DEEC Protocol with ACO Based Cluster Head Selection in Wireless Sensor Network

Renu Jangra[1(✉)] and Ramesh Kait[2]

[1] University of Engineering and Management, Jaipur, Rajasthan, India
renu.jangra@uem.edu.in
[2] Kurukshetra University, Kurukshetra, Haryana, India
ramesh.kait@kuk.ac.in

Abstract. When it comes to wireless sensor networks, the routing protocols have a major bearing on the network's power consumption, lifespan, and other metrics. Cost-based, chaining, and clustering models are just a few of the many that inform the creation of routing protocols. It can be challenging to keep track of all of the nodes in Wireless Sensor Networks because there are so many of them. The optimal strategy is to form a cluster out of several nodes. By grouping together, sensor nodes are able to conserve energy and reduce their overall impact on the network. Management and coordination of the cluster's nodes are performed by the cluster head. In its current configuration, the DEEC functions well during transmissions and has been around for some time in the network. However, a probability strategy based on ACO is used in this research to determine which node within a cluster will serve as the cluster's leader. It is the responsibility of the cluster head to collect data from each of the individual nodes and then transmit that data to the home station. The ACO-DEEC protocol chooses a leader for the cluster by putting a probability rule that is based on the parameters of the distance between the nodes and the quantity of power they have. As a consequence of this, this algorithm performs better than the conventional DEEC protocol in terms of energy efficiency, the number of packets reached at the base station, and the count of the nodes that fail entirely.

Keywords: Wireless sensor Network (WSN) · Ant Colony optimization (ACO) · Ant Colony Optimization-Distributed Energy Efficient Clustering protocol (ACO-DEEC) · Cluster Head · DEEC Protocol

1 Introduction

Without the sensor nodes, the wireless sensor network would be nothing more than a theory. Because the sensor nodes only have a limited amount of battery life, the network won't be able to function for as long as it could. A BS exists within or outside the sphere of influence of the node [1]. There are a wide variety of routing strategies that can be used to reduce network downtime, packet/data overflow, and node mortality. To achieve this, we used routing protocols based on clustering. When several nodes join together to form a cluster, one of them is designated as the CH, and the others become cluster nodes.

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Exchange of information between the higher-ups in the cluster. One such clustering-based protocol is the “Distributed energy efficient clustering” (DEEC) protocol. As one possible representation of the relationship between residual and node average energy [2, 3], DEEC employs the cluster leader. The cluster’s leader will almost certainly be the node with the highest residual and average energies. Clustering-based routing protocols define a mechanism for selecting the cluster head as well as cutting down on the distance travelled by the communication path between the cluster node (CH) and the base station. This enables the transmission of data to be carried out in a manner that is both more effective and less dependent on the consumption of power. There is now a bio-inspired clustering methodology available for use in selecting appropriate CHs. Some people have doubts about the dependability of wireless connections and prefer hardwired networks instead. Recently, WSNs have become increasingly interested in biomimetic design principles [4]. Swarm-theory based routing algorithms are highly resilient to unexpected topological changes. Seeing a group of ants foraging for food sparked the idea. In this paper, we introduced the ACO-DEEC algorithm, which determines a cluster head’s probability of being chosen by analyzing the cluster’s strength and its proximity to other nodes. In comparison to the DEEC protocol that is currently in use, the method that has been suggested improves energy efficiency, reduces the number of packets that are transmitted to the base station, and brings the number of dead nodes down.

