PREDICTION AND MULTI-CRITERIA-BASED SCHEMES FOR SEAMLESS HANDOVER MECHANISM IN MOBILE WIMAX NETWORK

MOHAMMED AWADH AHMED BEN MUBARAK

FK 2013 130
PREDICTION AND MULTI-CRITERIA-BASED SCHEMES FOR SEAMLESS HANDOVER MECHANISM IN MOBILE WiMAX NETWORKS

By

MOHAMMED AWADH AHMED BEN MUBARAK

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

July 2013
DEDICATION

"وَوَضْعَيْنَا الإِنسَانَ بِوَلَايَّتِهِ خَلْقًا أَمَّنْ وَعَادًا عَلَى وَهْنَ وَفِضْلًا فِي عَامِيَّ عَلَى أَنْ يُشْكِرَ لَهُمَا وَلَوَادَيْهِ اِلْمَصِيرِ"

To the most Merciful Allah S.W.T
To my dearest parents, whom I got the power from their Doa’a.
To my wife for her love, loyalty, and support
To my lovely daughters (Amaal, Maram and Basma), whom eased the alienation’s pains.
To my brothers and sisters for their extraordinary love, support, endless care and encouragement
To Mr. Abdurrahman Ahmed Taha, who supported me to achieve my first academic step (B.Sc degree) and I am now in this level because of him after Allah S.W.T.

Thank you All
Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Degree of Doctor of Philosophy

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By

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July 2013

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Mobile WiMAX introduces several interesting advantages including last mile wireless access, variable and high data rate, point to multi-point communication, large frequency range and QoS (Quality of Service) for various types of applications. However, mobility in WiMAX system is still an issue when a mobile station (MS) moves and its connection is handed over between base stations (BSs). This thesis focuses on three main stages of the handover procedure in Mobile WiMAX; scanning, cell selection and handover initiation and decision. It introduces four main schemes to optimize the handover mechanism. The first scheme is Mobile Station Movement Direction Prediction (MMDP) based handover scanning that reduces the redundant scanning activities, scanning delay and signalling overhead. Simulation results show that the proposed MMDP scheme reduces handover scanning delay and scanning interval duration by 50% and 25% respectively and reduces the signalling
overhead. The second scheme is Hybrid AHP (Analytic Hierarchy Process) and TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution)-based Cell Selection (HATCS) scheme based on a set of multiple criteria. Cell selection is a key element that insures that the QoS and user requirements during and after handover process is met. In the proposed HATSC scheme, the AHP method is use for criteria weighting, while the TOPSIS method uses for the selection technique based on a multi-criteria decision-making algorithm is proposed. This enables it to meet the MS application requirements based on some criteria such as CINR, BW, and delay. The third scheme is a fuzzy logic-based self-adaptive handover (called FuzSAHO) for handover decision to provide an intelligent self-adaptive handover parameters technique based on received signal strength indicator (RSSI) and MS velocity. Finally, the FuzSAHO decision algorithm is optimized for real-time application, by using a new handover criteria, namely queue length besides RSSI and MS velocity. This new self-adaptive handover scheme for real-time application called RFuzSAHO. Simulation results show that FuzSAHO reduces the ping-pong handover, and handover delay. It reduces the number of handovers by 29.7% and 26.9%, respectively, compared to the conventional RSSI based handover algorithm and the previous worked, mobility improved handover (MIHO) algorithm. In terms of handover delay, FuzSAHO reduce handover delay by 40% and 15% compared to RSSI based-HO and MIHO respectively. Also, it is shown that FuzSAHO enhances the overall handover operation in term of reduced overhead signalling, average E2E packet delay and satisfactory CINR which satisfies network end user requirements. For real-time applications, simulation results show that RFuzSAHO decision algorithm enhances the VoIP quality (Mean Opinion Score, MOS) up to 5.4% compared to FuzSAHO algorithm when the MS velocity is 20m/s.
Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

