UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF A RELIABLE MULTICAST PROTOCOL IN MOBILE AD HOC NETWORKS

TARIQ ABDULLAH AHMAD ALAHDAL

DEVELOPMENT OF A RELIABLE MULTICAST PROTOCOL IN MOBILE AD HOC NETWORKS

TARIQ ABDULLAH AHMAD AL-AHDAL

DOCTOR OF PHILOSOPHY
UNIVERSITI PUTRA MALAYSIA
2008

DEVELOPMENT OF A RELIABLE MULTICAST PROTOCOL IN MOBILE AD HOC NETWORKS

BY

TARIQ ABDULLAH AHMAD ALAHDAL

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

October 2008

Dedicated to my Parents,

to my wife and

my kids; Hadeel, Mohammed, Abdullah

and to my family.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy

DEVELOPMENT OF A RELIABLE MULTICAST PROTOCOL IN MOBILE AD HOC NETWORKS

BY

TARIQ A. A. ALAHDAL

October 2008

Chair: Shamala Subramaniam, PhD

Faculty: Computer Science and Information Technology

Mobile ad hoc network is a collection of mobile nodes forming dynamic and temporary network. The mobile nodes work in collaborative nature to carry out a given task. It can receive and transmit data packets without the use of any existing network infrastructure or centralized administration. Multicasting is among the pertinent issues of communication in such networks. The reliable delivery of multicast data packets needs feedback from all multicast receivers to indicate whether a retransmission is necessary. The Feedback Implosion Problem (FIP) states that reliable multicast in ad hoc networks suffers from redundant feedback packets, loss, duplication, and out-of-order delivery of data packets. To carry out this task, several reliable multicast protocols have been proposed to reduce the number of feedback packets from the receiver nodes. This is achieved by placing the responsibility to detect packet loss and initiating loss recovery timer on the receiver nodes which is complemented by feedback suppression. The initiating loss recovery timer depends on the number of hops between the nodes. As the dynamic nature of the number of hops between the nodes in ad hoc networks is unstable the loss

recovery timer become inaccurate. Thus, the inaccuracy of the loss recovery timer, in return, causes extra overhead and more delays. The main objectives of this research are to enhance the FIP and decrease the recovery delays in reliable multicast protocol for mobile ad hoc networks using suggested approaches. First, the Source Tree Reliable Multicast (STRM) protocol adopting a novel technique to select a subset of one-hop neighbors from the sender node as its Forward Servers (FS). The key idea behind selecting this subset one-hop neighbors is to forward the retransmitted lost data packets and to receive the feedback packets from the receiver nodes. Second, proposed two algorithms to improve the performance of the STRM protocol. The first algorithm is developed to avoid the buffer overflow in the FS nodes. This is achieved by managing the buffer of the FS nodes; by selecting the FS nodes depending on the empty buffer size it has and reducing the amount of feedback sent from the receiver nodes to their FS node. The second algorithm is developed to decrease the number of duplicated packets in the multicast members in the local group. This is achieved by sending the repair packets only to the member that has requested it. The FS in the local group should create a dynamic and temporary sub group whose members are only the members that requested the retransmission of the repair packet. The approaches were tested using detailed discrete-event simulation model which was developed encompassing messaging system that includes error, delay and mobility models to characterize the performance benefits of the proposed algorithms in comparison to ReMHoc protocol. Our approaches achieve up to 2.19% improvement on average packet delivery ratio, 3.3% on requested packets, and 46% on recovery latency time without incurring any additional communication or intense computation.