1.1 ACO

Communal behaviors in insects and other animals serve as inspiration for swarm intelligence. It’s a different way of thinking about fixing the issue at hand. In particular, many approaches and procedures make use of the idea of ant behavior. Ant colony optimization stands out as the most effective and methodical of these approaches (ACO). ACO was motivated by the foraging strategies of various ant species. Pheromone, a chemical substance, is laid down by the ants. The other ants in the colony should follow this substance because it indicates the right course of action. Optimization issues can be tackled with the help of a similar method used in ant colony optimization [5]. An example of a swarm intelligence technique is the ACO algorithm. This method uses probabilistic reasoning to locate a solution that is close to optimal. Dorigo.M, Maniezzo.V, and Colomi are the Italian researchers who carried out this study. A use the foraging behavior of ant colonies as the basis for their simulated evolutionary algorithm ACO Ant Colony Optimization. This method examines the evolution of an ant colony, which represents a pool of potential solutions, in order to identify the optimal one. This algorithm has shown excellent performance over the past decade in a wide range of settings, including Combinatorial optimization, routing in network, mining of data, functional optimization, and robot path development are just a few examples of the many optimization techniques available today. This algorithm possesses excellent robustness, as well as a reliable mechanism for distribution and an efficient mechanism for calculation. When combined with other approaches, ACO performs admirably in solving difficult optimization problems. More so than other approaches, it excels at optimizing composite environments. As a result, the development of theoretical analysis and valid study of ACO has enormous pedagogical significance and engineering value. The application of ACO has been beneficial to a variety of different industries, including the electrical power, mining operations, chemical, water conservancy, architectural, and traffic industries, amongst others. When dealing with the optimization of the travelling salesman route, the self-organization of ants can be put into play in four distinct ways. By searching the route in TSP iteratively, multiple ants are able to communicate with one another at once. Each ant is assumed to deal with its own issues on its own. Good comments: More pheromone on a path or along a graph edge results in more ants taking that route in the travelling salesman problem. It draws the conclusion that, in subsequent iterations, a larger number of ants will take that route. The following fictitious rule serves as the basis for the positive feedback system. The pheromone's value determines whether or not there will be a graph edge along the ant's path; in other words, the pheromone's value is directly proportional to the ant's path. Inversely proportional to the length of a path is the concentration of pheromones at its edge. More ants will use pheromones in the construction of new paths because the shorter path contains more pheromone than the longer path on the corresponding edges of the graph. Only considering positive responses leads to a situation known as stagnation, in which all of the ants take the same, inefficient route. Pheromone evaporation is thought of as a way to prevent the unfavorable reaction. Pheromone evaporation should not take place at an excessively high rate. if the bar is set too high, there will be no need to reduce in size and scope. If it happens too quickly, the ant colony will lose sight of the progress it has made in the past too soon (memory loss), undermining the efficacy of the ants' social support [4].

1.2 DEEC

The DEEC protocol is an efficient energy-saving method that operates in clusters. Network nodes are organized hierarchically, with CH collecting data from cluster nodes and relaying it to the base station. We take into account both "advanced" and "normal" nodes in the DEEC. Both the advanced node and the standard node have an initial energy of. As an example of the network's total initial energy, consider:

$$E_{total} = N(1-x)E_0 + NxE_0(1+a) = NE_0(1+ax)$$

Each DEEC cluster has its own CH because the network is divided into multiple smaller clusters. The network's residual energy and the nodes' initial energies are used to determine which CH to use. The probability function is defined as the product of these two quantities [5]. The probability function with a high value is more likely to produce a CH. The optimum count $C(T_i)$ of CHs in DEEC for each round is computed from the following equations.

$C(T_i) = p_{opt}E_i(r) \big/ \left(1 + axE'(r)\right)$, if $T(i)$ is a normal node. $C(T_i) = p_{opt}(1+a)E_i(r) \big/ (1+ax)E'(r)_{,}$ if $T(i)$ is an advanced node.

Where, the average energy $E_{energy}(r)$ of the network at round r and is stated by.

$E_i(r) = \sum_{i=1}^{N} r \big/ N$ $E_i(r)$ is the residual energy of the node at round r.

1.3 ACO-DEEC

Ant colony optimization is functional to the DEEC protocol in the proposed ACO-DEEC method. The DEEC uses a probability rule to determine who will serve as CH. This rule has its foundation in the comparison of the energy left with the nodes to the average energy across the network. When determining which node should serve as the cluster head, the ACO-DEEC takes into account the probability function as well as the energy level of the node and its distance from the base station. Large paths are assumed to have more energy than short ones between nodes, and vice versa. The following are the procedures followed by the ACO-DEEC ants: Ants use the start rule to choose the next cluster head and the revise rule to pick the best candidate.

