A novel Approach to Energy efficient low cost Routing in MANET by reduction in Packet Size

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Abstract: *Mobile ad-hoc networks (MANET) are infrastructure-less networks in which groups of nodes collaborate by forwarding packets such that each node can function without a common access point. The mobile nature of MANETs result in degradation of battery life and efficient routing is, thus, necessary for reducing energy consumption. In this paper we modify the existing AODV protocol to decrease energy required during transmission by reduction of packet size and maintain an 'Energy/Distance' ratio as a metric for tracing the best route. By combining these features we reduce required transmission power, as well as increase battery life.*

Keywords: *Ad-hoc Networking, Distance Vector Routing, Dynamic Routing, Mobile Networking, Wireless Networks, Energy efficiency, AODV, MANET.*

I. INTRODUCTION

A Mobile ad hoc network [13] [14] is an infrastructure-less network that consists of wireless mobile nodes capable of communicating independently. The nodes collaborate by forwarding packets such that each node may communicate outside its immediate wireless range. These networks are fully distributed, and lack strict top-down approach.

Since ad-hoc networks are decentralized, they do not require infrastructure such as base stations, and hence, can be easily set up at minimal cost when required. The participating nodes act as router and are free to move in network randomly. Thus, the network topology may change rapidly and unpredictably making it difficult to plot routes between different nodes. To complicate it further, each of the participating nodes has limited energy due to being battery operated and usually it is impossible to recharge or replace the batteries in a remote area.

Since battery life of nodes in wireless networks is limited, it poses a severe constraint network performance [1]. Transmission of packets consume significant battery power, thus degrading the overall quality of the network. To circumvent this, we need efficient routing mechanisms. Routing is a process of detecting various routes from source to destination nodes. Routing algorithms strive to select the best path from all available choices in a table

Routing tables are of two types Static Routing and Dynamic Routing. Static routing is a type of network routing technique. Dynamic routing is a networking technique that provides optimal data routing. The routing table is not affected by addition or deletions of router in case of static routing but it is affected in dynamic routing. Due changing of positions of nodes and connections, the energy and lifetime of network degrades. To overcome the problem, several solutions have been proposed. We have analyzed that no solution have feasible solution. So in this paper we have implemented an energy efficient Routing protocol of AODV that is able to enhance the energy and routing overhead of the network.

II. RELATED WORKS

A.Spyropoulos et al. presented an energy efficient algorithm using directed antennas such that the maximum longevity of the network could be achieved. By calculating the average flow of traffic between two nodes based on a stochastic distribution, the algorithm can determine the traffic between each node pair. The link flow matrix so created is updated to include topology information since no antenna can be directed at two different nodes at the same time, which was a previous assumption. The amount of time two nodes are thus pointed at each other is calculated. If the capacity of each link is greater than the traffic, a scheduling algorithm was formulated to effectively transmit packets. If, however, any link had capacity less than the traffic based, i.e., it did not have sufficient up time, the topology had to be reconfigured. The algorithm so presented can be optimized and modified for distributed networks. It has been shown to reduce energy cost by 45%. It is however computationally expensive. [1]

Su et al. presents an energy efficient modified version of AODV that uses fuzzy logic to choose best routes for packet transmission. The algorithm has four parameters, viz., Hop Count, number of Sent Packets, Minimum Energy and Lifetime to determine the best possible route. Minimum Energy is evaluated by finding the minimum of the battery life left of all nodes in that route. To do this, we first calculate energy consumption rate of each node and then define time left as ratio between remaining batter and power consumption. Next each metric is assigned a linguistic value applicable for each route. They vary from Very High to Very Low. An index value in [0,1] represents the linguistic value. To prevent extreme values each linguistic criterion is given a range of values based on a given graph. Lifetime of a node varies inversely with Hop Count and Sent Packets, and directly with Minimum Energy. Thus a Reverse Minimum Energy criterion which is the inverse of Minimum Energy was introduced. Using these the fuzzy index is calculated. [2]

Zijian Wang et al. has put forward an energy efficient and collision aware (EECA) node-disjoint routing algorithm for wireless sensor networks via multiple paths. With the aid of node position information, the EECA algorithm attempts to find two collision-free routes using constrained and power adjusted flooding and then transmits the data with minimum power required through power control component of the protocol. Instead of flooding the route request message to the whole network, it restricts the route discovery flooding to the neighbors of the nodes iteratively added to the route being discovered. [3]

