EEDR: Energy Efficient Dynamic Routing Approach for Mobile Ad-hoc Networks

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ABSTRACT

It is important to design energy-efficient routing protocols for mobile ad hoc networks. However, without a careful design, an energy-efficient routing protocol could have much worse performance than a normal routing protocol. This paper proposes an energy efficient routing based on the link cost metric evaluation. The proposed approach discovers and also maintains the efficient route even under dynamic characteristics of MANETs. Initially, the proposed approach discovers a minimum energy, shortest path among the available paths between source and destination by considering the transmitting power and the receiving power. The link which is having minimum cost is selected as the efficient path. During the route maintenance, the nodes on the path monitors using a power management algorithm and collaborates with neighboring nodes to maintain the suboptimal path. The simulation results show the efficiency of the proposed approach.

Keywords-MANETs, link cost metric, transmitting power, receiving power, power management and throughput.

1. INTRODUCTION

Mobile ad hoc networks (MANETs) have gained a great deal of attention because of its significant advantages brought about by multihop, infrastructure-less transmission. However, due to the de-centralization and independent infrastructure the communication or data transfer in the MANET is random in nature. This random nature and mobility of nodes consume more and more power for data transfer. Traditional topology-based MANET routing protocols (e.g., DSDV, AODV, DSR [1])are quite susceptible to node mobility. One of the main reasons is due to the predetermination of an end-to-end route before data transmission. Owing to the constant and even faster changing network topology, it is very difficult to maintain a deterministic route. The discovery and maintenance phases are also time and energy consuming. The nodes in the MANET consume more power to transmit the data, it further increases in the case of packet error and route failures. As well, for a multimedia data transfer in the MANET, there is a need of an optimal path which is having route failure probability very less.

Because, in the multimedia content, even the small packet loss causes more reduction in the quality of service (QoS). So design of a deterministic path which is able to adapt to the node mobility and efficient in power consumption and also robust to packet errors during the route failures is necessary in MANETs.

This paper proposes an energy efficient routing approach based on the link cost metric to reduce the energy consumption in MANETs. This approach proposed a new link cost evaluation model by taking the packet error rate and a new shortest path routing protocol. The proposed approach is done in two phases: route discovery and route maintenance. Route discovery phase finds an optimal path by evaluating the link cost for each and every link between source and destination nodes. Then the obtained path is maintained as a suboptimal path in the route maintenance phase through the power management algorithm.

The rest of the paper is organized as follows: section 2 provides the details about the earlier approaches. Section 3 gives the details about the link cost metric evaluation and also provides the information about the power management algorithm. Section 4 illustrates the complete details about the proposed energy efficient dynamic routing (EEDR) approach. It also gives the illustration of the proposed approach with an example. Section 5 gives the details about the performance evaluation of the proposed approach and also provides the comparative analysis of the EEDR with AODV, PEER protocols and final conclusions are given in section 6.

2. LITERATURE SURVEY

To conserve energy, many routing protocols have been proposed in earlier [2], [3], [4], [5], [6], [7]. Generally, these routing protocols are classified based on the link cost metric evaluation. Link cost metric measures the amount of the power required to transmit a data through that link. For each and every link there should be a link cost. Link cost metric considers the amount of power required to transmit RTS, CTS, data and ACK packets from and to of each and every node existing on that link. Based on the parameters used to evaluate the link cost the Minimum Energy routing protocol is divided into three classes: Minimum Total Transmission Power, Minimum Total TransCeiving Power, and Minimum Total Reliable Transmission Power. Scott in [2] proposed a distance reuse mechanism to modify the shortest path algorithm and to obtain minimum total transmission power. But it does not focus on the receiving power. In [4], a distributed bellman ford algorithm [8] was used to obtain the minimum TransCeiving power of a path. But [4] didn't focus on the retransmission of packets in the case of packet errors. Instead, the authors in [5] proposed a minimum total reliable transmission power protocol to take into account the energy consumption of packet retransmissions. The total transmission power consumed for reliably transmitting a data packet from one node to its neighboring node is used as the link cost. PARO in [6] also used transmission power as the link cost, however, its target is to reduce energy consumption between any two neighboring nodes. To reduce energy transmission between two nodes, one or more intermediate nodes elect to forward packets on behalf of the peer nodes. In [7] a comprehensive minimum energy routing approach was proposed by considering the total power taken by data packets to travel on the path. But it didn't consider the power consumed due to control packet transmission. In [14], a model and protocol were proposed to provide the energy efficient routing based on link cost metric evaluation. It considers the link cost metric as a reference parameter to establish the minimum energy efficient shortest path, however, it hasn't concentrated on the power management of the established path. For an established shortest path, by sending the data packets continuously, the power of the nodes on that gets drained up quickly. Then the source needs to discover a new route again, it consumes more power.

