



ORIGINAL ARTICLE

SMART AGRICULTURE: ENHANCING CROP YIELD PREDICTION AND FARM MANAGEMENT WITH AI-DRIVEN IOT SYSTEMS

¹*B.H.D.D. Priyanka, ²Pamula Udayaraju, ³Chandra Sekhar Koppireddy

¹ Department of IT, SRKR Engineering College, Affiliated to JNTUK, AP, India

² Department of CSE, SRKR Engineering College, Affiliated to JNTUK, AP, India

³ Department of CSE, Pragati Engineering College, Affiliated to JNTUK, AP, India

Corresponding Author Email: akhivarmas@gmail.com

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Abstract

The goal of Smart Agriculture: Improving Crop Yield Forecasting and Farm Administration with AI-Driven Internet of Things (IoT) Systems is to use Artificial Intelligence (AI) and the IoT to transform conventional agricultural methods. Using IoT sensors, this method gathers immediate information on vital parameters such as the condition of crops, climate, humidity, and soil moisture levels. Algorithms based on AI then evaluate the information to produce forecasting information. Precise agricultural output forecasts, efficient utilization of resources, and early identification of possible problems like insect infestations or water stress are all made possible by the system. The AI-driven IoT solution optimizes irrigation, fertilizer, and pest management while automating agricultural activities to increase overall output and decrease wasteful utilization of resources. Ultimately, the current structure for intelligent farming aims to support sustainable agricultural methods, boost crop yields, and enhance farmer decision-making, all of which will contribute to environmental preservation and food security worldwide.

Keywords: *smart agriculture; internet of things; artificial intelligence; crop yield prediction; precision farming; farm management; real-time data analytics; sustainable agriculture*

1. Introduction

The rapid development of technology to make electronics has enabled the availability of small and cheap sensor components or nodes. These available devices are able to withdraw multiple environmental features such as moisture, humidity, temperature, pressure and the likes. Sensors may be installed in large numbers in a field. These are able to communicate with each other through radio channels. They comprise the Wireless Sensor Network (WSN) [1] together. Applications that include intelligent transportation, precision farming, medical care and military surveillance, as well as forest fire detection are only but a few of the uses of WSNs. As an example, a farming area can be equipped with sensors to measure the location and soil moisture as part of precision farming based on the use of WSN. The sink node can be used to collect moisture information. A personalized application also allows farmers to access information. Through the humidity data, farmers are in a position to identify the portion of a crop field that dries up. Thus, an automatic sprinkler can be programmed to start watering in time in the agricultural area that has dried out [2].

Sensors are miniatures that operate on batteries. The perceiving and transferring information to other sensors consumes their limited energy. A sensor, or unmistakably, mote, is normally battery-operated and initially possesses a small amount of power, one Joule. The batteries are not normally replaced since the detectors are in hard-to-reach locations and they are not always readily available. WSNs commonly have one or more sink nodes that are responsible for collecting sensed information. It is likely that in most cases a single node is transmitting information to the sink node. Each of the nodes in this process consumes energy. There is duplication of information between sensors that are very nearby [3]. More energy will be consumed by the nodes that are far away compared to the sink in passing information to

the sink. Consequently, more energy is lost in nodes that are distant than those that are not. As a result of this aspect, distant sensors break down and sometimes lead to network breakage. The nodes that are more remote to the sink might not always be capable of relaying information to the sink without the help of the rest of the nodes which are relatively closer to the sink. A path between the source node and the sink has to be established. The energy will be used on every node on this path, [4]. The intermediary nodes of the path will only serve as forwarders of sensed data by the sources. A WSN is never more than as many nodes as it has been working. When a node is receiving, transmitting or transferring information, it consumes energy. In order to make sure that the WSN can be running over an extended period of time, consideration should be made to avoid the possibility of using up the anode energy as long as possible. Sensor nodes can be powered down by choosing the optimal route between the source and sink and transmitting the information over the optimal route. Routing refers to the procedure of finding a path through which the information flows through a source to a destination node. There is one more topological approach to WSN [5]. The WSN is designed so as to form node groupings or otherwise known as groups with similar nodes and a Cluster Head (CH) in each group that collects and transmits information to sink nodes in each cluster. This method is referred to as grouping and it is depicted in figure 1. A lot of energy is saved because certain nodes transmit information to their CHs only. Directly transmitting information that is sensed to sinks consumes more energy as compared to transmitting the same information to CHs. Although clustering offers a more cost-effective solution of information gathering, the selection of a CH remains an inconvenience. Election of the head of the cluster is conditional on such factors as the concentration of nodes and the energy left. CHs are computationally intensive nodes; excessive use of the batteries drains the batteries. The role of CHs is rotated in all the nodes of the network to compensate for the loss of energy [6].

