Presenting a New Approach for Clustering Optimization in Wireless Sensor Networks using Fuzzy Cuckoo Search Algorithm

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***Abstract*—Because of the developments in this technology, wireless sensor networks are now among the most commonly used in the domains of agriculture, harsh environments, medical, and the military. Among the many problems with these networks is their limited lifespan. Much work has been done in the fields of sensor communication, routing, and data gathering to reduce energy usage and increase network life. Routing protocols and clustering algorithms are two techniques for reducing energy use. Selecting the cluster head is the most important stage in any clustering technique. The objectives of this article are to decrease total energy consumption, increase packet delivery rates, and lengthen the network's lifetime. In order to do this, the LEACH protocol uses cuckoo search instead of probability distribution during the cluster head selection step and fuzzy logic during the routing phase. A MATLAB environment was utilized to evaluate the proposed method with the LEACH algorithm under identical conditions. The results of the comparison show that the recommended approach does a better job of prolonging the network's lifetime than the LEACH protocol.**

Keywords—Wireless sensor network; fuzzy cuckoo search algorithm; clustering; fuzzy model

I. Introduction

Recent improvements in electronics and telecommunications have made it possible to employ low-cost sensor networks. Sensor networks have been utilized due to the diverse properties of sensors, with researchers proposing several ways [1, 2, 3]. In military contexts, attributes such as fault tolerance, rapid operating speed, and network self-organization allow for network control, orderly calculations, and information reception. Sensors in medical settings can aid individuals with disabilities or oversee a patient inside a network. Sensor networks also have uses in business sectors such as management, remote area surveillance, and product quality supervision [4, 5].

Sensors send data across short distances and are small in size. Each small sensor contains a receiving unit, a processing unit, and an information transmission unit [6, 7, 8]. A sensor network consists of numerous sensors that are extensively spread across the surroundings. Engineering is unnecessary for determining the exact geographic locations of the sensors; thus, they are randomly scattered in remote, inaccessible areas. Protocols and algorithms provide the automatic transfer and processing of information in sensor networks [9]. We can identify the processor used in sensors along with their other unique features [10, 11]. The sensors utilize this processor to locally process the data before transmitting only the essential portion, instead of broadcasting the complete dataset. Clustering is a technique used to optimize coverage and efficiently send network-related data to a central base. Network nodes are segregated into distinct groups known as clusters using the clustering method. Each cluster is led by a cluster head that efficiently distributes information either immediately or progressively, using minimal steps or relying solely on cluster head nodes for data gathering and transmission to the central station. Clustering in sensor networks is utilized to efficiently manage network nodes, reduce energy usage, extend coverage across a wider geographic area, and decrease information transmission time. Each cluster needs a cluster head to send the collected data to the central station. Choosing the cluster head node is a critical part of clustering. Network nodes must consistently follow a specific pattern to select clusters and cluster heads in wireless sensor networks, as node performance can vary and be non-linear. Therefore, using methods that offer definitive solutions may not be advantageous. Using the LEACH (Low-Energy Adaptive Clustering Hierarchy) method is recommended as a clustering technique. Despite its advantages, this method has limitations, such as relying on one-step communication, which renders it impractical for extensive networks. Moreover, ensuring load balance is not possible by choosing Cluster Heads based on a uniform distribution probability. The clustering problem will be solved using the fuzzy approach and cuckoo search algorithm, with efforts made to reduce the algorithm's limitations. Each egg in the cuckoo search algorithm symbolizes a potential solution for a problem that requires selecting the center of a cluster. The goal is to find the clusters that result in the minimum cost function value, as the fuzzy technique will be used in the routing phase.

A more precise acknowledgment of the limitations of the proposed method, including things like the limitations imposed on the fuzzy duck search algorithm and their impact on the overall efficiency of the method, can be an important step to create a clear path in future research. To overcome these limitations, it is possible to improve and adjust algorithm parameters, apply changes in different phases of the method, or even use newer and more advanced methods. In addition, for further exploration and promotion of the discourse, it is possible to refer to the study of the effect of combining other algorithms with the proposed method, the study of different environmental effects on the performance of the method, and the possibility of applying this method in other fields of application. These suggestions not only enrich the discourse, but also encourage further research and contribute to the development and improvement of the field.

The proposed method in this paper, by combining the LEACH protocol with the fuzzy duckling search algorithm, designs a new approach to optimize clustering in wireless sensor networks. This approach focuses on the goals of reducing energy consumption, increasing packet delivery rate, and increasing network life by using fuzzy duck search algorithm instead of probabilistic distribution in the cluster head selection phase and using fuzzy logic in the routing phase. This approach is generally separated from existing methods in the field of clustering and routing in wireless sensor networks, and by combining fuzzy duck search algorithm and fuzzy logic, it increases its importance and efficiency. The writers' collective contribution to this work is summarized as follows:

- By using fuzzy clustering, the network's lifetime was extended.
- The cuckoo search technique was used to enhance clustering.
- More packages arrived at their destination thanks to clustering.

This is how the rest of the article is structured. The prior studies and their solutions are examined in the Section II. The suggested model is covered in Section III. The assessment and application of the suggested remedy are provided in Section IV and the conclusion and next steps are provided in the Section V.

II. Related Works

The limited energy of network sensors is one of the problems facing wireless sensor networks. In the areas of routing, network layer protocols, transmission layer research, management of distributed activities amongst sensors, and approaches inspired by nature, there are a lot of well-known studies and publications. It is offered to extend and enhance the network's life. Routing protocols are in charge of identifying and preserving communication channels that use less energy [12]. Because routing protocols have an impact on the network's energy consumption, researchers take routing techniques into account while designing their protocols, making adjustments to suit the application, environment, and service quality of the request. And they are separated into three groups: flat, clustered, and location-based routing. Nodes in clustering protocols are grouped in accordance with the necessary request [13]. The network's energy usage is impacted by the creation of clusters and the tasks given to the cluster heads. Considering that sending and processing need energy consumption, the cluster head receives data from all cluster members and forwards it to the destination after processing. As such, selecting the cluster head and routing is crucial to the network's longevity. The development of low-cost circuits to perceive and transmit the state of the surrounding environment is made feasible by the advancements in communication and sensor technologies [14]. Applications for wireless networks of these circuits, or wireless sensor networks (WSN), include environmental sensing, smart industries, healthcare, and military defense. Reliable data interchange between various sensors and effective connection with the data collecting center are the core issues facing WSNs. The best method for increasing WSN performance characteristics is clustering to get around clustering techniques' drawbacks, such as a shorter cluster head (CH) lifetime [15]. A successful WSN solution must have an efficient CH selection mechanism, an ideal routing protocol, and trust management. In order to extend the network's lifetime and boost confidence, a type 2 fuzzy logic clustering technique is used in [16] to propose an optimization algorithm for cuckoo searches. To minimize wasted energy from CHs remote from the BS, a multi-hop routing strategy is utilized for inter-cluster communication and a threshold-based data transmission algorithm is employed for intra-cluster communication. The outcomes of the simulation demonstrate that the suggested approach beats alternative communication methods in terms of effectively eliminating rogue nodes as well as energy usage, stability duration, and network longevity [17]. Sensor nodes use the most energy when transferring data since their energy consumption is constant when monitoring data and receiving data packets from other nodes. As a result, routing strategies built on systematic methodologies aim to use less energy. Clustering nodes and choosing string nodes based on data transmission parameters is one of the most promising ways to lower energy consumption in wireless sensor networks. This will increase the network's lifetime and lower the average energy consumption of the nodes [18]. For wireless sensor network clustering, a novel optimization strategy based on the cuckoo algorithm and multi-objective genetic algorithm is thus described in this study. The research in [19] used near-optimal routing based on the cuckoo optimization algorithm to transmit data between nodes in order to choose cluster nodes from a multi-objective genetic algorithm based on reducing intra-cluster distances and reducing energy consumption in cluster member nodes. The results of the implementation demonstrate that the suggested method has improved over previous methods in terms of energy consumption, efficiency, delivery rate, and packet transmission delay. This improvement can be attributed to the evolutionary capabilities of the multi-objective genetic algorithm and the cuckoo optimization algorithm.

