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An Energy Effectual Protocol Using Modified Ant Colony Optimization Algorithm for MANET

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Abstract: *In mobile Ad-hoc Network (MANET), each mobile device can move in the direction of its choice and hence will frequently change its links to other devices. A routing protocol in MANET has the challenges of facing frequently changing topology, symmetric links and low transmission power. Mobile devices are powered by batteries and if transmission and reception of data occurs frequently, it would be impossible for the battery power of the mobile device to withstand for a long time. Therefore, efficient power management is important to boost the lifetime of the battery. In this paper, a competent technique with modified Ant Colony Optimization (ACO) algorithm is proposed to improve the power management and routing of MANET. The proposed algorithm is implemented in Zone Routing Protocol (ZRP) which combines the benefits of proactive and reactive approaches, by maintaining a map of topology up-to-date.*
Keywords: *Mobile Ad-hoc Network, Multicast Routing Protocol, Intra Zone Routing Protocol, Inter zone Routing Protocol, Ant Colony Optimization.*

I. Introduction

MANETs are composed of devices with low power and a limited transmission range, so it's hard for the devices to cope up with the dynamic topology change in most of the cases. The communication between the source and the destination is not direct; the communication path is through various intermediate nodes resulting in multiple-hop communication to the destination [1, 5, 7, 13, 15 and 16]. MANETs can also be considered as a heterogeneous network composed with different types of devices differing in transmission ranges. Hence, a route from source to the destination in forward path may not be the same as in the reverse path. The routing is still being a challenge in MANET as the nodes frequently move out of the transmission range thus breaking the communication channel. The path has to be reconstructed often and the routing process needs to be efficient.

Despite the problems, MANETs are being used in various real-world situations where traditional network infrastructure is not possible and not suitable. The vital areas where MANETs are used include vehicular networks, battle field, rescue operations etc.

The Ant colony optimization algorithm (ACO) is proven to be an efficient one in such problem domains [1, 2, 3, 4 and 12].The ACO adapts the behaviour of real ants. Ants take random path initially forming multiple paths from food to nest. During their movement, they lay pheromone chemical substance, serving as a route mark through which the ants have traversed. Subsequently, the newer ants will follow the path which has increased pheromone concentration and also the path they have taken will be reinforced. As an outcome of this autocatalytic effect, the solution emerges quickly.

Ant Colony Optimization (ACO) technique is used to find feasible path between source and destination. ACO uses two types of control messages as forward ant (FAnt) and backward ant (BAnt) for the route discovery process. A neighbour discovery protocol is added to deal with mobility in route maintenance phase.

II. Related Work

This section presents the review of a handful of literature related to routing and energy management in mobile ad-hoc network (MANET). The topology of MANET is dynamic and hence is subjected to various attacks. The attacks are caused by the existence of malicious nodes or by the selfish nodes. Energy efficiency is obtained by selecting the optimal path by eliminating the selfish or malicious nodes [1, 2]. The Improved Energy Efficient Multicast Routing Protocol (EEMRP) lengthen the life time of each mobile node by considering transmission power control approach, load distribution approach and sleep/power-down mode approach [3]. The energy management is obtained by minimizing the discharge of battery power which in turn increases the lifetime of the nodes [4]. The feasible routing path is obtained by persistently monitoring the routing table in ACO based routing protocol. By limiting the number of control packet the control overhead is reduced [5]. The stagnation behaviour and premature convergence is avoided by using a well established distribution strategy of initial ants and heuristic parameter updating [6]. Ant colony optimization with power saving technique is introduced for energy management and to find the optimal path in MANET. The bandwidth consumption is reduced by controlling the number of control packets which in turn minimizes the power consumption [7].

The combination of border casting query detection and early termination reduces route query traffic which in turn reduces congestion overhead and increases the reliability and performance of ZRP [8]. Query packet ID is used in detection and prevention of overlapping query message. By limiting the control packet, Source Based ZRP (SBZRP) reduces the network load when establishing a new route [9]. By affixing the service information to the routing message extended ZRP (EZRP) achieves high service discoverability [10]. The secure ZRP foils single and multiple malicious black hole attacks [11].

