ADDIS ABABA INSTITUTE OF TECHNOLOGY
DEPARTMENET OF ELECTRICAL AND COMPUTER ENGINEERING

Congestion Control with Load Based Inter RAT Handover (3G to 2G): Case of Addis Ababa

By

Alemu Yadessa

Advisor

Dr. Eng. Yihenew Wondie

(Assistant Professor)

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SCHOOL OF ELECTRICAL AND COMPUTER ENGINEERING

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Approved by Board of Examiners

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2. ________________ ______________ _____________
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4. ________________ ______________ _____________
   Department Head Signature Date

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Declaration

I would like to declare that this thesis comprises my own work and also I have mentioned all used materials for this thesis.

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Date of submission 22/02/2020

Addis Ababa University

Advisor

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Abstract

Telecom operators have to manage their resources efficiently to minimize the congestion in their telecommunication network. In Ethiopia, heterogeneous wireless networking technologies such as GSM, UMTS, CDMA and LTE are being used to provide wireless access for both voice and data services. In big cities, the densely populated areas like town centres, shopping centres and train stations may have coverage of multiple wireless networks. Traditional Radio Access Technology (RAT) selection algorithms are mainly based on the 'Always Best Connected' paradigm whereby the mobile nodes are always directed towards the available network which has the strongest signal. Hence a large number of mobile users may be connected to the more common UMTS while the other networks like GSM and CDMA would be underutilised, thereby creating an unbalanced load across these different wireless networks. This high variation among the load across different co-located networks may cause congestion on overloaded network leading to high call blocking and call dropping probabilities. This can be alleviated by moving mobile users from heavily loaded networks to least loaded networks.

This thesis presents a load levelling algorithms which is used for load balancing in heterogeneous wireless networks. The technique comprises of load-aware RAT selection techniques and network load balancing mechanism. Different attributes like load distribution in all wireless networks, packet drops, throughput at mobile nodes and network utilization have been observed to evaluate the effects of load balancing using different scenarios. The simulation results indicate that with load balancing the performance efficiency improves as the overloaded situation is avoided by load balancing. The load change value is 11% for the sites in the focus area. This shows that the voice call has been pushed to the neighbour 2G cell and congestion in 3G network has been improved.

Keywords- WCDMA, Load control, Tele traffic Engineering, Load Balancing, load based InterRAT handover.

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Table of Contents

List of Figure

List of Tables

Abbreviations

3GPP	Third Generation Partnership Programme
AGCH	Access Granted Channel
ARQ	Automatic Repeat Request
BCCH	Broadcast control channel
BCH	Broadcast Channel
BCSU	Base Station Controlling Signalling Unit
BER	Bit Error Ratio
BSC	Base station controller
CAC	Call Admission Control
CDMA	Code Division multiple access
CN	Core Network
CPICH	Common Pilot Channel
DCH	Dedicated Channel
DCN	Data Communication Network
DPCCH	Dedicated Physical Control Channel
DPDCH	Dedicated Physical Data Channel
EDGE	Enhanced Data for Global Evolution
FACCH	Fast Associated Control Channel
FACH	Forward Access Channel
FCCH	Frequency control channel
FDMA	Frequency Division Multiple Access
GGSN	Gateway GPRS Support Node
GMSC	Gateway Mobile Switching Centre
GPRS	Weighted Least Square
GSWB	Group Switch of BSC
KPI	Key Performance Indicator
LAP-DM	Link Access Protocol on D Channel
LB	Load Balancing

LDR	Load Reshuffling
LMT	Local Maintenance Terminal
MCPC	Mega Chip per Second
ME	Mobile Equipment
MS	Mobile Station
MSC	Mobile Switching Centre
OLC	Overload Control
OMC	Operation and Maintenance Centre
OVFS	Orthogonal variable spreading factor
PCH	Paging Channel
PN	Pseudorandom Noise
PSK	Phase Shafting Key
PSTN	Public Switched Telephone Network
PUC	Potential User Control
QOS	Quality of Service
RACH	Random Access Channel
RAT	Radio Access Technology
RNC	Radio Network Controller
RRM	Radio Resource Management
RSCP	Received Signal Code Power
RTWP	Received Total Wideband Power
RU	Resource Utilization
SACCH	Slow Associated Control Channel
SC	Spreading Code
SCH	Synchronization Channel
SDCCH	Stand-alone Dedicated Control Channel
SF	Spreading Factor
SGSN	Serving GPRS Support Node
SIM	Subscriber Identity Module
TCH	Traffic Channel

TCH/F	Traffic Channel/Full
TCH/H	Traffic Channel/Half
TDMA	Time Division Multiple Access
TRX	Transceiver
UL	Uplink
UMTS	Universal Mobile Telecommunication System
USIM	User Subscriber Identity Module
UTRAN	UMTS Terrestrial Radio Access Network
UTRAN	Universal Terrestrial Radio Access Network
VLR	Visitor Location Register
WCDMA	Wide-band Code Division Multiple Access

Chapter 1 : Introduction

1.1 Overview

In the past years, a large increment of mobile users were observed in mobile network. In addition to this there is also an increment in types of data and the application they want to use. Usually, in many countries 2G mobile network is used for voice call and the 3G network is used by data users. The expectation of a mobile wireless network user is to get the service anywhere, any time with good quality of service. To manage the increasing needs of data service of the user technologies like 3G and 4G has been developed. These technologies have a better throughput and good coverage area [20].

Nowadays, the development of end users mobile is very fast. The modern apparatus has many features and can support different interfaces. Modern user mobile equipment can work with heterogeneous wireless technologies like 2G, 3G and 4G. They can configure their phone to work in a single or different radio access. This feature enables the operators to move the user from one technology to other when call congestion happened in the network. If the user wants to use a single radio access technology and set his phone to use that network operator cannot move this user to other radio access and the user will stay on the same network.

To handle the mobility of the users, current mobile wireless technology support seamless handover. The core network can handover the users between the same technologies which is called horizontal handover or it can push the user to different access network which is called vertical handover. The current user apparatus can scan different network and register on the best one by using different algorithm. When they are on conversation the mobile equipment send a measurement of different radio access and the core network will manage the handover according to the measurement. Also, the mobile network can make horizontal or inter RAT handover due to a lot of condition with the network like coverage issue, to balance the load and from service point of view [20].

1.2 Statement of the Problem

Despite the huge telecom expansion program of ethio telecom throughout the whole country before four years, there are many challenging issues such as 3G-network congestion and 2G voice quality and call drop especially in Addis Ababa.[45]

The first target of ethio telecom is to connect our country to other world through telecommunication. While doing this the quality of the service is must be good and also affordable by all citizen. When the coverage is good the development of our nation will be fast and the customer ensure high customer satisfaction. Therefore, to meet these target, the key performance indicator of the network has to be better [45].

There is a dramatic subscriber increment in the past years. Now a days it is so difficult to handle this traffic with defined grade of service. Before a year ethio telecom has decreased the tariff of both voice and data call and four million subscribers were upgraded from 2G to 3G [34]. Due to this, there is a big increment in data usage and there is a congestion in 3G network. These are the key points which motivated me to demonstrate how to off load some of the voice call to minimize this congestion from 3G to 2G by using load balancing techniques. To achieve this, one of the most congested area of Addis Ababa city, around Markato, has been selected to show how to decrease the congestion in the current network. Therefore, this study will address the above problem by using an Atoll simulation tool. Thus, this work can be deployed on the actual network to solve the congestion problem.

1.3 Target Solution

If the congestion rate of a network is very high, it will accumulate several drawbacks such as call drop and call setup failure. These negative impacts can be minimized by using different techniques in the heterogeneous mobile wireless networks to optimize their utilisation. There are two best ways to control radio networks capacity shortage. The first one is to add additional hardware to increase capacity and the second one is to use different inter RAT handover to balance the load between different RAT.

The first approach would requires new hardware and which is additional investment cost. However by deploying a new load balancing technique, the hardware utilization can be maximized by using the existing network and push the voice traffic from more congested 3G network to less congested 2G mobile network.

In this thesis the load balancing approach from 3G to 2G has been adapted to avoid the overloaded situation in the 3G radio access networks. The load balancing algorithm which fit best our network condition at this time will be checked and recommended to Addis Ababa network.

1.4 Thesis Objective

1.4.1 General Objective

The overall objective of the thesis is to shows the effect of load based inter radio access technology handover technique to solve data service congestion in 3G network of Addis Ababa.

1.4.2 Specific Objectives

This study is carried out mainly to address the following issues.

- To solve the 3G network congestion of business area in Addis Ababa.
- To use less congested resources of 2G network efficiently.
- To increase the data throughput of users.

1.5 Contributions

- To propose a load balancing scheme with load levelling algorithm solution to ethio telecom for the congested 3G wireless network in Addis Abeba.
- To recommend a load aware network to establish stable wireless network.
- To recommend future studies on load balancing in heterogeneous wireless network.

1.6 Literature Review

Several approaches in minimizing congestion and maximizing capacity of WCDMA are proposed in many literature. In [6], cell breathing and load balancing have been proposed. In wireless networks, cell breathing is not a feature, it is a phenomena which enable congested cells to push subscriber traffic to its neighbouring cells by changing the cell size of their service area. The Heavily congested cells decrease in size while neighbouring cells increase their coverage so that subscribers in this area will setup a new call with in neighbouring cell. A cell and its neighbour cells are interact with each other to release system congestion, balance network load between cells, maximize network resource utilization, while maintaining the required grade of service parameters for each mobile users. This techniques actually used for cell located in the same geographically area and the same RAT.

In [7], threshold segmentation scheme is proposed to minimize the congestion in 3G network. In this work we have three level of threshold which is divided into three segments in which users are entering in the system during a call with different levels. The final goal of this work is to show that many users can share the system without interfere to each other. This technique is part of the network optimization within the cell to use the available resources of the NodeB and will also decreasing the uplink interference.

In [2], it is demonstrated that services can be differentiated in different classes to decrease the effect of call congestion. This system provides better quality of service provisioning for all users according to their service requirements. This concept is already applied in WCDMA network. Configuration of service class is done during defining a SCTP link setup.

Load balancing in heterogeneous wireless communication network has been presented in [31]. The ultimate goal of this work is to balance the load between networks such as UMTS and WiMax. It give a good understanding of load balances between these networks. It neglects the tradition network, GSM, and focuses only on satellite, UMTS and WiMax technologies which different from our scenario.

My proposed congestion control scheme overcomes the above-mentioned shortcomings by implementing load balancing with inter RAT handover between different system. All the above solutions are applied for cells that geographically located in the same area and RAT. My proposal will give a solution for two cells located in different RAT.

1.7 Methodology

In this study, a related actual hardware and license capacity of sites were used as a first data. Secondly, different books written on load balancing, previous researcher's studies and different articles and journals were used to study all about 3G to 2G load balancing solution.

Based on the above inputs and actual congestion problems in mind the methodology of the thesis has been designed as follows.

System Design

System design comprises of preparing workflow for load balance and setup the network which have similar characteristics with actual network. To prepare a digital map as an input.

Simulation

It consists of loading of digital map, site information and finally run the simulation to evaluate load balancing parameters.

Result Analysis

This part analyse the simulation output to check either the target network requirement has met or not.

1.8 Thesis Layout

This thesis is composed of seven chapters. The first chapter describes about the introduction of the thesis. It introduces problems of statement, thesis objective, methodologies, thesis scope and limitation of the thesis. Chapter two describes about the basics of 2G and 3G technologies, system architecture, network element and different types of channel.

Chapter 3 discusses about different types of handover. Soft and softer, IRAT and hard handover will be discussed in detail. Radio resource managements such as call admission control, load control and congestion control of a mobile network is also described.

Chapter 5 is related to Chapter 3 and will discuss about IRAT handover and load balancing. By deploying some algorithm and using IRAT handover we can push some traffic from RAT to RAT to decrease traffic during high congestion.

Chapter 6 shows the final result and conclusion of the thesis. It covers about system model and the final output of the simulation. It compares all important parameters before and after the deployment of load balance. At last it shows the total load balance of the concerned site. Finally conclusion and future recommendation are also discussed in this chapter.

Chapter 2: Mobile Communication Technologies

A Mobile communication can be defined as an information interchange between wired and wireless equipment. The mobile device are a device that can be used by people on hand, in train and cars. The mobile equipment has additional features such as wireless connection of equipment through air interface, the users can move from place to place and it requires a reliable network and has good performance. This communication system has passed through different generation starting from around 1980's [1].

2.1 GSM

2.1.1 Introduction

The system referred to as GSM first named as the Groupe Speciale Mobile. After sometimes this was changed to represent its global nature, while maintaining the same initials, to Global System for Mobile wireless communications. The Global System for Mobile Communications was designed as a second generation (2G) cellular phone technology. The important target at that time was to provide a wireless system that have a greater capacity and a good quality of service than the previous first generation analogue systems. GSM achieved this criterion by using a time division multiple access modulation techniques [1].

By deploying this new modulation techniques more users can be served within the available bandwidth. In addition to this, the security issues has been solved by encrypting the digitally encoded speech to retain privacy. The earlier analogue cellular technologies was very simple for intruder to hack and listen a call. Voice calls are obviously the basic function for the GSM cellular network. To meet this the speech is digitally encoded and finally decoded using a vice coder. There are different types of voice coder are available for use, being aimed at different scenarios. The First aim was to use spectra in the 900-MHz region, later further bands have been used at 1800, 1900 and, more recently, 800 MHz At the beginning the GSM systems using the higher frequency bands were given the names DCS and PCS 1900 (Personal Communications System). Now a days they are simply named to as GSM 1800 for DCS and GSM 1900 respectively [1].

2.1.2 GSM Architecture

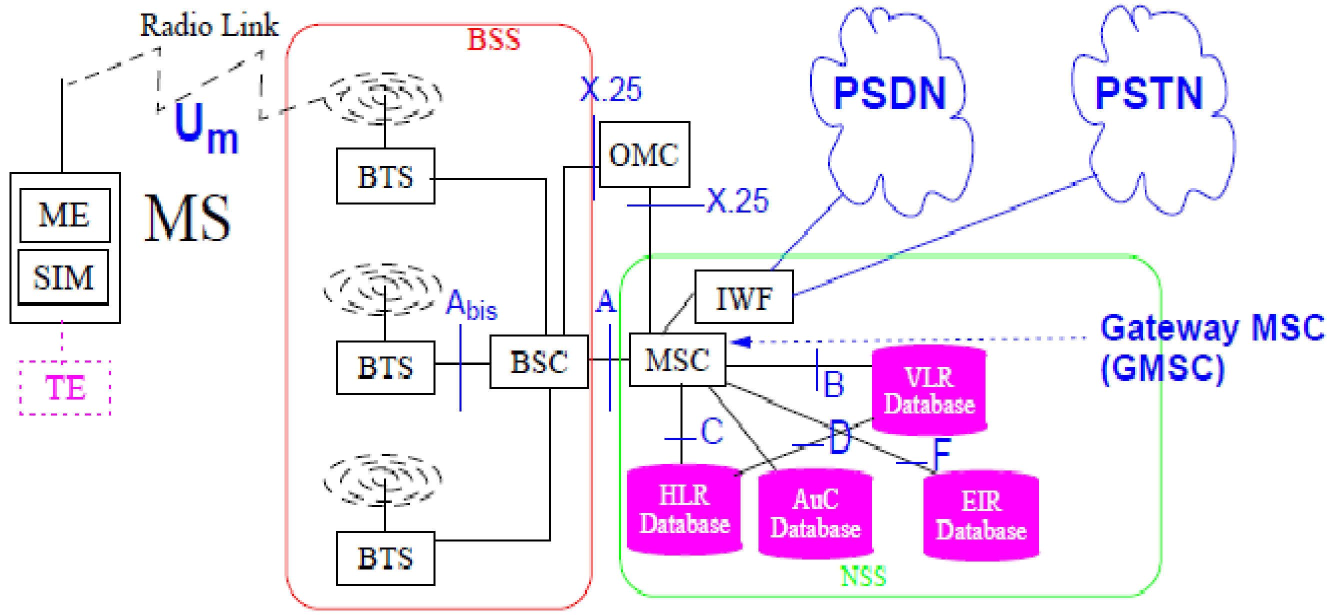

Figure 2. 1 : GSM architecture [28].

The RF or air interface part of GSM cellular network uses 200 kHz radio frequency channels. Each frequency are time division multiplexed to handle up to eight users to access each carrier. According to this it is a TDMA / FDMA system [1].

