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ACO Based Optimizing Power Consumption (ACO-OPC) Protocol for WSN

Pooja Kamboj[1], Meenakshi Arora[2]

[1]PG Student, Department of CSE, Sat Kabir Institute of Technology and Management, Haryana, India
[2]Assistant Professor, Department of CSE, Sat Kabir Institute of Technology and Management, Haryana, India

ABSTRACT

Energy efficiency in networks of sensors is a major and challenging subject. Consequently, a number of protocols have been created, all aimed at improving network energy efficiency. When data packets are directed, most of the energy is consumed. In this paper, we have routed data streams among sensor motes using the swarm cognition-based ant colony optimization (ACO) algorithm. Depending on the number and placement of sensor motes, a small number of them may also enter sleep mode, extending the network's lifespan and conserving resources. Reducing the energy consumption of a sensor network while routing can extend its lifespan. An ideal route for data delivery to the destination node is provided by the ant colony optimization approach. By choosing the quickest route to the sink, routing can use less energy. In addition to optimization, sleep scheduling among sensor nodes is crucial for obtaining long lifetime and effective energy conservation. Certain nodes may occasionally turn off their radios if there is a high node density in the vicinity. Many nodes in a network with high node density waste energy overhearing or idle listening. In order to maintain network power, we have employed a threshold energy-based sleep-awake scheduling and ant colony optimization method named *ACO based Optimizing Power Consumption (ACO-OPC)* to preserve the power in the network.

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INTRODUCTION

The rapid advancements in wireless communications, microfabrication, and motorized MEMS technologies have made it possible to create tiny, inexpensive, low-power nodes for sensors. These nodes have the ability to collect data, process it, and exchange it with other sensors via wireless radio frequency (RF) technology [1]. Numerous sensor nodes that are densely distributed throughout an area of interest make up a wireless sensor network (WSN). The process of monitoring the external and physical environment, gathering data, and transmitting the processed data to the sink node or base station can all be triggered by the network of sensors.

Since clustering enables MAC and routing scalability, we take into consideration sensor networks that are clustered. In order to decrease the quantity of data that is actually sent to the base station (BS), cluster heads (CH) also operate as fusion points for data aggregation. Homogeneous and heterogeneous sensor networks are the two main categories into which clustered sensor networks fall. Every sensor node in a homogenous network has the same hardware complexity and battery life. In a homogeneous network, it is obvious that the cluster head nodes will be overwhelmed with long-distance transmissions to the distant base station and the additional processing required for data aggregation and protocol coordination if static clustering is used (cluster heads, once elected, serve for the entirety of the network the lifespan). The cluster head nodes therefore die before other nodes. To ensure that very little remaining energy is lost when the system expires, it is preferable to make sure that each node runs out of battery at around the same time. As suggested in [2], rotating the cluster head position randomly and sporadically throughout all nodes is one method to be sure of this. The disadvantage of adopting role rotation and a homogeneous network is that each node must have the required hardware in order for it to function as a CH.

However, two or more distinct types of nodes with varying battery energy and functionality are employed in heterogeneous sensor networks. The idea is to lower the hardware expenses of the remainder of the network by embedding the more sophisticated hardware and additional battery energy in a small number of cluster head nodes. Role rotation is no longer feasible, though, due to the cluster head nodes needing to be fixed. The sensor nodes that are distant from the cluster heads always expend greater amounts of energy than the nodes that are nearer to the cluster heads when the cluster heads are reached by single hopping. Conversely, the nodes nearest to the cluster head have the biggest energy load because of relaying when nodes employ multihopping to get there. As a result, the network constantly exhibits a non-uniform pattern of energy draining. As a result, a sensor network should have both consistent energy drainage and a lower hardware cost.

