A QoS-Based Dynamic Source Routing for Multimedia Service in Mobile Ad Hoc Networks

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Abstract - The growth of real-time multimedia applications in mobile ad hoc networks (MANETs) will be increasingly popular in the near future. 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 a routing scheme for multimedia service based on multiple QoS constraint called QoS-Based Dynamic Source Routing (QDSR). It applies the source routing mechanism defined by the Dynamic Source Routing (DSR) to reduce routing overheads and improve throughput. 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 our proposed scheme by means of simulation. The result shows that QDSR provides the higher throughput and lower packet loss rate than those of DSR.

Keywords: QoS routing, mobile ad hoc networks, Dynamic Source Routing.

I. INTRODUCTION

A Mobile Ad Hoc Network (MANET) consists 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. 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 (educational buildings, 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], Layered QoS [2], QoS Medium Access Control (MAC) [7], and QoS routing [3, 8] 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 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 the paper is organized as follows. In Section II, we introduce all related works. The proposed scheme QDSR is presented in Section III. Section IV presents our simulation and results. Finally, conclusion and future work are given in Section V.

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 as shown in Fig. 1.

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 DSDV, WRP, CGSR [1] and so on. Since using periodic update, these protocols allow some significantly overheads and consume bandwidth in the network.

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 DSR, AODV, 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 this

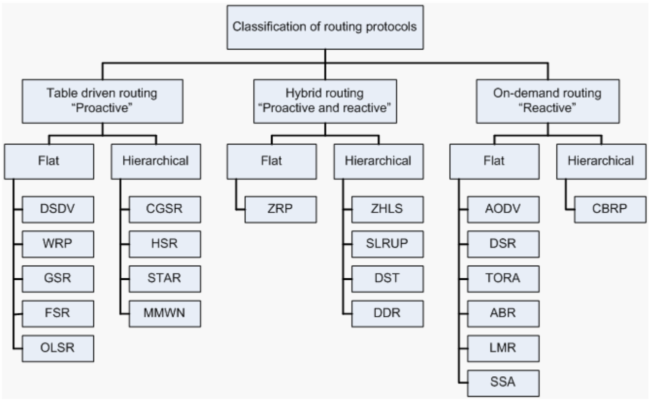

Figure 1. Classification of routing protocols

RREQ, adding its own address in the header of packet. When the RREQ is received by the destination or by a node that have 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 ZRP, ZHLS, 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, 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 the routing algorithm. Two types of constraints exist such as application specific [8, 10] (e.g. bandwidth or delay) and network specific features (e.g. congestion, energy constraint and link stability) [9, 11]. 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. 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 on the route. The proposed scheme constitutes an extension of DSR routing protocol, in which QoS features are embedded in the selection and maintenance of the 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, seq_num#, route_list, link_info (delay, bandwidth, signal), slot_array_list, traffic_type, bw_slot_req, qos_function, TTL, data>. The following QoS metrics are used in our proposed scheme to provide the network layer with QoS requirement 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 the 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 from source to destination.

a) Source node algorithm

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 route cache, the source node will place the information in RREQ header, initializes the QoS function and broadcasts the RREQ packet to its neighbors.

b) Intermediate node algorithm

This algorithm is executed by intermediate nodes on receiving a RREQ packet. From Fig. 2, we can explain the process of intermediate nodes as the following steps:

1. If the pair <dest_addr, seq_num#> 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

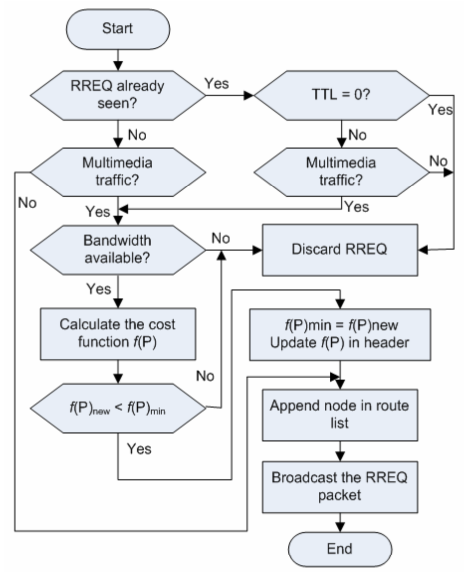

Figure 2. Intermediate node algorithm

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 available bandwidth from the source to this node using path bandwidth calculation and records the state of the data slots to the slot_array_list. If the result does not satisfy the QoS requirement, 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):

