Energy Efficient Routing Mechanism for Mobile Ad Hoc Networks

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***Abstract*—A mobile ad hoc network (MANET) includes a collection of self-organizing mobile nodes without any fixed physical infrastructures. Most of the nodes are small in size with limited battery energy. The dynamic network topology, limited energy and bandwidth constrain make routing is a critical problem. An efficient routing protocol can ensure high performance by increasing network lifetime. To make the network more efficient the routing protocol should ensure maximum use of the network resources like limited residual energy, bandwidth, etc. In this paper, we propose a routing approach called *Energy Efficient Routing Mechanism for Mobile Ad Hoc Networks* (EER), where a source node is capable of discovering an energy efficient route to its desired destination node. The propose EER mechanism enhances intelligence to mobile nodes and creates and fires fuzzy rules to develop a new route during the discovery phase. By taking into account, nodal energy and current queue status, our mechanism applies fuzzy based rules to develop the route which provides higher life longevity and improves network performance significantly. The performance result shows the EER mechanism outperforms the existing protocols which are simulated in Network Simulator-2(NS-2).**

Keywords- Mobile Ad Hoc Network; Energy Efficient Routing; Fuzzy logic; Residual Energy; Fuzzy Routing Metrics

I. INTRODUCTION

Mobile ad hoc network (MANET) is a collection of self-adaptive wireless mobile nodes in which nodes communicate with each without any centralized administration or coordination [1] [2] [3] [4] [5] [6]. Since there is no fixed physical infrastructure, nodes are capable of creating route dynamically. Nodes in such a network use and maintain multi-hop paths to the destination nodes via intermediate nodes. The nodes of such a network include tinny devices like mobile phones, laptops, or PDAs, etc which can move frequently. This type of network is applicable in an environment, where it is difficult or impossible to establish a fixed physical infrastructure. The application area includes exchanging information in battlefields, search and rescue operation, natural disasters, etc. The dynamic behavior and distributed environment make effective data delivery approach to a critical problem. Because of limited battery energy and bandwidth constrained, routing in such a network is a challenging problem.

The purposes of the mobile ad hoc networks are proper utilization of network resources to gain maximum throughput, reduce packet delivery delay and prolonged network lifetime. The lifetime of a mobile node depends largely upon the limited battery energy. Since the size of these mobile nodes is becoming tiny day by day, it is desirable to ensure the highest degree of utilization of limited battery power. To achieve this goal, routing protocols should design and implement in such a way that, they are highly concerned about the energy constraints. An efficient routing mechanism can improve network performance significantly and thus, ensure the maximum use of the limited power or resources. But designing and development of such a routing protocol is a challenging task. In this work, we propose a routing approach called ***Energy Efficient Routing Mechanism for Mobile Ad Hoc Networks*** (EER), where a source node is capable of discovering an energy efficient route to its desired destination node. During the route discovery phase, each of the nodes considers its own residual energy and local buffer occupancy to develop the route. The propose mechanism creates and fires fuzzy rules to develop a new route during the discovery phase. These rules help the nodes to take appropriate decisions for energy efficient route. By considering the nodal energy and queue status, the rules are generated. To develop and maintain an energy efficient route the intermediate node execute the rules and decides whether it is eligible candidate for the route or not. On finding an energy efficient route, source node delivers the data packets to the destination node. The goal of EER is to balance the energy level among the nodes to maximize the network lifespan and thus, improving the overall performance of the network. Thus, each node in the network can develop energy aware route that provides high throughput of the network by maximize use of the network resources.

Mobile nodes in a MANET network communicate through intermediate nodes and the topology of the network is dynamic. The node mobility causes the network topology to be changed infrequently. Since the nodes of such a network have limited battery energy, routing protocols are responsible for delivery the packets in an efficient and effective manner considering minimum use of the energy of the mobile nodes. The existing routing protocols of MANET networks are classified into three types, (i) Proactive, (ii) Reactive and (iii) Hybrid, respectively. In proactive or table driven routing protocols nodes exchange topological information among themselves for maintaining the route continuously. For large scale networking, maintaining information about the whole network introduces routing overhead and it is also a large scale resource consuming. This is because the nodes have to exchange a lot of control packets to update the routing information. In reactive routing protocols, data packets are delivered from source node to destination node using a multi-hop route, many intermediate nodes between source and destination node acts just forwarder node. These routes are created on demand basis and maintained dynamically.

The mobile nodes of a MANET network are operated on their battery energy and objectives of the routing protocols should include higher data delivery ratio keeping the energy consumption rate at minimum level. The successful packet delivery rate mostly depends on life time of the nodes, in other words on residual energy of the nodes. To make the network more convenient, routing protocol should operate in an efficient way, so that it can avoid early termination of the mobile nodes and expand the network lifespan significantly.

