Enhancement of Energy Control Routing Protocol for Mobile Ad Hoc Network Based on Hybrid Particle Swarm Optimization with Ant Colony-based Energy Control Routing

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Abstract

MANET is an autonomous collection of distributed mobile nodes. Every node in a MANET works as a source and a sink and that relays packets for other nodes. The key features of a MANET include dynamic network topology, distributed network nature, multi-hop communication, limited bandwidth, and limited energy constraints. Given that the battery of the nodes is limited, the energy of the nodes and the lifetime of network is a critical problem in MANETs. Moreover, nodes maintain static or less movement after being deployed. The energy of the MANET nodes cannot be recharged, which leads to dead nodes. This study improves the energy cost for the ACECR and boosts advancement through its contributions. Areas in the ad hoc network where much work is needed are discussed. This study only explored the impact of PSO on ACECR. Results indicate that ACECR-PSO performed better than the other protocols in terms of balanced energy consumption and extended network lifetime.

Keywords: ACECR, PSO, ACO

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1. Introduction

Wireless networks are utilized in various technology fields, such as in the military, in the industrial setting and in personal area networks [1]. Wireless networks possess valuable attributes, such as easy installation, cost-efficiency, and reliability, leading to their wide range of applications[2]. These networks are also independent of fixed infrastructure compared with wired networks[3]. Common examples of the usage of these networks are in cellular phone networks, Wi-Fi, satellite communication, and other applications [4, 5] as shown in Figure 1.

Figure 1. MANET structure

However, in recent years, wireless networks has become a major concern in the communications field [6]. In particular, the power problem in MANETs has been receiving significant attention. The problem of energy efficiency in mobile ad hoc networks (MANETs) can be addressed at various layers[7] and research work has focused on optimizing the energy...
consumption of mobile nodes from different viewpoints [8]. In recent years, power management schemes have two objectives, which are to minimize the total power consumption in the network and to minimize the power consumption per node. A method to reduce the energy costs among the different nodes, called the ant colony-based energy control routing (ACECR) protocol, has been suggested [9]; however, two major issues were found regarding their work, namely, pheromone evaporation and leak of routing efficacy protocol[10]. Therefore, a hybrid particle swarm optimization (PSO)–ACECR protocol is proposed to address the work of Zhou et al. (2016), in which the route decision does not depend on the QoS between the routing and the MANET energy. Therefore, this present study aims to develop a PSO for ACECR in terms of the best and nearest path and the minimal node power consumption, which focuses on each node that is consistently available and reduces the dead node numbers in the work of Zhou.

2. Proposed Approaches

There are two important characteristics in the proposed PSO-ACECR protocol. First, PSO uses a population of particles. Second, PSO has the “traditional” topologies, namely, gbest and pbest, to describe the interconnections among particles. The gbest topology is considered the fully interconnected population because each member of the population can be influenced by any other member. Specifically, the particles can be affected by the individual who found the best solution so far. Therefore, gbest is ultimately responsible for tracking the best solution found. The pbest topology is considered as a partially interconnected population, in which every particle is connected to the neighboring particles in the population array. Third, every particle changes its position according to the change rule. The interaction rule (or the velocity equation) determines the next point of the particle, which will be tested in the search space, where the previous success of the particle in the search space with the previous success of the other particles is considered. When a particle discovers a pattern that is better than any of the patterns that the particle had previously found, the particle stores the coordinates in the pbest(t). The difference between the pbest (the best point found so far) and the current position of the individual is stochastically added to the current velocity, causing the trajectory to oscillate around that point. Furthermore, each particle is defined within the context of a topological neighborhood. The PSO process is illustrated in Figure 2.

![PSO structure](image)

Several hybrid conventional algorithms, such as the genetic and the PSO algorithms, were used to resolve the route difficulty in MANETs[11]. The ACO approach is separate from the difficulties. The information attained utilizing ACO is enhanced with PSO[12]. Therefore, in this study, a mixed version of ACO and PSO is proposed for the optimization strategy outlined below.
The flowchart for the suggested hybrid design is demonstrated in Figure 3, and the procedures of the suggested multidisciplinary design are as follows:

Algorithm 1

1: The quantity of the particles is set, and its amount is often produced haphazardly.
2: All ACO variables are set.
3: Remedies from each ant haphazard walk are produced.
4: When the approach is not ideal, the swarm is set with haphazard placements and speeds.
5: The specific ideal value of the bird for every technology is selected.
6: The universal greatest value of a particle, i.e., a particle close to the goal between the birds, is picked and attained by evaluating the specific ideal amounts.
7: A decision is made on the particular least beneficial value of birds, i.e., the particle distance from its goal.
8: The speed and location of the particle are modified accordingly.
9: The procedure ends when the highest amount of iterations is obtained or the ideal value is acquired; otherwise, proceed to Stage 3.

