OPTIMIZATION OF HANDOVER DECISIONS FOR MULTIMEDIA NETWORK SERVICES THROUGH FUZZY LOGIC

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DECLARATION

I, the undersigned, declare that this is my original work and has not been submitted to any other college, institution or university for academic credit.

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This thesis has been submitted with our approval as the University supervisors.

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DEDICATION

I dedicate this thesis to my lovely wife Purity Ndinda whose love; understanding and sincere support gave me the inspiration to complete this work.

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First and foremost, I am very grateful to Jehovah God for providing me with capability to finish this work. My sincere gratitude goes to my supervisors, Professor Vitalice Oduol and Professor Stephen Musyoki, for their continuous guidance, support, encouragement and for helping me successfully finish my thesis. I thank them very much for believing in me and pushing me to complete this work.

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LIST OF ABBREVIATIONS

AC	Authentication Center.
ANFIS	Adaptive Neuro Fuzzy Inference
AV BW	Available Bandwidth
BSC	BTS Controller
BTS	Base Transceiver Station
CAC	Call Admission Control
DCA	Dynamic Channel Allocation
DCAS	Dynamic Channel Allocation Sc
Di f f Serv	Differentiated Services
FBA	Fixed bandwidth allocation
FCA	Fixed Channel Allocation
GERAN	GSM Edge Radio Access
GSM	Global System for Mobile c
HLR	Home Location Register.
IntServ	Integrated Service
IWF	Interworking Function.
MATLAB	Matrix Laboratory
MS	Mobile Station
MSC	Mobile Switching Centre
MS-VEL	Mobile Station Velocity
Mu	Mobile unit.
PDN	Public Data Network.
PSTN	Public Switched Telephone
QoS	Quality of Service
RSS	Received Signal Strength
SIGLEV	Signal Level
SIGQUAL	Signal Quality

SNR	Signal to Noise Ratio
Video Thr	Video traffic Threshold
VLR	Visitor Location Registe
Voice Thr	Voice traffic Threshold
Web Thr	Web traffic Threshold
WiMAX	Worldwide Interoperability
WLAN	Wireless Local Area Netwo

ABSTRACT

The increase of multimedia services in Telecommunication industry has made bandwidth a scarce valuable resource. A popular way to achieve higher capacity is the use of small cells that increases number of handovers as user move from a cell to another. Failure of handover process leads to a drop of Quality of Service, (QoS) making customers to be dissatisfied. Several handover algorithms have been proposed for handover decisions taking into consideration only few input parameters. Also, these algorithms do not take into consideration handover for multimedia services based on their QoS requirements and level of improvement on handover success rate. Service is a useful factor for the users and different services require respective QoS. This research aims at optimizing the process of handover through fuzzy logic method for cellular multimedia services by a combination of five input parameters to the Fuzzy Inference System (FIS). They are Base Transceiver Station, (BTS) traffic load, Mobile station, (MS) velocity, signal quality, signal level and the available bandwidth. In this research, the threshold for handover for the three forms of traffic (voice traffic, video traffic and web traffic) are calculated separately with priority being given to the voice call as compared to the web traffic since web traffic can tolerate some delay but voice traffic cannot tolerate any delay. Handover process is optimized by increasing the number of input parameters to the Fuzzy Inference System, (FIS). The system calculates the hand the obtained results over thresholds for the three multimedia services based on their quality of service requirements. From the obtained results voice traffic due to its stringent quality of service requirements has the highest threshold values. Voice traffic threshold values are 0.885, 0.638 and 0.337 when input parameters are worst, average and excellent respectively while web traffic the threshold values are 0.629, 0.156 and 0.110 when input parameters are worst, average and excellent respectively. Based on these threshold values, handover decision is executed. This algorithm ensures smooth and efficient handovers are executed. Many traditional handover algorithms such as Fuzzy logic based and hysteresis have short- comings. The fuzzy handover algorithm is not optimized thus needs attention from human experts. This work has analyzed the impact of using the adaptive neuro fuzzy inference system for the handover decision making. The

results from the different simulations have shown that, need to handoff varies depending on number of inputs to the Adaptive Neuro Fuzzy Inference System, (ANFIS). The outputs are 0.334, 0.42, 0.561, 0.607 and 0.714 when the number of inputs to the ANFIS are one, two, three, four and five respectively. As the number of inputs is increased up to five, the handover decision is optimized. The data used in training the ANFIS was obtained from the developed fuzzy logic system and safaricom LTD, Kenya.

CHAPTER ONE

INTRODUCTION

1.1 Back ground information

The growth in Mobile Telecommunication sector is tremendous and by 2019, the mobile phone users are expected to pass the 5billion mark. Due to increase in numbers of mobile users year after year, the demand of multimedia services that is video, data, and voice increases leading to increase in demand of the bandwidth, a scarce resource. One way of increasing the network capacity is by increasing number of the cells for the given coverage area which in turn leads to increase in the number of handovers [1] .The problem of taking this dimension is increased number of call handovers when users move from one cell to another which increases the network load, compromising on the quality of service [2]. In telecommunication industry, handover process is among the key performance factors that have direct impact on Quality of Service, (QoS) [3]. The failure of this process will lead to a drop of QoS which dissatisfies the customers.

This calls for development of an algorithm that will optimize the handover process and reduce the number of dropped calls for multimedia services thereby improving customer satisfaction. If the total number of users that are accessing network remains unchanged, then allocation of bandwidth to cells in a given coverage area can be done based on the traffic carried during the busy hour [4]. This causes under-utilization of bandwidth when amount of carried traffic is low. This leads to excess traffic from other cells being lost due to lack of bandwidth. A key challenge in deployment of QoS networks is development of the solutions that tracks traffic statistics while allocating network resources more efficiently satisfying the QoS requirements of the users while maximizing at the same time, utilizing and increasing network revenue [5]. With emergence of various multimedia applications, it becomes of high importance that the wireless network provides a guaranteed QoS to the users. This capability of cellular services providers to provide the satisfactory services includes consideration of the voice quality, the signal strength, the low call blocking and the call dropping probabilities, the high data rates for multimedia and data applications.

In a telecommunication network, more resources are given to call handovers to the disadvantage of incoming new calls. This results in the incoming calls being blocked. This problem can be solved by optimizing the handover process. The conventional handover schemes are normally based on one input parameter, the received signal strength. To maintain a reliable and continuous link between the Mobile Station, (MS) and Base Station, (BS) new and better handover algorithms need to be developed in order to maintain a guaranteed QoS [6]. Probability theory, genetic algorithms, fuzzy logic and the neural network are some of soft computing techniques that are used to develop handover algorithms. This work will determine the parameters that will improve the handover process and develop the fuzzy logic algorithm that will determine the best time of carrying out handovers. If handover process is improved, failure rate of handoff will be minimized. The increase in dropped calls rate makes users to be dissatisfied and eventually may move to another network. Frequency spectrum is a valuable resource hence should be used efficiently to give users high quality services [7].

Most of existing ANFIS handover algorithms have not taken into consideration how the number of the inputs to the ANFIS affects the performance of algorithm. The method used in this research consist of a five layer Adaptive Neuro Fuzzy Inference System (ANFIS), that takes in the following five inputs i.e. signal level, signal quality, available bandwidth, MS velocity and traffic load of the BTS.

1.2 Statement of the Problem

The freedom to receive and make calls anytime and everywhere has created a new dimension in communication industry. Handover is the main procedure that provides mobility in the mobile telecommunication industry. This procedure makes it possible for users to move from one cell to another while maintaining connection. According to the 2015/2016 and 2013/2014 reports generated by the Communication Authority of Kenya, none of the four main telecom firms in Kenya was able to meet Quality of service requirements. One of the reasons that the telecom firms in Kenya failed to achieve the desired quality of service is the handover failures [8]. These failures are brought about by the frequent handovers due to increased number of users of multimedia services. Cellular network ability to perform handovers efficiently is very important in offering attractive services to the customers.

The handover criterion for decision making is more critical with evolution of smaller size of cells that have been adopted to increase capacity of the network due to increase in the number of the multimedia services. In efficient and unreliable handover procedures reduces quality of services and their reliability.

Fuzzy logic algorithms being used today for handover have taken into consideration only a few input values. The input values being taken into consideration are: strength of the received signal, bandwidth or number of channels available, distance between MS and BTS and the cost [7]

These fuzzy logic handover techniques do not take into consideration handover for multimedia network services based on their quality of service requirements and at same time optimizing the handover process. In an effort to address the above, this work presents a fuzzy logic handover algorithm where the threshold for the three multimedia network services are calculated based on their quality of service requirements. Priority being given to the voice calls as compared to the web traffic since calls in progress cannot tolerate delay but web traffic can tolerate some delay. The developed algorithm optimizes the handover process by increasing handover success rate through parameter tuning and by increasing the number of parameters to the FIS. It has been demonstrated that it is possible to optimize the handoff decisions when they are made based on the QoS requirements for different multimedia network services.

When a training element is introduced to the Fuzzy logic, performance of algorithm improves. But most of existing Adaptive Neuro Fuzzy Inference System, (ANFIS) handover algorithms have not taken into consideration how the number of the inputs to

ANFIS affects performance of the algorithm.. An investigation is carried out on how increase in the number of inputs to the ANFIS affects the performance of algorithm.

1.3 Justification

The wireless network is usually characterized by its imprecise parameters, dynamic nature, and inherent uncertainty and constraints. Network parameters such as signal quality, signal level, interference level, distance between BTS and MS and MS velocity are vague, uncertain and intrinsically imprecise [9]. It is difficult to measure accurately these parameters in a network since they are fuzzy in nature. Fuzzy logic method produces better results when it is used for the system design in such condition.

The multimedia services users desire a guaranteed quality of service from the service providers. If this is not achieved then they can choose to move to another service provider. Hence the need of the service providers to ensure that the services they offer are of desired level of QoS. To achieve this they should use efficient methods of resource allocation and improvement of the handover process to reduce number of dropped calls thereby improving the QoS of multimedia services. Hence the need of developing a fuzzy logic controlled handover decision for multimedia services. Different multimedia services requires different quality of services hence becomes difficult in the allocation of the available bandwidth.

1.4 Objectives

1.4.1 Main Objective

The main objective of this research thesis was to develop a fuzzy logic algorithm that will optimize the handover decision for wireless multimedia network services to ensure a guaranteed Quality of Service.

1.4.2 Specific Objectives

1. To develop a fuzzy logic algorithm for optimization of handover decisions in a mobile cellular network for multimedia services.
2. To develop an ANFIS handover algorithm and evaluate its impact on handover decisions.
3. To compare the performance of the developed fuzzy logic handover algorithm with previously developed algorithm.

1.5 Research questions

This research work will aim at answering the following questions in order to achieve the expected results.

(i) How can a wireless multimedia network handle handovers efficiently with the scarce bandwidth?

(ii) Does the increase in the number of input parameters increase the performance of the handover process?

(iii) What is the impact of ANFIS on handover decisions?

1.5. Organization of Thesis

This thesis is organized in five chapters. Chapter one deals mainly with introduction, problem statements, significance and objectives of the study. Chapter two deals with the literature survey. In this chapter an overview of the related work, neuro-fuzzy systems, fuzzy logic will be covered together with the research gap. Chapter three provides methodology used; including design of fuzzy logic and ANFIS handover algorithms. Chapter four deals with the discussion of the results obtained from the simulations. In chapter five, conclusions and the recommendations are given. Also included in this section is further research that should be carried out to improve present case. Reference materials used to develop this thesis are given after this chapter. Appendixes are given at the end of chapter five.

1.6. Contribution of the Thesis

Key contribution made through this research work is the development of a fuzzy logic algorithm that optimizes the handover decision for wireless multimedia network services to ensure a guaranteed Quality of Service. The developed algorithm has better performance in terms of reduced number of handovers. Another contribution is the investigation of how the number of input parameters to the ANFIS affects the performance of the handover process. It has been found that the more the number of inputs used in ANFIS algorithm, the more the optimized the algorithm is.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

The chapter covers the various aspects of handover process, different algorithms that have been previously been developed and their limitations. Related work about this research is also brought out in detail. Based on the drawbacks of the previous handover algorithms, an improvement of handover decisions for multimedia network services using fuzzy logic is proposed in this chapter.

2.2 Overview of cellular networks

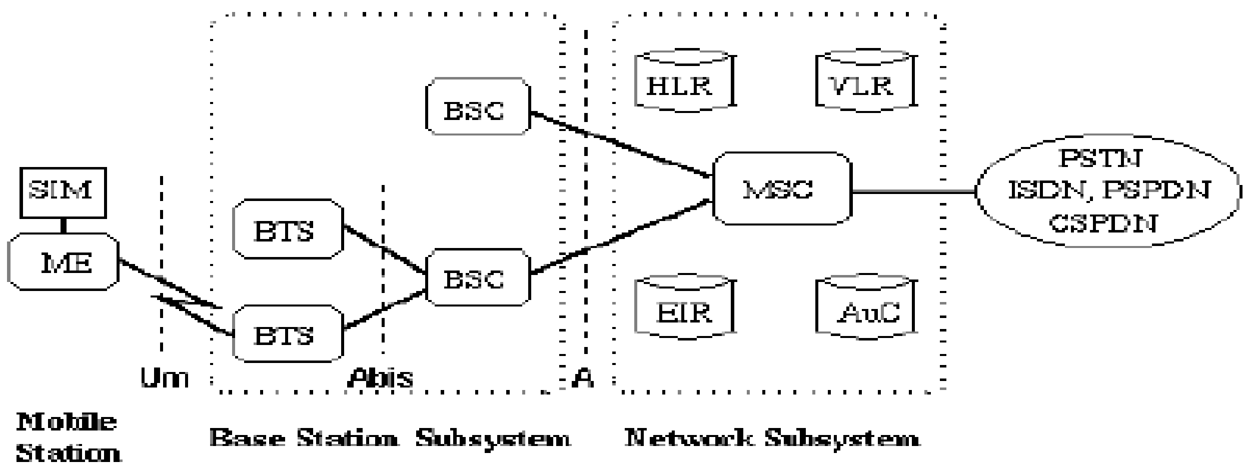

Figure 2. 1: Cellular Network [75]

Where:

MS - mobile station (MS) BTS – Base Transceiver Station.

BSC – Base Station Controller.

MSC – Mobile Switching center.

PDN – Public Data Network.

VLR – Visitor Location Register.

EIR – Equipment Identity Register

HLR – Home Location Register.

PSTN – Public Switched Telephone Network.

AC – Authentication Center.

Figure 2.1 shows the overview of the cellular network. The mobile station comprises of user equipment's and the software needed in communication with the mobile network. The BSC supervises a number of BTSs. It allocates radio resources to the mobile call and for handovers made between base stations under its control. The MSC is the telephone exchange that make a connection between users of the mobile within the network, or from users of the mobile to the PSTN and from users of the mobile to the other networks. MSC administers handovers to the neighboring BS keeping track of the mobile subscribers' location. Is also responsible for billing and subscribers services. BTS facilitates the communication between network and user equipment. Examples of the user equipments are handsets and computers connected to the internet [10].

HLR is a database of the permanent subscribers' information regarding the mobile network. It interacts with MSC, a switch that is used for control and processing of a call. It contains pertinent data in regard to the subscribers that have been authorized to use the global system for the mobile communication network. VLR is a data base containing information about subscribers roaming within the MSC location area.

It's primarily role is minimization of numbers of queries that the MSCs makes to HLR that holds permanent data in regard to cellular network subscribers. VLR performs the following functions:

a) Monitors subscribers' location in its jurisdiction.

b) Accepts information that HLR passes to it.

c) Deleting records of the inactive subscribers.

d) Allocating of roaming numbers during the incoming calls [10]

e) Determination of whether subscribers accesses a particular service.

PSTN is the combination of the telephone networks that are being used worldwide for example fiber optic cables, telephone lines, cellular networks, switching centers, cable systems and satellites. It's the world's collection of the interconnected voice oriented public telephone networks that can be either commercial or government owned or both. It uses circuit switching in allowing users in making landline calls. The AC validates the security information management card attempting to connect when the phone has live network signal. It ensures that third parties do not use the network subscribers' services. In short it performs the authentication function. It's located in HLR and is continuously accessing and updating subscribers' records. The IWF is a way of interfacing the PSTN with wireless telecommunication network. It converts data transmitted through air interface to the format suitable to PSTN. It contains both software and hardware elements that provide rate adaptation and protocol conversion between wireless network and PSTN. IWF provides a function that enables GSM system in interfacing with various forms of private and public data networks. PDN is a network that is established and operated by telecommunication administration for providing public with data transmission services. In communication, it's a circuit or packet switched network available to public that transmits data in the digital form [10]

A cellular network divides geographical coverage area into a number of cells in that same RF can be used again in two cells which are some distance apart. It operates based on frequency reuse idea which increases capacity of the network. Each BTS will be allocated part of total bandwidth that are available to the system while surrounding or nearby BTS should be assigned non overlapping sets of channel. The available channels later are assigned to proportionally small number of surrounding BTS [11]. BTS is used within small geographical area usually referred to as a cell. Due to increase in the number of users of cellular networks, number of BTSs has to be increased so as to increase number of the channels. Network coverage and its capacity are some of the factors determining cellular mobile network performance.

2.3 Handover

This is an important procedure in ensuring users of cellular networks can move freely in the network while maintaining the connection. It is a procedure that takes place when MS moves from one cell to another or from one sector of BS to another abandoning the connection with first base station while getting connection to the second one [21]. The success of this process is a good indication of user satisfaction. Therefore it should take place as seamlessly and as fast as possible. The failure of handover process makes the customers to be dissatisfied by the services being offered by the mobile network. When a mobile station switches from a set of radio resource to another set, then handover will have taken place. [12][13][14].

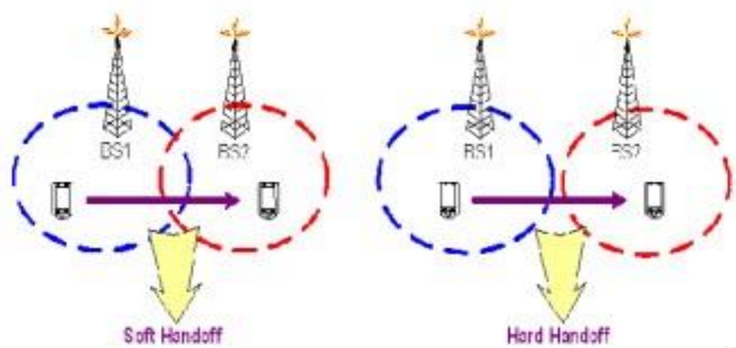

Figure 2. 2: Handover process**.** [13]

Figure 2.2 shows the handover process. Hard handoff is the handover technique that is used with the cellular networks requiring user's connection be entirely broken with existing BS before it can be switched to the other BS. It is also known as break before make handover. It is generally implemented in TDMA and FDMA based cellular networks. While in soft handover radio links needs to be added and removed in such a way that MS will keep at least a radio link to UTRAN. Soft handover involves creating the connection to the other station before it's broken, i.e. the link to current BS (BTS) is not broken till link to target BTS is formed. Hard handover is also called break before make handover involving only one BTS for a given time [15] [16].

2.3.1 Handover Classification

Handovers can are classified into several classes as shown below:

Vertical and Horizontal Handover: handover can be classified as either vertical or horizontal depending on type of the network technologies being involved. [16]. Horizontal handover occurs when mobile station switches between the different base transceiver stations of same access network for example when there is movement of users between two adjacent cells of GSM network. Vertical handover will involve two different network interfaces that represent different wireless access technologies [11, 16]

Soft and hard handover: This class of handover depends on the number cells to which a mobile station is associated with during any given moment. Hard handover (break before make) at any given time involves one BTS for example handover process in the GSM network [15]. The mobile station has to break its connection from current access network after then it connects to the new one. In soft handover (also called make before break) a mobile station will communicate and then connect to more than one Access Network during the handover process [16]. CDMA is an example of this type of handover.

2.3.2 Intra-cell BTS Handover

Figure 2.3 shows the Intra-cell BTS handover. Intra-cell BTS handover and the intra BTS handover both are used for the frequency change. Frequency change occurs during the time when the communication link degrades and when neighboring cells measurements are better than current one. If this happens, BSC controlling BTS that serves the MSC orders the MSC and the BTS to switch to other frequency that will offer better link for the communication. Interference causes degradation of the communication link. The cells involved in the handover are synchronized. This type of handover will occur when a new channel in same BTS is allocated to MS. This procedure being done independently by BSC, but mobile station controller can also be in charge. [17][18].

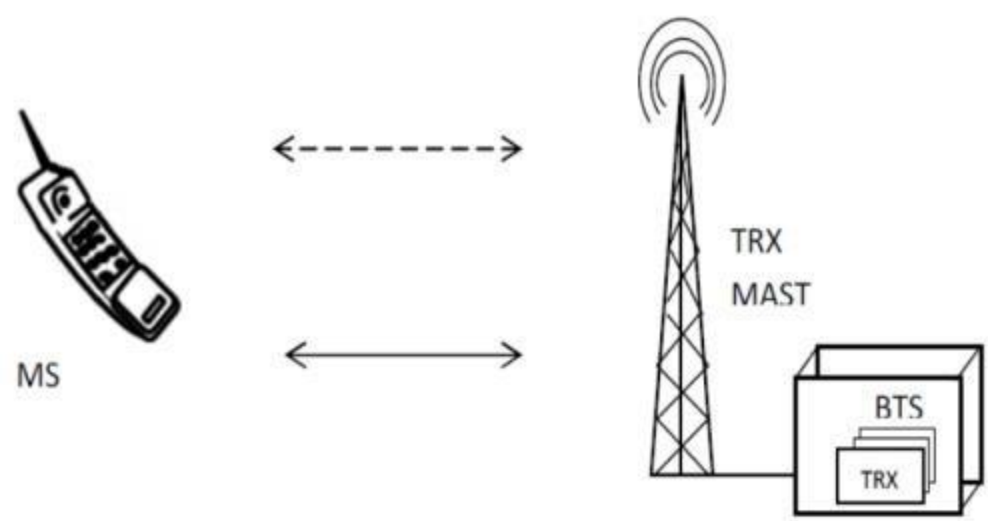

Figure 2. 3: Intra-cell BTS Handover **[18]**

2.3.3 Intra-BSC handover

Figure 2.4 shows the Intra-BSC handover. This type of handover will occur when call is to be relocated from BTS coverage area to another which controlled by the same BSC.

