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Anew Clustering Method to lmprove the Lifetime of Wireless Sensor Network Using Meta- Heuristic Methods

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Abstract

For greater performance, wireless sensor networks must have a longer lifespan. The lifespan of a wireless sensor network is based on how much energy each node consumes. Node energy consumption decreases as network lifespan grows. Because it requires less energy for information to go between nodes, proper clustering and the optimum selection of cluster heads are crucial to extending the network's lifespan. In this study, the K-means cluster method and the bat optimization algorithm were used to identify the optimum cluster head for the aggregation of a wireless sensor network. Based on the results of the simulated work, the K-means method and the bat algorithm together boost the efficiency of the wireless sensor system.

Keywords: Wireless sensor network, Clustering, Network lifetime, Bat algorithm.

1.1. Introduction

Numerous new applications for wireless communication are emerging. One of the parts of this form of communication that is growing quickly is wireless sensor networks. The sensor network, which was the subject of numerous recent scientific studies, is one of the most important tools for learning about and comprehending the environment. Battlefield monitoring, target detection, construction security, traffic control, air traffic control, monitoring systems, environmental monitoring, and framework monitoring are some of the most crucial uses for wireless sensor networks. This network is composed of many sensor nodes. The measurement, communication, memory, and computing components in each node consume a finite amount of energy. The most crucial factor to consider when assessing and evaluating a wireless sensor network is its longevity, which is dependent on the life of the sensor nodes. The efficiency of a sensor node is strongly influenced by the efficient and effective use of the source of energy, which can lengthen the network's lifetime. (Akyildiz ,2002 :422)

Recently, clustering protocols have been developed by researchers to lengthen the lifespan, bandwidth re - usability, and expandability of WSNs. Network clustering enables communication between nodes both within and between clusters. While intra-cluster communication includes the interaction of messages between cluster members and their respective cluster heads, inter-cluster interaction involves the delivery of emails from cluster heads to the ground station thru the single-stage or multi-stage routing. (Akyildiz ,2007:102)

Cluster heads that are far from the base station experience more energy dissipation in single-stage networks than nearby cluster heads at a significant distance. Since the task of data transmission is performed by the cluster heads near the base station in multi-hop networks, the energy consumption of the cluster heads near the base station is higher. Unbalanced energy consumption causes a certain number of nodes to fail before the scheduled time, which leads to the energy hole problem. In order to achieve constant energy consumption and avoid energy gap, clustering with unequal clusters is usually used.(Min, R., Bhardwaj ,2001 :210)

1.2. Statement of the Problem

A wireless sensor network can be considered as a set of independent and configured sensor nodes (SN) that are created to monitor environmental or physical activities such as sound and humidity. Some of these nodes have several sensors to monitor physical information. The task of these sensors, due to their low storage and computing power, receives the information through ADC (analog to digital converter) and sends it to the base station (BS) after processing.

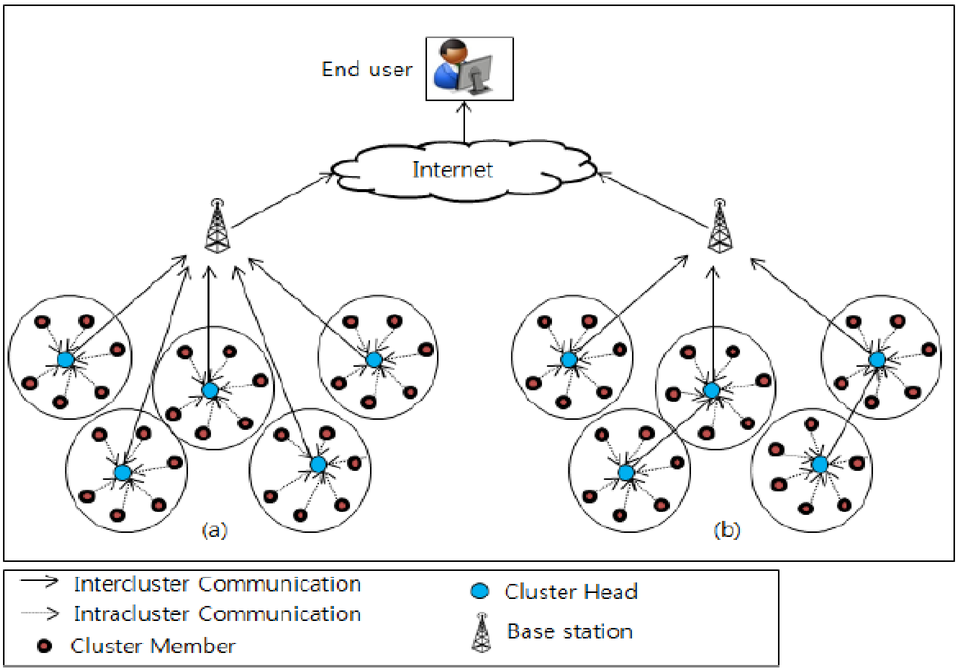
The base station checks and analyzes the received information. As nodes transmit data to the sink, these nodes are known to the repeater. Supplying the energy needs of processors, transmitters and sensors is the responsibility of the power source.

