Multipath Routing with Load Balancing and QoS in Ad hoc Network

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Summary
Mobile Ad hoc Networks (MANET) are wireless networks consisting of a collection of mobile nodes with no fixed infrastructure. Due to their decentralized, self-configuring and dynamic nature, MANETs offer many advantages and are easy to install. But many modern network applications, such as transmission of multimedia data require QoS which has raised a number of challenging technical issues for routing. To support multimedia applications, it is necessary for MANETs to have an efficient routing and QoS requirements. However, the rapid growth in number and diversity of real-time network applications has made it imperative to consider the impact of end-to-end delay requirements of traffic on network. In this article, by coupling a multipath routing protocol with load balancing mechanism according to some QoS, we present a new protocol called QLB-AOMDV (QoS and Load Balancing-AOMDV), a solution to achieve better load balancing with respect to the end-to-end QoS requirement. The simulation's result shows the significant performance improvement of the network for the multipath routing protocol with load balancing and QoS. The proposed solution QLB-AOMDV works better than other protocols in terms of delay, capacity and load balance.
Keyword:
Ad hoc network; multipath routing protocol; load balancing; QoS; AODV; DSR; MSR; AOMDV; QLB-AOMDV.

1. Introduction

A Mobile Ad hoc Network (MANET) consists in a collection of wireless mobile nodes, which form a temporary network without relying on any existing infrastructure or centralized administration.
Ad hoc network presents many specific problems which had influence on solution that assure QoS. The level of service that a user obtains from a network is known as the Quality of Service. The goal of QoS offered is to ensure a better delivery of information carried by the network, and a better utilization of the network's resources. The network provides a set of service guarantees such as minimum bandwidth, maximum delay, and maximum packet loss rate while transporting a packet stream from the source to the destination [1].
The main problems are: node mobility and link failure. However, node mobility provides dynamic change topology and route breaks occur frequently providing degradation of upstream on wireless network because not only high loss of packets but also delay occurs to search new route.
One of the most important aspects of the communications process is the design of the routing protocols used to establish and maintain multi-hop routes to allow the communication of data between nodes. While this might be sufficient for a certain class of MANET applications, it is not adequate for the support of more demanding applications such as multimedia audio and video. Such applications require the network to provide guarantees on the QoS. This is achieved by using some mechanism such as QoS routing to find the best route which satisfies these requirements in the best way. QoS routing appears to be a solution to handle these problems.
Qos routing requires not only to find a route from a source to a destination, but a route that satisfies the end-to-end QoS requirement, often given in terms of bandwidth, delay or loss probability. Quality of service is more difficult to achieve in ad hoc networks than in their wired counterparts, because the wireless bandwidth is shared among adjacent nodes and the network topology changes unpredicitibly as the nodes move. The objective of QoS routing in MANET is to optimize the network resource utilization while satisfying specific application requirements. The difficulties for supporting QoS in MANET environments are node mobility, routing overhead and limited battery life.
Contemporary research shows that using multipath routing in high-density ad hoc networks results in better throughput than using unipath routing [2]. Our motive in this paper is to design a routing technique, which considers the above problems. We define a metric that attempts to maintain a balance between load network and delay constraints in MANETs.
The remainder of the paper is organized as follows. We start with a review of the QoS routing on the ad hoc network. Then, we present the improvement to AOMDV protocol in order to support at once multipath routing and load balancing. Afterwards, we propose a solution called QLB-AOMDV *(QoS Load Balancing-AOMDV)* a QoS routing over AOMDV protocol which combines the

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advantage of the multipath routing protocol with load balancing mechanism to satisfy the QoS requirement.

2. QoS Routing Protocol

Depending on the application involved, the QoS constraints could be available bandwidth, end-to-end delay, delay variation (jitter), probability of packet loss, and so on. This kind of demand puts more pressure on the network and the routing protocols which are used to support the communications. Establishing multi-hop routes between nodes is not sufficient in this case.

In MANETs, node mobility often results in frequent topology changes, which presents a significant challenge when designing QoS routing protocols. High node mobility can make satisfying QoS requirements unreachable. Consequently, it is required that the network be combinatorically stable in order to achieve QoS support [3].

QoS based routing becomes challenging in MANETs, as nodes should keep an up-to-date information about link status. Also, due to the dynamic nature of MANETs, maintaining the precise link state information is very difficult. Finally, the reserved resource may not be guaranteed because of the mobility caused path breakage or power depletion of the mobile hosts. QoS routing should rapidly find a feasible new route to recover the service.

