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A QoS-Based DSR for Supporting Multimedia Services in Mobile Ad hoc Networks

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Abstract— **In this paper, we propose a routing scheme for multimedia service based on multiple QoS constraints in MANETs called QoS-Based Dynamic Source Routing (QDSR). QDSR gathers information about available bandwidth, link delay and signal strength during route discovery and uses the information in route decision process. We evaluate the performance of our proposed scheme via simulations. The simulation results show that QDSR provides the significant improvement in protocol performance metric applied in our measurement, such as throughput, packet delivery ratio, packet loss rate and routing load comparing with another on demand QoS routing protocol.**

Keywords—**Mobile Ad Hoc Networks, QoS routing, Dynamic Source Routing.**

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. MANETs technology can broadly applied in two main areas. The first area extends the current wired and wireless networks by adding new mobile nodes that use MANET technology at the edge of the network, for example MANET that used in home office, organization conferences and many other similar situation. The second area where MANETs provide a practical way to rapidly build a decentralized communication network in areas where either there is no any wireless communication infrastructure available or the pre-existing infrastructure cannot be used such as in battlefields, emergency search-and-rescue operations, and disaster environments [1]. Since MANET is characterized by its fast changing topology and unpredictable node connectivity, some extensive researches had been devoted to the design of routing protocols for MANETs [1, 4, 5, 6]. However, the most existing work is based on non-QoS requirement, for example the source attempts to transmit data to the destination without any delay or bandwidth guarantee. With the rising popularity of multimedia applications in MANETs such as digital video, live voice and video conference, QoS features become more important. However, the mobile nature including a variable capacity and bandwidth, limited power, and dynamic network topology of MANETs cause it to be complicated to provide QoS guarantee in such network.

There are many researches on QoS support in MANETs that include QoS models [7], Layered QoS [2], and QoS routing [3, 8, 9] which almost of all only consider with a single QoS constraint and sometimes they are not suitable to the highly unpredictable ad hoc environment. In order to guarantee the real-time and multimedia applications with QoS requirement, we propose an on-demand QoS routing scheme called QoS-Based Dynamic Source Routing (QDSR) protocol. This protocol attempts to find the route that satisfies the QoS requirements and has a better chance for surviving over a period of time after 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 detailed description of QDSR algorithm and its operations are given 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 are generally categorized into three groups [1]: *Proactive* (*Table Driven*), *Reactive* (*On-Demand*) and *Hybrid*. In proactive routing protocols, every mobile node changes its routing table and regularly updates nodes information. Since using periodic update, these protocols may incur some significantly overheads and consume bandwidth in the network. Contrarily to proactive protocols, reactive protocols neither maintain nor periodically update their route tables. These routing protocols were designed to overcome the overheads occurred in proactive protocols. Several reactive routing protocols have been proposed such as DSR, AODV, TORA [1, 5, 6] and so on. Hybrid routing protocols combine proactive and reactive routing protocols. These protocols are designed to increase scalability when the wireless networks become larger.

DSR is one of the more commonly accepted routing protocols in MANET[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

RREQ, adding its own address in the header of packet. When the RREQ is received by the destination or by an intermediate node on the route to destination, a route reply (RREP) is generated and sent back to the source node along with the addresses accumulated in the RREQ header. Route maintenance is invoked when the source node detects the broken link and then it attempts any other route or invokes the route discovery again to find the new route for the subsequent packets.

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.

In [10] Sinha *et al.* presented the Core-Extraction Distributed Ad Hoc Routing (CEDAR). CEDAR is designed to select routes with sufficient bandwidth resources. The protocol in [8] also works to make a routing decision on accepting an arriving request with a specific bandwidth requirement. While QoS-AODV extends the Ad hoc On-demand Distance Vector (AODV) routing mechanism which tries to find a suitable path and combined with bandwidth reservation mechanism for providing end-to-end QoS in an ad hoc environment [9]. Most of existing QoS routing protocols merely focus on one application's QoS requirement based on a single QoS constraint which sometimes is not usually suitable to the highly unpredictable and dynamic ad hoc environment.

