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FAST HANDOVER TECHNIQUE IN HETEROGENEOUS WIRELESS NETWORKS

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By

RADHWAN MOHAMED ABDULLAH

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

July 2014

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DEDICATION

To my Dearest and First Teachers: My Father and Mother
To my lovely wife "Eman"

I will always be grateful for your endless love, unlimited support and deep faith in me

To my beloved daughters Yara and Tara

To my lovely brothers and sisters

Radhwan

Abstract of thesis presented to Senate of Universiti Putra Malaysia in fulfillment of the requirement for the degree of Doctor of Philosophy

FAST HANDOVER TECHNIQUE IN HETEROGENEOUS WIRELESS NETWORKS

By

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July 2014

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The next generation of wireless communication systems are facing many challenges that need solutions so that it can coexist with each other. One of these challenges is the mobility solutions that facilitate users with seamless inter-technology roaming capabilities that in turn require a seamless inter-system handover. Naturally, every inter-system roaming which leads to vertical handover requires that both link layer and network layer handovers happen, since network point of attachment as well as the device interface is changed. Several investigations and efforts in standardization are being made by several institutes and individuals to finally design and implement each of these communication layers. However, for the specific purpose of vertical handover in a heterogeneous wireless network, the information preparation for these two layers before any operations of handover can directly affect the significant performance parameters and consequently lead to seamless handover. This thesis is intended for detailing out a study of vertical handover in a heterogeneous wireless network that includes two main aspects. These aspects are the network information gathering and then the use of these information during the vertical handover.

First, we proposed an Enhance Access Router Discovery (EARD) method for exchanging the information between the access routers that overlap in the coverage area. The gathered information includes a list of unique IP addresses that are generated and checked by their access router, the media access control (MAC) address of the device, channel number and additional information related to the network characteristics and requirements. Second, the use of these information to support all the handover operations, which includes network discovery, handover decision and handover execution.

In the first operation, the previous access router provides information about the neighboring networks for Mobile Node (MN) to discover available networks as soon as possible. The second operation is selecting the best available network for MN through the network side and taking into consideration the traffic type. The last

operation, the previous access router rapidly provides a unique Ipv6 address instead of new access router for MNs to execute the last operation of handover.

The results show the benefits of our EARD method by improving the discovery time of networks, giving the best performance in terms of network selections and minimizing the handover latency and packet loss in handover execution when compared to the conventional technique.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

TEKNIK PENYERAHAN PANTAS DALAM RANGKAIAN WIRELESS PELABGAI

Oleh

RADHWAN M ABDULLAH

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Pengerusi : Azizol Abdullah, PhD

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Sistem komunikasi wireless generasi akan datang menghadapi pelbagai cabaran yang memerlukan penyelesaian supaya ia boleh wujud bersama-sama antara satu sama lain. Salah satu daripada cabaran ini adalah penyelesaian mobiliti yang memudahkan pengguna dengan memberi keupayaan perayauan antara teknologi yang seterusnya memerlukan satu penyerahan antara sistem yang lancar. Sememangnya, setiap perayauan antara sistem yang membawa kepada penyerahan menegak memerlukan pelaku penyerahan terhadap kedua-dua lapisan pautan dan lapisan rangkaian kerana rangkaian dan juga antara muka peranti telah bertukar. Terdapat kajian dan usaha dalam mewujudkan piawaian yang sedang dibuat oleh beberapa institusi dan individu akhirnya mereka bentuk dan melaksanakannya pada setiap lapisan komunikasi. Walau bagaimanapun, bagi tujuan khusus penyerahan menegak dalam rangkaian wayarles pelbagai, penyediaan maklumat bagi kedua-dua lapisan sebelum sebarang operasi penyerahan secara langsung, diharapkan akan memberi kesan kepada parameter prestasi dan seterusnya membawa kepada penyerahan yang lancar. Tesis ini akan memperincikan satu kajian penyerahan menegak dalam rangkaian wayarles pelbagai yang dijalankan dalam dua aspek utama. Aspek-aspek ini adalah pengumpulan maklumat rangkaian dan kemudian menggunakan maklumat ini semasa penyerahan menegak.