![Figure 3. PSO-ACO hybrid process for the ACECR](image)

The multi-paths are found using ACO algorithm and the best path is chosen using PSO algorithm. The particles agents can deposit pheromones and sense local attributes in each pattern. The pattern agent is responsible for executing dynamics of pheromones aggregation, dispersion and evaporation. There are two levels of pheromones; one for pattern pheromone and the other is the attribute pheromone inside the pattern[13]. The PSO algorithm is used to update the pattern pheromone and attribute pheromone comparing the fitness of the path and their corresponding attributes[14]. The fitness is repeated for a fixed number of iteration and the pattern with maximum fitness is returned as a solution that satisfies all the constraints.

However, to understand the process for implementing the Hybrid algorithm in MATLAB, we need to know the Pseudo-code for the hybrid PSO/ ACECR, and after that to show how PSO and ACECR mapping can be gathered to enhance the energy cost and reduce the dead nodes as shown at Zho et al. and other previous works. Initially, PSO will negotiate with ACECR by candidate agents in which "n" discriminating candidate patterns are generated randomly. These patterns are filled into the grids in the search space of dimension k × l, where each
pattern corresponds to one grid based on the order of their generation. Next, n particle agents are generated and uniformly distributed to the search space, where each particle agent occupies one grid. Then, the iteration starts, and for each iteration, first each particle agent evaluates the fitness value of the tree pattern from the cost of the tree, where it is currently located. Using the ACO algorithm which belong to ACECR, pheromones are deposited on each attribute based on their attribute value by the particle agents. Figure 4 shows the grid of dimension 5 x 6 in which thirty tree patterns are filled. The pattern agent Ti is associated with ith tree pattern and filled sequentially in row major fashion. Thirty mobile particle agents are randomly distributed in the search space where each particle agent is attached to one pattern agent, and that will increase the active nodes energy life. This is due to the fixed topology of the particle agents in the search grid.

Hence, the particle agent can interact with the maximum of only its 8 neighbouring particle agents. If the fitness of the best neighbor is higher than the current pattern, then it is set as the agent’s best previous position.

The PSO algorithm is then used to update the pattern pheromone and attribute pheromone comparing the fitness of the trees and their corresponding attributes. This process is repeated for a fixed number of iterations, and the pattern with the maximum fitness is considered as the solution that satisfies all the constraints.

The multicast tree VT[15] is initially set to the source node s, which is also set as the current node. Accumulated delay and loss up to source node s, delay dead node (s) and I cost of dead node (s), are set to 0 and 1, respectively. Then, a node j is selected randomly from the neighboring nodes of the current node that satisfies the QoS constraints. End condition and cost of dead node(j) = cost of dead node (current node) + C( current _node,j) . In pheromone(j) = 1/ cost of dead node (j). However, If the node j is not the destination node, then the current node is set to otherwise, the current node is selected randomly from VT. This process is repeated until all the group members are added to the multicast tree. The particle moves to the new position and brings the last position’s attribute and its associated fitness values along with its movement to the new position. The new position is updated with better quality attributes discarding the low-quality attribute of the new position. The outcome is a new combined pattern with higher quality than both the original ones. During the next iteration, the newly built pattern will be executed by the agents and deposit the pheromone as appropriate. After much iteration, eventually, the strongest pheromone trail will be the fittest discriminating pattern. Therefore, it will find the best way by using the enhanced phonome with PSO.

### 3. Implementation Setup

Simulation was done in MATLAB [16], and the results were evaluated and compared with standard ACECR routing protocols and recent approaches. We used different simulation parameters, such as varying the number of nodes and the node speed, to evaluate the performance using Zhou parameters as summarized in Table1.
Table 1. Zhou Parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>1000 m</td>
</tr>
<tr>
<td>Nodes</td>
<td>25 nodes</td>
</tr>
<tr>
<td>Simulation time</td>
<td>100 ms</td>
</tr>
<tr>
<td>Nodes speed</td>
<td>5 m/s</td>
</tr>
<tr>
<td>Traffic type</td>
<td>CBR</td>
</tr>
<tr>
<td>Initial energy</td>
<td>200 J</td>
</tr>
<tr>
<td>Packet size</td>
<td>64 byte</td>
</tr>
<tr>
<td>Simulation model</td>
<td>IEEE 802.15.4a</td>
</tr>
</tbody>
</table>

