QUALITY OF SERVICE ENABLED CROSS-LAYER MULTICAST FRAMEWORK FOR MOBILE AD HOC NETWORKS

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LIST OF ABBREVIATION

Abbreviation	Full
ABW:	Available Bandwidth
AIMD:	Additive Increase Multiplicative Decrease
AQM:	Ad hoc Quality of Service Multicast Routing
BE:	Best-Effort
BW:	Bandwidth
CAMP:	Core Assisted Mesh Protocol
CBR:	Constant Bit Rate
CDMA:	Code Division Multiple Access
CP:	Control Packet
CSMA/CA:	Carrier Sense Multiple Access/ Collision Avoidance
CSPA:	Constrained Shortest Path Algorithm
DiffServ:	Differentiated Service
EQMGA:	Entropy-based Genetic Algorithm Model to Support QoS Multicast Routing
E-QMR:	Enhance QoS Multicast Routing
FGMP:	Forwarding Group Multicast Protocol
FPS:	Fuzzy-based Priority Scheduler
FQM:	Framework for QoS Multicast Applications
FIFO:	First In First Out
FTP:	File Transfer Protocol
GAT:	Group Application Throughput
GloMoSim:	Global Mobile information system Simulator

GOWL:	Group One Way Latency
GPDR:	Group Packet Delivery Ratio
GPS:	Global Positioning System
GR:	Group Reliability
HVDB:	logical Hypercube-based Virtual Dynamic Backbone
HQMRP:	Hybrid QoS Multicast Routing Protocol
IEEE:	Institute of Electrical and Electronics Engineers
ILUP:	Intra-cluster Link-state Update Protocol
IntServ:	Integrated Service
IP:	Internet Protocol
ITU-T:	International Telecommunications Union-Telecommunication Standardization Sector
JOIN_REQ:	Join Request
JOIN_REP:	Join Reply
JOIN_RES:	Join Reserve
KB:	Kilo Byte
Kbps	Kilo bit per second
LAT:	Local Application Throughput
LCTM:	Least Cost Tree Based Multiple-Paths
LPR:	Local Packet Received
LPS:	Local Packet Should Received
LOWL:	Local One Way Latency
LTM:	lantern-Tree-Based QoS Multicast Protocol
MAB:	Minimum Available Bandwidth
MAC:	Media Access Control

MANET:	Mobile Ad hoc Network
MAODV:	Multicast-Ad hoc, On Demand Distance Vector
M-CAMP:	Call-Admission Multicast Protocol for Mobile Ad hoc Network
MH:	Max-Hop
MLCT:	Multiple Least Cost Trees
NDP:	Neighbor Discovery Protocol
ODMRP:	On Demand Multicast Routing Protocol
ODQMM:	On-Demand QoS Multicast Routing and Reservation Protocol for MANET
OH:	Overhead
OLSR	Optimized Link State Routing
PARSEC:	Parallel Simulation Environment for Complex Systems
PDR:	Packet Delivery Ratio
PR:	Packet Received
PS:	Packet Should be Received
QAMNet:	Providing Quality of Service to Ad hoc Multicast Networks
QMR:	QoS Multicast Routing Protocol
QMRPCAH:	A QoS Multicast Routing Protocol for Clustering Mobile Ad hoc Networks
QoS:	Quality of Service
QRREQ:	Quality of Service Route Request
RBW:	Required Bandwidth
RREP:	Route Reply
RREQ:	Route Request
RT:	Real-Time
RTCP:	Real-Time Transport Control Protocol

RTP:	Real-Time Transport Protocol
RTS/CTS:	Request To Send / Clear To Send
SNR:	Signal to Noise Ratio
SPTM:	Shortest Path Tree based Multiple-paths
SWAN:	Service Differentiation in Stateless Wireless Ad Hoc Networks
TDMA:	Time Division Multiple Access
ToS:	Type of Service
UDP:	User Datagram Protocol
VOIP:	Voice Over IP

KERANGKA MULTIKAS LAPISAN SILANG YANG BERKUALITI PERKHIDMATAN UNTUK RANGKAIAN AD HOC BERGERAK

ABSTRAK

Rangkaian ad hoc bergerak merupakan suatu rangkaian tanpa wayar yang boleh dibentuk secara bebas, dinamik serta disusunatur dan ditadbir dalam bentuk topologi rangkaian sementara dan arbitrari. Pengguna rangkaian ad hoc bergerak untuk komunikasi berkumpulan seperti sidang video, siaran tayangan langsung dan tutur suara memerlukan strategi multikas kualiti berkhidmatan yang efisyen. Selain dari keperluan memperkasakan kualiti perkhidmatan untuk kegunaan aplikasi multikas, terdapat beberapa kesukaran dan cabaran yang perlu ditangani agar dapat menyokong kegunaan aplikasi sedemikian dalam rangkaian ad hoc bergerak. Lantaran itu, timbul keperluan merekacipta suatu kerangka/rangka bentuk bagi menyokong aplikasi multikas berkualiti perkhidmatan.

Dalam kajian ini, suatu kerangka baru (FQM) dicadang bagi menyokong aplikasi multikas berkualiti perkhidmatan. Komponen pertama kerangka ini ialah suatu protokol penghalaan multikas bertujuan merangka laluan yang mempunyai lebarjalur yang dikehendaki kumpulan multikas. Kedua, suatu sistem kawalan masuk teragih berasaskan kaedah pendengaran pasif bagi menganggar lebarjalur digunapakai untuk menghalang nod perantara daripada mengalami bebanan berlebihan, mengurangkan kawalan overhed serta mengadakan pengagihan beban. Ketiga, suatu sistem kawalan masuk berasaskan sumber dengan tiada kawalan overhed digunapakai bagi menghalang sumber baru dari menganggu sumber-sumber sedia ada dalam sesuatu kumpulan multikas. Keempat, suatu senibina lapisan silang dicadangkan digunapakai oleh para pengawal bagi membuat keputusan yang tepat.

