UNIVERSITI PUTRA MALAYSIA

AN ENHANCED IPv6 ANYCAST ROUTING PROTOCOL USING PROTOCOL INDEPENDENT MULTICAST-SPARSE MODE WITH MOBILE IPv6

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By

AUS M. SULAIMAN

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

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Dedicated to

My dearest mother

For her extraordinary love and her kindness

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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Chairman: Professor Borhanuddin Mohd. Ali, PhD

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Anycast routing is an efficient routing mechanism that enables the network to choose the nearest and most appropriate server very quickly. However, IPv6 Anycast is not used widely in practice yet, and there are many reasons for this. Firstly, IPv6 Anycast does not have its own standard protocol because anycast builds its anycast membership tree like multicast does but unlike multicast it sends only to one of the groups using unicast mechanism. The other problem is that IPv6 Anycast mechanism could not provide stateful connections between the sender and the receiver because the sender always change the receiver based on the metric or the distance. In this thesis a new IPv6 anycast routing protocol is developed to provide a stateful communication between the anycast sender and the receiver. Protocol Independent Multicast-Sparse Mode (PIM-SM) has been chosen to establish the new IPv6 anycast mechanism because of many similar properties between multicast and anycast. A new variable is proposed in the routing table called Best Metric Factor (BMF) to describe the status of the receiver (free or Busy). This factor is used to decide the appropriate receiver to choose, the advantage of

the proposed design can be observed easily when there are multi-anycast senders sending their traffic to the appropriate receiver at the same time. Next we improve the mechanism by building a direct connection between the anycast sender and the anycast receiver using route optimization by mapping the objects in Mobile IPv6 to the objects in the proposed mechanism. This is because there are many similar properties between Mobile IPv6 and the proposed design. The proposed mechanism has been shown to achieve a good performance with multi-anycast senders and can provide a stateful communication between the sender and the appropriate receiver.

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

SUATU PROTOKOL PENGHALAAN ANYCAST IPv6 YANG DITINGKATKAN MENGGUNAKAN PROTOKOL MULTICAST MOD JARANG BEBAS DENGAN IPv6 BERGERAK

Oleh

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Penghalaan anycast adalah satu mekanisme penghalaan berkesan yang membolehkan rangkaian memilih pelayan yang terdekat dan bersesuaian dengan cepat. Walau bagaimanapun Anycast IPv6 belum lagi digunakan dengan meluas dan terdapat beberapa perkara yang menyebabkannya. Pertama, Anycast IPv6 tidak mempunyai piawaiannya sendiri kerana anycast membina pohon keahlian anycast seperti pohon multicast juga, tetapi berbeza dengan multicast, ia menghantar kepada salah satu dari kumpulan menggunakan mekanisme unicast. Masalah lain ia lah mekanisme anycast IPv6 tidak mampu menyediakan sambungan “stateful”, di antara penghantar dan penerima kerana penghantar sentiasa menukar penerima berdasarkan pengukuran atau jarak. Dalam tesis ini satu protokol anycast yang baru telah dibangunkan yang menyediakan komunikasi “stateful” di antara penghantar anycast dan penerima. Protokol Multicast Bebas-Mod Jarang (PIM-SM) telah dipilih untuk membentuk mekanisme baru IPv6 anycast kerana banyak ciri ciri serupa. Suatu pembolehubah

adalah dicadangkan dalam jadual penghalaan yang dipanggil sebagai Faktor Pengukuran Terbaik (BMF) untuk memerihalkan status penerima (lapang atau sibuk). Faktor ini digunakan untuk memutuskan penerima yang paling sesuai untuk dipilih; kelebihan rekabentuk yang dicadangkan boleh dilihat dengan mudah bila terdapat beberapa penghantar anycast menghantar trafik mereka kepada penerima yang bersesuaian pada masa yang sama. Seterusnya, kami menambahbaikkan mekanisme dengan membina sambungan langsung di antara penghantar dan penerima anycast menggunakan pengoptimuman halaan dengan memetakan objek dalam IPv6 Bergerak kepada objek dalam mekanisme cadangan ini. Ini adalah kerana terdapat beberapa ciri yang serupa di antara IPv6 bergerak dan rekabentuk cadangan ini. Mekanisme cadangan ini telah ditunjukkan mencapai prestasi yang baik dengan penghantar anycast berbilang dan memberikan komunikasi “stateful” di antara penghantar dan penerima yang bersesuaian.