For the best CH selection to preserve energy stability over a long network lifetime, a dynamic clustering protocol based on the seagull and whale optimization algorithm (HSWOA-DCP) with WOA exploitation advantages and SEOA discovery advantages is suggested in study [20]. The Seagull Optimization Algorithm (SEOA) was updated for this HSWOA-DCP in order to solve the early convergence issue and maximize computational accuracy during CH selection. Due to SEOA's helix attack behavior's resemblance to the characteristics of WOA's bubble network, its integration into the CH selection process enhanced the global search capability and inhibited the selection of the lowest fitness nodes as CH. The concepts of WOA surrounding contraction mechanism and SEOA spiral attack are integrated into this CH selection to increase computation accuracy and prevent repetitive election processes.

A clustering mechanism based on the Dingo Optimization Algorithm (MDOACM) is presented in study [21] to overcome the cluster head (CH) lifetime and cluster quality restrictions of the clustering protocol. The trust level of each sensor node is ascertained using this MDOACM-based clustering technique using Distance Type 2 Fuzzy Logic (IT2FL), as the existence of an untrusted node negatively impacts the quality and reliability of the data. In order to prevent frequent re-clustering, it explicitly used MDOA to improve clustering with a balanced trade-off between exploration and exploitation rates. With low energy usage, it effectively blocks malicious nodes and lengthens the lifespan of the network. Additionally, during the entire exploration data transfer, it made use of a communication system that helps the sensors reach the goal with the least amount of energy and the highest degree of certainty.

In order to increase node density and coverage area for scalable scenarios, researchers in study [22] presented a clustering strategy based on the fuzzy method and applied it to agriculture. They concentrated on network and data link level optimizations as well as energy consumption optimization. The suggested technique outperforms other methods for scalable scenarios in terms of half-dead and final-dead nodes, according to simulation results. As a result, IoT systems can be used.

In the [23] method, CHs work together to route data packets over many hops in order to reduce WSN energy usage. However, data forwarding nodes may experience congestion during the data routing phase. In order to address the issue of congestion, they have proposed a variant of the Random Early Congestion (RED) control approach that is distance-based and allows for more intelligent packet drops. Additionally, the Moth-Flame Optimization algorithm was used to modify and minimize the rules of the suggested FLCs in order to maximize their efficacy [24]. The simulation results demonstrate how well the suggested distance-based RED clustering and congestion control strategy works to increase packet loss percentage, decrease retransmissions, and improve WSN lifetime.

Research in [25] suggests a hybrid particle swarm optimization-cuckoo search optimization approach for clustering sensor nodes in a QoS-aware multipath routing protocol. The suggested protocol then uses Cluster Heads to choose several stable paths (optimal network routing) for data transmission based on multi-hop communication. In contrast to current protocols, it uses routes for quick data transport that don't impact QoS. Not only does it use the appropriate number of pathways for data transmission, unlike other QoS-centric protocols, but it also extends the lifetime of the network by periodically changing the Cluster Head based on the remaining energy. Using the NS-2 simulator, the suggested protocol's performance is assessed in several scenarios. The suggested protocol performs better than the current protocols in terms of QoS metrics, including throughput, packet delivery ratio, end-to-end delay, and network lifetime, according to the simulation findings.

III. The Proposed Method

Every node in the LEACH protocol has a defined probability of being chosen as the cluster head; nevertheless, some unsuitable sensor nodes may also be chosen, adding to the expense. Clusters with a single member may form using this protocol; in such cases, the nodes' energy will run out rapidly since they are transmitting data straight to the central station. On the other hand, these clusters can be eliminated by cluster mergers. Due to the random nature of this method's cluster head selection, there is a chance that some choices will result in significant energy consumption for critical sensor nodes that connect two sub-networks within the network, which could lead to the network's disconnection [26, 27]. The cluster head is chosen using the cuckoo search algorithm in the suggested strategy to optimize the LEACH protocol. The process of laying eggs and raising cuckoos served as the inspiration for this algorithm, which belongs to the population-based algorithm category. Each bird lays only one egg at a time, placing it in a randomly chosen nest (each nest holds one solution) in accordance with this procedure. Nests with higher-quality eggs (solutions) pass on to the next generation.

Throughout the algorithm's execution, the number of nests that are available stays constant, and the host bird has a probability of pa to identifying the guest egg. The host bird, in this case, has two options: either discard the guest's egg or relocate the nest entirely [28]. N percent of the current nests are replaced by new nests (with new random solutions in new locations) in Young's method to simplify pa. In actuality, each cuckoo egg that is laid in a nest symbolizes a solution. Each nest is a potential solution in the hunt for the common cuckoo (single criteria), as each nest only contains one egg deposited in it. Stated differently, the concept being discussed is shared by the solution, the nest, and the egg. With the aid of Levi's flight, new cuckoo search strategies are developed [29, 30]. A random walk with random steps whose durations adhere to a Lévy distribution is called a Lévy flight. Generally speaking, the cuckoo search algorithm selects the head of the suggested approach as follows:

- Using Levi's flight path, randomly produce a new answer (cluster vertices) such as i.
- Select a small number of nodes as network heads.
- Next, using the fitness function, the chosen node's quality is assessed.
- The fitness function is used to assess the new answer's quality.
- The revised answer's quality is contrasted with the chosen answer's quality. In the event that the new response meets higher quality standards, it takes the place of the chosen response.
- With the aid of Levi's flight, it discards the worst nests (wrong locations) and rebuilds them in a new location.
- Continue until the termination requirements are satisfied by going back to step two (optimal solution).
- Show the top response that was received.

As the aforementioned stages are repeated, the nests progressively approach the optimal points, and at the conclusion of the algorithm's execution, all N nests congregate near the optimal sites.

The probability of a node not being suitable and selecting a new one is measured by the implemented method, and its Pa value is 0.25. This decision was made based on Yang's simulation results, which indicate that the algorithm's convergence rate is independent of this parameter's value. Yang thought that a value of 0.25 would work well in a variety of situations. All of the randomly generated solutions must be found within the problem's solution space. When performing random steps, care should be given to ensure that the destination locations stay inside the potential space boundary, as the step length follows a certain probability distribution [9]. The simulation environment described in this article has square dimensions. The area where every requirement of the problem is met is the space of potential solutions. The following two limitations need to be followed when generating and modifying the values of each answer (nest):

- All the elements of the vector must have a value ranging from zero to one.
- It is necessary for each vector's component values to add up to one.
- The available responses do not include the vectors that do not apply to the two conditions mentioned above.

The available responses do not include the vectors that do not apply to the two conditions mentioned above.

