Energy and Link Quality Aware Multipath Routing Protocol for MANET

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Abstract—**Mobile Ad hoc Network (MANET) is established by the cooperative effort of the mobile nodes, which communicates in a wireless medium. Due to the mobile nature of the nodes, link between the adjacent nodes break very often and the topology of the network changes over time. Thus, as compared to fixed infrastructure wireless network, routing in MANET requires frequent route discovery and route repair processes. In MANET, nodes are powered by battery and they have limited lifetime. So, routing protocol used in MANET must consider the quality of link and energy of the node while selecting path from the source to destination node. In this paper, we have enhanced an existing protocol namely, AOMDV to incorporate both the energy of the node and the link quality while establishing path from the source to destination node. The proposed protocol is simulated using NS2 simulator and the results of the simulation are compared with AOMDV. It is observed that, the proposed protocol ELQ-AOMDV is able to provide better packet delivery and throughput in comparison with the existing AOMDV protocol.**

Keywords—*AOMDV; CETX; ETX; Energy; MRE;, EQL-AOMDV;*

I. INTRODUCTION

A mobile Ad-hoc network (MANET) is an interconnection of autonomous mobile nodes which are connected using wireless links and which form a multi-hop network with dynamic topology. In such a network, every node acts as a router and cooperatively help in communication. There are two categories of routing in MANET, namely Proactive routing and Reactive routing. In proactive routing nodes periodically broadcast routing advertisement and maintain routes between all nodes at all times. This approach induces increased overhead on routing and lacks the flexibility to respond in a dynamic topology. On the other hand, reactive routing discovers the route on demand, there by reduces overhead and adds required flexibility to the dynamic changes in the topology.

AODMV is an extension to the AODV protocol for creating multiple loop-free, link disjoint paths between source and destination node [1]. As there are multiple paths available for communication, the protocol can easily switch to other path without resorting to a fresh route discovery process. When all paths to the destination fail, route discovery process gets reinitiated. AOMDV is a reactive protocol, it invokes route discovery process by broadcasting RREQ that contains fields like, *last-hop* and *next-hop*, that are used to create a link-disjoint reverse path to the source. Whenever an intermediate node receives duplicate RREQ it checks whether an alternate reverse path to the source is formed, which is loop free and link disjoint, if so it creates an alternate reverse path to the source. Then the node checks its routing table for a valid path to the destination.

If it has a valid path, it generates RREP packets, containing forwarding path that was not used in any previous RREPs for the given RREQ. Then the RREP is sent back to the source via reverse path. Otherwise, RREQ is forwarded the neighbors, provided such a request was not forwarded before. However, when the destination receives RREQ packet, it checks whether the request arrived on a loop-free path. If so, it forms a reverse path towards the source and generates RREP packet. In fact, destination generates RREP for every RREQ which traversed a loop-free path, this helps in finding multiple disjoint paths. When the intermediate node receives an RREP packet, it checks for a loop-free, disjoint path towards the destination. If a such a path does not exist, it drops the RREP packet. However, if a loop-free disjoint path exists to the destination, then the intermediate node checks if any previously unused path for the same route discovery exists to the source. If such an unused path exists, it forwards the RREP along this path, otherwise it drops the RREP packet.

II. RELATED WORK

There has been a lot of work related to energy saving and link quality improvement in MANET. Yumei Liu et al. proposed MAX-MIN Residual Energy Multipath Protocol (MMRE-AOMDV) [2]. It uses the minimum residual energy of a node as a metric during the route discovery process and then uses the route with maximal residual energy among the available paths data transmission to destination.

May Cho Aye et. al [3] proposed a new protocol called Modified Energy Constrained Protocol based on AOMDV (MEC-AOMDV). The protocol uses the same route discovery procedure as that in AOMDV protocol, but uses the residual energy of each mobile node and transmission power for determining the best routes.

Koffka Khan et al [4]. proposed a new Energy Aware AOMDV protocol in which each node will store the state information such as hop count and the path energy metric. Here the reliability of the path is determined by the weakest node in the path. While forwarding the data to the destination, weakest nodes are avoided and communication is forced through the nodes with high residual energy.