Homogeneous networks accomplish the latter, whereas heterogeneous networks accomplish the former. Nevertheless, the same network cannot have both properties. This research compares homogeneous and heterogeneous sensor networks based on the total cost of the network, accounting for the energy-hardware tradeoff mentioned above. Another way to categorize clustered sensor networks is as single-hop and multi-hop. A single hop network is one in which sensor nodes communicate with the cluster head by single hopping. Nodes in a multi-hop network hop across nodes to get to the cluster head. Since we assume a remote base station in both scenarios, the cluster heads utilize single hopping to get to the base station. The sensor nodes in a single hop network use a single hop transmission to connect directly with the cluster head. In order to regulate their transmit power, it is expected that the nodes have power control characteristics. In general, it might not be the best option to use single hop communication within a cluster for communication between the cluster heads and the sensor nodes. This is probably going to be the case if the sensor nodes are placed in areas with a lot of vegetation or uneven ground. To contact the cluster head in such circumstances, multi-hop communication between cluster nodes may be advantageous.

RELATED WORK

The writers tackle the issue of dependability and energy efficiency for forest fires tracked by a dispersed (WSN) with limited bandwidth. In the context of WSNs, data routing is a crucial strategy that is being investigated to increase energy efficiency[3]. The (ACO) algorithm is a popular and effective way to determine the best communication channels. Nevertheless, the entire network dependability (both before and after failures), which is crucial in the context of WSNs, is ignored by the conventional ACO-based routing algorithms, which solely take energy efficiency into account. A unique (E-RARP) for WSNs is proposed by the authors. In regard to energy efficiency, the suggested protocol not only assures reliable communication but also provides excellent communication pathways. Reliable transmission is necessary for critical events in delay-intolerant applications (such as forest fire detection) so that choices can be made with confidence and relevant actions may be taken promptly. According to the simulation outcomes, E-RARP performs significantly better in terms of network endurance and time to response (30.55%) than both Load Balanced Cluster-based Routing using ACO and Enhanced Ant-based QoS-aware routing protocol for Heterogeneous Wireless Sensor Networks.

According to authors in [4], In order to fulfill hardware and resource limits and overcome inherent obstacles, (WSN) protocols must be designed with efficient routing. Here, we describe an energy-efficient scalable routing algorithm for (WSNs) based on ant colony optimization (ACO). This algorithm finds the best data transmission channel while using the least amount of energy, extending the network's lifespan. The majority of ACO-based routing algorithms now in use are built with the premise that sinks and sensor nodes are immobile. As a result, they do not account for the overhead of mobility or the energy consumption of the present node, which may cause some nodes to pass suddenly. An ACO based WSN routing algorithm has been suggested and investigated in this research to address the current issues with accommodating node mobility, decreasing initialization time for ant based routing algorithms, and maintaining scalability in WSN for time-sensitive applications. MATLAB has been used to simulate and verify the suggested technique. Compared with the conventional ACO and an existing ant-based routing algorithm, the assessment findings show that it has reduced energy consumption, about 50% less spent energy even with the increasing number of nodes. Additionally, it lengthens the lifespan of the network and the nodes.

In order to effectively decrease energy consumption, an energy-efficient sleep scheduling mechanism with a similarity gauge for WSN (ESSM) is suggested [5]. This mechanism would schedule the sensors into either the active or sleep mode [6]. In order to balance energy usage, all sensor nodes are first grouped into many clusters using the ideal competition radius that has been computed. Second, a fuzzy matrix measuring the degree of similarity can be produced based on the data collected by member nodes, and the correlation function based on fuzzy theory may be constructed to categorize the sensor nodes. In order to protect the network's overall data integrity, the redundant nodes will then be chosen to enter a sleep state in the following round. Simulations and findings demonstrate that, with data accuracy guaranteed, our method may do better in both optimizing the energy efficiency of the networks and ensuring optimal cluster dispersion.

Instead of using LEACH's fixed sleep/wake-up mode, Wu et al. [7] created a dynamic sleep scheduling mode that significantly extends network lifetime. The aforementioned issues were looked at by the authors in [8], who also suggested an unequal clustering algorithm for inter-cluster multi-hop routing that separates all nodes into unevenly sized clusters. More compact clusters will be those that are closer to the base station. As a result, the "hot-spots" issue may be successfully resolved and the CHs of those clusters can save a little more power for the inter-cluster relay communication. A distributive energy efficient adaptive clustering protocol (DEEAC) was suggested by Sajjanhar et al. [9]. It picks the sensor node to be a CH based on its residual energy and hotness value, and it owns spatiotemporal differences in data reporting rates across various geographic areas. Advanced LEACH routing strategy for WSNs was suggested by Ali et al. [10]. It uses the general probability and the current state probability to choose which CH to select in each round.

