MULTI-CELLULAR HETEROGENOUS VHO Algorithm using Fuzzy Logic System

A THESIS SUBMITTED IN THE PARTIAL FULFILMENT OF THE REQUIRMENTS FOR THE DEGREE OF

BACHELOR OF TECHNOLOGY
In
ELECTRONICS AND COMMUNICATION ENGINEERING

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MAY 2015

NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA

CERTIFICATE

This is to certify that the thesis titled "MULTI-CELLULAR HETEROGENOUS VHO Algorithm using Fuzzy Logic System", submitted by Ms. Samahita Biswal (111EC0168) for the award of Bachelor of Technology Degree in Electronics and CommunicationEngineering at National Institute of Technology (NIT), Rourkela is an authentic work carried out by her under my supervision.

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ACKNOWLEDGEMENT

I would like to take this opportunity to express my gratitude and sincere thanks to my respected supervisor **Prof. Sarat Kumar Patra** for the guidance, insight, and support that he has provided throughout the course of this work. The present work would never have been possible without his vital inputs and mentoring.

I express my special thanks to **Mr. Pallab Maji** for helping me with the basics of the project.

DATE: **SAMAHITA BISWAL**

ABSTRACT

The need for data services with more bandwidth is increasing. Highspeedinternet and intranet access, video conferencing, various multimedia services, is in demand. WLANs (Wireless Local Area Networks) can providehighspeed access to network resources. WLANs working at the datarate of as high of 600 Mbps are already in use.

Now new mobile generations are emerging thatcan provide data services like GPRS technology *(2.5G),* which is already in use, can support up to 171 Kbps data rate and UMTS *(3G)* can provide up to 2 Mbps. An interworking can be implemented between WLANs and mobile networks so that they complement each other. Thus we can utilize the benefits of both these kind of technologies which can be useful for the mobile users.

In certain places very high speed and low cost data services are highly desired. These are the hotspots. WLANs can give both low cost data services with a high speed.So WLANs can be highly useful to the mobile users in the hotspots. WLANs help to provide the user with cheap and cost effective high bandwidth data services. A mobile terminal can easily change its point of contact from a WLAN to a cellular network while roaming, thus availing a seamless connection. Hence here support of mobility is highly essential. This will make the availability of a large amount of bandwidth possible for the user thus it will save both cost and power consumption. This interworking will reduce traffic and interference in the mobile network.

A reliable handoff (HO) algorithm is highly essential for a seamless connection in cellular communication. New HO algorithms based on advanced techniques like neural networks and fuzzy logic systems are slowly emerging which are comparatively more robust than the conventional handoff algorithms. The algorithm designed be such that it can deal with dynamic conditions appearing in a wireless scenario.

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LIST OF ABBREVIATIONS

DESCRIPTIONABBREVIATION

Artificial Neural Networks……ANN

Base Station……BS

Code Division for Multiple Access……CDMA

Fuzzy Logic Controller……FLC

General Packet Radio System……GPRS

Handoff……HO

Horizontal Handoff……HHO

Mobile Station……MS

Mobile Terminal……MT

Mobile Switching Centre……MSC

Quality of Service……QoS

Received Signal Strength……RSS

Signal to Interference Ratio……SIR

Universal Mobile Telecommunication System……UMTS

Vertical Handoff……VHO

Wireless Local Area Network……WLAN

CHAPTER-1

CHAPTER 1

1. INTRODUCTION

The need for data services with more bandwidth is increasing. Highspeedinternet and intranet access, video conferencing, various multimedia services, is in demand. WLANs (Wireless Local Area Networks) can providehighspeed access to network resources. WLANs working at the datarate of as high of 600 Mbps are already in use.

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1.1 Introduction to Handoff

Some of the terminologies used in cellular communications are as follows.

A-Mobile Station (MS)
The mobile station is used when the device is in motionat an unspecified location.

B-Base Station (BS)
The communication from the Mobile stations is received via the base stations (BSs) which are the fixed stations.

C-Mobile Switching Center (MSC)
The Mobile Switching Center controls the calls in a large service area. It is also known as Mobile Telephone Switching Office.

D-Forward Channel
The transfer of information from base station to the mobile station takes through the forward channel

E-Reverse Channel
The transfer of information from mobile station to the base station takes through the forward channel

F-Handoff
It is the process by which a Mobile Terminal keeps its connection when it moves from one point of attachment (base station or access point) toanother.

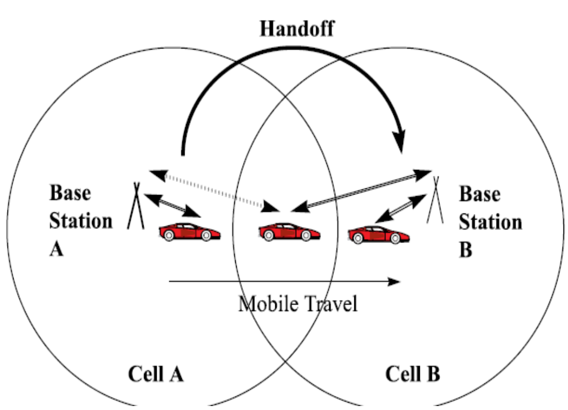

Figure 1.1 Handoff Scenario in Cellular System

1.2 Need for Handoff

A-Radio Link Related Causes

This generally refers to the factors that affects the quality of signal received by the user. The factorsaffecting the quality of signal are the Received Signal Strength, Signal to Interference Ratio (SIR), system related constraints.

B-Network Management Related Causes

To avoid the congestion of a cell, the cellular network may handoff a call. Since the same channel has to be used by other users hence the handoff of calls in progress may be essential.

C-Service Options Related Causes

To receive the desired service, the MS will ask the Base Station for it. But if the current base station doesnot provide that service, handoff will take place.

1.3 Planning of Cellular Communication

The following phases are involved in the planning of cellular communications

A-Assessment of traffic density

It is essential to take into consideration the traffic density of a place before planning of cellular communication

B-Determination of cell sizes and capacity

The cell radius and capacity be decided based on the traffic density as well as the transmit power of the transmitting antennas.

C-Selection of best BS sites to cover the required area

Taking into account the size of cell as well as the traffic density the best base station be selected.

D-Selection of handoff parameters

The set of handoff parameters be chosen properly to design a robust handoff mechanism for the area under consideration

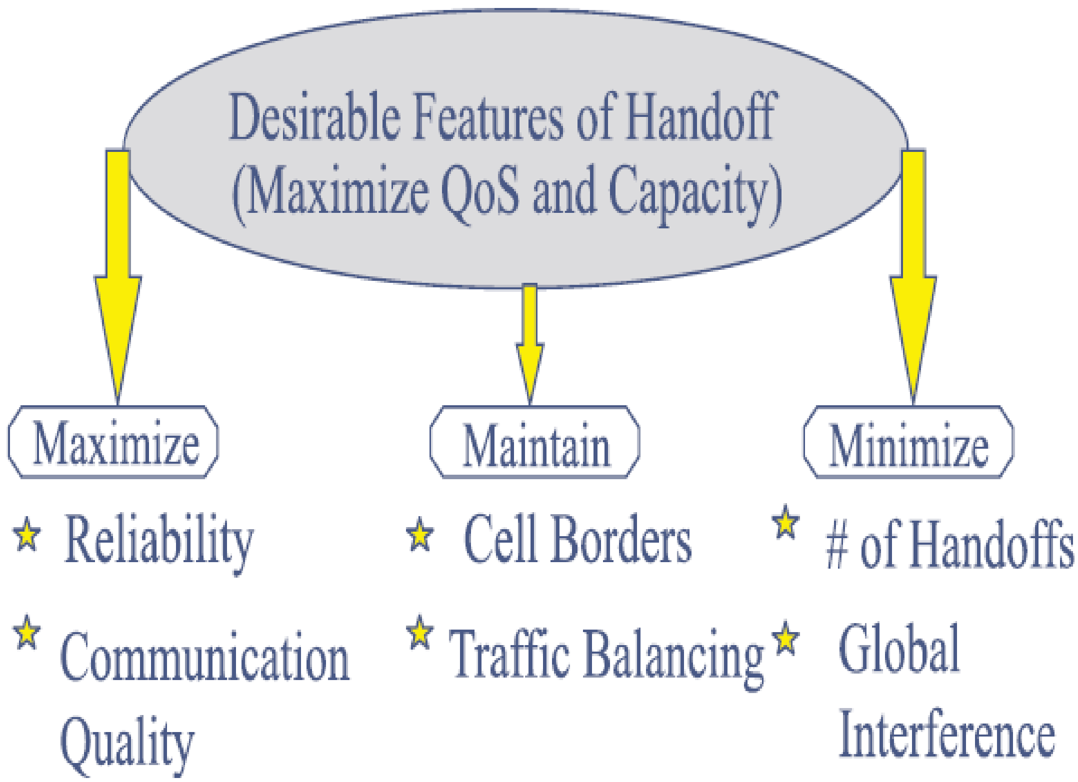

Figure 1.2 Desirable Features of Handoff Algorithms

1.4 Macrocells

The radius of macrocell is generally in kilometers. There is a low cell – crossing rate inside the macrocells. Generally it consists of a large number of Mobile Stations , hence due to low cell – crossing rate centralized handoff takes place which the Mobile Switching Centre has to handle. Here the QOS in both the reverse and forward channel is same. Between the Base Stations the transition region is large.Whenever handoff takes place in a macrocell, they should allow delay to avoid flip – flopping. But the duration of this allowed delay should be short enough so as to not affect QOS as when the Mobile Station enters a new cell the interference increases. This kind of cell penetration by a Mobile Station is called as cell dragging. The path loss characteristics for a Macrocell is generally very gentle. The time interval used to average the Received Signal Strength be long enough to avoid the effect of fading fluctuations. The first generation and second generation of cellular system provide coverage across a wide area even in urban areas using macrocells.In a macrocell, the Base Station transceiver antenna is mounted at a very high height and this transmits a very high amount of power.

