Journal of Theoretical and Applied Information Technology
20th November 2014. Vol. 69 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

A NOVEL APPROACH TO ENHANCE THE QUALITY OF AOMDV ROUTING PROTOCOL FOR MOBILE AD HOC NETWORKS

[1]P.PERIYASAMY, [2]E.KARTHIKEYAN

[1] Department of Computer Science and Applications, Sree Saraswathi Thyagaraja College, Pollachi - 642 107, Tamil Nadu, India

[2] Department of Computer Science, Government Arts College, Udumalpet - 642 126, Tamil Nadu, India

E-mail: [1] pereee@yahoo.com, [2] e_karthi@yahoo.com

ABSTRACT

Since the AOMDV routing protocol selects multiple node disjoint paths based on minimal hop count, the link failures and route breaks occurred in highly dynamic ad hoc networks. For eliminating such problems, we proposed a novel link quality based multipath routing protocol called ***Link Quality Based Multipath Routing (LQBMR)*** protocol which is the extension of a well known AOMDV routing protocol. The proposed protocol finds multiple link reliable paths using ***Path-Link Quality Estimator (P-LQE)*** such as ***Cumulative Expected Transmission Count (CETX)***. The LQBMR protocol uses only CETX instead of hop count as path metric for determining more link reliable paths between any source and destination pair for data transmission. We have evaluated the performance of LQBMR protocol using NS 2.34 and compared it with AOMDV routing protocol. The LQBMR protocol reduces the routing overhead, packet loss ratio, normalized routing overhead and energy consumption. It also increases the packet delivery ratio and throughput. From the simulation results, it is found that the LQBMR protocol has performed better than AOMDV routing protocol.

Keywords: *Mobile Ad Hoc Networks, Multipath Routing, Packet Delivery Ratio, Throughput, Average End To End Delay, Normalized Routing Overhead, AOMDV And Link Quality Estimator.*

1. INTRODUCTION

A Mobile Ad hoc Network (MANET) is an interconnection of autonomous mobile nodes by wireless links forming dynamic topology and providing multi-hop communications without using much physical network infrastructure such as routers, servers, access points or cables or centralized administration. Each mobile node is acting as a router as well as a node. The properties of these networks make them to be very highly desirable in war zones, disaster recovery, aircraft and marine communications, industrial, home and other scenarios. The issues of MANET [1,2,3] are: ***(i) unpredictable link properties*** that expose packet collision and signal propagation, ***(ii) node mobility*** creates dynamic topology, ***(iii) limited battery life*** of mobile devices, ***(iv) hidden and exposed terminal problems*** occur when signals of two nodes are colliding with each other. ***(v) route maintenance*** is very difficult because of changing behavior of the communication medium, and ***(vi) lacking in security*** in boundaries of MANET leads to attacks such as passive eavesdropping, active interfering, and leakage of secret information, data tampering, message replay, message contamination, and denial-of-service (DoS).

Among the many issues to be addressed, routing is one of the very important problems to consider. Normally single path routing protocols find an optimal route (single route) between a pair of source and destination. Here a new route discovery is needed for every route break that leads to high overhead and latency. But multipath routing protocols establish a communication from source to destination by having backup routes. During end-to-end communication, if a primary route fails, the backup routes are used for efficient delivery of messages at their destination. These protocols [4] are generally classified into three groups such as ***(i) proactive***, ***(ii) reactive*** and ***(iii) hybrid*** based on route discovery and maintenance mechanisms. The proactive (table-driven) routing protocols determine the routes to all destinations at start up and maintain using periodic update process based on distance vector-based or link state-based routing strategies. Examples for multipath proactive routing protocols are the multipath destination-sequenced distance-

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

vector (MDSDV) [5] and multipath optimized link state routing (MP-OLSR) [6]. The drawbacks of these algorithms are to update the routing tables frequently which consume a large amount of memory, bandwidth and power.

But, in the reactive (on-demand) routing protocol, there is no need to maintain the routing information in routing table by each node. The routes are determined and maintained only when they are required by the source for data transmission during route discovery process and the routing overhead is also reduced. Examples for multipath reactive routing protocols are the multipath dynamic source routing (MP-DSR) [7] and the ad hoc on-demand multipath distance vector (AOMDV) [8] protocol is a multipath extension of AODV[9]. AOMDV provides link-disjoint, loop free and fault tolerance paths which improves the network lifetime by minimizing packet loss, routing overhead and energy consumption. The main goal of a **Quality of Service (QoS)** multipath routing protocol is to identify loop free energy efficient paths from any source to destination with the available resources to meet the QoS requirements of the desired service.

The features of both proactive and reactive protocols are combined together to form a new generation of protocols called hybrid multipath routing protocols. This type of protocols are used to increase scalability by allowing nodes with close proximity to work together to form some sort of a backbone to reduce the route discovery overheads. This can be achieved by proactively maintaining routes to nearby nodes and determining routes to far away nodes using reactive route discovery strategy. Example for this category is Zone Routing Protocol (ZRP)[10].

Wireless ad hoc networks, due to their ad hoc nature and mobile environment, make frequent use of broadcast primitives such as bandwidth, energy, delay, load, etc. to adapt with network changes. Reliable data transmission in MANET is an issue due to the frequent failures of wireless links between nodes. Therefore, it is essential to develop link reliable reactive routing protocol that selects reliable links during data transmission. The major contribution of this work is to introduce link reliable energy efficient and modified version of AOMDV routing protocol for wireless ad hoc networks, called **Link Quality Based Multipath Routing (LQBMR)** protocol.

