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Energy Aware Ant Colony Optimization (ENAANT) to Enhance Throughput in Mobile Ad hoc Networks

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***Abstract*—** Mobile Ad hoc Network (MANET) is a network of mobile nodes having communication without a predefined infrastructure. The applications of MANETs are increasing from home appliances to defense communications. As the mobile nodes are operated by the batteries, all the processes which are taking place in the node should aware of the consumed energy. Maintaining the link stability is one of the challenges and it is one of the factors to ensure the high throughput in the networks. Due to the limited energy, the links of the networks often goes off which affects the throughput of MANETs. Energy aware ACO is proposed to optimize the utilization of energy that is available in the mobile nodes to increase throughput by ensuring link stability. Based on the remaining energy and the amount of packets to be sent, the nodes are selected for routing. The simulation is done through Network Simulator 2 and the results show that the proposed research work performs well in increasing the throughput.

Keywords*-energy, manet, throughput, ant colony*

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I. INTRODUCTION

MANET has become a popular and most attracting concept for researchers and various industries because of the wide range of applications. Some applications of MANET technology could include industrial and commercial applications involving cooperative mobile data exchange [1]. MANETs have several salient characteristics like dynamic topology, Bandwidth-constrained, variable capacity links, energy-constrained operation and limited physical security. Mobile devices of MANET can move in any direction independently and the devices can change the location at any time which causes changes in the topology. Each device should have the capability of routing because there is neither a centralized administration nor a predefined infrastructure. The characteristic of dynamic topology makes the communication more difficult because providing quality of service (QoS) became a challenging one. One of the parameters of QoS is throughput which makes the communication more efficient. In any network, the throughput is defined as the rate of successful delivery of message.

The motivation behind the Ant Colony Optimization (ACO) is the foraging behavior of real ant colonies. This is exploited in artificial ant colonies for the search of optimal solutions to discrete optimization problems, to continuous optimization problems, and to optimize the communications in telecommunications, such as routing and load balancing. At the core of this behavior is the indirect communication between the ants by means of chemical pheromone trails, which enables them to find short paths between their nest and food sources [2]. The amount of pheromone is the guidance for the other ants. This research work is also inspired by this ACO and the ants are the control packets to be used for finding the paths between the intended mobile nodes. Ants are small control packets, which have the task to find a path towards their destination and gather information about it. Like ants in nature, artificial ants follow and drop pheromone. This pheromone takes the form of routing tables maintained locally by all the nodes of the network. They indicate the relative quality of different routes from the current node towards possible destination nodes. Ants normally take probabilistic routing decisions based on these pheromone tables, giving a positive bias to routes of higher pheromone intensity, to balance exploration and exploitation of routing information.

Since the mobile nodes are equipped with limited energy the routing protocols and algorithms should consider the energy of the mobile devices. The efficiency of the routing protocols is not only to provide a better path between the mobile nodes, but also to utilize the energy of the node in an optimized manner. The energy consumption of a node includes the overall energy, energy consumed per layer, energy consumed for different operation modes, energy consumed for MAC and routing overhead and energy consumed for each packet. Even when a node is in idle mode, the energy is consumed for listening to the channel. In MANET energy consumption is calculated based on a mobile device operations, which can be classified into four different modes: transmit, receive, idle and sleep mode [3][4][5]. The average power consumed by a network interface is calculated by adding power consumed in all four modes such as sleep, idle, receive, and transmit.

The routing protocols proposed for MANETs are generally categorized as table-driven and on-demand driven, based on the timing of when the routes are updated. With table-driven routing protocols, each node attempts to maintain consistent, up-to-date routing information to every other node in the network. Thus, it is proactive in the sense that when a packet needs to be forwarded, the route is already known and can be immediately used. In on-demand driven routing, routes are discovered only when a source node desires them and there are two major procedures such as route discovery and route maintenance [11].

MANETs face challenges during communication because of the factors like dynamic topology and limited energy. Due to the dynamic topology and limited energy, link stability became another big challenge. Ensuring good throughput in MANET is also affected by this reason. This research paper concentrates on enhancing the throughput through ACO and energy aware routing algorithm named as ENAANT. As the MANETs are having asymmetrical links, a source node as a single node cannot determine the status of the intermediate nodes. Each node during the path set up has to calculate its available energy and inform it to the source node through the ants. This research work considers four different scenarios as follows: (i) all the nodes have sufficient energy, (ii) all the nodes have lower energy but capable of handling the transactions, (iii) fewer nodes have higher energy and fewer nodes have lower energy and (iv) all the nodes have zero energy.

