ESAR: An Energy Saving Ad Hoc Routing Algorithm for MANET

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Abstract— **Mobile ad hoc networks (MANET) support multi hop routing in the absence of central base station. The change in network topology due to the node movement associated with the link failure and creation, scarce in radio resources and bandwidth, limited battery power and computing capability pose challenges in packet routing in MANET. The proposed Energy Saving Ad hoc Routing (ESAR) algorithm targets to achieve better energy efficient with a longer network life time. The algorithm selects a path for routing by considering the actual distance between the source and destination along with the minimum available energy of a node in the path. This selected path is chosen as the best path for packet transmission till any node in the path exhausts battery power beyond a threshold value. At this point of time, a backup path is selected as an alternate path for packet transmission. The process is repeated till all the paths from the same source to destination are exhausted with their battery power. The simulation result of the proposed algorithm ESAR indicates that the network life time is improved upon the existing routing algorithms.**

Keywords: Mobile ad hoc networks, Multi path routing, Energy Efficiency, Network Life Time.

I. INTRODUCTION

Mobile ad hoc network supports multi hop routing where the deployment of central base station is neither economic nor easy. Recent developments in the technologies of laptops, PDAs and sensors and the reduction in their cost have exponentially raised the interest in mobile ad hoc networks. The research in the development of routing protocols for mobile ad hoc networks has taken an exponential growth in the recent years. Mobile Ad Hoc Networks supports the users to communicate with each other even on-the-fly. This enhances the applications of mobile ad hoc networks from disaster recovery to battle field communications and from law enforcement operations to remote conferencing. However, frequent changes in the topology of the network due to node mobility and the expiry of the energy constrained nodes perturb the routing of the packets in the dynamic networks.

Efficient routing of the packets is a major challenge in the ad hoc networks. The dynamic network uses multi-hop routing instead of single-hop routing to deliver the packets to the destination. The conventional routing algorithms like distance-vector and link-state algorithms are no more applicable for the ad hoc networks due to the need of the periodic updation of the routing table. There exist several proactive (like DSDV etc.) and reactive (Like AODV etc.) routing algorithms for the dynamic networks. The proactive or the table driven routing algorithms maintain consistent information about the path from each node to every other destination by periodically updating their routing tables. The on demand or the reactive routing protocols aim to reduce the amount of bandwidth consumed by maintaining routes to only those destinations to which a path request is required.

MANET supports multi hop routing where the nodes other than the source and the destination nodes also take part in packet forwarding from one end to the other end. This results in the energy consumption of the intermediate nodes even though they are not the actual sender or receiver of the data. The available battery power of the nodes decides the life time of the node as well as the whole network. In certain existing routing algorithms like AODV [4] and DSR [5], few nodes are selected in such a way that they always take part in packet forwarding resulting in their early death. Such conventional routing algorithms do not consider the energy available with the nodes. Thus it is wise to design a routing algorithm such that minimum number of nodes takes part in packet transfer or the routing paths should be chosen in such a way that the total energy consumption for packet transfer is fairly distributed among the nodes in the path so that none of the nodes expire due to battery power consumption.

There exist some energy efficient routing algorithms [2,10] that aim to increase the network life time by searching alternate paths between the same source and destination, so that the best path among them is chosen for packet routing. As the job of packet forwarding is fairly distributed among the nodes, the energy drainage by individual nodes are reduced resulting in longer network life time.

The rest of this paper is organized as follows. Section II describes the related work done in routing in ad hoc networks. The proposed algorithm is described in details in section III. Section IV represents the simulations results and finally the paper is concluded in section V.

II. Related Works

There exists some very well known routing algorithms for mobile ad hoc networks [1]. Some of them are proactive or table driven routing algorithms like DSDV [6] and GSR [7] whereas some are event driven or reactive routing protocols like AODV [4] and DSR [5]. In proactive routing protocols, every node maintains the complete routing information of the network. Any possible change in the network is flooded periodically into the network to help the other nodes update their routing table. On the other hand, in the reactive routing algorithm a route search is required for every new destination. The nodes maintain the information of the active paths only reducing the communication overhead [8]. The AODV routing protocol searches the route to the destination by broadcasting the route request packet RREQ. Upon receiving the RREQ message, the destination sends back the route reply RREP message and uses that path for packet forwarding. The AODV algorithm usually finds the shortest path among all possible paths from source to destination. Thus in terms of energy consumption by the nodes in the forwarding path, this algorithm consumes less energy in comparison to any other algorithms.