QoS is an agreement to provide guaranteed services, such as bandwidth, delay, delay jitter and packet delivery rate, to users. Supporting more than one QoS constraint makes the QoS routing problem NP-complete [4]. Therefore, we only consider the delay constraint when studying QoS-aware routing for supporting real-time video or audio transmission.

End-to-end delay estimation is a vital element of any QoS enabled routing protocol. We determine the time taken to route RREQ and RREP packets along the specified path in order to estimate end-to-end delay. By using a proactive fault tolerant routing with QoS aware multipath route discovery, smaller end-to-end delay and large throughput to a host can be achieved. Multipath routing is also more promising for QoS provisioning in ad hoc networks. The reason is multipath routing can provide load-balancing, fault-tolerance and higher throughput. Load balancing can be achieved by spreading the traffic along multiple routes. To alleviate congestion as well as bottlenecks and maximize the resources for MANET, the ideal number of multipath routing should be taken into consideration. It is also beneficial to avoid traffic congestion and frequent link breaks in communication because of the mobility of nodes. It has to be able to satisfy the QoS requirements.

In this paper, we employ the facility to determine multiple routes to a host and switch between them to expand the definition of AOMDV [5]. Enabling a QoS constrained route from source to destination is one of the objectives of the routing protocol. The route chosen by the protocol must send packets with minimum bandwidth and end-to-end latency, without facing congestion. The protocol should satisfy the above constraints and also select the most robust among all possible candidate routes. The quality of the service can be estimated and specified in terms of some parameters (called metrics) that are of prime importance to the application under consideration. These parameters are used to express the applications requirements that must be guaranteed by the underlying network.

3. AOMDV multipath protocol

AOMDV (Ad hoc On-demand Multipath Distance Vector) routing protocol is a multipath extension to AODV protocol aims to find loop-free and link-disjoint multipaths during the route discovery process. AOMDV uses advertised hop-count to guarantee the loop free feature. Advertised hop-count is defined as the maximum hop-count of the multiple paths to a destination node d available at an intermediate node i. It ensures that alternate paths at every node are disjoint, therefore achieves path disjointness without using source routing. To support multipath routing, route tables in AOMDV contain a list of paths for each destination. All the paths to a destination have the same destination sequence number. Once a route advertisement with a higher sequence number is received, all routes with the old sequence number are removed. Two additional fields, hop count and last hop, are stored in the route entry to help address the problems of loop freedom, and path disjointness, respectively. Because the protocol implement multipath discovery, the loop freedom guarantee from AODV no longer holds. AOMDV address this issue as follows. The hop count field contains the length of the longest path for a particular destination sequence number, and is only initialised once, at the time of the first advertisement for that sequence number. Hence, the hop count remains unchanged until a path for a higher destination sequence number is received. It follows that loop freedom is ensured as long as a node never advertises a route shorter than one already advertised, and never accepts a route longer than one already advertised.

To ensure that paths in the route table are link-disjoint, a node discards a path advertisement that has either a common next hop or a common last hop as one already in the route table. It was observed that, as long as each node adheres to this rule, all paths for the same destination

sequence number are guaranteed to be link-disjoint. Node-disjoint paths can be obtained with an additional restriction that for a particular destination sequence number, every node always advertises the same designated path to other nodes. Route maintenance in AOMDV is similar to that in AODV. A RERR for a destination is generated when the last path to that destination fails.
In AOMDV, advertised_hopcount replaces hopcount in AODV. A route_list replaces the nexthop, and essentially defines multiple next hops with respective hopcounts. However, all next hops still have the same destination sequence number.

4. The Proposed Modifications

4.1 LB-AOMDV Protocol

In this part, we propose an extension to AOMDV protocol in order to support certain mechanism and technique to improve its performance. AOMDV can allow finding many routes between source and destination during the same route discovery procedure but only one path is used to transmit data.
When the source receives one or many RREP packets from many disjoint paths, it decides:
If one RREP is received, therefore only one route layout from source to destination is used to send data packets.
- If many RREP are received, the source chooses the best route based on the short number of “hopcount”. The other routes remain waiting the RERR packet that indicates the failure of the principal route; in this case the best path from alternate paths is used to transmit data. The routing decision is as follow:

If (no route to destination)
{
Initiate route discovery as in AOMDV;
}
If (single known route)
{
Forward data packet to specified route;
}
Else
{
Forward data packet to best route;
}