SKIM BERASASKAN RAMALAN DAN KRITERIA BERGANDA UNTUK MEKANISME PENYERAHAN LANCAR DALAM RANGKAIAN WIMAX MUDAH ALIH

Oleh

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Mobile WiMAX memperkenalkan beberapa kelebihan yang menarik termasuk lepas akses sambungan tanpa wayar, kadar data berubah dan tinggi, mata untuk komunikasi pelbagai titik, julat frekuensi yang besar dan QoS (Kualiti Perkhidmatan) untuk pelbagai jenis aplikasi. Walau bagaimanapun, pergerakan dalam sistem WiMAX masih satu isu apabila stesen mudah alih (MS) bergerak dan sambungan yang diserahkan antara stesen pangkalan (BSS). Tesis ini memberi tumpuan kepada tiga peringkat utama prosedur penyerahan dalam Mobile WiMAX pengimbasan, pemilihan sel dan penyerahan permulaan dan keputusan. Ia memperkenalkan empat skim utama untuk mengoptimumkan mekanisme penyerahan. Skim pertama adalah Mobile Station Pergerakan Arah Ramalan (MMDP) berdasarkan penyerahan imbasan yang mengurangkan aktiviti pengimbasan berlebihan, imbasan kelewatan dan isyarat atas. Keputusan simulasi menunjukkan bahawa skim MMDP cadangan mengurangkan penyerahan imbasan

v
kelewatan dan masing-masing mengimbas tempoh selang sebanyak 50% dan 25% dan mengurangkan overhed isyarat.

Skim kedua adalah hibrid AHP (Proses Hierark Analisis) dan TOPSIS (Teknik Perintah Keutamaan oleh Persamaan untuk Penyelesaian Ideal) Pemilihan your-berasaskan (HATCS) Skim berdasarkan satu set kriteria berganda. Pemilihan sel adalah elemen utama yang akan memastikan bahawa QoS dan keperluan pengguna semasa dan selepas proses penyerahan dipenuhi. Dalam skim HATSC cadangan, kaedah AHP adalah uese untuk kriteria pemberat, manakala kaedah TOPSIS menggunakan untuk teknik pemilihan berdasarkan pelbagai kriteria algoritma membuat keputusan dicadangkan. Ini membolehkan ia untuk memenuhi keperluan permohonan MS berdasarkan beberapa kriteria seperti CINR, BW, dan kelewatan. Skim ketiga adalah kabur berasaskan logik sendiri penyesuaian penyerahan (dipanggil FuzSAHO) untuk penyerahan keputusan untuk menyediakan diri penyesuaian parameter penyerahan teknik pintar berdasarkan kepada kekuatan isyarat yang diterima penunjuk (RSSI) dan halaju MS. Akhirnya, keputusan FuzSAHO algorithm dioptimumkan untuk aplikasi masa nyata, dengan menggunakan baru penyerahan kriteria, iaitu panjang beratur selain RSSI dan halaju MS. Ini baru skim diri penyesuaian penyerahan bagi permohonan masa nyata dipanggil RFuzSAHO. Keputusan simulasi menunjukkan bahawa FuzSAHO mengurangkan ping-pong penyerahan, dan penyerahan kelewatan. Ia mengurangkan bilangan handovers sebanyak 29.7% dan 26.9%, masing-masing, berbanding dengan RSSI konvensional berdasarkan penyerahan algoritma dan sebelumnya bekerja, pergerakan penyerahan (Miho) bertambah baik algoritma. Dari segi penyerahan kelewatan, FuzSAHO mengurangkan kelewatan penyerahan sebanyak 40% dan 15%
berbanding dengan RSSI berasaskan HO dan Miho masing-masing. Selain itu, ia menunjukkan bahawa FuzSAHO meningkatkan penyerahan operasi keseluruhan dalam tempoh dikurangkan isyarat atas, purata kelewatan paket E2E dan CINR memuaskan yang memenuhi keperluan pengguna rangkaian akhir. Untuk aplikasi masa nyata, keputusan simulasi menunjukkan bahawa RFuzSAHO keputusan algoritma meningkatkan kualiti VoIP (Min Skor Pendapat, MOS) sehingga kepada 5.4% berbanding dengan FuzSAHO algoritma apabila halaju MS adalah 20m/s.
ACKNOWLEDGEMENTS

