different algorithms.
Steps followed for sequential paging

Step 0: paging request for n number of users arrive
Step 1: find the last known LA for user i (for, $1 \leq i \leq n$)
Step 2: flood all cells of the LA with paging message for i in a probabilistic manner.
Step 3: if i is found then report paging successful for user i' status and the location to MSC. Else report 'paging failed for user i'.
Step 4: repeat the steps for user i+1 till all the requests are paged or the queued requests are cleared due to time out.
Steps followed for concurrent paging

Step 0: paging request for n number of users arrive in a LA with N number of cells.
Step 1: for user i ($1 \leq i \leq n$) find P(c,i) where P(c,i) is the probability of finding user i in cell c ($for, 1 \leq c \leq N$)
Step 2: repeat for all values of c i.e. from 1 to N
Step 3: repeat step 1 and step 2 for all i
Step 4: start paging n users from the cell having highest P(c,i) values for user i.
Step 5: if user i is found then report paging successful for user i' status to MSC and repeat from step 4 for remaining n-1 users.
Step 6: if paging fails for user i in cell c then make P(c,i)=0 and repeat step 4.
Step 7: if all the cells N for a user gets P(c,i)=0 then report MSC paging failed for user i'
Step 8: repeat till all the n users are paged.

3.2.2 Results and Discussion

A Matlab simulation of the concurrent paging algorithm is done comparing it with sequential paging at different Erlang values and the changes in different parameters like probability of channel being busy, average waiting time, average time in the system etc. is monitored. The blue line shows the normal sequential paging characteristics and the red line shows the concurrent paging characteristics. The simulation is carried out taking a Location area consisting of seven cells and each cell has one paging channel each.
From the graph obtained by using Erlang C formulae (Fig 1) it is quite clear that as the traffic increases, probability of channel being busy increases exponentially in case of sequential paging and in concurrent paging the rise is slow and gradual. Considering this rapid growth in channel being busy we can expect similar characteristics in case of sequential paging for average delay for all users' as it is directly proportional

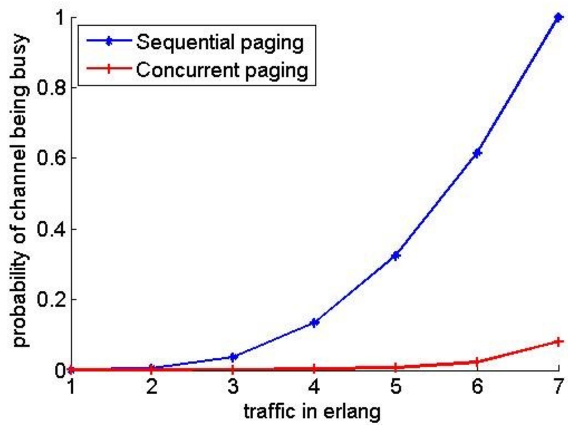


Figure 3.1: traffic in erlang Vs probability of channel being busy

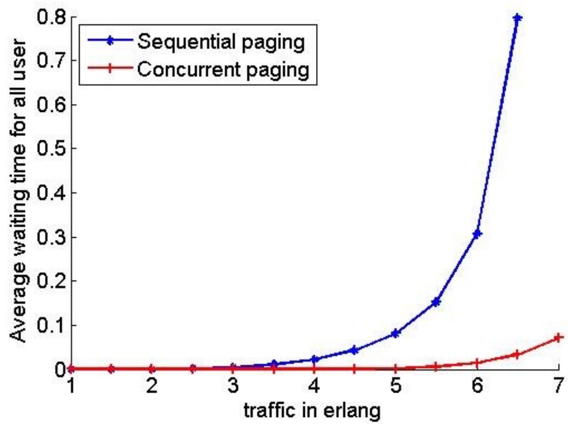


Figure 3.2: traffic in Erlang Vs. avg. waiting time for all users

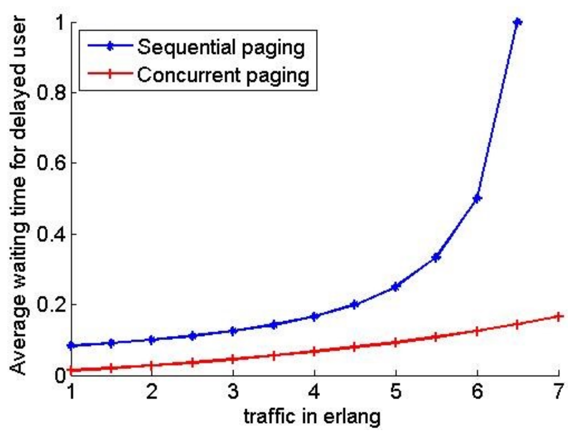


Figure 3.3: Traffic in Erlang Vs. avg. waiting time for delayed users

to probability of channel being busy. But in case of concurrent paging it is very small. The results for average waiting time for delayed user are similar. In the entire process, the total time for which the resources are exploited is the sum of waiting and holding time. But in sequential paging even though the holding time is same but the waiting time is very large compared to concurrent paging, the total time for a user becomes

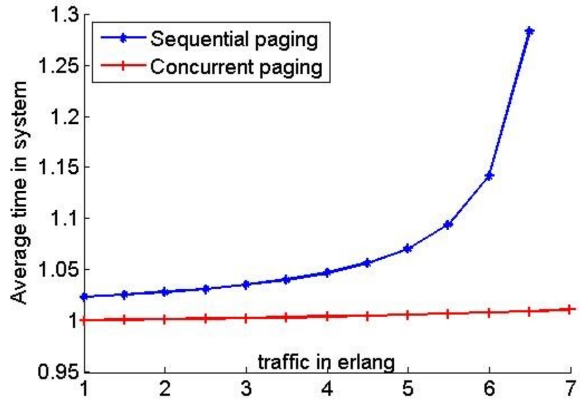


Figure 3.4: Traffic in Erlang Vs. avg. time in the system

large which in turn results in higher probability of channel being busy and the whole cycle continues as a feed-forward loop. But in case of concurrent paging this value is nearly constant as both the waiting time and holding time are close to constant. So the system acts in a stabilized manner even during heavy traffic condition.

3.3 Conclusion

It is clear from the above simulation results that for high Erlang values concurrent paging system works better than the conventional sequential paging system. It decreases the probability of channel being busy as the number of channel increases because instead of paging two users one after other sequentially, it pages them through 2 different sets of channel simultaneously. And as probability of channel being busy decreases the average waiting time for delayed user and average waiting time for all users is decreased. Due to reduction in average waiting time, the average time in the system for a user remains nearly constant. These all parameters suggest that for peak durations or during heavy traffic, concurrent system performs well and in a stable manner. But when the traffic is low then both the systems nearly give the same results. It is worth noting that concurrent system needs additional probability calculation. So the computational load on MSC increases. But looking at the improvement in performance, Concurrent paging system is no doubt far better than sequential paging.