Battery limitation has caused problems in networks where the lifetime of the network is important, because this limitation has made the network unavailable and also in complex environments where nodes are located, recharging the battery is limited. Due to energy efficiency and reduction of energy consumption, the lifetime of the network can be increased. One of the ways to increase network lifetime is clustering. Nodes in each cluster send data to the cluster head to reduce energy consumption. Data collected at the cluster head is transmitted to the base station.

(Othman MF, Shazali K ,2012 :1204)

As a result, it helps to reduce energy.

Figure (1-1) shows the method of Energy management in wireless sensor nodes is a critical issue that directly



affects the lifetime of the network Unbalanced energy consumption and improper energy management are two issues that the network is facing and endangering its life. This problem may cause energy depletion and premature death of some sensor nodes before the scheduled time. The entire operation of the network also faces problems due to energy deficit. As a result, we decided to present a technique to increase the lifetime of the network in this research. (Kahn JM ,1999 :271) clustering and sensor network components [1].

1.3. Research objectives

The main purpose of this project is:

• Increasing energy efficiency as well as increasing the lifetime of the sensor network through the clustering algorithm. Also, the sub-goals are:

• Increasing the optimization of nodes
• Selection of the optimal and suitable head group
• Increasing the productivity of the entire system

1.4. Hypotheses

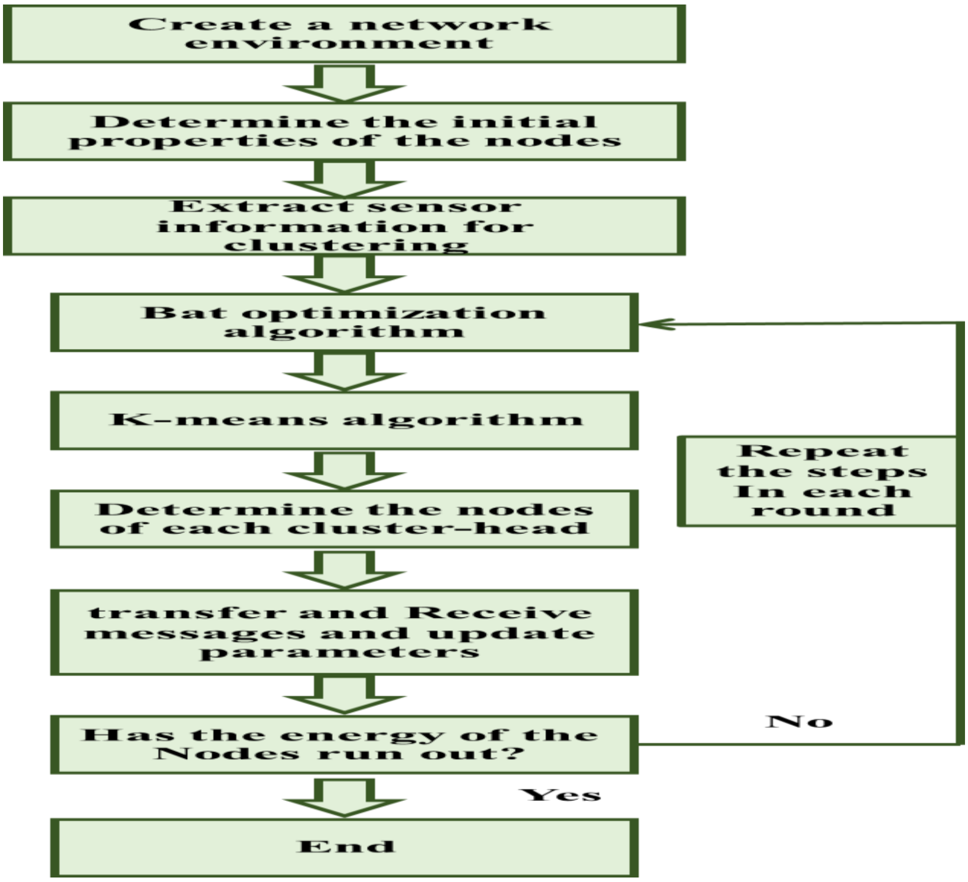
• If the cluster head in a wireless sensor network is optimally selected, then the lifetime of the network increases.

