DYNAMIC MOBILE ACCESS GATEWAY FOR HETEROGENEOUS NETWORK USING ANALYTIC HIERARCHY PROCESS

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I lovingly dedicate this thesis to my understanding and patience husband, Khairul Aizat Mohd. Hatta, to our precious daughters; Ayumi Humaira' and Athirah Hana and our son, Muhammad Ammar.

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ABSTRACT

The recent internet and telecommunication networks are expected to be combined together in all-Internet Protocol (IP) platform. Therefore, IP mobility is important to maintain the connectivity of a mobile user (MU) when the MU roams throughout the heterogeneous networks. Common IP mobility protocols such as Mobile IPv6 (MIPv6) has issue of high handover latency. Considering this issue, Proxy Mobile IPv6 (PMIPv6) is proposed in this research as the IP mobility protocol. Even though PMIPv6 overcomes the problem of the signalling overhead in MIPv6 and reduces Layer 3 (L3) handover latency, PMIPv6 suffers from Layer 2 (L2) high handover latency which influences the total handover latency of PMIPv6. Prior to this, multi-threshold handover algorithm is proposed in this research to be implemented in Mobile Access Gateway (MAG) to reduce the L2 handover latency in PMIPv6. Multi-threshold handover algorithm considers user's speed for the handover decision and the speed is categorized into three groups which are slow speed, medium speed and fast speed. PMIPv6 using multi-threshold handover algorithm shows up to 17% improvement compared to the PMIPv6 using dynamic handover decision method and improvement up to 99% compared to the PMIPv6 with static handover decision method. Another issue in heterogenous network is to decide the preferable network for a specific application. Thus in this research, MAG overcomes the network selection problem using Analytic Hierarchy Process (AHP). Here, five parameters are considered for the decision making, which are cell radius, data rate, applications, cost per bit and user's speed. In short, Dynamic Mobile Access Gateway (DMAG) is developed by combining multi-threshold handover algorithm and AHP to offer seamless handover process. The performance of DMAG has been simulated using three networks which are WiFi network, 3G network and LTE network. Simulation results prove that DMAG selects the network dynamically using the five parameters compared to a method that used Dynamic Received Signal Strength. The selection reduces handover frequency for the medium speed and fast speed MU.

ABSTRAK

Pada masa kini, rangkaian telekomunikasi dan internet dijangka digabungkan dalam semua platform Protokol Internet (IP). Oleh itu, kebolehgerakan IP adalah sangat penting untuk mengekalkan sambungan daripada pengguna mudah alih (MU) apabila MU bergerak di dalam rangkaian heterogen. Protokol kebolehgerakan IP yang biasa seperti Mobiliti Protokol Internet v6 (MIPv6) mempunyai isu kependaman penyerahan tinggi. Memandangkan isu ini, Proksi Mobile IPv6 (PMIPv6) dicadangkan dalam kajian ini sebagai mobiliti IP protokol. Walaupun PMIPv6 mengatasi masalah isyarat berlebihan dalam MIPv6 dan mengurangkan penyerahan kependaman Lapisan 3 (L3), PMIPv6 menghadapi masalah penyerahan kependaman yang tinggi di Lapisan 2 (L2) yang mempengaruhi jumlah kependaman penyerahan dalam PMIPv6. Disebabkan ini, algoritma penyerahan pelbagai-ambang dicadangkan dalam kajian ini untuk dilaksanakan di dalam Laluan Akses Mobiliti (MAG) bagi mengurangkan L2 penyerahan kependaman dalam PMIPv6. Algoritma penyerahan pelbagai-ambang mengambil kira tiga kumpulan kelajuan pengguna iaitu kelajuan perlahan, sederhana dan laju. PMIPv6 yang menggunakan algoritma penyerahan pelbagai-ambang menunjukkan peningkatan sebanyak 17% berbanding PMIPv6 yang menggunakan penyerahan dinamik dan sebanyak 99% peningkatan berbanding PMIPv6 yang menggunakan kaedah penyerahan statik. Isu lain di dalam rangkaian heterogen ialah pemilihan rangkaian yang lebih baik untuk aplikasi tertentu. Maka dalam kajian ini, MAG yang menggunakan Proses Hierarki Analisis (AHP) dicadangkan bagi mengatasi masalah pemilihan rangkaian. Terdapat lima parameter yang dipilih untuk tesis ini iaitu sel radius, kadar data, aplikasi, kos per bit dan kelajuan pengguna. Ringkasnya, Get Laluan Akses Pergerakan Dinamik (DMAG) dibangunkan dalam kajian ini dengan menggabungkan algoritma penyerahan pelbagai-ambang dan AHP untuk menawarkan proses penyerahan yang lancar. Prestasi DMAG telah disimulasi dengan menggunakan tiga rangkaian iaitu rangkaian WiFi, rangkaian 3G dan rangkaian LTE. Keputusan simulasi membuktikan bahawa DMAG memilih rangkaian secara dinamik dengan menggunakan kelima-lima parameter berbanding kaedah yang menggunakan kekuatan isyarat yang diterima dinamik. Pemilihan itu mengurangkan kekerapan penyerahan MU dengan kelajuan sederhana dan laju.