It is feasible to produce random values that satisfy the first two requirements since the current nodes are dispersed randomly throughout the environment using various techniques. Making up positive random values and dividing them all by their sum is one of the easiest methods [31, 32]. Values between zero and one are generated using this straightforward method, and their sum equals one. An alternative method involves producing a random value at random and mapping it to the interval between zero and one. We then assign a random replacement to the generated answer at the end, and the subsequent random values are mapped to the interval between zero and the sum of the created values. Cuckoos are the group of cluster heads, or network clusters that are not a part of the network nodes after the cuckoo search algorithm has completed its clustering.

Consequently, in this article, the position and energy of the cluster heads found using the cuckoo search algorithm will be discussed. The node chosen to be the cluster head is the one with the smallest Euclidean distance to the cluster center. The LEACH protocol's routing employs one-step communication, sending data straight from the cluster head to the sink and from the cluster head's delivery node.

The suggested method of routing makes use of multi-step communication. The transfer from the source node to the source cluster node occurs in the first phase, between the source node and the source cluster node in the second, and between two cluster nodes depending on the cluster nodes in the third. There will probably be multiple routes in each stage, chosen using the fuzzy approach. Fazi examines and analyzes from zero to one as opposed to working with zero and one. To put it another way, fuzzy logic transforms sets with two members—zero and one in Aristotelian logic into sets with infinite members that have values ranging from zero to one. As such, it is appropriate to select the best course of action.

A. *The Role of the Cuckoo Search Algorithm in Improving LEACH Protocol Clustering*

Inspired by the life of the cuckoo bird, Cuckoo Search is a revolutionary way of global conscious search that begins with a cuckoo population. Numerous host birds' nests are home to the numerous eggs that cuckoos lay there. More of these eggs that resemble the host bird's eggs will have a better chance of developing into adult cuckoos. The host bird recognizes other eggs and destroys them. The quantity of fully developed eggs indicates how appropriate the nests are there. A location receives greater attention the more eggs that can survive there and are preserved. Therefore, a parameter that seeks to optimize it will be the scenario in which the greatest number of eggs are rescued. Cuckoos search for the ideal location to increase the chances that their eggs will survive [33, 34]. Every cuckoo randomly deposits its eggs in the host bird's nest, which is within its egg-laying radius.

A random process has a random course that consists of a succession of random stages. S_N forms a random walk if, in mathematical terms [35], X_N is the total of consecutive random steps of X_i:

$$S_N = \sum_{i=1}^{N} X_i = X_1 + \cdots + X_N \tag{1}$$

where, is a random distribution with a random step. It is also possible to write the connection (1) recursively:

$$S_N = \sum_{i=1}^{N-1} X_i = X_{N-1} + X_N \tag{2}$$

Relation (2) illustrates how S_N and X_N pass from one state to the next in a dependent manner. The primary characteristic of the Markov chain is this one. Numerous fields, including physics, economics, statistics, computer science, the environment, and engineering, use random walks [36]. One of the few stable distributions that is continuous for non-negative random variables is the Levy distribution. The Levy distribution's density function is as follows (3):

$$L(s,\gamma,\mu) = \sqrt{\frac{\gamma}{2\pi}}\frac{1}{(s-\mu)^{\frac{3}{2}}}\exp\left(-\frac{\gamma}{2(s-\mu)}\right) \qquad 0<\mu<s<\infty \tag{3}$$

where γ is the size parameter, and μ is the minimum number of steps. Assuming $s \to \infty$

$$s \to \infty\ L(s,\gamma,\mu) = \sqrt{\frac{\gamma}{2\pi}}\frac{1}{(s-\mu)^{\frac{3}{2}}} \tag{4}$$

The random steps, s can be produced by Mantegna's algorithm [37]. The step lengths s for this algorithm will be as follows:

$$s = \frac{u}{|v|^{1/\beta}} \tag{5}$$

that the variables v and u have a normal distribution.

$$u \sim N(0,\sigma_u^2) \quad , \quad v \sim N(0,\sigma_u^2) \tag{6}$$

where relation (7) provides the value of σ.

$$\sigma = \left\{\frac{\Gamma(1+\beta)\sin\left(\pi\beta/2\right)}{\Gamma\left|(1+\beta)/2\right|\beta\times 2^{(\beta-1)/2}}\right\}^{1/\beta} \tag{7}$$

In Eq. (7), Γ represents the gamma function. For $|s|\geq|s0|$, where s0 is the smallest step, the distribution obtained for s will be a Lévy distribution. As previously indicated, a Lévy walk, also known as a Lévy flight, is a unique kind of random walk in which the step length complies with the Lévy distribution. Levy flight is actually just a random walk with random steps that have lengths that correspond to Levy distributions. The findings of numerous research on the flying of insects and birds have demonstrated that many of these species' flight patterns resemble Levi's flight. Fig. 1 illustrates the flight of Levi.

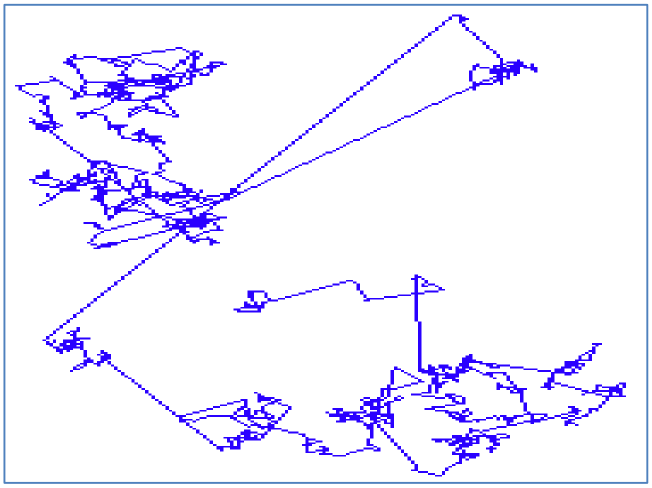

Fig. 1. Levi's flight display.

The cuckoo search yields new solutions through the application of Lévy flight and relation in Eq. (8):

$$x_i^{(t+1)} = x_i^{(t)} + \alpha \otimes \text{Levy}(\lambda) \tag{8}$$

Where, $\otimes$ is the component-to-component multiplication operator and α is the step size. It makes sense that the number of algorithmic steps determines how much the optimal solution differs from the current one since, in the real world, the more the cuckoo eggs resemble the host bird's eggs, the higher the likelihood of survival and the greater the chance of misidentification [38].

$$\alpha \propto \left|x_i^{(t)} - x_{\text{best}}^{(t)}\right| \tag{9}$$

The following ten steps can be used to describe the cuckoo search algorithm:

- Create N nests of x_i at random; each x_i is a vector of dimension n or the N dimensions of the answer space (search space).
- Create a fresh response at random, similar to mine, using Lévy flight.
- Apply the evaluation function F to determine the answer's quality.
- Select a random nest from N, such as j, then assess the quality of j's response (F_j).
- In the event where $Fi>F_j$, substitute response i for j.
- With the aid of Levi's flying, destroy the worst nests (a portion of the worst nests) and rebuild them in a new area.
- Save your best responses or nests.
- Sort the responses to identify which ones are best.
- Continue to the second stage until the requirements for termination are satisfied.
- Display your best response (number 32).

As a result, cuckoo search can be crucial to the LEACH protocol's optimal cluster head selection. As a result, by selecting the best node to serve as the cluster head in the sensor network, energy consumption is saved and decreased [39, 40, 41].

B. Suggested Method

Clustering and routing are the two stages of the suggested methodology. The cuckoo search algorithm is utilized to create clusters during the clustering phase, while fuzzy logic is employed for routing during the routing phase.