To provide an energy aware routing mechanism we propose a fuzzy based routing mechanism, where each node is capable of developing an energy efficient route. By considering the energy level and queue status nodes execute fuzzy rules. These fuzzy rules exploit the node capability to develop a route that provides longer lifetime and avoid unnecessary flooding of control packets and thus, consumes less energy. The mechanism preserves longer lifetime of an active route and delivers lot of data packets than the existing routing protocols and thus, packet delivery ratio and throughput of the network increases. The main contributions of EER are as follows:

- The Fuzzy based approach provide an intelligence power to the node for developing and maintaining an energy efficient route that exist longer.
- The developed energy efficient route provides high performance of the network significantly.
- The higher longevity of the route provides high performance of the network in terms of packet delivery, throughput and make the network resources more useful.
- The developed stable route minimizes the link failure probability by exploiting the maximum residual battery energy and longer life time with minimum hop count.

The rest of this paper is organized as follows. We describe related works in Section II, Overview of Fuzzy logic in Section III and Network model and assumptions in Section IV. Our proposed mechanism is presented in Section V and the simulation results are presented in Section VI. Finally, we conclude the paper in Section VII along with future research direction.

II. RELATED WORKS

Developing an energy efficient route is a challenging issue in mobile ad hoc networks. The lifetime of any active route is depends on the lifespan of each individual node in that route. The route between any source-destination pair will be considered as an invalid route, if any node of the entire route becomes dead due to shortage of energy. To overcome the problem, the routing protocol should be aware of residual energy. Ensuring proper utilization of network resources during the routing is a challenging task [7] [8].

Many research works are found in the literature, where the authors kept focus for developing energy efficient route [8] [9] [10]. Some research works has been found, where the authors tried to find a route using some underused nodes of the network [11] [12]. During the route discovery process, nodes having higher energy can take parts in developing the route. Thus, the network can balance energy between the nodes of the network. But finding such nodes during discovery process and developing a route with higher residual energy is not so easy, if the node does not have enough energy. Again, many control packets may be broadcast, if the route discovery process fails to find a path. SRDR finds a stable route from source to destination node [13]. The SRDR provides longer life time of any route by considering the energy efficient route. Threshold energy is required to develop the stable route during the development of new route.

Many research works have been done in last few years, where the authors tried to develop energy efficient route based on load balancing [14]. To increase the network lifetime, a cross-layer load balancing algorithm for DSR (CLB-DSR) is proposed to balance the load between data link layer and network layer. The CLB-DSR is capable of exchanging information between data link layer and network layer to handle the load properly and thus, ensure minimum consumption of network energy. The authors explore an adaptive load balancing technique by route caching [15]. The authors modified the original DSR protocols and proposed a Power Aware Dynamic Source Routing approach [16]. If the energy level of a node goes beyond a predefined threshold, the node will broadcast special packets. These packets inform the neighbor nodes that, the originating node is not capable of forwarding any new request message for shortage of residual energy. So, the neighbor nodes do not propagate any message to these nodes. Problem of such protocol is that, broadcasting of such special control packets consumes a large amount of energy of the mobile nodes. Besides, overhead of the network increases as more nodes try to forward such control packets over the time.

The aforementioned routing protocols develop an energy efficient routing in MANET by using some unused node containing higher energy, where the others try to balance the load of the network and thus, ensure less consumption of residual energy. Finding the node having higher energy introduced overhead and cross-layer load balancing need effective mechanism, requires extra overhead. The increasing overhead of the threshold base approach leads to lower performance of the network. To overcome the problems, we propose a mechanism for developing energy efficient route between any source-destination pair that provides high longevity of the network lifetime by efficient and effective use of nodal energy. By taking into account, nodal energy and current queue status, our mechanism applies fuzzy based rules that make the nodes intelligent enough to develop the route which provides higher life longevity and improves network performance significantly.

III. OVERVIEW OF FUZZY LOGIC

As mentioned earlier, EER introduces fuzzy based rules and the nodes in the network apply these rules during the route discovery process. A brief description of fuzzy logic is described in this section. Fuzzy logic was proposed by L.A. Zadeh for realize control system where the real world problems cannot express by mathematical models in an efficient way [17]. In traditional crisp set theory an object x in a set A is either true (1) or false (0). According to fuzzy logic, if x is a member of A then, it may give some degree that has a value in [0, 1]. A fuzzy set A in a universe of discourse U is characterized by a membership function expressed using membership function as follows:

$$\mu_A: U \rightarrow [0,1] \qquad (1)$$

In fuzzy logic, each object x can be labeled by a linguistic variable and a fuzzy set is defined as a linguistic terms i.e. a word such as low, medium, high, etc. The main component of a fuzzy logic is the Fuzzy Control Logic (FLC) shown in figure 1. Fuzzy Logic Controllers (FLCs) contains a fuzzy rule base consists of fuzzy rules of the form [17]:

IF (*a set of conditions are satisfied*)

THEN (*a set of consequences can be inferred*)

The IF part of the fuzzy rule, implies a set of evidences and the THEN part, implies the corresponding consequence or output. Let consider for two mobile nodes of a link of an active route. If the mobility of two mobile nodes is very high, then link will exist for shorter period of time. So a fuzzy rule can be defined to determine whether the link is exists or not as follows.

