SEAMLESS HORIZONTAL HANDOVER ALGORITHM FOR HOMOGENEOUS WIRELESS MOBILE NETWORKS USING FUZZY LOGIC

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ABSTRACT

The wireless networks of the near future will be capable of successfully handling various kinds of communication systems. Worldwide Interoperability for Microwave Access (referred to as WiMAX) is a physical layer wireless communications technology for outdoor broadband wireless coverage. The most important and society application of WiMAX is the mobile communication. When a mobile station changes its geographical position, it may also need to change its attachment point in the network in order to retain the quality of the connection. Currently, the mobility of a terminal is a requirement of great importance, supported by a procedure known as handover. One of the main challenges for robust mobility is the availability of simple and seamless handover algorithms, which allow a mobile node to connect among homogeneous or heterogeneous wireless networks. Two types of handover could take place: horizontal handover between wireless Access Points at the same wireless network, and vertical handover between different wireless networks. During the handover procedure the mobile node can neither send nor receive any data packets. This results in packet delay and in some cases packet loss. This project proposes an efficient horizontal handover decision based on fuzzy logic principle in order to decrease unnecessary handover. Three systems used in this studying to know which one can obtain the best results system A , system B and system C plus applying the eight steps of horizontal handover scenario on each system. System A used three parameters : Received Signal Strength (RSS), Available BandWidth (ABW) and Bit Error Rate (BER) , System B used two parameters : RSS , ABW while system C used the conventional method. After comparison between the three systems, it is observed that system A is the best scenario among the three. The result shows that by using this method, handover number and the time delay was reduced plus a decrease in proper lost calls number.

ABSTRAK

Rangkaian tanpa wayar masa terdekat mampu mengendalikan pelbagai jenis sistem komunikasi. Interoperability Seluruh Dunia bagi Akses Gelombang Mikro (dirujuk sebagai WiMAX) adalah lapisan teknologi tanpa wayar komunikasi fizikal untuk liputan jalur lebar tanpa wayar. Yang paling penting dan aplikasi pengunaan WiMAX adalah komunikasi mudah alih. Apabila stesen mudah alih mengubah kedudukan geografinya, ia juga mungkin perlu menukar titik lampiran dalam rangkaian untuk mengekalkan kualiti sambungan. Pada masa ini, mobiliti terminal adalah satu keperluan yang amat penting, yang disokong oleh prosedur yang dikenali sebagai pemindahan. Salah satu cabaran utama untuk mobiliti yang mantap adalah adanya mudah dan lancar pemindahan algoritma, yang membolehkan nod mudah alih untuk menyambung antara rangkaian tanpa wayar homogen atau heterogen. Dua jenis pemindahan boleh berlaku: pemindahan mendatar antara Access Points tanpa wayar pada rangkaian wayarles yang sama, dan pemindahan menegak antara rangkaian tanpa wayar yang berbeza. Semasa prosedur pemindahan nod bimbit tidak boleh menghantar atau menerima apa-apa paket data. Ini menyebabkan kelewatan paket dan dalam beberapa kes kehilangan paket. Projek ini mencadangkan pemindahan mendatar yang cekap berdasarkan prinsip logik kabur untuk mengurangkan pemindahan yang tidak diperlukan. Tiga sistem digunakan dalam pengajian ini untuk mengetahui yang mana satu boleh mendapatkan keputusan sistem yang terbaik system A, system B dan sistem C serta menggunakan lapan langkah pemindahan senario mendatar pada setiap sistem. Sistem A merrlunakan tiga parameter: Diterima Kekuatan Isyarat (RSS), jalur lebar Disediakan (ABW) dan Kadar Ralat Bit (BER), Sistem B menggunakan dua parameter: RSS, ABW manakala sistem C menggunakan kaedah konvensional. Selepas perbandingan antara ketiga-tiga sistem, ia menunjukkan sistem A adalah senario terbaik di antara tiga sistem tersebut. Hasil kajian menunjukkan bahawa dengan menggunakan kaedah ini, pemindahan bilangan dan masa lengah berkurangan beserta penurunan jumlah kehilangan nombor panggilan.

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LIST OF SYMBOLS

IEEE	-	Institute of Electrical and Electronics Engineers
WLAN	-	Wireless Local Area Network
WiMAX	-	Worldwide Interoperability for Microwave Access
GPRS	-	General Packet Radio Service
LTE	-	Long Term Evolution
3G	-	3rd Generation
4G	-	4th Generation
WAN	-	Wide Area Network
RSS	-	Received Signal Strength
MN	-	Mobile Node
HHO	-	Horizontal Handover
AP	-	Access Point
ABW	-	Available Bandwidth
BER	-	Bit Error Rate
QoS	-	Quality of service
WMAN	-	Wireless
MSC	-	Mobile Switching Centre
MTSO	-	Mobile Telephone Switching Office
SNREQ	-	Source Node Request Packet
NDREP	-	Neighbor Discovery Request Packet
NPER	-	Neighbor Reply Packets
LPER	-	List Replay Packet
MLREP	-	MH List Reply Packet
MLREQ	-	MH List Request Packet
SNREP	-	Source Node Replay Packet
RREQ	-	Route Request Packet
RREP	-	Route Replay Packet
BTS	-	Base Transceiver Station

MF	-	Membership Function
IS	-	Information Server
VoIP	-	Voice over Internet Protocol
GUI	-	Graphical User Interface
FIS	-	Fuzzy Inference System
OW	-	Optical Wireless
MSCTP	-	Mobile Stream Control Transmission Protocol
SIP	-	Session Initiation Protocol
NGWS	-	Next Generation Wireless system
CHMP	-	Cross Layer Handover Management Protocol
COG	-	Centre Of Gravity

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Communication is one of the integral parts of science that has always been a focus point for exchanging information among parties at physically apart locations. After its discovery, wireless communications has replaced the telegraphs and letters.

Wireless networking is becoming increasingly important and a popular way of providing global information access to users on the move. Various popular protocols such as IEEE 802.11/16/21 (Sharif & Maeda, 2011; Wong *et al*., 2009), and technologies such as; WLAN, WiMAX, GPRS, Long Term Evolution (LTE) and 3G/4G Cellular wireless networks providing mobile users universal and seamless mobility for all kinds of traffic. Worldwide Interoperability for Microwave Access (WiMAX) is a recent wireless broadband standard that has promised high bandwidth overlong-range transmission (Mohammed *et al*., 2010). WiMax is one of the technologies that is being used for 4G networks and can be used in both point to point and the typical WAN type configurations that are also used by 2G and 3G mobile network carriers. Its formal name is IEEE standard 802.16 (Rogers & Edwards, 2003). Mobile devices are able to configure multiple wireless network interfaces which simply give them the ability to access resources in heterogeneous wireless networks (Niyato&Hossain, 2008).

Today, mobile communication has become the backbone of society. All the mobile system technologies have improved the way of living. It's main plus point is that it has privileged a common mass of society. One of the most important problem of the mobile communication is handover. Basically, its happen when the phone moving away from the area covered by one cell and entering the area covered by another cell the call is transferred to the second cell in order to avoid call termination when the phone gets outside the range of the first cell. Many have proposed newer approaches to solve this problem and one of them is the incorporation of fuzzy logic into the decision making process (Edward & Shankar, 1998).

Fuzzy logic has long been used successfully in applications' controls and predictions. Its nature of using language based approach, i.e. employing if-then rules, will allow less dependence on the precise quantitative analysis. This makes fuzzy logic suitable for analysis in an environment of uncertainty (Foong& Maeda, 2011).

