ISSN 2278-3091
Volume 9, No.5, September - October 2020
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse111952020.pdf
https://doi.org/10.30534/ijatcse/2020/111952020

Optimal Path Selection In MANET'S

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ABSTRACT

Mobile Ad-hoc Network, are built with battery-powered nodes that have limited energy and network lifetime depends on several nodes. Hence, energy efficient routing is a critical issue to be addressed. Both network and node's lifetime has to be extended through efficient routing mechanism considering energy metrics. Failure in nodes or links requires re-routing, causing additional energy consumption. This paper discusses mechanism to maximize the lifetime of the network through appropriate design of routing technique and its evaluation is measured with metrics such as energy consumption, number of paths used for packet transmission, throughput, number of packets forwarded.

Key words: AODV, MANET, Network Lifetime, Energy Consumption, Residual Energy.

1. INTRODUCTION

Mobile Ad-Hoc Network (MANET) is a self-configuring network connected by wireless links with no fixed infrastructure and built using battery-powered nodes, which have limited energy hence the network's lifetime, is dependent on several key nodes [1]. Every node in network is independent to move around randomly and reorganize arbitrarily. Hence, have dynamic network topologies [2]. Nodes can communicate with each other regardless of their location. Users in MANETs can access and exchange information regardless of their location, this infrastructure-less network offers an advantage of decentralized working, making it more flexible and robust. Minimizing the energy consumption at per packet level, at flow or at path level, transmission power control, managing system power are the important ways to save energy [3].

Restricted availability of energy resource is one of the most important challenges in the design, working and performance of MANET protocols. Node failures that occur due to low energy not only affect the performance of individual node but also affect the nodes' ability to forward packets on behalf of other neighborhood nodes impacting network performance. Energy is consumed from every node when packets are sent, forwarded, received and in idle state. Making use of the node's energy efficiently to extend network lifetime is a critical concern as any node without energy becomes useless [4]. The methods discussed in papers [5-6] is to minimize the total energy consumed to reach destination through minimizing the energy consumed per flow or per unit.

One of the main objectives of routing protocol is to maintain the network functioning for a longer time, apart from finding right and proficient routes between source and destination. In this paper, the proposed method E-AODV is the alteration of AODV protocol to improve the performance through modification in Route Request (RREQ) packets considering the cumulative nodes residual energy along the path (path energy), hop count and node's energy as parameters to decide on path between source and destination.

The rest of paper is organized as follows: Section 2 briefs the related work, AODV protocol is briefed in Section 3, the proposed work is detailed in Section 4, Simulation results and analysis is briefed in Section 5, finally Section 6 concludes the paper.

2. RELATED WORK

In [7] the authors propose a method where nodes are divided into three categories Danger state, Critical State and Active state based on the battery status. Based on their states, nodes respond to RREQ by sending back Route Reply (RREP) or by forwarding RREQ or dropping the received RREQ performing no action. The proposed method is applied on Ad-hoc on- demand Distance vector (AODV) and Dynamic Source Routing (DSR) protocol. The method discussed works better in thick populated network, as more nodes are on hand for better route selection.

The authors in [8] propose and evaluate Energy Efficient Routing Protocol, which selects an energy rich path amongst available alternative disjoint paths. The method prevents unequal nodes energy consumption and minimizes path breakages. The probability of breakage of the communication path and routing overhead is reduced. Here sender always uses highest energy path for transmitting data, leading to overuse of such nodes. When the current route fails, another alternate route from routing table is considered. The drawback of this approach being the alternate route would have become stale because of node mobility by the time it is used.

In [9] the author's idea is to make use of load balanced approach by using lightly loaded paths avoiding usage of heavily loaded paths for data transmission. Every node calculates two metrics namely load energy and cumulative load energy and updates the RREQ packets. The task of selecting best energy route is left to source node. Destination node responds to every RREQ received with RREP, thereby consuming resources and involves movement of control packets. There is also delay incurred to start with data transmission as the source node waits till it receives many RREP to process and select one best route among them.

