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ANT Colony Based Energy Efficient Multipath Routing

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Abstract: Multipath routing in MANET is a way of utilizing multiple alternative paths in the network, which can provide a variety of benefit like preventing delays due to stale routes, increased available bandwidth on different links etc as compared to the protocols like DSR and AODV. In the present paper, the various existing multipath routing techniques for MANET have been elaborated along with their weak zones. This paper also introduces Ant colony based energy efficient multipath routing (ACBEEMR) technique. The ACBEEMR uses pheromone probability function to decide the next node in the network.

Keywords: Multipath, Routing, On demand, Proactive, energy efficient**.**

I. INTRODUCTION

Routing in MANETs is the way of finding a path from a source to destination among randomly distributed nodes. On the basis of the kind of mechanism the routing protocol in MANET are divided into proactive and reactive routing protocols. In proactive or table driven approach the information about each node in the network is maintained. As the topology in MANET is dynamic so the routing information needs to be updated frequently. Destination Sequenced Distance Vector Routing (DSDV) is an example of proactive routing protocol. Whereas the reactive routing protocols or the protocol based on on-demand behaviour [1] [2] discover and create the route as and when they are required. So the overhead of sending the regular update packets is not there in case of on demand routing protocols. Reactive routing [3] protocols include Dynamic Source Routing (DSR). Both of the approaches have their own merits so a hybrid protocol proposed here includes the advantages of both the approaches. The Ant colony based energy efficient multipath routing (ACBEEMR) protocol deals with following issues:

1) Whether the protocol should be Proactive or reactive.
2) How to prevent same route from being used again and again.
3) How to minimize the overhead.
4) How to prevent the energy of the nodes from getting exhausted.

The ACBEEMR protocol is based on the concept of energy efficiency and the multipath routing. It also utilizes the benefits of Ant colony optimization. This paper has been divided into four sections. Section II contains the various existing Multipath routing protocols along with the various aspects of routing that they cover. This section also covers the various benefits that are provided by ACBEEMR as compared to earlier existing approaches. The Section III introduces the basic algorithm of ACBEEMR protocols along with the various data structures that it uses. The Section IV provides the conclusion and the future work that may be carried out on ABCBEEMR.

II. SURVEY OF ENERGY EFFICIENT MULTIPATH ROUTING

Multipath routing in MANETs uses multiple paths for sending data packet from source node to destination node. The existing multipath routing protocols like Ad-hoc On-demand Multi path Distance Vector Routing protocol (AOMDV), ACO-AOMDV and ABEAR have been discussed in this section. AOMDV is an advancement of the AODV protocol for finding out multiple loop-free paths. Like AODV, AOMDV also consist of route discovery and maintenance phases. AOMDV also utilizes the concept of distance vector routing and discovers the routes on-demand in route discovery phase. AOMDV finds multiple disjoint paths during route discovery process. The discovered paths are also loop free. AOMDV supports hop-by-hop routing so the intermediate nodes between source and destination maintain multiple route entries in their routing tables. Routing tables in AOMDV consist of destination node, sequence number, hop count and route list.

The Modified AOMDV[4] modified the AOMDV protocol by utilizing the concept of residual energy of node for selecting the path, It finds the path according to energy of node and then the routes are sorted in descending order on the basis of residual energy. The data packets are forwarded using the route with maximum residual energy of nodes. In this way the overall energy state of network can be improved and also increases the lifetime of network. The steps involved are:

1. In the first step, the nodal residual energy of every route discovered during the route discovery process is computed.

2. Second step involves finding out the route having the minimum nodal residual energy.
3. All the routes are then sorted in the descending order of the nodal residual energy.
4. The route with maximum nodal residual energy is selected for forwarding the data packets.

EM-AODV [5] calculated the route establishment cost based on the residual energy of node but it does not involve any procedure to modify the values of routing table based on the current state of network.

In another variant of AODV protocol [6] the protocol is modified and converted to work on multiple paths to send data in such a way that it is much energy friendly. A new parameter named as RATE_LIMIT parameter has been introduced. The RATE_LIMIT computes the number of route requests that can be accepted and can be processed normally by a node for a unit time. During the discovery process of protocol [6] when a destination receives a RREQ packet a check is performed. If the rate of the route request originator is below the RATE_LIMIT, the RREQ packet is processed as normal. Otherwise the RREQ originator is blacklisted.

ACO-AOMDV [7] improves multipath routing performance by using the ant colony optimization [8][9] along with Ad-hoc on-demand multipath distance vector (AOMDV). In ACO-AOMDV, simulated pheromone deposited by ant packets is a function of various parameters. The parameters like average link count of path, average load of path, hop count and current value of pheromone the nodes possess are the factors responsible for deciding the amount of simulated pheromone. This information provided to the visiting nodes is used to update the pheromone tables. Simulation of ACO-AOMDV on the metrics like packet delivery ratio, end-to-end delay and route discovery frequency proves that it performs better than AOMDV. Thus ACO-AOMDV presents a new approach of reactive routing algorithm, which is based on the concept of ant colony optimization and also has the benefit of being a multipath routing protocol like AOMDV.

