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MANET Energy Efficient Multi-Path Routing using Ant Colony Optimization and Binary Particle Swarm Optimization

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Abstract: The MANET is a network of autonomous mobile devices that are wirelessly connected to one another. Because of their high energy consumption, the nodes in this network have a short life expectancy compared to other networks. When it comes to extending the life of a network, optimization approaches are often used. The optimization techniques of Ant Colony Optimization (ACO) and Binary Particle Swarm Optimization (BPSO) are merged in this study to develop an ACO: BPSO hybrid strategy that is designed to extend the lifespan of the network by increasing its density of ants. The ACO assists nodes in transitioning from ACTIVE to SLEEP state. With the use of the NS2 simulator, it was discovered that the proposed method outperforms existing strategies in terms of throughput, PDR, and residual energy.

Keywords — Energy efficiency, ACO, PDR, MANET, Optimization, BPSO

I. INTRODUCTION

The fact that MANETs do not have a defined network means that they are nothing more than a collection of self-routing devices that link to one another and to the rest of the world. In the absence of a centralized authority, people are more likely to depend on their neighbours to interact with one another and create social groupings. Because of the mobility of the devices, the topology changes over time. The energy consumption of a device is more important in multi-hop networks than it is in mobile networks, which is the norm. However, even if energy economy is an important issue, the routing mechanism should also be taken into account in terms of the session's overall reliability and scalability. In many situations, the energy of mobile devices is required in order to ensure that the connection is stable and that continuous communication may continue indefinitely without interruption. Because the most energy-efficient route is selected, the routing strategies that are used contribute to a reduction in energy consumption. Most routing systems choose nodes that are the minimum feasible hop distance apart from one another based on the protocol they are using. Many current network optimization algorithms, such as those described in [1, 2, and 3], are focused on selecting optimal nodes based on the amount of residual energy that is present in the network. A valid interpretation of multi-node route selection as an optimization problem may be made in light of this fact. Recent years have seen an explosion of novel optimization approaches being developed with the objective of enhancing the energy efficiency of networks and communication systems. The numbers [4, 5, and 6] One in which there are a variety of possibilities, each with its own set of pros and drawbacks. One of the objectives of this research is to develop an energy-conscious path by using a hybrid optimization approach that combines Ant Colony Optimization with Binary Particle Swarm Optimization (Binary PSO). In order to determine whether the technique is preferred, the efficacy of this two-pronged approach is evaluated in comparison to the conventional AODV methodology, as well as the generic ACO and PASO processes, and the results are discussed. To summarise, the general structure is divided into three sections: A timeline of the previous study on the topic is provided in the second part, followed by an explanation of what has been done to address the problem at hand in-depth in the third section, and finally, Section 4 gives an explanation of the solution that has been presented. The design of the experiment, as well as its results, are explained in Section 5. Part 5. With the completion of this section, we have effectively finished our project," says the author.

II. RELATED WORKS

A great deal of study has been done in an attempt to build a MANET that is both energy efficient and reasonably priced. A number of techniques are based on the concept of maximizing energy efficiency while concurrently improving the lifespan of the network. Additional strategies, such as routing route optimization, which minimizes energy usage while a particular node is in standby mode, may be used to maximize the amount of available residual energy. Following that, we'll go through some of the ways that mobile ad-hoc networks may be improved to be more energy-efficient in the future.

In a power-aware multi-path (PAMP) system proposed by [7] Leslie Perez et al. energy remaining on the active route is conveyed between source and destination through REQ signals. A path that has failed to owe to insufficient energy is replaced by the next available route by the PAMP whenever it receives a response from the PAMP. Because of the mobility of the nodes, the bandwidth of neighbouring nodes is reduced, while the energy consumption of the nodes is raised. According to [8,]Amilkar et al. when utilized in conjunction with various transmission pathways, the LAMOR has the potential to double the network's lifespan. The Lifetime Aware Multi-path and Optimized Route makes use of one or more pathways that have been relocated in order to support multi-path transmission. It also eliminates nodes that use less energy since the LAMOR sleeps them, hence lowering the lifespan of the network. [9] In , J. P. Goux et al. presented the A-ESR, which is an abbreviation for "energy aware routing with the help of ACO." In this strategy, the packets are handled by nodes that are not overburdened by packet forwarding processes, which are picked at random. A substantial reduction in the ability to retain large quantities of residual energy, which is essential to keep communication systems operational, results from the use of this load balancing approach.