• If the clustering algorithm is used for the nodes of a wireless sensor network, then the energy efficiency of the network increases.

1.5 Proposed method

The Proposed Method is

As stated earlier, the k-means clustering approach is the basis of our work for node clustering in this thesis. However, since k-means clustering randomly selects the initial cluster centers, its performance is affected by local optimal points and degrades. In this work, we combine k-means clustering with the bat algorithm to increase the clustering performance. The bat algorithm excels in finding the global optimum in the fastest possible time. Figure (3-1) shows the flowchart of the proposed method, which will be explained in more detail in the next steps. (Mhatre V, Rosenberg C ,2004 :45) .



Protocols and architectures for wireless sensor networks. John Wiley & Sons; 2007 Oct 8.

1.6 Steps of the Proposed Method

When it comes to network energy problems, the clustering process in WSN is thought to be an effective solution. The main goals of clustering algorithms are to increase the durability and performance of the network. In WSNs, each cluster has an elected cluster head that manages all critical operations such as data collection, communication, and transmission. Choosing an effective cluster head can increase network performance and reduce energy consumption. Cluster head selection is assumed to be an NP problem. In this thesis, a clustering technique based on bat algorithm is proposed to increase network lifetime and performance. The best cluster head node is determined using the proposed method. Then the steps of the proposed method are described in detail.(Tripathi, R. K.,2012 :202) .

1.7 Network Environment Modeling

The first step is to simulate the environment in which nodes are expected to exchange information. In this context, we model an environment with a certain number of nodes and dimensions and calculate the starting energy of each node. The nodes then start transmitting information in several rounds while measuring properties such as energy and lifetime. Then the clustering process begins. (Liu X,2012 ,102)

1.8 Clustering with k-means Algorithm

k-means algorithm is used in the clustering stage. The clustering steps in this algorithm are described below:

1. Determining the number of clusters (K)

First, it is necessary to determine the number of clusters by the user.

2. Determining the cluster head

In the second step, the heads of the clusters are determined. In the k-means algorithm, the heads of the clusters are randomly selected.

3. Distance measurement and clustering

After determining the center of each cluster, the distance of each data with the data center should be calculated. This distance is done using the Euclidean distance formula: (Y. HAN, G. LI, R. XU ,2020 :301)

$$d(p,q) = \sqrt{\sum_{i=1}^{n} (q_i - p_i)^2} \qquad (3.1)$$

(1-1 Euclidean distance formula)

After the distance of each data to the data center is determined, it should be determined which cluster each data belongs to. Each data sample belongs to a cluster that has the smallest distance to the center of that cluster. (Zahedi Zeynab,2016 :55)

The mentioned steps are repeated until all the data are clustered.

4. Updating the cluster heads

As previously mentioned, the k-means algorithm randomly chooses the initial cluster heads. However, there is a very significant likelihood that these cluster members are not ideal after clustering. The algorithm then chooses the proper cluster head once again. K-means is being used to choose the most effective cluster head from among the cluster's members, and the resultant average is chosen as the initial cluster head. (Cai Xuelian,2015:11) .

