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FEECA: Fuzzy based Energy Efficient Clustering Approach in Wireless Sensor Network

Anshu Kumar Dwivedi[1,*], A. K. Sharma[1]

[1]Department of Computer Science & Engineering, Madan Mohan Malaviya University of Technology, Gorakhpur, India

Abstract

With huge advancements in Microelectronics, Wireless Sensor Network (WSN) is conquering its domain with low powered tiny sensors. These sensors are commonly used in monitoring and surveillance of remote and urban areas. Since the power supply to these tiny sensors is a battery, for the maximal efficiency of WSN, there arises a need for a maximal lifetime of these tiny sensors wherever they are deployed. Clustering is a promising solution but there is uncertainty in the selection of cluster heads. Fuzzy logic, however, can contribute to the selection of optimal candidates to play the role of such cluster heads. To muddle through the issue, we have proposed a fuzzy-based energy-efficient clustering approach (FEECA) in wireless sensor networks and also designed a fuzzy inference system that defines influential parameters for selecting optimal candidates for cluster head(CH) role. To reduce the expenditure borne by communication, master nodes are selected among the chosen cluster heads so that their communication distance to the sink can be reduced. In the proposed scenario the area is divided into the diagonal form to reduce the load of the network. Each part consists of a Sensor Node (SN), cluster head, and master node. In the diagonal form, the network is divided so that the distance travelled by the data packet through the diagonal path is always smaller than the distance in which the horizontal path exists, based on the triangular inequality theorem. Simulation experiments were conducted and experimental results unveiled better performance of proposed work in terms of stability period, more packet delivery to sink and extended lifetime.

Keywords: Fuzzy, clustering, energy efficiency, wireless sensor network, stability period, cluster head.

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*Corresponding author: anshucse.dwivedi@gmail.com

1. Introduction

These days, WSN is integrated with various bleeding edge technologies including IoT, cloud computing, artificial intelligence. WSN comprises of tiny electronic devices called sensors along with wireless technology[1], [2].Each SN has four components *viz.* sensing unit, microcontroller, radio circuitry and power supply. All these four components work altogether to perform necessary tasks of monitoring, tracking, surveillance etc. There are different physical phenomena like, infrared, temperature, acoustic signal, pressure, elastic module, humidity, moisture,vibration, shear rigidity, etc. that can be captured by SN[3]. WSN can be deployed in various areas like battlefield, military surveillance, home monitoring, health monitoring, agriculture monitoring, and vehicle tracing etc.[4]–[7]. In some of the applications, multiple sensors are deployed and arranged intelligently to capture sensitive information which is to be forwarded to the sink but in some applications, it is very difficult to deploy sensors deterministically[8][9]. In that situation, SNs are deployed on the fly and self-organising network is made operational. Prudent energy utilisation is utmost requirement as transceiver, microcontroller and sensing unit are operated using battery which is irreplaceable or very difficult to replace in WSN [10],[11].

To solve the energy problem, clustering is the most significant technique to diminish the irregular energy dissipation in WSN and improving the network life span[12],[13]. Nodes are structured into group termed as cluster. In a cluster, there are cluster members (CMs) and a CH coordinating the data collection activities. The cluster members (CMs) sense the valuable parameters and send those to their respective CH. The CHs collect the entire message, eliminate redundant information, aggregate them, and send the aggregated information to the sink. CMs cannot directly communicate to the sink because if they communicated to the sink, they will die earlier because of long distance from CMs to sink, and if SN die a hole will be generated in that area of WSN after that communication break in the network. So that clustering is important for data routing. The data routing through clustering in WSN is depicted in Fig. 1.

