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Performance Analysis of Profile Based Paging for Addis Ababa UMTS Networks

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THESIS

Submitted in partial fulfillment of the requirements for the degree of Master of Science in Telecommunication Engineering.

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Declaration

I, the undersigned, declare that the thesis comprises my own work in compliance with internationally accepted practices; I have fully acknowledged and referred all materials used in this thesis work.

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This is to certify that the thesis prepared by **Getachew Challa**, entitled *Performance Analysis of Profile Based Paging for Addis Ababa UMTS Networks* and submitted in partial fulfillment of the requirements for the degree of Master of Science in Telecommunication Engineering complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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DEDICATION

This research work is dedicated to my mother Wro. Mulunesh Gudeta, my father Ato Challa Gemtessa, my beloved wife Wro. Genet Degefa and my children's Hawi, Samuel and Daniel.

ABSTRACT

Paging is an important mobile network procedure that is performed to locate and connect mobile users when they receive calls/sessions. It is needed as users are mobile, and continuously updating their serving cells is not bandwidth efficient. In traditional broadcast paging, all cells of a network are grouped into clusters that are identified by Location Area Code (LAC). Users update their LAC and network look for a paged user by sending paging messages for all cells within the user's LAC. A decision on cluster size is an important factor that determines the paging overhead and connection delay. The larger cluster size, the smaller LAC update but the larger capacity for the paging message. To minimize the capacity required for paging messages while maintaining a larger cluster size, profile-based paging has been proposed and studied. Yet, such a paging approach has not been investigated and applied for Addis Ababa third-generation network.

In this thesis work, we analyzed the performance of profile-based paging algorithm for Addis Ababa third-generation network based on call detail record data collected from the network management system and compared it with conventional one. The algorithms considered were static and dynamic profile based paging. We analyzed the paging algorithms for users with less, moderate and highly mobile. A user's mobility is modeled using a Markov model.

Achieved results show that the profile-based algorithm considerably increases the efficiency of utilization with slight or no effect in the overall paging success rate.

KEYWORDS

Location Area Code, Paging Area, User Equipment, Universal Mobile Telecommunications System.

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ACRONYMS

AGCH	Access Grant Channel
AuC	Authentication Center
BCCH	Broadcast Control Channel
BCH	Broadcast Channel
CCCH	Common Control Channel
CCH	Control Channel
CCPCH	Common Control Physical Channel
CDR	Call Detailed Record
CN	Core Network
CP	Conventional Paging
CRM	Customer Relation Management
CS	Circuit Switch
DCCH	Dedicated Control Channel
DPBP	Dynamic Profile Based Paging
EIR	Equipment Identity Register
FACH	Forward Access Channel
FCCH	Frequency Correction Channel
HLR	Home Location Register
IMEI	International Mobile Equipment Identification
IMSI	International Mobile Subscriber Identity

ISDN	Integrated Services Digital Network
LA	Location Area
LAC	Location Area Code
LAI	Location Area Identity
MSC	Mobile Switching Center
PA	Paging Area
PBP	Profile Based Paging
PCH	Paging Channel
PCMD	Per Call Measurement Data
PR	Paging Request
PS	Packet Switch
PSR	Paging Success Rate
PSTN	Public Switched Telephone Network
PTMSI	Packet Temporary Mobile Subscriber Identity
QoS	Quality of Service
RACH	Random Access Channel
RAN	Random Access Network
RANAP	Radio Access Network Application Part
RNC	Radio Network Controller
RRC	Radio Resource Controller
SACCH	Slow Associated Control Channel
SCH	Synchronization Channel
SDCCH	Stand Alone Dedicated Control Channel
SGSN	Serving GPRS Support Node

SPBP	Static Profile Based Paging
SRNC	Serving RNC
TCH	Traffic Channel
TMSI	Temporary Mobile Subscriber Identity
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
USIM	Universal Subscriber Identity Module
UTRAN	UMTS Terrestrial Radio Access Network
VLR	Visitor Location Register

1

INTRODUCTION

1.1 MOTIVATION AND BACKGROUND

A continual increase in mobile subscribers and the emergence of bandwidth-intensive applications and services has resulted in highly increasing mobile network traffic. To meet resulted network capacity demand, besides introducing innovative network capacity enhancing techniques, various mechanisms to reduce signaling overhead from radio management techniques and procedures have been applied [1].

One important procedure in a mobile network is a paging procedure that is applied to successfully locate users' locations in the network when they need to receive calls or data sessions. Thus, paging is an important network procedure that generates significant signaling overhead [2].

In traditional paging, cells of the network are grouped into clusters that are assigned unique Location Area Code (LAC) and users update their LACs to the network when LAC change occurs [3]. See Figure 1.1.1 for the depiction of cells, paging and location areas. Users initiate the location update process by sending an update request to the network periodically or on a predefined timing. Then, when paging call or session comes, the network looks for a paged user by sending paging message for all cells within a cluster identified by the user's LAC.

A decision on cluster size is an important factor that determines the paging overhead and connection delay. The larger cluster size, the smaller LAC update but the larger capacity for paging message [2]. To minimize capacity required for paging messages while maintaining larger cluster size, sequential and profile-based paging have been proposed and studied [4], [5].

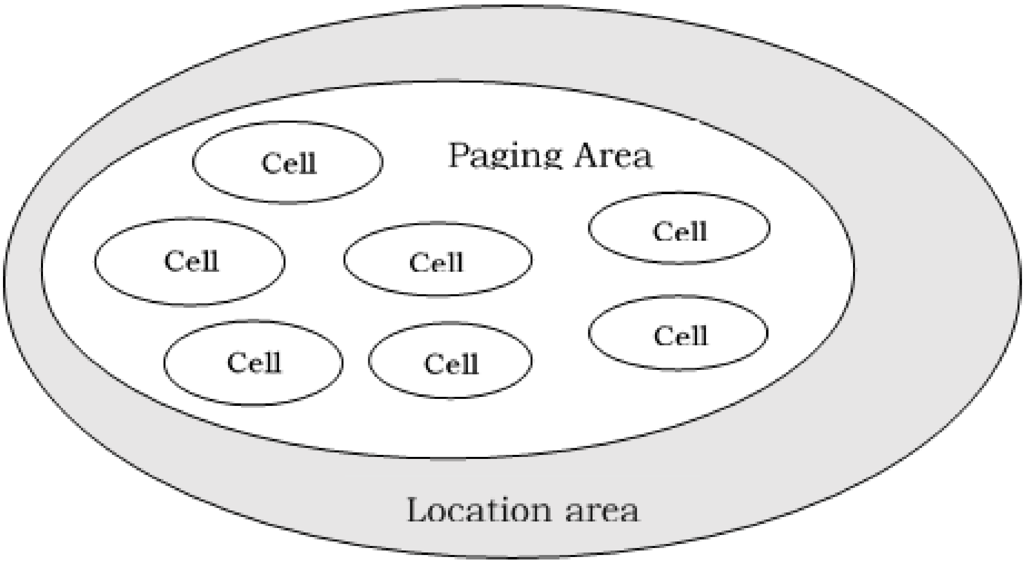


Figure 1.1.1: Relationship between Cell, Paging Area (PA) and Location Area (LA) adopted from [6]

In sequential paging, as the name indicates, searches for a paged user is performed in a sequential way [7], [8]. For that location area cells are grouped into smaller groups and these groups are named as Paging Area (PA). To decrease paging delay, first, a location area is created with a very high probability of finding the user for optimal paging delay and bandwidth conservation. Sequential paging breaks the paging load over different PAs. Location Area Splitting in Paging Areas. This decreases the network congestions and problems that are related to conventional paging and makes the system more stable and robust. On the other hand, the implementation cost of sequential paging is a bit higher compared to conventional paging but the overhead reduction advantage it produces is overwhelming [8].

User mobility profile is a combination of historic records and predictive pasterns of mobile terminals. Profile-based paging is a modified version of sequential paging. It minimizes the bandwidth requirement and improves users locating capabilities, by considering other user's behavioral patterns in addition to a user's probability of presence in a certain cell, like in the sequential paging. In this approach bandwidth conservation is the main advantage [9], [10]. This approach relies on the fact that a user's behavior is predictable. For example, if a user is at 'x' location on Tuesday at 6 am when a call arrived, then there is a high probability the person will be on the same location at the same time. Therefore, when a call arrives around 6 am on Tuesday then such an approach will page cell 'x' first then the other cells

Figure 1.1.2 shows a paging message flow from a Core Network (CN) to User Equipment (UE). Paging is initiated in the CN, by sending the paging message to the Radio Network Controller (RNC) [4]. The paging message contains a permanent or temporary UE identity. A permanent UE identity is International Mobile Subscriber Identity (IMSI) of the UE and temporary UE identity is temporary mobile subscriber identity (Temporary Mobile Subscriber Identity (TMSI) or P-TMSI). The purpose of IMSI information in paging message is to make RNC to decide whether to send Paging type 1 or Paging type 2. The detail description of Paging type 1 or Paging type 2 found in Chapter two paging type section of this document.

Figure 1.1.2: Paging message flow adopted from [11]

1.2 RELATED WORKS

Many studies have been presented in the area of location management techniques, specifically, much attention has been focused on paging procedure with the objective to reduce channel utilization associated with paging. It has been widely studied in the literature and is still an interesting line of research [12]–[35]. In [36] author's proposed an efficient way of assigning PAs by using mobility models. A mobility model is used to determine the most probable locations of each mobile subscriber, and this information, in turn, is used to assign paging areas. This paging strategy is evaluated by taking into account different probability thresholds and time-delay constraints, in a multiobjective way. Furthermore, the feasibility of this paging scheme is evaluated by means of performance analysis, in which it is compared with other paging schemes which are widely used in the recent works of literature. In [37] author's proposed a profile based paging algorithm and compared it with other paging algorithms in terms of paging success rate and bandwidth conservation. They validate their approach by using actual user data.

In [5], author's proposed a dynamic intelligent paging technique that uses user behavior and past location to predict the user's next location, with the help of Call Detailed Record (CDR) data. As a result, they can reduce the paging resources utilization, and their approach can be used along with the existing system without any modifications. In [38], Followed a data-driven approach by using more than 300 million call records from a large cellular operator to characterize user mobility and create a mobility profile. The authors consider both a static and a dynamic scheme that continuously updating the user's profile.Their approach could reduce signaling load (up to 80%) with minimal increase in paging delay (usually less than 10%).In [36], the authors used a real data collected from a service provider farm to profile the users and had validated the algorithm with actual user data. The proposed algorithm gives 2 to 8 percent better paging success rate and saves 50% to 30% of the bandwidth compared to conventional paging and sequential paging respectively.

In [39], the authors followed a mobility pattern based strategy scheme, which incorporates both the mobility pattern and time information in the profile. In their schema, a mobile user can be in one of four identified states and different location update and paging strategies will be used for different states. Performance evaluation of the proposed scheme is carried out under various mobility-call patterns, paging costs, and distribution probability. The results show that the mobility pattern based strategy scheme incurs significantly less signaling traffic and less paging delay than the PBS scheme. In [40] author's proposed a user pattern learning strategy using neural networks to reduce location update signaling cost by increasing the intelligence of the location procedure in Universal Mobile Telecommunications System (UMTS). This strategy associates each user a list of cells where it is likely to be with a given probability in each time interval. The list is ranked from the most likely to the least likely place where a user may be found. When a call arrives for a mobile, it is paged sequentially in each location within the list. When a user moves between location areas in the list, no location updates are required.

1.3 PROBLEM STATEMENT

Conventional paging incurs significant signaling overhead to mobile network and as a result reduce network capacity available for payload communication. The main reason is the paging applies limited user location information and does not consider user's mobility profile history that is available at the network management system. To address this challenge, profile-based paging that exploits user's mobility profile history has been investigated and applied. Yet, such paging approach performance analysis has not been investigated and applied for Addis Ababa UMTS context. In order to improve the performance in the above-mentioned context further investigation and research need to be conducted.

1.4 OBJECTIVE

1.4.1 *Main objective*

The main goal of this thesis is to investigate profile paging algorithm and analyze the performance of profile-based paging using a Markov model in the case of Addis Ababa UMTS network.

1.4.2 *Specific objectives*

- Assess current ethio telecom location management techniques;
- Study the user's mobility pattern (user's behavior) from previous data;

- Cluster users into less mobile, moderately mobile and highly mobile groups;
- Model user's mobility for different paging algorithms using Markov model;
- Assess the performances of different paging algorithm.

1.5 METHODOLOGY

The necessary background information about location management techniques in general and particularly different paging algorithm used by cellular system are covered through literature review from journals and books. As a data collecting tool ethio telecom Customer Relation Management (CRM) application software is used to collect CDR data from Mobile Switching Center (MSC) and for the implementation of the paging algorithm a MATLAB simulation software was used. The methodologies followed to achieve the general and specific objectives of this thesis are:

1. Literature Review
   An extensive literature review covering research articles, books and industry white papers was performed. In addition Network architecture and location management system are reviewed. Although, Informal meeting conducted with ethio telecom's experts regarding the limitation of the existing location management system.
2. Data collection and preprocessing
   In order to get the data from ethio telecom, we have got a formal supporting letter from Addis Ababa Institute of Technology (AAiT). Accordingly, CDR data from ethio telecom CRM system were collected and preprocessed. Finally the datasets were converted to appropriate format.
3. Tools and model experiment
   The paging algorithm were experimented using MATLAB simulation software.

4. Result Analysis and evaluation

   The output result were analyzed in line with conventional paging channel utilization. Then the results were evaluated applying different performance measure metrics.