Start Rule: When there is an ant on the cluster head node named i, use Eqs. 1 and 2 to determine which cluster head node j should be selected as the next cluster head node.

$$P = \frac{Dis\tan ce_i * \alpha + Phero_i * \beta}{\sum_{i=0}^{N_i} (Dis\tan ce_i * \alpha + Phero_i * \beta)} \quad (1)$$

where the probability function P assists the node in selecting the cluster head, and $Phero_i$ refers to the value of the pheromone.

$$Phero_i = \frac{\tau_{i,j}^{\alpha} * \eta_i^{\beta}}{\sum_{i=0}^{N_i} \tau_{i,j}^{\alpha} * \eta_i^{\beta}} \quad (2)$$

where, pheromone intensity denotes by $\tau_{i,j}^{\alpha}$, η_i denotes the heuristic information and α& β denotes controlling parameters,

$$\eta_i = \frac{1}{I_e - e} \quad (3)$$

where, I_e is the energy initially provided to the node and e is present energy that a node has. The node that has a power level that is lower than its actual energy level has a lower probability of being selected as a Cluster Head.

Revision Rule: There is an update in the current value of pheromone when an ant selects the next CH. This update is done by the rule given in Eq. 4.

$$\tau_{i,j}(t+1) = (1-\rho)\tau_{i,j}(t) + \rho\Delta\tau_{i,j}(t) \quad (4)$$

The change in the pheromone value is represented by $\Delta\tau_{i,j}(t)$ and ρ denotes the parameter that helps to stop the extra accumulation of the pheromone.

2 Literature Review

An E-DEEC algorithm with normal, advanced, and super nodes was proposed by P. Saini and A.K. Sharma [6]. The introduction of a super node, which is more powerful than both regular and advanced nodes, introduces heterogeneity into the network. E-DEEC performed better in simulations than SEP did. The proposed algorithm improves the network's longevity and reliability.

S. B. ALLA and colleagues [7] developed the BCDEEC protocol for use in WSN that have varying degrees of homogeneity. In the algorithm, it was suggested that the Base Station should ensure that the nodes with the most energy could act as a path and a becomes a CH in order to save the average amount of energy that the nodes consume. This was done in a direction to lessen the entire volume of energy that was consumed by the nodes. Data is delivered to the base station using cluster head to gateway routing, which results in lower overall power consumption and a smaller number of faulty nodes. The findings of the simulation made it abundantly clear that Balanced and Centralized DEEC performed well than SEP and DEEC, thereby extending the lifetime of the network.

Distributed Energy-Efficient Clustering, Developed DEEC, Enhanced DEEC, and Threshold DEEC were the four protocols that were compared by T. N. Qureshi et al. [8] using scenarios that ranged from top to bottom levels of heterogeneity. Although both EDEEC and TDEEC performed admirably under the test conditions, the outcomes exhibited that TDEEC was superior in way of stability and longevity.

The new MDEEC, which was proposed by C.Divya et al. [9], makes it possible to transmit more data from the BS to CH within a specified time gap than the conventional DEEC does. In comparison to DEEC, the results of the simulation demonstrated that MDEEC possessed 15% higher message throughput and 15% lower delay in data transmission. As a direct consequence of this, the energy efficiency of the network increased.

ITDEEC is a novel method that was introduced by Mostafa Bogouri et al. [10]. It enhances the threshold DEEC for heterogeneous WSN by removing the nearer nodes to the BS during the clustering process. These closer nodes consumed extra energy than the other nodes. According to the results of the MATLAB simulation, the network lifetime in ITDEEC had increased by 46% when compared to TDEEC, and the amount of data that could be transmitted had increased by 184%.

In WSN, many sensor nodes equipped with modest computing and sensing capabilities perform the necessary tasks. The benefits and drawbacks of routing protocols were discussed by K. Yaeghoobi et al. [11]. They compared the protocols SEP, HEED, LEACH, and DEEC in simulations and found similar outcomes. The outcome proved that HEED outperformed LEACH and SEP in both heterogeneous and unified settings.

Sarin Vencin and Ebubekir Erdem proposed TBSDEEC (Threshold balanced sampled DEEC) for three-level heterogeneous clustering [12]. Our model competed against the DEEC, EDEEC, and EDDEEC in two MATLAB scenarios on quality metrics like number of packets reached at the BS, the average latency, the number of nodes that were online, and the amount of energy that was consumed. In order to evaluate how effective our new method is, we evaluate it in relation to two other methods: the artificial bee colony optimization algorithm and the energy harvesting WSN clustering method. In simulations, the proposed model demonstrates superior performance to alternative protocols and significantly increases the lifetime of sensor networks.