3. POWER MANAGEMENT THROUGH LINK COST METRIC

3.1 Link cost metric evaluation

The proposed approach is a cost-based energy-efficient routing protocol. In a cost-based routing protocol[14], the total cost of all the links available on each path between the source node and the destination node will be calculated, and a minimum cost path (meeting certain criteria) will be selected. As link cost is very important in the cost-based energy-efficient routing protocols, it is critical to derive an accurate link cost metric to obtain an optimal path. This section gives the details about the derivation of link cost.

Denote the packet error rates for RTS, CTS, DATA, and ACK packets between node i and j by $p_{r,i,j}, p_{c,i,j}, p_{i,j}, p_{a,i,j}$. For a node i, to establish a link to a node j, first it will send an RTS packet with probability $p^{*}_{r,i,j}$. If the RTS packet is not delivered to node j, then the packet is said to packet loss with the packet error rate $p_{r,i,j}$. If node j receives the RTS packet, it will send out the CTS packet with probability $p^{*}_{c,i,j}$. If the CTS are not received by node I, then is said to be lost with the packet error rate $p_{c,i,j}$. With probability $p^{*}_{i,j}$, node i sends the data packet, and the node j sends the acknowledgment with probability $p^{*}_{a,i,j}$. If the data packet is not received at node j the data packet is lost the packet error rate is $p_{i,j}$. Similarly, if the acknowledgment was not received at node i, the packet is said to be lost with the packet error rate $p_{a,i,j}$. In this procedure, the numbers of packet retransmissions are unlimited. From this discussion, we can observe that, on average node ineed to transmit $1/p^{*}_{r,i,j}$ Packets so that node j can receive one correctly. Similarly, node j needs to transmit $1/p^{*}_{c,i,j}$ CTS packets, node i needs to transmit $1/p^{*}_{i,j}$ data packets, and node j needs to transmit $1/p^{*}_{a,i,j}$ ACK packets. Therefore, the average numbers of RTS, CTS, data, and ACK transmissions in the whole process are as follows:

RTS: $1/(p^{*}_{r,i,j}p^{*}_{c,i,j}p^{*}_{i,j}p^{*}_{a,i,j})$

CTS: $1/(p^{*}_{c,i,j}p^{*}_{i,j}p^{*}_{a,i,j})$

Data packets: $1/(p^{*}_{i,j}p^{*}_{a,i,j})$

ACK: $1/(p^{*}_{a,i,j})$

With the power control scheme, RTS and CTS packets are transmitted at the maximum power level P_m. In order to reduce the hidden terminal problem, while DATA and ACK packets are transmitted at the minimum required transmission power level $P_{i,j}$ between node i and j for energy conservation. Let, denote the data size, the header size, the RTS packet size, the CTS packet size, and ACK packet size by $N, N_{hdr}, N_{rts}, N_{cts}$ and N_{ack}, respectively.Then, the average total transmission power for successful transmission of a packet from node i to node j is

$$\overline{P_T(i,j)} = \frac{P_m N_{rts}}{(p^{*}_{r,i,j}p^{*}_{c,i,j}p^{*}_{i,j}p^{*}_{a,i,j})} + \frac{P_m N_{cts}}{(p^{*}_{c,i,j}p^{*}_{i,j}p^{*}_{a,i,j})} + \frac{P_{i,j} N_{hdr} N}{(p^{*}_{i,j}p^{*}_{a,i,j})} + \frac{P_{i,j} N_{ack}}{(p^{*}_{a,i,j})}$$

