DYNAMIC TECHNIQUE FOR OPTIMIZING UNIVERSAL MOBILE TELECOMMUNICATION SYSTEM ACTIVE SET

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DYNAMIC TECHNIQUE FOR OPTIMIZING UNIVERSAL MOBILE TELECOMMUNICATION SYSTEM ACTIVE SET

By

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DECLARATION

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النـاسُ مِن جِهَةِ التِمثالِ اَكفاءُ أَبو هُمُ آدَمُ وَالأُمُ حَوّاءُ

نَفسٌ كَنَفسٍ وَأَرواحٌ مُشاكَلَة وَأَعظُمٍ خُلِقَت فيها وَأَعضاءُ

وَإِنَّما أُمَّهاتُ الناسِ أَوعِيَةٌ مُستَودِعاتٌ وَلِلأَحسابِ آباءُ

فَإِن يَكُن لَهُمُ مِن أَصلِهِم شَرَفٌ يُفاخِرونَ بِهِ فَالطينُ وَالماءُ

ما الفَضلُ إِلا لِأَهلِ العِلمِ إِنَّهُمُ عَلى الهُدى لِمَنِ اِستَهدى أَدِلّاءُ

وَقَدرُ كُلِّ اِمرِئٍ ما كاَن يُحسِنُهُ وَلِلرِجالِ عَلى الأَفعالِ اسماءُ

وَضِدُّ كُلِّ اِمرِئٍ ما كانَ يَجهَلُهُ وَالجاهِلونَ لِأَهلِ العِلمِ أَعداءُ

وَإِن أَتَيتَ بِجودٍ مِن ذَوي نَسَبٍ فَإِنَّ نِسبَتَنا جودٌ وَعَلياءُ

فَفُز بِعِلمٍ وَلا تَطلُب بِهِ بَدَلاً فَالناسُ مَوتى وَأَهْلُ العِلمِ أَحياءُ

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TABLE OF CONTENTS

Page

CHAPTER 4: SIMULATION RESULTS AND DISCUSSION

LIST OF TABLES

TABLE OF FIGURES

ABBREVIATIONS

1G	First Generation
2G	Second Generation
3G	Third Generation
3GPP	Third Generation Partnership Project
AAL2	ATM Adaptation Layer 2
AS	Adjacency Set
ATM	Asynchronous Transfer Mode
BS	Base Station
CDMA	Code Division Multiple Access
CN	Core Network
CPICH	Common Pilot Channel
CRS	Cell Re-selection
CS	Cell Selection
DAS	Dynamic Active Set
DCS	Dynamic Candidate Set
DL	Downlink
DR	Dynamic Relationship
DRNS	Drifting RNS
ETSI	European Telecommunication Standard Institute
DS-CDMA	Direct Sequence CDMA
EURANE	Enhanced UMTS Radio Access Network Extensions

GGSN	Gateway GPRS Support Node
GMSC	Gateway MSC
GPRS	General Packet Radio Service
GSM	Global System for Mobile Telecommunication
HHO	Hard Handover
HO	Handover
HSDPA	High-Speed Downlink Packet Access
IP	Internet Protocol
LA	Location Area
LR	Loss Ratio
MSC	Mobile Switching Center
Node Bs	Set of Base Station
NS2	Network Simulator
OPNET	Optimal Network Simulator
PCR	Packet Consumption Ratio
PDR	Packet Delivery Ratio
PRR	Packet Reduction Ratio
PS	Packets Switched
QoS	Quality of Service
RA	Routing Area
RAB	Radio Access Bearer
RANAP	Radio Access Network Application Part
RAT	Radio Access Technology

RLC	Radio Link Control
RMI	Remote Method Invocation
RNC	Radio Network Controller
RNS	Radio Network Subsystems
RPC	Remote Procedure Call
RRC	Radio Resource Control
SCCP	Signal Connection Control Part
SGSN	Serving GPRS Support Node
SHO	Soft Handover
SRNS	Serving RN
UE	User Equipment
UL	Uplink
UMM	UMTS Mobility Management
UMTS	Universal Mobile Telecommunication Services
URA	UTRAN Routing Area
UTRA	UMTS Terrestrial Radio Access
UTRAN	UMTS Terrestrial Radio Access Network
WCDMA	Wideband Code Division Multiple Access
WLAN	Wireless Local Access Network

Cara Dinamik Pengoptimuman Set Aktif Sistem Telekomuikasi Selular Menyeluruh

ABSTRAK

Dalam tesis ini, High-Speed Down Load Packet (HSDPA) diselidik dengan menggunakan Nisbah Kehilangan Paket (Packet Loss Ratio) dan Nisbah Penggunaan Paket (Packet Comsumption Ratio), disebabkan perubahan bilangan sel dalam set aktif. Berdasarkan dapatan tesis, apabila mekanisme HSDPA dilaksanakan dengan set aktif daripada tiga sel, tiada paket data yang hilang. Walaupun bilangan paket yang dihantar (packets sent) kepada sel bukan – pelayan (non-serving cell) adalah lebih daripada bilangan sebenar paket yang diterima (packets received) oleh User Equipment (UE), namun paket tersebut tidak digunakan. Oleh itu, mekanisme ini menyebabkan sumber overhed. Pendekatan baru kami, yang dikenali sebagai Set Aktif Dinamik (Dynamic Active Set, DAS), dicadangkan sebagai suatu mekanisme terbaik untuk menentukan bilangan sel yang optimum dalam set aktif. Secara dinamik, DAS bergantung pada lokasi UE, semasa pergerakannya. Sesuatu lokasi boleh menjadi kawasan-tindanan (overlapping region) di antara dua atau tiga sel, atau boleh juga menjadi kawasan bukan-tindanan (non-overlapping region). DAS mengurangkan penggunaan paket data melalui penskalaan bilangan sel bukan-pelayan dalam sel aktif. Berdasarkan dapatan simulasi, DAS menjamin penyampaian kualiti paket sebagaimana dalam HSDPA. Di samping itu, DAS juga mengurangkan penggunaan nisbah paket. Sebagai kesimpulannya, DAS mampu mengurangkan total paket yang digunakan oleh HSDPA sebanyak 33.64%, yang lebih baik daripada HSDPA.

