An Efficient Cluster Head Selection for Wireless Sensor Network-Based Smart Agriculture Systems

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Abstract— With the increasing availability of high-resolution satellite and drone images and the Internet of Things (IoT) has begun transforming remote sensing of agriculture by improving accessibility and frequency of updates. Modern IoT-based smart agriculture systems use Wireless Sensor Networks (WSNs) to gather information from an ecosystem that regulates the quantity of water in agricultural fields could be one of these activities. The WSNs remained a challenge to transfer data to drones for analysis purposes. These are composed of tiny sensory architectures organized together to bring efficiency and scalability features to a network. WSN nodes are controlled and managed by a cluster. It is quite difficult to design an efficient leader election protocol. The computation power, storage space, and energy supply of sensor nodes make them unable to frequently switch to a different cluster. The WSN cluster-head election process requires a lot of energy (evaluation and computational process to select the most appropriate node with the least impact on network fragmentation in energy consumption of selected node). Then it is necessary to formulate a mechanism where WSNs utilize the least energy to coordinate with the remote sensing sources. This study presents a cluster election algorithm using the fuzzy logic inference system. It uses a coordinates system to map network nodes and map them based on prioritized scheduling. Lifetime augmentation in wireless sensor networks has always been of great interest. During data transmission from normal sensor nodes to the base station (sink), excess energy is dissipated. Optimizing the energy dissipation of WSNs through the selection of cluster heads is a powerful way to increase the lifespan. By electing more efficient nodes as cluster heads, the proposed method extends the network's lifetime by reducing the number of unimportant communications between nodes. With the utilization of network resources efficiently, the network's lifetime is extended. The proposed algorithm is evaluated with the LEACH (Low Energy Adaptive Clustering Structure) algorithm and FCA method based on the remaining energy and the number of active nodes. The simulation results show that the proposed algorithm utilizes less energy for communication with remote sensory equipment for intelligent agriculture. The performance of the method improved for remaining energy by 9%, the number of active nodes rate by 24%, and indirectly network resource utilization than other states of the art solutions.

***Index Terms*— Smart Agriculture, Fuzzy Logic, Wireless Sensors, WSN, Clustering, Decision System**

1 INTRODUCTION

Remote sensing is extensively used in smart agriculture systems to manage and monitor agriculture yields both in productivity and sustainability [1,2]. These systems consist of modern communication equipment aimed at helping farmers improve crop productivity. A smart agriculture system consists of precision equipment such as sensors, actuators, and unmanned aerial vehicles. Sensors are installed on agriculture farms to monitor variations and trends. Most of the time, these sensors communicate by using wireless communication. Wireless Sensor Networks (WSN) constitute an important component of a smart agriculture system. It is extensively used both for monitoring and tracking applications [3]. It has been used widely in environments such as temperature, pressure measurement, and environment monitoring [4-5]. However, if we want to use WSN, we have to keep in mind that WSN does not have an external power supply, and sensors rely on their internal power and are almost difficult to recharge and replace. However, work has been done to compensate for this problem. Energy consumption can be reduced or compensated as much as possible [43].

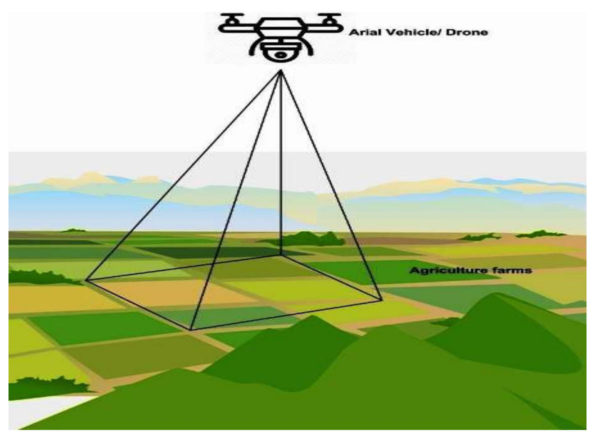


Fig. 1. Remote monitoring of agriculture farms

Therefore, power consumption has become one of the most critical issues in WSN. Most researchers in this field have focused on reducing energy consumption by presenting different approaches that have greatly improved our focus on the subject. With the help of proper messaging and optimal use of network resources, we aim to reduce energy consumption. WSN architecture consists of interconnected sensor nodes [6-8]. Each sensor node is a single, tiny device equipped with a simple microcontroller. WSN-based systems are used in many fields such as industry, civilian application, healthcare, and agriculture. The biggest challenge in maintaining sensor efficiency is the complex nature of the optimized algorithms.

Their complexity often constrains the WSN nodes, such as processing power and size. WSN node management is a complicated task [9-11]. Many works of literature are available on the topic of network node management [12-13]. Apart from those mentioned above, most sensor nodes detect functions such as motion, temperature, humidity, and light. These sensors use a Pico-power microcontroller. It helps control the power transceiver and the communication function of the sensors. The recovery of the captured information from dead nodes is a complicated task. Therefore, various localization methods ensure that the information arrives at the right time from the active nodes.

In remote sensing environments, agriculture farms are monitored using aerial vehicles such, e.g. drones, as shown in Fig 1. These drones monitor the farms by communicating with the cluster leader of the WSN for exchange and update of information. The cluster heads do not send information directly to aerial vehicles but rather through a base station (Sink). WSN classification is based on performance, network architecture, and user requirements. Includes creating a cluster with the features required for the classification phase [46]. Romika et al. In 2020 [22] proposed a new distributed algorithm for selecting cluster heads. This algorithm has three main features and is based on symmetric key operations.

The cluster nodes unanimously elect the leader. These are resilient against hacking attacks and have no impact on cluster leader election decisions. The node is also considered fault-tolerant to ensure safety for messages lost or altered through malicious attacks. Tao et al., in 2019 [23], also presented a cluster head selection algorithm. The proposed algorithm uses fuzzy rules. It considers the section's three main characteristics: the energy available from the nodes, the number of neighboring nodes, and the distance from the base station (or sink). This method is compared to hierarchical distributed clustering. The results show that this method improves the performance in terms of network lifetime. The research proposed by Baby and Vasudevan [24] introduced a distributed and stable algorithm for cluster head election. The proposed algorithm works with the calculation of probability values. It considers two parameters, i.e., residual energy of the sensor node, and compares it with the average energy of the combined WSN node. The results show that the proposed algorithm is stable and efficient compared to traditional technology. The main disadvantage of this algorithm is that it sends or receives a relatively high number of data packets to the sink compared to other algorithms. Mirel et al. (2020) [25] Proposed a multilayer clustering algorithm. Consider three centralized algorithms that share distributed functions to reduce the number of CH (Cluster Head) candidates. The multilayer algorithm also reduces the message exchange load using efficient topology architecture.