The rest of the paper is organized as follows. Section 2 gives a brief description about AOMDV routing protocol. Section 3 presents the proposed routing protocol. The simulation environment and experimental results are discussed in Section 4. Finally, conclusions and future work are given in Section 5.

2. AD HOC ON-DEMAND MULTIPATH DISTANCE VECTOR ROUTING (AOMDV)

AOMDV is an enhanced version of a prominent and well-studied on-demand single path routing protocol known as AODV. AOMDV eliminates the occurrence of frequent link failures and route breaks due to node mobility, node failures, congestion in traffic, packet collisions, and so on in highly dynamic ad hoc networks by adding some extra fields in routing tables and control packets in order to compute loop-free and link-disjoint multiple routes between the source and destination.

Routing Process of AOMDV has three phases such as (i) route discovery, (ii) route selection, and (iii) route maintenance. In AOMDV, the RREQ (Route REQuest), RREP (Route REPly) or HELLO packets are transmitted over links of nodes in order to establish, select and maintain routes between any source and destination. These packets are called ***Received Signal Strength Indicators (RSSI)***[11]. In AOMDV, the propagation of RREQs from a source to a destination via intermediate nodes are used to establish multiple reverse routes, the propagation of RREPs from a destination to a source via intermediate nodes are used to establish multiple forward routes and the flooding of HELLO packets between nodes are used mainly to obtain local link connectivity after route establishment [12]. Every node locally updates its routing table upon receiving HELLO packets, called **Local Path Update (LPU)**.

3. PROPOSED PROTOCOL

3.1 Routing Metrics

Routing Metrics [13] are the qualitative measures to select best routes among multiple routes under certain aspects of the routing process of a protocol. These metrics are classified as ***(i) node based routing metrics*** that are used to select best routes among multiple routes based on available information of participating nodes such as energy, hop count, etc., and ***(ii) link based routing metrics*** that are used to select best routes among multiple routes based on available information of participating links such as throughput, reliability, etc. Reliable data transmission has been an issue in

Journal of Theoretical and Applied Information Technology
20th November 2014. Vol. 69 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

multipath routing of MANET since nodes prone to failures due to uncertainty links between them.

Hop count is the conventional node based routing metric used to select a route with less number of hops among the available routes to the intended destination from the source. Most of the routing protocols in MANET use hop count as their base metric. It is very simple and easy to evaluate the suitability of a route based purely on the path length and it does not take packet loss or bandwidth into account.

Expected Transmission Count (ETX) is a qualitative link based routing metric proposed by De Couto, et al [14] for estimating the number of transmissions and retransmissions needed to send a data packet over a link, called *link ETX* [15]. **Cumulative Expected Transmission Count (CETX)** is the summation of the ETX of all participating links of the route, called *path ETX*. *RSSI* is determined initially by RREQ or RREP during route discovery and then by HELLO packets during route selection and maintenance. Since the RREQ or RREP packets are used to determine the stability of links between nodes during route discovery, they are used to calculate both ETX and CETX in this protocol. In this paper, the ETX of a link between nodes along the forward path is computed using RREP packets as well as the ETX of a link between nodes along the reverse path is computed using RREQ packets.

The AOMDV uses the traditional routing metric hop count for finding multiple routes and selects a route with few hop count among them for data transmission. During data transmission if any link between the nodes of that route fails, data loss occurs in AOMDV. To rectify this problem, we propose a novel routing protocol by modifying AOMDV routing protocol which uses CETX as path selection metric instead of hop count.

3.2 General Procedure

The Proposed protocol is an extension of AOMDV which uses Path-Link Quality Estimator (P-LQE) [16,17,18] such as Cumulative Expected Transmission Count (CETX) as a route metric in order to select link reliable paths for data transmission. It reduces the routing overhead, packet loss ratio, normalized routing overhead and energy consumption. It also improves the packet delivery ratio and throughput. The following is the general procedure of LQBMR protocol:

(i) Finding Expected Transmission Count (ETX)
(ii) Finding Cumulative Expected Transmission Count (CETX)
(iii) Selection of routes based on CETX

(i) Finding Expected Transmission Count (ETX)

Expected Transmission Count (ETX) is the quality of a link between the participating nodes of the path determined in terms of number of RREQ or RREP packets over a period of time. The traditional routing metric hop count is not considered as a criterion in our protocol to select the multiple routes between any source and destination pair. During route discovery phase, the LQBMR protocol calculates $PRR_{forward(i,j)}$, $PRR_{backward(i,j)}$, and $ETX_{link(i,j)}$ as follows:

$$PRR_{forward}(i,j) = \frac{No.of\ RREQ\ /\ RREP\ Packets\ generated\ at\ node\ i}{w\ seconds} \quad (1)$$

$PRR_{forward(i,j)}$ is the Packet Reception Rate of uplink quality from the sender to the receiver, that is, the number of RREQ or RREP packets generated from the sender to the receiver over a period of time.

$$PRR_{backward}(i,j) = \frac{No.of\ RREQ\ /\ RREP\ Packets\ received\ at\ node\ j}{w\ seconds} \quad (2)$$

$PRR_{backward(i,j)}$ is the Packet Reception Rate of downlink quality from the receiver to the sender, that is, the number of RREQ or RREP packets received by the receiver from the sender over a period of time.

$$ETX_{link}(i,j) = \frac{1}{PRR_{forword}(i,j) * PRR_{backward}(i,j)} \quad (3)$$

The value of $ETX_{link(i,j)}$ is calculated from both uplink quality from the sender to the receiver $PRR_{forward(i,j)}$ and downlink quality from the receiver to the sender, $PRR_{backward(i,j)}$. The structure of routing table entries of AOMDV and LQBMR protocols are illustrated in **Fig. 1** and the notations and their descriptions used in this paper are shown in **Table 1**.

