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Optimizing Energy Utilization in Ant Based Multipath Routing

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Abstract: Energy is an important resource in the field of Mobile Ad hoc Networks (MANETs). Limited energy at a particular node may lead to failure of a route in MANETs. The energy is consumed each and every time a node participates in transmission and forwarding of the packets. Controlling the number of packets to be forwarded through a particular node i.e. controlling participation of a node as an intermediate node may improve the overall energy state of the network. Ant colony Based Energy Efficient Routing Protocol (ACBEEMR) works on this principal and controls the number of packets to be forwarded through a particular node. For achieving this goal, it uses a threshold value known as energy factor. ACBEEMR utilizes the benefits of Ant Colony Optimization along with the feature of being an energy efficient protocol. In this paper, a modified variant of ACBEEMR i.e. MACBEEMR with some added functionalities has been introduced. This variant of ACBEEMR aims to increase the lifetime of the network. The Modified ACBEEMR (MACBEEMR) has also been compared with other multipath protocols.

Keywords: Ants, Energy, Multipath, Proactive, Reactive and Threshold.

I. INTRODUCTION

Mobile Ad hoc Networks (MANETs) [1] [2] consist of mobile nodes that move from one location to another. An important constraint associated with the MANETs is limited battery of mobile nodes. The transmission, reception and processing of data packets use considerable amount of energy and lead to depletion in the energy levels of nodes. Thus energy is an important constraint in MANETs. Another factor that can contribute to the quality of service in MANETs routing is the use of multi-paths. Multi-path routing provides alternative paths for transmission of data packets and hence decreases the probability of link failure from source to the destination. Considerable work has been done in this field. AOMDV [3] is an example of one such attempt. In this paper, a variant of earlier proposed Ant Colony Based Energy Efficient Multipath Routing Algorithm (ACBEEMR) [4] has been introduced. Various limitations observed in the design of ACBEEMR have been rectified using this modified variant.

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This variant has been named as Modified ACBEEMR (MACBEEMR). The paper has been divided into five sections. Section II presents the work reviewed related to energy efficiency and use of meta-heuristics in multipath routing in MANETs. Section III presents the limitations of ACBEEMR algorithm along with possible rectifications in the design of ACBEEMR. Section IV presents a modified variant of ACBEEMR i.e. MACBEEMR. This variant aims to increase the lifetime of network. The Section V presents the simulation based comparison of the MACBEEMR with other multipath routing protocols. Section VI concludes the findings of the paper.

II. RELATED WORKS

Mobile Ad Hoc networks being the infrastructure less networks have a number of associated problems. These problems are diverse in the sense that solution to one problem may give rise to other problems. Thus using the meta-heuristics for optimization of these problems related to Mobile Ad Hoc Networks can prove to be a better approach. This section introduces various kinds of multipath approaches that can be applied to solve the problems in MANETs.

Smail et. al. [5] proposed a multipath routing protocol exploiting the field of energy conservation. This proposed protocol has been named as Ad hoc on-demand multipath routing with lifetime maximization (AOMR-LM). The AOMR-LM works on the principal of preservation of energy for mobile nodes. It works on balancing and controlling the energy consumption of nodes to increase the life of nodes in networks. The concept of residual energy has also been used by AOMR-LM for assigning the energy levels. These energy levels have further been used for the classification of paths in the network. Two factors, namely β and α are used for the classification of nodes. α is a coefficient while β represents a threshold on energy.

The discovery mechanism results in the discovery of multiple disjoint paths. The selection of the path for the transmission of data is done on the basis of residual energy of the nodes. The classification of the paths is done in order to balance the energy consumption of network. The data is transmitted by using a path from higher class.

The paper also provided a simulation based comparison of AOMR-LM with AOMDV and ZD-AOMDV protocols. Results proved the contribution of AOMR-LM in controlling the energy consumed and increasing the lifetime of the network.

Taha et. al. [6] proposed an energy efficient multipath strategy i.e. FF-AOMDV. It has been simulated using NS-2 simulator for different speeds, packet sizes and simulation run time.

