ORIGINAL RESEARCH PAPER
Pages: 109-126

Energy Efficient Clustering in IOT-Based Wireless Sensor Networks using Whale Optimization Algorithm

[1]Seyedeh Mahnaz Raeisosadat, [2]Abbas ali Rezaee
[1]Department of Computer Engineering, Khavaran Institute of Higher Education, Mashhad
[2]Department of Computer Eng. and Information Tech., Payame Noor University, Tehran, Iran,
raeisi.mahnaz@yahoo.com, a_rezaee@pnu.ac.ir
Corresponding Author: a_rezaee@pnu.ac.ir

DOI: 10.22070/JCE.2022.15455.1202

Abstract: Due to the many applications of wireless sensor networks in various fields, the use of these networks has attracted much attention today. One of the most critical challenges of wireless sensor networks is the limited energy of the nodes, which has tried to manage energy consumption in these networks by using more accurate clustering. So far, many methods have been proposed to increase the accuracy of clustering, which reduces the energy consumption of nodes and thus increases network throughput. In this paper, we propose a method for clustering wireless sensor networks using the whale optimization algorithm, which results in increased throughput in these networks. Although much work has been done in this area in terms of energy, some do not have good throughput. Therefore, in this paper, a clustering method based on the whale optimization algorithm is proposed. Features of this algorithm include easy implementation, providing high- quality solutions, quick convergence, and the ability to escape from local minima. Also, in terms of clustering, in addition to paying attention to energy consumption, it has appropriate throughput. In the proposed method, the Euclidean distance is used to assign data to the cluster and determine the cluster centers by the whale optimization algorithm. In other words, concentrated clusters are created. Then, according to the two remaining energy parameters and the distance of the nodes to the centers of the cluster, two clusters are selected. To evaluate the research, we have used MATLAB software and compared the proposed method with one of the latest works. The results show an improvement in throughput and are comparable in terms of energy.

Index Terms- Clustering, energy consumption, throughput, Wireless Sensor Networks, whale optimization algorithm

Manuscript received 1-March-2021 and revised 17-May-2021, *P- ISSN: 2322-4088*
Accepted on 15- June-2021 *E- ISSN: 2322-3936*

I. INTRODUCTION

Smart environments, due to the recent evolution of wireless communication technologies, have witnessed the emergence of small-sized sensors that collect information such as temperature, pressure, humidity, water content, presence of gas and send it to the base station. In order to create more result coverage in space, several sensors are connected to each other and thus form a wireless sensor network [1]. Today, due to the many applications of wireless sensor networks in daily life and the ability to sense, calculate and communicate, these devices are of particular importance. One of the important applications of wireless sensor networks is environmental sensing and monitoring services, in parallel with which the Internet of Things is mentioned as an interconnector between devices connected to the Internet in the important process of measuring and monitoring the environment [2].

In recent times, IOT-based wireless systems have developed rapidly in various sectors. In these networks, physical devices, sensors and other objects communicate with each other without human intervention. Wireless sensor networks are a central component of IOT, and WSN nodes are usually small and battery-oriented machines, so energy compression techniques that lead to increasing network lifetime are very important in this field [3].

Internet of Things (IOT) as an intelligent technology connects everything anywhere and anytime Objects interact with other objects through Internet connection or communication tools and share their information with each other or with humans and provide a new service [4].

Wireless sensor networks are used due to their many applications in various fields such as agriculture, environmental monitoring, vehicle tracking, healthcare monitoring, smart buildings, security, and animal monitoring and tracking. In fact, due to the various applications mentioned, the lack of energy in the nodes is one of the most critical limitations of wireless sensor networks. Because it is impossible to recharge or replace the nodes in the sensor nodes. Therefore, providing an appropriate protocol that can save energy will increase the network's lifetime [5]. One of the strategies to extend the lifetime of the network is the use of the clustering approach, which, including the hierarchical architecture, can be useful in the lifetime and energy consumption of wireless sensor networks. In other words, in this architecture, clustering sensors have other advantages such as saving the power of sensor elements, increasing system adaptability and maintaining data transfer speed [6]. In hierarchical architecture, the network is divided into different sections called clusters. Each cluster consists of cluster members (CM) and a cluster head to collect data from cluster members and then send it to the base station. The benefits of the clustering approach can reduce the routing overhead of nodes, and eliminate additional information and thus reduce energy consumption due to reduced data transfer in nodes, increase network scalability, and protect bandwidth. In clustering strategy, selecting the appropriate cluster head is an NP-hard problem in this area. The whale optimization algorithm is effective in solving NP-hard problems [7].

Also, the data space is entirely compatible with the problem-solving space in terms of geometry. Another reason for choosing this algorithm is the rotational contraction technique to solve the problem, which will cause optimization and speed of operation in a circular space. Also one of the useful features of the whale optimization algorithm for problem approaches is easy implementation, providing high- quality solutions, quick convergence, and the ability to escape from local minima.

In this paper, the main focus is on selecting two clusters to reduce the pressure on a node to increase clustering accuracy and achieve the appropriate throughput in the network. An algorithm based on a whale optimization algorithm called WOA-O-leach is presented. The proposed algorithm helps to select the best cluster head by considering the residual energy of the nodes and the distance close to the center.

The rest of the paper is organized as follows: Section 2 is about related work, and Section 3 presents the whale optimization algorithm. The proposed method and performance evaluation are presented in Section 4 and in section 5, the simulation results are explained, and then in the last section, we will present the conclusion.

II. RELATED WORKS

As mentioned before, wireless sensor networks have energy limitations. Also the direct transfer of data to the base station will quickly deplete the energy of nodes farther from the center of the network and thus lead to a significant reduction in the lifetime of these networks. Therefore, clustering is one of the critical solutions to achieve energy efficiency in wireless sensor networks, which is of particular importance in this area. Many clustering algorithms have been proposed for these networks that we can refer to the heuristic and nature-inspired methods.

A. Heuristic methods

The LEACH algorithm [8],[9] is a distributed hierarchical method for clustering wireless sensor networks. Considering that each cluster head combines all the data of the cluster sensors, this algorithm saves the amount of data sent to the base station and as a result energy consumption, but the random selection of the cluster head causes a lower efficiency than other algorithms. This algorithm has increased the lifetime of the network compared to previous protocols, and this is a distributed algorithm that does not need to have global information of the entire system. Among the disadvantages of this algorithm, it can be mentioned that it is a single hop to communicate with the sink, which makes LEACH unusable for large networks. Another disadvantage of this algorithm is the random selection of nodes as the cluster head without considering the distance or the current energy of the nodes or assuming the initial energy of the sensors to be the same, which reduces the efficiency, so all kinds of algorithms have been developed to strengthen the LEACH protocol**.**

DSBCA algorithm [10],[11] calculates the radius of the clusters based on the distance and distribution of nodes and then uses the connection density and residual energy of the nodes to form clusters, which in general can be said to pay attention to the random distribution of sensor nodes. The primary purpose of this algorithm is to create clusters with higher energy balance and prevent the formation of clusters with many nodes. Its main idea is to calculate the radius of the cluster based on the connection density and distance from the base station. The advantages of this algorithm include creating a stable and reasonable cluster structure and the possibility of using it for networks of different sizes. However, if the node distribution algorithm does not work well, it will lead to an unbalanced topological structure and some nodes will die due to excessive energy reduction.