III. ESTIMATING CETX AND ENERGY METRICS

A. Cumulative Expected Transmission Count (CETX)

Among the multiple paths available for transmission, AOMDV protocol chooses a path with least number of hop count for data transmission. However, minimizing hop count does not assure that the distance between the communicating

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node gets reduced. In fact, minimizing hop count usually maximizes the distance between each hop, which intern leads to minimal signal strength and maximum loss ratio. In 802.11b transmission errors fixed by using ACK mechanism, wherein lost packets are resent. Such retransmissions do not correct any lossy links, rather they reduce the throughput and interfere with other traffics in the channel. Expected Transmission Count (ETX) is a routing matric that is used to estimate the number of transmissions and retransmission required to deliver a data packet over the link to its destination [5]. It is also called as link ETX and is primarily used to find paths with high throughput. Summation of the ETX of all participating links of the route called path ETX [6]. It is referred to as Cumulative Expected Transmission Count (CETX) [7]. Received signal strength indicator (RSSI) is a measurement of the power present in a received radio signal. It is initially determined during route discovery by RREQ or RREP and then During route selection and maintenance by using HELLO packets.

Expected Transmission Count (ETX) is computed as the number of RREQ or RREP packets per unit time and is calculated as (1) [8].

$$ETX_{link(p,q)} = \frac{1}{PRR_{forward(p,q)} * PRR_{backward(p,q)}} \qquad (1)$$

Where PRR$_{forward(p,q)}$ is the Packet Reception Rate from the sender to the receiver and is calculated as the number of RREQ or RREP packets generated from the sender to the receiver in a unit time (2) [8].

$$PRR_{forward(p,q)} = \frac{No\ of\ RREQ\ or\ RREP\ recieved\ at\ node\ q}{unit\ time\ in\ seconds} \qquad (2)$$

PRR$_{backward(p,q)}$ is the Packet Reception Rate from the receiver to the sender and is calculated as the number of RREQ or RREP packets send by the sender, that were received at receiver (3) [8].

$$PRR_{bacckward(p,q)} = \frac{No\ of\ RREQ\ or\ RREP\ recieved\ at\ node\ p}{unit\ time\ in\ seconds} \qquad (3)$$

B. Energy Metric

Since the mobile nodes are powered by batteries, residual energy left with the nodes become the main limiting factor in path selection. In order to maintain an active path between the source and destination, the routing algorithm must choose only those paths in which participating nodes have residual energy greater than a threshold value. We can compute Minimum Residual Energy (MRE) [9] for a given path as the minimum value of residual energy of all participating nodes in the path. This can be equated as (4),

$$MRE = min\ \{E(i) \mid a \le i \le N\} \qquad (4)$$

Where E(i) it the residual energy of ith node in the path and N is the total number of nodes in the selected path. We can also compute the Path Residual Energy (PRE) as sum of residual energies of every node along the path and it can be shown using the equation (5).

$$PRE = \sum_{i=1}^{N} E(i) \qquad (5)$$

Every intermediate node along the path can estimate the energy metric [9] of the path based on the value of the PRE and MRE using the equation (6)

$$EM = \alpha\ MRE + \beta\ ARE \qquad (6)$$

Where ARE is the Average Residual Energy of the path and is computed using equation (7)

$$ARE = \frac{PRE}{N} \qquad (7)$$

α and β can take any value between [0,1], they represent the weights associated with MRE and ARE. To provide higher weightage to MHE, α is set to 0.6 and ARE is set to 0.4

IV. ENERGY AND LINK AWARE AOMDV PROTOCOL (ELQ-AOMDV)

ELQ-AOMDV is an enhancement into Ad hoc Multipath Distance Vector routing (AOMDV) protocol. It takes into consideration both the quality of the link and the residual energy of the node while selecting the path during communication. When the source node wants to communicate with a destination, whose path does not exist in the routing table, source node broadcasts route request packet (RREQ) to all its neighbors. The RREQ packet contains all the fields that were present in AOMDV, but also include some additional fields. Fig. 1. shows the format of RREQ.

Original AOMDV RREQ Structure	+	PRE	MRE	CETX

Fig. 1.   Modified Route Request of ELQ-AOMDV

When the packet is being broadcasted by the source node, it initializes PRE and MRE value to its residual energy. In order to accommodate link quality and residual energy values in route process, the routing table of AOMDV is modified as shown in Fig. 2.