Chapter 4

Profile based paging using PCMD

In this section, a new profile based paging scheme is proposed. The proposed technique uses PCMD (Per Call Measurement Data) or CDR (Call Data Record)to profile the users. Utilising these profile a paging algorithm is developed that is more bandwidth efficient and has a better paging success rate.

4.1 Introduction

As discussed in section 2.4 paging is the process through which a mobile subscriber is notified about an incoming call. As in most cases the exact location of the mobile subscriber is unknown, a group of cells are paged. And in case the paging is not successful then another group of cells are paged. This process continues till the user is found or the paging request expires. Each paging consumes both the spectral and computational resources. The bandwidth used in paging is directly proportional to the number of cells paged. Also the **paging delay**, time duration between the paging request and paging success, must be small so that the user experience will not be affected. To satisfy all these criteria a profile based paging scheme is designed [34].
In profile based paging, certain attributes (call arrival rate, rate of movement, etc.) of the user are measured and a profile is created according to that. Now those profiles are used to design an algorithm that gives the best solution to the problem. So if a user has a higher movement rate then the area to be paged is kept higher to achieve a greater paging success rate. Whereas the user with less movement is paged over a relative short area to conserve bandwidth. So in this way the approach for each user is different and the overall process is more optimized [35].
In the proposed work we have taken relatively new approach for profiling the user. We had tried to extract the periodicity in user's movement and utilise that for a better paging scenario. To correlate the user's movement with time we choose to use CDR. Every time a call comes through a CDR is generated. It contains information related to **call arrival time and date, call end time, call initiation cell, call end cell, location area, call type etc.**. CDR is stored in MSC for system analysis purpose. From this we extracted the user-data to correlate the call arrival time and location.

4.2 Proposed method

The CDR data of nearly 200 subscribers are collected for over a period of 2 months. After analysing the CDR data the following observations are made:

- **Most of the user (over 90%) only travel 33% of the location area.**
- **Almost one sixth of these location areas holds more than 60 percent of the total presence of the user.(Figure 4.1)**
- **When we correlate user's presence with a particular day and time, nearly 60 percent of the user showed a higher degree of correlation.**

So the proposed method is based on these observations.

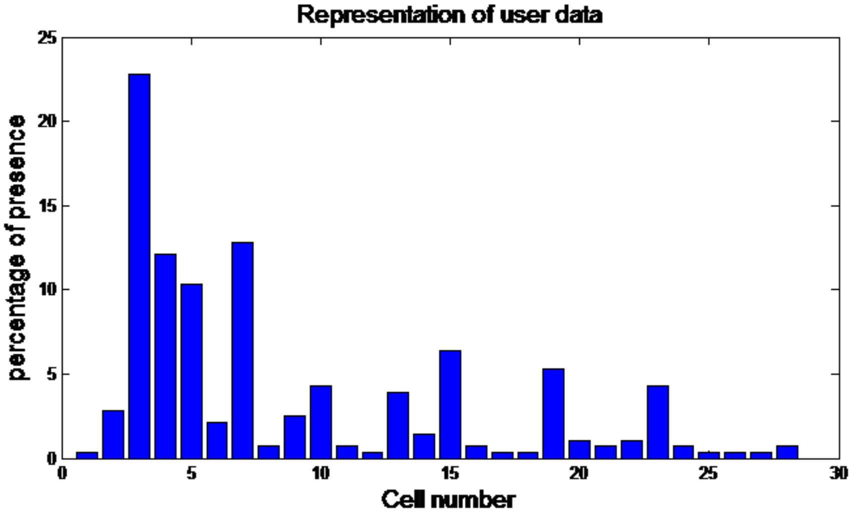


Figure 4.1: A typical user's presence over different cells

4.2.1 Initialisation of data

Then the CDR data is divided into different days like Monday, Tuesday etc.. The day is then further divided into slots of one hour according to time of the day in 24 hour format. Each slot contains three parameters,
1) Location (loc):- it's an array that stores the different cell location visited by the user during that hour.
2) Weight (wt):- it's an array having the same length of location array. It stores the weights of the cell based upon their correlation with earlier measurements. A cell having higher weightage indicates that during that hour it has higher probability of having the user. This value changes with each update i.e. if the user is found in the given location in successive updating then its weight will increase or else its weight will decrease.
3) History (ht):- it stores the number of times the user is found in the same location. This along with weight is used for redistribution of weights and is also used to determine the cells to be paged in case more than one cell has same weight.
This information are stored in a structure. So each user will have a structure of its own identified by its MIN. The general structure will be as given bellow,

4.2.2 Correlating data and updating

With every update the data are correlated and the weight vector is calculated again. A location update or timely CDR data can be regarded for an update. The correlation is done for the particular day and time. The update data is stored in a structure similar to the data.
The program goes through the data and checks whether the cell (or cells) present in the update data are already present in the day.time slot or not.

If the cell is present: If the cell is present then ht corresponding to the loc is incremented and the new weight wt is calculated. Let loc (n) be the cell that is found to be present. Then wt corresponding to loc (n) will be calculated as:

$$wt(n) = \frac{[(user.day.time.wt(n)) * (user.day.time.ht(n))] + tw}{\sum(user.day.time.ht) + th} \tag{4.1}$$

$$ht(n) = ht(n) + th \tag{4.2}$$

And for other loc i.e. $loc(m)$, where, $m \neq n$.

$$wt(m) = \frac{[(user.day.time.wt(m)) * (user.day.time.ht(m))]}{\sum(user.day.time.ht) + th} \tag{4.3}$$

$$ht(m) = ht(m) \tag{4.4}$$

Where, tw stands for temporary weight and is computed by dividing 1 by the total number of distinct cells visited by the user in that hour. th stands for temporary history and is computed similar to tw, so they both have same numerical value. So, during the time when user is not moving at all or is moving slowly tw and th values will be ≈ 1.0 and hence, wt of loc(n) is increased while, wt of other loc are decreased gradually. But during the time when user movement is excessive, like travelling etc. or in case of highly mobile user, tw and th values will be small. So although, wt of loc(n) will be higher than other but still on total, value of wt will decrease. So, the sum of wt array will also decrease, this will help us in determining the cells to be paged; as we will see in further discussions.

the cell is not present: In this case the new cell is added to loc array and wt and ht corresponding to it are also added to the respective arrays. Whose values are calculated as:

$$wt(new) = \frac{tw}{\sum(user.day.time.ht) + th} \tag{4.5}$$

$$ht(new) = th \tag{4.6}$$

And for other loc i.e. $loc(m')$, where, $m' \neq new$.

$$wt(m') = \frac{[(user.day.time.wt(m')) * (user.day.time.ht(m'))]}{\sum(user.day.time.ht) + th} \tag{4.7}$$

$$ht(m') = ht(m') \tag{4.8}$$

Initially the weight of new cell will be low so that if loc (new) is just a temporary de-route from the normal cycle then its weight will reduce and soon it will be removed from the loc list. But if that is not the case then the wt value will increase with successive input and it will be regarded as an important cell to be paged. As it can be inferred that if the value of (wt*ht) decreases below a certain value then then the loc along with all the elements are deleted.