II. BACKGROUND

Many researchers have contributed to improve the performance of MANET. An energy constrained routing scheme was proposed by Chitra et al. [6] which was implemented with the strength of ACO. The routing decisions were facilitated based on the nodes' residual energy. Palak [7] proposed an approach for routing which considers the energy and ACO. In these two research works mentioned above, the details of how the nodes calculate the energy which is utilized by various resources of the mobile device are not clearly stated. The schemes introduced in the existing works didn't consider the different scenarios and the calculation of energy for different operation modes.

Seema et al. [8] proposed an energy saving multipath AODV routing protocol that is based on node residual energy. They selected two paths for routing in which one path was used as main path and another path was used as alternate path. Ravinder et al. [9] proposed a mechanism which considers only the nodes which are all having maximum energy and they stated that using ACO the performance can be improved. Vaibhav et al. [10] proposed a research work in which they fixed some threshold value for the energy to every node which are all participating in the communication and when the threshold value is crossed the particular node must be disconnected by itself from the path.

Baisakh et al. [12] proposed a method based on Dynamic Source Routing (DSR) protocol by considering the residual battery power. If a node is out of energy immediately the particular path will be terminated and the new path should be executed. During the process packet loss is going high. Manali at al. [13] also proposed a method based on DSR and they used Received Signal Strength Indicator (RSSI) to predict the link breakages. Salwa et al. [14] proposed a new protocol, called Power and Delay-Aware Routing Protocol for Ad Hoc networks (PDRP) that is based on the research work Stable Path Routing Protocol based on Power Awareness (SPR) [15]. They claimed that the proposed protocol balances tradeoff between energy consumption and end-to-end delay. Shahram [16] et al. stated in their research work that Temporally Ordered Routing Algorithm (TORA) is one of these routing protocols that offer high degree of scalability. They employed the Binary Particle Swarm Optimization algorithm (BPSO) to add the energy awareness feature to the TORA routing protocol. The protocol considers routes length in its route selection process and also includes routes energy level in its calculations. It formulates the routing issue as an optimization problem and then employs BPSO to choose a route that maximizes a weighted function of the route length and the route energy level.

Amit et al. [19] proposed a protocol which is based on source routing whereby all the routing information is maintained (continually updated) at mobile nodes. Ans also they claimed that the Dynamic source routing (DSR) protocol is more efficient than AODV protocol because Dynamic source routing (DSR) protocol supports high mobility environment than AODV protocol. Alok et al. [20] proposed a protocol, called Power and Delay aware Temporally Ordered Routing Algorithm (PDTORA), based on Temporally Ordered Routing Algorithm (TORA) Protocol, where verification of power and delay requirements is carried out with a query packet at each node along the path between source and destination. The nodes in the network which do not satisfy to the QoS requirements of maximum delay and minimum power levels, are eliminated from the route of communication, during query phase. Bander et al. [21] presented a model for multicasting named as Reliable and Energy Efficient Protocol Depending on Distance and Remaining Energy (REEDDRE) and it is based on a tone system. It combined solutions over the MAC layer. The protocol consists of a new construction method for mobile nodes using a clustering approach that depends on distance and remaining energy to provide more stability and to reduce energy consumption. They also proposed an adjustment to the typical multicast flow by adding unicast links between clusters.

The existing research works attempt to utilize the energy in an optimized way but, the details of calculating the energy, who calculates for the particular node, energy for different transmission modes and the different scenarios that exist among the MANETs are not clear and some of the protocols add overhead by introducing many changes in the existing protocols. And also existing research works execute the procedure by having a fixed threshold value which cannot be determined in advance because the energy consumption of a node will vary from time to time based on the number of processes being executed. As the ACO produces good results in searching the shortest path, it could be improved further to support the energy aware routing in order increase the throughput and this research work shows a good performance.

III. PROPOSED ALGORITHM ENAANT

Based on the literatures, it is understood that the performance of MANETs depends on the energy of the mobile nodes which participate in the communication and there is a need for a new approach to utilize the energy of the mobile nodes of MANET. The energy of each node is known by the node itself and the source node cannot calculate the energy level of all the participating nodes because the energy consumption differs from one node to another. So, the energy level must be calculated by the respective node itself and it should be noticed to the source node to choose the best path based on the available energy.

ACO process is started to find a shortest path from the source to the destination as per the procedure proposed in the research work OPTANT [17]. Between the source node *S* and the destination node *D*, the two types of ants as shown in Figure 1, called as *path_request_ant* and *path_reply_ant* are used for finding the path and *path_reply_ant* carries the energy parameters to help the source node for deciding the best path. In order to ensure the link stability to reduce packet loss and delay and to increase throughput, energy of each node should be calculated. This calculation is done by the participating nodes based on the available energy and the processes that they are executing. The energy is measured in Joule.