IF (*The velocity of the two nodes is high*)
AND (*They moves in opposite direction*)
THEN (*The link lifetime is shorter*).

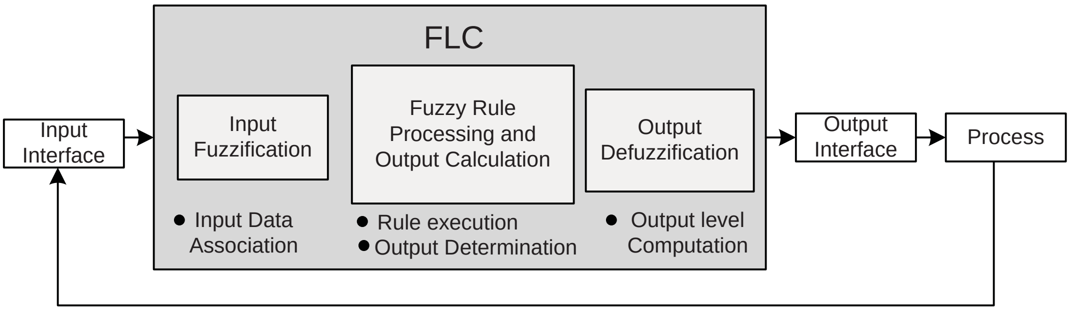

Figure 1. Operations of Fuzzy Logic Controller

A FLC the following performs three basic operations as follows:

- Fuzzification
- Fuzzy processing
- Defuzzification

Fuzzification is the process of translate the real world input data into fuzzy input form, that can understand by the FLC. The *Fuzzy processing* involves the evaluation of the input information by executing the rules stored in fuzzy rule base that has an *IF...THEN* forms. Once FLC completes rules processing, *defuzzification* is started. Finally the fuzzy control logic converts the output into real world output data.

IV. Network Model and Assumption

In a MANET network, nodes lifetime is mainly depends on their battery energy. Since size of the nodes is small so the network lifetime entirely depends on individual battery energy. For this reason, the routing protocol should operate in efficient way so that, it ensures higher longevity of the overall network.

In our propose mechanism, EER considers a highly deploy-able mobile nodes connected with each other via intermediate nodes. For simulation purpose, we also assume that all the nodes of the network have equal energy level. Based on packet transmission, nodes will consume their energy. For comparing the performance of our mechanism, we modify AODV [1], one of the widely used on demand routing protocol.

V. Proposed Model

The intermediate nodes in a mobile ad hoc network act like a forwarder node. Each of the intermediate nodes receives the packets from neighbor nodes and forwards them to the next hop of the active routes. For a longer route, the lifetime of the active route basically depends on the longevity of each and every forwarder nodes. The route becomes dead if any of these forwarder nodes becomes invalid or dead due to shortage of energy. To ensure the reliable data delivery the routing protocol should be energy efficient and should provide longer lifetime. Due to node mobility, tiny size of battery and limited resources, developing such an efficient, stable route in terms of energy, is a challenging problem for Mobile Ad Hoc network. In our propose mechanism, nodes can execute some fuzzy based rules to find an energy efficient route which take into accounts the nodal residual energy and queue occupancy of each nodes. These rules help to find the nodes having enough energy for developing new route. The fuzzy based approach enhances the intelligence capability in each mobile node so that, nodes can take proper actions in developing energy efficient route. What follows we describe our propose EER routing mechanism in details.

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A. *Fuzzy routing metrics*

As mentioned earlier, fuzzy logic helps to create and execute rules of having IF…..THEN structure. To create the rules stored in fuzzy base, EER considers the following metrics:

- Remaining Battery Energy
- Queue Status

What follows we describe each of this metrics in details.