After determining the new cluster heads, it is possible that not all members have the smallest distance to the cluster center. So, the second and third stages are repeated and this process continues until a stable state is reached. (Shankar T, 2016: 10) .

1.9 Clustering with Bat Meta-heuristic Algorithm

In the proposed method for optimization, we used bat meta-heuristic algorithm. This algorithm is inspired by the collective behavior of bats and generally follows three general rules for development: (Bouyer Asgarali ,2015 :140) .

Echolocation is a technique used by all bats to determine the distance and distinction between prey and immovable objects.

Bats randomly search for prey at position Xi, speed Vi, constant frequency fmin, variable wavelength, and loudness A0. According to the proximity of their prey, they can automatically change the amount of pulse emission i.e. r ∈(0,1) and the wavelength of their pulses. The loudness is assumed to vary from a large (positive) number A0 to a fixed minimum value, Amin, despite the fact that the loudness can be varied in many ways. (Leu Je-Shiou,2015 :402) .

Furthermore, it can be estimated that, in general, the frequency f is in the range $[\boldsymbol{fmin}.\boldsymbol{fmax}]$, which is equal to the range of wavelength $[\boldsymbol{\lambda min}.\boldsymbol{\lambda max}]$.

1.10 Determining the Nodes of Each Cluster Head and Exchanging Information between Nodes

First, the clustering was finished and the cluster centers were chosen in the earlier phases. This stage involves choosing the cluster head nodes for each cluster depending on how close they are to the cluster. As soon as the cluster head receives the data from the nodes, it gathers it and sends it to the ground station. Then, until all nodes have reached the end of its useful lives, node parameters like energy use and the number of packets delivered are updated. (Leu Je-Shiou,2015 :12)

2.1 Simulated Software

A suitable programming environment should be used to test the presented method and the proposed system. In this work, MATLAB 2020 program is used to model and simulate the presented approach. Table 5-1 lists the system properties used for this. (Shi Lei, Yao Zheng,2015:28) .

Table (2.1) Specifications of the system and software used in this work

Items	Features
software	MATLAB 2020a
Processor	Intel Core i7 (4210U) 2.7 GHz
Main memory	8.0 GB
hard disk	2 TB
operating system	Microsoft Windows 10

2.2 Simulations and Results

In order to simulate the network, in this section we will introduce its parameters. The proposed approach will be evaluated using a number of tests and compared with other methods. In the following section, the proposed approach is compared with other methods to measure its effectiveness. (Y. HAN,2020:24) .

2.3. Evaluation Criteria

Our goal in this work is to try to increase the lifetime of the network, so we will use the criteria related to this goal that is used in the reference article [53].

- Review of dead HND half-nodes
- Network lifetime (the frequency in which the last node dies.)
- The number of live nodes in each iteration (round) of the algorithm (A. Seyyedabbasi,2020:39) .

$$N_{alive} = N - N_{dead} \tag{2-1}$$

- Checking the first dead node FND

$$N_{HND} = N - N_{50\%}$$ (2-2)

In the above relationships, N is the total number of nodes and Ndead is the number of dead nodes. The meaning of the dead node is the node whose energy has ended. (E. Heidaria,2021 :45)

2.4 Primary Parameters

All sensor networks must consider variables such as the number of nodes, the energy required to communicate, the primary energy, the size of the delivered packet, and the spatial coordinates. Table (2-2) provides a list of parameters used in this study.

Table (2.2) Initial parameter values

Parameters	Amounts
Network size	200*200
The number of nodes	200
primary location of base stations	(100*100),(100*200),(0*200)
Initial location of nodes	random
The energy of sending information	nJ/bit 50
Primary energy of the nodes	0/1j
Packet size	Bytes 500

2.5 Designing Experiments

To evaluate the efficiency of the proposed model more precisely, the following three situations are considered in this work:

Scenario 1: The primary node is located in the center of the environment. (100.100)

The figure below shows this scenario visually. The most common mode used in sensor networks is this. Naturally, in this case, all strategies will be more effective than other scenarios. (Cai Xuelian,2015 :11)