1) Clustering: Three parameters, energy, x, and y, that represent the components of the node location are utilized in the cuckoo search to create clusters. The method illustrated in Fig. 2 selects a fixed number of nodes as the best cluster head initially. Then, based on the Euclidean distance and energy of the nodes in the network containing the selected nodes, the fitness level of the nodes that is calculated as the best-selected cluster head is determined at random using Levi's flight within the space and energy network of multiple nodes, and is assessed using the fitness function. Finally, the fitness level of Levi's flight clusters with the optimal cluster head's fitness is contrasted. The Levi cluster heads are chosen as the best cluster heads if their fitness is higher, and more locations are chosen utilizing the Levi flight once again. The distance between the chosen places in Levi's flight and the optimal position is determined by the distance between the current location of Levi's flight and the locations that Levi's flight has already obtained. Levi's flight is used to select a site. It then compares its appropriateness to a better place and selects the best suitability. This procedure is repeated until the algorithm finds the ideal solution, which in this article's implementation is 200. There are locations chosen by the algorithm that are not appropriate; their chance is estimated to be 25%. If these locations show up in the program, they are disregarded, and another location is selected by the new place's flight. The nodes with the closest energy and distance to them are referred to as the cluster head, while the remaining nodes select their head based on their energy and distance from the cluster head after the optimal energy and locations are found using the Cuckoo Search method.

The proposed method can be more suitable for some types of data. This could be due to the specific characteristics of this method compared to other methods and the type of data that are commonly used in wireless sensor networks. In particular, the proposed method can be considered suitable for data that needs clustering and routing.

For example, if wireless sensor data are grouped based on their physical location and need to be sent to a specific hub (e.g., a data center), the proposed method that uses clustering with Cocoa search algorithm and fuzzy logic for routing, it can be very convenient. This method uses good clustering facilities with Cocoa search algorithm to form clusters and fuzzy logic to select the optimal path for data transmission, which can significantly improve network performance and efficiency.

In addition, if the data needs to be routed from several nodes and the network is topologically complex, using fuzzy logic to select the route can be effective. Fuzzy logic is capable of managing complex conditions and uncertainty in the network, and this can help improve network performance.

In general, if the data needs to be clustered and routed and has special characteristics such as topology complexity or the need for good energy management, the proposed method can be a suitable option. But for data that requires more complex processing or unstructured data management, other methods may be more appropriate.

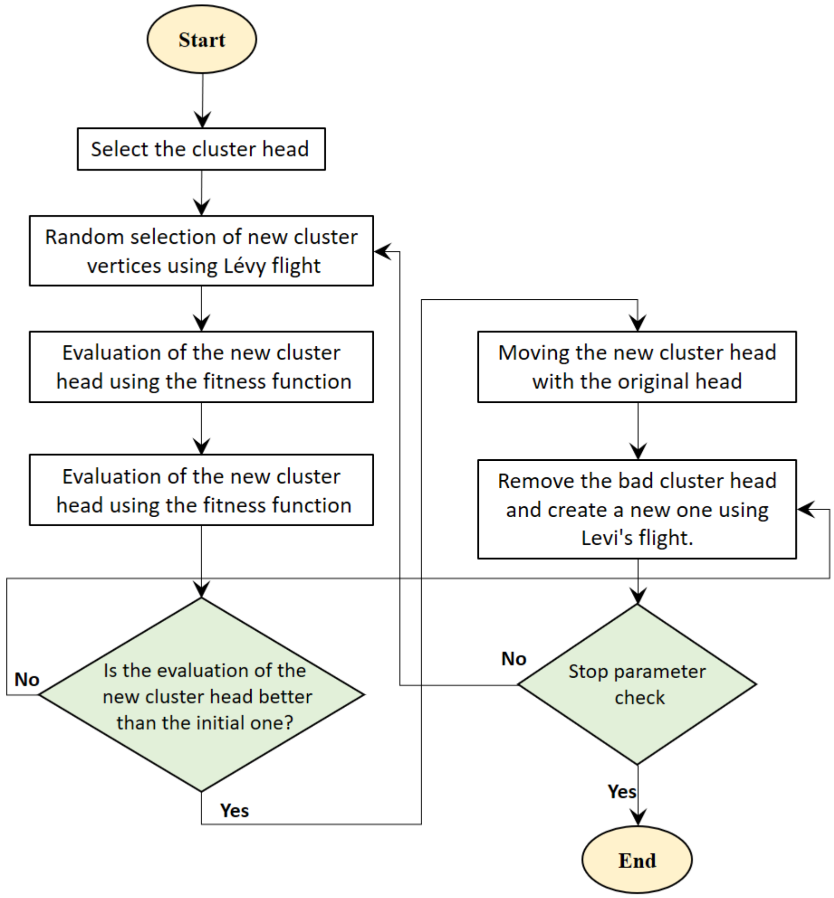

Fig. 2. Flowchart of choosing the cluster head location of the proposed algorithm.

2) Routing: The process of sending data from a source node to a destination node involves sending the data from the node to the cluster head [42, 43]. If the cluster head is not connected to the source, it forwards the data to another cluster head. Information is therefore sent via a number of paths for each of them to communicate with one another: from the head of the source node to the head of the destination node, from the head of the destination node to the head of the source node, and so on. Fuzzy logic is employed in this process. The four-parameter fuzzy logic uses the energy of the path nodes, the load value of the path nodes, the signal strength at each path step, and the total number of steps as the input fuzzy set of the fuzzy inference system to determine which path is optimal. Every fuzzy set in the input has two membership functions.

The input membership functions, which are given in relation (10), are fitted with the Gaussian function [44].

$$f(x,\sigma,c) = e^{\frac{-(x-c)^2}{2\sigma^2}} \tag{10}$$

Fuzzy if-then rules and the composite Gaussian function are the results of the fuzzy system. Given that every node has a fuzzy inference system, the optimal path is chosen by taking into account the node's energy rate, path load, signal strength, and number of steps.

IV. Discussion and Evaluation

To simulate the application, MATLAB version R2014a 64-bit was utilized. MATLAB is one of the most advanced scientific software packages available today, offering a wide range of features easily accessible. This software allows you to add your chosen algorithm with a few simple keystrokes, in addition to the many functionalities that MATLAB itself offers. MATLAB stands different from other scientific software programs thanks to this characteristic. You may effortlessly complete difficult mathematical computations in science and engineering with this program. Numerous implementation techniques in MATLAB make it simple to carry out a wide range of calculations in the fields of electrical engineering, computers, mechanics, chemistry, and medical engineering. If necessary, you can even use the box. Purchase the specialist instruments you require online. To simulate the suggested technique, a computer with the hardware requirements given in Table I was utilized.

TABLE I. HARDWARE SPECIFICATIONS FOR SIMULATING THE PROPOSED METHOD

Processor:	**Intel Pentium(R) CPU, 2.60 GHz 2.60GHz**
Installed memory (RAM):	4.00 GB
Display Adaptor:	ATI Radeon HD 5570, 2048 MB
System type:	64-bit Operating system
Operating Systems:	Windows 8 Enterprise

The following parameters will be used to evaluate the simulation results.

- The initial test has defined environment dimensions of 500 x 500 square meters and a predetermined transmitting rate of 100 packets per second. This experiment involves changing the number of sensors to 70, 120, 170, 220, and 250. It is then done thirty times, with the average outcomes of those thirty repeats being shown.
- In the second experiment, the sending rate is fixed at 100 packets per second, the number of nodes is also fixed at (70, 120, 170, 220, and 250) and the environment's dimensions are variable while the network's density is fixed (i.e., as the number of sensors increases, the environment's dimensions increase and vice versa). The average of the thirty repetitions of this experiment is displayed in the results.