The BSC can do the handover allocating a new channel and there by dismissing the discarded Base Transceiver Station (BTS) from connecting with the mobile handset. The handover can be independently done by BSC without MSC intervention however, it MSC is alerted when handover occurs. In this type, mobile station changes between the two cells that belong to the same BSC. BSC being in control over the handover. It is performed when Mobile Station Controller changes only the BTS and not BSC. It is entirely performed by BSC. When the target cell is in different area of location, the MSC will have to perform location update procedures after the call. In this type of handover non synchronized and synchronized handovers are possible [17] [18].

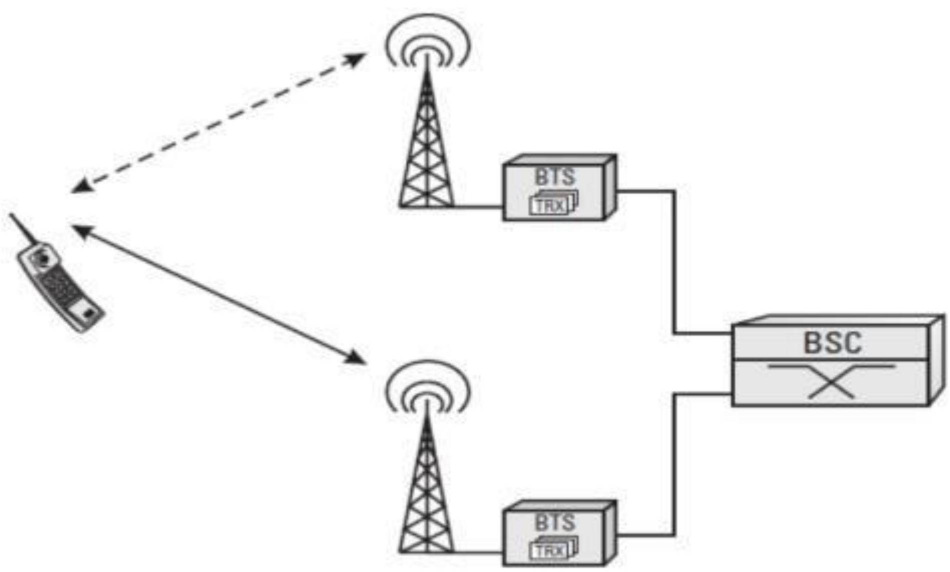

Figure 2. 4: Intra-BSC handover [18]

2.3.4 Intra-MSC Handover

Figure 2.5 shows the Intra-MSC handover. In this handover, when Base Station Controller decides that the handover is required but the target cell is in control of by a different Base

Station Controller, it needs the assistance from the MSC connected to it. For this handover to take place then MSC is mandatory. The work of MSC being to conclude the handover. This kind of the handover can either be inter-MSC or intra-MSC. In intra-MSC handover the target cell is located in a different BSC that is connected by same MSC. The MSC will contact the target BSC so that it is allocated required resources and another function being to inform the BSC the time when they are ready. When the resources are successful allocated, MSC will be instructed to access new channel or bandwidth so that the call is transferred to new BSC [18] [19].

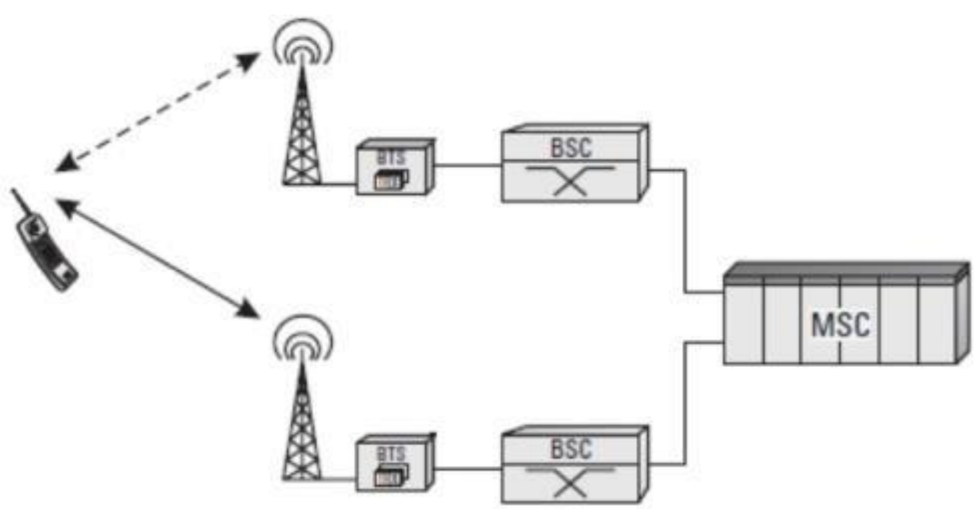

Figure 2. 5 Inter-MSC Handover [18]

2.3.5 Inter-MSC Handover

Figure 2.6 shows the Inter-MSC handover. This type of handover will occur when there exists two cells that belong to different Mobile Switching Center in same system. [18]. It has been illustrated in the diagram below. For the inter-MSC handover, the old (current serving) MSC is referred to as anchor the MSC and new (target) MSC is referred to as relay MSC [20].

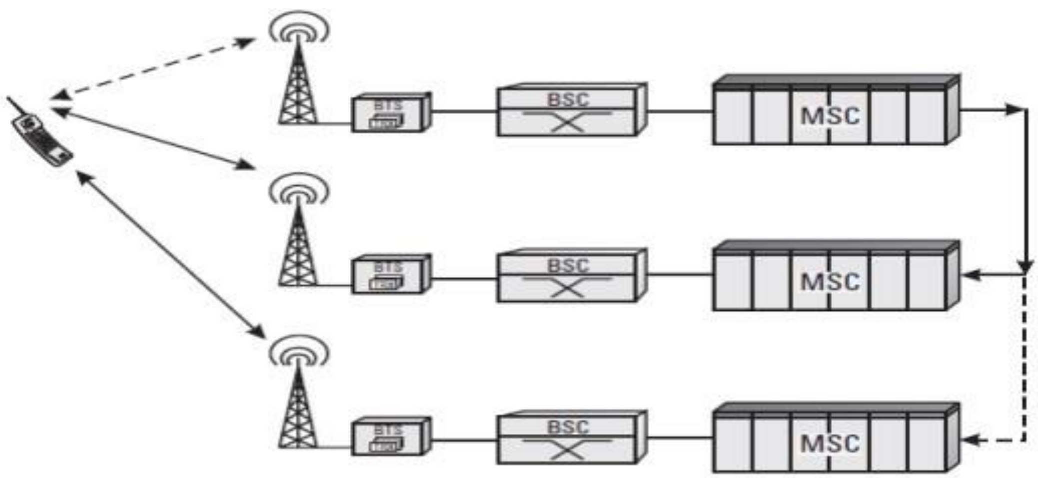

Figure 2. 6 Inter-MSC Handover. [18]

2.3.6 Desirable Elements of Handover

Some of the desirable features of handover algorithms have been discussed in [21], [22], [23], and they include:

a) Speed - Handovers should be as fast as possible in order to avoid service deterioration and interruption at MS. Mobility of the MS at high speed will require the handover to be executed promptly.

b) Reliability - Handovers has to be reliable in that the MS is able to maintain required QoS after handover.

c) Successful - Free resources and channels has to be available at target access network in order to make the handover successful.

d) Number of Handovers - The number of handovers has to be minimized as far as possible. Excessive number of the handovers result in poor QoS, excessive processing overheads and power loss.

e) Multiple-Criteria Handovers - Target access network has to be intelligently chosen based on the multiple-criteria. Choosing of the correct BTS will prevent frequent and unnecessary handovers.

2.3.7 Performance Evaluation of Handover Algorithms

Performance of the different vertical handover algorithms is compared and evaluated when the following metrics are measured [21].

a) Handover Delay - It represent the time that has elapsed between the handover initiation up to its completion. Difficulty of the handover algorithm has direct effect on the handover delay metric. For example a simple algorithm will result in the smaller value of the metric. Smallest possible value of the handover delay is the best for delay sensitive and real-time applications.

b) Number of Handovers - unwanted handovers has to be reduced to avoid wastage of network resources while increasing the processing overheads on system.

c) Number of Handover Failures - A handover failures occurs when target network has failed to assign required resources to the MS which is handed over from the neighboring network. This type of failure is also possible, when the moving MS goes out of serving area of the network before completion of the handover process. This metric leads the mobile users eventually to drop the call.

2.4 Call Handling Methods

2.4.1 Conventional Handover Methods

Both the BTS and the MS measures regularly the strength of the signal in the cellular network, and then the MS will continuously transmit its report of measurements to the BTS. A handover will be initiated if BTS will detect a drop in signal strength below a threshold of the radio signal. The BSC is informed about the request by the BTS which will verify the possibility of transferring the call to a new adjacent cell. The work of BSC will be to check the availability of free channel in the adjacent new cell. The BSC in this situation cannot differentiate between channel requests for the fresh call or for the handover. In case the adjacent new cell has a free channel then the handover request can be granted and the MS will switch to the new cell. If free channel is not available in new adjacent cell then dropping probability increases for the handover call. One of the disadvantages of this method is that handover request for the channel being the same as that used for the fresh calls. In this method the quality of service is greatly affected that can lead to users dissatisfaction since the users prefers the blockage of a new call than dropping of the calls already in transmission [12] [14].

2.4.2 Channel Carrying Handover Method

The mobile station, MS is allowed to carry the current channel number from the cell to another cell by the channel carrying mechanism when moving across boundaries under certain conditions. This channel carrying mechanism use the linear cellular model in that the BTS or cells will be arranged in the linear configuration. [24].

2.4.3 Handover Prioritization method

In order to reduce dropping probability of handing over calls, different approaches have been proposed. One of the mechanism in the reduction of the handovers failure rates is the prioritization of handover calls over the new calls. The handover prioritization method has the significant impact on probabilities of call blocking and call dropping. The different types of the handover prioritization scheme is the handover queuing scheme, guard channels (GC) and call admission control (CAC). The schemes may be combined to achieve better results [25].

2.4.4 Guard Channel Prioritization Scheme

In the case where dropping rate of handover is equal to blocking rate of originated call then QoS will not be guaranteed. In this scheme the static numbers of frequencies in each one of the cell is allocated mainly to support the handoff calls. It aims at improving probability of successful handover since they are taking highest priority in assigning static or the dynamic adjustable number of the channels only for the handovers among total number of the channels in network, while remaining channels are shared equally by originated calls and handover calls [26]. Arriving calls in this scheme being categorized into two groups, handover calls and new originated calls. Dropping handover calls is more dangerous than blocking new call since handover calls are existing and working calls. Care must be taken not to disconnect communicating call by dropping handover calls [27].

This scheme improves probability of the successful handover where it reserves number of the channels in each cell for handover purposes. The new calls and handover calls sharing equally remaining channels. Guard channels state transition diagram is given in Figure 2.7.

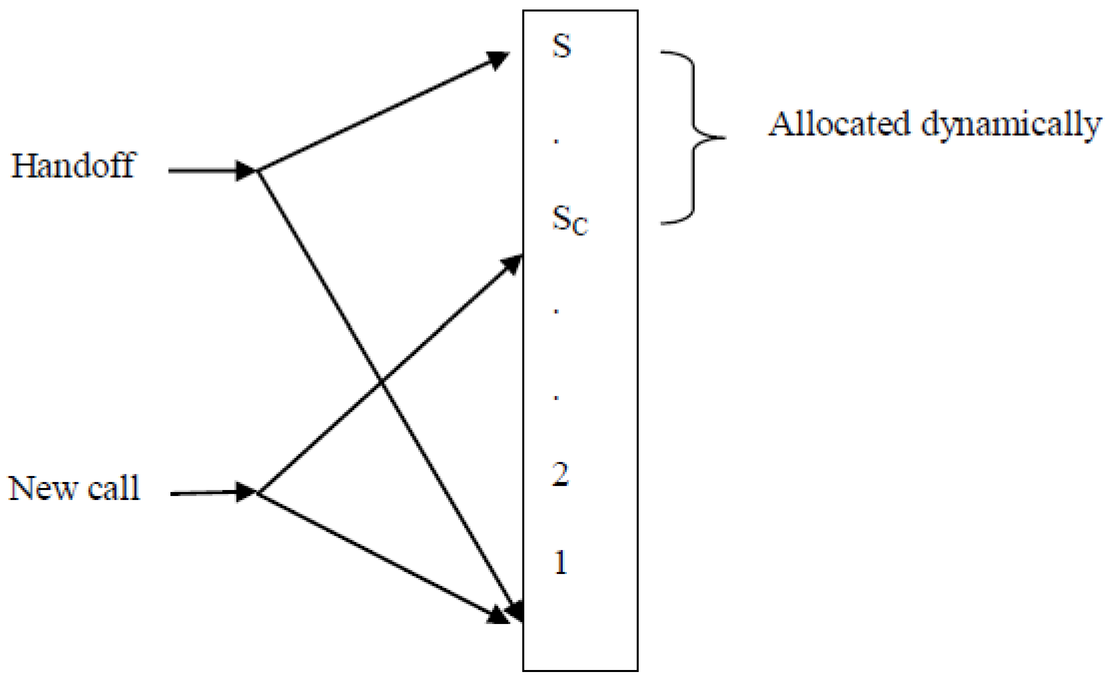

Figure 2. 7 Guard channels diagram. [18]

2.4.5 Call Admission Control Prioritization Scheme

CAC is the task that decides whether the new call request is to be admitted in the network or is to be blocked. In this scheme, arrival of the new calls is continuously estimated. If the arrival time is found to be higher than predefined level of threshold, then some of the calls will be blocked irrespective of availability of bandwidth and decreases probability of the handover calls. Both the handover calls and new calls have access to the bandwidth/channels. For the case where a new call is generated in the cell will not find idle channel, immediately call is discarded. In this scheme, no queue is provided for new call to wait. CAC will keep the track of the available capacity of the system and accommodates new call requests that ensures a guaranteed QoS for the existing customers (users). Decisions in this scheme being performed in the BSC in distributed manner since it lack central coordination [28].

This method is used in maintaining QoS by estimating the handover probability of unexpected termination and originated blocking rate of call where mean holding time of the channel is useful term in calculating the QoS. The measurements can be specified in the cellular systems that handover call termination rate being lower than five percent for the voice calls [29]. GoS is the measure of traffic congestion in telephone network. Congestion in network results in call loses. Is also referred to as blocking probability. The probability of the call's being delayed or blocked more than the specified interval being expressed as the decimal fraction. Grade of service is applied to the busy hour or onto some other specified period or set of the traffic conditions. Grade of service is viewed independently from perspective of the incoming versus the outgoing calls, unnecessarily equal in each direction. Erlang B formula, is used to calculate blocking probability for a given traffic.

$$\frac{a^{n}/_{n!}}{\sum_{k=0}^{n}\frac{a^{k}}{k!}} \quad \dots\dots\dots\dots\dots\dots\dots\dots \; 2.1$$

Where:

n is the number of the trunks, summation undertaken from k = 0 to N

When handovers are handled in the proper way, handovers failures will be minimized hence free channels will be available. If the value of n increases it will result in reduction of the blocking probability.

2.5 Membership Functions

Membership functions (MFs) is the curve defining how each one of the point in input space is being mapped to the membership value (or the degree of membership) between 0 and 1. Fuzzy set is defined by enumerating the membership values of elements in a set if it's discrete or if it's continuous, defining the membership function mathematically. Although there exists numerous types of the MFs, commonly used are Gaussian, triangular, trapezoidal, and bell curves [30] [31].

2.6. Fuzzy Inference Systems (FIS)

The Fuzzy inference is actual process of mapping from the given input to output using the fuzzy logic. Typical FIS will consist of MFs, rule base and the inference procedure. Basic structure of the FIS consist of the three conceptual components, namely:

a) A rule base that contains a selection of the fuzzy rules;

b) A database that defines the MFs used in fuzzy rules;

c) A reasoning mechanism that performs inference procedure upon rules and using facts to derive the conclusion or the reasonable output. The inputs of FIS can either be crisp values (viewed as the fuzzy singletons) or fuzzy sets. A method of Defuzzification will be required in extraction of crisp value best representing fuzzy set if a system produces the fuzzy sets as the output while the crisp output is needed [20] [31]. Most of the FIS can be grouped into two, namely Sugeno and Mamdani fuzzy depending on types of if – then rules employed and fuzzy reasoning.

2.6.1. Mamdani Fuzzy Model

The Mamdani fuzzy model was proposed by Mamdani in the year 1975 [30] in an attempt to control the steam engine and the boiler combination using a set of the control rules. The Mamdani fuzzy system, uses the fuzzy sets as the rule consequent.

2.6.2. Sugeno Fuzzy Model

The Sugeno fuzzy model was proposed by Takagi Sugeno, and Kang [30] in their effort to develop the systematic procedure of generating the fuzzy rules from the given input-output data set models. These adaptive techniques are used to customize MFs so that fuzzy system best models data.

2.7. Artificial Neural Networks

The Artificial Neural Network, (ANN) is an information processing technique that has the capability of performing the computations similar to the biological neural network or the human. ANN is the technique seek to come up with an intelligent program that can implement intelligence similar to the one of the human brain processing. The ANN incorporates models that simulate inter-connection of the neurons so that the neuron outputs are connected via weights, to the other neurons including themselves. ANN works in a similar way just like human brain learns and remembers. With a set of the input data patterns, ANN network is trained to give the corresponding desired patterns at output [32] [33]. The reasons why this artificial intelligence technique has become famous are;

(i) Real Time Operation - ANN computations are carried out in parallel with the simulations.

(ii) Parallel Computation - ANN is a massive and fast parallel input parallel output (PIPO) multidimensional computing system. Two Learning methods are used for ANN and they are supervised and unsupervised learning.

(iii) The ability to derive the meaning from the imprecise or complicated data.

(iv) The Adaptive learning – The ability to get to learn how to accomplish tasks based on data given for initial experience and training.

(v) Self-Organization - An ANN can build its own representation or organization of information it receives during the learning time.

2.7.1. Supervised Learning

The aim of the supervised learning is to assist in shaping the input-output mappings of the network based on a given training data set. First desired input-output data sets has to be known. Resulting networks must have adjustable parameters that needs to be updated by the supervised learning rule. Adjustable parameters are also referred to as the weights. In the supervised training both inputs and outputs are provided. The network processes inputs and then compares its outputs against desired outputs. The Errors are then propagated back through system causing it to adjust the weights which will control the network. The process will occur over and over as weights are continually tweaked [33]. That set of the data that enables training is known as the 'training set'. During the training process of the network, same set of the data will be processed many times as the connection weights are refined. The important issue that concerns the supervised learning is problem of the error convergence (i.e. the minimization of the error between desired and the computed unit values. The training process will involve two steps namely; backward propagating step and a forward propagating step. Forward pass allows the training input data to be presented to input layer. Data propagates through the hidden layer(s) until when it reaches output layer where it will be displayed as output pattern. For backward pass, error term is calculated and then propagated back in order to change assigned weights of inputs. Magnitude of error value will indicate how large the adjustment need to be done and sign of error value whether positive or negative will give the direction of change [34].

2.7.2. Unsupervised Learning

In an unsupervised training, network will be provided with the inputs but desired outputs are not provided. The system then decides what features will be used to group input data oftenly referred to as the self-organization or the adaption. It's learning with no availability of information concerning desired output. The network updates the weights only based on input patterns. Self-organizing means ability to get knowledge through trial and error learning process that involves organization and reorganization in the response to the external stimuli [33] [34]. The most common example of unsupervised learning algorithm is the Kohonen self-organizing maps sometimes known as Kohonen self-organizing feature maps, [34].

2.8. Neuro-Fuzzy Systems

Fuzzy logic and neural networks are two complementary technologies. This is so because the neural networks have learning ability that can learn knowledge using the training examples, while FIS deduces knowledge from given fuzzy rules. The combination of the two outperforms either fuzzy logic or neural network method used exclusively [35]. Factors that have made neuro fuzzy systems popular in recent past are: [36] [34]

a) Accurate and fast learning

b) The Excellent explanation facilities in form of semantically meaningful fuzzy rules

c) Ability to accommodate both the data and the existing expert knowledge on the problem.

d) Good generalization capability.

2.8.1. Adaptive Neuro-Fuzzy Inference System (ANFIS)

Fundamentally the ANFIS is all about taking the FIS and tuning it with the ANN algorithm using some collection of the input-output data. With the given input and output data set, toolbox function ANFIS will construct the FIS whose MF parameters are adjusted (tuned) using backpropagation algorithm alone or the combination with the least squares type. The adjustment will allow the fuzzy systems to learn from data they are modeling [34] [37]. Parameters associated with MFs changes through learning process. The adjustment of these parameters (or their computation) is facilitated by the gradient vector. The gradient vector will provide the measure of how well FIS is modeling input and output data for the given set of parameters. Any of the several optimization routines will be applied to adjust parameters and reduce measure of error when gradient vector is obtained. The measure of the error is the sum of squared difference between the actual and the desired outputs [35] [38]. The process is known as the supervised learning in the neural network terms. By combining advantages of the imprecise data sampling of the fuzzy logic and intelligence of the ANN, neuro-fuzzy performs better than the two AI, therefore this AI method was chosen for the development of ANFIS algorithm. In this work supervised learning was used since data sets for training the ANFIS was available and clusters or categories were known.