The lifetime and stability of a WSN are ensured through a proper energy utilization method. This issue is enabled through the concept of clustering [14,15]. Clustering improves energy efficiency through cluster-head selection methods. Several ways to select cluster heads in sensor networks [16,17]. If a suitable cluster is selected, it will help reduce the transmission distance of the communication distance of the main node that is not the cluster head. The Low Energy Adaptive Clustering Hierarchy (LEACH) protocol [18,19] is considered an important clustering method because it improves energy efficiency in a very efficient way. Besides, other swarm intelligence approaches, such as [20,21], have also improved computing power usage. This research proposes a WSN cluster leader selection algorithm that uses fuzzy logic, reducing communication overhead, improving energy efficiency, and reducing memory requirements. Fuzzy logic is one of the most effective methods for combining and evaluating parameters in wireless sensor networks since it allows us to combine and evaluate data more effectively. However, it is possible to use it to improve the performance of sensor networks, which has led us to use this logic. The author compares the proposed algorithm with the advanced algorithm (such as LEACH) in energy consumption.

The research offers a fuzzy-based system that will lead to smart agriculture and effective crop development. The model's goal is to monitor agricultural fields for effective water consumption. The suggested approach demonstrates high water utilization in irrigation and is advantageous for the restricted water area.

The contributions of this study are highlighted as follows:

a. Improve decision making by the fuzzy choice of cluster leader, reduce resource consumption, and generally improve performance;
b. The proposed model considers both cluster leader selection and the power consumption;
c. Evaluation and extension lifetime of the network;
d. The network consists of homogeneous nodes with the same energy level;

1.1 WSN in agriculture

WSN is an important enabler for precision agriculture. Because it helps gather, monitor, and analyze data from agricultural areas [48]. WSN might connect IoT sensors, allowing for real-time detection of soil and climatic conditions as well as irrigation automation [49]. IoT, clustering, RFID, and unmanned aerial vehicles (UAV) are important enablers for creating smarter, more sustainable agriculture that benefits farmers and consumers. WSN solutions drew a lot of attention and gained much traction because of their potential capacity to improve farmers' awareness of crop conditions, resource utilization, and environmental conditions. The proposed method recommends improvement approaches for existing WSN deficiencies in the context of energy efficiency in order to provide an information platform for WSN to play a more important role in crop production.

The authors propose a novel cluster-head selection mechanism using fuzzy logic to establish a fully connected network with efficiency and network resource utilization in an agriculture environment. Using the proposed algorithm, full connectivity between sensor nodes is assumed to be energy-efficient while enhancing network lifetime. This increases the network's longevity by reducing the dead node count considerably. The fundamental point of the proposed strategy appropriation in horticulture is information collection, environmental monitoring, and data analysis.

The rest of the study is organized as follows. Section 2 summarizes the related work. Section 3 briefly explains the methodology used in the proposed study. Section 4 reports on the evaluation, results, and discussion of the proposed system. Finally, Section 5 summarizes the article.

2 RELATED WORK

Remote sensing is the concept of using sensors to accumulate data. The sensor detects statistics by using gathering energy reflected from the ground. Sensors are often established on satellites or statistics series drones [35, 36]. Remote sensing explores treasured records due to the fact it affords an overview. Remote sensing science is active and passive, based totally on sensory responses to goal stimuli. This statistics can be used for correct estimations because it uses a large vicinity with repetitive calibrated sensory measurements to estimate changes in one-of-a-kind resolutions [37]. This issue helps accomplish correct effects in contrast to the usual facts series methods.

The world summit on food security concluded on a note that the world population would grow by 10 billion by the year 2050 [38]. With the evaluated rate of growth, agriculture production must also increase. This issue will help in accommodating the increasing food demands. Agricultural land management can improve agriculture production by improving water resources, land up-grading, and crop monitoring. In modern agriculture systems, monitoring is performed through remote sensing techniques. Remote sensing in agriculture is of fundamental importance because it provides ways and means to monitor agriculture yields and crops effectively. Agriculture systems involving remote sensing technologies are widely known as smart agriculture systems. These systems involve sensors and sensory equipment for monitoring agriculture crops. These sensors are connected to exchange information using a cluster head sensor [39, 40]. A cluster head later communicates information to a base station, which can be based or mounted on a drone or satellite.

This section discusses the latest developments in WSN cluster leader selection. In [29], the LEACH algorithm was proposed. It was developed to achieve energy efficiency in a clustered hierarchical network. This methodology proposes to use a dedicated central location for storing and collecting cluster data. Each cluster has a specified location where data collection is performed. It also uses probabilistic methods to select cluster heads; however, it does not consider the remaining energy sources of the cluster. This issue is because information can only be obtained after transmitting and receiving information. However, this is a complex and energy-consuming task. In [30], an improved LEACH algorithm for cluster head selection was proposed. To solve the problem of selecting the head of the cluster uses the time division multiple access (TDMA) method. The base station updates the nominated cluster head to synchronize future transmission. The cluster head also checks its immediate neighbors to reduce future data and time-related delays. The presented LEACH-C performs the same cluster head selections for other components of the networks to find sensor nodes with a smaller number of computational power and communication resources. Performing all computing tasks at the base station would result in higher energy consumption, adversely affecting its performance.

Several research proposals target improving the performance of cluster head selection [1-3, 23, 27]. Cluster head selection is given more importance because it helps in improving the computational complexity of the wireless sensor network. Several particle swarm optimizations (PSO) based approaches are presented to address these challenges. PSO concepts are vastly used in computing to optimize challenges by relating their availability to given quality value.