1.5 Microcells

Capacity improvement techniques like speech coding, channel coding and modulation cannot satisfy the required service demand. Use of microcell is a very effective method to improve the capacity of the cellular system.Though the microcells improve the capacity quite effectively but radio resource management is the disadvantage here. Microcells can be one-dimensional, two-dimensional or three- dimensionalwhich depends on whether they are on a road or on a highway or covering an area with adjacent roads or in multi- level building. Microcells can be categorized into

A-Hotspots
Areas of coverage that have a high traffic density or which have a poor coverage

B-Downtown Clustered Microcells
It is a contiguous area basically used to serve pedestrians and mobiles

C-3D cells in buildings
This is used in office buildings generally.

The overlap between the adjacent cells is highly essential to provide seamless connectivity by facilitating handoff. The area that has to come under the overlapping region decides the cell size here.Thus there has to be a balance between the overlap region which facilitates the handoff here and the cell size that decides the capacity of the system. The boundary of the microcells may expand or contract due to fading.

1.6 Macrocell/Microcell Overlays

Due to availability of cheap and high bandwidth services inside a microcell, there is always a congestion inside a microcell. The high speed of users inside a microcell can also be a reason for poor QOS inside a microcell. These disadvantages leads to a heavy signaling load as well as high handoff rates inside a microcell. To overcome these problems found in a microcell, a mixed cell architecture called an overlay/underlay system has to be designed. It consists of large sized macrocells called the umbrella cells or the overlay cells surrounding the small sized microcells generally few hundreds of meter in radius. This macrocell/microcell overlay design helps to keep a balance between the number of users in a unit area and the signaling load on a network. Macrocells facilitate wide coverage area beyond the microcell and provide good intercell handoff.

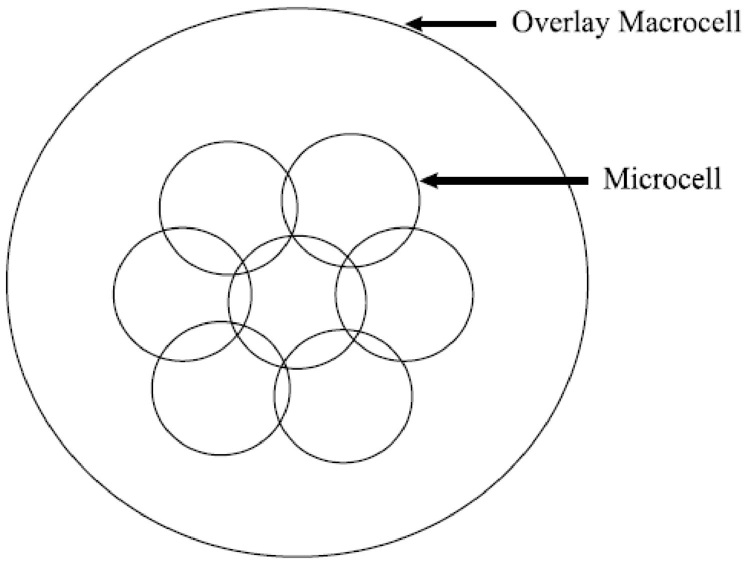

Figure 1.3 A Microcell / Macrocell Overlay System

CHAPTER-2

CHAPTER 2

2 INTRODUCTION TO SOFT COMPUTING TECHNIQUES

The design of intelligent control systems can be done by using many techniques such as fuzzy logic, neural networks, genetic algorithms etc or else a combination of these techniques may be used. While Fuzzy logic is a superset of conventional (Boolean) logic that has been extended to handle the concept of partial truth -- truth values between "completely true" and "completely false". A form of knowledge representation suitable for notions that cannot be defined precisely, but which depend upon their context. It enables computerized devices to reason more like humans.While the fuzzy logic technique can be useful for reasoning, the artificial neural networks can be useful for learning. A hybrid of the both can lead a really intelligent inference system.

2.1 Basic Elements of Fuzzy Logic System

2.1.1Fuzzification

Mapping of the crisp input values to the respective fuzzy sets which is called fuzzification. The degree of membership for each of the crisp input values is determined.

2.1.2 Firing of Fuzzy Rules

The power of If-then-Else is enhanced using linguistic parameters. The fuzzy sets and linguistic variables are used to generate the fuzzy rules.Now depending on the crisp input parameters, the fuzzy set membership function is decided. Depending on the fuzzy set to which a particular input parameter belongs that the required rule is fired

2.1.3 Defuzzification

It converts the fuzzy values to the crisp values.

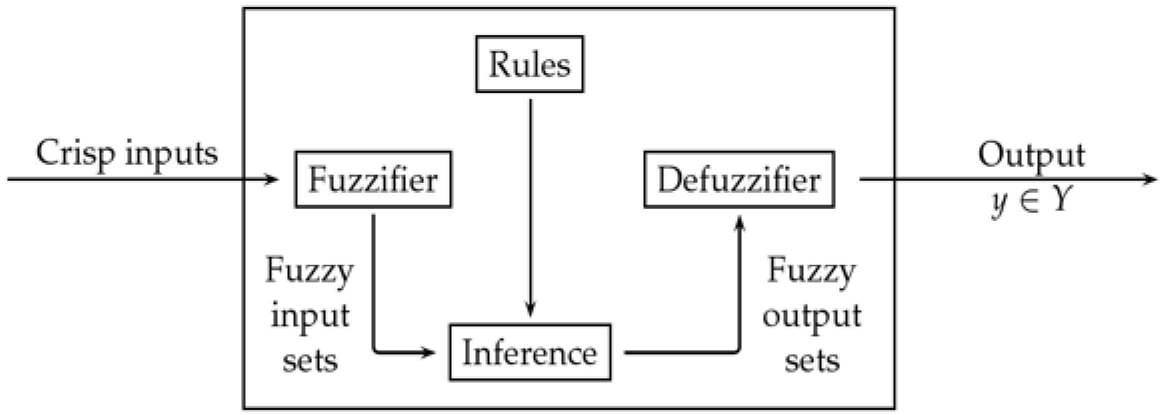

Figure 2.1 Basic Elements of Fuzzy Logic System

2.2 Advantages of Fuzzy Logic Controller

PID controllers can be approximated by Fuzzy logic controllers (FLC). Though FLCs are designed on the basis of approximation, but they can provide the necessary amount of accuracy just like a PID controller along with a number of other advantages, which are given below:

1. Fuzzy controllers have a very convenient user interface. Users without knowledge of control engineering can interpret the system as well.

2. Fuzzy logic provides a certain level of artificial intelligence to the conventional controllers, leading to the effective fuzzy controllers.

3. Process loops that can benefit from a non-linear control response are excellent candidates for fuzzy control.

4. Fuzzy logic provides fast response times with virtually no overshoot, loops with noisy process signals have better stability and tighter control when fuzzy logic control is applied.

5. Input and output ranges can be subdivided as per the performance requirements and can be given different treatment.

6. Control rules can be added to cover important interactions among variables. Every control system can be incorporated by a FLC and fine-tuned to plant non-linearity due to universal approximation capabilities

2.3 Function Approximation Using Fuzzy Logic

Fuzzy Logic can be used in function approximation problems (sine wave in this case). The variation of the output of the function i.e the range of the function has to be carefully observed by diving the inputs i.e the domain into sub-intervals. This variation of slope of output with input is essential to design various membership functions.

Like in our case the domain can be divided easily as follows:-

Function Approximation using Fuzzy Logic for sine wave in the domain [-∏/2,∏/2]

Y= 1 ,|x|>1.43

= 1.008*e $(-0.5 * (x - 1.55)^2)$,0.75 ≤|x|≤1.43

= 0.906*e $(-0.5 * (x - 1.55)^2)$,0 ≤|x|<0.75

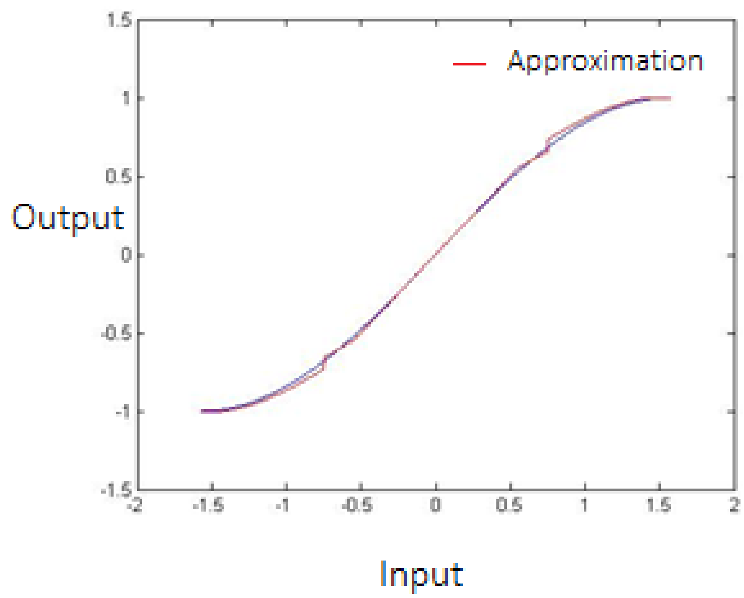

Figure 2.2 Function Approximation for sine wave

2.4Artificial Neural Networks

In machine learning and related fields, artificial neural networks (ANNs) are computational models inspired by biological neural networks and are used to estimate or approximate functions that can depend on a large number of inputs

There are different methods to train a neural network, namely back propagation, lavenburg marquardt, radial basis network, simulated annealing, neuro fuzzy system, pi-sigma systems etc. The drawbacks in older algorithms always leads to generation of a new algorithm.

