Design Issues and Performance Analysis in QoS-based Multicast Routing with MST on the MANET

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ABSTRACT

In recent years, wireless technologies and applications are getting more and more popular. How to maintain link connection and link flow efficiently and effectively is an important issue on the MANET for achieving good performance, high reliability and profound availability. According to these demands, it appears that multicast routing is essential on the wireless network. First, we describe the background and find out the QoS requirements on the MANET. Then, we trace and revise the establishment of the multicast tree with MST (Minimum Spanning Tree) to consider the mobility speed of mobile nodes to make the complexity of the multicast tree on the MANET. We also design a multicast routing method with satisfying QoS parameters called QMRM (QoS-based Multicast Routing with MST Algorithm) on the MANET. In concept of OLSR (Optimal Link State Routing) protocol, QMRM is to support QoS guarantee of unicast, broadcast and multicast on the MANET. Based on the QualNet, we design a simulator with QMRM to perform the simulation and to compare the performance among QMRM, ODMRP, OLSR and DSR. Consequently, the proposed QMRM can be used in multicast routing on the MANET to achieve better routing performance and to provide a more flexible real-time application.

***Keywords**: QMRM, Multicast Routing, MST, OLSR*

1: INTRODUCTION

With recent developments in transmission and computing technologies, distributed multimedia applications have become widely used lately. As wireless era comes, functions of wired network are popularized to wireless network, such as video conferencing and video on demand. Wireless technologies make it possible to access the Web from mobile phones, print documents from PDAs, and synchronize data among various office devices. However, some applications still rely at some points on mobility support routers or base stations, and it is often necessary to establish communication when the wired infrastructure is inaccessible, overloaded, damaged, or destroyed.

An ad-hoc network is a dynamic multi-hop wireless network that is established by a group of mobile nodes on a shared wireless channel. Much work has been done on routing in ad-hoc networks, but most of them focus only on best-effort data traffic. Therefore, Mobile ad hoc networks attract a large amount of research recently, since MANET can remove the dependence on a fixed network infrastructure by treating every available mobile node as an intermediate switch, thereby extending the range of mobile nodes well beyond that of their base transceivers [9]. Recently, because of the rising popularity of multimedia applications and potential commercial usage of MANETs, QoS (Quality-of-Service) supports in ad-hoc networks has become a topic of great interest in the wireless area. However, the topology of ad hoc networks may be highly dynamic due to unpredictable node mobility, which makes QoS provisioning to applications running in such networks inherently hard. To support QoS, the link state information such as delay, bandwidth, jitter, cost, loss rate and error rate in the network should be available and manageable. However, getting and managing the link state information in a MANET is by all means not trivial because the quality of a wireless link changes with the surrounding circumstance. Furthermore, the resource limitations and the mobility of hosts add to the complexity. In spite of these difficulties, some protocols on QoS routing in MANETs have been proposed, such as CEDAR or ticket-based probing [10].

In order to avoid wasting bandwidth and exacerbating the limited bandwidth of wireless channels between nodes, message exchange overheads of any QoS-provisioning algorithms must be at the minimum level. This requires that the algorithms need to be fully distributed to all nodes, rather than centralized to a small subset of nodes. Link-state routing algorithm exploits the periodic exchange of control messages between routers, ensuring that the route to every host is always known and immediately providing required routes. Optimized link-state routing compacts control packet size by declaring only multipoint relay (MPR) selectors, a subnet of neighboring links [6]. By integrating the above advantages, in this paper, we propose an algorithm to establish a QoS-based multicast tree with minimum spanning tree structure in combining optimized link-state routing algorithm to find out an optimal route on the MANET.

The remainder of this paper is organized as follows. In Section 2, we describe some previous studies and survey the related work. In Section 3, we illustrate some related definitions of required QoS services on the MANET. Also, we examine all relevant procedures to design the QMRM (QoS-based Multicast Routing with MST Algorithm). In Section 4, we design pseudo code for QMRM algorithm. In Section 5, we perform the simulation based on QualNet with QMRM. Then, we present and analyze the simulation results. Finally, we draw the conclusion and indicate future work in Section 6.

2: PREVIOUS STUDIES AND RELATED WORK

The best solution for connecting many electronic devices is to create a mobile ad hoc network using surrounding electronic devices as intermediate switches as shown in Figure 1. The multicast connection model can facilitate effective and collaborative communication among groups. Tree-based and flooding routings represent two ends of the multicast spectrum. The tree-based approach generates minimal data traffic in the network, but maintenance and updates of tree structure require many control-traffic exchanges [4]. Flooding, on the other hand, is a simple approach that offers the lowest control overheads at the expense of generating very high data traffic in the wireless environment, e.g., HMRP [8]. Both flooding and tree-based approaches scale poorly.