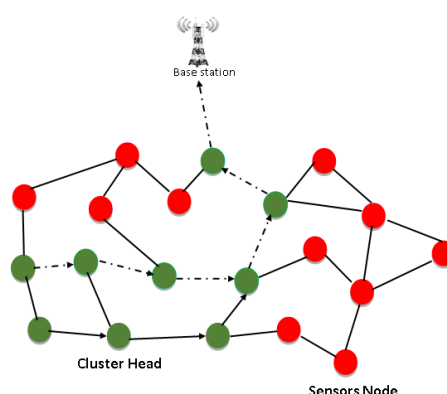


Figure 1: Multi-hop clustering network

The IoT is a novel paradigm in the information and communication technology (ICT) discipline. IoT is the system of intelligent devices, including smartphones, RFids, and sensors, which have the ability to communicate with one another over the Internet. IoT allows smooth communication between smart devices. Some of the IoT application areas include Medical Care, smart cities, farming, transport and logistics. When operating in a smart city, city administration of resources such as water, traffic, parking, etc. is possible to better the individuals. In an intelligent city, a traveler can receive an alert concerning the parking space or traffic flows [7]. A visitor may follow the free parking space, therefore parking his/her automobile towards a space that is available. Again, a driver will be able to choose a route and drive his or her car depending on the traffic pattern. Water waste can also be prevented in case there is an observation on a region's water consumption pattern. Water supply can be centralized and controlled according to the patterns of use. As an example, the time of water supply of a region can be established. Through the installation of smart electric meters in residential buildings, one can establish the trends of electricity usage. In case the energy use pattern in a city is identified, it is possible to balance the electric grid loads [8]. WSN may be the foundation of the IoT. The opportunities of IoT in precision agriculture can be explored with the application of WSN. Very different sensors could be applied in the agricultural sector and collect relevant information by measuring the levels of different factors of the environment (water content in the soil, temperature, and nutrient levels, etc.). A WSN can be easily set up in an agricultural

region by placing sensors. This data could then be availed to the farmers via IoT. Based on the gathered information, farmers can implement agricultural activities such as irrigation, harvesting, and other agricultural practices to enhance the production of crops and ensure that the quality of crops is highly successful. The introduction of smart precision farming may result in the rise of the economies of countries [9]. The efficiency of a program of this nature can be enhanced by ensuring there is energy saving and geographic knowledge about the underlying WSN. Due to the limited power, bandwidth and the processing capacity of sensors, it is hard to carry out tasks such as routing, localization of the operations and other functions of the WSN. However, the challenges have to be conquered to enable the future use of WSN in the future [10].

1.1 Motivation

The lifetime of WSNs is measured by the Time to First Node Death (FND), Time to Half Node Death (HND), Time to ten Percent Node Death (TND), Time to Last Node Death (LND) and so on. There is a need to maximize the life span of WSNs in agricultural fields so as to gain financial gains. Grouping is one approach of attaining energy saving in WSN. Clustering is used to partition the network into non-overlapping clusters with one CH. The most important part of the clustering effectiveness is the selection of the CHs. A large variety of CH election techniques are provided in the literature. The limitations of current algorithms to clustering restrain the use of the methods of clustering in real-world networks. Most algorithms select CH randomly in all the network nodes which results in imbalanced clustering. The death of a node is a result of unbalanced energy dissipation caused by unbalanced grouping. To get the equilibrium dissipated energy across the network, the CHs have been chosen based on numerous criteria such as the remaining power of the node, the distribution of the nodes surrounding the node, its proximity to the sink, its distance to the network center, etc. None of these, in the meantime, have been recognized as being ideal. The alteration of clustering protocols is usually done without considering application requirements.

1.2 Problem Statement

Precision farming sometimes requires the knowledge of where a field that is significant is located in order to make timely agricultural choices. Localization without GPS becomes possible by using the signal strength that was received, the time-of-arrival and the angle-of-arrival to determine the distance between two nodes. There is inaccuracy of approximations and uncertainty in this process. Soft computing such as ant colony efficiency, fuzzy logic, neural networks, and genetic programming can be applied to resolve the issues based on uncertainty. The localization algorithms are influenced by precision, processing overhead, node density, number of anchor nodes, and others. Each algorithm has both strengths and weaknesses that render it suitable to a wide range of applications. Localization techniques are either scattered or centralized in WSN. The centralized methods are more accurate when it comes to giving locations and thus, they are suitable in the applications that require the accuracy to be absolute. Distributed algorithms, in their turn, are hypothetically more scalable and require no massive centralized systems, which is why they can be used in agriculture. When localization is dispersed not all a node floods out the network with location messages. In this way, the energy of sensors can be stored and their lifespan increased due to the low connection cost. It is here that the effect of the variables of the IoT such as flexibility, mobility, and various information traffic can be analyzed. The common localization research challenges are localization in ambient and noisy environments (e.g., moisture, radiation), localization safety during translation, localization in the Mobile Wireless Sensor Networks (MWSN), and localization in three-dimensional space. In case the anchor nodes being employed in the process of localization are attacked by malicious entities, then this may affect the process. The anchor nodes must be secured against malicious attacks in localization. Thus, a safe method of localization should be developed to counter malicious attacks.

2. Related Works

IoT is a global system of connected objects, which relies on ICT infrastructure. It is linked to mobile phones, fridges, RFIDs, sensors, and an assortment of others. As an example, an app used in a smart home can use sensors to use the IoT to notify an individual of the temperature of a given room. The individual will then use the air conditioning to alter the temperatures in the home. In the same way that a smart

refrigerator can send information to professional requesting assistance after it begins to malfunction. The market opportunity is large to those who develop applications, provide service and make devices. It is estimated that a billion smart devices would be added to the IoT [11]. It shows that the majority of the share is owned by healthcare and allied industries with the rest of the stake being occupied by power, farming and safety. Smart appliances will include appliances that possess processing and communications capabilities i.e. refrigerators, washing machines, ovens, light bulbs etc. They are controllable anywhere. More so, the connected devices will communicate with each other over the Internet, a ubiquitous computer world. The devices of the IoT are heterogeneous, and they have device constraints, which offer numerous challenges [12]. IoT in the agricultural sector can help such countries as India. With the help of such an application, farmers would have an opportunity to monitor numerous field parameters, including moisture, temperature, fertilizers, etc. There is no physical supervision of the agricultural field. Hierarchical clustering method was developed to reduce the traffic of the network to the sink. Cluster heads send data directly to the sink in the proposed Secure Energy-Efficient Data transfer (SEED) [13]. The network is divided into three areas based on the energy. Sub-clusters that are made up of sensors with the same applications are created when one awake node transmits data when the rest are in the sleeping state. The lifetime of the network is increased by a followed sleep-wake schedule. A heterogeneous WSN routing scheme named Decentralized Energy-Efficient Clustering (DEEC) was invented. The nodes are considered independent of battery power and hardware complications. DEEC uses the ratio between the remaining energy and the projected energy used by the network to elect the leader of the cluster. Similar to EDDEEC and IDEEC, there are a number of improvements that DEEC can make. The authors of IDEEC do better compare with the DEEC and EDDEEC by maximizing the likelihood of cluster head election and the estimated mean energy of the cluster [14]. Gifts a presented distributing method of multi-target WSN. Clusters are formed in a network by the nodes which share a target. Also, topological optimization attempts are performed to eliminate limited sensor resources. The results of the simulation reveal that this method is effective in tracking and fusion. The other advantage of the distributed clustering strategy is that it offers a longer network lifespan [15]. A method based on the game theory and the dual cluster head election algorithm in environmentally friendly clustering in WSN. Dual election of the cluster head can be used to reduce the energy utilization by using motion of cluster heads. The game strategy is a non-cooperative strategy that is used to equal the electrical power consumption of leaders of clusters. The results of a simulation require the clustering strategy with maximum energy usage [16].