[10] F. Xhafa, C et al. suggested a technique based on Ant Colony Optimization, Ad-hoc: MMP, which is detailed in detail further down in the section on strategy. An essential objective of this technique is to maximize the amount of time that nodes along a route spend actively sharing information with one another. It is necessary to update the pheromone values

of the ants that progress depending on the amount of energy given and the cost functions of the various courses taken. It was also used to identify any earlier connection failures, which allowed the broadcast to continue uninterrupted over other channels. The delivery of packets is enhanced, and the lifetime of the network is prolonged, as is the number of packets that are retransmitted. [11] R. M. Chen et al. suggested an integrated technique of optimization that merged Ant colony optimization with Genetic Algorithms in order to get better results faster. It eliminates ineffective pathways and selects the most suitable one based on the value of the Fitness function. With this integrated strategy, it is feasible to increase bandwidth utilization while simultaneously lowering energy usage. Overall service quality has improved as a consequence of the use of heuristic techniques in combination with this strategy. [12] L. Melo et al. claim to have developed a patch for RREQ and AODV that allows information about the energy consumption of intermediary nodes to be saved. When the RREQ signal is received, the energy values are updated in real-time. The approach's key goals also include energy savings and an improvement in the expected network life expectancy.

EMPSON, a multi-path energy conservation routing approach developed by [13], Mavrovouniotis et al. was presented. Particle Swarm Optimization is a method that is used in the design process and is based on the Particle Swarm Optimization approach. Multiple variables, including the cost of transmission and the traffic ratio on each individual intermediary node, are involved in this process. When employing the technique mentioned above to generate weights depending on multiple parameters, the best results are obtained from the nodes in the network that have the most weights accumulated. According [14], Melo, Let al. they devised a random network encoding approach that made use of the cyclic technique in order to reduce energy consumption by transferring active and sleepy nodes amongst nodes in different states. According to the network encoding, increased packet delivery rates are projected to arise as a consequence of the implementation.

[15] K. M. Yu et al. that developed the ALEEP approach for ACO. This approach determines which nodes should be neighbours based on the placements of the network's nodes and the remaining energy of the network. Therefore, the nearest node with the greatest residual energy and the shortest distance between the nodes may be picked as the closest node to which the packets should be sent. It is possible to assure that only a small proportion of packets are lost using this strategy if speed is not of concern.

III. PROBLEM DEFINITION

There must be some kind of trade-off between energy efficiency and other quality of service measures like latency, transmission speed, or distance travelled in order to find a solution. As a result, a method for minimizing trade-offs as the network's size expands is necessary. Energy optimization is addressed in this study using a hybrid technique, with the objective of compromising the least amount of other quality-of-service metrics. ACO and BPSO work together in this technique to increase network efficiency. Both the Ant Colony Optimization and the Binary Particle agent swarm optimization assist to extend the life of a distributed network by minimizing the amount of energy used by the nodes in a networked environment.

The amount of energy used by a node may be expressed as follows: (1).

$$E_C = E_{TR} + E_R \qquad (1)$$

E_R in this equation stands for receiving energy, while $_{ETR}$ represents transmission energy. The equations (2) and (3) may be used to compute these energy values (3).

$$E_{TR} = D_t * E_{ut} * T_t \qquad (2)$$

In terms of data transmission, D_t is the rate, E ut is the energy used, and T_t is the entire transmission time.

$$E_{UR} = D_R * e * t_r \qquad (3)$$

EUR is the sum of three variables: D_R is for data reception rate, tr stands for transmission time, and EUR is the total of these three variables. In an n-node set MANET environment, links denoted with the letters 'l' and distance connect all nodes to their closest neighbour. It is assumed that the diameters di and j, as well as the distance between them, are within the transmission range of node I, as shown in diagram (4).

$$d_{i,j} \leq T_{R(i)} \qquad (4)$$

According to the movement pattern, all the nodes are supposed to be moving in the same direction, but at an arbitrary random velocity (RWP).