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LIST OF ABBREVIATIONS

3G	-	Third Generation
4G	-	Fourth Generation
3GPP	-	Third Generation Partnership Project
3GPP2	-	Third Generation Partnership Project 2
ABC	-	Always Best Connected
AHP	-	Analytic Hierarchy Process
AMPS	-	Advanced Mobile Phone System
AMTS	-	Advanced Mobile Telephone System
AP	-	Access Point
BCE	-	Binding Cache Entry
BU	-	Binding Update
BS	-	Base Station
BSC	-	Base Station Controller
CBR	-	Case-based Reasoning
CDMA	-	Code Division Multiple Access
CI	-	Consistency Index
CN	-	Correspondance Node
CoA	-	Care of Address
CR	-	Consistency Ratio
C-RNTI	-	Cell Radio Network Temporary Identifier
DAD	-	Duplicate Address Detection
D-AMPS	-	Digital Advanced Mobile Phone System
DEA	-	Data Envelopmeny Analysis
DHCPv6	-	Dynamic Host Configuration Protocol version 6
ECGI	-	E-UTRAN Cell Global Identifier
EDGE	-	E-UTRAN Cell Global Identifier
ELECTRE	-	ELimination and Choice Expressing REality
EPS	-	Evolved Packet System
ETACS	-	European Total Access Communication Systems
FA	-	Foreign Agent

FDMA	-	Frequency Division Multiple Access
FMIPv6	-	Fast MIPv6
GPRS	-	General Packet Radio Service
GPS	-	Global Positioning System
GSM	-	Global System for Mobile Communications
HA	-	Home Agent
HMIPV6	-	Hierarchical MIPv6
HNP	-	Home Network Prefix
HoA	-	Home Address
ICMP	-	Internet Control Message Protocol
IETF	-	Internet Engineering Task Force
IMSI	-	International Mobile Subscriber Identity
IMT-2000	-	International Mobile Telecommunications-2000
IMTS	-	Improved Mobile Telephone Service
IP	-	Internet Protocol
IPv4	-	Internet Protocol version 4
IPv6	-	Internet Protocol version 6
IRDP	-	ICMP Router Discovery Protocol
ITU	-	International Telecommunication Union
L2	-	Layer 2
L3	-	Layer 3
LMA	-	Local Mobility Anchor
LMAA	-	Local Mobility Anchor Address
LMD	-	Local Mobility Domain
LTE	-	Long Term Evolution
LTE	-	Long Term Evolution
MAC	-	Media Access Control
MADM	-	Multi-attributes Decision Making
MAG	-	Mobile Access Gateway
MAUT	-	Multi-Attribute Utility Theory
MCDM	-	Multi-criteria Decision Analysis
MIH	-	Media Independent Handover
MIP	-	Mobile IP
MIPv4	-	Mobile IPv4
MIPv6	-	Mobile IPv6
MME	-	Mobility Management Entity