2.5 Related work

In [39] authors dealt with two parameters for the handover decision making. They include RSSI (Received Signal Strength Indicator) and relative direction of the mobile node towards a BTS. Then two inputs were considered as inputs to the fuzzy logic system in the facilitation of the handover decision. Other parameters such as bandwidth and analysis of the traffic were not considered in their work. Only one type of traffic i.e. voice call was considered.

Work done by Pooja Dhand and Parwinder Dhillon, explained in paper [40] included signal strength, speed of the Mobile Station (MS) and traffic pattern were considered as the inputs to the Fuzzy Logic System (FLS) in the facilitation of handover decision. It is also evident in their work that they didn't consider handover improvement for the multimedia services. For the future work, they proposed extension of their algorithm (FCHO) to handle the heterogeneous environment.

Work done by Emily Teresa and Vitalice K. Oduol explained in their paper [41] considered three inputs to the fuzzy logic system. Three parameters that were considered were signal quality in current serving cell, signal level and mobile station velocity. Their work was only centered on GSM network but proposed the extension of the idea to other networks and for future work they proposed a way in which the actual level of handover success rate improvement will be validated. Authors in [42] used process of signaling for the control of traffic between BTS and mobile node in the Wireless Local Area Networks (WLAN) for examination of handover latency was presented.

Work done by D. Sarddar, S.Chatterje, and U. Biswas in their paper [43] explained the reduction of handover latency. In their work ping pong effect could not be removed. This can be minimized if the input value i.e. received signal strength was included in their work. Also in their work they didn't take into consideration the management of handovers for multimedia services.

In [44], authors dealt with four parameters for handover decision in a heterogeneous wireless network. Their developed algorithm was based on multiple criteria which consisted of the three technology interfaces (LTE, WiMAX and WLAN) employing three kinds of vertical handover decisions algorithm (Network priority, Mobile priority and Equal priority). For future work, they proposed optimization of the vertical handoff decisions algorithm using a combination of multicriteria method with other methods for vertical handover such as fuzzy logic or cost function. They argued that a combination of the multiple strategies was to improve the network performance.

In [45], authors proposed a multi-criteria handoff algorithm basing on fuzzy logic. They considered four input parameters that included, path loss, SNR, RSS and traffic load of BTS. The main aim of their work was to develop an algorithm that was to balance traffic load among BTSs in the cluster through the handover process. For future work, they suggested a research to be carried out in order to find out different types of membership functions which can result in the optimal handoff performance.

In [46], authors proposed an 'optimized network selection and handover triggering scheme for heterogeneous self-organized wireless networks' that operated in two stages i.e. handoff triggering mechanism and network selection scheme. They presented an optimized scheme for network selection basing on speed of the Mobile Node. The proposed scheme performed few number of frequent handoffs as a result it suffered from small amount of the packet loss. Authors in [47], proposed fuzzy Q-learning algorithm that was used to find optimal set of the fuzzy rules for fuzzy logic controller in balancing traffic in GERAN (GSM – EDGE Radio Access Network. From obtained results, they were able to achieve significant reduction in the call blocking in the congested cells. The main drawback was the slight increment in the call dropping and increase in signaling load of the network as a result of higher number of handovers. Jae-wook Lee et al [48] proposed a method which probalistically estimated path in the femtocell and made a handover decision by comparison of available data capacity which could be obtained in estimated path. Actual handoff was performed only when expected capacity of data gain due to handoff existed in proposed probability model.

In [49], authors used fuzzy logic with AHP. They used fuzzy logic to calculate membership values for each of the parameter measured while they used AHP to find associated weights with parameters. The aim of the work was to select wireless network for a given service satisfying end users preference such as high reliability, optimum bandwidth, low cost, long battery life and good RSS. In [50], authors used AHP to trigger handover while fuzzy logic was used in selecting best access network from the list of the candidate networks. In [51], authors proposed adaptive handover management protocol based on fuzzy. Parameters used included distance and MS velocity that were fed to FLS in determination of value of the adaptive RSS threshold that was used in triggering off handover. The drawbacks of the proposed scheme is that it does not consider any Quality of Service related parameters.

Authors in [52], used loading conditions of candidate wireless networks and MS velocity in determination of best access network. The aim of this scheme was improvement of the handover efficiency when mobile stations are moving at high speed.

Authors in [53], proposed modular fuzzy logic based handover decision algorithm that utilized a number of QoS parameters. The aim of this scheme was reduction of execution time of traditional fuzzy logic system and computational complexity by using multiple parallel FLC. The algorithm divided the handover parameters to multiple groups where each group operated with different fuzzy engine. Outputs of each of the engine is then channeled to another fuzzy engine to determine degree of the overall satisfaction.

In [54], author developed an algorithm basing on separate MF for velocity, network loading and RSS parameters. The author created three separate fuzziefiers. The aim of this algorithm was to apply FL in achieving normalization of parameters of the network. The drawback of this algorithm is that no quality of service, QoS parameters were taken into consideration.

Authors in [55] proposed a QoS aware fuzzy rule based multicriteria scheme. FLS that was created accepted four parameters related to QoS as the inputs to calculate handover score for a given network. The network with highest handover score being selected as target of handover.

This research didn’t take into consideration important parameters such as user mobility, RSS and preferences when formulating handover decisions. The other issue is the large number of rules. Authors in [56] proposed multi criteria vertical handover decision algorithm that selected best network available with the optimized parameter values in the heterogeneous wireless environment. Other tools such as genetic algorithms and neural network have also been used in optimization of multi criteria vertical handover decision parameters. In [57], authors used FL with MODM (Multiple Objective Decision Making) in selecting best network segment, while in [58] implementation of handover initiation algorithm by combination of multiple parameters of the all available networks through a cost function was done. Selection of the target network was accomplished using FIS utilizing only two input parameters e.g. available bandwidth and velocity. Lack of important parameters might cause the scheme not to produce optimal results. Research paper in [59] proposed a FL with only RSS and QoS in estimation of necessity of handover. Authors in [60] proposed an algorithm that utilized FL in dealing with wrong traffic information, keeping the overall system stability and formulating load allocation decisions. They brought out new approach that specified when, how and by which Base Transceiver Station load balancing was to be implemented. Authors in [61] developed an algorithm for handover based on fuzzy logic. From their simulation results, they showed that their algorithm suppressed ping pong effect when compared to competitive algorithms. For future work they proposed the extension of the algorithm in order to optimize fuzzy rules base. Authors in [62] developed an algorithm for handover based on user mobility for LTE. Their only contribution was inclusion of user's equipment speed. For future work they proposed the study of the effects of other types of the fuzzy logic on handover with inclusion of user equipment speed. Authors in [63] developed a handover algorithm for the trunking system. They considered inputs such as delay, forecasting RSS, network loads, RSSI, and battery utilization. Authors in [64] developed a fuzzy logic algorithm for handover. They considered input parameters such as RSSI, user velocity, interference level and data rate to make handover decisions. Authors in [65] developed a multi-criteria handover decision algorithm in the wireless networks. They discussed several techniques for the multi-criteria handover. A number of inputs were considered when selecting a network. Authors in [66], proposed a fuzzy logic algorithm to optimize handover performance in the Hetnets. For future work they proposed its advancement through testing in a PMIPV6. They did not consider handover for multi-media network services.

In [67], authors presented dynamic load balancing scheme basing on the Sojourn time for the heterogeneous hierarchical wireless network. The Sojourn time being calculated by direction of motion, local position of mobile station and velocity. Authors in [68], proposed novel load balancing scheme that used fuzzy logic in the cloud computing. Authors in [69], [70] used velocity, mobile station and RSS as parameters in handover decision making using fuzzy logic. Authors in [71], proposed vertical handover decision algorithm for the wireless heterogeneous networks based on adaptive neuro fuzzy inference. Parameters that were considered were data rate, RSSI and monetary cost. From their results they concluded that ANFIS algorithm provided enhanced outcomes for the network and the user. According to their results, ANFIS reduced number of handovers as opposed to pure Fuzzy logic. Authors in [72], proposed the novel vertical handover algorithm based on ANFIS. They considered parameters such as subscriber speed, jitter, initial delay, and bandwidth and the received signal strength. Their results showed that the ANFIS in design is simpler and has less time delay. Authors in [73], proposed an ANFIS handover algorithm. Two input parameters were considered (RSSI and BER). Their aim was to introduce a training element to existing fuzzy handover algorithm. With the use of ANFIS, number of rules was reduced to only three reducing complexity of system and speed of training convergence. Authors in [74], proposed the ANFIS for the dynamic load balancing for 3GPP LTE. Three input parameters were considered (fairness index, hysteresis and satisfied users). Authors in [75], proposed adaptive netwok based on fuzzy inference system model for minimizing handover failure in mobile networks. They considered three inputs (signal to interference ratio, speed of the mobile phone users and distance. They concluded that rate of handover failure in the mobile wireless network was effectively controlled by ANFIS. Also the effectiveness of their algorithm was determined by the amount of data set used to train ANFIS.

2.6 Limitations of previously developed algorithms

All the above fuzzy logic handover techniques does not consider handover for multimedia network services based on their quality of service requirements and at same time optimizing the handover process. In the effort to address the above, this work presents a fuzzy logic handover algorithm where the threshold for the three multimedia network services are calculated based on their quality of service requirements. Priority being given to the voice calls as compared to the web traffic since calls in progress cannot tolerate delay but web traffic can tolerate some delay. The proposed algorithm will optimize handover by increasing handover success rate through parameter tuning and by increasing the number of parameters to the FIS.

From the ANFIS handover algorithms, it is evident that none of the authors have considered how number of inputs affects the performance of ANFIS handover algorithm. In this work, an investigation of how increase in number of the inputs to ANFIS affects the handover decision is also carried out.

CHAPTER THREE

METHODOLOGY

Section one of this chapter covers the design of fuzzy logic algorithm for optimization of handover decisions in a mobile cellular network for multimedia services. Section two covers the design of a multi criteria ANFIS handover algorithm. Data from the first section is used in development of the second section.

3.1 Development of fuzzy logic algorithm for optimization of handover decisions.

3.1.1 Model Description

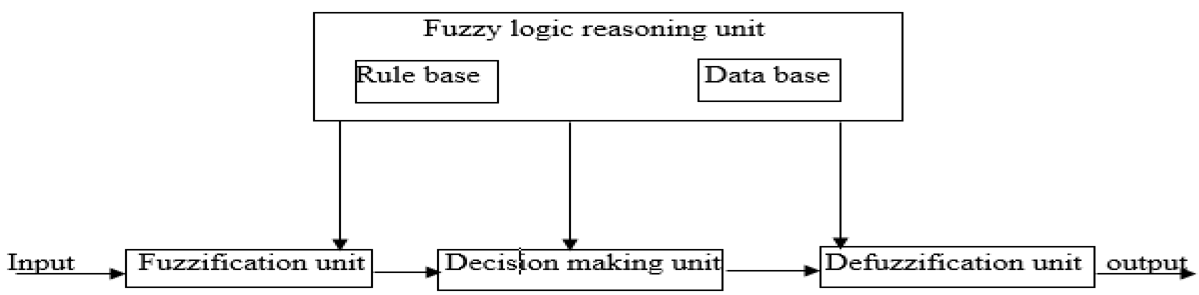

Figure 3. 1 Elements of a fuzzy system

Figure 3.1 shows the elements of a fuzzy system. The important unit of FIS is the fuzzy reasoning unit whose composition includes the rule base and data base. The fuzzy stage translates inputs into truth or real values while the rule base computes the output truth values.

Defuzzification stage will transfer the output values into output.

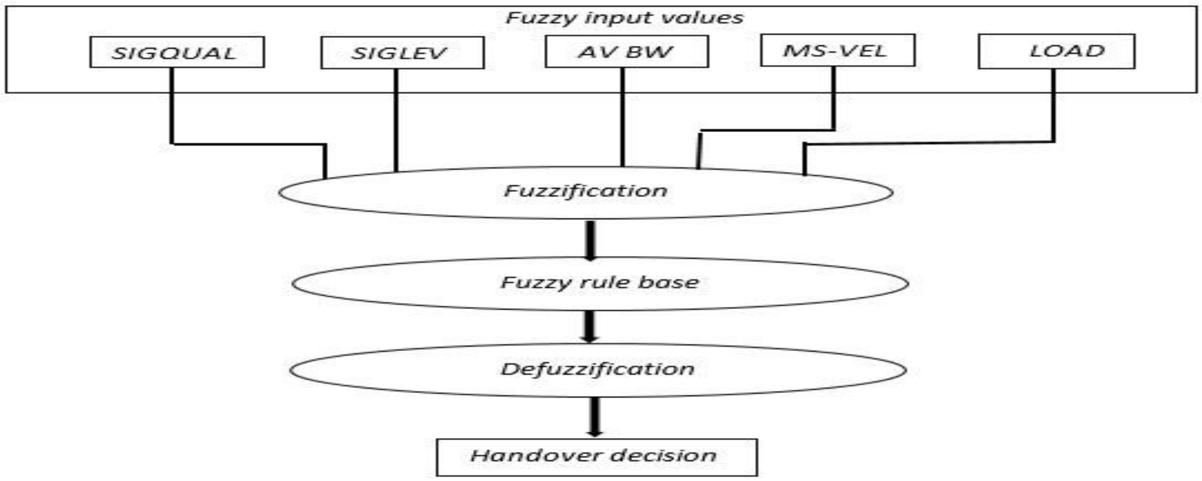

Figure 3. 2 Block diagram of the fuzzy system

Figure 3.2 shows the block diagram of the developed fuzzy system. Input parameters – signal quality, signal level, available bandwidth, MS velocity and traffic load of the BTS. Fuzzy stage translates inputs into truth or real values while rule base computes output truth values. Defuzzification stage transfers output values into output. Output of fuzzy logic system is handover decision used later in deciding if handover will be necessary or not.

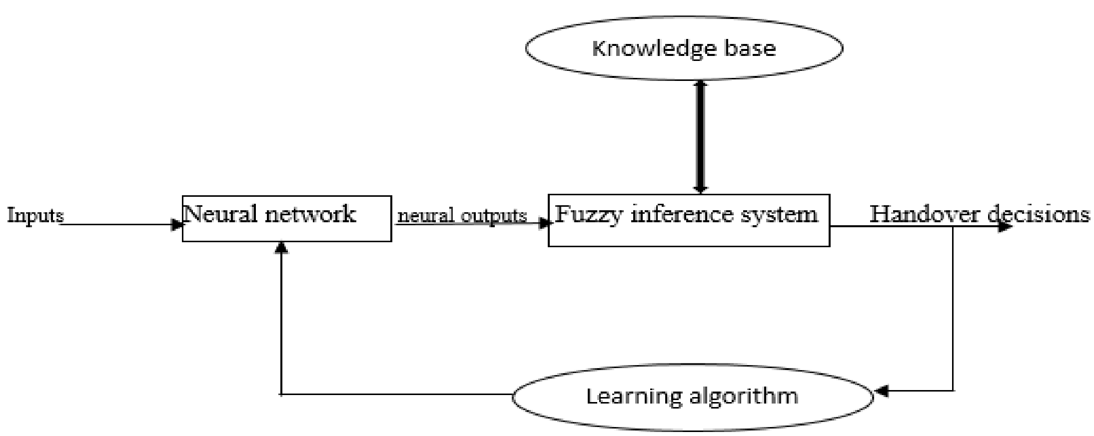

Figure 3. 3 Block diagram of the ANFIS system

Figure 3.3 shows the block diagram for the Adaptive Neuro Fuzzy Inference System, data was collected for the five inputs that is available bandwidth, signal level, MS velocity, traffic load of BTS and signal quality and fed to the ANFIS system. The output of the system was the handover decision.

3.1.2 Proposed algorithm Fuzzy Logic handover algorithm (FLHO)

In this research work, a fuzzy logic handover algorithm is presented whose aim is to improve the handover decision for multimedia network services. The three multimedia services i.e. voice call traffic, video traffic and web traffic have different QoS requirements. Therefore handover process should be handled differently for the three multimedia services.

For the handover to take place effectively, five parameters are considered. These parameters are BTS traffic load in percentage, velocity of the Mobile station (VEL-MS), signal quality (SIGQUAL) and signal level (SIGLEV) and available bandwidth. In the proposed algorithm a range of SIGLEV is taken to be 0 to 63 corresponding to the decibel referenced to milli watt (dBm) which is in a range between -48dBm to -110dBm, SIGQUAL varies from 1 to 7 measured in dBm, MS velocity range from 0 Km/hr to 100Km/hr, BTS traffic load range from 0 to 100%, and available bandwidth from 0 to 1Mb.

The algorithm is divided into two parts:

(i) The first phase is the setting up of the minimum threshold for handover.

(ii) Second phase is the handover decision making.

In the first phase, three input parameters are considered for setting the threshold, they include SIGQUAL, SIGLEV and AV BW. The threshold will have numerical values of numbers between [0 1]. The threshold is divided into four linguistic regions. VERY LOW [0-0.20], LOW [0.20-0.45], MEDIUM [0.45-0.70] and HIGH [0.70-1].

In the second phase, two input parameters are considered for handover decision making. They include MS-VEL and BTS traffic load in percentage.

3.1.2.1 Fuzzification

This is a process of making a crisp value fuzzy. In other words it represents the mapping from crisp value to a fuzzy set. The main aim of this step is the conversion of crisp values into fuzzy sets. Input values will have membership degree that varies in interval [0 1]. There are two types of fuzziefier that are being used. They include singleton and non-singleton. In this case non singleton fuzziefier is used i.e. the Gaussian which produces superior performance when compared to singleton fuzziefier.

Gaussian membership functions are used since they improve the robustness and reliability of the system. Gaussian MFs are used as an alternative to traditional triangular membership functions [76]. The membership values are obtained by mapping values obtained for particular parameter into the membership. For example if received signal quality is considered in crisps set, then it can be either weak or strong and not both at the same time. While in fuzzy set the signal quality can be either considered weak or medium at same time with graded membership.

Input parameters in this work are described by three linguistic regions: ‘WEAK’, ‘MEDIUM’, and ‘STRONG’ for signal level and signal quality input variables while ‘SMALL’, ‘MEDIUM’ and ‘LARGE’ for available bandwidth input variable and ‘LOW’, ‘AVERAGE’ and ‘HIGH’ for velocity of MS input variable and ‘VERY SMALL’, ‘SMALL’, ‘MEDIUM’ and ‘LARGE’ for BTS traffic load. Input variable. For the output variable, the linguistic regions are four and they include: ‘Handover’, No Handover’, ‘Wait’ and ‘Prepare to handover’.

The following antenna measurements from the previous research have been used when selecting the three linguistic regions [45].

Table 3. 1: Antenna measurements

RX quality	**Strength**	**Color on screen**
$0<x<4$	Excellent	Dark green color
$4<x<5$	Good	Yellow color
$5<x<7$	Poor	Red color

Table 3.1 is giving the antenna measurements. In this case, the three linguistic regions are excellent, good and poor. It’s for this reason that the linguistic regions for signal quality and signal level were chosen to be three.

3.1.2.2 Inference Engine and Rule Base

It consists of set of rules which will represent the knowledge base and the reasoning structure of the problem solution. The fuzzy engine will apply rules in the rule base to output a fuzzy value. The rule base has rules that are modeled based on knowledge and experience [77]. The number of the rules will depend on the number of input variables and distinguished linguistic regions for each input variable. For this problem, the number of input variables is five each having three distinguished linguistic regions. Previous references have shown that FLC has been successfully used to automate network parameter optimization. The merit of FLC is its capability to convert the human knowledge into set of basic rules.

When designing an FLC set of IF-THEN rules have to be defined that will represent mapping of input to output in the linguistic terms [78]. Such rules being extracted from operators experience. Mamdani method is used in the development of the rules where the simulation is done using MATLAB. System simulation is carried out using **Mamdani Fuzzy Inference system** because of its suitability to human inputs. Fuzzy inference will gather input values of signal quality, signal level, interference level, distance between BTS and MS and MS velocity as the crisp inputs then evaluating them according to fuzzy interference rule base. The aggregated and composed outputs of rule evaluation is then defuzzified using centroid of area method to obtain the crisp output.

3.1.3 First phase: Setting of the threshold

3.1.3.1 Voice call traffic

For handover to take place in this case, five input variables are considered. They include, BTS traffic load, signal quality (SIGQUAL), signal level (SIGLEV) and Mobile station Velocity (MSVEL) and Available bandwidth (AV BW). SIGQUAL, SIGLEV, available bandwidth inputs are used in setting up the minimum threshold for handover process. Some of the objectives for formulating rules for voice call traffic are:

(i) If SIGQUAL is weak and SIGLEV is also weak, the threshold for handover is increased to reduce handover failures.

(ii) If SIGQUAL is weak and SIGLEV is medium, the threshold for handover is increased to reduce handover failures.

(iii) If SIGQUAL is strong and SIGLEV is medium, the threshold for handover is decreased to reduce unnecessary handovers.

(iv) If SIGQUAL is strong and SIGLEV is strong, the threshold for handover is decreased to reduce unnecessary handovers.

3.1.3.2 Video traffic

For handover to take place in this case, five input variables are considered. They include, BTS traffic load, signal quality (SIGQUAL), signal level (SIGLEV) and Mobile station Velocity (MSVEL) and Available bandwidth (AV BW). SIGQUAL, SIGLEV, available bandwidth inputs are used in setting up the minimum threshold for handover process. Some of the objectives for formulating rules for video call traffic are:

i. If SIGQUAL is weak and SIGLEV is also weak, the threshold for handover is increased to reduce handover failures.

ii. ii. If SIGQUAL is medium and SIGLEV is medium, the threshold for handover is decreased to reduce unnecessary handovers.

iii. If SIGQUAL is strong and SIGLEV is medium, the threshold for handover is decreased to reduce unnecessary handovers.

iv. If SIGQUAL is strong and SIGLEV is strong, the threshold for handover is decreased to reduce unnecessary handovers.