We provide some modifications to this routing decision in order to AOMDV protocol uses many routes between source and destination and load balancing in the network.
The modifications to the routing decision above are presented as following:

If (no route to destination)
{
Initiate route discovery as in AOMDV;
}
If (single known route)
{
Forward data packet to specified route;
}
Else

/if N routes are known from source to destination*/
{
Distribute forwarding data packet to less congestion routes;
}

4.1 A new proposed metric

The AOMDV protocol selects the route with the lower hopcount to forward data. However, the less congestion routes can provide short end to end delay than routes providing lower hopcount. To choose the less congestion routes, we need a new metric which allow source node to select the less congestion routes. For this reason, we propose a new metric which achieve load balancing between the selected routes to take into account the number of active paths through every nodes according to the following equation (1):

$$Min\left[\frac{1}{n_p}\sum_{i=1}^{n_p}(buffer\_size(i))\right] \qquad (1)$$

Where buffer_size(i) means the size of occupation of the buffer of the link i traversing an intermediate node participating to the route p. The division with np hops, forming the route p, ensures that the metric takes into account the hopcount number to estimate the traffic load.
Maximum_buffer_sizei is defined as the maximum size of occupation of the link i buffer in each intermediate node. Exceeding this metric value indicates congestion at the route traversing this node. The buffer size mean of each routei (buffer_sizei) is always greater or equal than Maximum_buffer_sizei.
The Route maintenance is similar to AOMDV. In such protocols, link failures in the primary path, through which data transmission is actually taking place, cause the source to switch to an alternate path instead of initiating another route discovery. A new route discovery occurs only when all pre-computed paths break.
To build the LB-AOMDV protocol, we redefine the structure of RREP packet by adding a new field called buffer_size which take into account the traffic load on the route. This traffic load is expressed as the sum of buffer_size of intermediate nodes for each route between source and destination. When an intermediate node

receives a RREP packet, it increments the new field with the size of occupation of its buffer. On the other hand, when the source receives RREP packet, it divides the value of the buffer_size field by the hopcount of each route between source and destination in order to have the congestion level.
The algorithm to compute the congestion level of each route between source and destination is as follows:

```
if (node A receives    RREP)
{
if (node A not the source)
{
Buffer_size += buffer_size of node A ;
}
if (node A is the source)
{
*/compute the congestion level of route i from source to
  destination */
Congestion_ level(i)= buffer_size(i) / hopcount(i) ;
}
}
```

This algorithm is executed between source and destination to select a list of less congestion routes.
The new structure of routing table entries for LB-AOMDV is shown in Fig 1. We still add another additional field buffer_size in the route_list.

destination
sequence_number
advertised_hopcount
route_list {(nexthop1,hopcount1,**buffer_size1**), (nexthop2,hopcount2,**buffer_size2**), …}
expiration_timeout

Figure 1. Structure of routing table entries for LB- AOMDV

Each node sorts the *route_list* field by the descending value of *buffer size*. Each node sends data packets by using the route with the minimal *buffer size*. The LB-AOMDV protocol establishes three paths between source and destination nodes. The packets sent by source node are scheduled according to *Round-Robin* (RR) algorithm [6].

TABLE I. New structure of RREP packet

S A	D A	Sequence number	hopcount	timeout	**buffer_size**

5. The QLB-AOMDV Protocol

In this part, we add QoS to our proposal LB-AOMDV protocol which includes delay and throughput parameters. It takes advantage of the RREQ messages to exchange the essential information to achieve the QoS requirements. Enabling a QoS constrained from source to destination is the objective of our new protocol called QLB-AOMDV. Each node in the network estimates its quality of links with its one-hope neighbors.

5.1 Delay metric

A node can estimate the link delay by using the information in the RREQ message. For this reason, we redefine the structure of RREQ message by adding two new fields which indicates the received time of the packet (Tr) and the transmission delay of the packet (Delay).