The M_LEACH algorithm [12] is an improved version of the LEACH algorithm in which they communicate in a multi-hop style instead of sending information directly to the base station.

One of the most important reasons for creating the LEACH_C algorithm [13],[14] is the lack of attention to the number and placement of cluster heads in the LEACH method. In this algorithm, the task of determining the cluster head is the responsibility of the base station. In fact, due to the use of the center-based clustering algorithm, the cluster heads are scattered throughout the network environment, which will lead to the formation of better clusters. Although this algorithm has a better performance than the LEACH method, but to determine the geographical location of each sensor, they need hardware such as GPS, which is very expensive and consumes a lot of energy. So compared with LEACH, LEACH-C is more energy efficient, and the base station can form clusters with more energy efficiency, and there is no energy consumption among nodes during cluster formation.

The O-LEACH algorithm [9] which is another improved version of the LEACH algorithm, is more stable due to the discrimination between nodes according to their initial energy. The main task of this algorithm is to reduce nodes that do not belong to any cluster (orphan nodes). In general, this algorithm creates better access to data in the base station due to the collection of different values by orphan nodes to make better decisions and faster responses, increasing the connection and reliability of sensor networks. It also offers better performance in terms of coverage, connection rate, energy, and scalability than the LEACH algorithm, which in turn increases lifetime and minimal energy consumption.

B. Nature-Inspired Approaches

In order to remove the limitations of the previously mentioned algorithms, meta-heuristic algorithms are used to achieve efficient cluster heads in this field. In this regard, we can refer to the particle swarm optimization algorithm [6],[15] , bee colony optimization [16],[17] , ant colony optimization [18],[19] , genetic [20],[21] or fuzzy logic [22] in clustering. In this field, multiple different methods [23],[24] have been used to adjust the clustering parameters and to determine the efficient cluster heads. It should be noted that none of the meta-heuristic algorithms alone will perform better than other methods. For example, genetic methods reduce long-distance exchanges but have high operating costs Or particle swarm optimization methods alone consider the distance between clusters as the ratio of the initial energy of all nodes to the current residual energy of the nodes and they cannot consider the distance to the sink while communication between the cluster head and the base station is important. Therefore, hybrid algorithms are the best option for selecting efficient cluster heads. The Whale Optimization Algorithm is a new evolutionary optimization algorithm that performs similarly to the PSO and GA algorithms and is useful for solving NP-hard problems.

In this paper, a center-based clustering algorithm called WOA-O-leach is proposed to increase the performance of wireless sensor networks using the WOA algorithm. The proposed algorithm is designed so that the two cluster heads are selected based on the two residual energy and the minimum distance to the center of the cluster parameters, which will increase clustering accuracy and create more focused clusters, as well as increase network throughput.

III. WHALE OPTIMIZATION ALGORITHM

The Whale Optimization Algorithm (WOA) [25],[26] is a nature-inspired and meta-heuristic algorithm that mimics the social behavior of humpback whales and was introduced in 2016 by Mirjalili et al. In general; humpback whales use a special mechanism for hunting called the bubble net attacking method. This behavior is done by placing special bubbles in a spiral shape. In fact, the whales create a wall of bubbles around the group of fish and all together attack the group of fish that is the answer to the problem and hunt them. In the other words, in this algorithm, hunting is similar to the optimization method, and the location of the prey is similar to the best solution. The search process in the WOA Algorithm consists of two exploitation stages and exploration. This algorithm is started by an accidental population of whales with random positions. In the first iteration, the search agent positions are updated by a random whale search agent with random positions. And from the second iteration onwards, these positions will be updated by the best solution ever. And if $|A| > 1$, the global search algorithm starts. In the following, we will examine the hunting behavior, which includes three stages of searching, Encircling, and attacking the prey.

A. Encircling prey

Humpback whales detect the prey's location and then tighten their surroundings around the prey and consider it the best search agent. Then they update their position according to the best search factor, which is shown by the following equations.

$$\vec{D} = \left|\vec{C}\overrightarrow{X^*}(t) - \vec{X}(t)\right| \quad (1)$$

$$\vec{X}(t+1) = \overrightarrow{X^*} - \vec{A} . \vec{D}$$

 (2)

Where t indicates the current iteration, $\vec{A}$ and $\vec{C}$ are coefficient vectors, $\overrightarrow{X}$ is the position vector, | | is the absolute value, and · is an element-by-element multiplication. X* is the position vector of the best solution ever obtained, which is updated after each iteration if there is a better solution. The vectors $\vec{A}$ and $\vec{C}$ are calculated as follows:

$$\vec{A} = 2\vec{a} \cdot \vec{r} - \vec{a} \quad (3)$$

$$\vec{C} = 2 \cdot \vec{r} \quad (4)$$

Where $\overrightarrow{a}$ decreases linearly from 2 to 0 during iterations and $\overrightarrow{r}$ is a random vector between 0 and 1.

B. Bubble-net attacking method

Humpback whales use two mechanisms for hunting prey, called shrinking encircling mechanism and Spiral updating position. To model this behavior, assumes that there is a probability of 50% to choose between these two mechanisms to update the position of whales during optimization with a random variable p that the variable p is a random number between 0 and 1. In the shrinking encircling mechanism, the value $\vec{a}$ is obtained from Formula 3. In other words, $\vec{A}$ is a random value in the interval [−a, a] where a, is decreased from 2 to 0 during repetitions. In the spiral updating position mechanism, a spiral equation is created between the distance of the whale at (X, Y) and the prey at(X^*, Y^*) to mimic the spiral motion of the whales. In other words, humpback whales swim around the prey within a shrinking circle and along a spiral-shaped path. To model this behavior and assume a 50% probability of occurrence between the two mechanisms, the whale position update is as follows:

$$\vec{x}(t+1) = \begin{cases} \overrightarrow{X^*}(\mathrm{t}) - \vec{A}.\vec{D} & if\ p < 0.5 \\ \overrightarrow{D'}.e^{bl}.\cos(2\pi l) + \overrightarrow{X^*}(\mathrm{t}) & if\ p \geq 0.5 \end{cases} \quad (5)$$

C. Search for prey

In the exploration phase, the diversity of vector A is used to search for prey. In this step, we use $\vec{A}$ to force the search agent to move far away from a reference whale. This vector has random values greater than one or less than one. In contrast to the exploitation phase, the position of a search agent is selected based on a random search agent and is updated instead of the best search agent ever found. This mechanism and | A | > 1 emphasize exploration and allow the WOA algorithm to perform a global search. The search mechanism is modeled by formulas 6 and 7:

$$\vec{X}(\mathrm{t+1}) = \overrightarrow{X_{rand}} - \vec{A}.\vec{D} \quad (6)$$

$$\vec{D} = \left|\vec{C}.\overrightarrow{X_{rand}} - \vec{X}\right| \quad (7)$$

In this paper, the WOA algorithm is used for the cluster head selection process.