1.2 Problem Statement

With rapid development and deployment of wireless technologies, Mobile Telephone Systems tend to be smaller in order, the size of cells used in cellular phones is to increase traffic channels for more users in that area, especially in the city area because, the small size handovers occur more frequently (Loia*et al*., 2004). Moreover, there are many buildings built in various shapes and various location arrangements in the city area that affect the received signal strength's (RSS) level in the mobile stations (MS), by increasing fading which causes more number of handovers. One of the most challenging issues in homogeneous wireless network is the considerable amount of packet loss due to performing handover procedures (Moravejosharieh*et al*., 2011).

The handover falls into two categories such as; horizontal and vertical. The former is associated with the handover within the same wireless access technology whereas; the later is associated with the handover between different wireless accesses technologies, (Molina *et al*., 2008). In homogeneous wireless mobile networks, the Horizontal HandOver (HHO) occurs when a mobile node moves from one wireless Access Point (AP) to another wireless AP. During the handover process, the mobile node is unable to send or receive data packets since it is disconnected from the former AP and is trying to be connected to the new AP (Thumthawatwarn*et al*., 2011). The length of the period that the mobile node cannot send or receive data packets, is called handover latency. The handover process introduces a significant amount of latency, which prevents seamless services to the mobile user, especially for real-time applications such as; video conferencing and mobile video streaming (Thumthawatwarn*et al*., 2009). Another scenario where uncertainty took place is a phenomenon known as the Manhattan effect, where the sudden signals drop due to the high rise of buildings in the urban area (Foong*et al*., 2009).

There are many applications and techniques on horizontal handover that were developed in the past. However, limitations such as QoS and the efficiency of the model need to enhance the performance of the system. Therefore, continuous efforts are carried out to improve HHO in many fields, including fuzzy logic. Several related methods had been investigated and carried out. Thus, to overcome the drawbacks, this project focuses on enhancing the performance of the communication system by using a computing intelligence

1.3 Aim of Study

A seamless Horizontal Handover Decision Algorithm for homogeneous Wireless Mobile Network using fuzzy logic is studied. Horizontal Handover technique will enhance the QoS and then obtaining high efficiency in mobile communication.

1.4 Objectives of Study

At the end of this project the following objectives will be achieved:-

i. To develop a seamless and robust horizontal handover.
ii. To construct a mobile communication system based on horizontal handover using fuzzy logic.
iii. To obtain a high quality and faster system of better efficiency for mobile communication system.

1.5 Scope of Study

This project focuses on the use of fuzzy logic in the communication field. WiMAX network will used as a homogeneous wireless mobile network, depending on the fuzzy rule base. Three important parameters (RSS, ABW and BER) having high effect on the decision of horizontal handover, will act as input into Fuzzy inference system as a crisp value. After defuzzification and saving the output values, a comparator makes comparison between the output values of the fuzzy logic system and then choose which one will make the best and seamless horizontal handover decision as a new station.

1.6 Significance of Study

The importance of this project to increase the performance of the mobile communication system by using fuzzy logic into the communication field. In the conventional method, many handovers need to be change always before one is chosen, which causes a delay and fails some calls while, Fuzzy logic will decrease the number of handovers by choosing the best value, which decreases the fail call and requires a shorter time to obtain high efficiency.

1.7 Thesis Outline

This thesis is a documentary to deliver the generated idea, the concepts applied, the activities perform, and finally, the output project produced. The thesis consists of five chapters.

Chapter 1 discusses the background of the research. In addition, the objectives of project, problems statement, scopes of work and thesis structure outline are presented.

Chapter 2 contains literature review discussing the applications of wireless communication (WiMAX) and explain the mobility. In this chapter, the handover and their types and the advantage of each type are explained. Furthermore, a review of fuzzy logic and the reason of using fuzzy logic will be discusses in this chapter. On the others hand, this chapter also includes preview recent research of modulation schemes from the year 2006 until 2012 and the author's view on these research.

Chapter 3 provides the detailed properties of the proposed seamless horizontal handover decision in homogenous network using fuzzy logic, and briefly describe the simulation for HHO event. The methodology that being used in this study involved eight steps starting from choosing the parameters until decision of handover.

Chapter 4 presents the design of system architecture for a fuzzy logic system. Besides that, the design flow and simulation of the project is introduced. It provides a brief description on each procedure in completing the project. This chapter also covered MATLAB Fuzzy Inference System (FIS) result and analysis. The Fuzzy logic control module was developed to assist the adaptation process.

Finally, Chapter 5 presents the conclusions research contribution and recommendation of future work. Important results and methodology discussed from previous chapters are summarized, and the possibilities for future directions are discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The key objective of most "robust and seamless communication system" research projects is to ensure good mobility in homogeneous wireless network, and to allow a user to communicate with fast and high quality of service (Hua & Brieu, 2006). The most important parameter to measure the QoS is the efficiency of the system within depend on several parameters (Foongs *et al*., 2009; Agrawal & Zeng, 2011).

Handover decision is the ability to decide when to perform the horizontal handover. Handover metrics are the qualities that are measured to indicate whether or not a handover is required. Traditional handover decision metrics based on the received signal strength (RSS) and other parameters used for horizontal handover in cellular system. In order to take an intelligent and better decision as to which wireless network should be chosen and make it possible to deliver each service via the network that is the most suitable for it, the following metrics have been proposed for use in addition to the RSS measurements: available band width ABW and bit error rate BER (Hua & Brieu, 2006; Singh & Ahuja, 2011). Recently, new handover algorithm are emerging based on advanced techniques like pattern recognition, neural networks and fuzzy logic system (Salih *et al.*, 2012; Honman & Benjapolakul, 2008). These complicated algorithms are necessitated by the complexity of the handover problem and dynamic conditions of wireless networks (Israt *et al*., 2008). Therefore, in order to explain in depth of this field, this chapter provides the description of WiMAX which party reveal the applications and techniques that have been used in WiMAX. This chapter, describe the handover and its two types of technologies to reduce the number of handover using fuzzy logic.

This chapter also discussed the related works that will in line with the problem under study, seamless horizontal handover using fuzzy logic.

2.2 Worldwide Interoperability for Microwave Access (WiMAX)

Worldwide Interoperability for Microwave Access **(WiMAX)** is a MAC and physical layer wireless communications technology. WiMAX was designed to provide outdoor broadband wireless access at a municipal, state-wide, or regional level. The set of standards that define WiMAX are developed and maintained by the IEEE 802.16 Working Group (Martin *et al*., 2009). WiMAX is central to a number of new market and technology opportunities. The standard offers a range of broadband wireless technologies that are capable of delivering differentiated and optimized service models. WiMAX promises to combine high capacity services with wide area coverage (Martin *et al*., 2009; Hua & Brien, 2006; Singh & Ahuja, 2011). Provides up to 70 Mb/sec symmetric broadband speed without the need for cables. The technology is based on the IEEE 802.16 standard (also called Wireless MAN) (Mitra, 2009). 802.16 networks operating at licensed 2.5 GHz spectrum are being deployed by broadband wireless Internet Service Providers such as Sprint and Clearwire at specific locations around the country. States and cities are deploying WiMAX for Internet access in licensed 3.65 GHz spectrum (Martin *et al*., 2009; Bian *et al*., 2007), as shown in Figure 2.1.