METHODOLOGY

We have planned for the sleep-wake scheduling technique, which extends the network's lifespan. A sensor node can go into sleep mode and switch off its radio for a brief period of time in order to save energy. whereas if a sensor frequently flips between the awake and sleep states, it may fail and cease to operate, which could result in energy holes in the network. A specific portion of nodes, or *p1%* of all nodes, are always kept in sleep mode in order to prevent this scenario. The following describes the requirements to maintain a node in sleep mode. An active node enters a sleep state when its energy drops below a certain point, at which point another node from the sleep mode enters awaking mode. A node becomes active in this manner only when required. Each sensor node inside the network has an identical communication transmission range. At first, sensor nodes react to the sink node's Welcome packet by sending it information about their precise location and energies. When using multi-hop routing, nodes send data to a neighboring node. However, if there isn't a node close by, data is sent to the next closest node.

At first, there is sufficient energy for each sensor node to send data over the whole transmission range. A sink node determines how much energy a node needs for the specified transmission range and sends this data to other units. The energy used by the sink node during processing has no effect on the network's lifespan because it is not a power-constrained node. The threshold energy (Th_energy) is the amount of energy required for transmission. Following a few network connection cycles, a sensor node's energy level varies based on its function and location within the network. In comparison to other nodes, it uses more energy if it is a cluster head node. A node enters active mode and is ready for data transmission and communication if its residual energy exceeds the threshold energy; otherwise, it enters sleep mode. The node density affects the proportion of nodes that are in sleep mode. Our chosen sensor network is hierarchically clustered, in accordance with the LEACH protocol [11]. A small number of nodes are chosen as the cluster head nodes during the cluster setup phase and are re-established after each round. To accomplish load balancing across the sensor nodes, the cluster head role is rotated among the nodes during each round. A cluster head collects summaries after selection and sends data to the sink. As a result, the cluster head uses up its energy more quickly than other nodes. But since the cluster head's position shifts after each round, the network's nodes' consumption of energy is fairly distributed.

Data packets are transmitted from member nodes to the cluster head over many hops. Within a cluster, a construction graph is created. Ants move on the construction graph and construct solutions employing stochastic creative approaches. ACO combines domain knowledge (referred to as heuristic information) with search experience (referred to as pheromone) to expedite the search process. Ants are initially placed at random members of the cluster. In this case, member nodes select the best route for data transmission after the ants identify the best path from members to the cluster head.

For heterogeneous sensor networks, the suggested technique ACO based Optimizing Power Consumption (ACO-OPC) offers a sleep/wake scheduling strategy that utilizes clustering and ant colony optimization. It determines which path is the shortest and most efficient between the cluster head and its node members.

Step 1: *P1%* of all nodes in the network are initially maintained in the sleep mode.

Step 2: At first, there is sufficient energy for every node to carry out every task. The calculation of the nodes' threshold energy takes into account each node's transmission range and power expenditure for various functions.

Step 3: When the clustering procedure is carried out, certain nodes are chosen to be the cluster heads and others to be the cluster members**.**

Step 4: An ideal connection between the cluster leader and its members is selected for each cluster.

Step 5: Every member of the cluster uses the best path to send data to the cluster head. After compiling the received data, the cluster head sends it to the sink.

Step 6: If sufficient energy remains, determine the total node's residual energy. After that, each node's residual energy is compared to the threshold energy before the next round starts. Currently, each node's residual energy varies based on its function and location within the network. For instance, a cluster head will use more energy than remaining nodes, while the nodes chosen as the intermediate nodes in the best path in the earlier phase will use less energy than the former. The next cycle begins if the total remaining energy of all the nodes exceeds the threshold energy. This occurs during the first several rounds. Some nodes' energy gradually drops under the threshold level.

Step 7: A node enters sleep mode and one node from the group of sleep nodes is woken when its energy drops below a threshold value. Wake up two nodes from the sleep cluster if two are in the sleep mode, and so on. No beyond P1% of nodes may be in sleep mode at any given moment. The procedure can go on until the network has enough energy provided.

Figure 1 shows the ACO based optimal route selection between an active node and sink node. The red line shows a chain of active nodes towards sink node.