Pertama, kita mencadangkan satu kaedah iaitu Enhance Access Router Discovery (EARD) sebagai kaedah untuk bertukar-tukar maklumat antara penghala capaian yang bertindih dalam kawasan liputan. Maklumat yang dikumpulkan termasuk senarai alamat IP yang unik yang dijana dan diperiksa oleh penghala capaian, kawalan akses alamat media (MAC) peranti, nombor saluran dan maklumat tambahan yang berkaitan dengan ciri-ciri rangkaian dan keperluan. Kedua, menggunakan maklumat ini untuk menyokong semua operasi penyerahan, yang merangkumi termasuk penemuan rangkaian, keputusan penyerahan dan pelaksanaan penyerahan.

Dalam operasi yang pertama, penghala capaian sebelumnya menyediakan maklumat mengenai rangkaian jiran untuk Nod Mobil (MN) untuk menemui rangkaian yang tersedia secepat mungkin. Operasi kedua, pemilihan rangkaian yang terbaik untuk MN melalui sebelah rangkaian dan dengan mengambil kira jenis lalu lintas. Operasi dalam yang terakhir, penghala capaian sebelumnya dengan pesat akan menyediakan alamat IPv6 unik selain daripada penghala capaian baru untuk MNS untuk pelaksanaan operasi terakhir penyerahan.

Keputusan menunjukkan manfaat kaedah EARD kami dengan meningkatkan masa penemuan rangkaian, ianya memberikan prestasi yang terbaik dari segi pilihan rangkaian dan meminimumkan kependaman penyerahan dan kehilangan paket dalam pelaksanaan penyerahan apabila berbanding dengan teknik konvensional.

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Radhwan M Abdullah

July 2014

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.

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LIST OF ABBREVIATIONS

4G	Fourth Generation
AAA	Authorization, Authentication and Accounting
AP	Access Point
AR	Access Router
ARIP	Access Router Information Protocol
BA	Binding Acknowledgement
BS	Base Station
BSS	Basic Service Set
BU	Binding Update
CA	Collision Avoidance
CARD	Candidate Access Router Discovery
CN	Correspondent Node
CoA	Care-of-Address
CPE	Customer Premise Equipment
CRC	Cyclic Redundancy Check
CSMA	Carrier Sense Multiple Access
DAD	Duplicate Address Detection
DHCP	Dynamic Host Control Protocol
DS	Distribution System
EWND	Efficient Wireless Network Discovery
EARD	Enhanced Access Router Discovery
ESS	Extended Service Set
ETSI	European Telecommunications Standards Institute
FA	Foreign Agent
FBacK	Fast Binding Acknowledgement
FBack	Fast Binding Acknowledgement
FBU	Fast Binding Update
FMIPv6	Handover for Mobile IPv6
HA	Home Agent
HAcK	Handover Acknowledgement
HI	Handover Initiate
HoA	Home Address
i-ARD	improved Access Router Discovery
IBSS	Independent Basic Service Set
IEs	Information Elements
IETF	Internet Engineering Task Force
IP	Internet Protocol
IS	Information Server
ISM	Industrial, Scientific, and Medical
LS	Link switch
MAC	Media Access Control
MICS	Media Independent Command Services
MIES	Media Independent Event Service
MIH	Media Independent Handover
MIHF	Media Independent Handover Function
MIIS	Media Independent Information Services

MIPv6	Mobile IPv6
MN	Mobile Node
NAACK	Neighbor Advertisement Acknowledge
NRD	Neighbour Reach-ability Detection
NT	Neighbour Table
OSI	Open Systems Interconnection
PRMC	Prioritized Rating for Multiple Criteria
PrRtAdv	Proxy Router Advertisement
QoS	Quality of Service
R-VHO	Rapid Vertical Handover
RA	Router Advertisement
RAN	Radio Access Network
RAND	Radio Access Network Discovery
RF	Radio Frequency
RS	Router Solicitation
RSS	Received Signal Strength
RtSolPr	Router Solicitation for a Proxy Advertisement
SAPs	Service Access Points solution
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
UNA	Unsolicited Neighbour Advertisement
WiMAX	Worldwide Interoperability for Microwave Access
WISE	Wise Interface Selection
WLAN	Wireless Local Area Network
WMAN	Wireless Metropolitan Area Network
WPAN	Wireless Personal Area Network
WWAN	Wireless Wide Area Network