1.6 SCOPE

This thesis conducts a performance analysis of profile-based paging using a Markov model by taking ethio telecom's selected UMTS sites as a case study. The study conducted on a simulation environment using the raw CDR data collected from the operational network.

1.7 CONTRIBUTION

The result will have practical contribution to locate a user efficiently and to reduce a signaling load associated with a paging procedure. It enables ethio telecom to optimize the paging procedure of a cellular network using profile based paging algorithm which utilizes the user's mobility pattern as input to dynamically assign paging area in Addis Ababa UMTS context. In addition, it could be used as a reference for further researches in the area related to UMTS location management area.

1.8 THESIS STRUCTURE

The thesis organized into seven chapters. Chapter One discuss motivation and background information on location management techniques the introduction of the thesis. Chapter Two highlights paging in UMTS. It includes the different technical areas and literature related to the study area which had been considered for the development of this thesis. Chapter Three shows UMTS paging for Addis Ababa network, the paging algorithm that are currently in use and its advantages and disadvantages. Chapter Four discuss about the proposed dynamic profile based paging algorithm that uses the CDR data for creating the profile. Chapter Five discuss about network modeling and different scenarios. Chapter Six discuss about result and findings. Finally, Chapter Seven concluded this thesis and suggest the possible future works.

2

PAGING IN UMTS

2.1 UMTS ARCHITECTURE

In order to realize the location management functionalities, it is crucial to understand cellular system architecture and its implementations. A 3G architecture has three main parts, which are the UE, UMTS Terrestrial Radio Access Network (UTRAN) and CN as shown in Figure 2.1.1 [6]

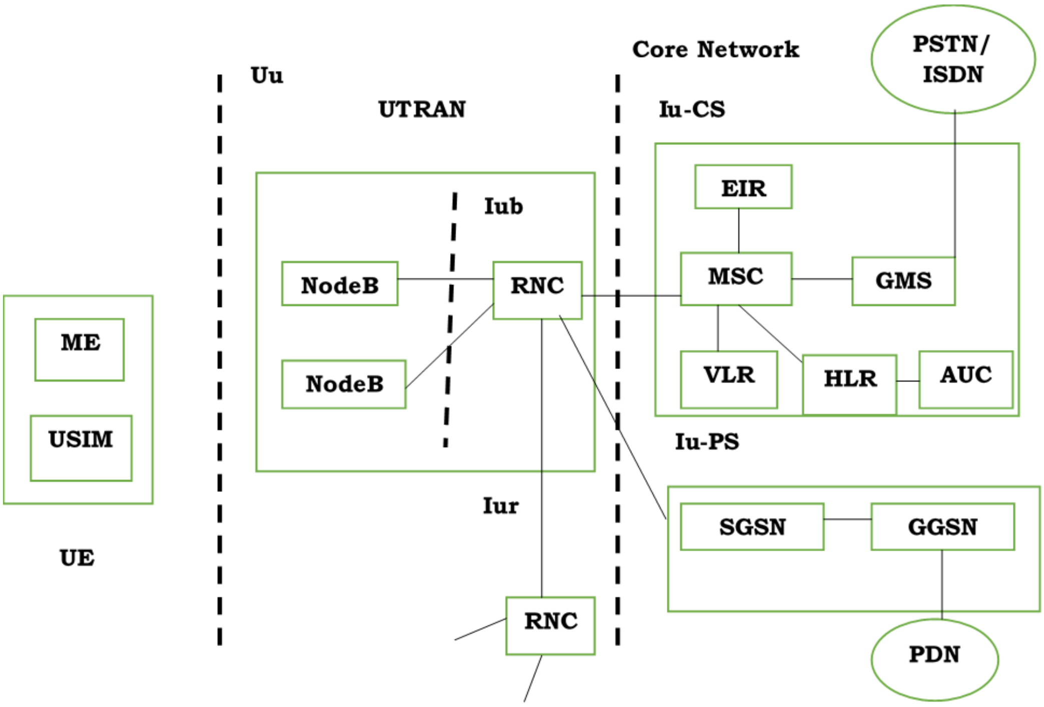


Figure 2.1.1: UMTS network architecture adopted from [41]

UE consists of the mobile equipment and a smart card called Universal Subscriber Identity Module (USIM). Mobile equipment is a device that allows the end-user to access the services offered by the cellular network, and USIM is a smart card, which stores subscriber information including the IMSI. It allows users mobility by yielding them a subscribed service, user can have access to the subscribed services regardless of the terminal.

The second component is Random Access Network (RAN). It is responsible for location management as well as sustaining the connectivity between the UE and the CN. Moreover, the RAN is also responsible for guaranteeing an efficient utilization of the available radio resources. As illustrated in Figure 2.1.1 UMTS RAN have two components called NodeB and RNC subsystem. NodeB providing the link or connectivity between the UEs and the network via the air interface. It has radio transmitters and receivers which define the extent or size of the cells in the network. The radio frequencies assigned to each NodeB operates in two ways called uplink and downlink. RNC manages the radio resources for one or more NodeBs. It is responsible for the allocation, release and management of the radio channels and handovers. It is the interface between the UE and the CN.

The third component is the CN, it is the key part of the UMTS network, and it is responsible for the access control, session control, and routing connections to external networks. It consists five main components such as MSC, Home Location Register (HLR), Authentication Center (AuC), Visitor Location Register (VLR) and other optional component such as Equipment Identity Register (EIR). MSC is the central component of mobile network system. It provides all the functionality needed to handle mobile subscriber applications, such as registration, authentication, location updates, handovers, and call routing to a roaming subscriber. It also provides the connection between the UMTS network and other networks such as Public Switched Telephone Network (PSTN) and Integrated Services Digital Network (ISDN) HLR is the database which contains all the administrative information of each subscriber that is registered in the network, along with the current location of the UE. The HLR, VLR, and the MSC provide the call routing and roaming capabilities required in a UMTS network. VLR is a temporary database that contains the data necessary to set up calls. It contains the registration area information, the user equipment roaming number, IMSI and Mobile Station ISDN number. The VLR keeps the HLR updated on the location of users. It also contains selected administrative information from the HLR, necessary for call control and provision of the subscribed services, for each UE located in the geographical area controlled by the

VLR. Authentication center is often considered part of HLR and it is a protected database that stores a copy of the secret key stored in each subscriber's SIM card. This secret key is used for authentication and encryption over the radio channel. EIR is a database in UMTS network that used to authenticate the mobile equipment using their International Mobile Equipment Identification (IMEI) number.

2.2 LOCATION AREA

A service coverage area is partitioned into Location Area (LA)s. A LA is a group of cells in which a paging message is broadcasted [6]. The serving area of a MSC is the size of upper boundary of a LA [42], the LAs may be smaller than serving area of MSC, due to the extreme paging load a large LA would have to handle. The lower boundary for the size of a LA is depend on the location updating load. In principle, a service area should be partitioned in a way such that both the location update cost and the paging cost are minimized. The NodeB broadcasts the identification (ID) of LA to which a cell belongs, and a user equipment will know in which LA it belongs. In Figure 2.2.1 illustrates a service area with five LA.

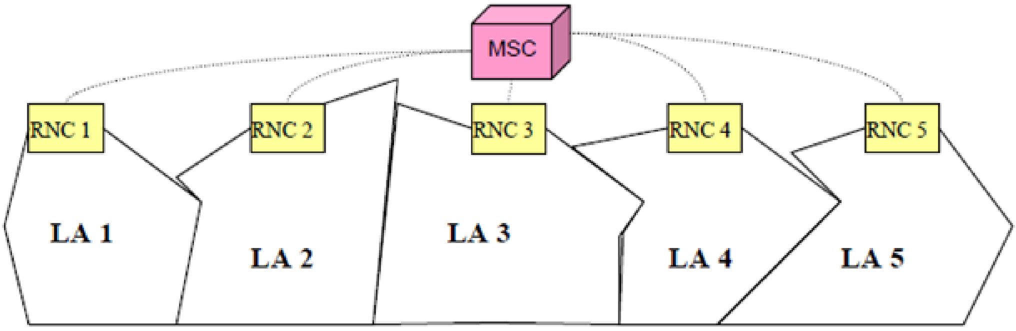


Figure 2.2.1: A service area with four location areas adopted from [9]

A UE will update its location (i.e. Location area) whenever it moves a new LA. For example, when a user equipment moves from LA 2 to LA 4 as shown in the Figure 2.2.1, it will report its new LA. A UE located around the boundary of a LA will perform more location updates. Because it moves back and forth between two LA more often.

2.3 PAGING

Paging is a procedure that is used when searching for a given UE within the network coverage area [6]. This procedure is only executed if the transaction originates from the network sides. After locating the target UE, the RNC performs the activity to allocating a radio resources to establish a traffic channel. As shown in Figure 2.2.1, when a call is initiated the MSC in which a called UE locates, will queries the local VLR for the location area where the UE is currently roaming. Then the MSC sends paging messages that carry the IMSI information or TMSI information of the UE to all RNCs in the location area. The RNC confirms the paging to NodeB based on the location area, determines the Paging Channel (PCH) of the UE based on the IMSI or TMSI, and sends the paging instruction to the NodeB. Then, the NodeB sends the paging message of the UE through the specified PCH. Based on the paging message received, the UE performs corresponding operation. For example, the UE accesses the network through the Random Access Channel (RACH) and starts the circuit connection setup after receiving the circuit paging message. For a paging request, if the first paging fails, the MSC auto originates the second paging to the UE. Generally, a paging request is repeated for three times.

Paging block can fit two IMSI pages or four TMSI pages or a combination of one IMSI and two TMSI pages as shown in the Figure 2.3.1 [16].

Figure 2.3.1: Paging block

2.4 PAGING TYPES

There are two types of paging in UMTS, which are type 1 and type 2 [6]. In type 1 the UE is in ideal status and has no active session to the network, hence, the paging request need to be sent on a paging channel. Whereas in type 2 the UE has a connection to the network, hence the paging request will be sent on the Forward Access Channel (FACH), where the connection already established.

2.4.1 *Paging type 1*

In this type of paging as shown in Figure 2.4.1 below the paging is performed for a UE in Radio Resource Controller (RRC) idle mode, and the RAN has no information about the user, but the CN has user's location information at registration location area level[6]. Therefore, the paging message must be distributed across the whole registration location area to reach the user. As shown in the Figure 2.4.1 the area spans one has one RNCs, thus the paging message will be sent to this. This procedure initiated by the CN by sending Radio Access Network Application

Part (RANAP) paging message, which contains parameters such as: domain type (Circuit Switch (CS) or Packet Switch (PS)), UE identity (i.e.IMSI or TMSI) and the paging cause, then the RNC will broadcast paging message type 1 to the NodeB through to the Iub interface using the Iub common channel frame. RANAP is a protocol specified by 3GPP in TS 25.413 [43] and used in UMTS for signaling between the Core Network, which can be a MSC or Serving GPRS Support Node (SGSN), and the UTRAN.

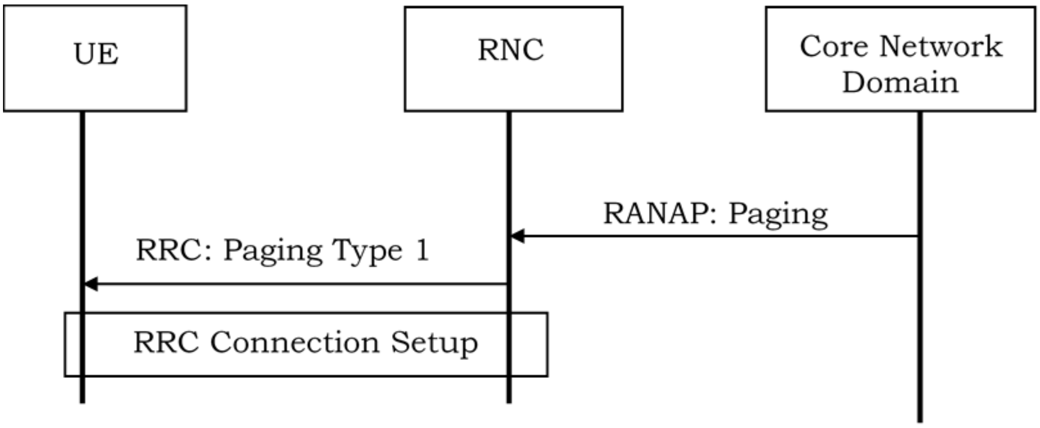


Figure 2.4.1: Paging Type 1 adopted from[6]

Then the NodeB will forward the message to all cells, through the physical secondary Common Control Physical Channel (CCPCH), and the UE will answer the page, and it will reinitiate RRC connection.

2.4.2 *Paging type 2*

Paging type 2 is used when an RRC connection has already been established for this particular UE. In this case, the UE is paged directly over the established RRC signaling link rather than the paging channel. Like in paging type 1 the CN initiates the procedure by sending RANAP paging message as shown in Figure 2.4.2 , then Serving RNC (SRNC), sends the RRC paging type 2 message through the established logical Dedicated Control Channel (DCCH) channels.

