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HANDOVER PARAMETER OPTIMISATION OF A CELLULAR NETWORK:

THE KENYAN CASE

BY

EMILY TERESA NYAMBATI

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DECLARATION OF ORIGINALITY

NAME OF STUDENT: EMILY TERESA NYAMBATI

REGISTRATION NUMBER: F56/69381/2013

COLLEGE: College of Architecture and Engineering

FACULTY/ SCHOOL/ INSTITUTE: School Of Engineering

DEPARTMENT: Electrical & Information Engineering

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This thesis has been submitted for examination with our approval as university supervisors.

Prof. V. K .Oduol

Signature………………………………………………….

Date……………………………………………………….

Dr. Peter Akuon

Signature………………………………………………….

Date……………………………………………………….

DEDICATION

This thesis is first dedicated to the Almighty God for His marvelous grace then, to my family and well-wishers.

PUBLICATIONS FROM THIS THESIS

[1] **Emily Teresa Nyambati** and Prof. Vitalice K. Oduol, ‘‘Handover Parameter Optimisation of a Cellular Network: The Kenyan Case,’’ International Journal for Innovation Education and Research Vol:-4 No-6, pp. 24-3, June 2016.

Abstract

Handover, also known as Handoff is a key procedure that ensures that the cellular users move freely through the network while still being connected and being offered quality services. It is an event taking place whenever a mobile node moves from one wireless cell to another, abandoning the connection with the first base station and getting attached to the second one. Since its success rate is a key indicator of user satisfaction, it is vital that this procedure happens as fast and as seamlessly as possible.

This paper aims to optimise the handover decision process of a cellular radio network for an in-vehicle mobile station.

This is done by determining the optimal handover parameters then developing an algorithm that determines the best time to handover using the fuzzy logic system.

[2] **Emily Teresa Nyambati** and Prof. Vitalice K. Oduol, ‘‘Analysis of the Impact of Fuzzy Logic Algorithm on Handover Decision in a Cellular Network,’’International Journal for Innovation Education and Research, Vol:-5 No-5, pp. 42-62, May 2017.

Abstract

Fuzzy logic is one of the intelligent systems that can be used to develop algorithms for handover. For success in handing over, the decision-making process is crucial and thus should be highly considered. The performance of fixed parameters is not proper in the changing cellular system environments. The work done on this paper aims to analyse the impact of utilising the fuzzy logic system for handover decision making considering the Global System for Mobile communication (GSM) network. The results from the different simulations show that the need to handover varies depending on the input(s) to the Fuzzy Inference System (FIS). By increasing the number of data, thus the criteria parameters used in the algorithm, an Optimal Handover Decision (OHOD) is realised.

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I thank my family. Your overwhelming confidence in me pushes me beyond frontiers I never thought existed.

Above all, I acknowledge God Almighty for all that I am.

ABSTRACT

Handover, also known as Handoff, is a key procedure that ensures that the cellular users move freely through the network while still being connected and being offered quality services. The handover parameter optimisation described here assumes a well-designed network with overlapping radio frequency (RF) coverage of neighbouring sites. Currently, handover (HO) optimisation for the mobile networks that are deployed is done manually over an extended period, say weeks or days and, on a need premise as it were. Handover parameter optimisation (HPO) targets the reduction of the inefficient use of network resources due to unnecessary or missed handovers. Fuzzy logic is one of the intelligent systems that can be used to develop algorithms for handover. Fixed parameters cannot perform well in the varying cellular system environments. The main aim of this thesis is to optimise the handover decision process of a cellular radio network for a mobile station given various conditions. The work done here considers the GSM network. The need to handover varies depending on the input(s) to the FIS (Fuzzy Inference System). The work done is by first determining the optimal handover parameters then developing an algorithm that determines the best time to handover using the fuzzy logic system and lastly analysing the impact of using a multi-input fuzzy logic system for handover. The simulations done captured the output when only one parameter, received signal level (RxLev) is used, two parameters, RxLev and received signal quality (RxQual), and when RxLev, RxQual and mobile station (MS) velocity are the input parameters. The fuzzy output is in the range of 0 to 1, where 1 means YES to handover and 0 implies NO to the handover process. Hence the output decision value of 0.646, for three inputs, is different from 0.108 for two inputs and 0.5 for one input at their mean values. By increasing the number of inputs, an Optimal Handover Decision (OHOD) is realised thus the parameters used in the algorithm.

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LIST OF ABBREVIATIONS AND ACRONYMS

AMR	Adaptive multi rate
ANN	Artificial Neural Networks
AP	Access Point
BER	Bit error rate
BSC	Base station controller
BS	Base Station
BTS	Base transceiver station
CA	Communications Authority of Kenya
CDMA	Code Division Multiple Access
CDP	Call dropping probability
EDGE	Enhanced Data Rate for GSM Evolution
FIS	Fuzzy Inference System
FLC	Fuzzy Logic Controller
G	Generation (2G-Second, 3G- Third, 4G-Fourth Generation)
GSM	Global system for mobile communication
HO	Handover
HOD	Handover Decision
HSPA	High Speed Packet Access
HSR	Handover success rate
KPI	Key Performance Indicator
LTE	Long Term Evolution
MSC	Mobile Switching Centre
MS	Mobile Station
MT	Mobile Terminal
NGMN	Next Generation Mobile Networks
NM	Network Management
OAM	Operations Administration and Maintenance
OHOD	Optimal Handover Decision
OPEX	Operational Expenditure
QoS	Quality of Service

RF	Radio Frequency
RLF	Radio Link Failure
RSS	Received Signal Strength
RSRP	Reference Signal Received Power
RRM	Radio Resource Management
RXLEV	Received Signal Level
RXQUAL	Received Signal Quality
SACCH	Slow Associated Control Channel
SINR	Signal to Interference and Noise Ratio
TDMA	Time Division Multiple Access
UE	User Equipment
UMTS	Universal Mobile Telecommunications System
VLR	Visitor Location Register
WLAN	Wireless Local Area Network
WCDMA	Wideband Code Division Multiple Access

CHAPTER 1: INTRODUCTION

1.1 BACKGROUND

The GSM network was designed by the standardisation committees from major telecommunications operators and manufacturers in Europe. It is a digital wireless system standard with cells, as the building blocks, which enable mobile users to be served. Kenya is mainly served by both the 2G and 3G networks even though the 4G has been introduced in the system. 2G is less costly than the 3G and 4G regarding the licensing, tariff and maintenance.

Fig. 1.1 shows the relative adoption of cellular technologies over some ten-year periods, and the duration it takes new technologies to be adopted widely on a global basis.

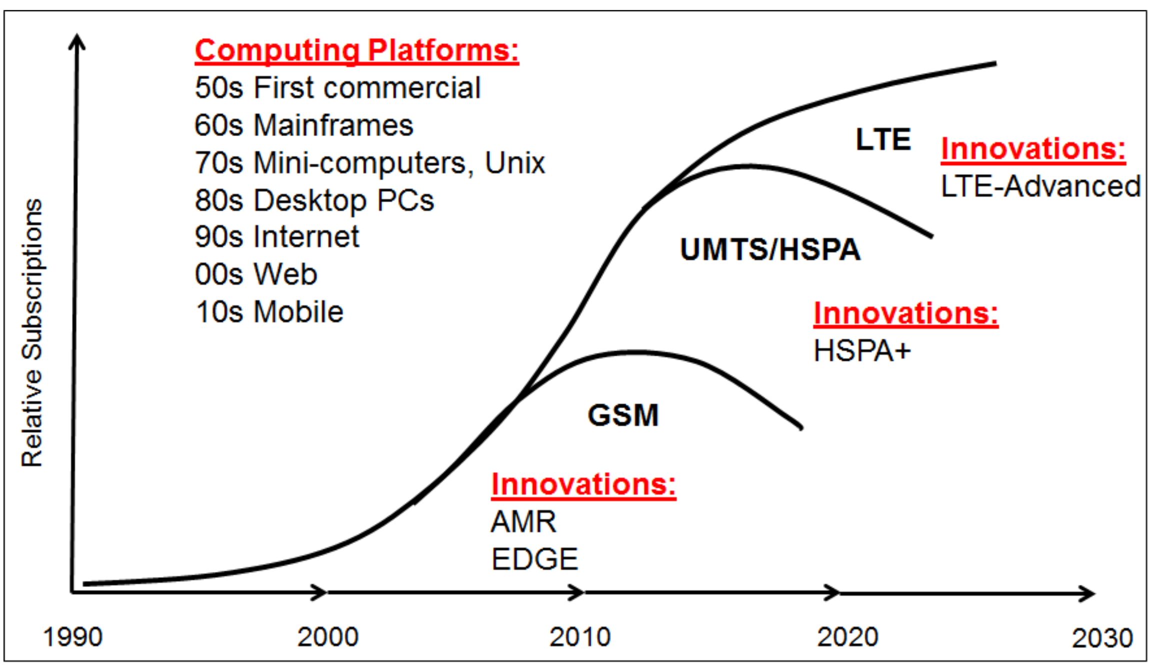

Fig. 1.1: Relative Adoption of Cellular Technologies [1]

The line at the top indicates the total number of subscribers. The curve of the GSM/EDGE shows the number of customers therein. The area between the GSM/EDGE curve and the UMTS/HSPA curve captures the number of UMTS/HSPA subscribers, while the area between the UMTS/HSPA and LTE curves represents the number of LTE customers. An elaborate discussion on the wireless technology evolution can be found in [2], [3], [4], [5], and [6].

A forecast on demand is evident; therefore, prior proper network planning is critical. It is expected that the ongoing change will create more multi-standard requirements and multi-vendor challenges. Efficient operations must overcome such challenges. The only way these challenges can be cost-effective, efficiently and humanely overcome is with more automated and autonomous systems. The 1G networks had little requirement for optimisation as the capacity demand was quite low. However, with the popularity of the 2G network, optimisation is becoming more challenging. Radio resources, such as power and frequency spectrum, are valuable, thus, there is need for efficient utilisation if the increasing capacity demand and users' experience boosting is to be achieved.

The current telecommunication networks, particularly wireless access networks, require a significant degree of self-organisation, as also recognised by the 3rd Generation Partnership Project (3GPP) standardisation body, and the Next Generation Mobile Networks (NGMN) operators lobby.

Key drivers to the introduction of self-organisation into the wireless networks include a substantial reduction in operational and capital expenditure (O/CAPEX) by reducing human involvement in the system operations, optimising the capacity of the network, coverage, and quality of service. The principal idea is to integrate network configuration, planning, and optimisation into a single, automated process that requires minimal manual intervention [2], [5], [7]. Kenya, like most developing countries, has some way to go to get to the global position of mobile telephony.

Fig. 1.2 shows a projection of data; predicting 50% data annual growth in the world cellular traffic for voice and data for the period between 2012 to 2018, indicating a twelve-fold growth.

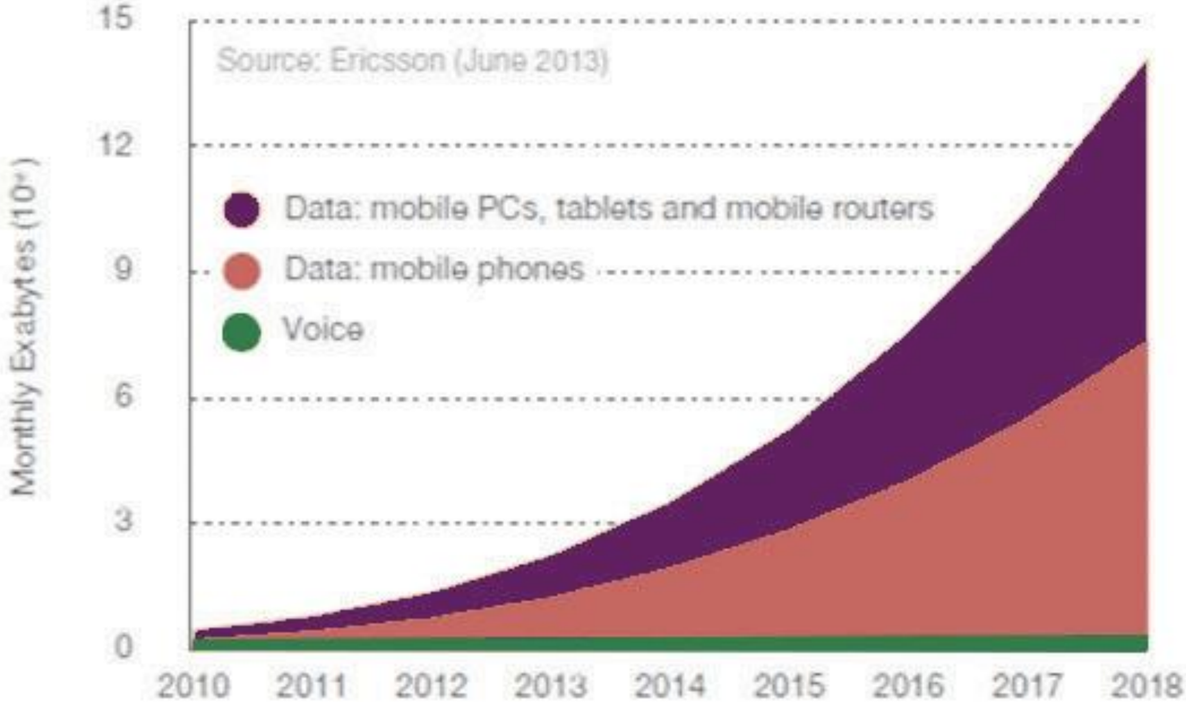

Fig. 1.2: World Cellular Traffic for Voice and Data 2010 to 2018 [8]

As much as data usage is increasing in Kenya, voice communication is still with us, and thus, the GSM network cannot be just wished away. This is the reason this work is based on the GSM voice communication. Limited resource and mobility characterise the GSM network. A base transceiver station serves a given geographical area (cell), and it changes depending on the user mobility. System resources are needed to route a call to the next BTS for every handover .Handover is the effect of the user mobility. Considering that spectrum is a limited resource, it is important that before a new site is deployed; the available systems must be exploited to the fullest by ensuring that they are operating to their maximum capacity. The complex nature of large-scale contemporary/future radio access technologies poses operational challenges, especially due to the number of tunable parameters and their complex relations.

They tend to pose problems of poor handling of site failures that is manual and delayed. It is important to note that changing the parameters accordingly on a particular day do not guarantee that the day(s) to come would not require other changes. Sometimes, due to a temporary event, one may want to address the problem with a temporary solution; say during public events and gatherings in an area resulting in traffic changes. Cellular handover is a core element implemented by mobile telecommunication systems.

Most problems associated with handover failures or sub-optimal system performance could be categorised as either too early or too late triggering of the handover. Currently, handover (HO) optimisation for the mobile networks that are deployed is done manually over an extended period, say weeks or days and, on a need premise as it were. This technique expends time and may not be done as frequently as necessary. A self-optimising algorithm that is online will tune the parameters of the handover procedure, with the point of enhancing the general system execution and client QoS. The primary targets incorporate to lessen the quantity of HO failures (handovers that are started yet not done to consummation), 'ping-pong' HOs (rehashed forward and backward HOs between two base stations) and call drops.

This work shows how auto-tuning of handover parameters can be done using the system of fuzzy logic. In particular, the decision process of handover has been optimised considering three inputs to the fuzzy system. A comparison has been drawn to prove the advantage of using more than one input value to make a handover decision.

The application of the results in this thesis is handy as it will result to:

- Faster fault clearance.
- Better customer experience regarding a smooth handover process.
- Better employee experience because they will work within regular working hours.

- Employees can concentrate on better planning and schedule maintenance without ad hoc need, to attend to handover problems.

1.2 PROBLEM STATEMENT

The handover procedure basically goes through two particular stages: the start, where the handover choice is made, and the period of execution where the mobile station is assigned a new channel or the call is forcefully terminated. Handover algorithms typically carry out the first step. Making the right decision is critical.

Therefore, efficient handover algorithms can enhance the capacity and cost-effectively preserve the service quality of the communication network [9]. Most of the algorithms for handover applied today are based only on one input value, such as the bandwidth, RSS (Received Signal Strength), cost or distance, which does not provide precise information for handover decision making [10],[11].

The advantage of using multiple input parameters to generate algorithms is that it is possible to optimise handover not only based on network requirements but also based on end user demand.

The capital expenditure (CAPEX) and operational expenditure (OPEX) reduction during deployment and expansion of mobile network systems are mainly achieved through well-organized network planning and optimisation. Automatic optimisation of radio network parameters is critical for both operability and performance [12].

Many issues arise during the development and deployment of mobile communication systems. Incorrect handover (HO) parameter settings can negatively affect user experience and waste network resources by causing HO ping-pongs, HO failures and Radio Link Failures (RLF). Fundamental issues such as interference in the limited wireless communications systems remain a challenge to be solved. Efficient algorithms and advanced technologies for combating interference are critical to boosting the network capacity. The optimisation of handover parameters by system operators typically involves focused drive-testing, detailed system log collection and post processing, or a combination of these manual and intensive tasks. By handover parameter optimisation using an autonomous system, the service provider can improve the grade of service and at the same time cut on overall cost.

1.3 OBJECTIVES

1.3.1 MAIN OBJECTIVE

1. To optimise the handover decision process of a mobile station in a cellular radio network.

1.3.2 SPECIFIC OBJECTIVES

1. To develop a fuzzy logic model for handover decision making based on Kenyan data.
2. To develop an algorithm that determines the best time to handover based on parameter thresholds.
3. To analyse the impact of using a multi-input fuzzy logic system for handover.

1.4 IMPACT OF THE RESEARCH OUTPUT ON REALITY

The thesis will facilitate the development of the telecommunication infrastructure in Kenya by providing an illustration of its present state and the gaps that can be addressed to facilitate the achievement of desired outcomes. The thesis' focus on the handover process will give local operators insights on how to provide a seamless customer experience. The creation of an efficient telecommunication operation will translate into increased opportunities for employees to work during regular working hours without being called to address emerging issues. Also, the information presented in this thesis will lead to better planning and maintenance, thus reducing handover problems across the network.

1.5 COMPARISON WITH EXISTING INFRASTRUCTURE IN KENYA

The telecommunication infrastructure in Kenya has a handover handling framework that may be improved. Mobile phone users have to move across different areas to find optimal cell reception. Also, there are high instances of cell phone calls being dropped or suffering from poor quality. Although the occurrence can be linked but not limited to insufficient base stations and telecommunication infrastructure in some parts of the country, it also points to the failure to adopt effective handover handling frameworks.

1.6 MOTIVATION

There is no greater offence to communication than a disrupted call especially when someone is willing to talk. It has happened to not only me but also many mobile subscribers in Kenya. This issue of phone interruptions, say the dropped calls, are caused by failed handovers among other factors. The phone client will only experience the drop of a call or a call that is not going through should the process of handover fail. This is more evident when the user is on motion and which involves a change of `the base station. Sometimes the user may be unaware of what is happening technically but the network engineer would talk of: "Insufficient reason for handing over. Or it is not easy to know the exact handover reason or the reason for camping in a specific cell." All in all, one may be required to be in a certain cell but for other reasons, they are handed over. The essence of studying handover optimisation is because it is a core element in the whole concept of cellular telecommunications performed by the networks.

Kenya has a high mobile phone usage. The case considered is a 2G network which has the highest penetration and mostly used for voice communication. The circuit switched voice traffic is the main service that is affected by the tuning process hence considered in this study. A self-organising network refers to any network that tries to organize itself by looking at the available parameters in its control. Self optimisation needs some form of artificial intelligence; which in this case will come in as fuzzy logic reasoning. The fuzzy rationale is used as it portrays the practicality of human reasoning into the generation of algorithms.

Network service providers need to score a QoS level to avoid heavy penalties from regulators line CA. The QoS are determined from such KPI as Handover Success Rate, Call Drop Rate, Call Set up Time, the Signal Strength and performance on the Speech Quality.

The Quality of Service is measured through eight Key Performance Indicators and their thresholds are given in Table 1.1. For any mobile operator to be deemed compliant with the QoS standards, they are required to meet a minimum threshold of at least 80% of the overall QoS KPIs against the targets [13].

Table 1.1: Kenyan Performance Targets

NO.	KEY PERFORMANCE INDICATOR	TARGET
1.	Handover Success Rate	≥90%
2.	Rx Lev	In car = - 100 dBm Indoor = -95 dBm Outdoor= - 102 dBm
3.	Call Drop Rate	≤2%
4.	Call Block Rate	≤5%
5.	Call Set Up Success Rate (CSSR)	≥95%
6.	Call Completion Rate	≥95%
7.	Speech Quality	95% of samples >3.1
8.	Call Set Up Time	<13.5 seconds

Going through various literatures, like those sited in chapter 2, a lot of the work on handover optimisation has focused on 4G which is very reasonable for other developed countries. The 4G network in Kenya is at infancy stage and the 3G is not fully operational in some places. Therefore optimisation would mean also to improve and utilise well that which we have most (2G).

The singleton output has the advantage of simplified mathematical computation. To produce a realistic case, the Gaussian distribution has been used in the algorithm. Assumptions considered in the fuzzy system include overlapping cells, without which the call would definitely drop, that all the other channels have no competition and that two channels have been allocated for consideration.

Fig. 1.3-1.6 are screenshots of a running phone application (Netmonitor v1.0.81) that I used to check the effect of user mobility on signal level changes. It is evident that the motion of the phone user affects the receptivity of the signal. Fig.1.3 and Fig. 1.4 show a difference of one minute with a 2dBm difference in the level of the signal.

Fig. 1.5 and Fig.1.6 have a difference of 49 minutes with 6 dBm difference in the signal level.