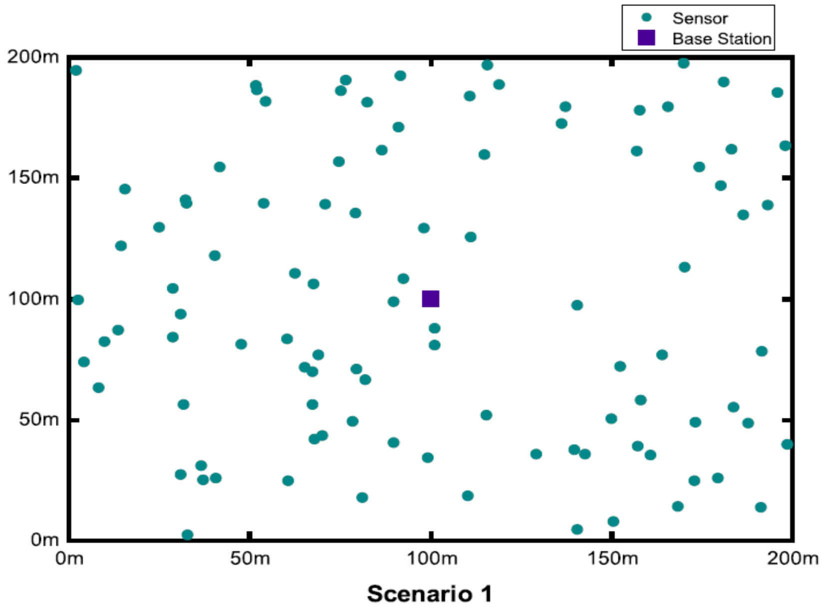


Figure (2.1) the primary node should be located in the center of the environment
. (100, 100)

(Fortino G,2012:35) .

Scenario 2: The primary node is located at the edge of the environment. (200.100)

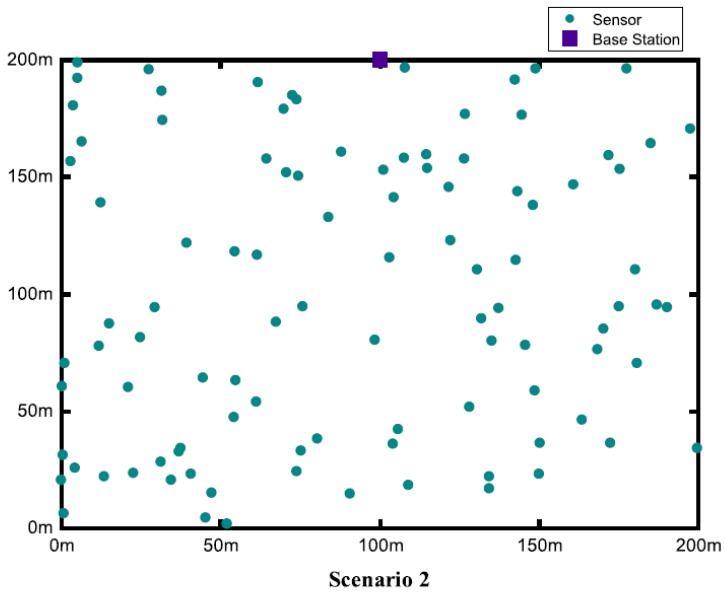


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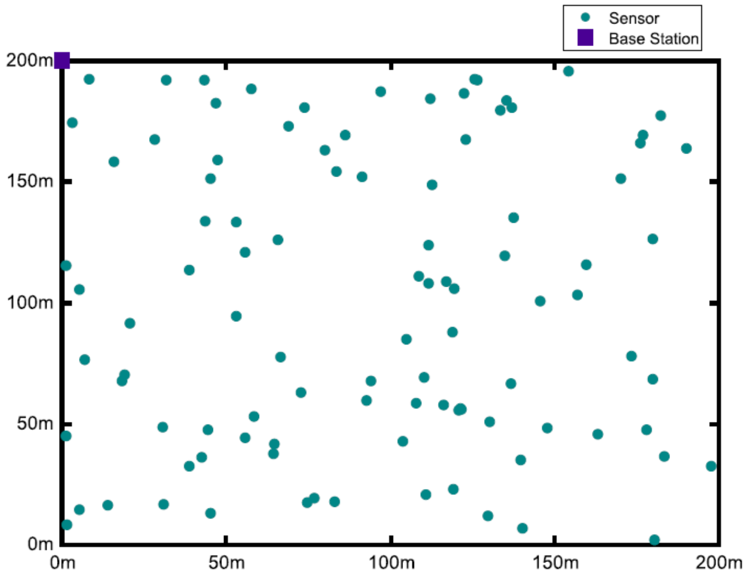
Figure (2.2) The primary node should be located at the edge of the environment. (100.200)

(Tripathi, R. K.,2012 :30) .