In [10-11] the authors present an efficient path selection method based on energy on AODV protocol for MANETs. This method increases network lifetime and minimize link breakage by selecting the path for routing with more available energy based on AODV protocol. The overhead of control packets is reduced by taking limited mobile nodes participation in routing and route discovery process. The RREQ control packet size is increased to include the coordinate position of the boundary region. Every node further needs to compare its position to process RREQ or discard. The method is able to find better paths in dense networks as it can have many nodes within the confined region, whereas it will not have much options compared to sparse network. Increase in size of RREQ packet as it should carry four coordinate positions of boundary (top left and bottom right) leads to overhead and small amount of delay is also incurred as every intermediate node that receives packet needs to check for its position with that mentioned in RREQ packet. In [12] the authors propose a formula to control packet residence time inside the queue further reducing the packet processing time and increasing the node lifetime. The RREQ and RREP packet processing is modified.

The work carried out in this paper considers the limitations of the above papers [6-12] and suitable solution has been proposed. In the proposed solution, RREQ size is increased only by one field out of the 4 bytes thus not leading to too much overhead. Any node satisfying the energy constraint can participate in route discovery process so that the method will perform well in dense as well as sparse network. As the destination node itself calculates the best path and sends the RREP only to that path towards source, it lessens the transmission of RREP packet transmission and its processing at every intermediate node along the path.

3. AODV Routing Protocol

AODV is on-demand reactive multihop routing protocol [13] where paths are established only when source has data to send. RREQ packets are broadcasted by source node to all its neighbors. If the neighbor node has valid route to destination it sends RREP to source node else broadcasts RREQ packet to its neighbors until it reaches destination node. Destination node responds to the first RREQ received. The intermediate nodes create a temporary reverse route back towards requesting node and forward the message.

AODV is union of both DSDV [14] and DSR [15] borrowing the use of sequence number from DSDV and path discovery procedure from DSR. The newness of routing information and prevention of routing loops is taken care by Sequence numbers. Broadcast Identifier records the number of times source initiated the path discovery process. Source address and broadcast identifier together form a unique pair to identify redundant RREQ packets.

Any path when not used within a specified route expiration time-period is cancelled and remains inactive. A path is considered active when data packets are being exchanged between source and destination pair along the path. When two nodes are communicating along active route and if link failure take place, the upstream node transmit Route Error (RERR) packet towards source to keep it informed about unreachable destination nodes. A source initiates route discovery process again if required.

AODV finds the path always based on shortest path as the destination always answers back to the first RREQ packet received. The possibility of nodes participating in forwarding data packets is more for nodes placed in the centre of network. This repeated selection of nodes drains their energy leading to inactive or dead nodes and link failure. Route re-establishment process must be initiated again to continue exchange of messages that causes excessive node's energy consumption [16].

4. PROPOSED WORK

The proposed protocol works similar to AODV routing protocol, with two main variations as stated below:

- Modification is done to RREQ packet that includes the nodes current residual energy it encounters. This field is used by destination node to compute the path for data transfer.
- Computing the best available route based on the metric values - path energy, hop count and node's threshold energy.

The RREQ is modified to include energy field as shown below in figure 1, which ultimately records the path energy by summing all intermediate nodes energy forming the path to the destination node.

<table>
<tr><td>Type</td><td>Reserved</td><td>Hop Count</td></tr>
<tr><td colspan="3">Broadcast ID</td></tr>
<tr><td colspan="3">Destination IP Address</td></tr>
<tr><td colspan="3">Destination Sequence Number</td></tr>
<tr><td colspan="3">Source IP Address</td></tr>
<tr><td colspan="3">Source Sequence Number</td></tr>
<tr><td colspan="3">Timestamp</td></tr>
<tr><td colspan="3">Threshold Energy (set by source node)</td></tr>
<tr><td colspan="3">Path Energy</td></tr>
</table>

Figure 1: Modified RREQ Packet format

The RREQ packets received are arranged in ascending order with respect to path energy. Among the available paths, the highest energy path is selected and RREP is sent to source node. If there are multiple paths with same energy then the second metric hop-count is considered. In this case, the path with least hop-count is considered. Each node that receives RREQ packet checks its energy with threshold energy (here threshold is set to 20J). If node's energy is higher than mentioned threshold, the packet is processed and further forwards it, else the packet is dropped which is detailed in figure 2.