2.1.2.1 Base Station Controller (BSC)

The Base station controller is one of the central network element of the Base station subsystem and it controls the radio resource. It has several important tasks. All calls to and from the mobile station are connected through the group switch of the BSC [33]. It manages the mobility of the users and initiate the handover if the users are out from the coverage of the base station. The decision to handover the user to the next BTS is based on deferent measurement reports sent by the MS during a call.

2.1.2.2 Base Transceiver Station (BTS)

The BTS is the network element between the BSC and mobile station which is responsible for maintaining the air interface and minimising the transmission problems (the air interface is very sensitive for disturbances). BTS has three sectors and each sectors can be configured with different numbers of TRx. It theoretical coverage is around 30 Kilometres [33].

2.1.3 Channel coding

Channel coding is normally used for decreasing the problem caused by channel fading. In this system, the user data is coded with standard algorithms. This coding is usually used for error detection and correction purposes. It requires extra information to be added to the user data. In the case of speech, the amount of bits is increased from 260 per 20 ms to 456 bits per 20 m. seconds. This gives the possibility to regenerate up to 12.5% of data loss [31].

2.1.4 Interleaving

In many types of communication channels, such as radio channels, the inherent noise causes bit errors to occur during transmission. In order to reduce bit errors, digital communication systems typically use error control codes to enable detection and/or correction of the bit errors at the receiver. These error control codes introduce controlled redundancy into the information transmitted over the communication channel, which can be used at the receiver to detect and/or correct errors in the received signal. Error detecting codes enable the receiver to detect bit errors. The receiver may then request retransmission of the information that was received in error. Error correcting codes enable the receiver to detect and correct bit errors without retransmission [31].

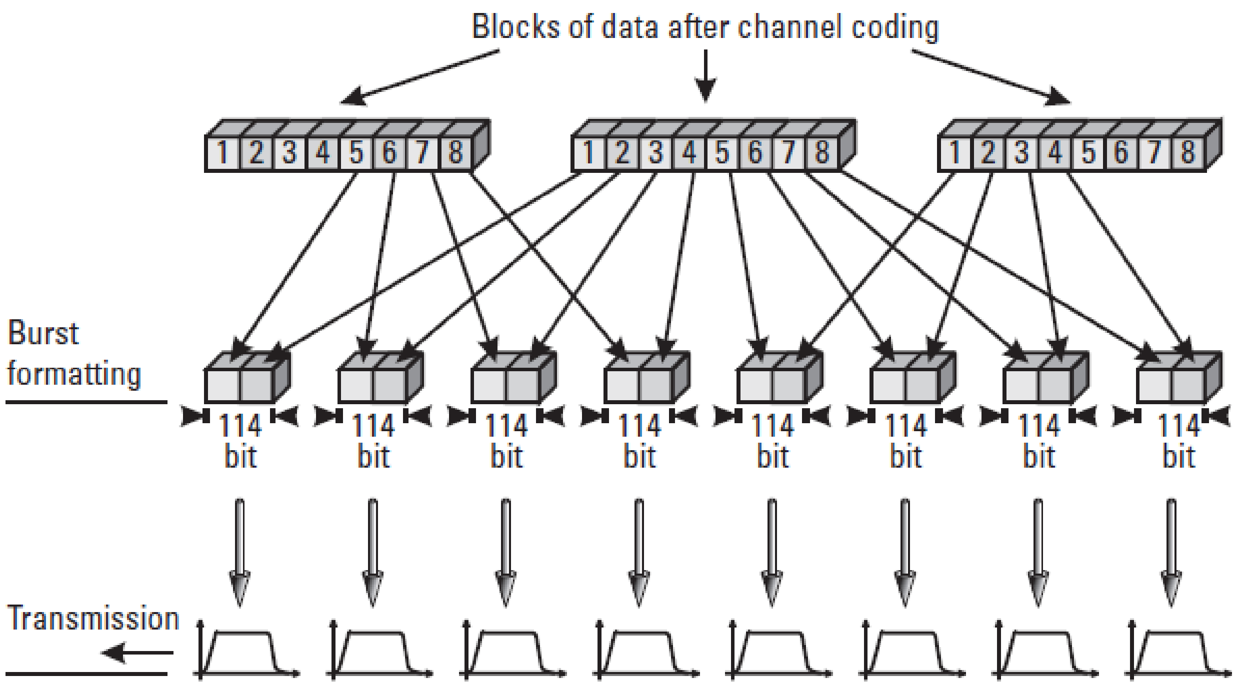

Figure 2. 2 : interleaving of speech traffic [31].

2.1.5 Frequency hopping

In this systems, the carrier transmitter changes with a predefined "hopping" pattern. The advantage of frequency hopping is that the signal will be transmitted in different channel and with different set of interfering signals during each hop. This prevents the problem of failing communication at a single frequency, because of a fade or a particular interference. We cannot use this techniques on BCCH TRx since BCCH TRx must transmit information continuously. This requirement limits the frequency hopping in a cell. There are two types of hopping. Which are Baseband Frequency Hopping (BB FH) and Synthesized Frequency Hopping (RF FH) [16].

2.1.5.1 Baseband frequency hopping

In the baseband frequency hopping system the TRxs always operates at same frequencies. Frequency hopping is deployed by switching consecutive bursts in each time slot through different TRXs according to the predefined hopping sequence [16]. The number of frequencies to hop over is related to the number of TRxs. Because the first time slot of the BCCH TRx is not allowed to hop, BCCH time slot must be excluded from the hopping sequence. This leads to three different hopping groups.

The first group doesn't hop and it has only the BCCH time slot. The second group includes the first time slots of those TRx which has no BCCH. The third group includes all time slots except BCCH in a TRx.

2.1.5.2 synthesized frequency hopping

In this techniques all the TRXs in a cell except the BCCH TRX change their frequency for every TDMA frame according pre-defined sequence. So the BCCH TRX doesn't hop. The number of frequencies to hop over is 63, which is the maximum number of frequencies in the Mobile Allocation (MA) list [16].

2.1.6 GSM Channels

GSM Channel are classified into two categories: Traffic channels (TCHs) and Control channels: The traffic channels are intended to carry encoded speech or user data and the Control channels carries a control signals to manage the call process [1].

2.1.6.1 Control channels

There is a number of different control channels that are used to provide the required functionality to enable the mobiles and the BTS to communicate, set up and manage the calls. There are a variety of channels, and they can be divided into groups, namely broadcast channels for initial synchronization, common control channels for initiating calls, and dedicated control channels to manage calls. The common channels include the following [1].

2.2 UMTS

2.2.1 Introduction

UMTS, the Universal Mobile Telecommunications System, is the third-generation (3G) which invented next to GSM technologies, including GPRS, and EDGE. WCDMA is the techniques usually used as air interface for UMTS. This new air interface was developed by the third generation partnership project (3GPP), which is the joint standardization body from countries like Europe, Japan, Korea, USA and China. In 3GPP, WCDMA is called Universal Terrestrial Radio Access (UTRA), which includes the Frequency Division Duplex (FDD) and Time Division Duplex (TDD) [1]. WCDMA fuses the CDMA spreading codes to spread the user data bit over a wide bandwidth by multiplying the user data with quasi-random bits. The chip rate for 3G system is 3.84 Mcps with bandwidth approximately around 5 MHz

2.2.2 Main Parameters in WCDMA

WCDMA can be defined as wideband Direct-Sequence Code Division Multiple Access (DS-CDMA) system, i.e. the user information bits are spread over a wide bandwidth by multiplying the user data with quasi-random bits extracted from CDMA spreading codes. WCDMA uses a variable spreading factor and multicore connections to support a high data rate which is up to 2Mbit rate. An example of this arrangement is shown in Table 2.1 [19].

Multiple access method	DS-CDMA
Duplexing method	Frequency division duplex/time division duplex
Base station synchronisation	Asynchronous operation
Chip rate	3.84 Mcps
Frame length	10 ms
Service multiplexing	services with different quality of service requirements multiplexed on one connection
Multirate concept	Variable spreading factor and multicode
Detection	Coherent using pilot symbols or common pilot
Multiuser detection, smart antennas	Supported by the standard, optional in the implementation

Table 2. 1: Main parameter of WCDMA [19].

The chip rate of 3.84 Mcps leads makes to achieve a carrier bandwidth of approximately 5 MHz DSCDMA systems which has a bandwidth of about 1 MHz, such as IS-95, are usually referred to as narrowband CDMA systems. The inherently wide carrier bandwidth of WCDMA can handle high user data rates and also has certain advantages, such as increased multipath diversity. According to its operating licence, the network operator can use multiple 5 MHz carriers to increase capacity, possibly in the form of hierarchical cell layers. Figure 2.3 also shows this feature. The actual carrier spacing can be selected on a 200 kHz spacing between approximately 4.4 and 5 MHz, depending on interference between the carriers [19].

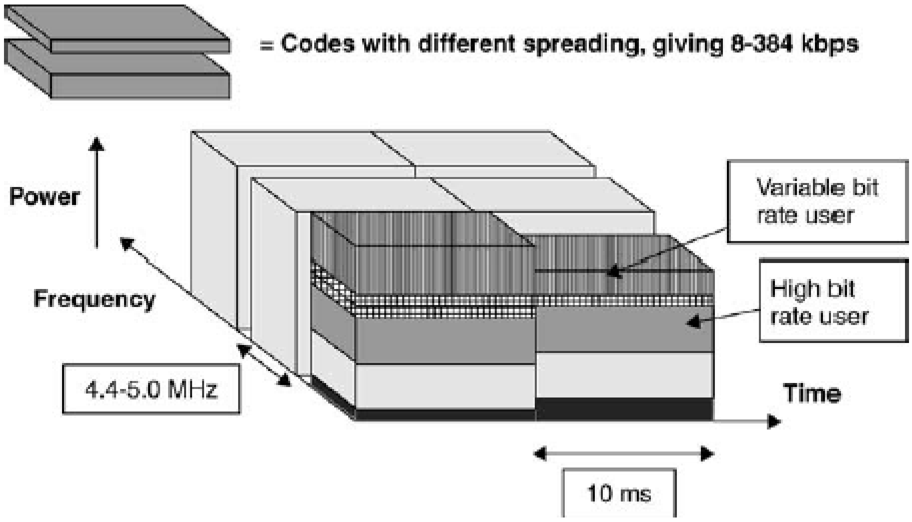

Figure 2. 3 : Allocation of bandwidth in WCDMA in the time–frequency–code space [19].

2.2.3 UMTS System architecture

The UMTS network architecture is mainly divided into three components, the User Equipment (UE), the UMTS Terrestrial RAN (UTRAN) and the CN. The UE is the equipment that the subscriber uses to communicate with the UTRAN. The UTRAN is the radio component of the network which connects the UEs to the CN. The CN is responsible for switching and routing calls and data within the network as well as to and from the external networks. Each of these components is made of a number of logical network elements with defined functionalities. One UMTS network can be composed of several sub-networks called Public Land Mobile Networks (PLMNs), each of these sub-networks contains all the elements required for a UMTS network and therefore one PLMN is enough to have an UMTS network [19].

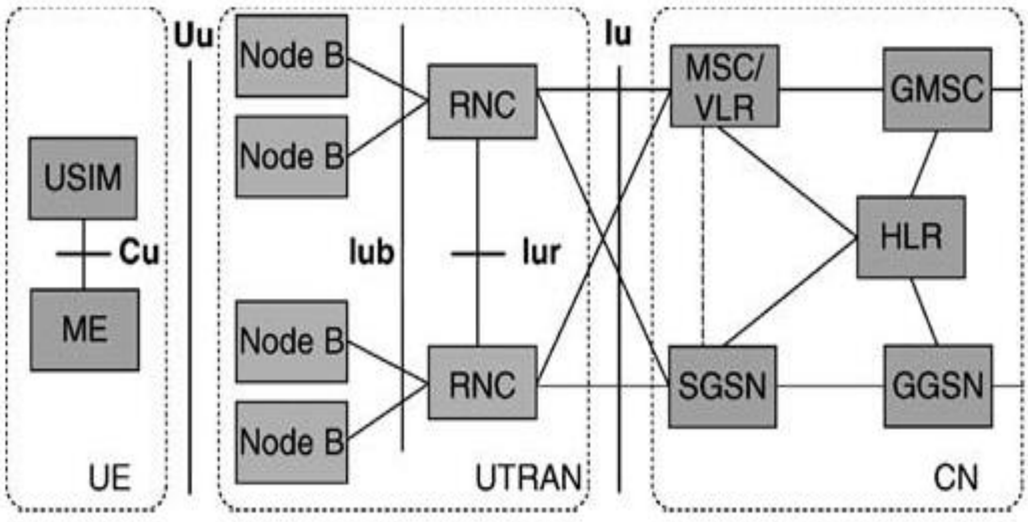

Figure 2. 4 : UMTS Network Architecture [19].

UTRAN consists of two basic network elements, the Base Station (Node B), and the Radio Network Controller (RNC). The Node B an equipment in the UTRAN that converts the data flow between the Iub and the Uu interfaces [29]. The Iub is the air interface between the Node B and the Radio Network Controller (RNC). The Node B is connected to the UE by the Uu and to the RNC by the Iub interfaces. One Node B can handle more than one cell and is connected to only one RNC .This is the terminal part for the radio resource management. The term Node B stands for the same as GSM standard Base Transceiver Station (BTS).

The Radio Network Controller (RNC) is responsible to manage all the radio resources in its own domain. The RNC forwards all the radio services that come from the UTRAN to the CN. It maintains three interfaces, Iub to the Node B, Iu to the CN and the Iur for the inter RNC communication. [29]

2.2.4 Channelization Codes

Channelization codes (or spreading codes) are used to separate transmissions from a single source. These codes are derived from Orthogonal Variable Spreading Factor (OVFS) technique which give them a cross correlation and an autocorrelation property. This in turn minimize that the inner product of the code with codes of other users. When a full orthogonality is achieved there is no interference between codes in ideal case. WCDMA has a fixed transmission chip rate of 3.84Mcps to use approximately the 5MHz Frequency bandwidth of the channel. WCDMA usually use this codes to transmit information at different bit rates. This will be done by transmitting each bit of information as a code at 3.84Mcps. The bit rate usually depends on the length of the code. The shorter the code the higher the information bit rate will be achieved. If the spreading code with a chip rate of 3.84Mcps is multiplied by every bit of information, it means that the bandwidth of the information signal is spread along the bandwidth used by the chip rate (approximately 5MHz) [30].

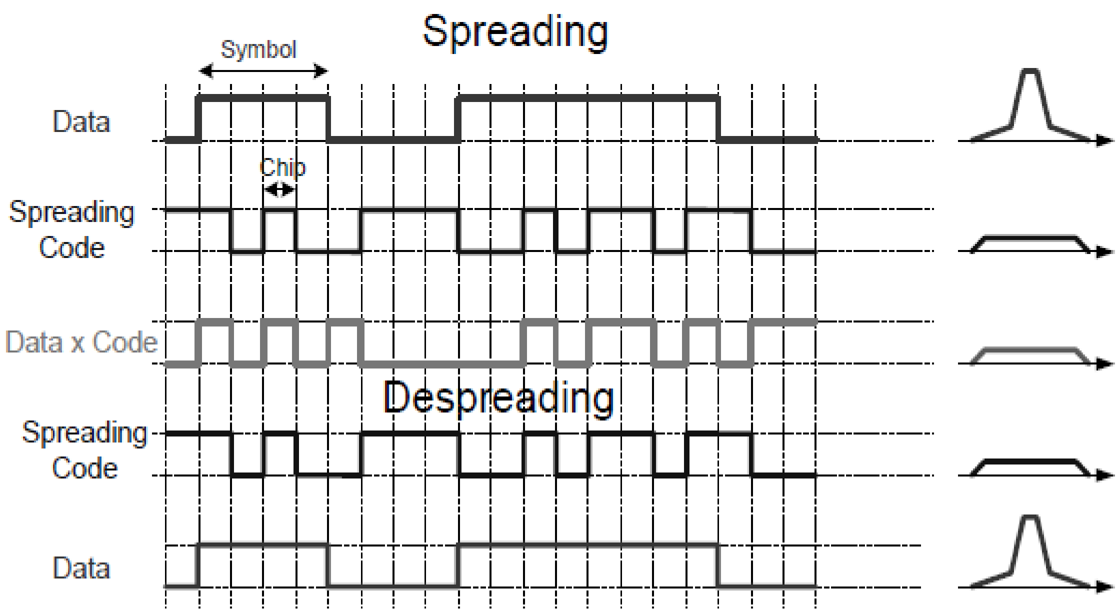

Figure 2. 5 : Spreading and dispreading in DS-CDMA [26].