4.2.3 Paging

This is the determining part of the algorithm. When a paging request is arrived at the MSC then usually the paging is done taking into account the previous known location via location update. But in this case the location to be paged are determined based upon the previous locations he has visited, hence the min referred in the paging request is searched in the database if that is present. Then the paging is done in such a fashion that all the locations having highest wt values are paged and the sum total of the location paged must be higher than 95% of total sum of wt. This is done to ensure that paging success rate is kept high for minimum paging delay. If the first paging is not successful then on the second paging all the cells that are there in the user's database are paged. And if still paging is not successful a blanket paging is done. This paging sequence can be altered based on the load on MSC i.e. if there is less load then, first paging can be skipped for less paging delay. But scenarios where paging requests are high with concern about bandwidth like in the peak hours, step two can be skipped for less paging delay and better bandwidth utilization which will be further discussed in section 2.4.

4.2.4 Special Cases

Provisions are also made for some special cases like being on a vacation or moving somewhere else to be incorporated so that the algorithm will be self-sufficient and will be adaptable to change in user mobility pattern. In this way the algorithm becomes future-proof and adaptable. For this we modified the structure to include another parameter named tag (not shown in the picture) into the structure. The logic is that, after 6 weeks if the user is found in a new location for more than 3 expected paging requests continuously then the user is classified as tag=nomad and is kept that way until it falls back in the previous mobility pattern for 2 pages. So if the tag is nomad i.e. the user has taken a detour then paging is done in the conventional way and a new temporary structure is created for the user. If the tag nomad stays for more than 4 weeks then the temporary structure replaces the previously stored structure and changes the tag back to tag=normal. In this way we will be able to extend the reach of the algorithm to users who frequently go on vacation etc. In scenarios like govt. holidays etc. the paging cells are chosen as the sum of paging areas of both the weekends, unless and of course the user tag is not nomad. But as we simulated our algorithms on the data that is available to us and it was not a real-time data and the data was limited so these features were only tested on simulated data which showed positive result which are matching with the theoretical expectations.

4.2.5 Algorithm

The detail algorithm of the above discussed process is depicted bellow as flow chart.

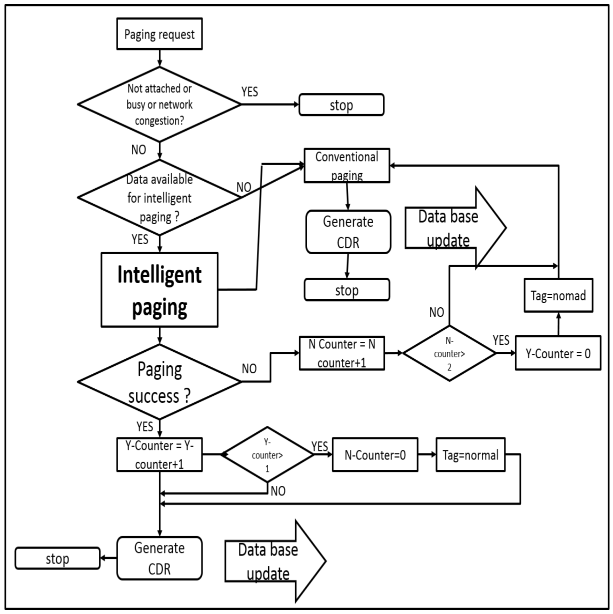
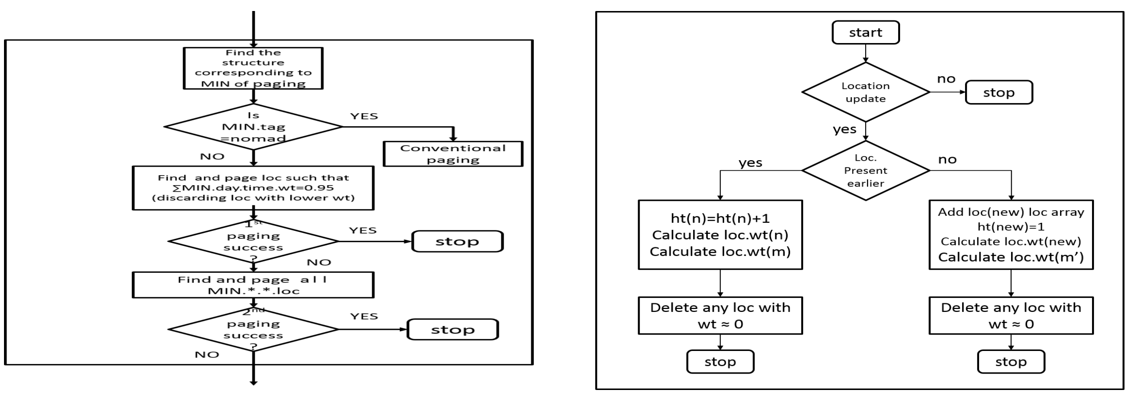


Figure 4.2: Flow chart of the algorithm (i)