Swarm intelligence has often been used in WSN protocols for optimizing energy-related constraints. PSO-C was implemented by Abdul Latiff et al. 2007 [31] in WSNs to determine optimal cluster head sections for clusters. By using PSO-C, location cluster heads can achieve effective results, thus conserving energy and improving the lifetime of sensors. Unfortunately, the selection process does not consider the cluster head distance concerning the base station. Ignoring the distance parameter may affect the energy efficiency and data transmission time. Srinivasa et al (2017) [32],. addressed this challenge. The author proposed a PSO-based Power Saving Cluster Head Selection (PSOECHS) algorithm. It uses an objective function that measures the cluster head and base station distance. Then it uses an objective function to select a node within each cluster.

PSOCHS is considered an optimal solution for environments where sensors can communicate with each other using normal traffic patterns; however, its performance degrades under higher values of power, energy consumption, and computational complexity. In Wang et al. (2019) [33], an even distribution strategy for network resource allocation is presented. It ensures that the amount of data spread across the WSN is distributed evenly across all locations.

Wang et al. (2018) [34] proposed a cluster election algorithm based on PSO. They calculate the amount of power allocated by evaluating the distribution of the energy levels of the sensor nodes and the energy of the cluster heads in the coverage area. Finally, choose the node with the highest energy.

Mehra et al. (2020) [42] proposed a fuzzy-based cluster head selection algorithm by choosing the best candidate for cluster head to provide load balancing. Therefore, in order to solve this problem, it uses the remaining energy, the distance of the sink point, and the density of the node as the input parameters of the fuzzy inference system. In other words, compared with the previous model mentioned in the document, the advantage of this model is that it is more efficient, and the network life is longer than before. Because this method attempts to reduce the data transmission between nodes by selecting cluster head nodes more efficiently than other methods, it has been mentioned in the document. On the other hand, the weakness of this system is that it largely depends on the distance of the nodes.

Fuzzy logic is a decision-making system in most aspects. It has been widely used in knowledge-based systems and multiobjective optimization techniques. Traditional control mechanisms require precise and concise information about their environment. However, fuzzy logic systems can make decisions based on many environmental parameters. Wang et al. (2019) [26] propose a fuzzy system and multiobjective technology based on predefined rules. Wireless sensor networks usually overcome the uncertainty problem by incorporating fuzzy logic into clustering algorithms. In the Fuzzy Clustering Algorithm (FCA) [47], fuzzy logic combines multiple parameters to determine a cluster head for WSNs. FCA uses the IF_THEN rule for better precision when using the defuzzification output method. If a node has a strong coupling with its neighbors, it will become the cluster's head. Fuzzy logic technology can be used in distributed and centralized systems.

Besides, positioning services and temporal remote sensing images are crucial to many countries for intelligent agriculture. For example, Brazil has developed functions in the Global Navigation Satellite System (GNSS) multi-constellation data processing and analysis, which can be used for various applications such as agriculture [44]. Another example is the New Zealand government. They allocated funds to support the Regional Satellite Augmentation System (SBAS) [45]. This issue will significantly improve the accuracy of the WSN GPS and apply it to intelligent farming and cadastral mapping purposes.

Table 1: Comparison of the existing studies

Paper	Main Context	Limitation
Wang et al. [33]	Strategy for network resource allocation	CHs depend on the energy center
Wang et al. [34]	A cluster election algorithm based on PSO	Not considered the effectiveness in the dying nodes
Mehra et al. [42]	A fuzzy-based cluster head selection	largely depends on the distance of the nodes
Wang et al. [26]	A fuzzy system and multiobjective technology	Based on predefined rules
V. Godbole [47]	Fuzzy logic to determine a cluster head	Limit in residual energy and lifespan of the network in large scale network
Srinivasa et al. [32]	A PSO-based Power Saving Cluster Head Selection	Higher values of power, energy consumption, and computational complexity
Abdul Latiff et al. [31]	PSO-C based optimal cluster head sections	Not consider the cluster head distance with a base station

3 Methodology

Several studies on energy consumption, resource scarcity, and global warming are now being conducted throughout the world. WSN and other supporting technologies can significantly improve the efficiency of agriculture. It demonstrates that optimal resource utilization is critical in agriculture. A helpful cluster-head selection approach might be utilized to collect data from sensor nodes, improve energy efficiency, and reduce channel congestion to preserve the stability of WSNs in the clustering aspect. As a result, it is critical to extend the life of sensor networks and respond to the demands of precision agriculture, which necessitates improved methodologies and technologies to reduce costs and enhance output.

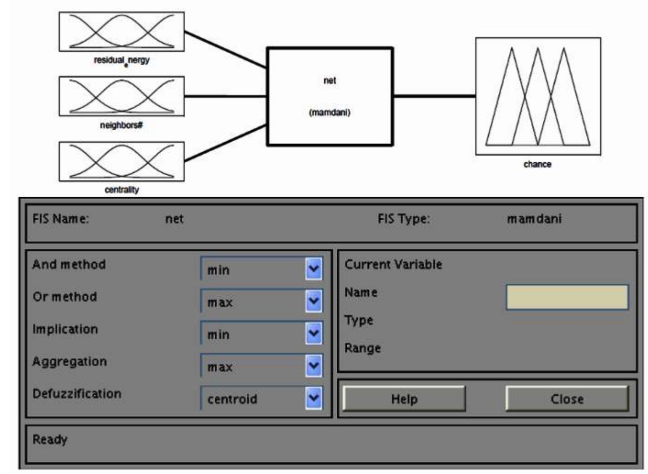


Fig. 2. Overview of a fuzzy system and its features

In this research, we use a fuzzy inference system to improve the performance of the previously proposed algorithm and propose an optimal cluster head selection algorithm by reducing memory and communication overhead. The proposed clustering algorithm is based on the functionality of the LEACH protocol. The LEACH protocol is one of the first and most popular layer protocols for selecting WSN cluster leaders. This protocol can divide network activity into four phases (Fig 2). At the beginning of each cycle, the resulting number of nodes is chosen as the cluster head in random order. For this purpose, each node generates a random number between 0 and 1 using Eq. 1. If the generated number is less than T(n), the node is selected as cluster-head. In Eq. 1, *P* represents the correlation between the number of nodes and clusters in the network. Here, *r* represents the current round, and *G* is the number of nodes in the previously selected cluster head.

$$T(n) = \begin{cases} \frac{P}{1 - P \times (r \bmod \frac{1}{p})}, & if\ n \in G \\ 0, & Otherwise \end{cases} \quad (1)$$

After the cluster head node is defined, other nodes can be classified according to the strength of the received signal. It helps design a strategy so that each cluster leader can decide to lead a cluster. The cluster head node uses the TDMA mechanism among the cluster members to divide its scope of responsibility for various time slots. In each time segment, a cluster leader communicates with a single cluster member and then shares their packets of information. Each time slot, the cluster leader sends cluster information to the master cluster node. According to this mechanism, cluster headers are modified to handle load distribution among different nodes. So, the algorithm works in the following four stages. Notification phase (advertising), cluster formation phase, forming phase schedule, and data transfer phase.