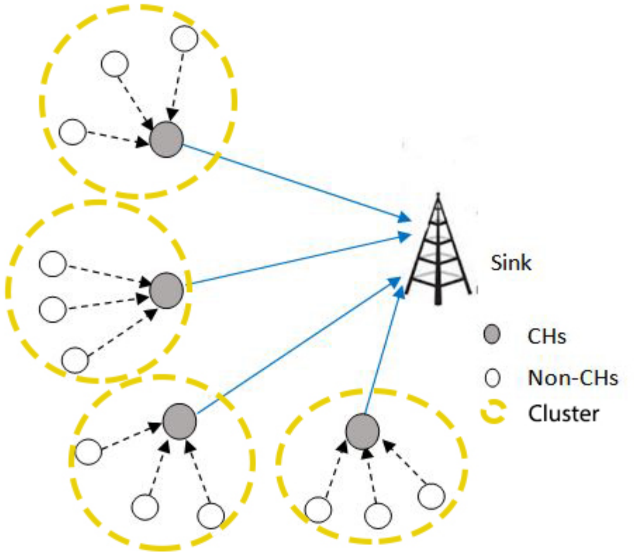

Figure 1. Data routing via cluster head in WSN

Huge numbers of approaches are propounded for clustering which select the CH either by probabilistic method or by weight-based method. There are some protocols that help select CH in both the approaches. In the selection of CH using probabilistic method, CHs are elected without using different parameters such as node density, distance, remaining energy etc. Thus, inappropriate nodes get selected as CHs, which creates problem in longevity of WSN. Hence good parameters to elect CHs should always be considered. In case of weight-based method, CH is selected by considering aforesaid lifetime parameters. But in this approach the selection of CH may be altered again and again in order to extend the First Node Died (FND)[14].Therefore, the FND metric show long the network is stable. Various algorithms like fuzzy based clustering algorithms, fuzzy based energy efficient clustering protocol combine probabilistic and weight-based approaches to give improved throughput of wireless sensor network. Communication bandwidth and remaining energy are two important barriers of WSN[15], [16].For battery preservation, a few selected SNs send information to every active sensor; overall energy utilization may be reduced[17],[18]. This is only possible if the redundant SNs legitimately go into sleep mode regularly.

In this paper, we have designed a fuzzy inference system which considers remnant energy, average communication distance and communication quality for selecting optimal candidates that is CH. Master node is selected out of the CH using fuzzy descriptors.The stability period and life span of the network is improved with the help of proposed protocol. In the anticipated scenario the region is divided into a diagonal form to minimize the energy utilization of SN of the network. Each part consists of a SN, cluster head, and master node. The network is divided into the diagonal form because the distance travelled by the data packets through the diagonal path is always smaller than the distance travelled by those in which the horizontal path exists, as per the triangular inequality[19].

The rest of the paper is as follow: In Sect. 2, relevant works are evaluated. In Sect. 3, the proposed algorithm describes procedure for selecting the best candidates as CH to minimize energy utilization and to exploit the network lifespan. A detailed explanation and simulation results are described in Sect.4 and finally in Sect. 5, the results are concluded.

2. Relevant Work

In this section, discuss recent fuzzy based routing protocols that are helpful to increase the network lifetime. Fuzzy logic based approaches and some energy based clustering approaches are being reviewed to find the research gap. LEACH is a very important and well known clustering algorithm. In [20] LEACH protocol selects a cluster head based upon probability and also uses various parameters that are helpful in minimizing the utilization of energy of WSNs. In [21], a fuzzy based approach to increase network life span and minimize energy utilization of WSN is introduced. It elects a CH on the basis of three parameters; energy stage, concentration and centrality; and one output that is calculating the chance to become CH. The concept of this protocol is inherited from LEACH. The main dissimilarity between Gupta protocol [7] and LEACH is in the setup phase where the sink wants to collect energy and position information for every SN and calculates the chance value of a SN with the help of fuzzy interference system (FIS) to become a CH or not, the sink selects the SN that has the greatest possibility of becoming a CH on the basis of their chance values. Gupta protocol [7] does not consider the farness between sink and SN.CH selection has many ambiguities as the number of selection parameters increases day by day in order to minimize the ambiguity in clustering process. To overcome this problem, we introduce fuzzy based clustering. It's a centralized clustering approach. Centrality evaluated through square distance of other nodes from given node, is one of the important parameters of selecting the CH. LEACH protocol has various limitations and to improve this limitation many of the researchers use a dynamic CH selection approach, CHEF [22]being one of those. With the help of this protocol, we can reduce overhead of network and enhance the lifetime of WSN resulting in improved network efficiency. Some researchers also use fuzzy logic (FL) based two tiers clustering approach. CH identification is based on various parameters that work in FIS as inputs. Information related to network is exchanged between the sensors. Various fuzzy based clustering techniques with advantages and disadvantages has been proposed in [23].