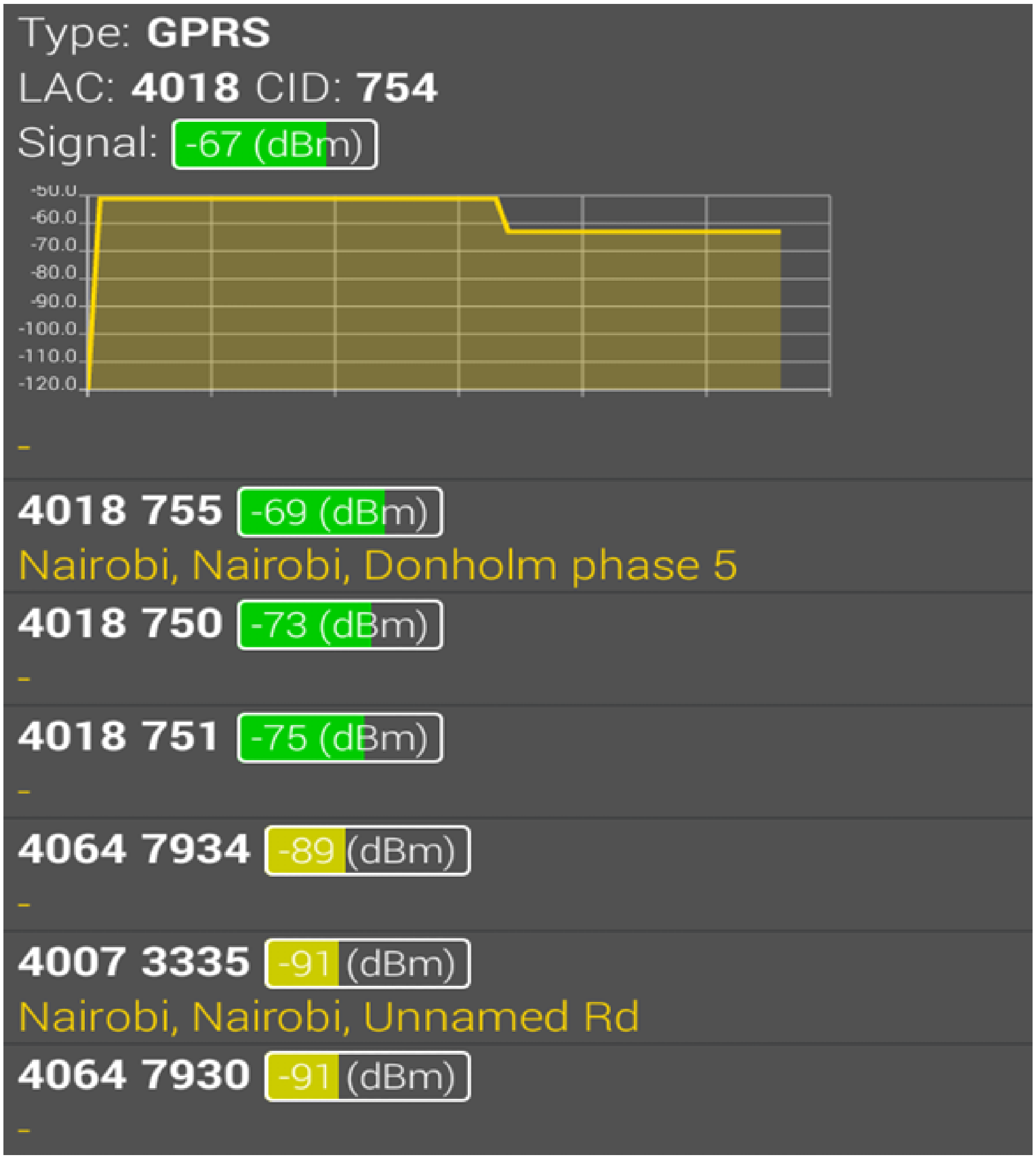

Fig. 1.3: Mobile Application Result at 1204hrs

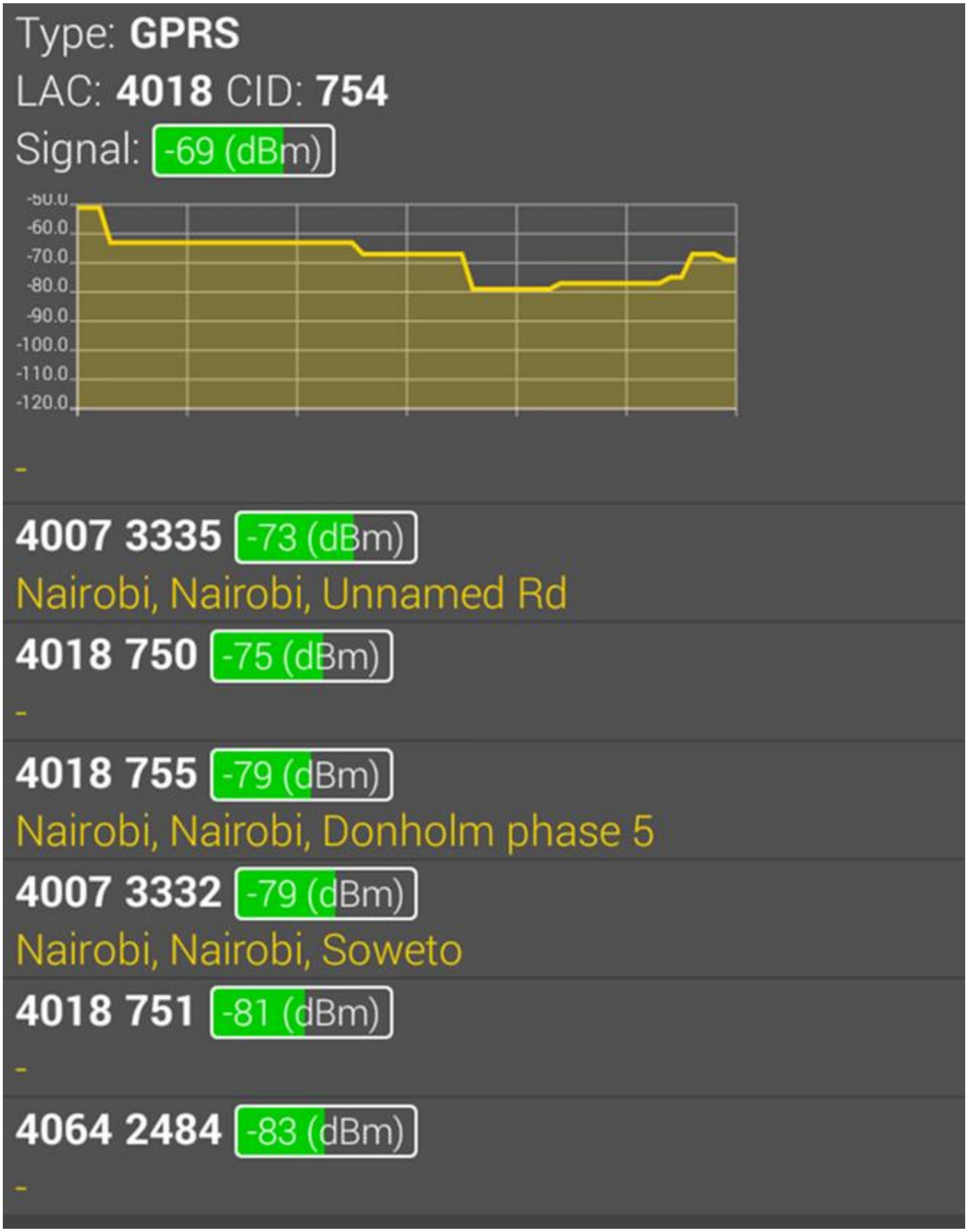

Fig. 1.4: Mobile Application Result at 1205hrs

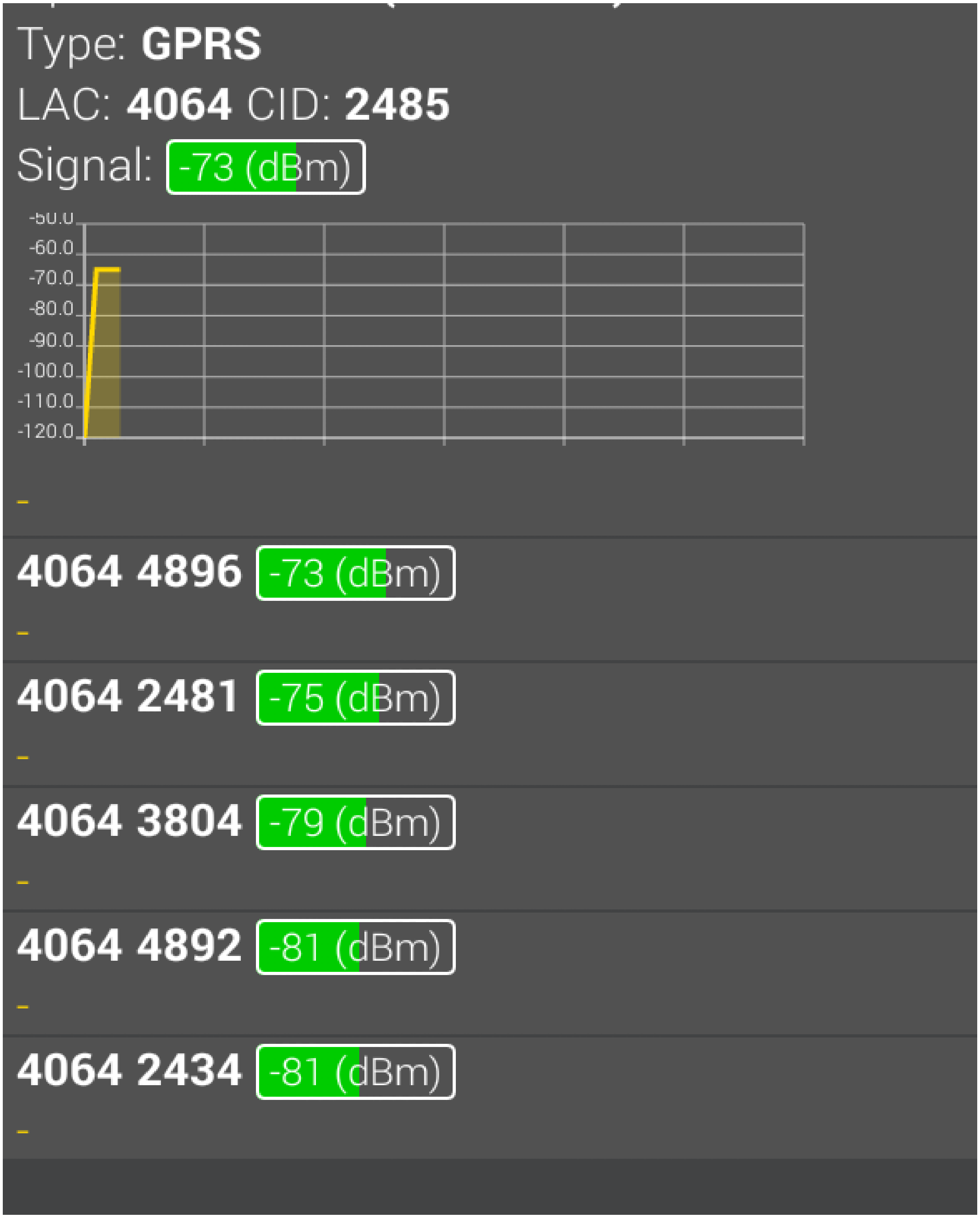

Fig. 1.5: Mobile Application Result at 1610hrs

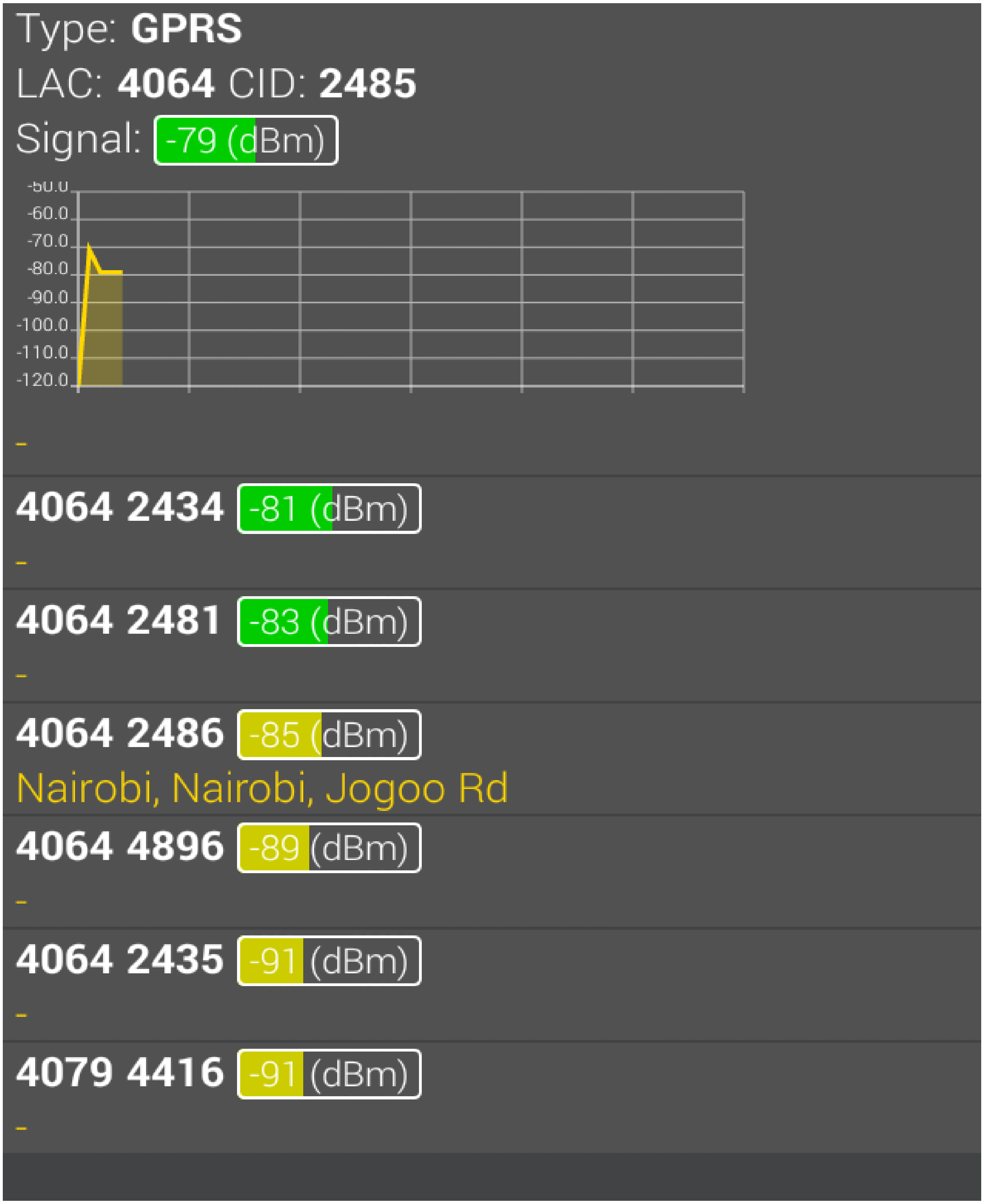

Fig. 1.6: Mobile Application Result at 1659hrs

1.7 SCOPE OF THE THESIS

This research covers the optimisation of the handover decision process based on the GSM network. The planning and execution stages of handover are not in the scope of this work. The output from one, two and three input parameters have been considered for simulation purposes in a fuzzy logic system.

The exact economic implications of handover drop rate due to inaccurate decision making are not considered in this research.

Implementation of the work to validate the actual level of improvement in handover success rate in reality has been suggested as an avenue for further work on this subject.

This thesis serves as bench mark of artificial intelligence in handover management specifically when MS Velocity, RxQual and RxLev are put into consideration. Therefore, no case study or implementation of the proposed method has been done. However the significance of this research work in handover decision making, network planning and maintenance and the good customer experience cannot be overlooked.

CHAPTER 2: LITERATURE REVIEW

2.1 INTRODUCTION TO HANDOVER

Handover is one of the main procedures that ensure mobile phone subscribers move freely in the system while still being connected and receiving services that are of good quality. It is also known as handoff. It is an event that takes place when anytime a mobile station moves from one wireless cell to its neighbour, abandoning its link with the first base station and being connected to the second one. Since the success rate of handover is a key performance indicator of customer satisfaction, it is critical for this process to be fast and seamless. The change of base station/channel because of handover occurs through a change in the slot of time (TDMA), the band of frequency (FDMA), the code word (CDMA), or a combination of these.

When a target cell is believed to provide better service than the cell that is serving currently, the mobile station (MS) sends a report of measurement to the network which decides whether to handover or not. The values needed when performing handover include the measurements of the radio link, the RxLev, and RXQUAL reported.

The mobility of the mobile station (MS) results to handover. Horizontal Handover and Vertical Handover are the two strategies that maintain mobility in the system.

Horizontal handover happens between two base stations (BS) or access points. Vertical handover happens when the access points (APs) or base stations are connected to wireless network of different technologies.

The Received Signal Level (RxLev) is used to determine how high a received signal is. The MS continuously checks the base stations' (that are available) RxLev values. It will then use this information to change from its current active connection. The Received Signal Quality (RxQual) describes the signal quality. It reflects the average bit error rate (BER) over a period of 0.5s. As much as the listeners' speech quality is affected by other factors, the RXQUAL is still an important measurement [14].There are eight RXQUAL categories: 0 to 7 (best to worst).The BER provides information on the DL quality which is measured, its average obtained and mapping done to the RXQUAL values as defined in the GSM specifications.

The ratio of Energy to Bit over Noise or Eb/N0 is between the wanted signal originating from the base station that one is talking to and the distorting signals emanating from the other base stations including white noise. The MS will change to another base station if it deems that the noise is too much. The Received Signal Level (RxLev) is used to show the strength of the received signal. Conventionally in a handover mechanism, both the MS and the BS measure the strength of the radio signal. The MS continuously communicates its measurement reports to the BS.

When the BS detects a decrease in the radio signal strength to be under a certain minimum level, it creates a handover request and then informs the BSC, for verification and determination of the need to move the call into a cell that is nearby. The BSC checks for availability of a free channel in the new cell but does not differentiate whether the channel request is for a call that is new or one that is being handed over.

If there is an available free channel in the new adjacent cell, then a handover occurs with the MS being switched to that cell. Should there be no channel that is free nearby, then the probability of dropping the handover calls increases.

This handover procedure has a disadvantage that the handover channel request is similar to the one used for new calls' request. The mechanism of conventional handover is problematic from the perspective of the user's quality of service as it would be better to block a new call rather than to drop a conversation that is ongoing.

Handover algorithms that are efficient do preserve and improve the capacity and QoS of the network. The three stages under which handover can be divided are [15]:

- Decision making,
- The planning, and
- Execution stages.

In making the decision, a set of parameters that are predefined are measured by the MS to determine a handover initiation or not.

The planning stage entails checking and assigning the necessary resource, like available channel in the candidate BS that the MS would be handed over to.

A transfer of the connection from the present serving base station to the target and performing the fundamental conventions make up the stage of execution.

Two types of handovers can be experienced by subscribers who move in urban microcells, the LOS (line of sight) handover between two LOS base stations and the non-line of sight (NLOS) handover that is from an LOS base station to a base station that is NLOS [16]. Reliable handovers are difficult due to a phenomenon in propagation called the "corner effect" [2], [17] where the MS encounters a sudden significant signal strength reduction of the serving BS as it goes round a corner and loses the line of sight. Consequently, there will be a call drop if the MS is moving quickly but not being handed over fast enough.

To mitigate this problem, the mobile stations that are fast moving can be linked to the "umbrella cells" (overlaid macro cells) so as to avoid the NLOS handovers. False handover initiation probability and the probability of failure increase with increasing the cell radius.

Handover with parameters that are fixed cannot do well in a dynamic environment of the system. The impact of the MS speed on the handover performance has not been considered in the existing link-layer assisted algorithms.

Take S_{min} to be the minimum RSS (Received Signal Strength) for satisfactory quality of voice for correspondence between a Mobile Station (MS) and base station BS1. Also consider S_{th} to be the value of threshold for the RSS to initiate handover.

The MS initiates handover to base station 2(BS2) when the RSS of BS1 drops below the Sth.

$$\Delta = S_{th} - S_{min}$$

Δ ought not to be substantial as this leads to pointless handover nor be too little as this prompts the calls to be dropped as a result of weak signal before completion of a handover.

2.1.1 HANDOVER FEATURES

Some of the features to admire in an algorithm for handover include:

- Speed in the handover process for there not to be a degrading of the service. Degradation of the service may be brought about by the signal strength reducing continuously. Interruption of service may be caused by the “break before make” concept of hard handover. A handover that occurs fast also reduces co-channel interference as the MS does not go very far inside the new cell that is adjacent.

- Reliability of the call is crucial such that there is good quality even after the handover. To determine the quality of service that the candidate BS has potentially, the SIR and RSS come in handy.
- Handover ought to be fruitful with the end goal that there ought to be a free channel at the hopeful BS.
- The impact on the nature of administration ought to be negligible. The QoS might be frail just before handover because of a persistent diminishment in the signal quality, the interference et cetera.
- Minimal number of handovers as an excessive number of handovers lessens the nature of correspondence:

(i) The more the endeavors, the more the odds that a channel will not be accessed by a call, therefore higher call drop probability.

(ii) A lot of handover tries causes greater delay in the MSC preparing the solicitations. This will make the signal quality reduction over a more extended time to inadmissible quality level. The call may likewise be dropped if adequate SIR is not obtained.

2.1.2 HANDOVER COMPLEXITIES

(a)Topographical features and structure of the cells: There could be little cells in urban regions (called microcells), huge cells in rustic or rural ranges (full scale cells), or an overlay framework, containing the small scale and large scale cells.

The distinction in huge scale and little scale blurring is noteworthy in urban microcells than in large scale cells in a provincial setup. Street corner effect which exists in urban microcells is described by a sudden drop in the strength of the signal in a short separation like when a mobile station moves around a corner, for example, at a road crossing point.

(b)Movement dissemination: A component of both time and space and ought to not antagonistically influence handover process.

Approaches to deal with traffic non-uniformities include dynamic channel allocation, the use of different cell sizes, and traffic balancing in adjacent cells.

(c)System constraints: The handover process should consider system requirements, for example, transmit power and delay in propagation.

(d)Versatility: The nature of a correspondence connection is influenced by the level of development. A rapid MS that is moving far from a serving BS encounters a speedier corruption of the signal than a low-speed MS.

2.1.3 WHY HANDOVER HAPPENS

The following are the reasons why handover happens in a cellular network:

• Prevent call end when the telephone moves from a range secured by one cell to one secured by another [18].

- In instances where the mobile phone user changes their behaviour.
- In cases where the capacity for connecting to new calls is exhausted.
- In situations where there is obstruction in the channels because of many mobile phones utilising a similar station crosswise over various cells.

Importance of Handling Handover

Managing handover is important because of the direct impact of the quality of calls made by users on customer satisfaction. Efficient handling of the handover results in increased customer satisfaction.

[19] It results in fewer dropped calls and improved cell reception. Handovers are shared and frequent occurrences in cellular communications that influence the QoS provided to the customers.

2.1.4 HORIZONTAL HANDOVER

In cellular network operations, there is a sub-categorisation into intra-cell ad inter-cell handovers. In between cell handovers, the client moves inside a system or cell with the radio channels changing to limit inter channel interference under a similar BS. [18]The horizontal handover occurs between access points or BSs of a similar innovation. The usefulness of a horizontal handover limits it to event between the homogenous cells of an access system. The system trades the scope duty from a hub of connection to another consequently. Horizontal handovers are obligatory on the grounds that the MS can't finish its correspondence without performing. Likewise, the intercell handover can just happen when the Mobile station moves into the neighboring cell of the base station. [20] The procedure of horizontal handover is characterised by four key phases:

1. Measurement: The received signal strength (RSS), distance measure, Signal to Interference Ratio (SIR) and the Bit Error Rate (BER) are conducted at the Base Station and the Mobile Station to give a reasonable delineation of the strength of the signal.

2. Initiation: During this stage, an assurance of the need for a handover is made. The handover procedure is required by a decay of the signal strength inside a cell, between two cells or when the MS moves along the common limit of the two cells.

3. Decision: The objective of this stage is to choose another channel by considering the real asset accessibility and the system load on the framework. [21] The decision-making procedure of a handover can be brought together or decentralized. The choice process point demonstrates that the handover decisions can be categorised into:

- Network assisted handover
- Mobile controlled handover
- Prioritization handover

4. Execution: The actual handover process is done at this stage.

2.1.5 VERTICAL HANDOVER

The procedure alludes to the exchanging between points of connection or base stations which have a place with various system technologies. The process is integral in facilitating communication processes in heterogeneous networks [22]. The implementation of a vertical handover is a complex endeavour because of the distinct features of the component networks. For example, the systems might be recognized by their transmission capacity, information rates, scope range and recurrence of operation [23]. The procedure of vertical handover can be ordered into three key strides:

- Network discovery
- Handover choice
- Handover execution

The vertical handovers can be further categorised into two:

- Downward vertical handover: The mobile user channel moves to the system with a higher bandwidth and limited coverage.
- Upward vertical handover: The phone client channel moves to a network with a lower bandwidth and more coverage.

Hard handover is alluded to as a 'break before break,' association. The connection to a prior station is ended earlier or as the mobile client is exchanged to another cell base station. The cell phone cannot be associated with more than one base station at any given moment. Users may experience an interruption during the handing over process because of the shifting of frequencies [24]. Network engineers perceive a hard handover as an event during the call underscoring the need to minimise disruptions that may occur during the call.

Soft handover: The fact that they are directed by mobile telephones has caused them also to be referred to as Mobile Directed Handover. It identifies with the capacity to choose between signals that have been gotten momentarily from various base stations [25]. The channel of the source cell is held, and after that utilised as a part of parallel with the channel of the objective cell. An association with the objective must be set up before the source interface is broken. The 'make-before-break' encourages a consistent correspondence between people. The interim amid which the two connections are in parallel might be brief or significant, with the network engineers seeing it as a condition of a call. They are classified into two:

- Multi ways: the soft handover involves the use of more than two cells.

- Softer handovers: the signal of all the available channels that is deemed to be superior to others is used at a particular moment. Then again, every one of the signs of the accessible channels can be joined to create a reasonable signal.

Albeit soft handover is more effective in giving a consistent communication service, it limits the capacity of a network by reducing the number of free channels that are available in a network. Soft handovers are permissible within members of a soft zone, but not between stations in different soft zones.

2.2 HANDOVER IN CELLULAR NETWORKS

Cellular networks are able to perform due to the handover process. The following are some of the ways in which handover is exhibited in the various networks.

2.2.1 HANDOVER IN CDMA

CDMA frameworks support handovers between two cells in the idle, the access or the traffic channel state:

1. Idle – movement between cells in this state must be a hard handover
2. Access-Handovers in this state can either be hard or soft handovers.
3. Traffic- The in-traffic transition can either be a soft handover or a hard one.

Handover in the state of access is not supported in IS-95(Interim Standard 95). The component has made the access process to be simple to actualize amid the improvement of early CDMA frameworks. It was found that execution was yielded in this condition for straightforwardness. The huge inadequacies that they made drove the improvement of the Telecommunications Industry Association standard (TIA/EIA-95) that incorporates the accompanying systems to upgrade execution:

• Entry handover

• test/probe handover

• Handover for access

• Assignment of channel into handover

2.2.2 HANDOVER IN GSM

GSM technologies using TDMA techniques have transmitters that only transmit for one opening in eight, and a beneficiary that gets a solitary space. The RF section in this technology may be idle for 6 out of 8 slots. When linking with the BTS, it examines the other radio channels to determine the most suitable and strong signals. The mobile correspondence with the BTS empowers it to produce a rundown of radio channels with reference point frequencies neighboring BTSs by means of the Broadcast Channel (BCCH). The MS checks and identifies the quality of radio signals which form the basis for the handover decision. The framework has resulted in this GSM hand over approach being categorised as MAHO (Mobile Assisted Hand over). The network has all the information it needs to make optimal decisions on handing the mobile from one BTS to another [26]. The information available to the system include; knowing the nature of connection between the cell phone and the BTS, the strength of the local BTS, and the availability of channels of cells in the environment. The network informs the BTS and mobile of impending changes when it assigns the later another channel and slot of time. The MS uses idle period to retune itself. The GSM hand over is defined by critical considerations of the role of timing and synchronization [26].

2.2.3 HANDOVER IN HETEROGENEOUS NETWORKS

In heterogeneous systems, the handover happens between traditional cell systems and WLANs in an indoor situation. The constrained condition frequently brings about the advancement of issues that influence the execution of handover forms [27]. The IEEE 802.21 standard was actualized to encourage data exchange between a MS and diverse systems to upgrade the mobility choices while giving proper functionalities to help the execution of different handovers [27]. The structure gathers data from the MS and the segment communication systems. The Media Independent Handover Function shapes the center that gives disconnected administrations to other higher layers in the system by making a homogeneous interface.

2.2.4 HANDOVER IN RATE ADAPTIVE WLAN

The IEEE 802.11 standards form the basis upon which the modern WLAN networking technique is created. The layer two handover is the first procedure that occurs between an AP and MT. The packet loss and round trip delay are critical considerations for the selection of handover at the upper layer. The expanded QoS prerequisites have made noteworthy difficulties for 802.11. As a result, the current handover delays average in the hundreds of milliseconds, creating transmission failures, loss of connectivity and undermining the quality of the communication infrastructure. The delays occasioned by a handover should not exceed 50ms, the interval upon which a human ear can detect disturbances in connectivity. In voice and video connection, quick handovers are critical to prevent connection latency. The IAPP (Inter-Access Point Protocol) can be utilised as a part of an Extended Service Set (ESS) and for secure exchange of the security settings between the current AP and the rising AP amid the handover time frame.

In assessing the current 802.11 wireless equipment, it is obvious that the most vital issue is that the framework can't distinguish when the QoS assets are accessible at another entrance point, amid and after the progress [28]. Consequently, it might be hard to recognize if the change will prompt an acceptable application execution. The 802.11 refines the progress procedure between mobile customer points of access. The convention empowers a remote customer to build up security and a QoS state at the new access point before the change, bringing about lesser network misfortune and lesser application disturbance [28].

The expanded utilisation of remote systems in Kenya may make a more density of points of access in a bid to give greater limit, bringing about more critical handovers. In a remote LAN, every gadget interfaces with the AP that has the most powerful signal [28]. However, the geological area and number of gadgets in its region may make an extreme request on a solitary AP while others are underutilised, undermining the execution of the system. The 802.11k convention guarantees that the AP with the most powerful signal is stacked to full limit before moving remote gadgets to its underutilised ones.

2.3 HANDOVER DECISION

Handover decision procedures are also referred to as algorithms. There are several algorithms in existence. For instance, the Received signal strength, Received signal quality and so on, can be used to make the decision of handing over an ongoing connection. Three phases are involved regardless of the nature of the algorithm [29], as explained below.

i. Measurement phase

Both or one of the BTS and MS check the general connection or communication quality. This estimation information is handled and re-assessed by either of them after which proper move is made depending on the assessment result which is either to perform handover or not. Some of the parameters that are considered when a handover decision is to be made include:

a) Measurements taken by the mobile station such as the downlink reception level of the serving cell and the transmission quality.

b) Measurements made by the base station such as the timing advance.

c) Static parameters, for example, the largest power transmitted by the MS and that of the serving BTS.

d) Traffic, for example, the cell capacity.