CHAPTER 1

INTRODUCTION

1.1 Preface

The next generation of wireless communication technologies are facing many challenges that need solutions so that it can coexist with each other. One of these challenges is the mobility solutions that facilitate users with seamless inter-technology roaming capabilities that in turn require a seamless inter-system handover. Naturally, every inter-system roaming which leads to vertical handover (VHO) requires that both link layer and network layer handovers happen, since network point of attachment as well as the device interface is changed. Several investigations and efforts in standardization are being made by several institutes and individuals to finally design and implement each of these communication layers. However, for the specific purpose of VHO in a heterogeneous wireless environment, the information preparation for the link layer and network layer before any operations of handover can be expect will directly affect the significant handover performance and consequently lead to seamless handover. This thesis is intended for detailing out a study of VHO in a heterogeneous wireless environment that conducted in two main aspects. These aspects are how to gathering about the surrounding networks information and then how to use this information during the VHO stages.

Therefore, we proposed a mechanism that is primarily introduced for exchanging the information between the networks that overlap in the coverage area and then use this information to support all the VHO stages that include radio access network discovery, handover selection and handover implementation. The gathered information includes a list of unique IP addresses that are generated and checked by their Access Router (AR), network prefix, the Media Access Control (MAC) address for a networking device, channel number and additional information related to the network characteristics and requirements.

Throughout this chapter, the premise of the research is set by describing the research problem and defining the scope of the research. Furthermore, research background, motivations, objectives, and the contributions of this work are also presented.

1.2 Background and Motivation

Due to the increasing demand to mobile devices and expectations from wireless Internet access during the recent years, the wireless communications have become a large concern of communication and network researches. However, since none of the existing wireless technologies can solely fulfill the Internet task from the network metrics point of view as well as the Internet users' demands, the integration or coexistence of various communication systems with different network characteristics (i.e. channel number, coverage area, available bandwidth, packet delay, cost of

service etc.) is inevitable. This leads to the need for evolving wireless communications towards the Fourth Generation (4G) of mobile communication systems that rely on exchange information between different wireless networks paradigms. Among several proposals for integrating wireless systems toward 4G, heterogeneous wireless network has drawn even more attention as they provide integration between different wireless network technologies such as Wireless Metropolitan Area Network (WMAN), Wireless Local Area Network (WLAN) and Wireless Personal Area Network (WPAN) with the Internet [1].

Since such integration encompasses the majority of the existing networks, there seems to be exciting user services and applications are facilitated through interoperation of these network parts, which in turn lies on the availability of various types of radio access network with different coverage, services and characteristics. Besides, more promising from heterogeneous wireless networks are the enhancements to the packet delivery system with reduced latencies and increased throughput. Further to end-user benefits, heterogeneous wireless networks are of more interest to service providers because of wider coverage, efficiency and consequently financial profits.

Another reason for the escalating demands for 4G is the existence of wireless user devices with interfaces to multiple wireless access technologies. For example a device might have both WLAN and Worldwide Interoperability for Microwave Access (WiMAX) interface card allowing it to connect and handover to either of the two network technologies wherever available and whenever needed. These interface cards support on-going session during movements. Moreover, users can establish a connection through a certain network that meets requirements such as Quality of Service (QoS) requirements, availability and offered bandwidths, the cost of service, or even their preference.

While the deployments in various aspects of heterogeneous wireless networks are still among the most interesting areas of investigations, the concept of media heterogeneity leaves more challenges, mainly concerning the issues of security, resource and mobility managements. For mobility, another issue besides latency and throughput is the necessity of supporting the transmission of stream media over a wireless mobile network due to a high probability of packet loss during a user's movement. This problem can also happen due to other reasons, such as the long time for the Mobile Node (MN) that is needed to discover available networks by scanning many radio channels on each interface, the disparity in the amount of the bandwidths available in each network and the increase of the number of messages during the handover operations. Hence, the concept of mobility in a heterogeneous wireless network implies the continuation of data transmission or maintaining an on-going session while the point of attachment changes during VHO. Hence, unlike a horizontal handover, which takes place due to roaming between two stations of a network, VHO is contrarily known as the change in direction of data session without interruption, which implies device interface switch in user side and technology switch from network point of view.