In [24], FL based protocol for MANET is propounded. The main objective of these algorithms is to increase throughput of the network by using fuzzy tools for suitable route selection in the system. Route selection based on three parameters i.e., power of battery, bandwidth, and mobile nodes, is used. In [25], fuzzy logic and game theory based protocol GTFL is presented which is a centralized energy-aware clustering protocol. The objective of this protocol is to reduce the energy consumption of a WSN. In GTFL, the BS is fixed and cluster formation is based on some input parameters. No distributed concepts are applied in this proposed model. In [26], a new fuzzy based protocol is introduced namely FLCFP, author used various parameters in clustering to reduce energy utilization in sensor network. FIS uses a different parameter as an input for cluster formation. If compared with LEACH protocol, the network performance is improved through FIS. In WSNs, if SNs communicate directly to BS, they die earlier because of distance. Continuing to minimize the communication cost of a network, the author proposed a protocol EAUCF[27] to solve the WSN problem. Author has used a distributed approach for cluster design in WSN. EAUCF used two parameters for cluster heads selection, remaining energy and farness to sink. In starting phase during a round, CH is selected on the basis of random number generation and then FIS play important role for CH selection of a network. This method uses arithmetical logic to handle uncertainties in CH's radius analysis. The goal of this model is to cut back the intra-cluster performance of CH either near to sink or the low powered SNs. All CHs broadcast their remaining energy and also ensure the presence of other hesitant CH nodes within competition radius. Suppose two CHs are there, then within competition radius of one node, nodes having less than required amount of energy is not considered for communication to BS. In selection of CH, degree of node is not considered as an important parameter which may prompt selection of CH with less and far off neighbours.

In [14], author discussed similar approach to EAUCF and FBUC, the only change are the node degree was added to find the absolute radius in the fuzzy logic system. Additionally, in this approach cluster formation and CH joining is based on the FIS. In [28], author proposed a new protocol, T-LEACH, a threshold-based CH selection protocol that reduces the amount of CH collection by processing the threshold for remaining energy. The objective of this protocol isto balancing energy utilization and network life time. In this approach decision regarding rounding is based on extra remaining energy for SNs to swap CHs. In different way, when CH maintains its remaining energy above the pre-established threshold, the role of CH will not change and energy deplete start of the network, hence all the possibility are used to select the CH and perform the role of CH.

In[29],author propounds FBECS, considering energy of SN, distance from BS and density as a input to the FIS. These parameters are used for selection of CH. Author has also discussed about load equalization by taking into consideration the chance allotted to every SN as CH, at every round of protocol. Once the network is established, the objective of this protocol is to gather the utmost information from the target area. FBECS authentication is performed only on the basis of First Node Dead (FND), Quarter Node Dead (QND), Half Node Dead (HND) and Average Residual Energy. The surviving node is distributed in order to measure throughput of network depending on maximum number of packets delivered to BS. It means that maximum information is collected from targeted area. In [30], a super CH election criteria among the CHs by considering three fuzzy descriptors. Super CH is only responsible for forwarding sensory data to BS considering appropriate descriptors such as battery power level, mobility of the sink and the centrality of the cluster. Mamdani's FIS [18] is used to select the possible values for the selection of super cluster heads.

In [31], another routing protocol E-CAFL is proposed to enhance the range of CAFL protocol by allowing node density. Its uses three parameters viz., remaining energy, node density and farness from sink as input for FIS. In WSN, it is not possible to place the base station inside the network area in every situation. SNs sometimes deploy on the fly in some applications. In E-CAFL base station has fixed in deterministic place in order to fulfil the requirement of WSNs. This protocol is used to extend the consistency period of network as comparison to LEACH and CAFL. In [32], author proposed fuzzy logic based protocol to reduce energy utilization and enhance the lifespan of network. It uses two important parameters, namely energy level and centrality, to enhance network lifetime. At all times attention to CH is not necessary in any particular area. In[33], author describes a new protocol UCFIA, CH information varies depending on parameters viz. distance from BS, remaining energy and density. CH changes role after evaluation of CH energy level. If CH's energy level is lower than non-CH, then the CH's role is changed time to time and select non-CH as a CH.

In [34],SCHFTL is proposed based on fuzzy logic system, in which the SN parameters are used at different levels. The first level parameter is remaining energy and centrality, the second level parameter used are communication quality and distance from BS and the third level are total energy and DOS attack, with the help of such parameters we select super cluster head out of the CH.SCHFTL avoids the data overload, data loss and data retransmission, increasing the network lifespan. In [35] DFCR routing protocol is proposed. In the proposed method, unequal clustering mechanism is applied to solve the hotspot problem of WSN by minimizing the size of clusters, which are closest to the sink.