S.-M. Senouci et al. proposes 3 extensions: LEAR-ADOV, PAR-ADOV and LPR-ADOV. Local Energy-Aware Routing based on AODV (LEAR-AODV): The proposed idea use the mechanism to extend the DSR (Dynamic Source Routing) protocol. In this approach, each mobile node relies on local information about the remaining battery level to decide whether to participate in the selection process of a routing path or not. An inefficiently energy-consuming node can conserve its battery power by not forwarding data packets on behalf of others. The decision-making process in LEAR-AODV is distributed to all relevant nodes. Power-Aware Routing based on AODV (PAR-AODV): PAR-AODV solves the problem of finding a route p, at route discovery time W, such that the following cost function is minimized. Lifetime Prediction Routing based on AODV (LPR-AODV): This protocol prefers the route with maximum lifetime, i.e. the route that does not consist of nodes with a low predicted lifetime. LPR-AODV solves the problem of finding a route ‘pi’ at route discovery time W, such that the following cost function is maximized. [4]

N.Sumathi et al. proposes to minimize energy consumption by randomly selecting a number of overhearing nodes based on probability. This probability based overhearing is integrated with AODV routing protocol. Probability based overhearing method controls the level of overhearing and forwarding of broadcast messages. Sender is able to specify the level of overhearing. Sender may choose no or probability or unconditional overhearing which is specified in ATIM frame control. Node is awakened if unconditional overhearing or probability overhearing is set or it is a destination node. Each node maintains overhearing probability Po and rebroadcast probability Pr. [5]

Zhu et al. devised PEER protocol which uses hop count and energy consumption to select lowest energy path. A packet is broadcasted by the source and on reaching the next hop it’s hop count and energy consumption is increased. The packet is then rebroadcasted only if there exists no known path to destination from the node, the packet uses lesser number of hops, or if the packet comes from a source whose path is already known, but the new path has lower energy consumption. Thus, the best path is always chosen. The algorithm, however, suffers, from path selection issues since the destination may receive multiple minimum energy paths and does not know which one to choose. Also since the destination does not know how many route request packets will be received, it does not know how long to wait and may not select the best path. One method to mitigate this is to send route replies for all route requests but that wastes energy. Another is to use a timer that resets when a new route request for the same packet arrives. The latter is more energy efficient but increases route set up time. Nodes passively monitor neighbors and collaborate with them to update paths to more energy efficient ones. There are three ways to do this –

Remove, Replace and Insert. Each node X removes a two hop path C->A->B if it finds a cheaper direct path X-> B. Node Replaces a two hop path X->A-B if it finds a less costly two-hop path to C->X->B and updates C. Finally it inserts a node in a one-hop path F-G if it find F->X->G is cheaper in terms of energy usage and updates F. Thus, it prioritizes energy over distance metric. PEER protocol reduces about 67% of routing overhead and setup delay. [6]

A.Kush proposed a scheme where each node has 3 power status – Active, Danger and Critical. When battery is less than 20% - Critical, when it is greater than 20% but less than 50% it is Danger, otherwise Active. Reply path uses only nodes with status greater than Critical. Was not simulated. [7]

K.Srinivasa Rao et al. suggests to design an energy efficient and reliable congestion control (EERCCP) protocol for multicasting with the following mentioned phases. In its first phase, they propose to build a multicast tree routed at the source, by including the nodes with higher residual energy towards the receivers. Most of the existing methods (AODV) are depending on individual receivers to identify the possibility of congestion and modify their receiving rates accordingly which are generally inefficient. In the second phase, they propose an admission control scheme in which a multicast flow is admitted or rejected depending upon on the output queue size. In the third phase, they propose a scheme which adjusts the multicast traffic rate at each bottleneck of a multicast tree. Energy efficient tree construction (1st phase): The distance i.e. the geographical location of the nodes is assumed. Their residual energy is measured. The nodes are sorted based on its location from the source and arranged in a sequence order. A threshold value denoted by 'Q' is set and the nodes which are less than Q (n<Q) are unicast from the source and the nodes which are greater than Q (n>Q) are multicast. In case of multicasting the node which has the minimum energy per corresponding receiver is set as the relay node. The relay node then forwards the required packets from the source to the corresponding receivers. Multicast Admission Control (2nd Phase): In this proposed scheme, based on the link's output queue state, multicast flows at a bottleneck can be blocked or released. Let the number of packets in the queue is N. Let QT1 and QT2 (QT1 < QT2) are two thresholds for the queue size. Then the flow is released or blocked based on the following conditions. If N<= QT1, then the multicast flow is released. If N > QT2, then the multicast flow is blocked. Adjustment of Multicast Traffic rate (3rd Phase): In case of the available bandwidth being less than the required bandwidth or the queue size being less than a minimum threshold value, it indicates the possibility of congestion or packet loss. [8]