AOMDV	LQBMR
destination	destination
sequence number	sequence number
advertised hop count	advertised hop count
route list {(nexthop$_1$,hopcount$_1$), (nexthop$_2$,hopcount$_2$),… }	route list {(nexthop$_1$,hopcount$_1$,**CETX$_1$**), (nexthop$_2$,hopcount$_2$,**CETX$_2$**), …}
expiration time out	expiration time out

Figure 1: Structure of Routing Table Entries of AOMDV and LQBMR protocols

Source Address	Destination Address	Sequence Number	Hop Count	Time Out	CETX

***Figure 2:** Extended RREQ Message Format*

Journal of Theoretical and Applied Information Technology
20th November 2014. Vol. 69 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Source Address	Destination Address	Sequence Number	Hop Count	Time Out	CETX

Figure 3: Extended RREP Message Format

Table 1: Notations and Descriptions

Notation	Description
$ETX_{link(i,j)}$	ETX value of link i and j
$ETX_{path(s,d)}/CETX_{path(s,d)}$	Path ETX, called as CETX
$PRR_{forward(i,j)}$	Forward Packet Reception Rate of a link at node i
$PRR_{backward(i,j)}$	Backward Packet Reception Rate of a link at node j
i,j	Intermediate Nodes
S,s	Source Node
D,d	Destination Node

(ii) Finding Cumulative Expected Transmission Count (CETX)

Each RREQ and RREP of LQBMR protocol now carries an additional field called **cetx** for holding the Cumulative Expected Transmission count is shown in **Fig. 2** and **Fig. 3** respectively. After calculating ETX of links in a wireless network, the Cumulative ETX of a path from a source node S to a destination node D is the summation of the ETX value of all participating links of the node disjoint path shown in **Line 1** of **Algorithm 1** and is calculated as follows:

$$CETX_{path(S,D)} = \sum_{link(i,j) \in path(S,D)} ETX_{link(i,j)} \quad (4)$$

Where *path(S, D)* is a set of successive links in the path from node S to D such as: $path(S, D) = \{(S, I_1), (I_1, I_2), \ldots, (I_{k-1}, I_k), (I_k, D)\}$.

(iii) Selection of routes based on CETX

Each RREQ and RREP of LQBMR protocol now carries the sum of the ETX value of link over which the RREQ or RREP has traversed, called CETX is shown in **Fig. 2** and **Fig. 3** respectively. Similar to AOMDV routing protocol, in LQBMR, when a node receives a RREQ packet first time, it rebroadcasts the RREQ packet immediately.

When a source S floods RREQ to a destination D or a destination D sends back RREP to a source S, the CETX of RREQ/RREP is initialized by 0. Upon receiving the RREQs or RREPs, the intermediate nodes find ETX value in terms of number of RREQ or RREP packets over the ends of the link and the CETX is updated periodically using **Algorithm 1** which deals with the following two cases in order to select the paths whose *CETX* is less than 1 and greater than 0:

Case 1: From **Lines 2 – 11** of **Algorithm 1**, the intermediate node updates its CETX with the *CETX* of RREQ/RREP of this node if the sequence number of just received packet is greater than this node.

Case 2: From **Lines 12 – 18** of **Algorithm 1**, the intermediate node updates its CETX with the *CETX* of RREQ/RREP of this node if the sequence number of just received packet is equal to this node.

Fig. 4 illustrates the route selection process of LQBMR protocol. Here the number in each link is the ETX value of that link, and S and D are the source and destination. In LQBMR protocol, the path with CETX value is less than 1 and greater than 0 selected for data transmission and the ETX value of a link between two nodes is zero, it is considered as a weak link which is not considered for data transmission. For example, node F sends 3 RREQ packets to node H per second, then the $PRR_{forward(F,H)}$ is 3 and the node H receives 1 RREQ packet from node F per second, then the $PRR_{backward(F,H)}$ is 1 and the ETX value of the link between nodes F and H is 0.3. The path S – A – F – H – D with CETX=0.6 is selected as a primary route for data transmission and the path S – B – E – I – D with CETX=0.7 is chosen as alternate route.

Whenever a node i receives a route advertisement to a destination d from a neighbor j, it invokes LQBMR route update rules in order to setup forward as well as reverse routes as shown in **Algorithm 1**. The variables $seqnum_i^d$, $advertised\_hopcount_i^d$, $route\_list_i^d$, and $cetx_i^d$ are the *sequence number*, *advertised hop count*, *route list* and *cumulative expected transmission count* for *destination d* at *node i* or *node j* respectively.