2.2.5 Scrambling Codes

Scrambling codes are used to identify the 3G cell in RNC to separate transmissions from different sources. We use the uplink scrambling codes to separate different mobiles and in the downlink it separate the NodeB cells or sectors in the RNC. This codes is usually used to separate the transmitter and has no effect on transmission bandwidth. There are two types of scrambling code (short and long codes). The short and long codes are usually used on the uplink depending on NodeB receiver. In the uplink there is no need for planning since there is many numbers of codes in a NodeB. In the downlink to prevent a delay in searching a cell the number of codes is limited to 512. In this case, since the number of codes is limited network planning is needed to define a scrambling code to a cell or sector [30].

2.2.6 Modulation and Demodulation

Radio signal can be used to carry information such as voice and data from a point to another point. This audio or data can be superimposed onto a single frequency called carrier frequency and then transmitted towards the receiver. At this point the transmitted signal can be reconstructed again to the original signal with a process called demodulation. There are different types of modulation techniques but in general the classified in to three types. They are amplitude modulation, frequency modulation and phase modulation. Frequency modulation and phase modulation is almost the same. Each type have its own advantage and disadvantage [1].

A carrier is a basis of all radio signal which used for transmission. This consists of a simple alternating current wave form. It is generated in the transmitter and radiated in the air. If there is no information is not added to the carrier it will be received as constant signal at the receiver end [1].

2.2.7 UMTS Radio Access Bearers

The UTRAN [2] provides radio access bearers for data services. They provide a bearer transport between the user equipment and the core network. In order to provide the quality of service according to service type a radio access bearer can be configured flexibly. A given radio access bearer is defined by with different parameters, like maximum bit rate, bit error rate and transmission delay. There are four types of quality of service classes which are defined for UMTS, they are real-time, streaming, Interactive (Web-browsing) and background (e-mail download).

2.2.8 Radio Resource management

Radio resource management is consisting of all methods that control the call setup from start point to end in ensuring it to fulfilling the required QoS, call continuity and to provide high capacity [42]. It is in charge of all air interface resources. The main tasks of the Radio Resource Management is to handle power Control, handover Control, admission Control, packet Scheduling and load and congestion Control.

2.2.8.1 Power Control

The Power control is an important feature of any CDMA based cellular system. Without proper adjustment of power control the system could be downgraded. There is some common phenomenon in WCDMA system like fading of the signal, intra cell interference and random nature of the wireless channel that deteriorate the signal quality to achieve the required QoS. And the most important issue is the near far problem that is mobile stations that are closer to the base station can dominate the mobile stations that are far away from the base stations. In order to mitigate these problems power control is necessary in WCDMA. Power control mechanism makes the power level of each transmitter at a certain level that it could not make interference to others transmission. As a result the capacity and also the throughput of the system is increased [42].

2.2.8.2 Handover Control

Handover control is one of the important issues in the WCDMA network. Handover enables the user mobility from one cell coverage area to another cell [42]. The basic concept is that when the subscriber moves from one coverage area to another, a new connection has to be set up with the target cell and the old connection has to be released. The handover process operates in the three steps:

i) Measurement

ii) Decision and

iii) Execution.

2.2.8.3 Load Calculation

The frequency reuse factor of WCDMA is one. The total system capacity is limited by the level of interference so that we can estimate the supported amount of users per base station. The load equation can be used to predict the average capacity of the system and the noise rise in the dimensioning phase. The system is generally limited by the air interface and the amount of interference [42]. In order to estimate the load calculation, there is a close relationship with the related connections. We need to define the connections. The can be defined as the required bit energy per noise spectral density.

2.2.8.4 Admission control

As there is an inverse proportionality between coverage and capacity in WCDMA system, the admission control functionality is used to decrease system congestion and to provide the planned coverage. Admission control is a techniques that guards the access to the radio access network. When a new subscriber request access to the network, admission control calculates the current network load and based on the new expected load, the new subscriber is either admitted or blocked out. This feature can be used by the operator to maximize the network usage within a set of network quality levels [4], i.e. levels depending on what kind of service the subscriber wants to use.

2.2.8.5 Congestion control

Congestion control attempts to manage the resource usage in the telecommunication network so that it will not become overloaded. The difference between these control procedures is that admission-control process considers each resource request as a separate case, whereas congestion control manages the network as a whole. Admission control decides whether a connection can be set up or not. Congestion control then monitors and manages the existing connections [4].

The possible load control actions in order to reduce load are Reduce the throughput of packet-data traffic, move part of the users to other WCDMA carriers reduce the bit rates of services that have adjustable bit rates and drop calls [14].

2.2.8.6 Load Control

The main important task of radio resource management is to maintain that the network is not overloaded. If the admission control and packet scheduling are well planned and work effectively well, the network will be stable and the overload will not the issue. However, if the network is happened there must be another mechanism which control and decrease the load to predefined point. This is what we call control [14].

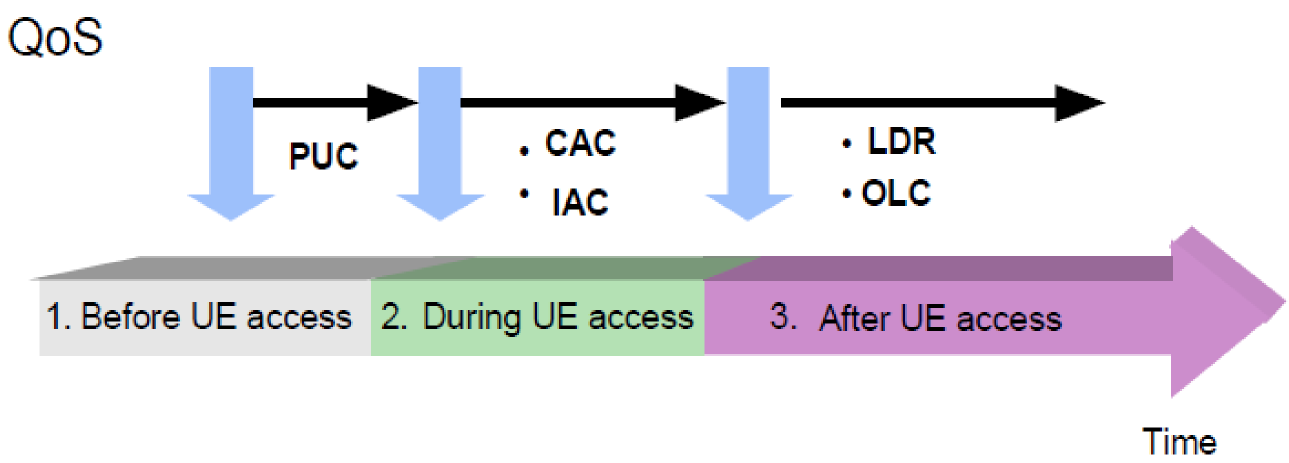

Figure 2 6 : Load control algorithm [14].

1. Before UE accesses

The PUC algorithms is used to control the UE before accessing the network. The cell load controlled by its RNC periodically. If the current cell load exceeds a specified threshold, RNC will modify the cell selection and re-selection parameters, so that that UE can select the less congested cell easily, when UE request to initiate some services and work at CELL-DCH state. The main task of this algorithm is to control UE working at IDLE mode, CELL-FACH state, CELL-PCH state or URA-PCH state in this cell.

2. During UE accesses

The CAC and IAC algorithms will control the UE during network access. Then RNC can decide whether the new access is admissible or not.

3. After UE accesses

After UE access the network, LDR and OLC, will function. These algorithm will decrease the cell load wwhen it is in a basic congestion state. The RNC will push some UEs with IRAT handover to neighbour 2G cell.

2.2.9 UMTS Advancements to HSPA+

HSPA+ results in an evolution of High Speed Packet Access in the network, from 3GPP Release-7 onwards with data rates up to 336Mbit/ in the downlink and 69 Mb/s from the mobile device (uplink) in 3GPP Release [11]. The new data rates can handle high bandwidth services like video streaming and the reduced delay improves the performance of real-time applications like VoIP. Data services like file transfer, online gaming, email etc. also give better performance with HSPA+. Higher order modulation is a way of increasing data rates. HSPA system uses a modulation of 16 QAM on the downlink direction and QPSK on the uplink direction. Radio links can attain higher throughputs by deploying 64 QAM on the downlink and 16 QAM on the uplink and this has been used in HSPA+ with further increase in order of modulation in later releases [38].

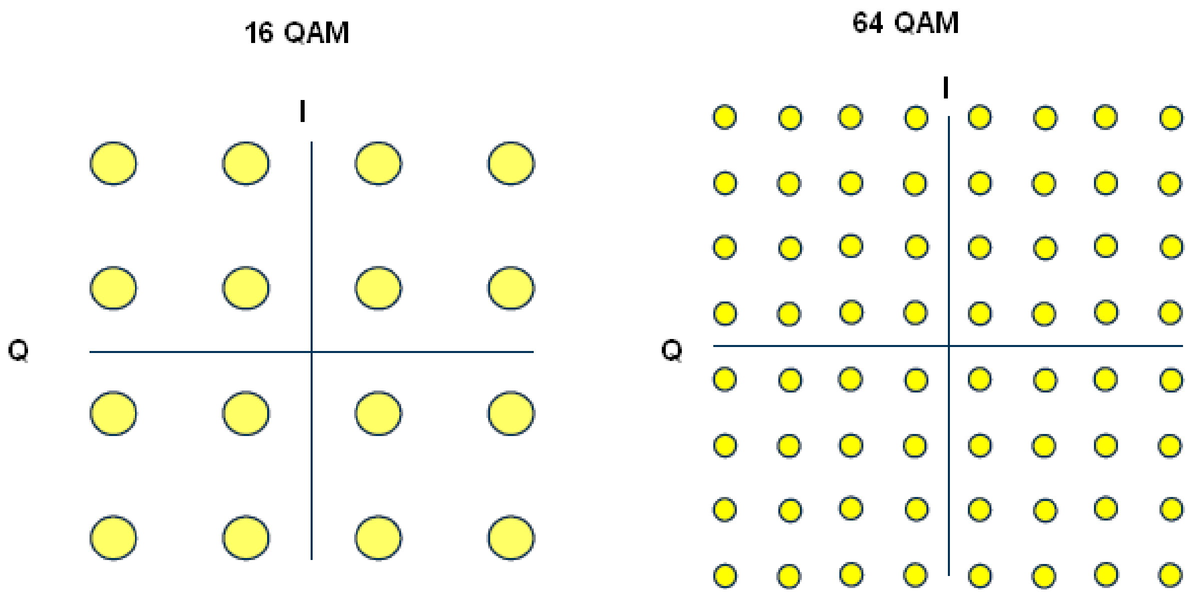

Figure 2 7 : Higher Order modulation [38].

Chapter 3: Handover

3.1 Introduction to Handover

A handover is a techniques in a wireless mobile communication system which used for the continuity of a connected call or a data session by transferring from one cell site to another without disconnecting the session. Mobile services are based on mobility and handover, enabling the users to move from one cell site range to another or to be switched to the nearest cell site for better service. Handovers are a basic element that must be considered in planning and optimization mobile network [17].

3.1.1. Handover in GSM

Handover is the procedure that transfers an ongoing call from one cell to another as the user's moves through the coverage area of cellular system. The purpose of the handover procedure it to preserve ongoing calls when the mobile station moving from one cell to another. In GSM measurements reports to perform the handover, which is made by the serving BSC which has no direct knowledge of the radio quality. These measurements reports contain the radio signal quality of the downlink from the BTS to MSC of the call and up to five neighbouring cells. There are four types of handover, i.e. Intra BTS handover, Intra-BSC handover, Inter-BSC handover and Inter-MSC handover [25].

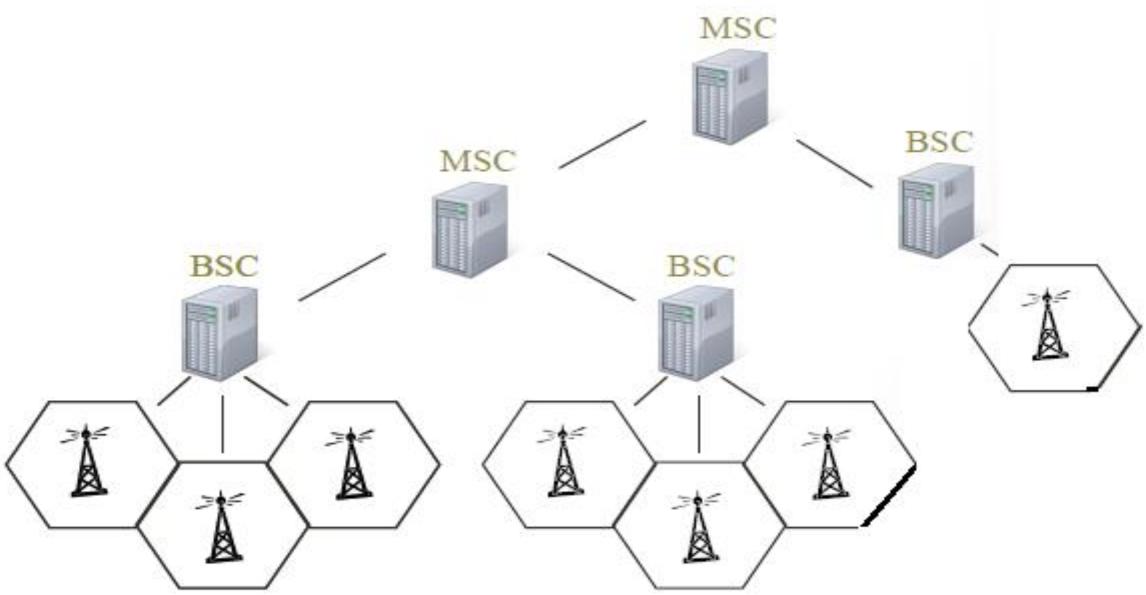

Figure 3. 1: Types of handover [25].

3.1.2. Handover in UMTS

Handover within UMTS can be divided into three basic types of handover. They are hard handover soft handover and softer handover.

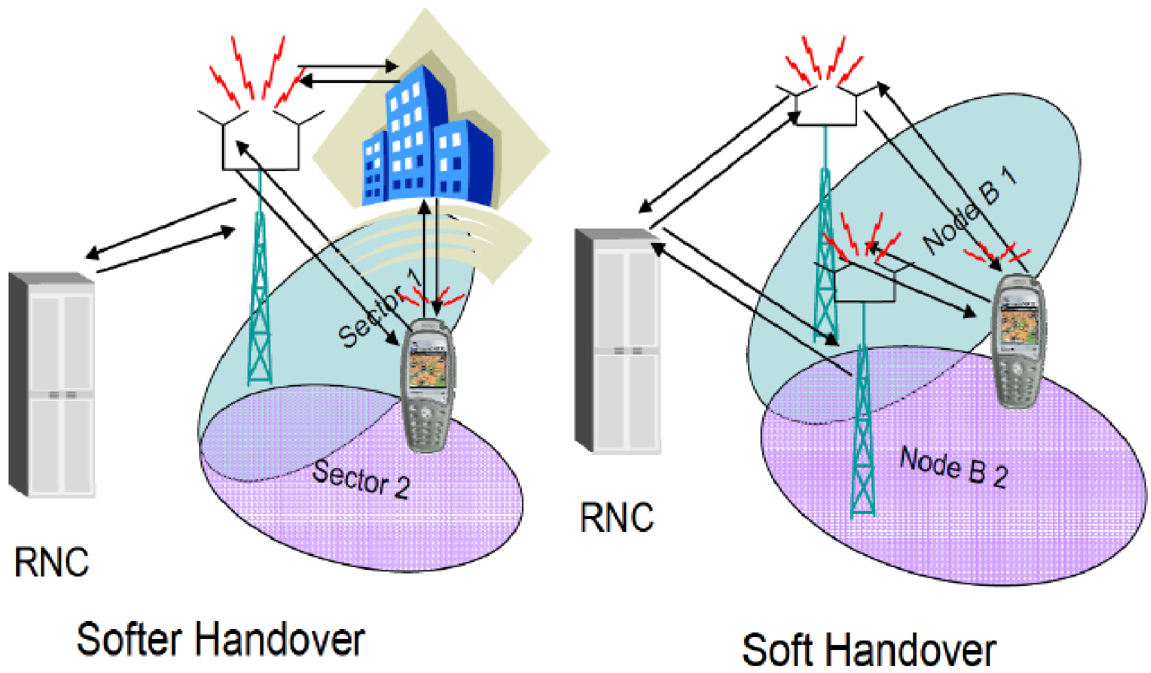

Figure 3. 2: Soft and Softer handover [25].