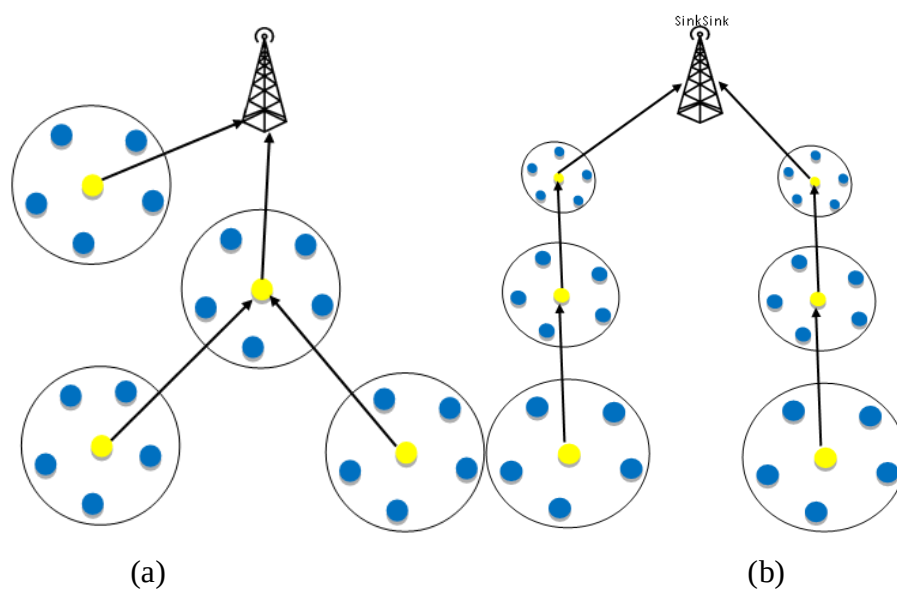


Figure 2: Size-based WSN clustering: (a) equal size clustering (b) unequal size clustering

Clustering techniques could be equal or unequal, as illustrated in Figure 2 depending on the size of the clusters. All clusters are equal in size when an equal-size balanced clustering strategy is used, including ER-HEED and HEED. This means that all CHs have equal communication radius no matter their distance off the base station. Inter-cluster and intra-cluster traffic makes CHs that are closer to BS dissipate their energy quicker than other CHs in comparable clustering situations. In this case, an energy hole is created near BS [17]. The remaining energy is employed in this method to elect CHs. The lifetime of the network is enhanced when nodes belong to the clusters with the least communication costs. The Hybrid Energy-Efficient Distributed Clustering (HEED) algorithm is used to make WSN routing efficient. It continues to sink through multi-hop information transmission. Unlike LEACH technique, a cluster head is determined by the remaining power of the nodes. Because inter-cluster communications will cause nodes nearer to the base station to die more quickly, equal clustering has a power-hole problem. In an uneven clustering situation, the radius of groups near BS is less than that of groups that are far away [18]. In uneven clustering algorithms like UHEED, CHs are elected by the proximity of nodes to their neighbor and energy remaining of nodes. This protocol decides the competition radius to generate uneven clusters based on the distance to BS. Further to BS, there is increased inter-cluster traffic and reduced intra-cluster traffic. It maintains closer nodes to BS to ensure that they do not die too early. It, therefore, addresses the issue of the power hole that HEED was faced with. RUHEED is an improvement of UHEED by rotating clusters to reduce the stages of election of the head of the cluster. The current CH selects the node whose members have the most power remaining [19]. The election process is delayed until one of the nodes dies. Using the residual power to rotate CHs between cluster members, proposed ER-HEED (energy-based rotated HEED) reduces the assembly steps of HEED. Came up with a Sybil detection algorithm using RSSI. Three cooperating nodes help the receiver node calculate the RSSI ratio, with the help of them. Sybil nodes are senders whose difference ratio between the two nodes based on RSSI is below a given threshold [20]. In a bid to detect sybil attacks, they checked the Time Difference of Arrival (TDOA) of packets. Two identities are considered to have the same TDOA ratios in two sessions, which are called to be Sybil nodes. Attacks are identified by the Angle of Arrival (AOA). The Sybil attack is made on the basis of the same physical location with multiple identities [21]. According to the signal phase difference between successive nodes, a trust value is calculated to detect Sybil attacks. In the case of sensor nodes that are in close proximity to each other, and there is a signal phase difference that is below some level of reliability, it is considered a Sybil node. TMCA is a strong specialization that is deployed as a counter to the famous attacks in WSN, specifically wormhole, sinkhole and sybil attacks. This method achieves this by initially splitting the set of all position connections into two sets: the regular set and the malicious set. The malicious referencing group is constituted of the hacked anchor nodes. Then, the malicious anchor nodes are identified by performing a simple assessment [22].

