SCALABLE QUALITY OF SERVICE MULTICAST ROUTING PROTOCOL FOR MOBILE AD HOC NETWORKS

BY

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ABSTRACT

Mobile Ad hoc Networks (MANETs) have gained significant interest and popularity since they have enormous potential in several fields of applications. Infrastructure-free, self-configuring and mobility are the main reasons behind this popularity. As the necessity of the group-oriented applications over MANET increases, Quality of Service (QoS) support is getting attention as one of the critical issues. Multicast communication is the ideal communication technique for supporting these types of applications. However, QoS multicast routing in large-scale networks faces several difficulties and challenges that need to be addressed. These challenges include dynamic MANET topology, multicast packet forwarding and shared wireless medium. Thus, it is necessary to design an efficient multicast routing protocol to support multimedia multicast applications in large networks with large group sizes. In this research, the problem of scalability of multicast routing protocols to support QoS over MANETs is investigated. In particular, a new Scalable QOS Multicast Routing Protocol (SQMRP) has been developed. The main objective of this protocol is to design a lightweight scalable QoS multicast routing scheme irrespective of the number of multicast members and network size. This is achieved by applying the following strategies: First, designing a novel and scalable virtual architecture that takes advantage of the geometric information of the mobile nodes, which provides efficient cluster management to handle dynamic movement of mobile nodes. Second, developing a new location service algorithm which reduces redundant propagation of packets between clusters. Third, proposing a simple and efficient hierarchical structure to manage the multicast members to further enhance the scalability. And finally, setting up a multicast forwarding tree through developing a route discovery algorithm guided by the geographic information which incurs lower overhead. The performance of the proposed protocol is evaluated through developing both an analytical investigation and extensive simulation using the GloMoSim simulator environment. The obtained results are compared with the well-known multicast protocol On-Demand Multicast Routing Protocol (ODMRP). It has been found that the proposed virtual construction can scale to large MANETs and effectively reduces the communication overhead for location service and multicast routing discovery. The simulation results showed that, the average PDR of SQMRP is higher by 7.9% and the NPO is reduced by an average of 57.7% compared to ODMRP considering different network sizes. Also, PDR is improved by 8.3% and the NPO is reduced by 55.6% for different multicast group sizes. In fact, it is observed that SQMRP out performs ODMRP protocol in most of the studied metrics and scenarios.