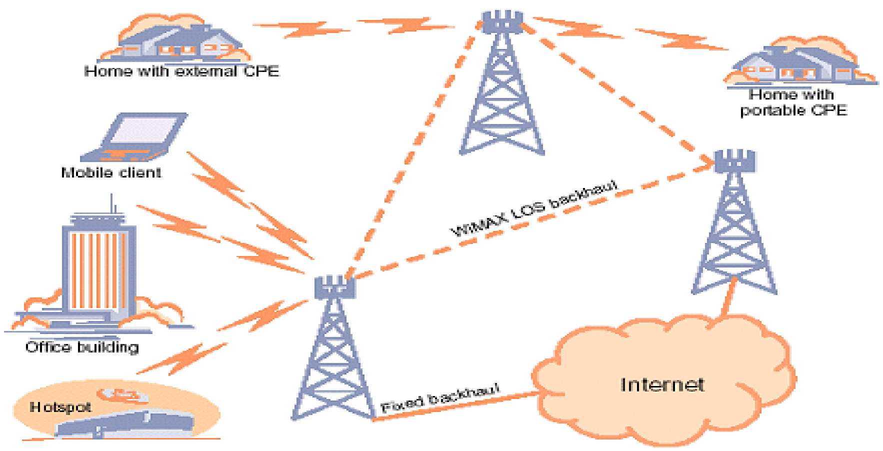

Figure 2.1: WiMAX (Bian *et al*., 2007)

IEEE 802.16 is a set of standards on broadband wireless access (BWA), which was established by the IEEE standards board in 1999 and aims for global deployment of broadband wireless metropolitan area networks (WMAN). As currently defined through IEEE standard 802.16, a wireless MAN provides network access to buildings through exterior antennas communicating with central radio-based stations (BSs) (Rogers & Edwards, 2003).

2.2.1 Mobile System

The definition of mobile radio terminal means any radio terminal that could be moved during its operation. In general, however, a Mobile Station (MS) or subscriber unit communicates to a fixed Base Station (BS) which in turn communicates to the desired user at the other end. The MS consists of transceiver, control circuitry, duplexer and an antenna while the BS consists of transceiver and channel multiplexer along with antennas mounted on the tower. The BS is also linked to a power source for the transmission of the radio signals for communication and connected to a fixed backbone network. Figure 2.2 shows a basic mobile communication with low power transmitters/receivers at the BS, the MS and also the Mobile Switching Center (MSC) (Mitra, 2009).

The MSC is sometimes called Mobile Telephone Switching Office (MTSO). The radio signal emitted by the BS decay as the signal travel away from it. A minimum amount of signal strength is requirement in order to be detected by the mobile stations or mobile sets which are the hand-held personal units (portables) or those installed in the vehicles (mobiles). The region over which the signal strength lies above such as threshold value is known as the coverage area of BS. The fixed backbone network is a wired network that links all the base stations and also the landline and other telephone networks through wires. The present day cellular communication uses a basic unit called cell. Each cell consists of small hexagonal area with a base station located at the center of the cell which communicates with the user.

2.2.2 The Mobility

When a mobile station transfers a user's session from one network to another, the IP address will change. In order to allow the Corresponding Node that the MN is communicating with to find it correctly and allow the session to continue, Mobility Management is used. The Mobility Management problem can be solved in different layers, such as the Application Layer, Transport Layer, IP Layer, etc. The most common method is to use SIP (Session Initiation Protocol) and Mobile IP.

If the Mobile Node (MN) in a congested cell is trying to make a call, it sends a source node request packet (snreq) to the home BS (see step 1 in Fig 2.2). After receiving a SNREQ, the home BS broadcast a MN list request packet (MLREQ) to al TDSs within the home cell (see step 2 in Fig 2.2). Once the TDS received the MLREQ, it broadcasts a Neighbor Discovery Request Packet (NDREP) to all MNs within it coverage (see step 3 in Fig 2.2), which respond neighbor Replay Packets (NREP) to the TDS (see step 4 in Fig 2.2). Then the TDS return a list of MNs to the home BS by sending a MN List Replay Packet (LREP) (see step 5 in Fig 2.2), which also contains the bandwidth status of the TDSs. After receiving the MLREPs from all the TDSs upper bounded to a timeout, the home BS applies a rational SSP algorithm to analyze the information included in MLREPs so as to choose a proper source node (see step 6 in Fig 2.2). Following this, the home BS sends a Source Node Replay Packet (SNREP) to the decided source if the source node is not the original source (see step 7 in Fig 2.2), so that the source starts a route discovery process by broadcasting Route Request Packet(RREQ)(see step8 in Fig 2.2). After receiving Route Replay Packet (RREP) (see step 9 in Fig 2.2), the source releases its occupied bandwidth and starts diverting its ongoing traffic through relaying route (see step 10 in Fig 2.2). Finally, the home BS reallocation the released bandwidth to the original source (see step 11 in Fig 2.2) (Hossain, 2008).

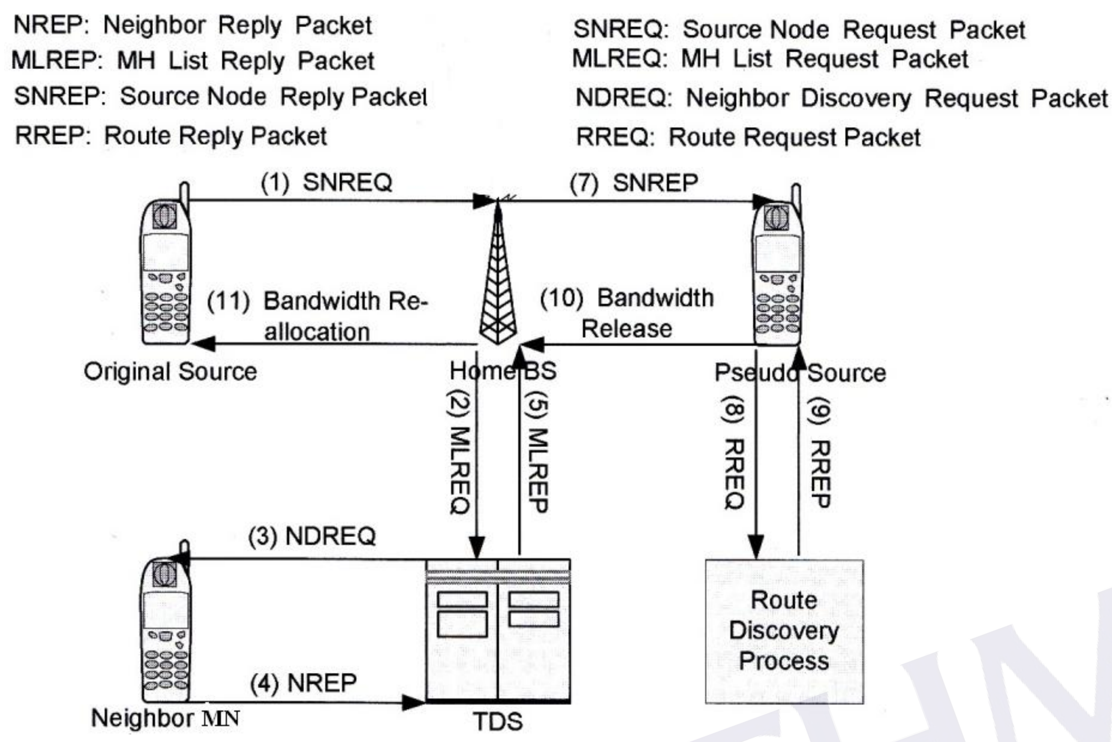

Figure 2.2: The Mobility Process (Hossain, 2008).

2.3 Handovers

The ability to maintain voice calls or packet sessions when moving from the coverage area of one call to another has been one of the most fundamental enabling features of mobile communication networks. This feature generally known as handover (HO) (handover is also written as handoff or handover, and as handover outside North America) (Agrawal & Zeng, 2011; Ramiro & Hamied, 2012).

2.3.1 Types of Handovers

A combination of technologies which includes Local Area Networks (WLANs), Wireless Personal Area Networks (PANs), Cellular Networks (GSM, GPRS, UTMS) and Community Area Networks (WiMax, 802.11) will provide the infrastructure required for this environment. One challenge faced for the designers of this scenario is to minimize the perception of the change in quality when a handover (the process of changing the point of network attachment) occurs.