IV. PROPOSED METHOD

A. Ant Colony Optimization

Using the Ant Colony Optimization method, it is feasible to get the optimum residual energy. To determine which node is most capable of transmitting data, a relative weight algorithm uses the quantity of leftover energy. This is done by returning to nodes that have previously been visited by traffic in order to find the most energy-efficient means of transporting data between the source and the destination. The ant's pheromone values are updated after it has visited all of its hops and completed the rest of its journey. Pheromones that are highly concentrated are then used to attract the remaining colony members, and their ancestors modify their connections. The ACO checks the remaining energy in each network node after a certain number of transmissions (k). To prevent further dispersion through transmission, the next generation of ants is drawn to nodes with the highest levels of remaining energy. It's important to remember that in this example, the letter a represents the node-set that's transmitting data at the moment in question. If you want to tell which one is active, you may use the characters a1, a2,...an. S1, S2,...Sn is all the nodes that are sleeping while "A" is active, and i=j is the set of nodes that are awake while "A" is active. Each node in set 'A' has energy remaining after each transmission, which can be determined using equation (5). State transitions occur when the quantity of residual energy in 'A' falls below the amount of energy in the node. Which method is best for leftover energy? The AO is in charge of determining this. The jth node from I may be selected within a specific time period to include "k" in the routing (5).

$$PijK = \frac{[Tij(t) * \vec{a}j]}{\sum_{i=1-N}^{j} \mu ij(t) \partial ij\beta} \quad (5)$$

This attraction between ants and certain pheromone-containing nodes may be used to predict whether a node will be seized. Because it's pre-set in node set N, the predefined heuristic value μ_{ij} likewise has a fixed place there as well.

The sum of a node's initial energy (E0) and its ultimate energy content (EC) is what's known as its residual energy (RE) (EC). E0 is the initial energy in this scenario. They are updated as soon as the ants are done with their hop count. Here is an example of this in action (6).

$$\delta i, j \leftarrow (1-\rho). \delta i, j + \sum_{m=1}^{n} \Delta\delta_{ij}^{n} \quad (6)$$

Example: The quantity of pheromone laid down by an ant (n) on the link (n-m) may be stated mathematically as 1/Hm, where 1/Hm is the rate at which an individual ant goes from link n-m to the next link. The hop count for that ant is Hm, and so forth. Whenever the ants return to their starting point, the energy value of the path they walked during their initial traversal is updated. There is more than one ant deployed, which implies that the source must learn more about the multi-path as well as the target in order to communicate effectively. A set of pheromone values is utilized to decide which path is most optimal, with the results of this determination being entered into the BPSO as the initial population.

B. Binary Particle Swarm Optimization

This approach uses the ACO to determine the optimum path, and it uses the binary particle swarm optimization method to determine the best path in three steps.

1. Representation of Position

Strings of bits are used to indicate the size of the particles in this diagram. If the current particle has been selected, the value of the bit will be 1, and if it hasn't, it will be 0. The same may be seen in Figure 1.

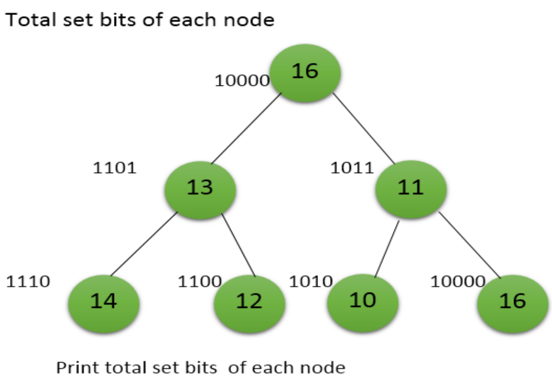

Fig. 1. Bit representation of Nodes

2. Modulation formulation

PSO's decision-making is guided by swarm intelligence and real values, rather than by rules. When looking for the optimal values in a given space, the PSO must apply modulation in order to discover them. The PSO is unable to make use of real values until they have been modulated into binary form by the user. Exactly the same information is provided in this exact circumstance as it is in the other cases (7).

$$x_{jk}(t+1)=\left\{\left\{ if\, P_{jk}(t) \geq \frac{1}{1+\exp(-v_k)(t)} \right\}\right. \quad \textbf{(7)}$$

3. Fitness Function Derivation

To calculate the fitness value, which is generated from the fitness function, it is necessary to address all optimization issues first. This graph depicts a particle with the highest possible value in the experiment. If a particle discovers a greater value than the previous one, it will modify its value. A fitness function was used to optimise the energy consumption of the network in question (8).

$$Fitness(Xi) = \phi.\, \gamma(Si(t)) + \varphi.\, (n - |Si(t)|) \quad (8)$$

The length of the particle's transmission at iteration t is denoted by the symbol |Si(t)|, and Si(t) indicates the subset of nodes recognised by particle I at iteration t. When determining fitness, the performance of the classifier and the transmission time are taken into consideration. The two parameters [0,1] and [0,1] control the lifetime of the network and the transmission time of nodes, respectively. There are a variety of methods for demonstrating the effect of node properties on network longevity, such as classifier performance and transmission time, among others. Figure 2 depicts a pseudocode representation of the proposed procedure.