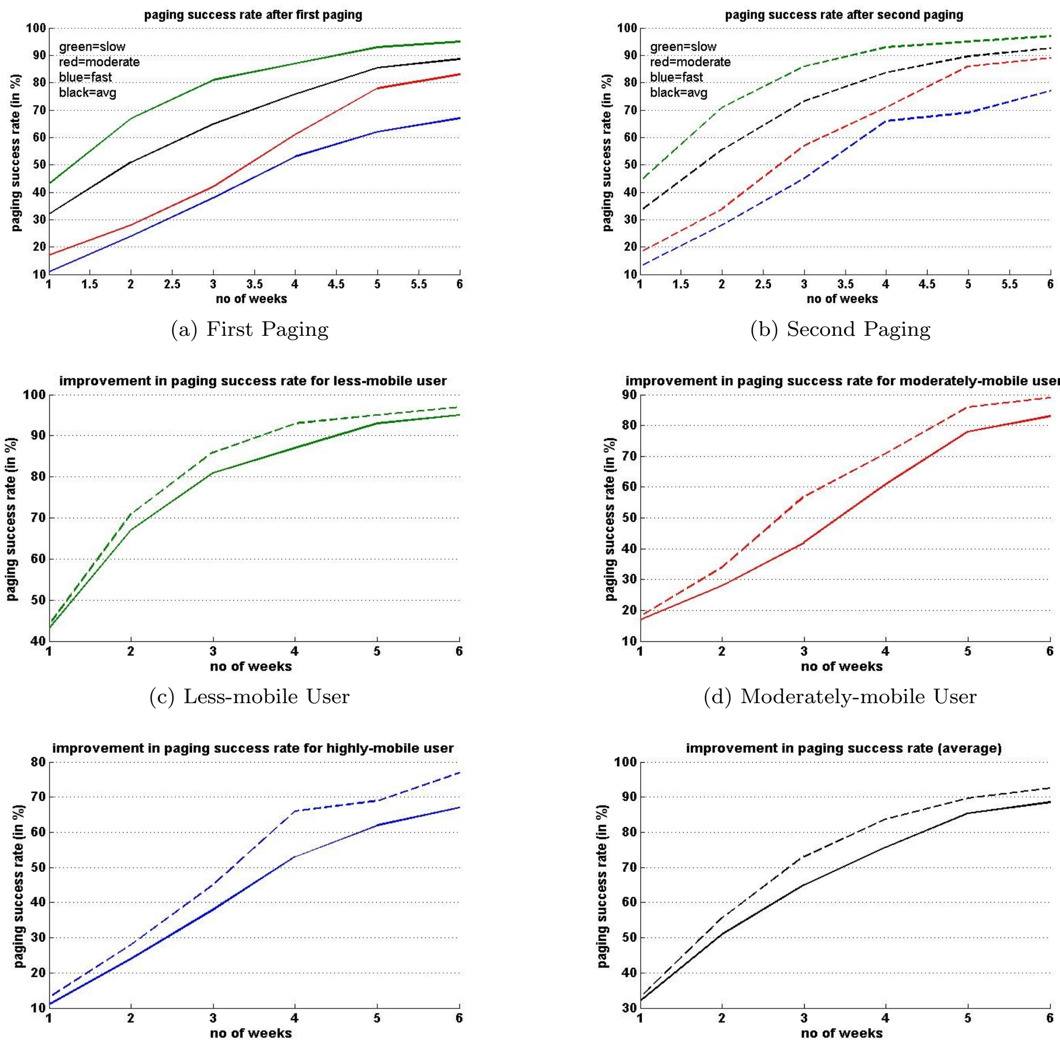


(a) Intelligent Paging (b) Conventional Paging

Figure 4.3: Flow chart of the algorithm (ii) and (iii)

4.3 Simulation and Result

The algorithm is simulated with the help of MATLAB software with BSNL CDR (Call data record) data from 1st Nov 2014 to 10th Jan 2015. The structure is initialised by taking 2 weeks of CDR data and then the cell to be paged are guessed for the third week and hence forth. The predicted data is compared with the actual data of the respective week and the paging outcome is taken into account and the calculation are made. After the simulation the following observations are made.



(a) First Paging (b) Second Paging

(c) Less-mobile User (d) Moderately-mobile User

(e) Highly-mobile User (f) Average

Figure 4.4: paging success rate of different users at different paging intervals

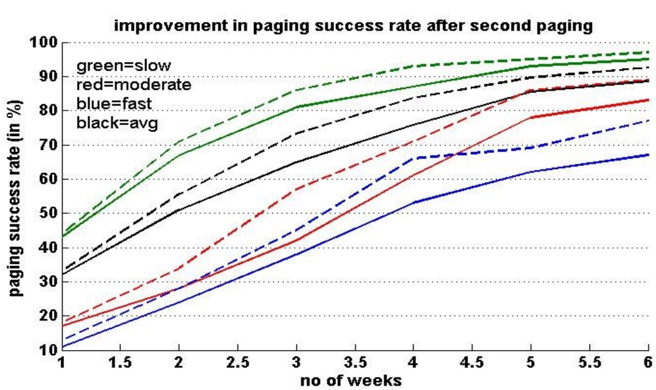


Figure 4.5: Comparative figure for paging success rate

For less-mobile user : These are the users that are mostly sedentary and their movement is confined to only one location area. So the number of cell visited by this type of user is generally low. This represents 40 to 50 percent of the total population which includes housewives, students and office workers who are nearer to their colleges or school. So there movement is mostly limited and periodical. Hence they show the highest paging success rate i.e. 43% in first week which then increases to over 95% at the end of 6th week. Although not much improvement is observed in second paging, which started with 44% and ends with 97% success rate. The maximum number of cells that are to be paged in a single paging request in first attempt are 8 and that in second attempt are 35.

For moderately-mobile user : These are the users like foot vendors, office workers whose office is at a distance from the residence etc. basically their movement frequency is greater than less-mobile user but is less than highly-mobile users. They constitute 30 to 40 percent of population and generally travel between one or two location area. For this category the paging success rate for them started at 17% and ended at 83% with an improvement rate faster than less-mobile user but final success rate less than them. In second paging however it started from 18% and got saturated at 89%. The maximum number of cell paged for a paging request in first page is 19 and in second page is 47.

For highly-mobile user : These are the user who travel more than 3 location area in a day. They make up only 5 to 10 percent of the population. This category mostly includes taxi drivers, salesman, vendors etc. their movement patterns are often random and not periodic hence their success rate starts at mere 11% and settles at just above the midpoint i.e. 65%. But on the second paging however the success rate increases rapidly from 13% to 76% at the end of 6 weeks. The maximum number of cells paged for a paging request in first page is 36 and that in second page is 102.

4.4 Comparison

On an average the paging success rate grew from nearly 32% in first week to 88% over 6th week for first paging. And for second paging it reached 93%, which is the general paging success rate of any paging strategy. Also this technique saves a lot of bandwidth compared to all other intelligent paging strategies here is a table comparing the maximum number of cells that are paged per paging request.

Type of user	Proposed paging		Hypo-la paging
	First paging	Second paging	
Less-mobile	8 cells (Max)	35 cells (Max)	1 BSC (200 to 400 cells approx.)
Moderately-mobile	19 cells (Max)	47 cells (Max)	1 BSC (200 to 400 cells approx.)
Highly-mobile	36 cells(Max)	102 cells(Max)	1 BSC (200 to 400 cells approx.)