Multi path Distance Vector ZRP (MDVZRP) is proposed for finding the shortest path. Periodic updating of routing table is not required in this and the control overhead is also reduced [10]. The scalable routing can be achieved in MANET through zone routing [13]. Independent zone routing protocol permits adaptive and distributed configuration of optimal size of each and every node within the routing zone. To detect and prevent overlapping query message, a query control mechanism is used [14]. The shortest path for communication is obtained by ACO, which also integrates congestion metrics to alleviate congestion in route discovery and maintenance [15]. The hybrid zone routing protocol analyzes the route acquisition delay and does quick reconfiguration during link failure [16].

III. Existing Work

In ACO the source node broadcasts FAnt to all the neighbouring nodes in order to establish the route to the destination. On receiving FAnt the nodes check whether the destination is itself. If it's being the destination it sends BAnt to the source node and establishes the path otherwise it again broadcasts to its neighbouring nodes. As FAnt is broadcast to all the nodes while route discovery is in process in ACO, each node receives unlimited ants which cause control overhead. Since ZRP has the advantage of both proactive and reactive approaches it seems to be efficient. While implementing this algorithm in ZRP a problem arises, while reconstructing path, the control packets will be sent with full energy and hence power is lost quickly.

IV. Proposed System

Energy Management increases lifetime of the nodes as each node consumes power to transfer the data. In intra-zone, direct communication is possible between source and destination, so low power is fixed. For inter-zone, several intermediate nodes are present, so it consumes more power compared to intra-zone routing. In this paper, it is achieved by using ZRP protocol with two power values viz 30mW for intra zone and 50mW for inter-zone based on the radius. To obtain shortest path in inter-zone, the modified ACO algorithm is used.

ZRP divides its network in different zones. ZRP includes two protocols viz., Intra zone Routing protocol (IARP) and Inter zone Routing Protocol (IERP). A modified ACO algorithm is introduced in IERP to find out the shortest path. In modified ACO algorithm, the number of ants to a node is restricted, so that the traffic is reduced and also the control overhead will be reduced. In initial stage heuristic value is set as high and then data transmission is done. All ants will follow that path resulting in redundancy. To avoid this, an entropy value is calculated. Equation for entropy calculation is given below.

The entropy of a random variable is stated as

$$E(x) = \sum_{i=1}^{r} P_i \log P_i \qquad (1)$$

where P_i is trail's occurrence probability in the pheromone matrix. There will be $n(n-1)/2$ discrete pheromone trails and $r = n(n-1)/2$ for a symmetric n nodes. The maximum entropy is given by

$$E_{max} = \sum_{i=1}^{r} \frac{1}{r} \log \frac{1}{r} = \log r \qquad (2)$$

Using entropy value the detail about the information gathered from pheromone trails and the heuristic parameter can be updated according to the rule given by

$$\beta = \begin{cases} 5 & \text{threshold } X < E' \leq 1 \\ 4 & \text{threshold } Y < E' \leq \text{threshold } X \\ 3 & \text{threshold } Z < E' \leq \text{threshold } Y \\ 2 & 0 < E' \leq \text{threshold } Z \end{cases} \qquad (3)$$

$$E' = 1 - \left(\frac{E_{max} - E_{current}}{E_{max}}\right) \qquad (4)$$

E' is the current pheromone matrix's Entropy value and X, Y, Z are threshold according to the node zone size. If the threshold value is high means the FAnt's are not allowed to visit a path.