  In the third experiment, the suggested algorithm is used to compute the node burning time and network lifetime, and the results are compared with the LEACH protocol.

A. Performance of the Proposed Algorithm

The suggested algorithm's performance was assessed and contrasted using various parameters. The energy usage and packet-to-well ratio of the suggested method were compared with that of the LEACH algorithm.

Assumedly, the network under investigation is situated in a square environment, with n^2 nodes arranged in a row or column. $N=n^2$ if the total number of nodes is assumed to be equal to N. To make things easier, we'll suppose that every node is only connected to other horizontal and vertical nodes. It isn't connected to any diagonal nodes [45, 46]. Fig. 3 illustrates this network with an example.

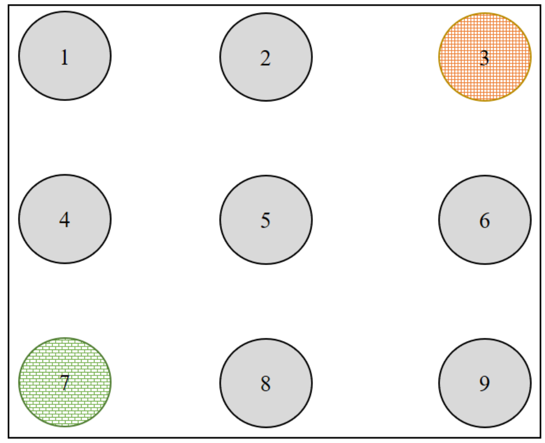

Fig. 3. Proposed sensor network with source (mesh) and sink (brick) where n=3 and n=7.

Fig. 4 depicts a sample of the network that this article simulates. The length and width of the area where the wireless sensor network is situated are shown by the vertical and horizontal axes. The nodes or wireless sensors in this network are represented by the triangles in this picture.

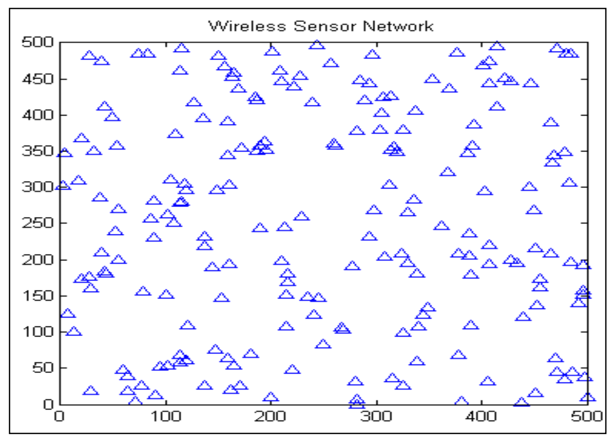

Fig. 4. Simulation of mobile wireless sensor network in MATLAB.

Three crucial network parameters are represented in the simulation: the total energy used, the proportion of successful transmissions, and the total number of transmissions that reach the well under various conditions, such as altering the network's node count while accounting for the fixed environment's dimensions and node density. It has been assessed and is shown in the proper chart format. Network clustering is accomplished via the Cuckoo Search Algorithm. Algorithm parameters for Cuckoo: There are 200 iterations of this algorithm, with a 0.25 discovery rate. A new solution has been developed using Levi's flight information and a random walk. Assume the network depicted in Fig. 5 exists. The source is node a, while the destination is node d.

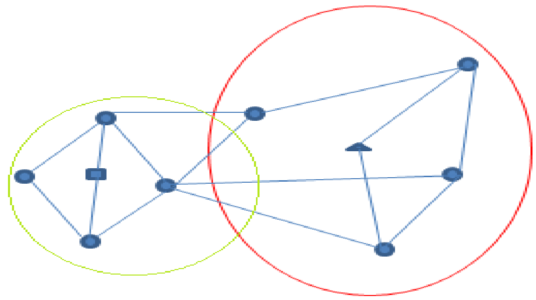

Fig. 5. A view of the wireless sensor network with the connection between the nodes.

Cuckoo is the algorithm that performs clustering. A cluster center that may or may not be a node makes up each cuckoo. As previously said, after the nodes are clustered, the cluster center is not among them. Consequently, the cluster center node is chosen from among the nodes based on its Euclidean distance to the cluster center. It is possible to choose the square and triangle nodes as the cluster's center nodes, as depicted in the figure. As previously stated, there are two distinct clusters where the source node, a, and the destination node, d, are situated. Thus, there are three phases involved in this routing. The transfer from the destination cluster head node to the destination node occurs in the third stage, which is the second stage between two cluster head nodes based on the cluster heads and the first stage between the source node and the source cluster head node [47, 48]. There will probably be multiple routes in each stage, chosen using the fuzzy approach. The best route between the pathways is found using the fuzzy processing system in the suggested method. Each of the four input fuzzy sets in the suggested fuzzy inference system has two membership functions.

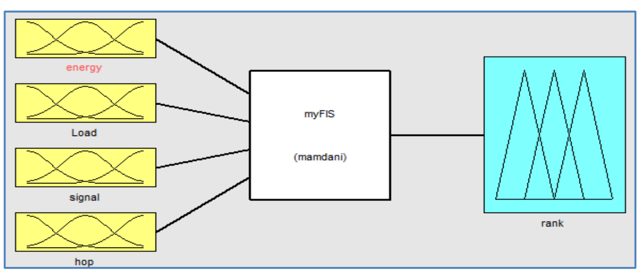

Fig. 6. Viewing the fuzzy system.

Four fuzzy input and output sets are displayed in Fig. 6. The energy of the path nodes is the initial input; this decides whether the node has a low or high energy level [15], [49]. Its membership function is displayed in Fig. 7 and Relation (11).

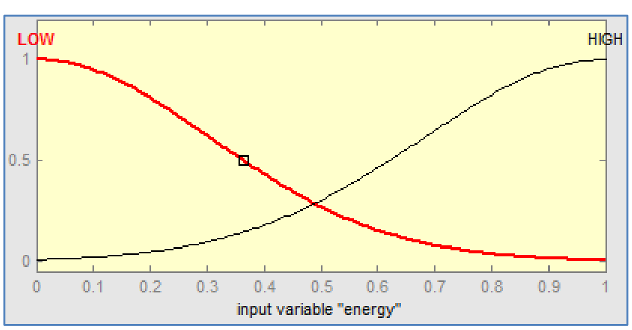

Fig. 7. Energy membership function in the fuzzy interface.

$$f(x,\sigma,c) = \begin{cases} Low \ : e^{\frac{-(x-c)^2}{2\sigma^2}} & [\sigma, c] = [0.3089 \ \ 0], x = [0,1] \\ High : e^{\frac{-(x-c)^2}{2\sigma^2}} & [\sigma, c] = [0.3224 \ \ 1], x = [0,1] \end{cases} \quad (11)$$

The load value of the route nodes, which shows whether the route's load level is low, medium, or high, is the second input. Its membership function is displayed in Fig. 8 and Relation (12).