Table 4.1: Comparison of Proposed paging and Hypo la paging on the basis of number of cell paged

Comparing them with the normal paging here is a brief look at the different parameters in the three types of paging.

	Normal paging	Hypo-la paging	Proposed paging
First Paging area	LA (600 cells)	BSC (300 cells on avg.)	36 cells
Success rate (in %)	92.81	87.94	89
Second paging type	IMSI	IMSI	IMSI
Second paging area	LA (600 cells)	LA (600 cells)	102 cells
Success rate (in %)	95	91	93

Table 4.2: Comparison between conventional paging, Hypo-la paging and proposed paging

So comparing it with the data provided by [29], we can clearly see the superiority of the proposed algorithm. It is not only better at reducing bandwidth consumption (evident by the less number of cells paged), but also gives better paging success rate.

Also we can see from the graph that the improvement in second paging for less-mobile user is very less. Hence to improve the paging delay and we can consider skipping it for less-mobile users in case the paging load on MSC is high. In that way we will trade-off a small part of paging success rate for improvement in paging delay. As the number of less-mobile user is large so this gain in paging delay will help reducing the congestion in MSC during high paging load by decreasing the holding time for other users. Similarly in highly-mobile user's case the first paging results in very less paging success rate while as the second paging include all the cells present in first page also so the first page for highly mobile user can be skipped to improve the paging characteristics in case of highly mobile user but since the number of cells paged for highly-mobile user in second page is very high so the bandwidth conservation will be less, compared to earlier.
Also a provision could be added to page the entire BTS (which consist of 3 cells) to improve the paging success rate further during the initial weeks when the available data is less. The graph resembles a curve with average success rate saturating around 95% (approx.) which is typical paging success rate of a typical paging scenario.

4.5 Conclusion

The proposed paging algorithm explores a new attribute that can be exploited for a better paging characteristics. The proposed algorithm increases the efficiency of bandwidth utilisation with little to no effect in overall paging success rate. Particularly bandwidth required in paging for less-mobile users will be very less with success rate more than 95%; and as most of the population has low mobility rate it will be efficient in any practical scenario. For moderately-mobile user and highly-mobile user the success rate is 89% and 76% respectively. The average paging success rate is 93%, with bandwidth saving up to 3 times the conventional system. When compared the other intelligent paging algorithm, the proposed paging algorithm outperforms it both in terms of bandwidth conservation (twice as efficient) and paging success rate (2% higher success rate).
This paper had taken a data-driven approach to optimise paging characteristics. The algorithm is designed to be implemented with the existing paging system while it learns and then it can replace the existing system which will take maximum 5 to 6 weeks. The algorithm is self-sufficient and it adapts to the change in user's movement pattern. In this way it makes the proposed algorithm a true intelligent paging algorithm.

Chapter 5

Profile based location update using PCMD

Both CDMA and GSM are cellular technologies, which means, the geographical location is divided into smaller segments for frequency reuse and to incorporate more number of users. But unlike PSTN the terminal in wireless communication is not static, that's where location update comes in play. Location update includes a set of technology that informs the MSC about MT's current position.

5.1 Introduction

Location update just like paging uses the available radio resources. Hence, a frequent location update will incur extra cost. Also, this will reduce the available bandwidth for the subscribers which will affect the grade of service (GOS). On the other hand if location update frequency is decreased the uncertainty in user's location will increase. So, at the time of paging the area to be paged becomes larger (i.e. increased paging cost). So the location update frequency should be optimum so that the net cost of the location management system will be less and also the spectral efficiency of the system will increase and subsequently increases the grade-of-service of the system.
To optimise the location update a lot of methods had been proposed. Which are discussed in details in section 2.3. Some of them are discussed in brief here.

- **Reporting cell concept**
  To optimise location update frequency, this scheme was proposed by [BNK93]. The geographical area is divided into a number of cells and in the proposed method some of the cells are marked as reporting cell. The difference between reporting cell and the normal cell is that. When a mobile enters a reporting cell a location update is triggered. In this way the uncertainty in user location is reduced. The reporting cells can be bound or unbound.

  The arrangement of reporting cells are often done taking user movement and call arrival rate into consideration. But this scheme is very old and suffers from a lot of problems which are discussed in section 2.3.1.

- **Location area concept**
  This is the development over the reporting cell concept. The cells are grouped together to form the location area. And when a mobile terminal leaves one location area and enters another location area a location update is triggered. It is mobile assisted location update so, the load on MSC is also reduced. The main advantage of this system is that it restricts the user's location uncertainty to a certain group of cells which improves the paging characteristics also. In the present scenario most of the systems are based on this concept.

- **Profile based location update**
  In profile based location update, like its paging counterpart, the MSC maintains a profile of the user. The profile is made by observing the users past attributes. The profiles can be static or dynamic. Dynamic profile based paging has an added advantage as the profile keeps changing to give an optimised result. In general the output of the profile based location update is more optimised compared to location

area based paging. This is because the threshold for different users are different. For example if a user gets more number of calls then its location update frequency will be higher compared to a user who receives less calls. Similarly a user who travels frequently his location update frequency will be more compared to a static user. In this way the system will be more bandwidth efficient.

In this paper we will be discussing the impact of the algorithm on different type of users. So the users are divided into three categories based on their mobility pattern.

- Highly-mobile
- Moderately-mobile
- Less-mobile

These categories are made based on the user's movement. And as their name suggest, Highly-mobile users are those who travels a lot, generally their movement ranges to few location areas. And the less-mobile users are mostly sedentary or have very predicted movement. And the moderately-mobile users come in between the two.

5.2 Proposed method

Our proposed location update method is dynamic profile based location update. In this paper, the random location update is referred as Mobility based location update because this location update characterizes the mobility of the user and in our proposed method we emphasize on the user mobility specifically. The algorithm is based on the observations made in section 4.2 that is:

- **Most of the user (over 90%) only travel 33% of the location area.**
- **Almost one sixth of these location areas holds more than 60 percent of the total presence of the user.**
- **When we correlate user's presence with a particular day and time, nearly 60 percent of the user showed a higher degree of correlation.**