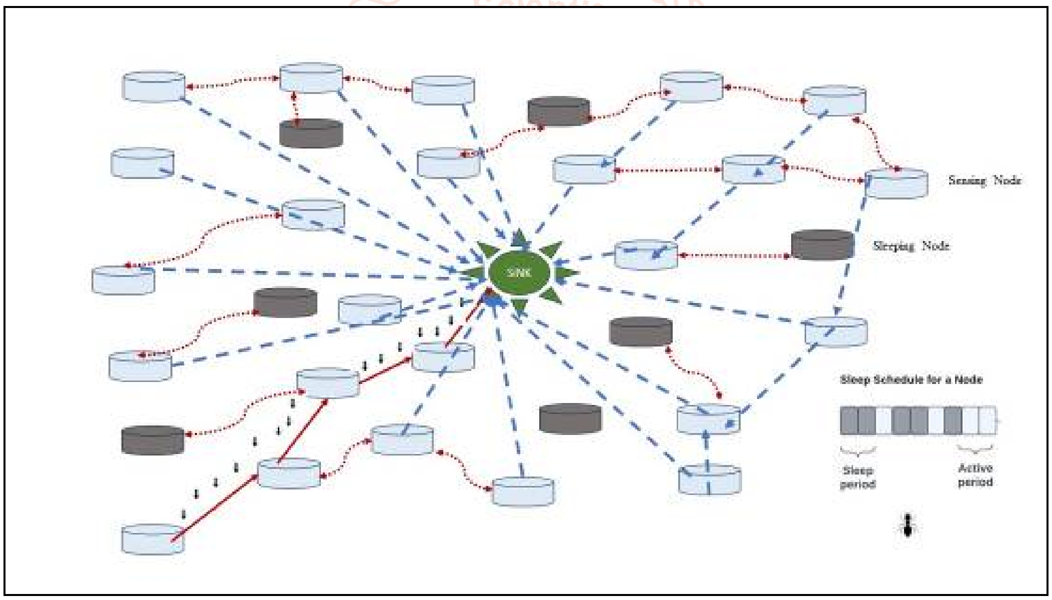

Figure 1: ACO Based optimal route selection

The network's remaining power has been assessed by taking into account the energy left in each node after each network cycle. There are enough live nodes for a significant number of rounds because of sleep-wake scheduling. The suggested approach results in roughly 10 cluster heads every round in a network with 100 nodes if we take the probability of choosing a cluster head to be 0.1. Five of the ten cluster heads are advanced nodes, and the other five are standard nodes. The network has an adequate number of cluster heads available. In order to reduce energy, every connected cluster also employs the ACO technique. Up until the first node dies, the network uses incredibly little energy. Figure 2 shows the process flow of the proposed method.