خلاصة البحث

مع الإنتشار الهائل والسريع للأجهزة الخلوية وأجهزة الحواسيب المحمولة أصبحت الشبكات اللاسلكية الديناميكية عديمة البنية التحتية Mobile Ad hoc Networks (MANETs) من أهم شبكات الحاسوب وأوسعها إنتشاراً، حيث أصبحت تستخدم في شتى مجالات الحياة اليومية مثل المؤتمرات والمحاضرات وفرق الإنقاذ والإطفاء والشرطة، مع زيادة إنتشار التطبيقات ذات المنحى الجماعي، إزداد الإهتمام بضمان جودة الخدمة بإعتبارها واحدة من القضايا المهمة. الإرسال المتعدد هو التقنية المستخدمة لدعم هذا النوع من التطبيقات. لسوء الحظ، فإن ضمان جودة الخدمة في الإرسال المتعدد لتوجيه البيانات في الشبكات واسعة النطاق يواجه عدة صعوبات وتحديات يتعين معالجتها. تعتبر الطبيعة الديناميكية لهذه الشبكات، نظراً للحركة السريعة والمستمرة للأجهزة المشاركة في الشبكة، من الأسباب الرئيسية لهذه التحديات. أما السبب الآخر فهو الحاجة إلى العمل بكفاءة في ظل وجود مصادر محدودة مثل كمية البيانات التي يمكن إرسالها وذاكرة الأجهزة المشاركة والحاجة إلى إعادة شحنها بشكل مستمر. وبالتالي، فقد بات من الضروري تصميم بروتوكول إرسال متعدد فعال لتوجيه البيانات لدعم جودة الخدمة في الشبكات واسعة النطاق والتي تضم عدد كبير من المشاركين. يهدف هذا البحث الى دعم جودة الخدمة في بروتوكولات الإرسال المتعدد لتوجيه البيانات في الشبكات واسعة النطاق. لقد تم إقتراح بروتوكول جديد (SQMRP)، حيث تظهر فاعلية البروتوكول الجديد عند تطبيقه في الشبكات التي تضم عدد كبير من المشاركين نتيجة توجيه البيانات بالإعتماد على مواقع الأجهزة المشاركة. يهدف البروتوكول إلى ضمان جودة الخدمة بالإضافة الى تقليل الضغط على الشبكة بغض النظر عن عدد الأعضاء وحجم شبكة الإرسال المتعدد. ويتحقق ذلك من خلال تطبيق الإستراتيجيات التالية. أولاً، إستخدام عمارة ظاهرية لإدارة ومعالجة الحركة الديناميكية للحواسيب المشاركة. ثانياً، إستخدام خوارزمية لتقديم خدمة الموقع. تهدف الخوارزمية المقترحة الى تمكين المرسل من الحصول على معلومات حول مواقع الاجهزة المراد ارسال البيانات إليها. ثالثاً، بناء هيكلية هرمية لإدارة أعضاء الإرسال المتعدد لتحسين أداء البروتوكول الجديد. وأخيراً تطبيق بروتوكول الإرسال المتعدد لإكتشاف المسارات التي تضمن جودة الخدمة وذلك بالإعتماد على مواقع الأجهزة المنوي إرسال البيانات لها. تم تقييم أداء البروتوكول المقترح ومقارنته مع بروتوكول ODMRP بإستخدام بيئة محاكاة GloMoSim وقد أظهرت النتائج أن البروتوكول الجديد فعال و تفوق على بروتوكول ODMRP في معظم السيناريوهات التي تم دراستها.

APPROVAL PAGE

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DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degree at IIUM or other institutions.

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To my dear wife ...

To my beloved mother ...

To my beloved childrens ...

for their love and support

To the soul of my beloved father

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LIST OF SYMBOLS AND ABBREVIATIONS

General

BB	Bottleneck bandwidth
BE	Best-effort
CBR	Constant Bit Rate
CDMA	Code Division Multiple Access
CH	Cluster-Head
CPU	Central Processing Unit
DARPA	Defense Advanced Research Projects Agency
FF	Fixed-Filter
GPS	Global Positioning System
HT	Hypercube Tier
IETF	Internet Engineering Task Force
km	Kilometer
m	Meter
MAC layer	Media Access Control layer
MACT	Multicast Activation message
MANET	Mobile Ad hoc NETwork
MN	Mobile Node
ms	Millisecond
MT	Mesh Tier
NP	Nondeterministic Polynomial
OSI	Open Systems Interconnection model
OTCL	Object Tool Command Language
PC	Personal Computer
PDA	Personal Digital Assistant
PRnet	Packet Radio Networks
QoS	Quality-of-Service
RB	Required bandwidth
RDF	Restricted Directional Flooding
RREP	Route Reply
RREQ	Route Request
RT	Real-time
s	Second
SF	Shared-Filter
TDMA	Time Division Multiple Access
ToS	Type of Service
UDP	User Datagram Protocol

Simulation tools

APIs	Application Programming Interfaces
DEM	Digital Elevation Model
GloMoSim	Global Mobile Information Systems Simulation
GUI	Graphic User Interface
ISI	Information Sciences Institute
MIT	Massachusetts Institute of Technology
NS-*2*	Network Simulator 2
NSF	National Science Foundation
OPNet	Optimized Network Engineering Tools
OTCL	Object Tool Command Language
Parsec	Parallel Simulation Environment for Complex systems
SANs	Storage Area Networks
UCLA	University of California, Los Angeles