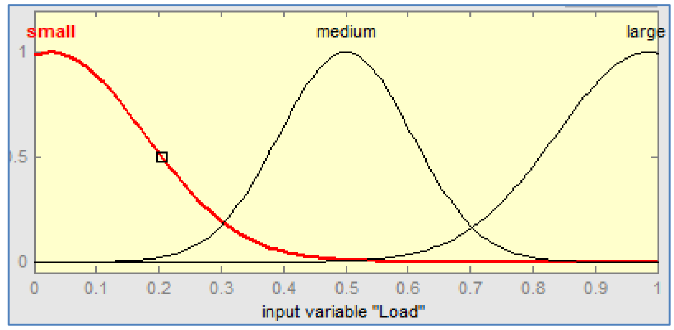

Fig. 8. Membership function of path load in fuzzy interface.

$$f(x,\sigma,c) = \begin{cases} Small \ : e^{\frac{-(x-c)^2}{2\sigma^2}} & [\sigma, c] = [0.1512 \ \ 0.027], x = [0,1] \\ Medium \ : e^{\frac{-(x-c)^2}{2\sigma^2}} & [\sigma, c] = [0.1067 \ \ 0.5], x = [0,1] \\ Large \ : e^{\frac{-(x-c)^2}{2\sigma^2}} & [\sigma, c] = [0.1479 \ \ 0.985], x = [0,1] \end{cases} \quad (12)$$

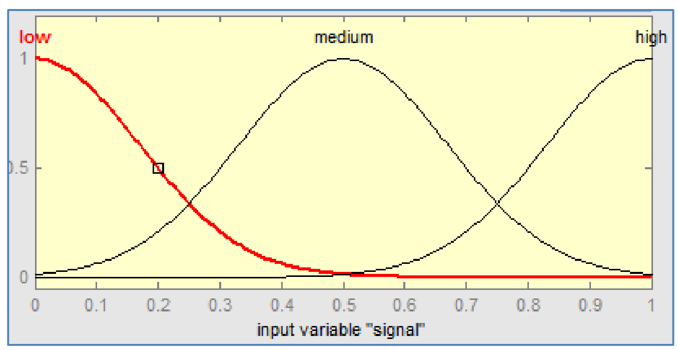

Fig. 9. Membership function of path signal in fuzzy interface.

The signal strength at each stage of the current path is determined by the third input. Three levels are also defined for this input: weak, medium, and powerful. Its membership function is given in Fig. 9 and Relation (13).

$$f(x,\sigma,c) = \begin{cases} low \ : e^{\frac{-(x-c)^2}{2\sigma^2}} & [\sigma, c] = [0.1699 \ \ 0], x = [0,1] \\ Medium \ : e^{\frac{-(x-c)^2}{2\sigma^2}} & [\sigma, c] = [0.1699 \ \ 0.5], x = [0,1] \\ high \ : e^{\frac{-(x-c)^2}{2\sigma^2}} & [\sigma, c] = [0.1699 \ \ 1], x = [0,1] \end{cases} \quad (13)$$

The number of steps on the path is indicated in the fourth entry. The three levels of definition for this entry are the number of little steps, the number of average steps, and the number of large steps [19], [47], [50]. Its membership function is also displayed in Fig. 10 and Relation (14).

$$f(x,\sigma,c) = \begin{cases} low \quad : e^{\frac{-(x-c)^2}{2\sigma^2}} & [\sigma, c] = [0.0999 \;\; 0], x = [0,1] \\ Medium \;: e^{\frac{-(x-c)^2}{2\sigma^2}} & [\sigma, c] = [0.169 \;\; 0.5], x = [0,1] \\ high \quad : e^{\frac{-(x-c)^2}{2\sigma^2}} & [\sigma, c] = [0.0933 \;\; 1], x = [0,1] \end{cases} \quad (14)$$

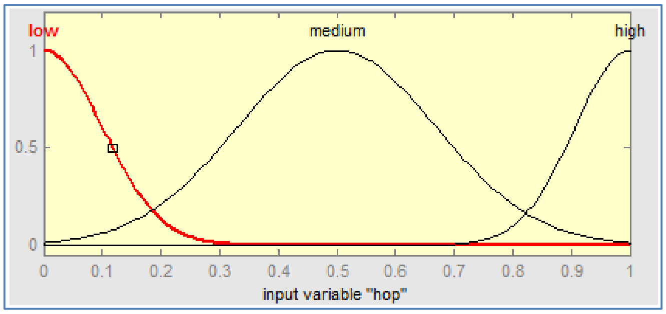

Fig. 10. The membership function of the number of path steps in the fuzzy interface.

A maximum of 2x3[3] rules can be directly generated for these four inputs, each of which has two membership functions, using and, where 54 rules with nine outputs are defined as relation (15) and displayed in Fig. 11:

$$f(x,\sigma,c) = \begin{cases} CWR \;: e^{\frac{-(x-c)^2}{2\sigma^2}} \; [\sigma_1, c_1, \sigma_2, c_2] = \\ [0.04247 \; -0.0125 \;\; 0.04247 \;\; 0.0125], x = [0,1] \\ WR \;: e^{\frac{-(x-c)^2}{2\sigma^2}} \; [\sigma_1, c_1, \sigma_2, c_2] = \\ [0.04247 \;\; 0.1125 \;\; 0.04247 \;\; 0.01375], x = [0,1] \\ NGR : e^{\frac{-(x-c)^2}{2\sigma^2}} \; [\sigma_1, c_1, \sigma_2, c_2] = \\ [0.04247 \;\; 0.2375 \;\; 0.04247 \;\; 0.2625], x = [0,1] \\ MGR : e^{\frac{-(x-c)^2}{2\sigma^2}} \; [\sigma_1, c_1, \sigma_2, c_2] = \\ [0.04247 \;\; 0.3625 \;\; 0.04247 \;\; 0.3875], x = [0,1] \\ GR \;: e^{\frac{-(x-c)^2}{2\sigma^2}} \; [\sigma_1, c_1, \sigma_2, c_2] = \\ [0.04247 \;\; 0.4875 \;\; 0.04247 \;\; 0.5125], x = [0,1] \\ UGR \;: e^{\frac{-(x-c)^2}{2\sigma^2}} \; [\sigma_1, c_1, \sigma_2, c_2] = \\ [0.04247 \;\; 0.6125 \;\; 0.04247 \;\; 0.6375], x = [0,1] \\ CGR \;: e^{\frac{-(x-c)^2}{2\sigma^2}} \; [\sigma_1, c_1, \sigma_2, c_2] = \\ [0.04247 \;\; 0.6125 \;\; 0.04247 \;\; 0.7625], x = [0,1] \\ BR \;: e^{\frac{-(x-c)^2}{2\sigma^2}} \; [\sigma_1, c_1, \sigma_2, c_2] = \\ [0.04247 \;\; 0.7375 \;\; 0.04247 \;\; 0.8875], x = [0,1] \\ CBR \;: e^{\frac{-(x-c)^2}{2\sigma^2}} \; [\sigma_1, c_1, \sigma_2, c_2] = \\ [0.04247 \;\; 0.9875 \;\; 0.04247 \;\; 1.013], x = [0,1] \end{cases} \quad (15)$$

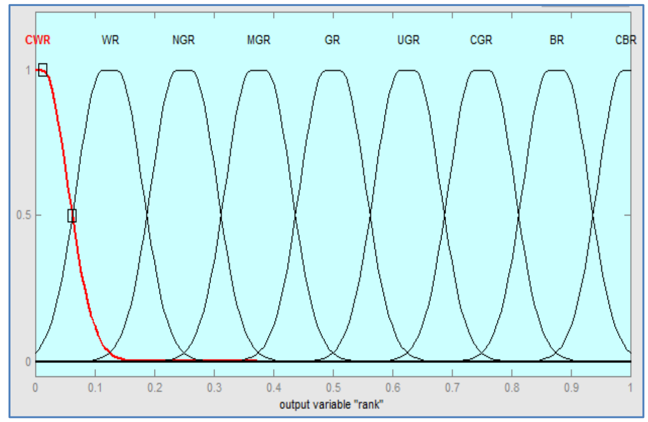

Fig. 11. Fuzzy system output.