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Finally, I want to say thank you to my family for their support and guidance to reach this point, without them I cannot be in the same position now. Thank you my beloved family.

I certify that an Examination Committee has met on to conduct the final examination of Aus M. Sulaiman on his Master of Science thesis entitled "An Enhanced IPv6 Anycast Routing Protocol Using Protocol Independent Multicast-Sparse mode (PIM-SM) with Mobile IPv6 (MIPv6) " 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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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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AUS M. SULAIMAN

Date: 7 FEBRUARY 2008

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LIST OF ABBREVIATIONS

AA	Anycast Address
ACK	Acknowledgement
AH	Authentication Header
AR	Anycast Receiver
AS	Anycast Sender
AS	Autonomous system
ASM	Any Source Multicast
BGP	Border Gateway Protocol
BMF	Best Metric Factor
BSR	Bootstrap Router
BU	Binding Update message
CBT	Core Based Tree
CN	Correspondent Node
CoA	Care of Address
C-RP	Candidate RP
DAD	Duplicate Address Detection
DHAAD	Dynamic Home Agent Address Discovery
DNS	Domain Name Service
DR	Designated Router
DVMRP	Distance Vector Multicast Routing Protocol
EIGRP	Enhanced Interior Gateway Routing Protocol
ESP	Encapsulation Security Payload

FA	Foreign Agent
GIA	Global IP Anycast
HA	Home Agent
HBMF	Highest Best Metric Factor
HoA	Home Address
ICMP	Internet Control Message Protocol
ICMPv6	Internet Control Message Protocol for IPv6
ICMPv6	Internet Control Message Protocol for IPv6
IDMR	Inter-Domain Multicast Routing
IETF	Internet Engineering Task Force
IGMP	Internet Group Message protocol
IGMPv3	Internet Group Message protocol version 3
IP	Internet Protocol
IPng	IP next generation
IPv4	Internet Protocol version 4
IPv6	Internet Protocol version 6
ISP	Internet Service Provider
LBMF	Lowest Best Metric Factor
LSA	Link State Advertisement
MGA	Mobile IPv6-based IPv6 Global Anycast
MIPv6	Mobile IPv6
MLD	Multicast Listener Discovery
MLDv2	Multicast Listener Discovery version 2
MN	Mobile Node

MOSPF	Multicast Open Shortest Path First
MTU	Maximum Transfer Unit
NAT	Network Address Translation
ND	Neighbour Discovery
NS	Network Simulator
NS-2.28	Network Simulator version 2.28
OSPF	Open shortest Path Forward
P2P	Peer to Peer
PIA-SM	Protocol Independent Anycast-Sparse Mode
PIM	Protocol Independent Multicast
PIM-DM	Protocol Independent Multicast-Dense Mode
PIM-SM	Protocol Independent Multicast-Sparse Mode
PIM-SMv2	Protocol Independent Multicast-Sparse Mode version 2
QoS	Quality of Service
RP	Rendezvous Point
RPF	Reserve Path Forwarding
SPT	Shortest Path Tree
SR	Sender Router
TCL	Tool Command Language
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
WAN	Wide Area Network

CHAPTER 1

INTRODUCTION

IPv6 supports a new routing protocol called “anycast”, in addition to unicast, and multicast. Anycast routing protocol allows a node to receive the services fast by choosing the closest server [10]. Anycast routing protocol delivers anycast packets to the “nearest” node in an anycast group. The “nearest node” is determined according to the routing protocol’s measure of distance. New features accompanied in IPv6 such as “neighbour discovery” and “autoconfiguration” give more flexibility to use anycast routing protocol.

The rapid growth of wireless communications increases the node movements in the global area network, this movement gives rise to the need to find a new mechanism which provides the mobile nodes with services from the nearest server. A mobile ad hoc is a network architecture that can rapidly be deployed without relying on pre-existing fixed network infrastructure; therefore it can further improve the robustness of ad hoc networks to use anycast services in a highly dynamic topology environment. Anycast also enables a generalization of services; this is achieved by identifying a well-known anycast address to the global services such as Domain Name Service (DNS) or proxy servers. Anycast routing protocol has yet to be set as a standard protocol and research on developing anycast mechanism is still ongoing.