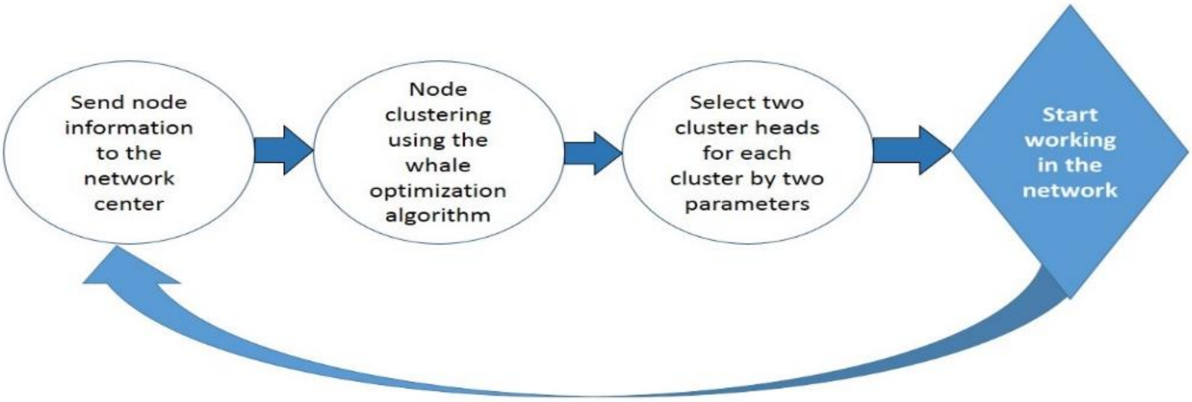

Fig. 1. Describtion of the phase of the proposed method.

IV. PROPOSED APPROACH

In this paper, a center-based clustering algorithm called WOA-O-leach is proposed. This algorithm selects the clusters by considering the two parameters of residual energy and distance, which increases the accuracy of clustering and creates concentrated clusters. In this method, the first cluster head receives and aggregates the information from its cluster nodes and then sends this information to the second cluster head, and the second cluster head sends the information to the base station. This technique distributes the energy of cluster heads and prevents overuse of the nodes and Fig. 1 is given for a better understanding. In the following, different parts of the proposed algorithm such as network model and energy model and cluster head selection model are explained.

Network model

The network model in this research is Free space, which we will examine the following hypotheses:

- The number of nodes is considered to be 100 and 300.
- All sensor nodes are homogeneous and randomly placed in the environment.
- The network environment is 100 x 100 square.
- The base station is fixed and is located in two areas, the middle (50m * 50m) and the corner (99m * 99m) of the desired space.
- Communication between nodes selected as cluster heads is done via TDMA and CDMA.
- Considered multi-hop communication.
- All nodes can be selected as cluster heads.
- Data aggregation used.

A. Energy model

In most of the implementations that have been done for the networks, most of the energy consumed in the network is for sending and receiving data. Other consumed energies such as the energies necessary to sense or process the received information are ignored, so the energy model is used. This article is also based on the reference model [13].

Equation 8 represents the communication energy and, as mentioned above, other energies are consumed. Also, E_C represents the communication energy, E_{TX} represents the data transmission energy, and E_{RX} represents the reception energy.

$$E_C = E_{TX} + E_{RX} \tag{8}$$

The amplifier energy is ε_{fs} for Free-space and ε_{mp} for Multipath, depending on the transmitter amplifier model. Therefore, an energy loss model with d_{ij}^2 is used for a short distances and will be converted to d_{ij}^4 for larger distances. Thus, the energy used to transmit K bits of data through the distance d is done by Formula 9.

$$E_{TX}\ (k,d) = E_{TX-elec}\,(k) + E_{TX-amp}\,(k,d) \tag{9}$$

$$E_{TX}\ (k,d) = \begin{cases} k\left(E_{elec} + \varepsilon_{fs} d^2\right) & d < d_0 \\ k\left(E_{elec} + \varepsilon_{mp} d^4\right) & d \geq d_0 \end{cases} \tag{10}$$

The energy consumed to receive k bits of data is calculated from Formula 10.

$$E_{RX}(k) = E_{RX-elec}(k) = kE_{elec} \tag{11}$$

B. Cluster head selection

The proposed algorithm is based on a centrally controlled algorithm that is executed in the base station. First, all nodes send their information such as residual energy, location, ID to the base station. Then the base station randomly assigns nodes whose residual energy is more than 10% of the other node's remaining energy as a candidate to select the cluster center. Then run the WOA algorithm to achieve the minimum possible value of the fitness function to obtain the best cluster centers and then choose two cluster heads. In the WOA algorithm, nodes are assumed to search for cluster centers. In other words, one whale is considered for each fixed node in the network, and the initial population is the position of the cluster centers that were selected as candidates in terms of energy. (Positions are 2D). Also, X^* or the best answer in the proposed method is the position of the best whale or in other words, the closest node to the center. To introduce the fitness function, we will first introduce the existing parameters:

To determine the belonging of each node to each cluster center, it is necessary to consider the cluster centers $M_1, M_2, \cdots, M_k$ and the set of nodes $X_1, X_2, \cdots, X_n$ Thus the first dimension M_i=

$\begin{bmatrix} m_i^1 \\ m_i^2 \end{bmatrix}$ and the second dimension is $X_j = \begin{bmatrix} X_j^1 \\ X_j^2 \end{bmatrix}$ In this case, nodeX_j and the center of the cluster, M_i calculate the distance from formula 12 [27]:

$$D_{ij} = \sqrt{(X_j^1 - M_i^1)^2 - (X_j^2 - M_i^2)^2} \tag{12}$$

After obtaining $D_1, \ldots, D_n$ in the function, the minimization operation is performed by the following formula, and each node is assigned to the cluster that has the shortest distance to it.

$$C_j = \text{Arg min } (D_{i,j} \ \forall\, i = 1:k) \tag{13}$$

As a result, the performance of the fitness function is calculated by the following formula:

$$\text{Fitness} = \sum_{j=1}^{n} \min(D_{i,j} \forall\, i = 1:k) \tag{14}$$

The whale optimization algorithm changes the clustered index using the best answers it obtains. It should be noted that the best answer to the problem is the answer that further reduces the cost function.