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

where D(P) is the delay at given path, d is the maximum 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.
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 lower QoS function than the first RREQ packet, otherwise the RREQ will be discarded.

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 lowest QoS function and sends the route reply (RREP) packet carrying this route 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. Fig. 3 shows the process of destination node when receive RREQ packets.

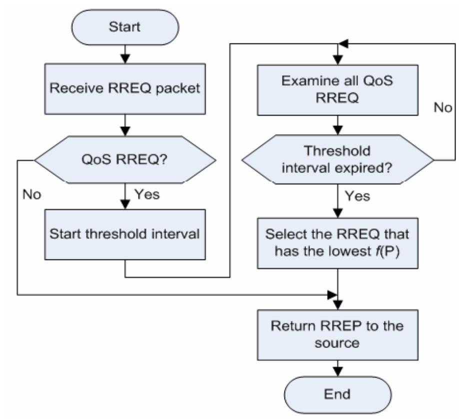

Figure 3. Destination node and route decision algorithm

2. Resource reservation procedure

On receiving the RREQ packet, the destination node reserves resource 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 resource 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 node 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. The performance of our proposed scheme is then compared to 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	3.65×10^{-10}

B. Simulation results

The result of simulation is shown in Fig. 4. 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.

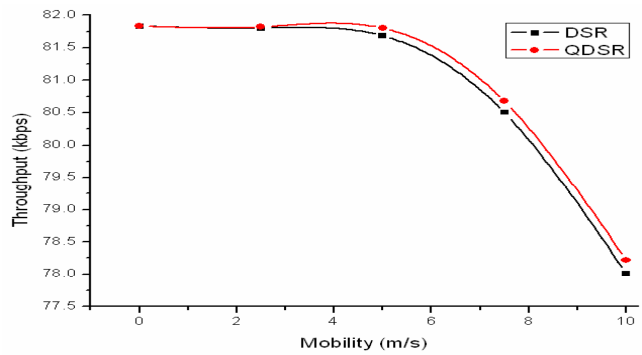

Figure 4. Average throughput versus mobility

In Fig. 5, we show the packet loss rate versus mobility. It also shows that the packet loss rate is proportional to the node's mobility. 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 our proposed scheme involves the multiple QoS constraints and selects the most feasible and stable route, the probability of broken route can be decreased and that leads the lower packet loss rate than those on DSR.

V. CONCLUSION AND FUTURE WORK

We propose a new approach for QoS-aware routing to support multimedia applications in mobile ad hoc networks.

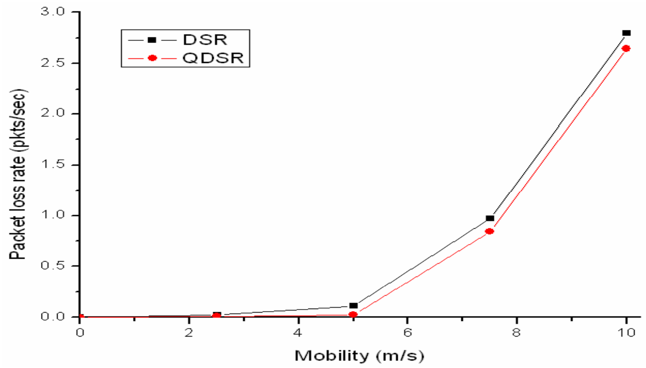

Figure 5. Packet loss rate versus mobility

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 routes and reduces route maintenance. We can conclude that our proposed scheme provides the improvement in terms of throughput and lower packets lost for real-time traffic and multimedia services in small networks.

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

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