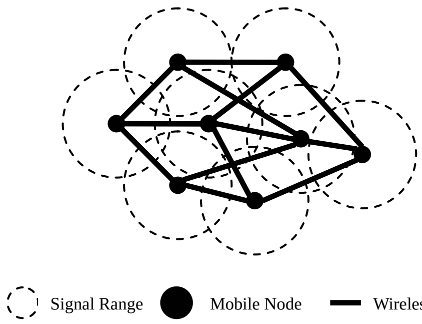

Figure 1. **A MANET Example**

Multicast routing protocols are important and practical in network environments. There are many applications and services achieved by multicast routing such as video conferencing, distance learning and video-on-demand, etc. Some multicast routing protocols have been recently proposed for ad hoc networks. Most proposed multicast protocols primarily exploit one or more specific characteristics of the MANET environment. These characteristics include variable topology, soft-state and state aggregations, knowledge of location, and communication pattern randomness [3, 5]. For example, mesh-based protocols exploit variable topologies; stateless multicasting exploits soft-state maintenance; location-aided multicasting exploits knowledge of location; and gossip-based multicasting exploits randomness in communication and mobility.

Some routing protocols for mobile ad hoc networks, such as ODMRP and DSR, are designed without explicitly considering QoS of the routes they generated [1]. QoS routing in ad hoc networks has been studied only recently. QoS routing requires that not only to find a route from a source to a destination, but the route needs to satisfy the end-to-end QoS requirement, often given in terms of bandwidth or delay. QoS is more difficult to guarantee in ad hoc networks than in other type of networks, because the wireless bandwidth is shared among adjacent nodes and the network topology changes as the nodes move. This requires extensive collaboration between the nodes, both to establish the route and to secure the resources necessary to provide the QoS [7]. QoS routing protocols search for routes with sufficient resources to support various QoS requirements. However, finding a path subject to multiple constraints is inherently hard. Polynomial-time algorithms for the problem may not exist [2]. Considering such difficulties, together with the fact that node movements in ad-hoc networks make the problem even more complex. Currently, the following decisions are made for our study. First, we consider "bandwidth" as the QoS routing constraint for the time period. This is because bandwidth guarantee is one of the most critical requirements of real-time applications. Our goal is to find an adaptive bandwidth path — the one has the highest bottleneck bandwidth among all the paths from source to destination. Second, we assume that the MANET topology is stable at one moment so that we can study the QoS routing problem on that stable graph. Actually, there are various circumstances where ad-hoc networks are rather stable. A wireless network consisting of desktops PCs, laptop computers and printers for home business may keep its original topology for a long time until someone moves one of the laptops to another room, for example. One avenue of future work pointed out below is to explore how fast our routing algorithm track changes, both to the underlying topology as well as the available link bandwidth.

Third, with bandwidth constraint as QoS metric, it is reasonable to view the "bandwidth" as available bandwidth. Most probably, the devices in the ad-hoc network will be configured with the same wireless card, which means that all nodes in the network have the same maximum bandwidth. Hence, we are only interested in how much of the remaining bandwidth is available for new traffic. However, bandwidth computation is a complex issue. Many previous papers have been discussed how to compute bandwidth in ad-hoc networks [2, 3, 11]. Here, we use a rather simple and straightforward approach to measure how much time a node monitors an idle channel and thus is available to transmit new messages over a link (node's idle time). MAC protocols such as IEEE 802.11 are based on a carrier-sense capability of each node. We exploit this capability to determine, locally at each node, for what percentage of time the medium has been busy in the recent past. A busy medium may indicate that a neighbor is transmitting data over the shared wireless channel. However, it may also indicate that nodes even further away, but still within interference range, are using the media. A node can only successfully transmit during times when neither its immediate neighbors nor other nodes in its interference range are transmitting. This characterization of the available bandwidth is superior to and with lower overhead than proposals where nodes communicate with their immediate neighbors to exchange information about their committed bandwidth, ignoring nodes further away. The “available bandwidth” over a link connecting nodes *a* and *b* is proportional to the minimum of *a*’s idle time and *b*’s idle time, since both nodes have to be available for a successful transmission. Since the number of nodes and the traffic between them in each node’s interference range is different, the idle times of two adjacent nodes may well be substantially different.