V. Algorithm

The proposed algorithm is combined with dynamic updating of heuristic parameter and well distribution strategy of initial ants. The proposed algorithm is defined as follows:

Procedure for Proposed modified ACO algorithm
Set parameters, initialize pheromone trails
Compute the maximum entropy
Loop
On a starting node according to distribution strategy, each ant is placed
For k=1 to m do
At the first step move each ant at different route
Repeat
Select node j to be visited next
Apply a local updating rule
Until ant k completes a tour
End for
Apply global updating rule
Calculate entropy value of current pheromone trails
Update the heuristic parameter
Until End-condition
End

ZRP protocol creates zones to cover an entire network with respect to hop count where, the prime issue happens to be power consumption. A source node uses maximum power to forward a packet to the destination. As a consequence of this, the sending node will be starving of power in a very short duration. To avoid this problem modified ZRP protocol is proposed. In modified ZRP protocol, zones are to be created with respect to two power levels.

Within the zone the route can be easily established and hence the nodes consume lesser energy. If the destination is not in the zone then the control messages will be sent to the border nodes and the route is discovered.

In Route discovery process of Fig. 1, if the destination is in the intra-zone the route is established based on the IARP. If the destination is in the Inter-zone then the IERP is used which uses the modified algorithm. Then the process is with two ants FAnts and BAnts. The FAnt contains packet with unique sequence number, which is used to detect duplicate packet and address of source node. This ant is broadcasted by the border nodes and it is forwarded by neighbor nodes. A node which receives FAnt message then it creates record in routing table. This record in routing table contains next hop, destination address, and pheromone value. The node decodes the source address of the forward ants as the destination address, the previous node address as the next hop, the number of hops as pheromone value that the FAnt needed to reach the destination node. After receiving the packet by destination, it extracts the information of FAnt and destroys it. Subsequently it creates the BAnt and transmits it to the source node from which it received. When process is completed, a route is established and data packets are transmitted.

Route maintenance is important in MANET. As shown in Fig. 2, when there is a link broken along an active path between Source and Destination within radio coverage, a local path repair procedure is initiated.

Repairing is the process of establishing a new path from source to destination. The neighbouring nodes routing zones overlap heavily since each node has its own routing zone. Without proper control the message can be reached to the same node multiple times since each peripheral node of a zone receives FAnt request message. The same request may be forwarded multiple times by each node.

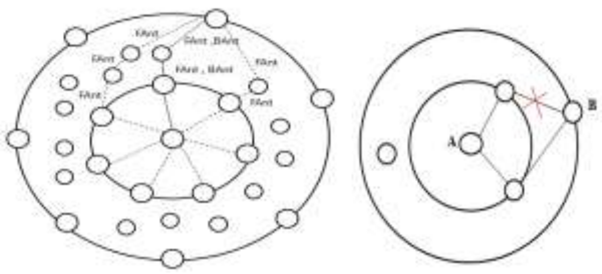


Fig. 1 Route Discovery   Fig. 2 Route Maintenance

----------- Route Request

——— Data Transfer

VI. Results And Discussion

To evaluate the performance of the proposed technique NS2 simulator has been used. The proposed technique has been implemented in ZRP and compared with AODV and traditional ZRP protocol. The scenario has been created with 23 nodes and the factors such as throughput, delay and packet delivery are taken as performance metrics. The implementation is done as three phases. As the first phase, the scenario is done with the use of ZRP and the performance metrics are analyzed. As the second phase ZRP is modified by introducing two power levels for IARP and IERP respectively and it is implemented as EZRP. Finally the modified ACO as proposed is introduced in EZRP and implemented as AEZRP and then the performance metrics are compared with other phases. As expected the proposed protocol gives good result when compared to others and the results are as follows

