Sudan University of Science and Technology

College of Engineering School Of Electronics Engineering

Vertical Handover Decision Making Using Fuzzy Logic

A Research Submitted In Partial Fulfillment for the Requirements of the Degree of B.Sc. (Honors) In Electronics Engineering

Prepared by

1. Eman Hassan Adam
2. Ethar Abdulmoneem Ahmed
3. Mutaz Mohammed Sa'eed
4. Razan Omar Abdullah

Supervised By

Dr. Fath Elrahman Ismael Khalifa

September 2014

DECLARATION

‘’*An Investigation in Knowledge Pays the Best Interest’’*

DEDICATION

We dedicated this thesis to our families, friends and teachers, and to everyone who supported and encouraged us along the way to reach our goal, present and absent, near or far, may god bless you wherever you are, and may happiness finds its way to you all, thank you.

ACKNOWLEDGMENT

Every challenging work needs self-effort as well as guidance of the elders, in our humble effort we wish to express our genuine appreciation, gratitude and respect to our guider and supervisor Dr. Fath Elrahman Ismael Khalifa, who has been a constant source of knowledge and inspiration for us throughout this research, without his support and patience this thesis would not be the same.

ABSTRACT

In recent years mobile users can move between heterogeneous networks (networks with different operating system and/or protocols) using end devices with multiple network interface. It's important to achieve the Always Best Connected (ABC) Concept to offer the best QoS available in the user's location. The issue of being connected to a network with poor parameters, while another network with better parameters is available arises, thus giving the users multiple options to choose from.

To move seamlessly from one network to the other, and without suffering from disconnecting and reconnecting delays, or loss of signal, Vertical Handover has been a proposed in many researches. Vertical Handover can offer the best and most efficient solution to such situation. In this research fuzzy logic method is used to obtain the best suited network to handover to, and marking the results with measuring multiple parameters to ensure the improvement of the situation in each user's case. The results indicate that the proposed vertical handover achieve an improvement in the parameters of each user's handover from one network to another network, multiple calculations show that 3G users throughput improves by 277% (triple its value in 3G) if handed over to Wi-Fi, the bandwidth of Wi-Fi users improves by 419% if handed over to WiMAX, WiMAX users throughput improves by 87% if handed over to Wi-Fi, while in LTE the bandwidth can be improved by 422 % if handed over to WiMAX.

المستخلص

في السنوات الاخيرة أصبح بمقدور مستخدمي الأجهزة المتنقلة التنقل بين شبكات متعددة ذات طرق وصول وبرتوكولات مختلفة ،مستخدمين أجهزة طرفية متعددة. وأصبح من المهم تحقيق مبدأ دوامية الأفضلية في الاتصال، لتقديم أفضل جودة خدمة متوفرة في موقع المستخدم.
بناء على ما سبق ،ظهرت مشكلة مفادها ان يكون المستخدم متصل بشبكة تقدم له خدمات ضعيفة ،مع وجود شبكة أخرى في نفس الموقع تقدم خدمات أفضل ،مما يعطي المستخدم خيارات متعددة ليختار الأفضل والأنسب.

من اجل غرض التحرك من شبكة لأخرى دون مشاكل الاتصال واعادة الاتصال، او التأخر، او فقدان الإشارة، أصبح التسليم الرأسي موضع دراسات عدة؛ لأنه يستطيع ان يقدم أفضل حل لمثل هذا الوضع. في هذا البحث تم استخدام طريقة المنطق الغامض للحصول على أفضل شبكة لتسليم اشارة المستخدم اليها، ولتوضيح النتائج تم قياس مجموعة من العوامل المتغيرة؛ لضمان تحسين الوضع لكل مستخدم في جميع الشبكات.