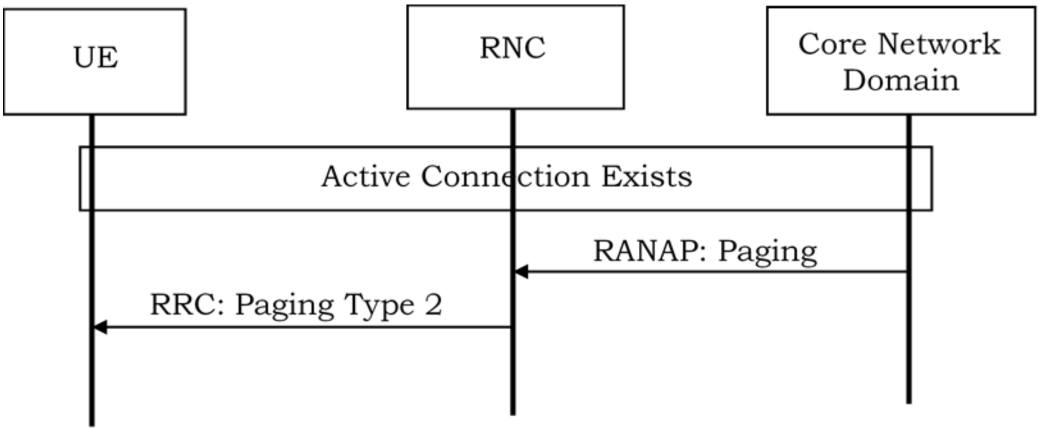


Figure 2.4.2: Paging Type 2 adopted from[6]

2.5 PAGING CHANNEL

A channel is a medium through which an information is transmitted to its intended receiver, it can be a wire, or a radio channel [44]. The channel can be divided into two types, such as a physical channel and logical channel. Physical channel is a medium over which the information is carried. Logical channel consists of information carried over a physical channel. A logical channel can be a Traffic Channel (TCH)s which are intended to carry user traffic or a Control Channel (CCH)s which are intended to carry signaling and synchronization data. Based on the way in which they are supported on the radio interface and the type of signaling information they carry a control channels further classified into three categories[45]

1. Broadcast Control Channel (BCCH)
2. Common Control Channel (CCCH)
3. Dedicated Control Channel (DCCH)

BCCH is a point to multi point, unidirectional channel used in the Um interface of the UMTS cellular standard. The paging is done on timeslot zero on the BCCH frequency. Timeslot zero consists of several channels; Broadcast Channel (BCH), CCCH and, DCCH. As shown in Figure 2.5.1 the BCH consists of Frequency Correction Channel (FCCH), Synchronization Channel (SCH) and BCCH. The CCCH consists of two sub channels; the PCH and the Access Grant Channel (AGCH). The DCCH consists of SDCCH, Slow Associated Control Channel (SACCH) [42].

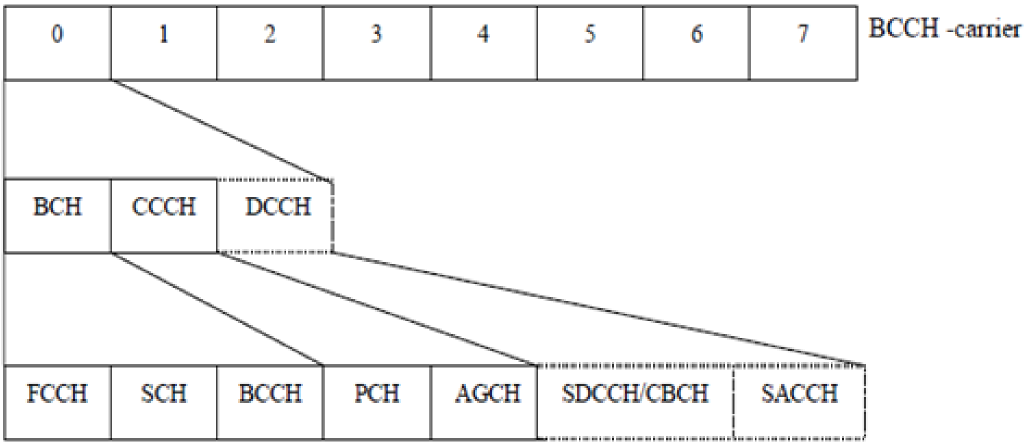


Figure 2.5.1: Channel configuration of time slot 0 adopted from [6]

Timeslot 0 is logically divided into multi-frames, where each multi-frame is235.4ms. One multi-frame equals to 51 frames. The multi-frames have different contents for the different channel configurations, and therefore the paging capacity varies: Non-combined BCCH/Stand Alone Dedicated Control Channel (SDCCH) can fit 9 paging blocks per multi-frame, whereas a combined BCCH/SDCCH can fit 3 paging blocks per multi-frame. To choose between combined and non-combined configuration, the parameter BCCHTYPE is used. The AGCH is used to assign an SDCCH to a UE during the call set-up phase. The AGCH shares the same resources as the PCH. The CCCH can be set up to either have dedicated blocks for Access Grant, or Access Grant can work in stealing mode which means replacing paging blocks with Access Grant blocks when needed. If dedicated blocks are used, each multi-frame will contain 2 paging blocks (for combined) or 8 paging blocks (for non-combined).

2.6 CHALLENGES IN PAGING PROCEDURE

A location area may contain one or more cells. One of the challenges in paging procedure is the size of the location area. If paging area is planned too large, the paging message sent to multi cells will overload the paging channel as well as increasing signaling flow at the Iub interface [16], the paging message sent to UE in the cell will be lost and the subscriber within the service area cannot be paged. On the contrary, if paging area is planned too small, subscribers will update their location frequently while moving. This will increase signaling flow of the system, and will influence the waiting time of UEs.

Another concern in paging procedure is paging lost (i.e. paging message is not delivered at the air interface at all). If paging message is not delivered at the air interface at all, it is most likely that paging is lost. Paging lost can be happened when RNC is in the paging flow control state, i.e. If the RNC's CPU utilization or message queuing occupation reaches the preset threshold, paging flow control state will be triggered and paging message will be lost unconditionally. On the other hand, paging loss can happen due to PCH capacity. Based on the PCH coding mode, If IMSI paging is utilized, only two UEs can be paged at the same paging period; and if TMSI and Packet Temporary Mobile Subscriber Identity (PTMSI) paging are utilized, only four UEs can be paged at the same paging period. Other causes for paging loss are transmission faults of Iub interface or equipment's faults. Other concern of paging procedure are: UE does not receive the paging message or receives the wrong message, and UE fails in responding after receiving paging messages.

3

UMTS PAGING FOR ADDIS ABABA MOBILE NETWORKS

3.1 TOPOLOGY

As shown in Figure 3.1.1 Addis Ababa network has three MSCs (i.e. MSC1, MSC2 and MSC3) which are connected as a pool. Each RNC connected to all three MSCs. The MSCs connected as mesh. In a traditional network, one RNC can be connected to only one MSC [46]. In the MSC Pool networking mode, one RNC can be connected to multiple MSCs. The MSC Pool networking mode has the following advantages.

- Multiple MSCs in the MSC Pool share the load of a network. This improves the utilization of resources of the core network and saves investment on equipment.
- Data can be backed up among the MSCs in the MSC Pool, as a result, it improves the reliability of the network.
- The number of inter-MSC location updates in the MSC Pool and signaling traffic on the C/D interface are reduced.
- The number of inter-MSC handovers in the MSC Pool is reduced, resulting in an improvement in conversation quality.

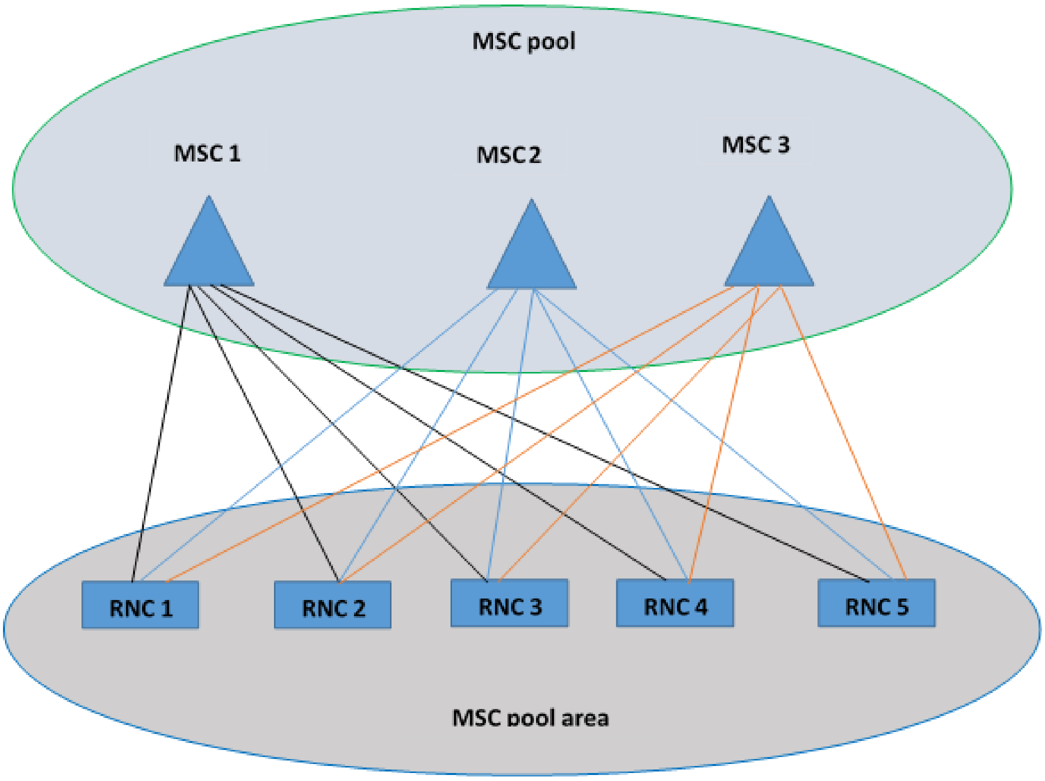


Figure 3.1.1: Core and radio network topology

In MSC Pool network, the non access stratum (NAS) node selection function (NNSF) enables RNC to select a service MSC server for a served subscriber from the pooled MSC servers that are connected to the RNC. The network element (NE) that provides the NNSF is called an NNSF entity[x]. A NAS node selection function NNSF entity is connected to multiple MSCs in the MSC Pool. When a UE in the service area of NNSF entity originates a service, the NNSF entity uses the load balancing algorithm to select a valid MSC as the serving MSC of the UE based on the subscriber capacity of all the valid MSCs in the MSC Pool.

When a UE uses the IMSI/IMEI to originate a service, the NNSF entity uses the load balancing algorithm to select a valid MSC as the serving MSC of the UE based on the subscriber capacity of all the valid MSCs in the MSC Pool. The selected MSC allocates a TMSI containing the local NRI to the UE.When a UE uses the TMSI to originate a service, the NNSF entity selects a serving MSC for the UE according to the mapping between the NRIs and the MSCs in the MSC Pool configured on the NNSF entity. When the selected MSC is invalid or the data of mapping between NRIs and MSCs is not available on the NNSF entity, the NNSF entity uses the load balancing algorithm to select a valid MSC as the serving MSC of the UE based on the subscriber capacity of all the valid MSCs in the MSC Pool. The selected MSC allocates a TMSI containing the local NRI to the MS/UE.

When the MSC sends a paging message to the called UE by matching the IMSI, the NNSF entity temporarily stores the mapping between the IMSI and the MSC that sends the paging message. When the called UE responds to the network by using the IMSI, the NNSF entity selects a serving MSC for the UE according to mapping between the NRIs and the MSCs if the response contains an NRI, or according to the mapping between the temporarily stored IMSIs and the MSCs if the response does not contain an NRI. This ensures that the paging response is sent to the MSC that sends the paging message and the call is successfully connected. When the selected MSC is invalid or no MSC can be selected according to the mapping, the NNSF entity uses the load balancing algorithm to select a valid MSC.

3.2 LOCATION MANAGEMENT IN ETHIO TELECOM

ethio telecom adopts a conventional paging scheme for paging and area-based strategies for a location update. To search the called UE the core network broadcasts polling messages to a location area using last updated information from the VLR. Addis Ababa networks covered with five RNCs (i.e. RNC1, RNC2, RNC3, RNC4 and RNC5). The number of cells per RNCs is shown in Table 3.2.1, and each RNC serve more than a thousand cell, this implies paging area for Addis Ababa is planned too large.

Table 3.2.1: Number of cells per RNCs

Location Area Identity	No. of Cells
101	1451
102	1950
103	1560
104	1473
105	1770

3.3 PAGING CHANNEL UTILIZATION

A week KPI data shown in Figure 3.3.1 starting from 1 am up to 6 am an average paging channel utilization of all RNCs is below 60%. Whereas, from 7 am till 11 am the paging channel utilize is above 90%. At 12 am the average paging channel utilization is drops below 80%. Starting from 1 pm till 12 pm the utilization raises above 90%. At some particular time, the paging channel utilization is above 100% this is because ethio telecom utilize RNC pooling schema.