So instead of updating the location update for each movement to and fro from the location area, we can suppress the location update request when the user is at his usual location (usual cells) at the desired time of the day. Moreover, only refresh the user location when it moves to a new location (new cells) that is not in the database. In this way, we will reduce the location update frequency for users who show a greater level of periodicity in their movement. Also, another added advantage of this method will in terms of bandwidth conservation for paging. The uncertainty in the user's location decreases from a whole location area to a number of cells. These cells are derived from the past movement of the user. Upon the arrival of a call, we only have to page a small group of cells. This will reduce the paging resource utilization.
This system is designed to be dynamic. The database is regularly iterated; the proposed method takes CDR (or PCMD) data of a day and updates the profile (database) at the end of the day to match any change of user movement. Detail of the process is discussed in the subsequent sections.
During the periodical location update, the MS will be supplied with the cell identities that are already stored in the MSC database. So when a user changes its location from one such cell to another, there will be no location update. Whereas if the user travels into or from a cell that is not in the lists of cells then the MS will request for a location update. The location update will be triggered for each new cell the user travels. However, in this way there might be a lot of location update if the user takes a different path or is on vacation. To overcome these provisions are added to the algorithm. After training if there are more than a particular number (taken 3 in this case) of location update consecutively then conventional location update will be followed. The conventional update will continue unless the user falls back to the usual behavior (determined by location update). A user who is not following its usual course is categorized as Nomad. If the user status stays nomad for a week, then the earlier profile is deleted, and a new profile creation is initialized. The details regarding the database are given in subsection 4.2.1.

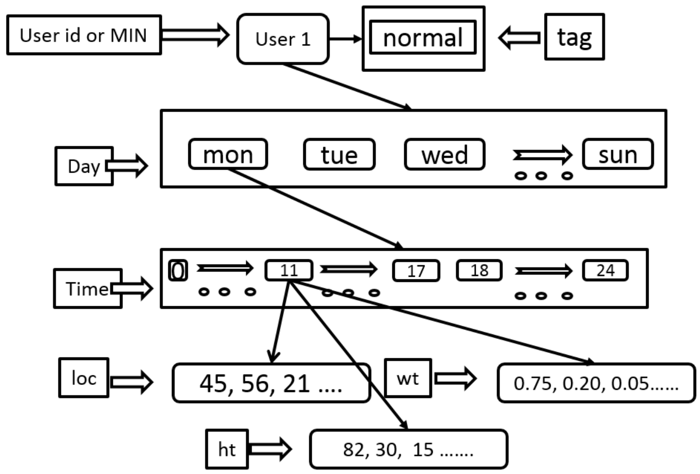


Figure 5.1: User Database

The CDR's data are divided into various days and then for each hour. The database arrangement is shown in the figure shown below. The cells are weighted for the probability of holding the user in that cell at that particular time of the day.

The database is similar to that of the paging database. The acronyms of the database has the same meaning as described in subsection 4.2.1. The weight (wt) of the location is computed from correlation. Correlation is performed for each hour of each day of the week. The final result relates to the probability of the user being in that cell at a particular time of the day. It can be done after each location update or at the end of the day. It first takes the location update data and isolates the number of location updates for each hour and the cells shown in the location update. Then it compares them with the past data. If the cell is present in the user database at that particular time, Then wt corresponding to loc (n) will be calculated as:

$$wt(n) = \frac{[(user.day.time.wt(n)) * (user.day.time.ht(n))] + tw}{\sum(user.day.time.ht) + th} \tag{5.1}$$

$$ht(n) = ht(n) + th \tag{5.2}$$

And for other loc i.e. $loc(m)$, where, $m \neq n$.

$$wt(m) = \frac{[(user.day.time.wt(m)) * (user.day.time.ht(m))]}{\sum(user.day.time.ht) + th} \tag{5.3}$$

$$ht(m) = ht(m) \tag{5.4}$$

If the cell depicted is not present in the user database then a new element is added to the array and the wt corresponding to that location is given by

$$wt(new) = \frac{tw}{\sum(user.day.time.ht) + th} \tag{5.5}$$

$$ht(new) = th \tag{5.6}$$

And for other loc i.e. $loc(m')$, where, $m' \neq new$.

$$wt(m') = \frac{[(user.day.time.wt(m')) * (user.day.time.ht(m'))]}{\sum(user.day.time.ht) + th} \tag{5.7}$$

$$ht(m') = ht(m') \tag{5.8}$$

So in a summarized way we can say that the first condition increases the wt value for those cell that are already present(Equation 5.1) and decreases the wt value of other cells(Equation 5.3). The tw (temporary weight) is the parameter that incorporates user's movement into the algorithm. Tw is approximately 1.0 when user is not moving and the value decreases if the user is moving. That is if the number of cells visited by the user during that hour is high then the wt values of the cells during that hour will be less.

This is the same correlation technique described in subsection 4.2.2. So The proposed method utilises the previously derived user database. The algorithm uses the wt values to determine the probability user's presence. And each time the user is not present in the predicted area a location update is triggered. Which is then used to enhance the user database. So while in profile based paging the update frequency was mainly dictated by the call arrival rate, in Location update the frequency is mainly dictated by user mobility. So the update frequency of location update algorithm will be higher than the paging algorithm.

5.2.1 Location update

Prior to the location update, the cells from the database are transferred to the Mobile Terminal along with the Tag status. This can be done once per day or can also be done during the periodic location update. The latter reduces the burden on the MSC and requires less storage space on the MT hence the latter is preferred. Not all the cell id are transferred to the user. Cells IDs are transferred in such a way that the sum of the wts will be 0.98. This is done in the decreasing order of wt value. So that all the cells having higher probability of having the user will be transferred to the MT.
The mobile terminal periodically checks the cell id and location area code. So if the mobile finds the current cell id is in the database, then it will not update its location. Moreover, if that is not the case then it will trigger a location update. With each location update acknowledgement, the MSC updates the value of Tag. So when the value of Tag is Nomad, instead of checking for the cell id. The mobile terminal will check the Location Area Code and will follow the conventional location update.

5.2.2 Flow Chart

The flow chart here summarizes the location update process described above. As location update is a continuous process, the algorithm here doesn't have a stop condition.

