UNIVERSITI PUTRA MALAYSIA

SCALABILITY IMPROVEMENT OF MULTICAST SOURCE MOVEMENT OVER MOBILE IPv6 USING CLUSTERING TECHNIQUE

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By

SAHAR A. M. ALI AL-TALIB

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

November 2006

Dedicated to

The memory of my father

And to my mother,

For their unconditional love and support throughout my life

To my husband and
my beloved children,
Shaymaa, Zainab, Rashad, Safa, and Abdullah

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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Chairman: Professor Borhanuddin Mohd. Ali, PhD

Faculty: Engineering

Mobile IPv6 (MIPv6) describes how a mobile node can change its point of attachment to the Internet. While MIPv6 focuses on unicast communications, it also proposes two basic mechanisms, known as bi-directional tunnelling and remote subscription, to handle multicast communications with mobile members. In the mean time, the deployment of Source-Specific Multicast (SSM) is of great interest, using the Protocol Independent Multicast-Sparse Mode (PIM-SM) and Multicast Listener Discovery (MLDv2) protocols. In the particular case of mobile IPv6 SSM sources, the mechanism proposed in MIPv6 to support multicast communications introduced a number of problems that need to be addressed. First, in most scenarios the MIPv6 solution leads to suboptimal routing by setting up a tunnel to forward packets between the home agent in its home network and the current location in the foreign network. The use of a third party when roaming which is the home agent leads to suboptimal routing. Second, it introduces a central point of failure (i.e. the Home Agent (HA)) that is not to be neglected. The proposed MIPv6 solution also induces a great traffic concentration around this central

point. Third, the processing task of the central point increases with the number of mobile sources it serves, thus reducing the efficiency of multicast delivery. The objective of this thesis is to remove some of the obstacles encountered in the way of multicast deployment in the Internet, thereby making Mobile IPv6 better equipped to support mobile SSM sources.

Recent proposals to provide multicasting over mobile IP focuses mainly on recipient mobility but little attention has been given to the case of source mobility. This thesis attempts to address this problem. The basic essence of the problem is that while the effect of receiver movement on the multicast tree is local, the effect of source movement may be global and it may affect the complete multicast delivery tree. The initial design was motivated by the need to support one-to-many and many-to-many applications in a scalable fashion. Such applications cannot be serviced efficiently with unicast delivery.

As the overall problem statement of "Scalability Improvement of Multicast Source Movement over IPv6 Using Clustering Technique" is extremely complex, we divide the problem into the following components: build the multicast delivery tree for source specific multicast which is a routing issue; clustering receivers based on their IPv6 addresses; improve the state scalability of these clusters which is a deployment issue; find an efficient way for service distribution which is a deployment issue as well; and finally, the seamless integration of the work with Mobile IPv6 allowing it to support multicast efficiently for mobile nodes. The combined solution provides a comprehensive procedure for planning and managing a multicast-based IPv6 network.

The outcome of this thesis are: a software to represent an architecture of a multicast delivery tree for one-to-many type of group communication, a group management scheme that could handle the end nodes subscription/un-subscription process with the

required updates, an average subscription delay of between 0.255 ms-0.530 ms and un-subscription delay of between 0.0456 ms-0.087 ms for up to 50000 nodes, an approach to multicast forwarding state reduction that could support small-size groups as well as large-size groups, and finally the integration of the work with Mobile IPv6 to handle the multicast source movement.

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

PENAMBAHBAIKAN KEBOLEHSKALAAN PERGERAKAN SUMBER BERBILANG SIAR DI ATAS IPv6 BERGERAK MENGGUNAKAN TEKNIK PENGGUGUSAN

Oleh

SAHAR A. M. ALI Al-TALIB

November 2006

Pengerusi : Profesor Borhanuddin Mohd Ali, PhD

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IPv6 bergerak (MIPv6) memerihalkan bagaimana satu nod bergerak boleh berubah titik penyambungannya pada Internet. Sementara MIPv6 menfokuskan kepada komunikasi siaran-sehala, ia juga mencadangkan dua mekanisma asas, dikenali sebagai penerowongan dwi-hala dan pelangganan jauh, untuk mengendali komunikasi berbilang siar dengan ahli-ahli bergerak. Dalam masa yang sama, penggunaan sumber khusus siaran-berbilang (SSM) menjadi keutamaan, dengan menggunakan Mod Jarang- Protokol berbilang siar Bebas, mod Jarang (PIM-SM) dan Protokol Penemuan Pendengar Berbilang Siar (MLDv2) . Dalam kes sumber-sumber IPv6 bergerak SSM yang tertentu, mekanisma yang dicadangkan dalam MIPv6 untuk menyokong komunikasi berbilang siar telah menimbulkan beberapa masalah untuk diselesaikan. Pertama, dalam kebanyakan senario, penyelesaian MIPv6 menuju kepada laluan sub-optimum dengan menetapkan satu terowong untuk menghalakan paket antara agen perumah dalam rangkaian perumahnya dan lokasi terkini di dalam rangkaian luar. Penggunaan pihak ketiga dalam

masa perantauan iaitu agen perumah mengakibattan laluan sub-optimum. Kedua, ia menimbulkan satu titik pusat kegagalan (contoh. Agen Perumah (HA)) yang tidak dapat diabaikan. Penyelesaian MIPv6 yang dicadangkan juga menyebabkan satu pemusatan trafik yang besar di sekitar titik pusat ini. Ketiga, tugas proses untuk titik pusat ini bertambah mengikut bilangan sumber bergerak yang diberi perkhidmatan, sekaligus menurunkan kecekapan penghantaran berbilang siar. Tujuan tesis ini adalah untuk mengatasi sebahagian dari halangan yang ditembungi dalam perjalanan penggunaan berbilang siar dalam Internet, sekaligus membuatkan MIPv6 menjadi lebih baik untuk menyokong sumber SSM bergerak.