Prestasi kaedah yang disarankan ini telah diujikaji menggunakan perisian simulasi GloMoSim serta dibandingkan dengan kaedah multikas berkualiti perkhidmatan sedia ada yakni QAMNet. Didapati bahawa perlaksanaan kawalan masuk di nod perantara adalah lebih berkesan daripada perlaksanaannya di nod sumber memandangkan ia mampu mengurangkan kawalan overhed, menjimatkan lebarjalur dan mengadakan pengimbangan beban melalui penghalangan paket permintaan dari menyusuri laluan yang tidak memiliki lebarjalur yang diperlukan. Kajian ini juga mendapati bahawa senibina lapisan silang menyokong interaksi di antara komponen-komponen kerangka dengan lebih baik serta membantu pengawal berkualiti perkhidmatan membuat keputusan-keputusan yang tepat. Hasil dari pada ini, terdapat penambahbaikan dalam kadar penghantaran paket, kebolehpercayaan kumpulan dan truput manakala purata masa lengah dan perbezaan masa lengah dikurangkan.

Keputusan simulasi menunjukkan bahawa, purata RT-GPDR dalam FQM adalah lebih tinggi daripada purata dalam QAMNet sebanyak 13% manakala RT-GR untuk FQM adalah lebih tinggi daripada purata dalam QAMNet sebanyak 23.7%. Di samping itu, purata RT-GOWL untuk FQM adalah lebih rendah daripada purata dalam QAMNet sebanyak 23.8 ms manakala purata RT-G-Jitter untuk FQM adalah lebih rendah daripada purata dalam QAMNet sebanyak 47.9 ms. Malah, FQM mengatasi QAMNet dalam kesemua senario dan metriks yang dikaji. Keputusan ini adalah hasil dari pada penghalangan trafik berlebihan, pengimbangan beban dan pengurangan kesan-kesan trafik bukan masa nyata ke atas trafik masa nyata.

QUALITY OF SERVICE ENABLED CROSS-LAYER MULTICAST FRAMEWORK FOR MOBILE AD HOC NETWORKS

ABSTRACT

Mobile ad hoc networks (MANETs) are wireless networks that can freely and dynamically be created, organized and administered into arbitrary and temporary network topologies. Users of mobile ad hoc networks who wish to use multimedia applications for group communication such as video conferencing, live movie streaming and voice conversation require efficient QoS multicast strategies. In addition to the need for enabling QoS for multicast applications, there are several difficulties and challenges that need to be addressed in order to support these applications in mobile ad hoc networks, thus requiring the design of a framework to support QoS multicast applications.

In this study, a new framework (FQM) is proposed to support QoS multicast applications. The first component of the framework is the QoS multicast routing protocol designed to construct paths for the multicast group with the required bandwidth. Second, a distributed admission control based on a passive listening method to estimate bandwidth is used to prevent intermediate nodes from being overloaded, to reduce the control overhead and to provide load balancing. Third, a source based admission control with no extra control overhead is used to prevent new source from affecting ongoing sources in the multicast group. Fourth, a cross-layer architecture is proposed to support the interaction between the framework's components and help the controllers to make accurate decisions.

The performance of the proposed approach is studied using the GloMoSim simulator and compared with an existing approach for QoS multicast applications (QAMNet). It was found that performing admission control at intermediate nodes was

more effective than performing it at destination nodes as this reduced the control overhead, conserved bandwidth and provided load balancing by preventing request packets from traveling through paths which did not have the required bandwidth. The study found that, the cross-layer architecture better supported interactions between the framework's components and helped QoS controllers to make accurate decisions. As a result, the packet delivery ratio, group reliability and throughput were improved while average latency and jitter were reduced.

The simulation results showed that, the average RT-GPDR in FQM was higher than that in QAMNet by 13% while the average RT-GR for FQM was higher than that in QAMNet by 23.7%. In addition, the average RT-GOWL for FQM was lower than that in QAMNet by 23.8 ms while the average RT-G-Jitter for FQM was lower than that in QAMNet by 47.9 ms. In fact, FQM out-performed QAMNet in most scenarios and for all metrics studied. This came about as a result of overload prevention, the provisioning for load balancing and mitigation of the effect of best-effort traffic on real-time traffic.

CHAPTER ONE

INTRODUCTION

The rapid growth of mobile computing devices has driven users of these devices to change their way of accessing services and resources as they communicate and exchange information with each other through their portable devices at their homes or offices. Therefore, they need the same communication capabilities found in wired networks. Wireless technology provides communication between portable devices by supporting portable computing so that users of mobile devices can enjoy both the advantages of mobility and of being connected at the same time. Moreover, it provides high-speed and high-quality information exchange between mobile devices.

Although wireless networks have become popular and many types of wireless applications are available to a large number of customers, the need to exchange digital information outside the typical network environment is growing and remains a challenging problem. This is because users of wireless networks still wish to use wireless applications in places where no infrastructure networks are available or when installation is expensive and temporary in nature. For instance where students need to interact during a lecture; participants in a business meeting wish to share files; disaster relief units need to coordinate relief information after a hurricane or flood; military units need to communicate where no routers or base stations can be found. Each device used in one of these scenarios can be called a node in a mobile ad hoc network. Figure 1.1 gives an overview on disaster recovery applications and military applications.