تشير النتائج الى ان التسليم الرأسي المقترح يحقق تحسن في العوامل المتغيرة لكل مستخدم سَّ لم من شبكة لأخرى .من خلال عدة حسابات يتضح ان الإنتاجية لمستخدمي شبكة الجيل الثالث قد تتحسن بنسبة 722%) ثلاثة اضعاف قيمتها في شبكة الجيل الثالث(إذاَّسَّ لم المستخدم لشبكة الواي-فاي. أيضا عرض النطاق الترددي لمستخدم شبكة الواي-فاي قد يتحسن بسبة 914% إذا حدث تسليم لشبكة الواي-ماكس. أيضا الإنتاجية لمستخدمي شبكة الواي-ماكس قد تتحسن بنسبة تصل إلى 72% إذا حدث تسليم الى شبكة الواي-فاي، بينما عرض النطاق الترددي لشبكة الإل-تي-إي قد يتحسن بنسبة 977% إذا سَّ لمت لشبكة الواي-ماكس.

TABLE OF CONTENTS

TITLE **PAGE**

DECLARATION II

DEDICATION III

ACKNOWLEDGMENT IV

ABSTRACT V

VI .....
المستخلص VI

TABLE OF CONTENTS VII

LIST OF FIGURES XI

LIST OF TABLES XIII

ABBREVIATIONS XIV

CHAPTER ONE INTRODUCTION 17

1.1. Preface 18

1.2. Problem Statement 19

1.3. Proposed Solution 20

1.4. Aim and Objectives 20

1.5. Methodology 21

1.6. Research Outlines 21

CHAPTER TWO LITERATURE REVIEW **Error! Bookmark not defined.**

2.1. Background ..... **Error! Bookmark not defined.**

2.1.1. Overview ..... **Error! Bookmark not defined.**

2.1.2. Networks Specifications ..... **Error! Bookmark not defined.**

2.1.2.1. Third Generation (3G) Networks **Error! Bookmark not defined.**

2.1.2.2. Wi-Fi..... **Error! Bookmark not defined.**

2.1.2.3. Long Term Evolution (LTE) **Error! Bookmark not defined.**

2.1.2.4. Mobile Worldwide Interoperability for Microwave Access (Mobile WiMAX) ..... **Error! Bookmark not defined.**

2.1.3. VHO stages ..... **Error! Bookmark not defined.**

2.1.3.1. Initiation Stage ..... **Error! Bookmark not defined.**

2.1.3.2. Decision Stage..... **Error! Bookmark not defined.**

2.1.3.3. Execution Stage..... **Error! Bookmark not defined.**

2.2. Related Works..... **Error! Bookmark not defined.**

CHAPTER THREE VERTICAL HANDOVER FOR PERFORMANCE IMPROVEMENT OF HETEROGENEOUS NETWORK ..... **Error! Bookmark not defined.**

1.1. Information Collecting..... **Error! Bookmark not defined.**

3.2. Fuzzy Sets Writing..... **Error! Bookmark not defined.**

3.3. Implementing the Fuzzy Sets in the Simulation and Connecting Them to Input/Output ..... **Error! Bookmark not defined.**