3.1.3.3 Web traffic

For handover to take place in this case, five input variables are considered. They include, BTS traffic load, signal quality (SIGQUAL), signal level (SIGLEV) and Mobile station Velocity (MSVEL) and Available bandwidth (AV BW). SIGQUAL, SIGLEV, available bandwidth are used in setting up the minimum threshold for handover process. Some of the objectives for formulating rules for web call traffic are:

a) If SIGQUAL is weak and SIGLEV is also weak, the threshold for handover is increased to minimize handover failures.

b) If SIGQUAL is medium and SIGLEV is medium, the threshold for handover is decreased to reduce unnecessary handovers.

c) If SIGQUAL is strong and SIGLEV is medium, the threshold for handover is further decreased to reduce unnecessary handovers.

d) If SIGQUAL is strong and SIGLEV is strong, the threshold for handover is further decreased to reduce unnecessary handovers.

3.1.4 Second phase: handover decision making.

In this phase two input parameters are considered. They are the MS-VEL and BTS traffic load. Since the quality requirements for voice traffic is high, handover for this case is given a higher priority. According to [79], the higher the threshold level the lower the mean number of handovers where the high threshold values reduces the average number of handovers but increases the delay in handover.

For voice traffic, threshold values in the [0.20-0.45], [0.45-0.70] and [0.70-1] ranges are considered for handover decision making process, since calls in progress are more sensitive to delay as compared to other forms of traffic. For video traffic threshold in the [0.45-0.70] and [0.70-1] ranges are considered for handover decision making process while for web traffic [0.70-1] threshold values are considered. Some of the objectives for setting up the rules are:

(i) If the MS-VEL is low and BTS traffic load is low and the threshold value is low, the output is 'No Handover'

(ii) If the MS-VEL is low and BTS traffic load average and the threshold value is low, the output is 'No Handover'

(iii) If the MS-VEL is high and BTS traffic load is High and the threshold value is high, the output is 'Handover'

(iv) If the MS-VEL is high and BTS traffic load is low and the threshold value is high, the output is 'Handover'

(v) If the MS-VEL is low and BTS traffic load is low and the threshold value is average, the output is 'wait'

(vi) If the MS-VEL is high and BTS traffic load is large and the threshold value is low, the output is 'get ready'

3.1.5 Fuzzification of input parameter SIGQUAL

The main objective is to develop a fuzzy logic algorithm for multimedia network services that will optimize the handover decisions for wireless multimedia network services to ensure a guaranteed Quality of Service. Signal quality will play an important role in achieving this objective.

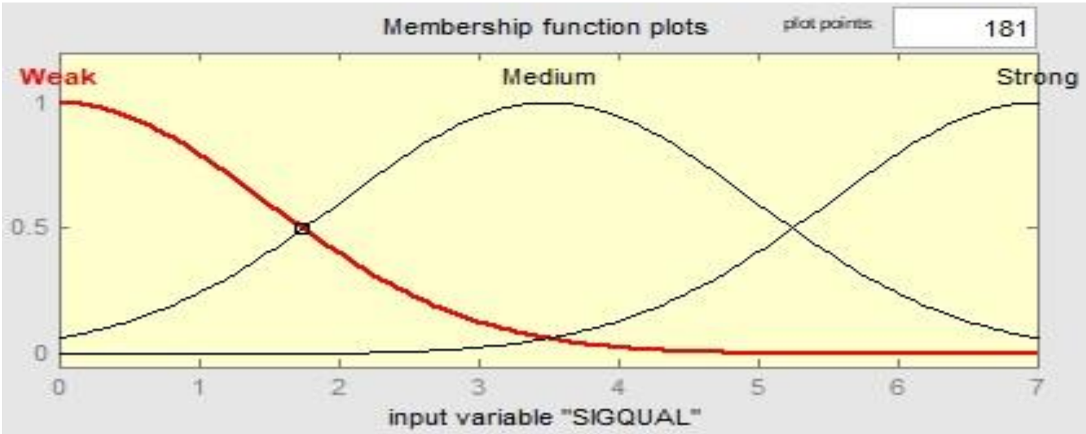

Figure 3. 4 Membership function of Signal Quality

Figure 3.4 is designed to ensure the threshold of handover is increased to a value that can guarantee handover once the signal quality is in the range 5 to 7.

Table 3. 2: Description on input variable signal quality**.**

SIGQUAL description	**SIGQUAL range**
Weak	5 to 7
Medium	4 to 5
Strong	0 to 4

The universe of discourse for SIGQUAL is between 0 to 7 as shown in Table 3.2 above. Weak signal quality is between 5 to7 meaning the MS in this region will have a higher threshold value since the signal quality is now deteriorating. Signal quality reflects mean bit error rate, (BER) for over a 0.5s period. It has eight categories from 0 to 7. Signal quality being measured according to the BER as shown in Table 3.3.

Table 3. 3: BER mapping to SIGQUAL [7]

RxQual	BER
RxQual_0	Less than 0.1 %
RxQual_1	0.26% to 0.30%
RxQual_2	0.51% to 0.64%
RxQual_3	1.0% to 1.3%
RxQual_4	1.9% to 2.7%
RxQual_5	3.8% to 5.4%
RxQual_6	7.6% to 11.0%
RxQual_7	Greater than 15.0%

3.1.6 Fuzzification of input parameter SIGLEV

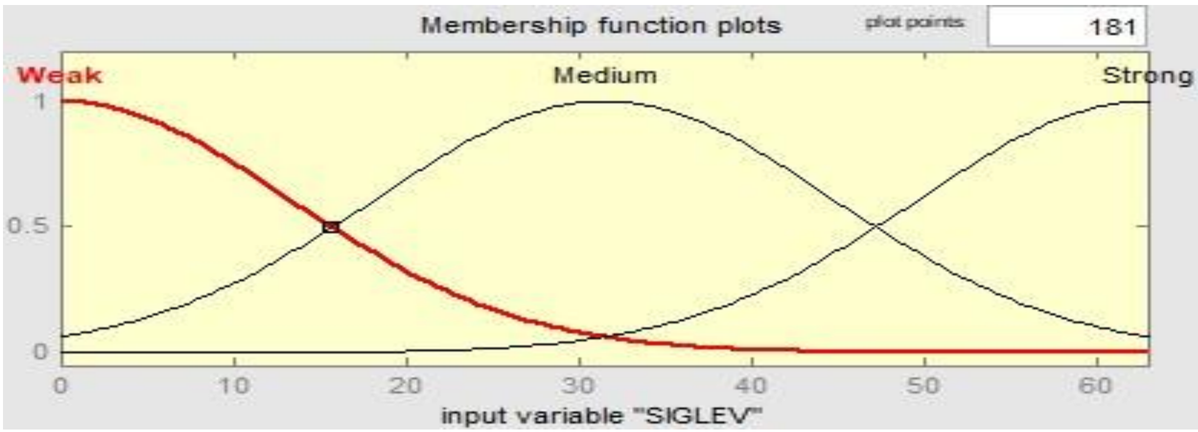

Figure 3. 5 Membership function of Signal Level

Figure 3.5 is designed to ensure the threshold of handover is increased to a value that can guarantee handover once the signal level is in the range 45 to 63.

Table 3. 4: Description on input variable signal level**.**

SIGLEV description	SIGLEV range
Weak	45 to 63
Medium	28 to 45
Strong	0 to 28

The universe of discourse for SIGLEV is between 0 to 63 as shown in Table 3.4 above. Weak signal level is between 45 to 63 meaning the MS in this region will have a higher threshold value since the signal level is now deteriorating. 0 is representing weakest signal while strongest signal is represented by 63 as shown in Table 3.5. In GSM any RSSI below -110 dBm is considered unreadable.

Table 3. 5: RSS mapping to SIGLEV ***[7].***

RxLev	dBm Range
0	<-110
1 to 62	- 110 to -48
63	> -48

3.1.7 Fuzzification of input 'available bandwidth'

Universe of discourse for this input is between 0 to 1MB as shown in the figure below.

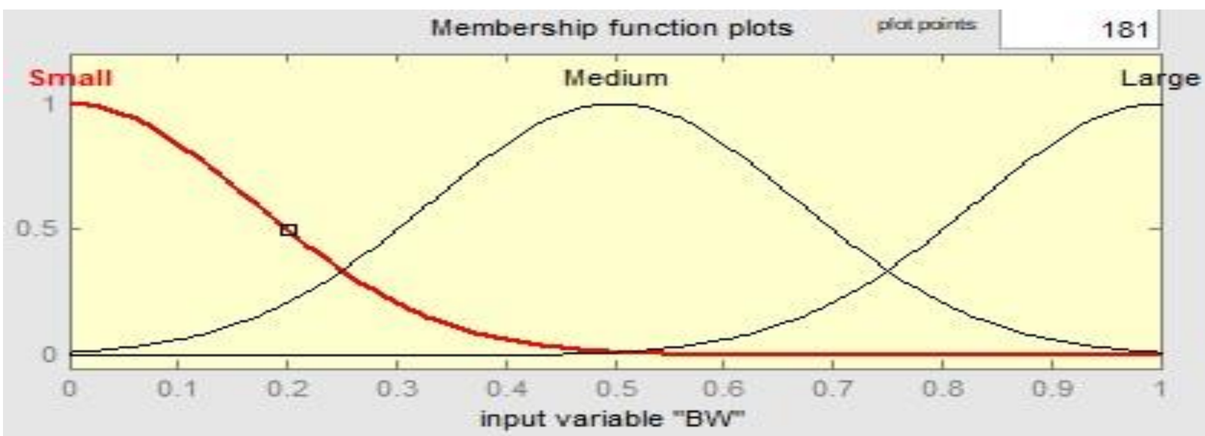

Figure 3. 6 Available bandwidth in megabytes Membership function

Figure 3.6 is designed to ensure the threshold of handover is increased to a value that can guarantee handover once the available bandwidth is in the range 0 to 0.25Mb.

Table 3. 6: Description on input variable ‘Available bandwidth’

Available bandwidth description	**Available bandwidth range (Mb)**
Small	[0 0.5]
Medium	[0 0.5 1]
Large	[0.5 1]

The universe of discourse for available bandwidth is between 0 to 1Mb as shown in Table 3.6 above. Low bandwidth is between 0 to 0.5 meaning the MS in this region will have a higher threshold value since the ‘available bandwidth’ is now decreasing.

3.1.8 Fuzzification of the Output Threshold values

Figures 3.7, 3.8 and 3.9 are giving membership function for threshold value for voice, video and web traffics respectively.

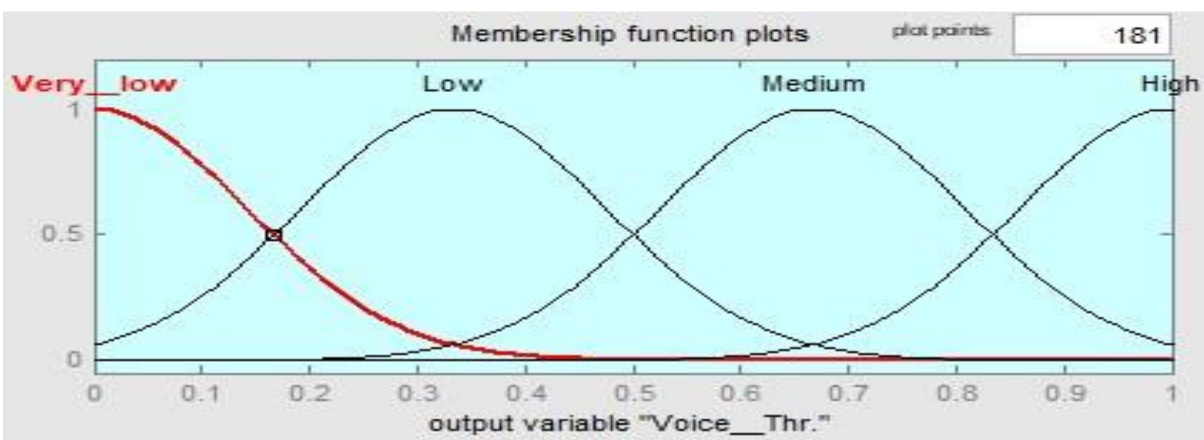

Figure 3. 7 Threshold values membership function for voice traffic

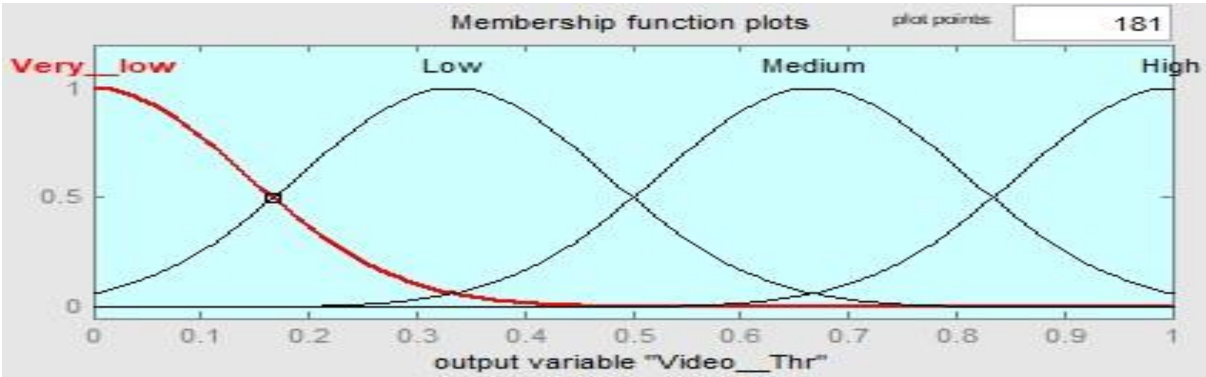

Figure 3. 8 Threshold values membership function for video traffic

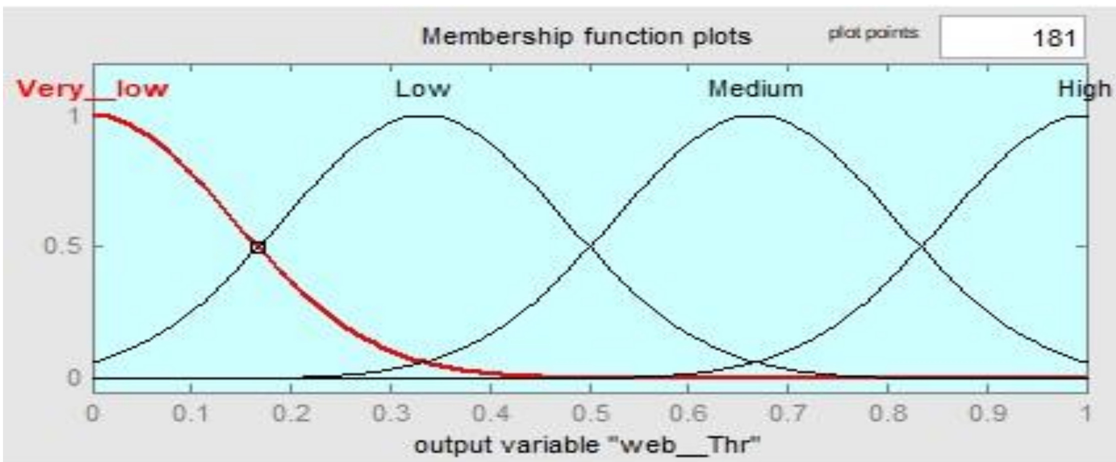

Figure 3. 9 Threshold values membership function for web traffic

Table 3. 7: Description of output variable threshold.

Threshold description	**Threshold range (which is a probability)**
Very low	0 to 2.5
Low	2.5 to 0.5
Medium	0.5 to 0.75
High	0.75 to 1.0

The universe of discourse for threshold is between 0 to 1 as shown in Table 3.7 above. Very low threshold is between 0 to 0.25 meaning the MS in this region will have a lower handover probability as compared to the one in the range 0.75 to 1.0 which has higher probability of handover.

3.1.9 Fuzzification of input parameter MS-Velocity

The main objective is to develop a fuzzy logic algorithm for multimedia network services that will optimize the handover decisions for wireless multimedia network services to ensure a guaranteed Quality of Service. MS-Velocity will play an important role in achieving this objective.

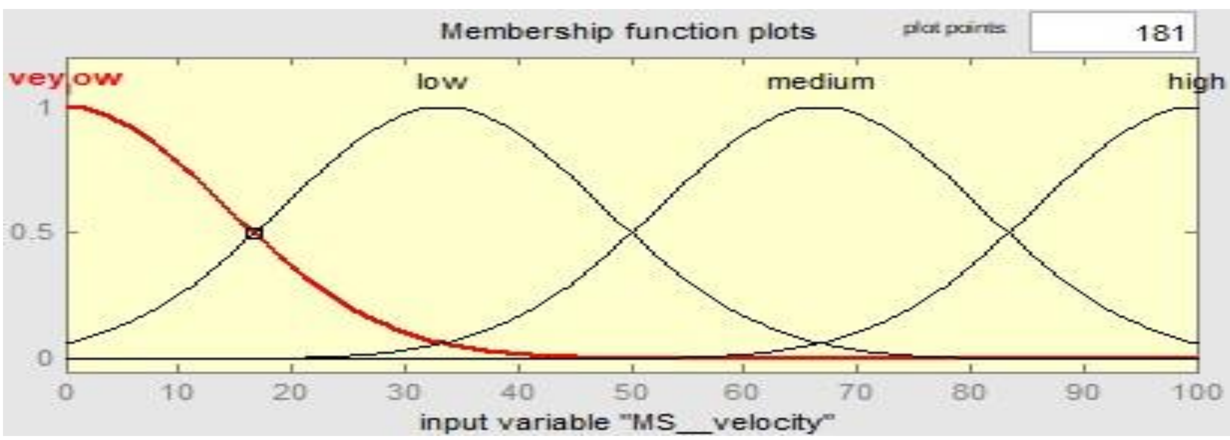

Figure 3. 10 Membership function of MS-Velocity

Figure 3.10 is designed to ensure the threshold of handover is increased to a value that can guarantee handover once the MS-Velocity is in the range 0 to 25.

Table 3. 8: Description on input variable MS-Velocity**.**

MS-Velocity description	MS-Velocity range (km/hr)
Very low	0 to 25
Low	25 to 50
Medium	50 to 75
High	75 to 100

The universe of discourse for MS-Velocity is between 0 to 100 as shown in Table 3.8 above. Very low MS-Velocity is between 0 to 25 meaning the MS in this region will have a lower handover probability as compared to the one in the range 75 to 100 which has higher probability of handover.

3.1.10 Fuzzification of Traffic Load input parameter

Universe of discourse for this input is between 100 to 0% as shown in the figure below.

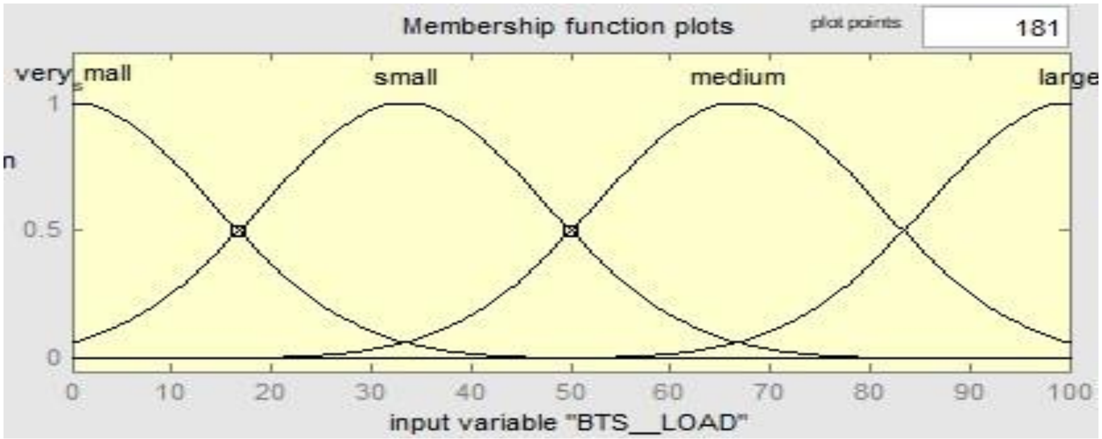

Figure 3. 11 Traffic load in percentage Membership function

Table 3. 9: Description on input variable 'traffic load in percentage'**.**

Traffic load in percentage description	**Traffic load in percentage range**
Very small	[0 50]
Low	[0 33 73]
Medium	[23 67 100]
Large	[60 100]

Figure 3.11 is giving the membership function for the input parameter traffic load (in percentage).This is one of the inputs that will be used in the second stage of the handover decision. When the BTS traffic load is in the range [60 100] as shown in Table 3.9, it means that it's overloaded hence the need of handing over some of its load to the

neighboring BTS. The fuzzy logic system is designed in a way that, overloaded BTS handovers some of its ongoing traffic.

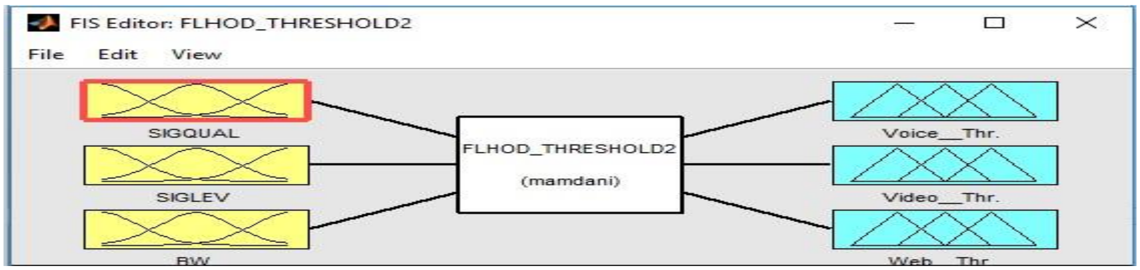

Figure 3. 12 Input Output representation for the threshold setting stage

Fuzzy knowledge base represents the complex system not as a set of nonlinear differential equation, complex but as simplified set of the input-output rule. The design of the rule base is very important stage in the development of the fuzzy knowledge based system. Figure 3.12 shows the input-output representation for the threshold setting stage. It has three inputs, which are signal quality, signal level and 'available bandwidth'. The system is giving three outputs that is voice, video and web traffics thresholds.