Along the way towards settling on a handover choice, the BSS will process, store and analyze certain parameters from the estimations made and the predefined edges. For each SACCH (slow associated control channel) multi-frame, the BSS contrasts each of the prepared estimations and the important limits.

ii. Start and resource designation stage

The choice of whether a handover is required is made at this stage. This choice is paying little heed to the real accessibility of another channel on an objective (or on the serving) base station. At the point when the requirement for the handover has been resolved, another channel is chosen considering the real radio asset accessibility and system load.

iii. Execution stage

The handover is executed once the new channel has been picked. These stages are inclined to blunders.

2.3.1 HANDOVER PROTOCOLS

Some protocols are associated with the handover delay and the availability of measurement information.

There are four fundamental handover conventions:

i. SHO-Soft handover

ii. MCHO-Mobile controlled handover

iii. MAHO- Mobile assisted handover

iv. NCHO- Network controlled handover

Soft handover

SHO is a "make before break" association, in that the association with the present base station (BTS) is not broken till an association with the objective BTS is realised.

Mobile controlled handover

In MCHO, the MS holds full control of the handover procedure.

The above is appropriate for microcellular framework kind of handover as it has a short response time [30]. In spite of the fact that the MS does not have data pertaining to the signal quality of different clients in the system, the handover must not make interruptions to other clients. The MS measures the signal qualities from encompassing base stations and assesses the obstruction levels over every one of the channels. Start of handover can be conceivable if the signal strength of the significant BTS is lower than that of the other by a specific threshold. The MS asks for the objective BTS for a channel with the slightest impedance. The MCHO is the most astounding level of handover decentralization. A portion of the upsides of decentralization of handover are that the handover choices can be made quick, with the MSC not making handover choices for each cell phone [31].

Network controlled handover

In this convention, the system settles on a handover choice in light of estimations of the RSSs of the MS at some base transceiver stations. The handover summon is sent on the voice channel by blanking the sound and sending information.

The signal quality data for all clients is domiciled at a solitary point (the MSC) which encourages resource allotment. Due to the related deferral, this sort of handover is not reasonable for a quickly changing condition and a high number of subscribers.

Mobile assisted handover

A MAHO convention, embraced by the GSM, circulates the handover choice process to such an extent that the MS makes estimations and the MSC takes the choices. Here the MS measures the RSS and sends to the BS. In view of the signal strength that is received, the BS or MSC grasps handover choice. The accompanying types of cell handover give an understanding of the issues that can happen.

There are three types of handover depending on the point of attachment for the GSM systems: Intra-BTS, Inter-BTS, and Inter- BSC. Intra-BTS handover occurs if it is required to change the frequency being used by a MS because of interference, or other reasons. The MS remains attached to the same BTS, but change the channel or slot. Inter-BTS or Intra BSC handover occurs when the mobile moves out of the coverage area of one BTS into the coverage area of another but controlled by the same BSC. In this case, the BSC is able to perform the handover and it assigns a new channel and slot to the MS, before releasing the old BTS from communicating with the MS. Inter-BSC handover occurs when the MS moves out of the range of cells controlled by one BSC, a more complex form of handover has to be performed, handing over the call not only from one BTS to another but also from one BSC to another. This handover is controlled by the MSC.

Handovers are grouped into two classifications depending on the connection procedure taken: hard and soft handovers. Hard handover (HHO) include a "break before make," functionality, which implies that the link to the initial BS is broken before an association with the hopeful BS is done. HHO happens between incoherent radio frameworks, occasions where distinctive frequency assignments, diverse air interface attributes or innovations [32].

The hard handover might be partitioned into two unique sorts—intra-cellular and inter-cellular. A handover done inside the present serving cell (for instance, by varying the frequency) is intracellular. The one produced from one cell to another is alluded to as an intercellular handover. Soft handover (SHO) includes a "make before break," usefulness which implies that the link to the old BS is not broken till an association with another BS is made. Truth be told, more than one BS is normally associated.

2.3.2 MODELING OF FUZZY BASED HANDOVER DECISION

The neural network and fuzzy logic algorithms are the most advanced algorithms that are used in mobile networks. Also, traditional voice-oriented phone networks involve the use of pattern recognition. The reduction in cell sizes may increase the number of handovers as the MT has to cross more cells during a call. In such architecture, handovers should occur quickly to prevent the degeneration of quality of service below the accepted quality of service [33]. To avoid disruptions and ensure appropriate handover levels are reached, a minimum threshold level has been set to ensure proper voice quality at the BS receiver. However, the moving vehicles create the need for the use of fuzzy logic system and pattern recognition to identify the variable threshold within which optimised handovers can be achieved. The variable limit likewise lightens the Ping-Pong impact. The fuzzy logic system is preferable because it gives decisions from imprecise data and enables network engineers to resolve ambiguous problem sets related to the handover decision [33].

The subsequent handover initiation in view of the relative level of the signal is:

• signal level

• signal level with the threshold

• signal level hysteresis

• signal level with threshold

FLC system based and algorithms related to it such as the ANFIS (Adaptive Neural Fuzzy Inference System) have been utilised as a part of the plan of shrewd handover choice systems. The vertical handover procedure can be optimised through a combination of RSS and sort of service. The fuzzy rationale framework can likewise be utilised to show the cell choice [33]. However, the RSS edge for vertical handover choice is settled in light of the fact that the Ping-Pong impact can't be mitigated.

Fuzzy rationale is utilised to work making use of vague information and can be viable in displaying nonlinear capacities. The development of a handover decision framework may involve the following parameters:

- The difference in signal quality of the present from the neighbor BS
- The separation amongst MS and BS.

A FLC based QoS management scheme for Actuator/Wireless Sensor Networks (WSAN) can be developed to support QoS in unique and unusual situations [33]. The Fuzzy rationale controller can be utilised to change the inspecting time frame progressively to mirror the due date miss proportion connected with information transmission.

2.4 PERFORMANCE EVALUATION OF THE HANDOVER ALGORITHMS

The performance algorithms that are used in handover evaluation should be influenced by the primary objectives of the procedure beginning with the minimisation of the number of connection exchanges. Second, limit the handover preparing delay by encouraging the reception of the right target BS/AP decision and guarantee there is rapid execution. The approach includes a minimisation of the event of association intrusions and diminishing the exchanging load that is influenced by a person. The assessment of handover ought to be educated by its effect on the versatile system association.

The accompanying measurements can be utilised as a part of the execution assessment process.

• The aggregate handovers amid the change of the MS between BSs/access points (Aps) that overlap. The assessment will emphasise the affectability of the handover calculation. Observing very high rate would feature the oversensitivity of the calculation to metric variances, high levels of radio system signaling and the rising risk of detachment. In occurrences where the handovers are excessively few, it is conceivable, making it impossible to bring about the interruption in the provision of service and cause connection loss.

• Ping-Pong handovers: handovers that happen amid the variation of the target and beginning AP/BS. They pointlessly use overlapping BS/AP coverage zones.

• The point where the handover is activated ought to be near the coveted limits of the scope given by the BS/AP. The limit can be resolved amid the system planning and deployment stages. In occasions where the handover happens far from the coveted limits, a BS/AP might be strained while another BS/AP might be not able use its assets adequately.

• Link transfer utilisation: The period between the choice to trigger the handover and the making of a solid connection with the target BS. The execution span ought to be as short as possible to limit the exchange time frame amid which the connection might be lost.

2.4.1 QUEUING MODEL

The handover threshold is characterised as the time at which the signal strength of another BS is more prominent than the current BS's. The threshold of the receiver is the time at which the present BS's signal is too small to be in any way usable. An MS must handover amid the interim between these thresholds; handover requests might be lined amid this interim. The essential analytic device that is utilised to assess frameworks is queuing theory, which is the use of stochastic procedures in the investigation of lines in waiting. The nonexclusive model for queuing frameworks is shown in the Fig.2.1 below.

Fig. 2.1: Generic model for queuing frameworks [34]

It comprises of three fundamental parts: (1) an arrival procedure, (2) a storeroom, and (3) a server.

The Poisson arrival process is the most broadly utilised model of the landing procedure, and is the most tractable numerically. The service time is an arbitrary variable, which is autonomous of the arrival procedure. We build up a general model for the service time where storerooms hold clients until the point that servers are accessible. There are two critical cases: The storerooms can be large to the point that they might be viewed as infinite. On the other end, we have facilities that hold just clients who are being served. Queuing models are pertinent. Queuing of handover happens when there is a limited time from when the signal dips under the threshold and when the call drops because of inadequate signal level.

2.4.2 HANDOVER PERFORMANCE INDICATORS (HPIS)

Handover failure ratio

This is the proportion of the quantity of handovers that have failed to the quantity of handover endeavors.

HOF ratio = #HOF / #HO attempts …………………………………….. (2.1)

Where HOF is the handover failure

#HO attempts is the number of attempts

NHOfail + NHOsucc= #HO attempts……………………………………. (2.2)

NHOsucc is the entirety of the successful quantity

NHOfail is that of failed handovers

Ping-Pong handover ratio

Handover is thought to be ping-pong if a call is given over to another cell and is then given back to the source cell in under the critical time (Tcrit). A conceivable reason for this could be a profoundly mobile client in a boundary of two base stations or overwhelming shadowing because of the huge object(s) that is in the observable pathway with the serving base station.

The ping-pong handover proportion (HPP) is given by:

HPP ratio = # NHOpp / Total # of HOs……………………………………………. (2.3)

NHOpp is the number of ping-pong handovers

Where: NHOpp + NHOnpp + NHOfail=Total # of HOs………………………….... (2.4)

NHOnpp is the quantity of handovers where no ping-pong happens

NHOfail is the quantity of fizzled handovers

Call dropping ratio

The call dropping ratio (CDR) is the likelihood that a current call is dropped before it was done. It is also known as Radio Link Failure (RLF).

RLF ratio = # RLFs / # accepted calls ……………………………………. ………… (2.5)

Handover failure probability (HFP)

A handover failure happens if the handover is started yet the objective system does not have adequate assets to finish it effectively. If h is the quantity of handovers all through the span of call at that point, Handover failure probability is given as 1-(1-Ph,j)h where, Ph,j indicates the likelihood that a handover endeavor for a call of sort j is blocked [35].

SDCCH Access Success Rate

This is the level of all SDCCH accesses got in the BSC. Poor SDCCH Access Performance could be because of blockage; False Accesses because of High Noise Floor, Too High Timing Advance or Access Burst from another Co-channel.

SDCCH Drop Rate

This measurement is a comparison of the aggregate number of connection losses as a percentage of the aggregate number of attempted calls in the SDCCH channels. It is expected to give a sign of how great the cell/framework is at preserving calls.

SDCCH RF Loss Rate could be caused by:

- Down or Up-link with low signal strength.
- Down or Up-link with poor quality.
- Congestion on TCH.
- Timing Advance that is very high.

Call Setup Success Rate (CSSR)

This is a measure of the fruitful TCH Assignments out of an aggregate number of TCH assignment endeavors. Some of the reasons behind low call setup success rate could be faulty equipment; congestion of the TCH; interference or poor coverage.

Call Setup Congestion Rate (CSCR)

The Call Setup TCH Congestion Rate measurement gives the level of endeavors to designate a TCH call setup that was hindered in a given cell.

Conceivable explanations behind blocking a call setup could be:

•Increased demand for traffic.

•Poor Dimensioning.

•Fault of the hardware installation.

•High position of the antenna.

•Mean Holding Time that is too high.

•Low activity of handover.

•Surrounding cells being congested.

Call Drop Rate

This performance indicator shows the rate of calls that have been dropped. It is the level of dropped TCH after TCH assignment complete. The reasons behind TCH Drop Call Rate could be:

•Down or Up-link signal strength that is low.

•Unavailable server that is the best.

•Neighboring cells that are congested.

•Flaw in the battery.

•Down or Up-link with poor quality.

•Timing Advance that is too high.

•Issues with the antenna.

•Low output power from the BTS.

•Neighboring cell definitions that are missing.

•Outgoing Handovers that are unsuccessful.

Handover Success Rate (HSR)

The handover success rate is the level of effective handovers of all handover attempts. A handover attempt is the point at which the command of handover is sent to the MS.

Conceivable purposes behind poor handover success rate could be:

• Congestion of traffic.

• Hardware or link connection failure.

• Antenna installation that is bad.

•The MS measuring the signal strength of another co-channel or adjacent cell than the one assumed.

• Handover relations that is inaccurate.

• Wrong setting of the locating parameter.

•Poor coverage of the radio.

• High interference from the co-channel or adjacent cell.

Handover probability – The likelihood that while speaking with a specific cell, a progressing call requires a handover before the call ends. This metric converts into the normal number of handovers per cell.

Call dropping probability – The likelihood that a call ends because of handover failure. This metric can be found from the handover blocking probability and the handover probability.

The rate of handover is the quantity of handover per unit time. Span of intrusion is the time span amid handover for which the mobile station is not in correspondence with a base station.

2.5 REVIEW OF SIMILAR WORKS

Most of the work done on this topic has mainly focused on the LTE for instance [36], [37], and [38]. A Vertical Handover Decision calculation is created in view of artificial neural networks (ANN) [39]. The cell phone gathers highlights of accessible wireless systems and sends them to a middle-ware called vertical handover manager through the current connections. A fuzzy rationale based calculation [40] is produced which is utilised to deal with handovers among WLAN and UMTS networks. Work done in the paper [41] incorporates two parameters: - a Received Signal Strength Indicator (RSSI) and the relative bearing of a Mobile Station towards an entrance point. These are the contributions to the fuzzy logic framework to encourage the handover decision process and pick the best access point around this MS. Traffic analysis and bandwidth have been left for future work.

The capacity and the Quality of service (QoS) of cell frameworks can be adequately improved by the utilisation of proficient handover algorithms [42]. In any case, this proposition did not give particular illustrations or models to be utilised with respect to inter-cell handover and channel assignment plans.

In [11], an investigation of the GSM handover in view of genuine information and utilising fuzzy logic strategy has been done.

It was discovered that the received signal strength and quality are the principle parameters during the time spent on a handover choice. Be that as it may, considering signal strength and quality that's received are just not adequate to give an exact outcome for ideal arrangement of handover management arrangement. A more powerful plan is required particularly for inter-cell handover that associate with channel assignment plans.

Work done in [43] demonstrates that, to have the capacity to quantify the system performance, the examples of a regular day ought to be considered. The execution pointers introduced are, Call Setup Success Rate, Traffic and Handover Success Rate (HSR), Standalone committed channel Blocking Rate and Channel Blocking Rate. The work was centered on general execution assessment and in that capacity; it didn't demonstrate the effect of the part among the parameters, particularly the elements of inter-cell handover success rate on system performance.

Handover is an essential segment of asset assignment of cell systems [44], executed on the voice channel, and the rate shifts with the measure of the cell.

In [45], a scientific investigation of handover and call dropping probabilities for cellular system demonstrated that regardless of the possibility that the handover dropping probabilities is controlled to be beneath a most extreme incentive in each phone in the system, the call dropping probability experienced by clients is not controlled autonomously.

Utilising simulation and accepting a settled estimation of 2% for handover dropping probability in every one of the cells, when assessed, it created a mean call dropping likelihood of 17.37%, which is great yet the work expected that handovers happened just at borders of the cells and did not consider constrains of the signal and the different impacts.

From the audit of comparative works, it has become clearer that, ineffectively performed handover operation and administration can adversely influence service quality and diminished asset usage. An ideal arrangement must coordinate a compelling and effective channel allotment plan. An endeavor was made at enhancing work by [46] by considering the effect of the relational conduct of handover to other QoS parameters by method for examination.

The level of mobility impacts the nature of correspondence connection with the end goal that a rapid mobile station moving far from a serving base station(BS), encounters degradation of the signal speedier than a low-speed MS[47].Therefore, it is important to consider the velocity of the mobile user when studying handover related issues. Handover algorithms based on artificial intelligence such as the neural networks have been proposed by various authors [48], [49]. It is better to work with an intelligent system than the traditional methods. A fuzzy logic based vertical handover technique has been proposed where weights have been assigned to the performance metrics and defined the scale and range for different networks taken [50]. [51] Proposed a hard handover calculation in view of the fuzzy logic framework. For this situation, the separation between a MS and a BS and the signal strength that a MS gets from a BS are utilised as data sources, while the yield is the decision value of the handover decision.

An intelligent Vertical handover (VHO) utilizes Fuzzy Logic to evaluate the need of giving over and finding the new point of connection. Distinctive Fuzzy Logic Controllers (FLC) can be utilised relying upon the movement sort to enhance the general execution of proposed framework in [52]. A

Fuzzy Multi-Attribute Decision Making (MADM) selection of the network allots weights to every parameter in heterogeneous situations. Another approach proposes a vertical handover choice calculation utilising fuzzy rationale properties with mindful setting procedure that empowers the MS to settle on a proactive choice in light of the quality of service and user preferences parameters [16]. The yield of the simulation demonstrates that the proposed approach satisfies nature of administration necessities of voice, video and text with respect to the loss of packet. The Sugeno FIS has been used to find the decision for vertical handover where the available bandwidth, network load, and signal strength are the input parameters to inference system [53]. The level of the candidacy of the related BS decides the handover initialization process [54]. The parameters used for the FIS input are the data rate, the speed of the MS and received signal strength indicator. Fuzzy rationale based basic handover controller is intended to accomplish a decision for the mobile systems: consider in Fig. 2.2.

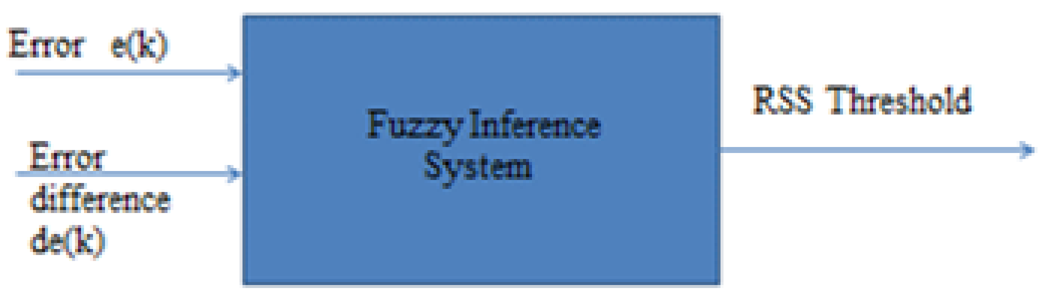

Fig. 2.2: Fuzzy Inference System to vary the RSS Threshold [55]

In the proposed controller, MS measures the Received Signal Strength (RSS) from the present BS. Here, the fuzzy logic framework is utilised to modify the threshold, utilising RSS, with the goal that limit level is kept at the coveted level to anticipate call dropping. The MS reports the measurements of the threshold to the BS.

From the proposed demonstration, an exchange work is utilised to determine the target BS. Lower limit level demonstrates frail signal quality at MS, so the odds of call-dropping are more. Henceforth, bring down estimation of threshold assigned to pass the control to another BS. For ideal handover choice, RSS threshold esteem ought to be exact. Consequently, the control of feedback is utilised to improve things and give the right choice by the error difference, de (k).

From the past value of threshold with error e(k) from the BS and RSS, the controller produces new threshold esteem utilising fuzzy rationale control calculation. This new threshold grasps esteem handover choice by the BS [55].This model is a motivation behind this paper. Since the handover choice is made considering just the new threshold estimation of the signal strength that is received, it is conceivable to have more than one parameter to influence the choice.

The vertical handover has been considered in most of the cases, hence the need to study how the GSM system responds to a fuzzy system that has three inputs. The interface to access the network changes in the case of a vertical but does not in the horizontal handover.

CHAPTER 3: THEORETICAL FRAMEWORK

3.1 CELLULAR CONCEPT

The cellular concept for mobile phone communication entails replacing large transmitter cells of high power with several smaller cells of lower power. Each cell gives scope to a little piece of the coverage territory. The issue of constrained client limit and spectral blockage by frequency reuse was in this way explained, and permitted high limit in a restricted distribution with minor framework upgrades [56]. The base transceiver station (BTS) at the focal point of the cell is taken to serve the MSs in the cell territory. A portion of the wordings famous in cell correspondences include:

MS (Mobile Station): Is planned for usage in an undesignated area while in movement.

BS (Base Station): which is a settled station utilised for radio correspondence with MS.

MSC (Mobile Switching Center: Also alluded to as the Mobile Telephone Switching Office (MTSO), organizes the directing of calls in a huge territory.

Forward Channel: This is otherwise called the down link. It is the radio channel that is utilised for transmission of data from the base station to the MS.

Reverse Channel: It is otherwise called the uplink. It is the radio channel utilised for the transmission of data from the MS to the BTS.

Handover: This is a procedure of exchanging a mobile station starting with one base station or channel then onto the next. The channel change because of handover happens through a schedule opening for time division multiple access(TDMA), a frequency band for frequency division multiple access(FDMA), and the code word for code division multiple access (CDMA) frameworks.

Co-channel Interference (CCI): Is caused when the signal of the predetermined cell is adulterated because of another signal in a remote cell utilising a similar frequency or channel.

The accompanying stages below are related with the arranging of cell correspondences:

- Assessment of movement density;
- Establishment of cell sizes and limit;
- Choices of unidirectional or sectored cells and antenna bearings;
- Identification of best BS locales to cover the needed region;
- Allotment of frequency;
- Choice of power control parameters; and
- Choice of handover parameters.

3.2 CELLULAR WIRELESS STANDARDS

There are four general classes of the mobile wireless principles in Kenya currently i.e. 1G, 2G, 3G and 4G. The 1G interchanges frameworks utilised FDMA as the multiple access technology. FDMA is a simple transmission strategy that is innately narrowband.

Each call utilised distinctive frequencies and shared the accessible range through FDMA. The radio interface innovation of the original first cellular framework is shown in Table 3.1. The handover procedure in the 1G wireless correspondence framework is Network Controlled (NCHO). 1G framework is not in operation right now. IP communication, access of ultra-broadband Internet, gaming administrations and streamed media might be given to clients.

Table 3.1:

First Generation Analog Cellular Systems

Region	**America**	**Europe**	**Japan**
Parameter	AMPS	ETACS	NTT
Multiple access	FDMA	FDMA	FDMA
Capacity	832 channels	1000 channels	600 channels
Duplexing	FDD	FDD	FDD
Forward channel	869-894MHz	935-960 MHz	870-885 MHz
Reverse channel	824-849MHz	890-915 MHz	924-940 MHz
Channel spacing	30 KHz	25 kHz	25 kHz
Data Rate	10kbps	8 kbps	0.3 kbps
Spectral efficiency	0.33 bps/Hz	0.33 bps/Hz	0.012 bps/Hz

3.2.1 THE GSM NETWORK

GSM is a 2G cellular framework. Advanced transmission was utilised rather than the analog transmission to enhance correspondence quality, framework limit, and scope range. GSM takes a shot at the 900 MHz, 1800 MHz and 1900 MHz frequencies. The GSM framework comprises of a few components like the MSC (mobile switching centers), BSC (base station Controllers), BTS (base transceiver stations), OMC (operation and maintenance Centre) and gateway MSC. The MS links over the Um interface, also known as the air interface, with a BTS in the little cell where the MS unit is. This correspondence happens through the radio channels. The coverage range is partitioned into little areas called cells. Various cells are assembled to have a LA (Locations Area) for the management of mobility. A link of radio communication or dedicated line associates the BSC to MSC. The MSC is the final component. Every MSC covers around 5-15 BSCs. The BSC holds radio frequencies and oversees handover starting with one cell then onto the next inside the base station subsystem (BSS).

Each service provider has no less than one MSC. Functions, for example, HLR (home location register), VLR (visitor location register), AuC (authentication register) and EIR (equipment identity register) are incorporated in the MSC. The routing of calls and roaming capabilities of GSM are provided by the HLR and VLR together with MSC.

The HLR stores both lasting and impermanent data about each of the MS that has a place with it. It has all the basic subtle elements of a specific client like the most recent coverage zones visited, the supplementary administrations, the points of interest of the MS, the service plan, and billing details. The VLR keeps data about the MS that is at present physically in the locale secured by MSC. VLR is critical when a client leaves the region served by his home MSC. It manages roaming and exchange subtle elements of clients gotten from various systems and furthermore holds most recent points of interest of its clients roaming in different systems. The VLR likewise aids handovers.

The two registers are for validation and security purposes. The EIR is a database containing a rundown of all substantial cell phones on the system, where each MS is recognized by its IMEI (International Mobile Equipment Identity). It aids in security and blocks mobile stations that have not been approved from using the network. Confirmation and encryption over a radio channel are made conceivable by the (AuC) which holds the authentication and encryptions keys kept in every client SIM card. There are three predominant interfaces, an interface between MSC and BSC (A Interface), A-bis Interface between BSC and BTS and an Um interface that links the BTS to MS.

AUTO-TUNING PRINCIPLE FUNCTIONALITIES OF THE GSM SYSTEM

The success of GSM networks is driven by RRM algorithms. RRM in such networks includes admission control and resource allocation, congestion control, packet scheduling, mobility control and cell reselection.

The success of GSM networks is driven by RRM algorithms. RRM algorithms and target auto-tuned parameters include:

RxLev_ACCESS_MIN which is an edge that enables MS to choose a BTS just if the level of the signal of the BTS is more noteworthy than a specific indicated esteem. The RxLev_ACCESS_MIN is a whole number in the scope of - 47 to - 110dBm. Its default esteem ought to be near the sensitivity of reception of the MS for instance - 102dBm. Increasing this parameter decreases the logical coverage area of the BTS. The sensitivity of the BTS is around -110 dBm higher than that of the MS of approximately -102 dBm. For example, on the off chance that you set this figure low at around - 110 dBm, then the MS, even in the terrible coverage territory will have the capacity to get to the cell. This will straightforwardly influence SDCCH drop and TCH task achievement rate (TASR).

Assuming the signal level is set to a high estimation of around - 90 dBm, this will prompt a drop in TCH activity as MS won't get to the cell in the range where level of the signal is underneath -90dBm. Legitimately, the scope region will become smaller, and traffic will diminish. It is along these lines that basic legitimate estimation of the signal level in light of a particular system situation is by experimentation technique. The prescribed figure is - 102dBm.

The traffic in the system is accomplished by altering the logical coverage zone of over-loaded and under-loaded BTS. RxLev_ACCESS_MIN can't be set past certain esteem else the MS will be in a blind area on the border of BTS. It is communicated on the BCCH. It identifies with the minimum signal that the service provider needs the system to get while an MS is accessing it.

