Enhancing Cluster Head Selection for Energy Efficiency in Wireless Sensor Networks: A Study of Swarm Intelligence Algorithms

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Abstract — Wireless sensor networks (WSNs) are becoming more important than ever because to the Internet of Things (IoT), which is facilitating increased worldwide interconnectivity. Micro sensor nodes in WSNs that communicate wirelessly have advanced to new levels of wide-scale application implementation. Due to their short battery lives, WSNs must be energy efficient. CH selection plays a crucial influence in WSN effectiveness. Both single-hop and multi-hop routing techniques are used, but multi-hop routing may result in higher node loads close to sink nodes. The increasing node load brought on by growing distance from sink nodes, however, may provide problems for single-hop cluster routing approaches. This study emphasizes the significant potential for wireless sensor networks (WSNs)-based energy efficiency algorithms to increase the longevity of WSNs. These protocols provide promising answers for boosting WSN durability and efficiency by optimizing energy consumption and resource utilization. For clustering optimization in WSNs, swarm intelligence approaches including fuzzy logic, ant colony optimization, and particle swarm optimization (PSO) have been successfully used by many researchers. To enhance cluster head selection, these methods make use of fitness functions based on variables including residual energy, intra-cluster distance, and node degree. The bee colony optimization algorithm is the main topic of this study. Examining this energy efficiency methods' performance in intricate and wide-ranging WSN infrastructures is essential to verifying their viability and effectiveness.

Keywords: Wireless Sensor Networks (WSNs), Internet of Things (IoT), Particle Swarm Optimization (PSO), Swarm Intelligence Algorithms

I. INTRODUCTION

The globe is moving closer to becoming fully interconnected. The Internet of Things (IoT) has emerged as a prominent topic for informational study. An important factor in advancing the IoT is the growth of wireless sensor networks. With this backdrop, the use of wireless sensor networks (WSNs) for large-scale applications has reached a new level. A huge number of inexpensive micro sensor nodes communicate wirelessly to form the multi-hop self-organizing network system known as WSN [1]. Hundreds or thousands of sensor nodes make up wireless sensor networks (WSNs), which typically also contain one or more sink nodes and many common nodes. Ordinary nodes are immovable once they have been placed in a space, typically in a random or contrived manner. In addition, Normal nodes typically use their own batteries, which are non-rechargeable, to power themselves while collecting environmental data periodically or in response to a situation and sending it to the sink node. In a sensor that is a wireless network, the sink node might move around or remain stationary. The sink node can be thought of as having infinite energy contrasted to regular nodes, and it typically has more processing power. Consequently, improving the longevity and efficiency of energy is a crucial concern [2]. In contrast, a cluster is formed in the cluster-based WSN architecture depicted in Figure 1 by a collection of sensor nodes and a Cluster Head (CH). From among the sensor nodes, the CH is chosen using some fitness function. This CH's job is to gather data from nearby sensor nodes and combine it with other data to extract some helpful data from them. The valuable data is sent to the base station by the CH following aggregation. The amount of energy used overall and network overhead is greatly reduced as a result of this aggregation.

When a WSN is cluster-based, it is split into a certain number of clusters, every of which houses one CH at a time. Using CH, all external communications are conducted. As communication nodes are separated by greater distances, energy usage rises. As a result, gathering data allows for flexible long-distance communication in cluster-based WSNs. Moreover, the major benefits of clustering include: (i) information aggregation is carried out at the CH level to prevent the redundant transfer of data, saving energy; (ii) WSN can be readily scaled; and (iii) increasing radio link utilization, i.e., bandwidth.