Due to the miniaturization of the portable mobile devices, they are installed with limited battery power. Further, the development in the battery technology is slower in comparison to the development of the computing devices. Such crisis in the available battery power of the mobile nodes demands the routing algorithms to be energy efficient. The authors of [3] have made a performance comparison of routing algorithms with respect to the energy consumption. The researchers and practitioners focus to save the limited battery power of the nodes in various issues of all the layers. The authors of [9] have proposed a transmission power control protocol that improves the channel utilization and end-to-end network throughput while decreasing the total energy consumption by the nodes.

The authors of [10] have proposed a general framework for multi path routing scheme for ad hoc network. The framework provides high reliability of routing for the mobile nodes. A multi path routing protocol for ad hoc networks using directional antenna is proposed by the authors of [11].

The authors of [2] have proposed a multi path routing scheme which is energy efficient and is known as EEAODR. Unlike the AODV routing algorithm, where particular nodes are selected all the time to forward packets through them, the proposed EEAODR algorithm selects alternate paths for the same purpose depending on an optimization function. In AODV, drainage of battery power for these set of selected nodes takes place very fast where as in EEAODR alternate paths are selected for routing of the packet, so that energy consumed by the individual nodes are reduced. The parameters considered for finding the cost of the path for EEAODR are individual node battery power, no. of hops present in the path and the time taken to travel the path. In this algorithm when the destination receives the 1st RREQ, it waits for t time and collects all other RREQ arriving during this time period. After the expiry of the time period, the optimization function is called upon to find the best path having the lowest cost. The algorithm also stores some back up paths that could be used in case of any path failure occurs between the source and destination.

The authors of EEAODR claims that the energy consumed by the nodes belong to the path of AODV consumes less energy than in that of AODV. The network life time of the EEAODR is increased as it avoids the repeated use of the same paths as in the case of AODV. The choice of alternate paths for packet forwarding eliminates the chance of energy depletion by specific nodes constantly.

III. ESAR: The Proposed Algorithm

A. *Basics of the algorithm*

The mobile ad hoc network can be modeled as a unidirectional graph G Є (V, E), where V is the set of mobile nodes and E is the set of links that exist between the nodes in the network. By the virtue of mobility of the nodes they change their position and the connectivity is also changed. Thus, the cardinality of the nodes |V| remains same throughout where as the cardinality of the edges |E| changes with the mobility of the nodes. The link between two nodes exists when the distance between nodes I and j is less than their transmission range, i.e. $dist_{ij} < t_{range}$.

In such a multi hop network, packet routing takes place by the intermediate nodes that play the role of the routers. Every node maintains a routing table that gets updated periodically or with the occurrence of a specific event. The current work basically focuses on the event driven updation of the routing table. ESAR is an on demand routing algorithm where the routes between the source and destination are determined and maintained when they require sending data among each other. It is a hop-by-hop routing algorithm where each data packet carries the destination address as well as the next hop address [review]. The routes are adaptable to the dynamic topology of the network as they update their routing table when receive any fresh information about the routes.

The nodes in the network may operate as a transmitter or as a receiver or even as an idle node that only listens to the packets and forward them to the next hop. The energy dissipation by the nodes is different as per their mode of operation in the network. The node that operates as the transmitter consumes maximum energy than that of the node that operates as the receiver. The idle nodes consume the least energy [12-14].

B. *Motivation for the work*

In the well known AODV routing algorithm, the source node sends RREQ and waits for RREP from the destination. As the destination gets the first RREQ, it sends back the RREP through that path as that path is considered as the shortest path. Then after any RREQ message received by the destination is discarded. Considering the energy impact on the routing path, it is understood that as the same path is used for packet transmission by the source and destination, the energy consumed by the nodes in that path is very high [4].