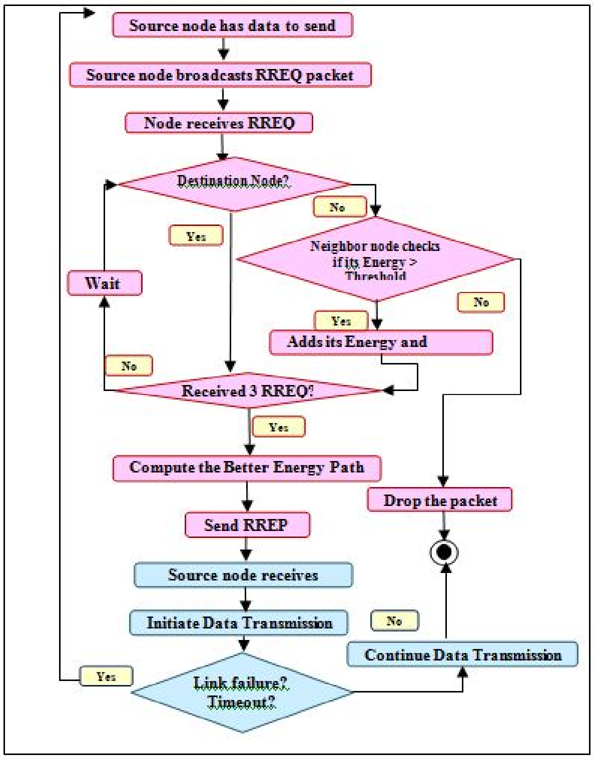

Figure 2: Working flow of Proposed Method

Route Discovery

When source needs to transmit packets to destination node it first searches for route availability in routing table. RREQ packets are broadcasted by source provided the required route is unavailable. The RREQ of proposed method is an extension of RREQ of AODV protocol. One new field is added to RREQ to store the cumulative energy of all nodes lying along the path. This helps in finding paths where all nodes along the path have energy greater than threshold energy avoiding path failure due to low node energy. Based on the received RREQ destination node further selects one best path with highest energy reducing link failures, increasing throughput, less routing load, reduced energy consumption.

Route Discovery at Intermediate Nodes

Every intermediary node that receives RREQ initially tests for its residual energy greater than specified threshold energy as depicted in figure 3. A node satisfying the condition makes a reverse route entry in routing table. RREQ packet is updated by its residual energy and further forwards the packet to its neighbors. Low energy nodes cannot be part of the path hence discards the packet.

```
if (Packet == RREQ && Node_Energy ≥ Threshold_Energy)
  { Path_Energy = Paht_Energy_Node_Energy
    Forward the packet }
else
  Discard RREQ
endif
```

Figure 3: Code Snippet at Intermediate Node

Route Discovery at Destination Node

RREQ packets are received by destination node from different possible routes. Upon receipt of the first RREQ packet, the destination does not respond immediately. It waits till it receives three RREQ packets (wait time is three times the node traversal time). It computes the best available path considering metrics, path energy and number of hops and responds with RREP to the source through reverse path only for the selected path as shown in figure 4. This noticeably reduces the control overhead that occurs during route establishment due to multiple RREP for single RREQ as in AODV. The routing table and reverse path is updated. Upon arrival of RREP at source node, data transfer process is initiated. If destination node doesn't receive data packets within the stipulated timeout period, then respective path entry from routing table is deleted.

```
RREQ_Count = 0;
if (Packet == RREQ)
  do{
    RREQ_Count ++;
    Store the details in temporary table;
    }while (RREQ_Count != 3);
endif
if (Energy_Path_i < Energy_Path_i+1)
    Best_Path = Energy_Path_i;
else
    Best_Path = Energy_Path_i+1;
endif
if (Energy_Path_i == Energy_Path_i+1)
   if(Hop_Count_i < Hop_Count_i+1)
      Best_Path = Energy_Path_i;
   else
      Best_Path = Energy_Path_i+1;
   endif
endif
Update Routing Table and Update Reverse Path
Send RREP corresponding to best path selected
```

