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AN ENERGY OPTIMIZED FUZZY BASED CLUSTERED ROUTING PROTOCOL FOR WIRELESS SENSOR NETWORK

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Abstract

Wireless sensor networks are fast developing technical platforms with a wide range of applications. It's tough to replace or recharge sensor nodes' power supply because they're battery-powered and may be employed in hazardous or inaccessible areas. In sensor networks, reducing energy consumption has long been a critical concern. Due to the lengthy distance between sensor nodes and the base station, data transmission from sensor nodes to the base station consumes the majority of the energy. Several academics have recently claimed that clustering is an effective approach to reduce energy consumption during data transmission while also extending the lifetime of networks. In this paper, an energy-optimized-fuzzy based clustering (EOFBC) strategy is used to improve the transmission efficiency and network longevity of network. The simulation findings suggest that proposed fuzzy logic-based techniques are superior to the existing clustering-based protocols. The simulation findings also reveal that the proposed scheme outperforms the other existing algorithms and significantly increases the lifetime of sensor networks.

Keywords:

Wireless Sensor Network, Fuzzy Logic, Lifetime

1. INTRODUCTION

Wireless sensor network (WSN) is a self-contained distributed sensor hub that can be readily integrated into any framework to monitor environmental conditions [1]. Furthermore, WSN hubs have the ability to broadcast information from one end node to another [2]. Furthermore, the cluster method in WSN was created to reduce energy consumption [3]. Because the WSN has made numerous advancements, yet the WSN environment's primary drawback is energy consumption, the cluster strategy was implemented in the WSN environment [4]. Fig.1 depicts the clustered WSN.

Some of the nodes are voted to be the head of each group (cluster), which are commonly referred to as cluster-heads, in order to efficiently allocate management work among them (CHs) [5]. Because a substantial amount of data produced by sensors in WSNs is similar, clustering takes use of the correlation between the data and then aggregates it to minimize network load, resulting in more efficient energy consumption. The CHs are then in charge of collecting data from member nodes, consolidating it, and sending it to the base station (BS) [6]. Many clustering algorithms for WSNs have been proposed in the recent decade, with the goal of energy conservation. Clustering methods are often broken down into three phases: CH selection, cluster formation, and data transmission. The CH selection process, which defines the network's energy efficiency, is the most important aspect of each approach. Several scattered clustering protocols have been proposed in various publications [7]-[30].

In this paper an energy-optimized-fuzzy based clustering (EOFBC) algorithm is proposed to find the optimal cluster head nodes and cluster the network in a balanced and efficient way, which leads to improve the energy consumption and increase the network lifetime. The performance of the proposed EOFBC algorithm is compared with the well-known algorithms; namely, LEACH [7], LEACH-Fuzzy [17], TTDFD [29] and UCMRPBF [30]. The results of the experiment prove that the proposed EOFBC algorithm has better performance than other algorithms in all the scenarios that have been applied.

The remaining sections of this article are summarized as follows: section 2 discusses recent related works based on the routing protocol for WSN, section 3 discusses the system model with that problem, section 4 demonstrates the workflow developed technique, section 5 discusses the obtained results and their comparison, and section 6 discusses the research conclusion.

2. RELATED WORK

Few recent works of literature related to this research work are described as follows

In WSN, the low energy adaptive clustering hierarchy (LEACH) [7] is a straightforward hierarchical clustering procedure. There are two parts to this protocol: Cluster formation via single-hop communication with CH to the BS is part of the setup phase, while cluster formation is part of the steady-state phase. LEACH includes flaws such as leftover energy among sensor nodes that isn't taken into account when choosing CHs and an unequal distribution of CH nodes. As a result, network performance suffers. One of the standard methods used in energy efficiency problems is the stable election protocol (SEP) [8]. It works on heterogeneous networks and is based on the LEACH protocol. Advanced and standard nodes are the two sorts of nodes that exist. The residual energy is used in the SEP protocol to determine the likelihood of a node becoming CH. The SEP protocol has a flaw in that the CHs are not dynamically selected amongst the two types of nodes. The Enhanced Clustering Hierarchy (ECH) technique is a clustering hierarchy algorithm that improves network lifetime by minimizing data redundancy [9]. To avoid data redundancy, it employs a sleeping-waking mechanism for surrounding and overlapping nodes. It does, however, have a low improvement in network longevity. It also ignores the impact of moving the sink node's position on the network's lifetime.