After performing the above steps, the first cluster head and the second one are determined according to the two remaining energy parameters and the distance of the nodes to the center of the cluster. The first cluster head is obtained by the WOA algorithm, and the second cluster head is selected based on the Euclidean distance. The first cluster head receives and aggregates information from its cluster nodes and then sends this information to the second cluster head. The second cluster head is responsible for sending data to the base station.

The flowchart of the whole process is given by Fig. 2.

V. EXPERIMENTAL SETUP

The proposed algorithm is simulated by MATLAB 2019b. To achieve more accurate results, experiments were performed on 20 different environments, and then we averaged the results. Also, the number of times the information was sent, or, in other words, the round number in this experiment is considered 3000. The simulation area of the network is 100m * 100m, and as mentioned before, we performed this experiment under two different scenarios. In other words, the experiment in two different positions of the base station at distances of 50m * 50m (first scenario) 99m * 99m (second scenario) and also with 100 and 300 nodes per scenario. It should be noted that this algorithm was

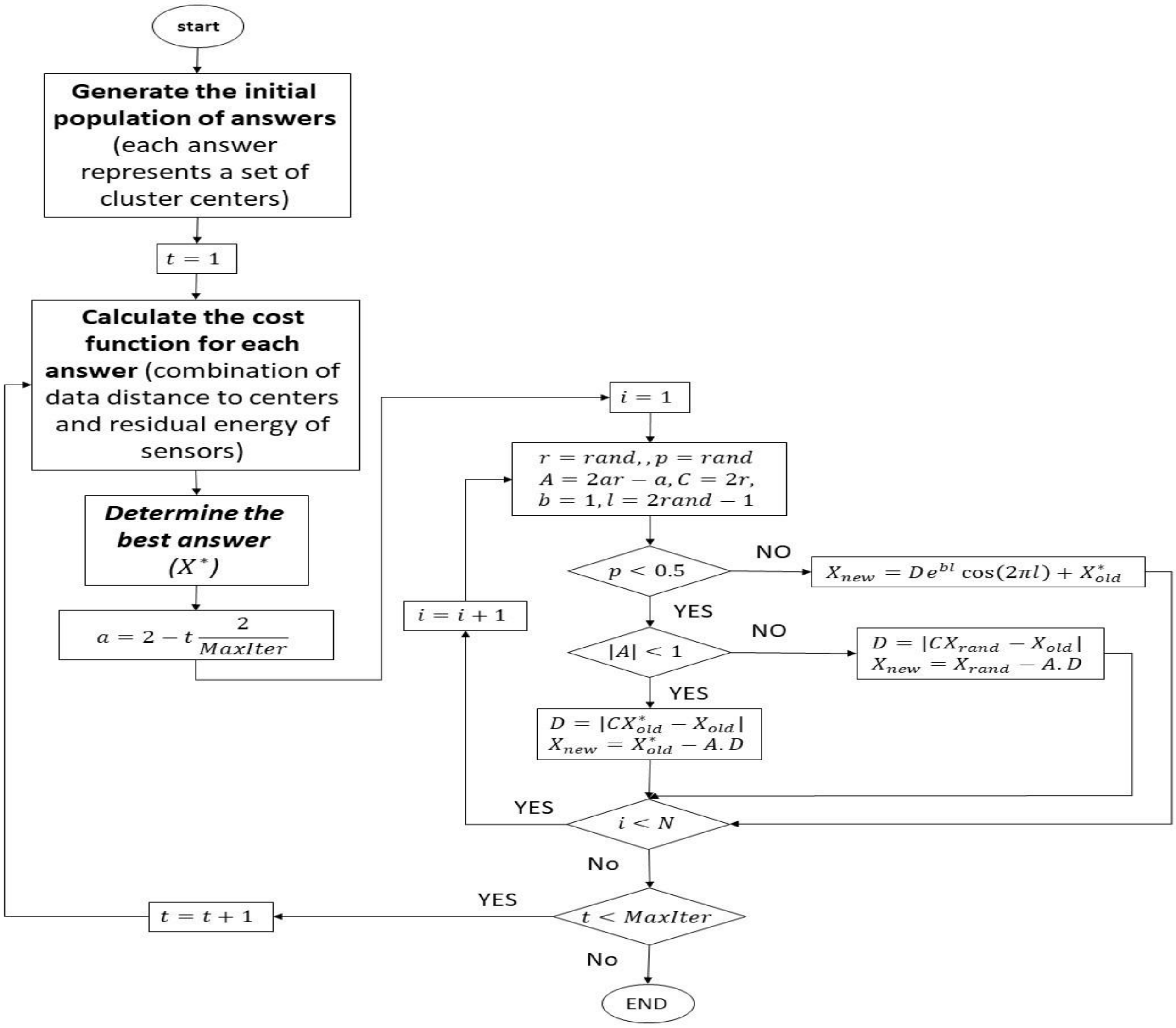

Fig. 2. Flowchart of the proposed method.

Table 1: Simulation parameter settings.

Parameters	Value
Simulation area	100m x 100m
Initial energy	0.5 J
Base station location	50m*50m & 99m*99m
Number of nodes	100, 300
Transmitter/Receiver Electronics	50x10^{-9} Jules/bit
ε_{mp}	0.0013x10^{-12} Jules/bit/m
ε_{fs}	10^{-11}Jules/bit/m
Packet length	6400 bit
Round length	100 s
Round number	3000

implemented 20 times, and the average of the obtained data was selected to draw the results. The parameters used to simulate the experiment are given in the table below.

VI. Results and Discussion

So far, many methods have been proposed to increase the accuracy of clustering, which reduces the energy consumption of nodes and increases throughput. The work was done also indicates the importance of increasing the throughput in wireless sensor networks. Therefore, our research has been done to increase throughput in wireless sensor networks. We were also able to increase throughput in wireless sensor networks while maintaining power consumption. One of the last works [13] done for clustering wireless sensor networks was not accurate enough in clustering due to random selection of cluster heads and used the LEACH-based method [9] for clustering. In this method, the cluster head is randomly selected, which reduces the throughput of wireless sensor networks. But the advantage of the O-LEACH method, which discriminates between nodes according to their initial energy and causes more stability in wireless sensor networks, should not be ignored.

In this research, more accurate clustering in wireless sensor networks led us to get the idea to use two cluster heads and to develop a WOA-based algorithm for setting clustering parameters. Because it performs clustering based on the residual energy of the nodes and the distance from the node to the center, and thus it increases the throughput of wireless sensor networks compared to previous examples. Therefore, we examined the advantages of the O-LEACH method, which was the same discrimination between nodes according to their initial energy, and decided that in addition to considering the residual energy of the nodes, we also consider the distance of the nodes to the center of the cluster to spend less energy for sending their information. Due to our attention to increasing the accuracy of clustering compared to previous methods, time execution increased in our method. It is suggested that in areas where time execution is important, other methods be substituted, or in future research, in addition to throughput, the issue of reducing time execution be examined. We named our proposed method WOA-O-LEACH. Each time in 20 different environments, we measured the amount of energy remaining, the number of dead nodes, and the number of packets received by the base station compared to the previous methods [9],[13].

