ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF ELECTRICAL AND COMPUTER ENGINEERING
TELECOMMUNICATION NETWORK ENGINEERING PROGRAM

Circuit Switched UMTS to GSM Handover Neighbor List and Parameter Optimization: The Case of Ethio Telecom Addis Ababa Network

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A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Electrical Engineering

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Declaration

I, the undersigned, declare that this thesis is my own work and does not incorporate without acknowledgment of any material previously submitted for a degree or diploma in any other university or institute of higher learning. To the best of my knowledge, it does not contain any material previously published or written by another person except where the acknowledgment is made in the text.

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Abstract

The rapid growth of mobile service users is forcing telecom operators to invest in new infrastructure. However, looking for techniques for optimum network utilization that can optimize the interoperability features among different technologies has the potential to reduce investment costs for the deployment of infrastructure. Optimizing the circuit switched inter radio access technology between universal mobile telephone system (UMTS) and global system for mobile (GSM)) handover success rate failure allows the operator to use the ubiquitous 2G network to provide service in the coverage discontinuity of the 3G network, as well as load sharing between the networks.

In this thesis, based on the circuit switched inter radio access technology (CS IRAT) 3G-to-2G handover success rate report data of the Addis Ababa network, a problematic sample IRAT network has been chosen, and the handover is optimized for the sample network and interpreted for the whole Addis Ababa network. First, with the help of Pareto techniques, the root cause of the handover (HO) failure rate is analyzed using two months report data, and it is found that physical channel failure is the main cause of the IRAT handover failure. Second, a sample network (study area) is selected based on the HO success rate and the number of handover attempts (success rate of 70% and number of attempts > 10,000 per day). Then methods to solve the root cause of the problems were suggested (adjusting the neighbor relations and tuning the target 2G network handover threshold) based on the different literature reviewed and the effects of the parameters on the IRAT handover. With Atoll (planning tool), the sample network (real network) identified is designed using engineering parameters of the network obtained from Ehtio Telecom. Finally, using the sample network as an input, the neighbor relation is redefined and the handover coverage of the network is optimized. It is found that the handover coverage area (a possible location where a handover could occur) shrinks with the increase in the target 2G network handover thresholds, which will lead to first a decrease in the total number of handover attempts and, second, from the total, an increase in the success of those attempted handovers, since the 2G cell gets stronger. The above two conditions result in an improvement in handover success rate since it is the ratio of successful handovers to the total number of handovers.

Keyword:- CS IRAT (3G-to-2G) handover success rate, Optimization, Handover, study area, Neighbor relation, Target(2G) Threshold

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List of Acronyms

1G	1st Generation
2G	2nd Generation
3G	3rd Generation
3GPP	3rd Generation Project Partnership
ACP	Automatic Cell Planning
AMPS	Advanced Mobile Phone Service
BCCH	Broadcast Control Channel
BS	Base Station
BSC	Base Station Controller
BTS	Base Transvers station
CDMA	Code Division Multiple Access
CPICH	Common Pilot Channel
CS	Circuit Switch
DL	Down link
EDGE	Enhanced Data for Global Evolution
FMEA	Failure Mode and Effect Analysis
GPRS	General Packet Radio Service
GSM	Global System for Mobile
HCS	Hierarchical Cell Structure
HetNet	Heterogeneous Network
HM	Handover Margin
HO	Handover
IRAT	Inter Radio Access Technology

ISCP	Interference Signal Code Power
KPI	Key Performance Indicator
LTE	Long Term Evolution
MS	Mobile Station
MSC	Mobile Switching Center
NEHO	Network Evolved Handover
NMS	Network Management System
NR	Neighbor Relation
O&M	Operation and Maintenance
P-CCPCH	Primary Controlled Common Pilot Channel
PDCA	Plan Do Check-Act
PRS	Performance Reporting System
PS	Packet Switching
QoS	Quality of Service
RCA	Root Cause Analysis
RF	Radio Frequency
RNC	Radio Network Controller
RSS	Received Signal Strength
RSS-H	Received Signal Strength and Hysteresis
RSS-HT	Received Signal Strength with Hysteresis and Threshold
RSS-T	Received Signal Strength and Threshold
SIR	Signal to Interference
TEP	Telecom Expansion Project
TS	Telecommunication System
UE	User Equipment

UL	Up link
UMTS	Universal Mobile Telecom System
UTRAN	Universal Telecom Radio Access Network
WCDMA	wide Band Code Division Multiple Access

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1. Introduction

Recently, based on different radio access technologies, various wireless communications systems have emerged worldwide. The challenge is getting the cooperation of the technologies to offer the best quality of service (QoS) while optimizing resources in each network. Handover is a key mechanism for ensuring interoperability between those systems. For telecom operators to ensure continuity of service and benefit from the existing GSM network, the inter-operability of the UMTS and GSM networks allows them to get an advantage, and the Inter Radio Access Technology (IRAT) handover from UMTS to GSM is a key feature in this task. Initial deployment of 3G wide band code division multiple access (WCDMA) is focusing mainly on city centers and business districts where higher subscriber density and concentration of demand for services beyond voice allow an early return on investment [1]. As a result, WCDMA coverage is available only on islands, as opposed to ubiquitous GSM coverage. In addition, imperfections within WCDMA islands result in coverage holes, limited indoor coverage, and, in the center, an increase in load. This drives the need for seamless transition between 3G and 2G networks, i.e., seamless inter-system handover for circuit switched (CS) services and seamless inter-system cell changes for packet switched (PS) services are required [2]. In other words, the purpose of IRAT handover functionality is to let a user who cannot access the 3G network or retain service on the 3G network handover to a 2G network. In addition, this inter-technology handover between UMTS and GSM networks enhances the network capacity since it allows load sharing between these two networks.

In Ethio Telecom, all the mobile voice services are provided through 3G and 2G networks. And the CS IRAT handover between the two networks has been working below the target success rate in the company. As a result it is vital to evaluate the handover performance between UMTS and GSM networks and optimize the handover parameters and revise the neighbor relation between them, these can greatly impact the system performance in related to handover. This is the main reason of this research.

In this thesis, the CS IRAT (3G–to–2G) handover performance data of Addis Ababa is analyzed and the root cause of the failure rate is identified. After performing the root causes analysis (RCA) using Pareto techniques and indicating the main reason for CS IRAT handover failure is physical channel failure, a solution is suggested based on reviewed literatures. The solutions are to revise the neighbor relations and tune the target (2G) network handover threshold margin.

1.1 Statement of the Problem

Ethio Telecom must manage the resources efficiently to provide good quality service. The network should be optimized continuously. Various radio access wireless technologies, such as GSM, UMTS, CDMA, and LTE, are being used to provide both voice and data services. In big cities, the densely populated areas like cities centers, shopping centers, and bus stations may have coverage from multiple wireless networks, especially GSM and UMTS networks, which are used to provide mobile voice service. One of the most interesting UMTS network features is the interoperability (interworking) with the 2G networks that provides seamless end-to-end services. Current widely deployed 2G and 3G networks provide IRAT (Inter Radio Access Technology) mechanisms, enabling interoperability between them. These enable maximum benefit.

The daily dashboard key performance indicator (KPI) report of Addis Ababa wireless network shows the CS inter system IRAT Handover Success Rate for 3G–2G is around 96%, as shown in table 1.1 below, which is less than the company's target of 98%. The success rate between some of the cells is in the range of 61-69, 71-79, and 81-89%. Even below that, the problem persisted for a long period of time as per the two-month NMS extract data portion of it shown in Figure 1.1 and informed by the optimization team.

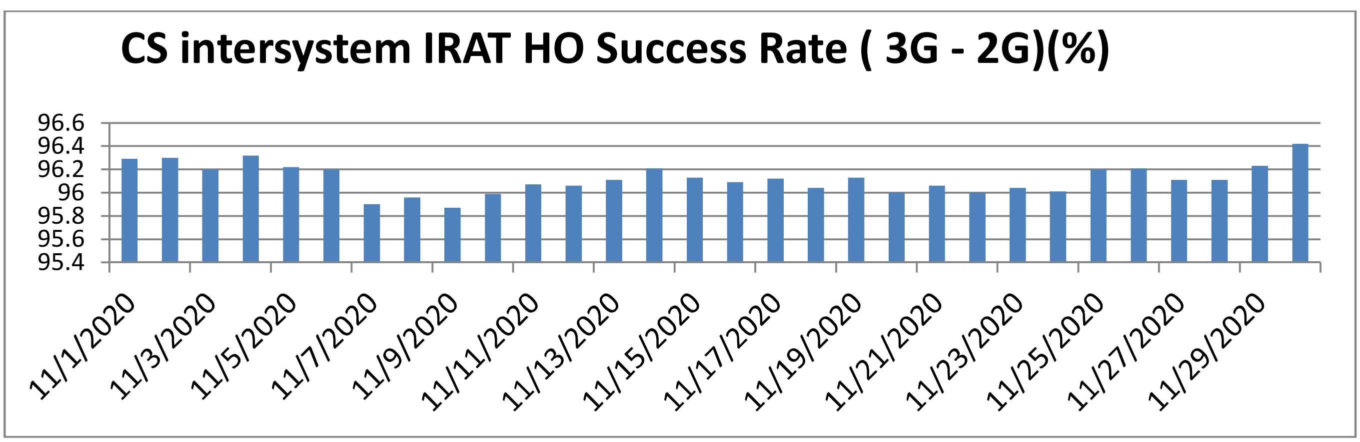

Figure 1.1: IRAT HO Success rate [Ethio Telecom]

1.2 Objective

1.2.1 General Objective

The main objective of this research is to optimize the circuit switched inter radio access technology(IRAT) handover between 3G - 2G Network in Addis Ababa. For that, Adjusting the Neighbor relation between 3G & 2G cells and tuning the TARGET IRAT CS THRESHOLD are applied.

1.2.2 Specific Objectives

The specific objects of the research are:

- Analyzing the IRAT handover (between 3G& 2G) performance data of Ethio Telecom's Addis Ababa network captured at the NMS for two months.
- Select sample network based on the analysis result of the IRAT performance data within Addis Ababa that includes both 3G and 2G sites.
- Perform Root cause Analysis for the degradation of the IRAT handover performance data of the sample network.
- Redefine the neighbor relation of the sample network.
- Simulate the sample network by tuning the TARGET IRAT CS THRESHOLD using Atoll.

1.3 Literature Review

For optimizing handover between 3G and 2G network (IRAT) different literatures have used different methodologies and found different results, here some of them are discussed. In [3], the intention of the paper is to keep the user equipment (UE) connected while moving from one UMTS to another GSM. The authors want to evaluate handover performance in IRAT (2G and 3G) networks in terms of handoff success rate probability and call drop probabilities. They use proposed analytical model and algorithm, live network measurements; then analyze the performance by HO probability and call drop probability calculation; obtain the following result:

tuning of algorithm parameters improves the HO probability and call drop probability, which improves the performance of IRAT HO b/n 3G and 2G.

In [4], effective HO from UMTS to GSM for mobile phones when they roam outside of the UMTS coverage studied. The intention of the paper is to give insights into the conditions and parameters involved in the IRAT handover from UMTS to GSM and show the result of system simulation. The authors' techniques include first studying and settling HO procedures and conditions, then selecting a model, and finally, simulation. Parameter setting is performed using Motorola's simulation tool, and the simulation result is analyzed. It is found that the presented results of system simulations, which provide insights into the optimal choice of measurement reporting quantities, conditions, and procedures for IRAT HO, are studied.

The authors in [5] evaluate the IRAT HO performance for a proposed network model. What they want to achieve is reduce the unnecessary handoffs and reduce the handoff decision delays. The study approach proposed a system model, proposed an algorithm, evaluated the algorithm in terms of the number of HO and decision delays for different values of shadow fading standard deviation and UE velocity, performed simulation using Matlab, and analyzed the results. The result is that the number of HO increases with the standard deviation of shadow fading, and the HO decision delay varies with velocity. The author doesn't consider Some HO decision metrics, such as cost and battery life time, are not considered.

In [6], the aim of the study was to optimize intra-frequency and inter-system HO. The authors want to discuss the impact of intra-frequency HO parameters on inter-system HO performance. Study inter-system HO parameter settings by processing field measurement data, illustrating the optimization trade-off with an example, and recommend parameters that led to a significant reduction in call drop rates. The methodology employed is designed to investigate inter-system HO mechanisms such as HO triggering and measurement in compressed mode, intra-frequency and inter-system HO simulation parameter setting, simulation, and simulation result analysis. The result obtained is the authors' proposed intra-frequency HO parameters, inter-system HO parameters, and parameters that reduce call drop in commercial networks.

The seamless interworking between GSM and UMTS is substantial for the successful launch of the UMTS service. The authors of [7] introduce a novel parameterization method for UMTS compressed mode operation and inter-system handover that reduces the compressed mode overhead by up to 20% and avoids unnecessary handovers. They review intersystem handover signaling and compressed mode techniques and simulate with cell-specific parameters sets for reporting events related to compressed mode and inter-system handover in the actual network topology and coverage situation. The method allows preconfiguring the network based on radio network planning data to avoid compressed mode overhead as well as unwanted inter-system handovers in the life network.

The authors in [8] design and evaluate the performance of an inter-system handover algorithm in the UMTS/GSM network. First, an intersystem handover algorithm that uses two pairs of UMTS and GSM HO thresholds for making HO decisions (Ec/Io threshold for UMTS and RSSI threshold for GSM) was introduced; one pair to handover from UMTS to GSM and another pair from GSM to UMTS. Then they built a simulation model of a 37 cells, 7 UMTS cells enclosed by 30 GSM cells. At the boundary between the UMTS and GSM cells, a test mobile move and, as a function of the various thresholds involved, evaluates the handover rate performance. The simulation model includes spatial correlation of the log-normal shadow losses in the 2.1 GHz (for UMTS) and 900 MHz (for GSM) bands and mobility of all users in the system. It had been shown that by properly building a hysteresis between the UMTS-to-GSM HO threshold pair and the GSM-to-UMTS HO threshold pair, a good compromise between intra- and inter system handover rates and call drop rate, can be achieved.

1.4 Methodology

The steps followed to perform this research are: IRAT (3G-2G) handover performance data of the Addis Ababa network collected from the Ethio telecom Performance Reporting System (PRS). The literature on cellular network 3G to 2G (IRAT) handover performance optimization and related topics was then reviewed. Using the hints from the papers reviewed, the performance report data has been analyzed. Solutions suggested include adjusting the neighbor relation and tuning the TARGET IRAT CS THRESHOLD. Then a sample network that incorporates both the UMTS and GSM sits is chosen. Finally, using the suggested solution, the neighbor definition is adjusted and optimization has been done using radio network planning and optimization tool Atoll on the sample network. It is shown in the Figure 1.2 below.