Traditional algorithms are simple to implement, are incapable of finding the best answer, particularly when the problem gets complex or huge. To address these non-deterministic polynomial-time (NP)–complete problems, metaheuristic methods are introduced.

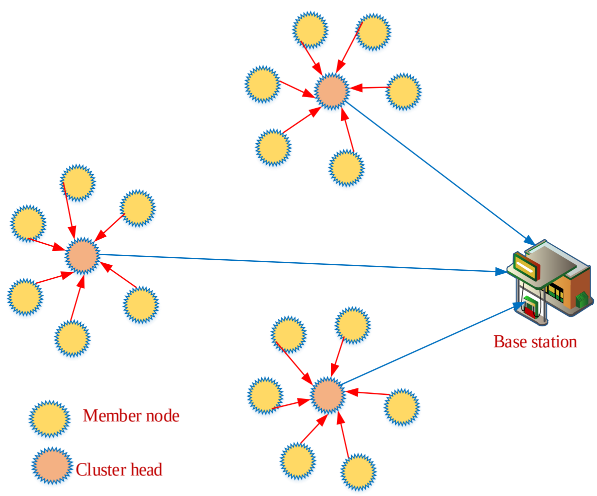

Fig.1. Clustered WSN

The genetic algorithm (GA) is a well-known method for prolonging network lifetime by lowering energy usage [10]. The procedure's drawbacks include its enormous memory footprint and lengthy computation time. [11] Introduces the fitness value-based enhanced GWO (FIGWO). The nodes with the highest energy, as well as the nodes closest to the BS, are used to create a fitness function. They stand a better possibility of being chosen as CHs. It does not, however, has trouble balancing the load among the CHs. The energy center-based routing protocol (EC-PSO), which is based on regular PSO, is used to maximize the energy of nodes near CHs and prevent hotspot problems [12]. Clustering was done in two steps in this method. The geometric method was utilized to pick the CH in the first stage. It employs the PSO algorithm in the second step. However, when creating a fitness function, this algorithm completely disregards the distance between nodes, CHs, and base stations, which has an impact on energy usage. It also excludes diverse sink node scenarios. CSOCA-GA, a chicken swarm optimization-based clustering technique, is proposed to improve network lifetime and CSOCA itself by utilizing GA to optimize energy utilization in WSNs [13]. The author used the CSOCA-GA crossover and mutation procedures to improve population diversity by arranging their fitness values in order to choose the best nodes that work as CHs in each cycle.

Gupta et al. [14] introduced the first fuzzy-based centralized cluster head selection algorithm for homogeneous networks, which takes into account node concentration, energy level, and node centrality as fuzzy input. When compared to the LEACH protocol, this strategy dramatically increased the network's lifetime. By making the protocol distributed and using energy and local distance as fuzzy parameters, CHEF [15] improved on Gupta et al. technique's The fuzzy input to the inference engine in the CFFL [16] protocol was residual energy and proximity to BS. LEACH-Fuzzy is a Fuzzy Logic based Clustering Algorithm for WSN that has been presented by Nayak and Devulapalli [17] and uses the concept of a super cluster head (SCH) that is only responsible for data transmission to mobile BS. A fuzzy descriptors technique is utilised to elect SCH among the elected CHs to fulfil the goal and improve the LEACH protocol performance. This method works effectively for choosing SCH that is based on fuzzy logic. As a result, it outperforms LEACH.