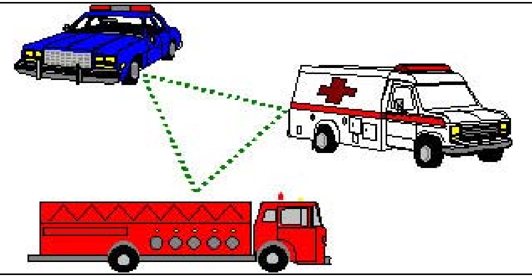
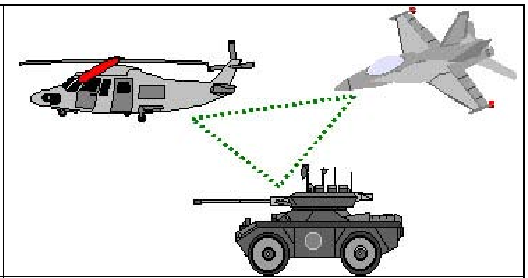
	
Ad hoc Communications for Disaster Relief Units	Ad hoc Communications for Military Units

Figure 1.1: Overview on Ad hoc Networks Applications (ANTD, 2007)

A mobile ad hoc network (MANET) is an autonomous system of mobile nodes communicated through a shared wireless channel (Corson et al., 1999). The communication between these mobile nodes uses a new self-organized communications paradigm. Among all types of wireless networks, a mobile ad hoc network provides flexible communication at low cost. This type of networks has been receiving much attention from researchers because users can share the required information on their wireless devices whenever they want, wherever they are.

1.1 Background Information

In mobile ad hoc networks, mobile nodes communicate through shared wireless channel with no pre-existing communication infrastructure. Since radio ranges for mobile nodes are limited, neighboring nodes communicate directly through wireless channel whereas distant nodes communicate through multi-hop paths (Chen and Nahrstedt, 1999). In other words, relaying data packets through multi-hop paths is the main principle behind ad hoc networking. Nodes in mobile ad hoc networks simultaneously act as hosts and routers to give the same functionality usually provided by a static network infrastructure. As routing and resource management are done in a distributed manner through multi-hop paths, mobile nodes need to be intelligent and cooperative in order to support self administration and multi-hop routing.

In addition to the limitations and challenges inherent in wireless infrastructure networks, mobile ad hoc networks face many other challenges and limitations which can be summarized as follows (Chakrabarti and Mishra, 2001):

- Dynamic topology changes: All components of a mobile ad hoc network are free to move so the network topology changes dynamically and this results in frequent path breaks, packet collisions, transient loops and difficulties in resource reservation.

- Lack of central coordination and accurate information: In ad hoc networks, there is no central controller to coordinate the activity of nodes and collect the information state at all times because nodes join, leave and rejoin the network at any place and time.

- Hidden terminal and shared radio channel: Packets may collide and be lost at a common destination because multiple sources start sending their packets simultaneously or the sources of packets are not within radio range of one another. Multi-hop paths also increase the probability of hidden terminal problems.

- Limited available resources: Mobile ad hoc networks consist of mobile nodes that communicate through wireless channels so resources such as: battery life, storage space, power processing and computation capability are very limited. In addition, available bandwidth is very limited because mobile ad hoc networks use shared wireless channels.

Supporting QoS multicast routing in mobile ad hoc network is more complicated than QoS unicast routing because QoS multicast routing has to cope with a large number of destinations and thus should be able to service them. In addition, paths to destinations with QoS requirements must be identified and continuously maintained.

Supporting real-time applications in mobile ad hoc networks also give rise to additional constraints. This is because real-time applications, by nature, require high packet delivery ratio, low average latency and low jitter. Due to this, real-time traffic needs to be assigned high priority. However, in mobile ad hoc networks there is no central controller and hence nodes that have non-QoS traffic would not give way to nodes that have QoS traffic. As a result, real-time applications will be affected. In addition to these problems, real-time applications also require high data rates whereas the capacity of mobile ad hoc networks is very limited. Due to these limitations, mobile ad hoc networks face many challenges to provide the needs of real-time traffic (Farkas et al., 2006).

1.2 Problem Statement

Due to the issues and challenges discussed in section 1.1, the goal of this research is to support real-time multicast applications for mobile users by providing QoS multicast capabilities for mobile ad hoc networks, which currently lack features such as:

- ❖ Enhanced QoS multicast by supporting real-time traffic to improve packet delivery ratio, reduce average latency and jitter and avoiding the limitations of existing QoS multicast approaches.

- ❖ Efficient QoS multicast routing protocols which exploit available bandwidth efficiently, reduce the congestion and mitigate the effect of mobility while transporting the traffic.

- ❖ Methods to estimate available bandwidth with little or no control overheads.

- ❖ Distributed admission controls, source based admission controls and dynamic rate controls to control the traffic efficiently with no additional control overhead.

- ❖ Cross-layer architecture for supporting the interactions of the various QoS control mechanisms and help make accurate decisions.

1.3 Research Motivation

QoS multicast routing in mobile ad hoc networks is a popular research topic due to the increasing popularity of multimedia applications and the potential commercial usage of mobile ad hoc networks in supporting group communications which is rapidly gaining in popularity (Wang et al., 2005). In addition, several approaches have been proposed to support QoS multicasting in mobile ad hoc networks. However, none of them cover all the requirements needed to support QoS multicasting in mobile ad hoc networks. As such, there is an urgent need for a new cross-layer framework to support QoS multicast applications in mobile ad hoc networks.

1.4 Objectives of the Thesis

The main objectives of this thesis are to:

- Study existing QoS multicast approaches, highlight their advantages and outline their limitations.
- Propose a new framework to support real-time multicast applications for group communication in mobile ad hoc networks which takes into account the limitations and constraints of this type of network by using cross-layer QoS architecture together with distributed control mechanisms to address existing constrain.
- Study and analyze the performance of the proposed framework through simulation.
- Compare the proposed framework to an existing approach for QoS multicasting in mobile ad hoc networks in order to evaluate and compare its effectiveness.