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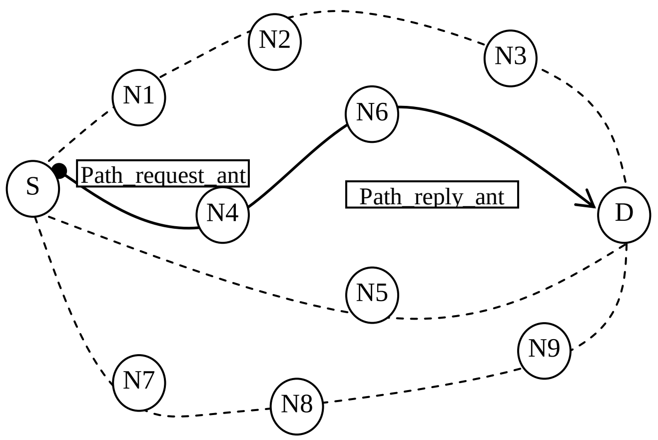

Figure 1. Example MANET with ACO

Power consumption of a wireless radio depends on the operation mode. Operation modes of a radio can be categorized into the following: (i) transmit mode, (ii) receive mode, (iii) idle mode, and (iv) sleep mode [18] (v) sense mode. During the sleep mode, very less power is consumed by electronic circuitry to keep the radio in a low power state that can return back to active mode. Energy consumed for transmission (ET_i) of a node *i* is calculated by adding the energy consumed for receiving the packet (ERe_i) and the energy consumed for transmitting a packet (ETr_i).

$$ET_i = ERe_i + ETr_i \quad (1)$$

The remaining energy (*REi*) for the node *i* is calculated as

$$RE_i = Energy\_before\_processin - Enegry\_after\_processing \quad (2)$$

which is applicable for all modes.

When a node is in idle mode, the mobile node is neither sending nor receiving the packets. During the sense mode, the node listens to the wireless signals which consume some energy. The energy of the node *i* consumed during the idle and sense mode (EI_i) is calculated for a period of time (t_1 to t_2).

$$EIi = Et_1 - Et_2 \quad (3)$$

Energy spent on the node's applications and other processes (*EAi*) are also considered to know whether the energy spent for the application is draining out the battery.

The source node calculates the energy needed to transmit the packets. The energy needed for the entire transaction is calculated by considering the time taken to complete the transaction and size of the packets to be transmitted. When the *path_reply_ant* is received, the different energy consumption of the intermediate nodes including the remaining energy is received by the source to choose the best path. Based on the energy consumption details received from the intermediate nodes, two different paths are constructed in which one path is activated immediately as a main path that contains the nodes having maximum energy and another path as an alternate. Though the main path is selected by considering the maximum energy, there is a possibility that the energy of any node is drained quickly due to the greedy nature of the applications or the node may involve in communication or routing for other set of nodes (source and destination nodes within the same network), so, an alternate path is chosen in order to avoid unnecessary delay. While choosing the paths, instead of calculating the cumulative energy of a path, the remaining energy of the each node is considered, because the energy level varies from one node to another node. The algorithm is as follows:

Algorithm ENAANT
1. Start
2. Initiate ACO // path-request, path-reply
3. Read *ETi*, *ERi*, *ETri*, *EIi*, *REi* for all nodes of path*i*
4. Calculate *size,duration* of the packet to be sent
5. Calculate *energy* needed to send the packets // set threshold
6. For node *i=1 to n* // of route j
7. If *node_energy* > *threshold* then
8. Construct route
9. Else ignore node *i*
10. Select next-route // step 5, check the nodes of next route
11. start communication //intimate nodes to check energy during communication
12. End

IV. Simulation and Discussion

ENAANT is simulated using NS2 as shown in the Figure 2(a) and 2(b) which shows the different number of nodes. The network coverage area is 1000x1000m and the number of nodes is set from 25 to 50. The packet length is set as 128bytes. The energy (unit as joule) of the nodes is set variably to all the nodes and the energy needed for various modes is also set for every node.

During the simulation, the proposed algorithm ENAANT is compared with OPTANT[17], EAODV[6] and EUACO[7]. The energy spent on different modes are calculated and the calculated values are intimated to the source node to construct the best route. Based on the remaining energy and the energy being consumed for different modes, the nodes are selected for route construction. Existing research works performs routing either by calculating the energy at a source node or by considering only the remaining energy. In both cases, the performance of MANET is not optimized to a considered level. Because, the source node cannot determine the energy spent by other nodes and the remaining energy may be drained by other greedy processes. This research work considers various factors of energy consumption and the route is constructed accordingly. Four different scenarios are considered as follows: when all the nodes have sufficient energy, there is no need to go for any alternate routes; when all the nodes have lower energy but capable of handling the transactions, periodically the energy is checked to make sure whether the node is able to continue or not; when fewer nodes have higher energy and fewer nodes have lower energy, the alternate route is made active if one of the nodes go below the threshold; if all the nodes have zero energy, then communication is terminated.