FF-AOMDV uses a Fitness Function along with the basic procedure of AOMDV protocol. The multipath procedure uses the broadcast of the Route requests from the source node that results in the discovery of number of routes from source to the destination. These routes can be used for forwarding data packets without taking into consideration the quality of routes.

The FF-AOMDV works on the qualitative aspect and selects the route on the basis of following information:

- Energy of each node in the network
- The distance of each discovered route
- Energy consumption during route discovery process.

If the initially selected route by FF-AOMDV fails, then the source node may use the alternative route from set of stored routes. The routes are selected considering the shortest possible route having minimum energy utilization. A fresh route discovery is initiated only in case of failure of transmission along all the discovered routes to the destination.

Taha et. al. also compared the performance of FF-AOMDV algorithm with the existing AOMDV and AOMR-LM protocols. Results proved better performance of FF-AOMDV as compared to both AOMR-LM and AOMDV. Simulation also proved the effectiveness of FF-AOMDV in conserving the energy and increasing the lifetime of network. The paper also mentioned the scope of extension of work in the direction of using bandwidth as another factor for calculating the fitness value.

Shangchao et. al. [7] presented a multipath approach for application in MANETs. This approach is based on the use of Fuzzy controller and has been named as Fuzzy Controller based Multipath Routing (FMRM). The use of fuzzy controller is based on the idea of reducing the number of reconstructions in the process of development of routes.

The Fuzzy scheduler works on the basis of priority index associated with packets. The fuzzy scheduler has been provided with three input variables and output consists of one variable. The input to the controller includes expiry time, rate of data packets and Queue length at each node. The output of this fuzzy controller is the priority index. Simulation results of FMRM prove the suitability of Fuzzy based approach for multipath routing.

Another meta-heuristic that has been applied to discover multipath in MANETs is genetic algorithm [8]. The genetic algorithm has been applied to the routes resulting from the route discovery phase. A route has been represented in the form of string of integers. The string cannot have a length more than the size of network. These strings represent the chromosomes. According to the principle of genetic algorithm, chromosome having higher fitness value has higher chances of entering into next generation. The fitness has been evaluated in terms of minimum delays. Thus, minimum delay over a route represents higher fitness value.

The most popular among all meta-heuristics for Mobile Ad hoc Networks is Ant colony optimization [9] [10] [11] [12]. Caro et. al. [13] presented AntHocNet Routing Algorithm by utilizing the benefits of ACO approach. AntHocNet is a hybrid protocol inspired from the behavior of biological ants. The algorithm is hybrid in the way that it employs the combination of reactive route setup with proactive route maintenance. The forward and backward ants are used for route setup procedure whereas proactive forward and backward ants are used for Route maintenance.

Taraka et. al. [10] compared the AntHocNet algorithm with the Ad hoc On demand distance Vector (AODV) [14] [15] routing protocol and Dynamic Source Routing (DSR) [16]. Simulation results prove the scalability of AntHocNet over AODV and DSR. The results of the study prove that AntHocNet is better at high data rates and for large number of nodes. However the performance is low as compared to AODV and DSR at low data rates and at less number of nodes. Thus AntHocNet is a suitable approach for large-scale and high data rate networks.

Literature proves the contribution of various meta-heuristics in field of multipath routing in Mobile Ad hoc Networks. However, considering the diversity of problems that need to be solved, Ant colony optimization is anticipated to be a better approach as compared to other Meta heuristics. ACO approach can be helpful in dealing with different parameters at the same time and it also considers the impact of environment on the agents. The role of environment is very crucial in case of MANETs. Thus ACO is much suitable approach for solving problems related to MANETs. Considering the benefits of ACO approach, the design of Ant colony Based Energy Efficient Multipath routing was proposed [4]. This paper presents an improved design of ACBEEMR in form of MACBEEMR, after considering few more important factors that can contribute towards the life time of the network and also can reduce the unnecessary overhead. The next section presents the limitation of earlier design along with necessary up gradations.

III. ACBEEMR AND ITS LIMITATIONS

The ACBEEMR utilizes the benefits of Ant colony optimization by mapping the various parameters associated with MANETs to the conceptual pheromone quantity. This conceptual pheromone is maintained in a similar way as in the case of biological pheromone. In ACBEEMR, the rate and quantity of pheromone along a route is inversely proportional to number of hops to the destination. Further, it has been mapped in a way so as to have more pheromone along a path with more residual energy.