A. Advertising stage (Notification phase)

Each sensor has chosen a random value between 0 and 1. If the random number is less than the threshold *T(n),* the node selects the cluster head by itself. This issue is indicated by the symbol *P*, representing the percentage of the required cluster head. It is represented by the symbol r, which indicates the number of cycles in the current period. *G* represents the percent of nodes cluster heads in *1 / P* of the last recording period. This threshold will determine that each node in period *1/P* is a cluster head. With probability *P*, any node can be the head of the cluster in the first round. The next step increases the probability of selecting a node that is not chosen as the cluster head. The fuzzy inference system (FIS) is described in this study. A broadcast message is sent from each node selected as a cluster head node to other sensors. This message is sent with residual energy from each cluster head node.

ADV = Node ID + Detectable header

In the next step, the non-cluster head node selects the cluster head to which it belongs. The non-cluster head node will join the partner/tightly coupled cluster head if it receives multiple advertisement messages. The strength and correlation of the sensors are determined by the strength of the signals received by the cluster.

B. Cluster formation stage (phase)

After determination, each node must deliver the following information to the cluster head in this phase. When each node decides to join one of the clusters, it sends a join-request message (Join-REQ) back to the cluster head. The messages contain the cluster head's ID, the node's ID, and the header. Each node transmits a join-request message (Join-REQ) back to the chosen cluster head using a CSMA MAC protocol.

Join-REQ = Node ID + Cluster-head ID + Header (2)

C. Forming stage schedule

The cluster head receives all data from the members and forms a TDMA program to coordinate data transmission within the cluster, and the TDMA prevents head nodes from colliding. The CH node broadcasts an advertisement message, and each non-cluster head node determines a cluster head node. Therefore, each non-cluster head node broadcasts a join request message (JoinREQ) to its cluster head.

D. Data transfer stage

In the data transfer phase, the data transfer begins. If the radio equipment on a non-cluster head node is interrupted, the system has the authority to turn it off. A fuzzy system calculates the number of opportunities (step messages) from each node to the parent node. Based on the "Mamdani" approach, we used a fuzzy system in our case [41]. This system has three input functions and a single output function. The fuzzy value is converted into a crisp value in the output defuzzification operation. The study used a defuzzification method called the central method. One of the more popular methods among defuzzification studies. This method is calculated using the following equation:

$$Centroid\ Method = \frac{\int x_i.\mu_i(x_i)dx}{\int \mu_i(x_i)dx} \quad (3)$$

The purpose of defuzzification is to put a numerical value on the fuzzy set resulting from the aggregation to be used by the designer (i.e., the tracking step x). Defuzzification can be performed using at least seven operators. Still, the most popular is the centroid, which is calculated by the above formula, for which $\mu(x)$ is the degree of membership of the aggregated fuzzy set for the output x.

An overview of the fuzzy system and its properties is shown in Fig 2. The membership functions (MF) used for our fuzzy system have been tested and optimized, i.e., Gaussian MF. The Gauss M.F. equation is as follows:

$$Gaussian\ MF(x; c, \sigma) = e^{-\frac{1}{2}\left(\frac{x-c}{\sigma}\right)^2} \quad (4)$$

Where *c* determines the center and σ represents the width of the Gaussian MF, Inputs and outputs are defined as follows:

The first input (residual energy): Indicates the remaining energy of each node. The higher the energy, the more information can be sent and received. This increases the battery life of the node.

The second input (neighbor's #): It displays the count of each neighboring node. A node with many neighbors is more likely to be a parent node. A proposed method for calculating the number of neighborhoods is given in [28]. This method uses the following formula:

$$N = 1 - e^{-\gamma\pi R^2} \quad (5)$$

Among them, *R* is the radius of the neighbor, $\gamma = 0.01$, so the radius of the operating neighborhood of the algorithm is 15 meters.

The third input (centrality): Is the distance from the central node to the node.

The output (chance): It uses fuzzy rules to combine three input values. The input and output membership functions are shown in Fig. 3.

Input values are defined by fuzzy rules combined to produce an output. The fuzzy system is expressed through the "fuzzy rule base" in Table 2. The relation between the three inputs and the output, which calculates the decision, is as follows:

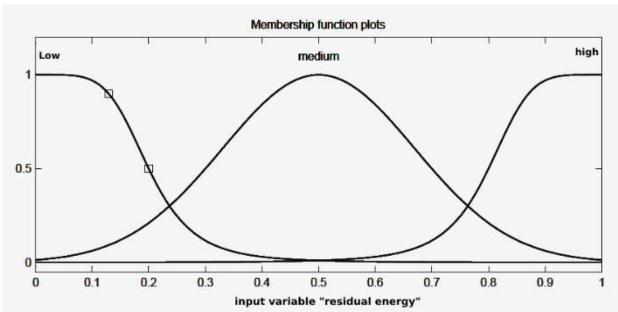
$$Ds = \sum_{k=1}^{n} E_r N\#(C) \quad (6)$$

Where three inputs are *Er, N#,* and *C*, in this equation, E_r denotes residual energy, *N#* denotes neighbors, and *C* denotes centrality. *Ds* represents the output, which is the selection decision.