Dynamic Technique for Optimizing Universal Mobile Telecommunication System Active Set

ABSTRACT

In this thesis, an investigation of High Speed Down Load Packet (HSDPA) is made with Packet Loss Ratio and Packet Consumption Ratio, which is caused by changing the number of cells in the active set. According to the results obtained in this thesis, when the HSDPA mechanism is implemented with an active set of three cells, it guaranteed no loss in data packets. Although the number of packets sent to the non-serving cells were more than the actual number of the packets received by User Equipment (UE), these sent packets were unused. Therefore, this mechanism caused overhead of resources. Our new approach, named Dynamic Active Set (DAS), is proposed as a better mechanism to determine the optimal number of cells in the active set dynamically. The dynamicity in DAS depends on the location of UE during its movement. A location can be an overlapping region between two or three cells, or it can be a non-overlapping region, as well. DAS has reduced the consumption in data packets through scaling down the number of non-serving cells in the active set. Based on The results depicted by the simulation, DAS guaranteed delivering packets quality as in HSDPA. Moreover, DAS produced a reduction in consumption packet ratio. Finally, DAS reduced the total packets consumed by HSDPA in 33.64%, which is better than HSDPA.

CHAPTER 1

INTRODUCTION

1.1 Introduction

The technological development between 2000 till date has affected our lives in a great deal. Technologies have impacted all aspects of our lives; it had changed everything and changed the face of life in many fields as well as our society. One of the most important fields that have witness a breakthrough is wireless communication (Phil, R. & James, K. 2006). With the advancement and modern techniques in wireless communication and computer technologies, mobile communication have been providing a more versatile, portable and affordable networks. Its services revenues totaling $1.2 trillion in 2004 in the U.S. between 1999-2006, the number of users of mobile communication networks has increased rapidly (30% -35%), where the number of mobile users is expected to be over 1.8 billion at year 2010 (Katia *et al*, 2007; Wadekar and Fagoonee, 2006). These huge numbers of present and future users technologies is associated with problems and difficulties to both manufacturers and the users. The convenience of communication does not only bring a new set of technical problems, but also raises a new class of interesting applications, especially in wireless communication like WI-FI and WIMAX. This is due to the change in communication from single - medium oriented into multimedia communication such as image, computing data, internet services, e-commerce and games (Iftikhar *et al*, 2007).

These new development and the advanced techniques and styles in multimedia communication require new data services that are highly bandwidth consuming. This leads to higher data rate requirements for future network systems. Universal Mobile Telecommunication System (UMTS) has played an important role in achieving these requirements in solving the difficulties and making it easy for the user to use these techniques (Yuan *et al*, 2007).

Mobile networks have become the platform that provides leading-edge Internet services, for instance a person can solve problems in any place without any need to go to his office or to travel, just by using his mobile phone or laptop. These services include both common voice services as well as multimedia and integrated data services (Pang *et al*, 2004). stated that, integration of the Internet Protocol (IP) with Third-Generation (3G) wireless communication through the UMTS All-IP network was proposed by Third-Generation Partnership Project (3GPP), as next-generation in the telecommunications networks (Phil & Jams, 2006).

The UMTS All-IP network is a new fascinating technology that supports users with a high level of performance in communication and information transfer as well as in security (Kun *et al*, 2006; Dekleva *et al*, 2007). It allows long time connections without waste of time, allow automatic access to the services of low-cost and high-capacity mobile communications with global roaming capabilities. There are several technologies that provide continuous access to mobile devices in different types of wireless networks, whether the device is stationary or mobile. This is called Handover (HO) (Lau, 2005; Abdel-Ghaffar *et al*, 2006).

UMTS Mobility Management (UMM) protocol supports mobility management functionality. Activities that can be seen in using this technology such as attach, paging, allocation management update and detach are defined for Packet Switching by different levels that include update Routing Area (RA), UMTS Terrestrial Radio Access Network RA (URA) update area and cell update area (Lin *et al*, 2001). The RA of an User Equipment (UE) is tracked by the Serving General Packet Radio Service (GPRS) Support Node (SGSN). The URA and the cell of an UE are tracked by the UMTS Terrestrial Radio Access Network (UTRAN).

The HO can be classified into two levels; HO SGSN level and HO UTRAN level. This implies that every Location Update Area is HO but not every HO is a Location Update Area. HO is divided into two main types, Hard Handover (HHO) and Soft Handover (SHO). It was proposed when Code Division Multiple Access (CDMA) technology was introduced in 3G. The focus of this thesis is on the active set of cells during the SHO. When a user accesses for services in UMTS network, UE communicates with all cells in an active set. That is the list of cells that are presently having connections with the mobile. This process will affect the transmission speed due to interference, as seen in Figure 1.1. The 3GPP (3G TR25.950, 2001) proposes a mechanism to support High-Speed Downlink Packet Access (HSDPA) (3GPP TR25.950, 2001; 3GPP TR25.848, 2001; 3GPP TR25.855, 2001), while UE selects one cell only to communicate with for high-speed downlink transmission. This is called the serving cell, which is involved in the active set, where the active set consists of three cells. The other two cells are referred to as the non-serving cells. The serving cell is selected by the fast cell selection mechanism (3G TR25.848, 2001), based on the common pilot-channel that received signal code power measurements of the cells in the active set.