Secondly, ACBEEMR introduced the concept of Energy Ants that are broadcasted by each node at regular intervals. These Ants are responsible for maintaining information about the energy state of the neighbor nodes. This energy information is further used to alter the pheromone quantity of the route according to the proportional energy change along a route.

The major limitations observed during the implementation of ACBEEMR along with possible solutions are as follows:

- ACBEEMR maintains two separate tables i.e. Pheromone table and the routing table. However the purpose of routing table can be served by the pheromone table and hence there is no need to maintain a separate routing table at each node.
- The most important limitation observed is in the case of energy ants. The energy ants are supposed to broadcast an energy level of zero to the neighbor node in case the energy of the current node falls below the threshold value.

This apparently leads to a state where every node looks to be exhausted after achieving a threshold value i.e. much before attaining an energy level of zero. Moreover, ACBEEMR only considers the amount of residual energy to update pheromone table, while ignoring the amount of energy consumed. Considering all these factors, a minor change has been introduced into the pheromone updating function to increase the life time of the network.

IV. MODIFIED ACBEEMR

MACBEEMR is a modified variant of ACBEEMR. MACBEEMR provides solutions to the limitations introduced in the last section. Beside, introducing the solution to the first limitation by using only pheromone table instead of separate pheromone and routing table, the major change has been introduced to the design of pheromone update function. The basic procedure for transmission of forward and backward ants is same for both ACBEEMR and MACBEEMR. The difference has been introduced in the process of updating the pheromone.

The ACBEEMR calculates the pheromone on the basis of hop count. The pheromone is regularly updated at node k by using the ratio of residual energy of neighbor node i in current energy ant i.e. R_{ki} and the energy level of neighbor node i at node k in last received energy ant i.e. E_{ki}. ACBEEMR considers only the residual energy in the process of updating the pheromone. It ignores the manner in which energy has been consumed. However the rate and the manner of consumption of energy is also an important factor. This factor can decide the rate of change in pheromone in a better way. Moreover, threshold value should also be used in the process of updating the pheromone, as the combination of both i.e. threshold value and the consumption of energy can decide the pace of decrease in the pheromone in an effective way.

$$P_{kij} = \left[\frac{1}{H_{kij}}\right] * \left[\frac{R_{ki}}{E_{ki}} - \frac{\phi}{100}\left(\frac{InitialEnergy - ResidualEnergy}{InitialEnergy}\right)\right] \tag{1}$$

MACBEEMR uses all these factors in updating the pheromone as shown in (1). Φ represents threshold value of the energy. The ratio of the consumed energy to the initial energy of neighbor i has also been depreciated from the pheromone probability after multiplying it with the threshold factor. This helps slowing the pace of use of the node whose energy has exhausted in a larger amount in comparison to other nodes.

The complete modified algorithm can be summarized by the pseudo code as follows:

Pseudo code for MACBEEMR Algorithm:

// Generation of Forward Ants //
Begin
Forward Ants are broadcasted toward the destination.
Intermediate Nodes are recorded on the stack by the Forward Ants
//Generation of Backward Ant//
After reaching the Destination Forward Ants are discarded and Backward ants are produced in the reverse direction.

Begin While (Node ≠Source Node)
Pheromone table at a node is updated by the Backward Ants based Number of Hops to destination through that node

$$P_{kij} = \left[\frac{1}{H_{kij}}\right] * \left[\frac{R_{ki}}{E_{ki}} - \frac{\phi}{100}\left(\frac{InitialEnergy - ResidualEnergy}{InitialEnergy}\right)\right]$$

i.e. P_{kij} & H_{kij} represents the pheromone and Number of Hops at Node k through neighbor i to destination j.
End While

// Updating Pheromone Table Using Energy Ants//
The Pheromone table is updated at a regular interval of time using the **Energy Ants** from neighbor.