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

PEMBANGUNAN PROTOKOL BERBILANGSIARAN BOLEHPERCAYA DALAM RANGKAIAN AD HOC BERGERAK

OLEH

TARIQ A. A. ALAHDAL

October 2008

Pengerusi: Shamala Subramaniam, PhD

Fakulti: Sains Komputer dan Teknologi Maklumat

Rangkaian ad hoc bergerak adalah satu gugusan nod bergerak yang membentuk rangkaian dinamik dan sementara. Nod nod bergerak tersebut bekerja dalam bentuk bekerjasama untuk menjalankan satu satu tugasan. Ia boleh menerima dan menghantar paket data tanpa menggunakan apa apa prasarana rangkaian yang ada atau pengurusan terpusat. Penyiaran berbilang adalah salah satu isu penting komunikasi dalam rangkaian sebegitu. Penghantaran paket data berbilang siar yang bolehdipercaya memerlukan suapbalik dari kesemua penerima berbilansiar untuk menunjukkan sama ada penghantaran semula adalah diperlukan. Masalah Implosi Suapbalik (FIP) menyatakan bahawa siaranberbilang yang bolehdipercayai dalam rangkaian ad hoc merana dari paket suapbalik berlebihan, kehilangan, duplikasi, dan penghantaran paket data yang tidak mengikut urutan. Untuk menjalankan tugasan ini, beberapa protokol berbilangsiaran bolehpercaya telah dicadangkan untuk mengurangkan bilangan paket suapbalik dari nod nod penerima. Ini dicapai dengan meletakkan tanggungjawab untuk mengesan kehilangan paket dan mencetuskan pemasa pemulihan kehilangan kepada nod nod penerima yang dilengkapi dengan

penyekatan suapbalik. Pemasa pemulaan pemulihan kehilangan bergantung kepada bilangan lumpatan di antara nod nod. Olehkerana sifat dinamik bilangan lumpatan di antara nod dalam rangkaian ad hoc adalah tidak stabil pemasa pemulihan kehilangan menjadi tidak tepat. Oleh itu, ketidaktepatan pemasa pemulihan kehilangan, sebagai balasan, menyebabkan overhed tambahan dan banyak lagi lengah. Objektif utama penyelidikan ini adalah untuk meningkatkan FIP dan mengurangkan kelengahan pemulihan dalam protokol berbilangsiaran bolehpercaya. Pertama, protokol Berbilangsiaran Bolehpercaya Pohon Sumber (STRM) mengambil teknik baru untuk memilih satu subset kepada jiran satu-lumpatan dari nod penghantar sebagai pelayan penghantar (FS). Idea utama di sebalik memillih subset jiran satu-lumpatan ialah untuk memajukan paket data hilang yang dihantarsemula dan untuk menerima paket suapbalik dari nod nod penerima. Kedua, mencadangkan dua algoritma untuk menambahbaik prestasi protokol STRM. Algoritma pertama telah dibangunkan untuk mengelakkan limpahan penimbal dalam nod nod FS. Ini dicapai dengan mengurus penimbal nod nod FS; dengan memilih nod nod FS bergantung kepada saiz penimbal yang kosong dan mengurangkan jumlah suapbalik yang dihantar dari nod nod penerima kepada nod FS. Algoritma kedua dibangunkan untuk mengurangkan bilangan paket duplikat dalam ahli berbilangsiaran dalam kumpulan tempatan. Ini dicapai dengan menghantar paket baikpulih hanya kepada ahli yang memohonnya. FS dalam kumpulan tempatan sepatutnya mencipta suatu sub kumpulan dinamik dan sementara yang mana ahli ahli mereka adalah ahli yang memohon penghantaran semula paket pembaikpulihan. Pendekatan tersebut telah diuji mengguna model simulasi acara-diskrit yang terperinci yang telah dibangunkan merangkumi sistem risalah yang mencakupi model ralat, lengah dan pergerakan untuk mencirikan manafaat prestasi algorithma cadangan berbanding dengan

protocol ReMHoc. Pendekatan kaimi mencapai sehingga 2.19% penambaikan pada nisbah penghantaran paket purata, 3.3% pada paket yang dipohon, dan 46% masa pendam pemulihan tanpa dikenakan apa apa komunikasi tambahan atau pengkomputeran yang amat sangat.

ACKNOWLEDGEMENTS

First of all, Alhamdullilah and thanks to Allah (s.w.t) for blessing me with health, strength and determinations, also for giving me the opportunity, the patient and perseverance to successfully complete this PhD Thesis.

Secondly, I wish to express my deepest gratitude to my advisor Dr. Shamala Subramaniam for her guidance, understanding and patience throughout my graduate study. I would like to thank Assoc. Prof. Dr. Mohamed Othman and Dr. Zuriati Zukarnain for their valuable comments and time in reviewing this thesis as my committee members. I owe thanks to university library, administrators and members of Faculty of Computer Science and Information Technology of the University Putra Malaysia for the high-class research, education and living facilities provided in such wonderful campus environment.