3.4. Measuring the Performance Matrix Parameters **Error! Bookmark not defined.**

3.4.1. Throughput..... **Error! Bookmark not defined.**

3.4.2. Bandwidth ..... **Error! Bookmark not defined.**

3.4.3. Spectral Efficiency..... **Error! Bookmark not defined.**

3.4.4. Channel Capacity ..... **Error! Bookmark not defined.**

3.4.5. Delay ..... **Error! Bookmark not defined.**

3.5. Plotting The Results ..... **Error! Bookmark not defined.**

CHAPTER FOUR RESULTS AND DECISIONS **Error! Bookmark not defined.**

4.1. Simulation Explanation ..... **Error! Bookmark not defined.**

4.2. Results ..... **Error! Bookmark not defined.**

4.2.1. The Performance Matrix ..... **Error! Bookmark not defined.**

4.2.1.1. Bandwidth ..... **Error! Bookmark not defined.**

4.2.1.2. Throughput ..... **Error! Bookmark not defined.**

4.2.1.3. Spectral Efficiency ..... **Error! Bookmark not defined.**

4.2.1.4. Delay ..... **Error! Bookmark not defined.**

4.2.1.5. Channel Capacity ..... **Error! Bookmark not defined.**

4.2.2. Improvement Measurments ..... **Error! Bookmark not defined.**

4.2.2.1. Performance Matrix Average Values **Error! Bookmark not defined.**

4.2.2.2. Improvement Percentage .. **Error! Bookmark not defined.**

CHAPTER FIVE CONCLUSION AND RECOMMENDATIONS ..... **Error! Bookmark not defined.**

5.1. Conclusion ..... **Error! Bookmark not defined.**

5.2. Recommendations ..... **Error! Bookmark not defined.**

REFERENCES ..... **Error! Bookmark not defined.**

APPENDIX A FUZZY SET RULES ..... **Error! Bookmark not defined.**

A.1. Wi-Fi Fuzzy Set Rules: ..... **Error! Bookmark not defined.**

A.2. 3G Fuzzy Set Rules: ..... **Error! Bookmark not defined.**

A.3. WiMAX Fuzzy Set Rules: ..... **Error! Bookmark not defined.**

A.4. LTE Fuzzy Set Rules: ..... **Error! Bookmark not defined.**

APPENDIX B SIMULATION CODES. **Error! Bookmark not defined.**

B.1. Throughput ..... **Error! Bookmark not defined.**

B.1.1. Wi-Fi Throughput ..... **Error! Bookmark not defined.**

B.1.2. 3G Throughput ..... **Error! Bookmark not defined.**

B.1.3. WiMAX Throughput..... **Error! Bookmark not defined.**

B.1.4. LTE Throughput..... **Error! Bookmark not defined.**

B.2. Channel Capacity ..... **Error! Bookmark not defined.**

B.3. Network Availability Scan ..... **Error! Bookmark not defined.**

LIST OF FIGURES

FIGURE NO. TITLE PAGE

Figure 2- 1: Handovers in Heterogeneous Wireless Networks..... 9
Figure 3- 1: Flow Chart of the Methodology Phases 23
Figure 3-2: 3G Fuzzy Set 25
Figure 3-3: Wi-Fi Fuzzy Set 25
Figure 3- 4: WiMAX Fuzzy Set 25
Figure 3- 5: LTE Fuzzy Set 26
Figure 3-6: RSS Membership Function 26
Figure 3-7: Wi-Fi Bandwidth Membership Function 27
Figure 3- 8: Wi-Fi User's Velocity Membership Function 27
Figure 3-9: 3G Bandwidth Membership Function 27
Figure 3-10: 3G User's Velocity Membership Function 28
Figure 3- 11: WiMAX Bandwidth Membership Function 28
Figure 3- 12: LTE Bandwidth Membership Function 28
Figure 3- 13: LTE & WiMAX user’s velocity Membership Function ... 29
Figure 3-14: 3G Handover Membership Function 30
Figure 3- 15: Wi-Fi Handover Membership Function 30
Figure 3- 16: WiMAX Handover Membership Function 30
Figure 3- 17: LTE Handover Membership Function 31
Figure 3-18: 3G Network Availability Membership Function 31
Figure 3-19: Wi-Fi Network Availability Membership Function 32

Figure 3- 20: WiMAX Network Availability Membership Function 32
Figure 3- 21: LTE Network Availability Membership Function 32
Figure 4- 1: Simulation Circuit 39
Figure 4- 2: Network Bandwidth (bit/sec) Vs Time (sec) in Individual Plots 40
Figure 4- 3: Network Bandwidth (bit/sec) Vs Time (sec) 41
Figure 4- 4: Networks Throughput (byte) Vs time (sec) in Individual Plots 41
Figure 4- 5: Networks Throughput (bytes) Vs Time (sec) 42
Figure 4- 6: Spectral Efficiency (bit/sec/Hz) Vs Time (sec) in Individual Plots 42
Figure 4- 7: Spectral Efficiency (bit/sec/Hz) Vs Time (sec) 43
Figure 4- 8: Delay (sec) Vs Time (sec) in Indivisual Plots 43
Figure 4- 9: Delay (sec) Vs Time (sec) 44
Figure 4- 10: Channel Capacity (bit/sec) Vs Time (sec) in Indivisual Plots 44
Figure 4- 11: Channel Capacity (bit/sec) Vs Time (sec) 45