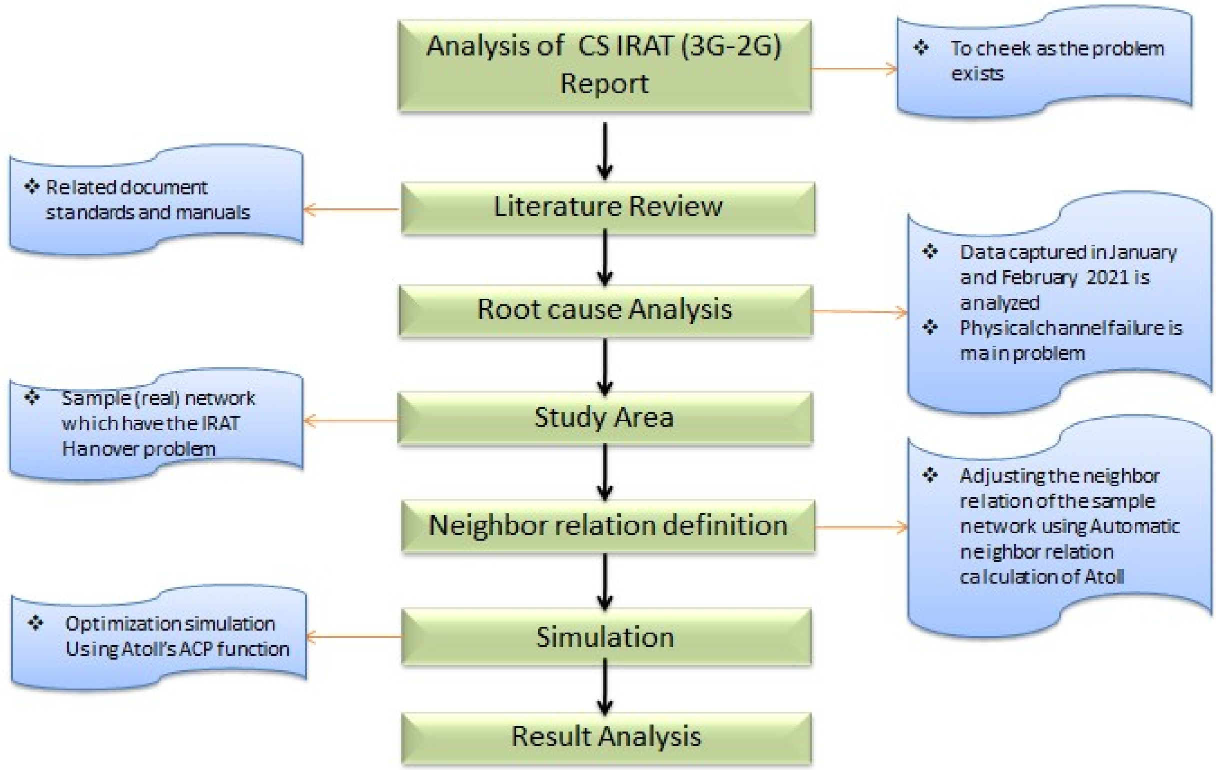

Figure 1.2: Methodology

1.5 Scope and Limitations

1.5.1 Scope of the Thesis

Circuit switched (voice service) IRAT handover coverage is optimized in this thesis. Since the research is a case study, sample networks that incorporate UMTS and GSM from Addis Ababa is considered in the modeling. The study is conducted only for the voice service from the perspective of the services delivered by the network.

1.5.2 Limitations of the Thesis

There are limitations while conducting research. The major limiting factor in this thesis is the simulation tool, since it doesn't consider the mobility KPI, handover success rate, and hence interpretation of the handover coverage has been considered in the result.

1.6 Contributions

The main contributions of this research are:

1. In mobile network, optimization and parameter selection techniques are keys in improving the performances of a mobile network. Without requiring additional investment benefits the operators a lot. This research has shown that tuning parameter and adjusting neighbor list assist to solve the problem (CS IRAT HO success rate failure).
2. It also shows how to analyze the root cause of the problem using the performance report data of the company.

1.7 Thesis Layout

The remaining part of the paper is organized as follows. In Chapter two handover in cellular network is presented in detailed. Chapter three CS UMTS to GSM (IRAT) Handover is discussed. In Chapter four Methods for 3G-to-2G Handover Optimization is discussed. In Chapter five Simulation Result and Discussion are presented. In Chapter six, the final chapter Conclusion and Recommendation has been made.

2. Handover in Mobile Networks

2.1 Overview

When the user is moving, the mobile networks allow users to access an uninterrupted service, which means give the user seamless mobility. However, there are some effects that bring uncertainties to mobile systems freedom of motion. That are dynamic variation in the interference level and link quality difference resulted from the mobility of the end users that needs sometimes to change its serving cell or base station. Changing the cell or base station is known as handover. While dealing the mobility of end users handover is the essential process. It assurances the continuity of the wireless services; when the mobile user moves crossing cellular boundaries. Handover was easy in first-generation (AMPS). In the Second-generation and subsequent cellular systems it is sophisticated relative to first-generation system in many ways, including the handover algorithms used, signal processing and handover decision procedures have been incorporated in these systems and the handover decision delay has been substantially reduced. Also handover between different generations of cellular system is introduced; this is the focus of the work in this thesis.

2.2 Handover Initiation

Handover can be initiated in one of the following ways: mobile initiated, mobile assisted and network initiated.

2.2.1 Mobile Initiated

This type of handover is generally triggered by the poor link quality measured by the mobile. The Mobile makes quality measurements, with the network's cooperation switches to the best base station (BS).

2.2.2 Network Initiated

The decision to handover or not is made after the BS makes the measurements of the signal strength of the link and reports to the radio network controller (RNC). The reason for network initiated handover is different from radio link control, e.g. to control traffic distribution between cells. An example of this is the Traffic reason handover controlled by BS. Traffic reason handover changes the handover threshold for one or more outgoing neighbor for a given source cell based on it load, it is a load-based algorithm. The load in the neighboring cell is below certain level and the load of the source cell exceeds a given level, then the source cell will shrink its coverage, handing over some traffic to the neighboring cell. Therefore, leading to more usage of the source cell the total blocking rate can be reduced.

2.2.3 Mobile Assisted

The measurements are made by both the network and the mobile. The network decides the handover while the mobile reports the measurement results.

2.3 The Objectives of Handover

Handover in mobile cellular network happens to meet one of the following objectives

1. Guaranteeing the continuity of wireless services when the mobile user moves across the cellular boundaries.
2. Keep required QoS(link quality will be maintained and service will not be interrupted).
3. Minimizing interference level of the whole system by keeping the mobile linked to the strongest BS or BSs.
4. Roaming between different networks.
5. Distributing load from hot spot areas (load balancing).

The link quality (UL or DL), the changing of service, the changing of speed, traffic reasons or O&M (Operation & Maintenance) intervention are the triggers that can be used for the initiation of a handover process in mobile network.

2.4 Handover in GSM

In GSM the handover process is classified as a hard handover, where the established call is carried out by one radio channel, when the handover occurs the mobile station (MS) is ordered to release the current radio channel before connecting to a new one [9] in short it means break before make (break the connection before making the connection).

2.4.1 Handover Classifications in GSM

In GSM there are four types of horizontal handover (within the technology), as shown in the Figure 2.1. It is the signaling path that differentiates them:

1. Intra-cell handover:

In this type, a handover request is triggered within the same cell, but to different physical channel (time slot) in the same carrier or in another carrier. It occurs due to high co-channel interference (low signal quality at the receiver).If the signal level is not satisfactory, moving the MS (call) to another time slot or frequency carrier can solve the problem (i.e. the co-channel transmitter might be using different time slots and/or carriers, therefore avoiding the interference).

As shown in the Figure 2.1 Base station controller(BSC)-A sees an MS in one of the cell in Base transverse station (BTS) 1 with bad signal quality, Since no other cells can provide a better signal level than the chosen, therefore BSC-A orders the MS in BTS 1 in the same cell to switch to another radio channel.

2. Inter-cell handover under the same BSC:

In Figure 2.1 the MS in BSC-A which is being served by one of the cell in BTS 1 could have better signal quality if neighbor cell in the same BTS served it. BSC-B has real time information about the two cells and controls both, hence for the handover of the MS BSC-B orders cell number four to assign a radio channel, also informs the MS to migrate to cell four. Even though the handover is hard and MS will use only one channel at the given time, the radio channel to cell number two will be kept reserved until the handover is successful to cell number four, since MS will reconnect again to the old cell if the handover fails.

3. Inter-cell handover between different BSCs in the same MSC service area:

This case is illustrated in Figure 2.1 the MS handover from a cell in BTS 3 to neighbor cell in BTS 4 7 controlled by BSC-A and B respectively where both BSCs are connected to mobile switching center (MSC)-A. The source BSC doesn’t know the target, only the MSC know that the target BSC. The roll of the MSC is to serve as switching device doesn’t make any decision about the handover. Except the MSC role the handover procedure is the same as the previous one.

4. Inter-cell handover between different BSCs in different MSCs service areas:

In this scenario Fig 2.1 as show the MS while moving switches its connection from cell in BTS 6 to cell in BTS 7 since the handover is mandatory. BSC-B look for the BSC to which cell of BTS 7 is connected and request MSC-A to short out this. MSC-A broadcast request to all MSCs until it receives a positive response from MSC-B with the information that BSC-C controls the cell , then the handover procedure follows the same step as the second type (mentioned above) way but involves additional switching nodes.

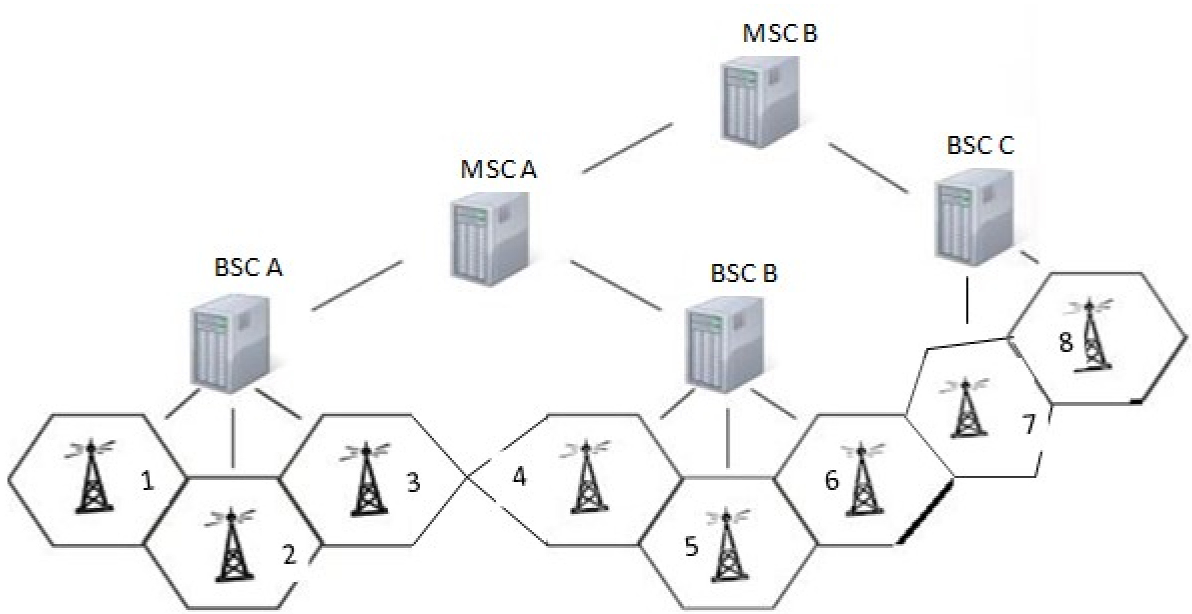

Figure 2.1 : Sample GSM network. [10]

2.4.2 Handover Initiation in GSM

It is by the BSC that the handover in GSM is carried either a radio triggered measures (the RF quality, signal strength, or the distance) or network management conditions not related to radio link status (e.g. cell off loading and maintenance).

The radio measures are collected by the mean of measurement reports delivered to the BSC. The MS constantly measures and reports not only its serving cell conditions, but also the signal strength of neighbor cells [11]. However the decision to carry out a handover is not defined as a

GSM standard, therefore it is up to the operator to choose how the handover algorithm works [12] [13].

2.5 Handover in WCDMA

2.5.1 Overview

In WCDMA, in circuit switched calls real-time handover is used. In the case of packet switched calls, handovers are mainly achieved when either the network or the UE has packet transfer activity. Especially in CDMA handover control is a complicated issue in cellular network [14].

Criteria used to decide to handover or not are listed regardless of the handover type also the execution depend on the strategy applied in the system. Most criteria for handover are signal quality, traffic distribution, user mobility and bandwidth utilization [14]. Handover as a result of signal quality happens while the signal strength is below limited threshold specified in the RNC. Handover due to traffic occurs when the cell capacity of traffic reached its maximum or approaches the limits. In this case, if a UE is close to the edge of source cell with high load, it may be handed over to neighboring target cells with less traffic load. This allows the system load to be distributed more uniformly. The number of handovers also relies on the mobility of the UE. UE will have frequent handover in the UTRAN, if it is moving fast in the same direction. To prohibit unwanted handovers, Slow moving UEs can be handed over to microcells and a UE with high speed may be handed over from microcells to macro cells.

2.5.2 Handover Process

Measurement, decision and execution are the three major phases of handover process specifically for WCDMA. Actually some of them apply for other cellular systems and all of them are discussed below [15][16].

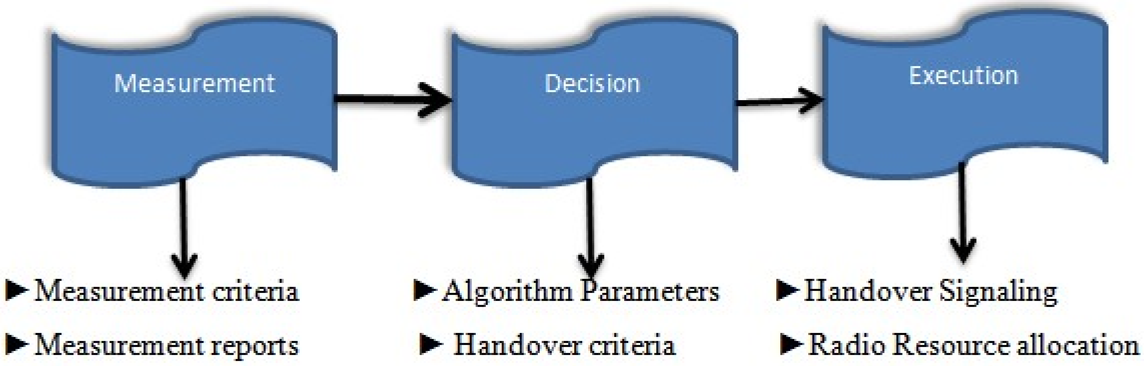

Figure 2.2 : Basic Handover Processes in WCDMA.

Handover measurement provisioning is a key task for better system performance for two main reasons fading and path loss [14]. The radio channel signal strength may vary drastically as a result of user mobility and cell environment. Increased network signaling which is not important caused by excess measurement reports by the UE or handover execution by the network.

The neighbor cells signal strength is reported to the RNC, which is constantly measured by the UE. The reported measurements are categorized into different groups by 3GPP TS 25.331. These measurements are [17]: intra-frequency measurements that measure the strength of the downlink physical channels (signals with the same frequencies); inter-frequency measurements that measure the strength of the downlink physical channels (for signals with different frequencies); inter-system measurements that evaluate the strength of the downlink physical channels (belonging to different radio access technologies other than UTRAN, e.g., GSM); measurements for uplink traffic volume are performed by traffic volume measurements; quality measurements include quality parameters, e.g., downlink transport block error rate; and internal measurements of the UE's received signal level and transmitted power.

The measurement events, which are initiated based on [17];

1. Change of best cell
2. Change in the primary common pilot channel (CPICH) signal level
3. Change in the primary common control pilot channel (P-CCPCH) signal level
4. Changes in the Signal-to-Interference (SIR) level
5. Changes in the Interference Signal Code Power (ISCP) level
6. Periodical reporting

Time-to-trigger to support handover mechanisms different measurement criteria is used in WCDMA system. For better performance it is important to choose the best measurement procedure. By fine tuning trade-off between handover measurement, handover criteria and the traffic model used in network planning [17]. Assessing the overall QoS of the connection and comparing it with the requested QoS attributes and estimates from neighboring cells the handover can be easily decided. The handover procedure may or may not be triggered, depending on the outcome of the comparison. The values indicated in the measurement reports trigger criteria were set is check by the source RN. If they trigger, then it allows handover execution. There are two main types of handover, based on handover decision-making [17];

Network Evaluated Handover and Mobile Evaluated Handover.