Dest Add	Seq. No	Advertised hopcount	Route list				Timeout
			Next_hop1	Hop_count1	CETX1	EM1	
			Next_hop2	Hop_count2	CETX2	EM2	

Fig. 2.   Modified Routing Table of ELQ-AOMDV

When the RREQ packet is received by the intermediate node, it updates its routing table based on the algorithm shown in Fig. 3.

1. cetx$_i^d$:= cetx$_j^d$ + etx$_i^d$
2. ARE = PRE / hop_count
3. EM = α MRE + β ARE
4. if (seq.no$_i^d$< seq.no$_j^d$) then
5.   seq.no$_i^d$:= seq.no$_j^d$
6.   if (i ≠ d) then
7.   cetx$_i^d$:= cetx$_j^d$
8.   advertised_hopcount$_i^d$:=∞
9.   else
10.   advertised_hopcount$_i^d$:= 0
11.   end if
12.   route_list$_i^d$:= NULL
13.   insert (j , advertised_hopcount$_j^d$ +1, cetx$_j^d$, EM) into route_list$_i^d$;
14. else if (seqnum$_i^d$=seqnum$_j^d$) and (cetx$_i^d$,i) > (cetx$_i^d$,j) then
15.   insert (j , advertised_hopcount$_j^d$ +1, cetx$_j^d$, EM) into route_list$_i^d$;
16.   if (num_paths$_i^d$=max_num_paths) and ((cetx$_j^d$- min(cetx$_i^d$,i)) <= 1.0) then
17.   insert (j , advertised_hopcount$_j^d$ +1, cetx$_j^d$,EM) into route_list$_i^d$
18.   cetx$_i^d$:=cetx$_j^d$
19.   end if

Fig. 3.   Algorithm for updating routing table.

Upon receiving RREQ, the destination node generates the RREP message and unicasts it back towards the source. This process is identical to that of AOMDV. The message format of RREP contains all the fields of AOMDV and some additional fields which is shown in Fig. 4.

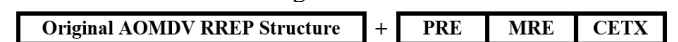| Original AOMDV RREP Structure	+	PRE	MRE	CETX

Fig. 4.   Modified Route Reply of ELQ-AOMDV

At the end of discovery phase, the source node selects one of the path as primary path and remaining paths are considered as alternate paths. The selection of primary path is based on the value of link quality and residual energy of the nodes

participating in the path. The selection is based on following conditions (8)

Selected path = $Max \{EM_i$ and $CETX_i\}$ and $Min\{Hop\_count_i\}$ (8)

where $1 \leq i \leq$ total number of paths.

It is a well-known fact that, hop count can also reduce end-to-end delay, the path selection also considers hop count while considering primary path. Route maintains procedure of ELQ-AOMDV follows similar steps as that of AOMDV.

V. PERFORMANCE EVALUATION

Simulation of the proposed routing protocol was carried out using NS2 simulator. We have used 802.11 is used as MAC layer Protocol with DCF (Distributed Coordination Function). CBR (Continuous Bit Rate) UDP, traffic with bit rate of 2 Mbit/s and radio range of 250 m is used. The simulation is carried out for 200 seconds over a rectangular area of 1000m×1000m and random waypoint model is applied. Table 1 shows the detailed description of simulation environment.

TABLE I
EXPERIMENTAL SETUP

Parameter	Value
Dimensions	1000X1000 sq. m.
Number of Nodes	10, 30, 50, 70, 90
Source Type	CBR
Propagation Radio Model	Two Ray Ground
Simulation Model	Random Way Point
Packet Size	512 bytes
Buffer Size	50 packets
Network load	4 packets/s
Mac Layer	802.11 b
Routing Protocols	AOMDV, ELQ-AOMDV
Maximal Speed	10 m/s
Pause Time	10 s
Simulation Time	200 s
Idle Power	0.0001 W
Transmission Power	1.0 W

Simulation is repeated by increasing the number of nodes from 10 to 90, incrementing each time by 20 nodes. Metrics were evaluated during simulations are,