RxLev_ACCESS_MIN = Body misfortune + Mobile Sensitivity +Interference Margin+ Multipath misfortune = 3 + - 104+ 2 +0 (ETSI standard for GSM 900)

= – 99 dBm

Mobile Sensitivity = - 104 for GSM 900

= - 102 for DCS 1800

Body loss:

= 3 dB is suggested by ETSI and for DCS 1800 by different Vendors

=5 dB for GSM 900 by different Vendors

Multipath loss = Lost Signal from BS because of reflection by structures, and so forth before getting to the MS.

It is usually around 3 dB, however can be overwhelmed by Antenna Diversity which has a gain of approximately 3 dB

Interference Margin is assigned to overcome the channel noise and interference; the prescribed figure is 2 dB.

RxLev-Min-Cell is the Minimum Downlink Power of Handover Candidate Cells. It is the minimum access level allowed for a cell to be a neighbor. When the cell level that is measured by an MS is greater than the set threshold, the BSS lists the cell into candidate cell list for handover judgment. It ranges from –110 dBm to –47 dBm. This parameter guarantees communication quality such that, the value ranges from –90 dBm to –80 dBm for a typical single layer network structure. It also helps to balance traffic between cells.

However, you cannot configure RxLev-Min-Cell over –65 dBm or lower than –95 dBm, otherwise communication quality is affected.

Parameter C1 is utilised to decide if a cell is reasonable to camp on. Cell selection C1 depends on two main parameters:

- Suitably averaged Received signal level.
- The parameter RxLev-Access-Min,

The parameter msTxPwrMaxCCH, which is communicated on the BCCH, is the most extreme power that a MS may utilize when first accessing the system.

• The highest MS power.

C2 is utilised for urging MSs to choose some appropriate cells in inclination to others that is, cell reselection. Cell reselection is required if:

- There is a better cell regarding C2 criterion
- Path Loss paradigm C1 < 0 for a cell camped on, for at least 5 sec
- The cell camped on has been barred
- There is DL signaling failure

The C2 criterion is connected in various hierarchical cell structures to keep quick moving MS in an upper layer and moderate moving MS in smaller scale cells. It is accepted that a quick moving MS goes through the smaller scale cell before PENALTY_TIME is arrived.

Path loss can be obtained from the difference of the radio's transmitted power and received power. The radio has just assessed both the power received and power of the noise. Both of these qualities are then changed over into the energy per bit (Eb) and noise energy (N0) to reflect the behaviour of modulation.

Bit Error rate (BER) is an essential goal for every single digital correspondence's needs. It gives a gauge to the measure of data exchanged.

All BER calculations rely on a very basic level on the signal to noise ratio (SNR) at the receiver. The BER equations rely on the power of noise with a distribution that is Gaussian.

The BER equations are displayed using EbN0 or the proportion of the energy per bit to the spectral density of the noise power, as the standard portrayal of the quality of the signal.

3.2.2 THE 3G NETWORK

The third generation cellular networks were developed with the aim of offering high speed data and multimedia connectivity to subscribers. The ITU under the initiative International Mobile Telecommunications (IMT)-2000 has defined 3G systems as being capable of supporting high speed data ranges of 144 kbps to greater than 2 Mbps. A few technologies are able to fulfil the IMT standards, such as CDMA, UMTS and some variation of GSM such as EDGE. A UMTS network consists of three interacting domains: Core Network (CN), UMTS Terrestrial Radio Access Network (UTRAN) and User Equipment (UE).

3.2.3 THE 4G NETWORK

The existence of multiple standards for 3G made it difficult to roam and interoperate across networks. There was therefore a need for a global standard providing global mobility and service portability so that the single-system vendors of proprietary equipment do not bind the customers.

Rather than being an entirely new standard, 4G basically resembles a conglomeration of existing technologies and is a convergence of more than one technology.

The 4G systems are intended to provide high quality video services providing data transfer speeds of about 100Mbps.The 4G technology offers transmission speeds of more than 20Mbps and is capable of offering high bandwidth services within the reach of local area network (LAN) hotspots, installed in airports, homes and offices.

3.3 INTELLIGENT SYSTEMS

The term intelligent portrays a framework or a technique that can adjust its activity as for progressing occasions. These frameworks are versatile and give the presence of being clever as they change their conduct without user intercession.

The two employments of the term intelligent are critical as they depict frameworks in ordinary usage. The principal use incorporates rule-based strategies such as fuzzy logic. The second utilisation includes methods, for example, neural systems which plan to see and grasp the importance of the information with which they are prepared. A class of factual models may usually be called "Neural" on the off chance that they have the accompanying qualities:

1. Comprise of sets of versatile weights, with the end goal that, numerical parameters are tuned by a learning algorithm.

2. Their nonlinear input functions can be approximated.

Simulated annealing is a way for finding a good response for an optimisation problem. In case you are in a circumstance where you need to amplify or limit something, your worry can likely be dealt with simulated annealing.

3.3.1 EVOLUTIONARY COMPUTATION

Seeking or streamlining calculations roused by natural development are called evolutionary computations. The highlights of the evolutionary calculation are that its hunt or advancement is led:

1. In light of various searching points or solution candidates (search that is population based).

2. Utilising operations motivated by biological development, for example, mutation and crossover.

3. In light of probabilistic inquiry and probabilistic operations.

4. Utilising little data of searching space.

Ideal models which comprise of the evolutionary computation incorporate GA (genetic algorithm), GP (genetic programming) ES (evolution strategies), and EP (evolutionary programming).

There are a few apparatuses of artificial intelligence that use human learning concerning the framework to grow superior frameworks. A portion of the significant AI apparatuses are the ANN (artificial neural network), FL (fuzzy logic), GA (genetic algorithm) and ES (expert systems). This research uses the ability of fuzzy rationale to create adaptive savvy handover calculations.

3.3.2 FUZZY LOGIC SYSTEM

Fuzzy controlling depends on the standards of fuzzy rationale, which maps, using membership functions, linguistic terms, for example," "high," "low," and so forth to the figures zero and one as well as to the entire interim [0; 1]. It is a computational worldview that depends on how people think.

Fuzzy Logic takes a gander at the world in uncertain terms, similarly that our mind takes in data (e.g. temperature is hot, speed is moderate), at that point reacts with exact actions.

The human mind can dissuade vulnerabilities, ambiguity, and judgments though PCs can just control precise valuations. Fuzzy rationale is an endeavor to consolidate these two methods by taking care of numerical information and semantic learning. Fuzzy logic varies from traditional rationale in that statements are never again dark or white, genuine or false, on or off. In conventional rationale, an object has a figure of either zero or one. In fuzzy rationale, an object can accept any genuine value in the vicinity of 0 and 1, speaking to the level to which a component has a place with a given set. The most critical thing to acknowledge about the logic of fuzzy reasoning is that it is a superset of the standard Boolean rationale. Should you keep the fuzzy esteems at their extremes of 1 (entirely true), and 0 (totally false), standard logical operations hold.

Fuzzy inference involves mapping a certain input to a yield utilising fuzzy rationale. The mapping at that point gives a premise from which choices can be made, or patterns observed.

FLC offers a straightforward programming execution. It depends on the if– then standards, which express the connection between the information and the output factors. The principles are gotten from explanations that are figured in normal dialect.

The strengths of the fuzzy logic include:

1. Its concepts are easy to comprehend.

2. Simple mathematical concepts.

3. Flexible reasoning.

4. It is not hard to incorporate more prominent usefulness without starting from scratch.

5. It can demonstrate nonlinear elements of arbitrary intricacy.

6. It is conceivable to make a framework to coordinate any arrangement of information at the input and output.

7 It is tolerant of uncertain information. Fuzzy thinking expands on the understanding that most things are dubious even on watchful assessment.

Based on these strengths, the Fuzzy Logic can be used to optimise the QoS of the cell phone systems.

Numbers or linguistic descriptions can represent information. Say, the temperature can be shown by the number 12 degrees Celsius (°C) or by a linguistic description of "Cold." This portrayal ―cold is fuzzy could be taken to be any temperature between 10 °C and 20 °C, which is known as the fuzzy region (or fuzzy set) for the variable temperature. Providing these depictions in some scientific form helps us to use human learning since people usually think regarding linguistic descriptions; fuzzy logic utilises the human information by giving the fuzzy portrayals an exact structure.

The Fuzzy Inference System

Fuzzy inference frameworks are moreover called fuzzy expert systems, fuzzy rule-based systems, fluffy models, and fuzzy models, and fuzzy associative memory. This is the essential unit of a fuzzy rationale framework. The decision-making unit is a fundamental piece of the whole framework. The FIS plans appropriate guidelines for deciding. This depends on the theory of the fuzzy set, IF– THEN guidelines, and the fuzzy thinking. FIS utilizes IF–THEN articulations and the connectors for the rule proclamation: 'OR' or 'AND' to settle on the vital choice. An essential FIS can take either fuzzy or crisp information sources, yet the yields are quite often fuzzy sets. A crisp output can be required when the FIS is utilised as a controller. The defuzzification technique is employed to best extract a crisp figure to show the fuzzy set.

The entire FIS is talked about circumspectly in the accompanying subsections:

The Mamdani FIS

Mamdani inferencing framework is a popular strategy. It was among the principal control frameworks made utilising the fuzzy set hypothesis. It was proposed by Mamdani (1975) when trying to control a steam motor and evaporator by an arrangement of semantic control rules which were acquired from versed individuals. The parts of the Mamdani FIS are the fuzzifier, the rule base, fuzzy inference engine, and the defuzzifier. This FIS arrangement has the accompanying points of interest contrasted with different FISs that make it generally utilised as a part of modern and consumer items [57]:

i. They have genuine esteemed factors as its data sources and yields, consequently more appropriate for building applications where the deliberate factors are not fuzzy.

ii. It provides a base of rules for fusing fuzzy IF-THEN rules that adventure man's reasoning.

iii. This FIS permits a few degrees of opportunity in the determination of its distinctive segments.

iv. It allows combination of numerical and semantic data.

The Sugeno Fuzzy System

The Sugeno FIS, otherwise called Sugeno– Takagi display, was proposed by Takagi, Sugeno, and Kang to formalise a framework to create fuzzy standards from a data set of input and output.

For a zero order Sugeno with two inputs x and y,

$$s = ax + by + k \tag{3.1}$$

Where $a = b = 0$

$$Final\ Output = \frac{\sum_{i=1}^{N} wisi}{\sum_{i=1}^{N} wi} \tag{3.2}$$

The final output is the weighted average of all the rule outputs.

Where for the AND rule:

$wi = And\ Method(F1(x), F2(y))$ Where $F1(x)\ and\ F2(y)$ are the membership functions for input 1 and 2.

And si Is the output level of each rule weighted by the rule firing strength; wi.

The upsides of this FIS include:

i. Efficient calculation.

ii. Works well with direct methods, for example, PID control.

iii. It functions admirably with streamlining and adaptive systems.

iv. It has progression of the yield surface.

v. It is appropriate for scientific investigating.

CHAPTER 4: METHODOLOGY

4.1 SIMULATION WORK

The simulation work has been done using Matlab Release R2009a Version 7.8.

There are two essential fluffy derivation frameworks; Sugeno and Mamdani. The fundamental distinction amongst Mamdani and Sugeno is that the Sugeno output membership functions are either straight or consistent.

The initial segments of the fuzzy inference process incorporate fuzzifying the sources of information and applying the fuzzy operator. Advantages of the Sugeno Method are that:

• It works better with optimisation and adaptive procedures.

• It is computationally efficient.

• It can be utilised to demonstrate any derivation framework in which the output membership functions are either direct or steady.

• It functions admirably with straight models.

• It has progression of the yield surface.

• It is appropriate for numerical examination.

The fuzzy logic system is considered to develop the algorithm and this comprises a series of steps as below [48]:

1. Choice of the Input Parameters

The network performance in terms of quality, capacity and operability may be improved should the characteristics of the cells and the changing environment be considered [47]. It is at this point that this case considers three input parameters: The level of the signal (RXLEV) the quality (RXQUAL) in the cell presently serving the mobile station and the velocity of the MS.

2. Fuzzification

The fuzzification step involves the conversion of the actual input figures into fuzzy sets. The membership degree is in the [0 1] interim and is controlled by the membership functions (MFs) of the measured input figures to the properties considered, which are Gaussian. The Gaussian function is represented by Equation (4.1).

$$f(x;\sigma,c) = \exp\left\{\frac{-(x-c)^2}{2\sigma^2}\right\} \qquad (4.1) \quad [59]$$

Where: c represents the MFs Centre and σ determines the MFs width.

Gaussian membership functions are used in this work to specify the fuzzy sets due to their concise notation (non- zero at all points) and smoothness.

The time-bandwidth product is a measure of combined time and frequency spread of a signal. It is essentially a property of the shape of the waveform.

The root mean square bandwidth (Wrms) is best suited for mathematical evaluation and has thus been considered in this work. We may define the root mean square (rms) bandwidth of a low pass signal g (t) with Fourier transform G (f) as follows:

$$Wrms = \left(\frac{\int_{-\infty}^{\infty} f^2 |G(f)|^2 df}{\int_{-\infty}^{\infty} |G(f)|^2 df}\right)^{1/2} \qquad (4.2) \quad [34]$$

The corresponding definition of the rms duration of the signal g(t) is given by:

$$Trms = \left(\frac{\int_{-\infty}^{\infty} t^2 |g(t)|^2 dt}{\int_{-\infty}^{\infty} |g(t)|^2 dt}\right)^{1/2} \quad (4.3) \quad [34]$$

The signal g (t) is assumed to be centred on the origin.

The time bandwidth product of a rectangular pulse is given by:

$$\frac{1}{T} * T = 1 \quad (4.4) \quad [34]$$

Generally, time*bandwidth=constant

$$Trms * Wrms \geq 1/4\pi \quad (4.5) \quad [34]$$

The constant in this case is the $\frac{1}{4\pi}$. [34]

The Gaussian function satisfies Equation 4.5 with an equality sign thence has the least time bandwidth product. [34]

The linguistic regions, which are additionally known as properties, depict the qualities measured for the information parameters. A linguistic region is related with one membership function. A fuzzy set concedes the likelihood of incomplete participation in it. For instance, the 90km/hr speed was rather high. A value of membership in the vicinity of 0 and 1 shows how much an object has a place with a fuzzy set. (E.g. the 90 km/hr. speed is high to the level of 0.8). A membership function related with a given fuzzy set maps value of input to its proper value of membership. The parameters at the input in this work are portrayed by three properties: "Low", "normal", and "high" and for parameter at the output, "Yes", "Be Ready", "Wait" and "No".

3. Inference Engine and Rule Base

The inference engine utilises the rules in the rule base and gives a value that is fuzzy. The guidelines in the rule base are made in light of information and experience [51]. The ‘if-then’ statements are used to formulate the restrictive rules: If x is Q, then y is T. Q and T are linguistic properties defined by fuzzy sets on the extents X and Y (universes of discourse). The "if-part" of the rule is known as the antecedent or premise, while the then-part "y is T" is called the consequent or conclusion. On the off chance that the antecedent is consistent with a specific level of membership, at that point the consequent is additionally consistent with that same degree. Their number relies upon the quantity of the factors at the input and on the quantity of the recognized properties for each information variable. Now, in a case where there are 3 input variables each with 3 properties, this results to 27 rules.

4. Defuzzification

The defuzzification step utilises the degree of membership at the output of every linguistic region of the output parameter as an input. The fuzzy yield figures are hereby changed over into genuine numbers. The Weighted Average (wtaver) strategy is utilised as a part of this work to such an extent that the yield is gotten by the weighted normal of the each yield of the arrangement of guidelines in the knowledge base. It is formed by weighting each function in the output by its respective maximum membership value [60]. It is given by:

$$z* = \frac{\sum \mu c(z).z}{\sum \mu c(z)} \tag{4.6}$$

Where *z* is the maximum point of the membership function (x-axis)

And μ*c* is the output value at the particular point (y-axis).

This technique gives a fairly accurate result and is computationally faster and easier.

4.2 THREE INPUT PARAMETER

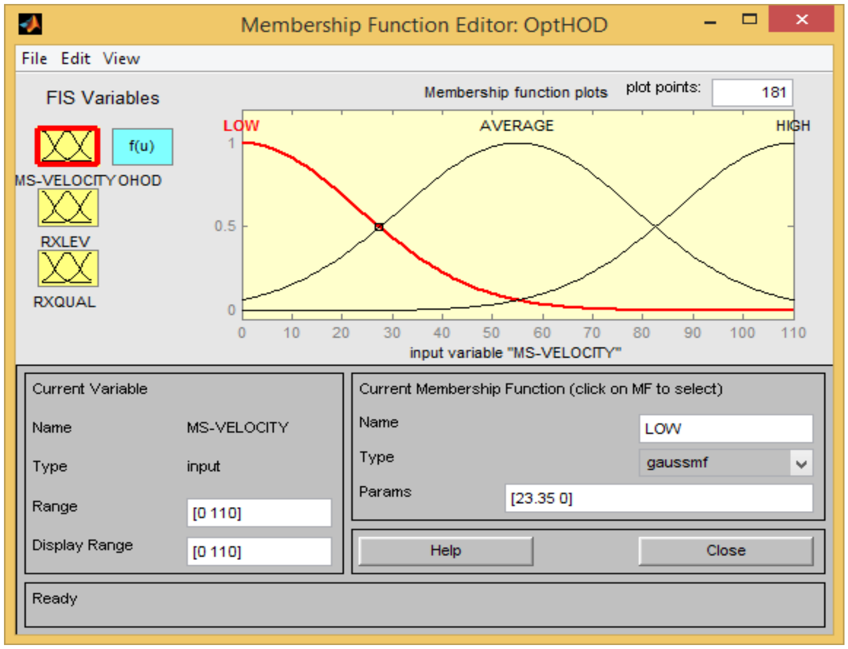

Fig. 4.1: MS Velocity Membership functions

Gaussian membership functions are used for the three attributes of low, average and high for the three input variables.

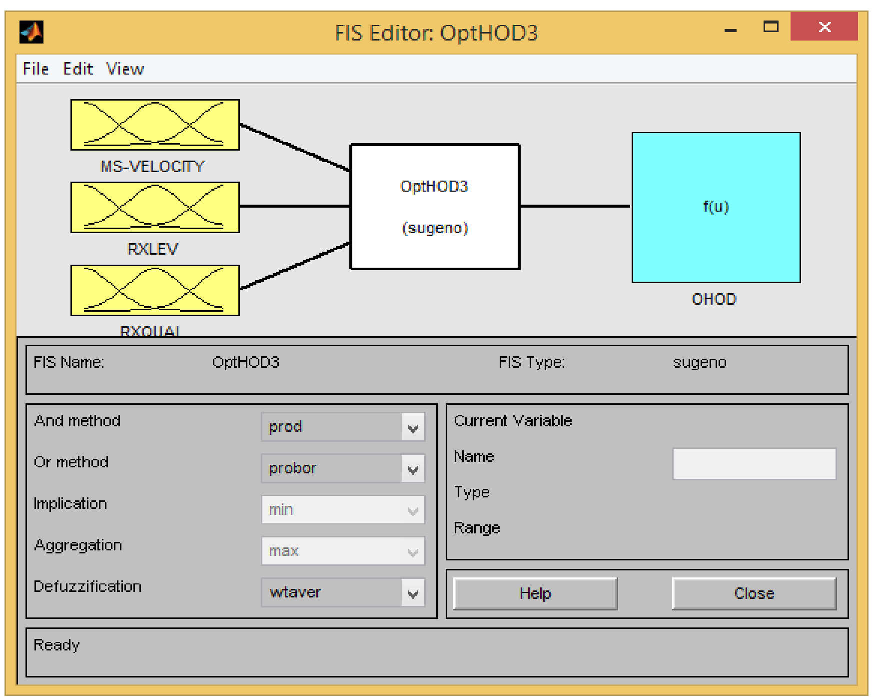

Fig. 4.2: Three inputs Fuzzy Logic System

MS Velocity, RxLev and RxQual are the inputs to the Sugeno FIS and an optimised handover decision is obtained at the output.

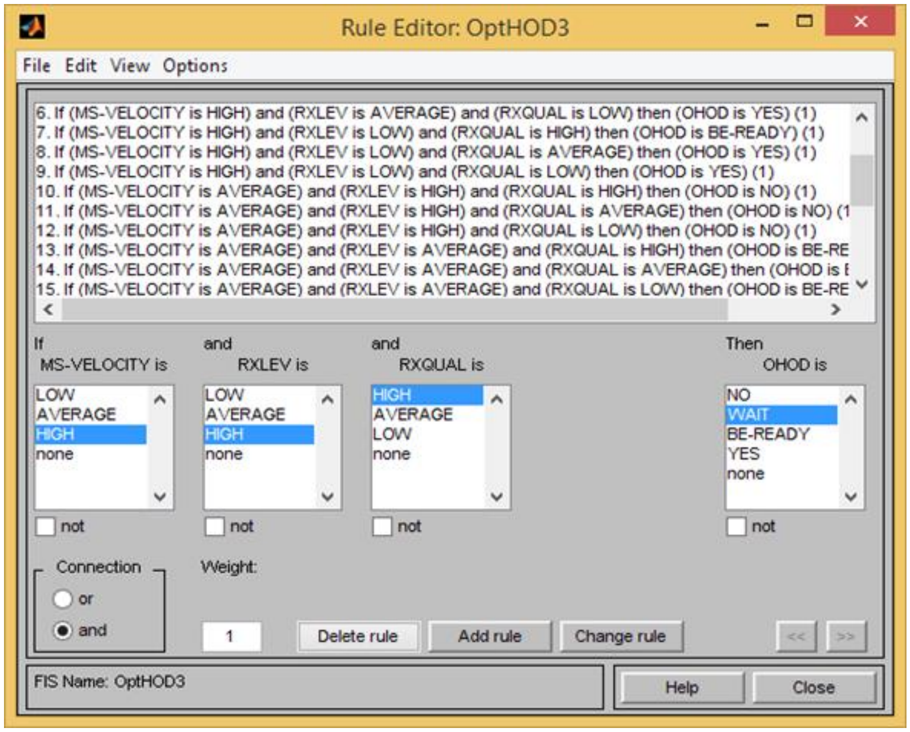

Fig. 4.3: Three input Sample set of rules

A total of 27 rules have been formulated for the three input parameter system.

A sample of them is shown in Fig. 4.3 above.

4.3 TWO INPUT PARAMETERS

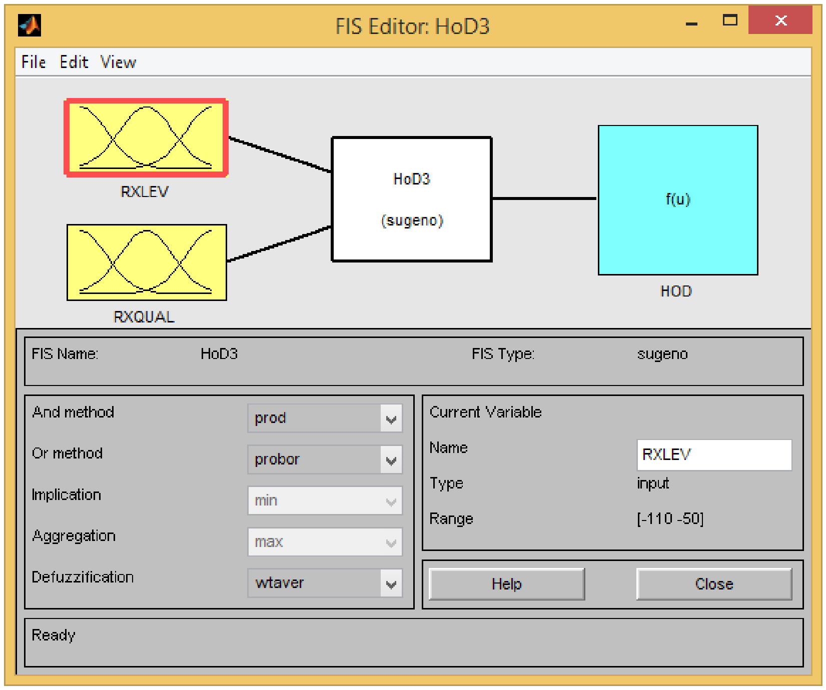

Fig. 4.4: Two input Fuzzy Inference System

Fig. 4.4 shows the Fuzzy Inference System for two input variables: RxLev and RXQUAL. The two parameters are fuzzified by the Sugeno method using a set of nine rules and output f (u) is obtained as the handover decision (HOD).

This case provides four possible outputs and thus membership functions for a given set of inputs: 0 to mean No, 0.3333 meaning Wait, 0.6667 to mean Be Ready and 1 for Yes.

Therefore, a higher value of the HOD will indicate a higher recommendation for handover and vice versa.

The rules as shown in Fig. 4.5 are made by logic, technical knowledge and experience. The handover decision (HOD) is a NO if either the RxLev or the RxQual is high or both of them are average. The HOD is YES when either of the two inputs is low. A total of nine rules are formulated.