J. Anno and L. Barolli et al. suggested a fuzzy logic-based power reduction technique [18] for sensor networks. They advocated using fuzzy logic to pick CHs in order to prevent the situation where CHs are chosen at random in a probabilistic manner. They choose the remaining battery power of the chosen sensor, the distance to the cluster centroid, and the network traffic as fuzzy inputs. Their simulation revealed that the sensor's remaining battery power is more important in extending the network's life. A modified version of LEACH was proposed by A. Messaoudi et al. in [19], which included a fuzzy logic module to govern the re-clustering process. They select the elected node's remaining energy, the current CH's remaining energy, and the distance between these two sensors as inputs. Torghabeh et al. [20] used two-level fuzzy logic to pick cluster heads. Node qualification is established at the local level using fuzzy characteristics such as energy and number of neighbours. The eligibility of qualifying nodes at the local level is tested for the fuzzy parameters' centrality, closeness to BS, and distance between cluster leaders at the global level. Siqing et al. [21] introduced a clustering technique for multi-hop wireless sensor networks based on fuzzy inputs such as neighbour node residual energy, count of neighbour nodes, and average residual energy of neighbour nodes. Mehra et al. have presented a distributed FBECS algorithm [22] that produces the node eligibility index using remnant energy, node centrality, and proximity to BS as fuzzy parameters. For determining the cluster head, this eligibility index is multiplied by LEACH's threshold function.

Shivappa et al. [23] suggested a method for selecting super CH and sending data to BS using fuzzy logic. Singh et al. [24] improved the HEED protocol for heterogeneous WSN by incorporating fuzzy logic. As fuzzy descriptors, they employed distance, node density, residual energy, and average energy. The tentative cluster heads are chosen based on energy, and the final cluster heads are determined using a fuzzy inference system with node degree and node centrality as parameters in the ECPF protocol [25]. [26] proposes the MOFCA protocol, in which CHs are chosen using a fuzzy logic approach. The major goal is to solve the hotspot problem that multi-hop communication causes. [27] proposes the CHEF algorithm, which uses two fuzzy parameters, residual energy and distance, to select CHs at random in each round. Each CH calculates its chance value and then uses fuzzy if-then logic to publicize it. CHEF extends the network's life, albeit at the cost of increased network overhead and traffic strain. The Fuzzy Logic-based Clustering Algorithm (CAFL) was developed to extend the lifetime of WSNs [28]. It used fuzzy logic for both the selection of CHs and the creation of clusters. Proximity to the sink and residual energy were the fuzzy logic's inputs in the case of CHs selection, while the closeness to CHs and residual energy of CH were the fuzzy logic's inputs in the case of cluster formation processes. The authors proposed increasing the data aggregation efficiency in two-tier sensor networks in Two-Tier Distributed Fuzzy Logic-Based Protocol (TTDFP) [29]. Initially, the best CH was chosen using probabilistic methods. TTDFP uses an optimization framework to fine-tune its performance. Model uses the threshold radius and the two parameters in this tier and the competition's maximum radius. The UCMRPBF protocol [30] creates unequal clusters by using fuzzy logic with a competition radius to select the cluster head. The input variables are node distance from the base station, concentration, and residual energy.

3. SYSTEM MODEL AND PROBLEM STATEMENT

WSN is made up of a number of static sensor nodes that all have the same capability. Sensor nodes are engaged as active sensors during the data broadcasting process. WSNs are associated with the distribution of topology features, energy consumption, packet sensing, and feature topology in general. The cluster head selection mechanism in WSN has various flaws that harm the system's performance and functionality. Each node interacts wirelessly through the cluster node that serves as the cluster head, as shown in Fig.2. Furthermore, throughout the data transmission process, fewer energy nodes can drop packets.

Currently, there is a great deal of research in the area of low energy radios. In this paper, the first-order radio model shown in [7] has been adopted to model the energy dissipation. As the distance between the transmitter and receiver is less than a threshold value d_0, the free space model (d^2 power loss) is employed. Otherwise, the multipath fading channel model (d^4 power loss) is used. Eq.(1) shows the amount of energy consumed for transmitting l bits of data to d distance, while Eq.(2) represents the amount of energy consumed for receiving l bits of data.