This energy consumption issue was well addressed by the authors of [2]. The authors in this work have considered alternate paths for packet routing so that specific nodes are not prone to energy consumption throughout. Unlike AODV, when the destination receives the first RREQ, it waits for a δt time period to collect any other RREQ during that period. These paths are stored as the alternate paths for packet routing in order to save the energy consumption by the nodes of a fixed path selected as in the AODV algorithm. After the expiry of the δt time period, a best path is selected by computing the cost of each path stored for packet routing. The cost of the path is calculated by considering the minimum battery power available with a node in a path, the number of hops present between the source and the destination and the time required to cover the distance between the source and the destination. The path having the minimum cost among all the paths is selected as the path for packet routing. The objective of the work is to use alternate paths for packet routing so that the nodes in a single path are not dead because of battery drainage. The simulation result of the work indicates that the energy consumed by the nodes selected in the path of AODV is reduced in EEAODR as alternate paths were selected for packet routing at times. This also results in increasing the network life time because the battery power of certain nodes is saved. But in actual it is seen that the energy consumed per packet by the nodes in the path of EEAODR is more than that of the energy consumed by the nodes in the path of AODV. This is because the AODV always provide the shortest path. So the energy consumed per packet is reduced. Fig. 1 compares the energy consumed by the nodes in the actual path of routing for both AODV and EEAODR. The novel concept of EEAODR provides a motivation for choosing alternate paths for packet forwarding that can save the battery power of the nodes as well as the network life time could be improved.

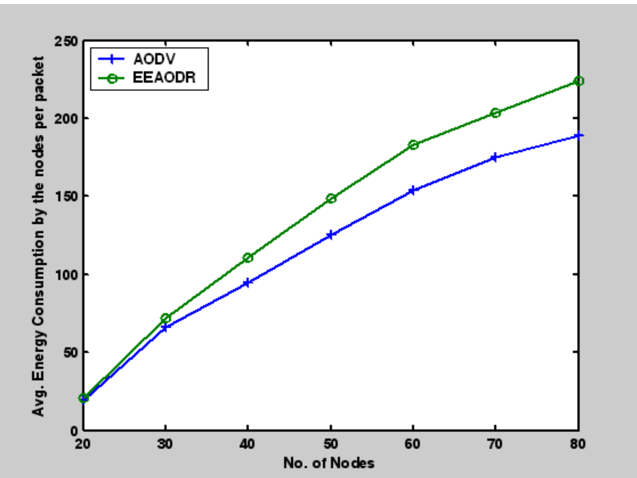

Figure 1. Energy consumption in actual path of routing

C. Proposed Algorithm ESAR

The proposed work targets to achieve better energy efficient routing algorithm with a longer network life time by using the strengths of both the AODV algorithm and EEAODR algorithm.The shortest path in terms of minimum hop counts is chosen by AODV for packet routing ensures that the transmission delay is reduced whereas the network life time is compromised. At the same time EEAODR chooses an alternate path for packet transmission to save the energy of the shortest path while compromising the delay in transmission. The current work selects a path for routing by considering the actual distance between the source and destination along with the minimum available energy of a node in the path. When a source does not find a path to the destination in its routing table, it broadcast the route request RREQ message. The receiver upon receiving the first RREQ waits for δt time period to collect more RREQ messages through other paths. All these RREQ message paths are stored for the selection of actual routing paths as and when required.

After storing all the possible paths from the source to the destination, the current algorithm considers the following two parameters to select a suitable path for packet transmission:

(i) The minimum available battery power of a node in the i^{th} path, E_i. Then a difference of E_i and a threshold value Δ is computed to find out D_{Ei}.

(ii) The actual distance between the source and the destination in the i^{th} path, $Dist_i$.

Then the cost of the path is calculated as:

$$Cost_i = \alpha * D_{Ei} + \beta * Dist_i \quad (1)$$

Where $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ are the weighing factors that decide the priority of the battery power or the distance between the nodes in a network topology. The authors of [2] have indicated that, in a network topology, if the number of hops is higher, then the distance between two hops will be more likely lesser. But the same is not true for all the time. For example in figure 2, the distance between hops in the path 1-3- 2 is lesser than that of the path 1-3-4-2. So the current work proposes to find the actual distances between the hops from the source to the destination rather than to find the number of hops between the two ends. The value of Δ is kept constant for all the paths in the simulation.