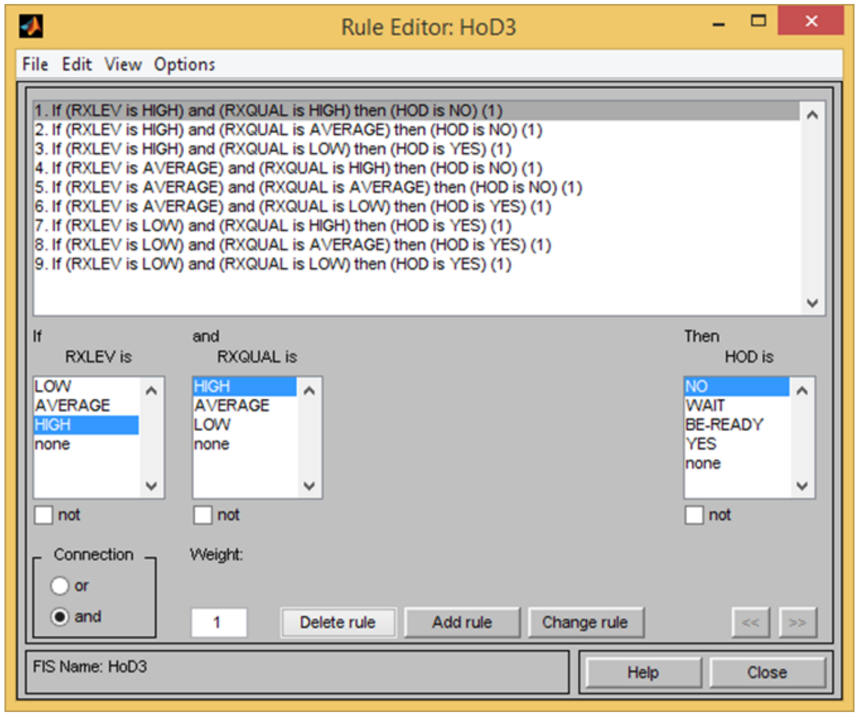

Fig. 4.5: Two input rules

4.4 SINGLE INPUT PARAMETER

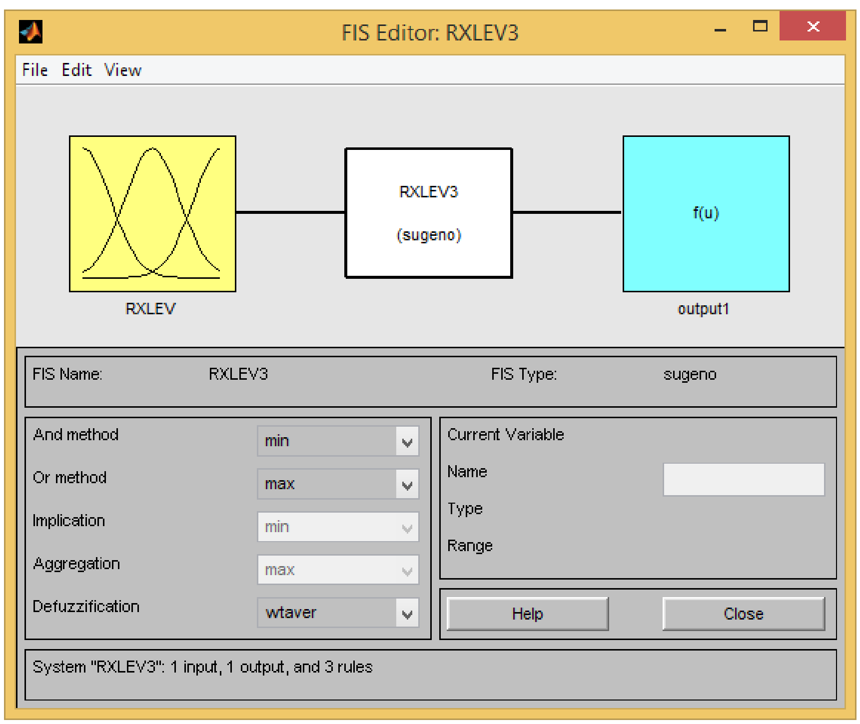

Fig. 4.6: Single input fuzzy inference system

The RxLev is the input parameter to the FIS in Fig. 4.6. The output is called Handover Decision (HOD).

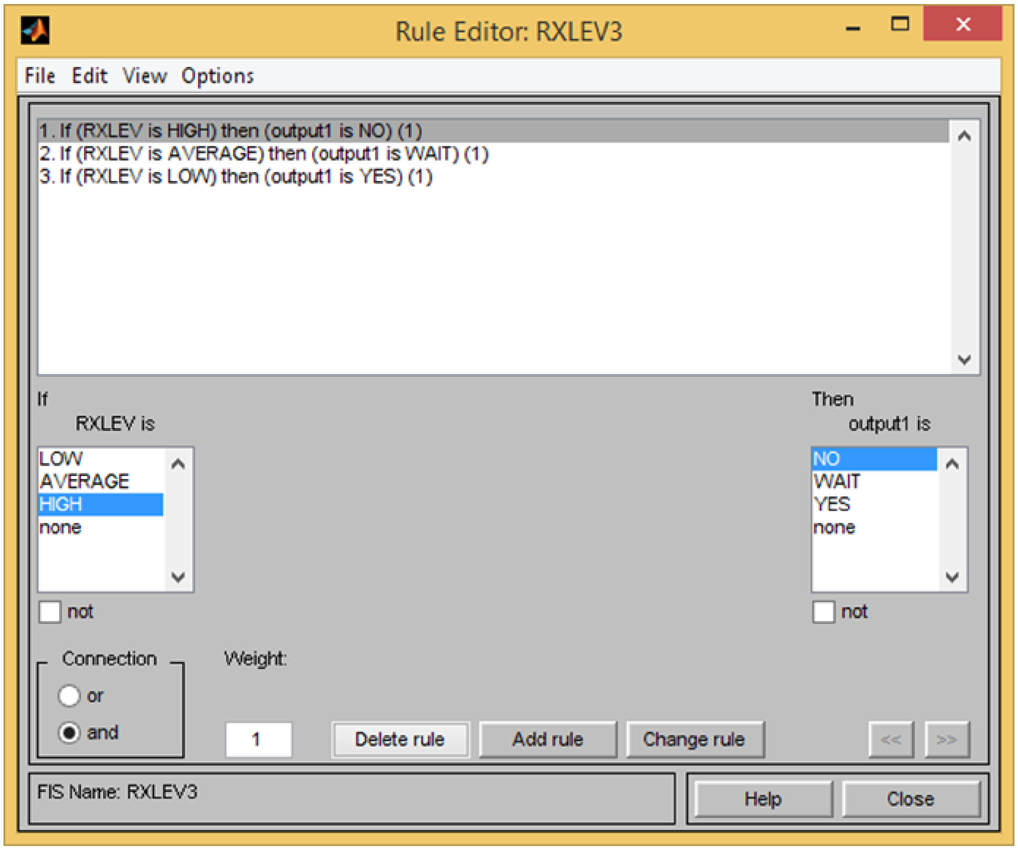

Fig. 4.7: Single input rules

Three rules are formulated for a single input system.

RxLev in the ranges of: 0-31.5 is regarded as ‘Low', 0-63 is ‘Average' and 31.5-63 is ‘High

CHAPTER 5: RESULTS AND DISCUSSION

5.1 THREE INPUT PARAMETERS

The fuzzy system output in this work is referred to as the Optimal Handover Decision (OHOD). It is in the range of 0 to 1. There are four possible outputs and thus membership functions for a given set of inputs: 0 to mean 'No', 0.3333 meaning 'Wait', 0.6667 to mean 'Be Ready' and 1 is for 'Yes'.

Therefore, a higher value of the OHOD will indicate a higher recommendation for handover and vice versa.

Fig. 5.1 to Fig. 5.7 show the results obtained from the simulation work. The rule viewer shows the number of rules being considered, say from 1-27 with their respective input(s) and output. The red vertical line indicates the value position of the input variables say it will be at the mid-point should it be at the mean value. The exact value is displayed at the top of the membership functions say the MS VELOCITY=55, RxLev=31.5, RXQUAL=3.5 and the OHOD=0.646 for Fig.5.1. The surface viewer is basically a graphical representation of the input(s) versus the output in the various axes.

When all the input parameters are at their average positions, Fig. 5.1, the user will be ready for handover. This output of 0.646 (in Fig.5.1) is different from the following two cases, as it can be seen, of 0.108 (in Fig.5.4) and 0.5 (in Fig.5.6) due to the aspect of the MS Velocity.

Fig. 5.2 shows the output of varying the RxLev and MS Velocity with the RxQual being held constant at 3.5.The OHOD increases as the MS Velocity increases and RxLev decreases. At low signal levels, the decision to handover has to be made thus increased OHOD values. At 110km/hr., RxLev say at level 20, handover decision will be yes due to the large relative decrease of the signal level with respect to time. At 0 km/hr and the signal level being at its best, there is no need for a handover.MS velocity at 0km/hr., and the RxLev is weak at level 60, handover should wait.

Fig.5.3 shows the output of varying RxQual and RxLev with the MS Velocity at 55km/hr. At low RxLev like 10, and high RxQual say 3, the handover decision is small due to the average MS Velocity and the good signal quality thus lower need to handover. Need to handover increases as the signal level and the signal quality decrease. The execution of handover when the MS Velocity is average, RxQual is low and RxLev is low will wait as the mobile station will cross the cell boundary shortly.

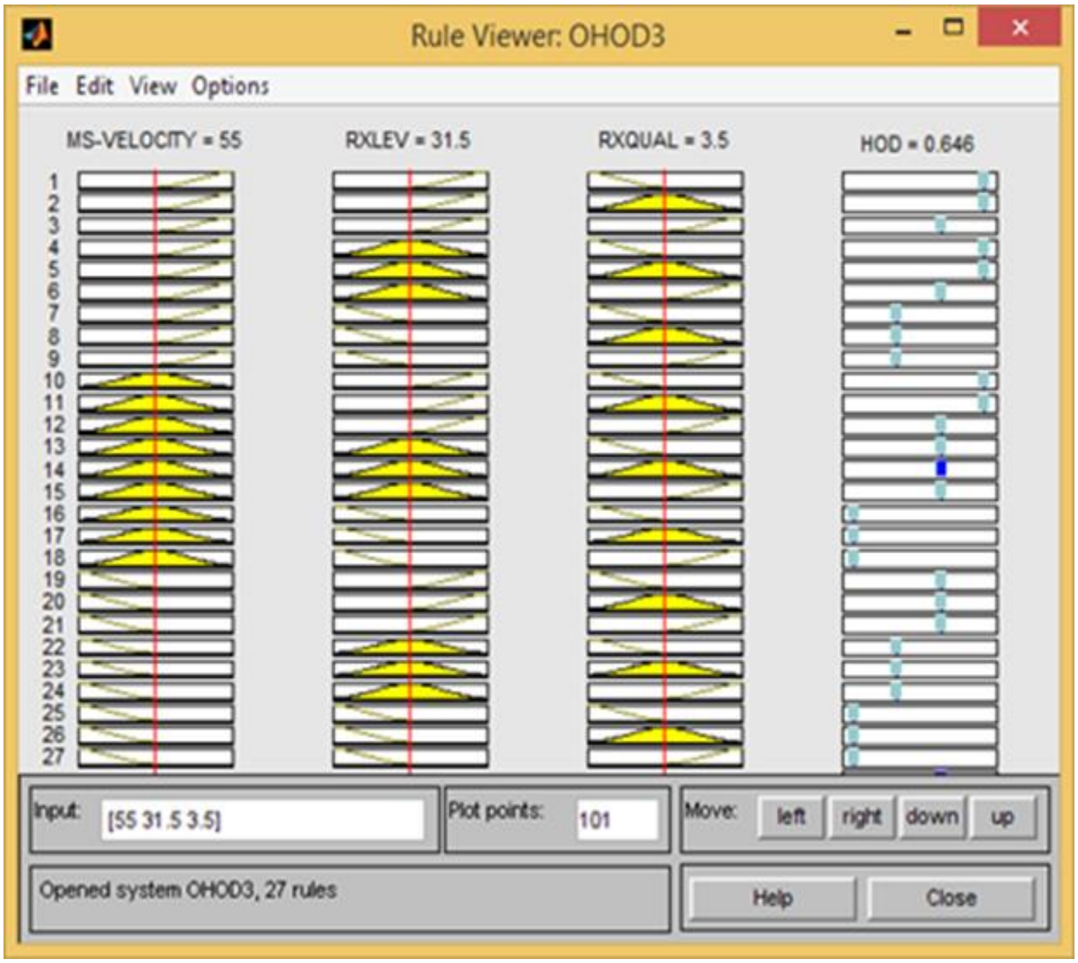

Fig. 5.1 Output at mean MS Velocity, RxLev and RxQual values

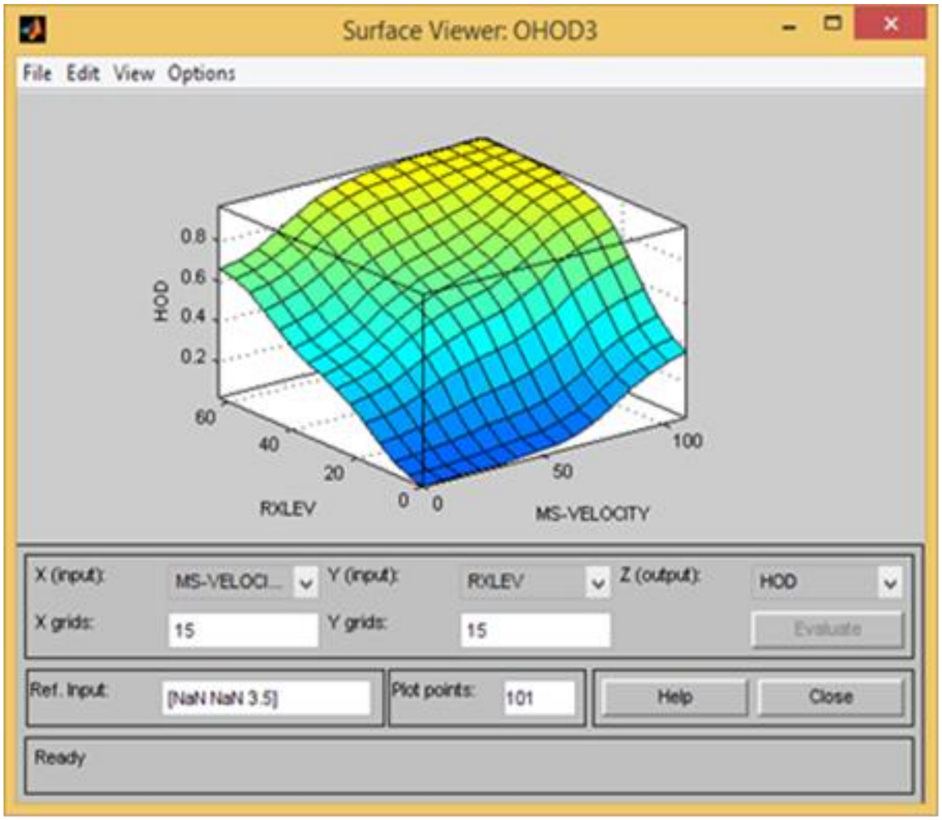

Fig. 5.2: Output at variedRxLev and MS Velocity

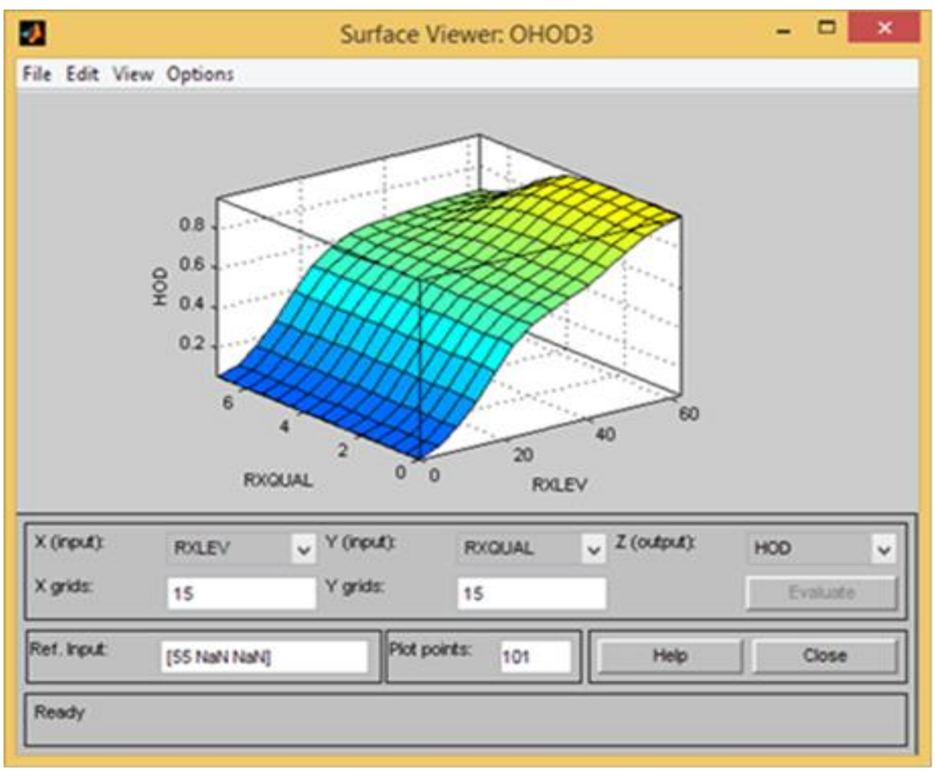

Fig. 5.3: Output at varied RxQual and RxLev

5.2 TWO INPUT PARAMETERS

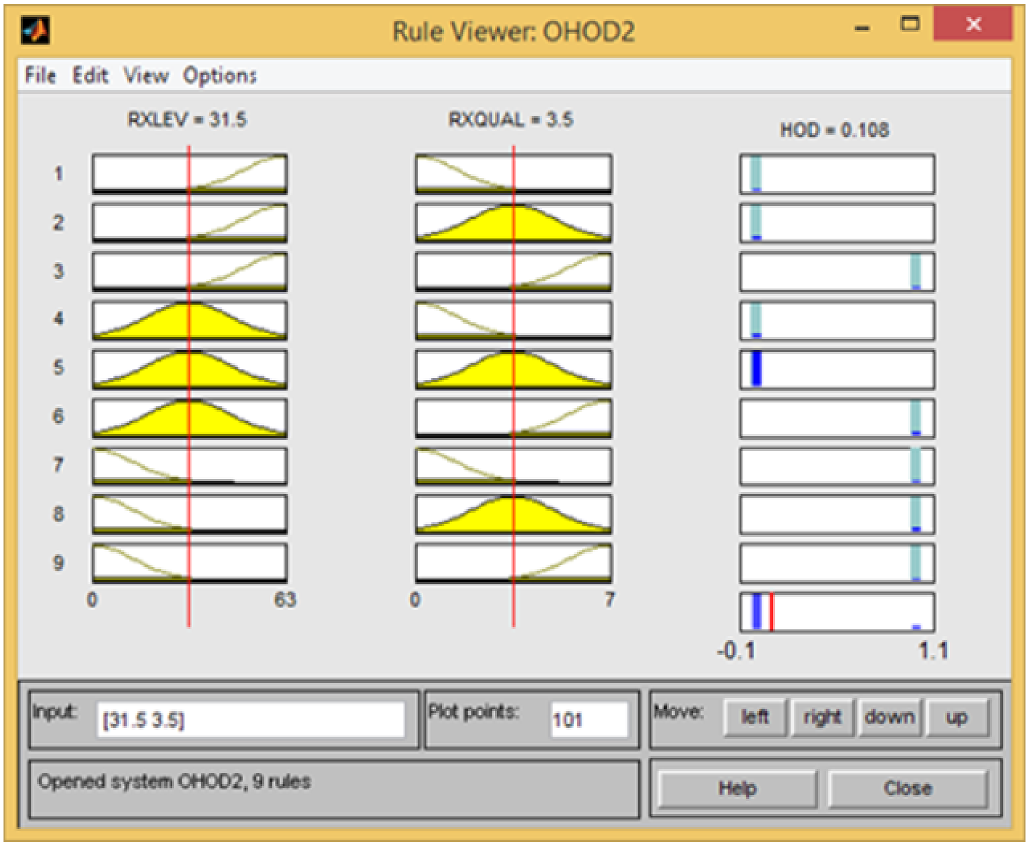

Fig. 5.4 Output at mean RxLev and RXQUAL values

The input parameters at their average position, Fig. 5.4, imply that there is no need to handover.

Compare this output of 0.108 versus the next output of 0.5 (in Fig.5.6) where RxLev is the only input: implying that there's more optimal network resource utilisation in this case. The need to handover has been optimised to suit the given situation.

From Fig. 5.5, the HOD is high when the RxLev and the RxQual are low and vice versa. The need to handover decreases as the signal level increases. The HOD increases as the RxQual becomes poorer at around the 4th level.

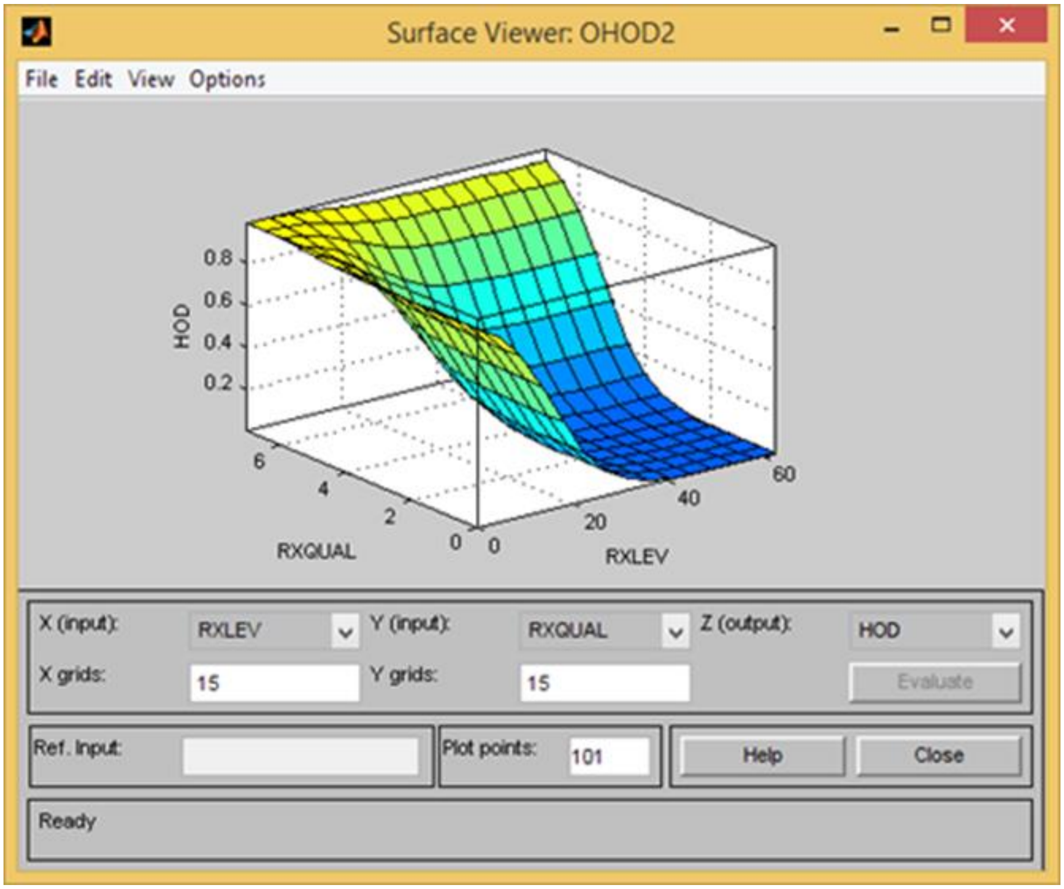

Fig. 5.5 Output at varied RXQUAL and RxLev

5.3 SINGLE INPUT PARAMETER

Fig. 5.6 shows the output of the fuzzy system when the RxLev is at the mean position of 31.5. The possible outputs are 'Yes' at 1, 'Wait' at 0.5 and 'No' at 0.The output shown means that the MS should wait for handing over to the next BS.

The deductions made from Fig. 5.7 are that at high RxLev, there is no need to handover as the conditions are favorable to sustain the current communication. At an average level, the MS should wait to be handed over as the signal level may change. If the RxLev becomes weak, there is need to handover to the next more appropriate BS.

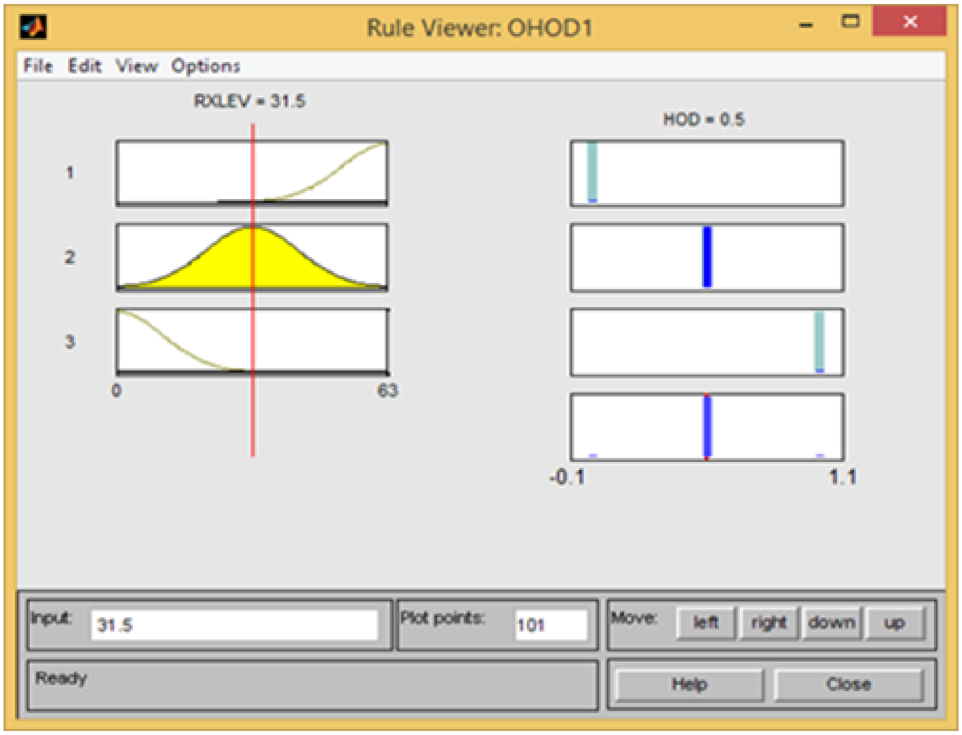

Fig. 5.6 Output at mean RxLev value

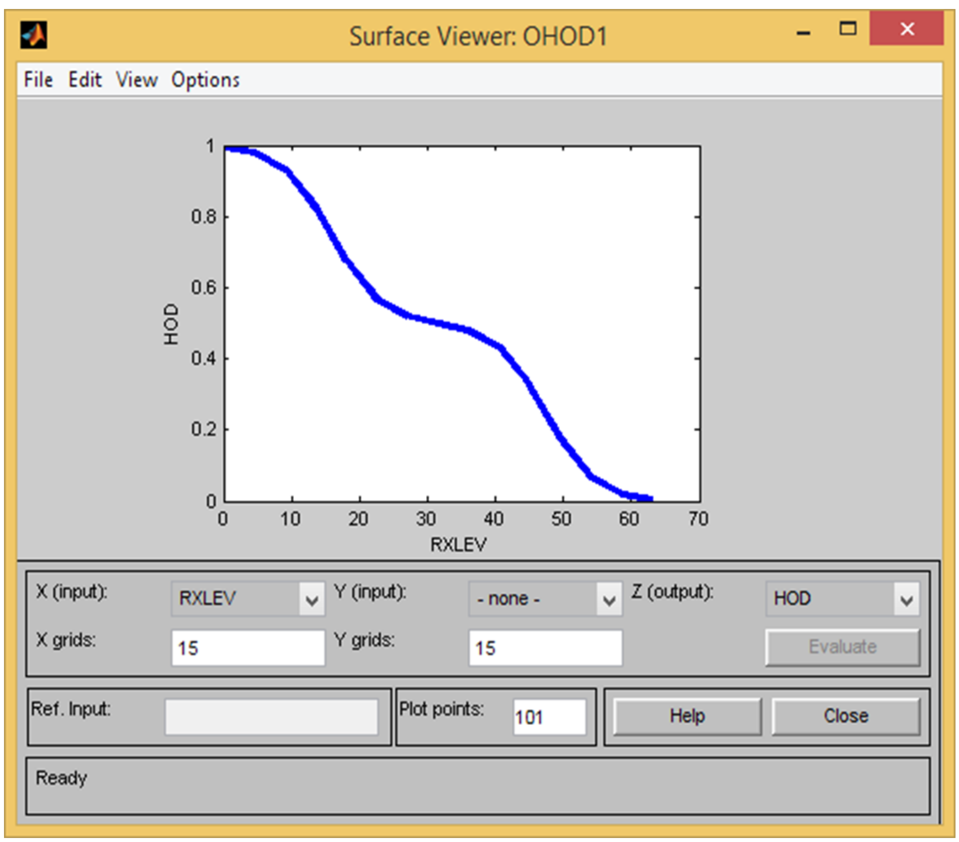

Fig. 5.7 Output at varied RxLev

5.4 VARIOUS COMPARISONS

Fig. 5.8 to Fig. 5.16 shows the results of the various sets of inputs giving their different outputs.