1.1 IPv6 Motivations

IPv6 introduces many special features which encourage researchers and developers to take advantage of, some of these appeared in RFC 2460 [1];

- Address expansion: The IP address size increases from 32 bits in IPv4 to 128 bits in IPv6 to increase the hierarchy addressing levels in the Internet.

- Header Format simplifications: Dropped some IPv4 headers to keep the link bandwidth usage within the minimum value.

- Support Mobility: IPv6 is designed to support mobility by modifying new functions such as IPv6 Neighbour Discovery (ND)[2] and Address Autoconfiguration [3], which allow hosts to operate in any location without any special support.

- Fixed format of all headers type: The fixed formats of all header types make the routers handle the IPv6 packets easily.

- Remove checksum header: This simplifies the computations needed in the router. The application will be responsible of handling this functionality.

- No hop-by-hop segmentation: This mean the sender must check the path Maximum Transfer Unit (MTU) before beginning the transmission. The router ignores the big size packet; also this simplifies the computation in the routers.

- Support the routing mechanisms: IPv6 defined the multicast address and make the multicast address independent of location and unique from normal unicast address. Besides defining some features supporting anycasting such as neighbour discovery and autoconfiguration, anycast is still not widely used.

- Improve the security: by adding two compulsory headers, Authentication Header (AH) [4] and Encapsulation Security Payload (ESP) [5].

- Support the Quality of Service (QoS): there are two fields in the IPv6 header to improve the QoS in the routers; they are the traffic class label, which is useful in real time applications, and the flow label to support multiple real time flows from the same user. Flow label is 20-bit in the packet header. It is randomly set to a value between 1 and FFFFF hex. It is used by routers to make a fast decision by checking in a hash table how the routers should handle this particular packet. It should be set to zero in packets that do not belong to a flow.

1.2 IPv6 Anycast Motivation

Although anycast mechanism is one of the most suitable mechanisms to choose the closest receiver, anycast is still not widely used in global network. This is because recent studies are still not sufficient and there is no such test bed readily available. This thesis proposes a new IPv6 anycast mechanism by deploying the existing multicast routing protocol directly. NS-2.28 has been used to build the simulation for IPv6 anycast routing protocol environment. From the literature the anycast routing protocols have been proposed to be

suitable for limited network topology. PIM-SM [6,7,8] is chosen in this thesis to build a new anycast mechanism because it scales well. The reason is that PIM-SM does not flood the multicast traffic to other non-member groups therefore the proposed anycast mechanism in this thesis will not succumb to an overload of multicast traffic. Additionally, the proposed mechanism deals with another issue, when we have more than one anycast sender trying to access the closest receiver at the same time.

Also the anycast mechanism alluded to above have difficulty in providing a stateful communication between the anycast sender and the closest receiver; this is because the receiver change very often since anycast sender always try to send to the best receiver based on a metric (the metric is based on distance or load over the receiver). Therefore the sender may send the first packet to a receiver and sends the following packet to another receiver based on the metric status. The design proposed in this thesis provides a stateful communication between the sender and the receiver; this is done by adopting the idea of route optimization, which is a new function in Mobile IPv6.

1.3 Problem Statement

Many researchers try to come out with suitable solutions to be adopted as the standard protocol to implement IPv6 anycast mechanism, since as highlighted earlier, IPv6 anycast is still not standardized yet. This happens because of two reasons; first the anycast address is indistinguishable from unicast address therefore the routers cannot recognize the anycast

address, second the anycast mechanism builds its anycast group like multicast protocol but send the packets to only one node from this group like unicast protocol.

In this thesis, a new IPv6 anycast mechanism is proposed to give a scalable implementation for anycasting in global area network and alleviate the overloading problem which can happen in the best receiver (closest receiver) when there are multiple anycast senders sending their traffic simultaneously.

Another problem is the stateless connection between the sender and the receiver because the sender always changes the transmission destination based on the metric of the receiver.

The proposed design also tackles the problem of the stateless communication between the sender and the receiver because stateful communication is very important in video or voice transmission which uses Transmission Control Protocol (TCP).

One of the most important issues is reliability; the network is vulnerable to the failure of the anycast router which is the node that routes the anycast traffic from anycast senders to the receivers. If a failure happens to this router, all the anycast traffic will fail in the network. The proposed stateful communication between the sender and the receiver increases reliability by building a direct connection between the sender and receiver and limit the role of anycast router in the network. Therefore the proposed mechanism can be considered as a solution to the most important problems in anycasting.