3. Materials and Methods

The layer devices in AgriTech are mobile phones, actuators and sensors to name but a few. They are used in the collection of different factors in crop fields, which include humidity, and nutrients. Between different objects and a local sink, a single-hop or a multi-hop communication protocol has to be employed. This layer must be able to break the barriers associated with radio signal capturing and communication. A possibility of collision of messages also exists since the system will contain multiple nodes sharing information with each other. The sensors must be location-aware in an application as depicted in Figure 3. The data gathered is of no use without information on the place. The sensor localization method will need to be developed in this layer. Among the valuable and important resources in WSN is energy. As such, collection of information must be carried out in an energy efficient way in such applications. This is required to increase the life of WSN.

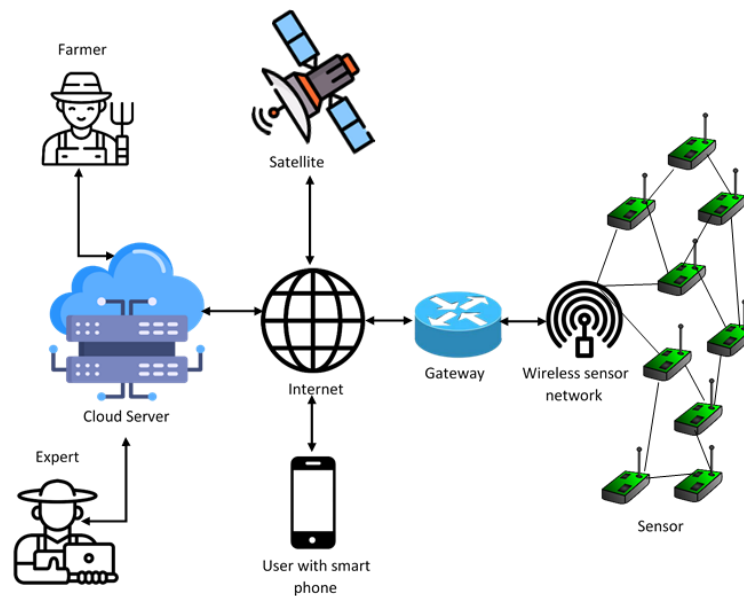


Figure 3: Proposed Architecture

3.1 Local Gateway

The underlying WSN sends the data to the local gateway in precision agriculture. In order to eliminate duplication, the local gateway consolidates all the information that it has gathered. Similar values of characteristics are transmitted by closely spaced sensors. Redundancy should be kept to bare minimum as the same parameter value consumes resources. The local gateway also transmits information to the cloud after aggregation. Cloud data can be accessed by a number of stockholders depending on their needs.

3.2 Internet

Agrotech is heavily dependent on the internet. Things Layer uploads information to the cloud via the Internet. It enables sharing information with all the stakeholders. Their field data can be accessed by farmers. The analysis of the information would help in finding the affected agricultural area. Farmers, as an example, get to know about the region that becomes dry. Irrigation can commence in the specified farmland. Through selective irrigation, water and other natural resources utilized are minimized. Based on information, farmers are able to make decisions regarding crop harvesting. AgriTech can also make use of weather projections to help it know when to harvest or irrigate. AgriTech can delay irrigation when it is likely to rain to save on water.

3.3 Data Cloud and Mobile Phone Application

AgriTech uses cloud services to store and retrieve agricultural related information. All the information obtained has been stored in the information cloud. The cloud provides a framework in which a user can access data and services by paying per usage. Cloud is used in layer 4 of AgriTech. Precise farming applications could be provided by cloud computing. The software can be accessed by the farmers through cloud-based Software as a Service (SaaS). With the installed software on their smartphones, farmers can have an opportunity to check their agricultural output remotely. A set-up cost is required initially during layers 1 and 2 which is a burden to farmers. However, farmers can use layer 3 and layer 4 cloud computing services. Most customers who use mobile phones are the users of smartphones who have a vast array of programs, and their population is increasing by the day. This program can be used to remotely operate a small number of farm gadgets. Water sprinklers can be customized to disperse water according to the levels of temperature and humidity. The cloud-based expertise in agriculture could be of benefit to farmers. They can also provide guidance to farmers on how to control pests, harvest and how to transport their products to the international markets.

3.4 Message Communication in Framework

Message exchanges that follow include: person-object, object-internet, person-internet and person-object. Deployed sensors sensitize information associated with crop fields. The first type of communication is where farmers receive sensed information via the Internet. In these days, the farming activity has very minimal use of the mechanized or semi-automated equipment. The second type of connection is the one that allows the sharing of information between a device and a second device. The humidity sensors can send the information to water sprinklers, for example. Semi-automated sprinklers can be now activated based on the humidity. Devices that are based on the third type of communication can post data directly to cloud servers. The fourth way of communication is by means of the World Wide Web which allows farmers to gain access to information stored in the cloud. Cloud computing provides on-demand applications to numerous stakeholders of the application.