Scenario 3: The primary node is located in the corner of the environment. (0.200)



Scenario 3

Figure (2.3) The primary node should be located in the corner of the environment. (100.200)

2.6 Evaluation of Network Lifetime in Scenario 1

In the first scenario of this test, where the first node is located in the center of the environment, our algorithm has been compared with different algorithms. In this work, 100 primary alive nodes are used and the graph depicts the gradual destruction of nodes. In the first situation, as shown in Figure 5-1, LEACH lost its first node at lap 239 and all of its nodes at lap 370. In addition, in the method of the reference article have been used, in rounds 370 and 387, respectively, the first and last nodes are destroyed. In our method, the nodes last longer and the first and last nodes areremoved in steps 395 and 412, respectively. (Zahedi Zeynab Molay,2016 :32) .

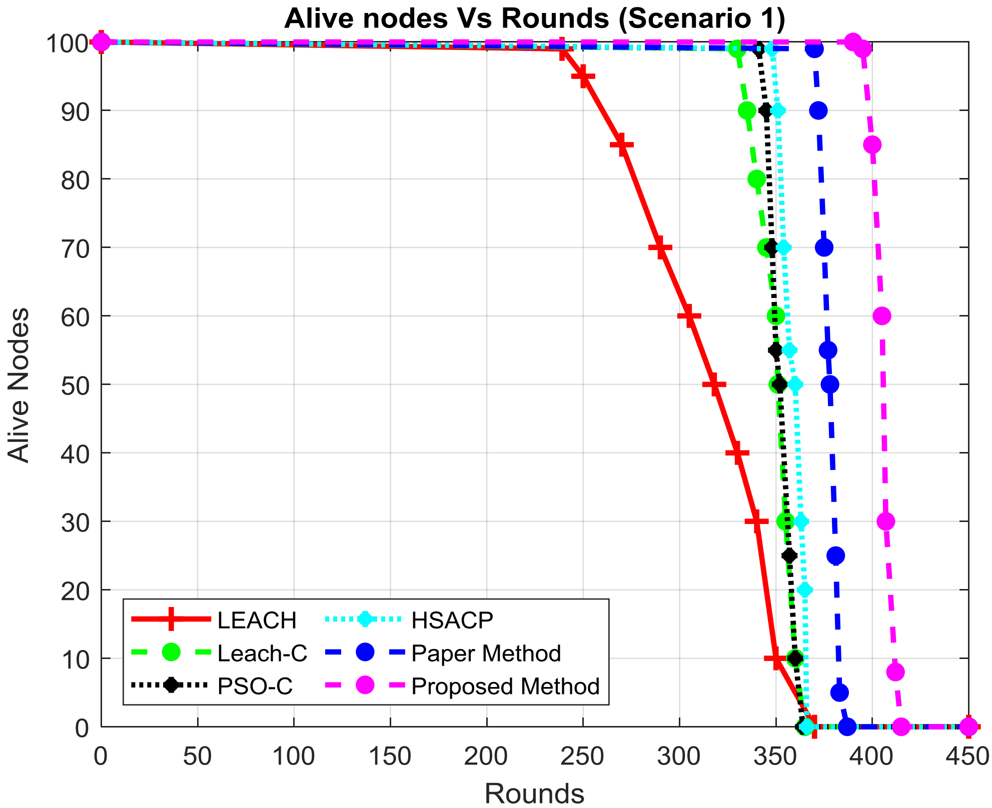


Figure (2.4) Graph of the number of alive nodes during the period for scenario 1

Table 2-3 presents the data numerically to further verify the network lifetime. This table compares the performance of the proposed method with Ref-Paper [53] and other methods.