To be more specific, “AM-DisCNT” and “iAM-DisCNT” were both developed by Akbar et al. [13]. In the first iteration of the algorithm, nodes were dispersed across the space in a circular pattern to ensure that each one consumed an equal amount of power. The second algorithm increased throughput by combining mobile and fixed base stations in the most efficient way possible. It was discovered that both proposed algorithms are superior to DEEC and LEACH in extending the stability period by 32% and 48%, respectively, then those two other compounds.

The authors of this work proposed [14] a modified heterogeneous algorithm that takes distance of the super nodes to the Base station as well as its the average distance of the nodes. The goal of this algorithm is to determine which nodes should serve as cluster heads. They have considered various levels of amplification energy for use in communication both within and between clusters, as well as between the cluster head and the BS, in an effort to diminish the quantity of power that is consumed. The simulation results that were tested in MATLAB 2017a show that the one that was proposed performs better than E-DEEC across all three parameters that were evaluated.

S. Kurumbanshi and S. Rathkanthiwar [15] discussed about the problems, routing, probabilistic approaches and issues exist in wireless sensor network with their solution. They also describe various operations by setting them one can get the better network with better energy level. When working with large networks, delay is taken as a metric. There are many applications of the wireless sensor network, but still there are many challenges in it. The issue with channel state information is explained which is used for operation in the network and processing of the signal. The neural network is used by the authors to set the threshold and particle swarm optimization is used to adjust the weight. They use the Pareto distribution of energy saving.

Silki Baghla and Savina Bansal [16] explained that the energy saving concept is very critical issue in a heterogeneous network. The new technology arises in which mobile are equipped with multiple networks at the same time. All these consume more energy. So, vertical handover technique is used by authors t handle this issue. A new algorithm is proposed VIKOR to manage the handover. This will consume less energy when work with WLAN, cellular network and WiMax simultaneously.

Sowjanya Ramisetty, Mahesh Murthy, and Anand S. Reddy [17] Using the moth flame optimisation al-gorithm, we found the optimal placements for the sensor nodes in the partitioned network to improve throughput, range, and power consumption (OPS-MFO). The proposed model has been shown to perform better than state-of-the-art algorithms in experimental evaluations.

3 Proposed Algorithm (ACO-DEEC)

Start

1. Make the network that have some parameters like initial probability (p), node count (n), round count $r_{\max}$, initial energy E_0, $rho(\rho)$, $E_{f,s}$, E_{amp}, E_{TX}, E_{RX}.
2. Determine the network's typical energy consumption.
3. Compute the probability function for each node by basing it on the node's strength as well as its distance from the base station.
4. A formula is used to calculate the probability function