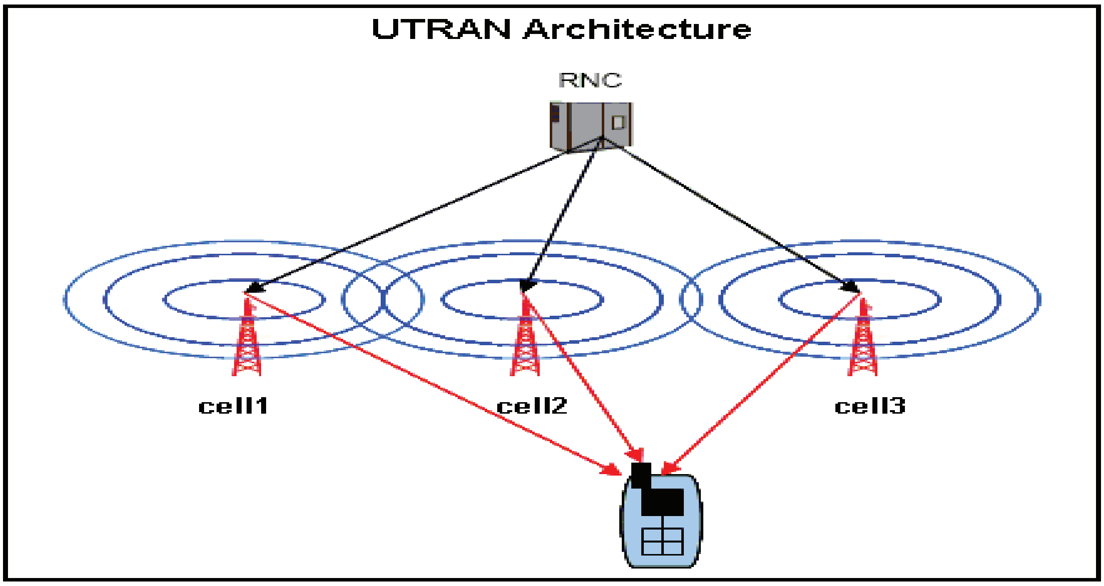

Figure 1.1: Network Architecture of Standard UTRAN (Ghadialy, 2004)

In HSDPA, the Radio Network Controller (RNC) sends the packet frames to the cells in the active set. For the serving cell, the packet frames are forwarded to the UE, as seen in Figure 1.2. on the other hand, every non-serving cell in the active set queues the packet frames in a buffer. If the link quality between the serving cell and the UE degrades below some threshold, the UE selects the best cell in the active set as the new serving cell. Since the non-serving cells do not send packet frames to the UE, their buffers may overflow. Therefore, the interference within a cell is potentially decreased, and the system capacity is increased. Several feasibility studies have been contributed by HSDPA (Jeon *et al*, 2000; Morimoto *et al*, 2002).

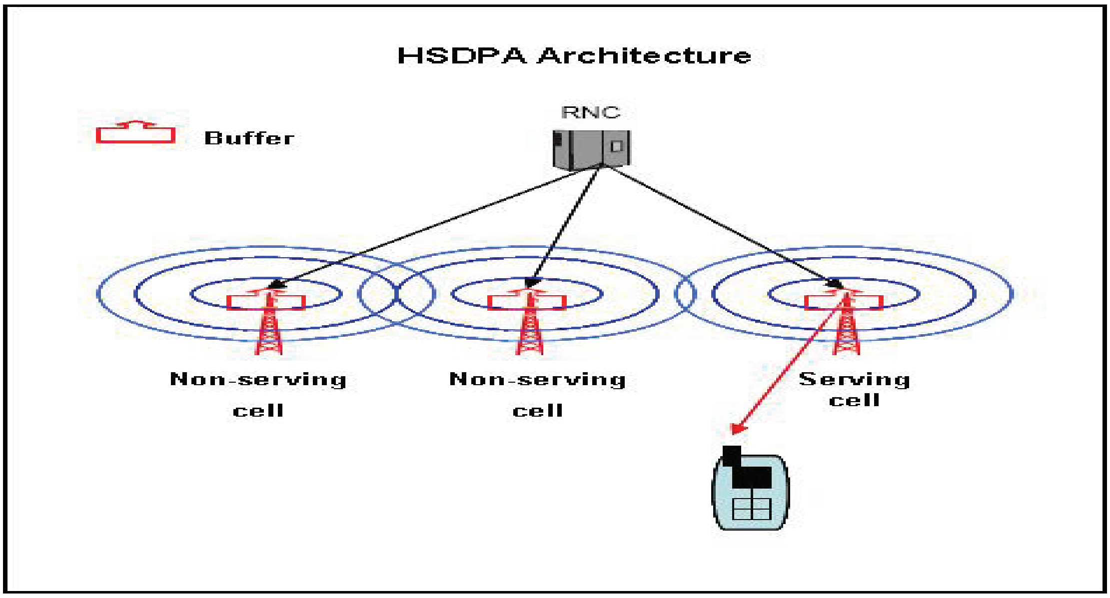

Figure 1.2: Network Architecture of HSDPA (Ghadialy, 2004)

Some schemes were proposed to improve signaling over head. In this thesis deferent approach for solving the problem of decrease signal over head in active set in UMTS network is introduced.

1.2 Problem Statement

In standard UTRAN (3G TS25.430, 2001), there are three cells in the active set. Multiple paths exist between the UE and all cells in the active set. While in HSDPA, the radio network controller RNC sends the packet frames to the cells in the active set and the serving cell forwards the packet frames to the UE. In the non-serving cells, the packet frames are queued in a buffer in order to ensure that no packet is lost if the link quality degrades below some threshold.

The size of the active set is static. This standardization does not take into account the number of cells in an active set in different cases. When implementing soft handover it is believed that the size of the active set should be dynamic to avoid extra resource consumption and increased signaling that comes with unnecessary number of cell.

1.3 Objectives

The objectives of this thesis are as following:

1. To investigate the optimal number of cells in the active set in different scenarios of UE movement, taking into consideration the reduction of the packets number that may be lost, and insure that no overflow occurs.
2. To avoid consume extra resources caused by the non serving cells.

In addition, a study of the soft handover effects on the downlink direction of Wideband Code Division Multiple Access (WCDMA) networks is carried out, leading to a new method for optimizing soft handover proportionally with the size of the active cell, which is dynamically determined in accordance to the location of UE.

1.4 Contributions

The contributions of this research are:

1) Designing and implementing the proposed scheme to control the size of the active set dynamically, relevant to the location of UE, and using Java language.

2) Performance modeling analysis of the proposed scheme and comparing it to existing schemes.