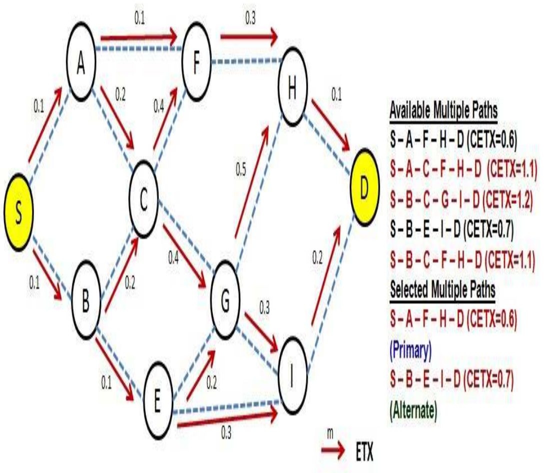

Figure 4: Route Selection Process of LQBMR protocol

Journal of Theoretical and Applied Information Technology
20th November 2014. Vol. 69 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Algorithm 1: Route Update Rules of LQBMR Protocol

```
cetx_j^d := cetx_j^d + etx_j^d;
if (seqnum_i^d < seqnum_j^d) then
    seqnum_i^d := seqnum_j^d;
    if (i≠d) then
        cetx_i^d := cetx_j^d;
        advertised_hopcount_i^d := ∞;
    else
        advertised_hopcount_i^d := 0;
    end if
    route_list_i^d := NULL;
    insert ( j , advertised_hopcount_j^d +1, cetx_j^d) into route_list_i^d ;
else if (seqnum_i^d = seqnum_j^d ) and (cetx_i^d,i) > (cetx_j^d,j) then
    insert ( j , advertised_hopcount_j^d +1, cetx_j^d) into route_list_i^d;
    /* Got a new node disjoint alternate path and insert it into routing table */
    if (num_paths_i^d = max_num_paths) and ((cetx_j^d - min(cetx_i^d,i)) <= 1.0) then
        insert ( j , advertised_hopcount_j^d +1, cetx_j^d) into route_list_i^d;
        cetx_i^d := cetx_j^d;
    end if
end if
```

4. SIMULATION ENVIRONMENT AND EXPERIMENTAL RESULTS

4.1 Environmental Setup

Table 2: *Simulation Parameters*

Parameter	Value
Simulator	NS-2.34
MAC Type	802.11 DCF
Simulation Time	300 seconds
Channel Type	Wireless Channel
Routing Protocols	AOMDV & LQBMR
Antenna Model	Omni
Simulation Area	1500 m x 1500 m
Traffic Type	CBR(udp)
Data Payload	512 bytes/packet
Network Loads	4 packets/sec.
Number of Connections	1, 5, 10, 20, 30, 40 **(Scenario 1)** 20 **(Scenario 2)**
Radio Propagation Model	TwoRayGround
Idle Power	0.0001 W
Transmission Power	1.0 W
Receiving Power	1.0 W
Sleep Power	0.0001 W
Transition Power	0.002 W
Transition Time	0.005 Sec.
Initial Energy	100 Joules
Interface Queue Length	50
Interface Queue Type	DropTail/PriQueue
Number of nodes	100 **(Scenario 1)** 20, 40, 60, 80, 100 **(Scenario 2)**
Pause Time	0 sec.
Speed	5 m/sec.
Mobility Model	Random Waypoint (RWM)
Frequency	2.4 GHz
Data Rate	11.4 Mbps
Carrier sensing range	500 m
Carrier receiving range	250 m

The performance of **LQBMR** and **AOMDV** routing protocols are evaluated using NS 2.34 [19,20,21,22,23,24] and the simulation parameters shown in **Table 2**. In **Table 2**, Scenario 1 is varying number of connections and Scenario 2 is varying number of nodes.

4.2 Performance metrics

Performance metrics are qualitative measures used to evaluate any MANET routing protocol in terms of Quality of Service (QoS). We have evaluated the following seven different performance metrics:

(i) *Packet Loss Ratio (%)* – the ratio of data packets not delivered to the destination to those generated by the sources calculated by

$$Packet\ Loss\ Ratio = \frac{Number\ of\ Data\ Packets\ Sent - Number\ of\ Data\ Packets\ Received}{Number\ of\ Data\ Packets\ Sent} x\,100 \quad (5)$$

(ii) *Normalized Routing overhead (%)* – the number of routing packets transmitted per data packet towards destination during simulation and is calculated as follows:

$$Normalized\ Routing Overhead = \frac{Number\ of\ Routing\ Packets\ Transmitted}{Number\ of\ Data\ Packets\ Received} \quad (6)$$

(iii) Total Energy consumed (in Joules) – the summation of the energy consumed by all nodes in

Journal of Theoretical and Applied Information Technology
20th November 2014. Vol. 69 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

the simulation environment. The Total energy consumption is calculated as follows:

$$Total\ Energy\ Consumed = \sum_{i=1}^{n} (Initial\ Energy_i - Residual\ Energy_i) \quad (7)$$

(iv) *Throughput* (in Kbps)– is the number of bytes received successfully and is calculated by

$$Throughput = \frac{Number\ of\ Bytes\ Received\ x\ 8}{Simulation\ time\ x\ 1000}\ kbps \quad (8)$$

(v) *Packet Delivery Ratio (%)* – the ratio of data packets delivered to the destination to those generated by the sources and is calculated as follows:

$$Packet\ Delivery\ Ratio = \frac{Number\ of\ Data\ Packets\ Received}{Number\ of\ Data\ Packets\ Sent}\ x\ 100 \quad (9)$$

(vi) *Routing Overhead (Pkts)* – the total number of control or routing packets generated by routing protocol during simulation and is obtained as follows:

$$Routing\ Overhead = Number\ of\ RTR\ Packets \quad (10)$$

(vii) *Average End-to-End delay (in ms)* – the average time of the data packet to be successfully transmitted across a MANET from source to destination. It includes all possible delays such as buffering during the route discovery latency, queuing at the interface queue, retransmission delay at the MAC, the propagation and the transfer time and is calculated as follows:

$$Average - e2e - delay = \frac{\sum_{i=1}^{n} (R_i - S_i)}{n} \quad (11)$$

Where n is the number of data packets successfully transmitted over the MANET, ' i ' is the unique packet identifier, R_i is the time at which a packet with unique identifier ' i ' is received and S_i is the time at which a packet with unique identifier ' i ' is sent. The Average End-to-End Delay should be less for high performance.