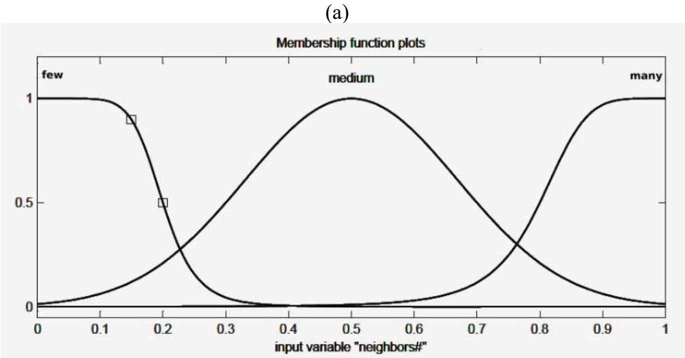
Proposed Fuzzy-Logic based cluster-head selection algorithm

```
Input← Non-cluster head WSN
Output← Cluster-head WSN
Cluster Head ← empty
# All parameters are included
# In the beginning, nodes are chosen as the cluster head in random order
Start Advertising stage
        R← Rand (0,1)
        If (R<T(N)), Then the node selected as Cluster Head
        # Each node selected as CH with P probability
        broadcast message ()
Start Cluster formation stage
        Each node joined to a cluster
```

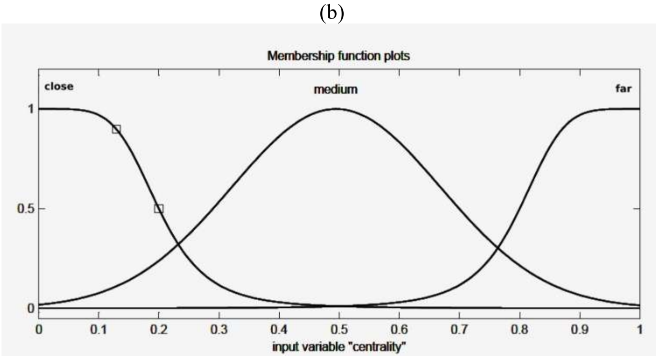
```
            Each Node join-request message (Join-REQ) to cluster head
Start Forming stage schedule
            Cluster Head (X) ← Data of Cluster nodes
            Cluster Head broadcast advertising
Start Data transfer stage
        data transfer begins
        If (Radio equipment non-cluster== False) Node turn off
        Else
        Data transfer continue
        the fuzzy system calculates the number of step messages (Nodes
to CH.)
End
```



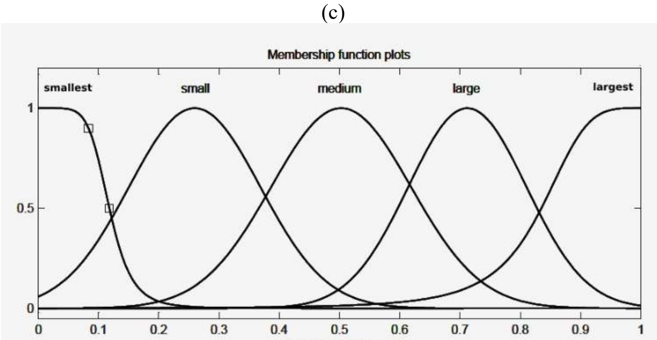
(a)



(b)



(c)



(d)

Fig. 3. (a), (b), and (c) the input belonging functions, (d) the belonging output function of the fuzzy system

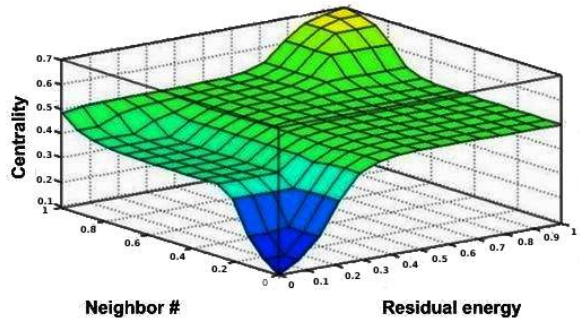


Fig. 4. The combination of input parameters

Figs 4 and 5 show a combination of the inputs to produce an output.

TABLE 2 **Fuzzy Inference Rule Base**

Rules	**Inputs (if. . .)**	**Output (then …)**
1	(Er==Less) && (N# ==few) && (C==far)	smallest
2	(Er==medium) && (N# ==few) && (C==far)	smallest
3	(Er==Less) &&(N# ==medium) && (C==far)	smallest
4	(Er==Less) &&(N#==few) && (C==medium)	smallest
5	(Er==Less) &&(N#==medium) && (C==medium)	small
6	(Er==medium) && (N# ==medium) && (C==far)	small
7	(Er==high) && (N# ==many) && (C==close)	largest
8	(Er==high) && (N# ==medium) &&(C==close)	large
9	(Er==medium) && (N# ==many) &&(C==close)	large
10	(Er==high) && (N# ==many) &&(C==medium)	large
11	(Er==medium) && (N# ==medium) &&(C==medium)	medium
12	(Er==medium) && (N# ==many) &&(C==medium)	medium
13	(Er==medium) && (N# ==medium) &&(C==close)	medium
14	(Er==medium) &&(N#==medium) &&(C==far)	medium
15	(Er==medium) &&(N#==few) &&(C==medium)	medium
16	(Er==medium) &&(N#==many) && (C is medium)	medium
17	(Er==Less) &&(N#==medium) &&(C==medium)	medium
18	(Er==high) && (N# ==medium) &&(C==medium)	medium

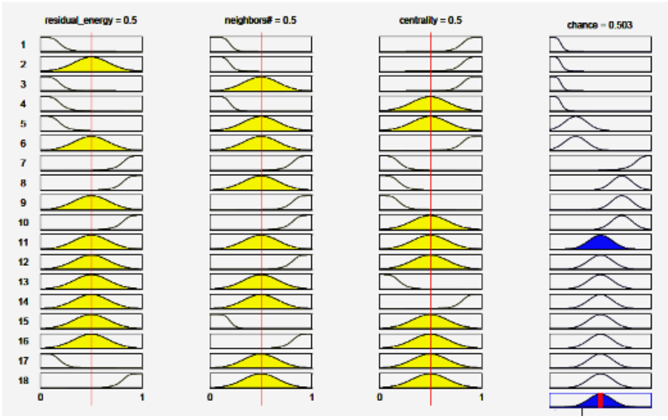


Fig. 5. Combination of inputs to produce outputs

We considered a network of 100 randomly distributed nodes to test the method. Other network parameters modified in the algorithm are shown below:

TABLE 3 **Parameters Initialization**

% Maximum value of fields - x and y maximum (in meters)	
Xm	100m
Ym	100m
%Number of Nodes in the field	
N	100
%x and y Coordinates of the sink	
Sink.x	0.5*xm
Sink.y	0.5*ym
%The probability that the initial selection of a node becomes the head of the cluster	
P	0.1
%Energy Model (all values in Joules) %Initial Energy:	
E_o	0.5j
%Eelec=Etx=Erx	
Etx	50*0.000000001
Erx	50*0.000000001
%Data Aggregation Energy	
EDA	5*0.000000001
%Transmit Amplifier types	
Efs	10*0.000000000001
Emp	0.0013*0.000000000001

3.1 Simulation setup

Simulation parameters used in the proposed method's experimental analysis are presented in this section. Network Simulator2 (NS2) was used in the simulation experiments, which is a well-known and reliable simulation tool for analyzing network routing and communication. Table 3 shows the default values for the simulation parameters. The dimension of the network extends to an area of 100 m × 100 m, and the coordinates of the base station are [50.50]. There are different numbers of rounds in which the simulation results are evaluated. The period of a single simulation round is set to 1000. Additionally, the number of agriculture sensors is set to 100, respectively. All of the agricultural sensors, i.e., temperature sensors, light sensors, soil moisture sensors, location sensors, airflow sensors, etc. are scattered randomly. Packet size (k) and payload size are set to 64 bits and 256 bytes. The energy required to run a running transmitter of agriculture sensors is uniform, i.e., 50nj. A Constant Bit Rate (CBR) is used between sensor nodes, and the sensor nodes' transmission range is set to 20m.

4 Results and Discussion

The features of the provided system model are explained. First, we announce the assumptions of the network model. To confirm the design method, we use a randomization form to consider a test platform network consisting of 100 nodes. The dimension of the network extends to an area of 100 m × 100 m. In this case, the base station coordinates are considered [50.50], and the probability value is set at 0.1. The initial energy is set to 0.5 joules. All sensor nodes are considered to have the same energy state. At the beginning of Cluster head selection, all nodes have the same probability of being a CH. The probability that an initial selection of a node will become a header is determined by P. The energy model of nodes in Joules is determined. Regarding Pseudocode in the previous chapter, the simulation continues until the radio equipment of normal node(s) goes down. So, the algorithm has the propriety of turning the node off and continuing to transfer data by other nodes.

In addition, all nodes and the sink are located in a fixed position with similar computational and memory capacity. The network is considered in a homogenous form. The distance between nodes is calculated as the intensity of the received signal and means that the sensor node does not recognize its exact position. The following is a description of the radio energy model.

The model of K-bit packet transmission radio energy is modeled over distance as follows:

$$E_{kk}(k,d) = \begin{Bmatrix} k * E_{elcc} + k * \varepsilon_{fx} * d^2, d < d_0 \\ k * E_{elcc} + k * \varepsilon_{mp} * d^4, d < d_0 \end{Bmatrix} \quad (7)$$

The radio energy model receives a K-bit package which can be represented as

$$E_{kk} = E_{elec} \times k \quad (8)$$

E_{elec} considers the energy required to run a running transmitter circuit depending on the distance. The radio parameters used in the simulation are defined as follows:

Table 5 **Radio parameters in the simulation**

E_{elec}	50nJ/bit
EDA	5nJ/bit/report
ϵ_f	10pJ/bit/m^2
ϵ_{mp}	0.0013pJ/bit/m^4

Algorithms are tested for other values of the case. After about 1000 runs, optimal cluster head values can be obtained. Fig. 6 shows the changes in the system parameters during iteration.

TABLE 4
SENSOR LIFETIME COMPARISON (TIME IN MILLISECONDS)

Type	1st run	2nd run	3rd run	4th run
LEACH	1417	1509	1497	1441
Proposed	1651	1704	1659	1696

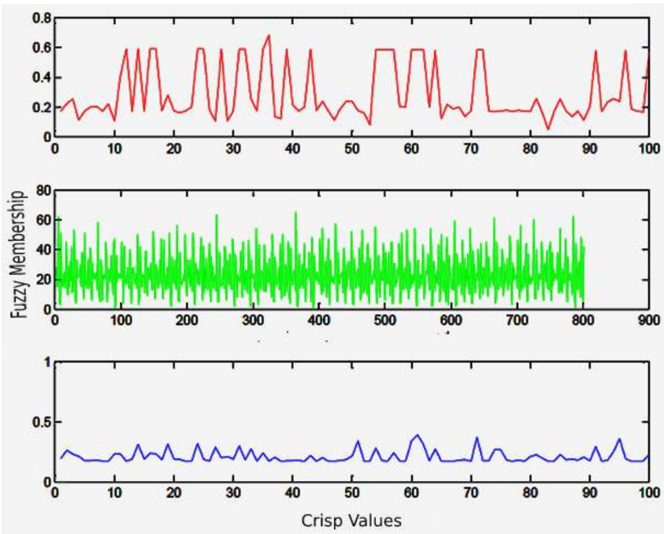


Fig. 6. The difference in system values by changing parameters (Distance)

Fig. 7 shows the resulting output of this system applied at 1000 rounds for 100 nodes with a random distribution. Table 4 illustrates the four-run simulations to compare the lifetime of our algorithm and LEACH.