The RxLev scale used is in the -110dBm to -47dBm range which proves a mapping to the 0 to 63 scale. Simulation of the three input parameters is discussed in the following cases.

As shown in Fig. 5.8, the optimal handover decision decreases as the RxLev increases. The MS Velocity and RxQual are held constant at 55km/hr. and 3.5 respectively. At low signal levels, the decision to handover has to be made so as not to drop the communication and thus increased OHOD values.

From Fig. 5.9 an increase in the velocity of the mobile station will need a handover decision to be made as there's limited time to stay in a given serving cell.

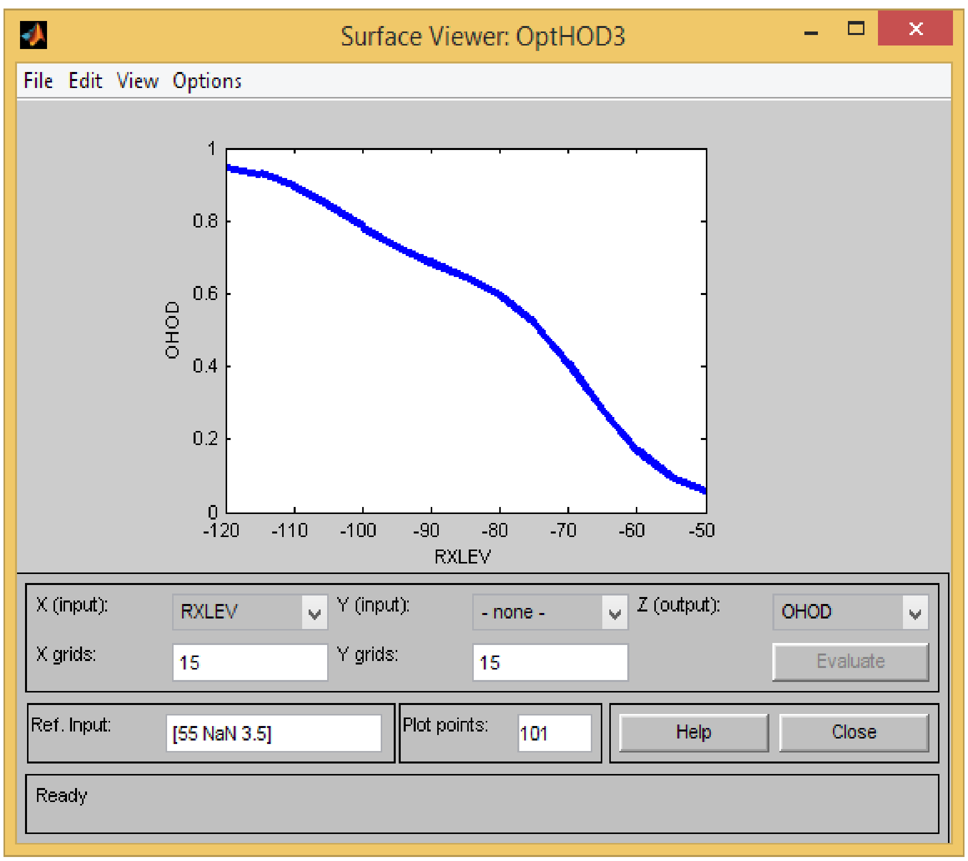

Fig. 5.8 Output at varied RxLev

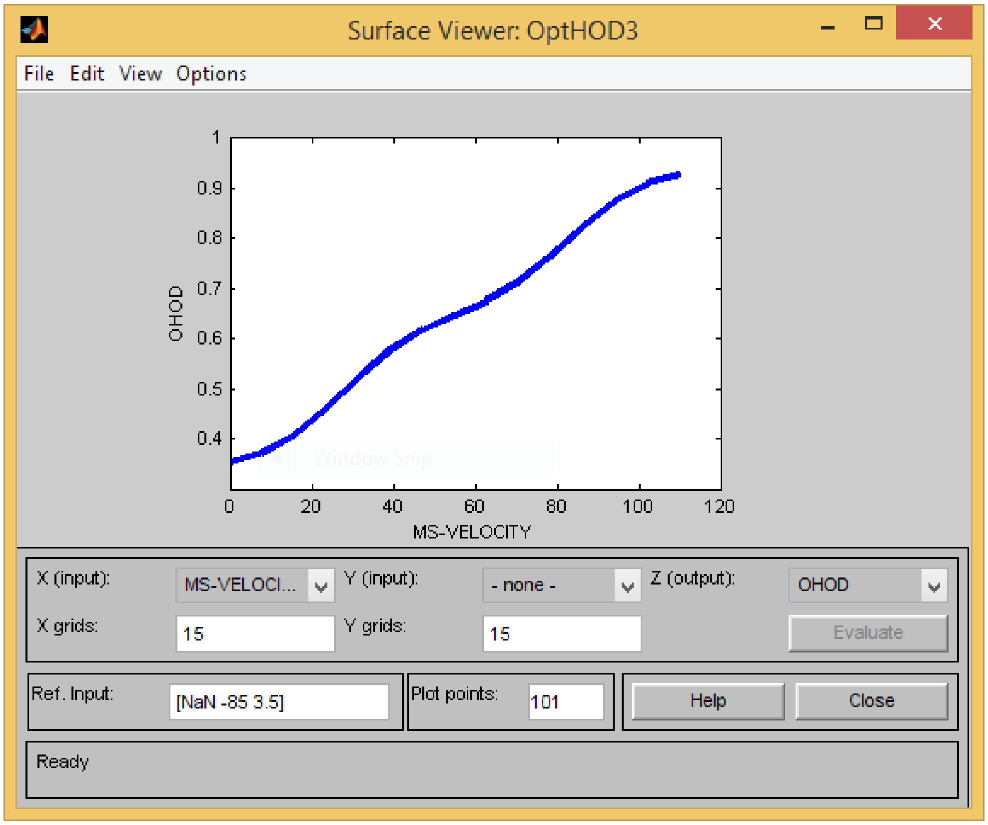

Fig. 5.9 Output at varied MS Velocity

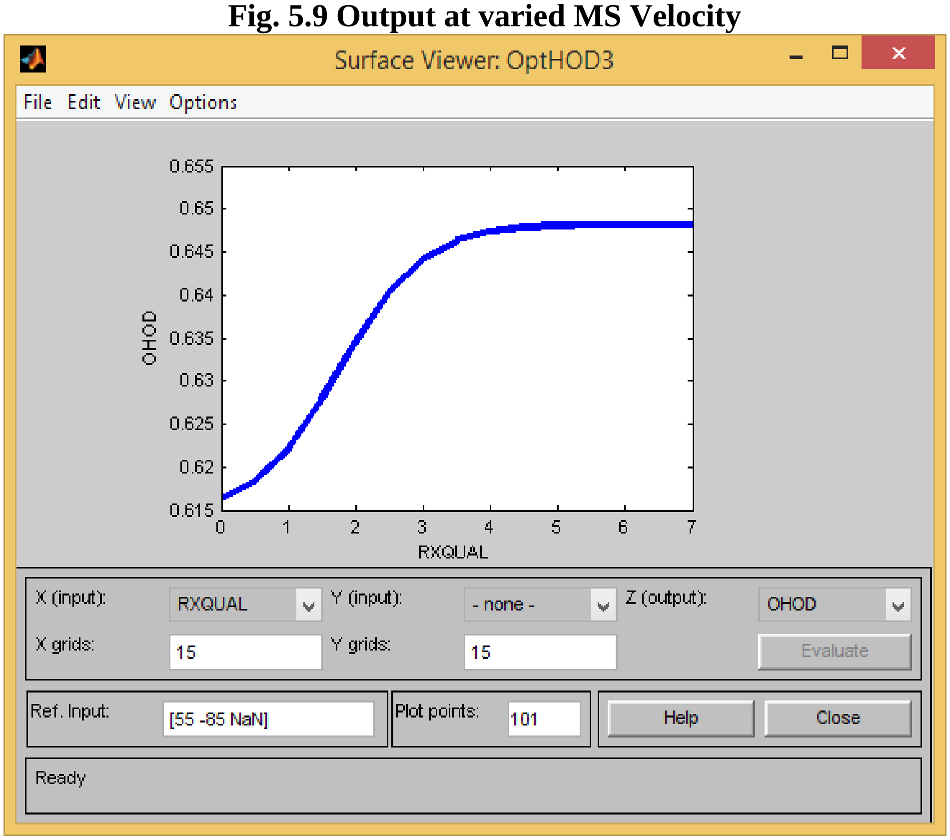

Fig. 5.10 Output at varied RXQUAL

The need to handover increases when the signal quality decreases as shown in Fig. 5.10. By the time the signal quality is at the 4^{th} level, the decision is that the user should be ready for handover.

When the velocity of the mobile station is at 0km/hr as shown in Fig. 5.11, for instance when the user is in a traffic jam that's at a stop, and the other two parameters are still appropriate for handover, then the decision made is that the process should wait.

Taking a case when there is no relative movement of the mobile station as shown in Fig. 5.12, the signal level and quality being at their best, the OHOD is 0.0208-which is pretty low hence no need of handing over.

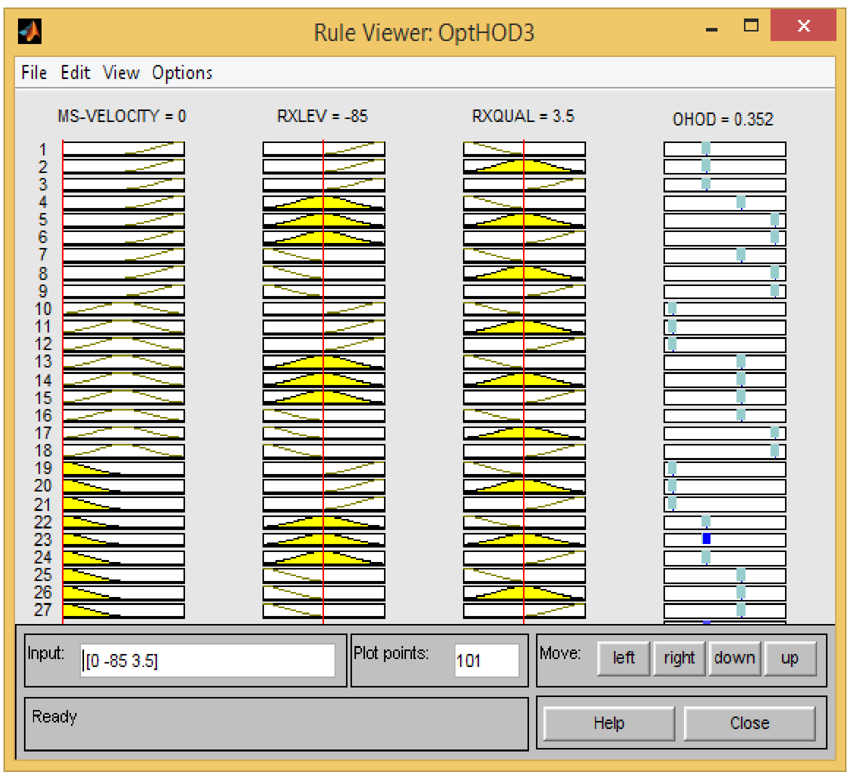

Fig. 5.11: Output at 0km/hr. MS Velocity

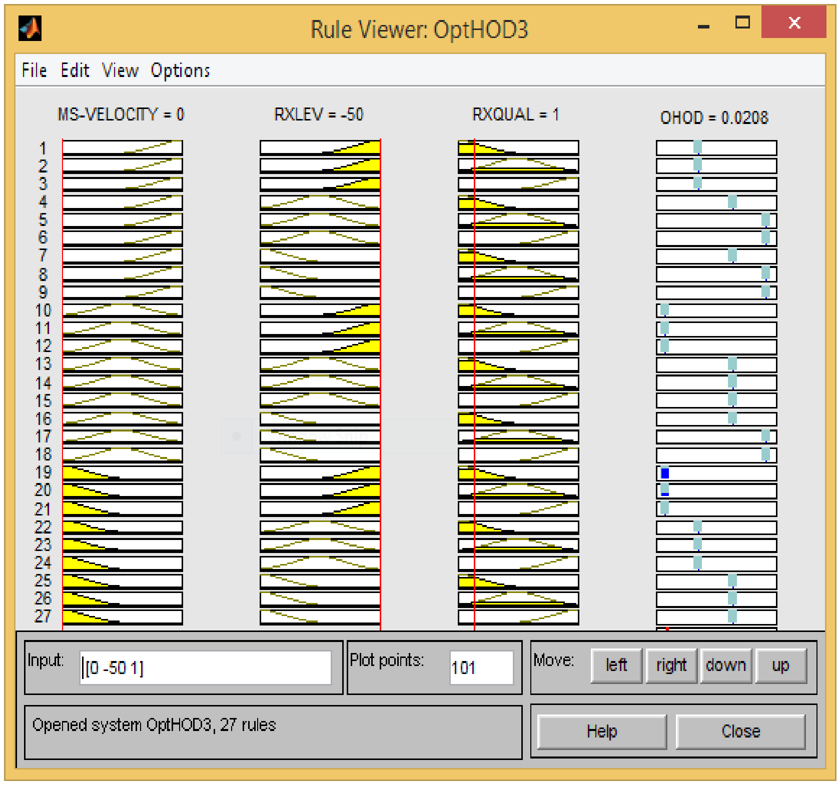

Fig. 5.12: Another output at 0 km/hr. MS Velocity

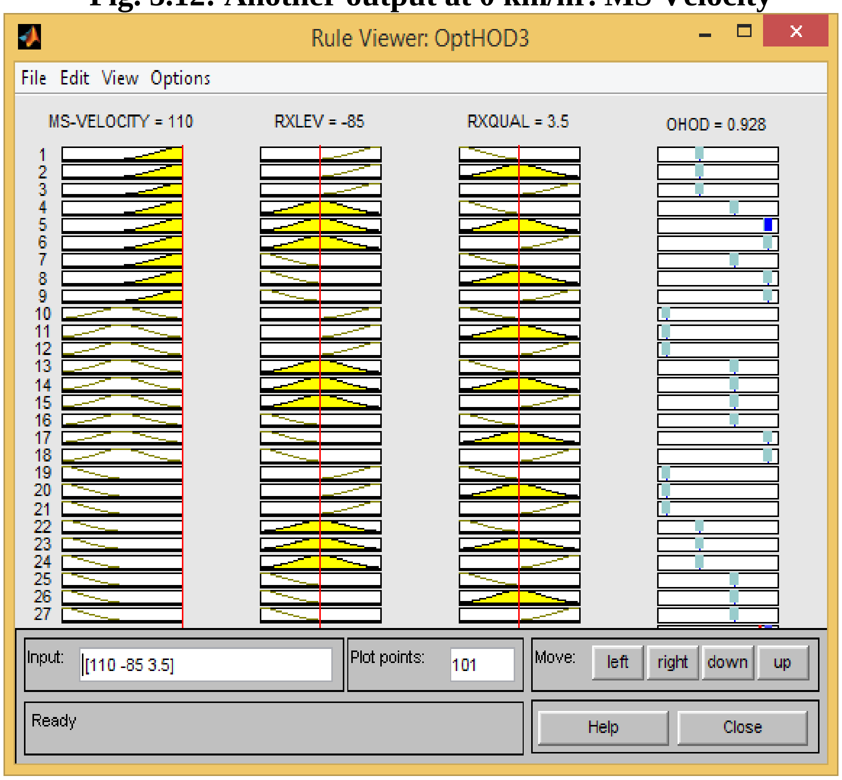

Fig. 5.13: Output at 110km/hr. MS Velocity

Say the roads are clear and the mobile station is at 110km/hr as shown in Fig. 5.13, the handover decision will be a yes since the OHOD is 0.928.

Fig.5.14 shows a plot of OHOD against the MS Velocity when the RxLev is at 30 and the RxQual is at 3.1. This graph displays a scenario for a mobile station on motion and where the signal level and quality numbers are practically common. Taking a case of a walking person on phone at 5km/hr, the OHOD is approximately 0.35 which indicates that the MS should wait to be transferred to another cell. A learner under instructions driving between 20 to 55km/hr should still wait to be handed over. While moving between 55 and 110km/hr, the MS should be ready for handover as it will cross the cell boundary in the near future.

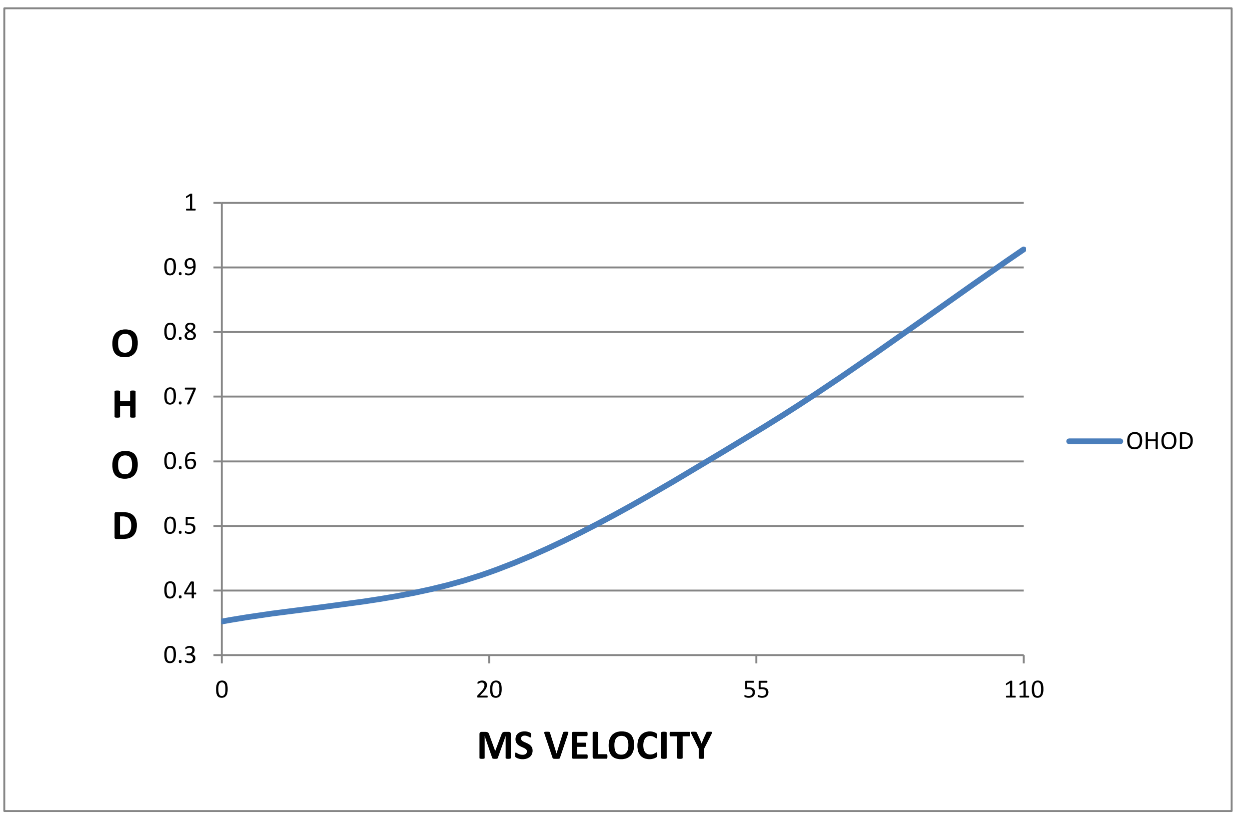

Fig. 5.14: OHOD VS MS Velocity at RxLev =30 and RxQual=3.5

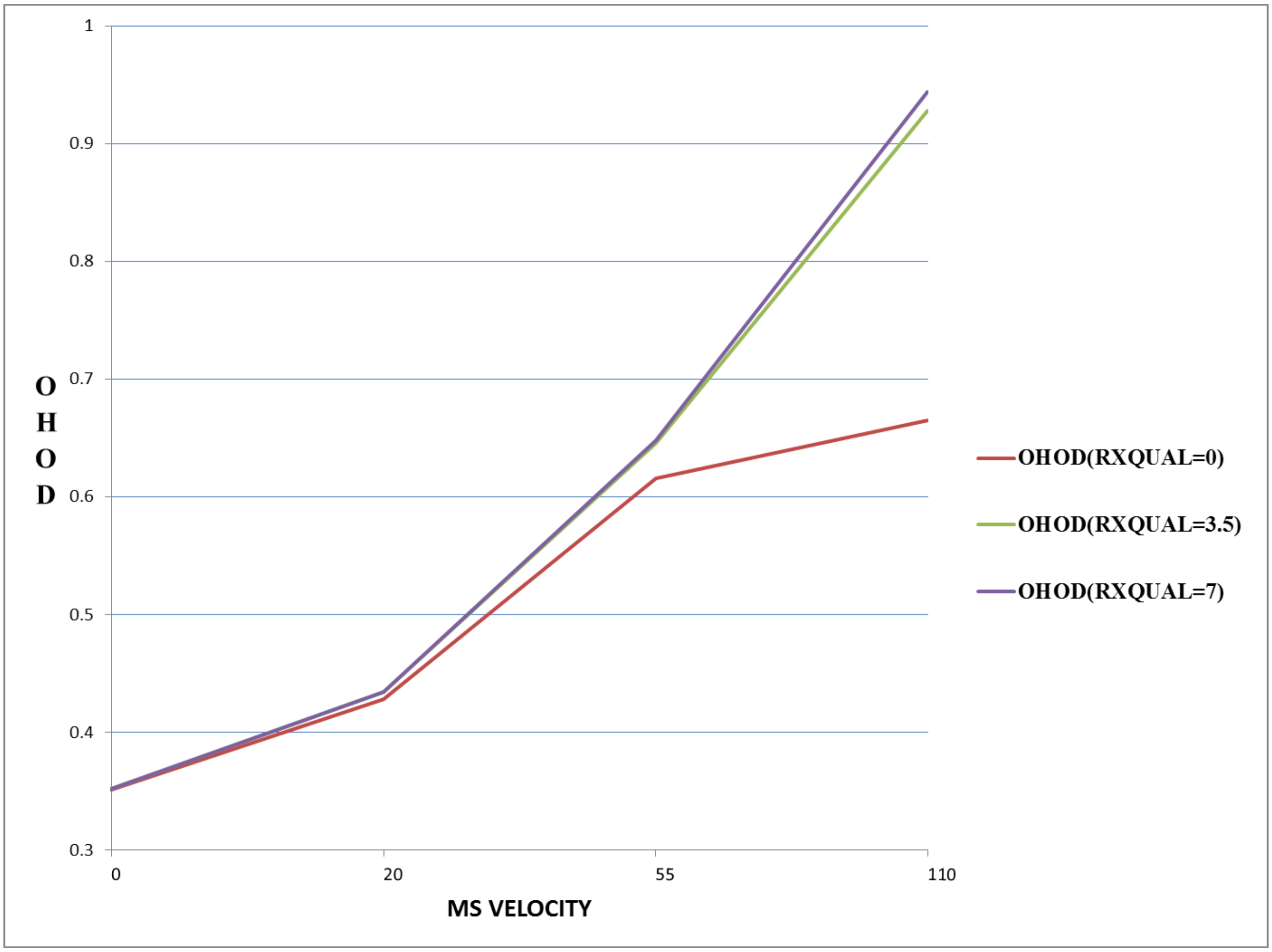

Fig. 5.15: MS Velocity VS OHOD at different RxQual level

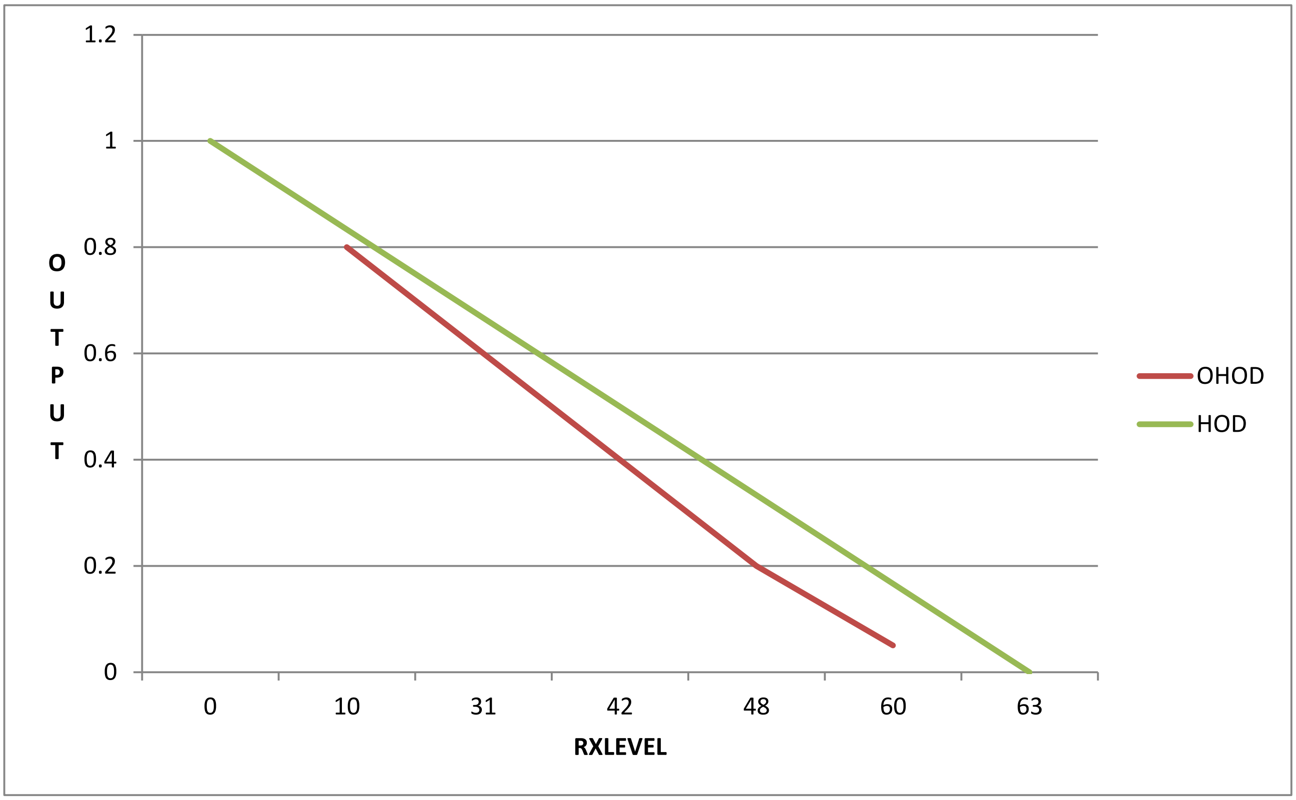

Fig. 5.16: Output with (OHOD) and without (HOD) Fuzzy Logic System

Fig. 5.15 shows the MS Velocity against the OHOD at different RxQual levels. The need for handover increases with increased MS Velocity. There is a noticeable difference between the graph of RxQual=0, and those of RxQual =3.5 and RxQual=7. Considering that the latter are more practical, there is little difference between the two graphs.