1.5 Scope and Limitations

The focus of this study is to propose and design a new framework to support real-time applications for group communications in mobile ad hoc networks by taking into consideration the need for high mobility nodes in the network. The proposed framework includes: a QoS multicast routing protocol to find paths with the required bandwidth to all destinations, a distributed admission control to prevent intermediate nodes from being overloaded and to provide load balancing through traffic distribution, a source based admission control to prevent new sources from affecting existing sources, and a method to estimate the available bandwidth and cross-layer architecture needed to support interactions between components within the framework. In addition, many QoS mechanisms such as: classifier, shaper, dynamic rate control and priority queue are used in the framework to support real-time traffic.

The performance of the proposed framework is studied under general QoS requirements for real-time applications and does not focus on specific real-time applications which need different specifications and different QoS requirements. As a result, only two types of QoS classes which are real-time and best-effort classes are defined and only the bandwidth requirements are considered when identifying the suitable paths from source to destinations. Since the framework proposes to support real-time applications, the framework only considers real-time traffic and assigns it high priority. Although security is one of the major QoS issues in mobile ad hoc networks; it is out of the scope of the design objectives of the proposed framework.

1.6 Organization

The organization of the rest of the thesis is as follows:

Chapter Two gives a background on mobile ad hoc networks and elaborates on the existing approaches for QoS multicasting in mobile ad hoc networks.

Chapter Three describes the proposed framework and all its components: a QoS multicast routing protocol (QMR), a distributed admission control, bandwidth estimation method, a source based admission control, a cross-layer architecture and many QoS schemes to support QoS multicast applications in mobile ad hoc network.

Chapter Four describes simulation environments, network scenarios and metrics.

Chapter Five presents the results analysis and discussion.

Chapter Six contains concluding remarks and suggestions for future research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Mobile Ad hoc Networks

A mobile ad hoc network (MANET) is a type of wireless networks that can by freely and dynamically self-created, self-organized and self-administered into arbitrary and temporary network topologies (Chakrabarti and Mishra, 2001). In mobile ad hoc networks, mobile nodes can continuously inter-network and share their services and resources without any pre-existing infrastructure (Grigoras and Riordan, 2005) (Malik and Kim, 2006). The typical ad hoc network consists of a group of mobile nodes that communicate with each other for a period of time and continue moving randomly within a specific area while they do so (Maltz, 1999). Figure 2.1 gives an overview of the infrastructure network vs. ad hoc network.

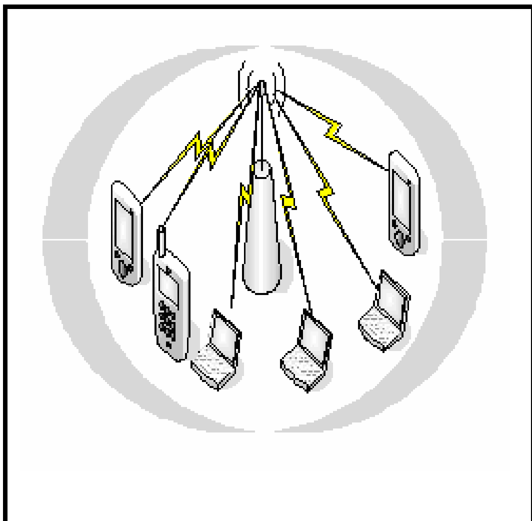
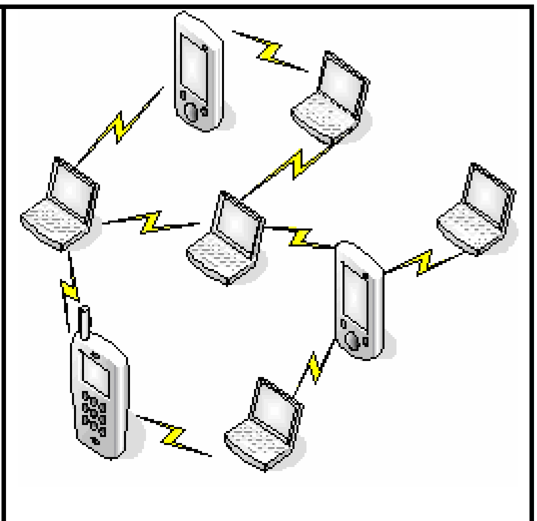
	
Infrastructure Network	Ad hoc Network

Figure 2.1: Overview on the Infrastructure Network vs. Ad hoc Network.

The applications of ad hoc networks can be used in several areas due to their quick and economic deployment. These applications include military operations, emergency operations, meeting applications, collaborative and distributed applications (Murthy and Manoj, 2004). For military applications, mobile ad hoc networks can provide the required communication between groups of soldiers in unknown areas where installing fixed infrastructure may be impossible. In emergency situations such as search and rescue operations, mobile ad hoc networks are very useful for establishing communication when conventional infrastructure communications are destroyed due to war or natural disaster. Mobile ad hoc networks are also useful in meeting applications where students in a class, researchers in a conference, or business people need to establish a communication link for voice conversation, video chatting or video conferencing. In addition, ad hoc networks can be used to support collaborative and distributed applications where the decision of one participant depends on the current environmental conditions and on the actions of other users. An example of this type of applications is the coordination between team members in a rescue team, where the network infrastructure has been destroyed or is unavailable due to difficult terrain.

Mobile ad hoc networks are not only useful where fixed infrastructure is impossible, but also when the required infrastructure network will only be used temporarily and is expensive to install and maintain. Ad hoc networks can be initiated independently and operated in isolation or may have gateways to connect to the fixed network (Corson et al., 1999). Furthermore, ad hoc networks can be used to extend the fixed network in two cases. First, mobile nodes can act as a getaway to the Internet for other mobile nodes. Second, mobile nodes enable routing capability to limit the range of communication in geographical locations instead of communicating through base station and this reduces the congestion on fixed network base station. (Nordstrom, 2002). In short, the combination of cellular and ad hoc wireless networks will improve the efficiency of the hybrid architecture and provide good solutions for users to connect to the Internet and support multimedia applications.