Table (2.3) Simulation results for scenario 1

The proposed method	reference article method	HSACP method	PSO-C method	LEACH-C method	LEACH method	FND (First Dead node) HND (Half node dead)
395	380	348	341	330	239	FND
405	378	357	352	351	318	HLND

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2.7 Evaluation of Network Lifetime in Scenario 2

The main node in this scenario is located at the edge of the environment. The graph of node lifetime over period for the proposed method compared to other methods is shown in Figure 2-2. In the second scenario, the LEACH approach lost its first node at round 120 and all of its nodes at round 380, as shown in Figure 2-2. The first and last nodes in the reference paper technique are removed in rounds 251 and 425, respectively. Our method, which has a longer lifetime than previous methods, loses the initial node at step 280 and the last node at step 435. By comparing this scenario with the previous scenario, the slope of the graph has increased.

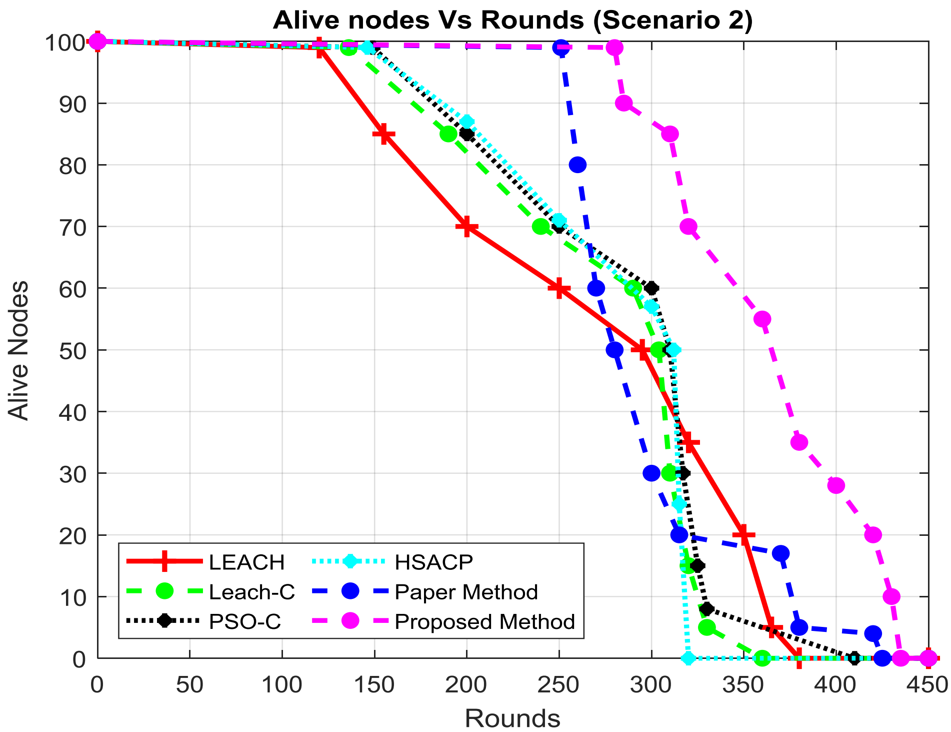

Figure (2.5) Graph of the number of alive nodes during the period for scenario 2

The time when the first node and half of the nodes are lost for each method are shown in Table 2-4.

Table (2.4) Simulation results for scenario 2

The proposed method	reference article method	HSACP method	PSO-C method	LEACH-C method	LEACH method	FND (First Dead node) HND (Half node dead)
280	251	146	149	136	120	FND
435	280	312	310	304	295	HND

2.8 Evaluation of Network Lifetime in Scenario 3

A diagram of live nodes over time for the third scenario is shown in Figure 2-3. The main node in the third scenario is placed in the corner of the environment. In the third scenario of the LEACH approach, as seen in Figure 4-3, the first node is lost in round 53 and all nodes are removed in round 360. The first node is removed in round 227 in the reference article approach, and the final node is removed in round 405 of that method. Finally, our method is superior to others because it misses the first node at step 280 and the last node at step 430.