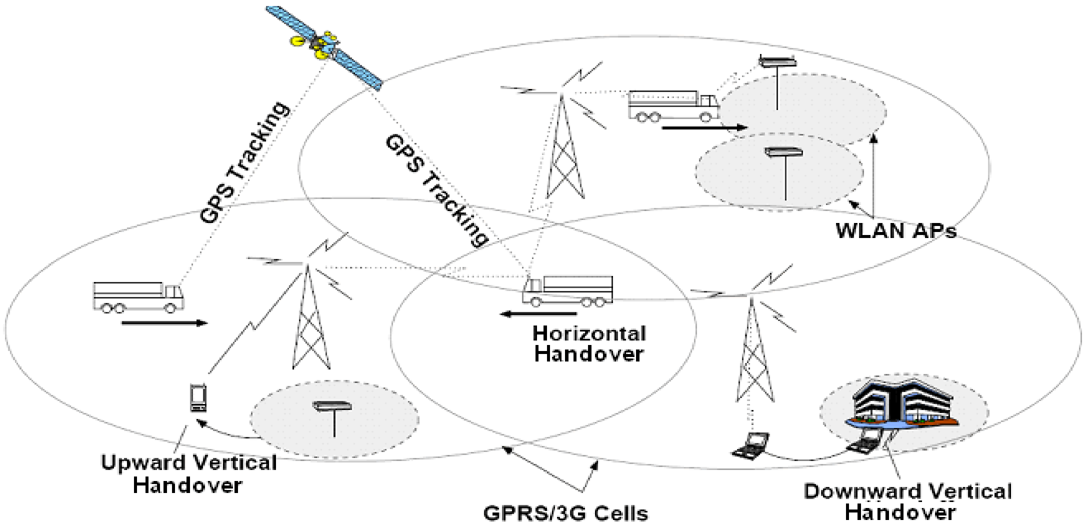

Figure 2.3: Vertical and horizontal handover (Wong *et al,* 2009).

There are two types of handover (vertical handover) and (horizontal handover). Vertical handovers refer to the automatic fall over from one technology to another in order to maintain communication. This is different from a horizontal handover between different wireless access points that use the same technology in that a vertical handover involves changing the data link layer technology used to access the network. Vertical handover happen when a mobile station transfers a user's session from one network to another, the IP address will change. In order to allow the corresponding node that the MS is communicating that is to find it correctly and allow the session to continue. The Mobility Management problem can be solved in different layers, such as the Application Layer, Transport Layer, IP Layer, etc. In horizontal handovers, there are two types, hard handover (break before make) and soft handovers (make before break).

2.3.1.1 Hard Handover

Figure 2.4 shows a hard handover process, with Figure 2.4(a) showing the mobile terminal (TM) connected to base station (BTS) A initially. Figure 2.4(b) shows that the MN is disconnected from BTS A. Finally, the MN is connected to BTS B in Figure 2.4(c). The MN is connected to only one BTS at any time. The old connection is terminated before a new connection is activated. This also, known as break before make.

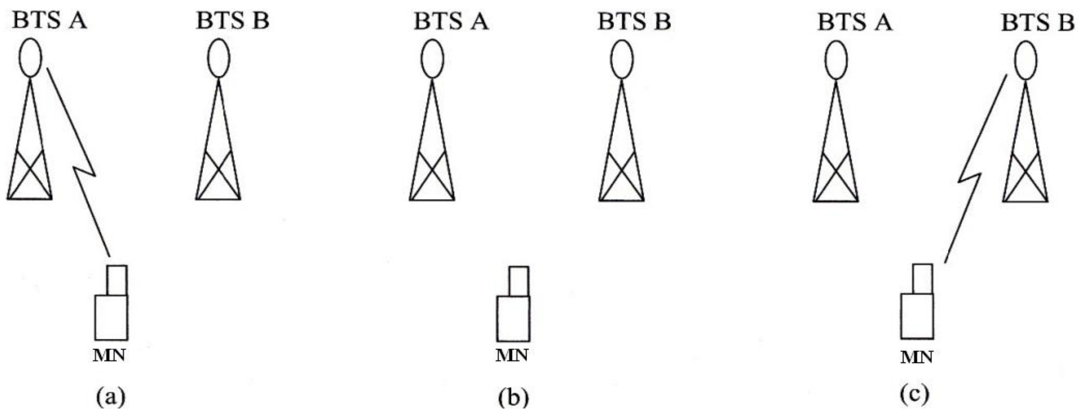

Figure 2.4: Hard handover (Wong *et al*, 2009).

2.3.1.2 Soft Handover

Figure 2.5 shows a soft handover process, with Figure 2.5(a) showing the MN connected to BTS A initially. Figure 2.5(b) shows that the MN in connected with BTS A and B. Finally, the MN is disconnected from BTS A but still connected to BTS B in Figure 2.5(c). This is also known as make before breaking (Wong *et al*, 2009). The MSC evaluates the signal strengths received from different BS for a single user and then shifts the user from one BS to the other without actually changing the channel. These types of handovers are called as soft handover as there is no change in the channel.

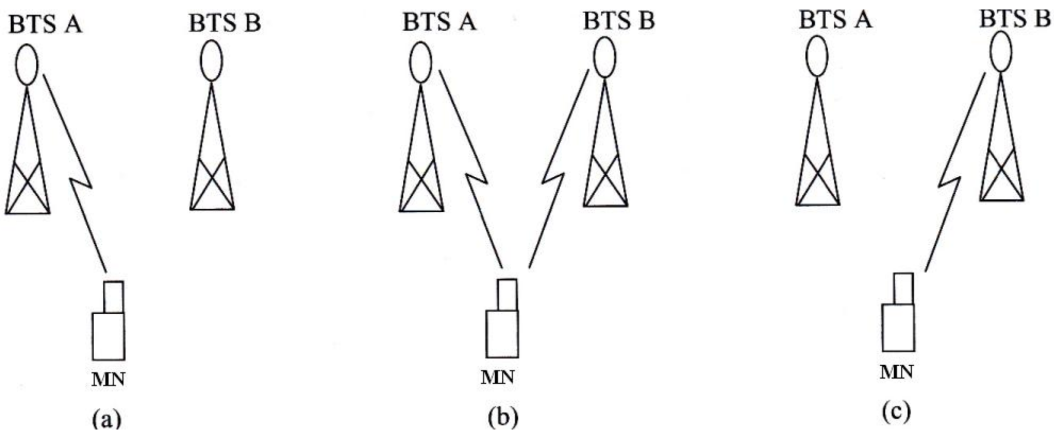

Figure 2.5: Soft handover (Wong *et al*, 2009).

2.4 Fuzzy Logic

Fuzzy logic was invented by Dr. Lotfi Zadeh at the University of California at Berkeley in 1965. In very simple terms, fuzzy logic allows situations or problems to be described and processed in linguistic terms such as “hot” or “heavy” instead of precise numeric values such as “140 degrees” or “180 kg”.

Fuzzy logic is much more than a logical system. It has many facets. The principal facets are: logical, fuzzy-set-theoretic, epistemic and relational. Most of the practical applications of fuzzy logic are associated with its relational facet (Zadeh, 2008).