PSEUDO CODE

1. ACO parameter initialization
2. Using eq(4) Construct the solution with Pheromone Based on RE
3. Update Pheromone till Max is reached
4. Optimal paths identified by ACO
5. Input results from ACO to BPSO
6. Obtain Modulation formula
7. Update position and velocity
8. Calculate the fitness function
9. IF Max(Iterations) Print energy efficient paths
10. ELSE goto 7.

V. EXPERIMENTAL SETUP AND RESULTS

In order to do testing, we utilise MATLAB. With 50 nodes and a 100x100 metre footprint, the network is built. An industry-standard protocol like AODV and a wireless connection between the nodes are anticipated to be used to communicate with each other. The initial amount of energy needed to maintain a 512 Kb /s bit rate is 250 J. A maximum of 100 seconds must be allotted for the simulation technique (S).

When compared to ACO-ALEEP and ACO-PCBCP, the new method beats both of these current strategies, as shown in Table 1 of this paper. Using the strategy proposed thusly boosts the network's efficiency while also reducing its energy consumption. As can be seen in this figure, it is quite similar to Fig. 3. Using the recommended approach, the average packet delivery ration is 98 percent, which is much greater than the other strategies under review, according to Table 2. The same idea is shown in Figure 4.

TABLE I. COMPARISONS OF THOROUGHPUT

Throughput (Kbps)			
No. of nodes	**ACO-ALEEP**	**ACO-PCBCP**	**ACO: PBSO**
10	892	925	**1300**
20	802	896	**1200**
30	765	819	**1086**
40	692	764	**960**
50	**589**	**648**	**851**