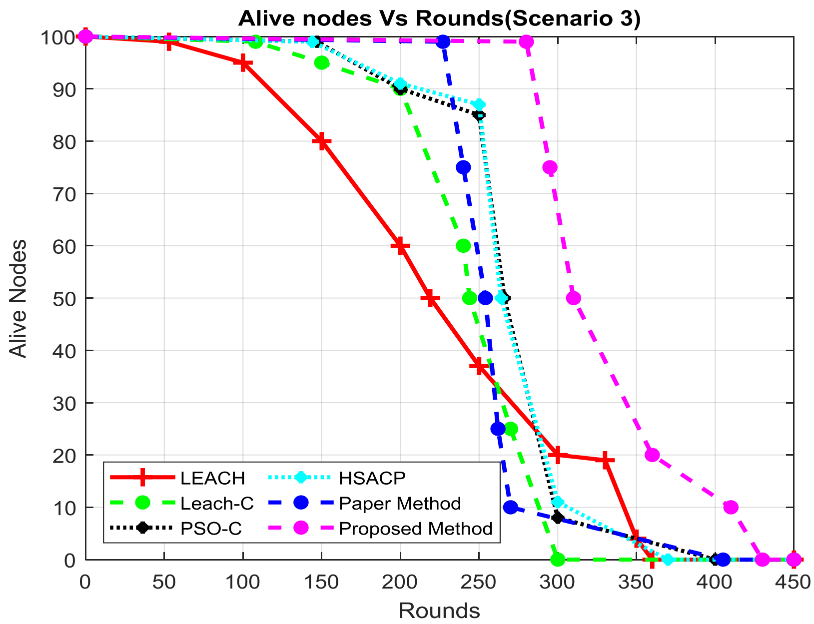

Figure (2.6) Graph of the number of alive nodes during the period for scenario 3

The table below contains the numerical values of the node loss period for each method.

Table (2.5) Simulation results for scenario 3

The proposed method	reference article method	HSACP method	PSO-C method	LEACH-C method	LEACH method	FND (First Dead node) HND (Half node dead)
270	227	144	147	108	53	FND
310	254	264	266	244	219	HND

The table below shows the comparison of three scenarios for the proposed method. As can be seen, the nodes died later in the first scenario where the primary node is located in the center, which indicates a better allocation of resources due to better clustering in this case.

Table (2.4) Simulation results for 3 scenarios

presented method (third scenario)	presented method (Second scenario)	presented method (first scenario)	FND (First Dead node) HND (Half node dead)
270	280	395	FND
310	370	405	HND

2.9 Summary of the Results

By choosing the ideal cluster head and clustering the nodes using the improved fuzzy clustering technique called FPCM, we were able to increase the lifetime of the WSN network in this project.

In this work, the results of the techniques discussed in the reference article were compared with our technique in 3 different scenarios, where the position of the main node in the environment is related. From the graphs created for each of the three examples, it is clear that the presented technique performs better than the existing approaches and increases the lifetime of the node. Experiments were performed for three alternative base station embedding positions. The results show that in the first, second and third scenarios, the lifetime of the network is improved by 70, 40 and 50 iterations, respectively. This improvement is the result of using the fuzzy-possibilistic c-means (FPCM) algorithm and selecting cluster head nodes. Because fuzzy clustering techniques are especially effective in selecting the best possible clusters. The ability to adapt to real environmental conditions and deal with uncertainty in decision-making is one of the characteristics of fuzzy logic.

Conclusion

3.1. Conclusion

The lifespan of the network and node energy usage are adversely associated in wireless sensor networks. In other words, the network will live longer if the nodes use less energy. In order to save energy, nodes should be clustered precisely and with the shortest distance feasible between each cluster and the cluster head. In this case, data transmission requires less energy from the nodes. In this thesis, we enhance clustering and carefully choose the cluster heads to boost the effectiveness of a sensor network.

K-means clustering, which allows nodes to be placed in many clusters simultaneously, is one of the best clustering techniques. But as mentioned, one problem in K-means clustering is that the cluster heads are randomly selected, which can harm the clustering process. In this work, the ideal cluster head was determined using the bat optimization technique. When K-means clustering and the bat method are combined, the wireless sensor network consumes less energy and lasts longer. According to the findings of the fifth word, the proposed method in this thesis works better than the alternative strategies.

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