The second step of handover process involve feeding of the fuzzy sets to an inference engine, where by a set of the fuzzy IF-THEN rules is applied in order to obtain the fuzzy decision sets. The fuzzy rules are defined as the set of possible scenarios that decides whether handover is going to be necessary or not. For this case we used sets [Handover, Prepare to handover, Wait and Handover] to represent fuzzy set of the output handover decision, the range of decision matrix being from zero to one, where 1 is Handover and 0 is exactly No Handover.

Figure 3.13 indicates three inputs to FIS for the second stage of the algorithm. The output of the FIS is the decision if handover process is to be executed or not. Decision to execute handover process will depend on preset probability value (i.e. threshold handover execution has to meet).

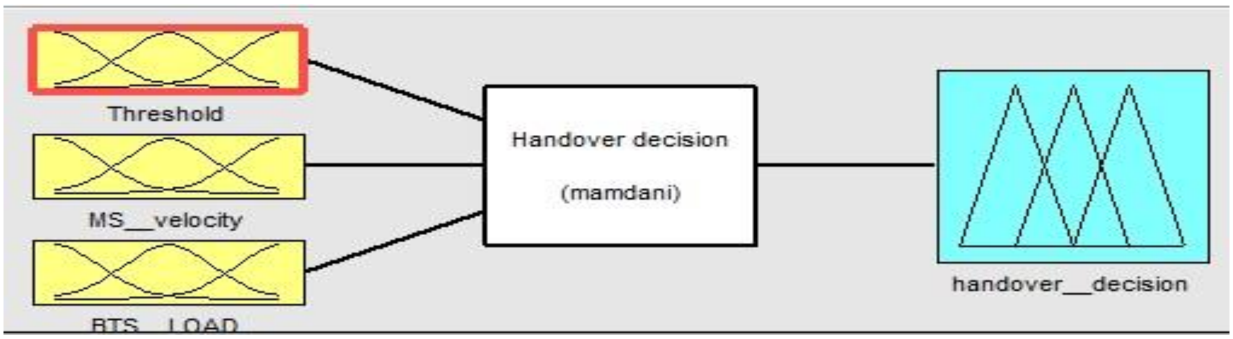

Figure 3. 13 Input and output representation for the handover decision stage

To formulate the first stage of the Fuzzy Logic algorithm, 27 IF- THEN rules with the minimum operator are specified using the logical reasoning and extracting from knowledge of an expert that is human operator who previously has monitored the behavior of system. A section of developed fuzzy rules for the first stage are given in the Figure 3.14

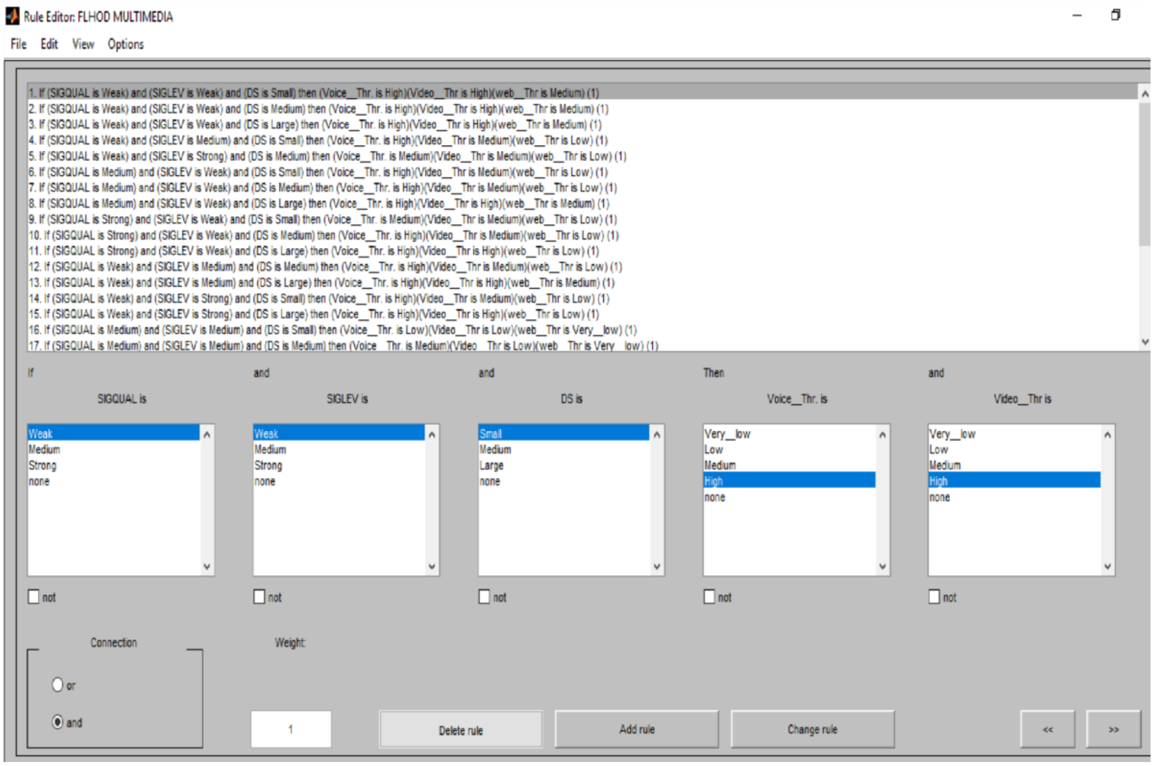

Figure 3. 14 IF-Then rules for threshold setting

To formulate the second stage of the Fuzzy Logic algorithm, 64 IF- THEN rules with the minimum operator are specified using the logical reasoning and extracting from knowledge of an expert that is human operator who previously has monitored the behavior of system. A section of developed fuzzy rules for the second stage are given in the Figure 3.15

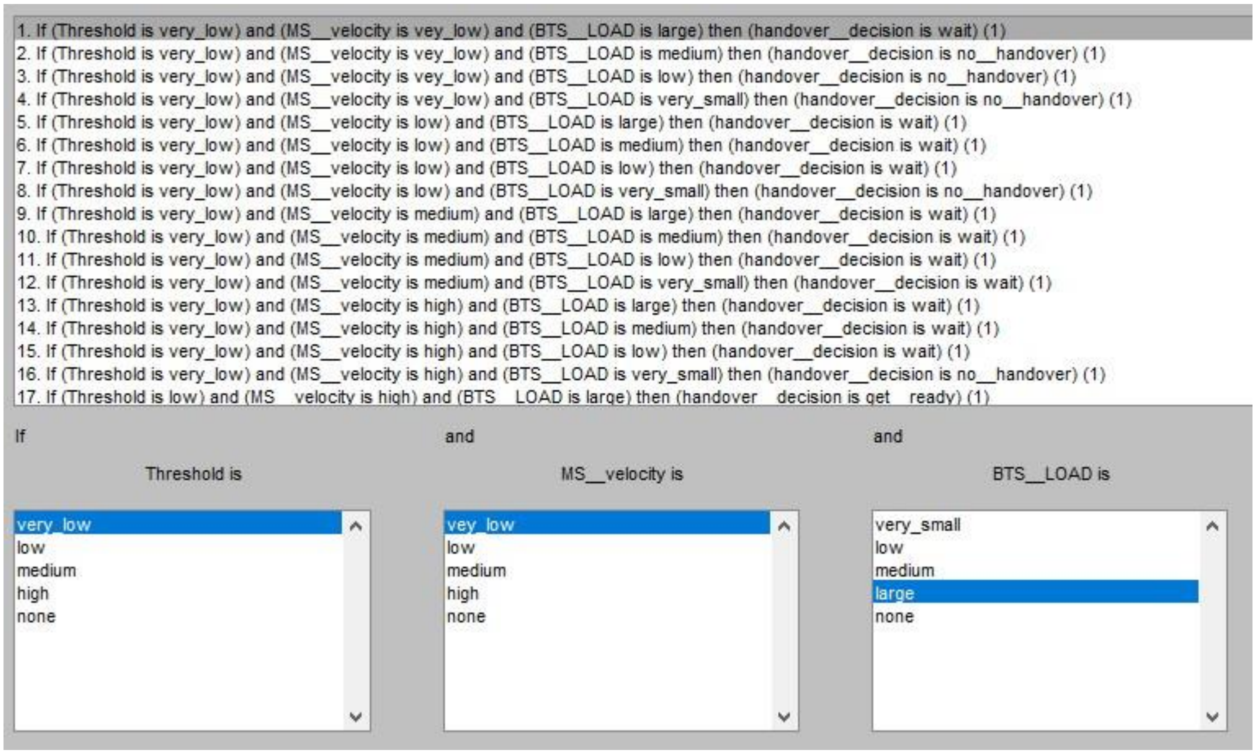

Figure 3. 15 IF-Then rules for handover decision

3.1.11 Defuzzification

Output membership degree each for the linguistic regions is applied as inputs to the Fuzzification process. The major aim of this process is to convert output values to real numbers (back to crisp values).

The fuzzy logic will form basis of control. Linguistic terms such as low, medium, high etc. is mapped into the interval [0 1] applying the membership functions. Fuzzy logic is based on IFTHEN rules that expresses relationship between input and output variables. The rules are derived from the statements written in the natural language.

As a result of these merits, Fuzzy Logic can be used to improve the quality of service, QoS of multimedia services in the cellular networks.

Different multimedia services require different levels of QoS. Of the three multimedia services voice call, video traffic and web traffic, voice traffic requires a high level of QoS than the rest. The available bandwidth can be shared among the three multimedia services.

Most of the conventional algorithms are based on RSS which is unreliable as it keeps on fluctuating. This is because elements in a heterogeneous network have different RSS thresholds. This results in handover failure, excessive handover, packet delay and low throughput. Fuzzy logic algorithm is highly accurate providing higher network efficiency. Fuzzy logic is an intelligent system that can be used in developing handover algorithms. The process of decision making is very important for handover process to be successful.

The results of the developed algorithm will be compared with the results from the previous work developed by authors in [45]. It is expected that the developed system will make the handover success rate to increase thereby reducing handover failures.

3.2 Development of a multi criteria ANFIS handover algorithm.

In this section, an ANFIS handover algorithm is presented with aim of investigating the performance of algorithm with increase in number of the input parameters. Five input parameters were considered which are, signal quality, signal level, available bandwidth, MS velocity and traffic load of the BTS. In this research, after introduction of the training element by ANFIS, an investigation of how increase in number of the inputs to ANFIS affects the handover decision is carried out. The comparison was made based on number of the iterations and time it takes for convergence to take place. The number of inputs that were considered for this case were five and they were signal quality, signal level, available bandwidth, Mobile station velocity and traffic load of the BTS. A threshold of 0.5 is used in order to reduce unnecessary handovers. Gauss membership function, (MF) was used as MFs due to its capability in achieving better handover performance. Number of membership functions used was three and the MF type was constant.

ANFIS typical architecture is shown in figure 3.16 where a circle represents the fixed node while a square represents the adaptive node [61]. A two inputs y, x and a one output z ANFIS structure is considered for simplicity.

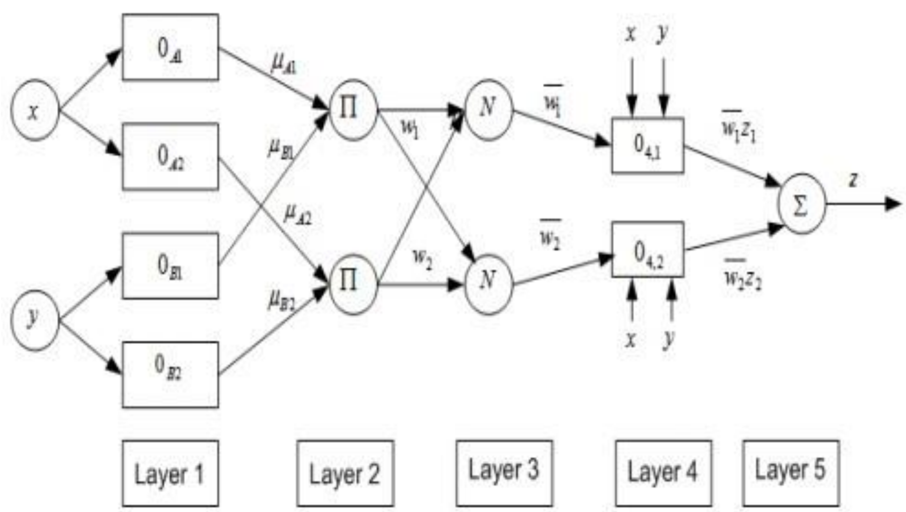

Figure 3. 16 A Typical ANFIS architecture

For 1st order Sugeno fuzzy model that has two if – then fuzzy rules, common rule set is expressed in equations 3.1 and 3.2. [80]

Rule 1: If x is A_1 and y is B_1, then:

$$z_1 = p_1x + q_1y + r_1 \tag{3.1}$$

Rule 2: If x is A_2 and y is B_2, then:

$$z_2 = p_2x + q_2y + r_2 \tag{3.2}$$

Where A_i and B_i are fuzzy sets while p_i and q_i and r_i are design parameters.

ANFIS is tuned automatically by hybrid learning algorithm using least square estimation.

3.2.1 Neuro-Fuzzy System Controller Design

Figure 3.15 has five layers and description of each layer is outlined below:

Layer 1: Is known as Fuzzification layer and it allows entry of raw data also known as crisp inputs to the ANFIS. It is made up of a computing nodes which uses fuzzy logic MFs that is gauss membership function in this thesis. Each of the adaptive nodes generates membership grades. Layer 2: is known as the rule layer in which each node is fixed. Product of degrees to which inputs satisfy MFs will be found once locations of the inputs are identified in fuzzy space.

Layer3: is the normalization layer where ratio of each rule firing strength will be calculated based on the sums of firing strength of the total rules. The nodes in this layer are also fixed.

Layer 4: is the Defuzzification layer. Output of each node is weighted consequent value. Contribution of each rule towards overall output is calculated by adaptive node found in this layer.

Layer 5: is known as the summation layer. The summation of all outputs found in layer 4 gives the output of this layer. This gives overall output for respective inputs within fuzzy space. It has a single fixed node that calculates overall output as sum of each rule contribution.

In MATLAB, there is an ANFIS editor GUI, a window that has four distinct in support of ANFIS work of design shown in Figure 3.17 below. The GUI window allows the following to be done:

1. Loading, the plotting and the clearing of data.

2. Loading or generating initial FIS structure.

3. Training FIS

4. Validating the Trained FIS [80].

The disadvantage of using this method of MATLAB ANFIS is that:

1. Only the Sugeno type decision method can be used

2. Only one output can be generated.

3. Defuzzification method is the weighted mean value. In generating the FIS structure, the gauss MF is used for the five input parameters and the output type is constant. The number of MFs for each input is three.

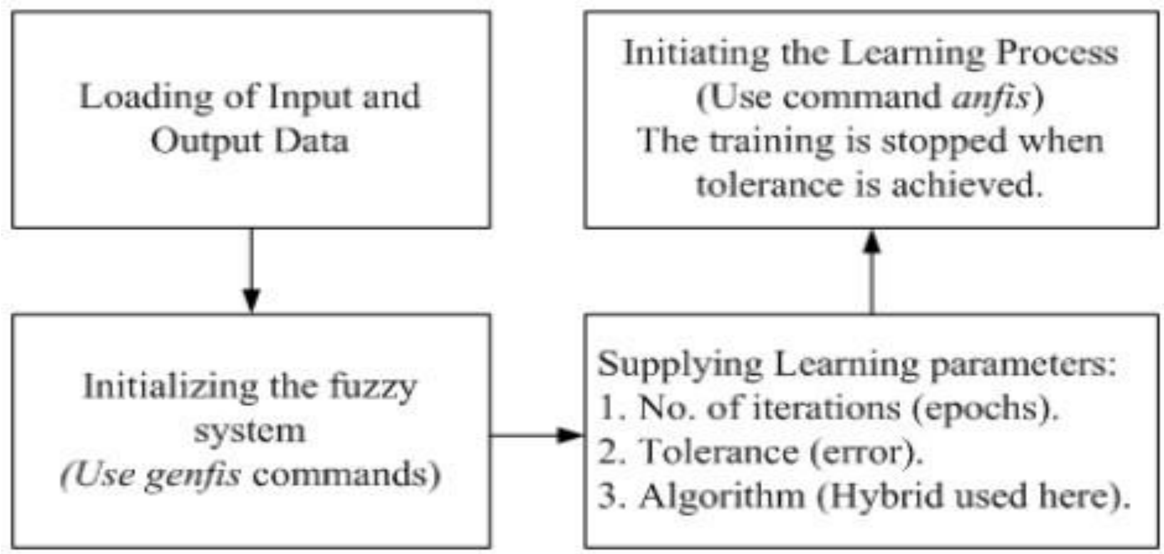

Figure 3. 17 Steps for ANFIS controller design

After loading the training data from the work space to the ANFIS, FIS was generated using gauss MF and the membership function type used was constant. Training error and number of epochs for the different set of inputs was also investigated as shown below.

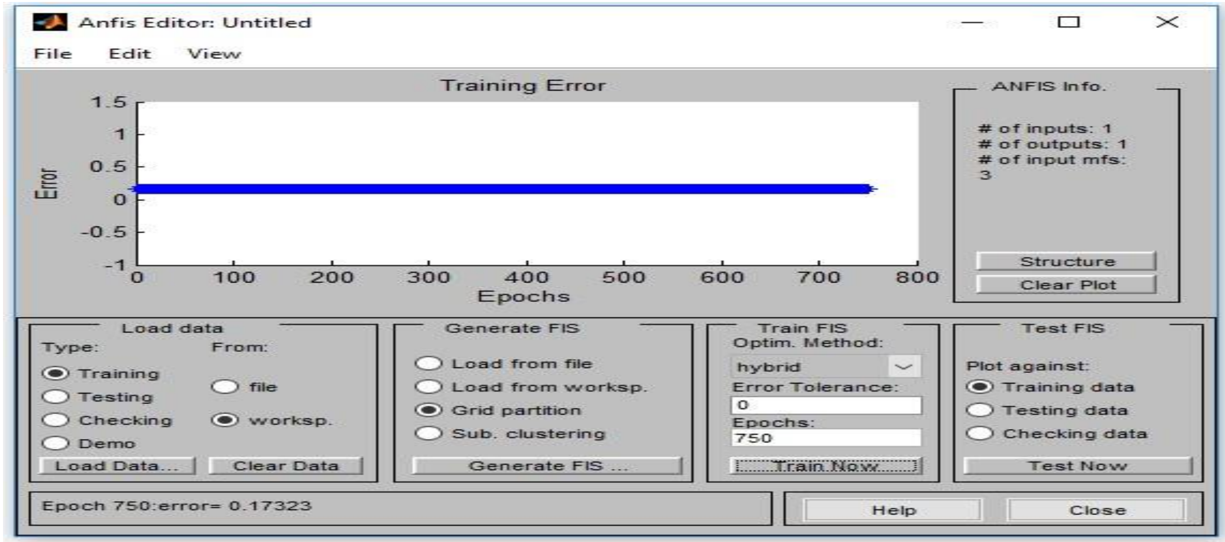

Figure 3. 18 Training error and number of the epochs for one input

As shown in Figure 3.18, when number of the inputs to ANFIS is one (signal quality), the training error is high and it takes large number of the epochs for convergence to take place.

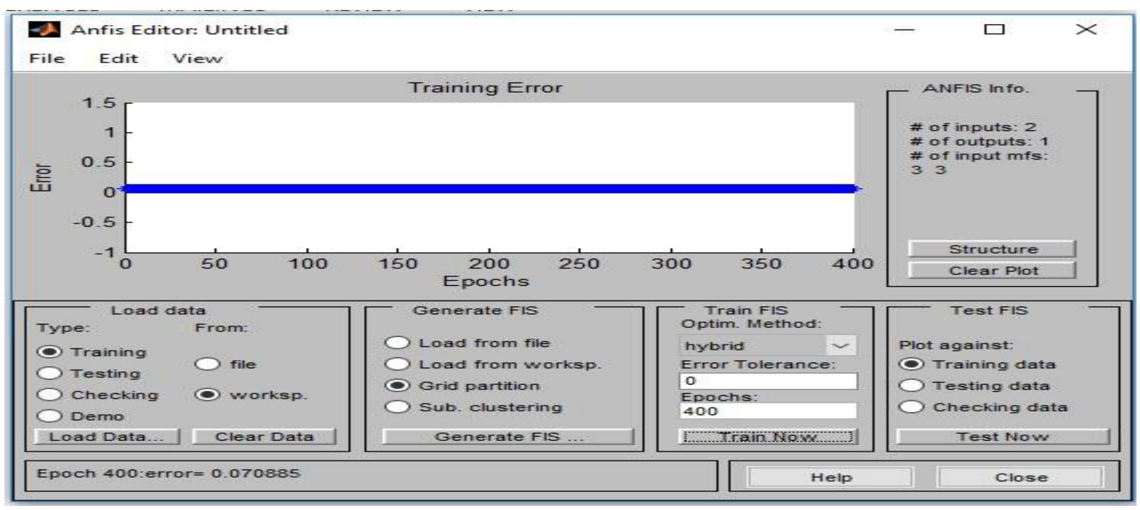

Figure 3. 19 Training error and number of the epochs for the two inputs

As shown in Figure 3.19, when number of the inputs to ANFIS is two (signal quality and signal level), the training error reduces further as compared to previous case of only one input. It also takes a short time for convergence to take place (only 400 epochs) when compared to the case of one input.