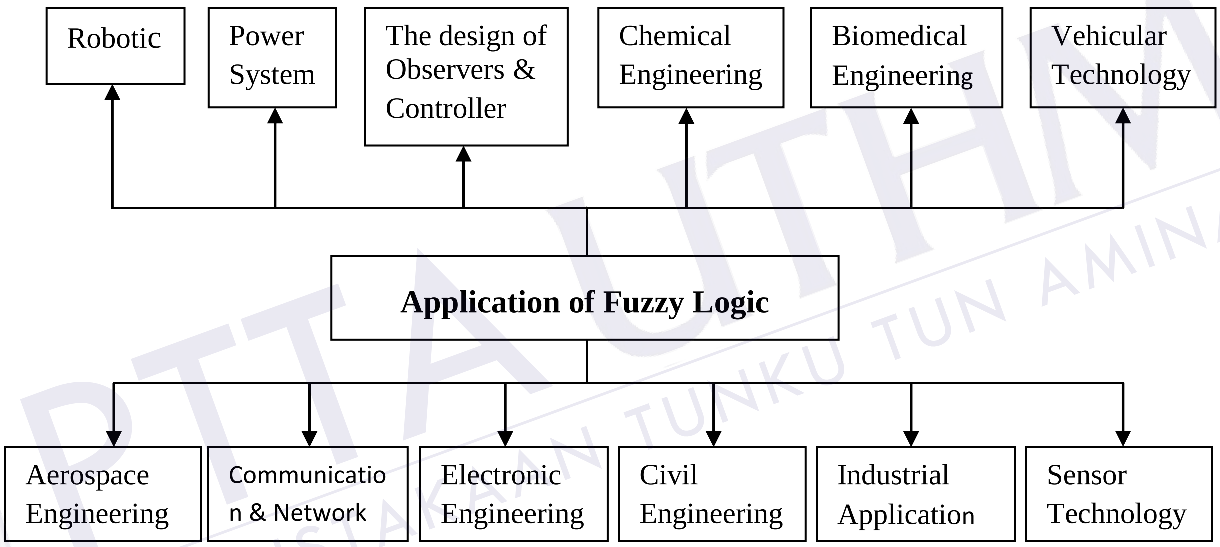

Figure 2.6: The application of Fuzzy logic.

The application of fuzzy logic techniques has been increasing rapidly. Its implementation can be seen in many branches of engineering such as linguistic system, the areas of application for fuzzy logic have spread from consumer electronics to industrial control, information processing, financial analysis, communication, network and others as shown in Figure 2.6. In Communications and networking field, the fuzzy logic is used for ATM network traffic modeling, management, and rate control as well as nonlinear channel equalization, telecommunication ranking and network admission control. Besides that, Fuzzy Logic has been successfully applied in various areas pertaining to wireless communication systems.

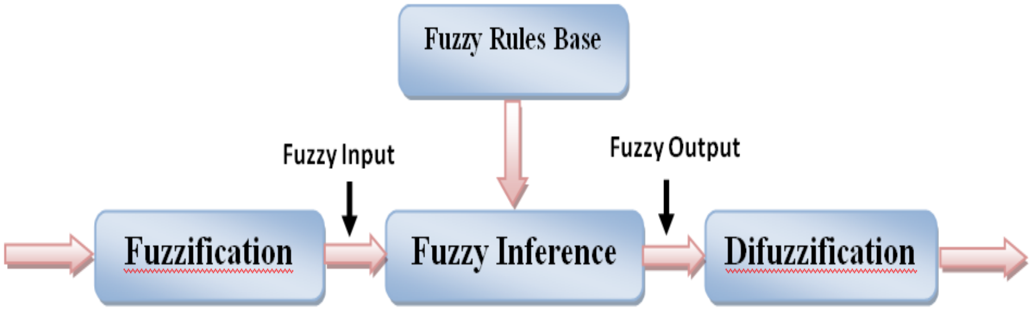

Figure 2.7: Fuzzy logic (Zadeh, 2008).

Fuzzy logic incorporates a simple, rule-based *IF X AND Y THEN Z* approach for solving control problem rather than attempting to model a system mathematically (Nguyen & Walker, 2000).

2.4.1 Fuzzification

The fuzzification comprises the process of transforming crisp values into grades of membership for linguistic terms of fuzzy sets. The membership function (MF) is used to associate a grade to each linguistic term (Salih *et al.*, 2012).

Reznik (1997) reported that, Trapezoidal or Triangular functions as shown in Figure 2.8 & 2.9 have proved to be more popular with fuzzy logic theoretic and practitioners rather than higher order based functions such as Gaussian, etc. However, the problem of the membership function has not yet been solved theoretically. Different researchers choose numerous shapes in various application problems. Membership function need to be assigned (m=z….. [0,1]) to each fuzzy subset, its can have many different shapes, depending on definition.

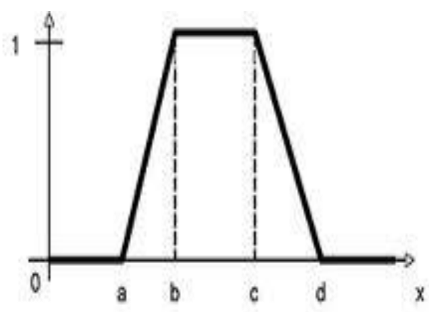

Figure 2.8: Trapezoidal membership Function

$$f(x;a,b,c,d)=\begin{cases} 0, & x \le a \\ \dfrac{x-a}{b-a}, & a \le x \le b \\ 1, & b \le x \le c \\ \dfrac{d-x}{d-c}, & c \le x \le d \\ 0, & d \le x \end{cases} \quad (2.1)$$

The trapezoidal curve is a function of a vector, x, and depends on four scalar parameters *a*, *b*, *c*, and *d*, as given equation 2.1. The parameters *a* and *d* locate the "feet" of the trapezoid and the parameters *b* and *c* locate the "shoulders."
The simplified equation 2.1 for trapezoidal is as follows:

$$\text{Trapezoid}(x;a,b,c,d) = \max\left(\min\left(\frac{x-a}{b-a}, 1, \frac{d-x}{d-c}\right), 0\right) \quad (2.2)$$

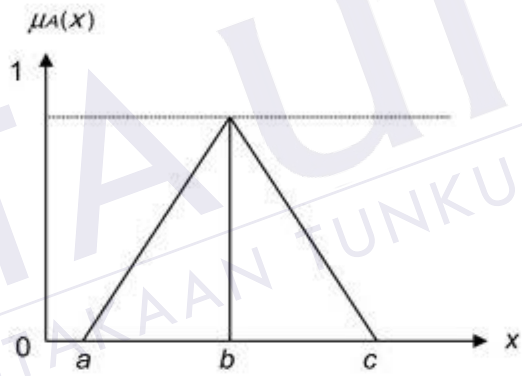

Figure 2.9: Triangular Membership Function

$$f(x;a,b,c)=\begin{cases} 0, & x \le a \\ \dfrac{x-a}{b-a}, & a \le x \le b \\ \dfrac{c-x}{c-b}, & b \le x \le c \\ 0, & c \le x \end{cases} \quad (2.3)$$

The triangular curve is a function of a vector, x, and depends on three scalar parameters *a*, *b*, and *c*, as given equation 2.3. The parameters *a* and *c* locate the "feet" of the triangle and the parameter *b* locates the peak.

The simplified equation 2.1 for triangular is as follows:

$$\text{Triangle}\,(x;a,b,c) = \max\left(\min\left(\frac{x-a}{b-a},\frac{c-x}{c-b}\right),0\right) \quad (2.4)$$

The following example demonstrate how trapezoidal and triangular for the above equations is used in horizontal handover.