In this section, we evaluate the proposed method (WOA-O-leach) and its parameters, including energy consumption [28], lifetime [29], and throughput [30] in the first scenario (50m * 50m) and then, in the second scenario (99m * 99m):

A. Energy consumption

Wireless sensor networks use techniques such as clustering, routing, duty cycle, data reduction, Data Prediction, Data acquisition and Data processing to reduce energy consumption. In these networks, a significant portion of the nodes' energy is spent transmitting data to the network center. Therefore, the energy used by the data from the source to the base station is the same as the energy consumed by the nodes [28]. In the following figure, the energy consumption forms of the proposed method with reference methods [9],[13] are presented under two scenarios. In Figs. 3 and 4, the

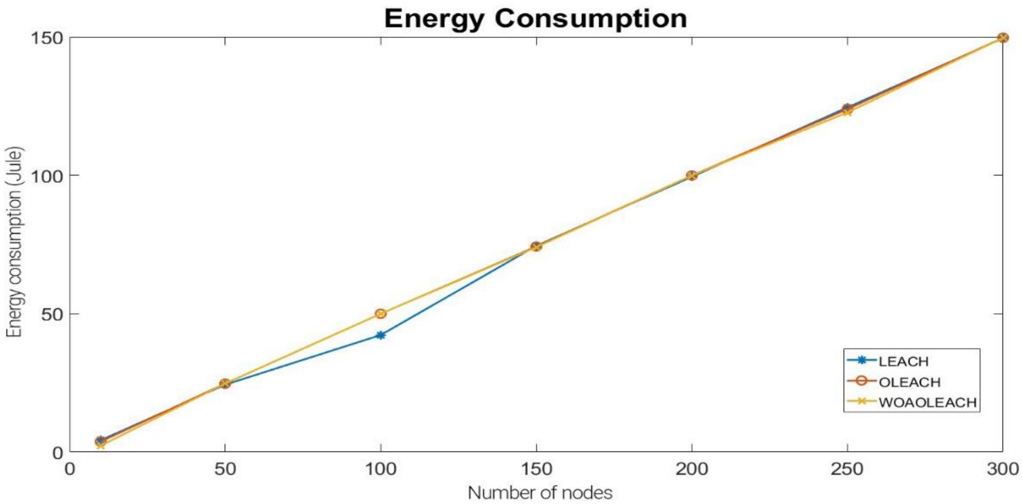

Fig. 3. Energy consumption in the first scenario.

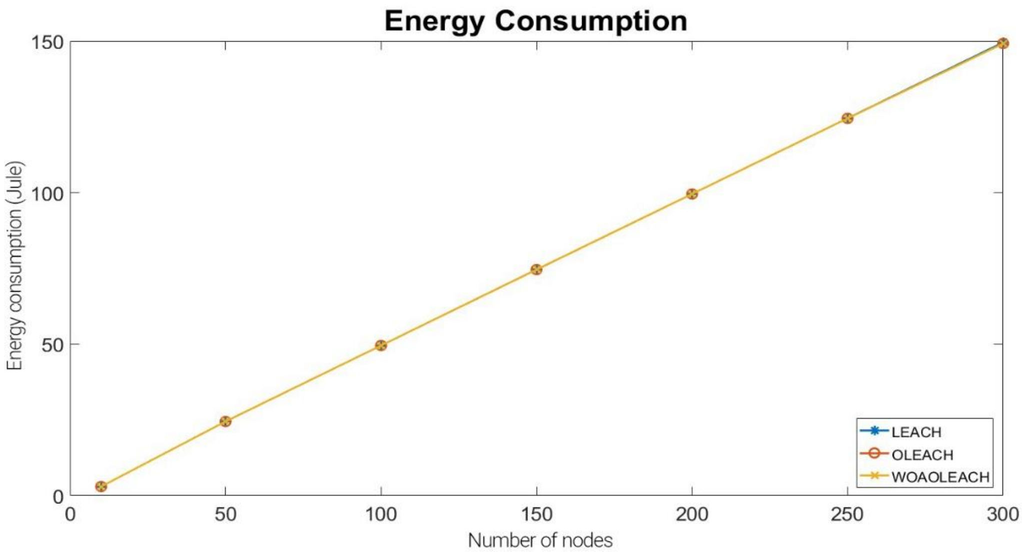

Fig. 4. Energy consumption in the second scenario.

horizontal axis represents the nodes in the network, and the vertical axis represents the amount of energy that the nodes have used to send their packets to the base station. It should also be noted that the unit of measurement for this energy is the joule. The following is shown in Fig. 3, which is the same comparison diagram of the energy consumption of the methods in the first scenario. As can be seen, the proposed method in this scenario has grown in terms of throughput while maintaining energy consumption.

A diagram of the energy consumption of the methods in the second scenario is shown in Fig. 4. It can be seen that the proposed method in this scenario has somewhat reduced energy consumption in the network or has grown in terms of throughput while maintaining energy consumption.

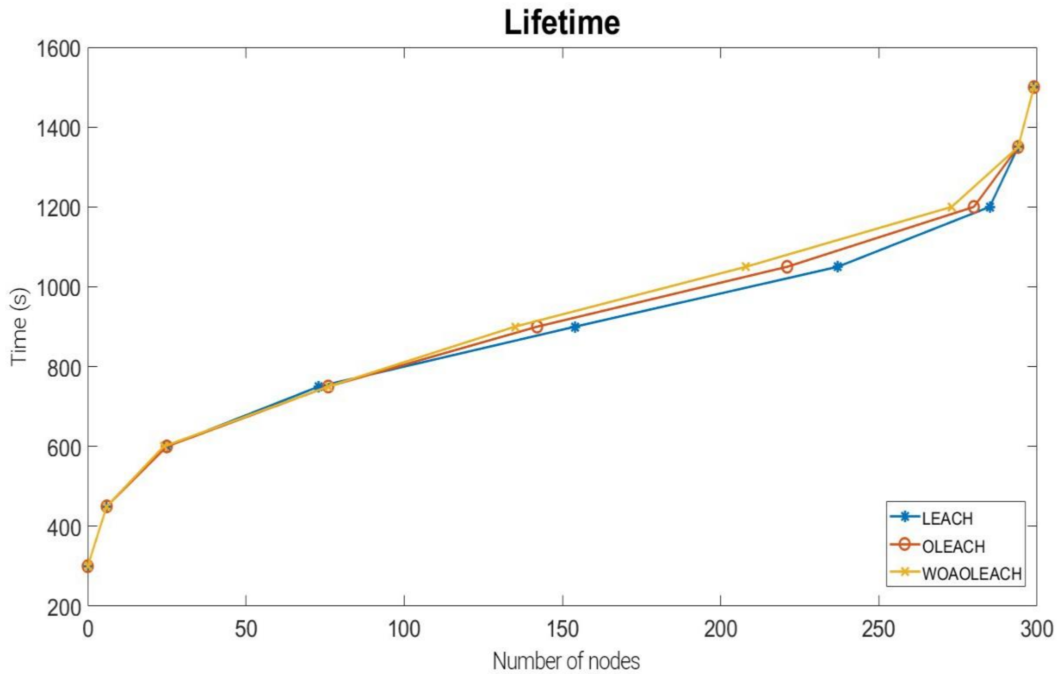

Fig. 5. Network lifetime in the first scenario.