Routing protocols

AMRoute	Ad hoc Multicast Routing protocol
AODV	Ad hoc On-Demand Distance Vector
AQM	Ad hoc Quality of Service Multicast Routing Protocol
CAMP	Core Assisted Mesh Protocol
CSPA	Constrained Shortest Path Algorithm
DDM	Differential Destination Multicast
DSDV	Destination Sequenced Distance Vector protocol
DSM	Dynamic Source Multicast
EGMP	Efficient Geographic Multicast Protocol
FGMP	Forwarding Group Multicast Protocol
FQM	Framework for QoS multicasting routing protocol
GMZRP	Geography-aided multicast zone routing protocol
HQMRP	Hierarchical QoS Multicast Routing Protocol
HVDB	Hypercube-based Virtual Dynamic back-bone
LACMQR	Location-Aware Cluster Multicast QoS Routing protocol
LAR	Location-Aided Routing
SQMRP	Scalable QoS Multicast Routing Protocol
LCTM	The Least cost tree based multiple-paths
LGD	Location-Guided Directional tree
LGK	Location-Guided *K*-array tree
LGS	Location-Guided Steiner tree
LTM	Lantern-Tree-based QoS On-Demand Multicast Protocol
MAODV	Multicast Ad hoc on-demand distance vector routing protocol
MCEDAR	Multicast core-extraction distributed Ad hoc routing
MLCT	Multiple Least Cost Trees
ODMRP	On-demand Multicast Routing Protocol
ODQMM	On-Demand QoS Multicast for MANETs

PBM	Position–based multicast
QAMNet	Quality of Service to Ad hoc Multicast Enabled Network
QMRP	QoS aware Multicast Routing Protocol
SPBM	Scalable Position-Based Multicast Protocol
STAMP	Shared-Tree Ad hoc Multicast Protocol
ZRP	Zone Routing Protocol

Variables and notations for *SQMRP* protocol

(x_c, y_c)	Coordinates of center of a particular cell
(x_n, y_n)	Coordinates of the position of a particular node
b	Coefficient
$Cap_{[i]}$	Node *i* capability to be a leader in the cell
$Cell\_ID_{[x,y]}$	Cell Identity [*x*,*y*]
CL	Cell Leader node
$CL\_ID_{[x,y]}$	*CL* node of $Cell\_ID_{[x,y]}$
$CL\_Pos_{[x,y]}$	Position coordinates of $CL\_ID_{[x,y]}$
CLB	Cell Leader Backup node
Co	Coordinator
CPU_{max}	Maximum possible computation ability
Dest	Destination node
Dist	Distance between the sender *CL* and the destined *CL*
Dist_move_th	Threshold distance to notify of node movement
$Distc_{max}$	Maximum distance of a node from the center point of a hexagonal cell
d_x	Distance between 2 successive points in X-axis
d_y	Distance between 2 successive points in Y-axis
Eng_{max}	Maximum possible battery life
Fwd	Forwarding node
G_ID	ID of the multicast group
H	Height of one triangle inside the hexagon cell
Invcell_Seq_ID	Sequence number for each cell which increased monotonically
Invsource_Seq_ID	Sequence number for each source to detect duplicate location discovery packets which is increased monotonically
L	Side length of hexagon cell
Leader_Ref_Time	Time between two successive elections
m	Line slope
Mem_{max}	Maximum memory available
$Nbr\_Cell_{[x,y]}$	Six neighbors of $Cell\_ID_{[x,y]}$
$Node\_CPU_{[i]}$	Computation ability of node *i*
$Node\_Distc_{[i]}$	Distance between node *i* and the cell center
$Node\_Eng_{[i]}$	Current remaining battery life at node *i*
$Node\_G\_list_{[i]}$	List of the multicast groups that node *i* interested to join
Node_ID	Node Identity
$Node\_ID_{[i]}$	Node identifier of node *i*
$Node\_Mem_{[i]}$	Memory capacity of node *i*
$Node\_Pos_{[i]}$	Current position of node *i*