3.5 The Network and Energy Model

The proposed method OFCA is premised on the following assumptions. In order to measure a 100 m² of a field that is used in agriculture, 100 nodes are randomly dispersed in the field with a non-uniform distribution method. This creates the WSN. CHs closer to BS consume more energy in the multi-hop transmission of data as compared to those far because of the intra-cluster traffic and the inter-cluster traffic. This generates a hole in energy near BS. In order to remove the energy problem, disproportional groupings of different competitiveness radii are generated. The WSN in this instance is believed to be divided into a number of levels. According to the amount of left power by a specific node, difference between the node and the base station, and the density of nodes at each level, the OFCA algorithms cluster the nodes and decide on a CH to serve each cluster. Clustering minimizes the dissipation of energy by transmitting information between every node to the corresponding CH. All CHs gather sensed data on their member nodes and transmit this over a multi-hop connection with a TDMA schedule to the base station. There is no aggregation of the traffic between CHs or inter-cluster messaging. It means that a CH transmits messages without aggregating them which are transmitted by other CHs. The science which collects and structures the information of CHs revolves around the BS. The combined data are used to make decisions regarding irrigation, harvest, and use of fertilizers in the selected area of the agricultural field. As an example, water can be released when the automatic sprinklers detect that soil is dry. All of the nodes except the BS are stationary. The BS does not limit its power and has enhanced processing power. Each of the nodes could be a CH and a normal sensor node. The first order energy model for consumed energy (during communication) is as follows. The energy consumed by the transmitter for transmitting k bits over a distance of d is given by Equation (1). The transmitter dissipates energy to run the radio electronics (E_{elec}) and the power amplifier (E_{amp}). If the distance is less than d_0 , the algorithm adopts the free space model (d^2 power loss) else adopts multi path fading channel model (d^4 power loss).

$$E_T(k, d) = E_{Telec}(k) + E_{Tamp}(k, d) \quad (1)$$

$$= \{kE_{elec} + k\varepsilon_{fs}d^2, \quad d \leq d_0 \quad kE_{elec} + k\varepsilon_{amp}d^4, \quad d > d_0\}$$

But the receiver consumes energy to run the radio electronics (E_{Relec}) only and is given in Equation (2)

$$E_R(k) = E_{Relec}(k) = kE_{elec} \quad (2)$$

Where E_{elec} represents electronics energy consumption for transmitting or receiving 1 bit. Also, ε_{fs} , and ε_{amp} are the coefficients of energy consumption of transmitter amplifier for different channel propagation models, namely, free space and multi-path. While d_0 is the threshold distance between transmitter and receiver calculated by Equation (3)

$$d_0 = \sqrt{\varepsilon_{fs}/\varepsilon_{amp}} \quad (3)$$

3.6 Cluster Head Election and Calculation of Communication Radii using Fuzzy Logic

It has been established that fuzzy logic is beneficial in decision-making within unpredictable and chaotic environments. A WSN has uncertainties in many aspects. The network is more useful in managing the uncertainties in CH elections using FIS. FIS evaluates fuzzy inputs with the help of fuzzy rules and then converts them into fuzzy outputs. The set of regulations that are outlined in FIS to determine the fuzzy

probability or possibility of a node turning into CH is referred to as the fuzzy rule base. Mamdani and Sugeno fuzzy inference models are used by investigators of this field. Each of the frameworks is based on the principles like "if antecedence then consequence. The type-1 Sugeno FIS is used in this study to calculate communication radii and elect good CHs. The proposed FIS utilizes three fuzzy inputs namely: residual power, distance between the sink and the number of nodes covering a particular node. The two are communications radii and CF. Residual power is the energy which can be discovered in a sensor node. The concentration is the number of nodes within the transmission assortment of a node and the second input is the distance between the node and the base station. The higher the CF of a sensor node, the higher its chances of becoming a CH. Ensuring that CHs have the best energy efficiency by being electrified can result in longer life. CH has the responsibility of assembling data obtained by sensor nodes in its membership and relaying it to the sink. Consequently, CHs consume energy as compared to other normal nodes (non-CH). The more energy a node remains, the more it is likely to become a CH. The further apart the BS the lower the likelihood of being elected as CH. The third fuzzy input is concentration which is a measure of the number of nodes surrounding a node. The higher the level of focus, the higher the probability. The three fuzzy inputs vary dynamically within the network with node-to-node variation. The fuzzy inputs and fuzzy criteria used by the Sugeno FIS to calculate the CF of a node and then elect the node as a CH. The calculation of CF in the FIS of the proposed method uses the rule base as a foundation of the calculation. An example of this is that the CF is regarded as extremely bad in cases with low amounts of residual energy, a close range and low concentrations. In the same vein, the CF is regarded as being really ordinary, in that the quantity of it is not very large, the distance is the greatest, and the rest of the energy is less. In the same manner, the CF is described as highly powerful with the rest power being high, distance being far and concentrations being high. In the initial rounds, the elected CHs are the ones that are located near BS, however in later rounds (when the initial node dies) more distant CHs will be elected due to their larger residual energy and are favored by comparison with the closer nodes. This rotation and dispersion of CHs over time as well as around the network with more rounds will result in an energy hole near the base station being avoided. The distance to BS is used to compute the communication radii of CHs. The communication radii of CHs that are closer to BS are set smaller than those of the further ones to conserve energy.

Algorithm 1: Proposed OFCA Clustering Algorithm

Input:

W: network, r: round number, a: node in W, c: cluster

CF(a): fuzzy chance to become a CH

L: number of clusters, max_round: maximum round number

b: fuzzy inference system

Output:

CH(y): cluster head of the y-th cluster

Function:

eval_fiscf(residual_energy, distance_from_BS, concentration, fis): calculates fuzzy confidence factor

eval_fiscr(distance from BS, fis): calculates communication radius

find_maxCF(cluster): returns node with maximum CF value

broadcast(information, destination): advertises message

Initialization:

1: Define fuzzy rule base

2: $b \leftarrow \text{read_fiscf}()$ and $d \leftarrow \text{read_fiscr}()$ // read fuzzy system into a and b

3: $r \leftarrow 0$ // initialization of round

Main:

4: For each r until max round

/*setup phase*/

5: For each node $a \in W$

6: $CF(a) \leftarrow \text{eval_fiscf}(\text{residual_energy}(a), \text{distance_from_BS}(a), \text{concentration}(a), b);$