The input membership functions, whose association was established for each input, have been fitted with a Gaussian function. The fuzzy system output makes use of the composite Gaussian function. In reality, this function combines two Gaussian functions with varying values of σ and c on the left and right sides [32] in order for c1<c2 and σ1<σ2. The path's optimality is determined by the outputs from CWR to CBR. As a result, CBR will have the finest routes and CWR the most inappropriate [33, 34]. When the destination is a communication, each mobile node has a fuzzy inference system unit that it uses to identify the set of best routes. When a source wants to transfer data to a destination, it first determines if it has a memory route to the destination. If so, it sends the data and uses the fuzzy system to choose the best route based on the traffic. If not, it initiates the route discovery procedure by transmitting the RREQ packet to other nodes. The lowest energy rate of the node in the traveled path, path load, lowest signal intensity in the traveled path, and the number of path steps will all be present in every RREQ packet flowing in the path.

If an intermediate node has not received a packet previously, it rebroadcasts it; if it has, the new packet has fewer steps than the old one.

B. Comparison of the Proposed Method with the LEACH Protocol

- First test: variable density

Initially, the impact of the wireless sensor network's node count on metrics like energy usage and the number of successful transmissions to the well was assessed. There are several numbers of nodes; in the intended environment, 70, 120, 170, 220, and 250 nodes were chosen. The package was sent at a continuous speed of one hundred packages per second. The environment's width and length, where the nodes are situated, are fixed at 500 square meters.

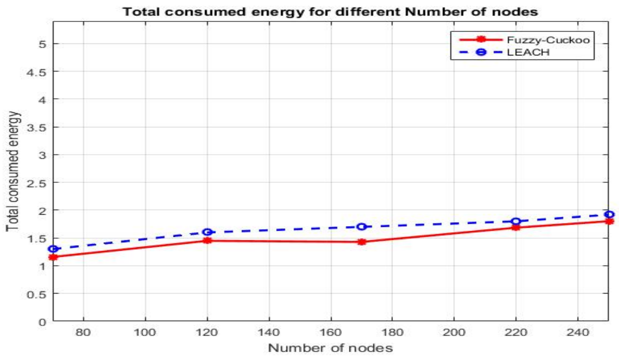

Fig. 12. The overall energy usage as a function of node count in a variable density.

The difference between the total energy consumption and the number of nodes in the network is depicted in Fig. 12. As can be seen, as the number of nodes in the network increases, so does the quantity of energy consumed. There are several possible causes for this rise, including an increase in node connections, congestion, or the volume of transfers. The energy consumption is less than that of the LEACH process, as demonstrated.

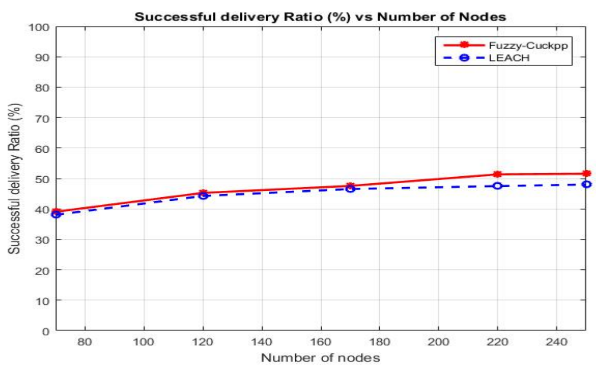

Fig. 13. The number of nodes in the density determines the packet delivery speed to the well.

The number of packets that reach the well in relation to the total number of network nodes is displayed in Fig. 13. As can be seen, the percentage of packets reached rises as the number of nodes or node density in the network environment grows. As a result, the suggested approach performs better in environments with high densities. However, it should be highlighted that the findings are an average of 30 repeats and that the node distribution in the network environment is random. Thus, it can be concluded that while the suggested approach is sensitive to network density, it is not sensitive to network topology. Based on the preceding graphs, it is projected that as energy consumption and the number of steps in the path grow, the ratio of successfully sent packets will also increase. This means that more packets should reach the well. As a result, Fig. 14 validates the earlier graphs' findings.

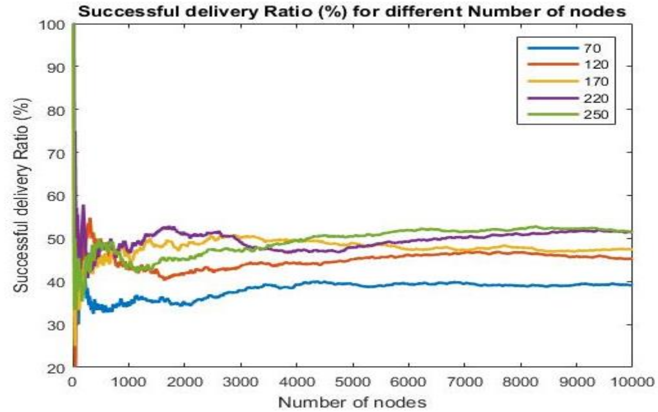

Fig. 14. The success rate of transmissions over time in various nodes with varying densities.

- Second test: constant density

In this case, the impact of a fixed-density wireless sensor network's node count on several metrics was assessed, including energy usage, the proportion of successful transmissions, the number of successful transmissions that reach the well, etc. There were different numbers of nodes in the environment; nodes 70, 120, 170, 220, and 250 were taken into consideration. The package was sent at a continuous speed of one hundred packages per second. Eq. (16) is used to determine the length and width of the environment where the nodes are located. It should be mentioned that there are 20 nodes per square meter at a fixed node density in the network.

$$x\_coordinate = \left[\sqrt{\frac{No\_Node \times \pi \times w\ range^2}{density}} \right] \quad (16)$$

The percentage of successful transmissions over time with various nodes at a fixed density is displayed in Fig. 15. As you can see, the fixed density of successful transmissions drops as the number of nodes rises. Consequently, the network performs better in terms of successful transmissions and reaches a stable state more quickly the fewer nodes there are in the network.

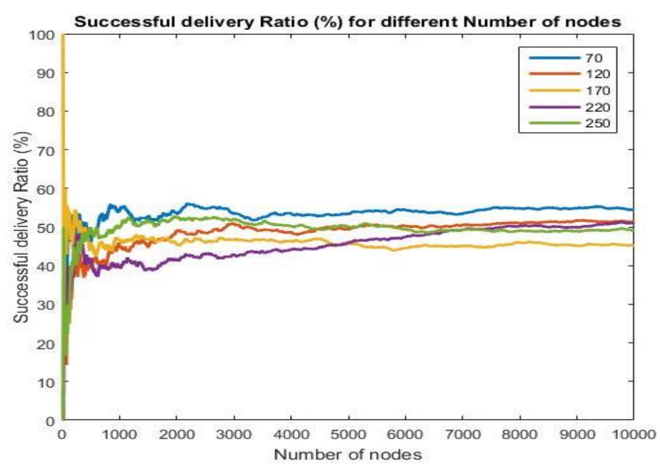

Fig. 15. Time-series chart illustrating the percentage of successful transmissions in various nodes with constant density.