MODM	-	Multi-objective Decision Making
MSC	-	Mobile Switching Center
MTS	-	Mobile Telephone System
MU	-	Mobile User
MU ID	-	MU Identifier
MU-HoA	-	Mobile User Home Address
MU-HNP	-	Mobile User Home Network Prefix
NetLMM WG	-	Network-based Localized Mobility Management Working Group
NS-3	-	Network Simulator 3
NTT	-	Nippon Telegraph and Telephone
OFDMA	-	Orthogonal Frequency-Division Multiple Access
OS	-	Operating System
PBAck	-	Proxy Binding Acknowledgement
PBU	-	Proxy Binding Update
PCoA	-	Proxy Care of Address
PDC	-	Personal Digital Cellular
PDCP	-	Packet Data Convergence Protocol
PDCP SN	-	Packet Data Convergence Protocol Serial Number
PDN	-	Packet Data Network
PLMN	-	Public Land Mobile Network
PL-PMIPv6	-	Packet Lossless PMIPv6
PMIPv6	-	Proxy Mobile IPv6
PSTN	-	Public Switched Telephone Network
QoS	-	Quality of Service
RA	-	Router Advertisement
RACH	-	Radio Access Channel
RNC	-	Radio Network Controller
RRM	-	Radio Resource Management
RSS	-	Received Signal Strength
RSSI	-	Received Signal Strength Indicator
SAW	-	Simple Additive Weighting
SDU	-	Service Data Unit
SeNB	-	Source eNB
SIM	-	Subscriber Identity Module
SINR	-	Signal-to-Interference-plus-Noise Ratio

SMAG	-	Smart Mobile Access Gateway
SMART	-	Simple Multi-Attribute Rating Technique
TA	-	Tracking Area
TAI	-	Tracking Area Identity
TEID	-	Tunnel Endpoint Identifier
TeNB	-	Target eNB
TCP/IP	-	Transmission Control Protocol/Internet Protocol
TDMA	-	Time Division Multiple Access
TOPSIS	-	Technique for Order of Preference by Similarly to Ideal Solution
UMTS	-	Universal Mobile Telecommunications Service
VoD	-	Video on Demand
W-CDMA	-	Wideband-CDMA
WiFi	-	Wireless Fidelity
WiMAX	-	Worldwide Interoperability for Microwave Access
WLAN	-	Wireless Local Area Network
WWAN	-	Wireless Wide Area Network

LIST OF SYMBOLS

δ	-	Hysteresis

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CHAPTER 1

INTRODUCTION

1.1 Background

The 3^{rd} Generation Partnership Project (3GPP) introduced Long Term Evolution (LTE) to replace the 3^{rd} Generation (3G) cellular technology. The extension of LTE is a 4^{th} Generation (4G) candidates, which is known as LTE-Advanced. LTE offers 100 Mbps downlink and 50 Mbps uplink at peak data rates while LTE-Advanced promises 1 Gbps at peak data rate. LTE is an Internet Protocol (IP)-based cellular technology where the cellular architecture evolved from the 3G architecture. Prior to LTE technology the cellular technology was based on Global System for Mobile Communications (GSM) in 2nd Generation (2G) [1].

There are two features of LTE that relates to mobility. The first feature is that LTE has to support Mobile User (MU) for various speeds up to 350 km/h regardless of the access network and the second feature is that LTE has to enhance the performance of low speed user; 0-10 km/h [2, 3]. Moreover, LTE does not have a standard operating frequency band and this depends on the country and region. Higher frequency band decreases the cell coverage and increases handovers [4]. Mobility management consists of two elements which are the location management and the handover management. The location management is a process of identifying and tracking the current position of an MU whilst the process of changing the associated network is called handover management [5].