[End for]

```

7: For y =1 to L //form L clusters
8. CH(y) ← find_maxCF (cy) //elect node with max. CF as CH
9. //calculate competition radius of CH(y)
R(y) ← eval_fiscr(distance_from_BS(y),d);
10: Broadcast(CH-message, CH) //BS informs all elected CHs
[End for]
/* steady state phase*/
11: For each cluster c_y ∈ {c_1, c_2, ..., c_L}
12: Find an optimal routing path applying PSO.
13: Collect data and aggregate.
14: Forward data to BS using optimal path.
[End for]
15: r ← r+1
[End for]
16: Exit

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4. Results and Discussions

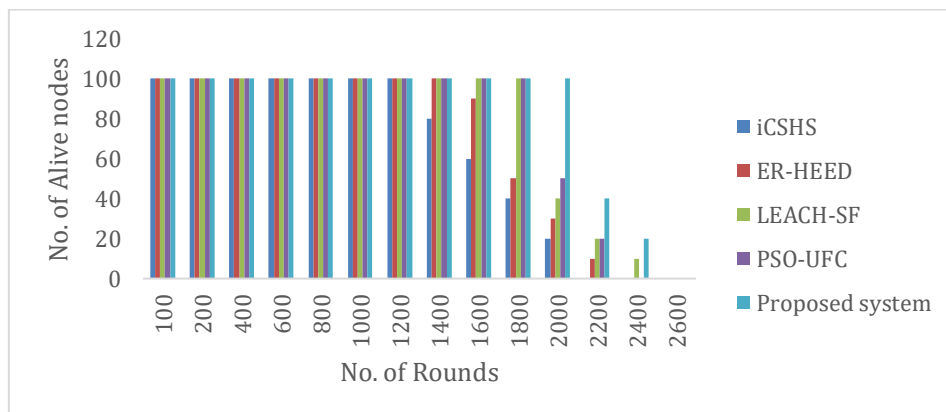
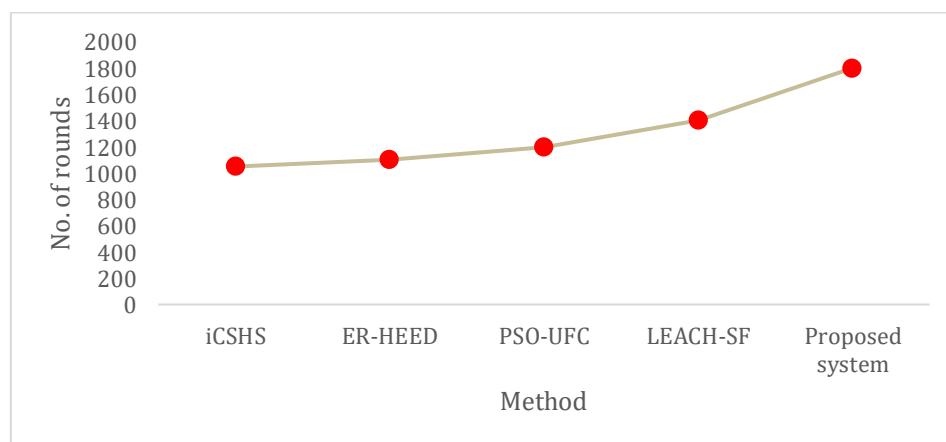
iCSHS, ER-HEED, PSO-UFC, and LEACH-SF are simulated on the same platform with the same settings as in the case of OFCA. These approaches are validated using the results of simulations in the Matlab R2013a framework by the findings available in the body of existing literature. The initial node death, ten percent node death, half node death, living and dead node and number of packets that were handled in the BS are then compared to the simulation results of the use of the above techniques in OFCA. The average of every statistic of the 40 runs is used in order to compare them with alternative methods. The results of the simulation on the homogeneous sensor network in which they had been applied to represent different data. This has been confirmed in a heterogeneous sensor system. Owing to uneven grouping, successful CHs election using FIS, and transmissions of data using multiple hops between the CHs and the BS, OFCA extends the life of WSN with regard to improved FND, TND, and HND. In the suggested method, effective CHs are dynamically selected in every group using an optimized basis of fuzzy rules. Unlike other fuzzy-based methods, the fuzzy rule basis is optimized to extensive WSNs applications, including agricultural surveillance, to select the best CHs. Multi-hop data forwarding between CH and BS via other CHs ensures that the possibility of energy holes and packet loss at the BS is completely eliminated. Again, the hot spot problem is overlooked by means of the introduction of unequal clustering. Figure 4 shows the effectiveness of the suggested approach in terms of the number of live nodes to the total number of rounds. Owing to equal grouping, OFCA is better compared to the others, as shown in Figure 4.