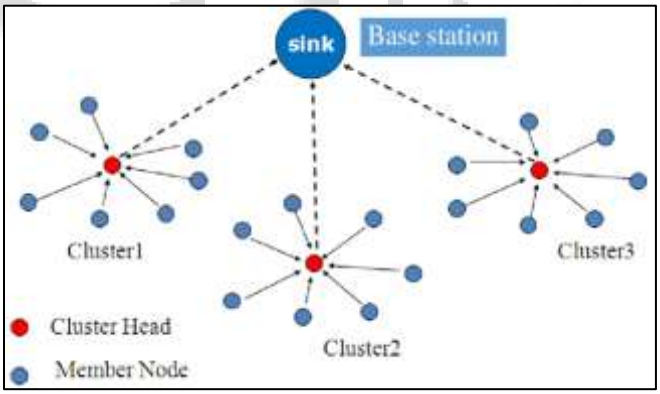

Fig. 1:An architecture for WSNs based on clusters

The choice of the CH has a significant impact on WSN effectiveness. There have been several suggested cluster-based protocols. Various protocols use various techniques for CH selection [3]. Single-hop routing and multi-hop routing are the two primary routing algorithms used in WSNs. Ordinary nodes' load in both single-hop and multi-hop routing is frequently correlated with their geographic location. Additionally, The issue of greater node load distance from the sink nodes plagues single-hop cluster routing techniques like low-energy adaptive cluster hierarchical (LEACH), energy efficient clustering scheme (EECS), and most upgraded protocols according to LEACH. In multi-hop networks, such as those using the mobile sink-based data gathering (MSDG) and economic-environmental unit-commitment (EEUC)

routing protocol, it is unavoidable that nodes within a hop's communication radius of sink nodes will be called upon to serve as nodes for relaying information in routing paths, and nodes close to sinking nodes will experience greater load [4].

Additionally, fuzzy logic has been used to create clustering methods. Effective metaheuristic tools are provided by swarm intelligence and can be successfully used in WSNs. The optimization issue of clustering is widely recognized. According to surveys, swarm intelligence is effectively resolving this problem. The metaheuristic ant colony optimization has additionally been used in clustering. Clustering optimization also uses the Particle Swarm Optimization (PSO) technique. The remaining energy, intracluster distance, and node degree are used as fitness functions in the protocol's PSO for cluster head choice. In order to cluster nodes in sensor networks, a hybrid centralized protocol integrating PSO and the harmony search algorithm (HSA) is also utilized. A successful solution to the clustering issue in WSNs was found by the bee colony metaheuristic [5]. An effective strategy for organizing and clustering bees inside a colony needs a methodical approach. Such a procedure aims to guarantee the effective distribution of resources and the bee colony's best performance. In order to optimize dynamic and multiobjective issues, this protocol make utilizes artificial bee colonies. Moreover, the suggested method was contrasted with other state-of-the-art existing algorithms to determine the method's competitiveness. As fitness function parameters, the residual energy, the travel time between nodes and sinks, and the link quality are used. For event-driven sensor networks, Bee-Sensor-C is created. When an event happens, Bee-Sensor-C creates a cluster design and chooses the cluster heads. The cluster head is the initial sensor that announces the event, and all subsequent sensors have to obey it. Performance across the board is enhanced by Bee-Sensor-C. A meta-heuristic method influenced by the Honey Bee Mating Optimization is proposed via the clustering protocol Bee-C. It depends on the ways that honeybees reproduce [6].

II. LITERATURE SURVEY

Over the past few years, a number of models have been put forward by many researchers in order to enhance the lifespan of WSN networks. This section of paper reviews some of the recent publications regarding WSN on renowned sites like IEEE, Springer, Elsevier, Hindwai and so on.