III. QoS-BASED DYNAMIC SOURCE ROUTING PROTOCOL

QDSR is our proposed scheme that separates the data service 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. These kinds of traffic need QoS guarantee on the route. QDSR constitutes an extension of DSR routing protocol, in which QoS features are embedded in the routes selection procedures.

A. QDSR procedures

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

1a. Route discovery

When receiving a connection request for multimedia traffic, the source node will check 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. Otherwise, if it 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 initiate Route Discovery procedure.

QDSR also adopt the source routing mechanism in which the source node places the information in RREQ header, initializes the QoS function and broadcasts the RREQ packet to all of its neighbors. QDSR adds a QoS header to an ordinary route request (RREQ) packet and has the following fields: *<packet_type, source_addr, dest_addr, req_id#, route_list, qos_enabled, link_info (delay, signal), slot_array_list, bw_slot_req, qos_function, TTL>.*

Each intermediate node which has received the RREQ packet, it computes the link bandwidth and path bandwidth based on slot information recorded in RREQ packet to this node. If the result satisfies the QoS requirement, the intermediate node records the state of its slot to the *slot_array_list*. Otherwise, the RREQ packet will be dropped. Bandwidth guarantee is considered as the primary importance in this research. For the secondary importance, we consider with the routing optimally to give the mobile nodes a better chance for surviving over a period of time from node movement and path broken. This can be achieved by calculates the link delay and signal strength from the sources to this intermediate node and compute the QoS function including the link delay and received signal strength. The intermediate node then decreases TTL in RREQ packet by one, if the resulted number is equal to zero, the RREQ packet will be discarded. Otherwise, intermediate node appends the address of this node to the *route_list* to track the route which the packet has traversed. Finally the intermediate node performs selectively re-broadcast mechanism based on the QoS function which intermediate node re-broadcasts the second RREQ packet only if it has higher QoS function than the previous RREQ packet with the same sequence number, otherwise the RREQ will be discarded. With such mechanism, the broadcast storm and routing overhead can be reduced within the node. Fig. 1 shows the process of intermediate when receive RREQ packet.

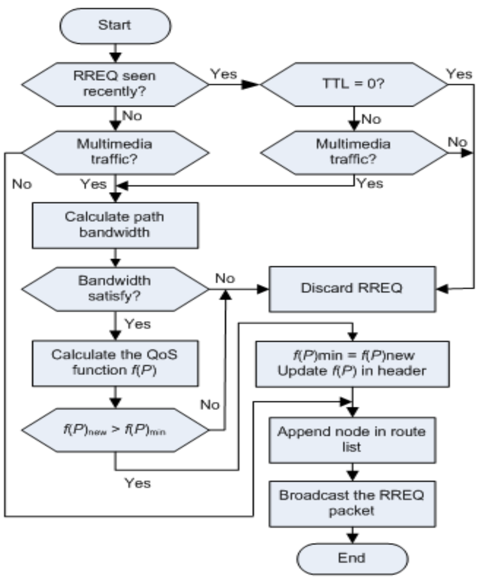

Figure 1. Intermediate node algorithm

When the RREQ reaches the destination node, the node starts the timer interval (T_r) and during that time the destination node examines the QoS function of every arrived RREQ packet and lists it on a Route Information Table. When the timer interval expired, the destination node selects the RREQ packet that has the highest QoS function, generates a corresponding RREP and unicast it back to the source node along the coming route. To support QoS, the format of RREP is also extended and has the following field: <*source_addr, dest_addr, req_id#, route_list, slot_array_list, bw_slot_req, TTL*>. When another RREQ with the same sequence number arrives after the time interval, it will not be considered and do not process it further.