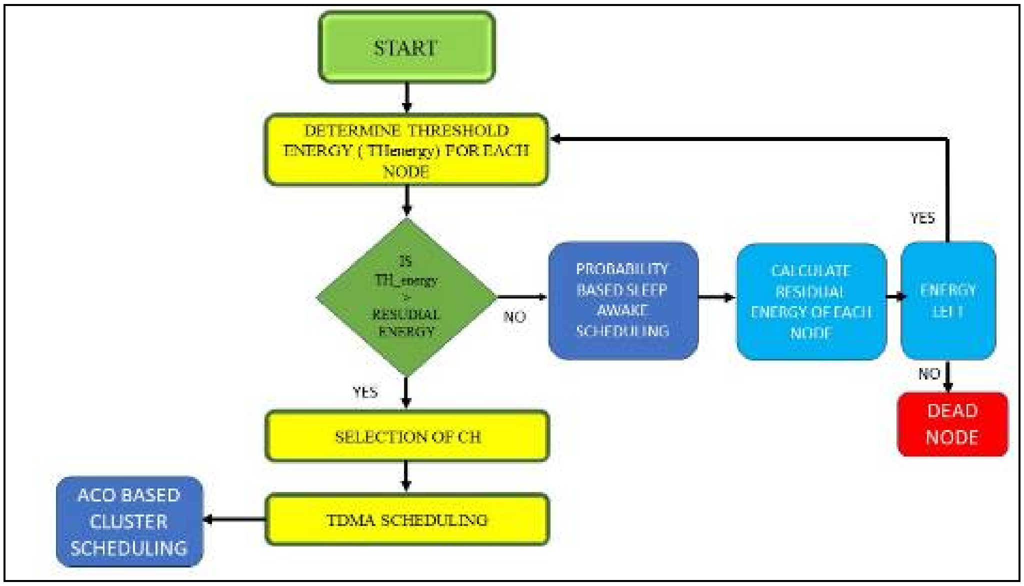

Figure 2: Process Flow of the Proposed Method ACO-OPC

SIMULATION RESULTS ANALYSIS

When comparing the ACO-OPC protocol to the LEACH protocol, more packets are transferred. The cluster's effective utilization of energy is the cause of this. Every member node automatically chooses the best transmission route. Arriving at the CH, a packet does so with little to no delay. Member nodes may choose a different course in subsequent rounds in the event that an intermediary node dies. Additionally, advanced nodes use a lot more energy and stay connected to the network for extended periods of time. In subsequent rounds, there are very few available nodes in a homogenous network. The quantity of packets sent to the cluster head consequently decreases dramatically. Table 1 shows the parameters used in Simulation Setup.

The total amount of live nodes for the ACO-OPC and SEP protocols is shown in Figure 3 for each round. The clustering process is the foundation for the SEP protocol's operation. The nodes' main strength is not uniform, though. In comparison to the other nodes in the WSN, a certain fraction of nodes have more energy.

Table 1: Simulation Parameters

Parameters	Values
Simulation Area	100 m x 100 m
Number of sensor nodes	100
Percentage of advanced sensor nodes	Advanced $f = 0.2$, 0
Initial Energy of normal sensor nodes	0.5 J
Initial energy of Advance nodes	Extra energy $y = 0.3$, 1, 0
E_{elec}	50nJ/bit
E_{fs}	10pJ/bits m^2
E_{mp}	0.0013 pJ/bit/m^4
E_{DA}	5 pJ/bit
Transmission Range	10 m
Packet Size	4000 bits
Number of ants	10
α	1
β	5
μ	5
ρ	0.65

The number of live nodes in the network per round determines how long a WSN will last. The entire region is still covered when every node is operational. Nodes begin to lose power over time, and as a result, they start to die. Eventually, the network's lifecycle ends when there are no more nodes. As a result, we may state that the round number at which every node dies (AND) indicates the network's termination. The round number at which the network's first node fails serves as an expression of the network's durability span.