2.2 Quality of Service for Mobile Ad hoc Networks

The set of service requirements for users and applications which must be supported by a network while transporting real-time traffic is called Quality of Service (QoS) (Crawley et al., 1998). To support end-to-end QoS, the network should guarantee a set of measurable service requirements: minimum bandwidth, maximum delay, maximum jitter, maximum packet loss and minimum security (Punde et al., 2003). After a network accepts a request of service from the user or source, it should guarantee the required level of service (Reddy et al., 2006).

QoS in mobile ad hoc networks is highly dependent on routing and medium access control. As such, the performance of a routing protocol affects the service quality of real-time traffic whilst it travels from source to destination (Lee et al., 2000b).

2.3 Multicast Routing Protocols

Multicast routing is a communication scheme used to send data packets from source to multicast groups. It is a promising technique because it improves wireless link efficiency. This is because the packets are only replicated when they need to reach two or more destinations on disjointed paths. In this way, bandwidth consumption, node processing and packet delivery delay will be reduced (Das et al., 2005). The multicast scheme can be performed in one-to-many or many-to-many communication patterns. Examples of one-to-many communication patterns include chat system and the multimedia streaming of news, while many-to-many communication patterns include videoconferencing and team-based collaborative work.

As wireless communications is inherently broadcast by nature, multicast routing is more efficient in wireless ad hoc networks (Wang et al., 2005). The combination of the advanced features of a mobile systems (global roaming capability and coordination with other network structures) and the advantages of multicast routing enable mobile ad hoc networks to efficiently support group communication applications (De-Morais et al., 2003). Multicast scheme is very important for group communications and collaborate applications (e.g. rescue teams, search teams) when audio, video, images, and other data need to be shared among team members (Das et al., 2005). In fact, group communication applications is one of the primary applications that targeted by future of mobile ad hoc networks (Viswanath et al., 2006). This is because these applications are very important for the users and need ad hoc communication environments.

The multicast scheme is expected to play a major role in the future of mobile ad hoc networks. This is because most communications applications scenarios for mobile ad hoc networks are performed in groups and are based on many-to-many interactions (Ruiz and Gomez-Skarmeta, 2004). Furthermore, in mobile ad hoc networks there are many applications which naturally require the collaboration between the members of the group in the multicasting scenario. Examples of these applications are: communications in battlefield scenario, disaster relief scenarios, multi-party gaming and remote monitoring.

Nevertheless, routing in mobile ad hoc networks is very difficult and challenges and these challenges are attributable to the features of the network. In addition to these inherent difficulties, there arises an additional difficulty such as the need to locate paths from sources to destinations. However, the routing protocol periodically needs to find alternative paths during ongoing sessions (Lee et al., 2000b).

Several multicast routing protocols have been developed to perform ad hoc multicast routing: Forwarding Group Multicast Protocol (FGMP) (Chiang et al., 1998), On Demand Multicast Routing protocol (ODMRP) (Lee et al., 999), Multicast-Ad hoc, On Demand Distance Vector (MAODV) (Royer and Perkins, 2000) and Core Assisted Mesh Protocol (CAMP) (Garcia-Luna-Aceves and Madruga, 1999). However, these multicast routing protocols do not address the QoS multicast in ad hoc communication because they are designed for best-effort multicast applications rather than QoS multicast applications. Many protocols proposed for QoS unicast routing. However, these protocols are not suitable for QoS multicast routing as QoS multicast routing is more complicated. This is because QoS multicast routing are designed to cope with paths to large number of destinations and should be able to fully utilize them (Yi et al., 2004). As such, all paths to destinations with QoS requirements must be discovered.

2.4 QoS Multicast Approaches in Mobile Ad hoc Network

The strong motivation for supporting real-time multicast applications in mobile ad hoc networks is the need for using these applications in mobile ad hoc networks (Bur and Ersoy, 2005). Real-time applications are applications most expected to be used over mobile ad hoc network. This is because multimedia applications are very important for users and the communication technologies in such networks provide users with a great way to interact in ad hoc real-time fashions. In addition to real-time applications, users of mobile ad hoc networks use best-effort applications such as Email and File Transfer Protocol (FTP).

The design of QoS multicast routing in mobile ad hoc network is more complicated than in traditional networks. This is because in ad hoc networks, the topology changes dynamically and there is no central controller to coordinate the activity of nodes. Moreover, available resources are very limited and are constantly changing. The traffic load for sources must be distributed to eliminate hot spots and provide load balancing. Designing QoS multicast routing has additional challenges because real-time applications have critical QoS requirements; they are very sensitive to packet delay and jitter whereas packet delay and jitter are not big issues for best-effort applications. Because of this, the use of equal priority processing in mobile ad hoc networks will affect the performance of real-time applications. Therefore many QoS schemes must be used to support real-time traffic with high priority.

In the following sections, the approaches that are directly relevant to QoS multicast routing in mobile ad hoc networks are discussed. Some of the following approaches proposed routing protocols with some models to support QoS multicast in mobile ad hoc networks whereas others use the existing protocols for multicast routing with new algorithms and admission controls to support QoS multicast routing in mobile ad hoc networks.

2.4.1 On-Demand QoS Multicast Routing and Reservation Protocol for MANETs

Ng et al. (2004) proposed an On-Demand QoS Multicast routing and reservation protocol for MANETs (ODQMM) which extends the multicast routing protocol (MAODV) (Royer and Perkins, 2000) to support QoS multicast routing in mobile ad hoc networks. To provide bandwidth reservation for multicast groups, the ODQMM protocol performed both the resource reservation protocol and the on-demand routing protocol simultaneously. The process of resource reservation protocol starts with searching for feasible resources and reserving them temporarily. After the path is chosen, the reserved resources in the path are fixed. This protocol uses two types of reservation namely fixed reservation and shared reservation. The first type fixes the resources for each source whereas the second type shares the resources for all sources that do not need fix reservations during the same session. The first type is suitable in applications where a receiver can receive multiple flows simultaneously like video streaming whereas the second type can be used for audio conversation because only one individual can be talking at any one time.