3.1.3. IRAT handover

IRAT (Inter Radio Access Technology) is a handover take place between different mobile technologies. It is one type of hard handover. Due to many reason there is a time when we need to handover a user from UMTS radio access network to 2G GSM network. WCDMA and GSM mobile technology can support handovers both ways between WCDMA and GSM. These handovers may be required for one of a variety of reasons [24].

In general based on the triggering causes of handover, inter-RAT handover can be categorized into five types. They are Coverage-based, QoS-based, Load-based, Service-based and Speed-based. The coverage of the UMTS is in continuous at the initial stage of the 3G network. On the border of the coverage, the poor signal quality of UMTS triggers the UMTS-to-GSM measurement. If the signal quality of GSM is good enough and all the services of the UE are supported by the GSM, the coverage-based UMTS-to-GSM handover is triggered. According to the Link Stability Control Algorithm, the RNC needs to trigger the QoS-based UMTS-to-GSM handover to avoid call drops. If the load of the UMTS is heavy and all the RAB of a UE are supported by the GSM, the load-based UMTS-to-GSM handover is triggered. Based on layered services, the traffic of different classes is handed over to different systems. For example, when an Adaptive Multi Rate (AMR) speech service is requested, this service can be handed over to the GSM. When the Hierarchical Cell Structure (HCS) is used, the cells are divided into different layers on the basis of coverage. Typically, a macro cell has large coverage and low priority, whereas a micro cell has small coverage and high priority.UMTS-to-GSM handover can be triggered by the UE speed estimation algorithm of the HCS. A UE moving at high speed is handed over to a cell with larger coverage to reduce the times of handover, whereas a UE moving at low speed is handed over to a cell with smaller coverage [24].

The most common form of intersystem or inter-RAT handover is usually between UMTS and GSM.

There are two further divisions of handover. They are compressed mode handover and blind mode. In the first techniques UE uses the gaps in transmission channels and send the measurement to analyse the reception of local GSM base stations. So according to this measurement and the neighbour list provided by the UMTS network to monitor and select a suitable candidate base station. After selecting a suitable base station the handover will be done. In blind handover occurs when the MS handover from the GSM serving cell to UTRAN cell without knowing any information about destination cell. This type of handover can be resulted into call drop in a cell. In this mode, the network selects a BTS or NodeB which is believes to be less congested system[24].

A user mobile equipment while working in a RAT performs different measurement of neighbor cells and sends the report to the upper network. The upper network uses this measurement report which is provided by mobile terminal and then can initiate the handover from one RAT to the other RAT. The measurement report can be updated sometimes by using an interface call Iurg. It is an interface between RNC and BSC [24].

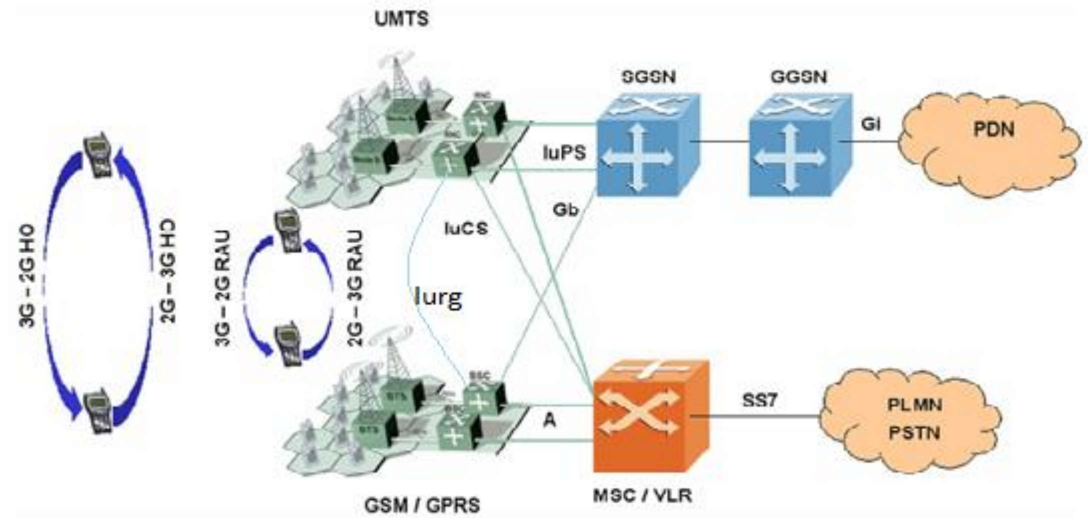

Figure 3. 3: Inter system Handover [9].

IRAT handover from WCDMA to GSM

When the load of UMTS cell exceed a predefined threshold or when the signal strength falls below a given threshold, the RNC network orders the user equipment to perform GSM measurements. The UE send a measurement report to RNC to add or delete cells from active set. In down link the channel quality is monitored based on both CPICH Ec/No and CPICH RSCP values. Also the Up link is depends on UE TX power [43]. The UE reports the measurement of connection quality with

2d, 2f and 3a events, and RNC continuously monitors whether the DL Ec/No, the DL RSCP or the UL coverage is good or weak. When at least one of these gets bad, a GSM HO attempt will be initiated, and if the coverage returns to good condition for all then the IRAT HO attempt will be discarded.

Reporting Events 2d, 2f and 3a

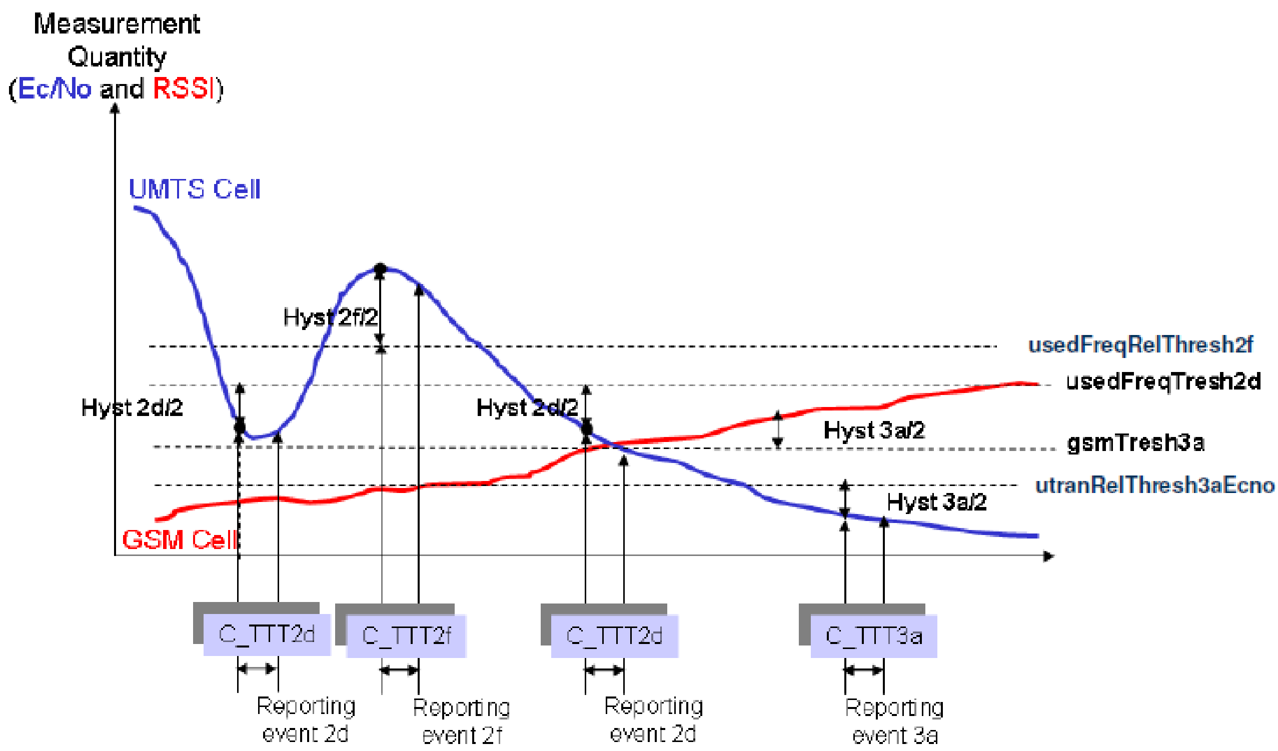

Figure 3. 4: Reporting Events 2d, 2f and 3a [43].

Reporting event description

Event 2a: Change of best frequency.

Event 2d: The estimated quality of the currently used frequency is below a certain threshold

Event 2f: The estimated quality of the currently used frequency is above a certain threshold

Event 3a: The estimated quality of the currently used UTRAN frequency is below a certain threshold and the estimated quality of the other system is above a certain threshold

When RNC receives the measurement report message sent from the user equipment, it initiates handover. RNC then asks the target base station control to reserve some transceiver resources.

Figure 3.5 depicts typical handover procedure between User equipment and network for handover from WCDMA to GSM. In the way the handover from GSM to WCDMA network is also performed. The only difference here is that measurement report is sent by GSM mobile terminal to the GSM network (BTS) in case of GSM to WCDMA handover. Then in both case the information reaches to the core network.

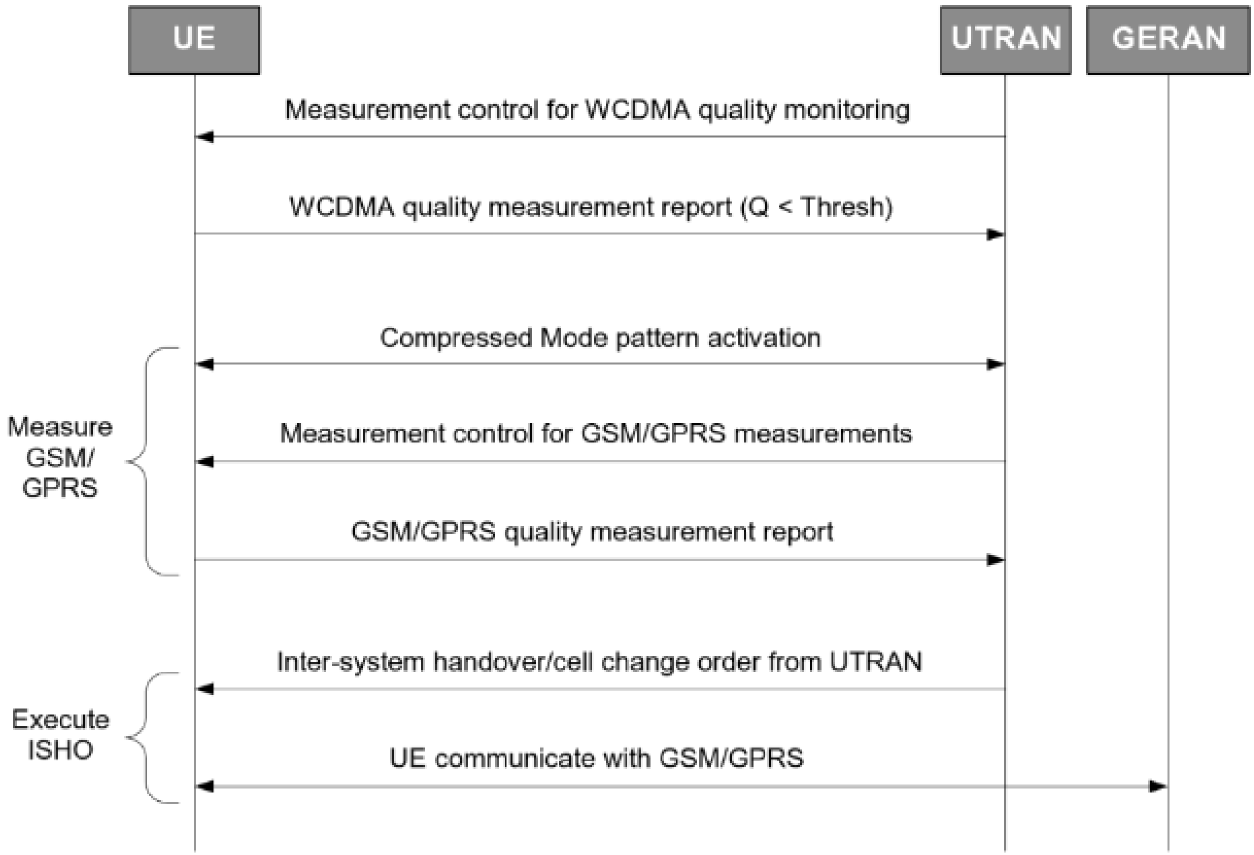

Figure 3. 5: UMTS to GSM handover message flow [14].

As both RNC and BSC are connected to a core network, it plays a vital role for the handover between the two systems. Once the handover to the GSM is completed the UMTS channels are released.

3.1.3.1 Preconditions for WCDMA-to-GSM Handover

Basic condition should be full filled to handover the call from UMTS to GSM. They are capabilities of deciding UMTS-to-GSM Handover, GSM neighbouring cell capability, service capability and UE capability. Before handover, the RNC has to manage whether the preconditions fulfil the triggering requirements of the handover between UMTS-to-GSM. The preconditions include the service handover indicator, GSM cell capability, service capability, and UE capability [43]. Before deciding the handover between UMTS-to-GSM, the RNC checks GSM cell capability, service capability and UE capability.

The network orders the dual-mode MT to perform UMTS measurements by sending the measurement information message, which contains information on neighbouring UMTS cells and the criteria for performing and reporting measurements. When the criteria for HO to UMTS have been met, the BSS initiates the allocation of resources to the UMTS cell. Encapsulated in these messages, the BSS also sends information to UTRAN on the UMTS capabilities of the MT. When the resources of the UMTS target cell have been allocated, UTRAN compiles the HO-to-UTRAN-command message, which typically includes the identity of the pre-defined configuration for the service in use. This message is then sent transparently to the MT through the core network and BSS. When the MT receives the HO-to-UTRAN command message it tunes to the UMTS frequency and begins radio synchronisation. The MT then indicates that the HO was successful by sending the HO-to-UTRAN-complete message, after which the resources in GSM are released [43].

Chapter 4: Load balancing between UMTS and GSM

4.1 Overview

The ever increasing user's needs for best quality of services and the number of new mobile application makes the job of wireless network more complicated. The mobility of users and specially the area covered by different types of wireless technology makes the traffic flow more difficult. In ethio telecom case there are four wireless technologies (2G, 3G, 4G and CDMA) that were deployed to provide mobile services in Addis Abeba and country wide. So there must be a mechanism to handle the mobile users in heterogeneous network to make a seamless connection and make the traffic balance between different technologies. By doing this we can utilize the available radio resource efficiently and provide a service better quality of services [20].

In this thesis the main goal is to balance a load from 3G to 2G network to minimize the congestion in 3G wireless network.

4.2 UMTS Load Definition

Load metrics differ from device to device, and depend on the number of users in a given cell, services being provided, quality of service and many other different parameters. Capacity per system is a very important variable in load balancing [8]. In GSM, capacity depends mainly on the number of RF Transceivers (TRX) installed in the Base Station (BS), since each user is assigned its own timeslot (at full-rate). As for UMTS, capacity strongly depends on the interference level among users, since all UEs (User Equipment) are operating at the same frequency due to CDMA.

In general load is the occupancy of capacity and can be divided in two types of capacity in UMTS system

- Hard capacity
    - Code channels
    - NodeB processing capability
- Soft capacity
    - Interference (UL)

- Power (DL)
- License

In general the capacity of UMTS system depends on the hardware installed and the license used for the hardware.

4.2.1 Channel Element

The software licensed capacity resources required for data or voice for a dedicated channel (DCH or E-DCH) are called Channel Element (CE). The number of channel elements required in a NodeB is configured according to the traffic condition and the radio bearer.

4.2.1.1 Hardware

Channel elements is usually consumed in uplink and downlink when dedicated channel is allocated by the system to the user. Depending on the type of radio bearer for the dedicated channel, the consumption can be described as a cost and the channel element cost can be estimated. Call rejection will be happen when there is no sufficient size of channel elements are not allocated. To avoid blocking the call congestion control function in RNC will switched down the user data rate to a lower and to make channel elements available for the requested dedicated channel. [32]

4.2.1.2 Channel Element (CE) Resource

One of the NodeB hardware resource is a CE resources. The capabilities of a NodeB is determined by the number of CEs supported by it. The more CEs a NodeB supports, the more powerful the channel demodulation and service processing capabilities for serving the users. Different number of CEs will be assigned for different services to ensure proper channel demodulation [32].