First and foremost, Alhamdulillah for giving me the strength, patience, courage, and determination in completing this work. All grace and thanks belongs to Almighty Allah (S.W.T). This works would not have been accomplished without the help of so many people. In the following lines is a brief account of some but not all who deserve to be thanked.

I would like to extend my gratitude to my supervisor, Professor Dr. Borhanuddin Mohd. Ali for his supervision, advice, and guidance from the very early stage of this research as well as giving me extraordinary experiences throughout the work. Above all and the most needed, he provided me unflinching encouragement and support in various ways. In fact, I learnt from him a lot not only in my academic discipline, but also in the social life, how to me kind and modest with others, really he is a great model for me to follow in my life.

Very special thanks go to my co-supervisor Professor Dr. Nor Kamariah Noordin, for her great guidance, supports, kindness and motivations throughout my PhD study. She helped me a lot financially to attend the conferences and parented my works. Also, I would like to thank Associate Professor Dr. Alyani Ismail for serving on my thesis committee. Their helpful suggestions and advices on various aspects of my research work have certainly been very constructive. Without their kind cooperation and support, my graduate study would not have been accomplished.
Last but not least, I would like to send a big thank to Dr. Michael Ng for giving me precious comments and suggestions on my research project. He is always friendly and kind to us and deals with as brother and friend. I also learned invaluable paper writing skills from him.

I do not know how to thank my family for their endless support encouragement and love: my beloved father, Awadh Ahmed Ben-Mubarak and my beloved mother, Fatima Salem Ba-majbor, and I would like to say to them that I am so sorry to be away from you in the time that you need me. Thanks to my brothers (Khaled, Ahmed, Ibrahim and Salem) and sisters (Amaal and Ibtihal) were always there for me and shared my joys and sorrows and for their moral and financial support. I say to them I love you a lot my dears brothers and sisters. My beloved wife, Ghada Al-najar. is the meaning of my life, she always believed in me more than I believe in myself. In fact, words cannot express my thanks and gratitude for her support and encouragements. Thanks to my beloved daughters, Amaal, Maram and Basma. Really, you eased my study stress. Many thanks also to my brother in-law, Sami Al-mowalled and his family for their continuing support; really, I cannot reply your favour and I will never forget that. I know his blessings will always be with me in all my endeavours and I dedicate this success to him. I ask Allah (S.W.T) to keep my family safe, and support them with good health.

I must extend my sincere thanks to the University Putra Malaysia (UPM) for their support by sponsoring me for five semesters of my study under the Graduate Research Fellowship, GRF scheme. None the less, my gratitude to the Malaysian
people in general for their perfect hospitality in their green land during my study period.

I want to thank my research collaborator and all my colleagues in lab and (Ahmed Almashraqi, Ali Alkazmi, Asem Salah, Sammer, Yaaqop, Omar, Yassen, Bashar, Abdullnaser, Ayyoup, Mehdi and Abbas) for the illuminating discussions and invaluable help in the development of this research. Thanks to friends in Malaysia who made my life more lively and colourful. In the final note, I would like to extend my sincere thanks to all and sundry, who helped me in one way or other, but whose names I have not been able to mention one by one.
I certify that a Thesis Examination Committee has met on **date of viva voce** to conduct the final examination of Mohammed Awadh Ahmed Ben Mubarak on his doctoral of philosophy thesis entitled “Prediction and Multi-criteria-based Schemes for Seamless Handover Mechanism in Mobile WiMAX Networks” in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P. U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the degree of Doctoral of Philosophy.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Doctor of Philosophy. The members of the Supervisory Committee were as follows:

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Date:
DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously, and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or at any other institutions.