2.4.1 Iris Data Set

To train the neural network using the previously mentioned algorithms and compare their performance, a data set namely iris data set was used.The data set consists of 150 sets of data consisting the sepal length, sepal width, petal length, petal width. And the problem is that of classification

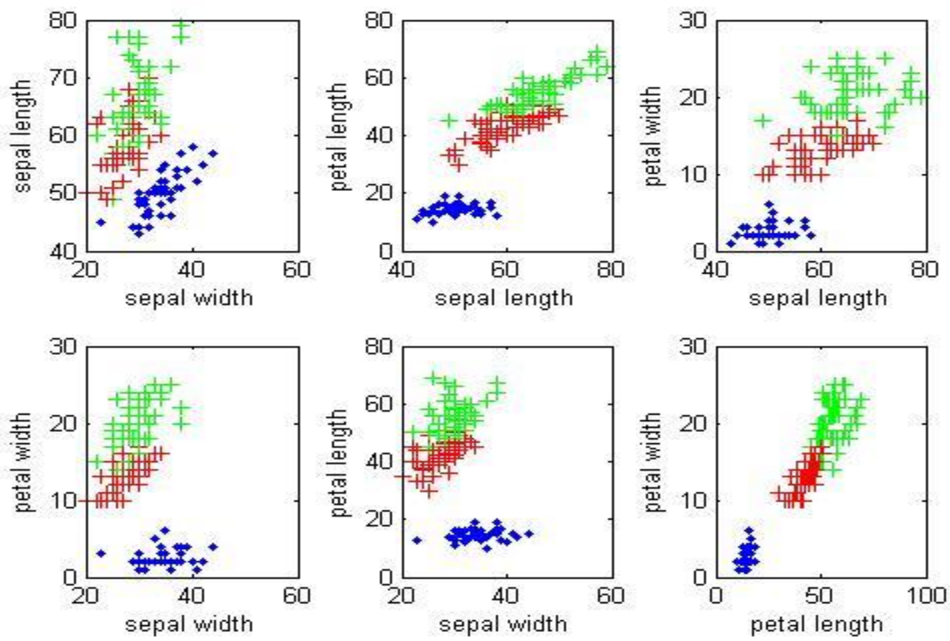

Figure 2.3 Iris Data Set

2.4.2Back Propagation Algorithm

A-Function Signal

A function signal is an input signal (stimulus) that comes in at the input end of the network, propagates forward (neuron by neuron) through the network, and emerges at the output end of the network as an output signal.

B-Error Signal

An error signal originates at an output neuron of the network, and propagates backward (layer by layer) through the network.

C-Procedure of Back Propagation Algorithm

To train the neural network using this algorithm, 4 input neurons, 15 hidden neurons and 1 output neuron is used

The 4 parameters that each sample of iris data set contains is fed to each of the input neurons.

This value from i/p neuron excites the hidden neuron by an activation function say sigmoidal function or log sigmoidal function, which is further multiplied by their weights

Now the summation of values of the hidden neuron goes to the output again weighed by their weights which again excites it by an activation function

Now to exactly train the network, the main part is updation of the weights, which is dependent on both the error and the previous value of the layer

D-Weight Updation

$$\text{wout}=\text{wout}+\acute{\eta}\times\text{output}\times(1-\text{output})\times(\text{desired output}-\text{output})\times\text{hidden}$$

$$\text{delta}=\sum\text{output}\times(1-\text{output})\times(\text{desired output}-\text{output})\times\text{wout}$$

$$\text{win}=\text{win}+\acute{\eta}\times\text{delta}\times\text{hidden}\times(1-\text{hidden})$$

Here $\acute{\eta}$->learning rate

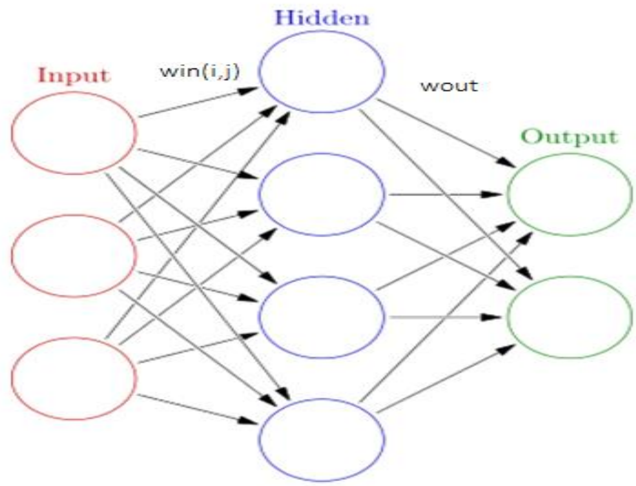

Figure 2.4 Back Propagation Algorithm

Now on using the 150 samples of the iris data set to train a neural network for 1000 iterations, the simulated output for error versus iteration was found as shown

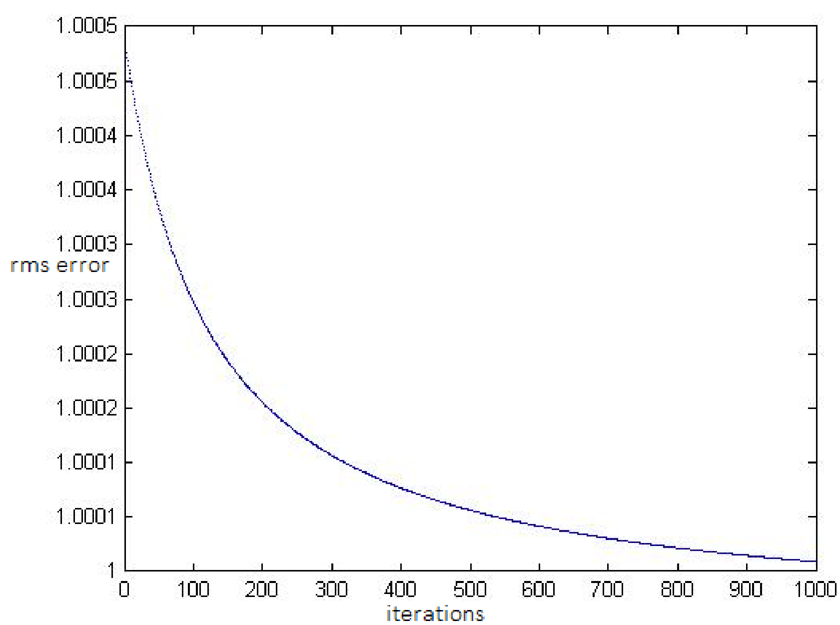

Figure 2.5 RMS error versus iterations for back propagation algorithm

2.4.3Radial Basis Network

A-Procedure of Radial Basis Network

To train the neural network using this algorithm, 4 input neurons, 15 hidden neurons and 1 output neuron is used

The 4 parameters that each sample of iris data set contains is fed to each of the input neurons.

The clusters have a randomly chosen value from the data set itself. For every input sample, the output of each cluster is given by,

$\Phi(i)=e\hat{}(-\left(\frac{h}{d}\right)^2 * \left(||x-c(i)||\right))$

where h-number of clusters used

d - maximum distance between the clusters

x-input

c-Value at cluster

Here Φ is a Gaussian function.

Now the summation of values of the hidden neuron goes to the output again weighed by their weights

B-Weight and Cluster Updation

Wout=wout+ή×output× (1-output) × (desired output-output) × hidden

Since each cluster has 4 parameters as the values of the cluster are chosen from the input data set itself,

For 1 ≤t ≤4, 1 ≤j≤15

cluster(j,t)=cluster(j,t)+ ή×(desired output-output) × wout(j) ×phi(j) ×($2^{(1/2)}$ ×$(h/d)^2$) ×(input(t)-cluster(j,t))

Here ή->learning rate

Now on using the 150 samples of the iris data set to train a neural network for 1000 iterations, the simulated output for error versus iteration was found as shown

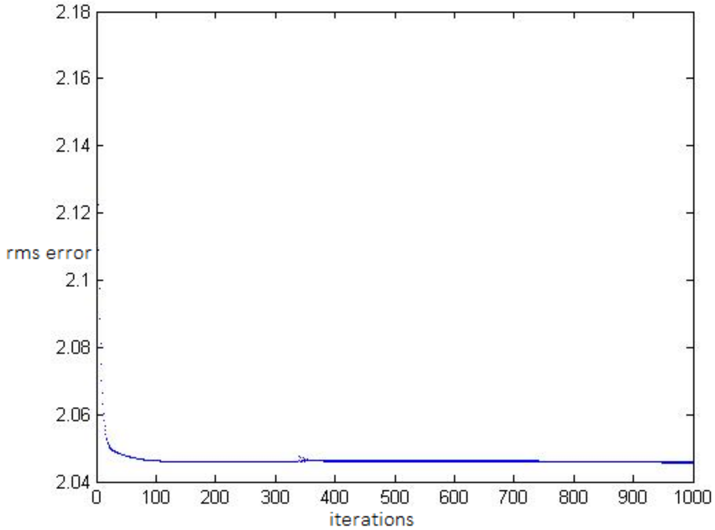

Figure 2.6 RMS error versus iterations for radial basis networks

2.4.4 Simulated Annealing

A-Procedure for Simulated Annealing

Now this is quite a different method a training a neural network. It is found to perform way better than radial basis function but slightly better than the back propagation algorithm.