Sengathir, J., et al. [7], In order to ensure energy stabilization, delay minimization, and inter-node distance minimization for enhancing the network lifespan, a Hybrid Modified Artificial Bee Colony and Firefly Algorithm (HMABCFA)-Based Cluster Head Selection was suggested in this research. In order to create a new position that can replace the position that is not updated during the scout bee stage of ABC, this suggested HMABCFA incorporated the advantages of the Firefly optimization technique. The new ABC-based clustering approach substantially increased the expanded viable dimensions for enhancing the exploitation and exploration process. In comparison to benchmarked methodologies, the HMABCFA findings consistently demonstrated improvements in energy stability, the lifetime of networks, and latency reduction of 19.84%, 23.21%, and 22.88%, respectively. Ahmad, Tauseef, et al. [8], This research used a technique dealing with choosing the cluster leader based on the function of fitness. The Artificial Bees Colony (ABC) optimization method is a nature-inspired optimization approach that is used to optimize the fitness function once the cluster of sensor nodes has been established utilizing the k-means clustering technique. The objective function for optimization is made up of the energy of the sensor, the sink's separation from the cluster leader, and the cluster's separation between its members. The advantage of the selected goal function was that it generated the ideal cluster leaders. Simulated findings were observed to be superior to those of other comparable studies.

Sixu, L., Muqing, et al. [9], designed an artificial bee colony and particle swarm optimization technique for software-defined wireless sensor networks that were based on mobile devices and used for clustering. Reduced energy and compute overhead in sensor nodes were achieved through the usage of software defined network architecture. Also identified were the base station's heads of clusters and sojourn positions by a cluster routing technique utilizing particle swarm optimization. An artificial bee colony algorithm-based traversal path approach was used to build the base station's shifting path. The suggested protocol improved network longevity, lowers control overhead, and consumed less energy when compared to similar protocols.

Ankit Gambhir, et al. [10], the ABCO-based LEACH technique was thoroughly evaluated in a wide range of WSN situations by varying the maximum number of rounds (rmax) and the number of sensor nodes (n). The assessment of performance takes into consideration a variety of numbers, including the number of dead nodes per round, living nodes per round, and packets sent to base stations (BS) per round. The presentation also included a comparison of every parameter from traditional LEACH. Utilizing MATLAB, the simulation was completed. Agrawal, Deepika, et al. [11], To increase the network's lifespan, a technique called "fuzzy-based unequal clustering algorithm" was suggested in this research. Uneven clusters were formed by this procedure. To balance energy utilization, do this. Through the use of fuzzy logic, cluster heads were chosen. The base station's separation from the user, remaining energy, and density were input variables. The two fuzzy output variables were competition radius and rank. To make fuzzy inferences, the Mamdani method was used. Under various network situations, the protocol was contrasted with popular techniques such as low-energy adaptive clustering hierarchy, fuzzy-based unequal clustering, multi-objective fuzzy clustering algorithm, and energy-aware unequal clustering fuzzy. The suggested procedure worked better in every circumstance. Compared to alternatives, it increased the network's lifespan.

S. Lata, et al. [12], To increase the network lifespan, the authors developed the LEACH-Fuzzy Clustering (LEACH-FC) protocol and applied fuzzy logic-based cluster head selection and cluster creation. Instead of using dispersed methods, they have utilized a centralized method for choosing the cluster head and creating the cluster. In order to select the vice cluster head, another centralized process, they again used fuzzy logic. The energy burden at every node can be balanced by using the suggested approach, which increased the dependability of WSN. For increasing the lifespan of networks and energy usage, it performed better than other suggested

techniques. Rezaeipanah, et al. [13], presented an online clustering method for upgrading the sensor clustering, if necessary when routing is being carried out. Reduced distances between nodes within clusters, decreased distances between cluster head (CH) applicant nodes and sink nodes, and online suitable distribution of energy of the nodes in every cluster during every routing round were the three goals of the suggested clustering. Clustering was carried out using the enhanced fuzzy C-means (FCM) technique. The routing method was also based on the genetic algorithm (GA). The Direct Transmission, SH-MEER, and MH-FEER techniques were put up against FCM-GA in order to gauge how well it performed. The findings demonstrate that the suggested FCM-GA technique outperformed competing methods with regard to network lifespan and packet volume.