Network lifespan is tested in Figures 5 and 6 under FND, TND and HND. In the simulation, FND, TND, and HND have a quantitative measurement based on the number of rounds. Figure 5 shows the representation of WSN lifespan in terms of FND and TND. It demonstrates that due to its fault-tolerant and uneven clustering, PSO-UFC is more effective than iCSHS. Whereas ER-HEED performs better in comparison with LEACH-SF when considering FND, it outperforms them by 18 per cent when considering TND. Notably asymmetrical clustering, OFCA enhances FND by 27, 58 and 11 percent respectively than LEACH-FL, ER-HEED and LEACH-SF. The removal of the former or some nodes will have no impact on the agricultural data collection, HND will be more applicable compared to FND where agriculture is needed like in agriculture monitoring. Betterment of TND and HND are thus preferable to FND in this genre of WSNs use. The proposed strategy produces a significant increase in regards to HND, as indicated in Figure 6. The reason is that, in contrast with LEACH-SF, which relies on the concept of single-hop routing, the presented technique implies the implementation of multi-hop routing and uneven clustering. OFCA capabilities are evaluated in a heterogeneous network where the heterogeneity of FND is varying in degree. The simulation parameters are the same as those being used in Table 1 except the nodes who start randomly with a beginning energy of 0.2-0.8J.

Parameter	Value
Network Size	100x100m
No. of nodes	100
Initial energy	IJ
Eelec	50nJ/bit
ε_{fs}	100pJ/bit/m
ε_{amp}	0.013pJ/bit/m

Table 1: Details of simulation parameters

Parameter	Value
Number of particles	30
Iterations	100
W1	0.5
W2	0.3
W3	0.2

Table 2: Parameters for PSO**Figure 4:** Number of alive nodes versus rounds with 100 sensor nodes

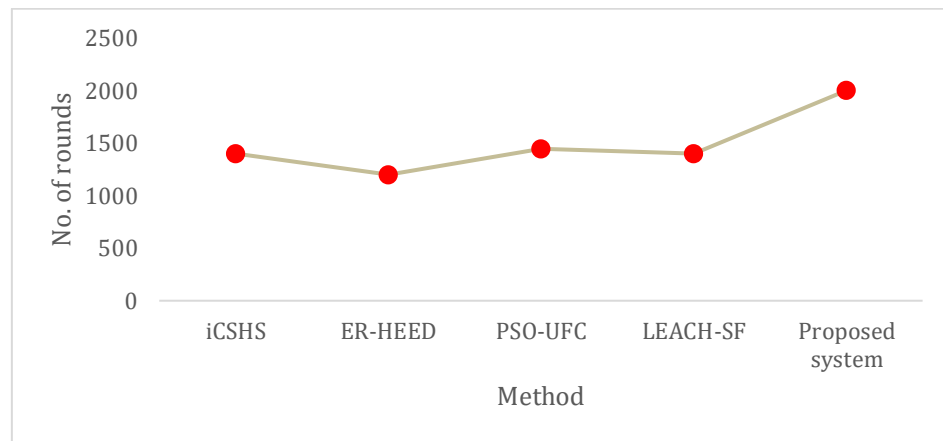


Figure 5: Lifetime (a) First Node Death (FND) (b) Ten percent Node Death (TND), with 100 nodes

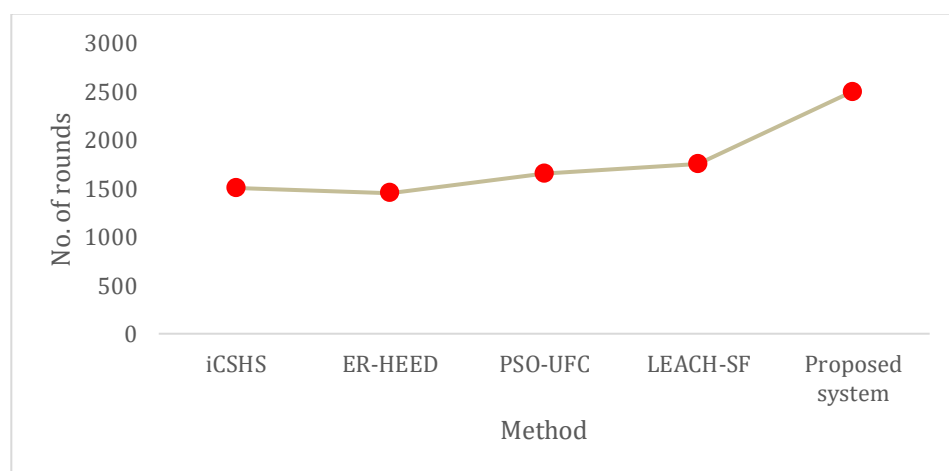


Figure 6: Time to Half of Nodes Die (HND) [rounds], with 100 nodes

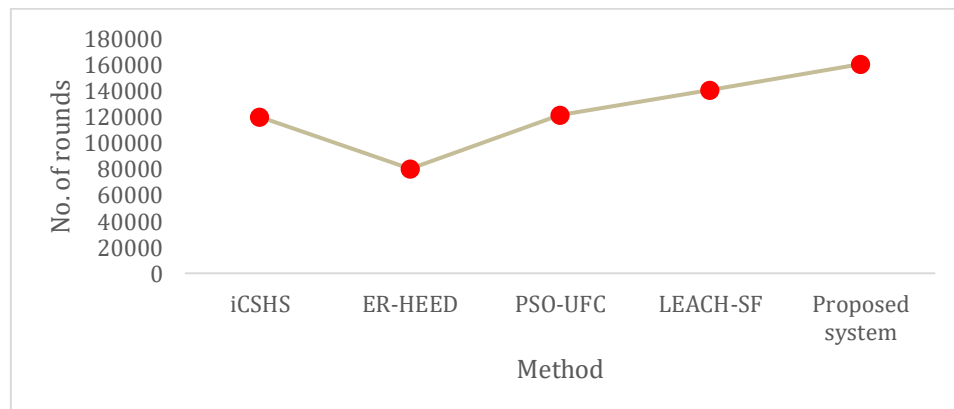


Figure 7: Number of packets received at sink until FND

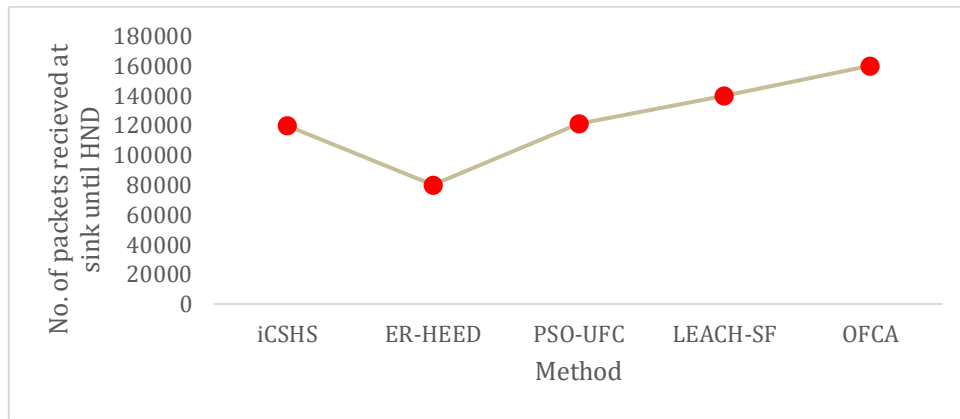


Figure 8: Number of packets received at sink until HND

The count of packets gathered in BS until FND and HND respectively is presented in Figures 7 and 8. The number of packets received at BS is counted in order to demonstrate that the WSN does not collapse after the occurrence of FND and HND. This approach is shown to work better as compared to the rest because it involves multi-hop transmission of information between CHs and BS. It is found that, compared to FMUC and DEBUC, used in the heterogeneous WSN, or UHEED and REECHD that are commonly used in the homogeneous WSN, with 10% heterogeneous nodes (Figure 9(a)). The reason is that the intra-cluster traffic is reduced close to sink in the case of OFCA and that uncertainty in CH election is dealt with in a superior manner. Figure 9(b) of a greater heterogeneity level of 40% indicates that the proposed procedure OFCA is behind REECHD. This is probably due to the fact that although 