Figure 4: Code Snippet at Destination Node

5. RESULTS

Network Simulator version 2.35 (NS 2.35) is used [17]. Performance analysis is done by comparing the results of the two protocols. The values are taken with respect to simulation time. The nodes are placed randomly in 1500 x 1500 m^2 areas. Each node is assigned with different initial energy to start the simulation process which imitates the real world scenario. The nodes are also set to mobility randomly with different speeds [varying from 0m/s to 20m/s] and direction. The nodes are assumed to take straight-line paths in motion. The number of nodes is varied starting from smaller network size of 6 nodes to a network with 100 nodes. Figure 5 demonstrates snapshot captured for 15 and 50 nodes respectively in execution. Constant Bit Rate (CBR) traffic with one packet per second is the average packet rate considered. The HELLO message is periodically sent out, every second with a maximum latency time of 5 seconds.

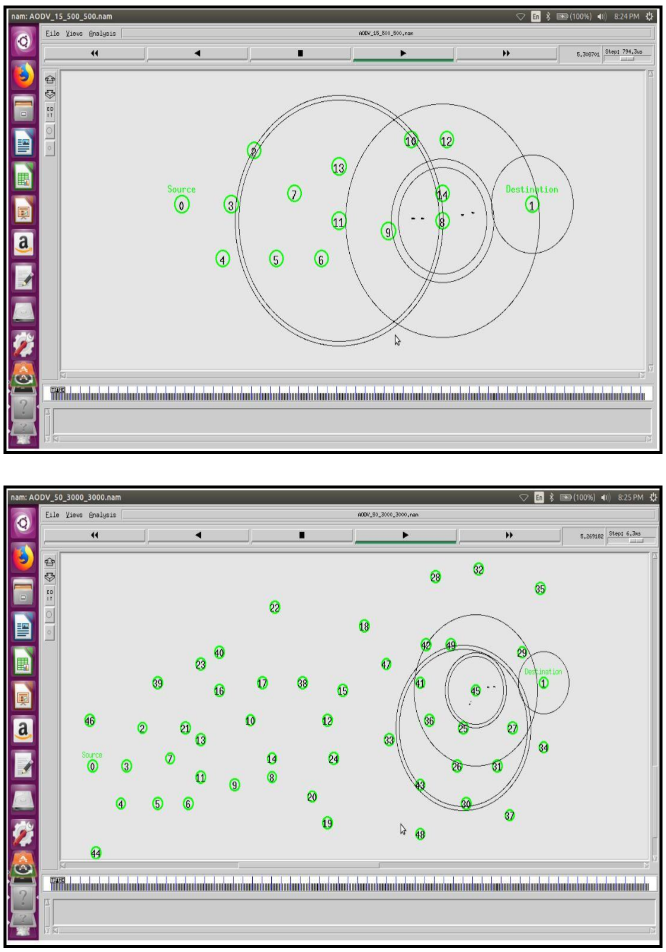

Figure 5: Simulation Environment for 15 nodes and 20 nodes

The number of paths used by AODV as compared to the proposed method is approximately in the average ratio of 2:1 numbers of paths. This indicates that the number of paths taken by AODV is double that of the proposed method. The switching in-between paths depend on various factors and some of these cab be listed as: (1) Node's Energy drain rate. (2) A node moving out of its predecessor node range along the path. (3) Route Lifetime. (4) Node failure.

AODV always selects the shortest path. The destination always responds with RREP packet for the first RREQ packet received. This path formed may not be the better path always. The proposed method takes care of energy of the nodes in selecting path, so that low energy nodes do not affect the path. The number of path used in proposed method is lower (almost half) than the number of paths used by traditional routing method as illustrated in figure 6.