Finally, I am grateful to my parents, brothers, sisters and my wife for their continuous love and support during my entire life. I was fortunate to have such great to all my friends for their help and encouragement.

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:

Shamala K. Subramaniam, PhD
Faculty of Computer Science and Information Technology
Universiti Putra Malaysia
(Chairman)

Mohamed Othman, PhD
Associate Professor
Faculty of Computer Science and Information Technology
Universiti Putra Malaysia
(Member)

Zuriati Ahmad Zukarnin, PhD
Faculty of Computer Science and Information Technology
Universiti Putra Malaysia
(Member)

HASANAH MOHD. GHAZALI, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date : **15 January 2009**

DECLARATION

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

_____

TARIQ A. A. ALAHDAL

Date : **November 2008**

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

ACK	Acknowledgement
ADMR	Adaptive Demand-driven Multicast Routing protocol
AG	Anonymous Gossip
BF	Buffer Fullness
BMP	Bimodal Multicast Protocol
CAMP	Core Assisted Mesh Protocol
DSR	Dynamic Source Routing
FAT	Family ACK Tree
FG	Forwarding Group
FG_FLAG	Forwarding Group Flag
FGMP	Forwarding Group Multicast Protocol
FIFO	First In First Out
FIP	Feedback Implosion Problem
FS	Forward Server
FSL	Forward Server List
HB	Heartbeat
IEEE	Institute of Electrical and Electronics Engineers
LRU	Least Recently Used
MANET	Mobile Ad-hoc Network
MAODV	Multicast Ad-hoc On-Demand Distance Vector
MobiHoc	Mobile Ad-hoc Networking and Computing
MZR	Multicast Zone Routing protocol
NAK	Negative Acknowledgement
NSMP	Neighbor Supporting Multicast Protocol
NS-2	Network Simulator-2
OACK	Ordered ACK buffer management algorithm
ODMRP	On-Demand Multicast Routing Protocol

PSB	Pure Sender-Based
PIDIS	Protocol-Independent Packet Delivery Improvement Service
QoS	Quality of Service
RALM	Reliable Adaptive Lightweight Multicast Protocol
RDG	Route Driven Gossip
ReAct	Reliable Adaptive Congestion-Controlled Ad-hoc Multicast Transport Protocol
ReMHoc	Reliable Multicast Protocol for Wireless Mobile Multi-hop Ad-hoc Networks
RMA	Reliable Multicast Algorithm
RMTP	Reliable Multicast Transport Protocol
RREP	Route Reply
RREQ	Route Request
RRMP	Randomized Reliable Multicast Protocol
RWM	Random Waypoint Mobility
SFSP	Selection Forward Server Process
STRM	Source Tree Reliable Multicast
SSC	Sub Sub-Casting
SSC-I	Improvement Sub Sub-Casting
STL	Steps-To-Live
STRM	Source Tree Reliable Multicast protocol
TCP	Transmission Control Protocol
WLAN	Wireless Local Area Network

LIST OF PUBLICATIONS

A. JOURNALS:

1. T.Alahdal, S.Shamala, M.Othman and Z.Zukarnain, 2008. A Source Tree Reliable Multicast Protocol for Ad-Hoc Networks (STRM). *International Arab Journal of Information Technology*, vol. 5, no. 3, July 2008, pp. 273-280.

2. T.Alahdal, S.Shamala, M.Othman and Z.Zukarnain, 2008. Forward Server Error Recovery Algorithm for Reliable Multicast in Ad-hoc Networks using Sub Sub-Casting Algorithm. *Accepted at International Journal of Soft Computing Applications, EUROJOURNALS, 2008.*

3. T.Alahdal, S.Shamala, M.Othman and Z.Zukarnain, 2008. A Simulation Engine Model Analysis for Reliable Multicast Protocol in Ad-hoc Network. *International Journal of Computer Science and Network Security*, vol. 8, no. 5, pp. 1-10.