LIST OF TABLES

TABLE NO. TITLE PAGE

Table 2- 1: Modulation, Multiplexing, and Duplexing Techniques in the Four Networks 15

Table 3- 1: Frame Duration and Size for the Four Networks 34

Table 4- 1: Average Values for the Network Performance Matrix Parameters 46

Table 4- 2: Improvement Percentage for 3G 47

Table 4- 3: Improvement Percentage for Wi-Fi 47

Table 4- 4: Improvement Percentage for WiMAX 48

Table 4- 5: Improvement Percentage for LTE 48

ABBREVIATIONS

1x EV-DO	1x Evolution Data Optimized
16QAM	16Quadrature Amplitude Modulation
3G	Third Generation
3GPP	Third Generation Partnership Project
4G	Fourth Generation
8PSK	8Phase Shift Keying
ABC	Always Best Connected
AHP	Analytic Hierarchy Process
AMC	Adaptive Modulation and Coding
ASK	Amplitude Shift Keying
BER	Bet Error Rate
BPSK	Binary Phase Shift Keying
CDMA	Code Division Multiple Access
CSMA/CA	Carrier Sensing Multiple Access/Collision Avoidance
DAB	Digital Audio Broadcast
DBA	Dynamic Bandwidth Allocation
DSSS	Direct Sequence Spread Spectrum
DVB	Digital Video Broadcast
FDD	Frequency Division Duplex
FHSS	Frequency Hopping Spread Spectrum

GoS	Grade of Service
HSDPA	High Speed Downlink Packet Access
HSPA	High Speed Packet Access
HSUPA	High Speed Uplink Packet Access
IFS	Inter-Frame Space
ITS	Intelligent Transportation System
LTE	Long Term Evolution
MEW	Multiplicative Exponent Weighting
MIMO	Multiple Input/Multiple Output
MT	Mobile Terminal
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiple Access
PSK	Phase Shift Keying
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
QPSK	Quadrature Phase Shift Keying
RSS	Received Signal Strength
SAW	Simple Additional Weight
SHF	Super High Frequency
SNR	Signal to Noise Ratio
SS	Spread Spectrum

TDD	Time Division Duplex
TDM	Time Division Modulation
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
UHF	Ultra High Frequency
UMTS	Universal Mobile Telephone System
VHO	Vertical Handover
VoIP	Voice over IP
WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network
WWAN	Wireless Wide Area Network

CHAPTER ONE
INTRODUCTION

CHAPTER ONE INTRODUCTION

1.1. Preface

The deployment of various wireless technologies (2G, 3G, WLAN, WMAN, etc.) in combination with the evolution of Mobile Terminals (MTs) with multiple network interfaces and the development of IP-based applications (non-real-time or real-time), has allowed the user to have access to IP services anywhere at any time from any network. [1]

In the ever changing world of today customer demands regarding quality has increased dramatically, at the core of wireless communication comes the idea of Always Best Connected (ABC). According to this concept, the customer should be able to take advantage of the best available access network at any point in time, choosing among the large array of solutions offered by the available networks. To truly achieve an ABC connection, the connection should be made between heterogeneous networks, which are not the case of horizontal handover that only guarantees connectivity to the user between different cells of the same network. A mechanism able to provide the concept of ABC effortlessly and painlessly between heterogeneous networks is called Vertical Handover (VHO) also Vertical Handoff.[2, 3]