1.5 Scope of the Study

In UMTS, the bit rate of the wireless traffic in the downlink is much heavier than that in the uplink. Therefore, the downlink is more likely to be the bottleneck of the system. For this reason our work will focus on the downlink packet in SHO.

1.6 Research methodology

This section will discuss the main points related to the methodology parts of this research. These points include the research procedure, the theoretical framework and the research design.

1.6.1 Research Procedure

The procedure of this research comprises of different steps, there are three high-level steps, the first step is investigation of packet loss, consumption of packet within the active set in different speeds of UE movement.

The second step is development of a dynamic active set cell selection (CS)/reselection (CRS) as a new method is proposed for optimizing SHO proportional with the size of active set dynamically according to UE location.

The final step is prove the validate of proposed model by comparing between the result of original model (HSDPA) and the proposed model (DAS), and show the positive properties of DAS over the original model. Figure 1.3 shows the procedure's steps of this research.

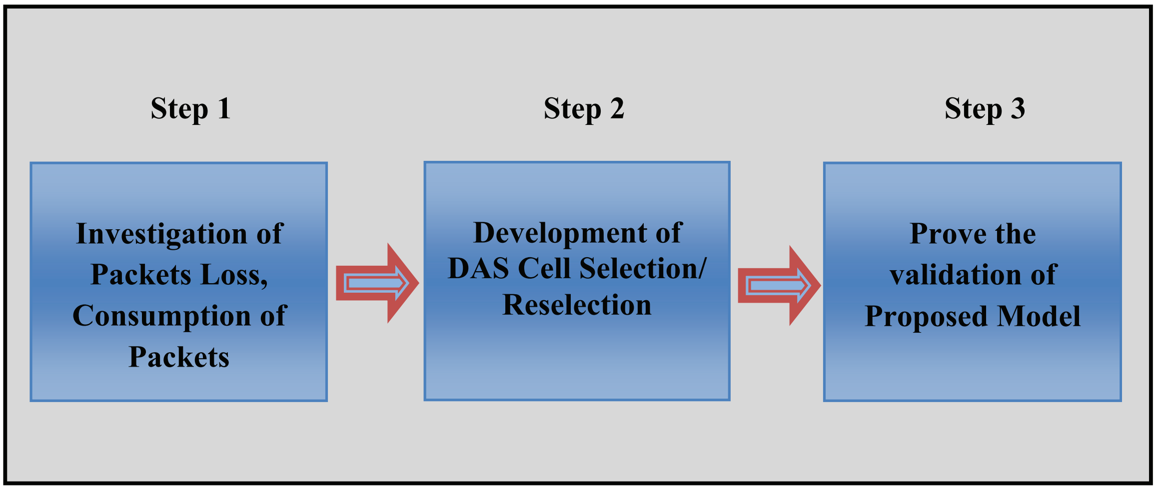

Figure 1.3: Research Procedure

1.6.2 Theoretical Framework

UMTS is the third generation system, it provides vital link between today's multiple GSM system and the ultimate worldwide system for all mobile telecommunication. A simple architecture of UMTS is divided into three main components: the air interface, UTRAN, and Core Network. The Base Station and the Radio Network Controllers are connection known as the UTRAN.

There are several concepts discussed in chapter two for example the mobility management, location updating, handover, and cell selection/reselection schemes. The cell selection is response for finding a cell and for the mobile to site on, the cell reselection is response for insures the quality of service. From this point the method of this research is generated.

1.6.3 Research Design

This section will discuss the attributes that used in the research design. These attributes are: purpose of the study, type of investigation, study setting and its time horizon. The study purpose in this thesis is case study since the new method support the qualitative in nature. To prove the correctness, the methodology is conducted by implementing steps to apply the DAS technique.

The investigation of this thesis is "Causal" because the proposed model is changing the original model by adding new technique over the HSDPA. The study's setting was a "Lab Experiment" since it presented by creating new technique that will solve the static size in active set and the consumption of packet within the active set by making the size of active set dynamic during the UE movement across the active set. The time horizon for this research is a "Cross Sectional Studies", since we gather data at one time for each experiment.

1.7 Organization of the Thesis

This thesis is structured as follows: In addition to the introduction chapter, there are four other chapters. Chapter 2 presents an overview of Soft handover, and discusses the existing schemes that are relevant to mobile network and may assist in conducting of this research. Chapter 3 presents research methods and approaches employed throughout this thesis. It also presents a new scheme based on dynamic procedure to determine the size of the active set, which involves explanation of the simulation model. Chapter 4 discusses and explains the performance modeling analysis proposed along with other schemes that involve the simulation experiments. Finally, Chapter 5 draws conclusions and suggests future work for this research area.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter an overview of UMTS architecture is described. Next, this chapter focuses on the handover types in 3G-UMTS for Packets Switched (PS) services. The description of handover technologies in older systems based on circuits switched is ignored. Hence, at first, the background of mobility management is introduced. Then, the measurements, principles, and features of Soft Handover (SHO) are presented. In addition, this chapter introduced the different Cell Selection (CS) and Reselection (CR) schemes. Finally, the SHO algorithms IS-95A and UMTS Terrestrial Radio Access (UTRA) are briefly explained.

2.2 UMTS Architecture

UMTS is the third generation system promoted by European Telecommunication Standard Institute (ETSI) and provides vital link between today's multiple GSM systems and the ultimate single worldwide system for all mobile telecommunications, International Mobile Telecommunications-2000 (IMT-2000). It is also referred to as wideband code division multiple access (W-CDMA) and is one of the most significant advances to the evolution of telecommunications into 3G networks. It will address the growing demands of the mobile and Internet applications in the overcrowded mobile communications sky. It will increase the network speeds and establishes a global roaming standard (Cauwenberge, 2003).

In order to express the mobility management schemes of a UMTS network, the researchers shall introduce its network elements. A simplified architecture of a UMTS system is shown in Figure 2.1. UMTS is divided into three main components: the air interface UE, UTRAN, and Core Network (CN), with the corresponding interfaces among them (Moustafa *et al*, 2005). The CN, which is responsible for connecting UMTS to external networks, provides functionalities of switching calls for voice communications, and PS services for data connections.