For a network evaluated handover, the network Source RNC makes the handover decision, for the mobile evaluated handover process the UE prepares the handover decision and for joint handover the decision is made by both UE and the source RNC. It's vital to note that even with a mobile evaluated handover; the final decision is made by the Source RNC. This is because the Radio network controller is responsible for the overall Radio Resource Management of the system and it is aware of the system's overall load and other information required for handover decision.

It is from the UE, BS measurements and handover algorithm criteria that the handover decision-making is based on. Based on measurement capabilities and available parameters and advanced handover algorithms may be utilized. Shown in the Figure 2.3 below is the general principle of a handover algorithm; in here, the pilot signal strength which is reported by the UE the decision making input.

The following parameters are used [17];

1. Upper threshold: the level at which the signal strength of the connection is at the maximum acceptable level in respect to the requested QoS.
2. Lower threshold: minimum acceptable level of the signal the signal strength of the connection.

3. Handover margin: pre-defined parameter, where the signal strength of the neighboring cell (B) starts to exceed the signal strength of current cell by a certain amount of a certain time.
4. Active set: list of cells through which the UE has simultaneously connected to the UTRAN.

As the UE moves towards cell B starting from cell A, the pilot signal of cell A at the UE continually decreases, approaching the lower threshold as in Figure 2.3. This causes the handover to be triggered in the following steps [17]: First, the signal strength of A becomes equal to the defined lower threshold. Based on measurements, UE also recognizes that B has better signal strength. It adds B to the active set. The UE thus has simultaneous connections to the UTRAN and benefits from the summed signal from both A and B. Second, when the signal of B becomes better than that of A, the RNC keeps this information and starts calculating the handover margin calculation. Third, the strength of signal B becomes much better than the defined lower threshold. This is sufficient to satisfy the required QoS. The strength of the summed signal exceeds the upper threshold, causing interference. As a result, the RNC deletes signal A from the active set.

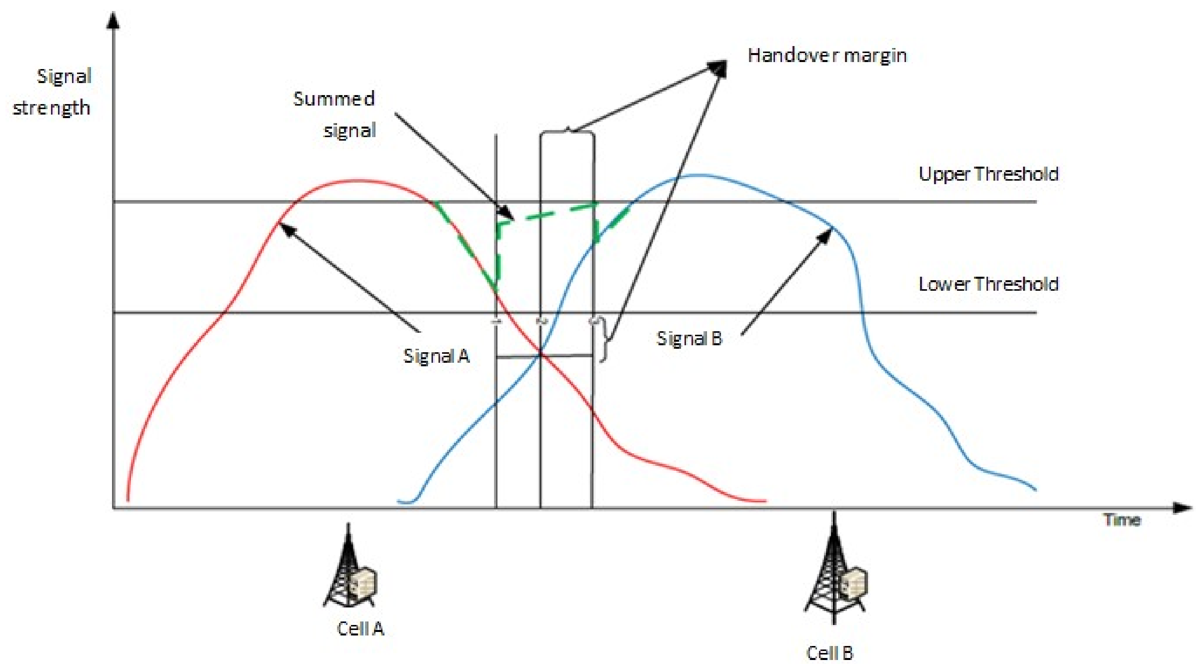

Figure 2.3 : Principles of handover algorithm [10].

It is possible for the UE to return to cell A after handover, due to the random nature of the UE. This results in handover *Ping- Pong* effect which is harmful to system performance and capacity .Hence we use margin or hysteresis parameter is to avoid undesired handover and signaling to the UTRAN [17].

2.5.3 Types of Handover

In UMTS network technology handover process mainly categorized as hard handover and soft handover. The other types of handovers are under these two classifications [18]. In the following subsection the different types of UMTS handovers are explained in detail.

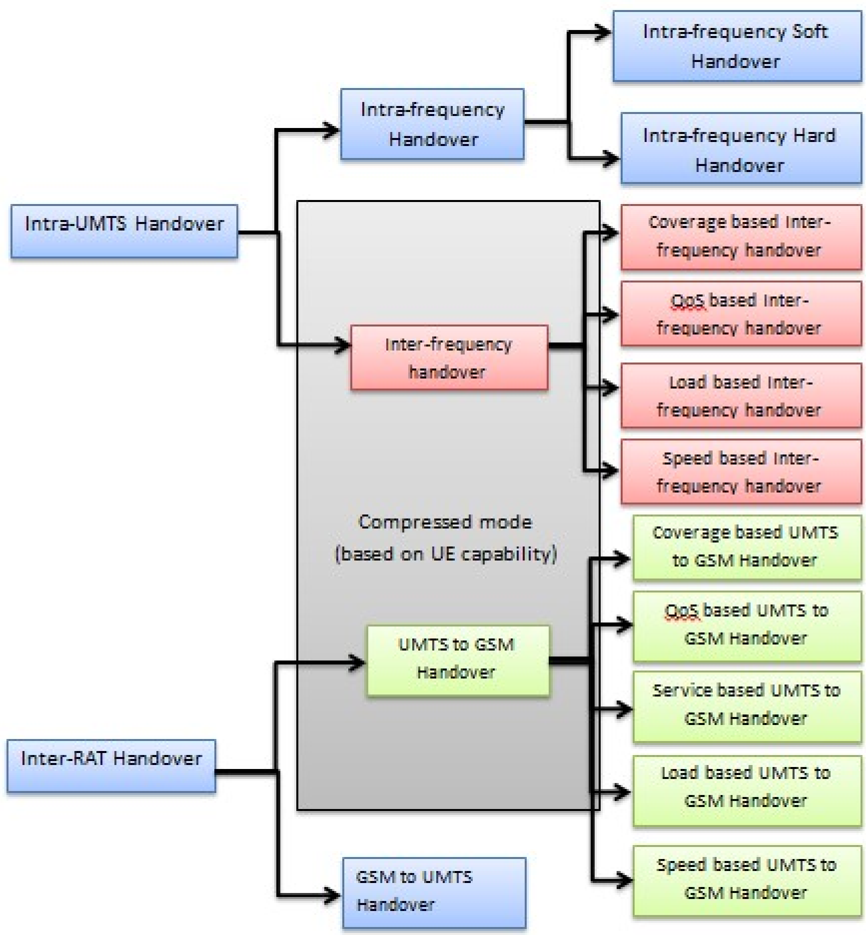

Figure 2.4: Handover supported by UMTS.

1. Soft and Softer Handovers

Soft handover occurs when new connection is made with target cell before breaking with the source cell [18]. Most of the handovers are intra-frequency soft handovers in WCDMA network as depicted in Figure 2.5. Soft handover is occurred not necessarily the same RNC but between two cells of different BS's. Over the Iur Interface the involved RN coordinate the soft handover. In this type of handover the UE is between overlapping cell coverage of the two sectors belonging to different base stations [18]. UE and BS communicate over two air interface channels from source and target BS independently .Both cells (source and destination) have the same frequency. If the radio network has small cells then the terminal does the soft handover almost all the time in case of a circuit switched call. The softer and soft-softer are types of soft handovers. Soft and softer handovers are almost the same from the UE point of view [18].

A softer handover happened when new signal is either added or deleted from the active set or replaced by a stronger signal within different sectors of the same BS as shown in Figure 2.6

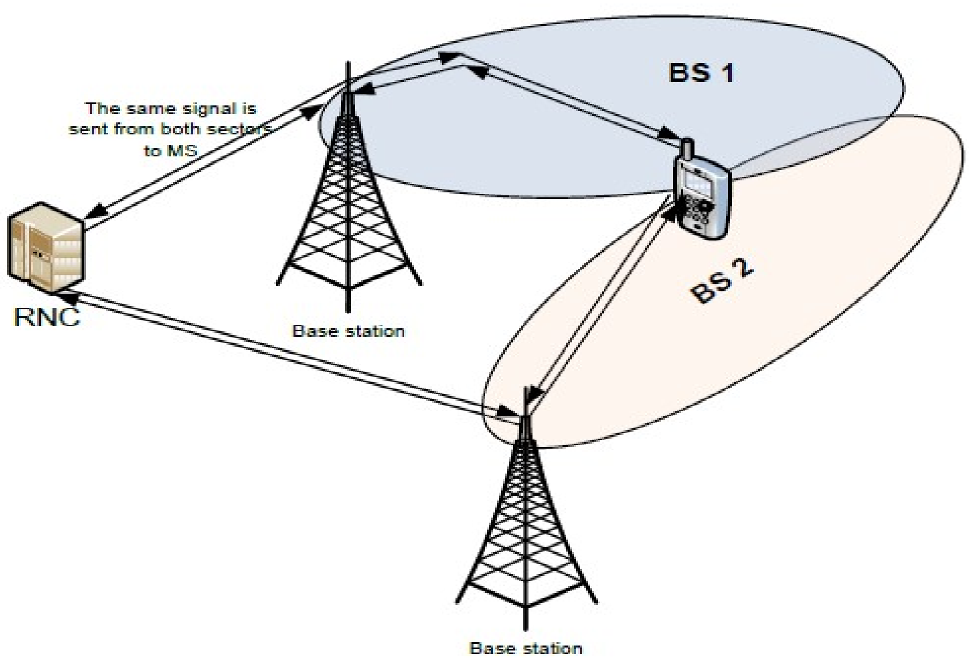

Figure 2.5: Intra-frequency Soft handover [10]

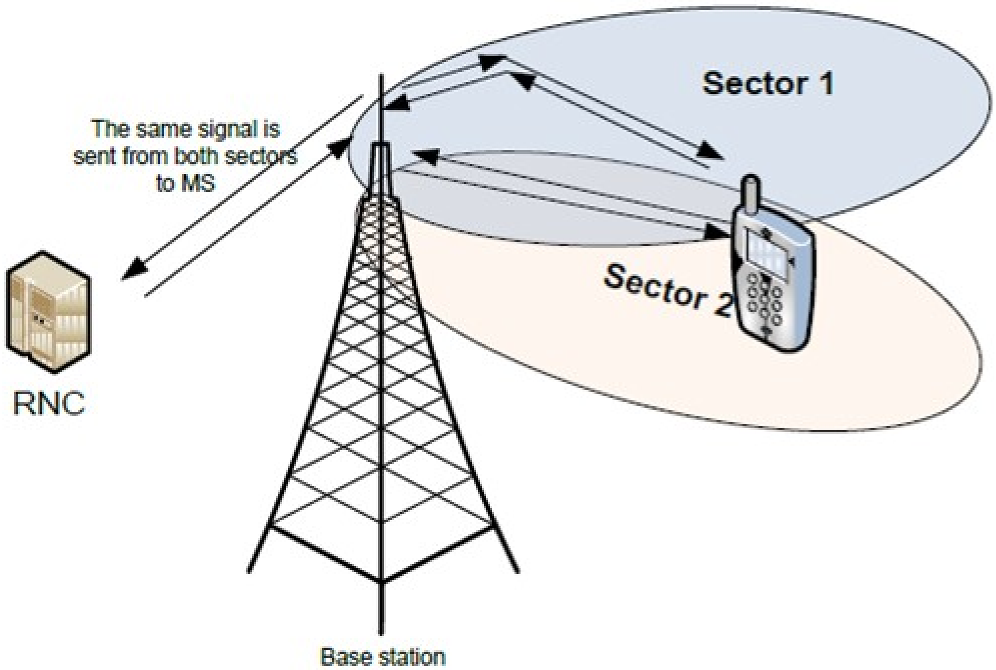

Figure 2.6: Softer handover [10]

The BS transmits through one sector but receives from one or more sectors in softer handover. Only one power control loop per connection is active during softer handover [18].

The term soft-softer handover is used, when soft and softer handovers occur simultaneously. In association with inter-RNC handover a soft-softer handover may occur, while along with adding a new signal via another cell controlled by another RNC an inter-sector signal is added to the UE's active set [18].

2. Hard Handover

In hard handover before making new connection to the target cell the old connection with the source cell is released for a very short time difficult to sense for the user. Can be divided in to Intra – frequency and inter –frequency handovers.

3. Inter-frequency and Intra-frequency Handover

The carriers frequency of the source and target cells to which the UE was and is connected are different in the Inter-frequency handover. But, if the new carriers are the same then it is termed as an intra-frequency handover. Following the two types of handovers are very well illustrated.

In Figure 2.7, the two RNCs are not connected using Iur interface for different reason and hence inter- RNC soft handover is impossible. In this case the only option is Intra-frequency hard handover . This results in an inter-RNC handover in which the MSC is also involved.

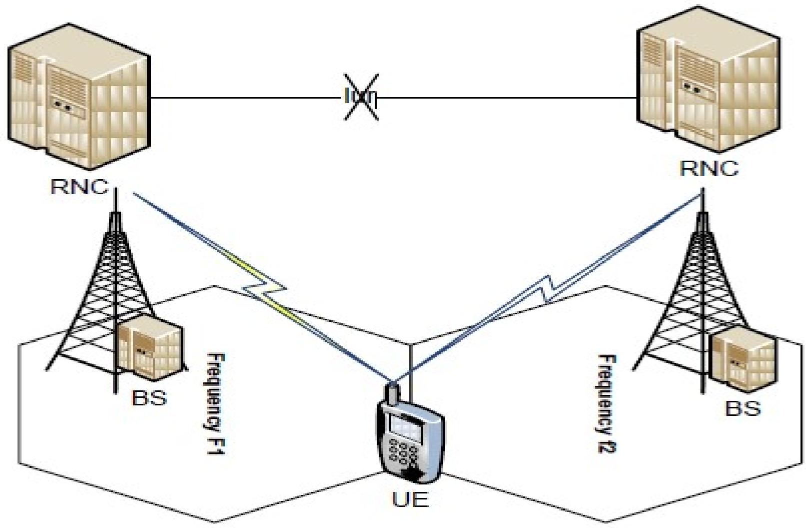

Figure 2.7: Inter-frequency hard handover [10].

All UEs uses the same frequency and all BS's transmit with the same frequency hence the frequency reuse factor for WCDMA is one. This does not however imply that frequency reuse is not utilized in WCDMA networks. Inter-frequency hard handover is required from one cell to another in a cell cluster, if different carriers are allocated to cells for some reason [16]. Also for Hierarchical Cell Structure (HCS) (network between separate cell layers) inter-frequency handover occurs, for example between macro and micro cells which use different carrier frequencies within the same coverage area. Here, to increase the system performance in terms of QoS and capacity the inter-frequency handover is used in addition to the UE would lose its connection to the network. Inter-frequency hard handover is always a network evaluated handover.