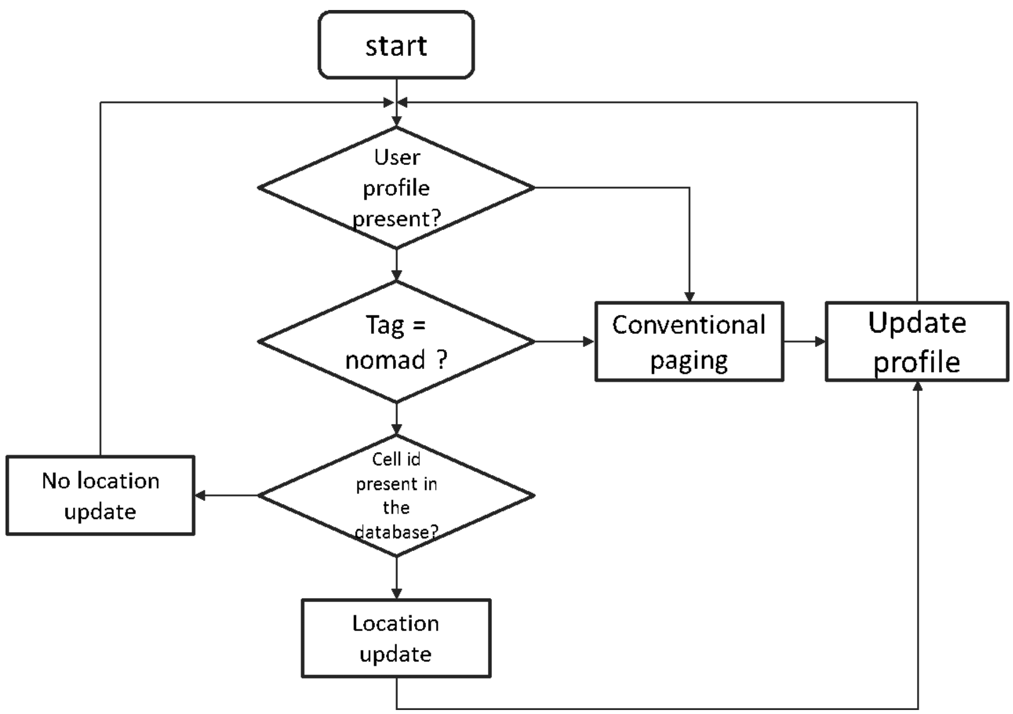
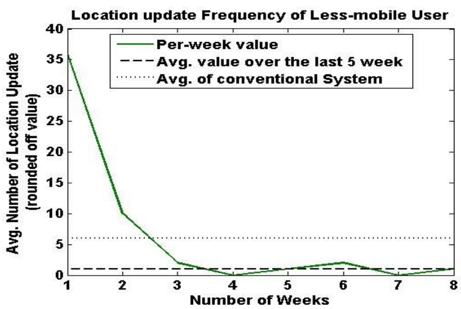


Figure 5.2: User Database

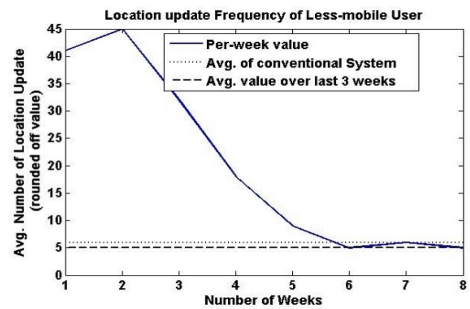
5.3 Simulation and Result

The algorithm is simulated taking user CDR data of 300 users over a period of 8 weeks in Mathwork's MATLAB. The output of the algorithm is rounded off to the nearest whole number and the resultant graph

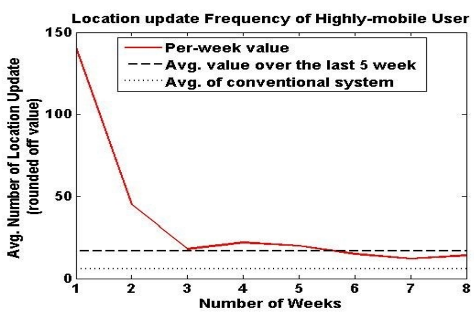
is plotted along with the rounded average of the last 5 weeks to give a perspective of the final output. In the final figure the location update of each type of user is plotted along with the per week location update average of conventional system for a better comparative analysis.
From the location update data, the total number of location update and the total number of subscriber in the location area are taken and the average number of location update per user is found out by dividing the two. After subtracting the number of periodic update (6 as per the data provided by BSNL) the total number of movement based location update are plotted.



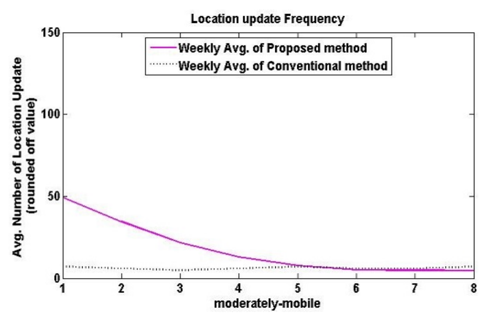
(a) Less-mobile User



(b) Moderately-mobile User



(c) Highly-mobile User



(d) Average

Figure 5.3: location update frequency of different types of user

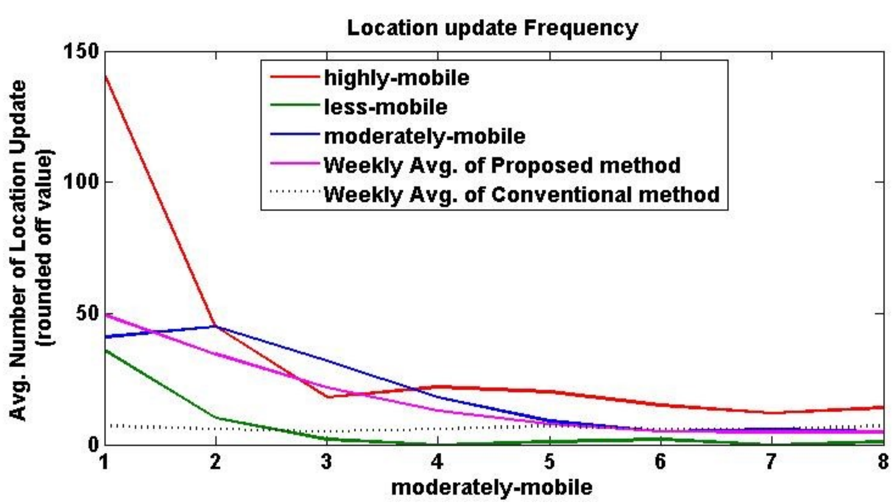


Figure 5.4: comparative figure for location update frequency

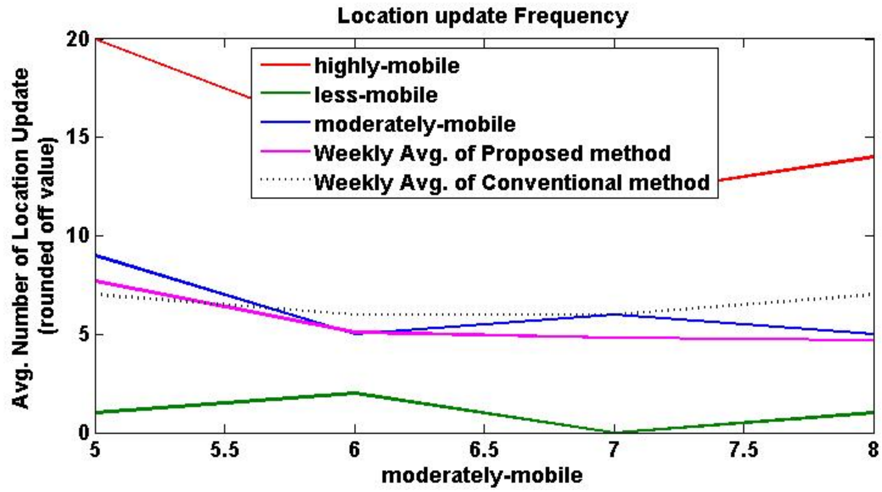


Figure 5.5: comparative figure for location update frequency week 5 to week 8 (zoomed in view)

