UNIVERSITI PUTRA MALAYSIA

VERTICAL FAST HANDOFF TECHNIQUE FOR MOBILE IPv6 IN HETEROGENEOUS 4G NETWORKS

VAHID SOLOUK

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By

VAHID SOLOUK

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

August 2009

DEDICATION

To my dearest family,

…for their unconditional and everlasting love and support

To my kindest wife, Ayda, and my sweetest son, Ilkin

…in all love, humility, and gratitude

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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August 2009

Chairman: Professor Borhanuddin Mohd Ali, PhD

Faculty: Engineering

Over the recent years, mobility in wireless communications has become a big interest of communication and network researches due to the rising demand on and expectations of wireless Internet access. However, since none of the existing wireless technologies can individually fulfill all the tasks arising from the Internet users' demands, the integration or coexistence of different communication systems having different network characteristics is inevitable. This integration on the other hand, requires seamless inter-system mobility solutions. Every inter-system roaming which leads to vertical handoff requires proper interaction of both link and IP layers, since network point of attachment as well as the device interface are involved in handoff. Many investigations in

standardization are being made to finally design and implement each of these communication layers. This thesis details out the whole research, which is done in two main components. As for the first component, a link layer mechanism with the notion of a selection algorithm based on weighted mean is primarily introduced for collecting link layer information and discovering the candidate access router. This mechanism is then used as handoff decision phase with an improved mobile-assisted handoff method as an extension of Fast Mobile IPv6 Handoff (FMIPv6) in vertical mode. The performance of the proposed methods is discussed using analysis and comparison of simulation results with well-known methods in the field. The method has been shown to achieve performance improvements in terms of higher preference level of selection for various cases, and in terms of latency and packet loss, by 45% and 83% respectively, while maintaining comparatively lower buffer sizes. As the second component, a framework is proposed to incorporate an integration mode of cellular and wireless networks called semi tightly-coupled. This framework is further used to design and implement an end-to-end roaming solution as Vertical Fast Handoff (VFHO) for the integrated network. The performance of the proposed framework has been analyzed mathematically and through simulations which show the robustness of VFHO in terms of signaling cost, end-to-end packet delivery cost, overall handoff latency, and packet loss based on various system variables. Under several simulations, the number of lost packets encountered by VFHO stayed as low as 20 packets when the arrival rate was a

maximum of 50 packets per second, and did not exceed 10 packets in the case when packet sizes was at a maximum of 256 Bytes or when buffer size was set to 50 KB. Besides, the delay varied between 200 and 600 ms in cases when the Duplicate Address Detection (DAD) and wireless link delays reached up to 600 ms and 70 ms, respectively. In conclusion, the selection-based decision mechanism in vertical handoff such as VFHO, can be good for congestion control, and achieve long-term objectives such as load sharing.

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

TEKNIK PENYERAHAN PANTAS MENEGAK UNTUK IPV6 BERGERAK DALAM RANGKAIAN PELBAGAI JENIS 4G

Oleh

VAHID SOLOUK
Ogos 2009

Pengerusi: Profesor Borhanuddin Mohd Ali, PhD

Fakulti: Kejuruteraan

Semenjak kebelakangan ini, kebolehgerakan dalam komunikasi tanpa wayar telah menarik minat dalam penyelidikan komunikasi dan rangkaian; ini adalah disebabkan permintaan dan harapan yang meningkat dari pencapaian tanpa wayar berinternet. Walau bagaimanapun, oleh kerana tiada satu pun di antara teknologi tersebut mampu dengan sendirinya untuk memenuhi kesemua tugasan yang lahir dari permintaan pengguna Internet, penggabungan atau kewujudan bersama di kalangan sistem sistem komunikasi yang pelbagai yang mempunyai pelbagai ciri rangkaian, adalah tidak dapat dielakkan. Sebaliknya, pengintegrasian memerlukan penyelesaian pergerakan antara-sistem yang tak berklim. Setiap perayauan antara-sistem yang menjurus kepada penyerahan

menegak memerlukan interaksi yang sempurna untuk kedua dua lapisan pautan dan IP, oleh kerana titik penyambungan rangkaian dan juga pengantaramuka peranti adalah terlibat dalam penyerahan. Beberapa banyak kajian dalam piawaian sedang dibuat untuk akhirnya merekabentuk dan melaksanakan setiap lapisan komunikasi ini. Tesis ini mendetilkan keseluruhan penyelidikan ini, dan ia dilakukan dalam dua komponen utama. Untuk komponen pertama, suatu mekanisme lapisan pautan dengan tanggapan satu algoritma pemilihan berasaskan min pemberat adalah diperkenalkan untuk memungut maklumat lapisan pautan dan menemui penhala capaian calon. Mekanisme ini kemudian digunakan sebagai fasa keputusan penyerahan dengan kaedah penyerahan telefon bimbit-dibantu sebagai tambahan kepada Penyerahan Telefon-bergerak IPv6 Pantas (FMIPv6). Prestasi kaedah kaedah cadangan adalah dibincangkan menggunakan analisis dan bandingan hasil keputusan simulasi dengan kaedah yang terkenal dalam bidang ini. Kaedah ini telah menunjukkan bahawa ia telah mencapai penambahbaikan prestasi dalam bentuk pemilihan yang mempunyai tahap keutamaan yang lebih tinggi untuk beberap kes, dan dalam bentuk lengah dan kehilangan paket, dengan 45% dan 83% masing masing, sambil mengekalkan saiz penimbal yang lebih kecil. Sebagai komponen kedua, satu kerangka adalah dicadangkan untuk memasukkan model integrasi rangkaian bersel dan tanpa wayer dinamakan gabungan-ketat separa. Kerangka ini seterusnya digunakan untuk mereka dan melaksanakan satu penyelesaian perantauan hujung-ke-hujung sebagai