MOHAMMED AWADH AHMED BEN MUBARAK

Date: 19 July 2013
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LIST OF ABBREVIATIONS

AHOP  Actual Handover Phase
AHP   Analytic Hierarchy Process
ASN-GW Access Service Network Gateway
BER   Bit Error Rate
BS    Base Station
CDMA  Code-Division Multiple Access
CINR  Carrier to Interference-plus-Noise Ratio
CSN   Connectivity Service Network
FBSS  Fast Base Station Switching
HHO   Hard Handover
HO    Handover
IP    Internet Protocol
L2    Layer 2 (MAC Layer)
L3    Layer 3 (Network Layer)
LBS   Location-based Service
MAC   Media Access Control
MAHO  Mobile Assisted Handover
MCHO  Mobile Controlled Handover
MDHO  Macro Diversity Handover
MIP   Mobile Internet Protocol
MIPv6 Mobile Internet Protocol version 6
MOS   Mean Opinion Score
MS    Mobile Station
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<td>nBS</td>
<td>Neighbour Base Station</td>
</tr>
<tr>
<td>NCHO</td>
<td>Network Controlled Handover</td>
</tr>
<tr>
<td>NLOS</td>
<td>Non-Line-of-Sight</td>
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<tr>
<td>NRM</td>
<td>Network Reference Model</td>
</tr>
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<td>NTAP</td>
<td>Network Topology Acquisition Phase</td>
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<tr>
<td>OFDM</td>
<td>Orthogonal Frequency Division Multiplexing</td>
</tr>
<tr>
<td>OFDMA</td>
<td>Orthogonal Frequency Division Multiple Accesses</td>
</tr>
<tr>
<td>PHY</td>
<td>Physical</td>
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<td>PMIP</td>
<td>Proxy Mobile Internet Protocol</td>
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<td>QoS</td>
<td>Quality of Services</td>
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<td>RS</td>
<td>Relay Station</td>
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<td>RSS</td>
<td>Received Signal Strength</td>
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<td>RSSI</td>
<td>Received Signal Strength Indicator</td>
</tr>
<tr>
<td>RTD</td>
<td>Round Trip Delay</td>
</tr>
<tr>
<td>SBS</td>
<td>Serving Base Station</td>
</tr>
<tr>
<td>SNR</td>
<td>Signal-to-Noise Ratio</td>
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<td>TBS</td>
<td>Target Base Station</td>
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<tr>
<td>TOPSIS</td>
<td>Technique for Order of Preference by Similarity to Ideal Solution</td>
</tr>
<tr>
<td>UMTS</td>
<td>Universal Mobile Telecommunications System</td>
</tr>
<tr>
<td>VoIP</td>
<td>Voice over Internet Protocol</td>
</tr>
<tr>
<td>WiMAX</td>
<td>Worldwide Interoperability for Microwave Access</td>
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<td>WSM</td>
<td>Weighted Sum Model</td>
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CHAPTER 1

INTRODUCTION

1.1 Background

Over the past two decades, the Internet has played a very important role in the way we work and play. The proliferation of mobile devices, laptops, tablets, and smartphones significantly drives the demand for ubiquitous wireless Internet access for diverse sets of applications ranging from simple email, social networking, to real-time and bandwidth-intensive applications such as VoIP, streaming, and gaming.

To respond to this demand, the IEEE 802.16 set of standards has been developed for Metropolitan Wireless Access. It has developed over several versions and the latest version (802.16m) has been defined to satisfy 4G network specifications. It defines a new MAC layer protocol based on orthogonal frequency-division multiplexing (OFDM) which is robust against severe channel conditions. IEEE 802.16e adds the support of mobility and uses orthogonal frequency-division multiplexing access (OFDMA) as its air interface technique [1].