The handover can be categorized into two types which are hard handover and soft handover. The hard handover is also known as a break-before-made handover because the previously associated network is terminated before the new network connection is established. The scenario of hard handover is shown in Figure 1.1 (a), where in the overlapping area of the two Access Points (AP), the MU terminates the connection with the AP1 before it connects to the AP2. For that reason, no resources are wasted and the data overhead can be minimized. However, short interruption time of service occurs due to the process of break and then make a connection [6].

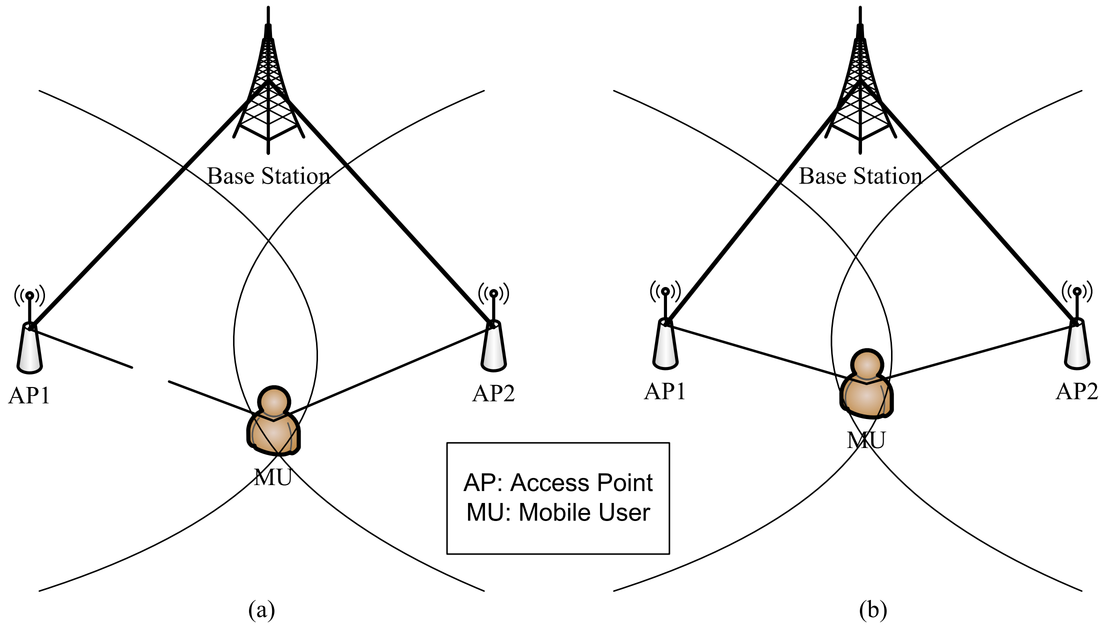

Figure 1.1: (a) Hard handover and (b) Soft handover

Differed from the hard handover, the soft handover terminates the previously associated network after the new networks is established, therefore it is also known as make-before-break handover. As a result, no interruption during handover but soft handover increases data overhead and leads to inefficient use of spectrum. Figure 1.1 (b) depicts the scenario of the soft handover. As can be seen in the Figure 1.1 (b), the MU connects to both APs in the overlapping area. MU will disconnect from AP1 after MU completely connects with AP2.

Soft handover is omitted in LTE since LTE operates on codes rather than frequency as in 3G system. The soft handover can be implemented in 3G because the adjacent cells are able to operate on the same frequency as long as using different codes. By contrast, LTE is Orthogonal Frequency-Division Multiple Access (OFDMA) based, thus LTE user has to handover to a different frequency. Furthermore, LTE has flat architecture. It means no central node controller like Base Station Controller (BSC) and Radio Network Controller (RNC) as in 3G system. Consequently, no need to sum up multiple signaling which cause complexity in LTE

[7]. The difference between 3G system and 4G system will be discussed later in section 2.2.2 and section 2.2.3.