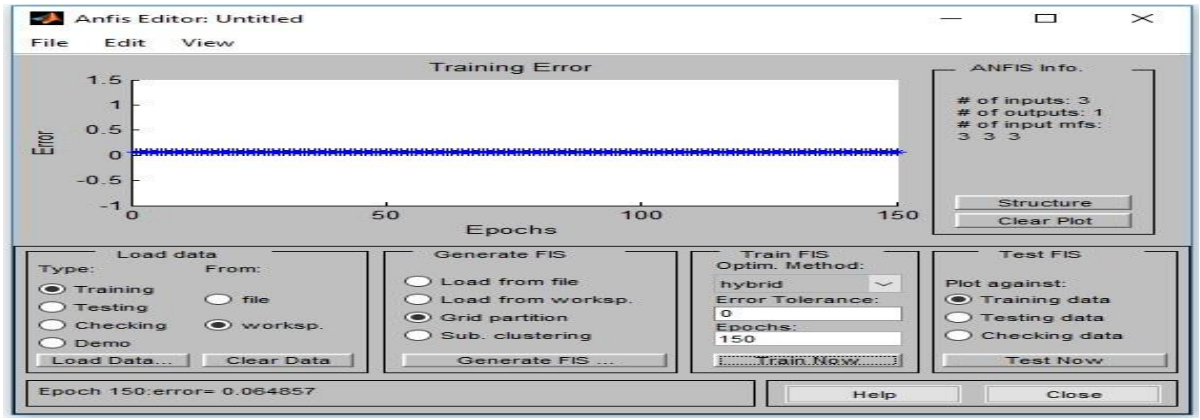

Figure 3. 20 Training error and number of the epochs for the three inputs

As shown in Figure 3.20, when number of inputs to ANFIS is three (signal quality, signal level and available bandwidth), the training error reduces further as compared to previous case of only two inputs. It also takes a short time for convergence to take place (only 150 epochs) when compared to the case of two inputs.

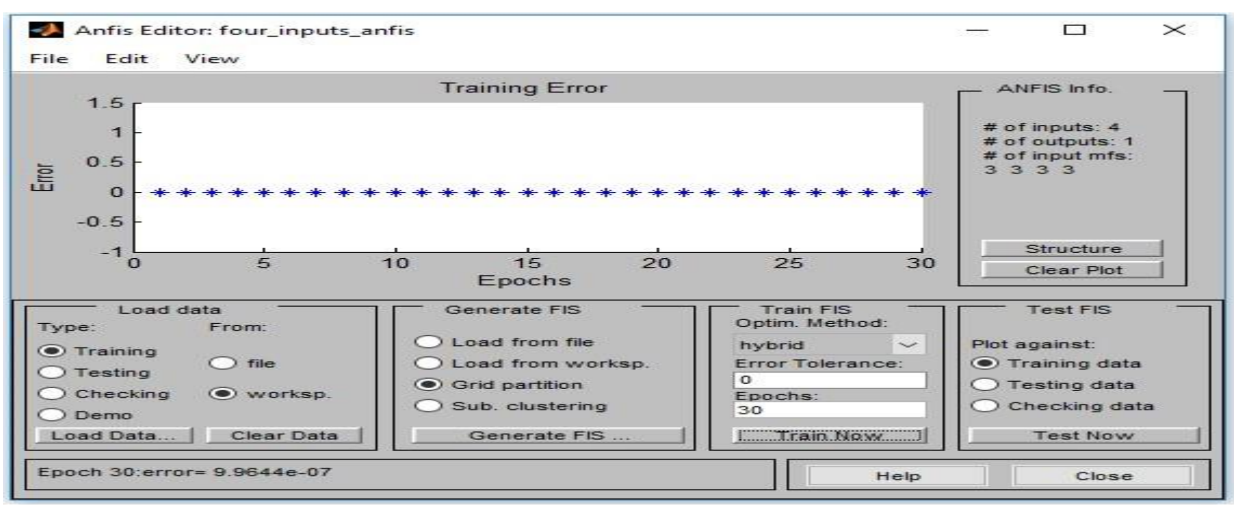

Figure 3. 21 Training error and the number of the epochs for the four inputs

As shown in Figure 3.21, when number of inputs to ANFIS is four (signal quality, signal level, available bandwidth and MS velocity), the training error reduces further as compared to previous case. It also takes a short time for convergence to take place (only 30 epochs) when compared to the case of three inputs.

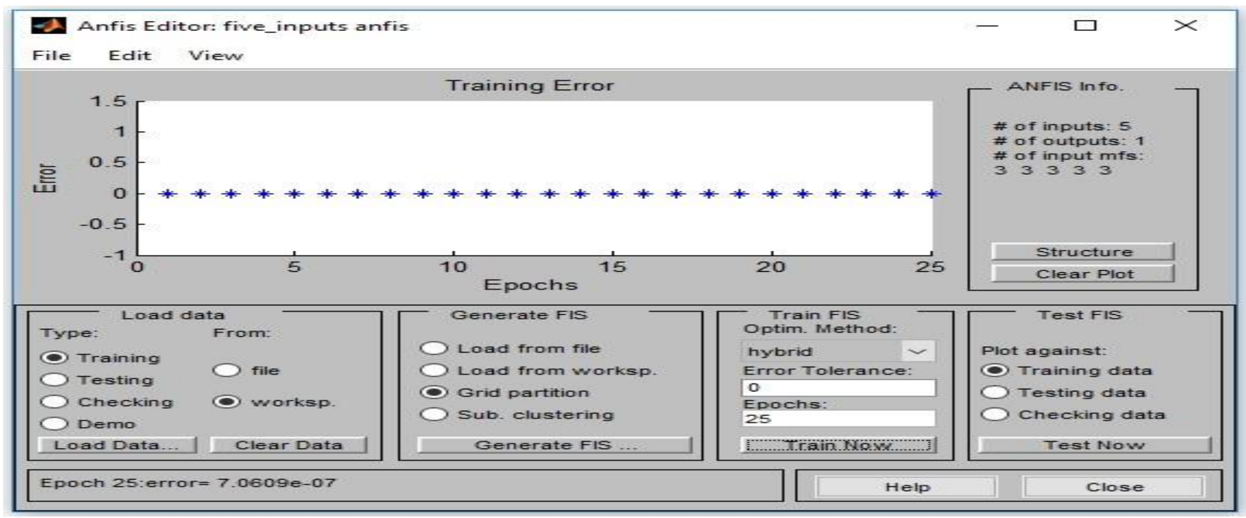

Figure 3. 22 Training error and the number of the epochs for the five inputs

As shown in Figure 3.22, when number of inputs to ANFIS is five (signal quality, signal level, available bandwidth, MS velocity and BTS traffic load), the training error reduces further. It also takes a short time for convergence to take place (only 25 epochs)

Table 3. 10: Relationship between number of inputs and number of iterations needed for convergence to occur.

No of inputs	**1**	**2**	**3**	**4**	**5**
No of iterations	**650**	**400**	**150**	**30**	**25**

Table 3.10, shows the relationship between the number of iterations required in order to get a constant error and number of inputs.

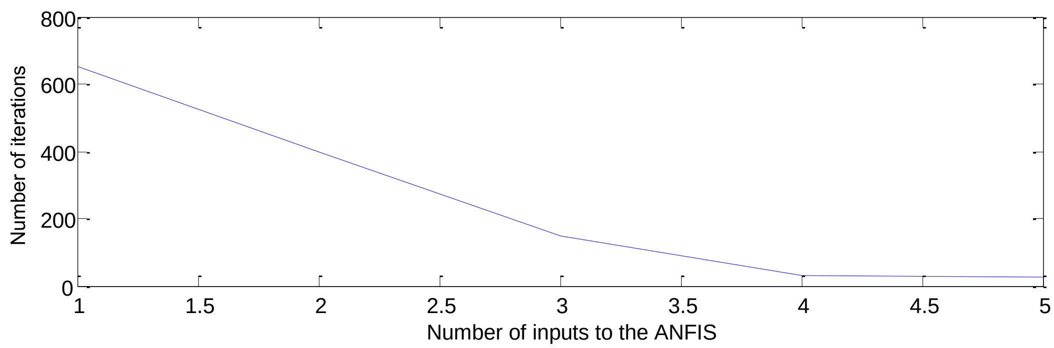

Figure 3. 23 Relationship between number of inputs to the ANFIS and number of iterations.

Figure 3.23, is the representation of table 1 graphically.

CHAPTER FOUR

RESULTS AND DISCUSSION

The aim of the chapter is presentation of analysis and the discussion of obtained results from this study. The algorithms were developed in MATLAB. The results obtained from the fuzzy logic algorithm is compared to those results of the algorithm developed in [45]. An evaluation on the impact of ANFIS algorithm on handover decisions is also carried out.

4.1 Result of fuzzy logic algorithm for optimization of handover decisions in a mobile Cellular network for multimedia services.

4.1.1 First stage - Setting of the threshold of handover

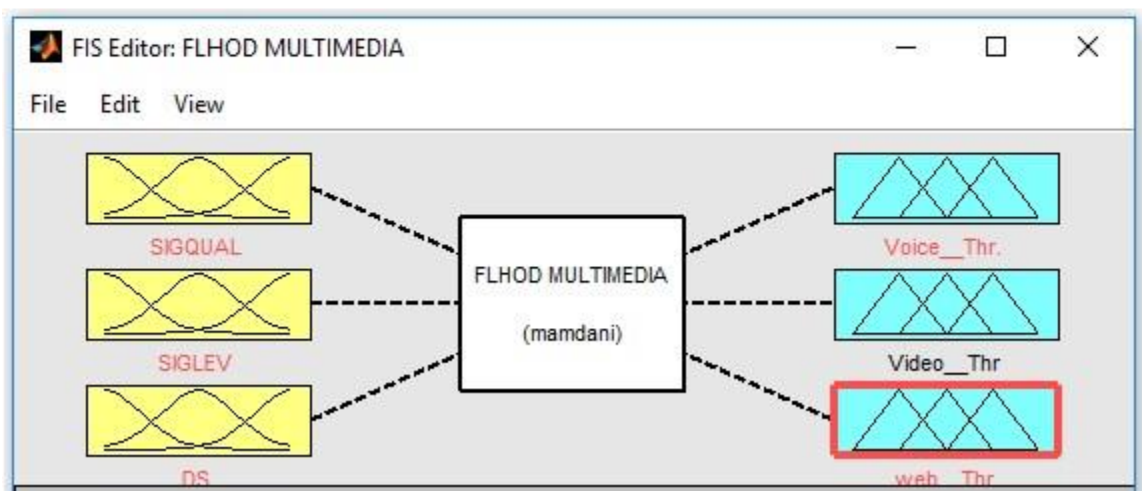

Figure 4. 1: FIS for the multimedia network services.

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 taken into consideration. It is at this point that this case considers five input parameters: The signal level (SIGLEV), the signal quality (SIGQUAL) in the current serving cell, the Velocity of the mobile station, the available bandwidth and the traffic load of the current serving cell in percentage.

Firstly, the system needs to detect the multimedia service type the mobile user needs to execute. After detecting the service type, the system collects inputs such as signal quality, signal level, the available bandwidth and the traffic load of the current serving cell in percentage.

The system will then calculate the handover thresholds. The system calculates the threshold for the three multimedia services based on their quality of service requirements. The results of the handover thresholds are shown in Figure 4.2, 4.3 and 4.4 which are summarized in Table 4.1

Table 4. 1: Comparison of handover threshold for the three multimedia services

	Voice traffic	**Video traffic**	**Web traffic**
Excellent	0.337	0.155	0.110
Average	0.638	0.362	0.156
worst	0.885	0.830	0.629

As shown in Table 4.1 voice traffic has the highest threshold values when input parameters are excellent, average and poor. This is followed by video traffic and finally the web traffic which has the lowest values among the three services. For example when the input parameters are poor, voice traffic has a threshold of 0.885 followed by video traffic (0.830) and finally the web traffic (0.629). This is due to the fact that voice traffic cannot tolerate delay but web traffic can tolerate it. Voice is the only service that its characteristics are determined strictly by the human perception. Thus, this service should have stringent quality of service requirements. Failure in provision of low transfer delays results in unacceptable low quality. This explains why web traffic has lower threshold values as compared to voice traffic. These delays influence the overall quality of a service as perceived by end users. This implies that if the system needs to carry out the handover for the three multimedia network services (i.e. voice, video and web traffic when the input parameters are average) simultaneously, then voice traffic will be given the first priority, followed by video traffic and finally the web traffic only when the surrounding BTSs do lack the capacity to accommodate handoffs from three multimedia services at the same time. In case the neighboring BTSs do have enough capacity, then handover will take place without preference.

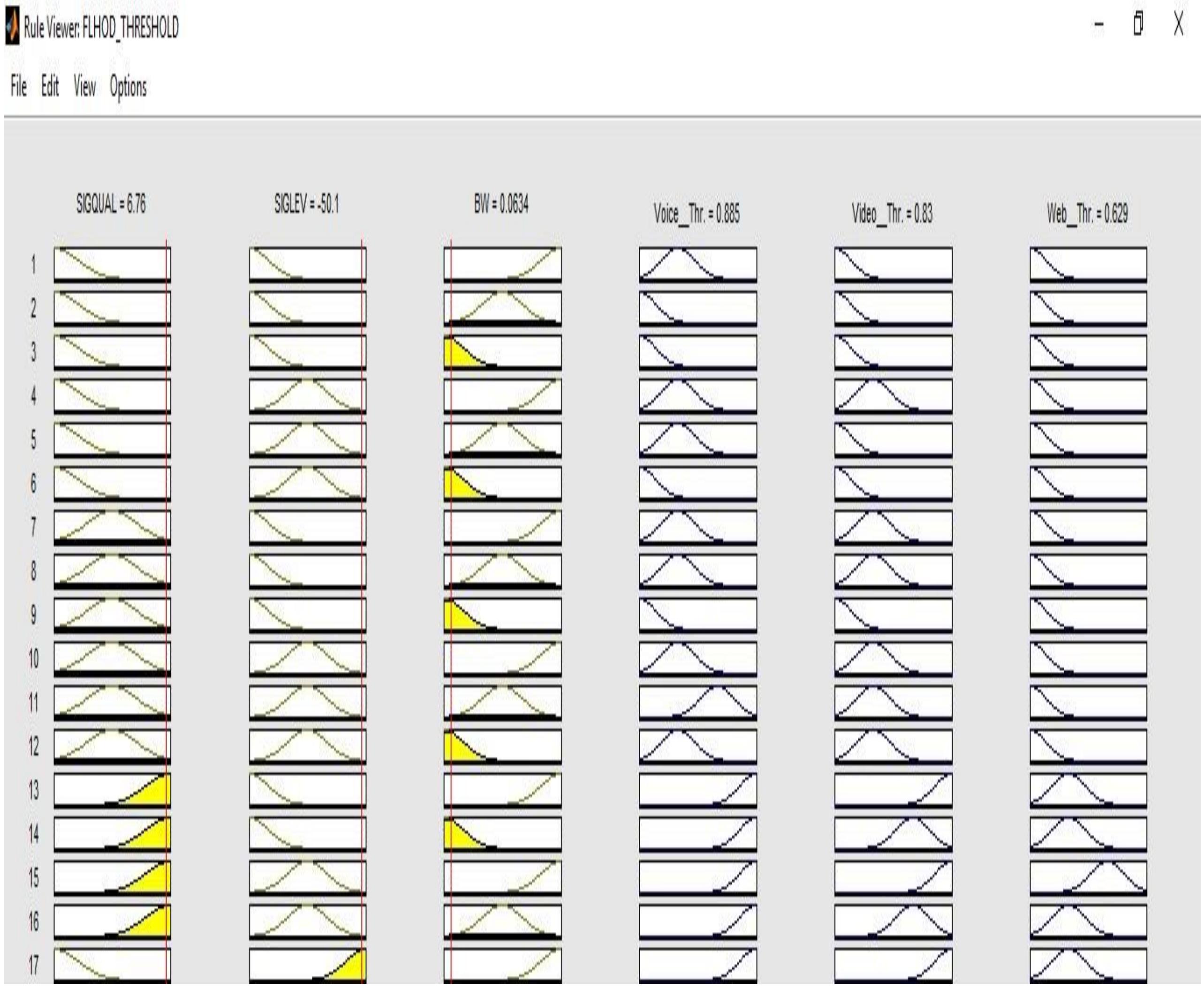

Figure 4. 2: Threshold values when input parameters are worst

Figure 4.2 indicates the threshold values when input parameters were worst. The threshold values were 0.885, 0.830 and 0.629 for voice, video and web traffics respectively.

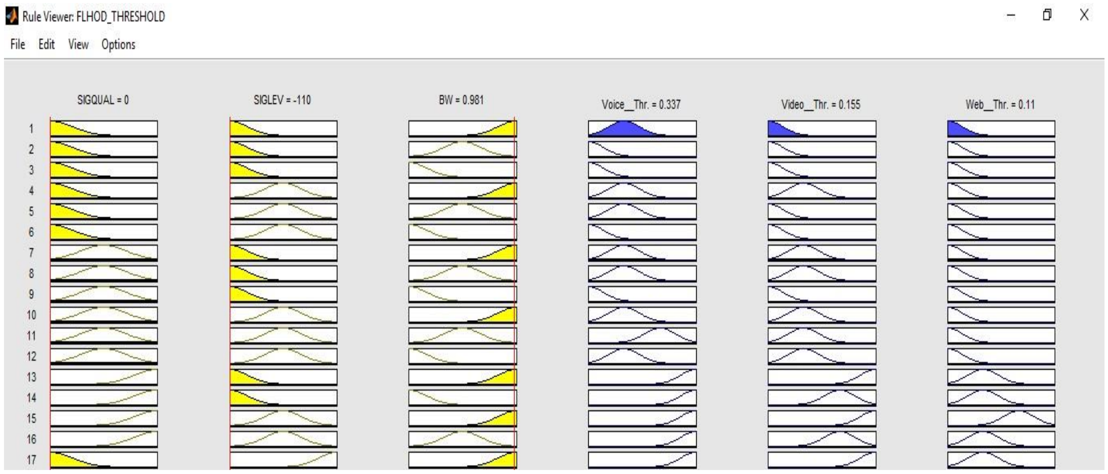

Figure 4. 3:Threshold values when input parameters are excellent.

Figure 4.3 indicates the threshold values when input parameters were excellent. The threshold values were 0.337, 0.155 and 0.110 for voice, video and web traffics respectively.

Figure 4. 4: Threshold values when input parameters are average

Figure 4.3 indicates the threshold values when input parameters were average. The threshold values were 0.638, 0.362 and 0.156 for voice, video and web traffics respectively.

4.1.2 Second stage- Handover decisions

The second phase, the system based on the calculated threshold, the handover decisions are made in coordination with MS-Vel and BTS traffic load. Figure 4.5 shows the FIS for handover decision. It takes in three inputs namely threshold, MS-Velocity and BTS traffic load. The output of the system is the handover decision which can be 'handover', 'no handover', 'wait' and 'get ready to handover'

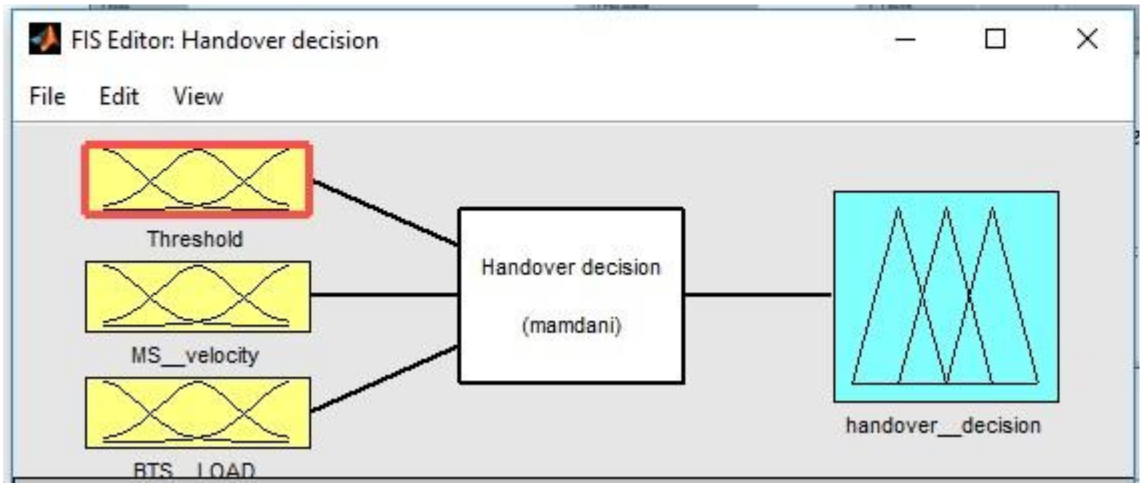

Figure 4. 5: FIS for handover decision**.**

The fuzzy inference system for handover decision stage is shown in Figure 4.5. The system has three inputs namely threshold value, MS velocity and BTS load while the output of the system is the handover decision.

Figures 4.6, 4.7, 4.8 and 4.9 are giving the output of the handover decision stage.