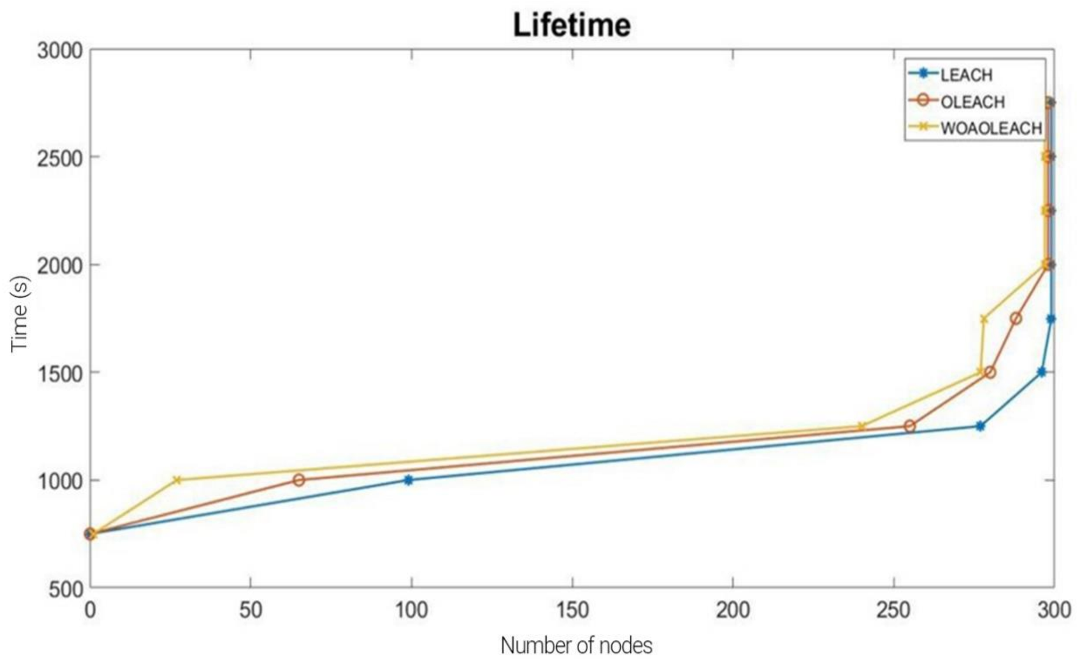

Fig. 6. Network lifetime in the second scenario.

A. Network Lifetime

One of the main limitations of wireless sensor networks is that the sensors are not rechargeable, or in other words, the lifetime of the network is limited. The time to end energy of the first node from the beginning of the network indicates the lifetime of the network [29]; this parameter strongly depends on how energy is consumed in the nodes. In this section, Figs. 5 and 6 show the lifetime of the proposed WOA-O-Leach method with reference methods [9],[13] in two scenarios. In these diagrams, the horizontal axis represents the number of dead nodes, and the vertical axis represents the round number in seconds. Fig. 5, which is the same diagram comparing the lifetime of the first scenario methods, is given. And as can be seen, the proposed method in this scenario has a lower number of dead nodes than other methods.

Fig. 6 shows a lifetime comparison diagram in the second scenario. It can be suggested that in both scenarios, the number of dead nodes is less than other methods, and as a result, the lifetime of the network is somewhat increased.

B. Throughput

Another major concern in wireless sensor networks is network throughput. Therefore, schemes to extend network lifetime or improve throughput are very useful in this area [30].Throughput indicates the ratio of data transfer information to the base station during the network run time. This is a function of the number of packets sent to the base station. Therefore, after recording the number of packets sent per node in different ways, they are converted to throughput by (15).

$$Throughput = \frac{Transmitted\ packet\ number * packet\ length}{Round\ Number * Round\ length(second)} \tag{15}$$

In the following, Figs. 7 and 8 show the throughput of the proposed WOA-O-Leach method with reference methods [9],[13] in two scenarios. In these diagrams, the horizontal axis represents the nodes in the network, and the vertical axis also shows the throughput of these nodes in bit/sec. Fig. 6, which is a comparison of the throughput in the first scenario, is also given. In the graph, the throughput is increased using WOA-O-Leach compared to Existing methods.

Fig. 8 shows a throughput comparison graph in the second scenario. It can be deduced that the proposed method in the second scenario has also increased throughput. Therefore, it can be said that the proposed method works better in both scenarios than the other methods, and throughput is improved in both scenarios by about 5.5%, which indicates the usefulness of using the whale optimization algorithm in clustering network nodes.

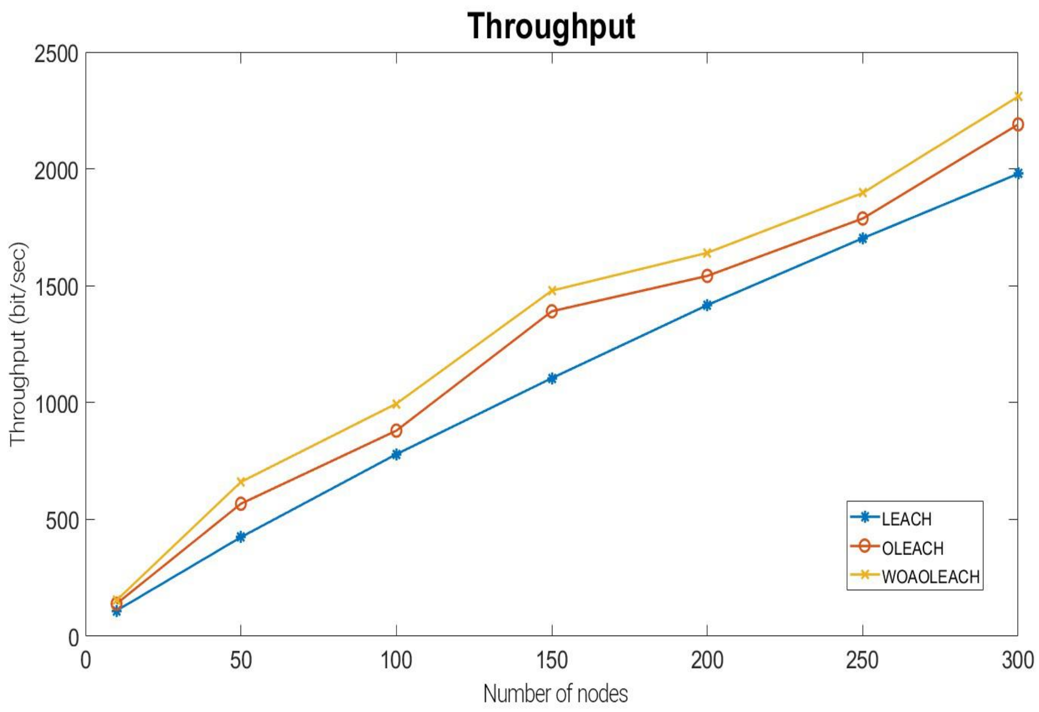

Fig. 7. Throughput in the first scenario.