As mentioned earlier, LTE aims to provide flat-IP architecture for cellular system. LTE current implementation does not support IP-based architecture. Infact, the IP implementation in LTE are still in research study. Based on this issue, NTT DOCOMO[1] [8][9] proposed Proxy Mobile IPv6 (PMIPv6) as the mobility management in LTE. They predicts that PMIPv6 can improve on utilization of wireless resources, handover performance, user privacy and network security compared to Mobile IPv6 (MIPv6).

1.2 Problem Statement

Mobile IP (MIP) or IP mobility is a protocol in maintaining an IP address while a user moves from one network to another network. To do this, Internet Engineering Task Force (IETF) proposed MIPv6, which is a user-based mobility management. However, the implementation of MIPv6 can be inefficient due to the high handover latency and high packet loss. There are several enhancement of MIPv6 to improve handover management such as Hierarchical Mobile IPv6, Fast Handovers for Mobile IPv6 and the combination of Hierarchical Mobile IPv6 and Fast Handovers for Mobile IPv6. Even though there are many protocols introduced to overcome the problem in MIP, it still cannot be solved [10, 11, 12, 13, 14, 15]. Moreover, interest on network mobility has increased recently. As a result, IETF created Network-based Localized Mobility Management Working Group (NetLMM WG). NetLMM proposed PMIPv6 as the solution for network-based mobility [16]. Since the development of PMIPv6 is based on MIPv6, it suffers the same problems with MIPv6 which is high handover latency and high packet loss.

The implementation of PMIPv6 is aimed to offer lower handover latency and lower packet loss compared to the MIPv6. However in [15], the handover latency of PMIPv6 is not acceptable for real-time application since the value is above 150ms. Regarding to authors in [17], delay less than 150ms is acceptable for real-time application. However, if the delay is 80ms, it is very good but if it reaches above 200ms, it is not acceptable for real-time application. This factor motivate researchers to improve the handover latency in PMIPv6. The total handover latency in PMIPv6

[1]NTT DOCOMO: Predominant mobile phone operator in Japan

is contributed by Layer 2 (L2) and Layer 3 (L3) handover latency. L2 handover occurs at the link layer and the processes involved are scanning, authentication and association. On the other hand, L3 handover occurs at the network layer and the processes involved are movement detection delay, address configuration delay and binding update delay. Regarding to [18], L2 handover latency contributes higher handover latency compared to L3 handover latency in PMIPv6 and cause unacceptable delay for real-time applications.

In future wireless network, the integration between different networks is considered to offer always best connectivity (ABC) to the users. The integration of various network is called a heterogeneous network. In order to answer the ABC requirement, vertical handover is very important when the users move within the heterogeneous network. The challenging issue in vertical handover is the decision to choose the preferable network amongst the different networks [19, 20] and seamlessness [21, 22]. Seamlessness means the handover delay should be low and little or no packet loss. So that, the MU will not realize the handover process.

Factors that influence the vertical handover are mobility scenarios, network conditions and user preferences [23, 24, 25, 26]. Furthermore, user's speed can influence the handover performance too. If the user's speed is low, the network topology architecture can be maintained for a long time. Therefore, the user can use the same network topology information and the delay to get the information of the neighboring cell can be reduced. In contrast, high speed user are facing a problem where the channel condition change frequently. This problem cause the pre-obtained information become useless. Thus, the scanning for all neighboring cell should be performed and the delay cannot be reduced [27]. Moreover, time to trigger the handover process is important for the medium and high speed user because the user may leave the network before it performed the handover process [28, 29].

1.3 Objectives of Research

The main objective of this research is to enhance the MAG that can decide on the proper network with low handover latency and done the network selection dynamically. The specific objectives of the work are:

1. To develop mechanism to reduce the handover latency in PMIPv6.

2. To develop decision algorithm to select a network in heterogeneous network.
3. To evaluate network selection of the enhanced MAG.