1) Remaining Battery Energy: Nodes in MANET networks are largely dependable on their limited battery energy. A route between any source-destination pair will be considered as energy efficient, if the nodes of the route provide higher longevity, consumes less energy and can delivers most of the data packets reliably. An active route becomes invalid if any one node of the route is dead. To develop a route with high lifetime, nodal remaining residual energy plays a vital role. Based on this nodal energy, a node can decide whether it is going to forward any new route request packets. In other words, it decides whether the node allows developing a new route or discards the message. We introduce three levels of energy as Low, Medium, High. The EER can generate appropriate rules using these energy levels. For example EER generates rules as follows:

IF (*Remaining energy level is high*)

THEN (*Select as routing node*)

EER calculates remaining residual energy ratio, R_{remain} using (2). Based on the values of R_{remain}, EER mechanism can choose one of the three decisions for participating to develop a new route.

$$R^i_{remain} = \frac{E^i_{remain}}{E^i_{initial}} \qquad (2)$$

Here, E^i_{remain} is the current energy at node *i* and $E^i_{initial}$ is initial energy. The table 1 shows details decision level based on the value of R^i_{remain}.

TABLE I. ASSIGNING DECISION LEVEL BASED ON R^i_{remain}

R^i_{remain}	**Level**
.1 - .6	Low
.5 - .8	Medium
.7 -1	High

2) Queue status of node: Queue overflow due to excessive packet arriving at any node causes the node to fall in a congestive state. Thus, a lot of data packets are loss due to the congestion. Congestion reduces the network limited energy. For a congested network nodes have to retransmit the dropping packets. This retransmission process consumes energy of the node and reduces the nodal lifetime at a great scale. The make congestion free network and thus for saving the network resource, EER considers the queue occupancy as a parameter for developing the route. For a lightly loaded node, the node is highly capable of building a route and thus, can exchange data packets through it. On the other hand, a new route developed using a loaded node will lead to a congestive state. To overcome the congestion problem, a lot of control packets have to exchange that waste the network energy unnecessarily. To make the network congestion free and thus, reduce the unnecessary energy consumption, EER consider current queue occupancy as an important metric for developing the fuzzy rules. A highly loaded node cannot take part in developing a new route since the node may lead to a congestive network. To measure the current queue occupancy nodes use (3). The average queue occupancy of any node i in the network can be measured by using Exponentially Weighted Moving Average (EWMA) formulae as follows:

$$Q^i_{avg} = (1-\alpha)Q^i_{avg} + Q^i_{cur} \times \alpha \qquad (3)$$

Where α is a weighted factor and Q^i_{cur} is the current queue size of node *i* and average queue occupancy of *i* is Q^i_{avg}. In EER, three level of queue status as *Low, Medium and High* are proposed. Based on priority level a node decides whether it will discover a new route or not. The table 2 summarizes the levels.

TABLE II. ASSIGNING DECISION LEVEL BASED ON Q^{i}_{avg}

Q^{i}_{avg}	Level
Up to $50\% \times Q_{size}$	Low
$50\% \times Q_{size}$ to $70\% \times Q_{size}$	Medium
$70\% \times Q_{size}$ to $90\% \times Q_{size}$	High

B. Developing Fuzzy Rules

In fuzzy logic, a Fuzzy Logic Controller (FLC) is the main component which is responsible for decision making in the occurrence of certain evidence. As mentioned earlier, Fuzzy Logic Controller (FLC) contains a fuzzy rule base that contains a set of fuzzy rules to be executed. For developing an energy efficient route, EER generates and execute the fuzzy rules by considering the two fuzzy inputs namely R^{i}_{remain} and Q^{i}_{avg} respectively. Some of the rules of FLC are given in table 3. When a node gets a new RREQ message, it will execute the fuzzy rules to determine if is eligible for creating the new route. Let explain the working principle with an example as follows:

IF (R^{i}_{remain} is High)

AND (Q^{i}_{avg} is Low)

THEN ($FC^{i}_{activity}$ is High)

TABLE III. RULES GENERATION IN EER

R^{i}_{remain}	Q^{i}_{avg}	$FC^{i}_{activity}$
Low	Low	Low
Low	Medium	Low
Low	High	Low
Medium	Low	High
Medium	Medium	Medium
Medium	High	High
High	Low	High
High	Medium	Medium
High	High	High

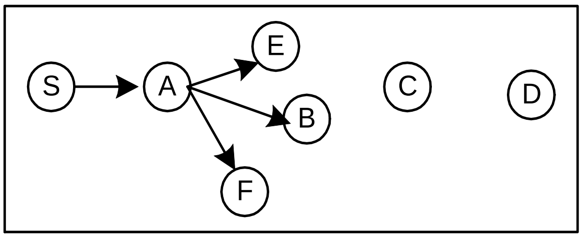
The rule implies that, if a node has higher residual energy and low queue occupancy then, the node is highly eligible as a candidate node and it can allow creating new route through it.