The idea is to only update randomly one weight for each iteration but if the error for this iteration is greater than the previous iteration by Δe, then to accept the current state with a probability

$$e(-^{\Delta e/T)}$$

B-Weight Updation

wout=wout+ή×output× (1-output) × (desired output-output) × hidden;

delta=∑output×(1-output) ×(desired output-output) ×wout;

win=win+ ή × delta × hidden ×(1-hidden);

Here ή->learning rate

Wnew= Wold× (1-$e(-^{\Delta e/T})$)+$e(-^{\Delta e/T})$ ×Wupdated

Now on using the 150 samples of the iris data set to train a neural network for 1000 iterations, the simulated output for error versus iteration was found as shown

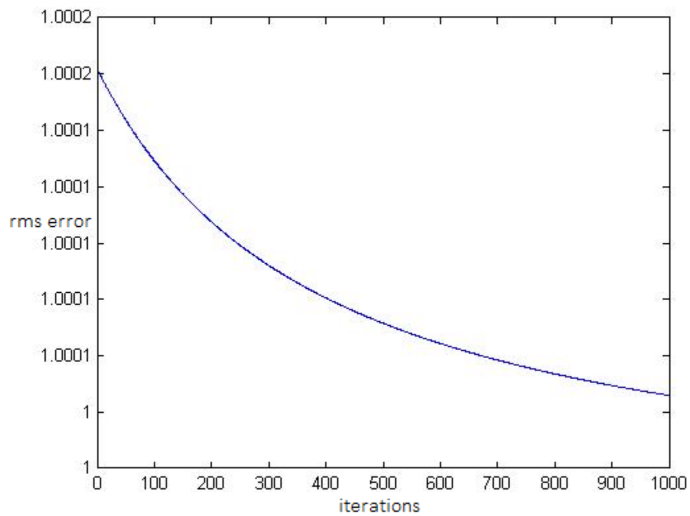

Figure 2.7 RMS error versus iterations for simulated annealing

2.4.5 Neuro Fuzzy System

A-Procedure for Neuro Fuzzy System

It is a combination of both the neural networks and fuzzy inference system.This method of training is remarkably different from other algorithms

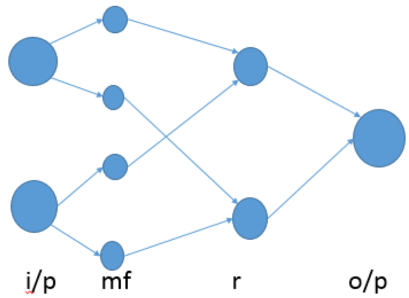

Figure 2.8 Neuro Fuzzy System

i/p->input layer

mf->membership function layer

r->rule layer

o/p->output layer

For the iris data set,

While the iris setosa part is easy to classify, there is a clear overlap between iris versicolor and iris virginica. Hence to devise the limits of the membership functions, one can take the minimum and maximum of a particular parameter of a flower into account.

a-If the value of a parameter for iris setosa goes above minimum limit of iris versicolor, the sample can belong to either of the 2 flowers or 3 flowers if its value also crosses the minimum value of iris virginica

b-If the value of a parameter for iris versicolor goes below maximum limit of iris setosa, the sample can belong to either of the 2 flowers or 3 flowers if its value also crosses the minimum value of iris virginica

c-If the value of a parameter for iris virginica goes below maximum limit of iris versicolor, the sample can belong to either of the 2 flowers or 3 flowers if its value also goes below the maximum value of iris setosa

If the value of the parameter for a sample is well within the bounds then the membership degree can be set equal to 1 else we can take the count of the samples with the same value of the same parameter to set the degree of membership function.

Now on using the 150 samples of the iris data set to train a neural network for 1000 iterations, the simulated output for error versus iteration was found as shown

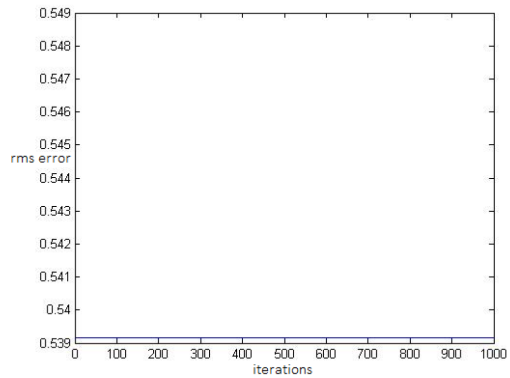

Figure 2.9 RMS error versus iterations for neuro fuzzy system

2.4.6 Pi Sigma Network

A-Procedure for Pi Sigma Network

It is a higher order neuron model. It’s output layer is different from that of back propagation model where in a product of the output from hidden layer is taken and it is passed through an activation function to get output

Output=sigmf($\prod h_i$) i.e wout=1

where h_i-> output of the hidden layer, 1 ≤i ≤m

m->number of neurons in the hidden layer

B-Weight Updation

delta=∑output×(1-output) ×(desired output-output) ×wout;

win=win+ ή × delta × hidden ×(1-hidden);

Here ή->learning rate

Now on using the 150 samples of the iris data set to train a neural network for 1000 iterations, the simulated output for error versus iteration was found as shown

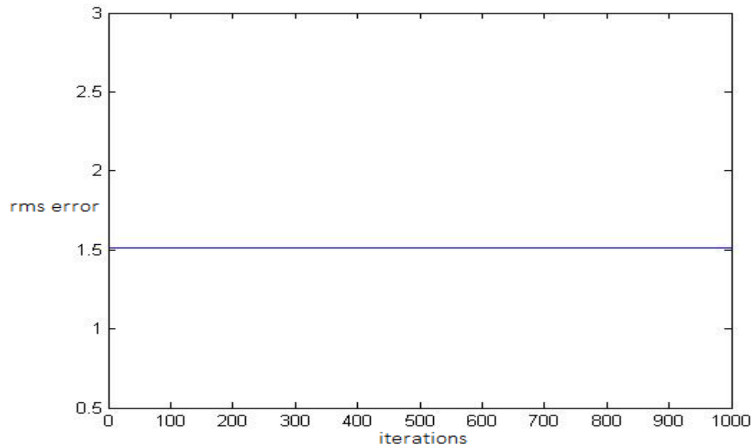

Figure 2.10 RMS error versus iterations for Pi- Sigma Network

2.4.7 Performance of various ANN Techniques on Iris Data Set

Clearly the performance of neuro fuzzy system was the best among all the four algorithms

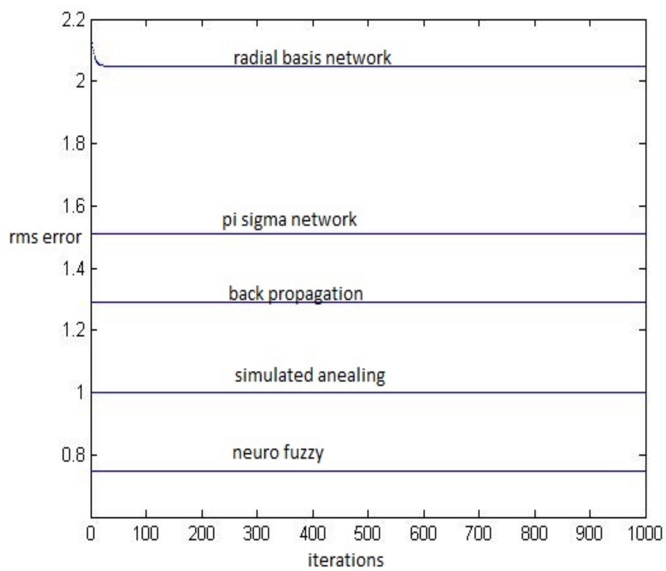

Figure 2.11 Performance of ANN Techniques

CHAPTER-3

CHAPTER 3

3 INTRODUCTION

3.1 Horizontal Handoff Algorithm (HHO)

Handoffs can be of two types namely horizontal handoff and vertical handoff. When the handoff takes place between cellular networks of same kind say gprs to gprs it is called horizontal handoff.

Whereas if the handoff takes place between cellular networks of different kind say umts to wlan or gprs to wlan, it is known as vertical handoff

To implement the horizontal handoff algorithm which is robust by nature a variety of handoff parameters can be taken into account like

A-Speed of user

B-Received Signal Strength

C-Distance between user and the base station

D- Datarate

3.1.1 Speed of User

Speed of user is one of the important factors in handoff decision. As the speed of the user increases, the quality of signal decreases. In case of overlay systems say a wlan inside a macrocell.

If the speed of the user is very high then the user will quickly cross the wlan which is generally hardly 100m in radius. Thus it will loose contact with the Access Point. Also in the case of macrocells, high speed users generally get low Received Signal Strength (RSS)

3.1.2 Received Signal Strength

It is also an important handoff parameter. It can vary due to increase in the distance between the user the transmitting point due to increase in distance as well as fading due to interference from other obstructions such as buildings or any sharp edges or other transmitting points (like jammer margin in CDMA).

3.1.3 Distance between user and Base Station

The strength of the signal decreases due to increase in distance between the user and the transmitting station. The RSS can decrease due to fading due to interference from other obstructions such as buildings or any sharp edges or other transmitting points (like jammer margin in CDMA).

3.1.4 Datarate

In this case, the horizontal handoff is taking place in 3G hence the minimum datarate is around 384 kbps which can go down to around 144 kbps, when the speed of user is very high. Now the datarate received by the user can be around 2 mbps when the speed of the user is very less i.e pedestrian case. Keeping this in mind the fuzzy membership functions have been designed.