Jaspreet Singh et al. proposes an energy efficient ADOV routing protocol in which Dijkstra's algorithm is improved to enhance the overall performance of the network. EE-AODV checks the Energy/Distance ratio of each path available in the network. When source node wants to communicate with destination node to transfer the data it starts the route discovery process and broadcast the route request packets to their neighbor along with its energy after receiving the RREQ the neighbor node update their routing table and forward request to their own neighbor along with energy level. When the destination node receives the route request packet (RREQ), it selects the path which has the maximum Energy/Distance ratio so that the chosen route has maximum Energy and minimum Distance to cover.. The node then sends the reply packet (RREP) to the source node via the selected path. After the latter receives the reply packet, it updates its routing table and begins data transmission. [9].

Paraskevas et al. modified the OLSR algorithm in order to make it more energy efficient. Since OLSR is a proactive algorithm, it wastes energy by periodically sending data packets to update tables. Instead the proposed mechanism uses TS packets by adding one weight field to the existing packets. The route tables are updated based on weights (i.e. energy transmission cost) instead of hop counts. The source is assigned 1 and thus any 1-hop route has cost 1. Route table is updated by choosing best path based on energy. It has been noted that on depletion of battery, longer routes have been selected. Drawbacks of this include power consumption due to messages sent over unused routes. Also, typical problems of link state protocol are high computation cost which this model suffers from as well. [10]

RK Sharma et al. use soft computing and artificial intelligence to design energy efficient routes. It modified the algorithm proposed by Su et al. to rate all routes available for packet transmission instead of choosing only two routes. Using energy and distance as parameters, the algorithm creates a fitness function using fuzzy logic. The fitness function F is defined as 1-mean of fuzzy index. Each route is given a parameter for distance and energy. The possible alternate route values are compiled and the mean gives the fuzzy mean. Using this index, the best routes are chosen for packet transmission. However, it is unknown how efficient it is in actual networks. [11]

III. PROPOSED IDEA

A. The E/D Ratio

The protocol we propose checks the *Energy/Distance* ratio of each path available in the network. When a packet is to be transmitted, the source node starts the route discovery process and broadcasts the route request packets to its neighbors along with its energy. After receiving the RREQ packets, the neighbor nodes update their routing table and forward request to their own neighbor along with energy level. When the destination node receives the route request (RREQ) packet, it checks each viable path such that the energy for that path is maximum and distance is minimum. To do this, it calculates the Energy/Distance ratio and chooses the route with the maximum E/D value. Once the path has been chosen, the destination node sends the route reply (RREP) packet back to the source node after which the source may begin data transmission.

III.A.1. Flowchart

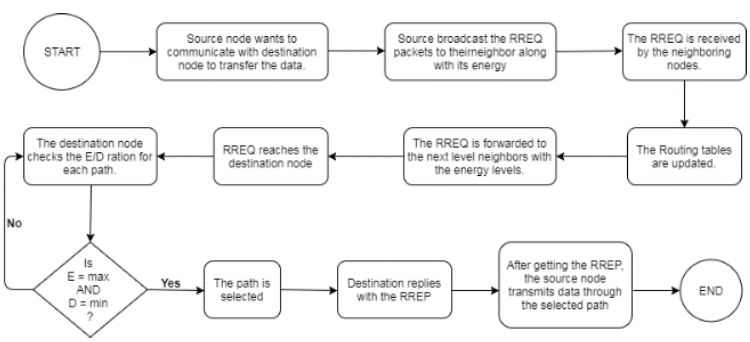

Fig 1: Flowchart of Proposed Algorithm

III.A.2. Algorithm

Step 1: START

Step 2: When source node wants to communicate with destination node to transfer the data it starts the route discovery process and broadcast the RREQ packets to their neighbor along with its energy.