End

Pseudo Code for Energy Ants:

Begin While (Energy of node < Threshold)
//Energy factor (Ø) → (Energy Consumption)/Use Count//

If (Ø > Current energy level)
Broad cast Energy ants with energy of transmitting Node equal to 0;
` **Else**
Broadcast the Energy ants with energy of transmitting Node equal to its current energy.
End While

The next section presents the simulation based comparison of MACBEEMR with other multipath routing protocols using NS2 simulator.

V. SIMULATION AND RESULTS

The modified ACBEEMR tries to avoid the state of null energy among the nodes of the network by delaying the energy utilization. This effectiveness in preventing the over utilization of energy of nodes is achieved through the use of pheromone update function. However, mathematically the pheromone update function proves its importance. But it needs to be tested using the simulation tool. For this purpose, the MACBEEMR has been simulated using NS2 and the results have been compared with ACBEEMR, AOMDV, FF-AOMDV and AOMR-LM protocol. Table I shows the various simulation parameters that have been employed for comparing the two protocols.

Table I: Simulation Parameters

Routing Protocol	ACBEEMR, MACBEEMR,AOMDV,FF-AOMDV, AOMR-LM
Network topology	1500 * 1500
MAC Type	802.11
Max. Packet in IFQ	50
Radio propagation model	Two ray ground
Number of Nodes	50
Packet size	64,128,256,512,1024
Max. Simulation time	50 s
Initial Energy	100 joule
Transmission Power	0.02 joule
Receiving Power	0.01 joule

Traffic Type	CBR
Transmission Range	250 m
Queue Size	50

The Packet Delivery Percentage represents the percentage of data packet delivered to destination with respect to the number of data packets originated from source.

The results obtained corresponding to the packet delivery percentage proves the edge of MACBEEMR over other protocols in most of the cases. The Packet delivery percentage for AOMDV varies from 89.56 to 70.67. For FF-AOMDV it varies from 95.45 to 81.06. In case of AOMR-LM it varies from 93.12 to 79.9. The results for ACBEEMR are comparable to other protocols but are slightly less with values from 90 to 81. However, in comparison to ACBEEMR, MACBEEMR has better performance with values ranging from 93.91 to 85.1. However, we may also conclude that the results are comparable in case of all the protocols for packet delivery percentage as shown in Figure 1.

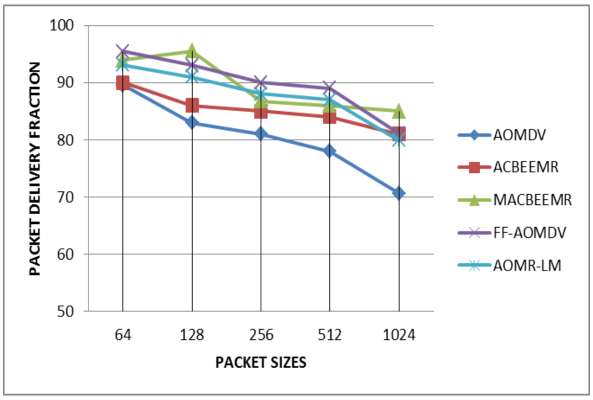

Figure 1: **Packet Delivery Percentage vs Packet Size**

The main objective behind designing Modified ACBEEMR protocol is to increase the life time of network by controlling the energy utilization of the network. The fulfillment of this objective can be observed from Figure 2. The results corresponding to energy utilization proves that MACBEEMR dominates all protocols with the very low values of energy consumption as compared to other protocols. The energy consumption in case of AOMDV ranges from 81 joule for packet size of 64 byte to 120 joule for packet size of 1024 byte whereas these values are very low in case of ACBEEMR i.e. 15.04 joule for 64 byte to 23.52 joule for 1024 byte. The energy consumption results for FF-AOMDV and AOMR-LM are better than AOMDV with values from 69 to 94 joule in FF-AOMDV and 63 to 87 joule in AOMR-LM. Here, MACBEEMR dominates all protocols with very low energy consumption i.e from 5.01 joule to 13.4 joule. The low energy consumptions in case MACBEEMR is attributed to the use of efficient energy based pheromone updating mechanism introduced in MACBEEMR. This helps in managing the energy resource effectively in case of MACBEEMR as can be seen in Figure 2.