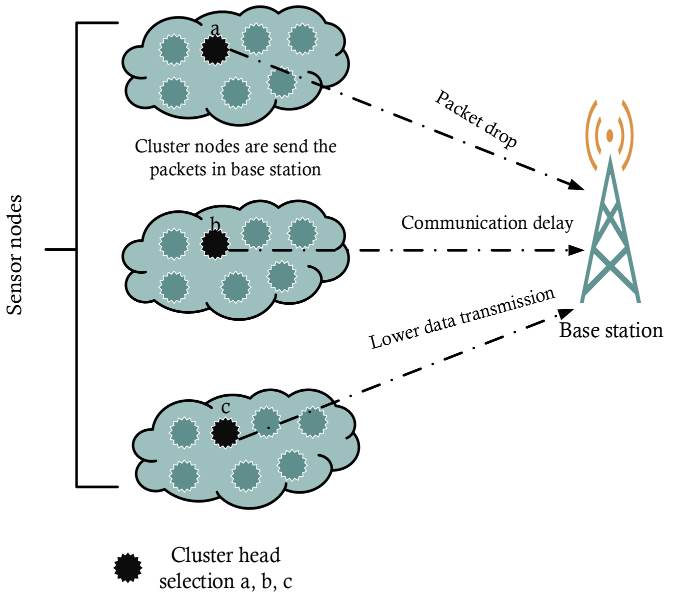

Fig.2. Cluster head selection in WSN

$$E_{TX}(l.d) = \begin{cases} lE_e + lE_{fs}d^2 & if\ d < d_o \\ lE_e + lE_{tg}d^4 & if\ d \geq d_o \end{cases} \quad (1)$$

$$E_{RX}(l) = lE_e \quad (2)$$

where, E_{TX} and E_{RX} are the energy consumption per bit in the transmitter and receiver circuits. Also, E_{fs} and E_{tg} are the energy consumption factor of amplification for the free space and multipath radio models, respectively.

The threshold value d_o could be obtained via Eq.(3).

$$d_o = \sqrt{E_{fs}/E_{tg}} \quad (3)$$

Sensor nodes typically take more power to broadcast data, so lowering energy consumption is one of the critical characteristics in the sensing environment. Many studies have been conducted in recent years to address concerns such as link failure, high energy use, and packet drop, among others. However, these methods were unable to accurately identify the node with a short lifetime and high energy consumption. As a result, the energy consumption issue remains unsolved. These issues have sparked the current investigation.

4. PROPOSED METHODOLOGY

WSN plays a vital job in many applications; however, energy consumption is the chief drawback behind this network failure. So, the present article has stepped down the research into the design of clustering based protocol that is named as energy-optimized-fuzzy based clustering (EOFBC) protocol.

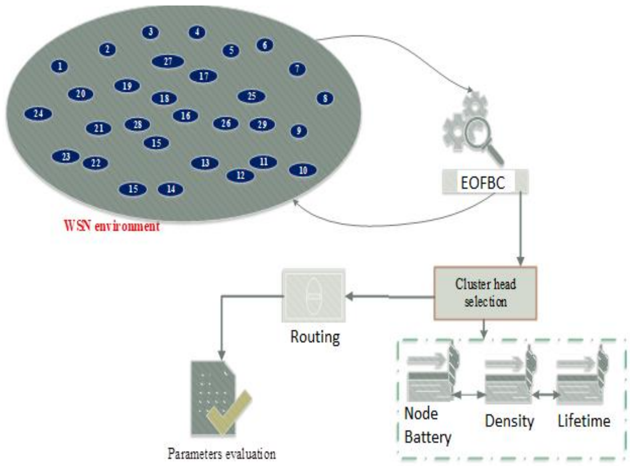

Fig.3. Proposed model

Hence, the clustering nodes are identified based on less energy consumption node, high density and long lifetime node. Hence, the proposed architecture is shown in Fig.3.

The presented clustering algorithm contains two phases. The appropriate size of each cluster is determined using an energy model study in the first phase. Then, utilising a fuzzy system, a clustering phase is carried out to discover the best CH for each cluster.

4.1 CLUSTER FORMATION PHASE

Neighbour finding and cluster head selection using a fuzzy logic technique are the two primary sub-phases of this phase. It's worth noting that because cluster heads aren't present during this phase, all nodes are simple nodes.

1) **Neighbour Finding**: In this subphase, an acknowledgement packet is sent from a simple node to other nodes of the same level in order to create a routing table that depicts all node positions and chances.

Every node will upgrade its routing table by inserting relevant details about its neighbours after getting this acknowledgement. Thus, all nodes are aware of their neighbours and the cluster to which they serve.

2) **Head Selection based Fuzzy**: Following the discovery of its neighbours, each node must compute its own chance of

becoming a CH based on three characteristics, which are node battery, density and lifetime.