1b. QoS function

A MANETs can be modeled as a undirected graph with weight G, $G=\{V,E\}$, V is the set of the mobile nodes, and the E the set of the bidirectional wireless link, for a link $e \in E$, have $e=(v_i, v_j)$, and node $v_i \in V$, $v_j \in V$, $i \neq j$, then v_i and v_j are the neighbor nodes. G and V are both dynamic set. For $s \in V$ is the source, $p \in \{V-\{s\}\}$ is the destination, if $e \in E$, define the metric function:

Delay function: $D(e) \; : E \rightarrow R^+$

Signal function: $S(e) \; : E \rightarrow R^+$

The QoS parameters of path p can be represented as:

$$\begin{cases} D(p) = \sum_{i=1}^{k-1} D(v_i, v_{i+1}) \\ S(p) = \min(S(v_i, v_{i+1}), (v_{i+1}, v_{i+2}), \ldots, (v_{i+1}, v_{i+2}) \end{cases} , \quad (1)$$

For the routing optimally which is considered as the secondary importance, the QoS function for remaining metrics on path P is given by a heuristic formula (2):

$$f(P) = ((d - D(P))/d) + \left(S(P)/Rt\right) \quad (2)$$

where $D(P)$ is the delay at given path, d is the maximum end-to-end delay that can be tolerated, $S(P)$ is the minimum signal strength along the path, and R_t is the received signal threshold. The higher value of QoS function implies the higher probability of lower delay and more stable link route.

2. Resource reservation procedure

On receiving the RREQ packet, the destination node reserves resources using a TDMA-based bandwidth reservation model by algorithms similar to one presented in [8]. As a RREQ 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 in according to the information recorded within this packet. The destination node can set up a QoS route and reserves resources (slots) hop-by-hop backward to the source node. If the reservation operation fails or the resources are not available, a route error (RRER) packet is sent to the destination along the coming route of RREP. When intermediate node receives RERR, this node will release slots reserved for the traffic. Upon receives RERR, destination node will check the Route Information Table to select the secondary route recorded and resend RREP. When RREP reaches the source, a QoS guarantee route is established and the source can start to send data.

3. Route maintenance

If the destination node does not receive the data packets 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 node. On receiving the RERR packet, the source node can re-establish a new RREQ for subsequent packets.

IV. SIMULATION AND RESULT

We simulate and analyze the performance of QDSR using the Network Simulator (NS-2). The performance of QDSR is then compared to another on-demand QoS routing protocol such as QoS-AODV. Specific functionalities are applied to support QoS criteria, such as delay, bandwidth and signal strength. Only the route discovery procedure has been implemented and the maintenance procedure is the one implemented in DSR.

A. *Simulation model and parameters*

Our simulation modeled an ad hoc network with mobile nodes placed randomly within 800 meter × 800 meter area. Radio transmission range for each node was 250 meter and random waypoint is used as the mobility model. With such mobility model, each node randomly selects a position, and moves toward that a position with a speed between the minimum and the maximum speed. Once the node reaches that position, it becomes stationary for a short predefined pause time. After that pause time, the node selects another position with random speed. We varied the upper bound speed to simulate different mobility speed. The minimum and the maximum speed were 0 and 10m/s, respectively.

A traffic generator was developed to represent the multimedia traffic which simulates constant bit rate sources and during 500 seconds of simulation, 3 source nodes send the constant bit rate (CBR) packet with rate 25 packet/second. In the experiments, we will pay more attention to the effect of mobility to the system performance. The detail of simulation parameters and constant values for *f(P)* in Eq. (2) are listed in Table I and II, respectively.

TABLE I. SIMULATION MODEL

Parameter	Value
Simulation area	800 x 800m
Number of nodes	8 nodes
Mobility	0 ~ 10 m/s
Node movement	Random way-point
Transmission range	250 m
Source / Packet size	CBR / 512 bytes
Sending rate	25 packets/sec
Num of CBR sources	3 sources

TABLE II. CONSTANT VALUES

Constant	Value
Max delay (d)	1 sec
R_t	$3.65\text{x}10^{-10}$ w

B. *Simulation results*

In the experiment, we evaluate the effect of mobility to the performance of our proposed scheme. As shown in Fig 2, we notice that QDSR improves the average throughput in comparison to DSR and QoS-AODV. Adding more QoS criteria in the selection of intermediate nodes along the path leads to a more reliable data transmission which improves the throughput.