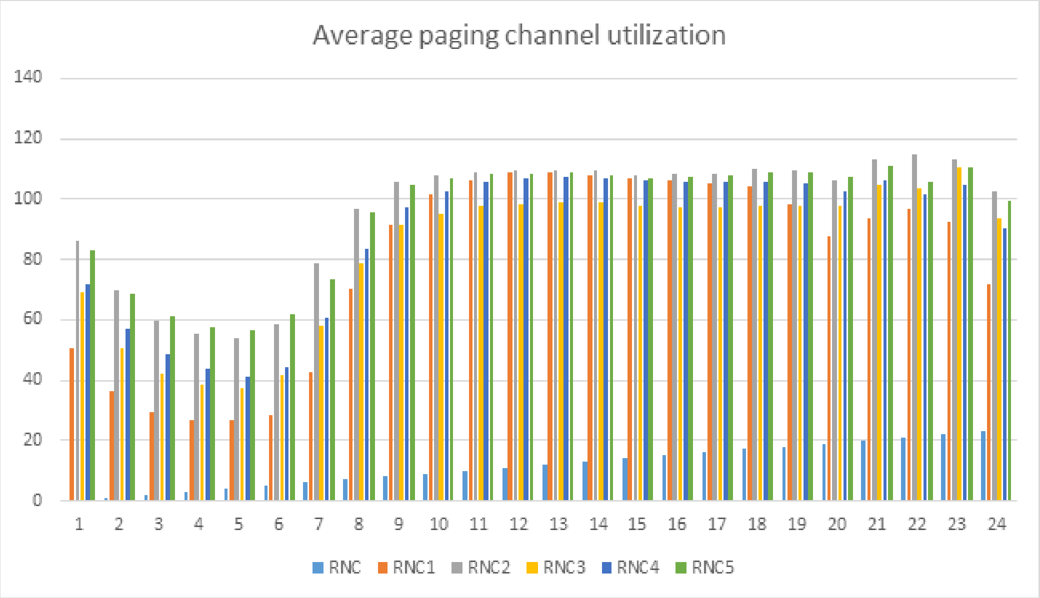


Figure 3.3.1: Paging channel utilization

3.4 PAGING CONFIGURATION

The paging configuration of ethio telecom is summarize in Table 3.4.1. As shown in Table 3.4.1 Location Area Identity (LAI) number specifies the exact location area of the local MSC to which the system delivers the specific paging control parameter. The wildcard e indicates all the location areas. Paging type indicates the possible paging options. Its default value is all paging types (i.e. for data, voice and SMS). Priority specifies the priority given for each paging options. It is configured as all priorities (i.e. all paging options have equal priority). Emergency data flag this parameter specifies whether to configure the paging policy for emergency or normal situations, and it is configured as No. Paging times indicates the maximum number of paging during a paging process, and it is configured as two times. Paging duration indicates the interval between the pages, and is configured as 13 second for two paging. TMSI/IMSI flag specifies whether the TMSI is contained or not in the paging messages sent by the MSOFTX3000 to the RNC.All RAN paging flag: This parameter is valid only if Paging type is set to Pre-paging, Short message paging, Normal call paging, GSS paging, PSI paging, or all paging types. LAI type specifies the format of the LAI IE in the Paging message that the MSOFTX3000 sends to the RNC. This parameter is valid only when Paging type is set to Normal call paging.

Table 3.4.1: Paging configuration

MSC	
LAI number	e
Paging type	Data, Voice and SMS
Priority	All priorities
Emergency data flag	NO
Paging times	2
First paging duration	7 sec
Second paging duration	6 sec
TMSI/IMSI flag	First paging (use TMSI)
	Second paging (use IMSI)
All RAN paging flag	First paging (one LAI)
	Second paging (one LAI)
LAI type	LAI

4

PROFILE PAGING SCHEMA

4.1 PROFILE SYSTEM MODEL

The general structure of the proposed system model for the profile-based paging algorithm has shown in Figure 4.1.1. The proposed model has two basic phases: profiling and paging phases. The basic activities under profiling phases are pre-processing and building user mobility model. Activates under each phase are described in detail below.

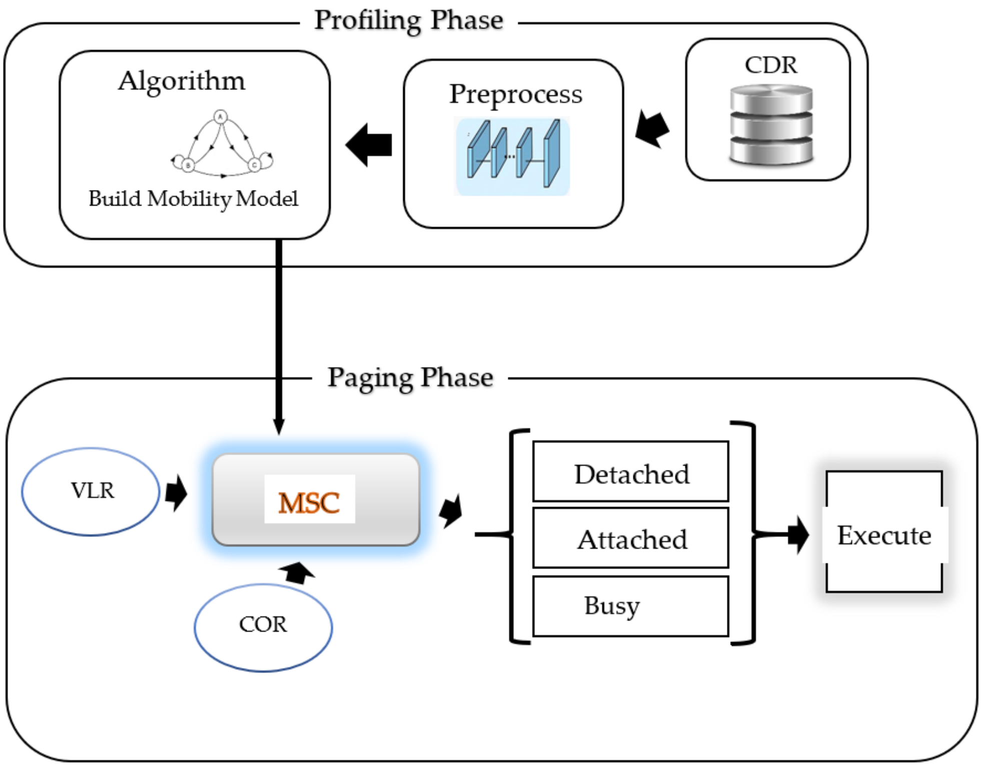


Figure 4.1.1: Proposed system model for profile-based paging algorithm

4.1.1 *Data Preprocessing*

The collected CDR dataset was in raw form, thus the dataset has a different type of impurities and irregularities[45]. Such irregularities include missing values, unrecognized numbers, and misleading patterns. Therefore data must be prepared before performing the analytical step. Data preparation is helpful in improving output quality and reducing processing overhead. Accordingly, the received CDR is checked and found null records with missing values for cell id attributes in SMS records and discarded them. And data transformation was done for cell id because cell id was found in hexadecimal. from hexadecimal form to decimal to identify the site and grid id. Again the cell id is mapped into $1, 2, 3 \ldots$ from five digits format.

4.1.2 *Feature extraction*

Feature extraction is conducted by selecting the only features that are relevant for profiling the user. In this phase, a set of features, whose values are derived from the collected CDR data are computed by applying numerical operations. A hexadecimal conversation is used for cell id feature. The system model takes One month's CDR data generated during a call to originate for billing purposes as input. The dataset is collected from the CRM of ethio telecom. Every time when a call comes to the system will generate a CDR for charging purpose. It contains information related to call arrival time and date, call end time, call initiation cell, call end cell, location area, call type, etc. From the CDR a mobility traces extracted and the steady-state probability is calculated. Based on the calculated steady-state probability the paging area is assigned. For profile-based paging, the first paging is sent to a set of cells obtained from the mobility profile of the target. If no reply received by the RNC, the second paging message is sent to paging area two. In this thesis, we consider static and dynamic profile-based paging algorithms. In static-profile based paging a PA contains a list of cells which are pre-computed using a mobility data. The profile remains unchanged for a relatively long period of time.

Whereas, in dynamic-profile based paging, a PA contains a list of cells which are dynamically selected using a transition matrix of a mobility data. A list of cells are dynamically adjusted to update the PA. In the paging phase, the activity is call originated request(COR) and it is described below. The **COR!** (**COR!**)

- If a UE attempts to call a mobile subscriber, the call is forwarded to MSC. The switch masses a query to HLR to find the current VLR of UE. The HLR queries the VLR in which UE resides to get a communicable address.
- The VLR returns the address to switch through HLR.
- Based on the address, a communication link is established between UE through visited MSC.

The system model takes CDR data generated during call originate for billing purposes as input. The dataset is collected from the CRM of ethio telecom.

4.1.3 *Building Mobility Model*

Profile Paging

The model used by the proposed paging algorithm is a Markov chain models. user movement can be modeled by Markov model using a UE movement trace of a user as an input [36]. Let us assume the user movement sequence is $\{1,2,3,3,3,2,2,2,4,2,4,2,2,2,2,1,5,1,1,1,1,1,2,5,1,1,1,5,1,5,1,1,2,6,6,2,2,2,2,6,1,2,2,2,2,2,2,2,6,4,4,4,4,7,7,7,2,2,1,5,2,2,2,2,1,1\}$. From this sequence, we can obtain the state transition probability (i.e. $P_{x,y} = P_r[X_t = y \mid X_{t-1} = x\ ]$, where x, y $\in \{1,2,3,4,5,6,7\}$) and construct the Markov model and the corresponding transition probability matrix (P). Occurrence state probability is obtained by

- $1- > 17/66 = 0.26$
- $2- > 28/66 = 0.42$
- $3- > 3/66 = 0.05$
- $4- > 6/66 = 0.09$

- $5- > 5/66 = 0.08$
- $6- > 4/66 = 0.06$
- $7- > 3/66 = 0.05$

Column vector $=\pi = [0.26, 0.42, 0.05, 0.09, 0.08, 0.06, 0.05]$

The cell residence probabilities then be obtained by solving $\pi = \pi \times P$. Furthermore, the cells which are not visited obtain a residence probability equal to zero.

4.2 PROFILE PAGING

As discussed in chapter one paging is the process through which a mobile subscriber is notified about an incoming call. In most cases the exact location of the mobile subscriber is unknown, thus a group of cells are going to be paged. If the paging process is not successful, then another group of cells are going to be paged. This process continues till the user is found or the paging request expires. paging consumes both spectral and computational resources [2] .The location tracking strategy currently used by PCS is a fixed paging area strategy [47].In this strategy, all cells of the PCS are partitioned into several LA. A mobile in this system is required to update its new location whenever it changes its LA. Whenever a call arrives, the exact location of the called is queried by paging all cells of the LA the call lastly updated [47]. Designing appropriate LAs could reduce the location tracking cost of the PCS effectively. Although the fixed paging area strategy could be easily implemented but could not reach the optimal location tracking cost since the paging area defined in this approach may be large to waste paging cost for low mobility mobiles or small for high mobility mobiles to unnecessary updates.

The profile-based strategy tries to reduce the location tracking cost by taking advantage of most mobiles highly predictable patterns. Although the performance of this strategy is much better than the fixed paging area strategy currently adopted by most PCS[10].A profile based paging scheme is designed to reduce bandwidth utilization and paging delay. In this paging schema, attribute like (user movement) are considered and a profile is created based on it. If a user is highly mobile, the area to be paged is kept bigger to gain better paging success rate. Whereas, the user with less mobile is paged over a certain paging area to conserve bandwidth. In this way the approach for each user is different and the overall process is more optimized. However, such paging approach performance analysis has not been investigated and applied for Addis Ababa UMTS context.

Every time when a call comes the system will generate a CDR for charging purpose. It contains information related to call arrival time and date, call end time, call initiation cell, call end cell, location area, call type etc. From the CDR a mobility traces extracted and the steady state probability is calculated. Based on the calculated steady state probability the paging area is assigned. For profile-based paging, the first paging is sent to a set of cells obtained from the mobility profile of the target. If no reply received by the RNC, the second paging message is sent to paging area two. In this thesis, we consider static and dynamic profile-base paging strategies. In static-profile based paging a PA contains a list of cells which are pre-computed using a mobility data. The profile remains unchanged for a relatively-long period of time. Whereas, in dynamic-profile based paging, a PA contains a list of cells which are dynamically selected using a transition matrix of a mobility data. A list of cells is dynamically adjusted to update the PA.

4.3 PAGING ALGORITHM

The paging algorithm in the proposed paging schema is a procedure used to search a called UE during an incoming call. The proposed technique has two main phases called profiling and paging. On profile phase the proposed technique will analyze historical CDR data of each users and model a user mobility behavior using Markov chain model. Whereas, the paging phase will locate the user when a paging request come using the model built in the profiling phase. Profiling phase has three main steps called preprocessing, feature extraction and building users mobility model. The proposed technique will use UE CDR and location information stored inside the VLR as input dataset. The input datasets collected from the CRM solution of ethio telecom. Table 4.3.1 shows list of features and their description which are extracted from the collected raw data.

Table 4.3.1: List of features and their description

Name	**Description**	**Justification**
Record type	The type of call (mobile terminate / mobile originate)	To capture the record type
Service type	It can be voice, Data, SMS	To show service type
Calling Number	A number used to identify a calling mobile phone number	To capture the calling number
Called Number	A number used to identify a called mobile phone number	To know for which paging request the core network send
Cell Id	It is generally unique number used to identify the RNC of WCDMA RAN system or sector of a NodeB within a location area code.	To know cell Id where the user visit during call terminate/originate
LAC	A unique number of current location area. It is a set of the radio controller of WCDMA RAN system that are grouped together to optimize signaling.	To know LAC information where the user visit during call terminate/originate
Date of call	The date at which call established.	

On the collected CDR data some of the fields have a missed null value (/0), in such case, a specific record is discarded from the dataset, and on the collected data the Cell id value is available in a hexadecimal format, and it is converted into decimal. Thus in advance the data must pass through the preprocessing step. Incomplete and error data are removed from the dataset, then feature extraction is performed by picking only feature that are input for proposed paging algorithm. In addition to this numerical operation is done to derive additional features whose values are derived from the selected features. Then on user's mobility model step, the occupancy probability vector [Pi], transition matrix [P] and steady state probability [π] are calculated. Using the mobility model users are categorized into three classes depending on their mobility rate.