The IEEE 802.16 known as Worldwide Interoperability for Microwave Access (WiMAX) introduces several interesting advantages including support of high data rate, covering large areas, corporate-grade security, dynamic quality-of-service (QoS), and good spectral efficiency. It also provides better support for non line-of-

1
sight (NLOS) technologies, multiple services with different QoS policies, fast and inexpensive deployment of “last mile access” to public networking, and being a cost-effective alternative to WiFi and 3G/4G cellular networks [2].

Full mobility management feature has been introduced in IEEE 802.16e called Mobile WiMAX. Although the basic handover procedure was introduced for IEEE 802.16e to support full mobility, the emerging standards of IEEE 802.16j and IEEE 802.16m also exploit the same handover principles of IEEE 802.16e with other amendments on the requirements of these new standards [1], [3]. Mobile WiMAX supports small cell size and high mobility in which MS will experience frequent handover between base stations (BSs) of WiMAX system. Therefore, handover mechanism is one of the critical operations in mobile WiMAX, when it handles mobile station (MS) for switching from one serving BS (SBS) to a target BS (TBS).

IEEE 802.16j introduces a relay station (RS) entity to provide larger coverage and better performance especially around blind alleys [4]. In contrast, the most recent standard of IEEE 802.16m promises to meet the IMT-Advance requirements to provide high data rates of at least 1 Gbps for fixed subscribers and 100 Mbps for mobile stations (MSs) at a vehicular speed of up to 350 km/h [5]. In addition, IEEE 802.16m supports the MAC and PHY features with the location based service (LBS) solution, where the BS can track the MS movement.
There are two components in mobility management feature: location and handover management [6]. Location management is used by the network to monitor and get updated information on the location of MS while moving into a new cell. Handover management is a mechanism that maintains uninterrupted mobile user communication session when a user moves from one location to another between the coverage areas of BSs, this is called handover.

Generally, handover can be categorised as either horizontal handover or vertical handover [7], [8]. Horizontal handover is handover that occurs between two BSs of the same network system, for example, handover between two cells of a WiMAX system. Vertical handover on the other hand, is defined as a handover that occurs between two BSs of different wireless access technologies, for example, between WLAN and WiMAX networks.

The horizontal handover in mobile WiMAX system can be further categorized into three types -- hard handover (HHO), macro diversity handover (MDHO), and fast base station switching (FBSS) [9], [10]. In HHO, the MS communicates with only one BS at a time. It means all connections with the serving BS (SBS) will be broken before the connection with a target BS (TBS) is established, this is break-before-make handover type. The other two types of handovers, MDHO and FBSS, are known as soft handover or make-before-break, where a connection to the TBS is established before MS leaves the connection from SBS [11]. Although the IEEE 802.16e standard has defined these three types of handover, the WiMAX Forum in
[2] only considers the HHO as a mandatory handover, whereas both MDHO and FBSS are taken as optional.

Further, handover process comprises of two main phases; the network topology acquisition phase (NTAP) also known as pre-handover phase, and the actual handover phase (AHOP). The first phase includes the network topology advertisement, the neighbouring BS scanning and association and cell selection. The second phase consists of handover decision and initiation, and network re-entry including ranging, authorization and re-registration [11]. These phases of handover procedure can be summarized as shown in Figure 1.1.

![Figure 1.1 Handover phases](image-url)
As mentioned earlier, Mobile WiMAX supports small cell size and high mobility which means that the MS will experience frequent handover between BSs. Thus, handover mechanism is considered as one of the critical operations in mobile WiMAX, when it handles MS for switching from one SBS to a TBS. Thus, the mobility management in WiMAX system should seamlessly perform the handover without affecting real-time sessions such as video conferencing, media streaming, and multiplayer interactive gaming. For this, they require suitable link quality from the underlying wireless networks in order to meet the specific QoS requirement.

This thesis focuses on handover management especially at the MAC layer or layer 2 handover. This is because layer 2 handover is more frequent than network layer (layer 3 handover); whereas the network layer handover happens only when the handover happens between two cells from different network subnets. Usually, a subnet covers a large area that consists of many of BSs.