C. Developing Energy Efficient Route

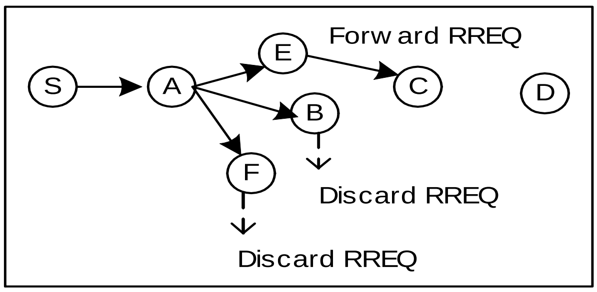
To develop an energy efficient route for any source to a destination node, EER considers the nodal energy and queue occupancy to generate the fuzzy rules. During the route discovery phase, when a source node floods a Route Request Message (RREQ) to its neighbor nodes; only eligible nodes can forward this message. The intermediate node applies the fuzzy rules described in the previous section and decides whether it can contribute to build the route. The node having lower energy cannot forward the RREQ message. Thus, EER restrict forwarding of RREQ messages to certain eligible nodes of having higher energy. The other nodes cannot forward the RREQ messages unnecessarily. This restriction reduces the network overhead significantly. The next eligible nodes will receive the message and forward to the next node in the same way; unless it is the desired destination node. This also save the network energy and ensure higher longevity of the network.

Again, the queue status of an intermediate node ensures efficient delivery of the data packets. This is because; a node does not service only one source destination pair. Rather, it may deliver data packets from multiple sources. By considering the queue status, if current queue occupancy goes to a higher level the node will simply discard the RREQ message. This is because; acceptance of the new RREQ message of the node would lead the node to a congested state. As a result, the network may suffer from packets dropping due to the congestion. To develop a efficient route EER provide the way so the intermediate node apply the fuzzy rules and take decisions to forward the message. When the destination node gets the RREQ message, it creates a Reply Message like conventional routing protocol and sends it back to the source node. After getting this reply message, the source node starts delivery of the data packets using the energy efficient route. The developed route provides higher throughput since it is capable of handling the queue overflow and ensures efficient use of network resource like limited energy. Thus, our propose EER mechanism can develop a route that is energy efficient and ensure high longevity of the network. What follows we describe the overall mechanism with an example.

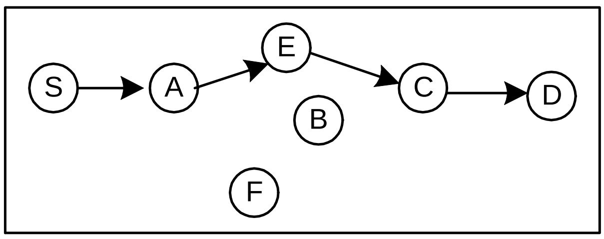
Consider Fig. 2, where a source node S try to communicate with node D. Node S forwards RREQ messages to all of its neighbor nodes namely E, B and F shown in Fig. 2(a). After getting the RREQ message the three nodes will further try to forward the message since they are not the destination nodes. But all of them cannot flood the RREQ message. Each of the nodes inspects the rules and makes the decision whether they can participate in developing a route. At this moment, EER executes the rules and selects the eligible nodes. As in Fig. 2(b) node B and F discard the RREQ messages. Since developing route through B or F will lead the network to a congested states or the route may have shorter life time, each of the node will discard the message.



(a)Forwarding RREQ by source node



(b)Forwarding RREQ by eligible nodes



(c) Developing an energy efficient route

Figure 2. Operations of EER during route discovery

As node E can develop a new route, it will forward the RREQ message to its neighbor nodes. The destination node D replies with a RREP message to inform the source node about the new route. Figure 2(c) shows that, a route has been developed using four nodes namely S $\rightarrow$E $\rightarrow$ C$\rightarrow$D. Node S can use this energy efficient route to send data to the destination node D. The algorithm 1 describes route development process of any intermediate node.

Algorithm 1 Route discovery process, at each node i∈ N

1. **for** each active new RREQ message **do**
2. Calculate R^{i}_{remain} and Q^{i}_{avg} using Eqn. 2 and 3
3. Find the eligibility by firing rules
4. **If** (FC_i= *MEDIUM* OR FC_i= *HIGH*) **then**
5. Forward RREQ packet
6. **else**
7. Discard RREQ packet
8. **end if**
9. **end for**

VI. PERFORMANCE EVALUATION

In this section, we describe the performance of our proposed EER mechanism. We simulate our proposed EER mechanism in NS-2 [18]. To evaluate the results, we compare the performance with AODV [1] and EAR [8]. The result of the simulation shows that EER outperforms the AODV and EAR.

A. Simulation Environment

We take 100 mobile nodes those are randomly connects to each other in an area of 1000 x 1000 m^2 with transmission range 150m. The simulation time is 200 seconds. The source nodes can generate 2 to 10 packets per second and the size of these data packets is 512 bytes. The mobility model for our network is Random Waypoint model, propagation model is free space and the underlying MAC protocol is 802.11. Table 4 summarizes the simulation parameters.