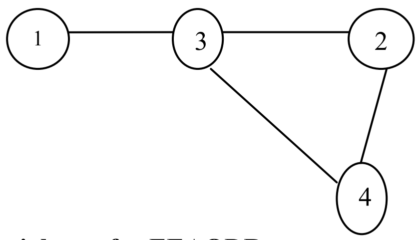

Figure 2: Special case for EEAODR

The algorithm selects the path with minimum cost value indicating that the path has the shortest distance to the destination and has the maximum of the minimum available battery power of the node among the different paths. This selected path is chosen as the best path for packet transmission till any node in the path exhausts battery power beyond a threshold value. At this point of time, a backup path having the next lower cost is selected as an alternate path for packet transmission. The process is repeated till all the paths from the same source to destination are exhausted with their battery power. When this situation occurs, the cost of the paths are re-calculated and the process continues.

IV. Simulation and Results

The simulation of the proposed work ESAR is carried on a 100 × 100 simulation area. The nodes were deployed randomly in the simulation area and the number of nodes vary from 20 to 100 in number. The nodes follow random walk mobility model . The nodes choose a direction between 0 to 360 degree for the movement and the speed is chosen randomly between 0 to 5m/s. Packets of different sizes are used during the simulation which vary from 256 bytes to 4098 bytes as per the network scenario. The value of Δ is kept 90 for the simulation. That is a node in a path is permitted to route a packet till it consumes 90% of its battery power. The simulation was carried out for the following network parameters:

A. Energy Consumed in data transmission

The motivation of ESAR comes from EEAODR that was designed to increase the network life by distributing the network load and selecting the paths containing nodes with higher power levels i.e. the power of the minimum battery node among all the paths are compared with each other. Whereas the primary objective of ESAR is to make use of all the available alternate paths (if available) with the help of a threshold power made constant throughout the simulation which helps in increasing the network life. After each packet transmission, newer paths are calculated. AODV selects the same path, as the mobility does not change the location of the node substantially and thus the same path will be shortest path used for the first packet transmission (minimum hop path), EEAODR selects the optimized path with the help of an optimality function (minimum cost value path), ESAR also selects the minimum distance path till a threshold value then we use an optimality function to further get an optimized path. So, newer paths are calculated every time in case of ESAR as well as EEAODR (if available) as compared to AODV but in case of ESAR all the alternate paths will be taken into consideration which ultimately results in increasing the network life. In this experiment we are sending six packets each of size 512 bytes and perform random data transmission, by selecting different sender and receiver and thus repeating the experiment with different number of nodes (20-100) in the network. As indicated in figure 3 it is concluded that ESAR has lesser energy consumed than EEAODR as well as AODV and thus we conclude the energy is saved as the minimum distance path if selected every time.

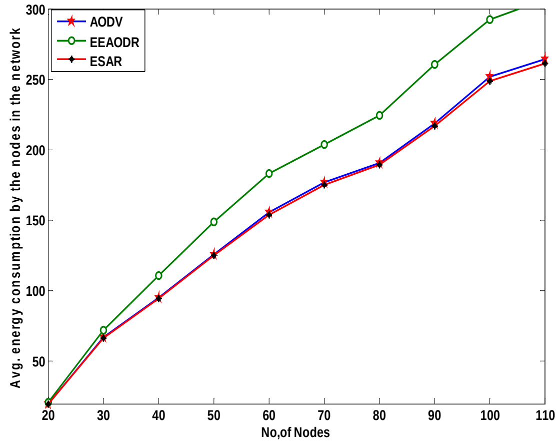

Figure 3: Average Energy consumption by the nodes.

B. Network Life

The whole network dies out whenever a single node dies out due to the depletion of energy i.e. the power of the node becomes zero or below some threshold Δ so that it can't be used as an intermediate node and thus the network fails and it degrades the network, as the node that has died out can't be further used for any packet transmission. As the energy consumption by any node is proportional to the packet size, so as the packet size increases, sooner the node dies out. ESAR increases the network life by using alternate paths thus avoiding the repeated use of a particular node.