As a result, VHO requires the change of point of attachment in network layer as well as lower layers and therefore, unlike horizontal handovers, the preparation of network layer mobility should be considered for this type of movements. However, regardless of the type of the handover performed, the main reason for data discontinuation is change of Internet Protocol (IP) address, which naturally requires the release of the earlier network connection. This in turn, causes the current session to be closed and hence the packet stream is interrupted. In order to avoid this data disruption, one solution could be hiding the movement from higher layers. For instance, if the changes in link layer connection are concealed from the network layer, the IP address change may no longer be required. Based on this concept, IP mobility [2] has been designed by introducing a temporary IP address to leave the main or permanent IP address untouched.

Among mobility management protocols, Fast Handover for Mobile IPv6 (FMIPv6) [3] from the Mobility for IP working group (mipshop) [4] of the Internet Engineering Task Force (IETF) [5] is a standardized IP layer handover solution when the mobility in the network layer of all sub-networks is handled with Mobile IPv6 (MIPv6). Despite utilizing some link layer messages for movement discovery and other purposes, FMIPv6 is barely a pure network layer handover solution, as it has never dealt with heterogeneity issues of physical and link layers.

On the other hand, Media Independent Handover (MIH) services deal with handover solutions in lower layers when the media type changes [6]. This standard interfaces and associates the heterogeneous media with the information compatible with higher layer requirements to enable a continuous seamless connectivity via various access technologies. Heterogeneous media refers to various types of access technologies such as WLAN and WiMAX interfaces. However, as each of these standards deal merely with specific aspect of mobility issues, none of the related standardization progresses suggests an ultimate solution for VHO between various networks. Therefore, far too little progress has been achieved in finding a comprehensive solution for VHO between various network compartments and VHO is yet to be commercialized.

1.3 Problem Statement

The management techniques for FMIPv6 and MIH services between different wireless technologies are very important to complete the handover operations with the least possible delay. In the FMIPv6 technique, when a MN moves to another network, it needs to do VHO operations. These operations (network discovery, handover selection and handover implementation) have a severe impact on the handover latency.

Throughout this research, three problems have been identified as follows:

1. One of the most difficult tasks in coordination the VHO is the discovering available radio access networks. Although the MN can easily access to the WiMAX network, but constantly scans all channels through its interface card to discover available WLAN networks, which provide high data rates but

have a limited coverage area. Thus, the length of time it takes to the scanning process for all channels to discover available network will contribute to increase the latency for handover. In addition, the time consuming to wait until the scan on all channels and switching between all interface cards can be translate to consumption battery power for mobile devices.

2. The handover selection for MNs between different available networks discovered is very important to ensure a QoS from certain level. Selecting the random available networks for mobile users lead to packet drop and delay for MN. Additionally, more fatigue on the selected network may occur.

3. The cost of time in the process of vertical handover implementation is very high because the MN needs to stay connected to the old link for a considerably long time to complete and process all the messages. These messages are important for assisting IP movement discovery and new care of address configuration. The link going down event in MIH services is triggered at any time by the degraded old link condition. As a result, the MN may not have a sufficient time to send and receive these signals of messages which may lead to connection lose or switch to the reactive handover mode in the best case.

1.4 Research Objectives

The aim of this thesis is to propose a seamless VHO solution in an integrated WiMAX-WLAN wireless heterogeneous network. By implementing this VHO method, it is aimed to achieve a solution for inter-System roaming with support of network and link layers. This support is presented through the preparation and gathering of the information for link and network layers that is obtained from a heterogeneous environment involving of WiMAX and WLAN technologies. With this information, we tackle many issues that are not concerned with the conventional handover protocol such as discovering radio access networks, selecting the best available networks and eliminating the deficiencies in conventional fast handover protocol. Hence, our aim is to achieve performance improvements by achieving lower overall VHO latency, tolerable packet loss and minimum signal messages when the MN switches from the old to the new connection during handover compared with conventional methods in vertical mode. Besides that, reduction the consumed battery power for MN can be achieved by having a minimum time for discovering the radio access network.

The objectives of this thesis can be summarized as follows:

1. To propose an efficient wireless network discovery algorithm based on the exchange of information between neighboring networks to improve the performance of MNs in terms of network discovery time and power consumption compared to the conventional network discovery techniques.