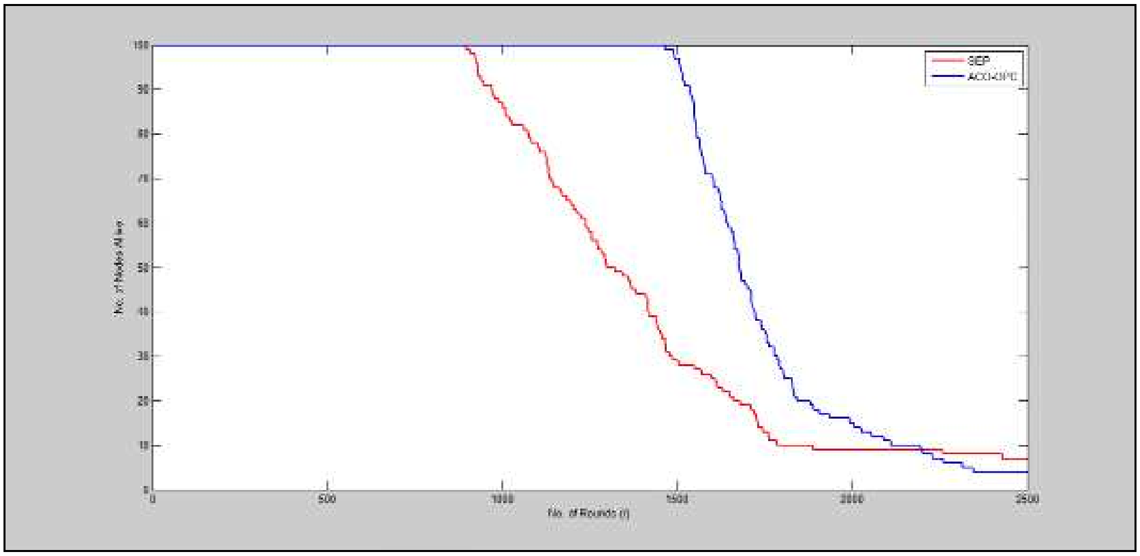

Figure 3: Nodes Alive in 2500 rotations

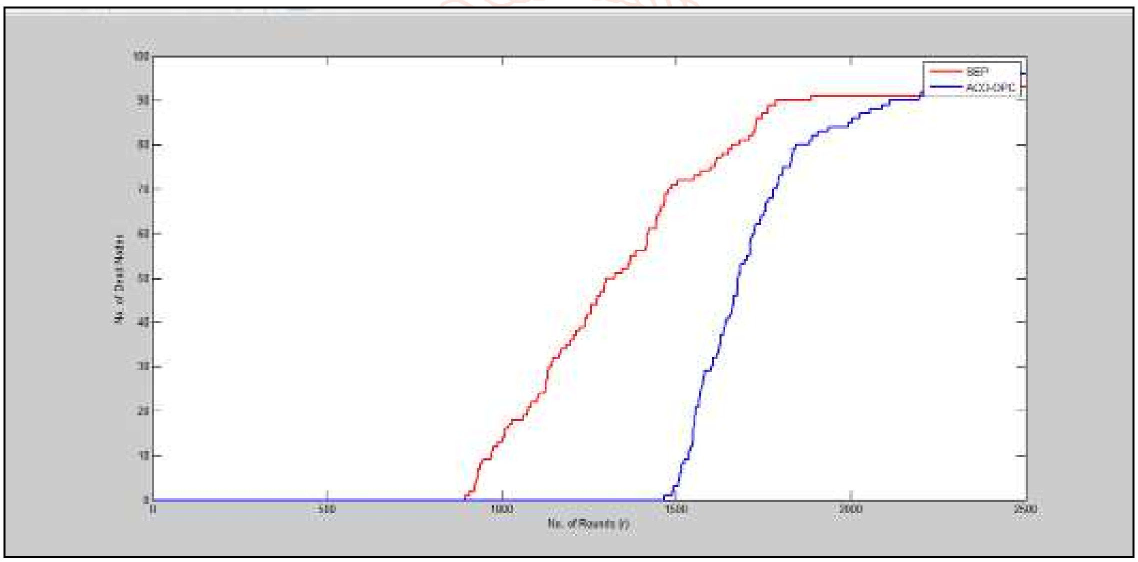

Figure 4: Dead Nodes in 2500 rotations

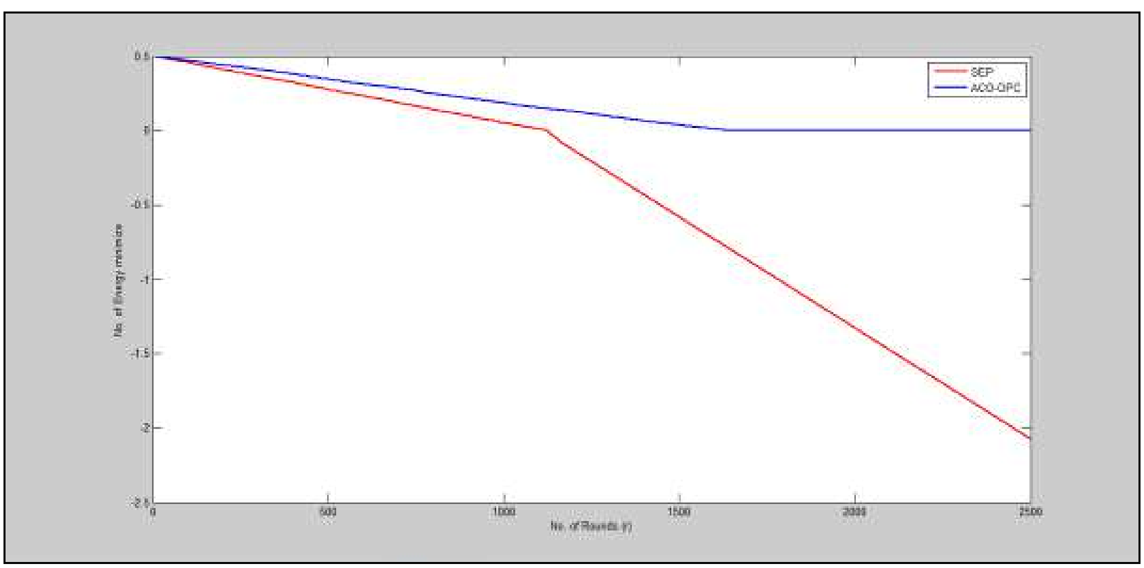

Figure 5: Remaining Energy in Network in 2500 rotations

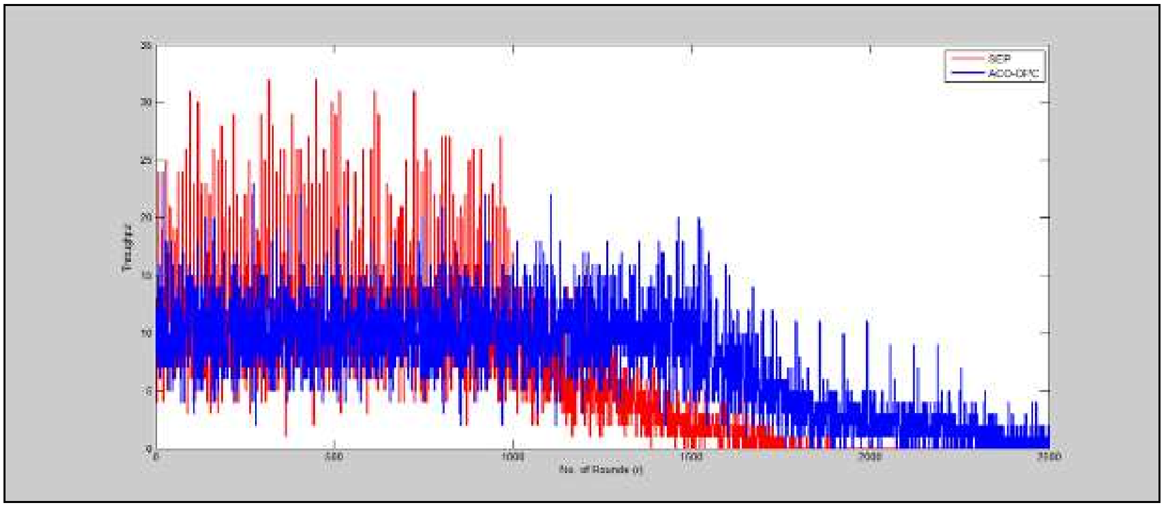

Figure 6: Throughput of Network in 2500 rotations

Figures show that when the number of rounds increases, the number of packets transmitted to the CH decreases. The ACO-OPC protocol transmits more packets than the other protocols combined. This is due to the cluster's effective usage of energy. Each member node selects the optimal transmission path at all times. A packet arrives at the CH with little or no wait. In the case that an intermediary node dies, member nodes may decide to take an alternative path in later rounds. Advanced nodes also consume a lot more energy and maintain a constant connection to the network. In a homogeneous network, there are very few available nodes in succeeding rounds. As a result, the number of packets transmitted is rapidly declining.

CONCLUSION

In the ACO-OPC protocol, every node in a cluster sends data to the cluster head via an optimal transmission method. This method is chosen to distribute the workload evenly among all member nodes based on a number of factors, including distance, pheromone trails, residual energy, and others. Furthermore, whereas a node in ACO-OPC enters sleep mode when its remaining energy is less than the energy needed for transmission, there is no sleep state in LEACH, which results in significant consumption of energy. Sleep-wake scheduling is determined by the nodes' threshold level of energy. The ant colony optimization methodology finds the best path between a cluster member and its cluster head to minimize energy consumption in the cluster. Setting ACO-OPC's parameters, such as ρ,α, β, and μ, will enhance the efficiency of the algorithm. We have determined the ideal values for these variables, and we have simulated the network using these values. The simulation's findings show that ACO-OPC uses less energy than the LEACH technique.

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