5.4 Comparison

From the result it is clear that after four to five weeks the number of location update decreases to a considerable level and nearly matches the conventional location update rate. The average location update shows an exponential decrease in the number of location update and after 6 weeks the location update average is less than the conventional system. This is the average decrease 17 percent location update frequency per user. Hence the total conservation of bandwidth is significant. The significance of this can be further realised if we take a look the output of different users separately.
For less mobile user the bandwidth conservation is tremendous. The average location update frequency is nearly 1 per day. Which is a great improvement over the conventional system which treats the less mobile user the same way as any other user. When we consider the moderately mobile user it takes longer to converse. So instead of last five weeks we compared its last three weeks data with the conventional system. Which shows an improvement over the conventional location update system. For the highly mobile users the number of location update are greater than the conventional system. But the number of such users are very less hence for the overall system the proposed algorithm outperforms the conventional system. Which is evident from fig no Figure 5.4. Which shows the average location update of both the system. The data is also presented in the table below Table 5.1. we can clearly see that after $5^t h$ week location update frequency for both the system becomes comparable. The average location update frequency shows a consistent decrease. This shows the credibility of the proposed algorithm.

week numbers	Avg. location update per user	
	conventional	profile based
week 1	7	49
week 2	6	34
week 3	5	21
week 4	6	13
week 5	7	7
week 6	6	**6**
week 7	7	**6**
week 8	8	**5**

Table 5.1: conventional location update Vs. profile based location update

Apart from the location update perspective the system also gives a better paging characteristics as shown in the previous chapter.

5.5 Conclusion

The proposed profile based technique uses the available CDR data and works in congestion with the conventional location update system to give around 17 percent efficient use of the spectrum on an average. If used specifically for the less mobile and moderately mobile user the bandwidth conservation is 23 to 30 percent. The system needs 4 to 5 weeks to train and then it can perform satisfactorily with any conventional system. The dynamic nature of the algorithm helps it to adapt to any change in user's mobility pattern or any change in radio pattern of the location area (like sectoring etc.). Apart from the improvement in spectral efficiency this algorithm also assists its paging counter part. So this combined with the Dynamic profile based location update gives a better location management technique compared to the conventional system.

Chapter 6

Conclusion and Future Work

This thesis has investigated the different location management techniques that are used in mobile communication And finally proposed a new and improved technique for location management.
The thesis compared the two widely used techniques, sequential paging and concurrent paging in chapter 3. In this comparison we found that at higher Erlang values the concurrent paging performs better than sequential paging. The probability of channel being busy decreases considerably and as a result the waiting time for users are less. So, the concurrent paging gives a stable characteristics even under high Erlang operation. (section 3.3)
In chapter 4 a new profile based paging is proposed as an attempt to further improve the paging characteristics. The proposed technique is dynamic and it offers better optimization of resources. In a comparative study made between the conventional method, Hypo-LA paging, and proposed paging, the proposed paging proved to be 3 times more bandwidth efficient compared to the conventional paging and 2 times more bandwidth efficient compared to the Hypo-LA paging. In terms of paging success rate the proposed paging have 93% paging success rate while Hypo-LA has 91% paging success rate. Which shows the superiority of the paging algorithm. Also the proposed algorithm is dynamic in nature which is an added advantage.
chapter 5, describes the location management counterpart of the algorithm, the algorithm is profile based and dynamic like the paging counterpart. The output of the proposed method uses 17% less resources on an average to report the location of the user to MSC. The proposed method can be used along with the conventional system to achieve this objective.
The dynamic location management technique described here profiles the users using their CDR. The optimization process takes 5 to 6 weeks and after that the system can be implemented alone or along with the conventional system. Because the algorithm treats each individual separately. The optimization offered is higher for users with less movement. The dynamic nature of the profile makes it more adaptable to any change in user movement pattern. The algorithm uses the MSC's computational and storage resources.
The algorithm is simulated with actual user data and the result so obtained are promising and can reduce the bandwidth utilization of the location management techniques to a considerable level.
The location management scheme proposed here is a significant departure from current research and signals a wide range of future work. Many issues and research topics related to this research thesis were not addressed and accomplished in this thesis due to limitations in time and resources. In this section, some of these issues are suggested and outlined for possible future study.

* Assessing the total implementation cost of the system and its comparison with the conventional system. Also, finding a way to minimise the cost of the system.
* Improving the algorithm by incorporating soft computing techniques into the update system.
* Implementing the algorithm in an actual environment and analysing its performance.
* Improving the proposed technique by incorporating more parameters into the profiling of the user.
* Future location prediction of the user by taking into account of CDR.

6.1 Publication

The following papers have resulted from this research:

1. N P Nath, S R Parija, P K Sahu, S S Singh, ”Cost Reduction Using Diffrential Evolution in Mobile Network”, published in IEEE Explorer, MedCom 2014 conference, proceedings page no. 30.

2. N P Nath, S R Parija, P K Sahu, S S Singh ”Survey Paper: Location Management in CDMA Network”, International journal of Advanced Science and technology (IJAST), Science and Engineering Research and Support Society, Vol.8, No.1 (2015), pp.287-298

3. N P Nath, S R Parija, P K Sahu, S S Singh, ”Brief Comparison of Sequential Paging and Concurrent Paging in Cellular Technology”, International Conference on Industrial Instrumentation and Control (ICIC 2015). [Accepted]

4. N P Nath, S R Parija, P K Sahu, S S Singh, ”Profile based location update using CDR data”, Advances in Electronics and Computer Systems - 2015(IAECS-2015). [Accepted]

The following paper is in preparation.

5. N P Nath, S R Parija, P K Sahu, S S Singh, ”A New Approach for Dynamic Intelligent Paging in Mobile Telecommunication Network” communicated to SADHANA journal.

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