- **Node Battery**: Describes the remaining energy of the battery during a period of time.
- **Density**: Presents how much a node is surrounded by its neighbors. The more neighbors, the node has, the more its density is higher. The importance of this input lies in the information given about the node neighbors.
- **Lifetime**: The expected Lifetime of a node to be a CH can be measured via Eq.(4)

$$Expected_{lifetime} = Node_{battery} - E_{expConsumed} \quad (4)$$

where the Node $_{battery}$ is the energy of a sensor node before the cluster head selection.

The expected consumed energy of a node to be a CH after a routing phase could be represented as Eq.(5).

$$E_{expConsumed} = N_{frame} \; E_{Tx} + nE_{Rx} \quad (5)$$

In a frame, suppose a CH has n cluster members, it would receive n messages from all the members and then transmit one combined message (N_{frame}) to the base station with a distance d to base station.

The CH will be chosen from each cluster based on the node with the greatest probability. The chosen CH will then send an announcement packet to their cluster members alerting them of the status of the cluster. Each node that receives this packet sends a join packet to the CH that was delivered. The data transmission sub-phase will begin after the clusters have been built and the CHs have been chosen.

Three basic inputs (Node battery, density and lifetime) and one output make up the fuzzy logic system (chance). As shown in Fig.4, each input contains three fuzzy sets, and the output has seven fuzzy sets:

- **Node Battery**: Low, Medium, High
- **Density**: Low, Medium, High
- **Lifetime**: High, Average, Less
- **Chance**: Very Small (VS), Small (S), Rather Small (RS), Medium (M), Rather High (RH), High (H), Very High (VH)

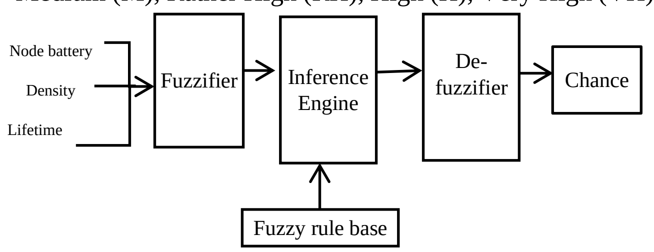

Fig.4. Structure of fuzzy inference system

The fuzzy model, most preferably Mamdani model is employed in the sensor network for selecting the CH as shown in Fig.5. The fuzzy set that describes the node battery input variable is depicted in Fig.6 (a). The linguistic variables for this fuzzy set are low, medium, and high. A trapezoidal membership function is used for low and high, while a triangular membership function is used for the medium linguistic variables. The second fuzzy input variable is the density. The fuzzy set that describes density input variable is illustrated in Fig.6 (b). The linguistic variables of this fuzzy set are low, medium, and high. A trapezoidal membership function is used for high and low, while a triangular membership function is used for medium. The third fuzzy input variable is the lifetime. The fuzzy set that describes lifetime input variable is illustrated in Fig.6 (c). The linguistic variables of this fuzzy set are high, average, less. A trapezoidal membership function is used for high and less, while a triangular membership function is used for average. The only fuzzy output variable is the chance. The fuzzy set for the chance output variable is demonstrated in Fig.6(d). Seven linguistic variables are Very Small, Small, Rather Small, Medium, Rather High, High, and Very High. The very high and very small have a trapezoidal membership function, and the remaining linguistic variables are represented by using triangular membership functions. In this work, for simplicity and reducing the cost of computation, the triangular membership functions are mostly chosen here.

