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An On-Demand QoS Routing with Multiple Metrics for Multimedia Service in Mobile Ad Hoc Networks

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Abstract - The emergence of real-time and multimedia applications in mobile ad hoc networks (MANETs) has recently generated much interest. To support such kind of applications, Quality of Service (QoS) features are desired. However, the mobile nature, limited resources, and dynamic topology of MANETs make it complicates to provide QoS guarantee in such network. In this paper, we propose an on-demand QoS routing scheme for multimedia service based on multiple QoS metrics called QoS-Based Dynamic Source Routing (QDSR). QDSR gathers information about end-to-end delay, available bandwidth and signal strength during route discovery and uses the information in route decision process. We evaluate the performance of QDSR by means of simulation. The result shows that QDSR provides the higher throughput, better packet delivery ratio and lower routing overhead than those of DSR.

Keywords: QoS routing, multimedia, mobile ad hoc networks, DSR.

I. INTRODUCTION

A Mobile Ad Hoc Network (MANET) is an autonomous collection of wireless mobile nodes with no predetermined topology or central control. The nodes intercommunicate through single-hop or multi-hop paths in a peer-to-peer fashion and operate both as hosts as well as routers as shown in Fig. 1. Such network can be used in the situation where either there is no any wireless communication infrastructure present or such infrastructure cannot be used such as in battlefields, emergency search-and-rescue operations, and disaster environments [1]. Collaborative computing and communication in smaller areas (home office, educational buildings, organization conferences, etc.) also can be set up using MANETs.

Since MANET is characterized by its fast changing topology, extensive research efforts have been devoted to the design of routing protocols for MANETs [1, 4, 5]. However, the most existing work is based on non-QoS requirement for example the source node attempts to transmit data to the destination node without any delay or bandwidth guarantee. As the real-time applications such as multimedia stream, live voice and video conference grow rapidly and sensitive with delay and bandwidth, QoS features become more important. However, the mobile nature, limited resource, and dynamic topology of MANETs make it complicates to provide QoS guarantee in such network.

There are many researches on QoS support in MANETs include QoS models [6, 7], Layered QoS [2], QoS Medium Access Control (MAC) [8], and QoS routing [3, 9, 10] which only consider with a single QoS constraint and sometimes it is not suitable to the highly unpredictable ad hoc environment. In order to guarantee the real-time and multimedia applications with multiple QoS requirement, we propose a QoS-Based Dynamic Source Routing (QDSR) protocol. The protocol finds the route that meets the multiple QoS constraints and has a better chance for surviving over a period of time from node movement. The multiple QoS constraints considered here are delay, bandwidth and signal strength. The rest of this paper is organized as follows. In Section II, we briefly introduce MANETs routing protocols and QoS routing. The proposed scheme QDSR is presented in Section III. Section IV presents our simulation and result. Finally, conclusion and future work are given in Section V.

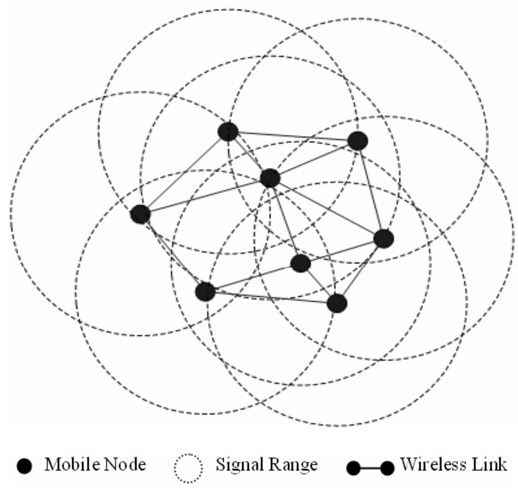

Figure 1. A mobile ad hoc network

II. RELATED WORK

A. MANETs Routing Protocols

Routing protocols in ad hoc networks can be classified into three groups [1]: Proactive (Table Driven), Reactive (On-Demand) and Hybrid routing protocols as shown in Fig. 2.

A.1 Proactive (Table Driven) routing protocols

Proactive routing protocols come as a natural extension of protocols for the wired network. In these routing protocols, each node has a number of tables to maintain routing information to every other node in the network and these tables are updated periodically. Examples of proactive routing protocols are Destination Sequence Distance Vector (DSDV), Wireless Routing Protocol (WRP), Cluster-head Gateway Switch Routing (CGSR) [1, 4] and so on. Since using periodic update, these protocols allow some significantly overheads and consume bandwidth in the network.