The Ant-Based Energy-Aware Routing Protocol (ABEAR)[10], is based on the Ant Colony Optimization (ACO) combines the benefit of route setting up procedure of reactive routing approach with the table driven neighbor maintenance process. ABEAR also utilizes route maintenance procedure for repairing the route. The lifetime of the network, the delay involved, and throughput of the network are the important factors in the ad hoc networks. This also asks for determining a trade-off among the above mentioned parameters in order to design the routing protocol. Among existing routing protocols most of the protocols do not consider aspect of increasing the life-time of a network. Moreover, network congestion in the ad hoc networks may cause retransmission of the packet and it may also lead to dropping of data packets. Both the retransmission as well as the packet dropping leads to waste of energy. The process of designing an energy-efficient routing protocol involves considering the parameters like congestion metric, pheromone value, the quality of link and the residual energy of the next node. This information is used for insuring that selected neighbour is not the one with less residual energy and thus increases the energy efficiency by reducing the loss of energy caused by retransmission of packets or packets being dropped. ABEAR with the energy-efficiency property contributes to increasing lifetime of the network.

The above approaches do suffer from few of the limitations. The AOMDV consider the route length as the only criteria for deciding the best route among the various possible routes. Energy is a vital resource and hence needs to be taken into consideration. The Modified AODV although considers the nodal residual energy but it alone cannot be the sole criteria for designing the efficient routing protocol.

Another variant of AODV [6] though provided a way of blacklisting the requesting nodes for a particular node on the basis of number of packets it has received from them. But this approach is not suitable as merely the number of request packets cannot decide the criteria for black listing a particular node. ABEAR has an energy efficient property and perform better than AODV but it does not support multipath routing .Keeping in view the above mentioned aspects, a new routing technique is proposed in section III.

III. ANT COLONY BASED ENERGY EFFICIENT MULTIPATH ROUTING(ACBEEMR)

Ant colony Based Energy Efficient Multipath Routing (ACBEEMR) incorporates the concepts of Ant colony optimization, the energy efficiency and multipath routing in order to present a protocol that may deal with the varying network conditions i.e. High load and low load. During the low load condition, the ACBEEMR performs same as that of AOMDV but during the high load conditions the energy ants start updating the pheromone probability table. Thus optimizing the routes based on the concept of residual energy of node.

The major issue with the earlier protocol is that every time the same route is likely to get selected again and again between two nodes. So the solution to this problem has also been provided with the help of concept of energy ants.

In ACBEEMR the routing table is prepared based on the route length as well as on the basis of the energy of the node to which the packet is being forwarded in the current state of the network. During the High load condition, the energy packets are broadcasted based on the Energy factor (Ø) which is inspired from the route establishment cost calculation in EM-AODV [5]. Here the thresh hold limit decides the limit on the residual energy of each node up to which the network may be said to be in low load condition.

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If(Current energy < Thresh hold limit)
{
Energy factor(Ø)=(Initial energy - Current energy level)/number of uses Count
IF (Ø < Current energy level)
{
Broadcast the energy ant with current energy level;
}
Else
{
Broad cast the energy Ant with current energy level set to 0;
}
}

The Pheromone probability table can be updated based on the backward ants received. The entries here is the function of Route length

$$P_{ij} = (1/R_{kij})/(1/\sum_{i=1}^{n} (R_{kij})$$

Further the new values of P_{ij} are updated based on the residual energy as follows.

$$P_{ij}=P_{ij}*(RE_i/E_i)$$

Algorithm

1) Initially Forward ants are broadcasted toward the destination D to discover all possible paths. Each Forward Ant contains following information i.e. Id, Destination Node, Source Node, Stack of Intermediate Nodes & the Hop Limit.
2) Whenever a node receiving the Forward ant has two or more than two links on which Forward ant can be forwarded, the Forward ants are replicated according to the number of neighbor node and each copy is given a new id.
3) All the intermediate nodes encountered by the Forward ants along different paths are recorded on the stack starting with source.
4) The Forward ant is discarded on reaching the destination node and corresponding Backward ant is produced. The stack which was being maintained by the Forward ant is copied to the corresponding Backward ant but in a reverse order.
5) The Route length table and the Pheromone probability table is updated based on the Backward ants received. The entries here is the function of route length

$$P_{ij} = (1/R_{kij})/(1/\sum_{i=1}^{n} (R_{kij})$$

6) The Pheromone probability table is updated as per step 5.
7) The Data packets can be sent based on the entries of the Pheromone probability table.
8) The Energy packets are broadcasted regularly by a node in order to update the probability table. The energy packets are broadcasted based on the **Energy factor (Ø).**

If(Current energy < Threshhold limit)
{
Energy factor (Ø) = (Initial energy - Current energy level)/number of uses Count
IF (Ø < Current energy level)
{
Broadcast the energy ant with current energy level;
}
Else
{
Broad cast the energy ant with current energy level set to 0;
}
}

The new values of P_{ij} are updated as follows

$$P_{ij}=P_{ij}*(RE_i/E_i)$$

1) The values of P_{kij} at node k is updated in the table as follows

$$P_{kij} = Pij / \sum_{j=1}^{n} P_{ij}$$

2) The Routing table T_{nj} for n best values of pheromone probability table is generated to decide, possible n nodes those may be selected for further transmission of packet from the current node.
3) The data packets may be forwarded based on the updated T_{nj}.