4.3 Experimental results and Discussion

4.3.1 Varying number of connections

(i) *Packet Loss Ratio (%)*

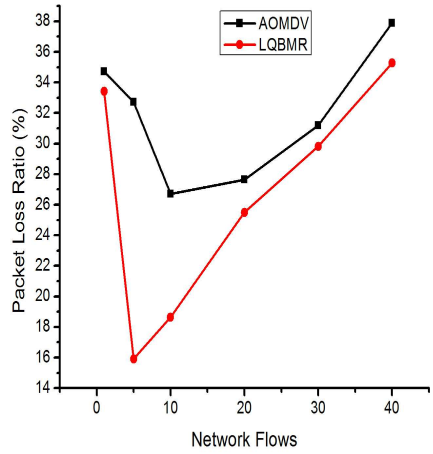

Figure 5: Packet Loss Ratio (%) of AOMDV and LQBMR

From **Fig. 5**, the packet loss ratio of LQBMR protocol is reduced than the packet loss ratio of AOMDV routing protocol because the LQBMR protocol selects the routes based on the value of CETX which should be less than 1 and greater than 0 but in AOMDV routing protocol the routes are selected based on hop count which does not ensure link reliability.

(ii) *Normalized Routing overhead (%)*

From **Fig. 6**, the normalized routing overhead of LQBMR protocol is reduced than the normalized routing overhead of AOMDV routing protocol.

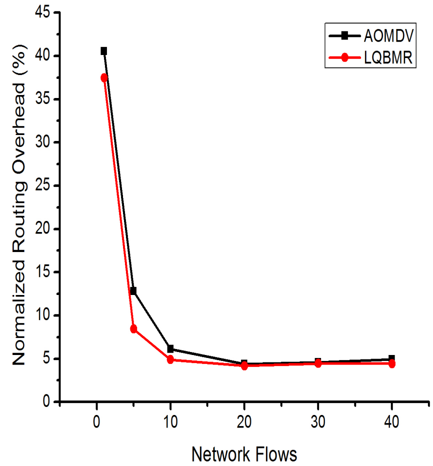

Figure 6: Normalized Routing Overhead (%) of AOMDV and LQBMR

(iii) *Total Energy consumed (in Joules)*

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

It is also found that the total energy consumption of LQBMR protocol is very less and more efficient than AOMDV routing protocol whenever there is a hike in the network flows as shown in **Fig. 7**.

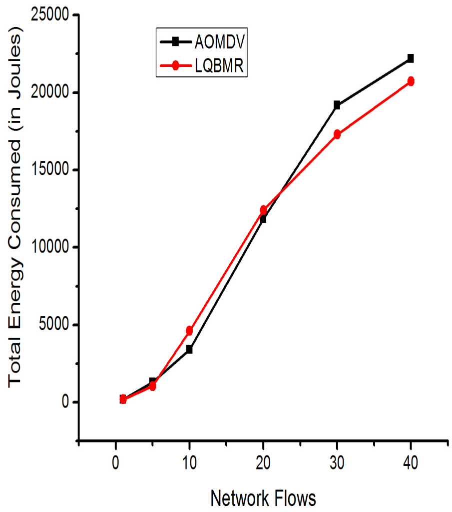

Figure 7: Total Energy Consumed (in Joules) of AOMDV and LQBMR

(iv) Throughput (in Kbps)

The LQBMR protocol gives high throughput than AOMDV routing protocol as shown in **Fig. 8**.

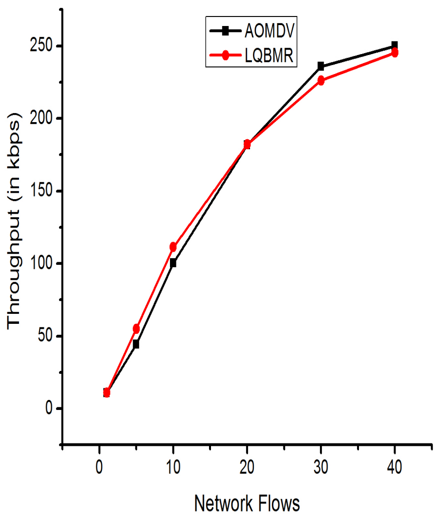

Figure 8: Throughput (in kbps) of AOMDV and LQBMR

The reason is the LQBMR protocol selects the routes based on the value of CETX which should be less than 1 and greater than 0 but in AOMDV routing protocol the routes are selected based on hop count which does not ensure link reliability.

(v) *Packet Delivery Ratio (%)*

The LQBMR protocol gives better packet delivery ratio than AOMDV routing protocol due to the selection of link reliable paths for data transmission as shown in **Fig. 9**.