TABLE IV. SIMULATION PARAMETERS

Parameter	Value
Network area	1000m x 1000m
Number of nodes	100
Number of sources	40
Energy of each node	120 joule
Max speed	0 to 10 m/s
Node movement model	Random waypoint
Transmission range	150m
Transport layer protocol	UDP
MAC layer protocol	IEEE 802.11 DCF
Bandwidth	11 Mbps
Data packet size	512 bytes
Data packet generation rate	2 to 8 packets/sec
Propagation model	Free Space
Weight factor α	0.002

B. Simulation Environment

To evaluate the performance of EER, following four performance metrics are used:

- **Packet Delivery Ratio**- It is the ratio of number of data packets received by the destination nodes to the number of generated packets.
- **Average end-to-end delay** - It refers to the average time required to deliver a packet successfully to destination node
- **Throughput**- For each successful transmission of data packet fraction of the channel capacity used refers the throughput.
- **Energy Consumption**- Total energy consumption indicates the energy consumption of network nodes due to the routing packets.

C. Varying Traffic Load

In this section, we describe performance metrics that reflects the various traffic loads in the network. We vary the traffic load by varying the packet generation rate. Each source node generates 2, 4, 6, 8 packets per seconds. In this case, we keep the speed of each mobile node at .8 m/s. We multiply the packet rate (512 bytes) with packet size to calculate the traffic load.

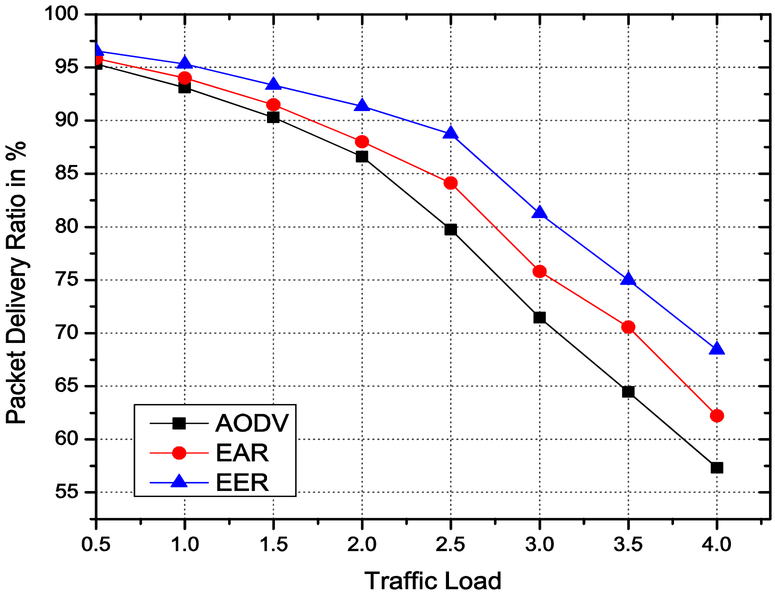


Figure 3. Packet Delivery Ratio

Fig. 3 shows the packet delivery ratio (PDR) of AODV, EAR and EER. The curves of the graph show that, the packet delivery ratio decreases as the traffic load of the network is increased. This is because; the increasing traffic load leads more routing and data packets to be exchange throughout the network. The figure indicates that, EER outperform than AODV, EAR. The efficient route development of EER can ensures the maximum usefulness of network energy and provides higher packet delivery ratio. Since the developed route has higher longevity, the packet delivery ratio is of our proposed method is higher than the studied routing protocols.

Average end-to-end delay is shown in Fig.4. The delay of the protocols increases over the time. Increasing number of connections increase the data delivery delays. AODV has higher end-to-end delay than other protocols. Increasing traffic load causes more links to be broken over time and the data delivery delay for AODV is higher than the others routing protocol. The proposed EER mechanism considers the queue occupancy as a routing metric during the route discovery process. Since the developed route of EER ensures limited queue overflow, nodes can deliver the data packets efficiently and the packet dropping rate of EER decreases and thus, the packet end-to-end delay is decreased.

Fig. 5 shows the per node throughput of AODV, EAR and EER. The throughput of the network increases with the increasing traffic load since the network can exchange more packets. The graph also indicates that, the throughput starts decreasing after a certain period of time.