ODQMM adds the total bandwidth reserved for fixed reservation and shared reservation to the group hello message already used in MAODV to update the multicast group. Six types of control messages are used in the ODQMM model to discover paths, reserve resources and update tables for each node. Five flags are also used in ODQMM for: fixed reservation, shared reservation, available bandwidth on each node in the group, link broken and the reserved bandwidth for the group. Before the new node joins the group, it must reserve the required bandwidth for the group. The node in the multicast group can be source or destination or both.

When a node wants to join the multicast group, it initiates a route request (RREQ) message with the five flags to indicate the type of reservation and to ask for multicast group information. Then, it broadcasts the request and waits for the reply. When a member of the multicast group receives a route request, it responds with a reply message if three conditions are satisfied. These conditions are that the request is not duplicated, the required bandwidth for the multicast group is known and all members of the multicast group have the required bandwidth for the request. When the source of the request receives a reply, it means that paths with the required bandwidth to the multicast group have been identified. The source then activates the reserved bandwidth on the selected path by sending an active-message.

A new node that has best-effort traffic can join the multicast group as a destination, whereas the new node that going to send real-time traffic must define the required bandwidth and the type of reservation (fixed or shared). The required bandwidth for the multicast group is updated periodically by the group hello message. For fixed reservation, the required bandwidth is the bandwidth required by a new node and should be reserved whereas in shared reservation no need to reserve extra bandwidth if the required bandwidth is less than the shared bandwidth for the group.

ODQMM focuses only on resource reservation to support QoS multicast and assumes that available bandwidth information comes from the underlying layer model such as TDMA model. However, mobile ad hoc network is a dynamic wireless environment and as a result, it is difficult to use a centralized MAC model where IEEE 802.11 is widely used (Xu et al., 2003). In addition, each node in the group needs to maintain four tables (route table, multicast route table, group leader table and reservation table) and all fields in these tables need to be periodically updated through the use of periodic message. This large number of tables and large number of control messages introduce a high control overhead. Beside these limitations, the second type of reservation is limited only to a few applications because most application scenarios for mobile ad hoc networks are performed in many-to-many interactions (Ruiz and Gomez-Skarmeta, 2004); in which multiple sources may need to send to the multicast session simultaneously.

2.4.2 A lantern-Tree-Based QoS Multicast Protocol

Chen and Ko (2004b) proposed a Lantern-Tree-based Multicast protocol (LTM) to find and discover all available resources from source to destinations in the multicast group and to reserve the demand resources for the multicast group. In this protocol, the source node that has data to send to the multicast group broadcasts a route request packet and each intermediate node relays the route request until the request is received by the destinations. After that, the destination sends a reply to the source to construct the path.

The lantern tree is a multicast tree which contains at least one lantern-path between any source and destination in the group whereas the lantern path is a path with one or more lanterns between source and destination. However, the lantern is a one or more sub-paths representing the total bandwidth between a two-hop neighboring nodes. Figure 2.2 describes the lantern tree concept. The data packets will be routed through single path if sufficient bandwidth is available or through a lantern-path if a single path with sufficient bandwidth is not available.

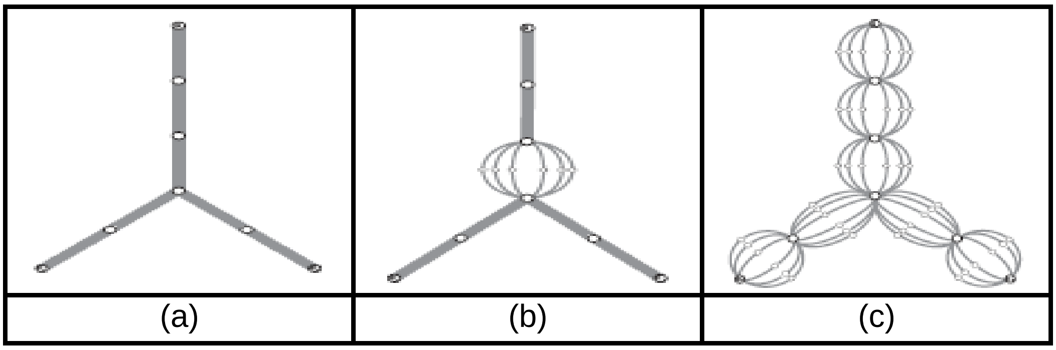


Figure 2.2: (a) A conventional Tree (left). (b) A Lantern-Tree (middle). (c) A Worst-Case Lantern-Tree (right) (Chen and Ko, 2004b)

The advantage of the lantern-tree protocol lies in its ability for finding paths with the required bandwidth through the use of many sub-paths if a single path with the required bandwidth is not available. This protocol uses TDMA/CDMA as its MAC layer model. However, this MAC layer model is more suitable for use in a single hop wireless network than in a multi-hop ad hoc networks (Xu et al., 2003). Besides this limitation, the lantern-tree takes a long time at startup to identify all possible paths and to share the time slots between these paths. In addition, it splits the flow into multiple sub-paths which add more complexity when multiple flows are admitted as the nodes need to store and process more information for all sub flows. In fact, many sub-paths are built and released without being used and this wastes the network resources.

Another limitation is the use of higher number of links which increases the contention at the MAC layer and as a result the complexity of maintaining all paths increases (Setton et al., 2005). Moreover, supporting multiple paths and constructing sub-paths in ad hoc networks is very difficult challenging. There are two main reasons for this. First, after all paths and sub-paths to the destination are discovered, the routing protocol must avoid shared links by selecting a set of disjointed paths. Second, the traffic sent through these multiple paths will be associated with the additional delay and high complexity due to the reordering operations for the packets of flow (Mao et al., 2003). Besides these drawbacks, the reliability of the backup paths can not be guaranteed as they may be subject to failure due to inherent mobility and as a result, resources are wasted.