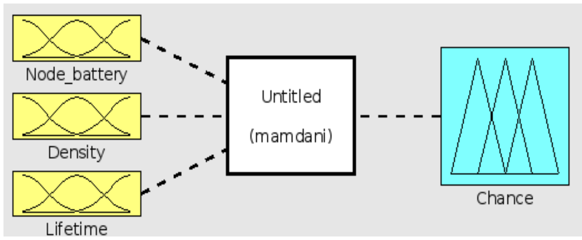

Fig.5. Modeled fuzzy system

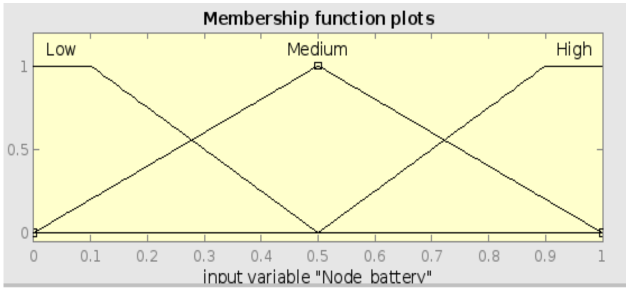

Fig.6(a). Node battery fuzzy set

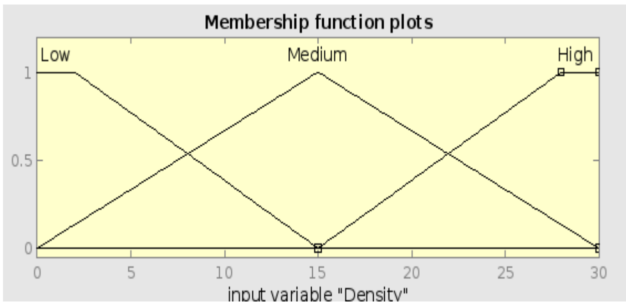

Fig.6 (b). Density fuzzy set

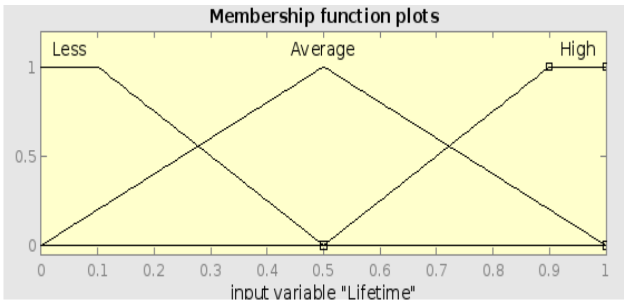

Fig.6(c). Lifetime fuzzy set

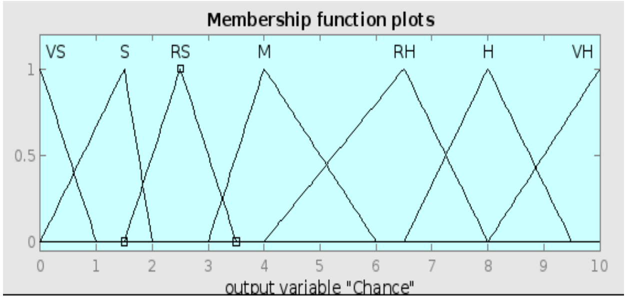

Fig.6(d). Fuzzy set of chance being selected as CH

The pseudocode for CH selection in each round is given by Algorithm. The following is a description of the algorithm. Each sensor node is turned on at the start of each round generates a random value between 1 and 0. In the event that the arbitrary value created by a single node falls above the prerequisite value, that node is designated as a candidate head. All candidate heads computes their chance. To handle the uncertainty, the chance calculation is done using specified fuzzy if-then mapping rules. Table 1 lists 27 fuzzy mapping rules based on the three fuzzy input variables. We can get the fuzzy variable chance from the fuzzy rules. This hazy variable must be reduced to a single, precise figure that can be used in practice. The center of area (COA) method is used in our approach to defuzzify the chance. Fuzzy rules can be produced using heuristics or experimental data in general. The heuristic fuzzy rule generation method is utilised in this research with the following principle: A node with more Node battery, density, and lifetime has a better possibility of becoming the head. The node's chance value and id will be included in this candidate- message. The final head is the candidate head with the highest chance value within the cluster.

4.2 ROUTING PHASE

It also comprises two sub-phases: intra-cluster and inter-cluster transmission.

1) Intra-cluster: Each node in the cluster sends its data packet to the appropriate CH. Intra-cluster transmission is the name given to this mechanism.
2) Inter-cluster: A CH will gather packets received from other nodes in the same cluster and send one packet directly to the base station if it is on the first level or to the next CH if the communication scheme is multi-hop.