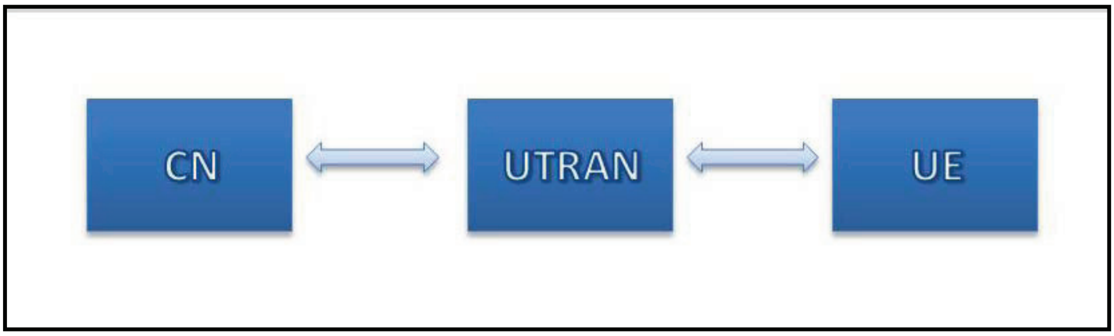

Figure 2.1: A Simplified Architecture of UMTS System

The Base Stations (BSs) and the Radio Network Controllers (RNCs) are collectively known as the UTRAN (Wardlaw, 2005). From the UTRAN to the CN, the RNC is responsible for handling of radio resources of UTRAN, Node B is the lowest element of UTRAN, which connects to UE directly. RNC will make a decision where the traffic will be transmitted. Packet traffic is sent to a new component, SGSN and then to the

Gateway GPRS Support Node (GGSN). The functions of the GGSN are very similar to the normal IP gateway, which transfer the receiving packets to the appropriate Internet (Lo *et al*, 2006). On the other hand, if there is a voice call from a subscriber, the RNC will transmit the traffic to the Mobile Switching Center (MSC). If the subscriber is authenticated before, the MSC switches the phone call to other MSC. When the called ends, there is another operation that follows. This operation is beyond the scope of this thesis. The call will be switched to the Gateway MSC (GMSC) if the called end is in the public fixed phone network. The UE is the terminal of UMTS. It interfaces with radio interface of UTRAN and user applications (3GPP TR23.821, 2000). A diagrammatic illustration of the UMTS's architecture is shown in Figure 2.2.

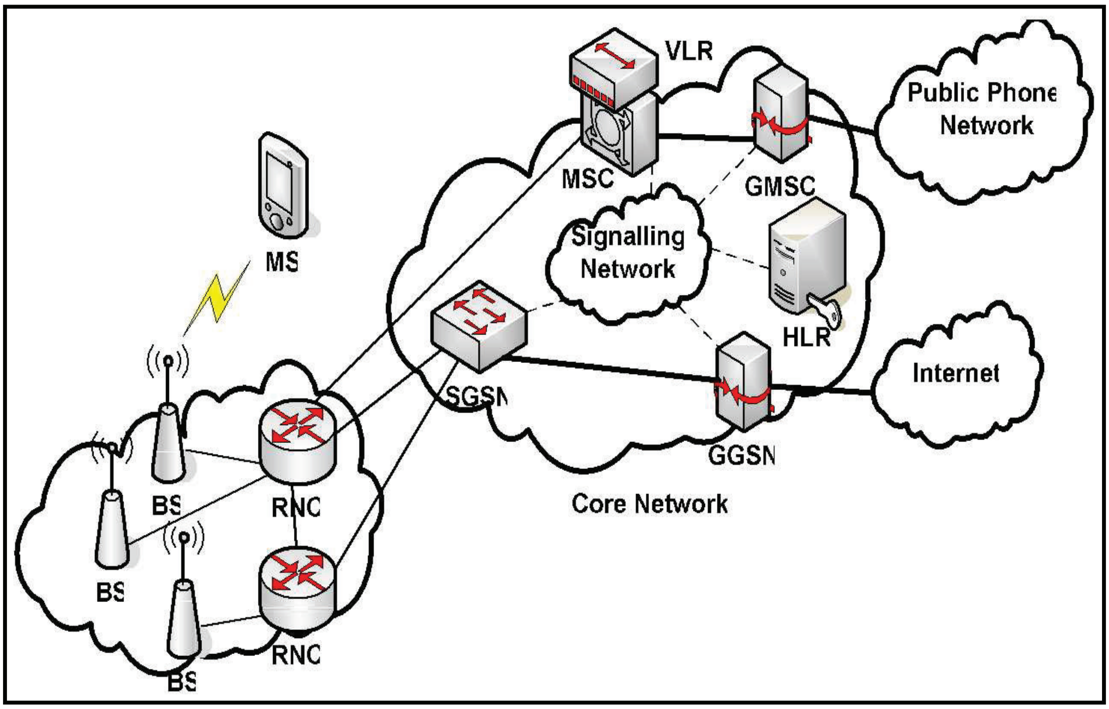

Figure 2.2: UMTS Architecture (3GPP TR23.821, 2000)

The components that compose UTRAN are the Radio Network Subsystems (RNS). A UTRAN contains one or more RNS, each of which is connected to the Core Network respectively. A RNS can be divided further into two entities: RNC and Base station called Node B in standards. One RNS contains only one RNC and one or more Node B (Mackaya *et al*, 2002). Figure 2.3 shows the intra-structure of UTRAN