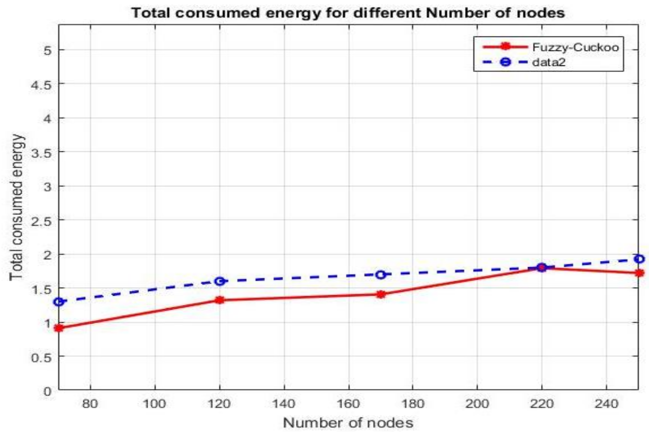

Fig. 16. The overall energy usage as a percentage of nodes with a constant density.

Fig. 16 illustrates the relationship between total energy usage and the number of nodes in the network while maintaining a constant density. It is evident that the energy consumption grows as the number of nodes in the network increases. The increase in this growth could be influenced by the volume of transfers and communications, congestion, and node connections. In this case, the rate and manner in which energy consumption is increasing differ from when the density was variable. Energy usage decreases after nodes increase in number. Energy consumption increased before reaching a stable level in the previous case. Optimizing both the environment's density and node count can improve its overall performance. It shows that the decrease in sent packets could also be a factor in reducing energy use.

Fig. 17 illustrates how the number of packets that arrive at the well varies with the number of network nodes that have fixed information. The graphic illustrates how fewer packets reach the well as the number of nodes in the network rises.

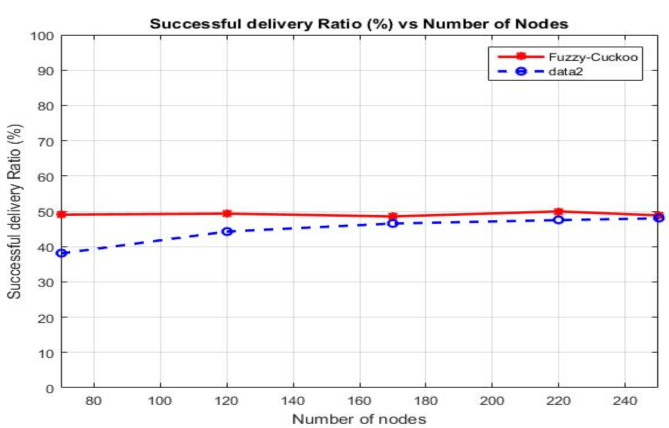

Fig. 17. The ratio of the number of nodes with constant density to the speed at which packets reach the well.

- The third test: the first burnt node

The time used by the LEACH method and the suggested algorithm is depicted in Fig. 18 and Fig. 19. As can be seen, the suggested algorithm outperformed the earlier findings.

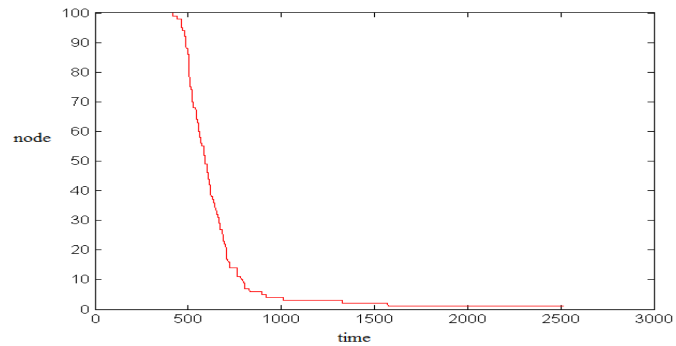

Fig. 18. Burned node time in the suggested approach.

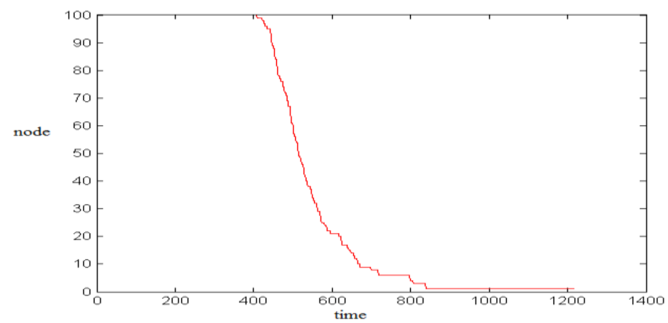

Fig. 19. Ninety burned time in LEACH.

C. Comparative Analysis

Table II displays the dead time analysis, and LEACH and Fuzzy-cuckoo are compared with its initial node [21].

TABLE II. PERFORMANCE ANALYSIS OF DEAD TIME

Energy (J)	Node location	LEACH	Fuzzy-cuckoo
0.01	25,75	13	36
0.02	25,75	17	38
0.03	25,75	21	47
0.04	25,75	26	56
0.05	25,75	43	94
0.01	25,75	15	42
0.02	25,75	19	55
0.03	25,75	34	69
0.04	25,75	66	117
0.05	25,75	89	148

The performance analysis leads to the conclusion that the suggested approach outperforms alternative approaches in terms of performance. Because the suggested method generates routing paths and chooses the best CH, it performs better. The distance between the stationary and mobile sensors of the WSN is taken into account in order to reduce the energy consumption of the suggested technique. As a result, the suggested method's dead time in WSN is extended. Furthermore, the fitness function in routing prevents node and link failures. Less packet drops occur during communication as a result. As a result, the suggested technique minimizes both energy use and packet loss.

V. Conclusion

The research findings that were derived from the simulation that were mentioned in the fourth section are the subject of this section. The cuckoo algorithm is used in the suggested algorithm to do clustering, as previously discussed in the article's parts. A cluster center, which may or may not be among nodes, makes up each cuckoo. As previously said, after the nodes are clustered, the cluster center is not one of the nodes; thus, the cluster center node is chosen from among the nodes based on its Euclidean distance to the center. Routing takes place in three phases. The transfer from the source node to the source cluster node occurs in the first phase, between the source node and the source cluster node in the second, and between two cluster nodes depending on the cluster nodes in the third.

As previously said, after the nodes are clustered, the cluster center is not one of the nodes; thus, the cluster center node is chosen from among the nodes based on its Euclidean distance to the center. Levy's flight path has a set step length and unpredictable step direction. Employing the cuckoo optimization algorithm, one of the most advanced and potent evolutionary optimization techniques, to determine the cluster's center. When compared to the cuckoo search, the cuckoo optimization technique exhibits increased convergence and comparatively higher accuracy. The Levy's flight step length in this manner is flexible and gets less as the cuckoo generation increases. Cuckoo search's fitness function uses fuzzy logic, which improves search accuracy.

The importance of studying this article and its findings are very important in two ways. First, the paper has detailed and comprehensively explained the proposed methods to improve the performance of wireless sensor networks. By using Cocoa search algorithm for clustering and fuzzy logic for routing, network performance is improved and productivity is increased. Meanwhile, the simulation results show that the proposed method has a significant improvement over conventional methods such as LEACH. Second, this paper can be used as a foundation for future research on improving the performance of wireless sensor networks. The ideas and algorithms presented in this paper can be used as a starting point for further research in the field of optimization and performance improvement of wireless sensor networks. On the other hand, considering the successes of this paper, it is suggested that more future research be done in the field of improving clustering and routing algorithms in wireless sensor networks, and also the use of fuzzy-based methods and artificial intelligence algorithms to improve the performance of networks is recommended.

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