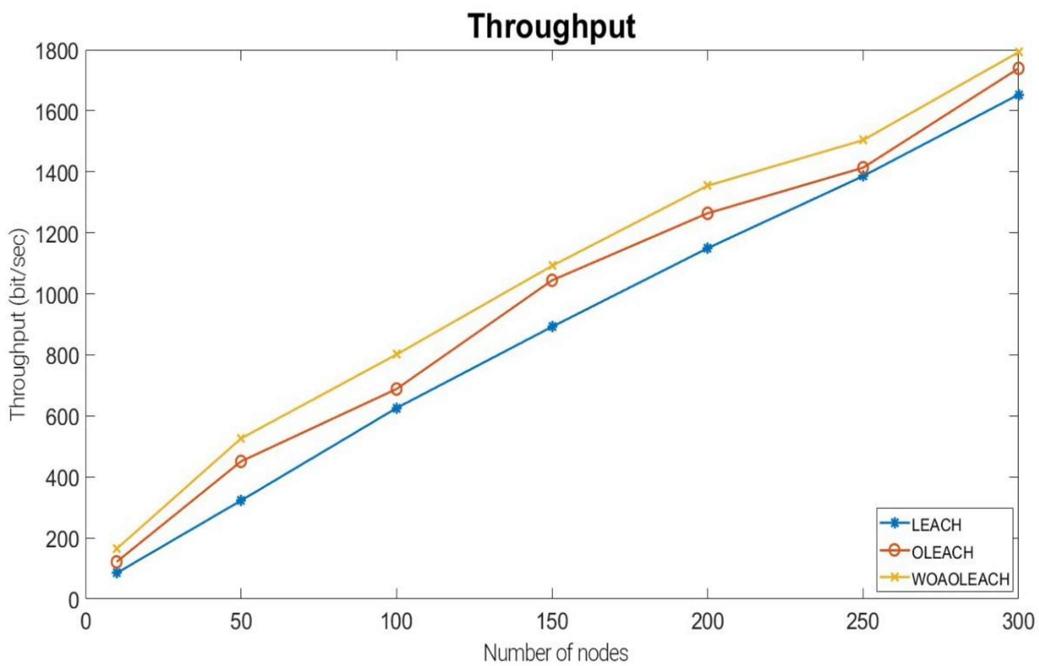

Fig. 8. Throughput in the second scenario.

VII. CONCLUSION

In this paper, an energy-efficient clustering algorithm in IOT-based wireless sensor networks using the Whale Optimization (WOA) algorithm called WOA-O-Leach is presented, the primary purpose of increasing the throughput in the wireless sensor networks. The performance of the fitness function saves energy as well as creates concentrated clusters by considering the residual energy and the minimum distance between the nodes and the center. Also, the usage of two cluster heads to collect data, aggregate data, and send them, has reduced the communication costs between the two clusters. Besides, the performance of the proposed method is evaluated against other previous protocols such as LEACH and O-LEACH, and the performance improvement of the proposed method in terms of energy consumption, lifetime, and throughput of the network is well shown. The results of our studies on the proposed method indicate that the two scenarios are not much different from each other; in other words, in both scenarios, we see a slight change in energy consumption and increase network lifetime, and in network throughput, we have increased by 5.5%. In order to simulate the research according to the dimensions of the network space, sensor nodes were randomly generated in space, and the desired idea was applied to them. Then all the values of the initial parameters for the research were determined. After implementing the WOA algorithm for clustering, this algorithm was able to improve the energy consumption and lifetime of the network and increase the throughput of the network. Given the many applications of wireless sensor networks, focusing on the most critical problem of these networks, namely energy limitation, can pave the way for practical applications of networks in all areas. We were able to increase the throughput by 5.5% in the proposed method using the WOA algorithm for more accurate clustering. However, in networks with many nodes, the complexity of the WOA-O-LEACH algorithm increases, so it is not recommended for networks with a large number of nodes. In future work, we can use other optimization algorithms or by changing the number of cluster heads and considering different parameters such as energy balance to examine the throughput of the network and take effective steps to increase the throughput of wireless sensor networks.

REFERENCES

[1] D. W. Sambo, B. O. Yenke, A. Förster, and P. Dayang, "Optimized clustering algorithms for large wireless sensor networks: A review," *Sensors*, vol. 19, no. 2, 2019, doi: 10.3390/s19020322.

[2] M. Kocakulak and I. Butun, "An overview of Wireless Sensor Networks towards internet of things," *2017 IEEE 7th Annu. Comput. Commun. Work. Conf. CCWC*, 2017, doi: 10.1109/CCWC.2017.7868374.

[3] K. Gulati, R. S. Kumar Boddu, D. Kapila, S. L. Bangare, N. Chandnani, and G. Saravanan, "A review paper on wireless sensor network techniques in Internet of Things (IoT)," *Materials Today Proc.*, vol. 51, part 1, pp. 161–165, 2022, doi: 10.1016/j.matpr.2021.05.067.

[4] N. Kaur and S. K. Sood, "An Energy-Efficient Architecture for the Internet of Things (IoT)," *IEEE Syst. J.*, vol. 11, no. 2, pp. 796–805, June 2017.

[5] S. R. Jino Ramson and D. Jackuline Moni, "Applications of Wireless Sensor Networks - A survey," *Proc. IEEE Int. Conf. Innov. Electr. Electron. Instrum. Media Technol. ICIEEIMT* 2017, vol. 2017-Janua, no. 978, pp. 325–329, 2017, doi: 10.1109/.2005.1467103.

[6] S. Kaur and R. Mahajan, "Energy efficient clustering protocol for wireless sensor networks," *Modern Phys. Lett. B*, vol. 32, no. 32, 2018, doi: 10.1142/S0217984918504006.

[7] M. M. Ahmed, E. H. Houssein, A. E. Hassanien, A. Taha, and E. Hassanien, “Maximizing lifetime of large-scale wireless sensor networks using multi-objective whale optimization algorithm,” *Telecommun. Syst.*, vol. 72, no. 2, pp. 243–259, 2019, doi: 10.1007/s11235-019-00559-7.