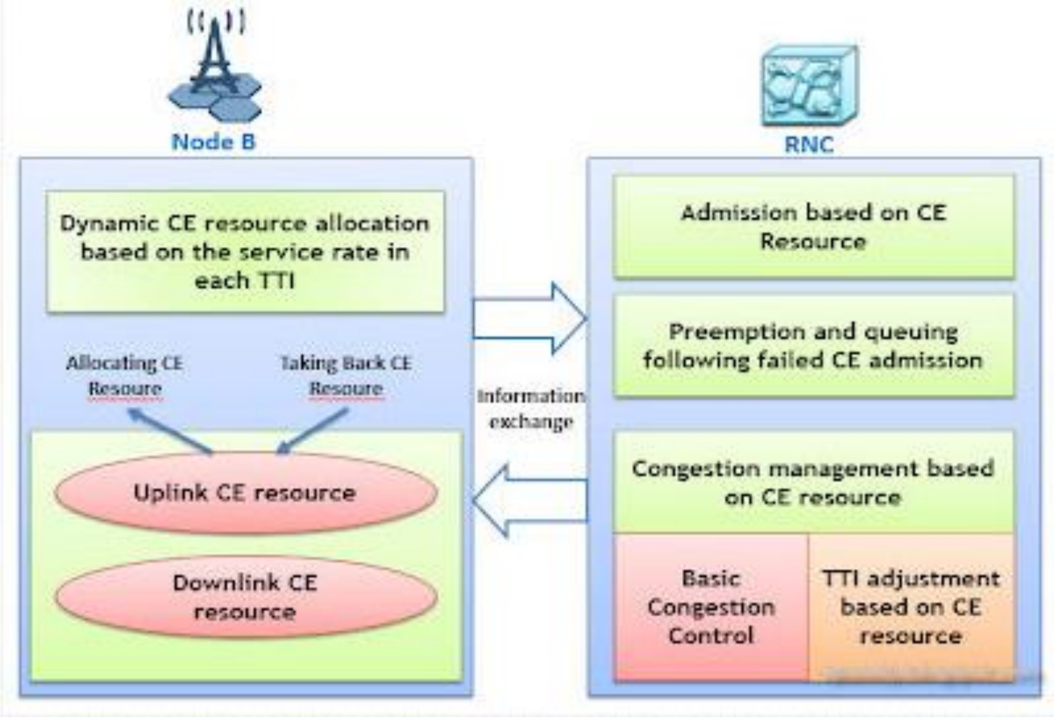

Figure 4. 1 Basic channel element concept [32].

In the RAN network RNC and NodeB are responsible to manage the CE resources. The NodeB is in charge of reporting its CE capacity to the RNC [32]. The RNC determines the service to admit depending on the reports from NodeB. The RNC uses some algorithm to decide either to admit or block the service based on the number of CEs that need to be consumed and controls CE resources during CE congestion. This results in better use of CE resources. The NodeB adjust the number of CE dynamically based on the actual rate of the user. This increases CE utilization.

4.2.2 Uplink Load Definition

Cell Load Factor:

$$\eta UL = 1 - \frac{1}{noiserise}, \qquad noiserise = \frac{RTWP}{PN} \qquad (4.1)$$

Where, P_N : Back ground Noise

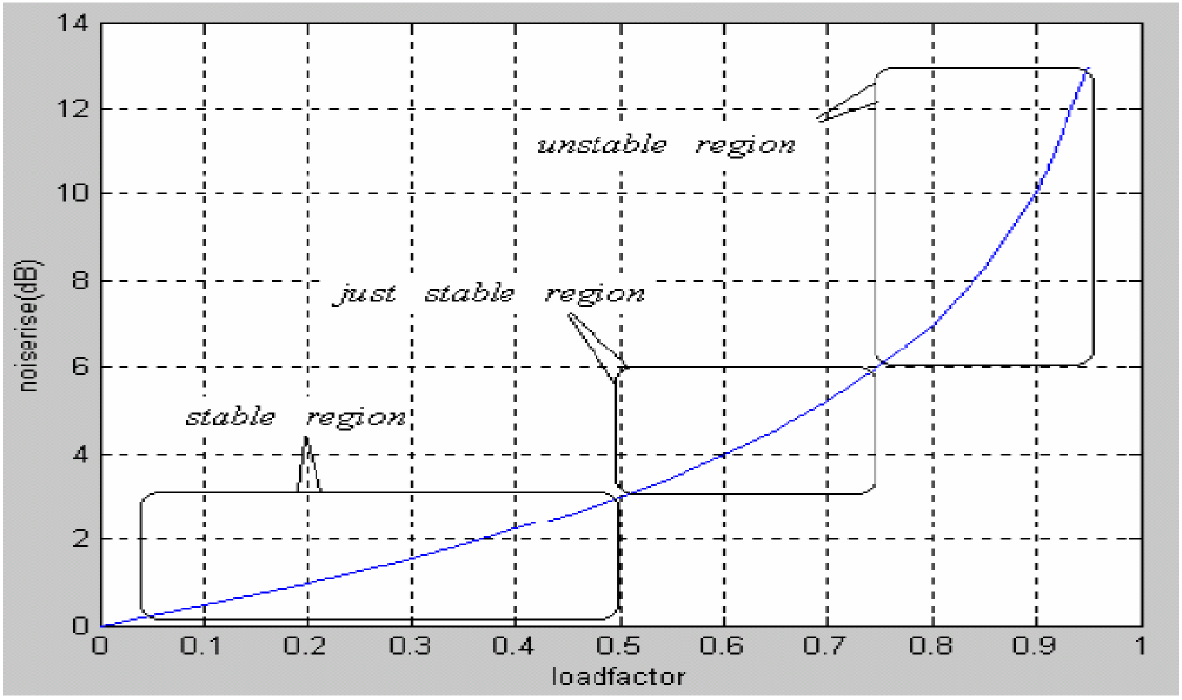

Figure 4. 2: WCDMA Load Control [23].

4.2.3 Downlink Load Definition

The definition of DL load is very different from the definition of UL load, the adjacent cell interference factor and the non-orthogonally factor in the downlink are very difficult to measure and calculate, therefore, the DL cell load factor cannot be used to describe the DL cell load. Then, the transmission power is used to describe DL load [23].

$$P_{total} = P_{own} = \sum_j pj + P_{cch} + P_{HSDPA} \qquad (4.2)$$

4.3 RAT Selection in heterogeneous wireless networks

The RAT selection algorithm is used to validate which RAT will fit the best connection at that time and select a RAT from heterogeneous wireless network. This algorithm should ensure the most efficient way of monitoring the available resource and a good quality for all active connection [20]. The RAT selection algorithms in heterogeneous wireless networks can be classified as follows:

- Random based RAT selection algorithm
- Fixed Policy based
    - Load balancing based RAT selection algorithm
    - Service-class based RAT selection algorithm
    - Service-cost based RAT selection algorithm
    - Layer based RAT selection algorithm

Most of the above load balancing techniques has been deployed by ethio telecom so I am going to discuss a Load based inter RAT selection algorithm.

4.3.1 Load balancing based RAT selection algorithm

The final goal of Load Balancing based algorithm is to evenly distribute the traffic among different RAT those have common or over lapping coverage area. A load balancing techniques can be used in different fashion in heterogeneous mobile network such as: performing load balancing when the resource utilization of a RAT is reaching a pre-defined threshold value. The load balancing between 3G and 2G can be carried out by forcefully handing over active call(s) from heavily loaded network to the least loaded network. The load balancing algorithm provides the high network stability and efficient resource utilization: however load balancing can be resulted in low user satisfaction and increases call drop due to forced handover [32].

4.3.2 Load Balancing by load levelling Algorithm

The mobile network element periodically monitor their own loads and the loads of the other network in overlapping area so that the load can be off from a RAT to another RAT. So in order to perform this a load balancing algorithm should be run on some entities of the network such as RNC and NodeB. The handover strategy used for the load balancing purpose is "network assisted mobile controlled" handover. Most of the information is collected at network side and forwarded to the mobile node. Then the load aware RAT selection algorithms running on the mobile node utilize this information in decision making. Therefore most of the processing for information gathering is performed at network side. The analytical representations of some important procedures performed at network side are given below [20].

4.3.3 Resource Utilization

The Resource Utilization (RU) of a network is evaluated at the network side to calculate the available resources on that network. The element a_{xy} of an association matrix A is used to describe the association status between MNy and BSx. If the MN 'y' is associated with BS 'x' then a_{xy} = 1, else a_{xy} = 0. Suppose there are **m** mobile nodes in the system registered with the different base stations [32]. A base station, **x**, is denoted by BSx then the equation for the resource utilization in each base station or the network entity can be represented as RU which is shown in Eq. [4.3].

$$A_{xy} = \begin{pmatrix} a_{11} & a_{13} & a_{13} & a_{14} \ldots\ldots & a_{1y} \\ a_{21} & a_{22} & a_{23} & a_{24} \ldots\ldots & a_{2y} \\ a_{31} & a_{32} & a_{33} & a_{34} \ldots\ldots & a_{3y} \\ a_{41} & a_{42} & a_{43} & a_{44} \ldots & a_{45} \\ \ldots. & \ldots.. & \ldots.. & \ldots & \ldots. \ldots \\ a_{x1} & a_{x2} & a_{x3} & a_{x4} \ldots & a_{xy} \end{pmatrix} \tag{4.2}$$

$$RU_x = \frac{\sum_{y=1}^{m}(a_{xy} * Throughput_y)}{\text{Bandwidth}_x} \qquad (4.3)$$

In Eq. (4.3) the through put denotes the throughput of MN 'y' and Bandwidth x, the bandwidth of network '*x*'.

4.3.4 Selection of neighbouring network

The network element such as BSC or RNC will periodically request for the load status of its neighbouring networks. The process of neighbouring networks selection is carried out using with the help of a simple distance formula. The local network sends out its location information in the Information. Request message to the RNC in order to get the load status of its neighbouring networks [32]. For simplicity it is assumed that the information it sends out contains the location coordinates of the network element (such as BS or UE) in the *'x-y'* plane, which is network element location and the range of network coverage which is shown as radius in Figure 4.3.

$$d < R, \text{ (Where, } R=(r_1 + r_2)) \qquad (4.5)$$

- d is the distance between center of two cells(P_1 and P_2)

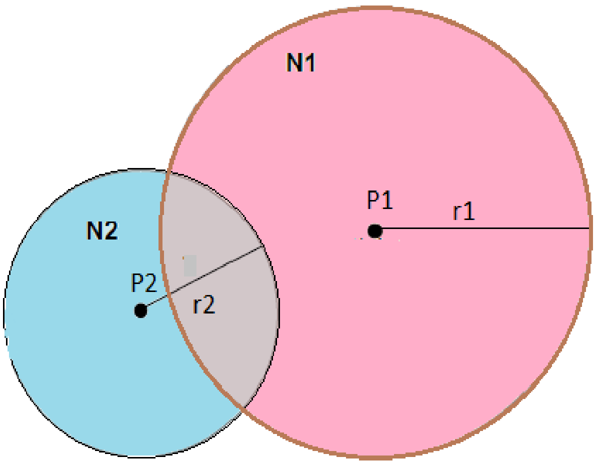

Figure 4. 3: Overlapping detection in network coverage areas [20].

P_1 and P_2 are the centre of the coverage area of the requesting and the neighbouring network. So 'd' is the distance between the two centres P_1 and P_2. 'R' is the sum of the radius of the candidate and the requesting network. It shows the maximum coverage area of both sites. RNC will respond to the requesting network with network information will reply to the neighbouring network those fulfil the criterion set in equation [32].

4.3.5 Suitable node selection

The overloaded network selects the least loaded neighbouring 2G network and the RNC will continue to searches more network from its locally registered network which has a common coverage area. So if it find a less loaded 2G nodes in overlapping area, it will push some traffic to this neighbour 2G nodes until the load of 3G node is less than or equal to the average CE resource in all 2G nodes in our case. If the local load fulfils the condition to trigger load balancing, the RNC looks for suitable UE to push to another 2G neighbouring cell. The decision of selecting the UE for load based handover depends on the distance equation shown above [20]. In this case the current position of the mobile node, the centre of the neighbouring network and the radius of the neighbouring network coverage area is used. The network will search for the mobile nodes registered locally which are in the common coverage areas of local network and the 2nd least loaded network from the list and so on until the load in the current network reaches less than or equal to the average load in all neighbouring networks.

4.4 Load balancing Using load Reshuffling Algorithm

Load reshuffling is one type of load control algorithm which takes action when the cell in in congestion state. The cell inters the congestion state if the usage of the resource exceed the basic congestion triggering threshold. In this case, LDR algorithm is triggered to release the over load condition by pushing some traffic with the same RAT or to another RAT. This will in turn increase the access success rate by taking the following actions. i.e. inter-frequency load handover, code reshuffling, BE service rate reduction, AMR voice service rate reduction, QoS renegotiation, CS inter-RAT load handover and PS inter-RAT load handover [11].

4.5.1 Basic congestion triggering

The main cause of basic cell congestion is occurs by insufficient resources. These resource are resources like power resource, code resource, Iub resource and NodeB credit resource. This resource are called RAN resource as shown in a cell where the basic congestion occurs is referred to as a cell the figure below. In the LDR state. RNC performs periodic measurement for power resource and checks whether the cells are congested or not. For code, Iub, and NodeB credit resources, the RNC checks whether the cells are congested during resource usage changes. If the congestion of all resources in NodeB is triggered, the basic congestion triggered by different resources will be realised in order of resource priority for load reshuffling [15].

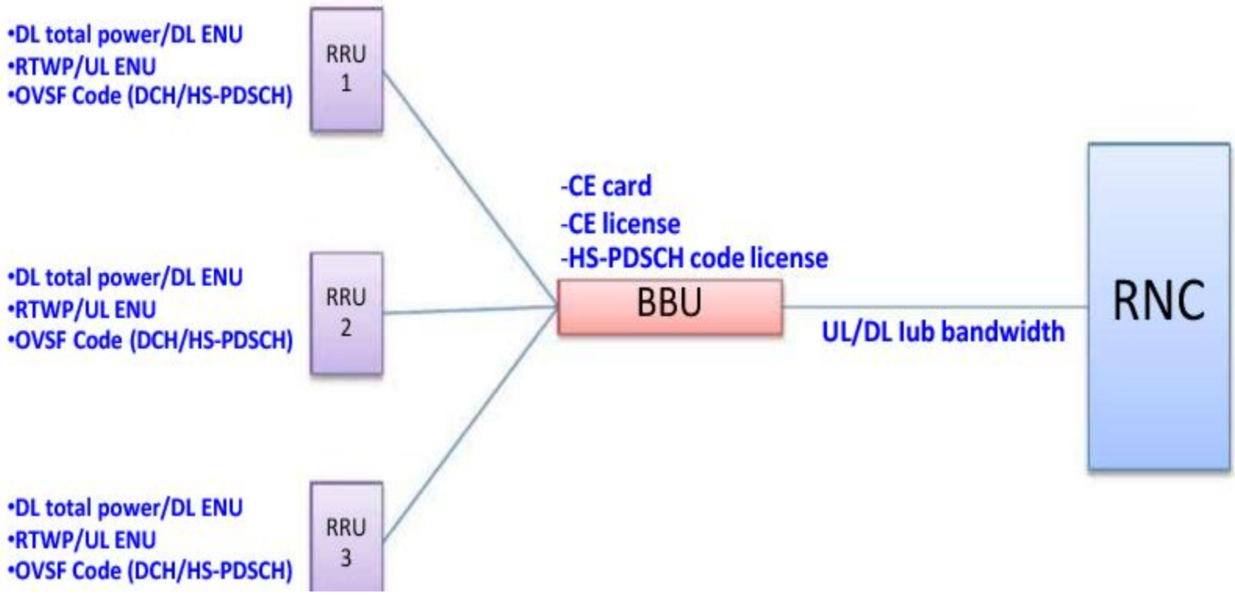

Figure 4. 4: RAN resource [15].

4.5. 1.1 Power Resource

A cell is usually served by one RRU (Remote Radio Unit) and the down link power is depends on the RRU power capacity. The typical power of RRU assigned for a cell is 20 watts and this power is distributed within the cell for all connected users. If the number of connected users are more and more there will a power congestion in the cell for down link. The power consumption of each service will be different as well as the radio condition of each UE (e.g. distance, RSCP, Ec/Io).HSDPA will use the remaining power left from R99 service [11]. Even the UL power is not limit corresponding to each UE power, but the noise raise will trigger the rejection due to Call Admission Control as well. Hence, the congestion in UL load can cause call rejection and data service degradation. If the current UL/DL load of the R99 cell is not lower than UL/DL LDR Trigger threshold (basic congestion control threshold in UL/DL), the cell works in basic congestion state and the related load reshuffling actions are taken.