Penyerahan Pantas Menegak untuk rangkaian bergabung. Prestasi kerangka yang dicadangkan ini telah dianalisis secara matematik dan melalui simulasi yang menunjukkan ketahanan VFHO dalam bentuk kos pengisyaratan, kos penghantaran paket hujung-ke-hujung, lengah serahan menyeluruh, dan kehilangan paket berdasarkan beberapa pembolehubah sistem. Dalam beberapa simulasi, bilangan paket hilang yang dihadapi oleh VFHO tetap rendah sehingga 20 paket apabila kadar ketibaan adalah pada maksimum 50 paket sesaat, dan tidak melebihi 10 paket dalam kes di mana saiz paket adalah pada peringkat maksmum 256 Bait atau saiz penimbal disetkan kepada 50KB. Selain dari itu, lengahnya berubah ubah di antara 200 dan 600ms dalam kes di mana Pengesanan Alamat Pendua (Duplicate Address Detection (DAD)) dan lengah pautan tanpa wayer mencapai sehingga 600ms dan 70ms, masing masing. Sebagai penutup, mekanisme keputusan berasaskan pemilihan dalam serahan menegak seperti VFHO, adalah baik untuk kawalan kesesakan, dan mencapai objektif jangka-panjang seperti perkongsian beban.

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At the very outset, it is my pleasure to express my gratitude to Professor Borhanuddin Mohd Ali, my advisor. His theoretical insight, his technical awareness, his great sense of responsibility, and not least, his relentless enthusiasm for help created such inspiration and eagerness to make this direction and finally, to succeed in this study. The completion of this thesis would not be possible without his reading and correction patience, as well as technical advices.

I am also delighted to convey my appreciations to my committee, Dr. Sabira Khatun and Dr. Daniel Wong for providing valuable suggestions and criticisms, for their unwavering scholarly support that led me to provide independent ideas and research skills.

Although few words do not justice to their contribution, I am grateful to have such helpful friends around who always showed concerns for my work, among those I would like to name Messrs Reza Kamel, Ayyoub Akbari, Wisam Al-Azzo, Khalid El-Tahir, and of course many others.

APROVAL

I certify that a Thesis Examination Committee has met on August 27, 2009 to conduct the final examination of Vahid Solouk on his thesis entitled "Vertical Fast Handoff Technique for Mobile IPv6 in Heterogeneous 4G Networks" in accordance with the universities and university colleges Act 1971 and the constitution of the Universiti Putra Malaysia [P.U. (A) 106] March 15, 1998. The Committee recommends that the candidate be awarded the Doctor of Philosophy.

Members of the Thesis Examination Committee were as follows:

Mohd Adzir Mahdi, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Raja Syamsul Azmir Raja Abdullah, PhD
Assistant Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Alyani Ismail, PhD
Assistant Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Kaharudin B. Dimyati, PhD
Professor
Faculty of Engineering
University of Malaya
(External Examiner)

BUJANG KIM HUAT, PhD

Professor and Deputy Dean
School Of Graduate Studies
Universiti Putra Malaysia

Date: 15 October 2009

APROVAL

Saya mengesahkan bahawa satu Jawatankuasa Peperiksaan Tesis telah berjumpa pada 28 Ogos 2009 untuk menjalankan peperiksaan akhir bagi Vahid Solouk bagi menilai tesis beliau yang bertajuk “Teknik Penyerahan Pantas Menegak Untuk Ipv6 Bergerak Dalam Rangkaian Pelbagai Jenis 4G” mengikut Akta Universiti dan Kolej Universiti 1971 dan Perlembagaan Universiti Putra Malaysia [P.U.(A) 106] 15 Mac 1998. Jawatankuasa tersebut telah memperakukan bahawa calon ini layak dianugerahi ijazah Doktor Falsafa.