Debasis, K., et al. [14], The energy-Efficient Clustering Algorithm (EECA), the suggested paradigm, increased the lifespan of WSNs by reducing energy usage in sensor nodes. The cluster head (CH) of the suggested framework was chosen from one node in every area using an artificial neural network (ANN). The CH selection procedure was only open to sensor nodes that meet a minimal energy requirement. Additionally, four factors residual energy, the number of events identified, the distance from the base station, and the number of neighbors were used by ANN to determine these nodes' ratings. The sensor node in a region was chosen as the CH based on its score. To prevent the establishment of massive clusters, a limit termed the highest cluster size was also established. Only sensor nodes that are near an event can communicate its details to the CH. By following this regulation, redundant data was prevented from being sent to CHs. Moreover, in the suggested approach, a CH scans the medium at the start of a slot for incoming transfers for a relatively brief period of time. Furthermore, The CH switches off its radio if it doesn't receive a signal within this time frame. By using this guideline, CHs' idle listening was reduced. To assess EECA's effectiveness, certain current media access control protocols were contrasted with it. The experimental findings demonstrated that EECA conserved energy in sensor nodes more effectively than alternative models. Robinson, Y.H., et al. [15], to improve energy effectiveness, they provided a new power-aware routing protocol for Wireless Sensor Networks (WSN) based on threshold rates and fuzzy logic in this research. The probability values of each node in the WSN, which were derived from the amount of energy that each node has left, were used to select the cluster chiefs. Additionally, the mean energy of the entire network of the current phase was calculated using the total amount of node energy that was still available. The cluster head, which collected packets from the cluster members via single hop communication, will frequently be chosen from the nodes with a high probability. Moreover, the cluster head used fuzzy control and multi-hop communication to transfer the information collected to the sink. Three factors were taken into consideration by fuzzy control: the queue length of a node, how far it is from the base station, and its remaining energy. Furthermore, the findings of the studies indicated that the suggested energy-efficient cluster-based routing protocol approach (known as MLSEEP) outperformed the current protocols with the addition of those strategies.

Lewandowski, et al. [16], a method for extending the life of WSNs using smart nodes was described in this research. The suggested approach combined the suppression of unwanted data transferred with a new technique for switching the sensor nodes acting as cluster heads. An early version of a wireless sensor network used this technique. An actual wireless sensor network's lifespan and usage of energy were precisely measured during the experimental assessment of the proposed technology. These practical experiments' findings showed that adopting the suggested method instead of the most advanced cluster-head rotation algorithms increased the lifespan of the network of sensors. A. A. -H. Hassan, et al. [17], In order to increase the lifespan of the WSN-based IoT, they suggested an improved energy-efficient clustering protocol (IEECP) in this paper. There were three successive components to the suggested IEECP. In order to create balanced, overlapping clusters, an ideal number of clusters must first be established. Following that, using a modified fuzzy C-means technique and a system to control and balance the energy usage of the sensor nodes, balanced-static clusters were constructed. Last but not least, a new CH selection-rotation algorithm that integrated a back-off timing mechanism for CH selection and a rotation process for CH rotation selects cluster heads (CHs) in ideal positions with rotation of the CH function amongst the members of the cluster. IEECP was appropriate for networks that need to last for a long period since it improved the clustering structure, which in turn lowers and balanced the energy usage of nodes. The evaluation's findings demonstrated that the IEECP outperformed current methods. Khediri, et al. [18], The Fixed Competition-based Clustering Approach (FCBA), a unique clustering method for WSNs, was suggested in this study. Based on residual energy and their respective distances, the cluster heads in the suggested FCBA were chosen. A preliminary group of cluster head candidates was formed by electing the nodes with the highest residual energy that were nearer to the nodes' density center under the new suggested competition system. After that, the candidates gathered information from their participants and transmitted it to the base station. The simulation outcomes demonstrated the effectiveness of the plan in reducing energy use and consumption when compared to the most recent clustering techniques.