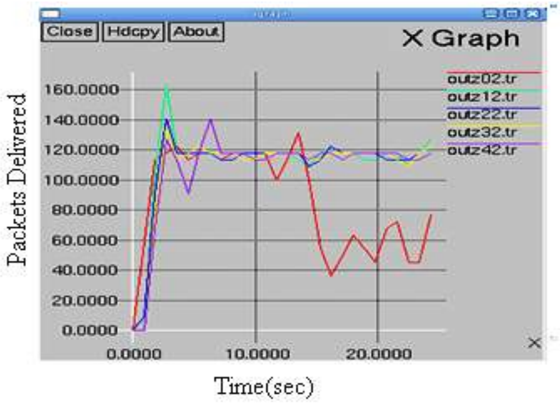


Fig 3 Packet delivery between the nodes while using ZRP

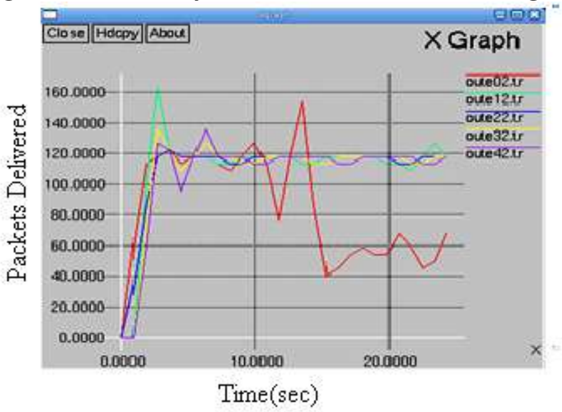


Fig 4 Packet delivery between the nodes while using EZRP

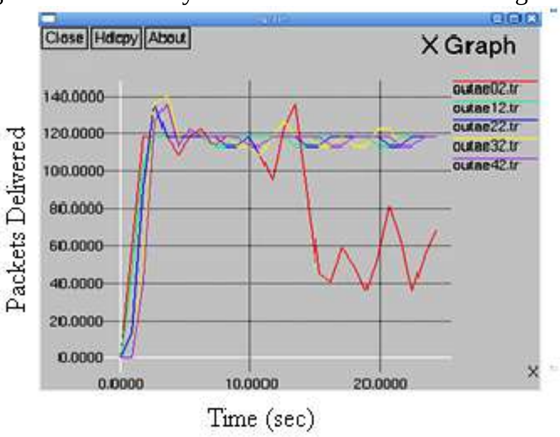


Fig 5 Packet delivery between the nodes in AEZRP protocol

From fig 3-5 the node to node packet delivery ratio in all four scenarios are clearly visible. The trace files out02.tr, out12.tr, out22.tr, out32.tr, out42.tr gives the traces between nodes 6-11, 11-13, 13-20, 20-21, 21-22 respectively. At 4 sec, the proposed technique gives high packet delivery when compared to others as all the nodes received increased packets. It gives an average of 135 units which is about 10% increase. Also the packet delivery is consistent throughout the simulation. There is a decrease after 10 sec in packet delivery between node 6 and 11 which indicates that the reception of control packets is being controlled and increases the performance.