Total Energy consumed provides the sum total of energy consumed by every node. It is measured in is Joules and can be equated as follows (9).

$$Total\ energy\ consumed = \sum_{i=1}^{n}(Initial\ Enegy_i - Residual\ Enegy_i) \quad (9)$$

Normalized Routing overhead, specifies the number of routing packets transmitted per data packet sent towards destination during simulation. It can be equated as follows (10).

$$Routing\ overhead = \frac{No.of\ packets\ transmitted}{No.of\ data\ packets\ recieved}$$
(10)

Throughput specifies the total number of bytes successfully received at the destination. It is measured in Kbps and can be computed as follows (11).

$$Throughput = \frac{Number\ of\ Bytes\ Recieved\ x\ 8}{Simulation\ time\ x\ 1000}$$
(11)

Packet Delivery Ratio gives the ratio of data packets delivered to the destination divided by the packets generated by the sources. It is computed as follows (12).

$$Packet\ Delivery\ Ratio(\%) = \frac{Total\ Number\ of\ Data\ Packet\ Recieved}{Total\ Number\ of\ Data\ Packet\ Sent}\ x\ 100$$
(12)

Routing Overhead is the count of total number of control packets generated by the protocol during simulation. It is calculated as follows (13).

$$Routing\ overhead = \sum Control\ packets$$
(13)

Average End-to-End delay is the average time consumed by the data packet while travelling from the source to the destination across the network. It is measured in milliseconds and it includes delays such as route discovery latency and buffering, queuing, retransmission at MAC, propagation and transfer time. It can be computed as (14).

$$Avg.\ End\ to\ End\ Delay = \frac{\sum_{i=1}^{n}(R_i - S_i)}{n}$$
(14)

Where S_i is the time at which packet i^{th} is sent from the source and R_i is the time at which i^{th} received at the destination. Total number of data packet delivered across the network is given by n.

From the simulated results it is found that, EQL-AOMDV delivers less packets in a network with less number of nodes. It is due to the fact that, the smaller network contains less number of paths and when the primary path fails, EQL-AOMDV puts more constraints on selection of paths, which results in lesser packets being delivered. However, with increasing number of nodes, number of possible paths will also increase and EQL-AOMDV is able to select better paths and delivers more packets. This is evident from the graph shown in Fig. 5.
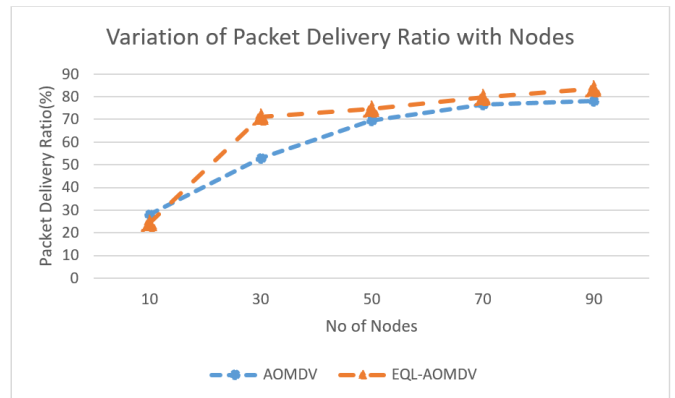

Fig. 5. Variation of PDR with increasing number of nodes.

Simulation results shows that, routing overhead of EQL-AOMDV decreases with an increase in number of nodes. This is due to the fact that, EQL-AOMDV selects more stable path and is thus able to reduce the control packets required for route maintain ace. This result is shown in Fig. 6.

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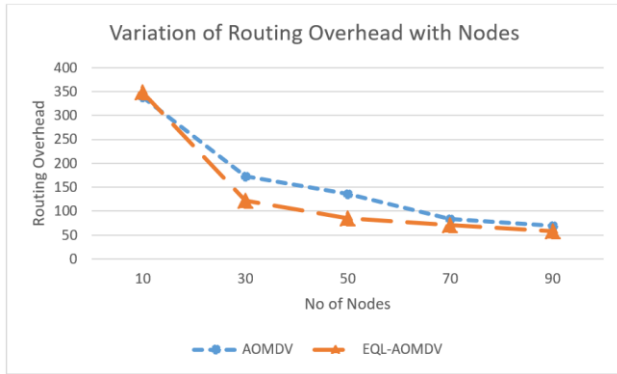**RTESIT - 2019 Conference Proceedings**

Fig. 6. Variation of Routing overhead with increasing number of nodes.