In addition, denoting the receiving power as P_r, then the average total receiving power for successful receiving a packet from node i to node j is

$$\overline{P_R(i,j)} = P_r \frac{\frac{N_{rts}}{N+N_{hdr}} + \left(\frac{N_{cts}}{N+N_{hdr}} + p^{*}_{i,j} + \frac{N_{ack}}{N+N_{hdr}} p^{*}_{i,j}p^{*}_{a,i,j}\right) p^{*}_{c,i,j}}{p^{*}_{c,i,j}p^{*}_{i,j}p^{*}_{a,i,j}}$$

Assume there are M-1 intermediate nodes between a source and a destination. Let the nodes along the path from the source to the destination be numbered from 0 to M in that order. Then, the average total power for reliable transmission along the path from the source (node 0) to the destination (node M) is

$$\overline{P_{Total}} = \sum_{i=0}^{M-1} \left(\overline{P_T(i,i+1)} + \overline{P_R(i,i+1)}\right)$$

Based on this formula the total link cost can be evaluated for node i to node i+1.

3.2 Power management algorithm

Once the paths are established between source and destination, each and every node in that path try to keep the record of next hop and previous hop node information. By evaluating the link cost for each and every link on the available paths, one final path which is having minimum link cost is going to be established. During this, at each and every node, by introducing a power management algorithm [12], the power consumption can be further reduced. In this power management algorithm, the node checks the power status of its neighboring nodes continuously by sending a request packet. If it found any one of its neighboring nodes is having more power and also the path going through it consuming less power, then the node changes the path and transmits the data through it. Because, by sending the data continuously through the established path, the power of intermediate nodes drains up quickly. This power management algorithm also works in the case of route failure. This power management algorithm is based on the fact that much energy can be saved if localized route recovery is deployed rather than global flooding during the process of route recovery.

3.2.1 Algorithm

Step 1: Once the route request process is over and the route is established, the destination node broadcasts the route reply packet. If the source node founds more paths having similar power consumption, then it will record the path through which the route reply packet came quickly.

Step 2: Once the data was sent from source node through the established path, the intermediate node sends a request packet to all of its next hop nodes and knows the power status.

Step 3: Then it checks for the node having more power and also the path established through it has minimum power consumption compared to the first established path. If it finds that any one of its next hop node is having more power to transmit compared to the next hop node in the first established path, then it will change the path otherwise it will follow the same path.

In the case of route failure, the entire process has to be done since starting. This consumes more power due to packet retransmissions. By implementing the power management algorithm, each and every node having up to date information about the power of its next hop nodes. Then it will get to know which node is draining up and sends the data with respect to the power or changes the path if the node is completely drained up.The example illustrated in section 4 gives the complete idea about this approach.

4. EEDR

Due to the node mobility in MANET, the path is going to change every time. So we need to propose a good routing strategy such that it has to discover and also has to maintain an optimal path. By taking this into consideration, EEDR proposed an energy efficient routing protocol, to search an energy efficient path quickly and also maintains the path according to the topology changes.