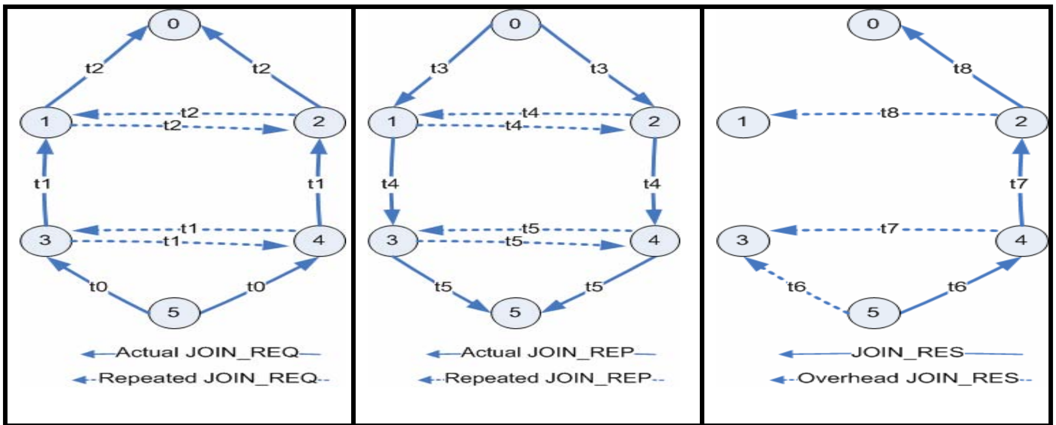
2.4.3 Ad hoc Quality of Service Multicast Routing

Bur and Ersoy (2005) proposed an Ad hoc Quality of service Multicast routing protocol (AQM) to support the real-time applications in mobile ad hoc networks. The AQM protocol finds and computes the available resources for each mobile node within its neighbor. After that, it uses these available resources to perform the multicast routing and forward the data traffic to the multicast group. A session can be initiated by any node that broadcast a session initiation packet which contains the bandwidth requirements and the number of hop-counts. The session initiation packet is then forwarded as long as the QoS requirements are met. The QoS status in the session is periodically updated by the session initiator.

The intermediate node must compute its available bandwidth and update the QoS information before it rebroadcasts the session initiation packet. The intermediate node checks the bandwidth already reserved for the existing session and the required bandwidth for its neighbors to compute the residual bandwidth. Generally, the available bandwidth for the forward node depends on the position of the node in the multicast tree and must be three times the required bandwidth for the session. In addition, the forward node must interact with its neighbors in order to detect overloading.

After the session initiation is finished and its information is disseminated through the network, the node joins the session. This is done by sending a request to find a QoS path to the session. When a node broadcasts a route request packet, only its upstream neighbors will accept this request and forward the packet as long as QoS can be satisfied. If the node that receives the request is a member of the session, it will directly send a reply back to the source of the request which will then select the best path with good QoS requirements and then send reservation message on these paths to reserve the resources. Figure 2.3 gives an overview on the AQM session joining process.

AQM uses a queue management scheme on each node to support QoS multicast applications and to determine the transmission order of data packets according to their traffic classes. Nevertheless, it does not consider a priority scheduling among neighbors which needs a cross-layer design (Bur and Ersoy, 2005). Furthermore, it adds complexity to the network by introducing many control messages and routing tables which affect scalability (Tebbe and Kassler, 2006).



(a) JOIN_REQ is send by node 5.	(b) JOIN_REP is send back to node 5.	(c) Node 5 Sends JOIN_RES to node 0

Figure 2.3: Overview on the Session Joining in AQM (Bur and Ersoy, 2005).

2.4.4 Providing Quality of Service to Ad hoc Multicast Networks

Tebbe and Kassler (2006) proposed an approach to provide QoS to Ad hoc Multicast Networks (QAMNet). This approach extends the existing On-demand Multicast Routing Protocol (ODMRP) (Lee et al., 1999) and the unicast QoS approach (Service Differentiation in Stateless Wireless Ad hoc Networks - SWAN) (Ahn et al., 2002). It introduces many QoS schemes: service differentiation, distributed resource probing, admission control and adaptive rate control to support QoS multicast routing. In addition, QAMNet uses the standard 802.11 protocol as the MAC layer model.

The ODMRP uses the concept of forwarding nodes where source node periodically broadcast route request packets to find all paths from the source to a group of destinations and defines the forward nodes. In this protocol, the intermediate nodes serve to relay the route request packets until they arrive at the destinations. When a destination node receives the route request packet it sends a route reply packet along the reverse path to the source. Normally, source node in ODMRP periodically sends route request packets to update the paths between source and destinations and to construct new paths.

When a QAMNet node has real-time traffic to send to a multicast group, it adds the minimum bandwidth and the required bandwidth to the route request and broadcasts it via the first data packet. When an intermediate node receives a route request packet, it rebroadcasts it after modifying the routing information in the request. Each intermediate node then updates the minimum bandwidth field if available local bandwidth is less than the minimum bandwidth in the route request packet. When a QoS route request arrives at the destination, the destination evaluates the available bandwidth in the path. If the minimum bandwidth is greater than or equals the required bandwidth, it creates a route reply with the minimum bandwidth and required bandwidth and broadcasts it. When the intermediate node receives the route reply, it sets a real-time forwarder flag for the given multicast group and rebroadcast the route reply packet. Hence, the forwarding mesh for real-time traffic is constructed in a similar way as in ODMRP. Figure 2.4 describes how intermediate nodes relay QoS route request packet until arrive at destinations.