3.1.5 Membership Functions

The membership functions for the above four parameters i.e

A-Speed of user

B-Received Signal Strength

C-Distance between user and the base station

D- Datarate

Has been designed so as to take into consideration the possible range of values of this handoff parameters

INPUT MEMBERSHIP FUNCTION

A - Speed of the User

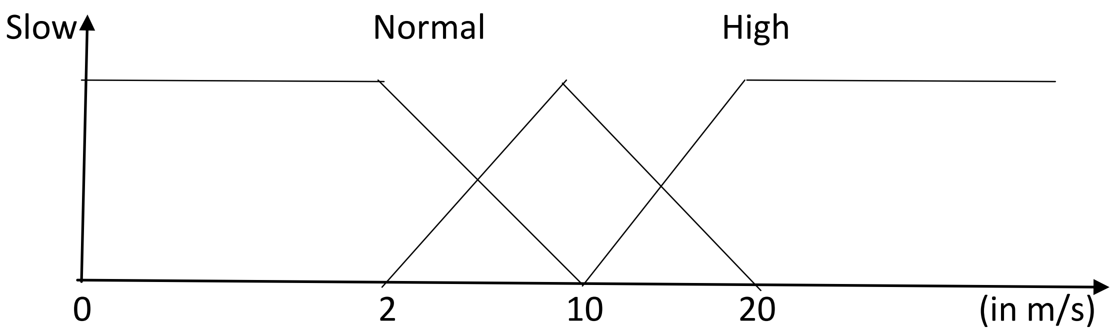

Figure 3.1 Membership Function for speed (HHO)

B - Received Signal Strength (RSS)

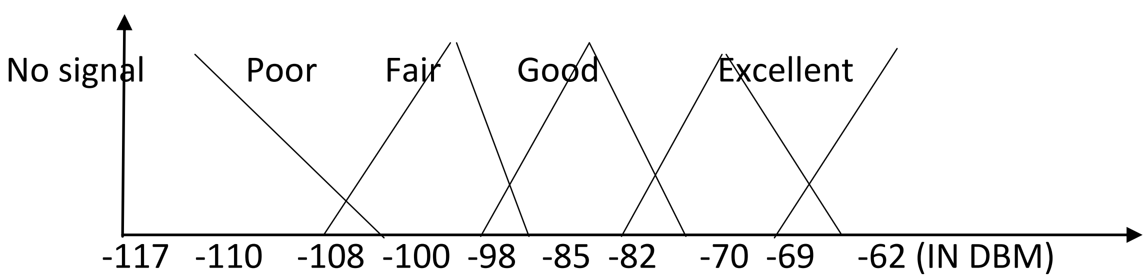

Figure 3.2 Membership Funcxtion for RSS (HHO)

C – Distance between Mobile Terminal and the Base Station

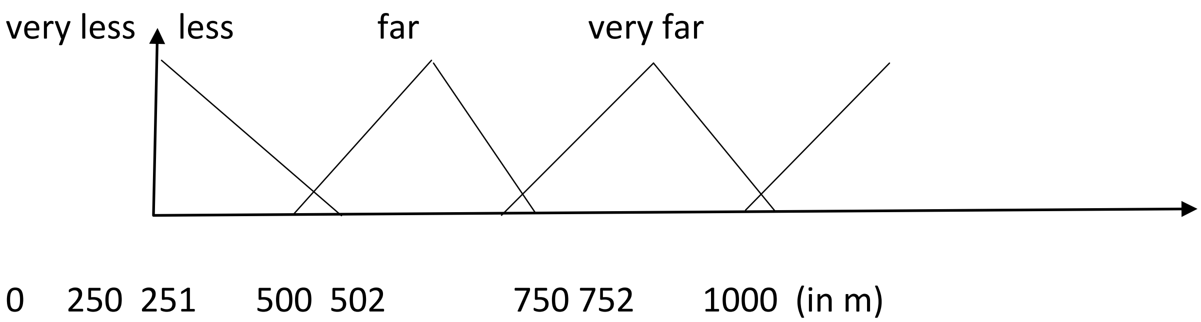

Figure 3.3 Membership Function for Distance

D- Datarate

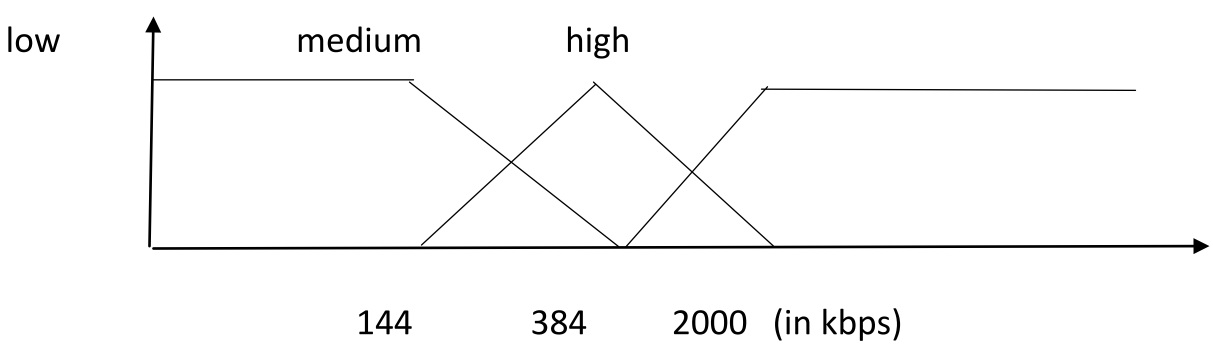

Figure 3.4 Membership Function for datarate (HHO)

OUTPUT MEMBERSHIP FUNCTION

A - RSS THRESHOLD

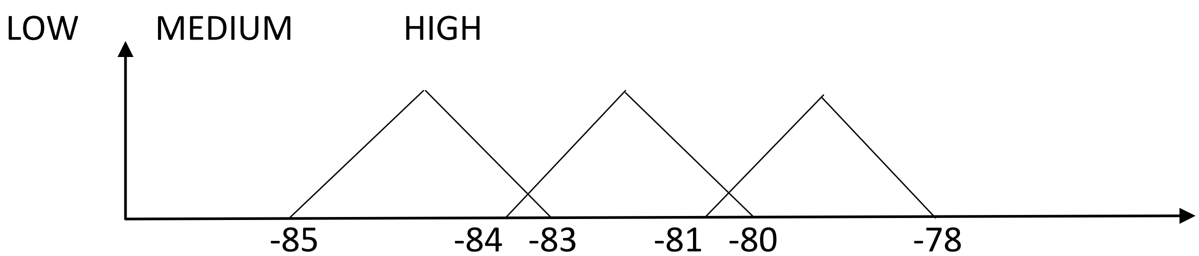

Figure 3.5 Membership Function for RSS Threshold (HHO)

B – RSS HYSTERESIS

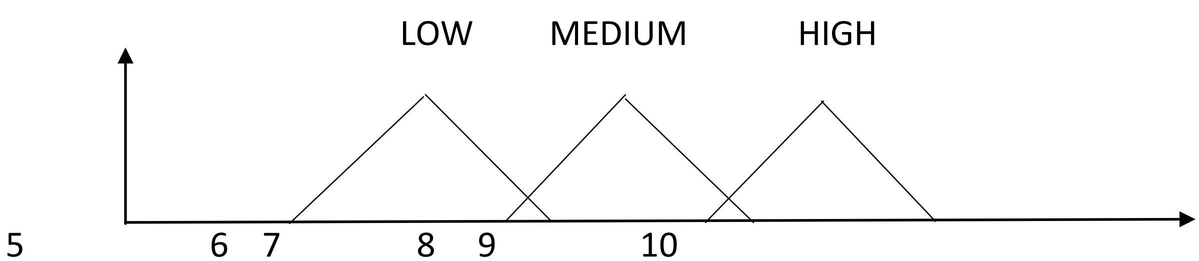

Figure 3.6 Membership Function for RSS hysteresis

3.1.5 Block Diagram for Horizontal Handoff Algorithm

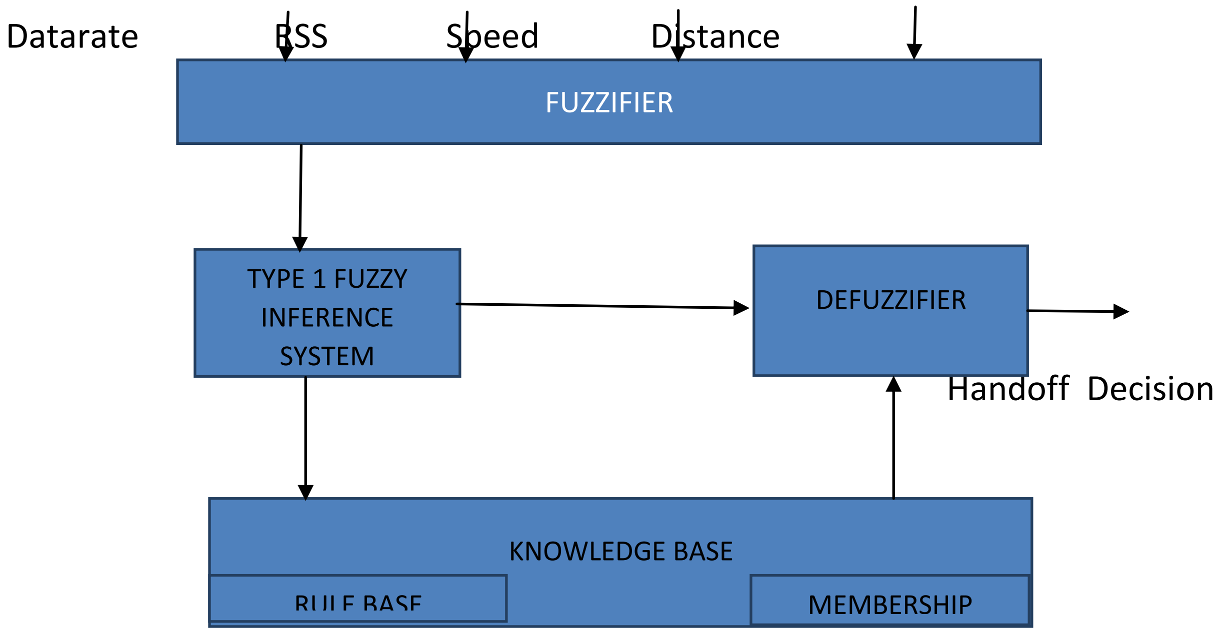

Figure 3.7 Block Diagram for HHO

<u>Description</u>

The input handoff parameters which are data rate, speed of user, distance between the user and the base station as well as the Received Signal Strength has to be measured.

The inputs so measured is given as the input to the fuzzy logic system. The fuzzifier helps to map the given crisp inputs according to the membership function as shown above.

There is a predefined rule base which is in this Horizontal Handoff case consists of 180 set of rules. The rule base has to be designed in such a way that it will take every possible combination of the input parameters into account.

In this fuzzy logic system there are three fuzzy sets for speed, three fuzzy sets for Datarate, five fuzzy sets for Received Signal Strength and four fuzzy sets for Distance . Thus the total number of rules will be, Number of rules in rule base = 3X5X4X3 = 180 rules

The logic used here for designing the rule base is that if the majority of the input handoff parameters are in favour of handoff then the Received Signal Strength Threshold is set low and the Received Signal Strength Hysteresis value is set high.