1.4 Scope of Research

This research focus on the developing Dynamic Mobile Access Gateway (DMAG). The DMAG which is one of the PMIPv6 entity, will decide when and where to perform the handover process. Two methods are considered in developing the DMAG. Firstly, handover algorithm is proposed to decide when to perform the handover. The proposed algorithm namely multi-threshold handover algorithm is proposed based on Received Signal Strength (RSS) and user's speed. Three group of user's speed is considered which are are slow speed, medium speed and fast speed. The range of the slow speed is 0-10 m/s, considering walking speed, cycling speed and very low car speed. The range for the medium speed is 11-25 m/s, considering normal car speed in urban and suburban area. The range of the fast speed is 26-35 m/s, considering car speed in Malaysia's highway. The performance is simulated using Network Simulator-3 (NS-3) that uses C++. The simulation scenario consists of two MAGs and one MU. The MU moves from MAG1 to MAG2 with constant speed. The performance is evaluated in link delay, packet variation and number of users.

Secondly, Analytic Hierarchy Process (AHP) is considered as the handover decision algorithm in heterogeneous networks. This is because the multi-threshold handover algorithm is not suitable to be used in vertical handover because accepted RSS value varied between technologies. The heterogeneous networks considered in this research are Wireless Fidelity (WiFi), 3G and LTE. AHP allows to have more than one parameters with different unit values in the handover decision. Therefore, five parameters consisting of networks and user's preferences are used in this research which are cell radius, data rate, service, cost per bit and user's speed. These parameters are considered as basic parameters that are very important to be used in choosing the suitable candidate to perform handover. Simulation is run using NS-3 for three scenarios. The first scenario considers MU initially attached to the WiFi network, the second scenario considers MU initially attached to the 3G network and the third scenario considers MU initially attached to the LTE network.

1.5 Contributions of Research

The proposed DMAG enhances the handover process in the LTE heterogeneous network. The proposed entity consists of two contributions as listed below:

- **Multi-threshold Handover Algorithm**: The first contribution is using user's speed that is divided into three group of speeds which are slow speed, medium speed and fast speed. Each group has its own algorithm. Thus, there are three thresholds for three groups of user's speed instead of one threshold for all user's speed. The handover latency for medium speed and fast speed is reduced.
- **DMAG**: The second contribution is the development of DMAG. DMAG decides whether to change to other network or stay to the attached network. AHP is used to solve the handover decision based on network parameter and user's preferences. In addition, DMAG decides to handover to a new network that can offer the best connectivity suitable to the user's speed and the ongoing service.

1.6 Organization of Thesis

This thesis is divided into six chapters. Chapter 1 introduces the motivation of doing this research. The problem statement is stated in this chapter and briefly explains the direction of this research. The significance of the research and the contribution of the research are concisely described.

Chapter 2 introduces the heterogeneous network as well as the mobility management in cellular and IP network. Multi-criteria Decision Making (MCDM) also discussed in this chapter. Moreover, the related works to reduce handover latency and vertical handover decision algorithm are presented.

Chapter 3 presents the framework of the research. The main idea of the proposed work is introduced. In addition, the description of other existing methods is discussed and as well as compared with the proposed method. The simulation scenario for PMIPv6 is shown in this chapter besides explanation on how the results are obtained. Furthermore, the mechanism of AHP is discussed in detail. All the formulas of AHP are stated in this chapter. Lastly, the process to develop DMAG is discussed in detail.

The proposed handover algorithm is evaluated in Chapter 4. Detailed explanation of the proposed method, multi-threshold handover algorithm method is stated. The results are compared with the static handover threshold method and the dynamic handover threshold method. The analysis is done for different link type, packet variation and increment number of users.

Chapter 5 focuses on the development of DMAG. The numerical results of AHP for vertical handover decision are also presented and discussed. Based on the proposed algorithm in Chapter 4 and AHP, DMAG is developed. The evaluation of the DMAG is presented based on real-time and non-real time cases.

Finally, the thesis concludes in Chapter 6 is summary of the research, significant achievements as well as possible future work that may be pursued to achieve further enhancement of the proposed work.

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APPENDIX A

LIST OF PUBLICATIONS

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