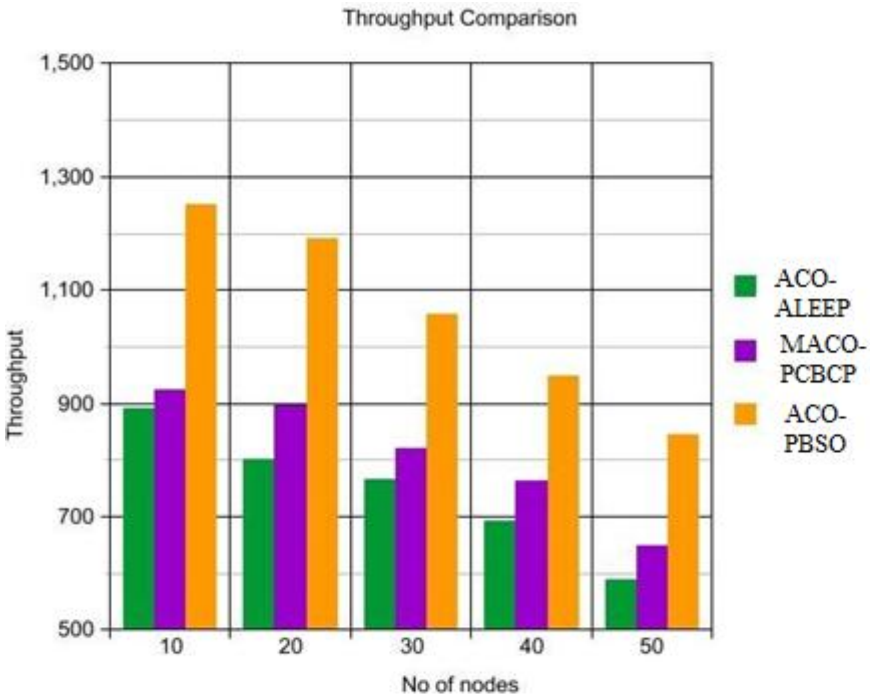

Fig. 2. **COMPARISONS OF THOROUGHPUT**

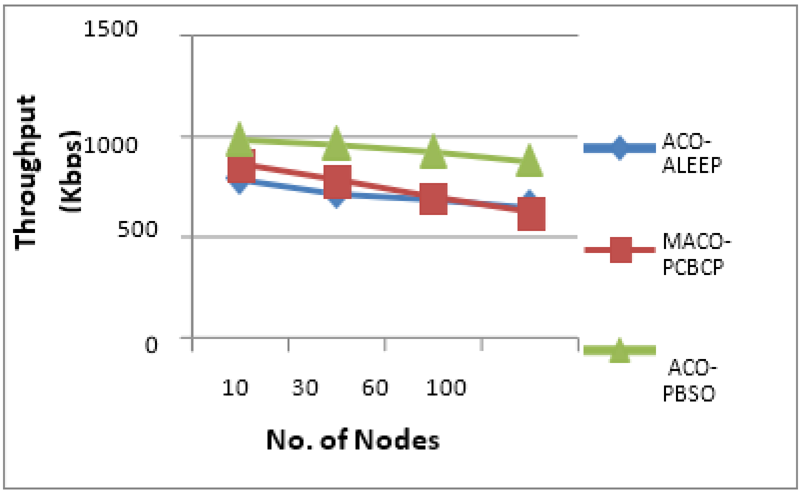

Fig 2a. No. of Nodes vs. Throughput

A network's throughput varies with the number of nodes it contains (see Figure 2a). ACO-PBSO has the best throughput compared to the other two algorithms, since the increased number of nodes leads to greater data transmission between the source and destination, thereby enhancing total throughput and efficiency.

TABLE 2. COMPARISON OF PDR

Packet Delivery Ratio

No. of nodes	ACO- ALEEP	ACO- PCBCP	ACO:PBSO
10	94.8	91.8	99.9
20	91.3	89.6	98.6
30	86.5	81.2	97.8
40	81.5	79.5	96.7
50	79.5	70.6	96.7

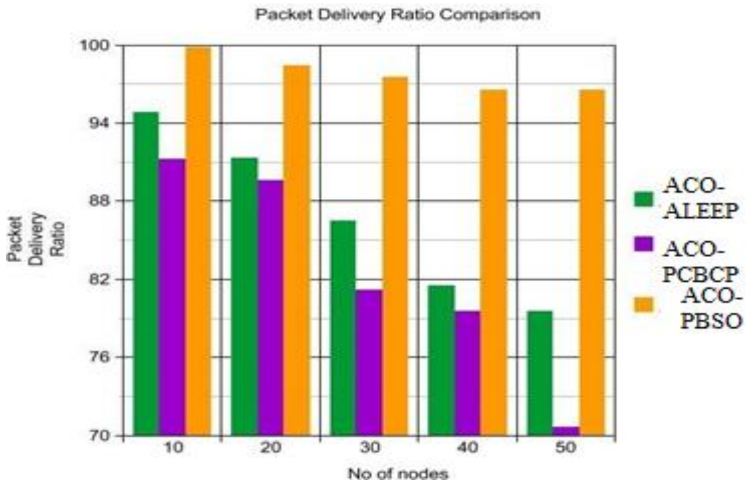

Fig. 3 Comparison of PDR

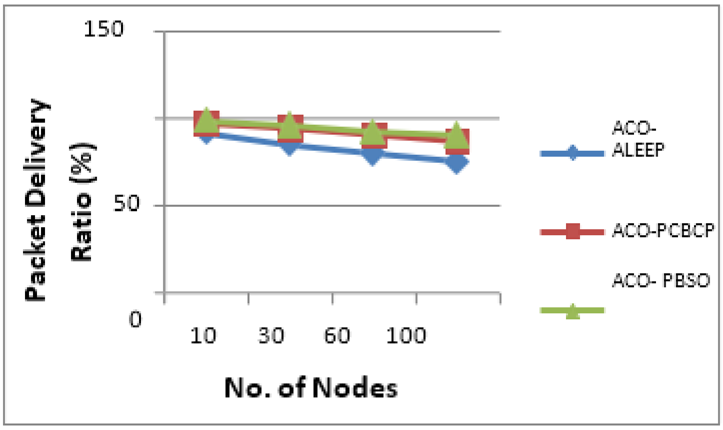

Fig 3 a. No of Nodes vs. Packet Delivery Ratio

This figure demonstrates the influence of nodes on the packet delivery ratio of a network (see Figure 3a). This study demonstrates that ACO-PBSO is the most successful of the three strategies in terms of delivering packets to their intended destinations, owing to its extended neighbour selection strategy.

VI. CONCLUSION

MANET energy consumption optimization is a difficult problem to address since the available power is restricted and communication is reliant on it. Throughout history, there has been a trade-off between energy efficiency and sacrificing other elements of service quality (QoS). Binary particle swarm optimization and Ant colony optimization techniques must be used to properly handle this problem. The ACO is in duty of determining the most energy-efficient method, while the BPSO is in charge of maximising the amount of energy used. With regards to throughput and packet delivery ratio, a variety of novel strategies are being examined.

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