Intentionally, few nodes are set to go off by assigning lower energy. When a node is losing its energy quickly, then the alternate route is set to active immediately without having packet loss. When the route is established by considering energy of the nodes, the link stability is ensured which helps in getting the higher throughput and lesser delay and packet loss. When comparing with existing algorithms, this research work, ENAANT performs well and increases the throughput. The proposed algorithm is compared with existing algorithms in the aspects of end-to-end delay and packet delivery ratio, and the results are shown in Figure 3 and Figure 4. When comparing throughput, the proposed algorithm, ENAANT gives almost 96% and the existing algorithms gave below this level.

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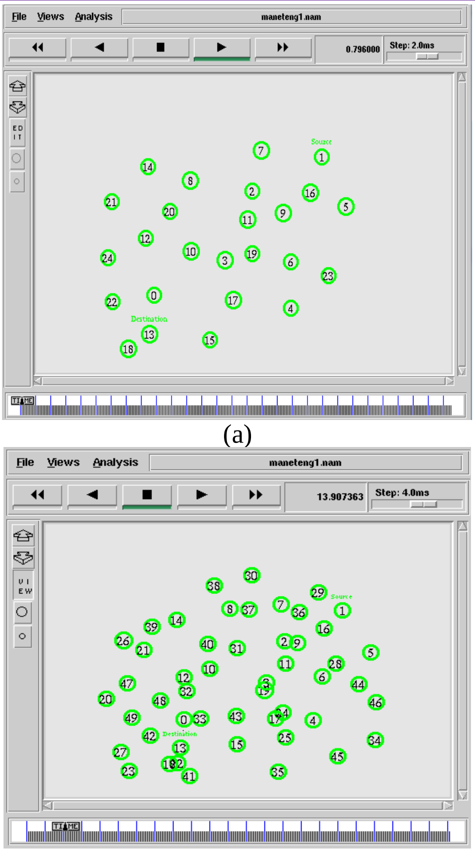

(a) (b)

Figure 2. Simulation of ENAANT with different nodes

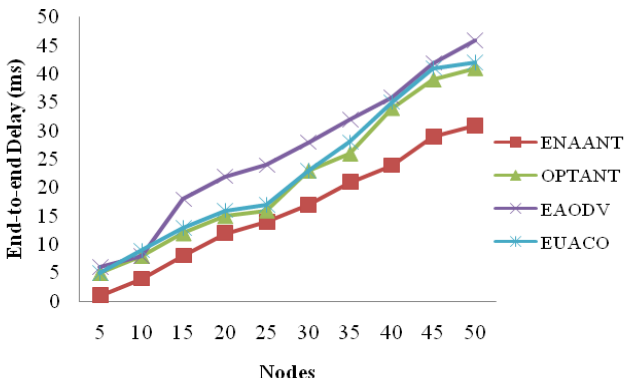

Figure 3. Comparing End-to-end delay

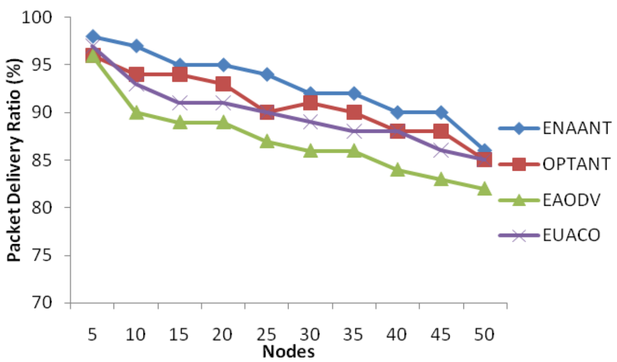

Figure 4. Comparing Packet Delivery Ratio

V. CONCLUSION

The mobile nodes of MANET have limited energy and this constrain restricts the MANET to achieve higher performance in the aspect of throughput and link stability. From the literatures, it is found that there is a need for a new algorithm to address the issue of limited energy. ACO is a good initiative for achieving higher performance in MANET, but because of the limited energy of the nodes, it needs further tuning. This research work, ENAANT considers the energy being spent on different modes like transmit, receive, idle, sense and sleep. And also it considers four different scenarios while establishing communication in MANET for the betterment of routing. The simulation is done by NS2 and the results show that the proposed algorithm, ENAANT performs well when comparing with existing research works. Further, this algorithm could be tuned to reduce the time consumed for calculating the different energy levels.

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