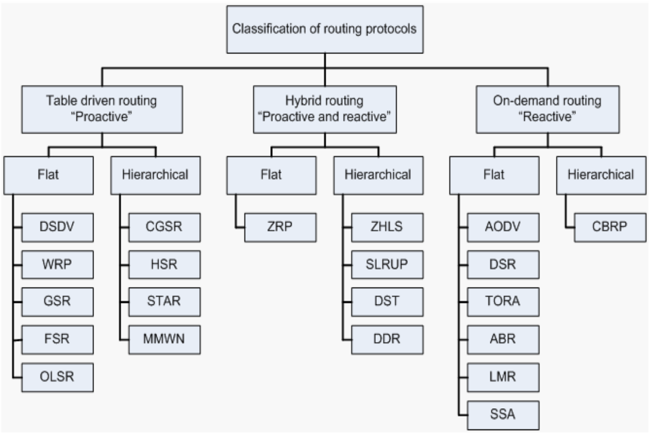

Figure 2. Classification of routing protocol

A.2 Reactive (On-Demand) routing protocols

Unlike proactive routing protocols, reactive routing protocols neither maintain nor periodically update their route tables. Several reactive routing protocols have been proposed such as Dynamic Source Routing (DSR), Ad Hoc On-Demand Distance Vector (AODV), Temporally Ordered Routing Algorithm (TORA) [1, 5] and so on. These routing protocols were designed to overcome the overheads occurred in proactive protocols.

DSR is one of the more commonly accepted routing protocols [5]. In DSR, when a node wishes to send data packets and does not have any routing information, it initiates a route discovery by flooding all of its neighbors with route request (RREQ) packets. Each neighbor broadcasts the RREQ, adds its own address in the header of packet. When the RREQ is received by the destination or by a node that has a route to destination, a route reply (RREP) is generated and sent back to the sender along with the addresses accumulated in the RREQ header. Route maintenance is invoked when the source node detects the broken link and then it can choose any other route to the destination node or invokes the route discovery again to find the new route to destination.

A.3 Hybrid routing protocols

Hybrid routing protocols combine proactive and reactive routing protocols. These protocols are designed to increase scalability when the wireless networks become larger. All nodes in the network are separated into groups. Each group is called a cluster. All clusters form a hierarchical infrastructure. In these routing protocols, the proactive maintains routes in a cluster and reactive maintains routes between clusters. Several Hybrid routing protocols have been proposed such as Zone Routing Protocol (ZRP), Zone-based Hierarchical Link State (ZHLS), Distributed Dynamic Routing (DDR) [1], and so on.

B. QoS Routing

QoS routing is the critical issue in MANETs due to mobility, mobile nature, and resource limitation. Some technical challenges are described in terms of designing optimal routes, providing reliable transmission and robustness, efficiency in resource utilization, adaptability, and unlimited mobility.

Normally, QoS routing protocols can be classified into two main groups. The first group concerns with some traditional protocols extended with QoS features. Their goal is to eliminate among the selected routes that do not meet the given criteria. The second group takes into account QoS aspect within routing algorithm. Two types of constraints exist such as application specific [9, 12] (e.g. bandwidth or delay) and network specific features (e.g. congestion, energy constraint, link stability) [10, 11, 13]. We can conclude that most of QoS routing protocols merely focus only on one application's QoS requirement based on a single QoS constraint which is not usually suitable to the highly unpredictable and dynamic ad hoc environment.

III. QoS-Based Dynamic Source Routing Protocol

In MANETs, the data service can be classified into two groups. The first group is the non real-time data service which bandwidth is not so sensitive and allows the delay during transmission. The routing protocol will do the best effort for such data service. Examples of this service are file transfer, web documents and other traditional datagram applications. The second group is the real-time data service which bandwidth and delay are very sensitive such as on-demand multimedia stream, video and audio conference, etc. This kind of traffic needs QoS guarantee. The proposed scheme constitutes an extension of DSR routing protocol, in which QoS features are embedded in the selection and maintenance of routes.

A. QDSR procedures

QDSR relies on three procedures: route discovery, route reservation and route maintenance.