Fig. 5.16 shows the Output with (OHOD) and without (HOD) the Fuzzy Logic System at different RxLev values. The need to handover decreases with increased RxLev as there is improved conditions to sustain the MS at the cell. The MS will be transferred to the next cell much later with the fuzzy logic system than the time taken to handover when without the fuzzy logic system. The FLS brings out its advantage of utilising the network resources optimally before handing over.

5.5 FINDINGS FROM APPENDICES

From Appendix A, it can be deduced that a handover (HO) call drop may not necessarily result to a radio call drop for instance cells 235NB (190) and 112(67).

Sometimes the HO call drop could result to a radio call drop say in 237NB (193), 156NB (46) and 043NB (88).

The logs can also form a discussion on why some sites have high numbers of call drops.

From Appendix B, two cells draw attention: Src cells 13572(in yellow) and 12512(in green). One can use the logs to follow up why the particular cells have high numbers of outgoing intercell handover success rate (HSR) that is below 90%.

All in all it can be gathered from the appendices that there are handover issues that could be improved.

CHAPTER 6: CONCLUSION

6.1 GENERAL CONCLUSION

The main objective of this thesis was to optimise handover decision process of a mobile station in a cellular radio network.This has been done specifically by developing a fuzzy logic model for handover decision making that was based on the situation in Kenya. Logs were obtained to show the Kenyan case. It was realised that there was still room for improvement to reduce the call drops due to handover problems.

An algorithm that determined the best time to handover was then developed. Since handover depends on environmental and other factors that vary, the fuzzy logic system provides good result as it works with imprecise data. Better decisions were made on the best time to handover to a given cell based on the thresholds of the input parameters. Sets of rules were formulated out of technical knowledge, logic and experience for three, two and single input parameters to the FIS. The general view of the algorithm development is given by Fig. 6.1. In the algorithm, it was deduced that, ping-pong effect can be avoided by keeping the other parameters at an optimal level as handover is reduced for a mobile station moving at high speed.

An analysis of using the multi-input fuzzy logic system for handover has been done. The need to handover varies depending on the input(s) to the FIS. The probability of handover can vary depending on the various factors: RxQual, RxLev, and the MS Velocity. An OHOD is realised with more inputs thus the criteria parameters used in the algorithm.

The OHOD output of 0.646, for three inputs, is different from, 0.108 for two inputs and 0.5 for one input when the mean input values are considered.

An optimised handover decision process was realised when the three inputs are considered.

With this idea, there will be better decisions made concerning the best time to handover to a given cell thus reduced handover dropping probabilities.

It has been realised that reasonable conditions for handing over based on one parameter does not necessarily mean that the mobile station will be moved to the next cell.

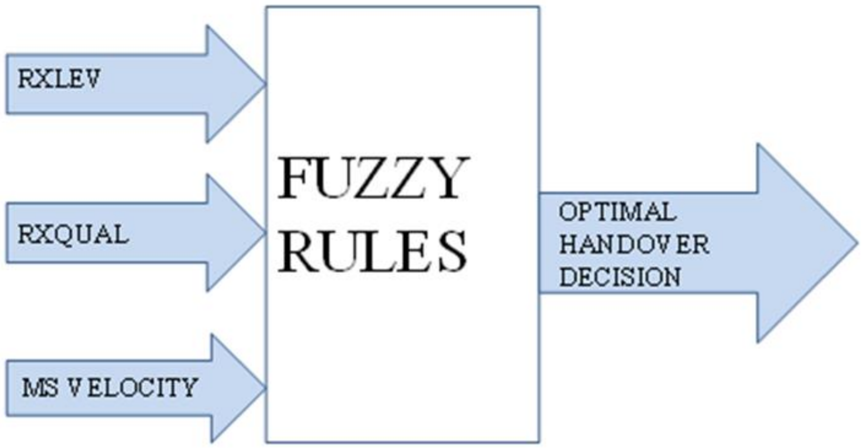

Fig. 6.1: Algorithm model

The application of the results and findings in this thesis include but not limited to:

Use by Mobile Communication System Developers when coming up with algorithms that checks out for handover issues. It has been realised that RxQual, RxLev and MS Velocity are key parameters in algorithms for handing over and the same can thus be included in the system.

The Kenyan mobile service providers can consider the three parameters when tuning the handover parameters.

6.2 CONTRIBUTION TO THE BODY OF KNOWLEDGE

This work has demonstrated the efforts that can be made by telecommunication professionals and their employers to optimise their network performance. For instance, the study has shown that handover latency can be reduced by leveraging the diversity between network interfaces.

The literature has also demonstrated the need for network engineers to implement handover techniques that ensure mobile users can be transferred to base stations without affecting the quality of their call. The study has provided indications for steps that can be used to improve the quality of the telecommunications service provided to mobile phone users. The appendix shows the logs from service providers with regards to handover. This portrays that there is room for improvement to attain the set target by the Communications Authority of Kenya. Numerous calculations that exist have not exploited the advantage of considering handover with multi-criteria that can give preferred execution over the single rule calculations because of the adaptable idea of handover measure. An Optimal Handover Decision (OHOD) making algorithm using fuzzy logic based on multi-criteria is provided here.

6.3 RECOMMENDATION AND FURTHER WORK

Optimisation of handover parameters is very essential in the telecommunication industry. The following can be done as advancements in the work presented here.

- Implement the work to validate the actual level of improvement in handover success rate in reality.
- An umbrella cell can be included to assess the impact of handover decision especially when the MS velocity is high.
- This work is based on the GSM network but the idea could be extended to the other networks.

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APPENDICES

APPENDIX A: NAIROBI LOGS EXTRACT

1. Index	3076	3071	12441	11627	11545	11025	10103	9436
2. Start Time	6/04/2015 00:00	6/04/2015 00:00	6/16/2015 0:00	6/15/2015 0:00	6/15/2015 0:00	6/14/2015 0:00	6/13/2015 0:00	06/12/2015 00:00
3. End Time	6/05/2015 00:00	6/05/2015 00:00	6/17/2015 0:00	6/16/2015 0:00	6/16/2015 0:00	6/15/2015 0:00	6/14/2015 0:00	6/13/2015 0:00
4. Query Granularity	1Day(s)	1Day(s)	1Day(s)	1Day(s)	1Day(s)	1Day(s)	1Day(s)	1Day(s)
5. SUBNETWORK	1	1	1	1	1	1	1	1
6. SUBNETWORK Name	NBBSC01 (1)	NBBSC01 (1)	NBBSC01(1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)
7. ME	1	1	1	1	1	1	1	1
8. ME Name	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)
9. SITE	193	190	67	67	46	112	88	136
10. SITE Name	237NB (193)	235NB (190)	112NB (67)	112NB (67)	156NB (46)	407NB (112)	043NB (88)	412NB_Hot Spot(136)
11. BTS	1	5	6	6	2	1	4	4
12. BTS NAME	237NBA	235NBBD	112NBCD	112NBCD	156NBB	407NBAD	043NBAD	412NBAD
13. Location(LAC)	11101	11101	11101	11101	11101	11101	11101	11101
14. CI(CI)	2371	2355	1126	1126	1562	4074	434	4124
15. cell latitude	90	90	90	90	90	90	90	90
16. cell longitude	180	180	180	180	180	180	180	180

17. cell ante Height	35	35	35	35	35	35	35	35
18. cell ante Azimuth	0	0	0	0	0	0	0	0
19. cell address								
20. ho_sr_y	1	1	1	1	1	1	1	1
21. NTW_A_2G Handover Success Rate	87.45%	77.70%	97.02%	97.08%	94.50%	87.50%	84.93%	85.71%
22. NTW_A_2G Handover Success Rate Global	87.21%	77.53%	95.07%	95.60%	94.25%	87.50%	84.72%	85.71%
23. Total number of dual band handover failure	35	726	3	4	0	0	39	1
24. Number of handover execution	1442	1350	4193	3155	3657	16	816	7
25. Total number of handover request	2526	4978	7235	6195	6436	25	1414	28
26. Total number of successful handover	2294	3931	7086	6076	6039	20	1249	25
27. Total number of dual band handover attempts	153	3317	923	456	0	4	384	12
28. Total number of successful dual band handover	118	2591	920	452	0	4	345	11
29. TCH attempt total number(exclude handover	2260	2239	13894	15527	5141	43	5149	23
30. TCH overflow total number(exclude handover)	0	0	972	1436	3	0	0	0

31. TCH attempt total number(include handover	3348	5874	19256	23501	7925	52	5763	44
32. TCH overflow total number(include handover)	0	0	3286	6365	4	0	0	0
33. TCH seizure total number(exclude handover	2227	2236	12907	14086	4836	43	5149	23
34. TCH seizure total number(include handover	3260	5118	15925	17099	7419	49	5705	42
35. TCH allocate failure number without handover	33	3	1701	2719	304	0	0	0
36. TCH allocate no success number without handover	33	3	1701	2719	304	0	0	0
37. TCH allocate no success number with handover	84	749	4039	7675	501	3	42	2
38. TCH allocate failure number with handover	84	749	4039	7675	501	3	42	2
39. Number of SDCCH handover attempts due to downlink rapid drop(Times)	0	0	0	0	0	0	0	0
40. Number of TCH/F handover attempts due to downlink rapid drop(Times)	0	0	0	0	0	0	0	0

41. Number of TCH/H handover attempts due to downlink rapid drop(Times)	0	0	0	0	0	0	0	0
42. Number of SDCCH handover attempts due to downlink quality rapid drop(Times)	0	0	0	0	0	0	0	0
43. Number of TCH/F handover attempts due to downlink quality rapid drop(Times)	0	0	0	0	0	0	0	0
44. Number of TCH/H handover attempts due to downlink quality rapid drop(Times)	0	0	0	0	0	0	0	0
45. 2G Dropped Call rate	0.94%	1.65%	0.31%	0.24%	3.65%	0.00%	0.31%	0.00%
46. TCH in call drop rate (include handover) (%)	0.64%	0.72%	0.33%	0.31%	2.39%	0.00%	0.28%	0.00%
47. TCH in call drop rate (exclude handover) (%)	0.94%	1.65%	0.40%	0.38%	3.66%	0.00%	0.31%	0.00%
48. SDCCH channel in call drop rate(%	0.21%	0.06%	0.06%	0.10%	0.14%	0.00%	0.06%	0.00%
49. TCH drop due to handover rate (%)	14.29%	54.05%	53.85%	49.06%	16.38%	0.00%	25.00%	0.00%
50. HO Call Drop	3	20	28	26	29	0	4	0

51. Radio Call Drop	18	17	24	27	148	0	12	0
1. Index	634	1442	676	3884	8850	7006	5539	5070
2. Start Time	06/01/2015 00:00	06/02/2015 00:00	06/01/2015 00:00	06/05/2015 00:00	06/11/2015 00:00	06/09/2015 00:00	06/07/2015 00:00	06/07/2015 00:00
3. End Time	06/02/2015 00:00	06/03/2015 00:00	06/02/2015 00:00	06/06/2015 00:00	06/12/2015 00:00	06/10/2015 00:00	06/08/2015 00:00	06/08/2015 00:00
4. Query Granularity	1Day(s)	1Day(s)	1Day(s)	1Day(s)	1Day(s)	1Day(s)	1Day(s)	1Day(s)
5. SUBNETWORK	1	1	1	1	1	1	1	1
6. SUBNETWORK Name	NBBSC1 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)
7. ME	1	1	1	1	1	1	1	1
8. ME Name	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)
9. SITE	193	190	207	190	217	140	199	58
10. SITE Name	237NB (193)	235NB (190)	265NB (207)	235NB (190)	167NB (217)	129NB (140)	254NB (199)	115NB (58)
11. BTS	1	4	5	4	2	5	4	5
12. BTS NAME	237NBA	235NBAD	265NBBD	235NBAD	167NBB	129NBBD	254NBAD	115NBBD
13. Location(LAC)	11101	11101	11101	11101	11101	11101	11101	11101
14. CI(CI)	2371	2354	2655	2354	1672	1295	2544	1155
15. cell latitude	90	90	90	90	90	90	90	90
16. cell longitude	180	180	180	180	180	180	180	180
17. cell ante Height	35	35	35	35	35	35	35	35
18. cell ante Azimuth	0	0	0	0	0	0	0	0
19. cell address								
20. ho_sr_y	1	1	1	1	1	1	1	1
21. NTW_A_2G Handover Success Rate	89.98%	76.81%	88.52%	85.90%	89.44%	89.03%	85.39%	84.67%

22. NTW_A_2G Handover Success Rate Global	89.70%	76.63%	87.80%	85.22%	89.44%	88.53%	85.39%	84.26%
23. Total number of dual band handover failure	39	437	4	397	0	12	1	2
24. Number of handover execution	1597	841	244	752	303	1231	89	809
25. Total number of handover request	2826	3032	511	2902	799	2914	207	1418
26. Total number of successful handover	2586	2389	474	2382	743	2721	192	1290
27. Total number of dual band handover attempts	155	1945	29	1923	0	800	35	160
28. Total number of successful dual band handover	116	1508	25	1526	0	788	34	158
29. TCH attempt total number(exclude handover	2132	2056	167	1895	459	367	144	382
30. TCH overflow total number(exclude handover)	0	0	0	0	0	0	0	0
31. TCH attempt total number(include handover	3363	4250	434	4049	955	2054	263	991
32. TCH overflow total number(include handover)	0	0	0	0	0	0	0	0
33. TCH seizure total number(exclude	2108	2053	164	1893	452	364	144	378

handover								
34. TCH seizure total number(include handover	3257	3796	422	3629	924	1989	260	983
35. TCH allocate failure number without handover	24	3	3	2	7	3	0	4
36. TCH allocate no success number without handover	24	3	3	2	7	3	0	4
37. TCH allocate no success number with handover	104	451	12	416	31	61	2	8
38. TCH allocate failure number with handover	104	451	12	416	31	61	2	8
39. Number of SDCCH handover attempts due to downlink rapid drop(Times)	0	0	0	0	0	0	0	0
40. Number of TCH/F handover attempts due to downlink rapid drop(Times)	0	0	0	0	0	0	0	0
41. Number of TCH/H handover attempts due to downlink rapid drop(Times)	0	0	0	0	0	0	0	0

42. Number of SDCCH handover attempts due to downlink quality rapid drop(Times)	0	0	0	0	0	0	0	0
43. Number of TCH/F handover attempts due to downlink quality rapid drop(Times)	0	0	0	0	0	0	0	0
44. Number of TCH/H handover attempts due to downlink quality rapid drop(Times)	0	0	0	0	0	0	0	0
45. 2G Dropped Call rate	1.04%	1.12%	1.22%	1.58%	1.11%	4.40%	0.69%	0.79%
46. TCH in call drop rate (include handover) (%)	0.68%	0.61%	0.47%	0.83%	0.54%	0.80%	0.38%	0.31%
47. TCH in call drop rate (exclude handover) (%)	1.04%	1.12%	1.22%	1.58%	1.11%	4.40%	0.69%	0.79%
48. SDCCH channel in call drop rate(%	0.04%	0.06%	0.23%	0.08%	0.07%	0.20%	0.00%	0.06%
49. TCH drop due to handover rate (%)	31.82%	34.78%	0.00%	43.33%	40.00%	50.00%	0.00%	0.00%
50. HO Call Drop	7	8	0	13	2	8	0	0
51. Radio Call Drop	15	15	2	17	2	8	1	3
1. Index	5067	4677	3886	3885	3395	3890	4667	9264
2. Start Time	06/07/2015	06/06/2015	06/05/2015	06/05/2015	06/05/2015	06/05/201	06/06/201	06/12/2015

	00:00	00:00	00:00	00:00	00:00	5 00:00	5 00:00	00:00
3. End Time	06/08/2015 00:00	06/07/2015 00:00	06/06/2015 00:00	06/06/2015 00:00	06/06/2015 00:00	06/06/201 5 00:00	06/07/201 5 00:00	6/13/2015 0:00
4. Query Granularity	1Day(s)	1Day(s)	1Day(s)	1Day(s)	1Day(s)	1Day(s)	1Day(s)	1Day(s)
5. SUBNETWORK	1	1	1	1	1	1	1	1
6. SUBNETWORK Name	NBBSC0 (1)	NBBSC0 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)
7. ME	1	1	1	1	1	1	1	1
8. ME Name	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)
9. SITE	58	182	190	190	44	193	178	84
10. SITE Name	115NB (58)	188NB (182)	235NB (190)	235NB (190)	021NB (44)	237NB (193)	206NB (178)	379NB (84)
11. BTS	2	4	6	5	3	1	6	5
12. BTS NAME	115NBB	188NBAD	235NBCD	235NBBD	021NBC	237NBA	206NBC	379NBBD
13. Location(LAC)	11101	11101	11101	11101	11101	11101	11101	11101
14. CI(CI)	1152	1884	2356	2355	213	2371	2063	3795
15. cell latitude	90	90	90	90	90	90	90	90
16. cell longitude	180	180	180	180	180	180	180	180
17. cell ante Height	35	35	35	35	35	35	35	35
18. cell ante Azimuth	0	0	0	0	0	0	0	0
19. cell address								
20. ho_sr_y	1	1	1	1	1	1	1	1
21. NTW_A_2G Handover Success Rate	87.40%	89.19%	85.45%	74.71%	88.69%	87.76%	88.89%	74.07%
22. NTW_A_2G Handover Success Rate Global	87.40%	88.51%	84.84%	74.35%	88.45%	87.45%	88.89%	68.54%

23. Total number of dual band handover failure	3	8	208	902	81	34	0	3
24. Number of handover execution	127	259	275	1455	5758	1413	9	2603
25. Total number of handover request	231	667	958	5371	9853	2414	22	6404
26. Total number of successful handover	211	629	708	4078	8952	2185	20	5706
27. Total number of dual band handover attempts	74	285	504	3595	451	109	2	1132
28. Total number of successful dual band handover	71	277	296	2693	370	75	2	1129
29. TCH attempt total number(exclude handover	38	605	489	2037	7841	1957	10	3859
30. TCH overflow total number(exclude handover)	0	0	0	0	0	0	0	0
31. TCH attempt total number(include handover	142	1014	1175	5963	11944	2962	23	7668
32. TCH overflow total number(include handover)	0	0	0	0	0	0	0	4
33. TCH seizure total number(exclude handover	38	603	488	2025	7780	1942	10	3854
34. TCH seizure total number(include handover	138	1001	961	5016	11625	2887	22	7632

35. TCH allocate failure number without handover	0	2	1	12	61	15	0	5
36. TCH allocate no success number without handover	0	2	1	12	61	15	0	5
37. TCH allocate no success number with handover	4	12	211	937	311	71	1	32
38. TCH allocate failure number with handover	4	12	211	937	311	71	1	32
39. Number of SDCCH handover attempts due to downlink rapid drop(Times)	0	0	0	0	0	0	0	0
40. Number of TCH/F handover attempts due to downlink rapid drop(Times)	0	0	0	0	0	0	0	0
41. Number of TCH/H handover attempts due to downlink rapid drop(Times)	0	0	0	0	0	0	0	0
42. Number of SDCCH handover attempts due to downlink quality rapid drop(Times)	0	0	0	0	0	0	0	0

43. Number of TCH/F handover attempts due to downlink quality rapid drop(Times)	0	0	0	0	0	0	0	0
44. Number of TCH/H handover attempts due to downlink quality rapid drop(Times)	0	0	0	0	0	0	0	0
45. 2G Dropped Call rate	2.63%	0.33%	1.64%	2.22%	0.77%	0.77%	0.00%	0.67%
46. TCH in call drop rate (include handover) (%)	0.72%	0.20%	0.83%	0.90%	0.52%	0.52%	0.00%	0.34%
47. TCH in call drop rate (exclude handover) (%)	2.63%	0.33%	1.64%	2.22%	0.77%	0.77%	0.00%	0.67%
48. SDCCH channel in call drop rate(%	0.54%	0.05%	0.10%	0.06%	0.09%	0.10%	0.00%	0.08%
49. TCH drop due to handover rate (%)	100.00%	100.00%	37.50%	42.22%	35.00%	40.00%	0.00%	53.85%
50. HO Call Drop	1	2	3	19	21	6	0	14
51. Radio Call Drop	0	0	5	26	39	9	0	12
1. Index	9263	7918	8748	8849	4668	4620	2263	1448
2. Start Time	06/12/2015 00:00	06/10/2015 00:00	06/11/2015 00:00	06/11/2015 00:00	06/06/2015 00:00	06/06/2015 00:00	06/03/2015 00:00	06/02/2015 00:00
3. End Time	6/13/2015 0:00	06/11/2015 00:00	06/12/2015 00:00	06/12/2015 00:00	06/07/2015 00:00	06/07/2015 00:00	06/04/2015 00:00	06/03/2015 00:00
4. Query Granularity	1Day(s)	1Day(s)	1Day(s)	1Day(s)	1Day(s)	1Day(s)	1Day(s)	1Day(s)
5. SUBNETWORK	1	1	1	1	1	1	1	1

6. SUBNETWORK Name	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)
7. ME	1	1	1	1	1	1	1	1
8. ME Name	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01(1)
9. SITE	84	174	180	217	179	161	193	193
10. SITE Name	379NB (84)	472NB (174)	241NB (180)	167NB (217)	567NB (179)	183NB (161)	237NB (193)	237NB (193)
11. BTS	4	5	5	1	1	3	2	1
12. BTS NAME	379NBAD	472NBBD	241NBBD	167NBA	567NBA	183NBC	237NBB	237NBA
13. Location(LAC)	11101	11101	11101	11101	11101	11101	11101	11101
14. CI(CI)	3794	4725	2415	1671	5671	1833	2372	2371
15. cell latitude	90	90	90	90	90	90	90	90
16. cell longitude	180	180	180	180	180	180	180	180
17. cell ante Height	35	35	35	35	35	35	35	35
18. cell ante Azimuth	0	0	0	0	0	0	0	0
19. cell address								
20. ho_sr_y	1	1	1	1	1	1	1	1
21. NTW_A_2G Handover Success Rate	79.55%	88.67%	82.66%	79.10%	85.19%	87.95%	89.51%	89.79%
22. NTW_A_2G Handover Success Rate Global	78.34%	88.67%	66.67%	77.35%	85.19%	87.95%	89.19%	89.34%
23. Total number of dual band handover failure	15	5	7	0	0	0	24	27
24. Number of handover execution	2606	406	2018	177	135	83	1392	1606

25. Total number of handover request	4038	909	4279	540	344	118	2649	2808
26. Total number of successful handover	3473	856	3901	484	256	104	2439	2599
27. Total number of dual band handover attempts	380	91	488	0	0	0	89	139
28. Total number of successful dual band handover	365	86	481	0	0	0	65	112
29. TCH attempt total number(exclude handover	10089	391	1760	950	832	425	1483	2092
30. TCH overflow total no.(exclude handover)	271	0	0	0	0	0	0	0
31. TCH attempt total number(include handover	11962	894	4024	1313	1041	460	2743	3297
32. TCH overflow total number(include handover)	709	0	1	0	0	0	0	0
33. TCH seizure total number(exclude handover	9812	391	1759	944	831	421	1463	2068
34. TCH seizure total number(include handover	11212	887	3992	1288	972	452	2656	3225
35. TCH allocate failure number without handover	453	0	1	6	1	4	20	24
36. TCH allocate no success number	453	0	1	6	1	4	20	24

without handover								
37. TCH allocate no success number with handover	923	7	30	25	69	8	84	69
38. TCH allocate failure number with handover	923	7	30	25	69	8	84	69
39. Number of SDCCH handover attempts due to downlink rapid drop(Times)	0	0	0	0	0	0	0	0
40. Number of TCH/F handover attempts due to downlink rapid drop(Times)	0	0	0	0	0	0	0	0
41. Number of TCH/H handover attempts due to downlink rapid drop(Times)	0	0	0	0	0	0	0	0
42. Number of SDCCH handover attempts due to downlink quality rapid drop(Times)	0	0	0	0	0	0	0	0
43. Number of TCH/F handover attempts due to downlink quality rapid drop(Times)	0	0	0	0	0	0	0	0

44. Number of TCH/H handover attempts due to downlink quality rapid drop(Times)	0	0	0	0	0	0	0	0
45. 2G Dropped Call rate	0.15%	1.02%	1.14%	0.21%	0.00%	0.24%	1.43%	0.68%
46. TCH in call drop rate (include handover) (%)	0.15%	0.45%	0.50%	0.16%	0.00%	0.22%	0.79%	0.43%
47. TCH in call drop rate (exclude handover) (%)	0.17%	1.02%	1.14%	0.21%	0.00%	0.24%	1.44%	0.68%
48. SDCCH channel in call drop rate(%	0.11%	0.15%	0.14%	0.01%	0.01%	0.14%	0.01%	0.09%
49. TCH drop due to handover rate (%)	11.76%	50.00%	40.00%	0.00%	0.00%	100.00%	47.62%	14.29%
50. HO Call Drop	2	2	8	0	0	1	10	2
51. Radio Call Drop	15	2	12	1	0	0	11	12