TABLE 2. New structure of RREQ message

S A	D A	Sequence number	hopcount	timeout	**Tr**	**Delay**

To initiate QoS routing discovery, the source node sends the extended RREQ message. When an intermediate node N1 receives this RREQ message from the source node, it saves the time of this event in the (Tr1) field and forwards it to its neighbors. When a neighbor node (N2) receives the RREQ message from N1, it calculates the difference between the value of (Tr1) field and the current time (Tr2), which represents the measured delay of the link N1N2 and stores it in the (Delay) field according equation (2).

$$Delay_{N1N2(RREQ)} = Tr_2 \quad - \qquad (2)$$

This measured delay includes the queuing time and the transmission time. A threshold delay (D_{th}) is defined on the intermediate nodes. Exceeding this threshold value indicates the link N1N2 is unavailable to use and the node does not forward the RREQ message. Otherwise, the intermediate node N_2 put the received time of the packet in the T_r field, adds the transmission delay value to Delay field and forwards the update RREQ message to the next node. When a RREQ message arrives at the destination, it contains the summation of all the nodal delay along the traversed path. However, by such selection mechanism, the delay Qos constraints can be verified before the route selection.
For successful measurement of the delay metric, a single global time axis is required. Clocks in ad hoc networks, wireless networks and sensor networks, when

synchronized via GPS [7], NTP [8], or any of many efficient synchronization protocols for wired as well as wireless media [9–11], allow the assumption about an approximate, but sufficient, single global time axis. Thereby, based on the above considerations, we assume synchronized clocks.

To calculate the transmission delay of data packets between node N_1 and node N_2, we use the same available paths used for RREQ message according equation (3).

$$Delay_{N1N2(Data)} = \frac{Delay_{N1N2(RREQ)}}{Size_{(RREQ)}} \times Size_{(Data)} \quad (3)$$

5.2 Throughput metric

The node N2 can calculate the throughput of the link N1N2 according equation (4)

$$Throughput_{N1N2(RREQ)} = \frac{Size_{(RREQ)}}{Delay_{N1N2(RREQ)}} \quad (4)$$

A minimum threshold throughput (Thr_{min}) is defined on the intermediate nodes. Exceeding this threshold value indicates the link N1N2 is unavailable to use. However, by such selection mechanism, the delay Qos constraints can be verified before the route selection.

The new structure of routing table entries for QLB-AOMDV is shown in Fig 2. We still add three additional field buffer_size, delay and throughput in the route_list.

destination
sequence_number
advertised_hopcount
route_list {(nexthop1,hopcount1,**buffer_size1,throughput1, delay1**),(nexthop2,hopcount2,**buffer_size2,throuput2, delay2**), …}
expiration_timeout

Figure 3. Structure of routing table entries for QLB- AOMDV

Each node sorts the *route_list* field that satisfied the end-to-end QoS requirement by the ascending value of *delay*. Each node sends data packets by using the route with the minimal *delay*. The QLB-AOMDV protocol establishes three paths between source and destination nodes. The packets sent by source node are scheduled according to *Round-Robin* (RR) algorithm [12].

6. Performance Evaluation

We use NS2 to simulate our QLB-AOMDV protocol. For the initial simulations and the validation of the system the following parameters have been chosen:

Parameter	**Value**
Dimensions	1000X1000 m^2
Number of nodes	30
Simulation time	300 s
Source type	CBR
Number of Connections	10
Packet size	512 bytes
MAC Layer	IEEE 802.11b
Buffer size	50 packets
Propagation Radio Model	Two Ray Ground
Physique Layer	Band Width as 2Mb/s
Maximal speed	10 m/s
Pause time	10 s
Interval time to send	2 packets/s

Figure 2. Structure of routing table entries for QLB- AOMDV

All nodes have the same transmission range of 200 meters. The mobility model selected is the random waypoint model. In this mobility model, a node moves in the direction of the destination with a speed uniformly chosen between the minimal speed and maximal speed.

6.2 Parameter to evaluate

With the aim to evaluate our QLB-AOMDV protocol, we compare it with AOMDV protocol and LB-AOMDV protocol. We study the variation effect on the following metrics:

(i) Packet Delivery Ratio (PDR).

(ii) Average end to end Packet Delay (APD).

(iii) Average Buffer Size (ABS).

(iv) Traffic Over Head (TOH).

A. Simulation results

1) *Success packet delivery ratio versus the network load*

Figure 3 shows that the packet delivery ratio decreases according to the connections number. When the traffic load is about 40 connections (which is a heavy load), the PDR achieved by QLB-AOMDV protocol is 5% better than the PDR achieved by LB-AOMDV and 9% better than the PDR of AOMDV.