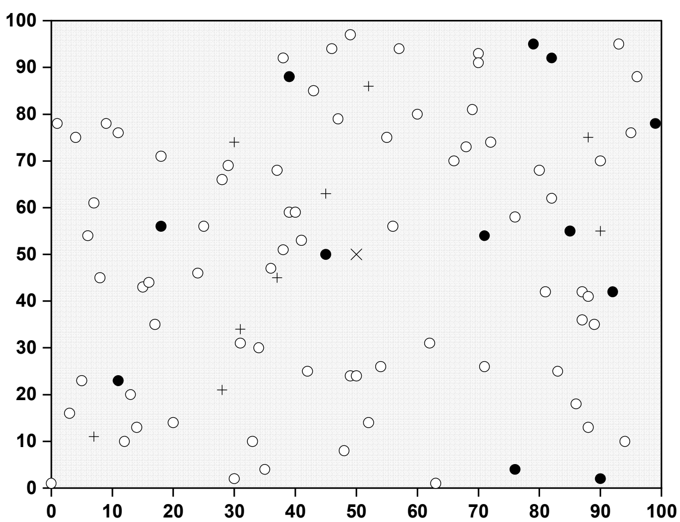
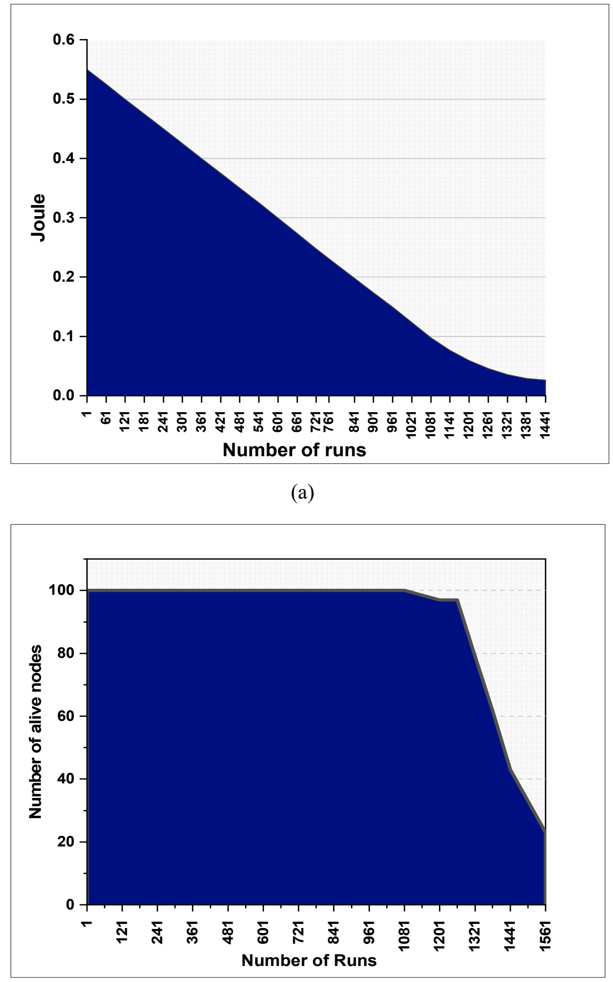
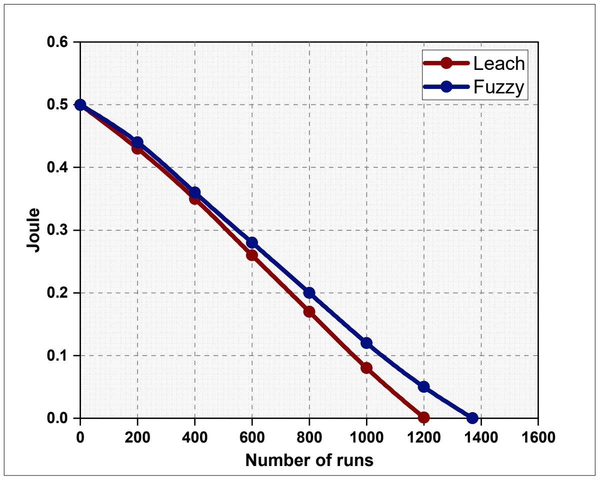


Fig. 7. Representation of 100 nodes on a 100m × 100m network

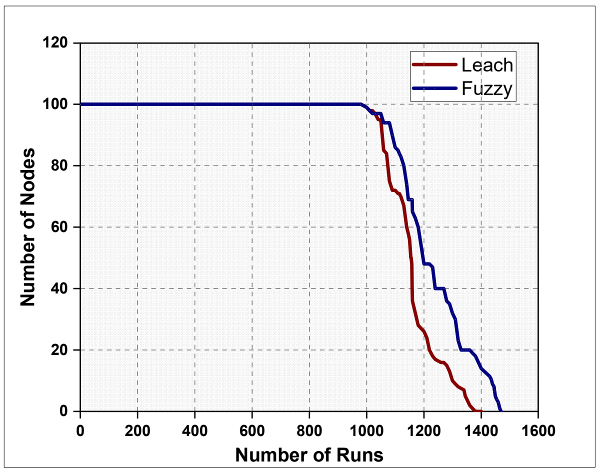


(b)
Fig. 8. (a) Remaining energy, (b) Number of active nodes (Proposed method)

The results show that the precision is higher than the traditional LEACH algorithm. Fig. 8 shows the performance analysis of our system in terms of remaining energy and the number of active nodes. Fig. 9 illustrates the performance comparison between the standard LEACH algorithm and the fuzzy inference system. Part (a) represents the remaining energy, and part (b) represents the number of active nodes. As shown in Fig. 9, using a fuzzy inference system produces better results.



(a)



(b)

Fig. 9. (a) Remaining energy (b) Number of live nodes

Also, in addition to the LEACH method, it is possible to compare the performance of the proposed method with the other methods. The performance of the proposed method is compared with the FCA method. Given that the FCA method is consistent with the proposed method and also uses fuzzy logic that can show the efficiency of the proposed method by comparison.

The FCA algorithm is designed for WSN with fixed sensor nodes. It adjusts the radius of the radio cluster head according to the remaining energy. It also adjusts the distance between the sensor nodes and the base station. This method aims to select the radius of the cluster head. In this algorithm, a number between 0 and 1 is generated for each node in each round. If the threshold (T(n)) is greater than a certain value, the node can be considered a cluster head. The fuzzy system considers three inputs. The results of this study were simulated. FCA is regarded as a stable and energy-efficient WSN clustering algorithm. Due to the similarity between our proposed method and the LEACH algorithm, we compared it with the LEACH algorithm. Fig. 10 shows the performance comparison between the FCA method and the LEACH algorithm. The results demonstrate that FCA has improved performance over the LEACH. Finally, in Fig. 11, it can be seen that the results of the comparison demonstrate the superiority and improvement of our proposed method. From the simulation results, it is evident that the proposed method results in a 24% improvement in the ratio of alive nodes compared to other methods. Fig. 12 illustrates the amount of residual energy algorithm in which the proposed method is more efficient than other methods, and the lifespan of the network is extended. Simulation results however indicate a 9% improvement in the residual energy ratio of the proposed method.