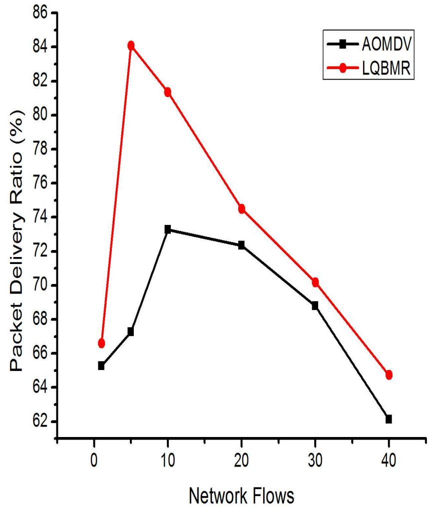

Figure 9: Packet Delivery Ratio (%) of AOMDV and LQBMR

(vi) *Routing Overhead (Pkts)*

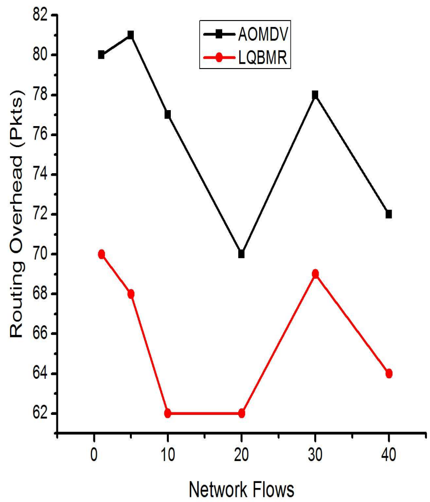

Figure 10: Routing Overhead (Pkts) of AOMDV and LQBMR

Journal of Theoretical and Applied Information Technology
20th November 2014. Vol. 69 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

The LQBMR protocol reduces the Routing Overhead than AOMDV routing protocol due to the selection of link reliable paths for data transmission as shown in **Fig. 10**.

(vii) *Average End-to-End delay (in ms)*

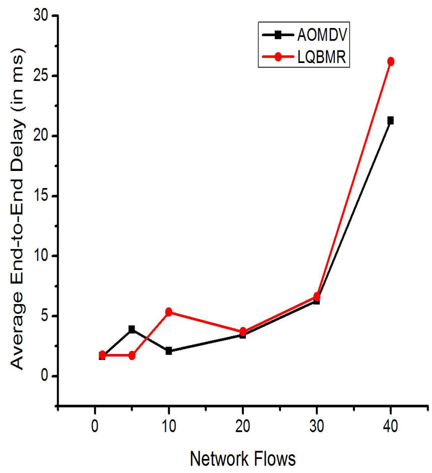

Figure 11: Average End-to-End delay (in ms) of AOMDV and LQBMR

From **Fig. 11**, the LQBMR protocol slightly increases the average end-to-end delay than AOMDV routing protocol.

4.3.2 Varying number of nodes

(i) *Packet Loss Ratio (%)*

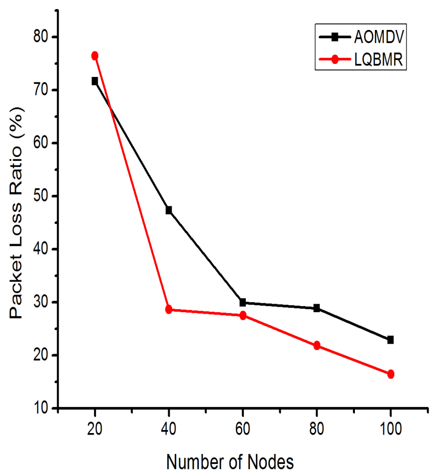

Figure 12: Packet Loss Ratio (%) of AOMDV and LQBMR

From **Fig. 12**, the packet loss ratio of LQBMR protocol is reduced than the packet loss ratio of AOMDV routing protocol because the LQBMR protocol selects the routes based on the value of CETX which should be less than 1 and greater than 0 but in AOMDV the routes are selected based on hop count which does not ensure link reliability.

(ii) *Normalized Routing overhead (%)*

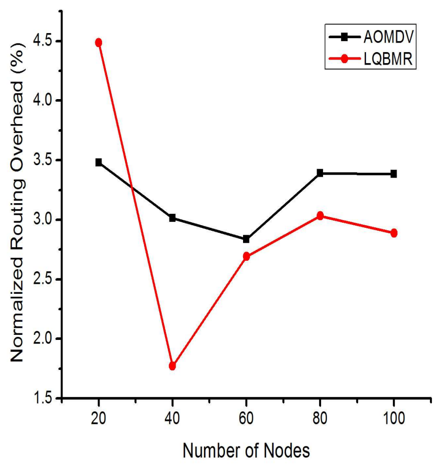

Figure 13: *Normalized Routing Overhead (%) of AOMDV and LQBMR*

From Fig. 13, the normalized routing overhead of LQBMR protocol is reduced than the normalized routing overhead of AOMDV routing protocol.

(iii) *Total Energy consumed (in Joules)*

It is also found that the total energy consumption of LQBMR protocol is less and more efficient than AOMDV routing protocol in scalable environment as shown in **Fig. 14**.

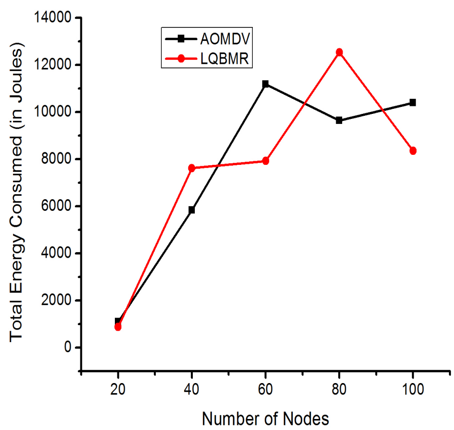

Figure 14: Total Energy Consumed (in Joules) of AOMDV and LQBMR

Journal of Theoretical and Applied Information Technology
20th November 2014. Vol. 69 No.2