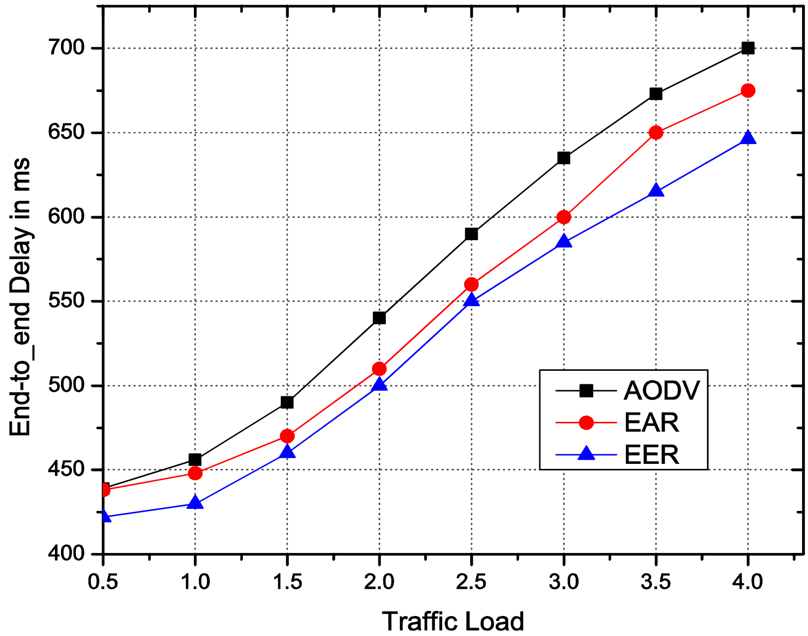


Figure 4. Average end-to-end delay

As the traffic load increases, the node have to develop more routes causing higher consumption of their residual energy and thus decreases the throughput. Fig. 5 also indicates that EER provides higher throughput. The higher data delivery ratio of EER provides higher throughput than other studied protocols. The efficient route can deliver most of the routing packets to the destinations nodes by using the network resources more effectively and thus, EER outperforms the other routing protocols.

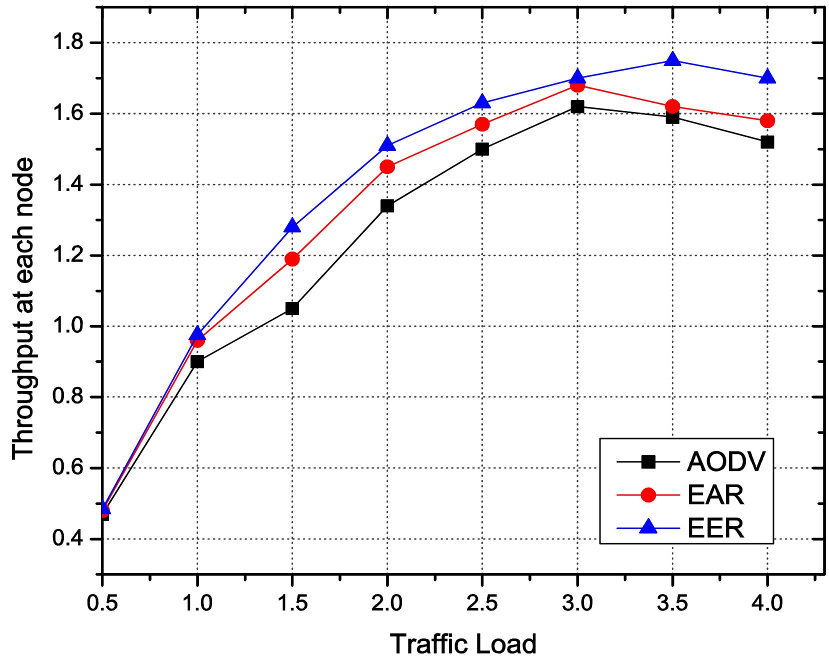


Figure 5. Per node throughput

D. Energy Consumption during Routing

The proposed energy efficient routing mechanism provides effective way to reduce energy consumption during the exchange of control packets. As described earlier, EER restrict the unnecessary flooding of RREQ message and capable of developing a route. For our simulation purpose, we consider energy consumption for a routing packet E_{tx} and E_{rx} respectively; where E_{tx} indicated the transmitted and E_{rx} received energy of a node. The values of these two parameters are given in [8] as follows: E_{tx} = (1.65× Size of the Packet)/2 × 10^6 and E_{rx} = (1.1× Size of the Packet)/2 × 10^6. For total energy consumption, we deploy the network with various numbers of nodes. To get steady results we conduct 10 times of each input parameters and take the average of the results.