4. Inter-system handover

It is between two different radio access technologies the inter-frequency handover may occur e.g. between WDMA and GSM. It can be called also inter -RAT or inter-system as shown in Figure 2.8. This research is done on this handover type.

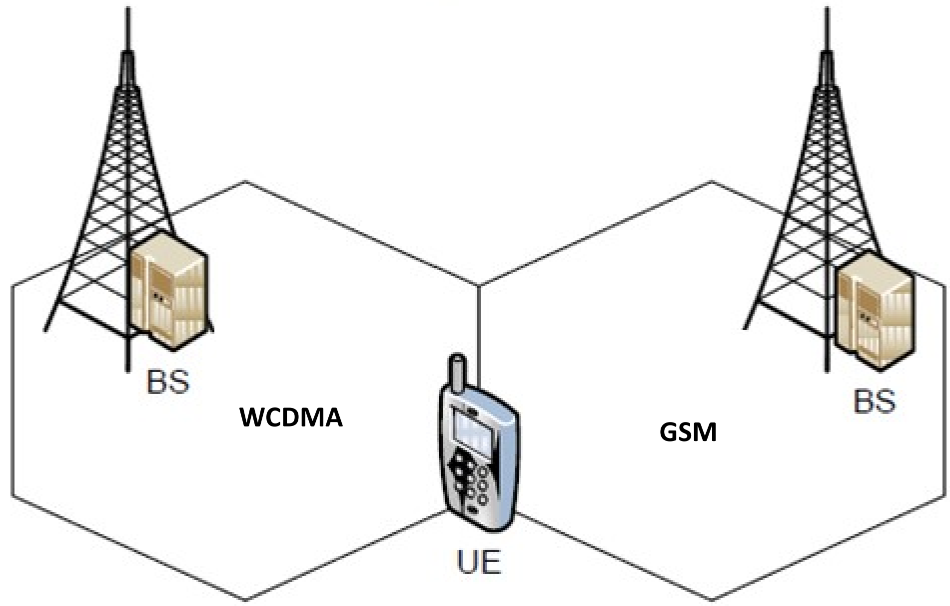

Figure 2.8: Inter-System handover [10].

In WCDMA Compressed Mode or slotted Mode function is enabled to perform inter-RAT handover. The spreading factor of the channel is decreased when the UE is in slotted mode. Consequently, only part of the WCDMA frame slot is used in the radio interface connection, the remaining slot used by UE for other task ; for instance it measure the surrounding GSM cells. The interoperability mechanism implemented in GSM/UMTS in UTRAN use this technique. Additionally, reducing the symbol rate in associated with physical layer multiplexing and reducing the data rate using the higher layer controlling the slotted mode is achieved. The Uu interface in this mode used by UE, in order to open a time window through which the UE is able to peek and decode the GSM BCCH information, the contents of the WCDMA frame are “compressed”. The UE is able to perform decoding after both WCDMA and GSM send each other’s identity information on the BCCH [15][14].

In the areas where two RANs exists together Inter-system handover is best, like the case of this thesis. To make sure the continuity of service it is important to complement each RANs. Also this type of handover is used to control load between the two technologies. Inter-system handover is a (NEHO); however the UE must have the capability to support this type of handover. The configuration of neighbor definition and other parameters that makes the RNC recognizes as there is a probability for an Inter- RAT handover [14].

In WCDMA /GSM handover, if the measurement is to be done on the GSM side no compressed mode is needed, because GSM uses discontinuous transmission and reception. In IRAT handover the service interruption time is 40ms maximum (this time is between the last received transport block on the old frequency and the time the UE starts transmission of the new uplink channel). Since the UE needs to get the dedicated channel out of the 31 channel running in GSM the total service gap is slightly more than the interruption time. Similar to intra-GSM handovers the service gap is typically below 80ms and such a gap does not degrade voice quality and is illustrated in Figure 2.9 [18].

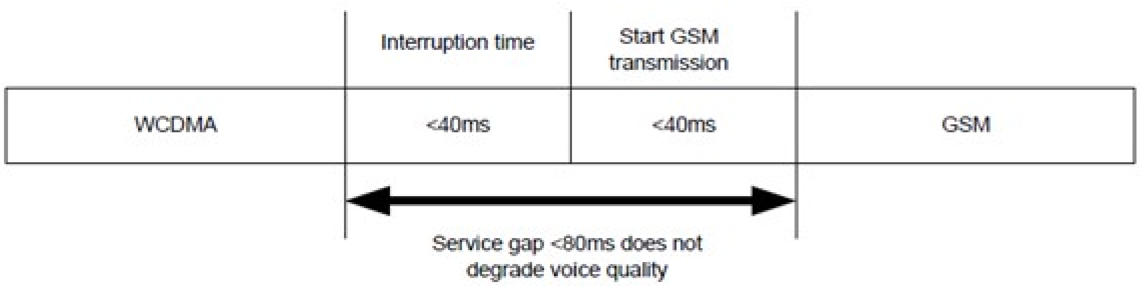

Figure 2.9: Service Interruption time between GSM and WCDMA handover.

2.5.4 Handover Decision Algorithms

Handover algorithms are formulated based on the factors that cause the handover. In WCDMA traditional handover algorithms can be classified as follows [19] [20];

- Handover based on Relative Signal Strength (RSS) : The base station with strong signal strength is selected at all times.
- Handover based on Relative Signal Strength with threshold (RSS-T):In this algorithm a user handovers if the source cell signal is very weak (less than a threshold) and the target cell signal is stronger than the sum of the source and threshold
- Handover based on Relative Signal Strength with hysteresis (RSS-H): This method prevents repeated handovers (Ping-Pong effect) and in which a user handover is done if the target BS is sufficiently stronger by hysteresis margin than the source.

- Handover based on Relative Signal Strength with Hysteresis and Threshold of serving base station (RSS-HT) in which the user handover to a new BS occurs only if the current signal level drops below a threshold and the target BS is stronger than the current one by a given hysteresis margin.
- Handover based on prediction techniques: in which based on the expected future value of the received signal the handover decision is made. There are wrong handover in cellular network and can be decreased by delaying the occurrences of handover till the signal strength of the new BS gets very stronger. To get this other criteria known as absolute signal strength taken as threshold of a new BS has been incorporated in the signal strength based on RSS-H algorithm. The new algorithm is named as RSS-HT new.

It upgrades the performance as follows [20][19]:

1. When the signal strength of the new BS is not sufficient to serve the call with the appropriate setting of the new BS threshold it reduces the number of unnecessary handovers to a new base station.
2. The number of handovers happening to the neighboring cell not intended for handover (wrong handover) can be reduced, with proper higher threshold adjustment.

3. Circuit Switched UMTS to GSM Handover

In this portion CS WCDMA to GSM handover is discussed in addition to those mentioned in Section 2.5.3 (inter –system handover). CS-WCDMA to GSM handover is an example of inter-RAT (inter-system) handover and also the main agenda of this thesis.

3.1 Introduction

It takes place between 3G and 2G network. This handover occurs due to load limitation, link stability or coverage limitation of the UMTS network. Hence with the help IRAT HO we could get full utilization of the ubiquitous 2G network which reduces operator's cost and also supports load sharing, HCS services and continuous coverage.

3.2 UMTS to GSM Handover Procedure

That can vary based on handover type. There are four phases in 3G-to-2G handover. These are handover triggering, handover measurement, handover decision, and handover execution.

- The triggering phase: if the signal quality or strength of a 3G cell is below a threshold value or else the load of the 3G cell that the UE accesses is higher, IRAT handover is triggered.
- Measurement phase: after handover is triggered, compressed mode is enabled and IRAT handover measurement is started by the RNC of the 3G network and carried out by UE.
- Decision phase: The RNC makes a decision after the UE reports event 3C (event 3C is discussed in the next section).
- The execution phase: handover execution procedure initiated by the RNC

3.3 UMTS to GSM Handover Measurement Events

With 2d, 2f, and 3a events, the UE communicates the measurement of connection quality to RNC, and RNC continuously monitors whether the down link (DL) Ec/No, DL received signal coded power (RSCP), or uplink (UL) coverage is good or weak. When at least one of these fails, or when the measurement criteria for starting the relevant handover processes are exceeded, the procedure is initiated; if the coverage improves for all, the IRAT HO attempt is abandoned. The events are listed and discussed below.

Event	Description
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.

Table 3.1: Events in inter-RAT handover.

All parameters defining the different thresholds used during the UMTS to GSM handover are set per RNC and per UMTS cell. The picture below describes the complete IRAT handover Event reporting.

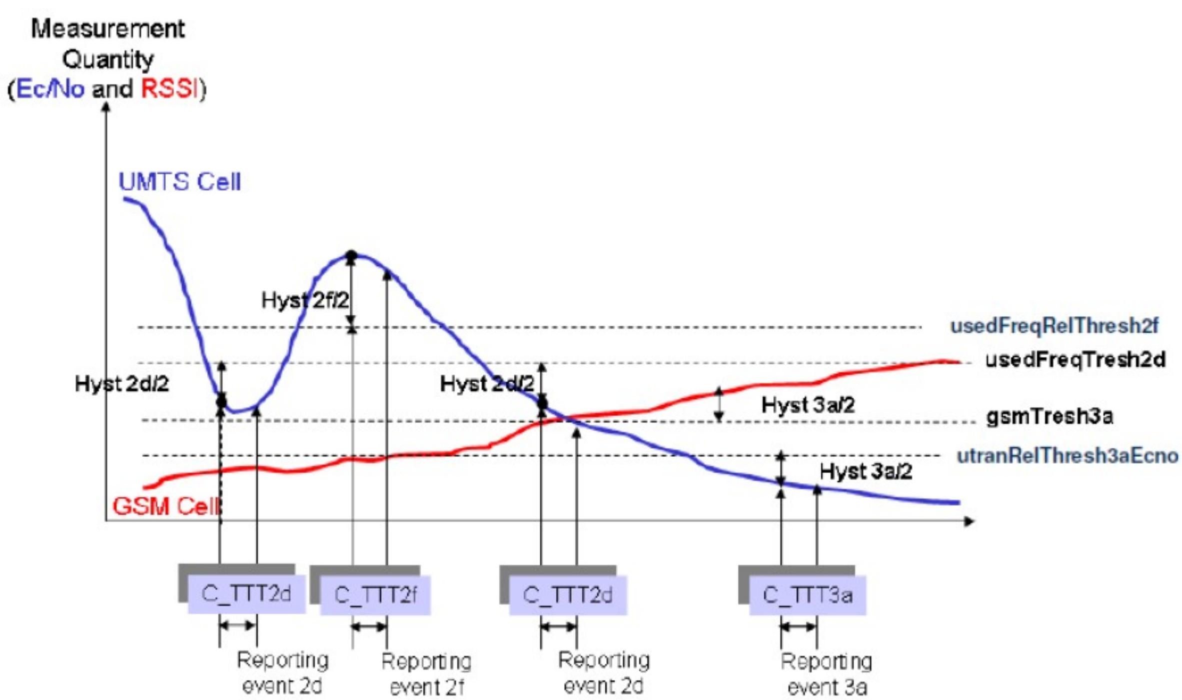

Figure 3.1 Reporting Events 2d,2f and 3a [21]

3.4 UMTS to GSM Handover Type

There are five types of 3G-to-2G handover based on the handover triggering causes. Each of them are explained in Table 3.2 below.

Type of Handover	Description
3G-to-2G handover based on coverage	When the coverage of the 3G network is discontinuous; the 3G –to-2G measurement is triggered on the border of the coverage where the signal quality of 3G network is poor. In the meantime if the signal quality of the 2G network is good enough and all the services of the UE that were supported by 3G are supported by the 2G network, the coverage-based 3G-to – 2G handover is triggered.
3G-to-2G handover based on QoS	According to the Link Stability Control Algorithm, the RNC needs to trigger the QoS based handover to avoid call drops.
3G-to -2G handover based on load	If all the RABs of the UE that were supported by 3G are supported by the 2G network and the load of the 3G network is heavy , the load based handover is triggered
3G-to-2G handover based on service	The traffic of various classes is handed over to different systems, based on layered services, example when an Adaptive Multi Rate (AMR) speech service is requested; this service can be handed over to the 2G network.
3G – to – 2G handover based on speed	The 3G-to-2G handover can be triggered by the UE speed estimation algorithm of the HCS (Hierarchical Cell Structure) , to reduce the frequencies of handover, the UE at a higher speed is handed over to a cell under a larger coverage(macro cell with low priority), whereas the UE at a lower speed is handover to a cell under smaller coverage (micro cell with higher priority).

Table 3.2: Types of handover in 3G –to-2G network.

3.5 Handover from UTRAN to GSM

The RNC try to assign resource in the destination GSM cell after receiving a measurement report showing the event 3a. Handover from UMTS (UTRAN) request is sent from the RNC to UE when the resources are available. After the handover from 3G to 2G UE will send confirmation message to BSC and then resources of UMTS network are released. If the handover fail UE send message to UTRAN as it fails, after that new handover attempt is down If possible without losing the call. In the figure below the successful handover signal path is shown for UMTS to GSM network [22].

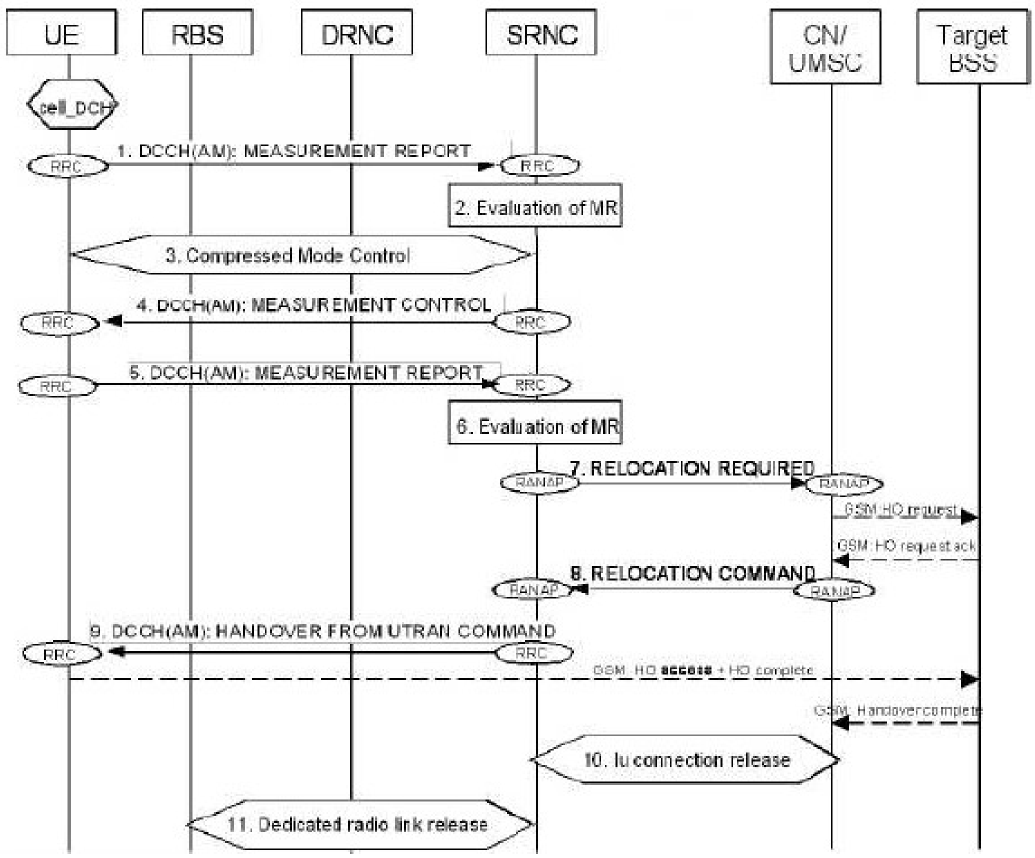

Figure 3.2:Message sequence chart for inter-system (UTRAN to GSM) handover.