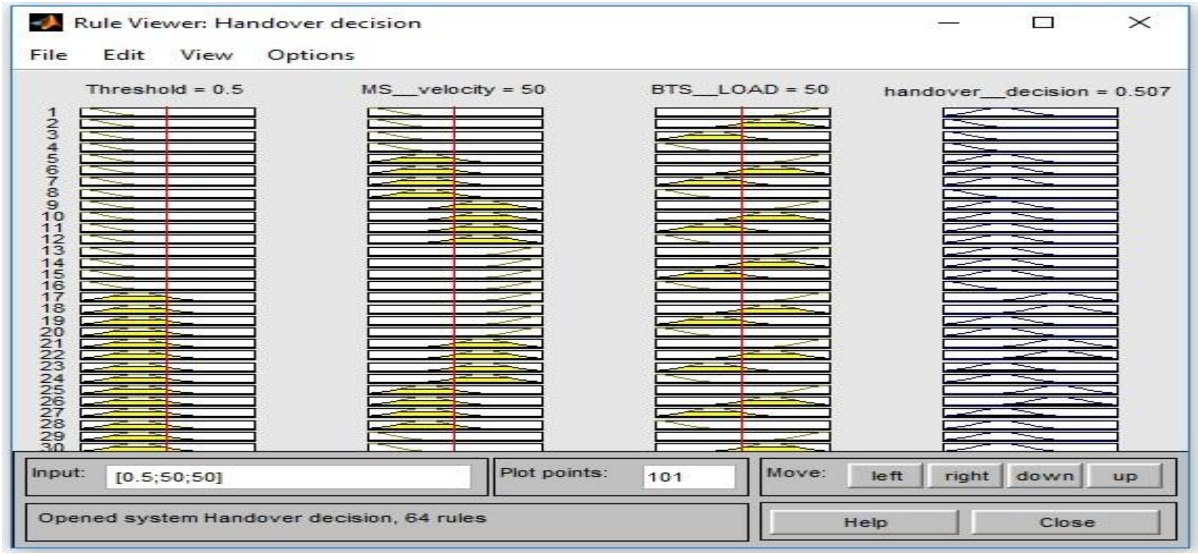

Figure 4. 6: System output for average threshold value.

The probability of handover for average threshold value is shown in Figure 4.6. The system output for this case was 0.507.

Figure 4. 7: The system output for high threshold value**.**

The probability of handover for high threshold value is shown in Figure 4.7. The system output for this case was 0.816.

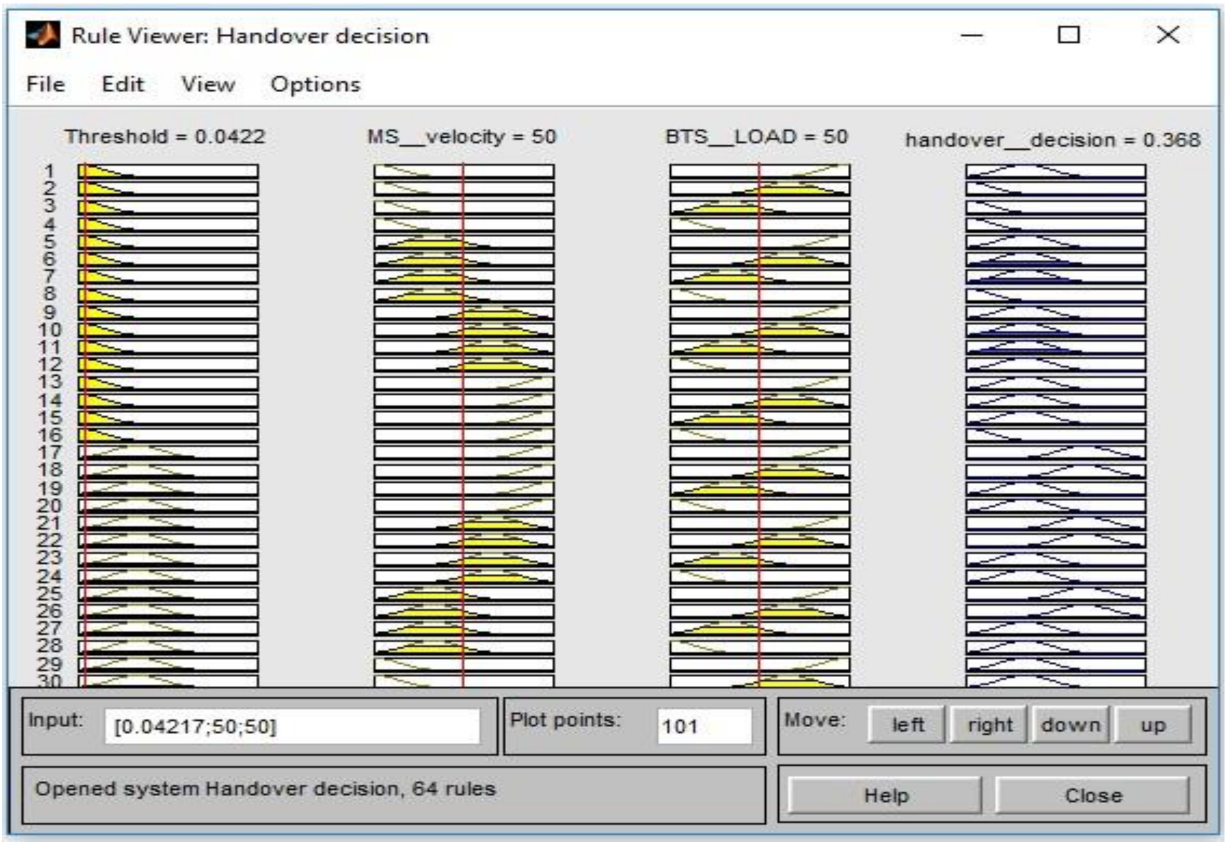

Figure 4. 8: The output of the system for low threshold value.

The probability of handover for low threshold value is shown in Figure 4.8. The system output for this case was 0.368.

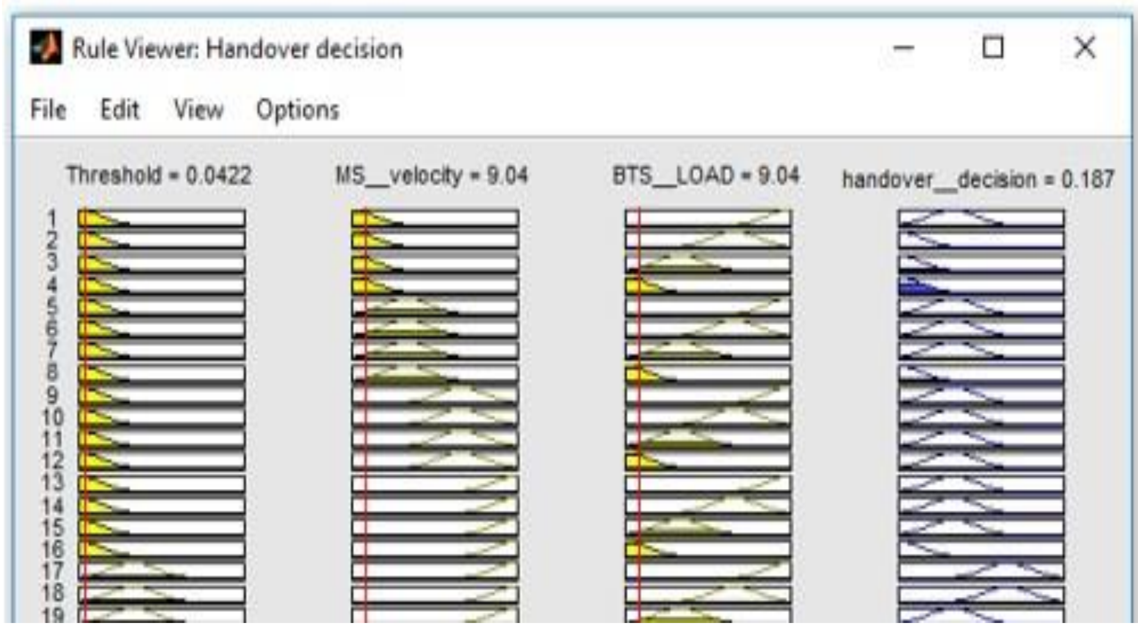

Figure 4. 9: The output of the system for low threshold value and BTS load.

The probability of handover for very low threshold values is shown in Figure 4.9. The system output for this case was 0.187.

When the threshold value is low, the probability of handover is low. For this case the probability is 0.368 (meaning that the best service is being offered by the current BTS, hence MS should not initiate the handover). The probability is 0.368 and not 0 implying that the threshold value can be very low but other factors such as the traffic load of current BTS and the MS velocity can have an effect on the handover probability. The signal quality and level can be strong but the current BTS can be overloaded hence increasing the need for handover. This is represented in Figure 4.8. In Figure 4.6, the value of threshold is average giving the handoff probability of 0.507. When the value of threshold is high, probability of handoff is high (0.816) as shown in Figure 4.7, meaning a worst service or services are being offered by the current BTS hence high need of handover.

Handover can take place only when the probability of handover is above 0.55. In Figure 4.6, the probability is 0.507 which is below the 0.55, hence the decision taken is “prepare to handover”. In Figure 4.7, the probability is 0.816 which is above 0.55, the decision taken is “handover”. In Figure 4.9, the probability is 0.187, the decision taken is “No handover”. In Figure 4.8, the probability is 0.368, the decision taken is “wait”.

4.2 Result for multi criteria ANFIS handover algorithm

This section investigates how number of inputs to ANFIS affects the performance of the algorithm. As number of the inputs to ANFIS is increased, performance of algorithm improves. The study begins with one input to the ANFIS where the output of the system is noted, then the number of inputs is increased in a step of one.

4.2.1 Signal quality based ANFIS handover algorithm

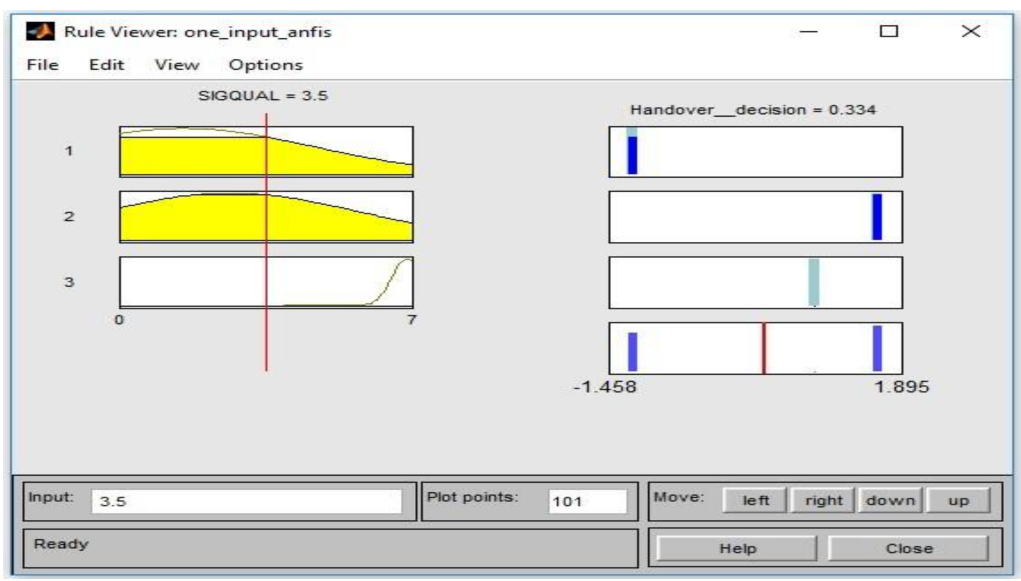

Figure 4. 10: Output of ANFIS at mean - one input.

The output of Figure 4.10 means that Mobile station has to wait before handing over to the next BTS.

4.2.2 Signal quality and signal level based ANFIS handover algorithm

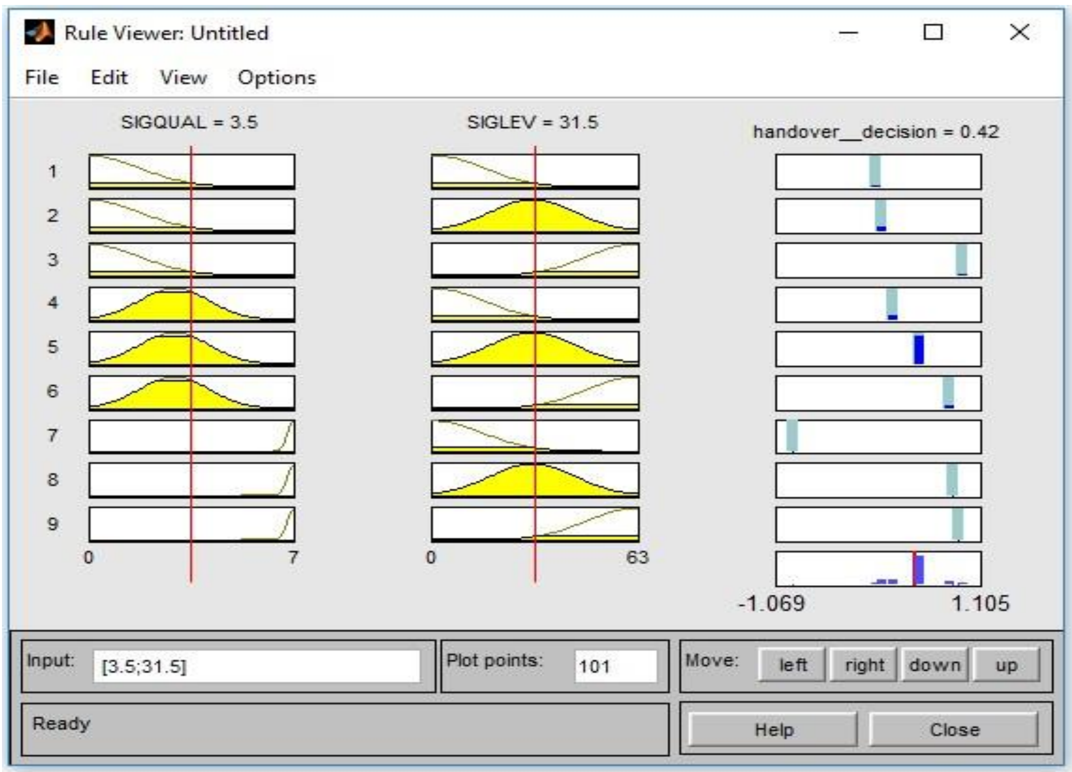

Figure 4. 11: Output of ANFIS at mean - two inputs

In Figure 4.11, two input parameters, that is signal quality and signal level are at their mean position giving an output of 0.42. Comparing this output with threshold value of 0.55 [45], it shows that there is no necessity of handing over to the next BTS since the current one can still offer best services.

4.2.3 Signal quality, signal level and available bandwidth based ANFIS handover algorithm

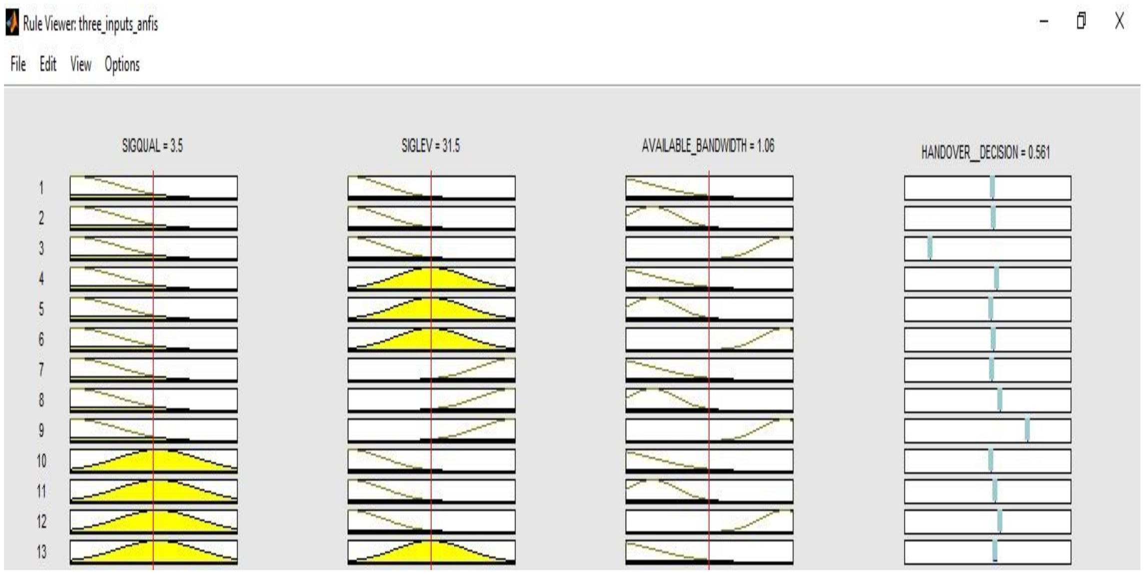

Figure 4. 12: Output of ANFIS at mean - three inputs**.**

In Figure 4.12, three input parameters, that is the signal quality, signal level and available bandwidth are at their mean position giving an output of 0.561. Comparing this to the threshold value implies that the current BTS can no longer support the service, hence the need to handover to the next BTS.

4.2.4 Signal quality, signal level, available bandwidth and MS velocity based ANFIS handover algorithm

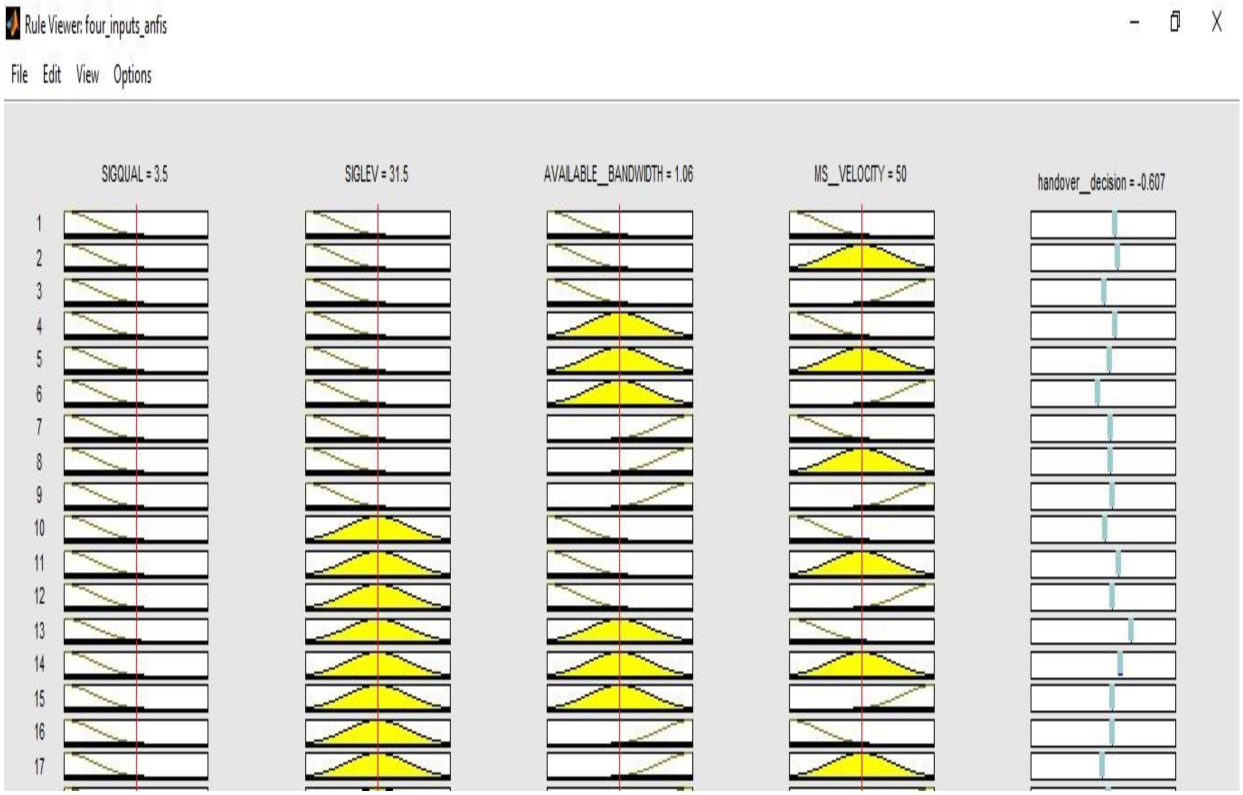

Figure 4. 13: Output of ANFIS at mean - four inputs**.**

In Figure 4.13, four input parameters, that is the signal quality, signal level, available bandwidth and MS velocity are at their mean position giving an output of 0.607. Comparing this to the threshold value implies that the current BTS can no longer support the service, hence the need to handover to the next BTS. This value is higher than the one in the previous case due to the effect of parameter "available bandwidth"

4.2.5 Signal quality, signal level, available bandwidth, MS velocity and traffic load of BTS based ANFIS handover algorithm

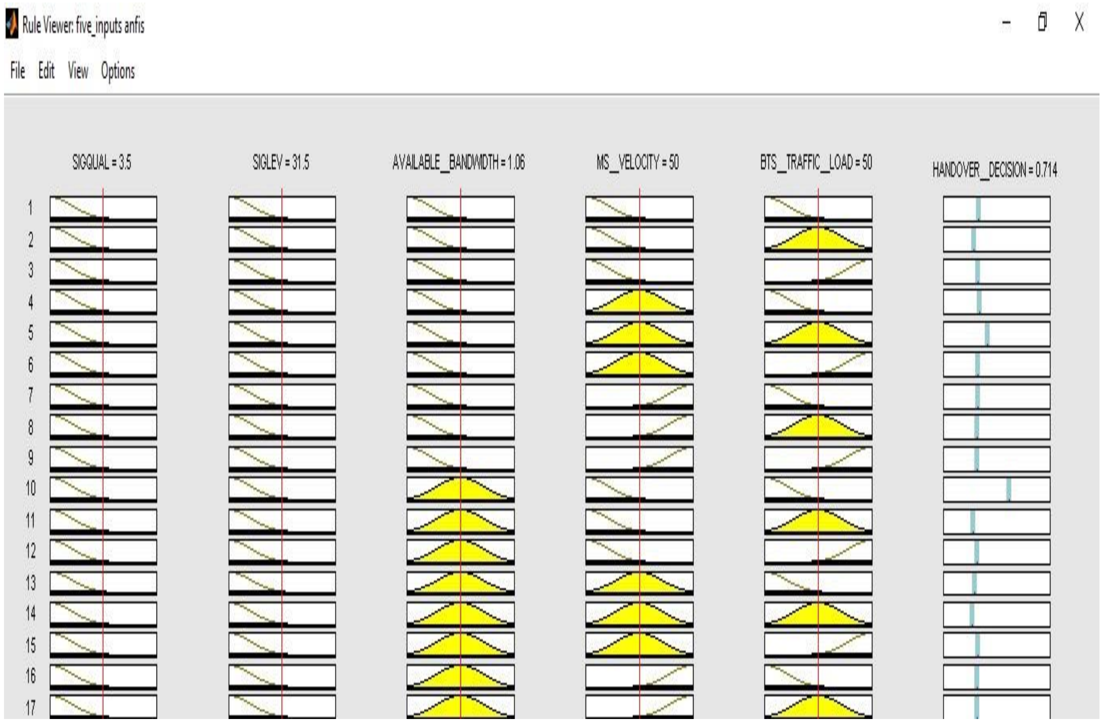

Figure 4. 14: Output of ANFIS at mean - five inputs

In Figure 4.14 when all the input parameters (signal quality, signal level, available bandwidth, MS velocity and BTS traffic load) are at their mean value gives an output of 0.714 implying that there is a high need for handover to the next BTS.