If the majority of the input handoff parameters are not in the favour of handoff then the Received Signal Strength Threshold is set high and the Received Signal Strength Hysteresis value is set low.

If the majority of the input handoff parameters lie in the fuzzy set normal then both the Received Signal Strength Threshold and the Received Signal Strength Hysteresis value are set normal.

An example of a sample rule is as given below,

If the speed is high and If datarate is low and If distance is high and if Received Signal Strength is no signal then Received Signal Strengthhysteresis is high and Received Signal Strength threshold is low

3.1.6 Simulated Outputs

Inputs:-

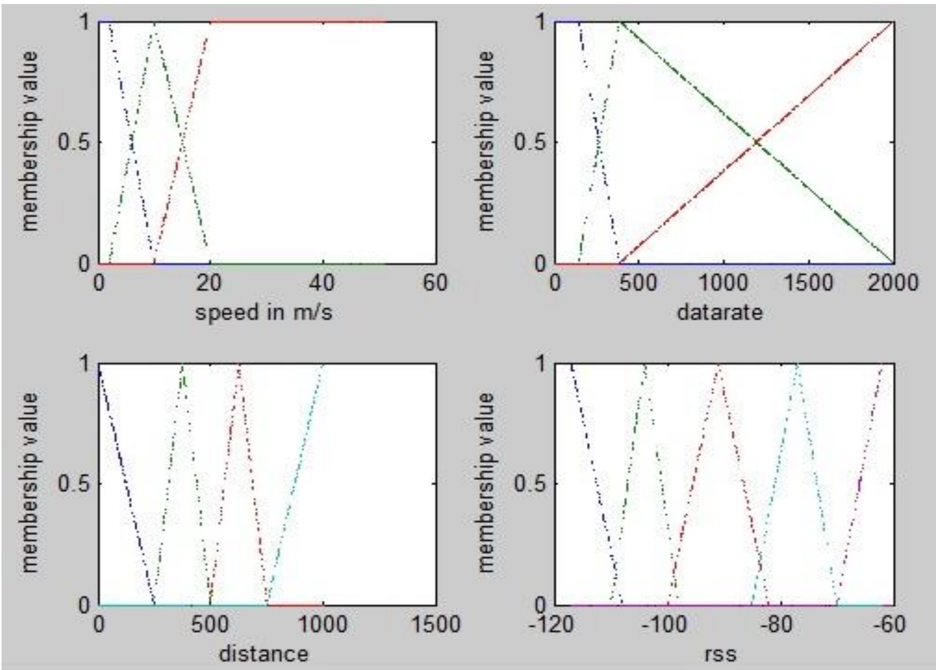

Figure 3.8 Simulated Inputs for HHO

Outputs

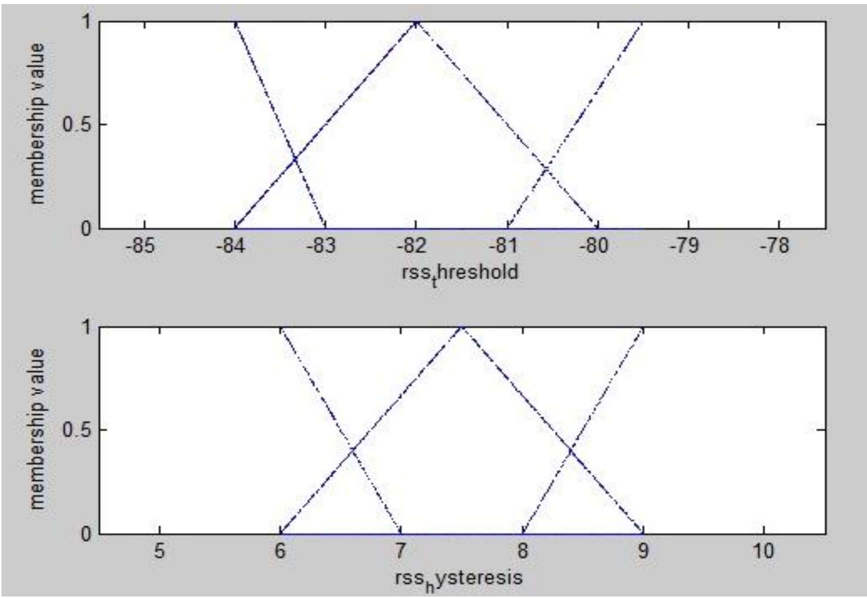

Figure 3.9 Simulated outputs for HHO

3.2 Vertical Handoff Algorithm (VHO)

The next generation wireless systems will consist of a heterogenous set of networks ranging from cellular networks to WiFi or WiMAX and other emerging technologies.Vertical handoff takes place when the mobile terminal switches from one type of network to another type of network say Cellular network to a WLAN. One of the important aspect here is to select an optimal network that will satisfy the users by maintaining a good Quality of Service .

To implement the vertical handoff algorithm which is robust by nature a variety of handoff parameters can be taken into account like

A-Speed of user

B-Received Signal Strength

C-Distance between user and the base station

D- Datarate

But for the implementation of this particular vertical handoff algorithm, the handoff parameters taken into account is the

A-Speed of user

B-Received Signal Strength

C-Traffic Density in the WLANs

3.2.1 Speed of User

Speed of user is one of the important factors in handoff decision. As the speed of the user increases, the quality of signal decreases. In case of overlay systems say a wlan inside a macrocell.

If the speed of the user is very high then the user will quickly cross the wlan which is generally hardly 100m in radius. Thus it will loose contact with the Access Point.

Also in the case of macrocells, high speed users generally get low Received Signal Strength (RSS)

In the case of the vertical handoff algorithm, if the speed of the mobile terminal is very high and it is inside a wlan, it is preferable to switch its contact from the wlan to the macrocell. Hence to do this the RSS Hysteresis value for the wlan is generally increased so as to facilitate handoff to the macrocell.

3.2.2 Received Signal Strength

It is also an important handoff parameter. It can vary due to increase in the distance between the user the transmitting point due to increase in distance as well as fading due to interference from other obstructions such as buildings or any sharp edges or other transmitting points (like jammer margin in CDMA).

3.2.3 Traffic Density in the WLANs

Due to cheap and high bandwidth available in WLANs more and more users are likely to use WLANs. But the traffic density and the speed of users be kept in mind while deciding the handoff inside a WLAN. When the traffic density is high or the speed of user is high, it is desirable to handoff to the overlay macrocell or the nearest WLAN (in our case).

3.2.4 Membership Functions

The membership functions for the above two parameters i.e

A-Speed of user

B- Traffic Density in the WLAN

Has been designed so as to take into consideration the possible range of values of this handoff parameters

INPUT MEMBERSHIP FUNCTIONS

A-SPEED OF USER

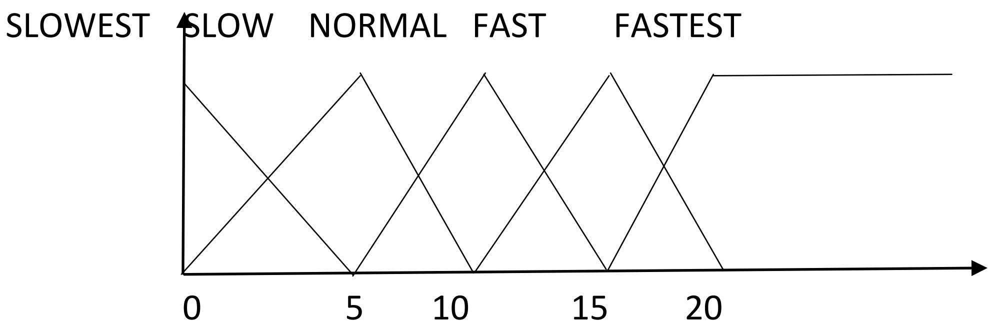

Figure 3.10 Membership function for speed (VHO)

B – TRAFFIC DENSITY IN WLANs

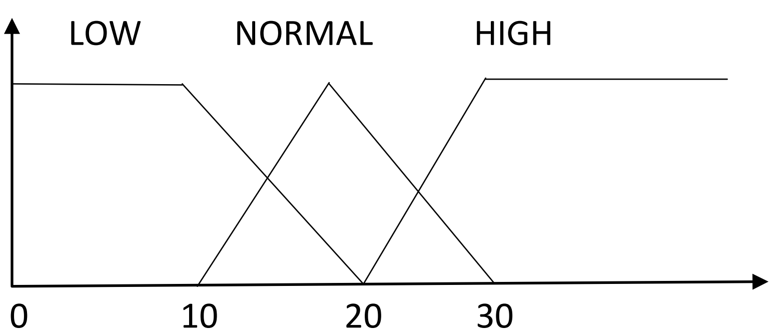

Figure 3.11 Membership function for traffic density (VHO)

<u>OUTPUT MEMBERSHIP FUNCTION</u>

RSS HYSTERESIS FOR WLAN

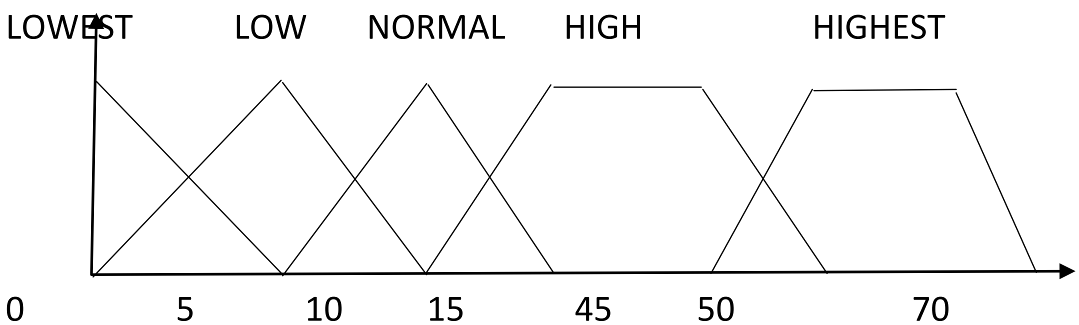

Figure 3.12 Membership function for RSS Hysteresis for WLAN (VHO)