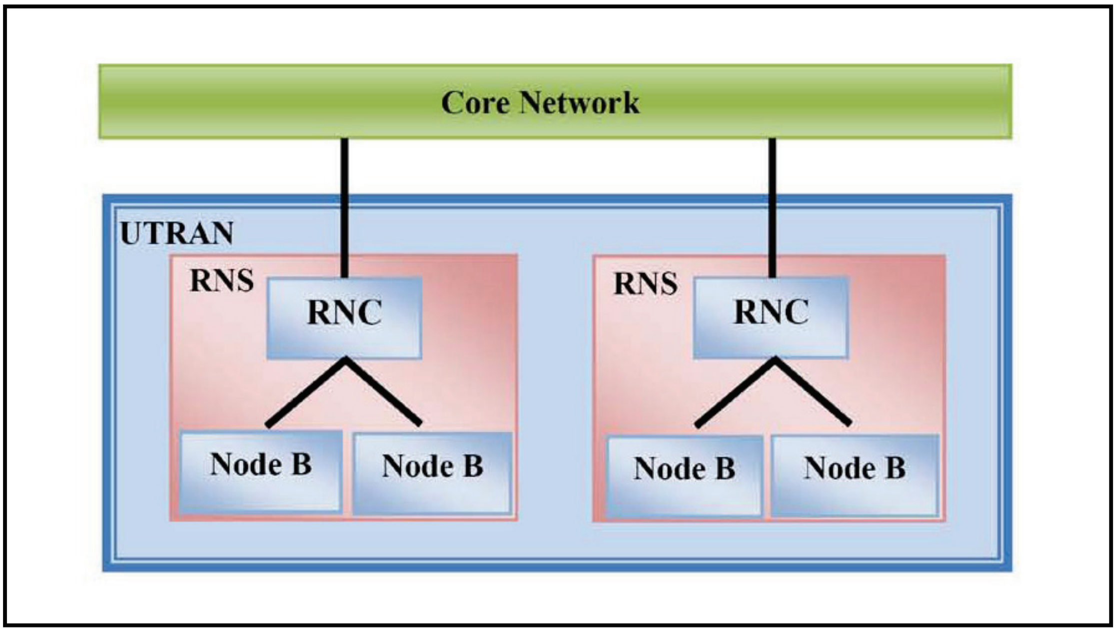

Figure 2.3 UTRAN Architecture (Mackaya et al, 2002)

The RNS is responsible for the resources and transmission/reception in a group of cells. For each connection between an UE and the UTRAN, there exists a RNS, namely Serving RNS (SRNS) to control the establishment and the release of specific radio resources to this connection. If the connect state changes because of the move of UE, the connection may be handed into a different RNS, namely Drifting RNS (DRNS) (Mackaya *et al*, 2002).

2.3 Concept of Mobility Management

With reference to the work (Holma & Toskala, 2004), Figure 2.4 shows the control plane of UMTS mobility management between UE - UTRAN and UTRAN - CN. On top of the Radio Link Control (RLC) there is the Radio Resource Control (RRC). It is responsible for a reliable connection between the UE and the UTRAN, especially managing radio resources. It is also involved in handovers (3GPP TS25.322, 2001). The Signal Connection Control Part (SCCP) and on top of that the Radio Access Network Application Part (RANAP) manages the connection between the UTRAN and the CN (Mackaya *et al*, 2002).

The RANAP also supports mobility management signaling transfer between the CN and the UE. However, those signals are not interpreted by the UTRAN. It also manages the relocation of RNCs, Radio Access Bearer (RAB) etc. On top of these layers UMM provides mobility management functions (Holma & Toskala, 2004).

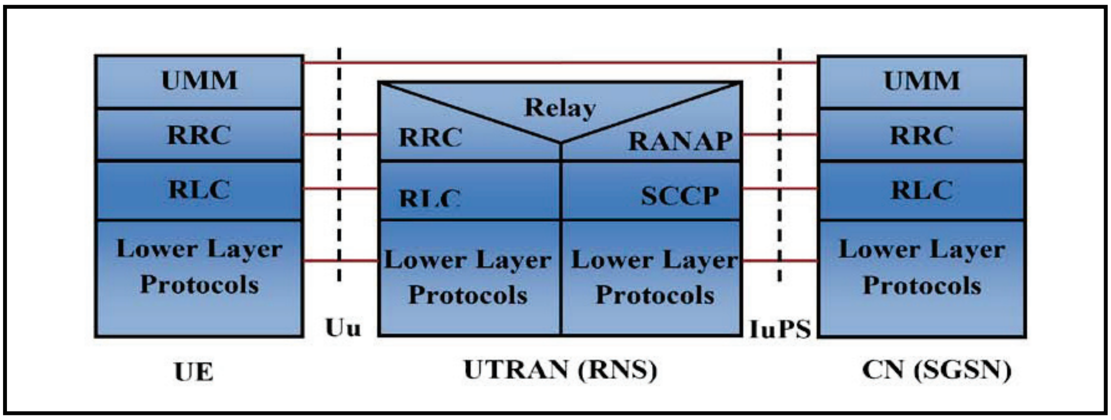

Figure 2.4: Control Plane of UMTS Mobility Management (Holma & Toskala, 2004)

In UMTS network, a SGSN manages one or more RNCs and a RNC manages many Node Bs. To track the location of an UE, some geographical groups are defined within the UTRAN (Holma & Toskala, 2004):

- Location Area (LA): A LA covers the area of one or even more RNS. A LA can only cover the area of more than one RNS if the corresponding RNCs are managed by the same SGSN.
- Routing Area (RA): A RA is a subset of a LA. It only covers one RNS or even only a subset of a RNS.
- UTRAN Routing Area (URA): An URA is a subset of an RA. It only covers some Node Bs of one RNS.

UMTS service area is partitioned into several groups by cells Node Bs. To deliver services to an UE, the cells in the group covering the UE will page the UE to establish the radio link. In order to track the location change of an UE, the cells broadcast their cell identities. The UE periodically listens to the broadcast cell identity, and compares it with the cell identity stored in the UE's buffer. If the comparison indicates that the location has been changed, then the UE sends the location update message to the network (Holma & Toskala, 2004).