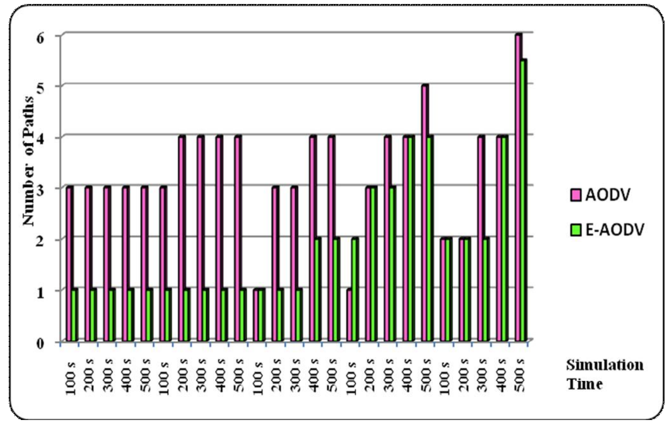

Figure 6: Number of Paths Used vs. Simulation Time

Forwarded Packets

The number of packets forwarded by proposed method is less compared to AODV. On an average considering the cumulative scenario the number of packets forwarded (control packets) by proposed method is 1.02% to 1.03 % less compared to AODV as depicted in figure 7.

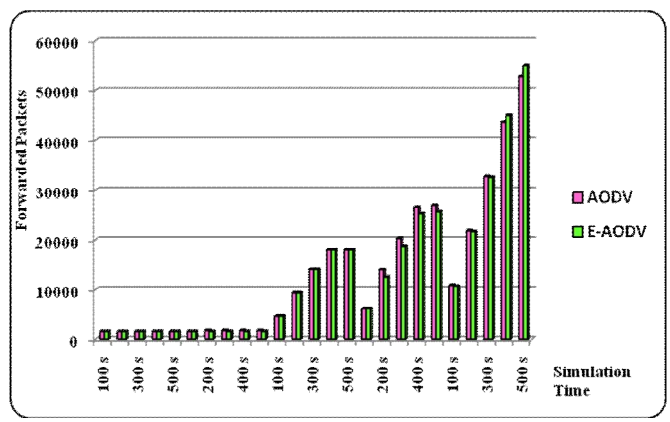

Figure 7: Forwarded Packets vs. Simulation Time

Throughput

Throughput is the total number of packets transmitted successfully to total packet generated. The proposed method shows an average improvement in throughput. Initially when the simulation is performed for 6 nodes for 100 sec. to 500 sec., AODV perform better than E-AODV. The reason analyzed is, that in this case when destination receives first RREQ it immediately responds with RREP and once source receives RREP packet, data transfer process is initiated. In the proposed method the destination node waits to receive many RREQ packets to decide on a better path and hence there is delay incurred in sending RREP from destination node, receiving RREP at source side and initiating data transfer process impacting the throughput. However, in the next part of experiment where the network density is increased, the possibility of receiving many RREQ also increases proportionally thus leading to quicker response from the destination node and source node having better throughput. figure 8 shows on an average considering various scenarios there is an increase in throughput from 0.6% to 1.5% compared to AODV.

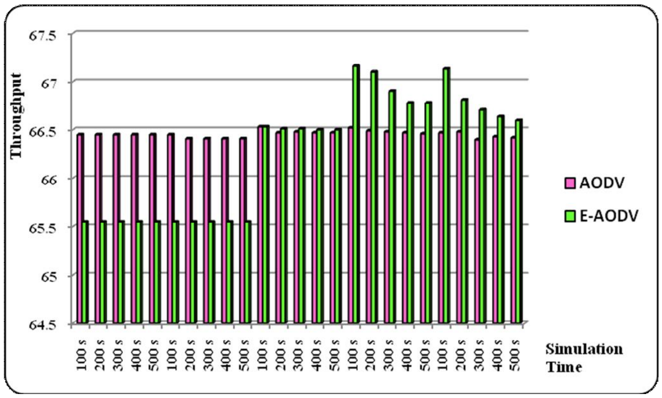

Figure 8: Throughput vs. Simulation Time

Routing Load

Nodes in MANETs exchange small sized control packets generated by routing algorithm to keep them updated of network information and routes. Both routing packets and data packets mostly use the same network bandwidth creating routing overhead or routing load. Node's mobility causes often change in network topology leading to stale routes. Nodes mobility often leads to change in network topology causing outdated routes in the routing table originating needless routing load [18]. The routing load of the proposed method is around 25% to 35% less compared to AODV as depicted in figure 9. The analysis proves that one of the components contributing to reduced routing load is reduction in the number of paths used for data transfer.