1. Route discovery

QDSR adds a QoS header to an ordinary route request (RREQ) packet and has the following fields: <packet_type, source_addr, dest_addr, sequence#, route_list, link_info (delay, bandwidth, signal), slot_array_list, qos_enabled, bw_slot_req, qos_function, TTL, data>. The following QoS metrics are used in our proposed scheme to provide the network layer with QoS requirements that are used during route discovery:

- **Delay**: The end-to-end delay from a source to a destination that the application can tolerate.
- **Bandwidth**: The lowest bandwidth that application can tolerate on the route.
- **Signal Strength**: More stable route through dynamic network topology that has probability of surviving longer.

In this paper, we consider the combination of delay, bandwidth, and signal strength as the QoS function for selecting the appropriate route.

a) Source node algorithm

As illustrated in Fig. 3, when a source node wishes to send the real-time data packets, it first checks its resource availability such as free slots for bandwidth. If there is no resource available, the route discovery is canceled and the upper layer is informed. If the source node has sufficient resource, it will check the route in the route cache whether there is a route to the destination that satisfies the traffic requirement. If no valid route is stored in the cache, the source node places the information in RREQ header, initializes the QoS function and broadcasts the RREQ packet to its neighbors.

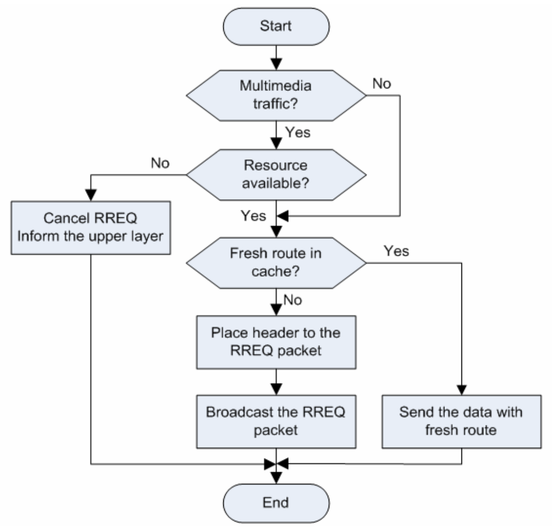

Figure 3. Source node algorithm

b) Intermediate node algorithm

This algorithm is executed by intermediate nodes on receiving a RREQ packet. From Fig. 4, we can explain the process of intermediate nodes as the following steps:

1. If the pair <dest_addr, sequence#> for the RREQ is seen recently, check whether Time to Live (TTL) is zero or not, if TTL counts down to zero, we drop the RREQ and do not process it further. TTL can limit the length of delivery path and control the flooding traffic.
2. Check whether the route request is searching for the path of multimedia traffic or common data traffic. If the traffic is multimedia traffic, the intermediate node calculates the link delay and available bandwidth from the sources to this node. If the result satisfies the QoS requirement, the intermediate node records the state of the data slots to the slot_array_list. Otherwise, we drop the RREQ.
3. Compute the QoS function including the link delay, available bandwidth and received signal strength. The QoS function of path P is given by a heuristic formula (1):

$$f(P) = (d - D(P))^{\alpha} + BW(P)^{\beta} + (S(P)/Rt)^{\gamma} \qquad (1)$$

where $D(P)$ is the delay at given path, d is the maximum end-to-end delay that application can tolerate, $BW(P)$ is the available path bandwidth, $S(P)$ is the minimum signal strength along the path, and Rt is the received signal threshold. α, β and γ are fixed parameters used to show relative importance about delay, bandwidth and signal strength in QoS routing based on application requirement.
4. Decrement TTL by one and append the address of this node to the route_list to track the route which the packet has traversed.
5. Selectively re-broadcast RREQ packet based on the QoS function. In order to reduce the broadcast storm and routing overhead, an intermediate node can re-broadcast a second RREQ packet only if it has higher QoS function than the first RREQ packet, otherwise the RREQ will be discarded.

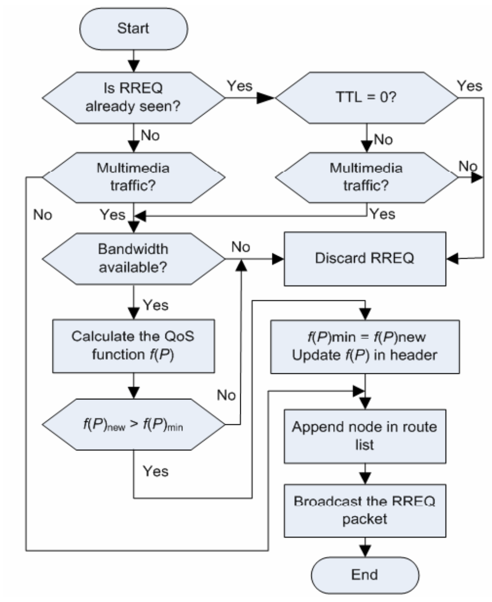

Figure 4. Intermediate node algorithm

c) Destination node algorithm

When the first RREQ packet with QoS enabled reaches the destination, the node starts the timer interval and during that time the node examines the QoS function of every arrived RREQ packet. When the timer interval expired, the destination node selects the RREQ packet that has the highest