B. CONFERENCES:

1. T.Alahdal, S.Shamala, M.Othman, Z.Zukarnain, 2006. A Simulation Tool for Reliable Multicast Transport Protocol Analysis in Ad-Hoc Network. *In the proceeding of International Conference on Advanced Technologies in Telecommunication and Control Engineering (ATTCE2006),* 28th-29th August 2006, INTI College Malaysia, Nilai, Malaysia, vol. 1, no. 1, pp. 73.

2. T.Alahdal, S.Shamala, M.Othman and Z.Zukarnain, 2007. Source Tree Reliable Multicast Protocol for MANET. *In proceeding of the National Conference on Computer Science & Information Technology VII SNIKTI 2007*, 29-30 January, Depok, Indonesia, vol. 1, no. 1, pp. 60-65.

3. T.Alahdal, S.Shamala, M.Othman and Z.Zukarnain, 2007. An Adaptive Reliable Multicast Protocol in Ad-hoc Networks. *In the Proceeding of the 14th IEEE International Conference on Telecommunications (ICT07) and 8th IEEE Malaysia International Conference on Communications (MICC07),* 14th-17th May, Penang, Malaysia, pp. 68-74.

C. MANUSCRIPTS:

1. T.Alahdal, S.Shamala, M.Othman and Z.Zukarnain, 2008. Ordered Buffer Management Algorithm for Forward Nodes in Reliable Multicast Ad-hoc Networks. *Submitted to International Journal of Electronics and Telecommunications Research Institute.*
2. T.Alahdal, S.Shamala, M.Othman and Z.Zukarnain, 2008. Tree-based Reliable Multicast Protocol for Ad-Hoc Networks. *Submitted to International Journal of Wireless Information Networks Springer Link.*
3. T.Alahdal, S.Shamala, M.Othman and Z.Zukarnain, 2008. Forward Server Error Recovery Enhancement Algorithm for Reliable Multicast in Ad-hoc Networks. *Submitted to International Journal of Engineering Simulation.*

CHAPTER 1

INTRODUCTION

There has always been growing interest and progress in the field of wireless networks. Users are able to stay connected anywhere, anytime and move freely while maintaining reliability and high-speed network connectivity. The development of high bandwidth low power communications technologies and standards such as IEEE 802.11 (IEEE, 1997) has removed barriers found in wired data communication. IEEE 802.11 has made it possible for the existing wired local area networks to be replaced with Wireless Local Area Networks (WLANs). These WLANs are composed of base stations that form cells of coverage and provide a fixed infrastructure without the need for fixed points of access. Thus, users can migrate between cells while maintaining connectivity with the network. However, there are situations where it may not be possible or feasible to have or to build an infrastructure due to fire, earth-quick, or other natural catastrophe (Milanovic *et al.,* 2004).

Mobile Ad Hoc Network (MANET) is a wireless communication that allows its nodes to communicate without the existence of an infrastructure. The nodes can receive and transmit data packets in an ad hoc manner without a base station. More importantly, nodes can act as routers hence they route packets between source and destination nodes which are outside transmission range of each other (Corson and Macker, 1999; Wu and Stojmenovic, 2004).

However, nodes are constrained by the battery power of the mobile devices. In addition, wireless connectivity is constructed between the nodes are limited by transmission range, signal attenuation, interference and terrain. Nodes have varying degrees of mobility; they can move into or out of range of other nodes in MANET. Therefore, they change the ad hoc network topology dynamically. Thus, ad hoc networks are characterized by a dynamic topology, high error rates, low bandwidth, and intermittent connectivity (Broch *et al.,* 1998; Corson and Macker, 1999; Chlamtac *et al.,* 2003; Murthy and Manoj, 2004).

1.1 Research Issues in MANETs

The research issues in MANETs present a unique set of challenges that vary from traditional wireless systems and wired networks. The multi-hop nature and the lack of fixed infrastructure add a number of characteristics, complexities, and design constraints that are specific to MANET (Corson and Macker, 1999; Chiasserini *et al.,* 2004). In order to devise optimal strategies, several challenges in MANETs should be researched. The following are among the challenges present in MANET:

1.1.1 Frequent and Unpredictable Topology

The dynamic environment of MANETs causes information derived from the network topology to become stale. This stale information including routing table, membership information for routing structure, induces frequent updates on the protocol states. The delivery of data packets can be obstructed during this update process. Thus,