3. Preliminaries

The objective of FEECA protocol is to address the issue of energy efficiency in WSN. Before proceeding with the description of FEECA protocol, some of the features of network are discussed hereafter.

3.1. Assumptions pertinent to network

There are some assumptions made while designing FEECA protocols which are mentioned below:

- SNs are positioned randomly in the network.
- Symmetric communication takes places between two nodes.
- Distance between two nodes is computed using Euclidean distance
- No SN can be recharge or replace after deployment.
- No mobility of SN and sink is considered.
- A node with zero energy level will be considered dead.
- All SN have equal capability in terms of memory, processing and power.

3.2. Network model

In the propound work, we have considered two cases i.e. S#1 and S#2. In S#1, the position of base station is inside the region as depicted in Fig.2 and base station kept outside the region in S#2 as shown in Fig.3. The targeted area is considered to be 100×100 m^2 in which the SNs are deployed randomly. The network is diagonally bisected into two parts.

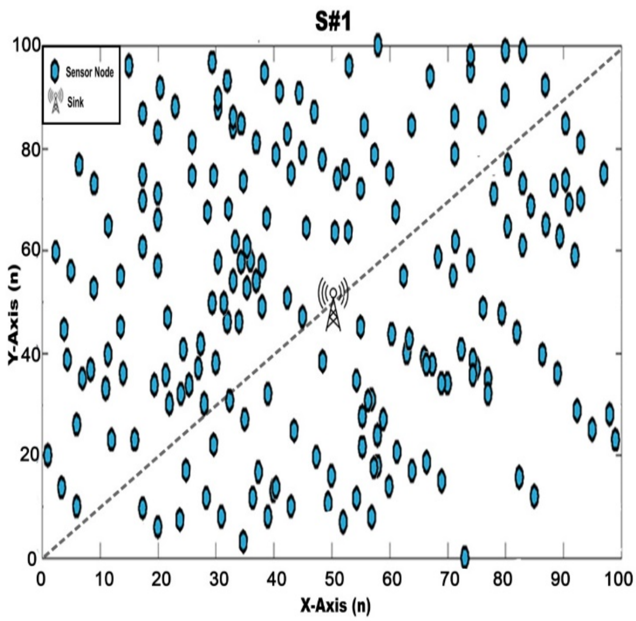

Figure 2. Network Layout S#1

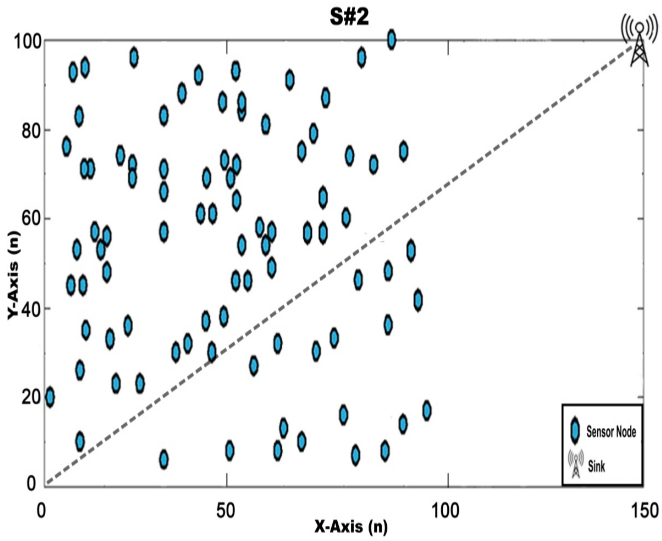

Figure 3. Network Layout S#2

3.3. Energy Model

FEECA has adapted first order radio model similar to [36]. For m bit communication, the energy for transmission (E_{Tx}) and reception (E_{Rx}) is computed as follow

$$E_{Tx}(m,d)=\begin{cases} mE_{elec}+m\varepsilon_{fs}d^{2}, & d<d_{o} \\ mE_{elec}+m\varepsilon_{mp}d^{4}, & d\geq d_{o} \end{cases} \quad (1)$$

Where $d_0=\sqrt{\frac{\varepsilon_{fs}}{\varepsilon_{mp}}}$ d is the division distance.