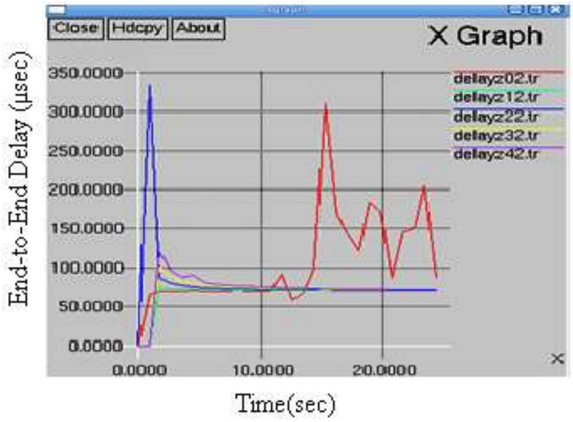


Fig 6 Delay between the nodes while using ZRP

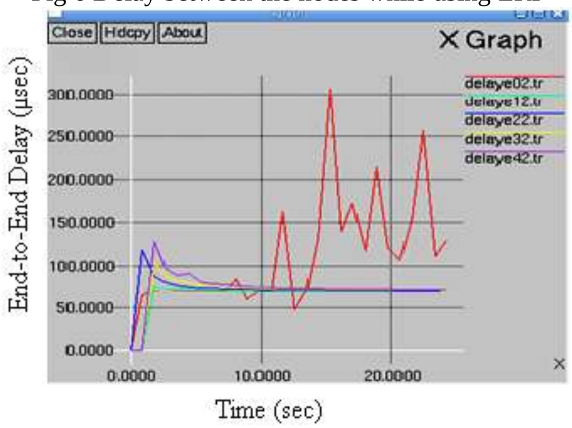


Fig 7 Delay of packets between the nodes while using EZRP

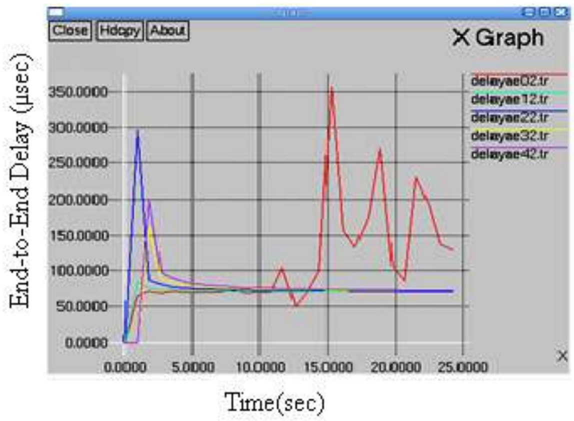
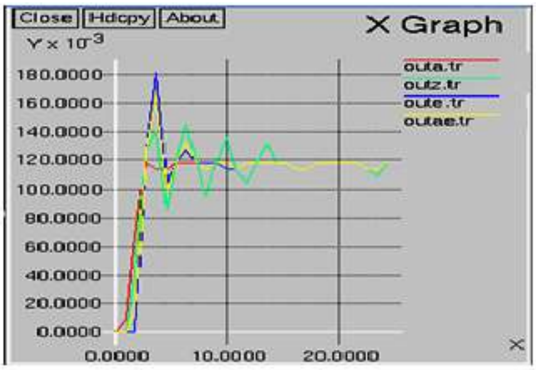


Fig 8 Various delays between the nodes in AEZRP protocol

Fig 6-8 gives the end to end delay of packets between the nodes during simulation. The trace files delay02.tr, delay12.tr, delay22.tr, delay32.tr, delay42.tr gives the traces between nodes 6-11, 11-13, 13-20, 20-21, 21-22 respectively. At the start the delay of packet in the proposed technique is increased when compared to others at delay02 and delay12 due to the broadcast of FAnts for route discovery. Then the delay is reduced and being consistent throughout the simulation.



Time(sec)

Fig 9 Comparison of throughputs of all the protocols

The fig 9 gives the comparison of throughputs of all the protocols. It is clear that there is no throughput after 15sec in all the cases except our proposed technique. In traditional ZRP protocol there is lots of variation in throughput and hence it results in poor performance. Whereas in our proposed modified ZRP the throughput is being consistent and results in better performance.

VII. Conclusion

A routing protocol in MANET has to face the challenges of frequent topology change, low transmission power and symmetric links. During route failure the nodes transmit the control messages with higher energy. By having two energy levels we can conserve energy at greater extent as the number of nodes increases. During route discovery process the control messages are broadcasted at greater extent which results in the control overhead and increased processing time at each node. Ant colony optimization algorithm deals this problem effectively by the use of FAnt and BAnt but the broadcast of FAnt still struggles with control overhead. The introduction of entropy value limits the broadcast of ants to the same node thus reducing the control overhead which ultimately reduces the delay and increases the throughput. The simulation results show that the throughput and the packet delivery ratio of the proposed protocol are better than traditional ZRP. Yet the proposed system lacks in reducing the end to end delay. Thus the proposed modified ZRP protocol reduces the power consumption with increased throughput with help of modified ant colony optimization algorithm.

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