Table 4. 2: relationship between output of ANFIS and number of inputs

No of inputs	1	2	3	4	5
Output of ANFIS	0.334	0.42	0.561	0.607	0.714

The relationship between number of inputs and the output of ANFIS is shown in table 4.2.

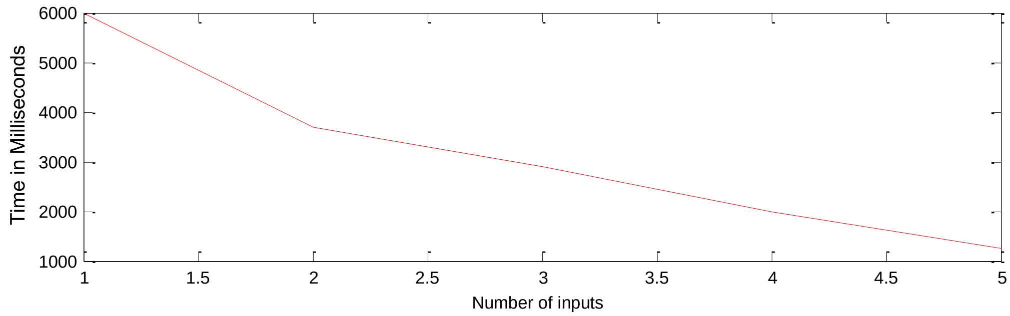

Figure 4. 15(a): Relationship between number of inputs and time taken for convergence to take place

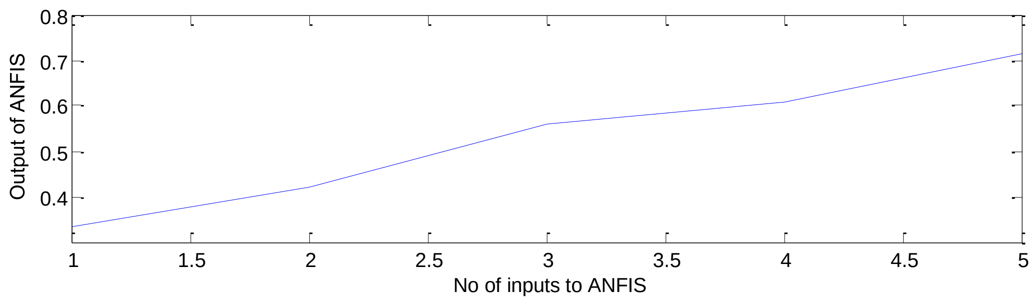

Figure 4. 15(b): Relationship between number of inputs and time taken for convergence to take place

Figure 4.15 shows the relationship between time taken for convergence to take place and the number of inputs to ANFIS. Form the graph it is clear that when the number of inputs to the ANFIS is increased, the time taken for convergence to take place reduces i.e. the more the number of inputs the less the convergence time. In Figure 4.15b it's noticed that as the number of inputs to the ANFIS is increased, the output improves.

4.3 Evaluation and comparison of performance of developed algorithm with the previously developed algorithm.

4.3.1 Results for the algorithm developed by authors in [45]

Figures 4.16, 4.17 and 4.18 are giving the outputs for the algorithm developed by authors in [45].

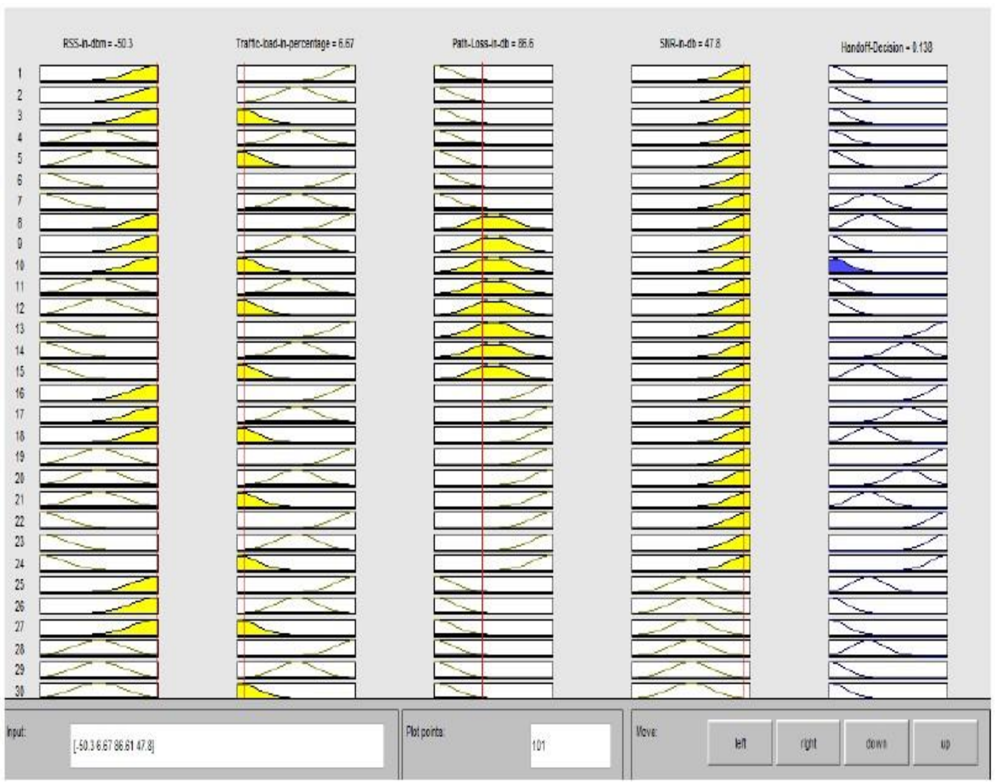

Figure 4. 16: Rule Base Evaluations when all the four parameters are excellent **[45]**

The rule base evaluations when the four parameters were excellent are shown in Figure 4.16 that was developed by authors in [45]. The output for this case was 0.138.

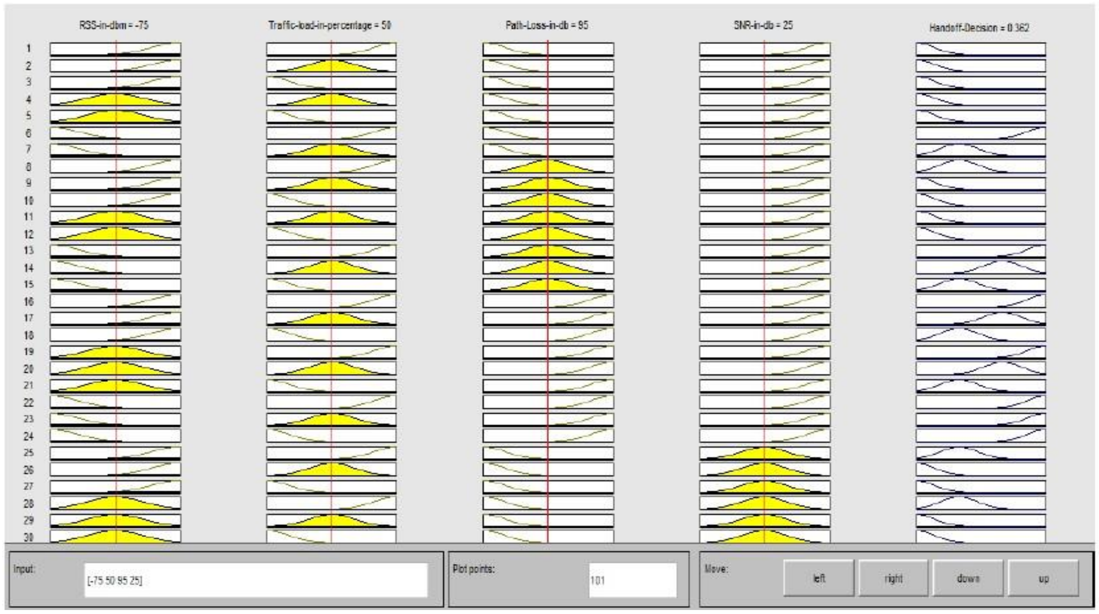

Figure 4. 17: Rule Base evaluations when all the four parameters are good **[45]**

The rule base evaluations when the four parameters were good are shown in Figure 4.17 that was developed by authors in [45]. The output for this case was 0.362.

Figure 4. 18: Rule Base evaluations when all the four parameters are worst **[45]**

The rule base evaluations when the four parameters were worst are shown in Figure 4.18 that was developed by authors in [45]. The output of the system for this case was 0.805.

4.3.2 Results from the developed algorithm.

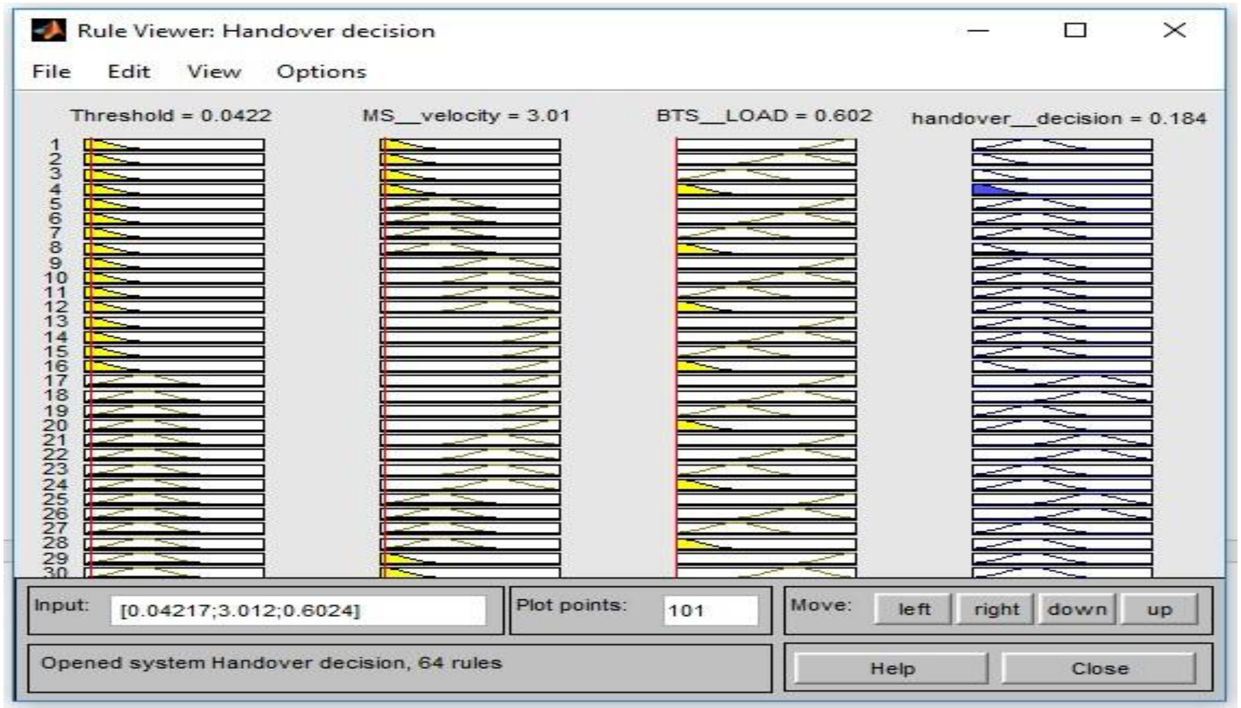

Figure 4. 19: The output of the system when input parameters are excellent.

Figure 4.19 shows the output of the system for excellent input parameters. The output for this case was 0.184.

Figure 4. 20: The output of the system when input parameters are average**.**

Figure 4.20 shows the output of the system for average input parameters. The output for this case was 0.507.

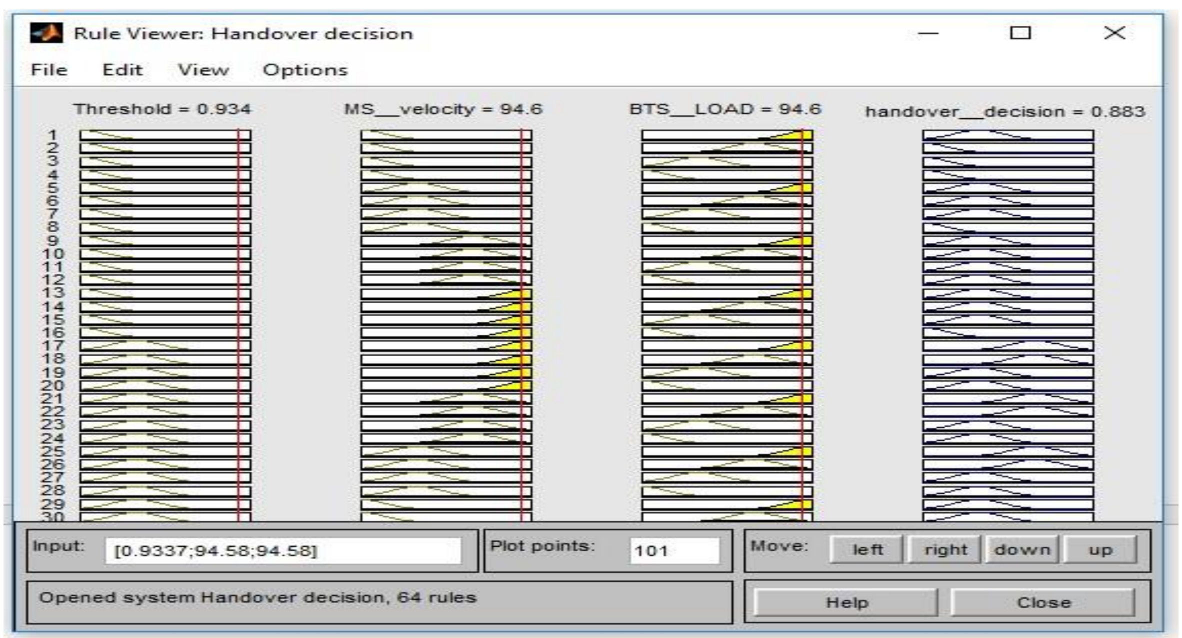

Figure 4. 21: The output of the system when input parameters are worst.

Figure 4.21 shows the output of the system when input parameters are worst. The output for this case was 0.883. Figures 4.16, 4.17 and 4.18 gives output of the system developed by authors in [45]. As shown the outputs are 0.138, 0.368 and 0.805 when input parameters are excellent, average and worst respectively. From the developed algorithm shown in Figures 4.19, 4.20 and 4.21, the outputs are 0.186, 0.507 and 0.883 when input parameters are excellent, average and worst respectively. It is evident that the developed algorithm gives high probabilities of handovers.

Table 4. 3: Comparison of the output values

Inputs	**Previous algorithm**	**Developed algorithm**
Excellent	0.138	0.186
Average	0.368	0.507
Worst	0.805	0.883

As shown in Table 4.3, the developed algorithm has better performance as compared to the previously developed algorithm. According to [73], the higher the threshold level the lower the mean number of handovers where the high threshold values reduces the average number of handovers but increases the delay in handover. Thus the developed algorithm has better performance in terms of reduced handovers since it has high threshold values as compared to the results from the other algorithm.

CHAPTER FIVE:

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

This work was on development of the fuzzy logic algorithm that can optimize handover decisions in a mobile cellular network for multimedia services. The main aim being coming up with an algorithm that will carry out handover decision for multimedia network services based on their QoS requirements. It has been shown that it is possible to optimize the handoff decisions when they are made based on the QoS requirements for different multimedia network services.

For the case of ANFIS algorithm, as the number of the inputs to ANFIS is increased, performance of algorithm improves. The output is 0.334 when number of inputs is one, and 0.561 when number of inputs is three and 0.714 when number of inputs is maximum (five). Thus increase in number of the inputs to ANFIS will increase performance of handover process.

5.2 Recommendations

For future work, an investigation should be carried out to find the maximum number of inputs to the ANFIS that increases performance of handover algorithm and above which no improvement will take place.

5.3 Publication from This Work

a) S.O Ung'ai, Oduol V.K and Musyoki S, "Fuzzy logic algorithm for optimization of handover decisions in a mobile cellular network for multimedia services" (To be considered after making corrections).

b) S.O Ung'ai, Oduol V.K and Musyoki S, "Analysis of the impact of Adaptive Neuro Fuzzy Inference System (ANFIS) Algorithm on Handover Decisions", International Journal of Engineering Research and Technology (IJERT), Vol. 11, No. 6, pp. 939 – 948, 2018.

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Appendix 1: Training data sets

SIGNAL LEVEL(dBm)	SIGNAL QUALITY(dBm)	AVAILABLE BANDWIDTH(Mb)	MS VELOCITY(km	BTS traffic load (%)	handover probability
-112.9	-12	0.981	0	0	0
-113	-14.49	0.145	2	3	0.14
-107.2	-15.42	0.477	5	7	0.17
-109.4	-15.42	0.145	8	11	0.2
-108.7	-15.49	0.427	13	15	0.241
-108	-17.72	0.317	19	23	0.248
-105.6	-14.36	0.341	28	33	0.247
-106.5	-17.01	0.125	25	39	0.254
-107.3	-16.86	0.815	21	18	0.257
-104.9	-17.56	0.348	11	21	0.261
101.7	-17.79	0.275	10	16	0.267
-104.8	-17.17	0.406	3	13	0.274
-96.9	-19.06	0.345	24	34	0.278
-95.3	12.21	0.274	18	86	0.279
-104.8	-12.05	0.545	69	37	0.281
-98.3	-18.54	0.806	66	66	0.251
-98.1	-13.39	0.545	15	60	0.256
-94.3	-9.47	0.275	18	27	0.287
-94.7	-8.34	0.412	26	11	0.345
-112.9	-7.447	0.545	30	41	0.378
-92.9	-4.559	0.425	36	63	0.41

-91.9	-3.098	0.278	39	93	0.472
-90.7	-9.586	0.145	43	34	0.745
-89.9	-11.249	0.125	47	74	0.723
-88.5	-5.85	1.986	49	94	0.695
-84.6	-12.427	0.145	56	56	0.643
-78.9	-5.607	0.275	52	87	0.302
-87.4	-15.072	1.272	19	21	0.4
-84.61	-14.703	0.145	44	14	0.43
-83.49	-24.456	0.425	25	52	0.44
-83	-16.502	0.806	79	61	0.447
-81.02	-12.788	0.345	67	39	0.448
-80.8	-13.118	0.125	89	9	0.449
-73.9	-13.324	1.343	66	6	0.452
-73.1	-15.428	0.345	99	10	0.453
-79.4	-16.803	0.275	100	100	0.458
-78.2	-17.235	0.797	89	98	0.459
-74.96	-17.21	0.345	77	37	0.46
-72.3	-7.67	0.425	72	28	0.47
-111.72	-8.92	0.564	78	81	0.52
-110.81	10.89	0.545	59	89	0.55
-45.42	-10.54	0.125	61	15	0.578
-69.64	-18.91	1.213	74	42	0.64
-67	-16.43	0.275	93	37	0.651
-68.8	-12.37	0.728	92	30	0.657
-65.42	13.72	0.545	91	23	0.662

-63	-13.54	0.425	86	64	0.665
-50.1	-9.56	0.526	85	53	0.673
-53.6	-9.25	0.145	88	78	0.683
-53.1	-8.17	0.125	69	94	0.717
-53.7	-2.98	1.567	43	31	0.732
-55	-7.86	0.275	17	75	0.75
-48.33	-19.41	1.622	55	48	0.798
-47.3	-19.67	0.145	10	19	0.806
-46.31	-16.79	0.425	71	15	0.823
-45.37	-16.17	1.062	98	76	0.834
-44.94	-16.56	0.345	62	26	0.849
-44	-16.72	0.125	57	70	0.854
-94.46	-17.54	1.191	50	5	0.879
-90.9	-19.29	0.345	44	49	0.883
-77.43	-4.89	0.275	41	18	0.889
-49.65	-2.63	0.876	38	82	0.991
-56.62	-12.78	0.345	62	83	0.996
-44.83	-20.87	0.45	74	71	1

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Analysis of the impact of Adaptive Neuro Fuzzy Inference System (ANFIS) Algorithm on Handover Decisions

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Abstract

Many traditional handover algorithms such as Fuzzy logic based and hysteresis have short comings. The fuzzy handover algorithm is not optimized thus needs attention from human experts. Fuzzy logic and neural networks are two complementary technologies. This is so because the neural networks have learning ability that can learn knowledge using the training examples, while FIS deduces knowledge from given fuzzy rules. The combination of the two outperforms either fuzzy logic or neural network method used exclusively. Most of existing ANFIS handover algorithms have not taken into consideration how the number of the inputs to ANFIS affects performance of the algorithm. This work aims at analyzing impact of using the adaptive neuro fuzzy inference system for the handover decision making. The number of inputs that were considered for this case were five and they were signal quality, signal level, available bandwidth, mobile station velocity and traffic load of the BTS. The results from the different simulations have shown that, need to handover vary depending on number of inputs to the ANFIS. As the number of inputs to the ANFIS is increased, the handover decision is optimized. The data used in training the ANFIS was obtained from the developed fuzzy logic system and Safaricom LTD, Kenya.

Keywords: ANFIS, Handover decisions, iterations, Signal level, signal quality