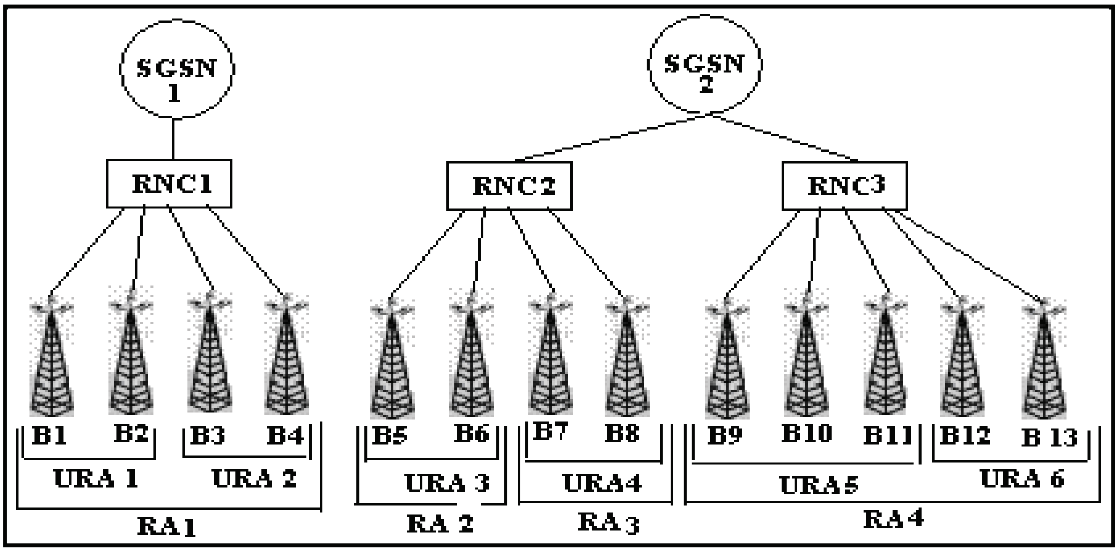

Figure 2.5: RA and URA Layout (Holma & Toskala, 2004)

In the CS-domain, the location Areas (LAs) are used, which is beyond the scope of this thesis. While in the PS-domain, the cells are portioned into RAs, which the PS-domain, in this work, focuses on. The RA of an UE is tracked by the CN (that means by the SGSN). In case of an active RRC connection the current URA and UE is located in and is tracked by the UTRAN. If the UE is also cell connected, the UTRAN even tracks the cell that UE is located in. Figure 2.5 illustrates an example of RA and URA layout. The areas controlled by SGSN and UTRAN are listed in Table 2.1 (Kawamura *et al*, 2002).

Table 2.1 Area Tracked by the Network Nodes

	SGSN	**UTRAN**
Cell	No	Yes
URA	No	Yes
RA	Yes	No

In UMTS, the UTRAN tracking is triggered by the establishment of the RRC connection. In the UE and the UTRAN, an RRC state machine is executed. Its state diagram is shown in Figure 2.6. In the RRC Idle mode, no RRC connection is established, and the UE is tracked by the SGSN at the RA level. When the RRC connection is established the state moves from RRC Idle to RRC Cell Connected, and the UE is tracked by the UTRAN at the cell level (Kawamura *et al*, 2002).

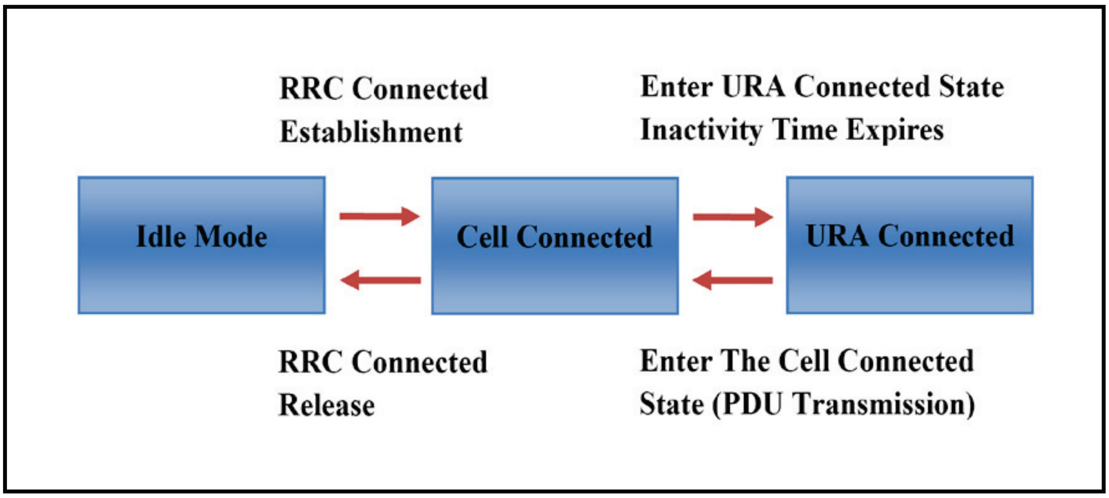

Figure 2.6: State Diagram of UE (Kawamura *et al*, 2002)

2.4 Location Update

In location management, the UE informs the network of its location through and RA through the update procedures in two situations (Kawamura *et al*, 2002).

2.4.1 Normal Location Update

This is performed when the UE detects that the location has been changed from cell in RA to another. In this case, the HO may be HHO or SHO (Chen & Xiao, 2006).

2.4.2 Periodic Location Update

This is exercised even if the UE does not move. That is, the UE periodically reports its 'presence' to the network. Periodic RA update allows the network to detect if an UE is still attached to the network. A periodic RA update timer is maintained in both the UE and the SGSN. Every time this timer expires, the UE performs periodic RA update. The periodic RA update timer value is set/changed by the SGSN, and is sent to the UE through the RA Update Accept or the Attach Accept messages when the UE visits an RA. This value cannot be changed before the UE leaves the RA (Chen & Xiao, 2004). Figure 2.5 illustrates the message flow of the RA.

2.5 Handover

The mobility of the end users causes dynamic variations both in the link quality and the interference level. Sometimes this requires a particular user change its serving base station. This process is known as HO. HO is the essential component for dealing with the mobility of end users. It quarantines the continuity the services in wireless mobile environment during the mobile user movement across the cell boundaries. The handover procedure can be divided into three phases (Chaegwon *et al*, 2007): measurement, decision and execution phases. In the handover measurement phase, the necessary information needed to make the handover decision is measured. In the handover decision phase, the measurement results are compared against the predefined thresholds and then it is decided whether to initiate the handover or not. Different handover algorithms have different trigger conditions. In the execution phase, the handover process is completed and the relative parameters are changed according to the different types of HO (Brahmjit, 2007).