4.1 Route Discovery

In the Route discovery phase, the proposed approach helps to find an optimal path based on the link power consumption and number of hops existing between source and destination.The quickest way to find a path between two nodes would be through a shortest path routing scheme. However,there may exist a few shortest (smallest number of hops)paths between the source node and destination node.Let L be the set of paths between source an destination, $N_l$be the number of hops for path l and $E_{l,I}$be the energy consumption for link i in the path l, The set of shortest paths L_s would be

$$L_s = argmin\,(N_l), l \in L$$

Then the minimum energy shortest paths L_{ms} would be

$$L_{ms} = argmin\left(\sum_{i=1}^{N_l} E_{l,i}\right), l \in L_s$$

To implement this algorithm, the route request packet should carry two pieces of information:one is the hop count, the other is the energy consumption. The source node first broadcasts the route request packet with both hop count and energy consumption set to 0. Once an intermediate node receives a route request packet, it first updates the hop count (increased by1) and energy consumption (increased by the energy consumption between the sender and itself) information in the route request packet. Then, it will rebroadcast such packet only if one of the following conditions holds:

1. The node hasn't received such a packet before or the packet comes from a shorter (smaller number of hops) path.

2. The packet comes from a path with the same number of hops as the best path so far, but the energy consumption is lower.

The first condition ensures that the shortest path is selected, while the second condition selects the minimum energy path from all the shortest ones. If the destination receives multiple shortest and energy efficient paths, it will set a timer to select the best one. The destination set up a timer after receiving a route request packet. If it receives another route request before the timer goes off, it will reset the timer.Otherwise, it will select the best path found before the timer goes off and reply the source with a route reply packet.

4.2 Route Maintenance

The network environment can change dramatically due to node movements and dynamic channel conditions, and the previous energy-efficient route may no longer be efficient as time goes on. Therefore, the route maintenance phase is very critical for energy-efficient routing protocols. Generally, with the help of extra signaling messages the discovered route can be maintained but it consumes more energy. Instead, in this approach, the node which was willing to send information will passively monitor data packets exchanged in its neighborhood and collaborate with its neighbors to look for a more energy-efficient path. For each data packet transmitted, received, or overheard by a node, it will record the following information into a link cost Table-:

(a) Sender,
(b) Receiver,
(c) Link cost between the sender and the receiver,
(d) Source,
(e) Destination,
(f) IP header ID, and
(g) The current time.

Among these parameters, (a) and (b) can be obtained from the MAC header, while (c)-(g) can be obtained from the IP header. The information for a link will be kept only for a short time for accurate information and reducing storage overhead. From the link cost Table-, a node can know how a packet passes through its neighborhood and the total link cost for that is based on the information recorded in its link cost Table, a node can help reduce the cost of a local path segment and hence the cost of the end-to-end path between a source and a destination by removing or replacing the intermediate links.

4.3 Proposed Algorithm

The complete illustration of the energy efficient dynamic routing (EEDR) is outlined in the algorithm below.

Algorithm

Step 1: Create a network with N number of nodes.

Step 2: Establish links between all nodes.

Step 3: Mention the source and destination nodes.

Step 4: Route discovery phase

Source node broadcasts the route request packet.

Upon receiving the RREQ intermediate node replies with RACK.

Among the received RACKs, source node finalizes one path depends on the time and energy.

Source node establishes a shortest minimum energy path to the destination.

Step 5: Route maintenance phase

Source node updates the established path using Power management algorithm

Step 6: end

4.4 Example

Let us consider a network shown in the below Figure-.

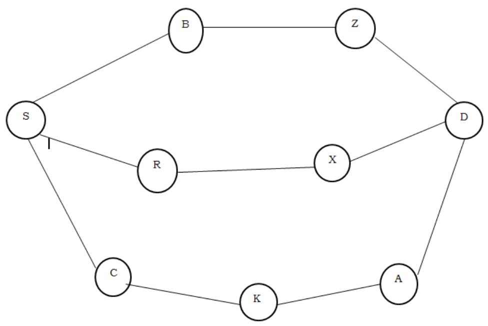

Figure-1: General Network

From Figure-1, the total available paths are SBZD, SRXD and SCKAD. The amount of power required by sending a packet through the above paths can be calculated by summing all the powers at each and every node. It is as Table-2.