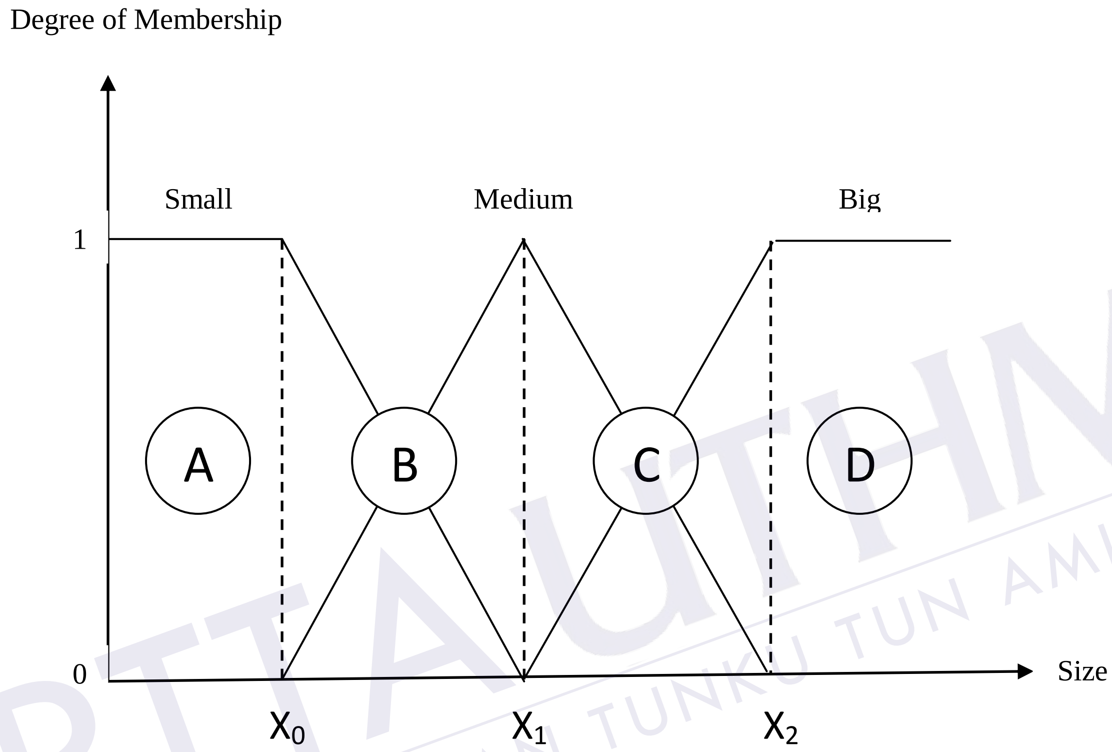

Figure 2.10: Trapezoidal & Triangular Membership Function

Table 2.1 explain each section in detail of Figure 2.10

Table 2.1: Trapezoidal and Triangular of Membership Function Calculation

Section	Rule	Calculation
A	$X \le X_0$	Small = 1 Medium = 0 Big = 0
B	$X_0 < X \le X_1$	Small = $(x_1 - x) / (x_1 - x_0)$ Medium = $(x - x_0) / (x_1 - x_0)$ Big = 0

C	$X_1 < X \le X_2$	Small = 0 Medium = (x2 – x) / ($x_2 - x_1$) Big = ($x - x_1$) / ($x_2 - x_1$)
D	$X_2 < X$	Small = 0 Medium = 0 Big = 1

2.4.2 Fuzzy Inference System

Inference is known as the process that draws conclusions from a set of facts using a collection of rules. The fuzzy inference system is a computing framework based on the concepts of fuzzy set theory, fuzzy if-then rules, and fuzzy reasoning. Two types of fuzzy inference systems that can be implemented are the Mamdani-type and the Sugeno-type (Hua & Brieu, 2006). The differences between these fuzzy inference systems lie in the consequents of their fuzzy rules, and therefore their aggregation and defuzzification processes differ accordingly.

Table 2.2: Fuzzy Set

parameters	Fuzzy set
RSS	LOW, MEDIUM , HIGH
ABW	LOW , MEDIUM , HIGH
BER	LOW , HIGH
HHO	LOW , MEDIUM , HIGH , VERY HIGH

2.4.3 Fuzzy Rule

This step involves with the definition by using “if-then’’ rules to be relevant to human sense and proper handover. Number of fuzzy rules generated increases significantly with the number of parameters used in a decision engine. This leads to an increased computational complexity of the decision algorithm (Thumthawatwarn *et al.*, 2011). This example, show the fuzzy rule:

1- If (RSS = low and BW = low and BER = low) then HHO_ decision = low
2- If (RSS = medium and BW = medium and BER = low) then HHO_ decision = medium.
3- If (RSS = high and BW = high and BER = high) then HHO_ decision = high.

Assignment of conditions in fuzzy logic can be changed in any case depending on the designer, so that the number of handover is reduce automatically because many conditions can be defined for this method.

2.4.4 Defuzzification

As a result of applying the previous steps, one obtains a fuzzy set from the reasoning process that describes, for each possible value how reasonable it is to use this particular value. In other words, for every possible value one gets a grade of membership that describes to what extent this value is reasonable to use. Using a fuzzy system as a controller, one wants to transform this fuzzy information into a single value that will actually be applied. This transformation from a fuzzy set to a crisp number is called a defuzzification. The fuzzy results generated cannot be used as such to the applications, hence it is necessary to convert the fuzzy quantities into crisp quantities for further processing.

There are five methods of defuzzifying a fuzzy set of a universe of discourse, Centre of gravity, Mean of maximum, weighted average, Smallest of maximum, Largest of maximum and Bisector of area, but probably the most popular one is the centroid technique. It finds the point where a vertical line would slice the aggregate set into equal masses. Mathematically this centre of gravity (COG) can be expressed as equation (2.5).

$$\textbf{COG} = \frac{\int_a^b \square\, A(x)\, dx}{\int_a^b \square\, A(x)\, dx} \qquad (2.5)$$

2.5 Horizontal Handover in Homogenous Network

Handover latency is one of the major problems in wireless mobile networks since it prevents users from seamless mobility. When a mobile node moves from one wireless access point to another in a homogeneous network environment, it has to perform horizontal handover. This results in packet delay and in some cases packet loss. These two factors severely affect the Quality of Service (QoS). A few researchers tried to find the best method for handover with the best QoS (Ortiz *et al.*, 2009).

Table 2.3: Related work for horizontal and vertical handover

No.	Author & Year	Title	HHO	VHO	FL	Others
1.	Hua & Brien (2006)	Vertical handover-decision-making algorithm using fuzzy logic for the integrated Radio-and-OW system		✓	✓	
2.	Nkansah,Y. & Agbinya,J. (2007)	Vertical Handoff Decision Algorithms Using Fuzzy Logic		✓	✓	
3.	Thumthawatuarn & Preues (2009)	Multi-level Threshold Handover for Homogeneous Wireless Mobile Networks	✓			✓
4.	Foong, K. C. , Chee, C. T. & Wei, L. S. (2009)	Adaptive Network Fuzzy Inference System(ANFIS) Handoff Algorithm	✓		✓	
5.	Thumthawatwarn *et al.*(2011)	Modular Handover Decision System based on Fuzzy Logic for Wireless Networks	✓		✓	
6.	Salih *et al.* (2012)	A Fuzzy Predictive Handover Mechanism based on MIH Links Triggering in Heterogeneous Wireless Networks		✓	✓	
7.	Israt, P. ;Chakma, N. &Hashem, M, M, A.(2008)	A Fuzzy Logic-Based Adaptive Handoff Management Protocol for Next-Generation Wireless Systems	✓	✓	✓	

8.	Bhosale, S. & Daruwala. D. (2011).	Evaluating the Reliability of Network Simulator during Wi-Fi toWi-Fi Horizontal Handover Simulation	✓			✓

Hua & Brien (2006) used fuzzy logic to enhance the performance of the communication system, he used the received signal strength, bandwidth, network coverage and preferred network parameters in his method. Due to the complementary nature of radio and optical wireless (OW) both in capacity and coverage, the combined use of both for data transmission could have advantages over a single media. Since excessive transfer delay results in disrupted connection and corrupted service, the proposed FL-based VHO decision-making algorithm has the potential to provide a better quality of service (QoS) to users in future wireless broadband communications.