As shown in Fig. 4.5 the LDR will triggered when the cell enters in the basic congestion state decreases the load.

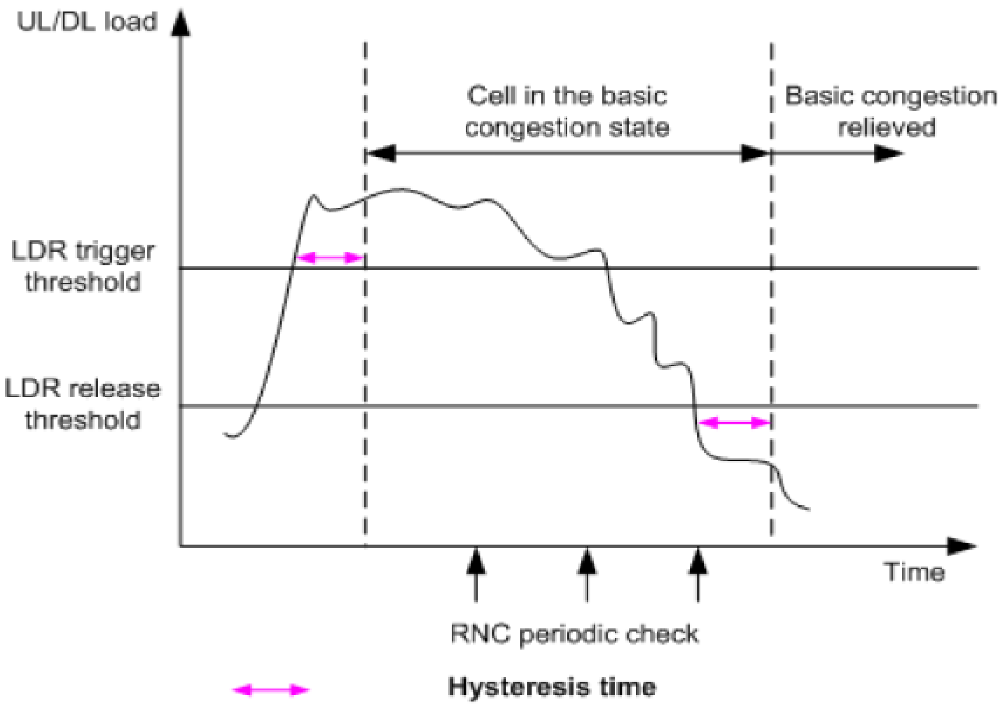

Figure 4. 5: Triggering and relieving of basic congestion [15].

4.5. 1.2 NodeB credit resource

In a NodeB CE resource is consisting of hardware and software. CE can be considered as the pool resource at NodeB level, all cells connected to NodeB will share the same CE resource for all sectors. The number of CE is depends on the number of board installed in the NodeB and also on the model of the boards. Those CE with license will used by the UE even if the NodeB has a large capacity of hardware capability. So If the UL/DL current remaining credit resource is higher than the defined threshold, credit congestion is triggered and related load reshuffling actions are taken [15].

4.5.2 Load Reshuffling Procedure

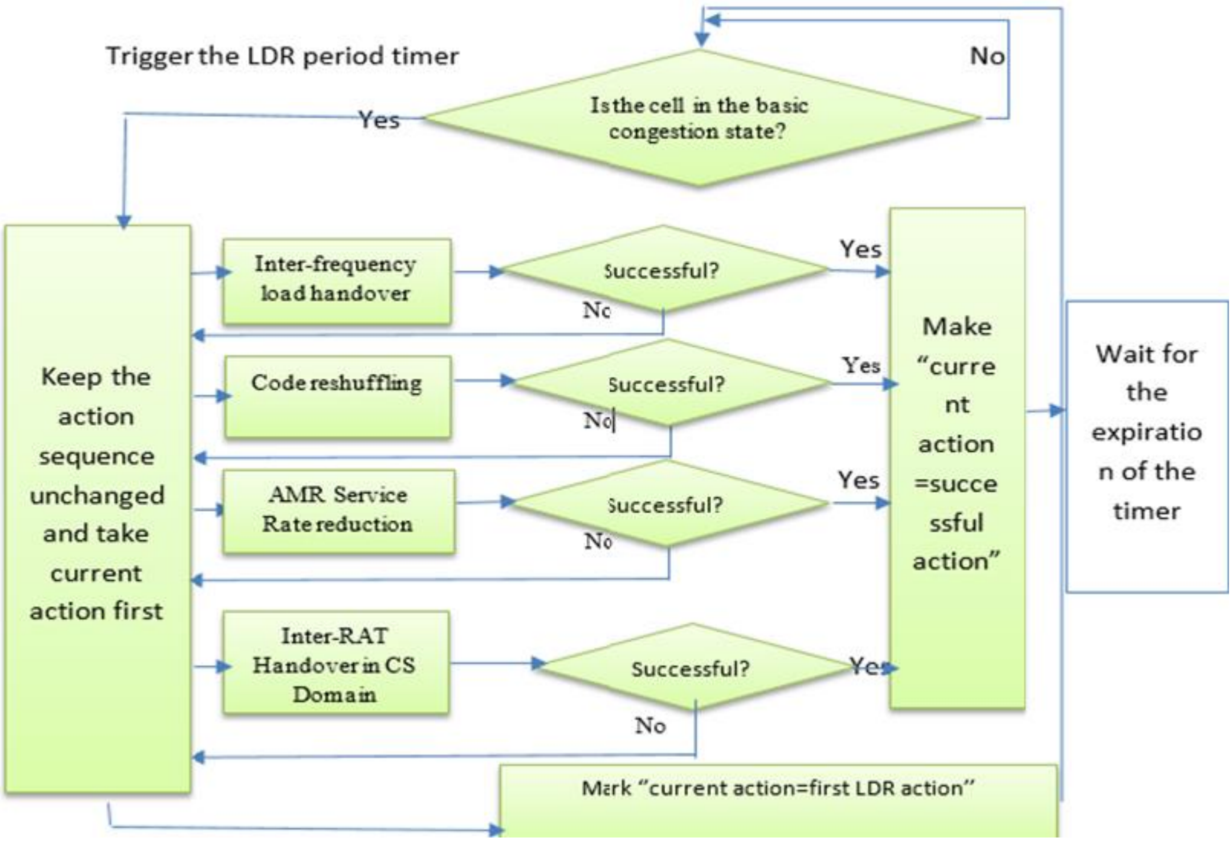

Figure 4. 6: Load Reshuffling Procedure [23].

The LDR Algorithm takes action according the following sequences when the cell is in congestion state. First it tries to decrease the load by load-based inter-frequency handover. If this is not possible it will try the rest accordingly. I.e. the code tree reshuffling, BE service rate reduction, inter-RAT handover in CS domain, inter-RAT handover in PS domain, AMR service rate reduction, QoS Renegotiation for Uncontrollable Real-Time Services will executed 23]. The LDR algorithm implements the "Inter-RAT Should Be Load-based Handover in the CS Domain" action as follows:

The LDR algorithm sorts UEs with the "service handover. The LDR algorithm will selects UEs with the lowest integrated priorities. After selecting a UE, the LDR module sends the load-based handover command to the inter-RAT handover module, requesting the inter-RAT handover module to handover the UE to the GSM system. The handover module checks the compressed mode capability of the UE to decide whether to trigger the inter-RAT handover. If the UE does not meet the inter-RAT handover criteria, the algorithm takes the next action [44].

Chapter 5: Result Analysis and Conclusion

A simulation is an approximate estimation of the operation of a process or system. In this thesis, simulation software is used to solve the problem of congestion occurred in Addis Ababa 3G network by using a load balancing techniques. The load balancing techniques is done by using a wireless simulation software called Atoll. The results of the target parameter are presented with the help of graphs and tables. Different evaluation parameters such as RSCP, EC/IO, relative load and load balancing are considered to performance evaluation with and without load balancing in different scenarios. The Atoll simulation system uses a load levelling algorithm. The output of this algorithm will be compared with the load reshuffling algorithm which is deployed on Addis Ababa mobile network. The output of the LDR has been taken from actual ethio telecom network. The two output will compared from load balance change after deployment [9].

5.1 Atoll

Atoll is a different mobile technologies wireless network design platform. It is an open, scalable and flexible multi-technology network design and optimization platform that supports wireless operators throughout the network lifecycle, from initial design to deployment. Atoll can be used to design and optimize the following wireless network [22]. They are GSM/GPRS/EDGE, UMTS/HSPA, Multi-RAT projects, CDMA2000 1xRTT/EV-DO, LTE, Microwave Links

5.2 Target Network

In this thesis one of the most congested area of Addis Ababa which is called Markato area is selected to study the load balance between UMTS and GSM when the 3G network is in loaded condition. The population of this area can be considered as dense urban. The coverage of focus area is 2 km^2. This area has large traffic volume and different user's behaviour since is a market area. The road passing through this area leads to two country side bus station. This also impose a big traffic on sites in this area. Thus the choice of this area as a test for load balancing is a right choice since the users in this area needs a continuous connectivity for to communicating and get information about their business issues.

5.2.1 Ethio telecom Mobile Network overview

Ethio telecom has carried out a vast project called TEP1 in 2015 which has covered all the countries. The first phase was to replace OLD mobile network of Addis Ababa. Now a days there are 743 sites serving the mobile services in the city. Three types of technologies are deployed in the network. They are 2G, 3G and 4G. The nature of our 3G and 2G network is not Overlapping Coverage instead it is Hierarchical Coverage as shown below Fig. 5.1.

In this scenario, two different size cells will not overlap each other. 3G Cell that has a smaller area is covered totally by 2G Cell, which has a bigger size. During load balancing all 3G users can be handed over to 2G without any network coverage issues.

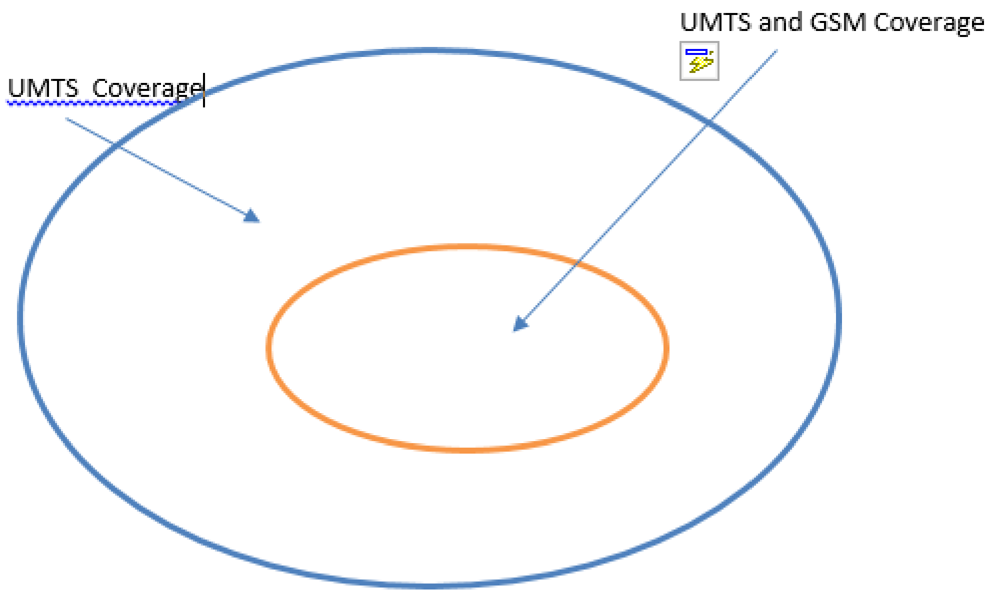

Figure 5. 1: UMTS/GSM Coverage [16].

5.2.2 Focus area

The focus zone can be defined as an area on which statistics can be drawn and on which reports are made. The main focus area in this thesis is consists of eight sites found around similar area. The sites were selected according to their high traffic and their neighbour relationship. The main site which is selected to balance its load from 3G to its 2G neighbour cell is a sites with site ID: MARK83_WL_GUL_BSCRNC3.HW.MERKATLASCLN.WAAZ.AA and the other sites are neighbours those share a load when the main site is congested.

5.2.3 System Model

The system model shown below comprises of different type of equipment. It also includes both technologies, GSM and UMTS. It has BSC, RNC, NodeB and BTS. Both RNC and BSC are connected to common core network. The NodeB and BTS assumed to have an overlapping coverage area so that inter RAT handover is possible.

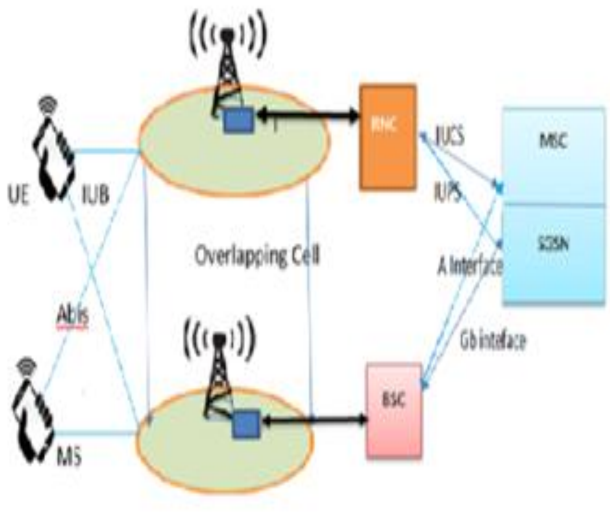

Figure 5. 2: system Model

5.2.4 Digital map

A digital map is a database of telecom operators containing geographical information. The primary function of this technology is to produce maps that give accurate representations of a particular area, detailing major roads, clutter height, clutter classes and vector data such as streets, secondary roads, highways, water body and railways. The technology is used to calculate the distances between two sites.

Figure 5. 3: Digital Map [ethio telecom].

5.2.5 Focus Zone on Atoll

The focus zone is an area on which the optimization is going to be done. This area contains a fixed number of network element. The difference between focus and computational zone is that the computation zone is used when the Atoll calculates parameters such as coverage prediction and simulation…etc. while the focus zone is the area used when we generate reports and results. When you create a coverage prediction report, it gives the results for the focus zone.

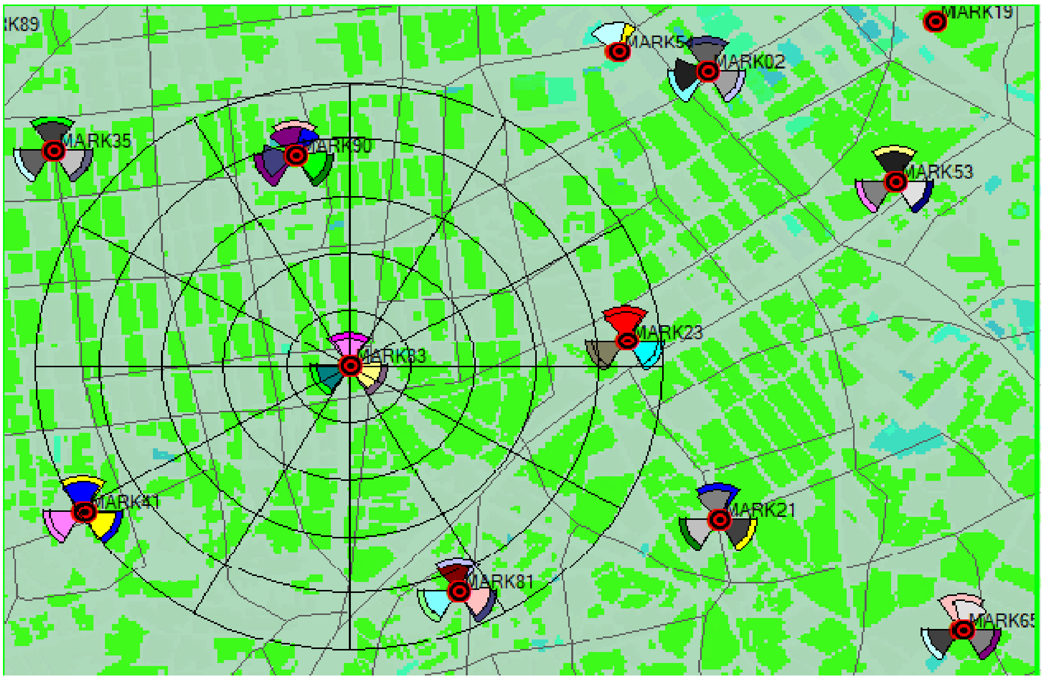

Figure 5. 4: Focus Zone.