Table-1: Power Table- of each and every node

Node	PT	PR	Ptotal	Power having
S	1	0.5	1.5	22
B	1	0.5	1.5	18
Z	1	0.5	1.5	20
R	1	0.5	1.5	16
X	1	0.5	1.5	18
C	1	0.5	1.5	20
K	1	0.5	1.5	17
A	1	0.5	1.5	11
D	1	0.5	1.5	20

Table-2: Power for each and every path

Path	Power required
SBZD	4.5
SRXD	4.5
SCKAD	6

From Table-2, compared to SCKAD, SBZD and SRXD have less power consumption. So they can be selected as the minimum energy consumption paths and the third path is kept an optional, because due to the node mobility, the node positions may change and the power consumption also increase. Among the two shortest paths the source selects one final path based on the reception of acknowledgment. The path through which the route acknowledgment receives quickly, it will be taken as a final shortest minimum energy path.

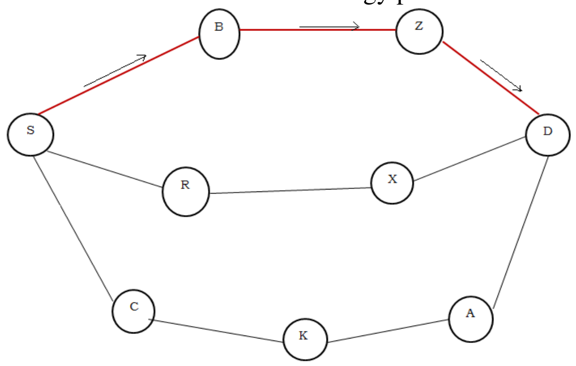

Figure-2: Shortest and minimum energy consuming path established network

Along with the power consumption, each and every node in the path having a particular amount of power capacity. Due to the mobility of nodes, the nodes may vary and distance increases, thus they get drained up quickly. By using the proposed power management algorithm, there should be the availability of power status of neighboring nodes for each and every node. The power managing algorithm checks the status continuously, and checks it with a predefined threshold and if the power of any node is less than the threshold, it changes the path, otherwise it continues on that path only. This can be explained as follows:

Number of packets=10
Sending times=10
Threshold=5

For the established path the total power consumed is as follows:

Table-3: Power consumed per each node on the established path

Node	Power for each packet	Total power consumed	Remaining power
S	1	10	22-10=12
B	1.5	15	18-15=3
Z	1.5	15	20-15=5
D	0.5	5	20-5=15

From Table-3, node B has less power than the threshold, so the path was changed to next shortest path SRXD. Similarly, this procedure continues in the above new established path also.

5. RESULTS

This section gives the details about the performance evaluation of the proposed approach. The proposed was tested over network parameters like speed and packet size. The performance of EEDR is evaluated with respect to routing overhead, the average energy consumption and packet delivery ratio and end-to-end delay. The proposed EEDR also compared with the earlier AODV protocol and also with PEER [14].

Case 1: Varying node mobility speed

The simulation parameters for the above case are summarized in Table-4.

Table-4: Simulation parameters

Configuration	**Parameter Values**
Simulation Area	1000m X 1000m
No. of Nodes	50
Mobility Speed	**0, 5, 10, 15, 20,25 m/s**
Source-Destination Pairs	15
Packet Size	512 bytes
CBR Rates	4 packets/Sec
Mobility	RWP
Pause Time (Sec)	60

In the first case the node mobility was varied and the respective packet delivery ratio, routing overhead, the average energy consumption and end-to-end delay were measured for AODV, PEER and the proposed EEDR. The respective performance Figure-s are shown in Figure- 3, Figure- 4, Figure- 5 and Figure- 6 respectively.