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

(iv) *Throughput (in Kbps)*

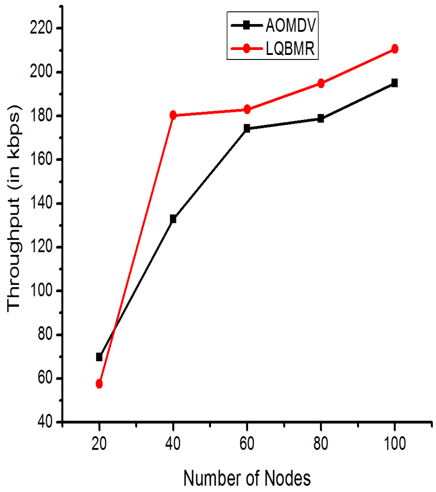

Figure 15: Throughput (in kbps) of AOMDV and LQBMR

The LQBMR protocol gives high throughput than AOMDV routing protocol as shown in **Fig. 15**. The reason is the LQBMR protocol selects the routes based on the value of CETX which should be less than 1 and greater than 0 but in AOMDV the routes are selected based on hop count which does not ensure link reliability.

(v) *Packet Delivery Ratio (%)*

The LQBMR protocol gives better packet delivery ratio than AOMDV routing protocol due to the selection of link reliable paths for data transmission as shown in **Fig. 16**.

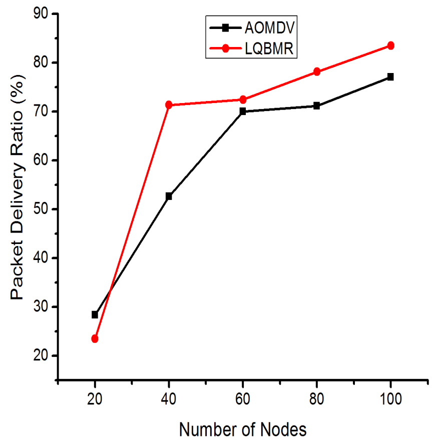

Figure 16: Packet Delivery Ratio (%) of AOMDV and LQBMR

(vi) *Routing Overhead (Pkts)*

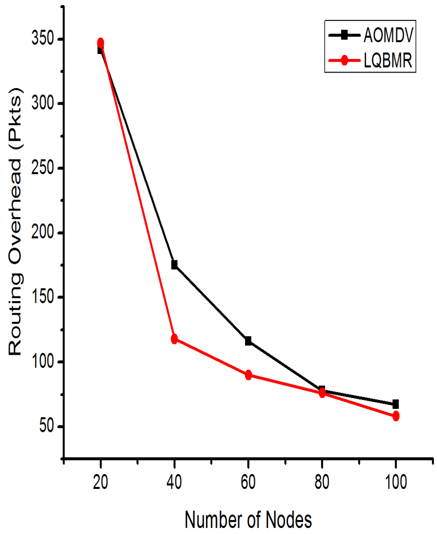

Figure 17: Routing Overhead (Pkts) of AOMDV and LQBMR

The LQBMR protocol reduces the Routing Overhead than AOMDV routing protocol due to the selection of link reliable paths for data transmission as shown in **Fig. 17**.

(vii) *Average End-to-End delay (in ms)*

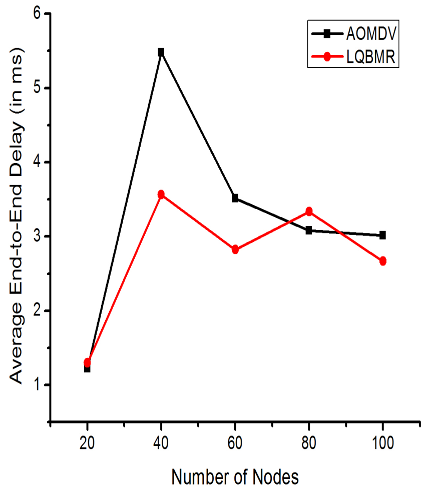

Figure 18: Average End-to-End delay (in ms) of AOMDV and LQBMR

From **Fig. 18**, the LQBMR protocol decreases the average end-to-end delay than AOMDV routing protocol.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

5. CONCLUSIONS AND FUTURE WORK

We proposed a novel multipath routing protocol called **Link Quality Based Multipath Routing (LQBMR)** protocol by modifying AOMDV routing protocol in order to avoid the occurrences of link failures and route breaks in highly dynamic ad hoc networks by discovering more link reliable paths between any source and destination pair. The LQBMR protocol uses Path-Link Quality Estimator (P-LQE), called CETX as route metric instead of the traditional route metric hop count in AOMDV routing protocol. This protocol reduces the routing overhead, packet loss ratio, normalized routing overhead and energy consumption than AOMDV routing protocol. It also improves the packet delivery ratio and throughput than AOMDV routing protocol under random way point mobility model. Simulation results show that the LQBMR protocol has performed better than AOMDV routing protocol.

In future we will put a greater effort to improve its overall performance considering new metrics associated with network nodes such as networks lifetime and reduction in average end-to-end delay and average number of nodes dying in different mobility models by enhancing recent power efficient strategies and routing metrics. We will also make changes in LQBMR to cooperate with MAC layer's multi-interface and multi-channel assignment schemes for wireless sensor or vehicular networks.

REFERENCES

[1] Elizabeth M. Royer, C-K Toh, A Review of Current Routing Protocols for Ad-Hoc Mobile Wireless Networks, IEEE Personal Communications, pp.46-55, April 1999.

[2] Mehran Abolhasan, Tadeusz Wysocki, and Eryk Dutkiewicz , A review of routing protocols for mobile ad hoc networks, Ad Hoc Networks, pp.1-22, June 2004.