3: RELATED DEFINITIONS AND PERFORMANCE ISSUES FOR QMRM

The main parameters which are taken into consideration for providing the required QoS services on the MANET are as follows.

(1) **Bandwidth**: The amount of data that can be transmitted in a fixed amount of time. The bandwidth is usually express in bits per second (bps) or bytes per second. The network congestion arises frequently with low bandwidth.

(2) **Latency**: The Latency means the average delay for all the packets. Also, the time it takes for a signal to go from the sending station to the receiver station.

(3) **Jitte**r: The inter-packet arrival time at the receiver is not a constant and it fluctuates. This is mainly attributable to the queuing delay introduced in performing packet switching among mobile nodes on the multi-hop network.

(4) **Packet loss**: An error that occurs when data networks are overly congested. When pieces of data ("packets") are unable to be transmitted, they are sometimes "thrown out" by the network. Packet loss may or may not be disruptive to the recipient of the data, depending on the severity of loss.

According to mentioned above, we define all the procedures and examine their operations for the QMRM (QoS-based Multicast Routing with MST) algorithm. Due to the throughput and results, we only consider bandwidth for providing the required QoS service presently. All procedures of QMRM are particularly described as following.

■ *GroupSetup* procedure:

When the group set up in a Figure 2 , or when a node *v* is added to the MANET, it executes the procedure *Init* in order to determine its own role. If there is at least a master node with bigger weight among its neighbors, then *v* will join it. Otherwise it will be a master node.

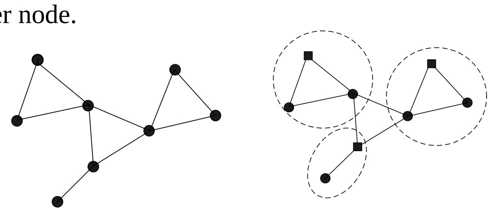

Figure 2. **Grouping on the MANET**

■ *MH(u)* procedure:

When a neighbor *u* becomes a master node, on calling the corresponding *CH* procedure, node *v* would be checked if it has to affiliate with *u* (it checks whether w_u is bigger than the weight of *v*’s master node or not). In this case, *v* joins *u*’s group.

■ *JOIN*(*u*, *z*) procedure :

When calling the procedure *JOIN*(*u*, *z*), the behavior of node *v* depends on whether is a master node or not. If yes, *v* has to check if *u* is joining its group or if *u* is originally belong to its group and joining another group now. If *v* is not a master node, it would be checked if *u* was its master node. The node *v* will join the biggest master node *x* in its neighborhood such that $w_x > w_v$ if such a node exists. Otherwise, *v* will be a master node.

■ *LinkBreak*(*u*) procedure:

whenever the node makes aware of the failure of the link with node *u*, it would be checked that if its own role is a master node and if *u* is originally belong to its group. If yes, *v* removes *u* from *Group*(*v*). If *v* is an ordinary node, and *u* was its master node, then it is necessary to determine a new role for *v*. Node *v* would be checked if there exists at least a master node *z* belong to *v*’s group such that $w_z > w_v$. If yes, then *v* joins the master node with the bigger weight, otherwise it becomes a master node.

■ *LinkEmbed*(*u*) procedure :

When node *v* is made aware of the presence of a new neighbor *u*, it checks if *u* is a master node. If yes, and if w_u is bigger than the weight of *v*’s current master node, then, *v* affiliates with *u*.

4: DESIGN OF QMRM ALGORITHM

Based on all relevant procedures as stated in previous section, the QMRM algorithm can be formally described in detail as follows:

ALGORITHM ***QMRM***;
Input :
A system in a network *G*(*V*, *E*), where *V* is the set of *n*-nodes.
Output :
Efficient routing path with minimum cost from source to destination.
Method:
begin
  /*initialize each variables*/
  Masternode = **nil**;
  for each node *z*
    begin
      w_z = random integer number;
      Ch(*z*) = **false**;
      Group(*z*) = **Ø**;
    end;
  /*QMRM main execution*/
  call *GroupSetup*;
  call *BuildMCtree*;
  call *RouteSelection*;

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        call RegularUpdate;
        if any node u is link failure then
                call LinkBreak(u);
        if any node u adds into the network then
                call LinkEmbed(u);
end;
END QMRM.
PROCEDURE GroupSetup;
begin
        if { w_z > w_v and Ch(z) }
            then begin
                send JOIN(v, z) ;
                Masternode :=z ;
            end
        else begin
                send MH(v) ;
                Ch(v) := true ;
                Masternode := v ;
                Group(v) := {v} ;
            end ;
end ;