Algorithm: Head selection phase of EOFBC protocol

Input:

SN: a sensor network

s : a node of SN

P: a prerequisite value to become a head candidate

q: the amount of times to be a head chance(s): a value for the node a's appropriateness as a head

n: the number of clusters

V: {v | v is neighborhood node which is a head candidate}

H_C(s): Head candidate

Head(s): Final Selected head

```
Function:
        fuzzylogic(node battery, density, lifetime);
        broadcast(data, distance);
        send(data, destination);
 Initialization:
chance(s)←fuzzylogic(node battery, density, lifetime);
        q ←0;
  Main:
        /* for every clustering round */
  for each node do
        if (rand(0,1) > P )
        H_C(s) ← s;
       H_C(s) = true;
else
       H_C(s) = false;
end if
if
       (Is H_C(s) = = true)
for all H_C(s) do
chance(s)←fuzzylogic(node battery, density, lifetime);
        broadcast(chance(s), V); //Candidate-Message
end for
end if
/*On receiving Candidate-Messages from Head candidates */
for each v ∈ V
  if
      (chance(s) < chance(v))
      Head(s)← v;
  end if
  if
      (Is Head(s) = =false);
      broadcast(Quit-Election-Message, V)
 else
     (Is Head(s) = = true);
      q =q+1;
      broadcast(CH-Message, V)
 end if
 end for
End
```

Table.1. Fuzzy Mapping Rules

Node battery	Density	Lifetime	Chance
Low	Low	High	Small
Low	Low	Average	Small
Low	Low	Less	Very Small
Low	Medium	High	Small
Low	Medium	Average	Small
Low	Medium	Less	Small
Low	High	High	Rather Small
Low	High	Average	Small

Low	High	Less	Very Small
Medium	Low	High	Rather High
Medium	Low	Average	Medium
Medium	Low	Less	Small
Medium	Medium	High	High
Medium	Medium	Average	Medium
Medium	Medium	Less	Rather Small
Medium	High	High	High
Medium	High	Average	Rather High
Medium	High	Less	Rather Small
High	Low	High	Rather High
High	Low	Average	Medium
High	Low	Less	Rather Small
High	Medium	High	High
High	Medium	Average	Rather High
High	Medium	Less	Medium
High	High	High	Very High
High	High	Average	Rather High
High	High	Less	Medium

Because the suggested fuzzy based protocol is highly effective, the cluster head node was chosen. As a result, the proposed protocol is able to successfully transport messages over the network. In comparison to existing prevention mechanisms, the suggested prevention mechanism performs a stronger function in terms of data in the network prevention. Process of Proposed protocol is shown in Fig.7.

5. RESULTS AND DISCUSSION

The findings of experimental simulations to test our proposed approach are presented in this section. In addition, we compare EOFBC, our proposed clustering technique with LEACH [7], LEACH-Fuzzy [17], TTDFD [29] and UCMRPBF [30]. Simulation results have proved that as compared to other methods, ours yields better results with the help of others

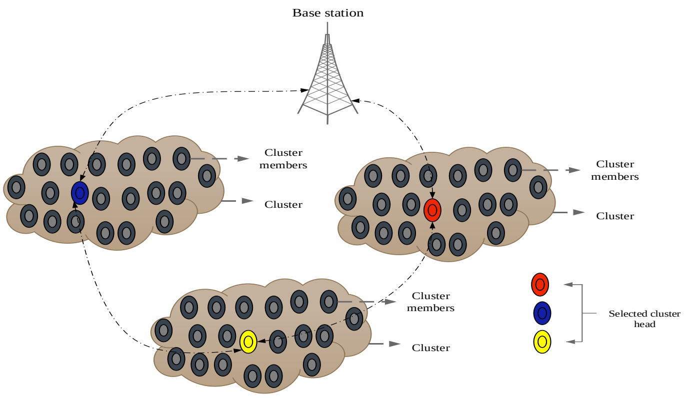

Fig.7. Process of Proposed protocol

The current research is executed in MATLAB platform. The 100 nodes are spread in a 100×100 region at random. The base station is situated at a certain location (50, 50). The Table.2 lists the parameters utilized in the first-order radio model.

Table.2. Simulation constraints

Parameters	**Value**
Area	100*100
Total number of nodes	100
Packet Size	4000 bits
E_{fs}	0.0013pj/bit/m^4
E_{tg}	50 nj/bit/m^2
Initial Energy	0.5j

In WSN, node lifetime is one of the important parameters for achieving effective communication. We are demonstrating three matrices: first node dead and half node dead.