5.2.6 Site Parameters

The simulation was done on actual sites located in Addis Ababa. These sites are connected to different RNC and BSC. They have different capacity according to the traffic they are serving. I have mentioned some the parameters such as number of CE and TRX.

5.2.6.1 Sites CE Capacity

There are seven sites in the focus area. Their Channel Element capacity can be described in two ways. I.e. hard capacity and soft capacity. Hard capacity is the number of UL and DL channel in a baseband processor board while the soft capacity is the number CEs that have license and can provide services.

No.	Site ID	HW Baseband Capacity(UL)	HW Baseband Capacity(DL)	Current UL CE Usage	Current DL CE Usage
1	Mark83	768	1024	496	720
2	Mark35	768	1024	544	624
3	Mark90	1152	1536	896	1232
4	Mark23	1152	1536	928	656
5	Mark21	1152	1536	896	608
6	Mark41	1152	1536	1136	688
7	Mark81	768	1024	336	240

Table 5. 1: 3G Sites CE Capacity [ethio telecom].

5.2.6.2 2G Site TRx Capacity

A transceiver (TRx) is a unit which can receive a signal from user and also transmit a signal towards a user. A transmitter have both transmitter and receiver unit. They share the same circuits. However, the only similarity of transmitter and receiver is they share a common housing and nothing else, the device is called a transmitter-receiver. The capacity of the BTS depends on the number TRx configured. One TRx have eight time slot or channel. These channel can be configured as SDDC, BCCH and TCH. The TRx shown in the below table is the total number of TRx in GSM900 and DCS (1800).

No.	Site ID	Alocated TRx license	Actual used TRx license
1	Mark83	31	22
2	Mark35	34	28
3	Mark90	54	45
4	Mark23	50	41
5	Mark21	47	38
6	Mark41	52	43
7	Mark81	35	28

Table 5. 2: 2G Sites TRx Capacity [ethio telecom].

5.3 Simulation Workflow

The Atoll simulation software is a powerful and flexible system. It includes all elements and integrated set of tools and features that enables an operators to create and define radio-planning project in one application. Atoll includes advanced multi-technology network planning features, and a combined single-RAN, multi-RAT GSM/UMTS/LTE Monte Carlo simulator and traffic model. Figure 5.5 depict a final simulation workflow that is used in this thesis to design and show how load balancing techniques used to relief a 3G congestion by using an Atoll wireless simulation software.

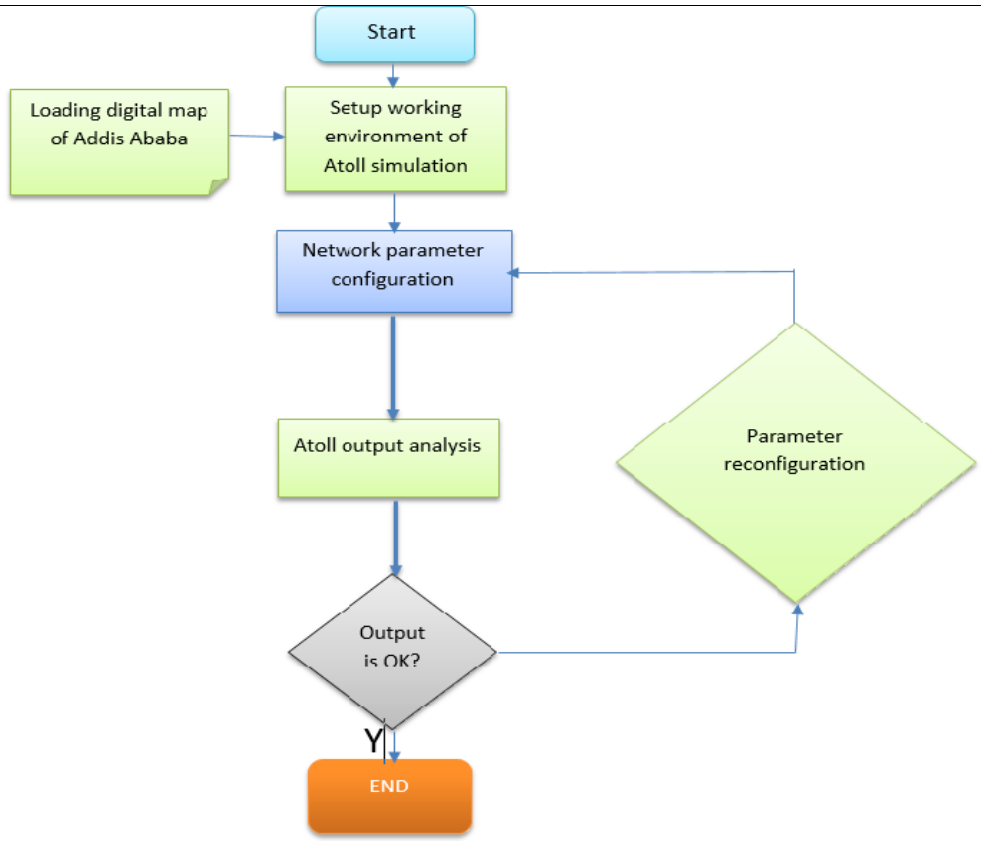

Figure 5. 5: UMTS Load Balancing Simulation Workflow.

The above workflow shows that it has two inputs. The first input is a digital map of Addis Ababa. It is used to setup the working environment in the Atoll tool. The map contains all 743 sites of Addis Ababa city. This thesis particularly focus on area around Markato as shown in figure 5.3 above.

5.4 Simulation Output Analysis

5.4.1 Initial Relative Load

The initial relative load of the selected site Mark83 is high before deploying a load balance. When we see specially sector three of the 3G site, its relative load is between 4dB and 5dB as shown in Fig. 5.6. These shows the 3G cells are congested with data and voice service.

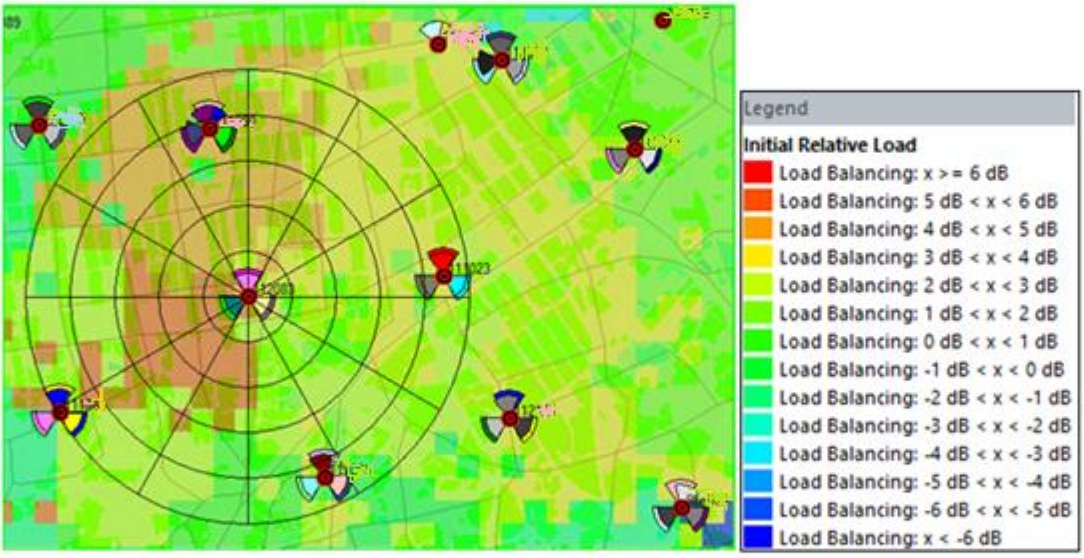

Figure 5. 6: Initial Relative Load.

5.4.2 Final Relative Load

In Figure 5.7 below the final relative load is very small after deploying load balancing. There is a decrement in relative load in all sector of the site. The final relative load shows a big decrement. It is between 1dB and 2 dB This shows the voice call on 3G cell has been handover to the neighbour 2G cell when the threshold set was exceeded. Now the cell can handle the 3G data service very well and will have a better throughput.

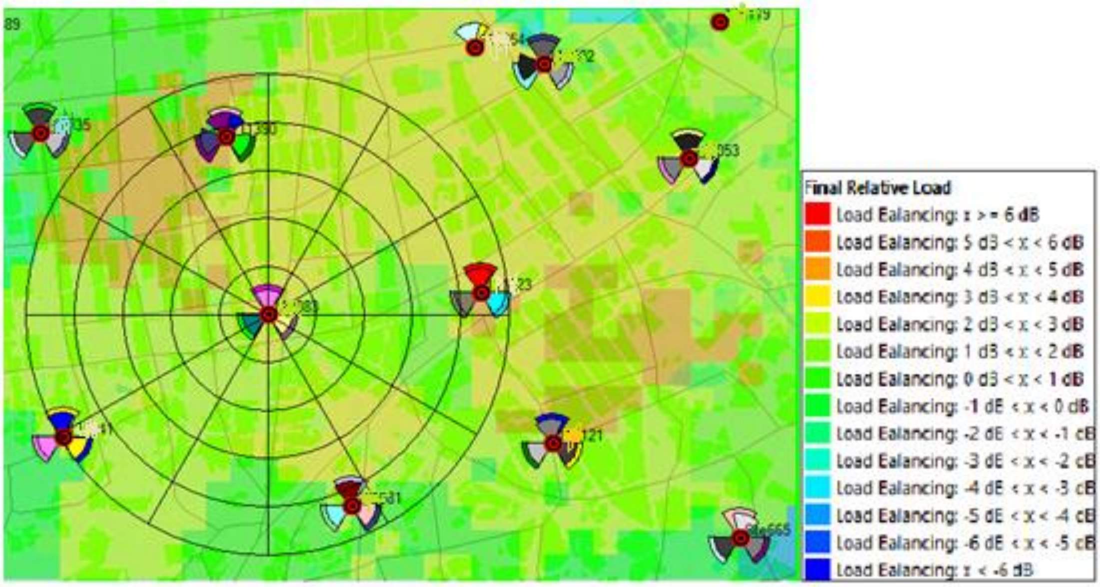

Figure 5. 7: Final Relative Load.

5.4.3 Initial Energy per chip to Interference power ratio

Ec/Io stands for Energy per chip to Interference power ratio. It is measured before dispreading. We have negative value to the ratio of energy on the total noise (the energy is lower than the Total Interference). It is measured at the input of the receiver (NodeB, UE, etc.).

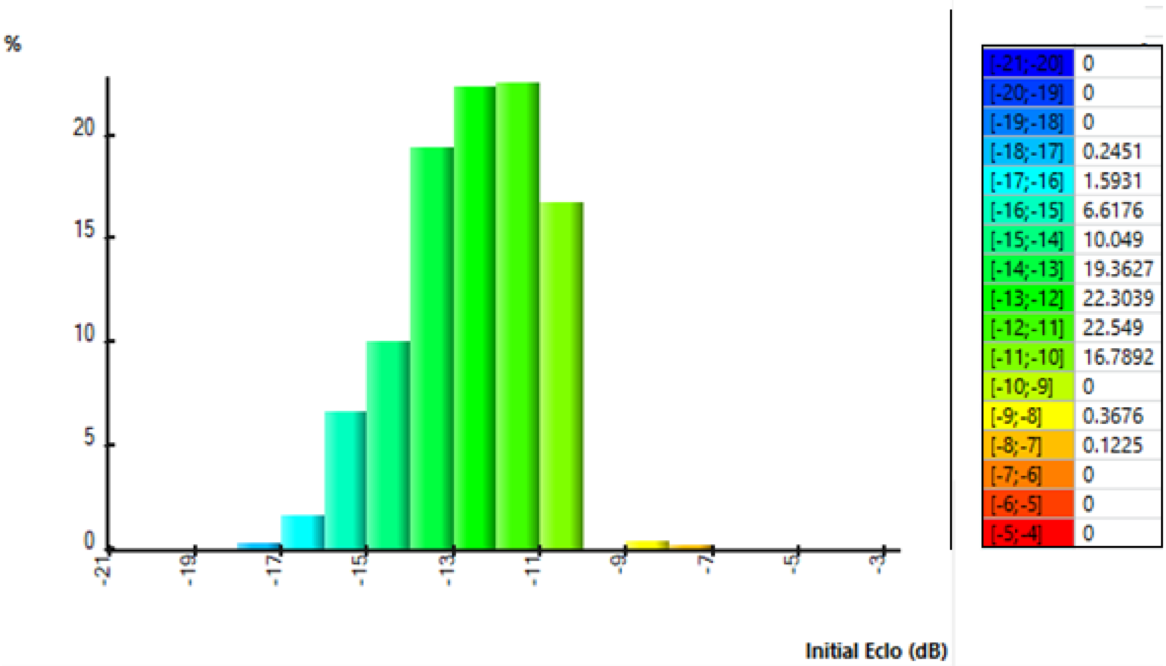

Figure 5. 8: Initial Ec/Io.

As shown in the Fig. 6.8, 65% of initial value of Ec/Io is between -13dB and -12dB. This value show that the signal was very low when compared to the interference. The Ec/Io value less than -11 dB is not acceptable. The cause of the result can be traffic load or interference. When traffic load is high, the users interfere each other since CDMA is a self-interfering technology.

5.4.4 Final Ec/Io

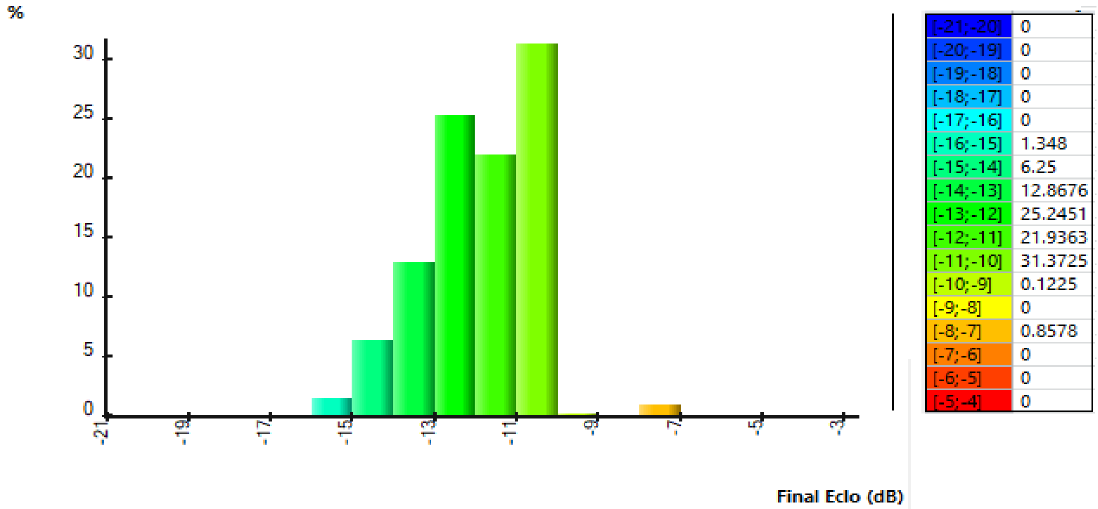

Figure 5. 9: Initial Ec/Io.

As we can see from the above histogram 55% of the Ec/Io is in the range of -10dB to -11dB. These shows that there is an improvement in Ec/Io due to the deployment of load balancing.

5.4.5 Final output of load levelling Algorithm

It is important to know the load of GSM and UMTS network before applying the load levelling algorithm. So, as we can see in the figure 5.10, Atoll can calculate the capacity load of each site in the focus area. The 3G cells of all sites were serving both voice and data service before deploying load balance algorithm. After the deployment almost the voice call will be handed over to the neighbour 2G cells. The final value of the load capacity of the cells show a decrement in value than the initial value. If we take site Mark83 as an example,

No	Sector	Initial Load	Final Load	Difference
1	Mark83_UMTS Sector _1	4.11	2.91	1.2
2	Mark83_UMTS Sector _2	2.25	2.20	0.05
3	Mark 83_UMTS Sector _3	4.85	2.03	2.82

Table 5. 3 Initial and Final load of site Mark83

The improved load balance percentage of all sites is shown below.

Total initial load balance: 56.30
Total final load balance: 67.69

Change in load balance in %=67.69%-56.3%=**11.39%**

Due to this load change in 3G network the following advantage can be achieved:

- Call setup success rate will be increased.
- Data through put will be better.
- RTWP becomes minimum.
- Call congestion will be decreased since voice call is pushed to 2G network.
- IRAT Call drop may be increase due to forced handover.