One of the major service required by the users is Voice over IP

(VoIP),others include internet access, fax, supplementary services, Short Message Service (SMS), and newer services like Digital Audio Broadcasting (DAB), Digital Video Broadcasting (DVB) location technologies and others.[4]

The next-generation of wireless systems represents a heterogeneous environment with different access networks technologies that differ in bandwidth, latency or data rate which are compared and accessed via VHO. [1]

Vertical Handover enables the user to optimally utilize several of these networks in parallel by connecting to the available network with the best conditions that are based on certain criteria like RSS (which can be effected by number of reasons like noise, signal fading etc.), available bandwidth (depends mainly on the number of customer accessing the network), velocity and application type etc. The significance of resource utilization is that the users currently connected to the network will be given an excellent service quality and connection of the available choices, and those users who are given that, will be connected to the network seamlessly and effortlessly. [4, 5]

This project is to present a vertical handover mechanism with a focus on the handover decision problem and to observe its contributions in the optimization of network performance and the Quality of Service (QoS) parameters. For that, the Fuzzy Logic methodology was chosen.

1.2. Problem Statement

Wireless access technologies such as Wi-Fi, 3G, WiMAX and LTE are commonly used nowadays. One of the main drawbacks in the use of such networks is the degradation in the link quality due to path loss or fading. Also the shared

resources of the network decrease as the users increase and thus affecting the quality of the services (QoS) offered to the users.

On the other hand, there may be another network available within the covered range with better link quality and available resources.

1.3. Proposed Solution

The solution to the above mentioned problems is to use vertical handover mechanism (VHO), by which the ongoing connection is transferred from one network technology to another network technology.

By such transfer the user can avoid the degradation in the link quality, can get a better satisfactory resources and QoS.

Accordingly the user will have the choice to move to a better network which offers better facilities.

1.4. Aim and Objectives

- The aim of this project is to design an efficient Vertical Handover mechanism based on Fuzzy Logic to achieve a high QoS for the user.
- The effectiveness is simulated using a MATLAB code to verify the following objectives

- Increasing the network throughput.
- Minimizing network delay
- Increasing spectral efficiency
- Increasing the channel capacity

- Increasing the available bandwidth

1.5. Methodology

The realization of this project was achieved in five major steps, first a sufficient amount of data was collected enough to get a detailed knowledge of the different parameters and characteristics in the four used networks (3G, Wi-Fi, WiMAX, LTE). Second, two networks were initially chosen (Wi-Fi and 3G), and a set of three parameters (RSS, bandwidth and user's velocity) was also selected to develop a primary scenario of the VHO mechanism. By using MATLAB a fuzzy rules set was written for the two networks at first, and then for each of the four networks mentioned above with the network parameters that were collected previously as inputs and network related characteristics as output. The next step was the implementation of the fuzzy sets in the simulation. Initial performance matrix results were collected to get an overall idea of the handover decision making algorithm. Adding the remaining networks and additional performance matrix's element as the project goes along. Fourth step was to calculate the exact amounts of the performance matrix parameters for the entire simulation time. Final step was plotting the performance matrix for each network for comparison purposes.

1.6. Research Outlines

Chapter one is an introduction that gives a background about the project, its aims and objectives, the problem statement and proposed solutions. It also gives a brief description on how to achieve those goals in the methodology.

Chapter two is the literature review that first gives an overall look on the vertical handover mechanism, and covers the specifications and requirements of the networks studied in the project. The second part of the chapter is related works which

include the analysis of several papers that were in the field of vertical handover highlighting the pros and cons of each.

Chapter three is the system design (Methodology) contains all the methods and steps in great details that were undertaken to achieve the project's objectives.

Chapter four is results and decisions includes simulation parameters, a discussion of the simulation and the resulted outcome from it, which are also justified.

Chapter five conclusion and recommendations is the achieved goals from the project and the recommendations for future studies.