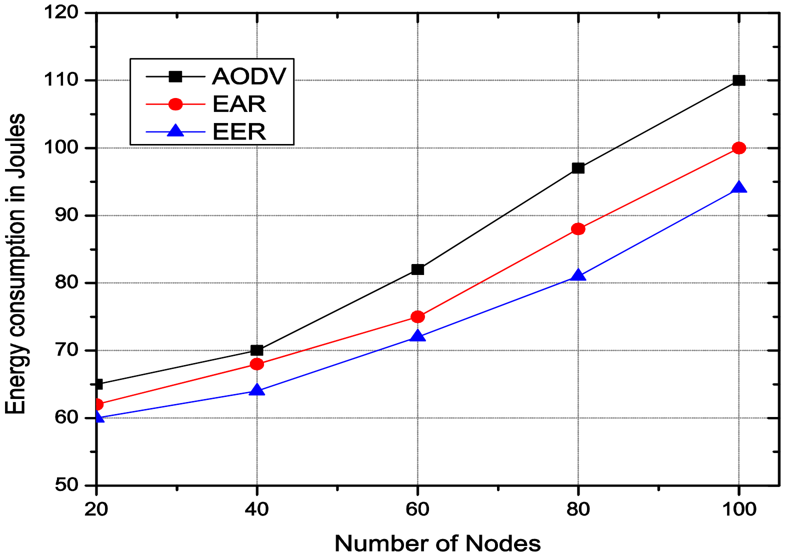


Figure 6. Total Energy Consumption Vs No. of Nodes

Fig. 6 shows the results of total energy consumption for each of studied routing protocol by varying the number of the nodes in the network. The graph indicates that, total energy consumption of the network increase sharply as the number of nodes in the network is increased. This is because; these increasing number of nodes increases number of connections and they exchanges more both data and control packets. Initially the outputs of three protocols are approximately same. But with the increasing rate of network density it started varying with the time.

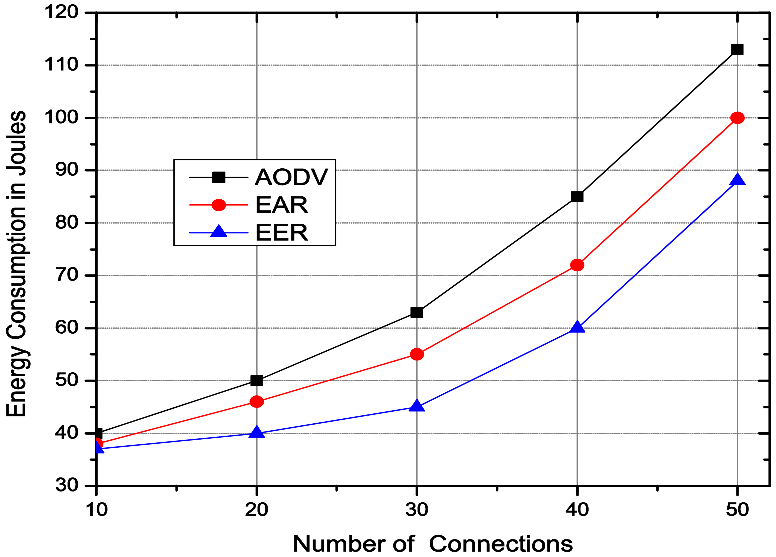


Figure 7. Total Energy Consumption Vs No. of Connection

EAR reduced the energy consumption rate 10%-15% than the basic AODV. As EER develops an energy efficient route and provides higher lifetime of the route it consumes less energy than the other protocols. Graph indicates, EER can save up to 7%-12% energy than EAR.

The total energy consumption for varying the number of connection is shown in Fig. 7. We vary the number of connections 10 to 50. Initially the packets of the networks move reliably as the number of connections or number of the routes is small. As the connections of the network are increased, nodes consume most of their energy. The increasing number of connections causes the node to exchange large amount of data and control packets throughout the network. The graph also shows that EER saves the energy of the network by consuming less amount of energy than AODV and EAR. While increasing the number of connections, EER can save 5%-12% total energy of the nodes in the network. Thus, EER provides high throughput, lowest energy consumption and higher longevity of the network.

VII. CONCLUSION

Developing an energy efficient route in MANET is a challenging issue. The nodal energy of the mobile nodes is limited and hence efficiency of a routing protocol depends on effective use of this limited energy. In this research work, we tried to explore an approach that develops energy efficient routes and provides longer lifetime. Proposed EER routing mechanism consumes less energy and saves the network energy significantly. Thus, EER provides higher life longevity of the mobile nodes. The developed route provides higher network throughput in terms of higher packet delivery ratio, lower data delivery delay and higher throughput and EER mechanism ensures higher performance than studied protocols. In future, we will try to find a more efficient mechanism that can save more energy while increasing the network connections without affecting the throughput.

ACKNOWLEDGMENT

This work was supported by the Network Research Lab, Department of Information and Communication Technology, Mawlana Bhashani Science and Technology University, Tangail, Bangladesh. The authors are grateful for this support. Md. Manowarul Islam is the corresponding author of this paper.

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