3.6 Size of Neighbor List

In order to enhance the chances of a successful handover, the neighbor list should be as small as feasible. The cell coverage may alter as the load increases. However, it is important to remember that CPICH Ec/No is utilized as a measuring quantity in both idle mode and G2U active mode, even if it may be less important in idle mode to constantly reselect to the strongest cell.

3.7 Performance Indicators

3.7.1 IRAT HO Success Rate (U2G)

The transfer of the IRAT the number of successful IRAT handovers divided by the number of occurrences where an IRAT handover may be predicted based on signal and quality levels equals the success rate. If the handover fails, the cause of the failure should be investigated. The drop call rate is significantly connected with this performance metric.

HSR= $\boldsymbol{CT07}+\boldsymbol{CT08}\ /\boldsymbol{CT09}+\boldsymbol{CT10} \times 100$. CT09 counts the number of outgoing HO requests and CT10 counts the number of receiving handover requests, where CT07 counts the number of incoming successful handovers and CT08 counts the number of outgoing successful handovers. [23].

4. Methods for IRAT 3G to 2G Handover Optimization

4.1 Ethio Telecom's 2G and 3G Mobile Network Coverage Nature

In the past few years, Ethio Telecom has carried out vast projects and has been carrying out projects. Among those projects is the Telecom Expansion Project (TEP), which has covered all of the country. In Addis Ababa, there are around 743 sites nowadays. At these sites, 2G, 3G, and 4G networks are deployed. The structure of the coverage of the 3G and 2G networks is shown in the figure below.

In this case, since the size of the two cells (2G and 3G) varies, their coverage also doesn't overlap each other. 3G cells that have smaller areas are covered totally by 2G cells, which have a bigger size. During coverage holes and load balancing, all 3G users can be handed over to 2G without any network coverage issues, especially for voice service, since 2G is good for voice service and, as shown in the figure, has wider coverage.

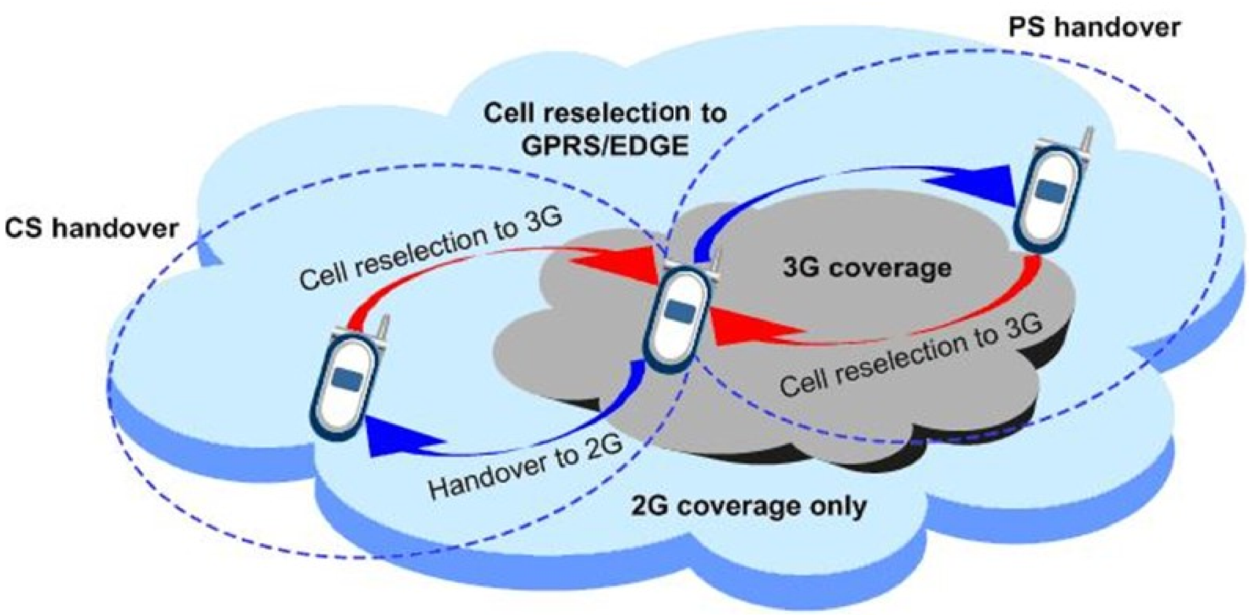

Figure 4.1: UMTS and GSM coverage [Huawei]

4.2 Root Cause Analysis of CS IRAT Handover Success Rate Failure for Addis Ababa Network

As stated in the statements of the problem above, the CS IRAT 3G-to-2G handover success rate that Ethio Telecom plans to achieve in the Addis Ababa network is 98%, but actually the company has been achieving around 95%, which is below the target value. In the CS IRAT (3G-to-2G) handover performance data captured from the NMS, there are eight different causes for the occurrence of the handover failure, and the frequency of occurrence of each cause is also shown in the report. Therefore, in this section, the root cause of the problem (handover success rate failure) has been analyzed using one of the different root cause analysis (RCA) techniques. Before applying to the RCA, let us discuss some points about it.

RCA is systematic approach used to analyze the fundamental problems before trying to solve them; it involves data collecting, cause factor charting, root cause identification and recommendation generation and implementation. Root causes are specific underlying causes that can be reasonably identified also used to target opportunities for system wide implementation. RCA can be done using multiple tools and techniques, some of these techniques are Pareto chart, five whys, Fishbone Diagram, Plan Do check-act cycle (PDCA) and Failure mode and effect analysis (FMEA).

For this thesis Pareto chart method has been used from the listed. It is statistical analysis method and in this thesis the types of the causes for the problem are identified and the frequencies of occurrence of the causes are available in the IRAT performance data collected from ethio telecom, hence Pareto chart method can be used .

A Pareto chart is a simple technique of RCA, which is a combination of a bar graph and a line graph. In the bar graph, each bar represents a type of defect, and they are presented in descending order, with the leftmost bars indicating the highest issues (cause of defect). The line in the graph represents the cumulative percentage of defects. It indicates the frequency of defects along with their cumulative impacts. The chart is built based on principles that state that 80% of the results are determined by 20% of the causes.

The data that contains the failure causes and frequency of occurrence of each cause has been extracted from the CS IRAT 3G-to-2G handover performance report of Ethio Telecom, captured at NMS for two months in January and February 2021 (only on Monday) and which is used in this thesis for the analysis of the root cause of the handover success rate failure. It is shown in table 4.1 below.

Failure Type	Total Failure
IRATHO.FailOutCS.PhyChFail	38713824
VS.IRATHO.FailOutCS.Other	4322568
VS.IRATHO.FailOutCS.Abort	3674374
VS.IRATHO.FailOutCS.CNUnspecFail	2522989
IRATHO.FailOutCS.CfgUnsupp	62601
VS.IRATHO.FailOutCS.InterRatRF	16165
VS.IRATHO.FailOutCS.SCRI	6406
VS.IRATHO.FailOutCS.NoReply	38

Table 4.1: Frequency of occurrence of CS IRAT (3G-to-2G) handover failure cause.

From the table 4.1 eight of the failure causes are

1. IRATHO.FailOutCS.PhyChFail :- The HO is failed because of physical channel failure
2. IRATHO.FailoutCS.cfgUnsupp:- The fail due to configuration unsupported, in 2G cell some configuration change made and if it is not updated in 3G cell.
3. IRATHO.FailoutCS.Abort :- due to handover aborted while progressing
4. IRATHO.FailOutCS.Inter RATRF:- due to the RF problem between the technology
5. IRATHO.FailOutCS.CNUnspecFail :- the fail due to Core Network unspecified failure
6. IRATHO.FailOutCS.NoReply :- due to no replay for the HO request
7. IRATHO.FailOutCS.SCRI:-
8. IRATHO.FailOutCS.Other :- the fail due to other reasons not mentioned above

To use the Pareto chart technique, the table 4.2 shown below is constructed. Here, total percentage means the ratio of the individual cause of failure to total failure, and cumulative percentage is the sum of the percentage of the failure cause and the causes above it.

Failure Type	Total Failure	Total percentage	Cumulative percentage
IRATHO.FailOutCS.PhyChFail	38713824	78%	78%
VS.IRATHO.FailOutCS.Other	4322568	9%	87%
VS.IRATHO.FailOutCS.Abort	3674374	7%	95%
VS.IRATHO.FailOutCS.CNUnspecFail	2522989	5%	100%
IRATHO.FailOutCS.CfgUnsupp	62601	0%	100%
VS.IRATHO.FailOutCS.InterRatRF	16165	0%	100%
VS.IRATHO.FailOutCS.SCRI	6406	0%	100%
VS.IRATHO.FailOutCS.NoReply	38	0%	100%

Table 4.2: Total Percentage and Cumulative Percentage of failure cause.

Hence using the above table 4.2 the pareto chart shown below is constructed with microsoft Excel

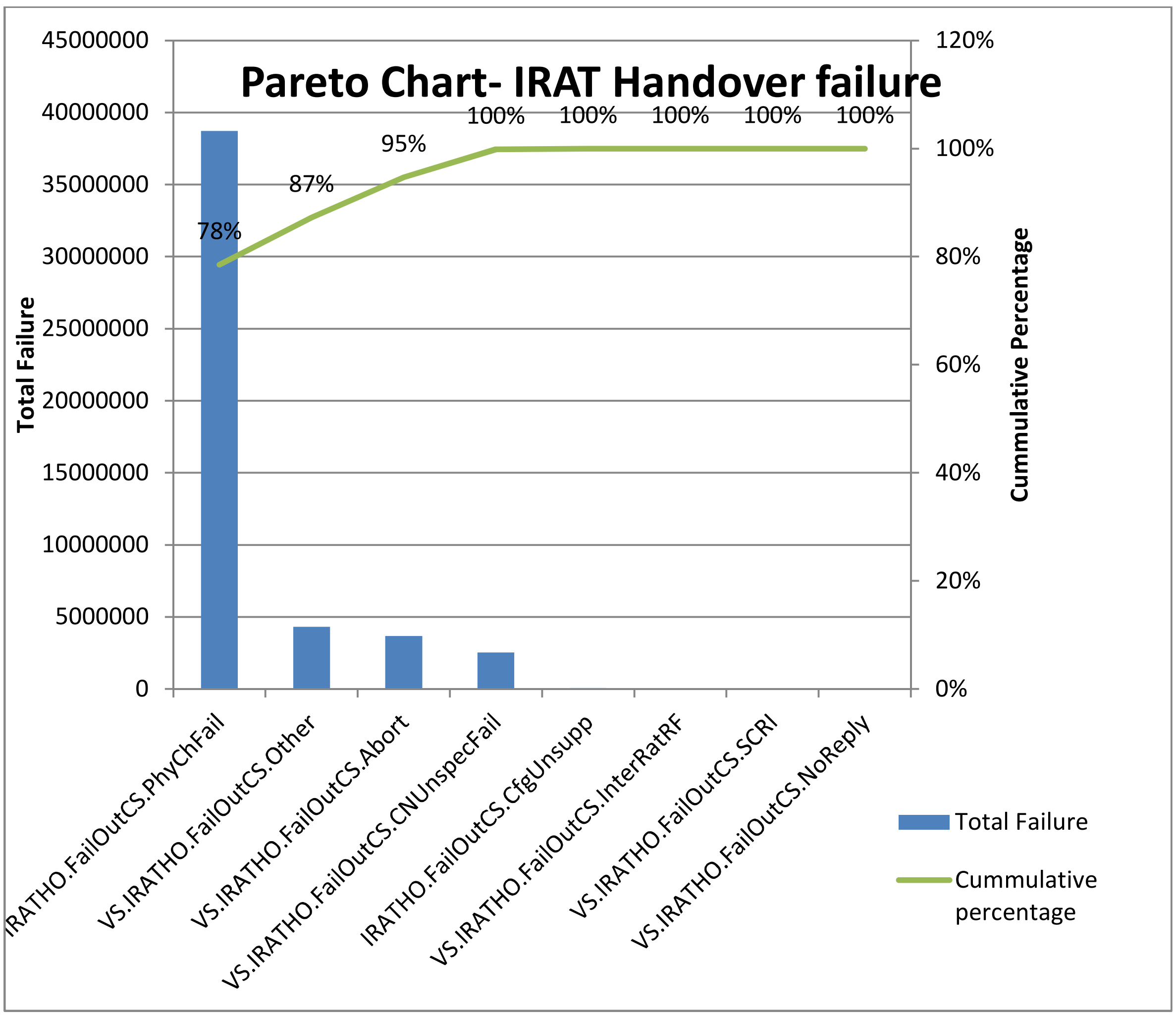

Figure 4.2 : Pareto chart for CS IRAT handover failure.

From Figure 4.2, it is clearly depicted that 78% of the CS IRAT (3G-to-2G) handover failures for the above mentioned durations (January and February, 2021) in the Addis Ababa network are caused by physical channel failure, which is the root cause of CS IRAT handover success rate failure. Hence, solving this cause can drastically change the network performance for the whole Addis Ababa network.

4.3 Sample Network (Study Area Selection)

In this thesis from the Addis Ababa network, sample networks which have one 3G site (SWAP_111169_DG+AC_H9_GUL_BSCRNC02.HW.BETHEL.SWAAZ.AA) around Betel and 26 neighboring 2G sites are selected, based on the handover success rate value of the 3G sites and the number of handover attempts from the 3G to 2G. But if a 3G site that has a lower handover success rate than the number of attempts has been selected, the selection may not be appropriate. The site should have sufficient handover attempts and a lower success rate. As shown in the table below, the site is selected by filtering the CS IRAT (3G-to-2G) HO performance data of the Addis Ababa network captured in the NMS for the stated duration based on the following two criteria:

- High handover attempt (more than 10,000 per day)
- Low handover success rate (less than 70%)

Date	NodeB Name	IRAT CS HO SR	IRATHO.AttOutCS	VS.IRATHO.FailOutCS
1/25/2021	SWAP_111169_DG+AC_H9_GUL_BSCRNC02.HW.BETHEL.SWAAZ.AA	21.269	85848	67589
1/18/2021	SWAP_111169_DG+AC_H9_GUL_BSCRNC02.HW.BETHEL.SWAAZ.AA	23.1627	88949	68346
2/1/2021	SWAP_111169_DG+AC_H9_GUL_BSCRNC02.HW.BETHEL.SWAAZ.AA	24.5416	80386	60658
2/8/2021	SWAP_111169_DG+AC_H9_GUL_BSCRNC02.HW.BETHEL.SWAAZ.AA	24.6511	66930	50431
2/15/2021	SWAP_111169_DG+AC_H9_GUL_BSCRNC02.HW.BETHEL.SWAAZ.AA	29.0255	35679	25323
2/22/2021	SWAP_111169_DG+AC_H9_GUL_BSCRNC02.HW.BETHEL.SWAAZ.AA	32.2137	37065	25125
1/11/2021	SWAP_111169_DG+AC_H9_GUL_BSCRNC02.HW.BETHEL.SWAAZ.AA	42.689	68308	39148
1/4/2021	SWAP_111169_DG+AC_H9_GUL_BSCRNC02.HW.BETHEL.SWAAZ.AA	42.7016	64932	37205
1/25/2021	SWAP_111169_DG+AC_H9_GUL_BSCRNC02.HW.BETHEL.SWAAZ.AA	47.9144	101867	53058
1/18/2021	SWAP_111169_DG+AC_H9_GUL_BSCRNC02.HW.BETHEL.SWAAZ.AA	48.3256	104545	54023
2/1/2021	SWAP_111169_DG+AC_H9_GUL_BSCRNC02.HW.BETHEL.SWAAZ.AA	49.6694	94388	47506

Table 4.3: Number of IRAT (3G to 2G) handover attempt and success rate failure.