The Table.3 provide an example of the network duration simulation findings (first node dead and half node dead). As a result, the proposed approach will outperform prior algorithms for FND and HND calculations as shown in Table 3.

LEACH has the lowest performance of the previously used algorithms. This is because LEACH selects CHs using a probabilistic mechanism. Nodes in LEACH begin to run out of battery after 118 rounds of cluster functions. Nodes in the LEACH-Fuzzy protocol, on the other hand, begin to lose battery after 144 rounds, while the first node in the TTDFP protocol loses battery after 285 rounds, and the UCMRPBF protocol loses battery after 353 rounds.

Our proposed approach, on the other hand, incorporates the first node running out of battery after 558 rounds. The FND recommended algorithm outperforms the UCMRPBF algorithm by 158.07%, the TTDFP algorithm by 195.78, the LEACH algorithm by 472.88 percent, and the LEACH-Fuzzy algorithm by 387.50 percent.

In Table.3, half node died at 372 in LEACH. In LEACH-Fuzzy, half node died at 398, in TTDFP, half of the node died at 593, in UCMRPBF, HND at 610, and in the proposed algorithm, half node died at 730, which is better than comparing to all these algorithms. The HND suggested algorithm has greater performance than the UCMRPBF by 119.67 %, TTDFP algorithm by 123.10%, LEACH algorithm by 196.23%, and LEACH-Fuzzy algorithm by 183.41 %.

Table.3. Validation of node lifetime

Techniques	**FND**	**HND**
LEACH	118 rounds	372 rounds
LEACH-Fuzzy	144 rounds	398 rounds
TTDFP	285 rounds	593 rounds
UCMRPBF	353 rounds	610 rounds
EOFBC (Proposed)	558 rounds	730 rounds

While compared with the existing models the proposed method is more efficient to transfer the messages that are mentioned in Table.3.

In this scenario, we try to assess the performance of clustering independently. The distribution of a total of 100 sensor nodes is done in different network sizes such as 100m*100m monitoring area, 200m*200m monitoring area, and 300m*300m monitoring area. We assume the initial energy is 0.5J. The Table 4 shows the energy dissipation of the proposed protocol with other algorithms at different network sizes.

It can be seen from Table.4 that the energy dissipation of the proposed protocol is less with respect to other protocols as LEACH, LEACH-Fuzzy, TTDFD and UCMRPBF, which leads to prolonging network lifetime. Also, the smaller cluster size near the BS in the proposed protocol balances the load among the nodes as well as solves the energy hole problem.

Table.4. Validation of energy dissipation with different network size

Network Size	Techniques	FND energy dissipation	HND energy dissipation
(Network 1) 100*100	LEACH	0.3032	0.0871
	LEACH-Fuzzy	0.2976	0.0771
	TTDFP Tier-1	0.2573	0.0671
	UCMRPBF	0.2345	0.0551
	EOFBC (Proposed)	0.2142	0.0581
(Network 2) 200*200	LEACH	0.3683	0.1237
	LEACH-Fuzzy	0.3524	0.0937
	TTDFP Tier-1	0.3581	0.0852
	UCMRPBF	0.3202	0.0760
	EOFBC (Proposed)	0.2267	0.0670
(Network 3) 300*300	LEACH	0.3481	0.1468
	LEACH-Fuzzy	0.3689	0.1410
	TTDFP Tier-1	0.3911	0.1395
	UCMRPBF	0.3830	0.1006
	EOFBC (Proposed)	0.3740	0.0986

6. CONCLUSION

In this modern era, WSN is applicable for all fields, thus it has several developments. The main of this research is to decrease the energy during the message transmission process. Therefore, a new EOFBC protocol is developed. The findings from the analysis demonstrate that the proposed method is useful for implementations that need minimization of energy consumption, load balancing, and prolonged network duration. Overall, the proposed algorithm is a better protocol compared to with LEACH, LEACH-Fuzzy, TTDFD and UCMRPBF clustering algorithms. In our future work, we will solve the secure clustering protocol for mobile ad-hoc networks and the light weight secure mechanism will be our research focus.

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