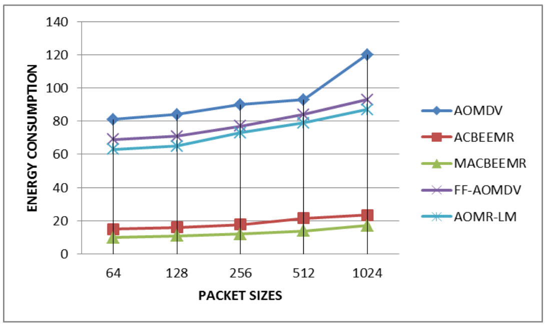

Figure 1: **Energy Consumption vs Packet Size**

Figure 3 also proves the effectiveness of both ACBEEMR and MACBEEMR, as number of nodes that have completely exhausted corresponding to various packets sizes are zero for both protocols. The results are better than other protocols. All other protocols have significant number of nodes that have been completely exhausted.

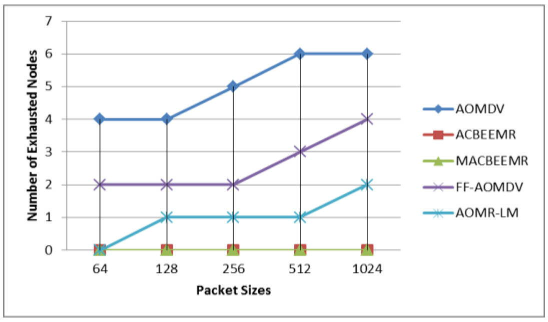

Figure 2 Number of node exhausted vs packet size

Smail et al. provided that AOMR-LM gives better results in terms of End to End delays. Figure 4 shows the simulation results for MACBEEMR corresponding to the End to End delays. For this purpose, a topology of 840 * 840 has been taken and the results have been compared by varying number of mobile nodes from 30 to 190. As can be seen from Figure 4, the delays are very less in case of both ACBEEMR and MACBEEMR as compared to AOMDV as well as AOMR-LM. The delays are nearly 600 ms for 30 nodes in case of both AOMDV and AOMR-LM. In case of ACBEEMR and MACBEEMR, the delays are 91.5 ms and 65 ms respectively. This proves the effectiveness of MACBEEMR over all other protocols.

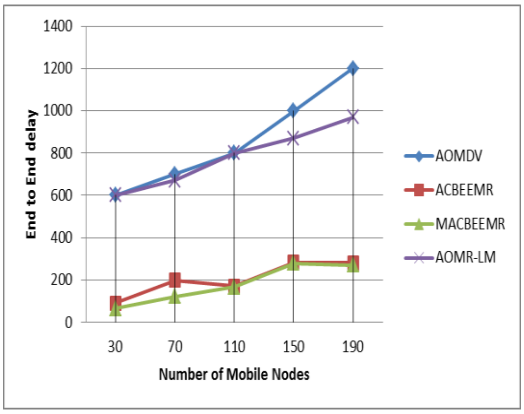

Figure 3 End to End Delay vs Number of Mobile Nodes

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The simulation based comparison of MACBEEMR with other protocols proves the role of MACBEEMR in decreasing the energy consumption and increasing the lifetime of network, while not compromising the performance in terms of packet delivery and end to End delays.

VI. CONCLUSION

The paper presented a modified variant of ACBEEMR referred as MACBEEMR. The simulation of routing protocols namely MACBEEMR with other multipath protocols prove the benefits of the proposed approach. The protocols have been tested for different number of nodes for Energy consumption, Packet Delivery Ratio and End to End delay. The Benefits of using Ant Colony based multipath routing can be seen in terms of higher packet delivery percentage and lower end to end delays in both MACBEEMR and ACBEEMR. The concept of energy ant also proves it's utility. However, MACBEEMR by rectifying limitations of ACBEEMR utilizes the energy ants in an effective way as compared to ACBEEMR. This has been proved from the results of energy consumption. The paper further establishes that the multipath routing is an effective method for optimizing the performance of network when used with the nature inspired techniques such as ACO.

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