Figure 4.3 shown below is considered the sample network for this thesis. As stated above, it has 26 2G neighbor sites and a selected 3G (111169) site. The 2G neighbor sites are from Ethio Telecom's neighbor definition data.

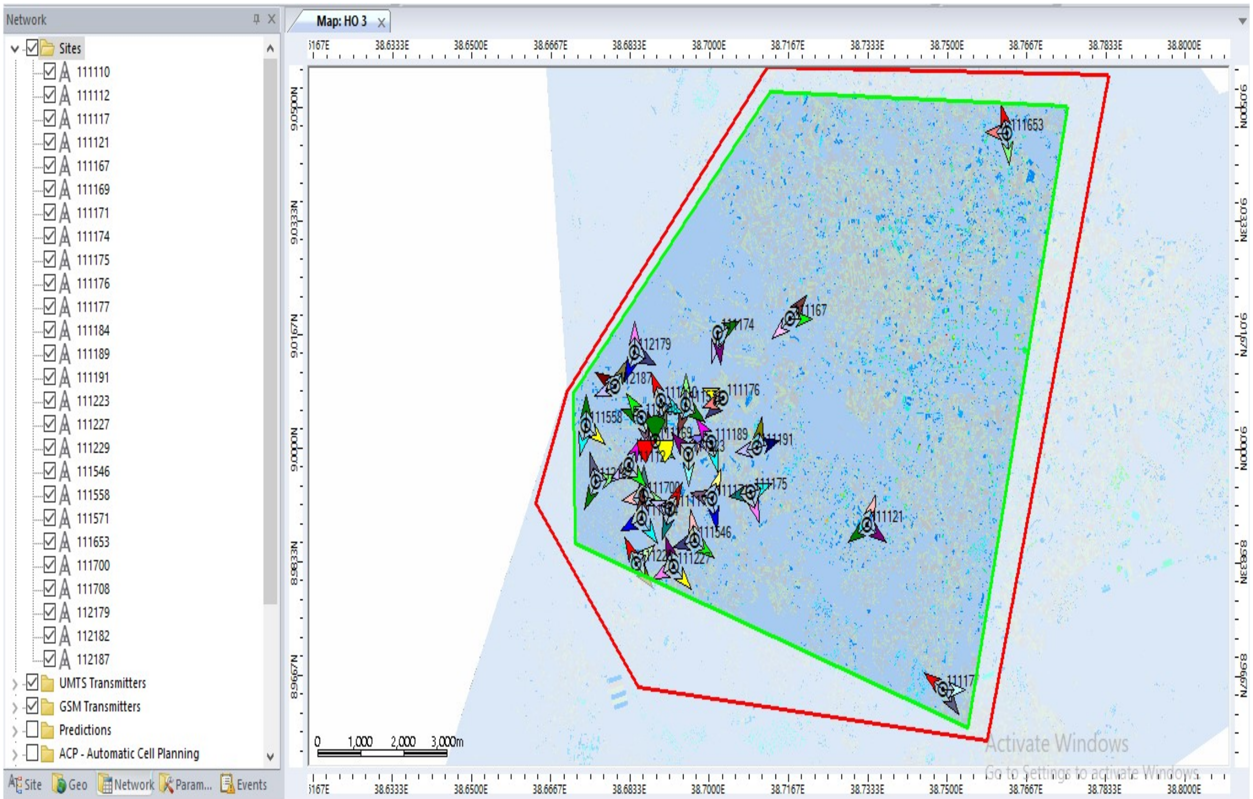

Figure 4.3: Sample network.

4.4 Reason of IRAT Handover Failure at the Sample Network

Previously, the root cause analysis was done for the whole Addis Ababa network. Here the analysis is for the sample network selected above in Addis Ababa. In the performance data, it is clearly shown that there are eight reasons for the handover failure.

As shown below in Pie chart Figure 4.4, the main reason for the IRAT HO failure for the sample sits is physical channel failure, which is 97%. The other seven reasons, all together, cumulatively count only 3%.

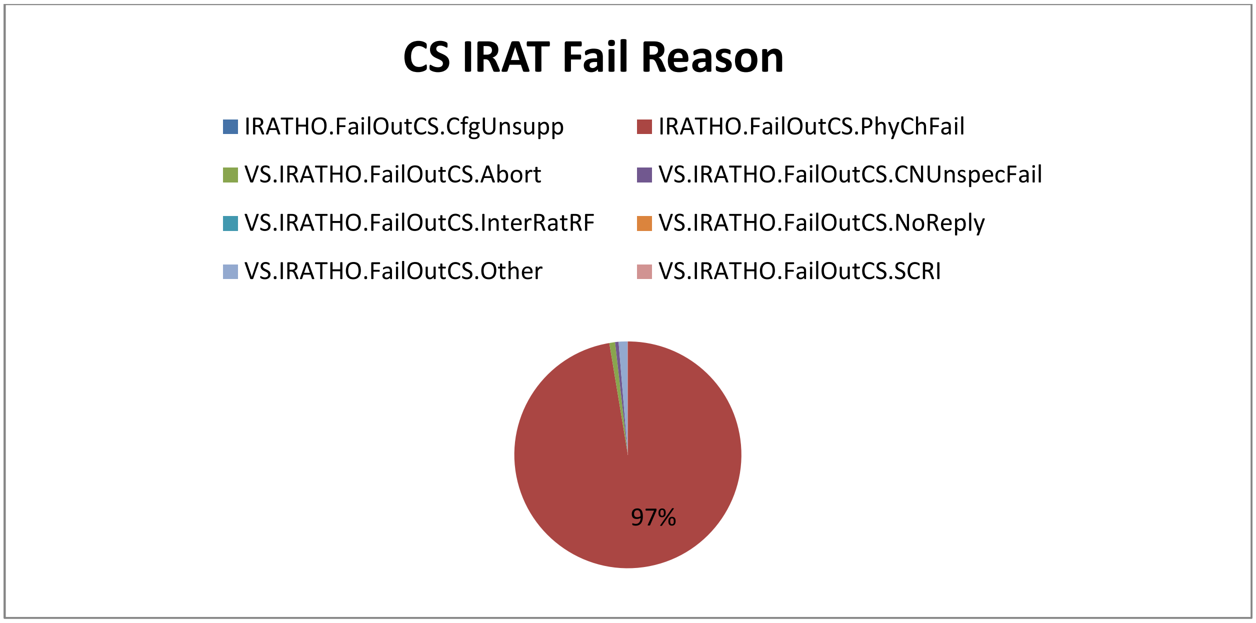

Figure 4.4: Chart of IRAT HO failure reasons.

4.5 Methods (Scenario)

In the above section it has been found that the main reason for the IRAT handover failure is the physical channel failure. In this section the physical channel failure is explained and the methods used to optimize it.

The drop reason counter in NMS counts that the main cause of drop in IRAT HO is due to physical channel fail it means that the 2G signal is too low , the 2G network is not available or the 2G network is congested. Hence one of the solution suggested below is to tune (increase) the TARGET (2G) IRAT CS THRESHOLD, it leads the UE to wait at the 3G source cell until the 2G signal get stronger and gives priority to handover to 2G cell that has strong signal and in the meantime the UE wait at the 3G that will give time for the congested 2G cell to be free [Huawei document].

Cell neighbor lists are necessary to ensure handovers between base stations. In Figure 4.4 shown above, some of the neighbors are very far away, and they are outside of the IRAT HO coverage success zone. And for each 3G cell, there are around 28 neighbors (ethio telecom neighbor definition data). Hence, the UE needs time to cheek all these neighbor 2G cells during handover. This will also lead the UE to fail before handover. Hence adjusting the neighbor relation will affects the handover.

- Optimization the 3G physical channel fail:
  - Adjust the Neighbor relation between 3G & 2G cells.
  - Tune the TARGET (2G) IRAT CS THRESHOLD, so as to choose the better 2G cell to decrease the fail due to the 2G cell.

4.6 System Model

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

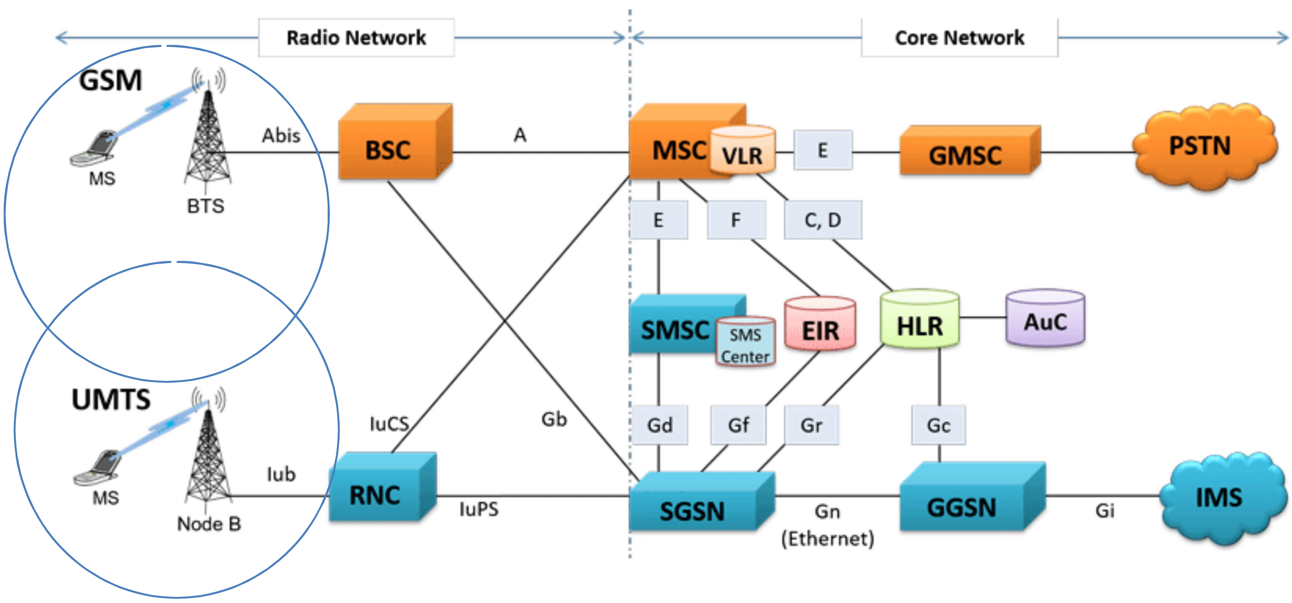

Figure 4.5: System Model [24]

5. Simulation Results and Discussion

In this chapter, simulation of the sample Addis Ababa IRAT (3G and 2G) network, which has been selected above, is carried out and the result obtained is discussed. The tool used for the simulation is explained. The same tool atoll is used for planning of the sample network (real network), adjusting the neighbor relation of the sample network, and optimization of the sample network handover process, and each of them is explained below. The preprocessing of the tool and different scenarios of the optimization simulation are discussed.

The flow chart below explains how the simulation is carried out.

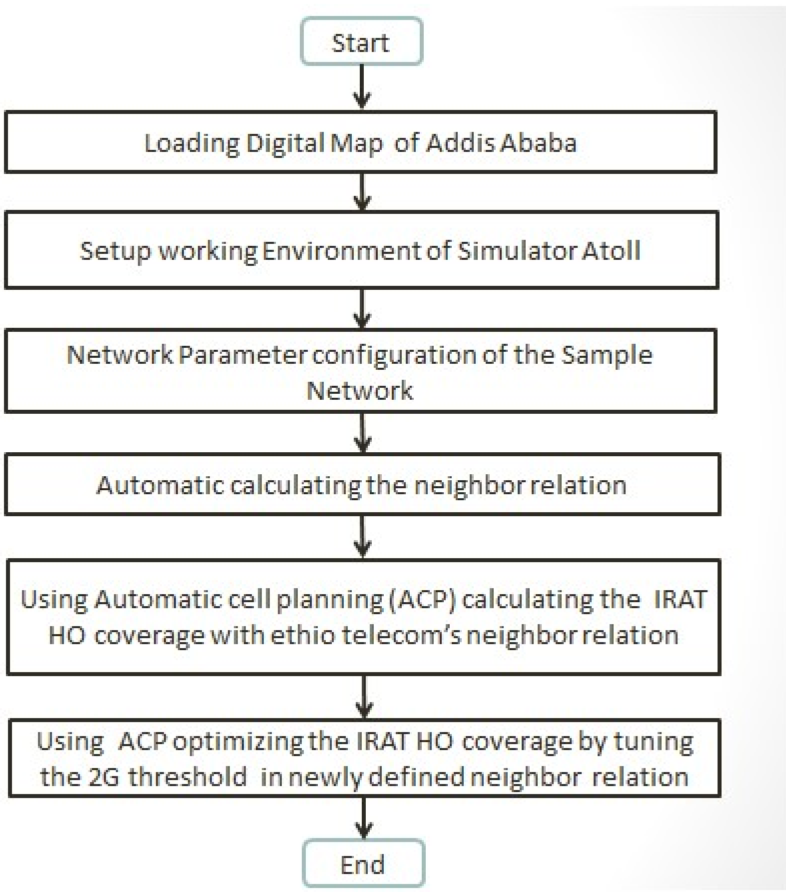

Figure 5.1: CS IRAT HO Optimization Simulation Workflow

5.1 Simulation Tool

5.1.1 Atoll

Atoll is a multi-technology wireless network design and optimization platform (tool) that aids wireless operators from basic design to densification and optimization. For both 3GPP

(GSM/UMTS/LTE) and 3GPP2 (CDMA/LTE) technology streams, Atoll features integrated single RAN-multiple RAT network design capabilities. It gives operators and vendors a powerful native foundation for planning and optimizing current and future multi-technology integrated networks. Multi-technology HetNets, small cell planning, and Wi-Fi offloading are all supported by Atoll [24]. For this thesis, the integrated multi-RAT capability of 3GPP (GSM/UMTS/LTE) has been used for the design of the selected sample network, and since there is no LTE network, it is excluded from the design. The optimization function ACP is used for the optimization task, which is embedded in the design tool.

5.1.2 Digital Map of Addis Ababa

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 bodies, and railways. The technology is used to calculate the distances between two sites. In this project, the digital map of Addis Ababa from Ethio Telecom has been used to locate the sites of the sample network.

5.1.3 Computational and Focus Zone

The computation zone is the area where Atoll does its work. When you construct a computation zone, Atoll does the calculation for all active, filtered (i.e., those selected by the current filter parameters) base stations whose propagation zone intersects the computation zone's rectangle. As a result, it takes into account both sites within the computation zone and sites outside the computation zone if they have an impact on the computation zone. In addition, the computation zone specifies the display region for the coverage prediction results. On the map, a red contour denotes the computation zone.

The focus zone can be defined as a region on which data and reports can be generated. Only one focus zone is possible. On the map, the focus zone is indicated by a green contour [25].

5.1.4 Parameters and Assumptions

Simulation parameters and assumptions used for the specified area are as per the Ethio Telecom's configuration and shown in Table 5.1

Parameters	3G	2G
Number of sectors	3	3
Number of cells	9	30- 1800 band 75- 900band
Maximum Power	46 dBm	43 dBm
Pilot power	33 dBm	N/A
SCH power	21 dBm	N/A
Power other CCH	30 dBm	N/A
Propagation Model	Cost-Hata	Standard
Antenna Type	Kathrein	Kathrein
Tx Antenna gain	18 dBi	17 dBi
Chip Rate	3.84 Mchips	N/A
Antenna Hight/Azim./Tilte	Ethio Telecom	Ethio Telecom
Carrier Frequency	2.11GHZ(10562,10587 & 10612 bands)	900(935MHz) 1800(1805MHz)
Resolution	5m	
Simulation	Static Simulation	

Table 5.1: Parameters and Assumptions in the Simulation.