In the proposed algorithm data packets of different sizes are sent for the same source and destination pairs. It is observed that as the energy consumption is directly proportional to the packet size so the residual energy decreases as the packet size increases and thus the network life increases. Now from the figure 4 it can be seen that network life of ESAR is higher than EEAODR as well as AODV. The reason is ESAR makes use of the alternate paths thus avoiding the repeated usage of nodes, but it is more than EEAODR because in ESAR we make use of all the available alternate paths and thus the energy consumption among the nodes is more distributed in ESAR than EEAODR, while in case of EEAODR the choice of alternate paths depends on the optimality function.

C. Average network delay in packet transmission

Delay as defined is the time taken by a packet to reach to a destination, i.e. the time for which destination has to wait before processing a packet. The time taken by a packet to reach to a destination depends on the actual distance between the source and destination i.e. time is directly proportional to the actual distance. The average network delay of ESAR is minimum because every time we search for a path having minimum actual distance between the source and the destination among the different available alternate path.

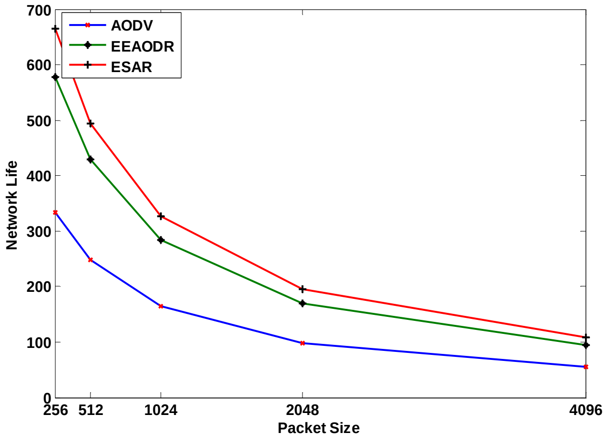

Figure 4: Comparison of network life time vs. packet size.

In the proposed algorithm packets of size 512 bytes are sent and random data transmission is performed by selecting different source and destination and thus repeating the experiment with different number of nodes (10-100) in the network. Now from the figure 5 it can be seen that the average network delay of ESAR is less than EEAODR as well as AODV. The delay of ESAR is less than AODV as well as EEAODR because ESAR every time selects that path which has the minimum distance among the alternate paths so it is minimum, as selection of path for EEAODR depends on the optimality function so EEAODR may not select a path with minimum distance because the optimality function depends also on other factors, while AODV always selects a path with minimum number of hops but not the shortest distance path.

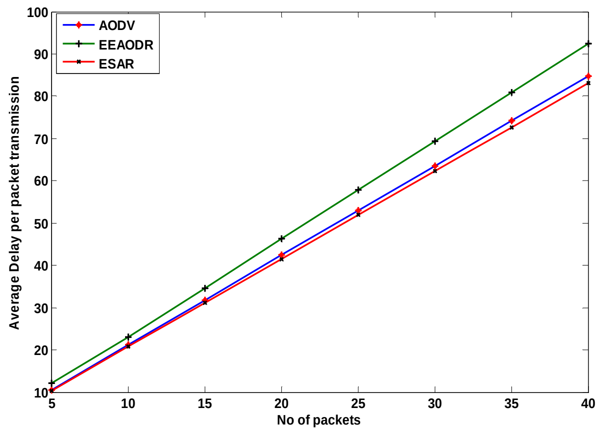

Figure 5: Comparison of average delay per packet.

V.CONCLUSION

Packet routing in a dynamic and energy constrained network is a challenging task. There exist some algorithms that either aim to achieve minimum routing delay like AODV or maximum network lifetime like EEAODR. In the proposed algorithm the actual distance between the source to destination as well as the minimum available battery power of a node in the path is considered to find the best path for packet routing. Backup paths are also stored for the purpose of routing when the best path is found suitable no more. The simulation results indicated shows that the proposed algorithm ESAR achieves better network life time when the delay in packet transmission is not compromised.

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