QoS function and sends the route reply (RREP) packet carrying the route information to the source node. When another RREQ packet with the same sequence number arrives after the threshold time interval, it will not be considered and do not process it further. Figure 5 shows the process of destination node when receive RREQ packets.

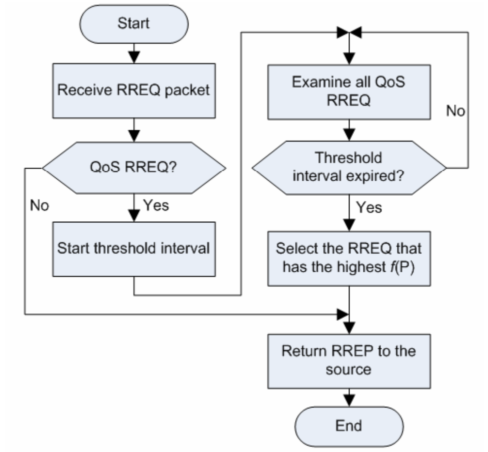

Figure 5. Route decision algorithm on the destination node

2. Resource reservation procedure

On receiving the RREQ packet, the destination node reserves resources using a TDMA-based bandwidth reservation model. As a RREQ packet travels from the source to the destination, it automatically sets up the reverse path from the destination back to the source. From the RREQ packet, we can obtain the state of data slots and according to the information recorded within the RREQ packet. The destination can set up a QoS route and reserves resources (slots) hop-by-hop backward to the source. If the reservation operation fails or the resources are not available, a route error (RRER) packet is sent.

3. Route maintenance

If the destination node does not receive the data packet in reserved time slot, it considers that the link is broken and uses its dedicated control time slot to broadcast a route error (RERR) packet with finite TTL. Any host in the QoS route will forward the RERR packet to the source. On receiving the RERR packet, the source can re-establish a new RREQ with QoS enabled.

IV. Simulation and Result

Network Simulator (NS-2) is used to analyze the performance of QDSR. Multiple QoS constraints are applied to the QoS function such as end-to-end delay, bandwidth and signal strength. The performance of our proposed scheme is then compared to the original DSR. Only the route discovery procedure has been implemented and the maintenance procedure is the one implemented in DSR.

A. Simulation model and parameters

The simulations were run using an ad hoc network model composed of 8 nodes that moved randomly at uniform speed over a rectangular area 800 x 800m flat space. The simulation parameters and constant values for f(P) in Eq.(1) are shown in Table I and II, respectively.

TABLE I. Simulation Model

Parameter	Value
Simulation area	800 x 800m
Number of nodes	8 nodes
Max. speed	0 - 10 m/s
Node movement	Random
Transmission range	250 m
Source / Packet size	CBR / 512 bytes
Sending rate	20 packets/sec

TABLE II. Constant Values

Constant	Value
α	0.3
β	0.3
γ	0.4
Max delay (d)	1 sec
Rt	$3.65x10^{-10}$

B. Simulation results

The result of simulation is shown in Fig. 6. We notice that QDSR improves the average throughput in comparison to DSR. When the mobility is increased, the performance of DSR will be significantly degraded. Adding more QoS criteria in the selection of intermediate nodes along the path leads to a more reliable data transmission which improves the throughput.