The following parts of the chapter is organized as follows. First, the problem statement of the thesis is discussed. This is followed by a listing of the objectives of the thesis, and its scope. Finally, the organization of the thesis is presented.
1.2 Problem Statement

As highlighted earlier, the handover procedure can be divided into several phases; network topology advertisement, cell reselection via scanning, handover decision and initiation, and network entry including ranging, re-authorization and re-registration. This thesis focuses on the problems explained below through scanning, cell reselection, and handover decision and initiation phases:

1. In the handover scanning process, the MS must synchronize with all the advertised neighbour BSs (nBSs) to select the best BS candidate for the incoming handover action. Without terminating the connection between the SBS and MS, the SBS will schedule the scanning intervals and sleep-intervals (called interleaving interval) to MS for the handover scanning. Due to the multiple stages in this phase causing redundant scanning, all data transmissions will be paused, and this may cause handover delay and throughput degradation. This issue will affect the real-time continuity of multimedia application sessions.

2. Cell selection scheme on Mobile WiMAX is based on a single criterion, normally, signal quality only. Due to the inefficient handover procedure of this scheme, single criteria based selection is not enough to choose the best BS for different application requirements. Suppose the MS is in an overlapping area of two or more BSs that have similar signal quality, which one will be chosen for different user application requirements? Putting a cell
selection criterion on signal quality entirely may make an MS to choose a TBS with good signal quality but with one high delay or less bandwidth; this may affect some applications. Choosing a TBS has to be smart to meet the end-user application requirements. There are many parameters that can be considered for cell selection criteria to meet the required QoS; some examples are signal quality, bandwidth, and delay.

3. For the handover initiation and decision, the WiMAX is based on a single criterion, which usually uses RSSI with fixed handover parameters of handover threshold and margin. Since handover criteria and handover decisions are key factors that determine a handover system efficiency, limited intelligence handover schemes may cause unnecessary handover (referred to as “ping pong” handover), handover failure, and handover delay which can affect real-time sessions

1.3 Aim and Objectives

Thus, the main aim of this thesis is to design and develop efficient and seamless handover schemes with the following objectives:

1. To enhance scanning scheme and reduce the number of redundant scanning, scanning delay and signalling overhead.
2. To optimize the selection of the best target Base Station (TBS) to meet the QoS requirements by way of reduced the delay and increased the BW after handover process.

3. To develop an adaptive handover parameters technique, to reduce the handover delay, number of unnecessary/ping-pong handover and signalling overhead.

1.4 Brief Methodology

To achieve a seamless handover mechanism in Mobile WiMAX, four schemes MS Movement Direction Prediction (MMDP), Hybrid AHP and TOPSIS Methods-based Cell Selection (HATCS), and Fuzzy logic based Self-Adaptive Handover (FuzSAHO) and Real-time Fuzzy logic based Self-Adaptive Handover (RFuzSAHO), each scheme being performed at a different handover phase. The MMDP scheme for the scanning phase, is proposed in Chapter 3. The scheme for the cell selection phase is proposed in Chapter 4. The FuzSAHO and RFuzSAHO schemes for the decision phase are proposed in Chapter 5. As highlighted earlier this thesis focuses on issues such as delay and signalling overhead. This is done through some handover phases, scanning, cell reselection, and handover decision and initiation phases.

In the conventional WiMAX handover scanning scheme the MS performs redundant scanning activities in this phase, and all the data transmissions will be paused, and
this may cause handover delay and throughput. These problems of handover scanning are addressed in the proposed MMDP scheme as shown in Chapter 3. MMDP predicts the MS movement direction and based on that, it only scans the BSs that the MS is heading towards.

The HATCS scheme on the other hand is proposed to help in choosing the most optimum TBS. It does TBS selection based on multiple criteria to meet application QoS requirements during and after the handover procedure, this is described in Chapter 4.