Nkansah,Y. & Agbinya,J. (2007) used fuzzy logic in heterogeneous vertical handoff by installing and test the Stream Control Transmission Protocol (SCTP) throughput performance of the OpenSS7 Linux kernel SCTP implementation on two Pentium 4 machines in our network laboratory as part of a scheme to implement vertical handoff using mobile SCTP (mSCTP) and the Session Initiation Protocol (SIP). The mSCTP is targeted for the client-server model, where a mobile node (MN) initiates an SCTP session with a fixed correspondent node (CN). For supporting vertical handoff where the fixed CN initiates an SCTP session with the MN, the mSCTP must be used with a location management scheme such as SIP. A major drawback of using SCTP is that almost all of the current Linux kernel implementations of SCTP do not provide the DAR extension features of SCTP and almost all open source SIP servers and user agents do not support SCTP.

Thumthawatuarn & Preues (2009) divided the received signal strength RSS to multi levels threshold, This implies that the handover procedure may be completed in n stages, each stage associated with one of n threshold levels. In this situation the handover process may be terminated at any stage if the RSS value remains constant or begins to increase. A three-level threshold handover approach has been developed to deal with the handover latency problem. The idea is to allow certain network layer operations to be executed at each threshold level, as shown in Figure 2.11.

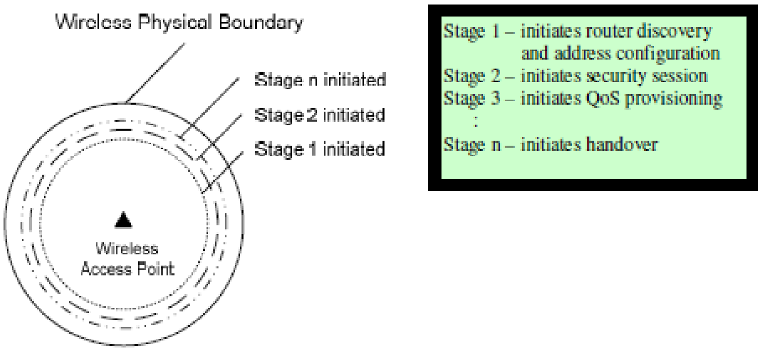

Figure 2.11: Multi-Level Threshold Handover Concept

Israt, P. ;Chakma, N. & Hashem, M, M, A.(2008) He try to develop a seamless handoff management protocol for next-generation wireless systems(NGWS). In this paper, a fuzzy logic-based adaptive handoff (FLAH) management protocol is developed which is then integrated with an existing cross layer handoff protocol used fuzzy logic as a based handover management protocol is introduced which is integrated with an existing Cross-Layer Handover Management Protocol (CHMP). The existing link-layer-assisted HMIP protocols propose to initiate the initiate Hierarchical Mobile IP (HMIP) registration when the RSS from the serving BS, as shown in Figure 2.12.

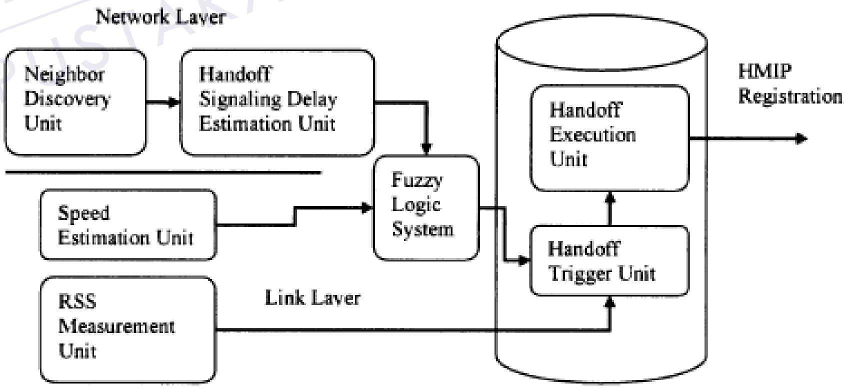

Figure 2.12: Proposed fuzzy logic based handoff architecture.

Foong, K. C. , Chee, C. T. & Wei, L. S. (2009) proposed a new approach using Adaptive Network Fuzzy Inference System (ANFIS) in heterogeneous networks where the training element is incorporated into the existing fuzzy handover algorithm. This technique was designed to allow if-then rules and membership function to be constructed based on the historical data of the metrics. It also included the adaptive nature for automatic tuning purposes. The training algorithm for ANFIS is based on the hybrid learning algorithm where premise and consequent parameters are to be updated after each data presented into the algorithm, known as *pattern learning*. The training algorithm consists of forward pass and backward pass.

Thumthawatwarn *et al*.(2011) proposed a new modular fuzzy rule-based (MFRB) handover decision system algorithm, which aims to address the issues of multiple QoS parameters and at the same time reduces the computational complexity significantly by reducing the total number of fuzzy rules, and hence minimizing the execution time (*T*). The proposed modular fuzzy rule-based (MFRB) decision system is introduced in the handover decision stage. The handover parameters are categorized into groups, and a different fuzzy engine deals with each group. There are three fuzzy engines, namely Network QoS (NQ), Efficiency (Eft) and Degree of Satisfaction (OS). The final score for each candidate network is jointly determined by the three fuzzy engines. The network with the highest final score is selected for handover.

While Salih *et al*. (2012) used fuzzy logic in heterogeneous network to enhance the vertical handover mechanism based on the Media Independent Handover (MIH) Links Triggering. He proposes a fuzzy based prediction algorithm with dynamic of links triggering for vertical handover by applying the Information Server (IS) of IEEE 802.21. Under the IEEE 802.21 [2] media independent handover function (MIHF), current network connecting with the terminal can easily collect the useful information of its neighboring networks (WiFi, WiMAX, and UMTS) by registering for MIH services. Most of the information is dynamic, changing with time such as RSS and ABW. Current network sends the dynamic information request to neighboring networks. The current network can collect them as soon as it senses the new neighboring network or any other time, and store them in its own database.

Bhosale, S. & Daruwala. D. (2011) used the same technology between different Wi-Fi cells. His proposal is an attempt to evaluate the reliability and scalability of the network simulator-2 (ns-2) tool in simulating multiple horizontal handovers between different Wi-Fi Access Points (APs).

However, all of the students mentioned above are considered as a black box models, in which they take and give out information without providing users with a function that describes the relationship between the input and output. On the other hand, they also suffer long time training times and often reach local minima. Furthermore, some researchers favioure to use many parameters to improve the performance of the communication system.

2.6 Chapter Summary

In horizontal handover, a few things such as the techniques and approaches of dealing with fuzzy logic need to be considered. Therefore, in this chapter, several methodology, applications and techniques have been discussed to improve the seamless and robust homogenous horizontal handover. Likewise, this chapter also highlights the HHO with the use of fuzzy logic that was used in estimating the current events of handover. Besides that, this chapter also discussed two types of handovers and the behavior of each type during mobile connection, in addition, the basic information of fuzzy logic also has been emphasized.