RSS HYSTERESIS FOR MACROCELL

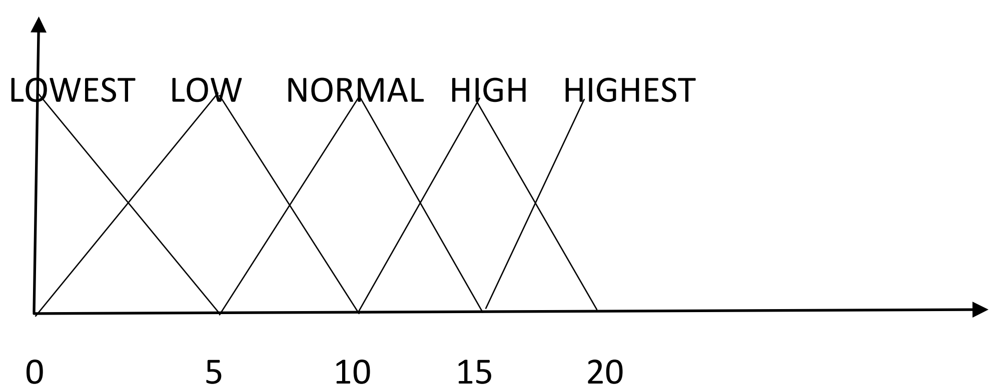

Figure 3.13 Membership function for speed (VHO)

3.2.5 FLOWCHART FOR VERTICAL HANDOFF

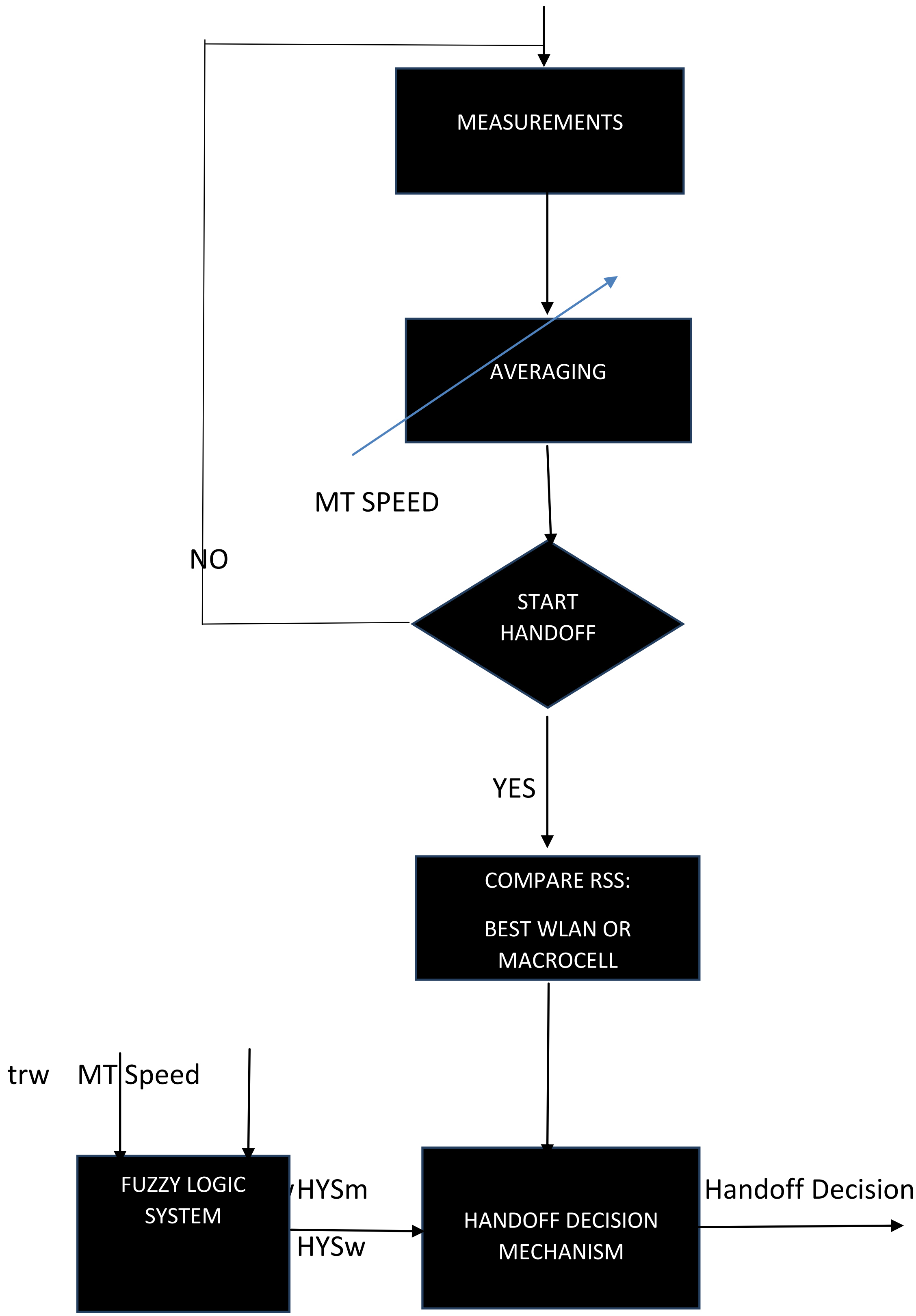

Figure 3.14 Flowchart for VHO

DESCRIPTION

The value of the input handoff parameters - Received Signal Strength , Received Signal Strength Threshold for both WLAN and Macrocell , Speed of the Mobile Terminal , Traffic Density in the WLAN are taken as the input for the fuzzy system

In order to take into account the fading fluctuations of the Received Signal Strength in a wireless system, the averaging of the Received Signal Strength is necessary.

As the speed of the user increases, it is essential to take a shorter interval for averaging the Received Signal Strength, whereas as the speed of the user decreases , it is essential to take a longer interval for averaging the Received Signal Strength

The time duration for averaging interval is given by:

T= (d- D/2)/ Speed of User

Here

d - Distance between mobile terminal and the current Access Point / Base Station

D - Half of distance between current Access Point / Base Station and the nearest and most optimal Access Point / Base Station

If the value of Received Signal Strength is below the Received Signal Strength Threshold of the current WLAN or Macrocell in use then we need to initiate the Vertical Handoff Algorithm.

In the algorithm Speed of User and Traffic Density of the WLAN are taken as the fuzzy inputs. If the speed of user is very high and the Traffic Density of the WLAN is high then it is preferable to handoff to the macrocell. Hence in this case the Received Signal Strength Hysteresis for the WLAN is made high and for the macrocell is made low.

If there is no need for the handoff it will continue by taking the inputs from the wireless system and keep on comparing.

3.2.6 BLOCK DIAGRAM FOR VHO

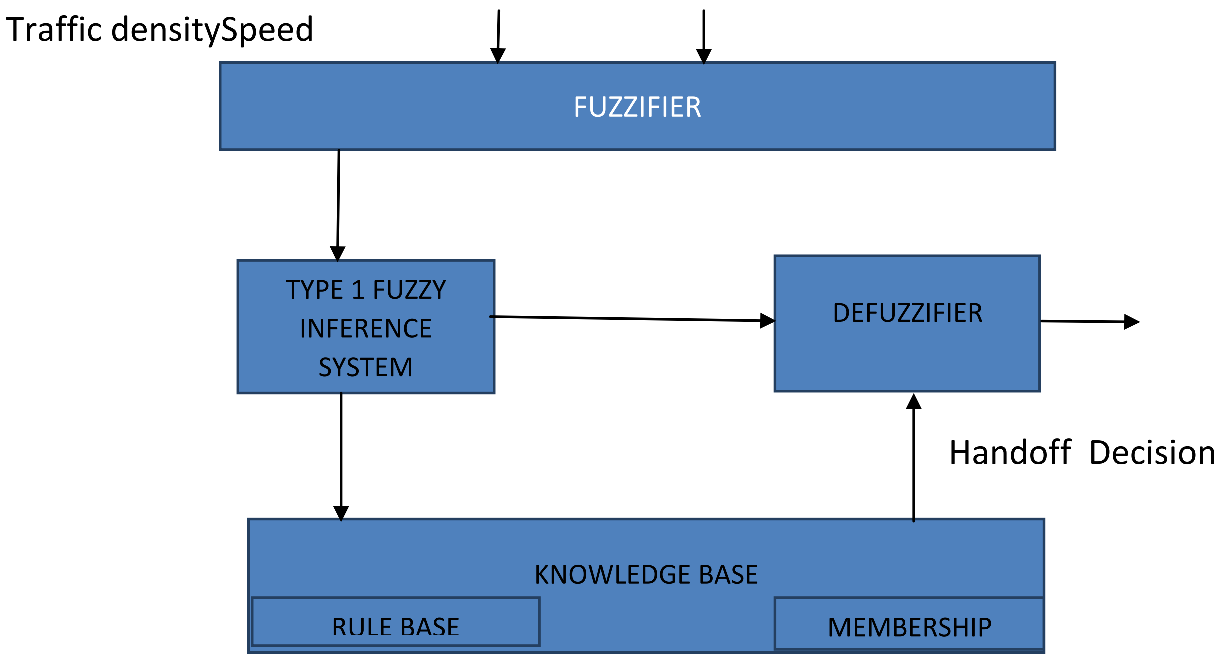

Figure 3.15 Block Diagram for VHO

Description

The value of the input handoff parameters - Received Signal Strength , Received Signal Strength Threshold for both WLAN and Macrocell , Speed of the Mobile Terminal , Traffic Density in the WLAN are taken as the input for the fuzzy system

The inputs so measured is given as the input to the fuzzy logic system. The fuzzifier helps to map the given crisp inputs according to the membership function as shown above.