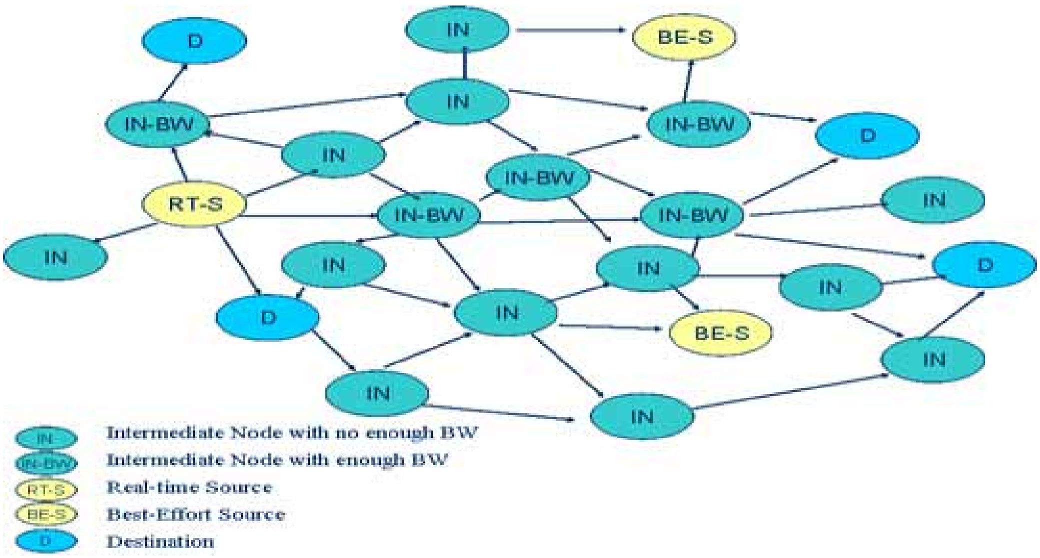


Figure 2.4: Intermediate Nodes Relay Route Request Packets

QAMNet calculates available bandwidth using the same method proposed by Ahn et al. (2002) where each node measures the actual rate of real-time traffic and calculate the available bandwidth as the difference between the threshold rate (the rate with maximum acceptable delay) and the current rate of real-time traffic. However, this method is not accurate because the threshold value changes dynamically based on traffic prototype (Ahn et al., 2002) (Zhu and Chlamtac, 2006). As such, the value of a threshold rates must be chosen sensibly as choosing high values would affect the performance of real-time traffic whereas choosing low values will affect the performance of the network where the available resources would enough.

The multicast source sets the Type of Service (ToS) bit in the IP-header for all real-time packets. When a forward node receives a real-time packet, the classifier checks the real-time flag. If it is set, the real-time packet will be rebroadcast directly and does not enter the shaper. If otherwise, the forward node resets real-time flag and put the packet in the queue of the shaper to deal with it as best-effort packet. The QAMNet uses the forward group scheme used in ODMRO to forward the best-effort packet. In this case all forward nodes that receive the real-time packet will re-forward the packet. Figure 2.5 describes how real-time forward nodes and forward group nodes forward real-time data packets. The forward node regulates the best-effort traffic using dynamic rate control based on the MAC layer back-off delay of the 802.11 model. The values of this rate control vary according to the Additive Increase Multiplicative Decrease (AIMD) algorithm.

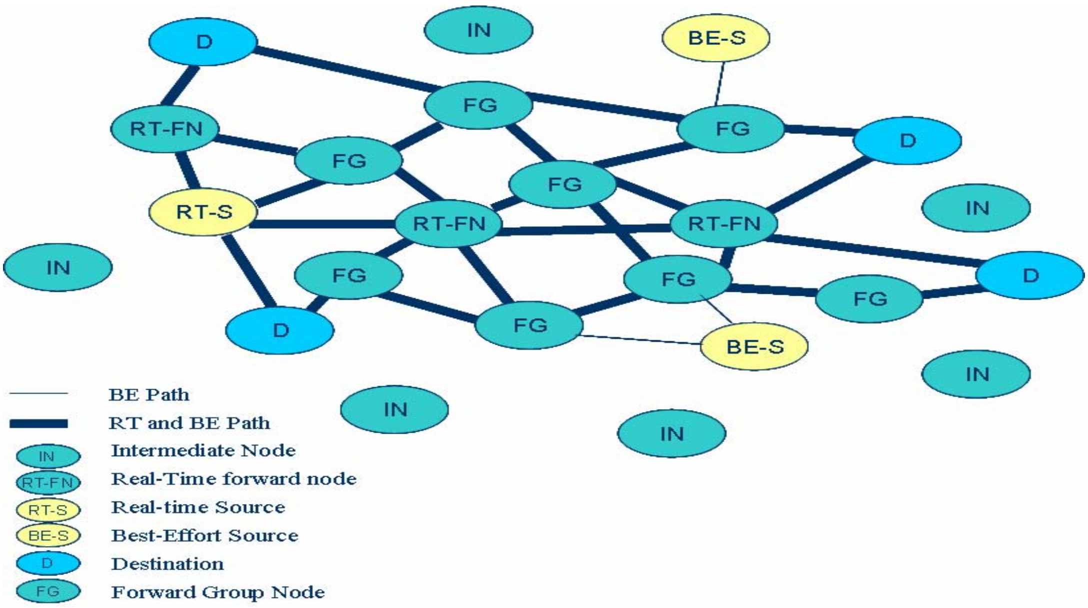


Figure 2.5: Forward Real-Time Data Packet

The drawbacks of QAMNet lie in the fact that the forward node will continue forwarding QoS route requests even when there is not enough available bandwidth and this wastes available bandwidth and increases packet delay and jitter. In addition, when real-time traffic flag at the forward node is not set, real-time packets are entered into the shaper and this introducing more