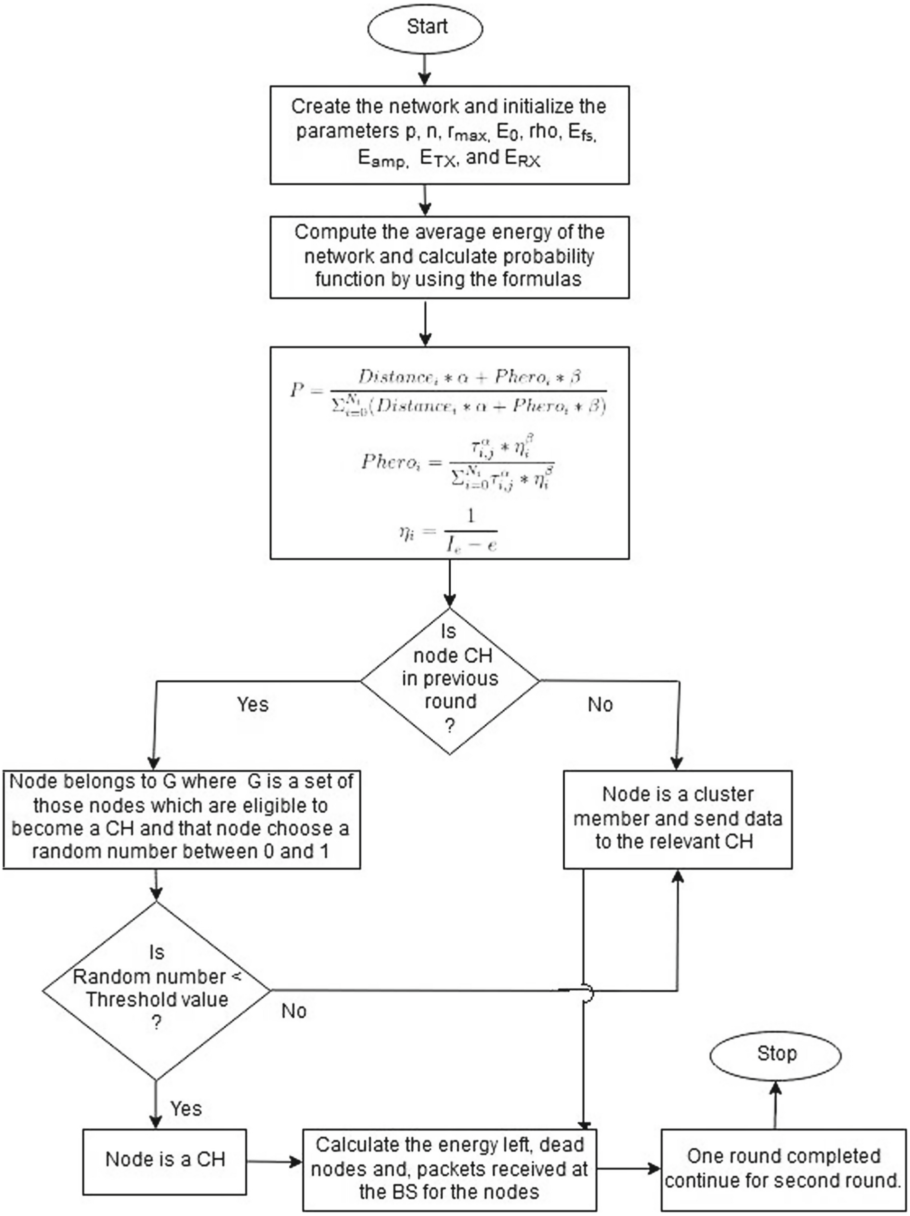
$$P = \frac{Distance_i * \alpha + Phero_i * \beta}{\sum_{i=0}^{N_i} (Distance_i * \alpha + Phero_i * \beta)}$$

$$Phero_i = \frac{\tau_{i,j}^{\alpha} * \eta_i^{\beta}}{\sum_{i=0}^{N_i} \tau_{i,j}^{\alpha} * \eta_i^{\beta}}$$

$$\eta_i = \frac{1}{I_e - e}$$

5. The set G contains all of the nodes that could potentially become CHs. If a node in the previous round was a cluster head, it is added to G. A node is a member of that cluster and has an obligation to contribute data to the proper CH if it is not a member of group G.
6. If the condition holds (choose random number > threshold function), then the node can be selected as a CH. If it is not meeting the condition, it will continue to function as a member of the cluster and report its data to the correct CH.
7. Figure out how much power is left in the node, how many nodes have died, and how many packets have been sent back to the hub.
8. One round/cycle has ended.
9. Stop

4 Flowchart of Proposed Algorithm



5 Experimental Result

The network is deployed in the real world while MATLAB is used for simulation. Parameter variation is used in the comparisons. Figure 1 presents a comparison between the amount of energy that is still available for a node in ACO-DEEC and DEEC, with the count of rounds and the nodes both initialize to 100, as well as various other values. Figure 2 depicts the proportion of packets deliver from the CH to the BS in ACO-DEEC and DEEC in comparison to the total quantity of nodes in the network. Figure 3's count of nodes was also set at 100, the same value as in previous figures. When compared against one another, ACO-DEEC and DEEC are evaluated according to how effectively they lower the total number of node deaths across a number of iterations. Figure 4 displays the results when 100 iterations are performed. DEEC and ACO-DEEC are compared with respect to the amount of energy available to a sensor node. Figure 5 compares DEEC and ACO-DEEC with regards to the packets deliver from CH to BS in a network, with a round count of 100 being used. When compared to DEEC, ACO-DEEC consistently produces superior results. The ACO-DEEC has more power for talking now. This means that sensor nodes work for longer than DEEC sensor nodes. Increase the network's durability as a result. ACO-DEEC has a longer lifetime than DEEC because its sensor nodes die later, keeping the network's communication channels open for longer. More information is sent to the BS as a result of a higher rate of packet transfers. As a result, the network's effectiveness is enhanced. The following diagrams illustrate the idea more clearly.