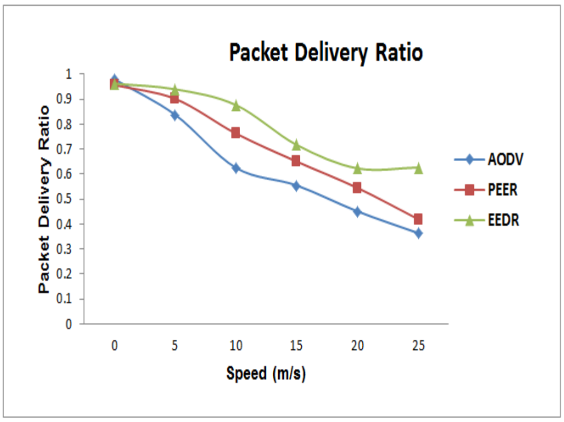

Figure-3: Packet delivery ratio v/s node mobility speed(m/s)

Figure-3 Describes the details about the packet delivery ratio of the EEDR with varying node mobility. From the above Figure-; it is clear that for a particular node speed, the packet delivery ratio of the proposed EEDR approach is high compared to AODV and PEER. Compared with the earlier approaches the percentage decrement of the packet delivery ratio of EEDR is about 0.06%, whereas AODV has 2.52% and PEER has 1.74%.

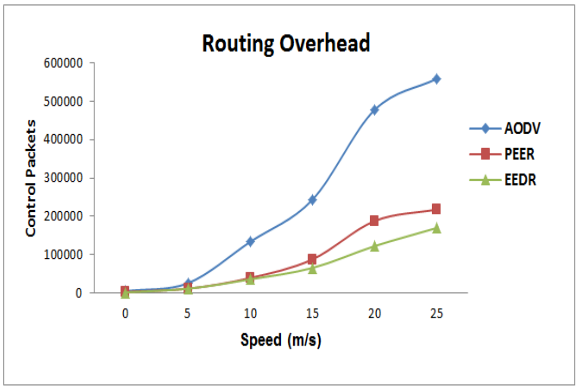

Figure-4: Routing overhead v/s node mobility speed (m/s)

Figure-4Describes the details about the routing overhead of the EEDR with varying node mobility. From the above Figure-; it is clear that for a particular node speed, the routing overhead of the proposed EEDR approach is low compared to AODV and PEER. Compared with earlier approaches, the routing overhead is less for the proposed approach. For a 5m/s increment in node mobility, the percentage of overhead for the proposed approach is increased by 56918 control packets (11.3836%) whereas AODV has 234149 control packets (46.8298%) and PEER has 99941 control packets (19.9882%). From this analysis, we can state that the percentage of increment in the routing overhead for the EEDR is less.

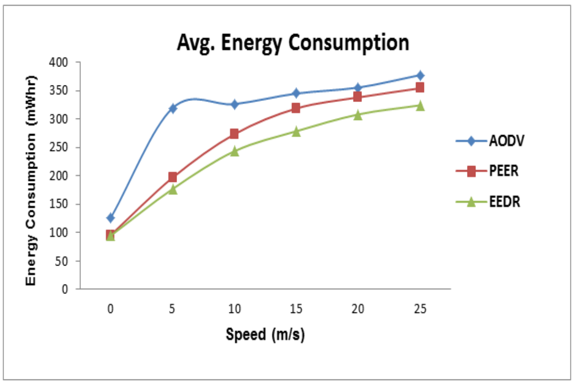

Figure-5: Average energy consumption v/s node mobility speed (m/s)

Figure-5 Describes the details about the routing average energy consumption of the EEDR with varying node mobility. From the above Figure-; it is clear that for a particular node speed, the average energy consumption of the proposed EEDR approach is low compared to AODV and PEER. Compared with earlier approaches, the average energy consumption is less for the proposed approach. For a 5m/s increment in node mobility, the percentage of average energy consumption for the proposed approach is increased by 22.8% whereas AODV has 43.4% and PEER has 32.8%. From this analysis, we can state that the percentage of increment in the average energy consumption for the EEDR is less.