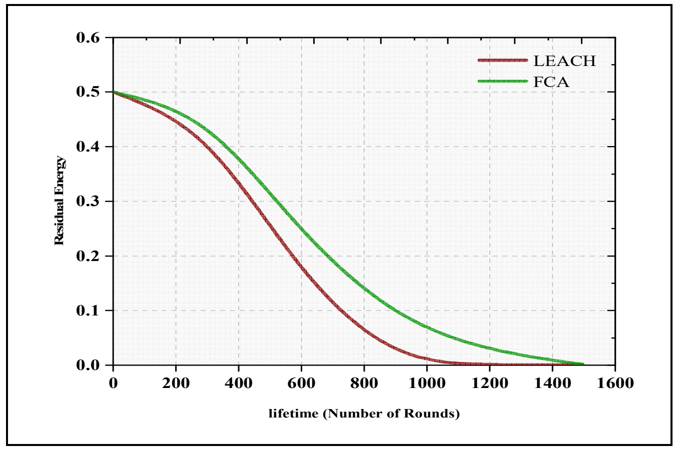


Fig. 10. Remaining energy comparison in terms of lifetime and residual energy

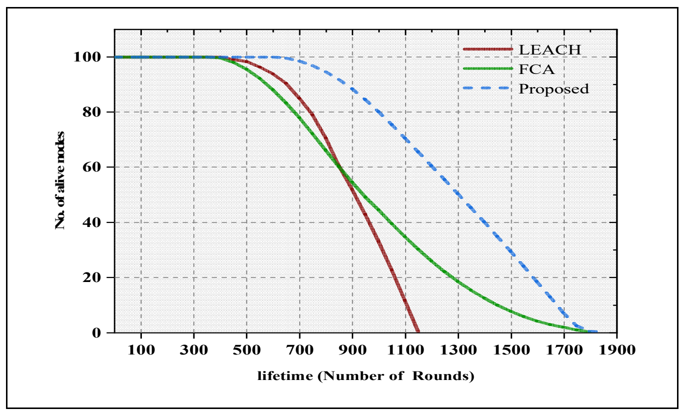


Fig. 11: The comparison of LEACH and FCA algorithm and the proposed method (No. of live nodes)

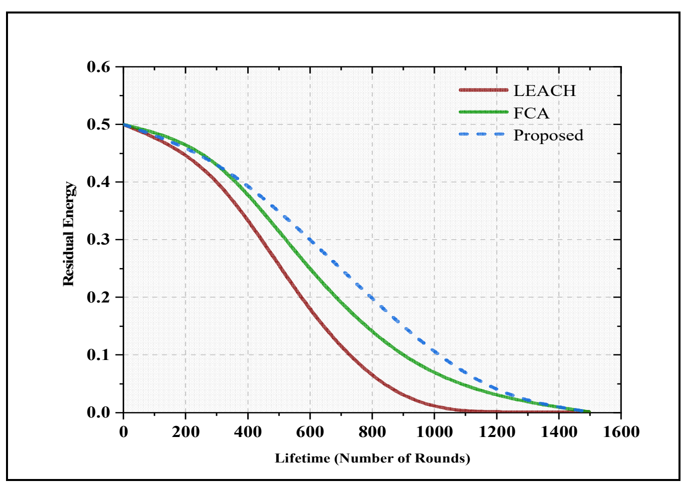


Fig. 12. Residual energy comparison between LEACH, FCA, and the proposed algorithm

5 Conclusion

We concluded that the WSNs constitute an essential contribution to remote sensing of smart agriculture systems for monitoring, temperature measurement, irrigation system measurement, and water supply measurement, among other things. It plays a vital role in enabling communication between several intelligent agriculture ecosystem computing components. WSN consists of a network of nodes, which communicate with each other and a base station. The sensors have several limitations, including topology management, mapping, and organization, battery power. These challenges adversely affect the intelligent agriculture system's performance. By improving the quality of WSN, data can be accessed remotely. This will enhance the connectivity and coverage area of the farm. An algorithm for fuzzy-based intelligent agricultural system cluster head selection is proposed to overcome the difficulties of unreasonable cluster head selection and excessive power consumption. An extensive evaluation and discussion of other related technologies in this field were conducted, followed by a brief comparison. By comparing this work with existing solutions, we conclude that the proposed method is more efficient than the existing methods. Energy consumption caused improving network lifetime. This study also concluded that the proposed algorithm could apply in innovative agriculture applications to analyze and use a simulation environment.

Abbreviation

WSN	Wireless Sensor Networks
IoT	Internet of Things
TDMA	Time Division Multiple Access
PSO	Particles Swarms Optimizations
FCA	Fuzzy Cluster Algorithm
GNSS	Global Navigation Satellite System
FIS	Fuzzy Inference System
CH	Cluster Head
MF	Membership Function
NS2	Network Simulator (Version 2)
SBAS	Satellite-Based Augmentation System

Declarations

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The authors are not affiliated with any organization having a direct or indirect financial interest in the subject dealt with in the manuscript.

Availability of data and materials

If necessary, the document will be provided.

Code availability

If necessary, the code will be provided.

Authors' contributions

All authors contributed to the idea and design of the study. The authors prepared the documents and collected and analyzed the data. Mahdi Safaei wrote the first draft of the manuscript, and all authors commented on earlier versions of the manuscript. The final manuscript was read and approved by all authors.

Ethics approval

All authors hereby ensure that the following contents of the manuscript are accurate:

- This material is the original work of the authors, never published elsewhere.
- This article is not currently being considered for publication elsewhere.
- This article truly and fully reflects the author's own research and analysis.
- This article duly acknowledges the significant contributions of co-authors and lead researchers.
- All sources used are properly disclosed (accurate citations).
- All authors have personally and actively participated in important work on the preparation of articles and are responsible to society for the content of their articles.

Consent to participate
Informed consent was obtained from all individual participants included in the study.

Consent for publication
Participants' informed consent to publish their data and photos.

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