Ahli Jawatankuasa Peperiksaan Tesis adalah seperti berikut:

Mohd Adzir Mahdi, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Raja Syamsul Azmir Raja Abdullah, PhD
Assistant Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Alyani Ismail, PhD
Assistant Professor
Faculty of Engineering
Universiti Putra Malaysia
(Internal Examiner)

Kaharudin B. Dimyati, PhD
Professor
Faculty of Engineering
University of Malaya
(External Examiner)

BUJANG KIM HUAT, PhD

Professor and Deputy Dean
School Of Graduate Studies
Universiti Putra Malaysia

Date: 15 October 2009

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

Borhanuddin Mohd Ali, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Chairman)

Sabira Khatun, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

Daniel Wong, PhD
Assistant Professor
Faculty of Engineering
Malaysian University of Science and Technology
(Member)

HASANAH MOHD GHAZALI, PhD

Professor and Dean
School Of Graduate Studies
Universiti Putra Malaysia

Date: 16 November 2009

DECLARATION

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

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VAHID SOLOUK

Date:

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LIST OF ABBREVIATIONS

3G	Third Generations of wireless systems
3GPP	Third Generation Partnership Project
4G	Fourth Generations of wireless systems
AHP	Analytic Hierarchy Process
AP	Access Point
AR	Access Router
ARD	Access Router Discovery
B3G	Beyond 3G wireless systems
BS	Base Station
BSS	Basic Service Set
BU/BA	Binding Update & Acknowledgement
cAR	candidate Access Router
CARD	Candidate Access Router Discovery
CLR	Central Location Register
CN	Correspondent Node
CoA	Care-of-Address
CRC	Cyclic Redundancy Check
CS	Circuit Switched
CSMA/CA	Carrier Sense Media Access with Collision Avoidance
CTS	Clear to Send
DAD	Duplicate Address Detection
DCF	Distributed Coordination Function
DS	Distribution System
ESS	Extended Service Set
FBU/FBAck	Fast Binding Update & Acknowledgement
FHMIPv6	Fast Handover for Hierarchical Mobile IPv6
FMIPv6	Fast Handover for MIPv6
GERAN	GSM EDGE Radio Access Network
GGSN	Gateway GPRS Support Node
GPRS	General Packet Radio System
GRA	Grey Relational Analysis
GSM	Global System for Mobile Communications
HA	Home Agent
HDE	Handoff Decision Engine
HI/HAck	Handoff Initiation & Acknowledgement
HIR	Handoff Information Register
HMIPv6	Hierarchical Mobile IPv6
HoA	Home-of-Address
HSDPA	High Speed Downlink Packet Access
IARD	Improved Access Router Discovery

IBSS	Independent Basic Service Set
ICMP	Internet Control Message Protocol
IEEE	Institute of Electrical and Electronic Engineering
IETF	Internet Engineering Task Force
IFMIP	Improved FMIPv6
IMS	IP Multimedia System
ISM	Frequency band for Industrial, Scientific, Medical purposes
IWU	Interworking Unit
LA	Link Available
LAR	Local Area Report
LBU	Local Binding Update
LCR	Link Change Report
LR	Link Ready
LRR	Local Registration Request
LUQ	Local Update Query
LUR	Local Update Request
MAC	Media Access Control
MGW	Media Gateway
MICS	Media Independent Command Service
MIES	Media Independent Event Services
MIH	Media Independent Handover
MIHF	Media Independent Handover Function
MIIS	Media Independent Information Service
Mipshop	Mobility for IP, services, handover, performance
MIPv6	Mobile Internet Protocol version 6
MN	Mobile Node
nAR	new Access Router
nCoA	new Care-of-Address
NS/NA	Neighbor Solicitation & Advertisement
pAR	previous Access Router
PCF	Point Coordination Function
PDA	Personal Digital Assistant
PDN	Packet Data Network
PHY	Physical Layer
PrRtAdv	Proxy Router Advertisement
PS	Packet Switched
QoS	Quality of Service
RAN	Radio Access Network
RBU	Remote Binding Update
RF	Radio Frequency
RNC	Radio Network Control
RO	Route Optimization
RSS	Received Signal Strength

RTS	Request to Send
RtSolPr	Router Advertisement for Proxy
SAP	Service Access Point
SAW	Simple Additive Weighting
SCTP	Stream Control Transmission Protocol
SGSN	Serving GPRS Support Node
SIP	Session Initiation Protocol
TOPSIS	Technique for Order Preference by Similarity to Ideal Solution
UMTS	Universal Mobile Telecommunication System
UNA	Unsolicited Neighbor Advertisement
UTRAN	UMTS Terrestrial Radio Access Network
VFHO	Vertical Fast Handoff
WCDMA	Wideband Code Division Multiple Access
WLAN	Wireless Local Area Network
WMAN	Wireless Metropolitan Area Network
WPAN	Wireless Personal Area Network
WWAN	Wireless Wide Area Network

TERMINOLOGY

Potential AR: Refers to all available ARs in the neighborhood of the AR reported by MN. Potential ARs are identified based on their local area ID (LAID).

Nominated AR: Each AR with the top three value of M_W is shortlisted and named as nominated AR.

Prospective AR: Any AR that is detected by the MN and reported to the previous Access Router (pAR) is called prospective AR.

Candidate AR: The AR that is selected from the list of nominee ARs as the MN's next point of attachment.

Case: During each phase of experiments, the protocols are studied in the presence of each traffic class as a separate case.

Scenario: As defined in the context, a scenario is referred to a phase of experiments where various cases with similar system parameters are investigated.

Distinguishing level: Defined as the difference between the best and the worst values of weighted mean (M_W) obtained for each AR.