CHAPTER 3

RESEARCH METHODOLOGY

3.1 Introduction

This section provides detailed properties of the proposed seamless Horizontal Handover (HHO) decision in homogenous network using fuzzy logic, and briefly describe the simulation for HHO event. The methodology that being used in the present study involved the following steps as shown in Figure 3.6: step (1) the variable selection for considerating Received Signal Strength (RSS), Available BandWidth (ABW) and Bit Error Rate (BER) to be used in the simulation. Step (2) the variable selection that enter the used fuzzy system. The process start by fuzzification,where in fuzzification, is converting the crisp values into variables and then defining Membership Function (MF) for each parameter. Step (3) is to define the linguistic variables and to consider the parameters for different states of RSS(low, medium, high), ABW (low, medium , high) and BER (low, high) and the output (low, medium, high, very high) before entering the fuzzy inference system (FIS). Step (4) is to elicit and construct fuzzy rules and then encode the fuzzy sets, fuzzy rules and procedures before performing fuzzy inference into the expert system.The rules of evaluation is evaluated by the combination of three inputs to produce an output for each rule as shown in Table3.1. Step (5) is the last step in the fuzzy inference process, that is defuzzification. The input for the defuzzification process is the aggregate (collective) output fuzzy set and the output is a single number. Step (6) is the output that will be store in the file saving for further processing. Step (7) is to compare the output value with the value which is already evaluated. Step (8) is event generation which is the last step of this simulation process. The unifying goal of this research method is to get the best performance by

REFERENCES

Agrawal, D. P. & Zeng, Q. A. (2011). Introduction to Wireless & Mobile System.3 rd addition.USA: Globel Engineering: Christopher M. Short.

Bhosale, S. & Daruwala, R. D. (2011). Experimental Analysis of Horizontal and Vertical Handovers in Wireless Access Networks using NS2. *World Congress on Information and Communication Technologies,* pp. 294-599.

Bian,Y,Q. ; Nix,A,R. ; Sun,Y. &Strauch, P. (2007). Performance Evaluation of Mobile WiMAX with MIMO and Relay Extensions . *This full text paper was peer reviewed at the direction of IEEE Communications Society subject matter experts for publication in the WCNC 2007 proceedings,* pp. 1816-1821.

Ciubotaru, B. & Muntean, G. M. (2009). SASHA—A Quality-Oriented Handover Algorithm for Multimedia Content Delivery to Mobile Users. *IEEE TRANSACTIONS ON BROADCASTING, VOL. 55, NO. 2*, pp. 437-450.

Edwards, G. & Shankar, R. (1998). Microcellular Handoff using Fuzzy Logic Techniques. *Wireless Networks, vol. 4*, pp. 401-409.

Foong, K. C. , Chee, C. T. & Wei, L. S. (2009). Adaptive Network Fuzzy Inference System (ANFIS) Handoff Algorithm . *IEEE, Future Computer and Communication, 2009. ICFCC 2009. International Conference on Communication, Networking & Broadcasting ;Computing & Processing (Hardware/Software)*, pp. 195 – 198.

He, D. ;Chi, C. ;Chan, S. ; Chen, C. ;Bu, J . & Yin, M. (2010)**.** A Simple and Robust Vertical Handoff Algorithm for Heterogeneous Wireless Mobile Networks. *Wireless Pers Commun*, pp. 361–373.

Honman, B. & Benjapolakul, W. (1998). A Handover Decision Procedure For Mobile Telephone Systems Using Fuzzy Logic. *Circuits and Systems, 1998. IEEE APCCAS 1998. The 1998 IEEE Asia-Pacific Conference on Communication, Networking & Broadcasting ;Components, Circuits,* *Devices & Systems ; Engineered Materials, Dielectrics & Plasmas*. pp. 503 – 506.

Hossain, E. (2008). Heterogeneous Wireless Access Network Architecture and Protocols.USA : Springer Science + Business Media, LLC.

Hua, j. & Brien, D. C. (2006). Vertical handover-decision-making algorithm using fuzzy logic for the integrated Radio-and-OW system. *IEEE Transactions on Wireless Communication*, pp. 176-185.

Israt, P. ;Chakma, N. &Hashem, M, M, A.(2008). A Fuzzy Logic-Based Adaptive Handoff Management Protocol for Next-Generation Wireless Systems. *Proceedings of 11 th International Conference on Computer and Information Technology (ICCIT 2008),* pp. 288-293.

Loia, V. ;Nikravesh, M. & Zadeh, L, A.(2004). Fuzzy Logic and the Internet .New York.

Martin, J. ; Li, B. ; Pressly, W. & Westall, J. (2009).WiMAX Performance at 4.9 GHz. IEEE, pp. 1-8.

Mitra, A. (2009) . *Lecture Notes on Mobile Communication*. India : Indian Institute of Technology Guwahati.

Molina-Garcia, M.; Duran, A.F.; Leal, R.P.; Alonso, J.I. (2008). Method to Assess the Effect of the Horizontal Handover Decision on Voice Quality in Wireless Convergent Networks. *Communication, Networking & Broadcasting ;Computing & Processing (Hardware/Software)*, pp. 226 – 229.

Moravejosharieh, A., Salleh, R.& Modares, H. (2011). Overview of Latest Approaches in Heterogeneous and Mobile IPv6 Homogeneous Wireless Networks Based on Location-Assisted Information. *IEEE Communication, Networking & Broadcasting ;Components, Circuits, Devices & Systems ; Computing & Processing (Hardware/Software)*, pp: 343 - 347.>

Md, A. I. ; Md, a.k. ; & Md, J.C. (2010). BER Performance Analysis of a Real Data Communication through WiMAX-PHY Layer over an AWGN and Fading Channels. *International Journal of Electrical & Computer Sciences IJECS-IJENS, Vol: 10 No 04*, pp. 13-16.

Niyato, D. & Hossain, E. (2008). Competitive Pricing in Heterogeneous Wireless Access Networks: Issues and Approaches. *IEEE,Network*, pp. 4-11.

Ortiz, J. H. ;López, J. C. & Lucero, C. (2009). Mechanisms of Quality of service and mobility in 4G Networks . *Sch. of Comput. Eng., Univ. of Castillay la Mancha, Ciudad Real, Spain*, pp. 1-4.

Ramiro, J. & Hamied, K. (2012). Self-Organizing Network.UK : John Wiley & Sons, Inc.

Rogers, G. S. & Edwards, J. (2003). An introduction to wireless technology. New Jersey.Prantice Hall.

Salih, Y.K. ;See, O. H. and Yussf, S. (2012). A Fuzzy Predictive Handover Mechanism based on MIH Links Triggering in Heterogeneous Wireless Networks. *The 2012 International Conference on Software and Computer Applications (ICSCA 2012),* pp. 225-229.

Sherif, M.H.& Maeda, Y. (2011). Some recent IEEE standards for wireless data communications. *Communication, Networking & Broadcasting,* pp. 112 – 113.

Singh, M. & Ahuja, K.(2011). Performance Evaluation Of Adaptive Modulation Techniques Of Wimax network with cyclic Prefix. *(Ijaest) International Journal Of Advanced Engineering SCIENCES AND TECHNOLOGIES Vol No. 3, Issue No. 1, 034 – 038,* pp. 34-38.

Singal, T. L. (2011). Wireless Communication .New Dellhi : Tha Tata McGraw Hill Education Private Limited.20- Martin, J. ; Li,B. ; Pressly, W. & Westall,J. (2010). WiMAX Performance at 4.9 GHz. *IEEE ,Aerospace Conference,* pp. 1-8.

Thumthawatwarn, T. ;Pervez, A. & Santiprabhob, P. (2011). Modular Handover Decision System based on Fuzzy Logic for Wireless Networks. *IEEE 8th Int, Conf. Computer, Telecommunications and Information Technology (ECTI-CON),* pp. 385-388.

Thumthawatworn, T. & Preves, A. (2009). Multi-level Threshold Handover for Homogeneous Wireless Mobile Networks.

Wong, D.T.C. Peng, Y.K. ,Ying, C.L. ,CHUA, K.C. & Mark, J.W. (2009). Wireless Broadband Network. Hoboken ,New Jersey : John Wiley & Sons, Inc.

Zadeh, L, A. (2008). Is There a Need for Fuzzy Logic?*. *IEEE Computing & Processing (Hardware/Software)*, pp. 1-3.

Bhosale, S. & Daruwala. D. (2011). Evaluating the Reliability of Network Simulator during Wi-Fi to Wi-Fi Horizontal Handover Simulation.