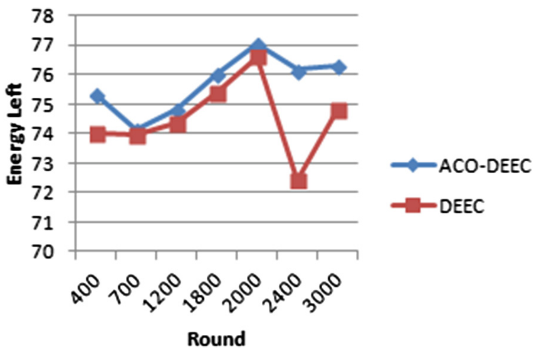


Fig. 1. ACO_DEEC and DEEC energy left at various rounds.

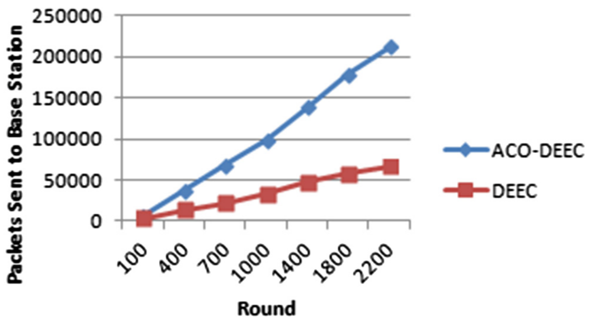


Fig. 2. Packets deliver to the BS at various rounds, comparing ACO-DEEC and DEEC.

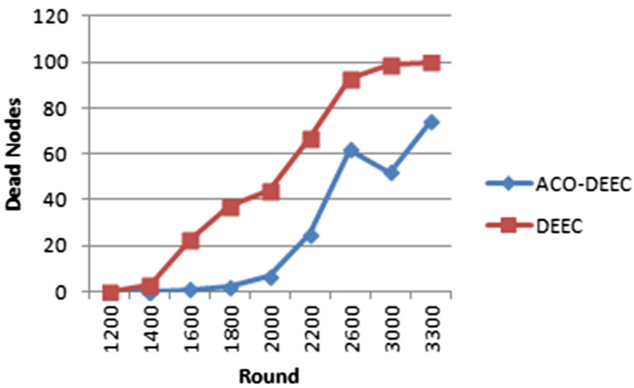


Fig. 3. ACO-DEEC and DEEC comparison of dead nodes at various iterations.

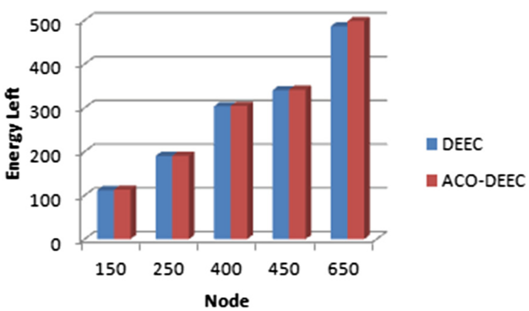


Fig. 4. Energy dissipated compared between ACO-DEEC and DEEC at various nodes.

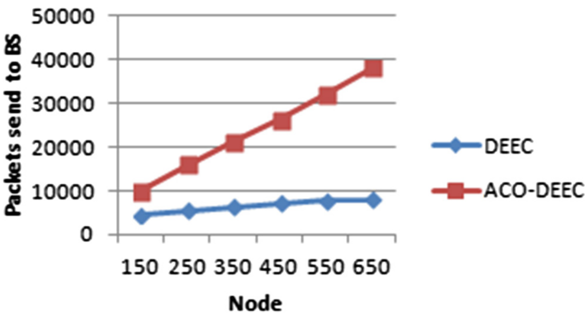


Fig. 5. Different nodes in ACO-DEEC and DEEC packets are compared.

6 Conclusion

Clustering is used by the WSN routing protocol to lessen the burden on individual sensor nodes' power supplies. Clusters are created in the extensive network by employing the energy-based ACO-DEEC and DEEC routing protocols. The cluster head is chosen using a probability function and the ant colony optimization method by the proposed algorithm ACO-DEEC. When compared to ACO-DEEC, DEEC performs poorly. MATLAB simulation is used to evaluate the two alternatives. The proposed method minimizes the amount of energy used, the number of nodes that have died, and the quantity of data that has been transmitted to the BS. Therefore, it boosts the network's power and keeps it operational for longer.

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