40 percent of the WSN is heterogeneous, node heterogeneity was not explicitly considered in the studies of OFCA, and all types of nodes were considered as a candidate to CH irrespective of their capabilities and capacities. It also appears that heterogeneous WSN is where additional characteristics which are not a necessity in homogeneous WSN should be considered. Thus, in this case the network life of OFCA is less compared to the network life of REECHD.

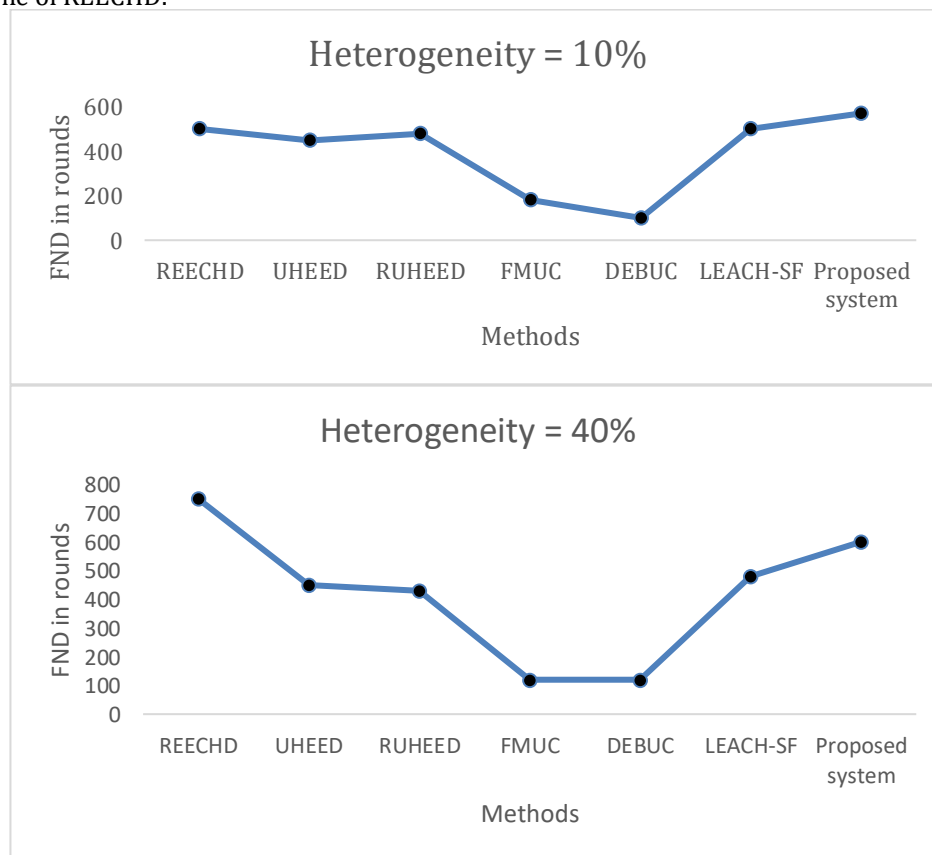


Figure 9: Network lifetime (FND) comparison of protocols in heterogeneous network with (a) 10% and (b) 40% heterogeneity levels, intra-traffic rate limit=50%

5. Conclusions

Basic calculation of the communication radii of the cluster heads through the use of fuzzy logic is determined based on their distance with the base station. The suggested work draws unequal groups of balancing by differentiating the communications radii of the cluster heads. Optimal route through cluster heads to the sink station has been tried to find out. The optimization issue is solved by the optimization of particle swarms and selecting relay heads in the cluster with the help of a fitness function. The multi-hop routing in larger programs is used to deliver packets to the sink and stop the premature death of cluster heads. Based on the simulation data, the proposed clustering approach outperforms other clustering algorithms in the lifespan and throughput departments. This method seems to be better than the past related approaches which had less heterogeneity and has been confirmed on heterogeneous networks. This is only suitable in stationary sensor nodes with this clustering approach. Future versions of the work can build the sink nodes and/or the sensor mobile nodes. Routing protocol of energy harvesting WSNs is also suggested. As also implied in this section, an adjustment run-time of a few network variables depending on the cross-layer protocol of energy harvesting in WSN. Over a certain period of time, the network will adapt its rules of cross-layer protocols depending on different factors such as the messaging density, density of nodes, and the energy available. Each node sends out the relative preferred when selecting the head node of a group. The suggested plan maintains the network and application as reliable and efficient as well as minimizing the time of sensor node activity. This approach is better than other algorithms in terms of the number of rounds and the energy left, since it is able to balance between the scheduling of sleep-wake and clustering.

Conflict of Interest Statement

There is no conflict of interest

Data Availability Statement

Data available based on reequest

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