[8] I. Daanoune, B. Abdennaceur, and A. Ballouk, “A comprehensive survey on LEACH-based clustering routing protocols in Wireless Sensor Networks,” *Ad Hoc Networks*, vol. 114, p. 102409, Apr. 2021, doi: 10.1016/j.adhoc.2020.102409.

[9] S. E. L. Khediri, N. Nasri, A. Wei, and A. Kachouri, “A new approach for clustering in wireless sensors networks based on LEACH,” *Procedia Comput. Sci*., vol. 32, pp. 1180–1185, 2014, doi: 10.1016/j.procs.2014.05.551.

[10] M. Arora, “Energy efficient DSBCA for the complex network,” J. Green Eng., vol. 10, no. 9, pp. 6143–6152, 2020.

[11] S. Siavoshi, Y. S. Kavian, and H. Sharif, “Load-balanced energy efficient clustering protocol for wireless sensor networks,” *IET Wirel. Sens. Syst.*, vol. 6, no. 3, pp. 67–73, 2016, doi: 10.1049/iet-wss.2015.0069.

[12] F. Chiti, R. Fantacci, R. Mastandrea, G. Rigazzi, Á. S. Sarmiento, and E. M. M. López, “A distributed clustering scheme with self nomination: proposal and application to critical monitoring,” *Wirel. Networks*, vol. 21, no. 1, pp. 329–345, 2015, doi: 10.1007/s11276-014-0785-z.

[13] S. A. Jesudurai and A. Senthilkumar, “An improved energy efficient cluster head selection protocol using the double cluster heads and data fusion methods for IoT applications,” *Cogn. Syst. Res.*, vol. 57, pp. 101–106, 2019, doi: 10.1016/j.cogsys.2018.10.021.

[14] Z.-F. MA and G.-M. LI, “Improvement on LEACH-C Protocol for Wireless Sensor Network,” *Artificial Intelligence Science and Technolo*gy, pp. 362-368, 2017, doi: 10.1142/9789813206823_0048.

[15] P. Kuila and P. K. Jana, “Energy efficient clustering and routing algorithms for wireless sensor networks: Particle swarm optimization approach,” *Eng. Appl. Artif. Intell.*, vol. 33, pp. 127–140, 2014, doi: 10.1016/j.engappai.2014.04.009.

[16] S. S. Kim, S. McLoone, J. H. Byeon, S. Lee, and H. Liu, “Cognitively Inspired Artificial Bee Colony Clustering for Cognitive Wireless Sensor Networks,” *Cognit. Comput.*, vol. 9, no. 2, pp. 207–224, 2017, doi: 10.1007/s12559-016-9447-z.

[17] P. Singh Mann and S. Singh, “Energy efficient clustering protocol based on improved metaheuristic in wireless sensor networks,” *J. Netw. Comput. Appl.*, vol. 83, pp. 40–52, 2017, doi: 10.1016/j.jnca.2017.01.031.

[18] V. Gupta and S. K. Sharma, “Cluster head selection using modified ACO,” *Adv. Intell. Syst. Comput.*, vol. 335, pp. 11–20, 2015, doi: 10.1007/978-81-322-2217-0_2.

[19] R. Bao, H. Pan, Q. Dong, L. Yu, and L. Shao, “Ant colony-based routing algorithm for wireless sensor networks,” *Chinese J. Sensors Actuators*, vol. 24, no. 11, pp. 1644–1648, 2011, doi: 10.3969/j.issn.1004-1699.2011.11.025.

[20] X. Yuan, M. Elhoseny, H. K. El-Minir, and A. M. Riad, “A Genetic Algorithm-Based, Dynamic Clustering Method Towards Improved WSN Longevity,” *J. Netw. Syst. Manag*., vol. 25, no. 1, pp. 21–46, 2017, doi: 10.1007/s10922-016-9379-7.

[21] T. Wang, G. Zhang, X. Yang, and A. Vajdi, “Genetic algorithm for energy-efficient clustering and routing in wireless sensor networks,” *J. Syst. Softw.*, vol. 146, pp. 196–214, 2018, doi: 10.1016/j.jss.2018.09.067.

[22] H. Echoukairi, K. Bourgba, and M. Ouzzif, “A survey on flat routing protocols in wireless sensor networks,” *Lect. Notes Electr. Eng.*, vol. 366, no. 5, pp. 311–324, 2016, doi: 10.1007/978-981-287-990-5_25.

[23] G. Kumar, H. Mehra, A. R. Seth, P. Radhakrishnan, N. Hemavathi, and S. Sudha, “An hybrid clustering algorithm for optimal clusters in wireless sensor networks,” *2014 IEEE Students’ Conf. Electr. Electron. Comput. Sci. SCEECS* 2014, pp. 1–6, 2014, doi: 10.1109/SCEECS.2014.6804442.

[24] H. Ali, “Energy Efficient Hierarchical Clustering Mechanism for Wireless Sensor Network Fields,” *Int. J. Comput. Appl.*, vol. 153, no. 8, pp. 42–46, 2016, doi: 10.5120/ijca2016912130.

[25] S. Mirjalili and A. Lewis, “The Whale Optimization Algorithm,” *Adv. Eng. Softw*are, vol. 95, pp. 51–67, 2016, doi: 10.1016/j.advengsoft.2016.01.008.

[26] F. S. Gharehchopogh and H. Gholizadeh, "A comprehensive survey: Whale Optimization Algorithm and its applications," *Swarm Evol. Comput.*, vol. 48, pp. 1–24, 2019, doi: 10.1016/j.swevo.2019.03.004.

[27] H. Wang, H. Chang, H. Zhao, and Y. Yue, "Research on LEACH algorithm based on double cluster head cluster clustering and data fusion," *2017 IEEE Int. Conf. Mechatronics Autom. ICMA*, pp. 342–346, 2017, doi: 10.1109/ICMA.2017.8015840.

[28] H. Patel and V. Shah, "A review on energy consumption and conservation techniques for sensor node in WSN," *Int. Conf. Signal Process. Commun. Power Embed. Syst. SCOPES* 2016 - Proc., pp. 594–599, 2017, doi: 10.1109/SCOPES.2016.7955508.

[29] C. W. Tsai, T. P. Hong, and G. N. Shiu, "Metaheuristics for the Lifetime of WSN: A Review," *IEEE Sens. J.*, vol. 16, no. 9, pp. 2812–2831, 2016, doi: 10.1109/JSEN.2016.2523061.

[30] S. Jabbar, A. A. Minhas, M. Imran, S. Khalid, and K. Saleem, "Energy efficient strategy for throughput improvement in wireless sensor networks," *Sensors*, vol. 15, no. 2, pp. 2473–2495, 2015, doi: 10.3390/s150202473.