5.2 Existing Neighbor Relation

Cell neighbor lists are necessary to ensure handovers between base stations. Here in Figure 5.2 below, "existing neighbor relation" means the neighbor relation that the current Ethio Telecom network has and is defined by Ethio Telecom. The data is obtained from Ethio Telecom. The selected 3G site which is located at the center has three transmitters, and each transmitter has three cells. Each cell has around 28 2G neighbor cells, both in the 900 and 1800 bands. It has been shown that in Figure 5.2 below, some of the neighbors are very far from the 3G site. Therefore, using automatic neighbor allocation of atoll, it is necessary to check the existing neighbor relation whether call can be handed over or not.

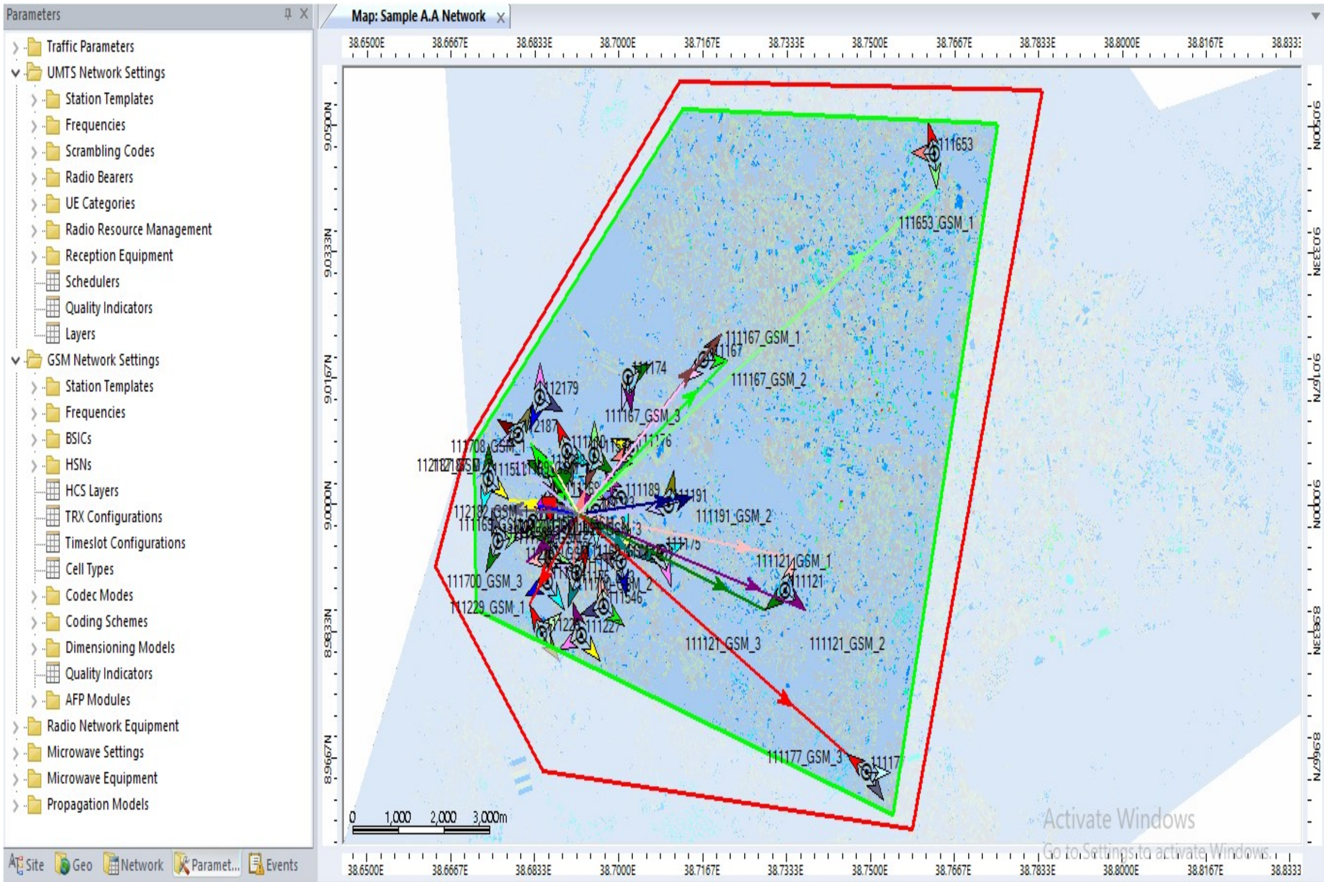

Figure 5.2: Existing Neighbor Definition of the Sample Network

5.3 Automatic Neighbor Relation Adjustment

In a radio network, Atoll can automatically assign intra-technology and inter-technology neighbors. The Automatic Neighbor Allocation dialog box's options determine how the neighbors are assigned. Automatic neighbor allocation in a multi-RAT environment helps identify handover relationships between networks of different technologies. Inter-technology handovers from UMTS to GSM can occur when UMTS coverage is not continuous, for example, if a network employs both UMTS and GSM. A UMTS-to-GSM handover expands the overall network reach [25]. As shown in Figure 5.3 below, the neighbor relation shrinks, deleting some of the neighbors which are far from the 3G (reference) cell. Hence, it gives the UE relief by minimizing the number of neighbors to check during the HO process.

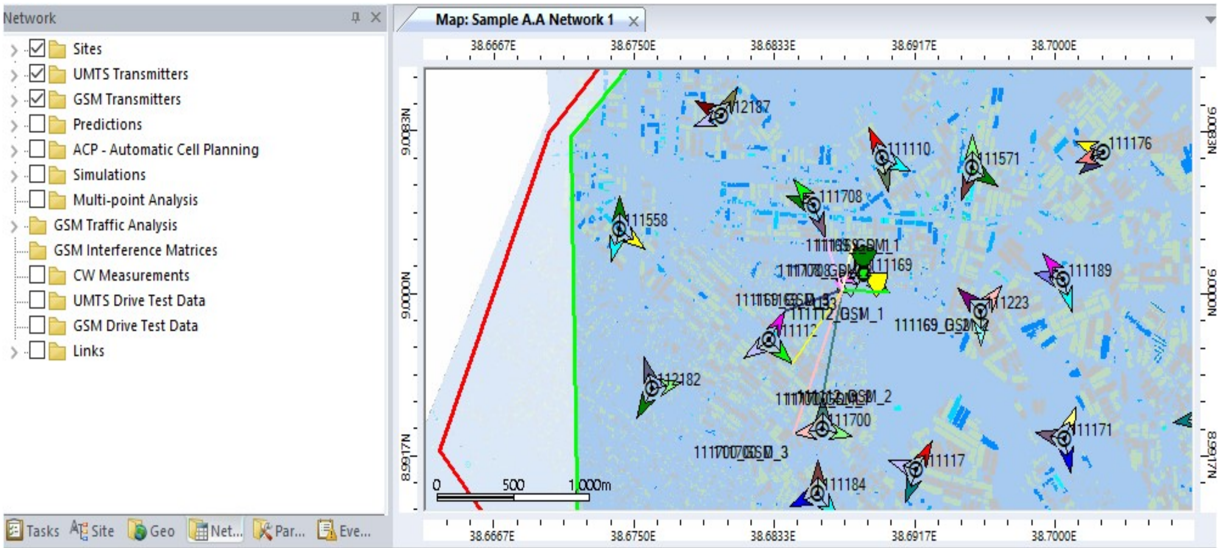

Figure 5.3: Automatically Allocated Neighbor Relation

Figure 5.4 is obtained after performing Automatic neighbor relation allocation and deleting some of the neighbors and adjusting the computational and focus area, no need to have all those 2G neighbor sites for the selected 3G sites since some of the sites are very far and a call couldn't be handover to the far sites. Those sites which are deleted from the neighbor relation have no overlap with the 3G site.

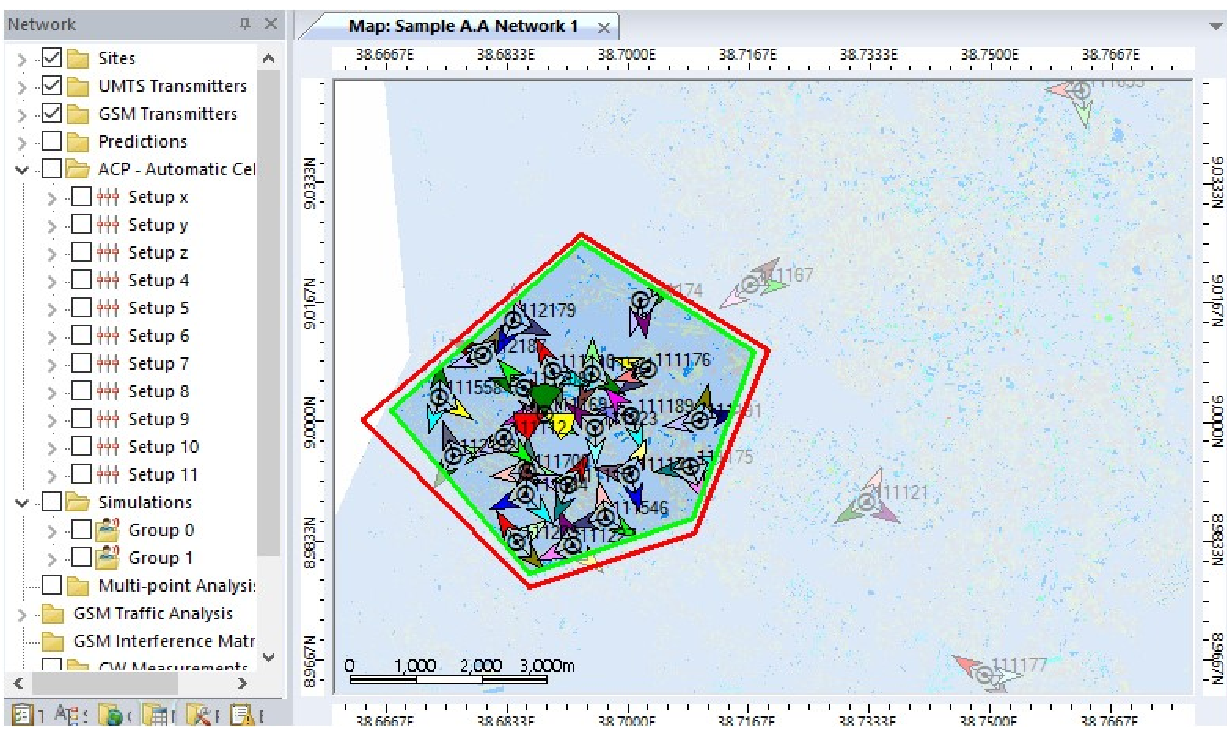

Figure 5.4: Adjusted Sample Network as per the new Neighbor Definition

5.4 Automatic Cell Planning (ACP)

The Atoll GUI's ACP (Automatic Cell Planning) feature allows radio engineers developing multi-RAT networks to automatically compute the best network settings in terms of coverage and quality. ACP can also be used to add sites from a list of candidate sites, as well as to remove sites or sectors that are no longer needed. The basic goal of ACP is to optimize existing network deployment by resetting the main settings. The optimization is evaluated by ACP using user-defined objectives. ACP uses an efficient global search method to test many network configurations and recommend reconfigurations once the objectives and network parameters to be optimized have been stated. ACP is technology-independent and can be used to optimize networks using different radio access technologies [25].

In this thesis, using ACP, defines an objective that is optimizing the hard IRAT handover coverage of the sample Ethio Telecom network, which has been selected in section 4.3 for this thesis. The objective has been set by setting the value of Tsource (handover threshold of a 3G cell), Ttarget (handover threshold of a target 2G cell) and overlapping (which limits to what extent the UE has to wait after the threshold is met) of the two networks [26]. ACP uses the following optimization parameters: site selection, antenna selection & parameter optimization (azimuth, height, mechanical & E tilt), antenna height, and power. But in this thesis, the intention is to tune the objective parameter Ttarget (TARGET (2G) CS THREHOLD) and to observe how the successful IRAT handover coverage varies rather than the mentioned optimization parameters.

The following two equations are the criteria set to be fulfilled during 3G –to-2G handover, the source cell (3G) should fulfill the first and the target cell (2G) should meet the second.

$$\mathrm{Qsource} \leq \mathrm{Tsource} - \mathrm{H}/2$$

Qsource: is the source (3G cell) signal strength measured by UE and reported to RNC it can be RSCP or Ec/No.

Tsource : is the threshold of the measured signal strength at the source cell that should be fulfilled to proceed the next handover phase.

H : is the handover margin set to prevent handover Ping-Pong

$$Qtarget + CIO \geq Ttarget + H/2$$

Qtarget : is the target (2G cell) signal strength measured by UE and reported to RNC it can be RSSI of the 2G.

CIO: is the cell individual offset set to identify the strength of cells in the neighbor list or active set .

Ttarget : is the threshold of the measured signal strength at the target 2G cell that should be fulfilled to proceed the next handover phase. In this thesis this value is adjusted to optimize the handover success rate.

H : is the handover margin set to prevent handover Ping-Pong

5.4.1 Optimizing the IRAT HO Coverage Using ACP

A. With Ethio Telecom's Neighbor Relation

The figures below show the result of IRAT handover coverage optimization using ACP. The output of the optimization is in different forms: general, statistics, sectors, graphs, and quality; for this study, the quality graphical analysis output format has been used to discuss since it easily shows the change. It has two parts, Final and Initial, which mean after and before optimization of the objective. Also, it shows in the histogram the success and failure of the objective with green and blue colors, respectively.

This optimization is performed for the existing Ethio Telecom sample network depicted in Figure 4.3. With the existing neighbor relationship depicted in Figure 5.5, the result shows that it has a larger area with the failure in the objective; thus, it is optimal to change Ethio Telecom's existing neighbor relations. And as shown in Figure 5.4, the neighbor definition is changed using Atoll automatic neighbor relation calculation, and onwards in Section B, the new sample network is used.