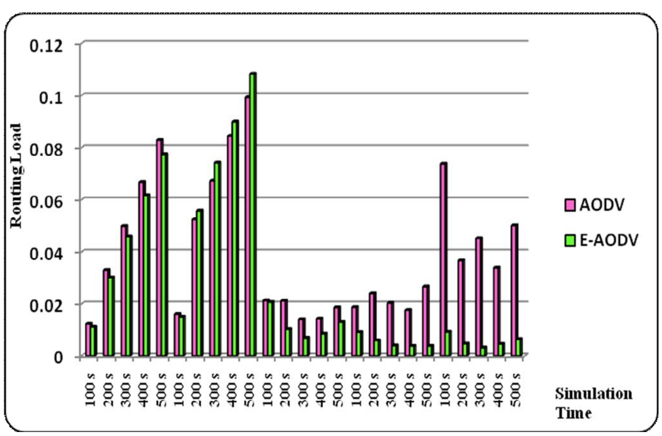

Figure 9: Routing Load vs. Simulation Time

Energy Consumption

Each node is assigned different energy individually and energy spent during data transmission by nodes is calculated as transmission energy. Transmission energy is directly proportional to the distance between two nodes. Equation (1) is used to calculate transmission energy required for a packet to transmit.

$$Energy_{Transmit} = \left(\frac{Packet_{Size} * Packet_{TransmittingPower}}{Bandwidth} \right) \quad (1)$$

The nodes along the path is counted with hop count field present in RREQ packet as in equation (2)

$$Node_{Count} = Hop_{Count} + 1 \quad (2)$$

The entire paths energy is stored in the RREQ packet and is the cumulative sum of all individual nodes' energy as in equation (3).

$$Path\_Energy = \sum_{i=1}^{Hop\_count} Node\_Energy_i \quad (3)$$

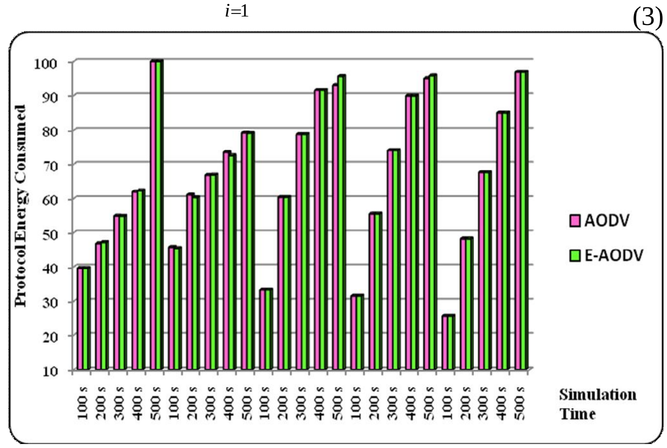

Figure 10: Protocol Energy Consumption vs. Simulation Time

The protocol energy utilization is slightly less than AODV as shown in figure 10 above, and this is related to the other two metrics number of paths and number of forwarded packets. The energy consumption of the protocol is calculated with respect to network energy. AODV shows 93.983% of energy consumption whereas proposed method shows 93.891% of energy consumption with a difference of 0.09789. Hence the proposed method works more efficiently with respect to three metrics throughput, routing load and energy utilization.

6. CONCLUSION

This paper puts forward an energy efficient reactive routing protocol, named as E-AODV gets better routes than traditional routing with respect to throughput, routing load, energy consumed and number of packets forwarded. As part of future work, priority assignment to packets taking part in data forwarding is to be experimented. This helps in differentiating nodes participating in data forwarding between other unwanted nodes that do not take part in data forwarding. This work can further be extended to data link layer- MAC layer.

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