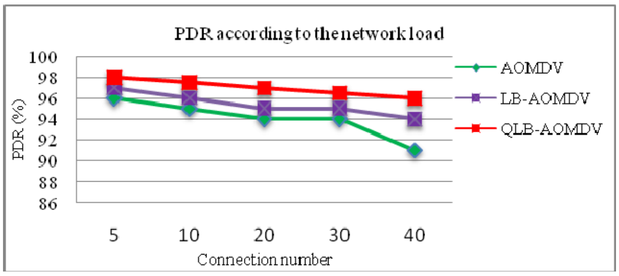

Figure 3. PDR versus the network load

2) Average end-to-end delay versus the network load

From figure 4, we note the increase of the average end-to-end delay according to the network load for all the routing protocols. The QLB-AOMDV protocol is the most efficient because, under heavy load (40 connections) its average end-to-end delay is about 16% less than AOMDV protocol and 4% less than LB-AOMDV protocol.

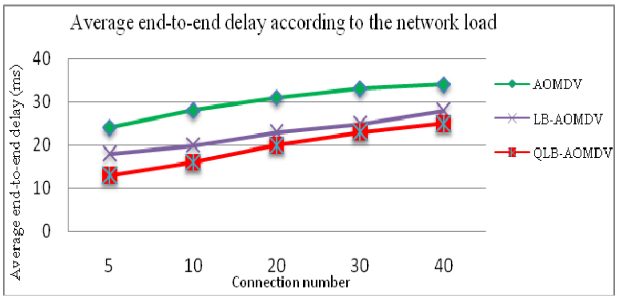

Figure 4. Average end-to-end delay versus the network load

3) *Average buffer size versus the network load*

Figure 5 shows that the average buffer sizes increase according to the network load for all the routing protocols. According to this figure, we note that our protocol reduces the congestion level of the network and increases its capacity.

4) Traffic Overhead versus the network load

The observation of figure 6 shows that our QLB-AOMDV protocol generates the highest traffic overhead. When the number of connections is equal to 5, the traffic overhead produced by all protocols is low. This traffic increases significantly when the network load increases (till 40 connections).

The traffic overhead (TOH) generated by AOMDV protocol under heavy load (40 connections) is about 50% less than that generated by QLB-AOMDV and LB-AOMDV protocol.

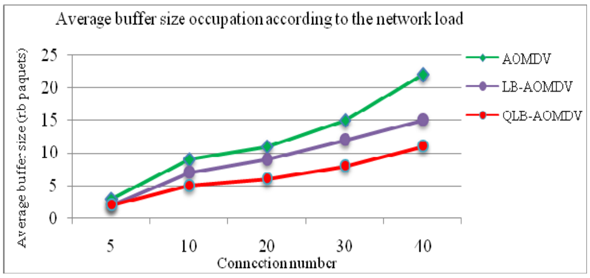

Figure 5. Average buffer size versus the network load

We can explain these results by the use of high number of control packets to search and maintain routes belonging to multipath routing protocols.

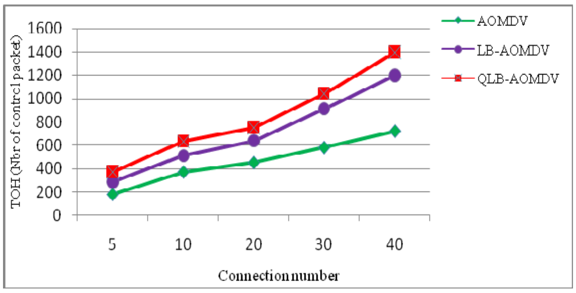

Figure 6. TOH versus the network load

7. Conclusion

In this work, we present a new multipath QoS routing protocol for MANET with load balancing mechanism. There are two main contributions in this work. One is load balancing mechanism to fairly distribute the traffic on different active routes, the other is the route discovery mechanism based on QoS parameters such as delay and throughput.

First, we have proposed a new multipath routing protocol called LB-AOMDV with a new metric which is the buffer size to select the less congested routes. Then, we add QoS to our proposal LB-AOMDV protocol which includes delay and throughput parameters. It takes advantage of the RREQ messages to exchange the essential information to achieve the QoS requirements. Enabling a QoS constrained from source to destination is the objective of our new protocol called QLB-AOMDV.

Among the performance evaluation of different routing protocols simulated: AOMDV and LB-AOMDV, we conclude that our protocol: QLB-AOMDV improves the network performance in terms of: capacity and congestion level compared to AOMDV protocol under heavy loaded network.

In the future work, we would like to introduce more categories of metric to our protocol such as energy constraint.

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