However, we compare the performance of our proposed protocol ACECR-PSO to the other three protocols: ACECR, EAAR[17], and AOMDA protocols. These protocols extend the single path AODV protocol to compute multiple paths, which always offers a superior overall routing performance than ADOV in a variety of mobility and traffic conditions. EAAR is an ACO-based energy-aware routing protocol, which does not only incorporate the effect of power consumption in routing a packet, but also exploits the multi-path transmission properties of ant swarms and use min-max energy to calculate pheromone value; hence, it increases the battery life of a node. Mobility is a natural characteristic of ad hoc networks. It is imperative to use a mobility model that accurately represents the mobile nodes that will eventually utilize the given protocol. The choice of a mobility model can have a significant effect on the performance of an ad hoc network routing protocol.

There are 100 nodes in a network, which move over a 1000 m * 1000 m flat space. For the RPGM model[18], we divided all nodes into four groups, with 25 nodes in each group. The node’s MAC layer uses IEEE-802.11 DCF media access control protocol, the radio transmission range and the interference range of nodes are all set to be 200 m [19]. Each node has a total energy of 100 J. Mobile nodes, and are assumed to move randomly according to the random walk, random waypoint, and RPGM mobility models. The speeds of nodes are set to be 1.5, 5, 10, 15, and 20 per second, each node starts moving from a randomly selected initial position to a target position, which is also selected randomly in the simulation. Each packet size is 512 bytes, and 10 Constant-Bit-Rate (CBR) flows are generated randomly at a rate of 10 packets per second for 1000s to test the performance of protocols[20].

3. Results and Discussion

The percentage of the number of data packets correctly delivered to the number of data packets sent by source nodes is presented. Figure 5 shows the packet delivery ratio of AOMDV, EAAR, ACECR and ACECR-PSO protocols at different speeds in different mobility models, where the packet delivery ratio for four routing protocols decreases when the speeds of the nodes increase. We observe that the packet delivery ratio for ACECR-PSO is better than all the other protocols. ACECR-PSO and EAAR protocols can balance the energy use of the network and reduce the link break caused by dead nodes because they are energy control routing protocols. Since both average energy and the minimum energy of a path is considered in ACECR-PSO, it can select a path with more residual energy on global view. ACECT and EAAR only consider the residual energy of nodes instead of paths, and the packet delivery ratio for ACECR protocols is higher than that for AOMDV protocol.

The average time between transmission of data packets at sources and successful reception at receivers is presented in Figure 6. Figure 6 shows the average end-to-end delay of data packets from source nodes to their destination nodes for AOMDV, EAAR, ACECR and ACECR-PSO in different mobility models. The end-to-end delays decrease with increase of node mobile speeds, because the increase of node mobile speeds will make network topology change, which in turn will cause data buffer and route rediscovery. The average end to-end delay for ACECR-PSO is less than ACECR and other protocol, because ACECR-PSO is enhanced energy control routing protocol. Moreover, since ant colony-based energy control routing protocol is multi-path routing protocols, they can balance the energy use of the network, and reduce the route rediscovery.
The communication overhead of dead-node has a profound effect on the performance of routing protocols. It represents the total size of exchanging packets in the network. The control packets increase the communication overhead and reduce the throughput of the network. Figure 7 shows that the routing overhead caused from dead node of ACECR-PSO is less than ACECR protocol, since ACECR-PSO is multi-path routing protocols, they use pheromone updating to maintain the route selection with best fitness function of PSO.

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Figure 5. Packet Delivery Ratio

Figure 6. End to End Delay

Figure 7. Dead Node Ratio
4. Conclusion

In this paper, we proposed an ant colony-based energy control routing protocol PSO-ACECR and evaluated the effect of different mobility models to the performance of PSO-ACECR in MANETs. In PSO-ACECR, the routing protocol will find the better route which has more energy than other routes through the analysis of average energy and the minimum energy of paths. Simulation results show that PSO-ACECR has a better performance than existing routing protocols, such as ACECR, EAAR and AOMDV, in terms of the number of dead nodes and the packet loss rate, which means that PSO-ACECR can extend the network’s lifetime. In addition, the simulations investigated the movement characteristics of different mobility models and the effect on routing protocols. Furthermore, results show that PSO-ACECR has a better performance than the other three protocols in balanced energy consumption and extended network lifetime.

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