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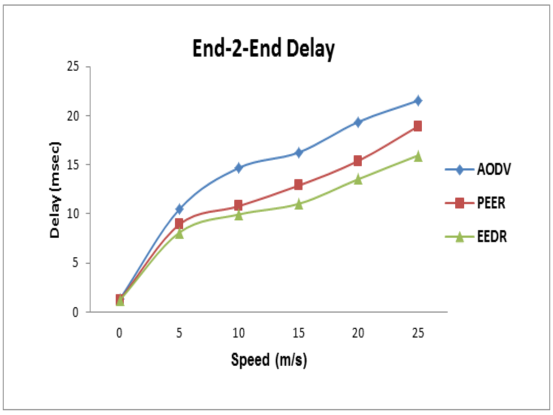

Figure-6: End to End delay versus node mobility speed (m/s)

Figure-6 Describes the details about the end to end delay of the proposed EEDR with varying node mobility speed. From the above Figure-, it is clear that for a particular node speed, the end to delay in low compared to AODV and PEER. Compared with earlier approaches, the end-to-end delay is less for the proposed approach. For a 5m/s increment in node mobility, the percentage of end-to-end delay for the proposed approach is increased by 1.38%) whereas AODV has 1.83% and PEER has 1.53%. From this analysis, we can state that the percentage of increment in the end-to-end delay for the EEDR is less.

Case 2: Varying packet size

The simulation parameters for the above case are summarized in Table-5.

Table-5: Simulation parameters

Configuration	**Parameter Values**
Simulation Area	1000m X 1000m
No. of Nodes	50
Mobility Speed	10 m/s
Source-Destination Pairs	15
Packet Size	**500, 600, 700, 800, 900 bytes**
CBR Rates	4 packets/Sec
Mobility	RWP
Pause Time (Sec)	60

In this case the packet size was varied and the respective packet delivery ratio, routing overhead, the average energy consumption and end-to-end delay were measured for AODV, PEER and the proposed EEDR. The respective performance Figures are shown in Figure-7, Figure-8, Figure-9 and Figure-10 respectively.

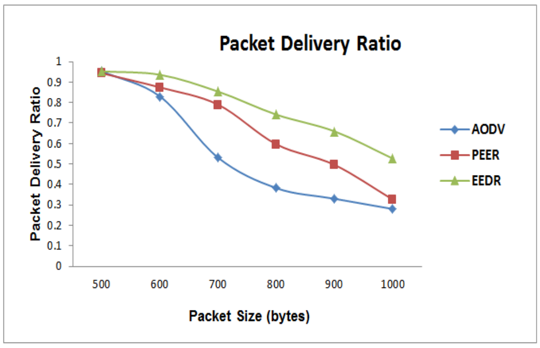

Figure-7: Packet delivery ratio v/s packet size (Bytes)

Figure-7 Describes the details about the packet delivery ratio of the EEDR with varying packet size. From the above Figure-; it is clear that for a particular packet size, the packet delivery ratio of the proposed EEDR approach is high compared to AODV and PEER. Compared with earlier approaches the packet delivery ratio for the proposed approach is less. For an increment of 100 packets the percentage of decrement in the packet delivery ratio of the proposed approach is 0.08%, whereas AODV has 0.29% and PEER has 0.09%. From this analysis, we can state that for an increment in the packet size, the percentage decrement of the packet delivery ratio of EEDR is less.