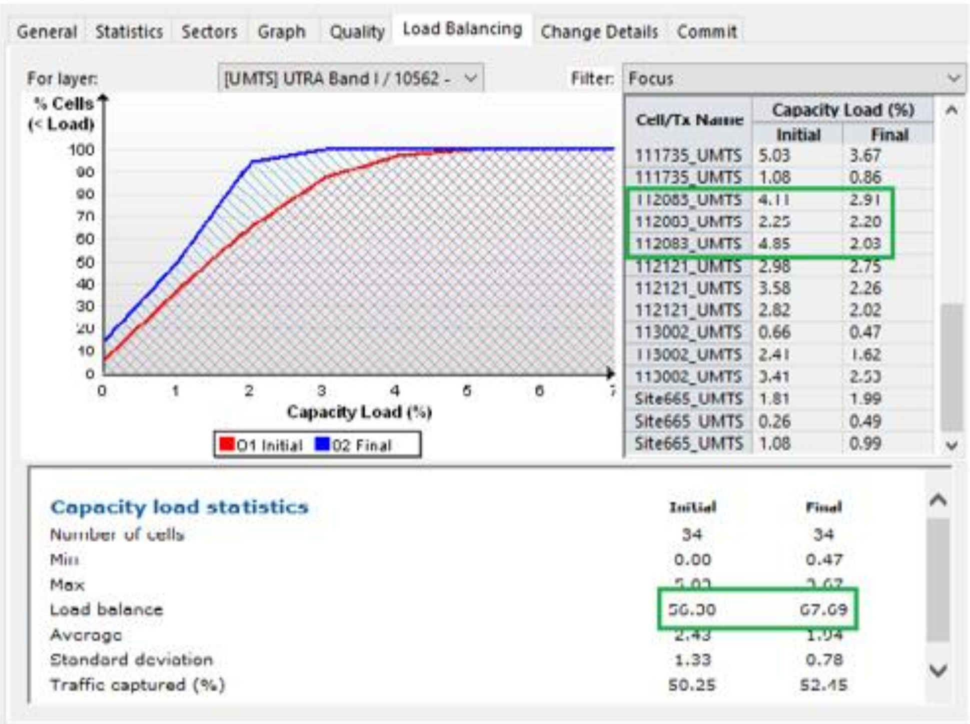

Figure 5. 10: Final Load Balance.

5.5 Load Reshuffling Algorithm

Load based inter RAT handover has been deployed in Addis Ababa mobile network to off load the voice service from 3G to 2G before a year. The algorithm used was load reshuffling. Load reshuffling algorithm is a vendor specific algorithm and it is difficult to get the formula to check on simulation network. So one way of comparing it with the load levelling algorithm is to collect the KPI from actual network. I have got all KPI from Addis Ababa 3G actual network as shown in table 6.4. The KPIs are the IRAT handover success rate and the CS traffic on the whole network before load balance deployment and after the deployment.

5.5.1 IRAT load based handover before deployment.

Date	Whole Network	Integrity	VS.IRATHO.AttRelocPrepOutCS.Load	VS.IRATHO.SuccRelocPrepOutCS.Load	CS Traffic (Erl)
2018-06-01	Whole Network	100%	0	0	17067.83
2018-06-02	Whole Network	100%	0	0	16206.42
2018-06-03	Whole Network	100%	0	0	16308.65
2018-06-04	Whole Network	100%	0	0	17741.35
2018-06-05	Whole Network	100%	0	0	17204.65
2018-06-06	Whole Network	100%	0	0	17147.03
2018-06-07	Whole Network	100%	0	0	17175.88
2018-06-08	Whole Network	100%	0	0	16954.73
2018-06-09	Whole Network	100%	0	0	16450.89
2018-06-10	Whole Network	100%	0	0	16571.69
2018-06-11	Whole Network	100%	0	0	17130.79
2018-06-12	Whole Network	100%	0	0	17185.15
2018-06-13	Whole Network	100%	0	0	17376.68
2018-06-14	Whole Network	100%	0	0	18367.1
2018-06-15	Whole Network	100%	0	0	18487.47
TOTAL					257376

Table 5. 4: IRAT load based handover before deployment [ethio telecom].

As we can see from figure 5.4, the load balance between 3G and 2G before load balance deployment is zero. I.e. there is no handover between two RAT on load based. The total traffic handled by five RNC of Addis Ababa within 15 day is 257,376 Erl.

5.5.2 IRAT load based handover after deployment

Date	Whole Network	Integrity	VS.IRATHO.AttRelocPrepOutCS.Load	VS.IRATHO.SuccRelocPrepOutCS.Load	CS Traffic (Erl)
2018-07-20	Whole Network	100%	892482	882251	16954.197
2018-07-21	Whole Network	100%	879606	869286	16734.0359
2018-07-22	Whole Network	100%	730172	719477	16733.7587
2018-07-23	Whole Network	100%	915661	904771	16974.6047
2018-07-24	Whole Network	100%	896759	886532	16724.939
2018-07-25	Whole Network	100%	757402	747632	15735.4653
2018-07-26	Whole Network	100%	800691	790729	15306.5222
2018-07-27	Whole Network	100%	792329	782250	15434.155
2018-07-28	Whole Network	100%	762962	751617	14826.886
2018-07-29	Whole Network	100%	616621	608781	14856.9583
2018-07-30	Whole Network	100%	833135	823715	16108.3471
2018-07-31	Whole Network	100%	895810	885546	16860.7993
2018-08-01	Whole Network	100%	827054	818000	16367.6163
2018-08-02	Whole Network	99%	828800	819406	16535.5941
2018-08-03	Whole Network	100%	837219	827890	16266.4688
TOTAL					242420

Table 5. 5: IRAT load based handover after deployment [ethio telecom].

After the deployment of IRAT load balancing, the KPI shows there is an IRAT handover attempt and a successful relocation from RNC side. The total CS traffic of 15 days after load balancing deployment has been calculated as 242,420 Erl. So the load balance from 3G to 2G network will be the difference of the two. i.e.

Load Balance=257,376 Erl -242,420 Erl=14,956 Erl

Load Balance in %=14956/257376=5.81%

Date	RNC	NODEBNAME	NodeB ID	VS.IRATHO.SuccOutCS.Load	VS.IRATHO.SuccOutCS.Service	VS.IRATHO.SuccOutCS.RF
12/16/2019	111168.RNC_03	Mark33_WL_GUL	544	740	18292	2867
12/17/2019	111168.RNC_03	Mark33_WL_GUL	544	726	19079	2962
12/18/2019	111168.RNC_03	Mark33_WL_GUL	544	701	18957	2841
12/19/2019	111168.RNC_03	Mark33_WL_GUL	544	114	18318	2312
12/20/2019	111168.RNC_03	Mark33_WL_GUL	544	139	17190	2215
12/21/2019	111168.RNC_03	Mark33_WL_GUL	544	176	18302	2555
12/22/2019	111168.RNC_03	Mark33_WL_GUL	544	9	16372	2619
12/23/2019	111168.RNC_03	Mark33_WL_GUL	544	915	20543	3803
12/24/2019	111168.RNC_03	Mark33_WL_GUL	544	1011	22286	3964
12/25/2019	111168.RNC_03	Mark33_WL_GUL	544	796	20362	3503
12/26/2019	111168.RNC_03	Mark33_WL_GUL	544	203	18916	2541
12/27/2019	111168.RNC_03	Mark33_WL_GUL	544	195	18589	2429
12/28/2019	111168.RNC_03	Mark33_WL_GUL	544	168	19153	2536
12/29/2019	111168.RNC_03	Mark33_WL_GUL	544	1	14444	1816
12/30/2019	111168.RNC_03	Mark33_WL_GUL	544	362	20036	2798

Table 5. 6: Current IRAT Handover [ethio telecom].

5.5.1 Load balanced comparison

The load Balance of load reshuffling techniques is half of that of a load levelling algorithm as shown below. There is a 5.58% difference between the two algorithms. This shows load levelling algorithm is more effective than load reshuffling algorithm.

Change in load balance with load levelling algorithm =67.69%-56.3%=11.39%

Change in load balance with load reshuffling algorithm=67.69%-56.3%=5.81%

<u>Difference in load balance=5.58%</u>

5.6 Limitation

5.6.1 User phone setting

Telecom service provider can't control the setting of their user's phone. The inter RAT load balancing technique works only if the user set his/her phone on dual mode. So that the user phone will operate in both 3G and 2G network. If the user set his/her phone as a 3G only (WCDMA only) or 2G (GSM) only, it will stay on the same RAT until he change the setting to other mode. The system can't force the UE to handover from 3G to 2G in case network congestion and we can't apply the load balance. So service providers should make an awareness creation for users to deploy this system.

5.7 Conclusion

The main objective of this thesis is to analyse the performance of load based inter RAT handover in heterogeneous mobile networks which aims at satisfying the following general benefits:

- Reduce the congestion in 3G network by sharing load to co-locating and neighbour 2G wireless network.
- To have an efficient utilization of the available radio resource of 2G network.
- Minimized call drop in 3G network which occurs due to call congestion.
- Increased capacity will lead to generating more revenue.

The load levelling algorithm amaze the imbalance factors between 3G and 2G to decide which sites have an improper load distribution and later tries to distribute the load Somehow equally between the two RATs. Whenever 3G site is loaded more than 60 percent, the RNC will push the voice call to 2G. So the 3G network can handle well the data traffic.

Finally, the simulation output of the load balanced by using load levelling algorithm and the load balanced output extracted from the actual ethio telecom network has been compared. The result is the load balanced by load levelling algorithm is twice that of load reshuffling algorithm.

5.8 Future Work

The load balancing techniques presented in thesis will provide a good direction for future studies to improve the call congestion occurs in Addis Ababa wireless network. This thesis can be extended and the load levelling algorithm can be applied on the real network instead of load reshuffling algorithm to bring the better load distribution between different RAT.

This thesis shows the load balance between 3G and 2G wireless network. So this idea can be extended between other RAT such as 4G network which is deployed in Addis Ababa. It can be applied for other circle of the ethio telecom mobile network.

References

[1]. Ian Poole, "UMTS," in *Cellular Communications Explained From Basics to 3G*, 1st ed. Elsevier Ltd, 2006, chapter 10, UMTS, pp. 155-158.

[2]. Joachim Sachs et al., "Congestion Control in WCDMA with Respect to Different Service Classes," Ericsson Allee 1, 52134 Herzogenrath, Munich, Germany, October 6 - 8, 1999.

[3]. HarriHolma, Antti Toskala, "introduction to WCDMA," *in Radio Access for Third Generation*, 3rd ed. Filand, john wiley, 2004, chapter 3, pp. 58-59.

[4]. JuhaKorhonen, " *Network planning, " in Introduction to 3G Mobile Communications* , 2nd ed. Boston , London , Artech House, 2003, chapter 9, congestion control, pp. 272-277.

[5]. T. S. Rappaport, "The cellular concept," in *Wireless Communication Principles & Practice*, 2nd ed. Prentice Hall PTR, 2002, chapter 2,p. 35.

[6]. Khaled Amer Ahmed Ali, "Directional Cell Breathing - A Framework for Congestion Control and Load Balancing in Broadband Wireless Networks,"Ph.Ddissertation,Queen's University, Kingston, Ontario, Canada, April 2009.

[7]. ArnikaKhare et al.,"Congestion Control for WCDMA Radio Access Network Using Threshold Segmentation,"International Journal of Engineering and Innovative Technology (IJEIT), Volume 2, Issue 3, September 2012.

[8]. Tiago Miguel de Almeida Pedro et al., "CapacityManagement and Load Balancing," May 2016.

[9]. Mary-Lou Murphy "Nexus8610, Intersystem Handover Simulation", 25 May 2007.

[10]. Service Continuity in 3GPP Mobile Networks Leo Bhebhe.

[11] https://www.scribd.com/presentation/122919071/Load-Reshuffling- Introduction.

[12]. https://docuri.com/download/load-control.

[13]. https://docuri.com/download/10-wcdma-load-controlling.

[14]. H. Holma and A. Toskala, Eds., WCDMA For UMTS - Radio Access For Third Generation Mobile Communications, 3rd ed. WILEY, 2004, pp 78-89.

[15]. Huawei Load Control, RAN15.0.

[16]. Ericsson, Handover between WCDMA and GSM, 2003.

[17]. WCDMA FOR UMTS, Radio Access for Third Generation Mobile Communications, Third Edition, pages 254-255.

[18]. M.Ali, P.Pillai, Y.F.Hu and K.Xu, "Load aware radio access selection in Heterogeneous terrestrial wireless networks", International Journal of Computer Networks & Communications (IJCNC) Vol.3, No.6, November 2011.

[19]. Radio Access for Third Generation Mobile Communications, third edition, pp. 78-81.

[20]. University of Bradford, "Load balancing in heterogeneous wireless communications networks", Ali, Muhammad.

[21]. A. Pillekeit, F. Derakhshan, E. Jugl, and A. Mitschele-Thiel, "Force-Based Load Balancing in Co-located UMTS/GSM Networks", 2004.

[22]. Atoll Radio Planning and Optimazation Technical Overview, Release AT310_TO_E0, 2011.

[23]. WCDMA Load Control, www.Huawei.com.

[24]. www.rfwireless-world.com/Terminology/Inter-RAT-handover.html.

[25]. Ericsson student book LTZ1381464 R1A, GSM RAN G14 BSC Infrastructure.

[26]. http://www.comlab.hut.fi/opetus/238/lecture4_Intro_to_WCDMA.

[27]. https://www.iith.ac.in/~tbr/teaching/docs/gsm.

[28]. https://www.kth.se/social/files/54803dfef27654772ca84b5a/P4-Lecture3-2002.

[29]. Blekinge Institute of Technology, Mathematical Modelling of Call Admission Control in WCDMA Network, September 2007 PP 20-29.

[30]. WCDMA – Enhanced Uplink performance evaluation *Camilo Orejuela Mesa*, May 2006, Enschede, the Netherland.

[31]. University of Bradford, "Load balancing in heterogeneous wireless Communications networks", Ali, Muhammad. PP 107-109.

[32]. https://moniem-tech.com/2018/03/16/channel-element-at-r99-hsdpa-Hsupa.

[33]. Gunnar Heine, Artech House "GSM Network, Protocols, Terminology and

Implimention".

[34]. https://www.ezega.com/News/NewsDetails/Ethio-Telecom-Announces-Major-Reduction-on-Internet-Voice-Call-SMS-Rates. [Accessed Sep 25, 2018].

[35]. Technical University of Denmark, "Teletraffic Engineering Handbook", June 20, 2001.

[36]. Dr. Hicham Aroudaki, "Teletraffic Engineering", Damascus, 13th March 2010.

[37]. Helsinki University of Technology, "introduction to traffic theory", spring 2005.

[38]. Khurshid Lal Bhawan, "Telecommunication Engineering Center" New Delhi – 110001, India.

[39].http://www.technologyuk.net/telecommunications/telecom-principles/amplitude-modulation.html.

[40]. Institute of communications Engineering, "Wireless Information Transmission Lab" t.ional Sun Yat-sen University.

[41]. Tektronix Communications, 3033 W President George Bush Highway.

[42]. https://www.academia.edu/6572434/3G Huawei RAN Resource Monitoring and management.

[43]. https://www.scribd.com/document/371660211/irathandoverbasics-120523054755-phpapp02-pdf.

[44]. Huawei Technologies Co., Ltd, "Load Reshuffling Feature Parameter Description", 2014-04-30.

[45]. www.scribd.com/document/402279531/Ethiotelcom-Background

Annex A

Sites Geographical Information

Name	Beamwidth	Latitude	Longitude
Mark83	65	38.733683	9.024731
Mark35	65	38.729394	9.028118
Mark90	65	38.732873	9.028062
Mark23	65	38.732873	9.028062
Mark21	65	38.73902	9.0223
Mark41	65	38.72982	9.02242
Mark81	65	38.73524	9.02112

Full Site Name in the Focus area

Mark83_WL_GUL_BSCRNC3.HW.MERKATLASCLN.WAAZ.AA

Mark35_WL_GU_BSCRNC3.HW.ADSKTWD2YUTHCNT.WAAZ.AA

Mark90_WL_GUL_BSCRNC3.HW.DIRBLD.WAAZ.AA

Mark23_DG_WL_GUL_BSCRNC1.HW.CHIDTERA.WAAZ.AA

Mark21_DG_WL_GUL_BSCRNC1.HW.LDTKIDSGARD.CAAZ.AA

Mark41_WL_GUL_BSCRNC3.HW.ABTSQ.WAAZ.AA

Mark81_WL_GUL_BSCRNC1.HW.MLMRKRBT.WAAZ.AA