Step 3: After receiving the RREQ the neighbor nodes update their routing table and forward request to their own neighbor along with energy level.

Step 4: After receiving the RREQ the destination node checks the Energy/Distance (E/D) ratio for each path:

If E = *maximum* and D = *minimum*
Then, E/D = *maximum* & path is selected.

Step 5: The destination replies back to source paths.

Step 6: After getting the RREP, the source node transmit data through path having maximum ratio.

Step 7: END

B. Packet Size Reduction

The AODV protocol [12] supports 4 Message Formats:

- Route Request (RREQ)
- Route Reply (RREP)
- Route Error (RERR)
- Route Reply Ack (RREP - ACK)

Mobile ad-hoc networks are characterized by high mobility and continuous change in topology. Nodes in this network usually have limited battery life and continuous change in position of nodes needs a lot of energy. Therefore, Energy efficiency is of utmost importance. As more and more fields become dependent on MANETs, the system needs to be low cost in order to commercialize MANETs.

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |J|R|G|D|U|   Reserved          |   Hop Count   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                            RREQ ID                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Destination IP Address                     |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Destination Sequence Number                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Originator IP Address                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Originator Sequence Number                   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Fig 2: Route Request (RREQ) Message Format

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |R|A|    Reserved     |Prefix Sz|   Hop Count   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                     Destination IP address                    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                  Destination Sequence Number                  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                    Originator IP address                      |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                           Lifetime                            |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Fig 3: Route Reply (RREP) Message Format

Fig 4: Route Error (RERR) Message Format

```
 0                   1
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |   Reserved    |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

```
 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |N|          Reserved           |   DestCount   |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|            Unreachable Destination IP Address (1)             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|         Unreachable Destination Sequence Number (1)           |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-|
|  Additional Unreachable Destination IP Addresses (if needed)  |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|Additional Unreachable Destination Sequence Numbers (if needed)|
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Fig 5: Route Reply Acknowledgment (RREP-ACK) Message Format

In this paper we propose to reduce the packet sizes by reduction of space allocated to determine the type of a message. One such method would to be to combine hop-count and lifetime nodes so that one field can be used to parse both information.

III.B.1. Prof of Proposed Idea

Required to Proof: Packet size reduction leads to decrease in routing overhead.

The *Shannon-Hartley theorem* [15] gives us the maximum amount of error-free digital data that can be transmitted over a communications channel with a specified *bandwidth* in the presence of *noise*.

From Shannon-Hartley theorem, we know,

$$C = B \log_2 (1 + S / N)$$

Where C = Channel Capacity, B = Bandwidth, S = Signal Power and N = Channel Noise. Noise is proportional to bandwidth.

The thermal or Johnson noise power [16][17] and bandwidth are related by the equation.

$$N = kTB$$

Where k = Boltzmann constant, T = temperature. Thus,

$$C = B \log 2 (1 + S / kTB)$$

For a given signal power, as B increases the channel capacity increases. Thus, if possible it is better to *use more rather than less bandwidth in transmitting a signal with a given power*. As the bandwidth B is made larger and larger, the channel capacity approaches the limiting value:

$$C = BS / kT \ln 2$$

This equation shows that the energy necessary to transmit one bit of information can never be less than $kT \ln 2 = 0.693\, kT$ *joule*.

Thus for n bits, the energy required to transmit a packet must be at least $0.693\, nkT$ *joule*.

Theoretically, the energy required per bit is not much, but in practice, noise is often much larger. Thus the energy requires increases considerably.

If we can reduce packet size from n to n-d, energy required drops substantially to:

$$0.693\, (n\text{-}d)kT \text{ joule}$$

Thus, we have focused on reducing routing overhead by packet size reduction.

IV. FUTURE WORK

We plan to make the following improvements in this paper in the future:

- Using techniques of Artificial Intelligence to determine the route.
- Determining efficient techniques to aid reduction of packet size, in order to facilitate energy efficient routing protocol.

V. CONCLUSION

In this paper we have seen that the energy degradation is a serious problem in MANET. So we have implemented a modified energy efficient AODV routing protocol which finds the optimal path between source and destination and reduces the energy consumption of the nodes in the network with better performance. We have proposed to make AODV protocol energy – efficient by maintaining an *E/D* ratio and the reduction of packet size. In the future, we also plan to implement techniques of Artificial Intelligence to determine the route in the protocol.

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