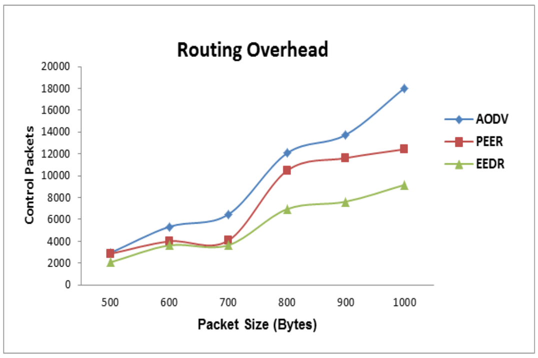

Figure-8: Routing overhead v/s packet size (Bytes)

Figure-8 Describes the details about the routing overhead of the EEDR with varying packet size. From the above Figure-; it is clear that for a particular packet size, the routing overhead of the proposed EEDR approach is low compared to AODV and PEER. Compared with earlier approaches the routing overhead for the proposed approach is less. For an increment of 100 packets the percentage of increment in the routing overhead of the proposed approach is 33.01%, whereas AODV has 64.01 and PEER has 56.06%. From this analysis, we can state that for an increment in the packet size, the percentage increments of routing overhead of EEDR are less.

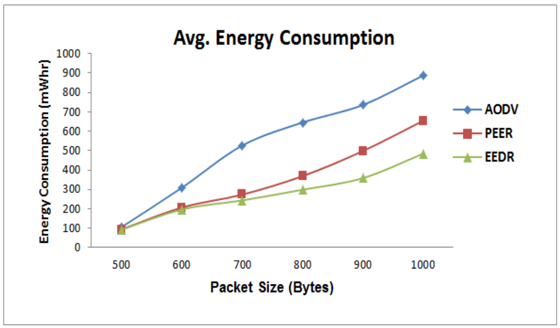

Figure-9: Average Energy consumption v/s packet size (Bytes)

Figure-9 Describes the details about the routing average energy consumption of the EEDR with varying packet size. From the above Figure-; it is clear that for a particular packet size, the average energy consumption of the proposed EEDR approach is low compared to AODV and PEER. Compared with earlier approaches the average energy consumption for the proposed approach is less. For an increment of 100 packets the percentage of increment in the average energy consumption of the proposed approach is 12.6%, whereas AODV has 15.6% and PEER has 15.2%. From this analysis, we can state that for an increment in the packet size, the percentage increments of average energy consumption of EEDR are less.

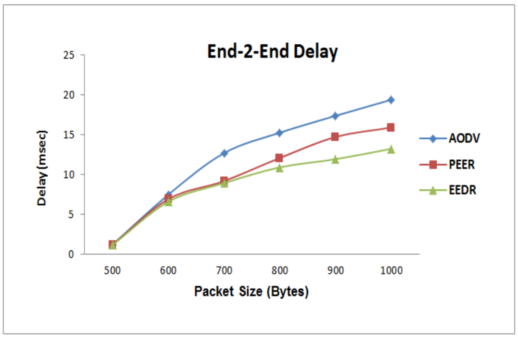

Figure-10: End to End delay versus packet size (Bytes)

Figure-10 Describes the details about the end to end delay of the proposed EEDR with varying packet size. From the above Figure-, it is clear that for a particular packet size, the end to delay in low compared to AODV and PEER. Compared with earlier approaches the end-to-end delay for the proposed approach is less. For an increment of 100 packets the percentage of increment in the end-to-end delay of the proposed approach is 5.42% whereas AODV has 6.3% and PEER has 5.68%. From this analysis, we can state that for an increment in the packet size, the percentage increments of end-to-end of EEDR is less.

6. CONCLUSION

This paper proposed an energy efficient dynamic routing (EEDR) approach for MANETs. This approach provides an efficient routing between source and destination even under dynamic mobility conditions. This approach manages the power based on link cost metric evaluation and establishes the energy efficient routing paths. The proposed approach reduces the wastage of energy and increases the throughput of the network. It also reduces the delay and overhead occurred. The performance of the proposed EEDR approach was evaluated by measuring the network simulation metrics, packet delivery ratio, routing overhead and the average energy consumption by varying the node mobility and packet size. The simulation results also revealed that the proposed approach is energy efficient and also gives better performance compared with conventional approaches.

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