2. To propose a candidate network selection algorithm at the network side to select the best available network connection for mobile users among the

heterogeneous wireless networks, with determines the delay and packet loss in order to ensure a QoS.

3. To propose a rapid VHO algorithm between WiMAX and WLAN technology that is controlled by the network in order to improve the cost of implementation in FMIPv6 protocol, and thus lead to decrease the message signals, packet delivery costs, and packet delay.

1.5 Research Scope

When MNs are roaming regardless of whether resulting of this moving to a VHO or horizontal handover needs many operations and thereby, changes in different layers. The switching between different interfaces that is happening in physical layer will lead to initialization delays for adoption with new channels, modulation etc., can be known as an example of this type in VHO. However, this study is achieved by concentrating on many issues that are related to link and network layers in both user and network sides. The primary focus of this research is on how to exchange and utilize the information between networks for support the MNs to discovering the available networks, select the best available network by Access Router (AR) and finally how to generate and manage unique IP addresses to implement the VHO. We assume that the exchange of information will happen only between ARs that have coverage overlap.

These information include groups from unique IP addresses that belong to the neighboring networks, the MAC address of the device, channel number, link delay, packet loss, cost of service and available bandwidth. The study does not concern about how the cost of service is calculated, nor is generated. The research also presume that the implementations of each technology with related physical specifications as denoted in standard documents and modeled in the simulator [7].

1.6 Contributions

The main contributions of this thesis can be explained as follows:

1. An efficient method Enhanced Access Router Discovery (EARD) for exchanging the information between the networks that overlap in the coverage area is proposed. EARD is able to provide all the necessary information that may be needed by the mobile devices during the stages of VHO. It is considered a suitable alternative to the MIH services which have many shortcomings.

2. A new algorithm named Efficient Wireless Network Discovery (EWND) is proposed and implemented for discovery the available networks. EWND works on running the interface only when available networks and uses the selective scanning channels to discover the networks. It aims to decrease the time of discovery network and reduce power consumption for mobile devices. We also present an evaluation of the proposed algorithm through an NS-2

simulator consisting of two heterogeneous wireless networks: WiMAX and WLAN.

3. A new algorithm to select the target network for special use in VHOs is designed and implemented. The algorithm is designed with support from EARD method to estimate and select a network with the best conditions based on types of traffic. It is contributed to enhance the packet loss, delay and average throughput in existing heterogeneous wireless networks.

4. A new algorithm for assigning a new IP address for a prospective network ahead of time from the VHO is proposed. This work contributed to overcome the problem of the high VHO latency in FMIPv6. Our proposed algorithm is implemented and evaluated in an NS-2 simulator consisting of two heterogeneous wireless networks: WiMAX and WLAN.

1.7 Thesis Organization

The thesis is organized as follows:

Chapter 1 provides a general introduction to the research with regards to the background as well as the objectives and scope of the research topic.

Chapter 2, the WiMAX and WLAN technologies are briefly background, followed by the discussions are then about the integration of these networks by evaluating the existing approaches. As for mobility, the chapter provides information on the VHO including the requirements and steps. Based on the described handover phases, relevant approaches are in line with justifications to the current research.

Chapter 3 presents the framework of the thesis and explores the stages in detail. Experimental setup and topologies as well as the performance metrics and their evaluation methods are presented in this chapter.

Chapter 4 explores the design and implementation of the efficient wireless network discovery method in heterogeneous networks. It discusses the EWND algorithm operates, and Its impact on the network discovery time. The chapter finishes with the evaluation of the proposed method in terms of network discovery time and power consumption.

Chapter 5 presents the new algorithm PRMC for network selection, which represents the second operation of VHO. We showed a detailed description of network selection method through separate sections. The procedures and implemented of the PRMC algorithm that is based on EARD method, as well as simulations are described in details. The chapter also presents the performance

evaluation of the PRMC and compares it with the traditional network selection methods.

Chapter 6 shows how the EARD method can be used for a Rapid-VHO (R-VHO) algorithm to enhance network layer operation. It also describes and evaluates an R-VHO algorithm in terms of handover latency and packet loss. It also presents an analytical model to show that by enabling EARD method can perform the fast handover processes with low handover latency compared with the FMIPv6 technique.

Chapter 7 concludes the work and recommends some promising directions for future research.

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