The objectives of handover are to ensure the continuity of wireless services when the mobile user moves across the cellular boundaries, keeping required QoS (Oumer, 2006; Antonios *et al*, 2007), minimizing interference level of the whole system by keeping the mobile linked to the strongest BS or BSs, roaming between different networks and distributing load from hot spot areas (load balancing). Studies such as (Benson and Thomas, 2002; Lugara *et al*, 2004; Singh, 2007) focus on handover types in different networks while packet switched/data connections between the network and the mobile device are active and data is transmitted. Some of these technologies are already in use for many years while some are quite new ones (Lugara *et al*, 2004).

2.5.1 Handover Types

There are several cases of handovers in UMTS. The cases describe the different possible positions of an UE and the cell organization and responsible nodes (Node Bs, RNCs etc.) within the UTRAN or SGSN. There are two types of HO (Benson & Thomas, 2002):

2.5.1.1 Hard Handover

Hard handover (or inter-frequency handover) is only needed if for some other reason the frequency has to be changed or the interface does not exist between two RNCs in case of a soft handover (inter Node B/inter RNS). A reason to change the frequency could be for example, a change of the UMTS cell level from a macro cell to a satellite or another change of the Radio Access Technology (RAT) such as from UMTS to a Wireless Local Access Network (WLAN) or GSM network. A HHO occurs quite rarely and differs a lot from the handover types above. The HHO type is beyond the scope this thesis (leeuwen *et al*, 2005).

2.5.1.2 Soft Handover

Hard handover was employed in 1G and 2G mobile networks. But when 3G mobile networks emerged based on CDMA, the SHO was introduced. This provides smoothing transmission and less ping-pong effects that ensure the continuity of the wireless services compared with hard handover. However, this technology is suffering from complexity and consumption of the resources (Holma & Toskala, 2000).

SHO is different from the traditional hard handover process. With hard handover, a definite decision is made on whether to handover or not and the mobile only communicates with one BS at a time. With SHO, a conditional decision is made on whether to handover or not. Depending on the changes in pilot signal strength from the two or more BSs involved, a hard decision will eventually be made to communicate with only one. This normally happens after it is clear that the signal coming from one BS is considerably stronger than those come from the others. In the temporary period of SHO, the mobile communicates simultaneously with all the BSs in the active set where active set is the list of cells that are presently having connections with the mobile. HHO happens on a time point, while soft handover lasts for a period of time (Cauwenberge, 2003).

The SHO may be divided into two main classes: SHO over SGSN level and SHO Soft over UTRAN level. In the SHO over SGSN level (inter Node B/inter RNC/inter SGSN), the UE moves from a cell in one Node B to a cell in another Node B that belongs to a different RNC. In other word, when the UE move from RA to RA in different SGSN. The Node Bs is connected to different RNCs and those two RNCs are also connected to different SGSNs. In this case, the UE even has to be relocated to the new SGSN. This type of SHO occurred if the interface exists between two RNCs; otherwise, this situation is called HHO. However, this case beyond scope of this thesis. In the other hand, in the SHO over UTRAN level, there are several cases of HO in UMTS whether at cell or URA. The cases describe the different possible positions of an UE and the cell organization and responsible nodes (Node Bs, RNCs etc.) within the UTRAN near this position. The following cases are consider parts from the HO occur frequently in UMTS networks (3GPP TR 25.922, 2002; Yang *et al*, 2000; Yang *et al*, 2001; 3GPP TR25.950, 2001). As a literature, this study will focus on the following parts.

- **Softer Handover (Intra Node B/Intra RNC)**

This handover type is done if the UE moves from one cell to another cell that both belong to the same Node B.

- **Soft Handover (Inter Node B/Intra RNC)**

A softer HO is done if the UE moves from a cell in one Node B to a cell in another Node B and both Node Bs belong to the same RNC. In other word, they are connected to and managed by the same RNC.

- **Soft handover (inter Node B/inter RNS/intra SGSN)**

If the UE moves from a cell in one Node B to a cell in another Node B that belong to different RNS ,the HO is called soft handover (intra RNC).

2.6 SHO Over UTRAN Level

GSM is superior to 1G system in many ways, the older connection has to be terminated before the new one can be set. The connection setup phases are the most vulnerable steps in a call. The connection between UE and BS is setup in a beginning of a call or later when HO occurs. If the setup is not successful, it is useful to have an existing connection to another BS like in 3G otherwise the call will be abnormally terminated.

Signal processing and HO decision procedures have been associated since the CDMA technology was introduced. In addition, new concept that has been proposed for enhanced the HO process is SHO.

In 3G networks such as UMTS, UTRAN consists of Node Bs and Radio Network Controllers (RNCs). When a user access for UMTS services, the UE communicates with all cells in an active set through the air interface Uu which based on WCDMA technology (3GPP TS 25.301 ,2000) as shown in Figure 1.1. The active set is the list of cells that are presently having connections with the mobile. If the quality of the wireless link between the UE and a cell is above some threshold, then this cell is included in the active set. When the quality of the wireless link of a cell in the active set is degrade a threshold, and then the cell is removed from the active set.

Basically, in standard UTRAN (3G TS25.430, 2001), multiple paths exist between the UE and all Node Bs in the active set where a UE communicates with cells not in the same manner to transmission directions either Uplink (UL) or Downlink (DL). This process will affect the transmission speed due to interference. These cells are selected by the cell selection mechanism based on the Common Pilot-Channel that received signal code power measurements (CPICH) of the cells in the active set. Cell Selection (CS) schemes are like distance-based CS, perfect CS and normal CS.

Third-Generation Partnership Project specification proposed a mechanism to support high-speed downlink packet access (HSDPA) (3GPP TR25.950, 2001; Yeung & Nanda, 1995), where a UE selects one cell only to communicates with it for high-speed downlink transmission. This is called the serving cell that is involved in the active set.