III. CONCLUSION

Energy efficiency is a critical challenge in the field of wireless sensor networks (WSNs), Several studies have focused on developing clustering protocol that increase the network lifetime. The use of clustering protocols has been shown to improve lifetime of Wireless Sensor Networks. Additionally, several studies have proposed using clustering techniques in WSNs to improve energy efficiency. By clustering the sensors, the network can reduce communication overhead and decrease energy consumption. The use of low-energy adaptive cluster hierarchical (LEACH) protocol has been shown to improve network lifetime. Moreover, researchers have suggested metaheuristic ant colony optimization in clustering to prolong the lifetime of WSNs. The use of clustering protocols such as LEACH, ant colony, optimization and Particle swarm optimization can

increase the lifetime of Wireless sensor networks. Furthermore, the proficient bee colony optimization is also utilized by researchers. The bee colony optimization performed well as compared to other algorithms to prolong the lifetime of WSNs. In conclusion, the use of clustering protocols in WSNs for enhancing the lifespan is crucial. The studies summarized above demonstrate the use of clustering protocol can significantly prolong the network lifetime in WSNs. Therefore, research should continue to explore the use of these techniques to further enhance the lifetime of Wireless sensor networks (WSNs).

Sr. No.	Author Name	Reference No.	Findings
1.	Sengathir, J., et al.	[7]	It was suggested that a Hybrid Modified Artificial Bee Colony and Firefly Algorithm (HMABCFA) be used in WSNs to enhance energy stabilization, cut down on delays, and shorten inter-node distances.
2.	Ahmad, Tauseef, et al.	[8]	developed a method for selecting cluster leaders in sensor networks with clusters. using a fitness function and the Artificial Bees Colony (ABC) optimization technique.
3.	Sixu, L., Muqing, et al.	[9]	introduced an innovative method for clustering in software-defined WSNs based on mobile devices utilizing an integration of particle swarm optimization and other algorithm was the artificial bee colony technique.
4.	Ankit Gambhir, et al.	[10]	By adjusting variables like the maximum number of rounds and the number of sensor nodes, the ABCO-based LEACH technique was thoroughly evaluated on numerous wireless sensor network (WSN) situations.
5.	Agrawal, Deepika, et al.	[11]	presented a technique for uneven clustering based on fuzzy sets to lengthen the network lifespan.
6.	S. Lata, et al.	[12]	In order to maximize the network lifespan, the fuzzy logic used in the LEACH-Fuzzy Clustering (LEACH-FC) method was added for choosing cluster heads and cluster creation.
7.	Rezaeipanah, et al.	[13]	a method for modifying sensor clustering while routing in wireless sensor networks was presented. Clustering was done using the enhanced fuzzy C-means (FCM) algorithm, and routing was done using the genetic algorithm (GA).
8.	Debasis, K., et al.	[14]	By reducing the consumption of energy in sensor nodes, the Energy-Efficient Clustering Algorithm (EECA) was developed as a model to increase the lifespan of wireless sensor networks (WSNs).
9.	Robinson, Y.H., et al.	[15]	introduced a cutting-edge, energy-conscious routing system for Wireless Sensor Networks (WSNs) that blends threshold rate with fuzzy logic.
10.	Lewandowski, et al.	[16]	suggested a technique that combines a cluster-head rotation algorithm and the suppression of pointless data transfers to increase the lifespan of WSNs.
11.	A. A. -H. Hassan, et al.	[17]	proposed the IEECP, a better energy-efficient clustering protocol intended to increase the lifespan of WSN-based IoT devices. By improving the clustering structure, the IEECP efficiently lowers and balances energy usage.
12.	Khediri, et al.	[18]	proposed the Fixed Competition-based Clustering Approach (FCBA) as a cutting-edge clustering technique for Wireless Sensor Networks (WSNs).

Table 1: Review of Literature Survey

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