An adaptive handover decision and initiation problems based on fuzzy logic is proposed in Chapters 5. Chapter 5 describes FuzSAHO a method which adapts to the handover parameters based on a set of criteria viz. the received signal strength indicator (RSSI), and MS velocity to reduce the unnecessary handover, delay, and signalling overhead. The next version designed for real time application called RFuzSAHO is also proposed in Chapter 5. In this method, queue length is being considered as an additional handover criterion besides RSSI, and MS velocity is considered for handover decision algorithm to enhance the VoIP quality during the handover procedure.

All the proposed schemes evaluate using Qualnet 5.0 simulation tools. All the results generates by Qualnet and plot using MATLAB. The proposed schemes makes up solutions for different handover phases, and every optimization in each phase will
optimize the following phase. For example, when the MMDP scheme reduces the number of the most likely TBS to visit next in the scanning phase, this will also optimize the HATCS scheme, because it will reduce the number of candidate TBS which will in turn speed up the HATCS scheme. In addition, choosing the right TBS that meets the user requirements in the cell selection phase, the FuzSAHO will take the handover decision to the right TBS, which will reduce the number of handovers.

A brief description of the methodology is shown in Figure 1.2.
Figure 1.2 The value chain of handover schemes showing the input parameters and their benefits respectively.

CHAPTER 3
Using the MMDP scheme the number of candidates TBSs will be reduced to two.

CHAPTER 4
The MMDP phase will optimize this phase; the HATCS cell selection scheme will be made between two BSs only.

CHAPTER 5
After HATCS choose the TBS that meet the end-user requirements, the FuzSAHO will take the handover decision to a right TBS.
1.5 Thesis Scope

The flow of this thesis is illustrated in Figure 1.3. The solid lines represent the direction followed in this thesis to achieve our goal and objectives while the dotted lines refer to other related research areas that are out of the scope of this work. The figure shows that mobility can be handled in several layers. In this thesis, the focus of study will be on L2 mobility management for Mobile WiMAX networks. We further propose handover schemes that support handover management for different handover procedure phases.

1.6 Contributions

The main contributions in this thesis are as follows:

- Developing a MS Movement Direction prediction (MMDP)-based handover scanning scheme. This method reduces redundant scanning and hence scanning delay.

- Improving cell selection based on Multi Criteria Decision Making (MCDM) methods using Analytic Hierarchy Process (AHP) for multi criteria weighting with Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) for the candidate BSs ranking.

- Introducing a fuzzy logic based handover initiation and decision called FuzSAHO to provide an intelligent self-adaptive HO parameters technique based on RSSI and MS velocity.
• Optimizing the fuzzy initiation and decision for real-time applications using RFuzSAHO with queue length consideration.

1.7 Thesis Organization

This thesis addresses an efficient handover mechanism for mobile WiMAX. The thesis is organized as follows. Chapter 1 introduces the research background on the issue of mobility and handover, and defines the objectives and scope of the research topic. In Chapter 2, the WiMAX technology is briefly reviewed, followed by the mobility management architectures for WiMAX. Handover schemes relevant for different handover procedure phases are also discussed. Chapter 3 describes the architecture and procedure for handover scanning in mobile WiMAX using MMDP. Chapter 4 described the proposed HATCS scheme using hybrid AHP/TOPSIS methods to improve cell selection phase in mobile WiMAX.

Chapter 5 introduces the proposed the FuzSAHO. It will self-adapt to the handover parameters based on received signal strength indicator (RSSI) and MS velocity, to reduce unnecessary handover, delay, and signalling overhead. For real-time applications such as VoIP, a real time extension called RFuzzSAHO is also proposed as in Chapter 5. In this scheme, queue length is considered as an additional handover criteria besides RSSI and MS velocity for handover decision algorithm. In Chapter 6, the thesis is summarized, followed by a discussion of the key contributions of the work. Several directions for future research are also suggested for further investigation.
Figure 1.3 Study Model
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