PROCEDURE MH(u) ;
begin
        if (w_u > w_Masternode) then begin
                send JOIN(v, u) ;
                Masternode := u ;
                if Ch(v) then Ch(v) := false
        end
end;

PORCEDURE JOIN(u, z) ;
begin
        if Ch(v)
            then if z = v ;
                then Group(v) := Group(v) + {u} ;
            /*add the u into the group of v*/
            else if u ∈ Group(v)
                then Group(v) := Group(v) − {u} ;
        else if Masternode = u then
            if { w_z > w_v and Ch(z) }
                then begin
                    send JOIN(v, z) ;
                    Masternode :=z ;
                end
            else begin
                send MH(v) ;
                Ch(v) := true ;
                Masternode := v ;
                Group(v) := {v} ;
            end
end ;

PROCEDURE BuildMCtree ;
/*V = {v_1, v_2,..., v_n}.: the set of master nodes and neighboring node which connect two groups*/
/*T = Ø : suppose that the MCtree is an empty set initially*/
/*U = {v_1 } : starting from node v_1 to build the MCtree*/
        while (U ≠ V)
        /*when the set U is not equal to set V, the operation will be done continually*/
                let (u, v) be the lowest cost edge
                such that u ∈ U and v ∈ V − U;
                T = T ∪ {(u, v)}
                U = U ∪ {v}
        end;

PROCEDURE RouteSelection ;
/*C(i, j) : the weighted average of bandwidth, delay, throughput, and delay-jitter form node i to j. cost infinite if not direct neighbors.*/
/*D(v) : current value of cost of path from source to destination V.*/
/*p(v) : predecessor node along path from source to v, that is next v.*/
/*N : set of nodes whose least cost path definitively known.*/
        N = {A} ; /*the source node A*/
        for all nodes v
                if v adjacent to A Then
                        D(v) = C(A, v)
                else D(v) = nil;
        loop
                find u not in N such that D(u) is a minimum ;
                add u to N ;
                update D(v) for all v adjacent to u and not in N ;
                D(v) = min(D(v), D(u) + C(u, v) ) ;
        until all nodes in N
/*new cost to v is either old cost to v or known shortest path cost to u plus cost form u to v*/

PROCEDURE RegularUpdate ;
        When (Adjust_Period is time up) then
                if the weight of all nodes changed
                    then Init ;
        end ;

PORCEDURE LinkBreak(u) ;
begin
        if Ch(v) and (u ∈ Group(v))
          then Group(v) := Group(v) − {u} ;
          /*delete the u from the group whose master node is "v"*/
          else if Masternode = u then
                if { w_z > w_v and Ch(z) }
                    then begin
                        send JOIN(v, z) ;
                        Masternode :=z ;
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            end
        else begin
            send MH(v) ;
            Ch(v) := true ;
            Masternode := v ;
            Group(v) := {v} ;
        end
end ;