After profiling phase finished the next phase is the paging phase, this phase has two steps called selection and execution. On selection step the network first examines whether paging is needed or not, by checking the current status of a called terminal or UE (i.e. detached, attached, busy or idle). Then after the UE status is identify the next step is execution phase. On the execution step, if a called terminal status is detached, the algorithm will cancel the paging request. If the status is busy, the terminal location is already known by the network, therefore it does not need paging request. Whereas, if the terminal status is idle, based on the user's mobility model and user's category the algorithm will determine list of cells in PA1 and PA2. Then the paging message is send to PA1, if the UE found it ends Paging Request (PR), else it will check the delay bound. If the delay reaches its bound, it will stop the process, otherwise it sends second paging message to the list of cell in PA2.The above description summarized using the flow chart as shown in Figure 4.3.1.

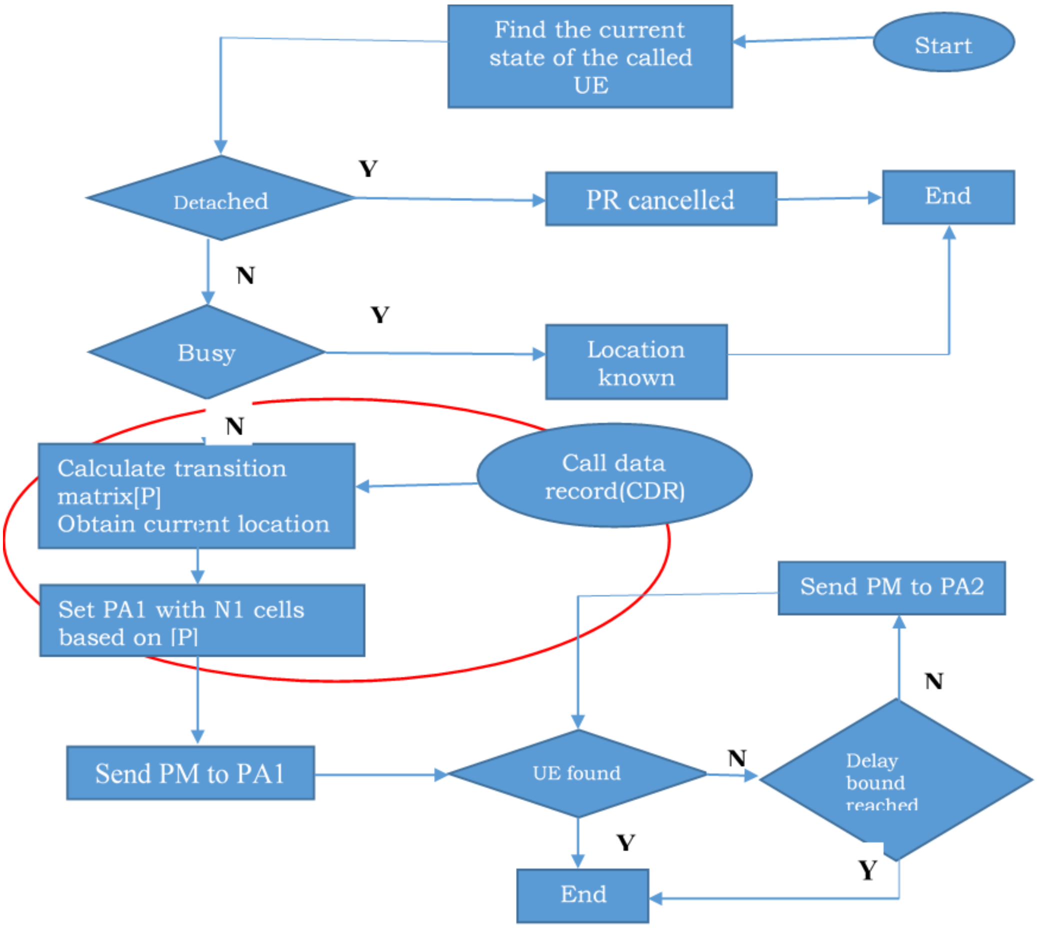


Figure 4.3.1: Flow chart of Dynamic profile based Paging algorithm

5

NETWORK MODELING SCENARIOS AND ASSUMPTIONS

5.1 MARKOV CHAINS

A Markov Chain consists of a countable (possibly finite) set S (called the state space) together with a countable family of random variables $X0$, $X1$, $X2$, ···with values in S such that

$$P\left[X_{l+1} = S\,|X_l = s_l, X_{l-1} = S_{l-1},\ \ldots, X_0 = s_o = P[X_{l+1} = S|\,X_l = s_l]\right.$$

The random variables $X0$, $X1$, $X2$, ···are dependent [48]. Markov chains are between sequences of dependent random variables. The subscript l of the random variable Xl as representing the time(discretely) and the random variables represent the development of a system whose behavior is only probabilistically known. Markov's property expresses the assumption that the knowledge of the present $(i.e., Xl = sl)$ is applicable to predictions about the future of the system, however additional information about the past (X_j = S_j, $j \leqslant l-1$) is unrelated.

Since the state space is countable (or even finite) it is normal (but not always the case) to use the integers Z or a subset such as non-negative integers, the natural numbers N= {1,2,3,···} or {0,1,2,···, m}as the state space. The specific Markov chain under consideration often determines the natural representation for the state space. In the general case where no specific Markov chain is singled out, we often use N or non-negative integers as the state space. We set

$$P_{ij}^{l,l+1} = P[X_{l+1} = j|X_l = i]$$

For fixed l the (possibly infinite) matrix

$$P_l = \left(P_{ij}^{l,l+1}\right)$$

is called the matrix of transition probabilities (at time l). In our discussion of Markov chains, the stress is on the case where the matrix Pl is independent of l which means that the law of the growth of the system is time-independent.

For this reason, one refers to such Markov chains as time homogeneous or having stationary transition probabilities. Unless stated to the opposing, all Markov chains considered in these notes are time-homogeneous and therefore the subscript l is omitted and we simply represent the matrix of transition probabilities as P= (Pij). P is called the transition matrix. The matrix P is not arbitrary. It satisfies

$$P_{ij} \geqslant 0, \quad \sum P_{ij} = 1 \;\; \mathtt{for\;\; all\;\; i}. \tag{5.1}$$

A Markov chain determines the matrix P and a matrix P satisfying the conditions of eq 1 determines a Markov chain. A matrix satisfying conditions of eq 1 is called Markov or stochastic. Given an initial distribution $P[X_o = i] = pi$, the matrix P allows us to compute the distribution at any subsequent time. For example, $P[X_1 = j, X_o = i] = P_{ij}P_i$ and more generally

$$P\left[X_l = j_l, \;\; \ldots, X_1 = j_1, X_0 = i\right] = P_{jl-1jl}P_{jl-2jl-1} \;\; \ldots P_{ij1}p_i. \tag{5.2}$$

Thus the distribution at time l= 1 is given by the row vector (p1, p2,···)P and more generally at time l by the row vector

$$(p1, p2, \;\; \ldots)\underbrace{PP\ldots P}_{l\ times} = (p1, p2, \;\; \ldots)P^l. \tag{5.3}$$

For instance, for l= 2, the probability of moving from state i to state j in two units of time is the sum of the probabilities of the events

$i \to 1 \to j, i \to 2 \to j, i \to 3 \to j, \;\; \ldots, \;\; i \to n \to j,$

since they are mutually exclusive. Therefore the required probability is $\sum kP_{ik}P_{kj}$ which is accomplished by matrix multiplication as given by Eq 3 Note that (p1,p2, $\ldots$)

is a row vector multiplying P on the left side. Equation 3 justifies the use of matrices is describing Markov chains since the transformation of the system after l units of time is described by l-fold multiplication of the matrix P with itself. It is convenient to make use of the notation . Then for r+s=l (r and s non-negative integers) we have

$$P^{l} = P^{r}P^{s} \quad \text{or} \quad P_{ij}^{(l)} = \sum_{k} P_{ik}^{(r)} P_{kj}^{(s)} \tag{5.4}$$

5.1.1 *Elements of Markov chains*

There are three important elements in Markov chains:

- Probability transition matrix P.
- Transition diagram.
- Steady-state vector π

Probability transition matrix

The switch between states is established in the probability transition matrix P. Each element of it represents the probability that switches or remains in the state. These switches are called transitions. P is a square matrix whose order is the same as the number of states. Equation (5) shows the structure of a probability transition matrix.

$$P = \begin{pmatrix} P_{00} & P_{01} & \dots & P_{0j} \\ P_{10} & P_{11} & \dots & P_{1j} \\ . & . & \dots & . \\ . & . & \dots & . \\ . & . & \dots & . \\ P_{i0} & P_{i1} & \dots & P_{ij} \end{pmatrix} \tag{5.5}$$

Each element of P must satisfy the next condition.

$$P_{ij} \geqslant 0, \qquad i, j = 0, 1, 2, 3 \ \dots \tag{5.6}$$

Where,

P_{ij}, Probability that current sample is in state i given the immediate precedent past time was in state j.

i, Transition state i.

j, Transition state j.

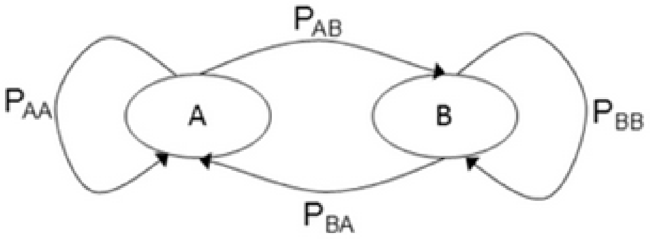
Condition of (7) is based on the argument that P_{ij} represents certain probability. Another important characteristic of the probability transition matrix is that the sum of each row must be equal to one.

$$\sum jP_{ij} = 1, \qquad i = 1, 2, 3, \dots \tag{5.7}$$

Where pij, Probability that current sample is in state i given the immediate precedent past time was in state j. i, Transition state i. j, Transition state j.

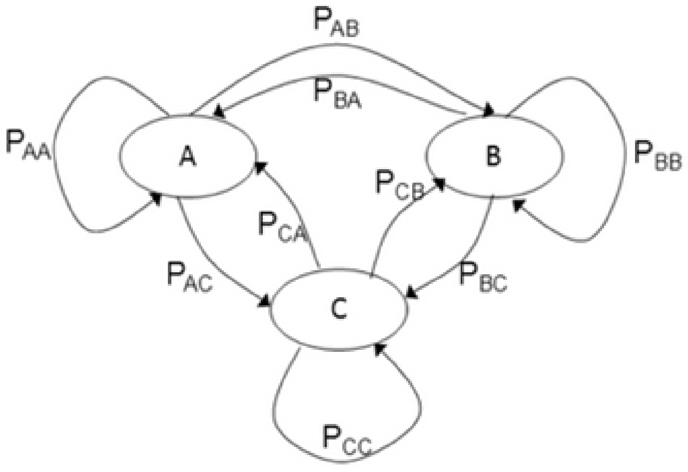
Transition diagram

A probability transition matrix can be also represented as a diagram called a transition diagram. Each node represents a state of the Markov chain indicated with a number inside; an arrow → connects state i with state j if a transition exists and the transition probability Pij is written on that connecting arrow, even if the transition is to the same state. Next figures show the probability transition diagram for a two, three and four states Markov chain with its transition matrix.



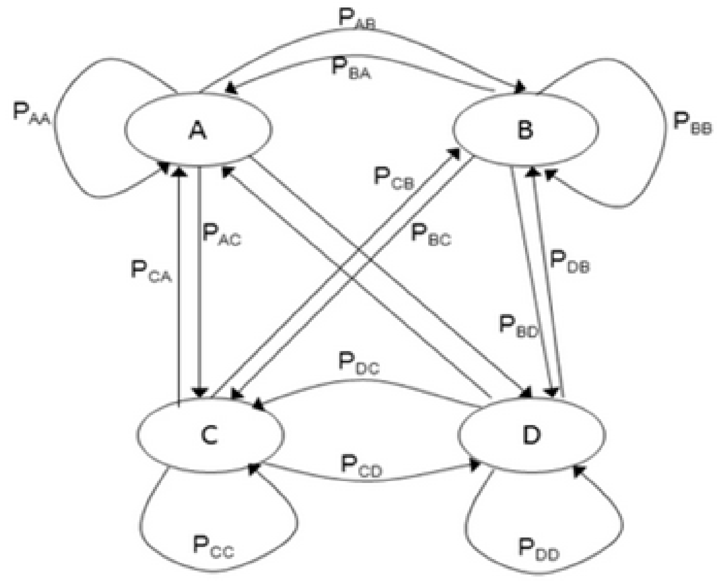
$$\mathbf{P}=\begin{bmatrix} p_{AA} & p_{AB} \\ p_{BA} & p_{BB} \end{bmatrix}$$

Figure 5.1.1: Probability transition diagram for 2-state Markov chain



$$\mathbf{P}=\begin{bmatrix} p_{AA} & p_{AB} & p_{AC} \\ p_{BA} & p_{BB} & p_{BC} \\ p_{CA} & p_{CB} & p_{CC} \end{bmatrix}$$

Figure 5.1.2: Probability transition diagram for 3-state Markov chain



$$P=\begin{bmatrix} P_{AA} & P_{AB} & P_{AC} & P_{AD} \\ P_{BA} & P_{BB} & P_{BC} & P_{BD} \\ P_{CA} & P_{CB} & P_{CC} & P_{CD} \\ P_{DA} & P_{DB} & P_{DC} & P_{DD} \end{bmatrix}$$

Figure 5.1.3: Probability transition diagram for 4-state Markov chain

Steady-state vector

Another important element in Markov chains is the steady-state vector π, which represents the total appearing percentage of a state in a Markov chain. This vector can be computed by raising P to a large power. This is shown in (9).

$$P^n \to 1\pi \tag{5.8}$$

Where,

P, Probability transition matrix.
π, Steady-state probability vector
1, Column vector of ones: $1^T = (1, 1 \ldots)$
One property of the π vector is that the sum of its elements must be equal to one as it is shown in (10).

$$\sum i\pi i = 1 \tag{5.9}$$

Where,

π_i, Steady-state probability for state i.