Cadangan mutakhir untuk menawarkan berbilang siar ke atas IP bergerak memfokus khususnya kepada penerima bergerak namun tumpuan yang sedikit telah diberikan untuk kes sumber pergerakan. Tesis ini cuba menyelesaikan masalah ini. Masalah asas yang penting adalah walaupun kesan daripada pergerakan penerima terhadap pokok siaran-berbilang ialah berbentuk tempatan, kesan daripada sumber pergerakan mungkin adalah sejagat dan ia mungkin menjejaskan penghantaran pokok siaran-berbilang sepenuhnya. Rekabentuk awal adalah dimotivasikan oleh keperluan menyokong aplikasi-aplikasi satu-ke-banyak dan banyak- ke-banyak dalam kaedah bolehskala. Aplikasi-aplikasi begini tidak boleh dilayan dengan berkesan oleh penghantaran siaran-sehala.

Oleh kerana keseluruhan penyataan masalah ”Pengendalian pergerakan sumber berbilang-siar pada IPv6 bergerak” adalah sangat kompleks, kami bahagikan masalah ini kepada komponen-komponen tertentu berikut: membina pokok penghantaran berbilang siar untuk sumber berbilang siar khas iaitu satu isu penghalaan; penggugusan penerima-penerima mengikut alamat-alamat IPv6nya; meningkatkan keadaan kebolehskalaan dari

gugusan-gugusan ini iaitu satu isu penggunaan; mencari satu langkah yang berkesan untuk penyebaran khidmat yang juga menjadi satu isu penggunaan; dan akhir sekali, kerja integrasi yang tidak berkelim untuk MIPv6 membolehkannya menyokong siaran-berbilang dengan berkesan untuk nod-nod bergerak. Gabungan penyelesaian tersebut menyediakan satu prosedur komprehensive untuk merancang dan mengurus rangkaian IPv6, berasaskan berbilang siaran.

Hasil-hasil daripada tesis ini ialah: satu perisian yang mewakili satu seni bina pohon penghantaran siaran-berbilang untuk komunikasi kumpulan jenis satu-ke-banyak; satu skim pengurusan kumpulan yang boleh mengendalikan proses langganan/nyah-langganan yang terakhir dengan kemas kini yang di perlukan; satu purata kelengah langganan antara 0.255 ms-0.530 ms dan kelengah tak langganan antara 0.0456 ms-0.087 ms untuk sehingga 50000 nod; satu pendekatan untuk mengurangkan jadual penghalaan berbilang siar yang boleh menyokong kumpulan-kumpulan saiz kecil dan juga kumpulan-kumpulan saiz besar; dan akhirsekali integrasi dengan MIPv6 untuk mengendalikan pergerakan sumber berbilang siar.

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My path would have been completely different if not for such positive research.

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I certify that an Examination Committee met on 27th November 2006 to conduct the final examination of Sahar A. M. Ali Al-Talib on her Doctor of Philosophy thesis entitled "Handling Multicast Source Movement over Mobile IPv6" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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This thesis 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 are as follows:

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Date: 8 FEBRUARY 2007

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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SAHAR A. M. ALI AL-TALIB

Date: 16/1/2007

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LIST OF ABBREVIATIONS

AAP	Address Allocation Protocol
AGCS	Alternative Group Communication Service
AS	Autonomous Systems
ASM	Any Source Multicast
BGMP	Border Gateway Multicast Protocol
BGP	Border Gateway Protocol
BT	Bi-directional Tunnelling
BU	Binding Update
CBT	Core-based Tree
CoA	Care-of Address
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name System
DVMRP	Data Vector Multicast Routing Protocol
EIGRP	Enhanced Interior Gateway Routing Protocol
ESP	Encryption Security Payload
EXPRESS	EXPlicitly REquested Single Source
GLOP	GLOP Addressing in 233/8
HA	Home Agent
HoA	Home Address
HIP	Hierarchical Multicast Routing Protocol
IANA	Internet Assigned Numbers Authority
ICMP	Internet Control Message Protocol

IETF	Internet Engineering Task Force
IGMP	Internet Group Management Protocol
IM	Instant Messaging
IP	Internet Protocol
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
LGM	Large Group Multicast
MA	Multicast Agent
MAAA	Multicast Address Allocation Architecture
MADCAP	Multicast Address Dynamic Client Allocation Protocol
MASC	Multicast Address Set Claim
MBGP	Multiprotocol Border Gateway Protocol
MBone	Multicast Backbone
MCT	Multicast Control Table
MFT	Multicast Forwarding Table
MLD	Multicast Listener Discovery
MN	Mobile Node
MOSPF	Multicast Extensions to Open Shortest Path First
MSC	Multicast Small Conference
MSDP	Multicast Source Discovery Protocol
OCBT	Ordered Core Based Tree
OM	Overlay Multicast
OSPF	Open Shortest Path First
PIM	Protocol Independent Multicast

PIM-DM	Protocol Independent Multicast - Dense Mode
PIM-SM	Protocol Independent Multicast – Sparse Mode
RIP	Routing Information Protocol
RP	RendezVous Point
RPF	Reverse Path Forwarding
RS	Remote Subscription
RTCP	Real Time Transport Control Protocol
RTP	Real Time Protocol
SAP	Session Announcement Protocol
SDP	Session Description Protocol
SGM	Small Group Multicast
SIM	Sender Initiated Multicast
SPT	Shortest-Path Tree
SSM	Source Specific Multicast
TCP	Transmission Control Protocol
UDP	User Datagram Protocol

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