PROCEDURE LinkEmbed(u) ;
begin
    if Ch(u) then
        if (w_u > w_Masternode)
            then begin
                send JOIN(v, u) ;
                Masternode := u ;
                if Ch(v) then Ch(v) := false
            end
end;
```

5: SIMULATION RESULTS

Our models are validated by using the simulator with QualNet. The mobile nodes are randomly placed in a 2200*m* × 600*m* area. There are 20, 50, and 100 nodes in different simulation sets with transmission range 250*m*. Node movement uses the random model with pause time 10 seconds. The mobility speed of node is varied from 1 *m/s* to 10 *m/s*. The multicast group size is from 10 to 40 nodes. The values of parameters used in the simulation model are summarized in Table 1.

Table 1. Simulation parameters

Parameters	Values
Simulation time (seconds)	900
Simulation area (m^2)	2200×600
Number of nodes	20, 50, 100
Transmission range (*m*)	250
Mobility speed (*m/s*)	1, 5, 10
Pause time (seconds)	10
Multicast group size (nodes)	10, 20, 40
Number of sources (nodes)	1, 5, 10
Packet size (octets)	500

To study the performance of the proposed QMRM, we compare our scheme with ODMRP, OLSR, and DSR. In general, OLSR and DSR are common dynamic routings on the MANET. ODMRP has been known as a high-performance multicast routing protocol. Also, we did design a simulator based on QualNet with QMRM to perform the simulation. However, all the experiments were subject to the same environment for running about five times before the mean average value was established. Actually, we expect that the simulation results can increase the reliability and accuracy of the experimental statistics. Tables 2, 3, and 4 show the performance results under different numbers of mobile nodes and mobility speed. To be summarized, the QMRM can obtain highest throughput than other routing approaches: ODMRP, OLSR, and DSR as illustrated in Figure 3..

Table 2. 20 nodes on the MANET

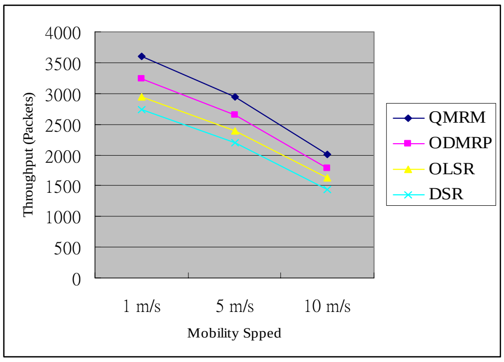
Routing Algorithm	Mobility Speed	Throughput (packets)
QMRM	1 *m/s*	3594
	5 *m/s*	2946
	10 *m/s*	2014
ODMRP	1 *m/s*	3237
	5 *m/s*	2645
	10 *m/s*	1778
OLSR	1 *m/s*	2947
	5 *m/s*	2392
	10 *m/s*	1624
DSR	1 *m/s*	2730
	5 *m/s*	2198
	10 *m/s*	1443

Table 3. 50 nodes on the MANET

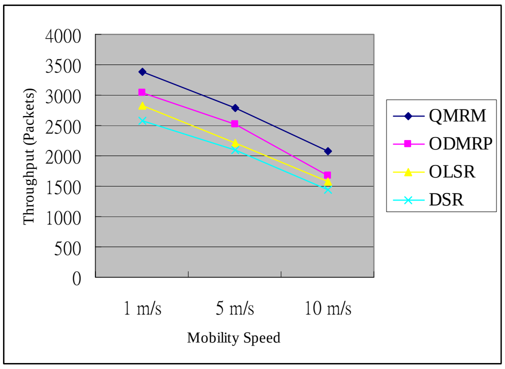
Routing Algorithm	Mobility Speed	Throughput (packets)
QMRM	1 *m/s*	3386
	5 *m/s*	2784
	10 *m/s*	2082
ODMRP	1 *m/s*	3043
	5 *m/s*	2516
	10 *m/s*	1672
OLSR	1 *m/s*	2835
	5 *m/s*	2213
	10 *m/s*	1568
DSR	1 *m/s*	2573
	5 *m/s*	2091
	10 *m/s*	1436

Table 4. 100 nodes on the MANET

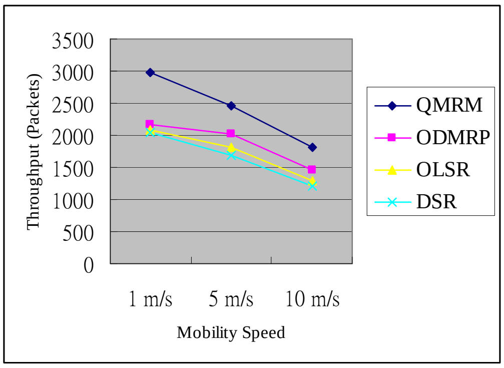
Routing Algorithm	Mobility Speed	Throughput (packets)
QMRM	1 *m/s*	2983
	5 *m/s*	2456
	10 *m/s*	1820
ODMRP	1 *m/s*	2173
	5 *m/s*	2029
	10 *m/s*	1452
OLSR	1 *m/s*	2075
	5 *m/s*	1809
	10 *m/s*	1283
DSR	1 *m/s*	2034
	5 *m/s*	1695
	10 *m/s*	1214



(a) 20 nodes



(b) 50 nodes



(c) 100 nodes

Figure 3. Throughput at 20, 50, and 100 nodes

6: CONCLUSION

The main objective of this paper is to propose the QMRM algorithm that improves efficiency and performance of the multicast routing on the MANET. Two key design issues of QMRM including setting up the MST and multicast routing with QoS parameters are proposed in this paper. In addition, the influential QoS parameters of the QMRM routing are considered in related cost including bandwidth, latency, jitter, and packet loss. Based on our simulations, the final results indicate that QMRM can obtain the higher throughput than other approaches: ODMRP, OLSR, and DSR. Consequently, the proposed QMRM can be used in multicast routing on the MANET to achieve better routing performance and to provide a more flexible real-time application.

In the future, the further researches mainly focus on performing some related experiments for comparing other KPIs such as bandwidth, latency, jitter, packet loss among ODMRP, OLSR and common DSR routings.

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