There is a predefined rule base which is in this Vertical Handoff case consists of 15 set of rules. The rule base has to be designed in such a way that it will take every possible combination of the input parameters into account.

In this fuzzy logic system there are three fuzzy sets for speed, three fuzzy sets for Traffic Density in the WLAN and five fuzzy sets for speed of the user. Thus the total number of rules will be,

Number of rules in rule base = 3X5 = 15 rules

The logic used here for designing the rule base is that if the majority of the input handoff parameters are in favour of handoff from the WLAN to the macrocell then the Received Signal Strength Hysteresis for macrocell is set low and the Received Signal Strength Hysteresis value for WLAN is set high.

If the majority of the input handoff parameters are not in the favour of handoff from the WLAN to the macrocell then the Received Signal Strength Hysteresis for macrocell is set high and the Received Signal Strength Hysteresis value for WLAN is set low.

If the majority of the input handoff parameters lie in the fuzzy set normal then both the Received Signal Strength Hysteresis for macrocell is set high and the Received Signal Strength Hysteresis value for WLAN is set normal.

3.2.7 Simulation Environment

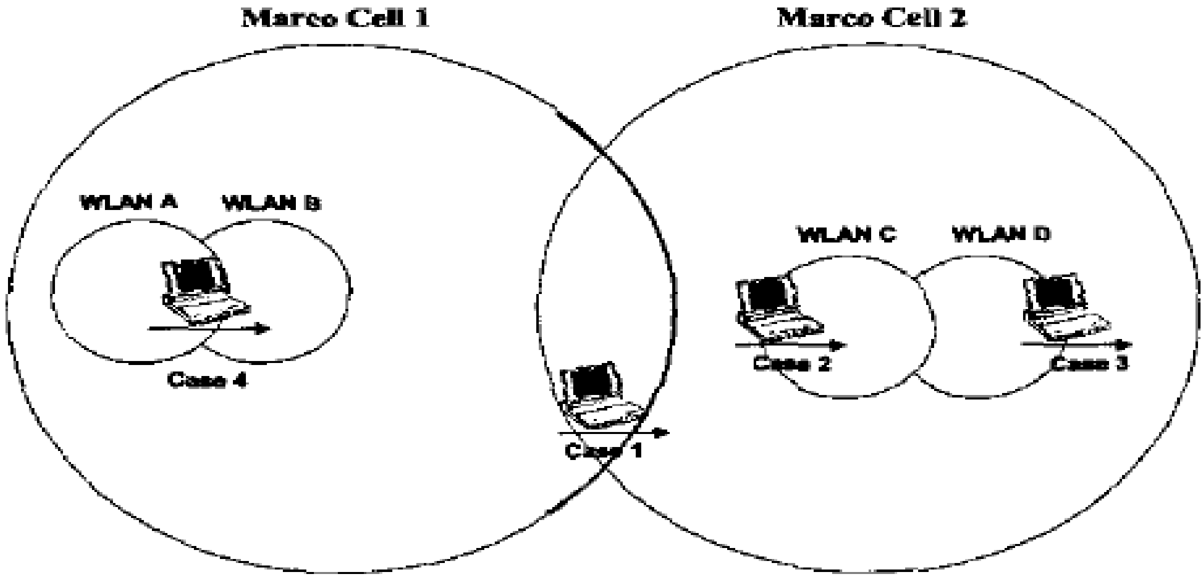

Figure 3.16 Simulation Environment

3.2.8 Simulation Values

Table 1 Simulation Values

Simulation Parameter	Macrocell	WLAN
Transmitted Power	1 Watt	100mw
Cell Size	1 km	100m
Path loss constant (S)	19 dBm	28.7 dBm
Threshold	-105 dBm	-85 dBm
Path Loss Exponent (n)	4	3.3

3.2.9 Fuzzy Rules

Table 2 Fuzzy Rules

Speed of User	**Traffic Density in WLAN**	**RSS Hysteresis WLAN**	**RSS Hysteresis Macrocell**
Fastest	High	Highest	Lowest
Fastest	Normal	Highest	Lowest
Fastest	Low	High	Low
Fast	High	Highest	Lowest
Fast	Normal	High	Low
Fast	Low	Normal	Normal
Normal	High	Low	Low
Normal	Normal	Normal	Normal
Normal	Low	Low	High
Slow	High	Normal	Normal
Slow	Normal	Low	High
Slow	Low	Lowest	Highest
Slowest	High	Low	High
Slowest	Normal	Lowest	Highest
Slowest	Low	Lowest	Highest

3.2.10 Simulation Outputs

Inputs

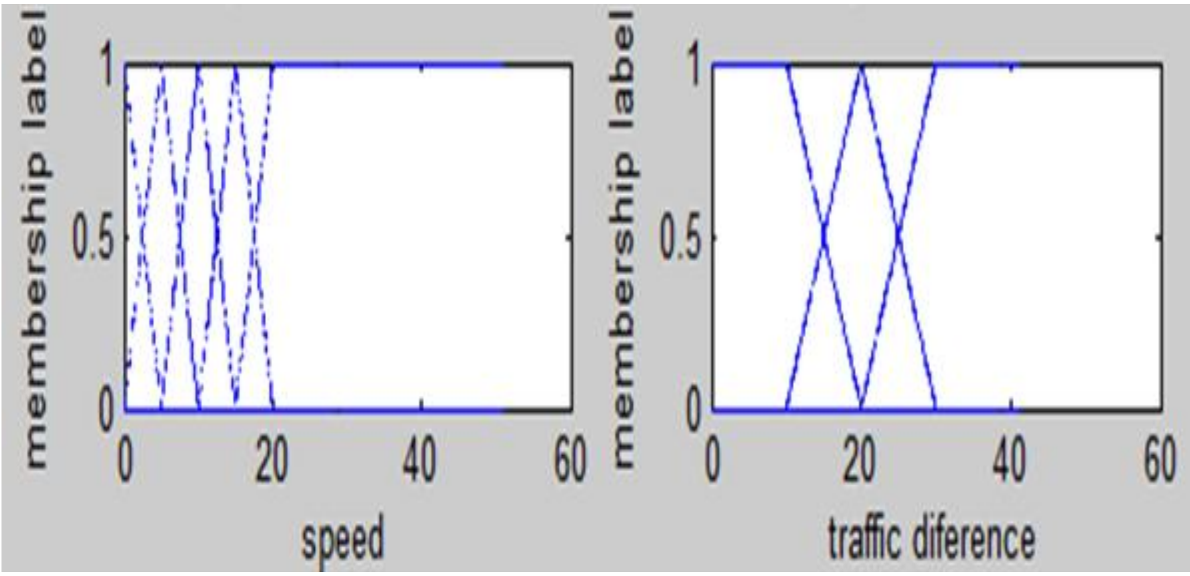

Figure 3.17 Simulated Inputs for VHO

Outputs

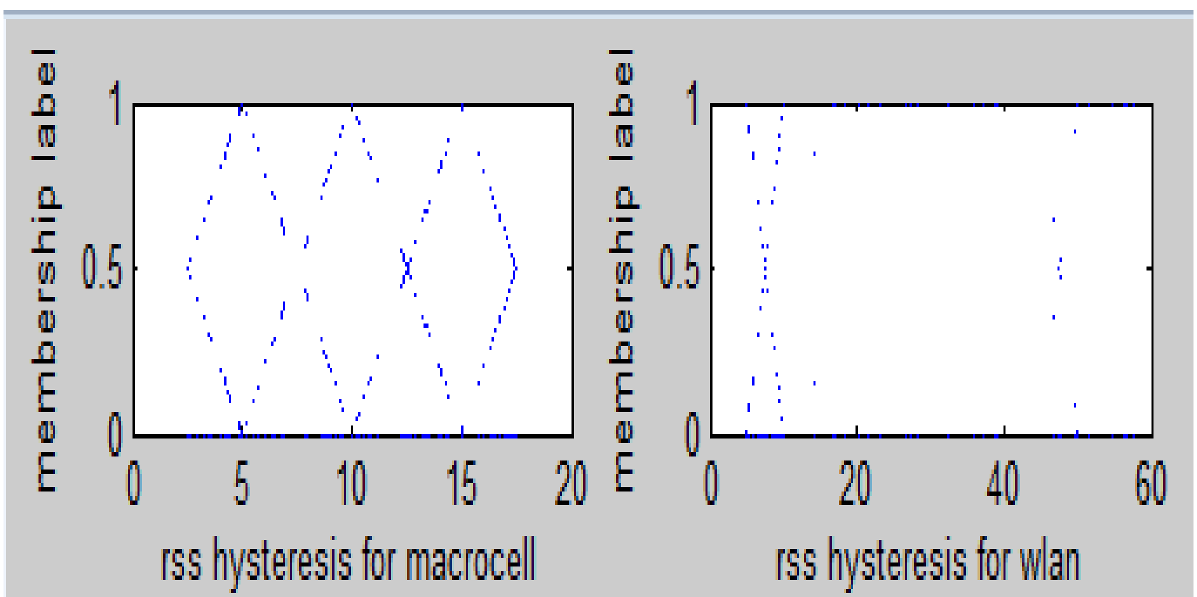

Figure 3.18 Simulated Outputs for VHO

CONCLUSION

In this thesis all the simulations using various Artificial Neural Network Techniques has been presented as well as a comparison of the performance of the techniques has been presented. The plot so obtained in Fig 14 is consistent with the desired results.

In Chapter 3 of this thesis two handoff algorithms have been presented. The first one is for the Horizontal Handoff case. In this case the datarate parameter taken as an input handoff parameter, its membership function has to be changed because as the traffic density increases, generally the datarate per user decreases

The second one is for vertical handoff case, it is more robust compared to conventional handoffs since the averaging of the RSS has been done keeping in mind the speed of the mobile terminal as well as the traffic density of the WLAN

The Vertical Handoff Algorithm can be further improvised by taking a set of other parameters into account, like the Interference, cost per network, delay of transmission of signals. Type -2 fuzzy can be used to take into account the unpredictability of various input parameters.

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