Steady-State theorem

Let P be the transition matrix for an s-state ergodic Markov chain. Then there exists a vector $\pi = [\pi 1 \quad \pi 2 \quad \dots \quad \pi s]$ (steady-state distribution)

$$\text{Such that} \quad \lim_{n\to\infty} P^n \begin{pmatrix} \pi 1 & \pi 2 & \dots & \pi s \\ \pi 1 & \pi 2 & \dots & \pi s \\ . & . & \dots & . \\ . & . & \dots & . \\ . & . & \dots & . \\ \pi 1 & \pi 2 & \dots & \pi s \end{pmatrix} \text{and} \lim_{n\to\infty} P_{ij}(n) = \pi_j$$

The steady-state distribution

$\prod 1 + \prod 2 + ... + \prod s = 1$

$\pi(n+1) = \pi(n).P$

5.2 EXPERIMENTAL SETUP

The aim of this experimental setup is to conduct a performance analysis of profile based paging for Addis Ababa UMTS networks. To conduct the study three scenarios are considered. The first scenario is considering a conventional paging algorithm, which broadcast the paging message for entire location area. The second scenario is a static-profile based paging with static paging area assignment. In this scenario, the paging areas contains list of pre-computed cells. A PA is assigned based on steady state probability, thus list of cells with a steady state probability $>= 0.005$ are assigned to PA1, and cells with steady state probability $> 0\& < 0.005$ are assigned to PA2. This list will remain unchanged for a relatively-long period of time. On the third scenario a dynamic paging algorithm is considered. In this scenario, a list of cells for a PA's are dynamically selected using a transition matrix. The last known location information is used to select the row matrix from the transition matrix, then the cells are assigned to a PAs similar to the second scenario. In all scenarios the study conducted for three user's category i.e. less, moderate and highly mobile. The above study scenarios are simulated on Matlab simulation environment. On this environment two paging attempts and wireless channel error is assumed with error probability of ep=0.1, 0.15, 0.2 and 0.25. To categorize the users, we assume users who travel less than fifteen unique cells per month as Less mobile, users who travel more than fifteen and less than twenty five unique cells per month as Moderate, and users who travel more than twenty five unique cells per month as Highly mobile.

5.3 DATA PREPARATION

CDR also known as Per Call Measurement Data (PCMD) [2], is a data generated and stored in MSC for each and every originate or terminated calls by a user through the RNC covered by it. It contains a lot of information regarding the call placed. Some of the features contained in the CDR are:

1. MSC calling number
2. MSC called number
3. MSC record type
4. Date of call
5. Call starting time and date
6. Call ending time and date
7. MSC call duration
8. MSC cell id
9. MSC LAC
10. MSC global area id, etc.

For our study the datasets are collected from ethio telecom CRM application in .xlsx format. The data collected from January 1st till the end of January, and only CDR of a voice service is considered.

5.4 PARAMETER SELECTION

In this work Markov chain models used for describing the movements of UEs. Different user categories can be modeled by Markov model using a UE movement trace of a user as an input. Let us assume the user movement shown in Figure 5.4.2. The sequence is {

$1, 2, 3, 3, 3, 2, 2, 2, 4, 2, 4, 2, 2, 2, 2, 1, 5, 1, 1, 1, 1, 1, 2, 5, 1, 1, 1, 5, 1, 5, 1, 1, 2, 6, 6, 2, 2, 2, 2, 6, 2, 2, 2, 2, 2, 2, 2, 6, 4, 4, 4, 4, 7, 7, 7, 2, 2, 1, 5, 2, 2, 2, 2, 1, 1\}$. the corresponding typical user movement and markov model is described in Figure 5.4.1 ,Figure 5.4.2 respectively and the corresponding transition probability matrix is (P)

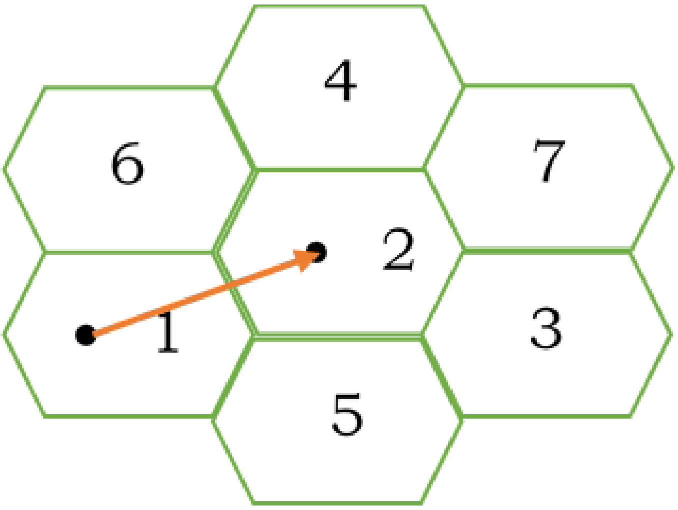


Figure 5.4.1: Typical movement of a user

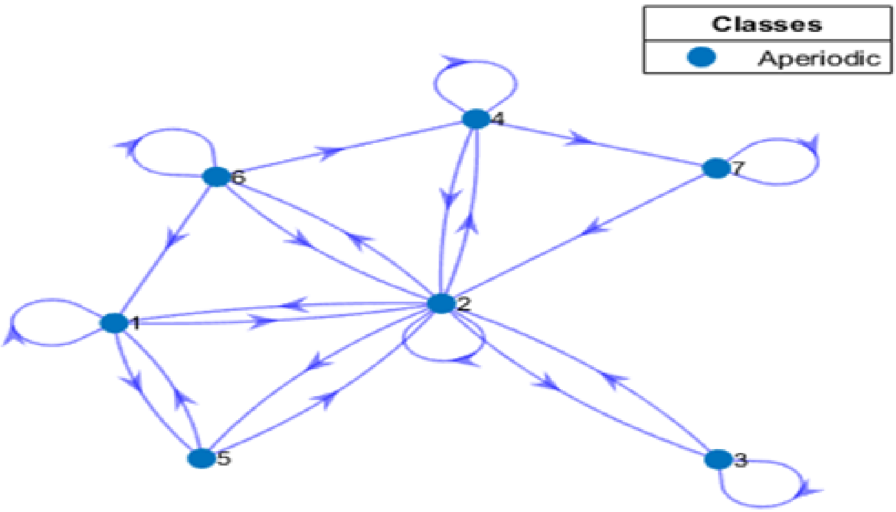


Figure 5.4.2: Markov model

$$P=\begin{bmatrix} 0.5 & 0.25 & 0 & 0 & 0.25 & 0 & 0 \\ 0.11 & 0.64 & 0.04 & 0.07 & 0.04 & 0.11 & 0 \\ 0 & 0.33 & 0.67 & 0 & 0 & 0 & 0 \\ 0 & 0.33 & 0 & 0.5 & 0 & 0 & 0.17 \\ 0.8 & 0.20 & 0 & 0 & 0 & 0 & 0 \\ 0.25 & 0.25 & 0 & 0.25 & 0 & 0.25 & 0 \\ 0 & 0.33 & 0 & 0 & 0 & 0 & 0.67 \end{bmatrix}$$

5.5 EVALUATION METRICS

The performance of a paging scheme characterized by three important performance parameters, they are

- Paging success rate
- Paging delay
- Bandwidth requirements

5.5.1 *Paging success rate*

Paging Success Rate(PSR) - It is the rate of successful page responses to the total number of page attempts in a registration area. It's calculated as: -

$$PSR = \frac{SuccessfulnumberofpagingontheAbisinterface}{MSC - InitiatedPagingRequests} \tag{5.10}$$

The higher value of Paging Success Rate (PSR) indicates a smaller paging delay and a better algorithm to locate the users. At normal condition paging success rate should be more than 80% [5], such as the MSC, RNC, NodeB and UE. If any part of the system is not functioning normally, the success rate of paging is affected.

X1 = N1/Np

X2 = N2/Np

Xr = Nr/Np

X1+X2+Xr = 1

Where

X1 = Ratio of first paging attempt

N1 = Successful paging on first attempt

Np = Number of paging

X2 = Ratio of second paging attempt

N2 = Successful paging on second attempt

Xr = Ratio of paging release

Nr = Number of paging release

5.5.2 *Paging delay*

Another parameter to measure paging performance, and it is the time elapsed between page request initiated and paging replay received. For better system performance and user experience this value should be taken as small as possible.

5.5.3 *Bandwidth requirements*

It is the amount of resources required to perform paging management. Paging load shares the available bandwidth with voice and data services. Since the number of subscribers are increasing exponentially, spectral efficiency is an essential parameter. When a paging load increase it reduce the available bandwidth and this will affect the system Quality of Service (QoS). The estimated bandwidth required for the different types of paging i.e. (Conventional Paging (CP), Static Profile Based Paging (SPBP) and Dynamic Profile Based Paging (DPBP)) is directly proportional to the number of cells paged[25]. The paging cost per polling cycle in Profile Based Paging (PBP) is Cost of Paging

$$CR2N = Npm \times Ncell \times CP(1 + X2) \tag{5.11}$$

$$CN2U = Npc \times Nn \times CP(1 + X2) \tag{5.12}$$

Also the paging delay, time duration between the paging request and paging success must be small, hence the user experience will not be affected.

$CR2N = Npm*Ncell*Cp\ (1+x2)$
Where
CR2N = Capacity of RNC to NodeB
Cpm = unique number of paging
Ncell = Number of cell paged
Cp = Required RNC to NodeB capacity per paging
X2 = Ratio of number of paging with second attempt
$CN2U = Np*Nn*CP(1+X2)$
Where
CN2U = Capacity of NodeB to User
Np = unique number of paging
Nn = Number of NodeB
Cp = Required RNC to NodeB capacity per paging
X2 = Ratio of number of paging with second attempt

6

RESULTS AND DISCUSSIONS

6.1 RESULTS

This chapter presents a mobility behavior of the three types of users at cell, cell site and grid level and performance evaluation of the three paging algorithms. In Figure 6.1.1 shows a state transition diagram of a less mobile user at the cell level. As shown in Figure there are 14 states and these are $(1, 2, 3, 4, 2, 2, 1, 1, 1, 1, 1, 1, 1, 5, 1, 6, 3, 7, 2, 1, 1, 3, 5, 6, 6, 6, 2, 2, 1, 1, 2, 6, 6, 2, 6, 3, 8, 7, 9, 10, 7, 9, 8, 10, 11, 11, 9, 9, 12, 13, 14, 11, 9, 8, 12, 13, 13, 13, 12, 13, 10, 10, 1, 10, 11, 3, 1, 6, 1, 1, 1, 1, 4, 6, 4, 4, 1, 3, 6, 6, 2, 2, 2, 1, 5, 6, 3, 5, 1, 5, 1, 1, 4, 1, 6)$. The total number of states the user vicell sited is smaller as compared to moderate and highly mobile users. A cell covers a smaller geographical area as compared to cell site and grid, the cell level transition diagram has the highest number of states as compared to cell site and grid level.

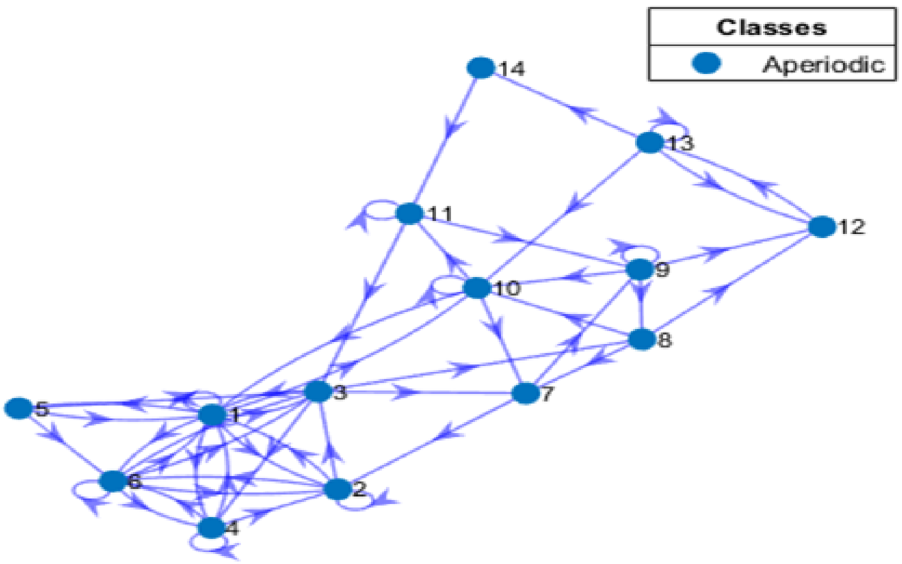


Figure 6.1.1: A state transition diagram (Less mobile) at a cell level.

Relatively a cell site covers more geographical areas as compared to a specific cell. Most of the time a cell site can have more than 3 cells, so when a user moves from one cell to other cells within the same cell site it does not consider it as state transition. Therefore, as shown in Figure 6.1.2 for a less mobile user a total number of state decrease by half as compared to a cell level.