$Node\_Seq\_No_{[Co]}$	Sequence number for each coordinator to detect duplicate route request packets
$Node\_Seq\_No_{[s]}$	Sequence number for each source to detect duplicate route request packets
$Node\_Spd_{[i]}$	Current mobility speed of node *i*
$Nodes\_Cell_{[x,y]}$	Nodes residing currently in $Cell\_ID_{[x,y]}$
Ord	Ordinary node
$P_1, P_2, \ldots, P_6$	Coordinates of the six corners of the hexagon cell
R	Transmission range
S	Source node
Spd_{max}	Maximum mobility speed
Uni	Flag to indicate if the packet sent using unicast broadcast
$w_1, w_2, \ldots, w_5$	Weighting factors
X_{max}	Maximum coordinate in X-axis
Y_{max}	Maximum coordinate in Y-axis

Notations of *SQMRP* packets

CL_CLB_BACKUP	Backup with the *CLB*
CL_NBR _STILL_ALIVE	*CL* to neighbor cells
CL_RETIRE	*CL* out of service
CLB_CELL_LEAVE	*CLB* node leave the cell
EMPTY_CELL	Empty cell
INCELL_INV_REP	Reply from *CL* of current cell to source node
INCELL_INV_REQ	Invitation from source to *CL* in same cell
INCELL_NODE_INFO	Node position and multicast group list
LEADER_ELECTION	Start leader election process
NEW_CL	New leader node is elected
NEW_CL_NBR	New neighbor leader node is elected
NODE_CAP	Node capability
NODE_CELL_JOIN	Node join new cell
NODE_CELL_LEAVE	Node leaving the cell
NODE_CELL_LEAVE_REP	Cell leave reply
OUTCELL_INV_REP	Out cell reply from the target *CL*s to sending *CL*
OUTCELL_INV_REQ	Out cell request from *CL* to neighbor *CL*s
POS_UPDATE	Position update
QOS_RERR	Route error
QOS_RREP	Route reply
QOS_RREQ	Route request
SUB_QOS_RREP	Sub-way route reply
SUB_QOS_RREQ	Sub-way route request

Notations use in performance evaluation of *SQMRP*

A	Network size
AEED	Average End-to-End Data Delay
A_h	The area of a single hexagon cell
APL	Average Path length
ARAL	Average Route Acquisition Latency
A_s	The area of a single square cell
A_t	The area of a single triangle cell
ATP	Average Throughput
C	Number of cells in the network
CBR	Constant Bit Rate
L	The gridding shape side length
Mb/s	Megabits per second
N	Total number of nodes
n	the average number of nodes per hexagon cell
NPO	Normalized Packet Overhead
OH_{LS}	overhead of location service
OH_{NC}	overhead of network construction
OH_{NM}	overhead of network maintenance
OH_{RD}	overhead of routing discovery
OH_{RM}	overhead of routing maintenance
PDR	Packet Delivery Ratio
RWP	Random WayPoint
$\mathrm{T_{OH}}$	Total overhead

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND INFORMATION

In the early 1972, Defense Advanced Research Projects Agency (DARPA) has initiated its research in Ad hoc networks by deploying Packet Radio Networks (PRnet) (Y. Chen, Liestman, & Liu, 2004). Since that time, the concept of Ad hoc wireless networks has been introduced. Ad hoc networks are formed when a collection of mobile devices communicate with each other without pre-established infrastructure. Nodes in Ad hoc network are often mobile, but it can also consist of stationary nodes. Each of the nodes has a wireless interface and communicates with others over radio channels.

Mobile Ad hoc NETwork (MANET) is a type of Ad hoc networks with rapidly changing topology. MANETs are composed of a collection of mobile nodes that communicate with each other over wireless links in the absence of any infrastructure or centralized administration. Recently, MANETs have gained worldwide popularity. Absence of infrastructure, mobility, self-organizing, self-configuring, self-administering are the main reasons of this popularity. In spite of their worldwide popularity, MANETs have several challenges and limitations (T. Lin, 2004; Mohapatra & Krishnamurthy, 2005; Murthy & Manoj, 2004). These challenges are summarized as follows:

1. **Dynamic topology changes:** All the nodes in the network are free to move arbitrarily. So, the network topology changes dynamically in unpredictable manner. Nodes mobility leads to frequent path breaks,