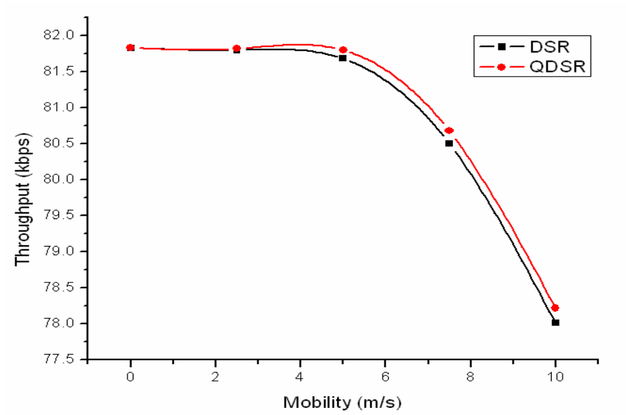

Figure 6. Average throughput versus mobility

From Table III, we can see that on average, QDSR sends about 43.6% fewer routing packets than those by DSR. Since one of the multiple constraint that considered by QDSR on selecting the route is signal strength, the chosen hop along the path is generally shorter and therefore, it can reduced the probability of route error. Moreover, normalized routing overhead informs the number of routing packets transmitted per data packet and it is proportional to node's mobility. From Fig. 7, we also shows that although the RREQ and RREP packets on QDSR have more fields that record the QoS information on the route, QDSR still achieves less overall overhead. It is resulted from the previous analysis that QDSR achieves lower route error and combined with selective re-broadcast mechanism based on QoS function in the intermediate nodes. Since RREQ packet on QDSR is sent less often as shown in Table III, lower overall routing overhead for multimedia traffic can be achieved.

TABLE III. NUMBER OF ROUTING PACKETS

Mobility (m/s)	0	2.5	5	7.5	10	Sum
DSR (non-multimedia)	21	47	97	124	209	498
QDSR (multimedia)	19	25	41	55	77	217

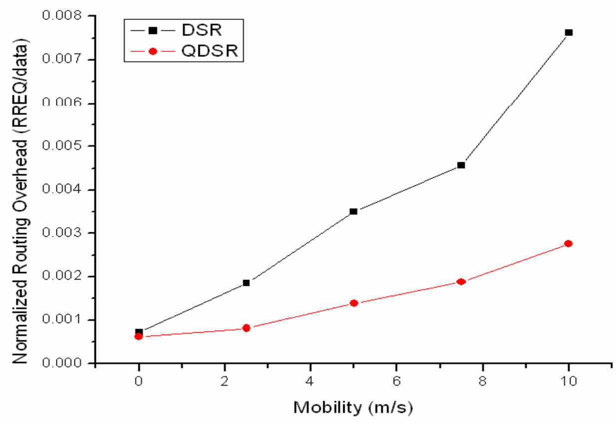

Figure 7. Normalized routing overhead versus mobility

As shown in Fig.8, the packet delivery ratio of multimedia traffic on QDSR is higher than one of common data traffic on DSR. When the network becomes congested or the route is broken frequently due the mobility, many packets will be discarded or lost. The lower packet loss rate implies the more stable route. Since QDSR selects the most feasible and stable route according to combination of delay, bandwidth and signal strength, the probability of broken route can be decreased and that leads to improvement on the packet delivery ratio which is higher than those on DSR.

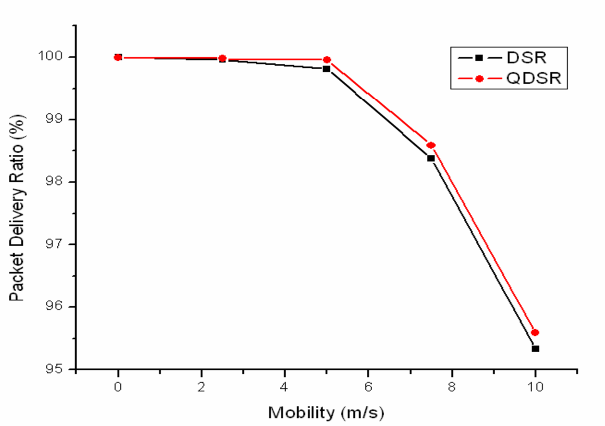

Figure 8. Packet delivery ratio versus mobility

V. CONCLUSION AND FUTURE WORK

We propose a new approach for QoS-aware routing to support the real-time and multimedia applications in mobile ad hoc networks. Our proposed scheme, QDSR, considers with multiple QoS constraints such as delay, bandwidth, and signal strength to find the most feasible route from the source node to the destination node. It also selects the most stable links which leads to longer-lived route and reduces route maintenance. We can conclude that our proposed scheme provides the improvement in terms of throughput, packet delivery ratio and lower routing overhead that is suitable for real-time and multimedia services in small networks.

Our future works will consequently consist in adding more functionalities such as improving the maintenance procedure, scalability issues and analyzing the effect of QoS function parameters on the performance of our proposed scheme.

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