[3] S. Corson and J. Macker, Mobile Ad hoc Networking (MANET): Routing Protocol Performance Issues and Evaluation Considerations, IETF WG Charter, http://www.ietf.org/html.charters/manet-charter.html, January 1999.

[4] Ankita Sharma, Sumit Vashistha, Improving the QOS in MANET by Enhancing the Routing Technique of AOMDV Protocol, ICT and Critical Infrastructure: Proceedings of the 48th Annual Convention of Computer Society of India- Vol I Advances in Intelligent Systems and Computing, Vol. 248, pp. 381-392, 2014.

[5] P.J.B. King, A. Etorban, and I.S. Ibrahim, A DSDV-based multipath routing protocol for mobile ad-hoc networks. In Proceedings of the 8th Annual Post Graduate Symposium on The Convergence of Telecommunications, Networking and Broadcasting, The School of Computing and Mathematical Sciences, Liverpool John Moores University, United Kingdom, pp. 93–98, 2007.

[6] Jiazi Yi, Asmaa Adnanea, Sylvain Davida and Benoît Parrein, Multipath Optimized Link State Routing for Mobile ad hoc Networks, Elsevier Ad Hoc Networks Journal, Vol. 9, No.1, pp. 28-47, Jan. 2011.

[7] R. Leung, J. Liu, E. Poon, A. Chan and B. Li, MP-DSR: A QoS-Aware Multi-Path Dynamic Source Routing Protocol for Wireless Ad-Hoc Networks, In Proc. of the 26th IEEE Annual Conference on Local Computer Networks (LCN 2001), pp. 132-141, November, 2001.

[8] M. Marina and S. Das, On-demand Multipath Distance Vector Routing in Ad Hoc Networks, in Proceedings of the International Conference for Network Procotols (ICNP), Riverside, Nov. 2001.

[9] S. Das, C. Perkins and E. Royer, Ad Hoc On Demand Distance Vector (AODV) Routing, IETF RFC3561, July 2003.

[10] Z. Haas and M. Pearlman, The zone routing protocol (ZRP) for Ad Hoc networks, IETF Internet Draft, draft-ietf-manet-zone-zrp-04.txt, July 2002.

[11] S. Tang, B. Zhang, M. Watanabe, and S. Tanaka, A link heterogeneity-aware on-demand routing (LHAOR) protocol utilizing local update and RSSI information, IEICE Trans. on Comm., Vol. 88-B, No.9, pp. 3588-3597, 2005.

[12] S. Khimsara, K. K. R. Kambhatla, J. Hwang, S. Kumar and John D. Matyjas, AM-AOMDV: Adaptive Multi-metric Ad-hoc On Demand Multipath Distance Vector Routing, Workshop on Cross-layer Design in Wireless Mobile Ad hoc Networks, 1st International Conf. Ad Hoc Networks (AdHocNets'09), Sept. 23-25, 2009, Niagara Falls, Canada.

[13] JP. Vasseur, M. Kim, K. Pister, N. Dejean, D. Barthel, Routing Metrics Used for Path Calculation in Low-Power and Lossy Networks, http://tools.ietf.org/pdf/rfc6551.pdf

[14] Couto DSJD, Aguayo D, Bicket J, Morris R, A high-throughput path metric for multi-hop wireless routing. In: MobiCom '03: proceedings

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

of the 9th annual international conference on mobile computing and networking. ACM, New York, pp. 134–146, 2003.

[15] Kim, M.-K., Ngo, H.P., Multipath-Based Reliable Routing Protocol with Fast-Recovery of Failures on MANETs, Future Information Technology, Application and Service, Lecture Notes in Electrical Engineering, Springer, pp. 81-90, 2012.

[16] J. Zhou, M. Jacobsson, E. Onur, I. Niemegeers, A novel link quality assessment method for mobile multi-rate multi-hop wireless networks. In Proc. IEEE CCNC'09, pp. 936–940, 2009.

[17] R. Draves, J. Padhye, and B. Zill, Comparison of Routing Metrics for Multi-Hop Wireless Networks, In Proceedings of ACM SIGCOMM, 2004.

[18] S. Kim, O. Lee, S. Choi, and S.-J. Lee, Comparative Analysis of Link Quality Metrics and Routing Protocols for Optimal Route Construction in Wireless Mesh Networks, Ad Hoc Networks, Vol.9, No.7, pp. 1343–1358, 2011.

[19] P.Periyasamy and E.Karthikeyan, Impact of variation in pause time and network load in AODV and AOMDV protocols, International Journal of Information Technology and Computer Science (IJITCS), Vol.4, No.3, pp. 38-44, 2012.

[20] P.Periyasamy and E.Karthikeyan, Performance comparison and evaluation of different multipath routing protocols based on various scenario and traffic patterns for mobile ad hoc networks, International Journal of Computer Network and Information Security (IJCNIS), Vol.5, No.1, pp. 24-32, 2013.

[21] Radhika Ranjan Roy, Handbook of Mobile Ad Hoc Networks for Mobility Models, Springer, 2011.

[22] The Network Simulator: ns-2. [Online]. Available: http://www.isi.edu/nsnam/ns/. [Accessed: 14-Nov-2012]

[23] Kevin Fall, K. Varadhan, The ns Manual, University of Southern California, Information Sciences Institute (ISI). [Online]. Available: http://www.isi.edu/nsnam/ns/ns-documentation.html. [Accessed: 14-Nov-2012]

[24] NS-2 with Wireless and Mobility Extensions. [Online]. Available: http://www.monarch.cs.cmu.edu. [Accessed: 14-Nov-2012]