It was found the average end to end delay in EQL-AOMDV is less as compared to AOMDV. This is because of the fact that EQL-AOMDV also considers the hop count while selecting path for routing packets. This is shown in Fig. 7.
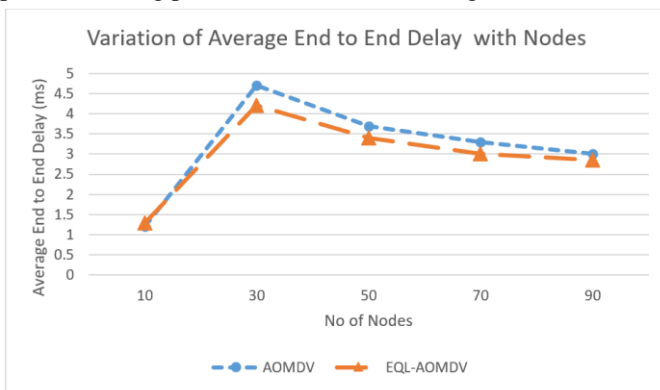

Fig. 7. Variation of Average E2E Delay with increasing number of nodes.

Simulation results shows that, as the network size increases, EQL-AOMDV is able provide better throughput than AOMDV. This is due to the fact that, EQL-AOMDV is considers only stable links during path selection. Simulation results of throughput is shown in Fig. 8.
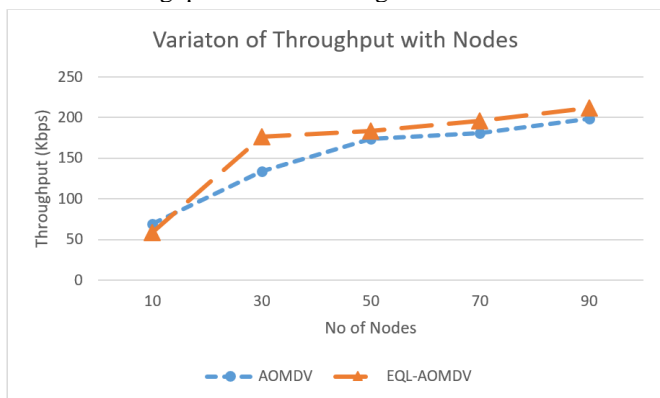

Fig. 8. Variation of Throughput with increasing number of nodes.

It is observed from the simulation results, that the energy consumed by EQL-AOMDV is slightly less than the AOMDV. This is because, the EQL-AOMDV is able to select the path with higher residual energy. The simulation results are shown in Fig. 9.
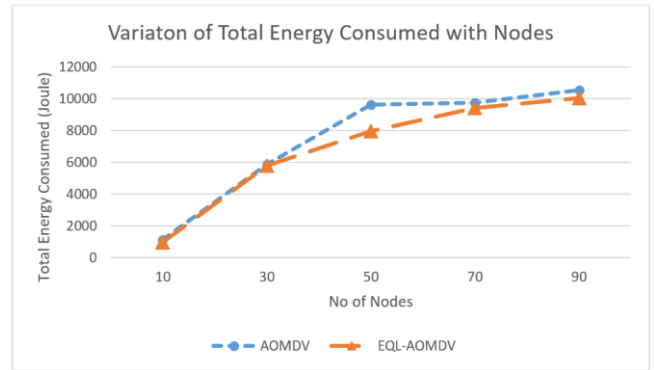

Fig. 9. Increase in Total Energy Consumed with increasing number of nodes.

VI. CONCLUSIONS

In this paper we have modified AOMDV protocol to incorporate link quality and residual energy during path selection process. The modified protocol EQL-AOMDV is simulated using NS2 simulator and the results are compared with existing AOMDV. From the simulated results it found that EQL-AOMDV is able to select more reliable link during route discovery phase and is able so choose those nodes which have a better residual energy. This is evident from the results of simulation, which indicate that, EQL-AOMDV provides better throughput, less end to end delay and consumes less energy as compared to AOMDV.

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