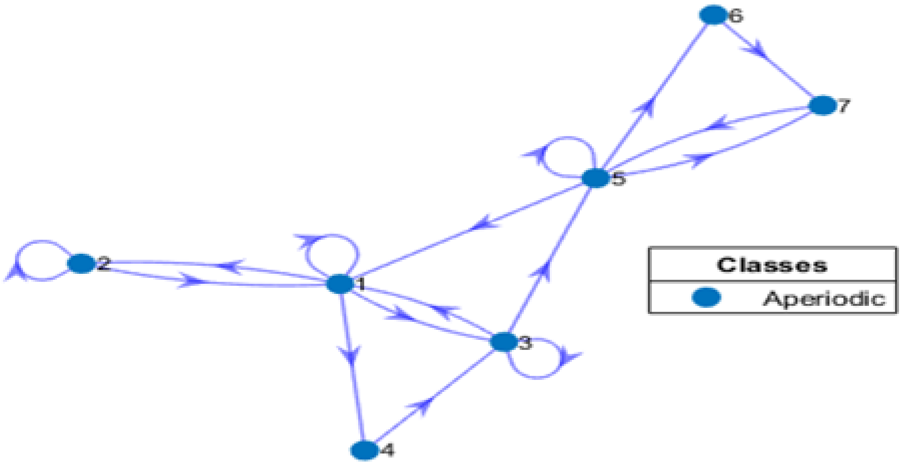


Figure 6.1.2: A state transition diagram (Less mobile) at cell site level.

Figure 6.1.3 shows a state transition diagram of a less mobile user at the grid level. A grid covered 2 x 2 km coverage area, and all cell sites in such coverage areas are considered as one. As shown in Figure there are 7 states. In this specific case, the number of states both at cell site and grid-level is equal. However, a grid covers more geographical area as compared to a cell site. Hence, at the grid level, it is expected that the total number of states less than the number of states at the cell site level. For moderate and highly mobile users the number of states between cell site and grid shows more significant deviation.

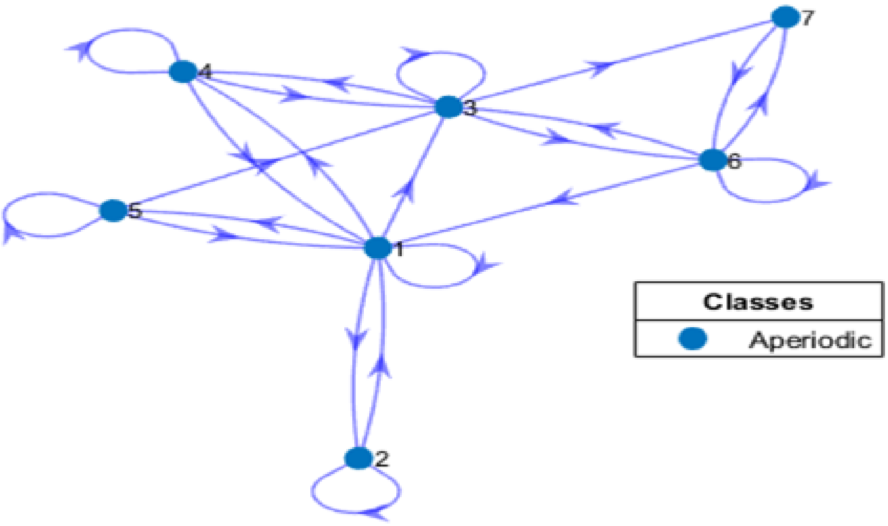


Figure 6.1.3: state transition diagram (Less mobile) at grid level.

Figure 6.1.4 shows a state transition diagram of a Moderate mobile user at the cell level. It is observed that the total number of the state at the cell level is 23. As compared to a less mobile user for a cell level, it has more number of states. As a result, it covers an area which is greater than less mobile user which means it move and vicell site more number of cells as compared to a less mobile user.

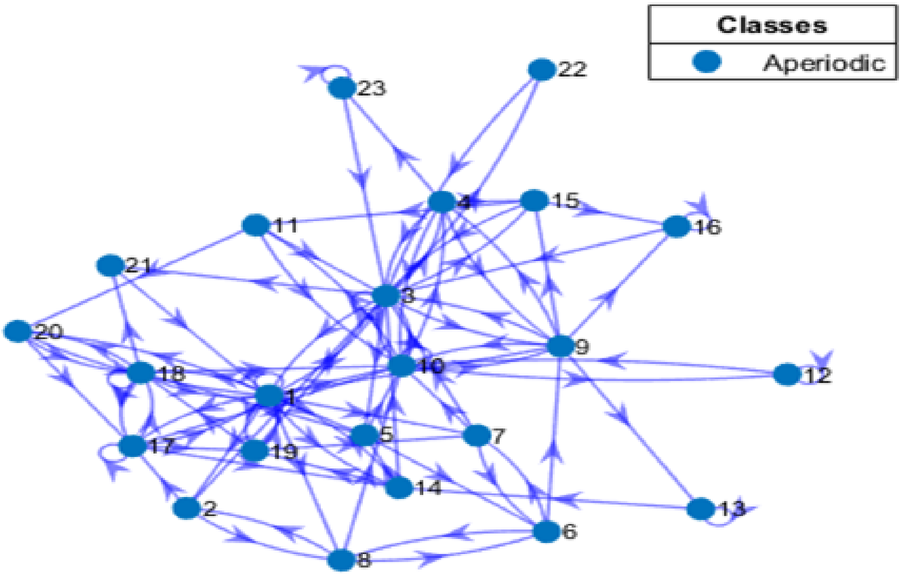


Figure 6.1.4: A state transition diagram (Moderately mobile) at cell level.

Figure 6.1.5 shows a state transition diagram of a Moderate mobile user at a cell site level. As shown in Figure there are 19 states. As described above for a cell level, a state transition diagram of a moderate mobile user has a higher number of a state as compared to less mobile users at the cell site level. The same is true for a moderate user at a gird level.

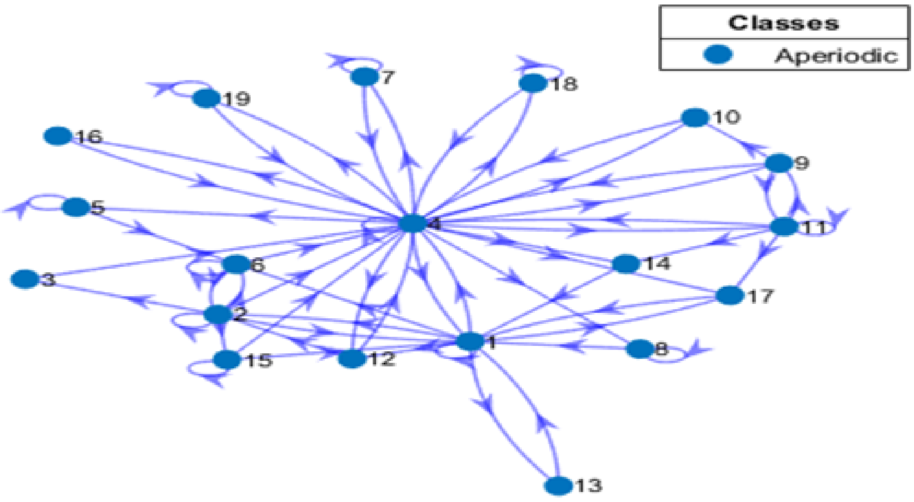


Figure 6.1.5: A state transition diagram (Moderately mobile) at cell site level.

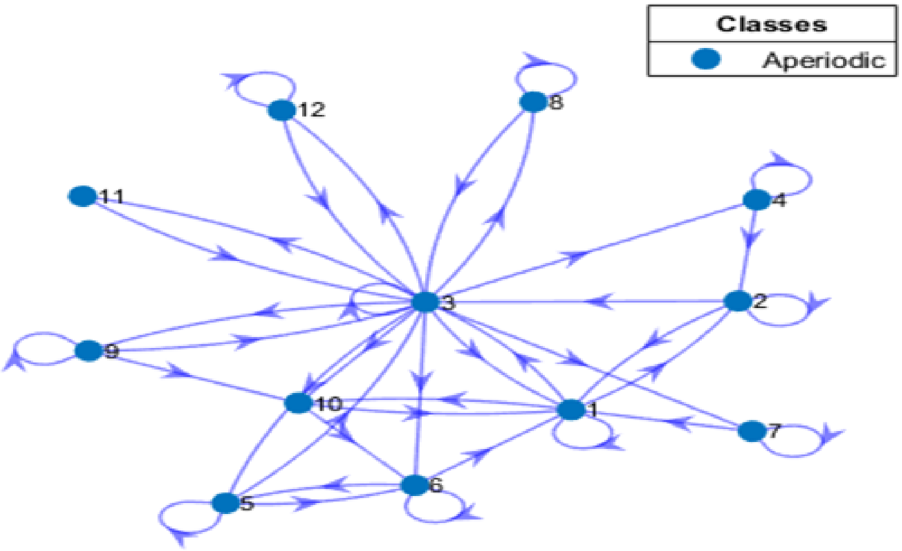


Figure 6.1.6: A state transition diagram (Moderately mobile) at grid level

A High mobile user, is a user which covers more geographical areas as compared to both moderate and less mobile user. As Figure 6.1.7 up to 6.1.9 shown it has 31, 20,19 number of states for cell, cell site, and grid-level respectively. It is higher than a moderate and less mobile user.

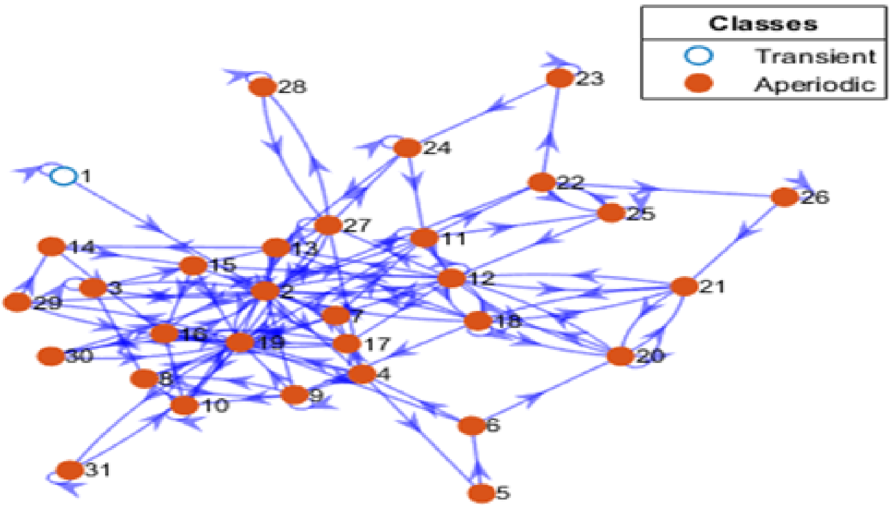


Figure 6.1.7: A state transition diagram (Highly mobile) at cell level.

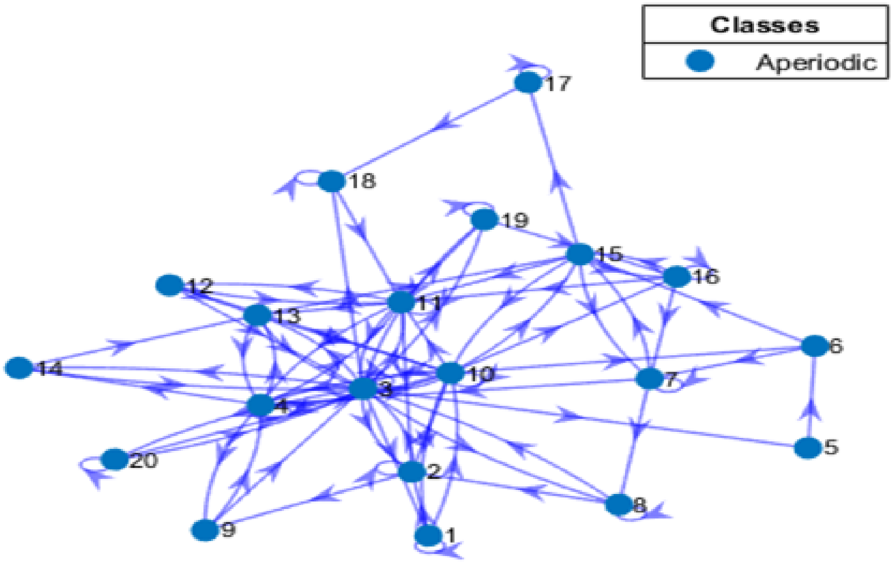


Figure 6.1.8: A state transition diagram (Highly mobile) at cell site level.