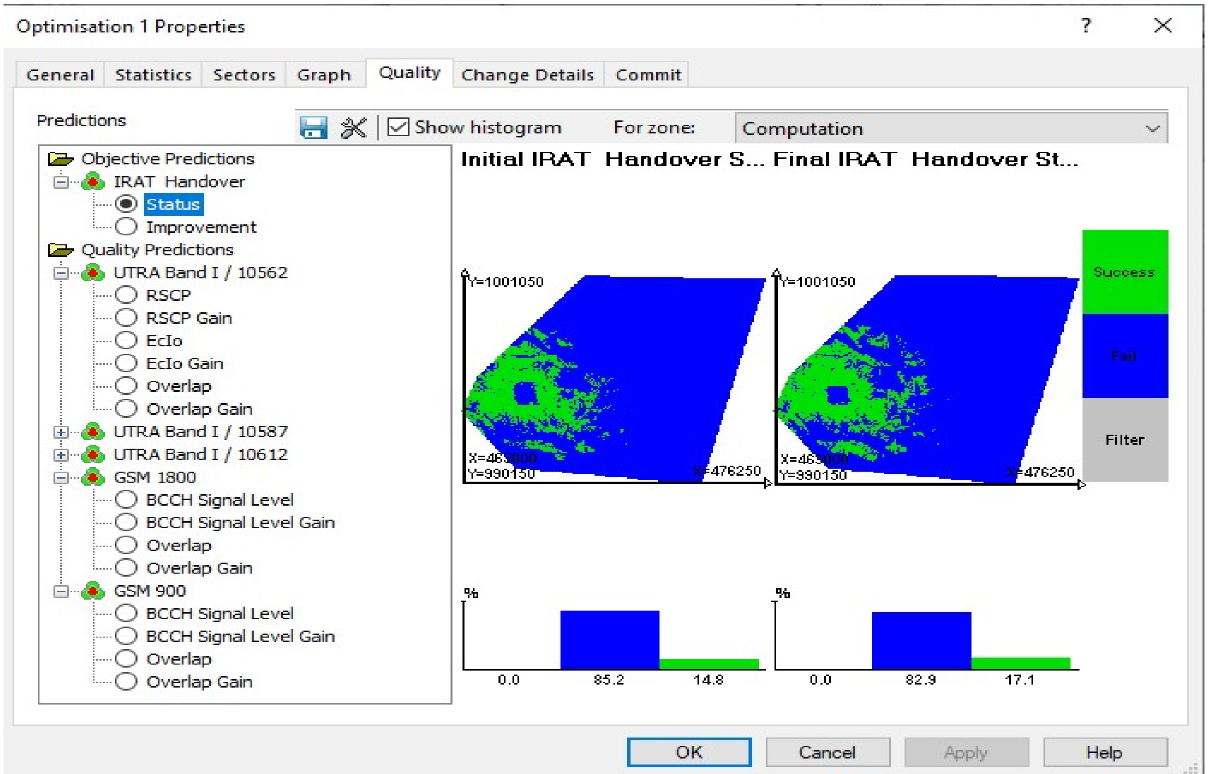

Figure 5.5: IRAT HO Coverage with Ethio Telecom Neighbor Definition

B. After Neighbor Relation Adjusted Optimization at Different TARGET (2G) CS THREHOLD

As it is mentioned above, the main intention is to study the change in IRAT HO coverage while changing the objective parameter, not the optimization parameter. The initial part of each graph, Figure 5.6, Figure 5.7, and Figure 5.8 shown in the circle below, has been considered, compared, and a decision has been made. The final part of each graph in Figure 5.6, Figure 5.7, and Figure 5.8 is achieved after tuning of the optimization parameters mentioned above. That is not the aim of the study. The aim of the study is to tune the objective parameter, the TARGET (2G) THRESHOLD, to see the change in the HO success coverage at the initial part of each graph.

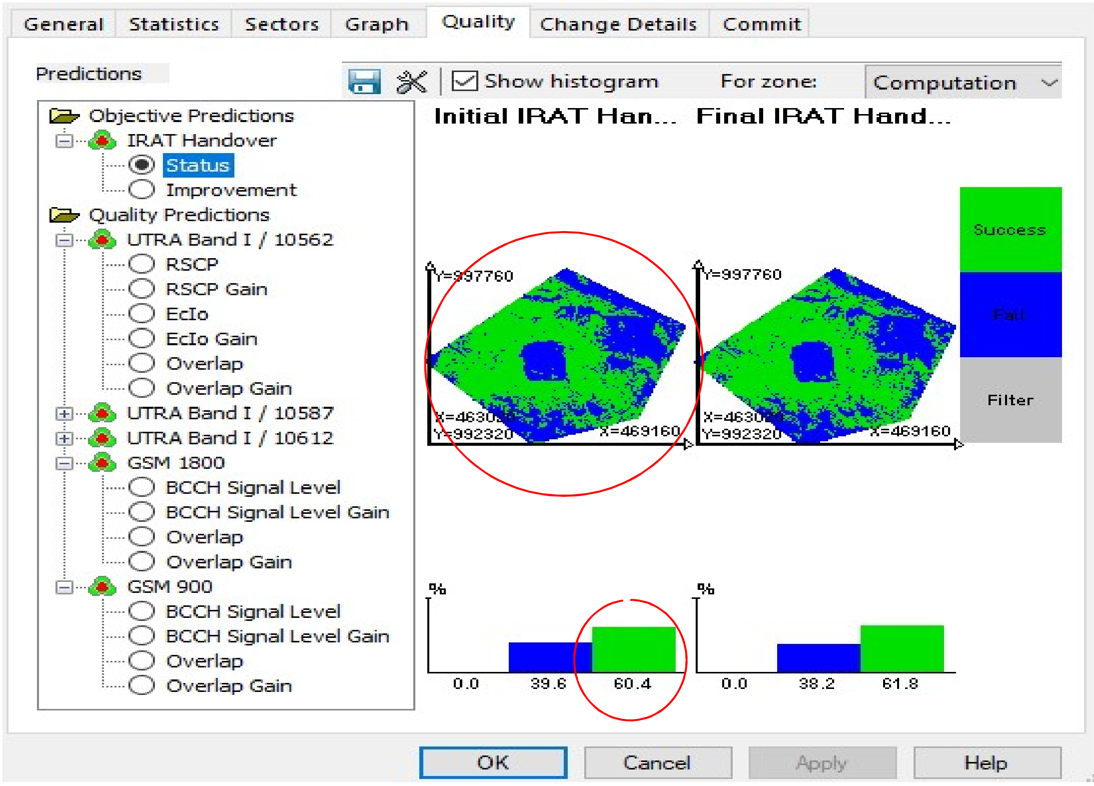

Figure 5.6: CS IRAT HO Coverage at Target Threshold value of -95 dBm

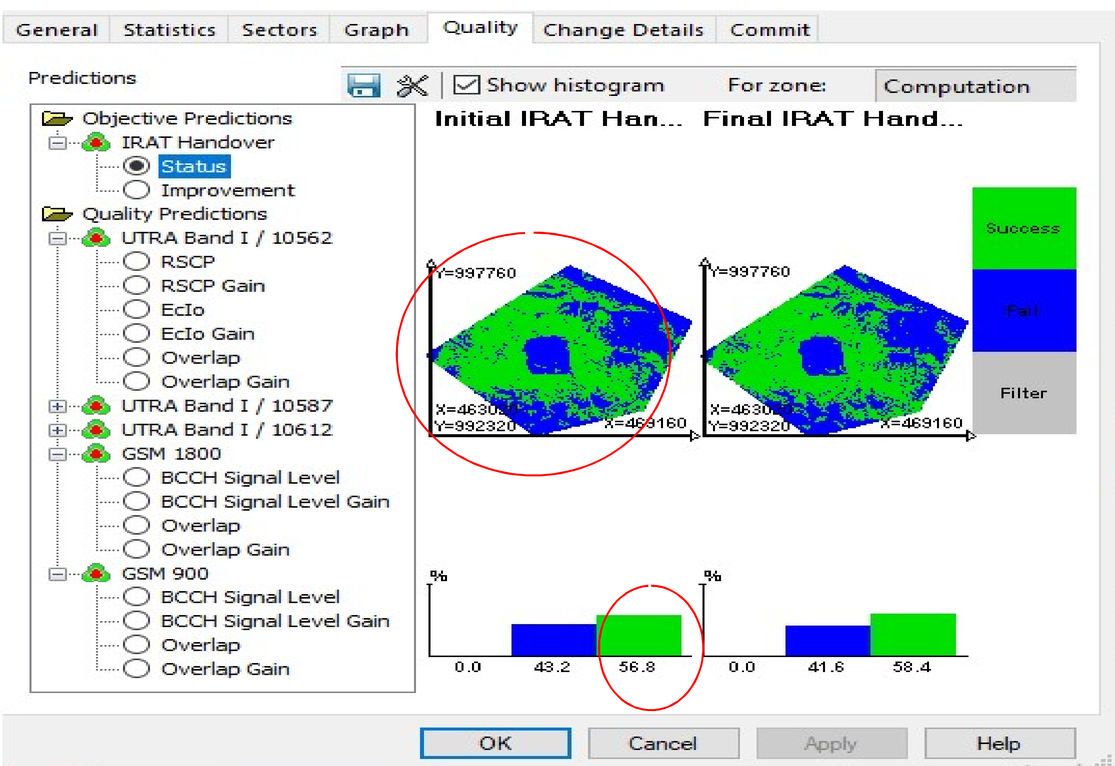

Figure 5.7:CS IRAT HO Coverage at Target Threshold value of -93 dBm

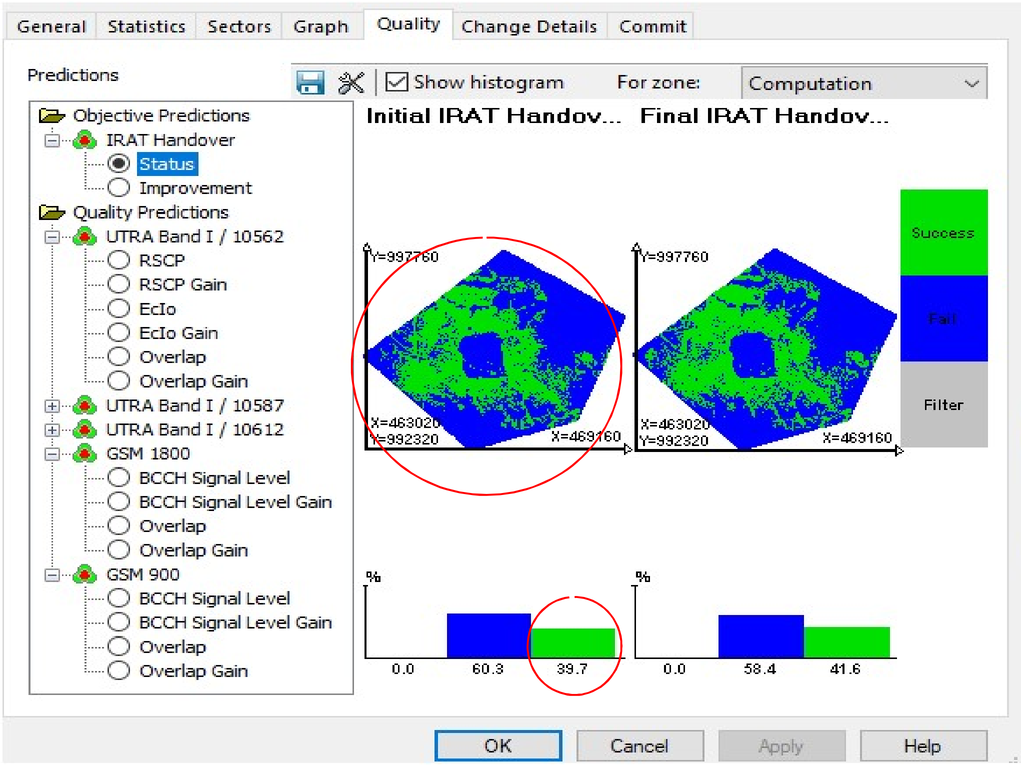

Figure 5.8: CS IRAT HO Coverage at Target Threshold value of -85 dBm

When we see the above three graphs, Figure 5.6, Figure 5.7, and Figure 5.8, it can be observed that the coverage at which the IRAT handover can be successful is decreasing from 60.4% to 39.7%, whereas the TARGET (2G) Threshold is increasing from -95 dBm to -85 dBm.

5.5 Results and Discussion

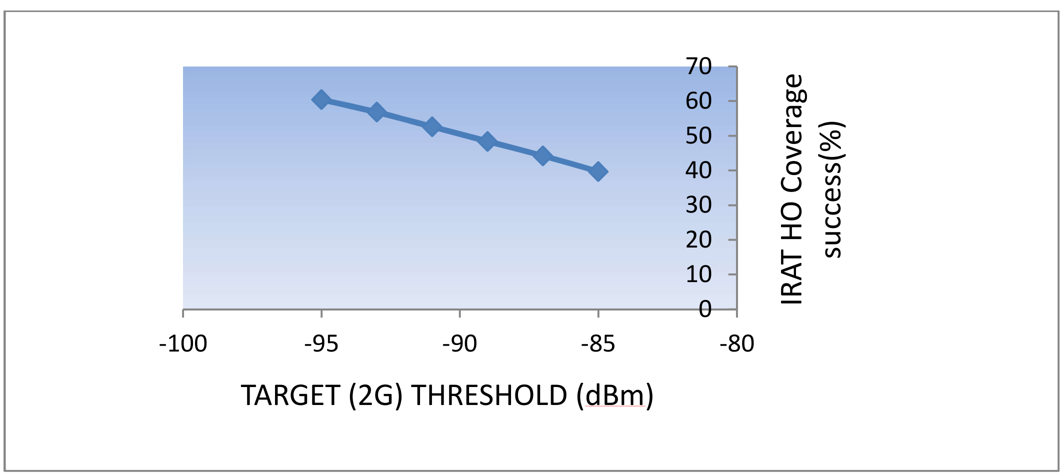

Figure 5.9: Target (2G) threshold versus IRAT HO coverage success

TARGET (2G) CS THRESHOLD	-95	-93	-91	-89	-87	-85
IRAT HO coverage success	60.4	56.8	52.6	48.4	44.2	39.7

Table 5.2: Target (2G) threshold versus IRAT HO coverage success

The sample network has been optimized for different values of the TARGET IRAT (2G) CS THRESHOLD. In Figure 5.9, the HO coverage success (the area where 3G to 2G HO is expected to be successful) continuously decreased, which implies the HO attempts that could be made by UE from 3G to 2G will also be minimized. And the likelihood of success for HO attempts will increase as the GSM signal strength where the handover is to be performed improves [27].

As it is explained in section 3.7.1 and also used by Ethio Telecom, the HO success rate is the ratio of successful full HO attempts to the total HO attempts shown in below equation. Therefore, it can be concluded that the HO success rate is improved while the HO coverage success (area) shrinks or decreases, but the TARGET (2G) CS THRESHOLD increases.

$$\text{HO success rate} = \frac{\text{Success full atempts}}{\text{Total attempts}}$$

6. Conclusions and Recommendations

6.1 Conclusions

The UMTS and GSM networks coexist in Ethio telecom throughout the country, handling all the voice services. The interoperability of the two networks has great advantages for the company. Ehtio Telecom should use this advantage optimally. It gives the company the chance to use the ubiquitous 2G network. Since the 2G network is very good for voice service, the interoperability feature will reduce the investment cost for expansion of the 3G network where there is a high load and coverage gap and voice service is needed. This research has been done for the Addis Ababa network; it can be used for different towns in the country.

This research has shown that the way to analyze the root cause of the problem is by using the Pareto chart root cause analysis technique. It is easily identified that physical channel failure has been causing most of the HO failures by far greater than the other seven types of causes. The physical channel failure cause has a great impact on the system and addressing it will solve around 80 percent of the problems in the Addis Ababa network.

This research has shown that the inter-RAT (between 3G and 2G) neighbor relations of the Addis Ababa network need adjustments. Some of the neighbors defined by Ethio Telecom are very far from the source cell. Calls couldn't be handover to these neighbors, but they are causing the UE to be busy while looking for the best target 2G neighbor to which calls from 3G can be handover.

Optimizing the Target (2G) IRAT CS Threshold will have an impact on the successful handover coverage area. If it affects the handover coverage area, it will also affect the handover success rate. As shown in the simulation, while increasing the target (2G) IRAT CS threshold, the successful handover coverage area shrinks, which means the number of handover attempts decreases and the success for those attempted handovers increases, since there are few attempts and while increasing the threshold of the 2G cell, the cell gets stronger and less congested. In general, the handover success rate will be improved with the target IRAT CS threshold, hence it can be concluded that the Addis Ababa network CS IRAT (3G-to-2G) handover success rate will be improved by tuning this parameter.

6.2 Recommendations

Further researches are needed on those areas listed below to find holistic solution for the problem:-

- One of the spaces in this research for a further study is using dynamic system simulation tool which measure the Mobility KPI (Handover success rate) , to simulate the sample network (real network) that has been chosen above and directly observe the impact of adjusting the neighbor relation and tuning the target IRAT CS threshold. In this thesis what was done is interpreting the effect on the handover coverage to handover success rate failure.
- Looking for in-depth avoiding mechanism for the 2G congestion , since there will be failure for the handover if the 2G is congested
- Also the user equipment contributes for the failure, if the user doesn't switch on automatic selection between the 2G and 3G network.

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