1. Index	1443	2082	3070	629	628
2. Start Time	06/02/2015 00:00	06/03/2015 00:00	06/04/2015 00:00	06/01/2015 00:00	06/01/2015 00:00
3. End Time	06/03/2015 00:00	06/04/2015 00:00	06/05/2015 00:00	06/02/2015 00:00	06/02/2015 00:00
4. Query Granularity	1Day(s)	1Day(s)	1Day(s)	1Day(s)	1Day(s)
5. SUBNETWORK	1	1	1	1	1
6. SUBNETWORK Name	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)
7. ME	1	1	1	1	1

8. ME Name	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)	NBBSC01 (1)
9. SITE	190	127	190	190	190
10. SITE Name	235NB (190)	122NB (127)	235NB (190)	235NB (190)	235NB (190)
11. BTS	5	5	4	5	4
12. BTS NAME	235NBBD	122NBBD	235NBAD	235NBBD	235NBAD
13. Location(LAC)	11101	11101	11101	11101	11101
14. CI(CI)	2355	1225	2354	2355	2354
15. cell latitude	90	90	90	90	90
16. cell longitude	180	180	180	180	180
17. cell ante Height	35	35	35	35	35
18. cell ante Azimuth	0	0	0	0	0
19. cell address					
20. ho_sr_y	1	1	1	1	1
21. NTW_A_2G Handover Success Rate	80.94%	89.30%	77.48%	79.51%	81.13%
22. NTW_A_2G Handover Success Rate Global	80.24%	88.89%	77.29%	79.06%	80.95%
23. Total number of dual band handover failure	844	8	381	706	386
24. Number of handover execution	1259	1532	795	1586	885
25. Total number of handover request	5009	3096	2775	5556	3099
26. Total number of successful handover	3908	2892	2210	4511	2536

27. Total number of dual band handover attempts	3439	244	1753	3615	1924
28. Total number of successful dual band handover	2595	236	1372	2909	1538
29. TCH attempt total number(exclude handover	2208	2859	1975	2801	2089
30. TCH overflow total number(exclude handover)	0	0	0	0	0
31. TCH attempt total number(include handover	5968	4426	3957	6778	4305
32. TCH overflow total number(include handover)	0	0	0	0	0
33. TCH seizure total number(exclude handover	2207	2852	1975	2800	2089
34. TCH seizure total number(include handover	5096	4376	3569	6050	3907
35. TCH allocate failure number without handover	1	7	0	1	0
36. TCH allocate no success number without handover	1	7	0	1	0
37. TCH allocate no success number with handover	862	47	386	721	396

38. TCH allocate failure number with handover	862	47	386	721	396
39. Number of SDCCH handover attempts due to downlink rapid drop(Times)	0	0	0	0	0
40. Number of TCH/F handover attempts due to downlink rapid drop(Times)	0	0	0	0	0
41. Number of TCH/H handover attempts due to downlink rapid drop(Times)	0	0	0	0	0
42. Number of SDCCH handover attempts due to downlink quality rapid drop(Times)	0	0	0	0	0
43. Number of TCH/F handover attempts due to downlink quality rapid drop(Times)	0	0	0	0	0
44. Number of TCH/H handover attempts due to downlink quality rapid drop(Times)	0	0	0	0	0
45. 2G Dropped Call rate	1.68%	0.95%	0.91%	1.36%	1.24%

46. TCH in call drop rate (include handover) (%)	0.73%	0.62%	0.50%	0.63%	0.67%
47. TCH in call drop rate (exclude handover) (%)	1.68%	0.95%	0.91%	1.36%	1.24%
48. SDCCH channel in call drop rate(%	0.11%	0.07%	0.03%	0.05%	0.04%
49. TCH drop due to handover rate (%)	54.05%	11.11%	38.89%	44.74%	61.54%
50. HO Call Drop	20	3	7	17	16
51. Radio Call Drop	17	24	11	21	10

APPENDIX B: NAKURU LOGS EXTRACT

Start Time	SRC CELL	TGT CELL	H370c:Out going Inter-Cell Handover Requests (None)	H372:Failed Outgoing Inter-Cell Handovers (None)	H373:Successful Outgoing Inter-Cell Handovers (None)	RH373: Outgoing Inter-Cell Handover Success Rate (%)
08/05/2015 22:00	15640	17832	67	18	49	73.134
08/05/2015 00:00	12455	15641	8	1	7	87.5
08/05/2015 00:00	15640	12451	14	2	12	85.714
08/05/2015 01:00	12455	15641	4	1	3	75
08/05/2015 02:00	13572	17832	5	1	4	80
08/05/2015 02:00	12512	12474	10	4	6	60
08/05/2015 02:00	12512	13564	23	16	7	30.435
08/05/2015 03:00	12531	13651	2	1	1	50
08/05/2015 04:00	13572	17832	3	2	1	33.333
08/05/2015 04:00	13572	17831	2	1	1	50
08/05/2015 06:00	14245	13506	7	1	6	85.714
08/05/2015 07:00	12512	13372	3	1	2	66.667
08/05/2015 07:00	12455	17831	29	3	26	89.655
08/05/2015 07:00	13740	12400	9	1	8	88.889
08/05/2015 07:00	13572	15640	11	2	9	81.818
08/05/2015 07:00	13744	15335	6	1	5	83.333
08/05/2015 07:00	12455	12452	4	1	3	75
08/05/2015 07:00	13740	15335	6	1	5	83.333
08/05/2015 07:00	13740	13741	2	1	1	50
08/05/2015 07:00	13740	15332	3	2	1	33.333
08/05/2015 07:00	12512	12514	13	5	8	61.538
08/05/2015 07:00	13740	15330	5	4	1	20
08/05/2015 07:00	14251	12505	5	1	4	80

08/05/2015 07:00	12512	14422	20	4	16	80
08/05/2015 08:00	13740	12401	9	1	8	88.889
08/05/2015 08:00	13572	17832	111	12	99	89.189
08/05/2015 08:00	13572	17831	29	3	26	89.655
08/05/2015 08:00	12455	17831	43	5	38	88.372
08/05/2015 08:00	13572	12472	44	5	39	88.636
08/05/2015 08:00	12512	12510	16	5	11	68.75
08/05/2015 08:00	12531	13651	9	1	8	88.889
08/05/2015 08:00	14251	12501	3	1	2	66.667
08/05/2015 08:00	13744	15331	17	3	14	82.353
08/05/2015 08:00	13744	12080	9	1	8	88.889
08/05/2015 08:00	13740	15332	3	1	2	66.667
08/05/2015 08:00	12512	12514	52	6	46	88.462
08/05/2015 08:00	13740	15334	6	1	5	83.333
08/05/2015 08:00	13740	15330	9	5	4	44.444
08/05/2015 08:00	14240	13374	13	2	11	84.615
08/05/2015 09:00	13372	13374	16	5	11	68.75
08/05/2015 09:00	12470	12475	13	2	11	84.615
08/05/2015 09:00	12512	13372	23	4	19	82.609
08/05/2015 09:00	13740	12401	9	2	7	77.778
08/05/2015 09:00	14240	13370	6	1	5	83.333
08/05/2015 09:00	13572	14312	18	2	16	88.889
08/05/2015 09:00	13744	16652	3	1	2	66.667
08/05/2015 09:00	13372	13370	3	1	2	66.667
08/05/2015 09:00	12162	12512	2	1	1	50
08/05/2015 09:00	13740	15331	32	4	28	87.5
08/05/2015 09:00	13744	15335	7	2	5	71.429
08/05/2015 09:00	13572	12471	4	1	3	75
08/05/2015 09:00	13572	13562	4	1	3	75
08/05/2015 09:00	13740	15332	3	2	1	33.333

08/05/2015 09:00	13740	15330	14	7	7	50
08/05/2015 09:00	12512	13562	4	1	3	75
08/05/2015 09:00	13572	13662	4	2	2	50
08/05/2015 09:00	15640	15331	3	1	2	66.667
08/05/2015 10:00	13572	17835	57	7	50	87.719
08/05/2015 10:00	15640	12472	3	1	2	66.667
08/05/2015 10:00	12455	17832	12	2	10	83.333
08/05/2015 10:00	13572	14312	16	5	11	84.615
08/05/2015 10:00	12531	15481	46	5	41	89.13
08/05/2015 10:00	12174	13360	8	1	7	87.5
08/05/2015 10:00	12470	13585	7	1	6	85.714
08/05/2015 10:00	13740	15331	51	8	43	84.314
08/05/2015 10:00	13740	12080	19	6	13	72.222
08/05/2015 10:00	15640	14312	29	4	25	86.207
08/05/2015 10:00	13572	12450	7	1	6	85.714
08/05/2015 10:00	12512	13562	6	3	3	75
08/05/2015 10:00	13372	13472	6	1	5	83.333
08/05/2015 10:00	13572	13662	3	1	2	66.667
08/05/2015 11:00	12455	17832	7	1	6	85.714
08/05/2015 11:00	12455	17831	78	10	68	87.179
08/05/2015 11:00	13572	14312	14	2	12	85.714
08/05/2015 11:00	12162	12164	3	1	2	66.667
08/05/2015 11:00	13372	13510	4	1	3	75
08/05/2015 11:00	13372	13370	4	1	3	75
08/05/2015 11:00	13572	15640	9	3	6	66.667
08/05/2015 11:00	12470	13530	3	1	2	66.667
08/05/2015 11:00	12470	13512	3	2	1	33.333
08/05/2015 11:00	12455	15641	141	18	123	87.234
08/05/2015 11:00	13740	15646	7	1	6	85.714
08/05/2015 11:00	13740	12410	3	1	2	66.667

08/05/2015 11:00	12162	13580	24	5	19	79.167
08/05/2015 11:00	13740	15330	4	1	3	75
08/05/2015 11:00	14251	12172	3	1	2	66.667
08/05/2015 12:00	12470	14426	9	1	8	88.889
08/05/2015 12:00	12162	12160	4	1	3	75
08/05/2015 12:00	15640	15642	9	1	8	88.889
08/05/2015 12:00	13572	15640	11	2	9	81.818
08/05/2015 12:00	12455	15641	153	32	121	79.085
08/05/2015 12:00	13572	14310	4	1	3	75
08/05/2015 12:00	13740	15646	4	1	3	75
08/05/2015 12:00	12512	13562	7	1	6	85.714
08/05/2015 12:00	13572	13662	9	3	6	66.667
08/05/2015 12:00	12162	13471	6	1	5	83.333
08/05/2015 13:00	12455	14312	29	4	25	86.207
08/05/2015 13:00	14245	13506	176	18	158	89.773
08/05/2015 13:00	13572	17831	30	4	26	86.667
08/05/2015 13:00	12162	13581	4	1	3	75
08/05/2015 13:00	14245	13504	98	22	76	77.551
08/05/2015 13:00	13740	16652	2	1	1	50
08/05/2015 13:00	13572	15640	16	4	12	75
08/05/2015 13:00	13372	12512	25	3	22	88
08/05/2015 13:00	12470	13531	8	1	7	87.5
08/05/2015 13:00	12531	13504	19	3	16	84.211
08/05/2015 13:00	13572	13571	3	1	2	66.667
08/05/2015 13:00	13740	15330	3	1	2	66.667
08/05/2015 13:00	12512	13562	13	2	11	84.615
08/05/2015 13:00	14251	12172	2	1	1	50
08/05/2015 13:00	12174	13365	6	1	5	83.333
08/05/2015 14:00	14245	15485	4	1	3	75
08/05/2015 14:00	13572	17831	32	4	28	87.5

08/05/2015 14:00	14245	13500	6	1	5	83.333
08/05/2015 14:00	15640	17835	3	1	2	66.667
08/05/2015 14:00	15640	12472	3	2	1	33.333
08/05/2015 14:00	13572	14312	9	1	8	88.889
08/05/2015 14:00	13572	15644	6	2	4	66.667
08/05/2015 14:00	12174	13364	5	1	4	80
08/05/2015 14:00	15644	13666	2	1	1	50
08/05/2015 14:00	12531	13651	11	2	9	81.818
08/05/2015 14:00	13744	15335	13	2	11	84.615
08/05/2015 14:00	14251	12501	3	1	2	66.667
08/05/2015 14:00	15644	17832	9	1	8	88.889
08/05/2015 14:00	13740	12080	26	4	22	84.615
08/05/2015 14:00	15640	13572	11	2	9	81.818
08/05/2015 14:00	13744	15331	22	3	19	86.364
08/05/2015 14:00	12531	13504	27	4	23	85.185
08/05/2015 14:00	13572	13741	1	1	0	0
08/05/2015 14:00	13740	12410	3	2	1	33.333
08/05/2015 14:00	13740	15330	6	1	5	83.333
08/05/2015 14:00	13372	13472	8	1	7	87.5
08/05/2015 14:00	12174	13365	6	2	4	66.667
08/05/2015 15:00	13572	17831	24	4	20	83.333
08/05/2015 15:00	12455	17832	8	3	5	62.5
08/05/2015 15:00	15644	13572	9	1	8	88.889
08/05/2015 15:00	12162	12160	8	1	7	87.5
08/05/2015 15:00	12162	12512	4	1	3	75
08/05/2015 15:00	15640	17832	24	6	18	75
08/05/2015 15:00	14251	13635	8	1	7	87.5
08/05/2015 15:00	15644	17832	19	2	17	89.474
08/05/2015 15:00	13744	15331	13	2	11	84.615
08/05/2015 15:00	12531	13504	28	4	24	85.714

08/05/2015 15:00	13740	15330	4	3	1	25
08/05/2015 15:00	13744	13741	2	1	1	50
08/05/2015 15:00	15640	13740	33	4	29	87.879
08/05/2015 15:00	12174	13365	9	1	8	88.889
08/05/2015 16:00	12512	12470	8	1	7	87.5
08/05/2015 16:00	15644	12472	2	1	1	50
08/05/2015 16:00	12512	12162	4	3	1	25
08/05/2015 16:00	15640	12512	2	1	1	50
08/05/2015 16:00	12455	17836	13	2	11	84.615
08/05/2015 16:00	12455	17832	8	1	7	87.5
08/05/2015 16:00	12162	12512	2	1	1	50
08/05/2015 16:00	14251	13571	1	1	0	0
08/05/2015 16:00	13744	15642	84	12	72	85.714
08/05/2015 16:00	13572	14310	1	1	0	0
08/05/2015 16:00	12455	13582	1	1	0	0
08/05/2015 16:00	13744	15331	19	3	16	84.211
08/05/2015 16:00	13572	12471	3	1	2	66.667
08/05/2015 16:00	13744	12080	1	1	0	0
08/05/2015 16:00	13572	12450	9	1	8	88.889
08/05/2015 16:00	13740	15330	3	1	2	66.667
08/05/2015 16:00	13372	13472	7	2	5	71.429
08/05/2015 16:00	13744	12401	2	1	1	50
08/05/2015 16:00	12455	14310	10	2	8	80
08/05/2015 16:00	13744	15645	1	1	0	0
08/05/2015 17:00	15485	14241	2	1	1	50
08/05/2015 17:00	12512	13362	1	1	0	0
08/05/2015 17:00	12455	17832	14	3	11	78.571
08/05/2015 17:00	13572	14312	12	3	9	75
08/05/2015 17:00	12162	13581	5	2	3	60
08/05/2015 17:00	13372	13506	2	1	1	50

08/05/2015 17:00	12162	12512	1	1	0	0
08/05/2015 17:00	13572	15640	24	4	20	83.333
08/05/2015 17:00	13740	15331	36	4	32	88.889
08/05/2015 17:00	13744	15335	16	2	14	87.5
08/05/2015 17:00	15640	17832	27	5	22	81.481
08/05/2015 17:00	14251	12501	1	1	0	0
08/05/2015 17:00	12531	13655	7	1	6	85.714
08/05/2015 17:00	13740	15332	3	1	2	66.667
08/05/2015 17:00	13740	15334	5	1	4	80
08/05/2015 17:00	13740	15330	7	3	4	57.143
08/05/2015 17:00	13372	13472	5	1	4	80
08/05/2015 17:00	13744	12401	1	1	0	0
08/05/2015 17:00	14251	12172	1	1	0	0
08/05/2015 17:00	14251	12505	5	1	4	80
08/05/2015 17:00	13572	12475	4	1	3	75
08/05/2015 17:00	12512	12170	5	1	4	80
08/05/2015 18:00	12174	12505	4	1	3	75
08/05/2015 18:00	15640	17835	5	1	4	80
08/05/2015 18:00	12162	12161	2	1	1	50
08/05/2015 18:00	12455	17832	11	2	9	81.818
08/05/2015 18:00	12455	17831	79	15	64	81.013
08/05/2015 18:00	13572	14312	16	2	14	87.5
08/05/2015 18:00	13372	12166	187	21	166	88.77
08/05/2015 18:00	14251	13636	15	2	13	86.667
08/05/2015 18:00	13372	13370	1	1	0	0
08/05/2015 18:00	14240	15481	7	1	6	85.714
08/05/2015 18:00	15640	13744	7	2	5	71.429
08/05/2015 18:00	13572	15640	34	6	28	82.353
08/05/2015 18:00	14251	13571	2	1	1	50
08/05/2015 18:00	13740	15331	29	6	23	79.31

08/05/2015 18:00	15640	17832	49	6	43	87.755
08/05/2015 18:00	13572	14310	3	1	2	66.667
08/05/2015 18:00	13740	15646	10	2	8	80
08/05/2015 18:00	13372	13471	1	1	0	0
08/05/2015 18:00	13744	15331	23	3	20	86.957
08/05/2015 18:00	12531	13504	32	4	28	87.5
08/05/2015 18:00	13572	13562	3	1	2	66.667
08/05/2015 18:00	13740	15330	17	4	13	76.471
08/05/2015 18:00	12512	13562	4	1	3	75
08/05/2015 18:00	15644	15331	1	1	0	0
08/05/2015 18:00	14251	12172	5	3	2	40
08/05/2015 18:00	15640	15331	1	1	0	0
08/05/2015 18:00	12470	12170	1	1	0	0
08/05/2015 19:00	12455	12451	582	198	384	89.095
08/05/2015 19:00	13572	17831	39	4	35	89.744
08/05/2015 19:00	12512	12502	9	1	8	88.889
08/05/2015 19:00	12455	17832	28	5	23	82.143
08/05/2015 19:00	12455	17831	109	17	92	85.185
08/05/2015 19:00	15644	13740	29	4	25	86.207
08/05/2015 19:00	12470	13562	8	1	7	87.5
08/05/2015 19:00	14240	14245	6	1	5	83.333
08/05/2015 19:00	12162	12512	4	1	3	75
08/05/2015 19:00	13572	15640	25	5	20	80
08/05/2015 19:00	15640	17832	102	22	80	78.431
08/05/2015 19:00	14251	12501	4	2	2	50
08/05/2015 19:00	12455	15641	278	32	246	88.489
08/05/2015 19:00	15644	17832	24	5	19	79.167
08/05/2015 19:00	13572	14310	2	2	0	0
08/05/2015 19:00	13744	15331	22	5	17	77.273
08/05/2015 19:00	12512	12476	2	1	1	50

08/05/2015 19:00	12531	13504	22	7	15	68.182
08/05/2015 19:00	13572	13562	8	2	6	75
08/05/2015 19:00	13740	15332	4	1	3	75
08/05/2015 19:00	13740	12410	1	1	0	0
08/05/2015 19:00	12174	13632	1	1	0	0
08/05/2015 19:00	13740	15330	8	2	6	75
08/05/2015 19:00	12512	13562	16	7	9	56.25
08/05/2015 19:00	13744	12401	1	1	0	0
08/05/2015 19:00	13572	13662	8	1	7	87.5
08/05/2015 19:00	14251	12172	4	1	3	75
08/05/2015 19:00	15640	15331	2	2	0	0
08/05/2015 20:00	13372	13374	19	4	15	78.947
08/05/2015 20:00	12512	13372	9	1	8	88.889
08/05/2015 20:00	12174	12505	3	1	2	66.667
08/05/2015 20:00	13572	17832	340	38	302	88.824
08/05/2015 20:00	12455	17832	39	7	32	82.051
08/05/2015 20:00	12455	17831	81	18	63	77.778
08/05/2015 20:00	15644	15642	23	3	20	86.957
08/05/2015 20:00	14240	14245	8	3	5	62.5
08/05/2015 20:00	12470	13585	4	4	0	0
08/05/2015 20:00	13572	15640	47	5	42	89.362
08/05/2015 20:00	12470	13564	3	1	2	66.667
08/05/2015 20:00	13740	15331	88	12	76	86.364
08/05/2015 20:00	15640	17832	126	23	103	81.746
08/05/2015 20:00	13372	13476	3	1	2	66.667
08/05/2015 20:00	12455	15641	262	28	234	89.655
08/05/2015 20:00	14251	12501	7	2	5	71.429
08/05/2015 20:00	12455	12452	26	14	12	48
08/05/2015 20:00	13740	12080	41	6	35	85.366
08/05/2015 20:00	13740	15646	9	1	8	88.889

08/05/2015 20:00	13744	15331	30	4	26	86.667
08/05/2015 20:00	13572	13666	3	3	0	0
08/05/2015 20:00	13740	15332	7	3	4	66.667
08/05/2015 20:00	13372	13516	9	4	5	55.556
08/05/2015 20:00	13740	15330	25	14	11	44
08/05/2015 20:00	13744	12452	10	4	6	85.714
08/05/2015 20:00	13744	12401	2	1	1	50
08/05/2015 20:00	13572	13662	8	1	7	87.5
08/05/2015 20:00	14251	12172	9	2	7	77.778
08/05/2015 20:00	14240	15496	5	5	0	0
08/05/2015 20:00	15640	13972	208	37	171	82.212
08/05/2015 20:00	14240	13374	3	1	2	66.667
08/05/2015 21:00	13572	17832	351	37	314	89.459
08/05/2015 21:00	12512	12162	3	1	2	66.667
08/05/2015 21:00	15640	12472	5	2	3	60
08/05/2015 21:00	15640	12512	1	1	0	0
08/05/2015 21:00	12455	17832	32	4	28	87.5
08/05/2015 21:00	12455	17831	78	10	68	87.179
08/05/2015 21:00	13372	12166	106	20	86	81.132
08/05/2015 21:00	12512	13531	3	1	2	66.667
08/05/2015 21:00	12174	13360	7	2	5	71.429
08/05/2015 21:00	12162	12512	5	2	3	60
08/05/2015 21:00	12470	12511	1	1	0	0
08/05/2015 21:00	15640	13744	2	1	1	50
08/05/2015 21:00	13744	15640	23	4	19	86.364
08/05/2015 21:00	13572	15640	44	9	35	81.395
08/05/2015 21:00	13744	15335	4	1	3	75
08/05/2015 21:00	15640	17832	117	29	88	75.214
08/05/2015 21:00	13372	13476	2	1	1	50
08/05/2015 21:00	12470	12512	19	3	16	84.211

08/05/2015 21:00	14251	12501	2	1	1	50
08/05/2015 21:00	12470	13512	1	1	0	0
08/05/2015 21:00	12455	15641	258	39	219	87.251
08/05/2015 21:00	13740	12080	30	8	22	73.333
08/05/2015 21:00	13572	14310	2	1	1	50
08/05/2015 21:00	12455	13582	4	4	0	0
08/05/2015 21:00	15640	13572	19	3	16	88.889
08/05/2015 21:00	13744	15331	16	3	13	81.25
08/05/2015 21:00	13744	12080	5	1	4	80
08/05/2015 21:00	13740	15332	7	2	5	71.429
08/05/2015 21:00	13740	15330	19	13	6	31.579
08/05/2015 21:00	12512	13562	13	5	8	61.538
08/05/2015 21:00	12455	13970	1	1	0	0
08/05/2015 21:00	13372	13472	12	3	9	75
08/05/2015 21:00	13744	12401	3	1	2	66.667
08/05/2015 21:00	14251	12172	11	2	9	81.818
08/05/2015 21:00	13372	13522	8	1	7	87.5
08/05/2015 22:00	13372	13374	15	3	12	80
08/05/2015 22:00	12512	13372	5	2	3	60
08/05/2015 22:00	13572	17832	215	30	185	86.047
08/05/2015 22:00	13572	17831	19	2	17	89.474
08/05/2015 22:00	12512	12502	7	1	6	85.714
08/05/2015 22:00	12455	17836	5	1	4	80
08/05/2015 22:00	12455	17832	16	2	14	87.5
08/05/2015 22:00	12455	17831	65	15	50	76.923
08/05/2015 22:00	12162	13581	2	2	0	0
08/05/2015 22:00	12162	12512	1	1	0	0
08/05/2015 22:00	13740	15331	29	3	26	89.655
08/05/2015 22:00	15640	17832	67	18	49	73.134
08/05/2015 22:00	14251	12501	2	1	1	50

08/05/2015 22:00	13572	14310	3	2	1	33.333
08/05/2015 22:00	13744	15331	9	3	6	66.667
08/05/2015 22:00	13740	15332	8	2	6	75
08/05/2015 22:00	12162	13580	34	4	30	88.235
08/05/2015 22:00	14251	12505	3	1	2	66.667
08/05/2015 22:00	13740	15330	3	1	2	66.667
08/05/2015 22:00	12512	13562	9	1	8	88.889
08/05/2015 22:00	13372	13472	3	1	2	66.667
08/05/2015 22:00	13572	13662	6	1	5	83.333
08/05/2015 22:00	14251	12172	7	1	6	85.714
08/05/2015 22:00	14251	12505	3	1	2	66.667
08/05/2015 23:00	12531	12534	7	1	6	85.714
08/05/2015 23:00	15485	15482	2	1	1	50
08/05/2015 23:00	12512	13372	3	1	2	66.667
08/05/2015 23:00	12512	13560	1	1	0	0
08/05/2015 23:00	15640	12472	1	1	0	0
08/05/2015 23:00	12455	17831	16	4	12	75
08/05/2015 23:00	12162	13581	2	1	1	50
08/05/2015 23:00	12512	13535	5	1	4	80
08/05/2015 23:00	15640	17832	27	3	24	88.889
08/05/2015 23:00	14251	12501	2	1	1	50
08/05/2015 23:00	12512	13564	13	2	11	84.615
08/05/2015 23:00	15640	13572	3	1	2	66.667
08/05/2015 23:00	13744	15331	10	3	7	70
08/05/2015 23:00	12162	13580	12	2	10	83.333
08/05/2015 23:00	13740	15334	1	1	0	0