For the next simulation, we compare the packet delivery ratio and packet loss rate for varying mobility as shown in Fig. 3 and 4, respectively. It also shows that QDSR has relatively higher packet delivery ratio and lower packet loss rate comparing with QoS-AODV. When the network becomes congested or the route is broken frequently due the mobility, many packets will be discarded or lost. The higher packer delivery ratio or lower packet loss rate implies the more stable route. 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 broken route.

Moreover, normalized routing load informs the fraction of the total number of routing packets forwarded at each node over the total number of data packets received at the destination nodes. This metric measures the efficiency of the routing protocol. Since QDSR selects the stable route, it can reduce the route maintenance process. In addition, the properties of QDSR is pure on-demand which no any periodic control packet comparing with QoS-AODV, therefore, the routing packet is also sent less often as shown in Fig. 5. As the result, the overall routing overhead can be achieved.

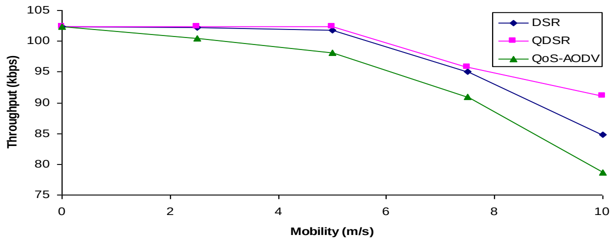

Figure 2. Average throughput versus mobility

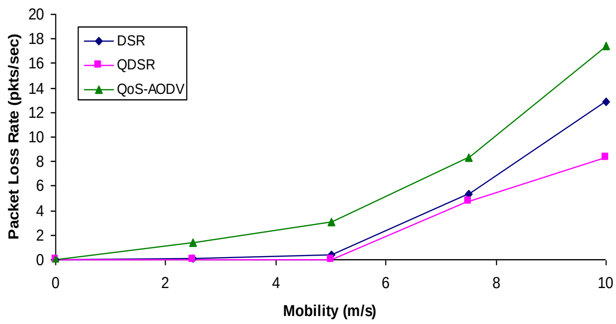

Figure 4. Packet loss rate versus mobility

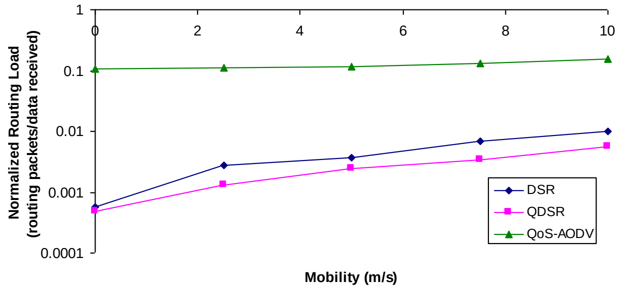

Figure 5. Normalized routing load versus mobility

V. CONCLUSION

In this paper, an on-demand QoS routing scheme to support multimedia applications in mobile ad hoc networks is introduced. QDSR considers with multiple QoS constraints such as delay, bandwidth, and signal strength. Bandwidth is considered as the first priority while combination between delay and signal strength is considered as the secondary importance. QDSR attempts 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. Simulation results proves that our proposed scheme provides the improvement in terms of average throughput, packet delivery ratio, lower packet loss rate and lower routing overhead.

VI. REFERENCES

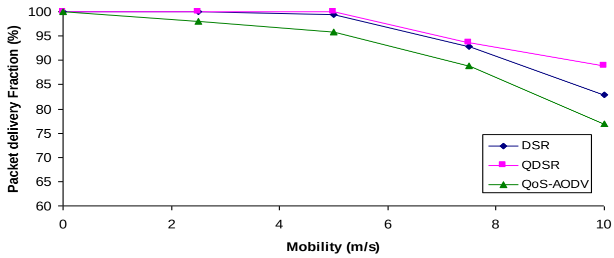

Figure 3. Packet delivery ratio versus mobility

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