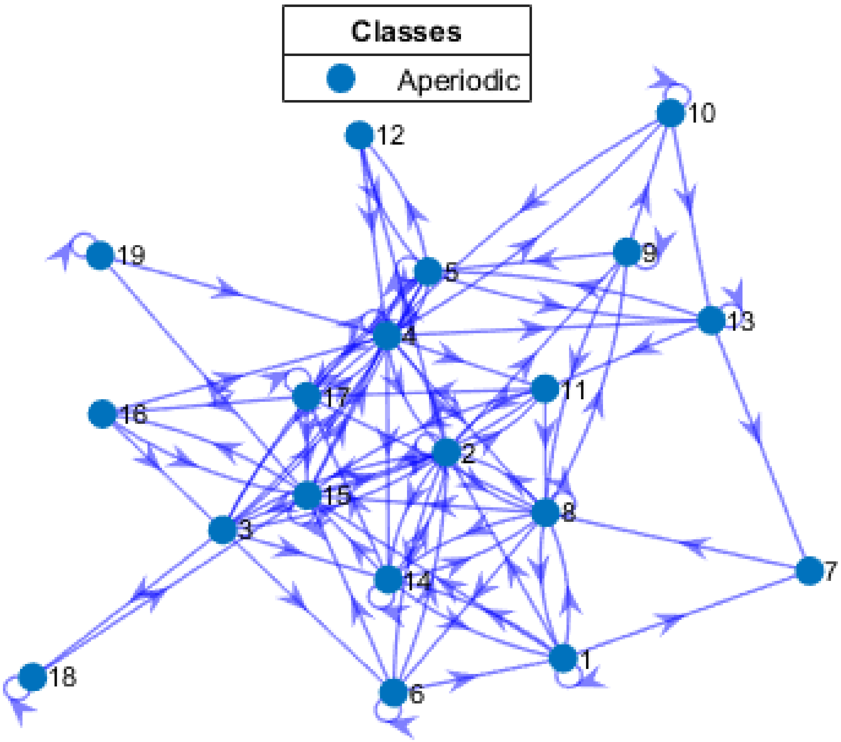


Figure 6.1.9: A state transition diagram (Highly mobile) at grid level

6.2 DISCUSSION

CDR data samples over a period of 1 month collected from ethio telecom CRM system were simulating with MATLAB using dynamic algorithm. For the simulation experiment 3 weeks' data are used for training the system and other 1-week data are used for validation purpose. The paging success rate of different mobile users obtained on Figure 6.1.10 and Figure 6.1.11.

To evaluate the performance of each paging algorithm, as shown in Figure 6-1-10 and Figure 6-1-11 in the case of less mobile users we got an average success rate of 94.75 % for CP, 85.5 % for a static paging algorithm, and 83 % for a dynamic paging algorithm. Their success rate is almost equal, because, less mobile users are the most inactive users and most of the time they confined to a specific geographical area. Whereas, for moderate mobile users, as shown in Figure 6-1-10 and Figure 6-1-11, we got a an average success rate of 94.75% for CP algorithms, 82.5 % for static paging algorithms and 69 % for a dynamic algorithm. Since the users move more geographical area and they have a higher movement frequency, it is relatively more difficult to predict and model their mobility trace as compared to less mobile users. That is why such users have less success rate as compare to less mobile users. High mobile users have an average success rate of 94.75% for a CP algorithm, 78.25 % for static paging algorithms, and 58 % for dynamic paging. The success rate of high mobile users is worst than moderate users. Because high mobile users have a higher mobility frequency than a moderate one. So it is more difficult to predict and model their mobility trace than a moderate one.

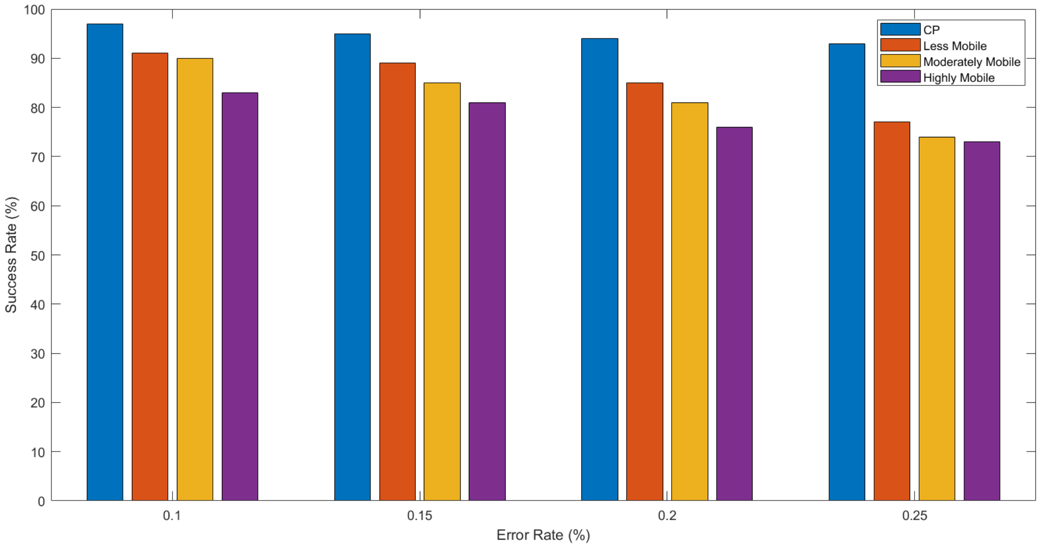


Figure 6.2.1: Paging success rate for static profile based paging on different users

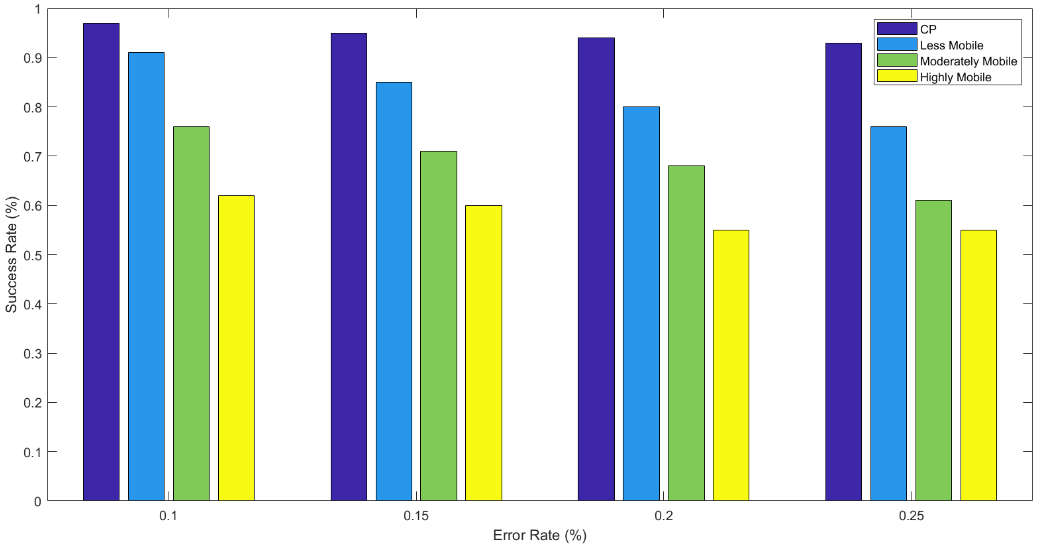


Figure 6.2.2: Paging success rate for dynamic profile based paging on different users

Whereas, in terms of bandwidth utilization as shown in Figure 6.2.3 for less mobile user conventional paging algorithm requires 2.9 times,6.7 times of the static and dynamic algorithms respectively.In addition to these a static algorithm requires 2.3 times of the dynamic one. In case of moderate mobile conventional paging algorithm requires 1.7 times,2.9 times of the static and dynamic algorithms respectively.And a static reqires 1.7 times of dynamic one. Finally for highly mobile users conventional paging algorithm requires 1.1 times,2.7 times of the static and dynamic algorithms respectively.And static requires 2.7 times dynamic one. This is because bandwidth utilization by the paging command is directly proportional to the total number of cells paged during call arrival. As a result, based on the two metrics, for less mobile users dynamic paging algorithm is most preferable than a conventional and static one.

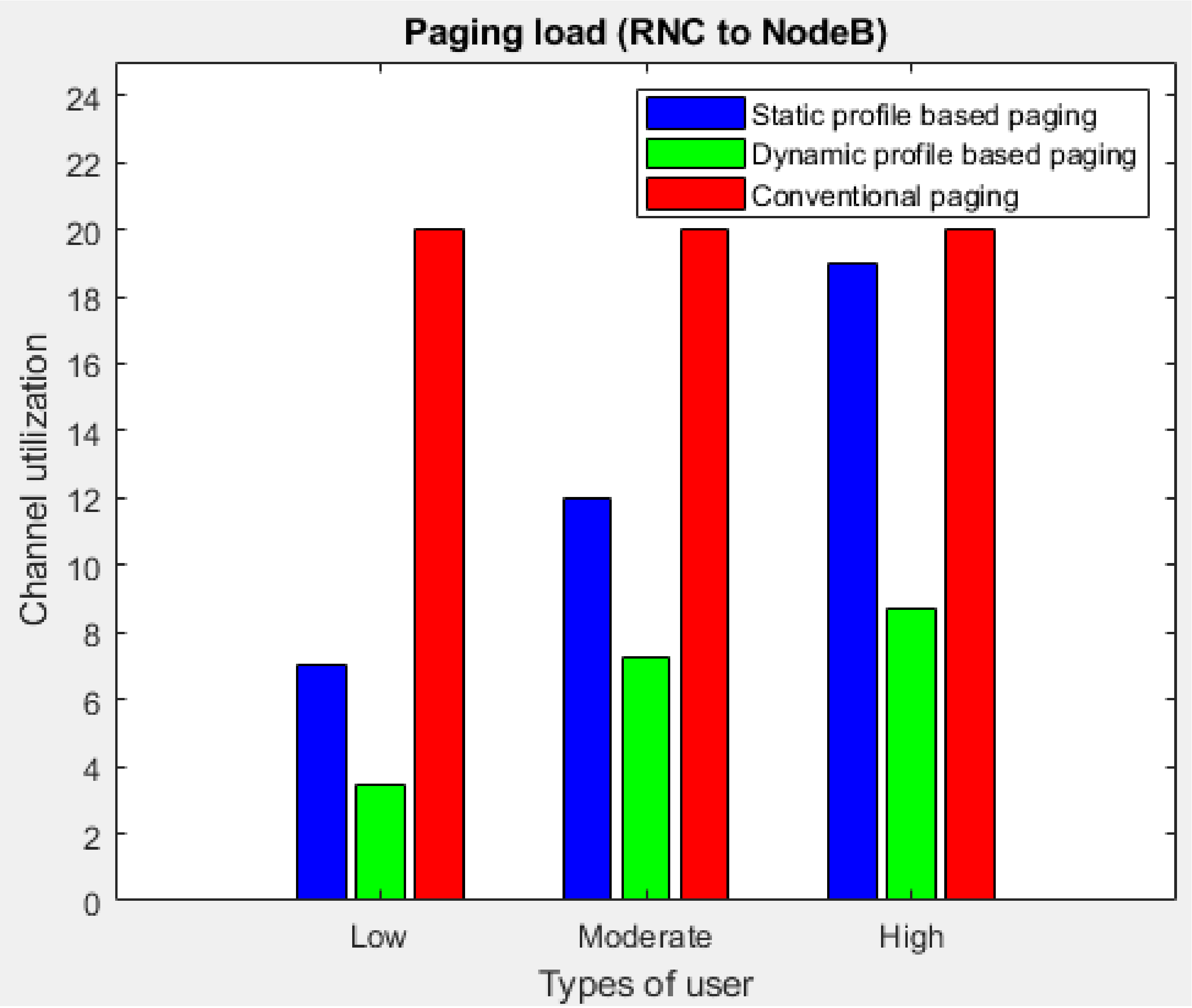


Figure 6.2.3: Paging required capacity for different user

7

CONCLUSION AND FUTURE WORK

7.1 CONCLUSION

In this thesis, we have seen different paging techniques for a cellular system. paging is classified into three based on the procedures followed to locate the user. These three types are conventional paging, sequential paging, and profile-based paging. In conventional paging, the entire registration area is paged at once. It is also called broadcast paging. The paging success rate in normal conditions remains high but, this type of paging needs a large amount of bandwidth. Another type of paging is sequential paging. As the name shows a search of the UE or paging is done in a sequential way i.e. one after the other. The cells in a registration area are grouped into smaller groups and these groups are named as PAs. To decrease the paging delay, the first registration area is created with a very high probability of finding the user for optimal paging delay and bandwidth conservation. Sequential paging breaks the paging load over different PAs. In profile based paging it is a modified version of sequential paging. It minimizes the bandwidth requirement and improves users locating capabilities, by considering other user's behavioral patterns in addition to a user′s probability of presence in a certain cell like in the sequential paging. This approach relies on the fact that a user′s behavior is predictable.

Various researches are done on cellular location management and it is a bandwidth-intensive activity which generates most of the unnecessary spectral overhead, and at busy hours, MSC is getting over-flooded with paging request. Currently, most operators deploy purely static location management, i.e. all users in a given region have the same location management characteristics regardless of their movement and call arrival rate. We present a profile based paging algorithm for minimizing bandwidth utilization associated with paging. Profile-based paging utilizes the mobile user mobility pattern to reduce signaling load due to paging for an efficient location management system. And in this work, we compared the two widely used techniques, conventional based paging and profile-based paging. In this comparison mostly we found that a profile based paging scheme outperforming for less mobile users because it increases the efficiency of bandwidth utilization with slight or no effect in overall paging success rate compared to conventional paging. It is also efficient for this category of users compared to moderate and highly-mobile users.

In a comparative study made between the conventional method and profile paging(static,dynamic) dynamic profile paging proved to be 5 times more bandwidth efficient compared to the conventional paging and 2.5 times more bandwidth efficient compared to the static profile based paging. The optimization offered is higher for users with less movement. The algorithm is simulated with a Matlab simulation by using actual user data and the result obtained is hopeful and can reduce the bandwidth utilization of the paging techniques to a considerable level.

7.2 FUTURE WORK

As future work, we suggested to study the proposed technique by incorporating more parameters into the profiling of the user.

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