The Various data structures those are required to be maintained by each node are as follows.

Data Structures to be Maintained at Node

Route length table
Pheromone Probability table
Routing table
Use count
Current energy level of node(C)
Energy of neighbor(E_i)

Fig.1 : Data Structures to be maintained by Node

The Pheromone probability: table contains the entries in the form of matrix P_{ij} where I denote the neighbour node or the next node and j denotes the destination node.

The Route length table: contains R_{ij} I denotes the neighbour node or the next node and j denotes the destination node.

Routing Table T_{ij} : T_{ij} contains the next node i to which the packet must be forwarded to reach the destination j.

Use Count: Contains the number of times the node has been used at a given point of time.

Current Energy level: Contains the Energy of the node at a given point of time.

Energy of neighbour (E_i): The E_i contains the energy corresponding to neighbor node I as per last Energy packet received from the node i.
The reactive routing is done by forward and backward ant packets.

Forward Ant
The Forward Ants are generated by the source node to find multiple paths from source to destination node.

Any forward ant packet on its way to destination records all the nodes that it has traversed before reaching the destination.

Forward ant packets carry the information like:

FWD ANT ID: it's a unique sequence number to identify the forward Ant.

Destination Node Id: This field contains the id of the destination node.

Source Node ID: this field contains the id of the node originating the Forward ant

Node[1…n]: These fields contain the nodes encountered by forward ant while moving from source to destination.

Hop limit: This field contains the maximum number of nodes that can be visited before reaching the destination. This prevents the same node from being visited again.

FWD ANT Id
Destination Node ID
Source Node ID
All the nodes recorded starting with source Node[1] □
Node [2]
Node [3]
Hop Limit

Fig 2. Forward Ant PACKET

Backward Ant
Backward ant packets are generated by the node after destroying the forward ant packet for which the current node was the destination.

BWD ANT Id: It's a unique sequence number to identify the Backward Ant.

Destination Node Id: This field contains the id of the destination node.

Source Node ID: This field contains the id of the node originating the backward ant

Node [1…n]: These fields contain the nodes encountered by forward ant while moving from source to destination but in the reverse order.

Hop limit: This field contains the Total number of nodes those were visited by the forward ant packet before reaching the destination i.e this field contains the total number of nodes on the path.

BWD Ant Id
Destination Node ID(source in forward ant)
Source Node ID(destination in forward ant)
All the nodes recorded by forward ants but in reverse order Node [1] □
Node [2]
Node [3]
Hop Limit

Fig. 3. Backward Ant Packet

How to prevent same route from being used again and again.
The concept of energy ants is introduced here in order to prevent the same route from being used again and again. Based on the value of the residual energy the pheromone probability table is modified. This also makes this approach energy friendly.

Energy Ants
The energy Ants are used to update the pheromone tables which are being maintained by each node. The energy Ant packets are broadcasted by each node with hop limit set to 1. These packets carry the information regarding the residual energy stored in the node.

Source id
Energy stored in the node(RE_i)
Hop limit

Fig 4. ENERGY ANT

Earlier energy was not given the due consideration. The protocols like AOMDV only considered the route length as the criteria for deciding the best route among the various possible routes. Whereas in ACBEEMR the routing table is prepared based on the route length as well as the current energy state of the node to which the packet is to be forwarded. ACBEEMR is better in the sense that under the low load conditions the pheromone tables are not affected. And probability of route getting selected is inversely proportional to route length only. In case of heavy load conditions, the energy ant starts updating the pheromone probability table thus the overhead is likely to be less at a particular node in ACBEEMR. Considering the shortcomings of AOMDV with respect to aspect of energy the ACBEEMR prevents the death of battery at a node by stopping its use. The shortcoming of ABEAR with respect usage of single path has been removed by the selecting the multiple path with the help of pheromone probability function. However as and when the level of energy level of the node will rise above the energy factor the node will again be available to take part in the data transmission. The major issue with the earlier protocol is that every time the same route is likely to get selected again and again between two nodes. So the solution to this problem has also been provided with help of the concept of energy ants. The energy ants are responsible for updating the pheromone probability table. Thus ACBEEMR a better energy efficient technique to deal with heavy load conditions in Ad-hoc networks. However, the pheromone probability function in ACBEEMR may further be optimized based on the values of packet delivery ratio, End to End Delay and bandwidth utilization.

IV. CONCLUSION & FUTURE SCOPE

The ACBEEMR takes into consideration both aspects of mobile ad hoc network, low load condition and heavy load condition. Further routing tables are modified only under the heavy load conditions. This feature further optimizes the ACBEEMR by reducing the unnecessary overhead. The ACBEEMR also has the benefit of being the multipath routing protocol. The multipath routing in the ACBEEMR is done based on the route length and the energy state of the node. Thus modifying the probabilities based on the current state of the network. The work is in progress for the implementation of strategy using Network Simulator 2.

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