Then requirement of energy for receiving m-bit message as follows

$$E_{Rx}(m)=E_{Rx-elec}(m)=m.E_{elec} \; (2)$$

For the network we have assume volume=$a \times b$ metre^2. In one round the total energy dissipated by CH is calculated by equation no. (3) As given below.

$$E_{CH} = (n|p)m(E_{elec}+\varepsilon_{fs}d_{BS}+E_{DA})(3)$$

Where the distance to BS is represented by d_{BS} and $n\,/\,p$ is a cluster member. The sum of energy consumption by a CM (cluster member) is calculated by Equation (4), d_{CM} is the distance from CH.

$$E_{CK} = (mE_{elec}+m\varepsilon_{fs}d_{cM}) \qquad (4)$$

Where, d_{CM}=$\sqrt{\frac{M^2}{2\Pi P}}$

4. FEECA Protocol

FEECA protocol is designed to enhance the life span of WSN. There are several fuzzy clustering protocols proposed but FEECA protocol considers three crucial characteristics of SN that change the life span of the network which are

- Ratio to current Energy level to average network energy level is called residual energy or remnant energy.
- Average communication distance to all nodes including sink
- Communication quality of the SN.

These three characteristics cover all aspects which can contribute in extending the lifetime. SN is positioned randomly in the network.

4.1 Fuzzy based model

Fuzzy-based model is used in proposed work. It is used to select a best candidate to serve as a CH. FL networking experience and persistence in decision making is the behavior of a human being. Fuzzy based model involved in the proposed work is depicted in Fig. 4. Basically FL consists of four units.

Fuzzifier: In this, input variable average energy level, average communication distance, and communication quality consider as crisp input that converted into fuzzy set.
Rule calculation: Fuzzy rule, based on IF-THEN rules determined by the user. This rule determines the active behavior of fuzzy system.
Fuzzy Inference Engine: It is a key block of a fuzzy logic system having decision making. This block uses "IF…THEN" rules along with operator "OR" or "AND" to design essential decision rules.
Defuzzification: It is a process to convert fuzzy set into crisp set with the help of inference engine. This is helpful to take a decision on the basis of result.

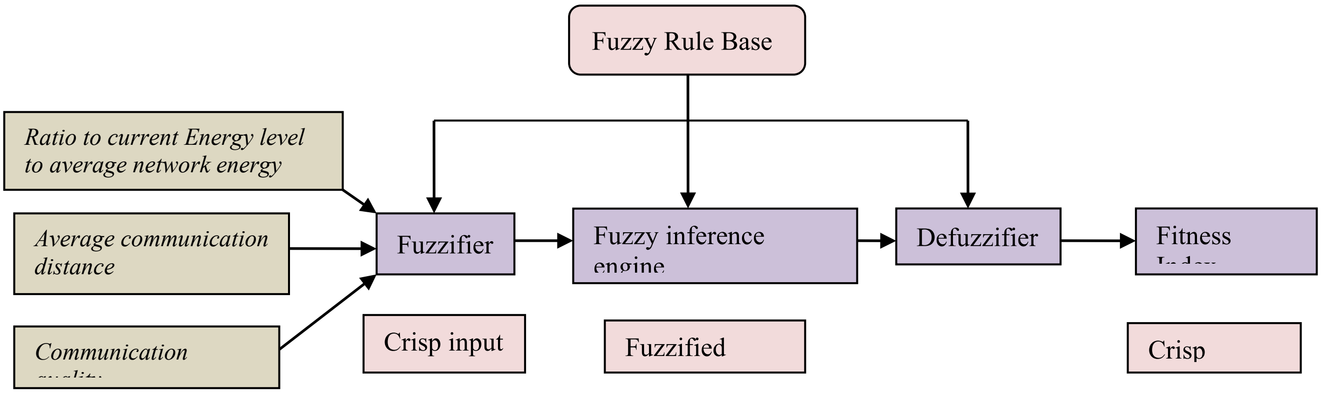

Figure 4. Block diagram of FIS

4.2 Pre-Deployment Stage

Prior to the deployment of SN in the field, it is mandatory for a user or administrator of a network to allocate an ID to the SN. The location of the BS is always determined and the information of the BS is also fed to the SN so that it can determine the location of the BS at the time of network operation. For initial setup of the network and determining the neighborhood, a TDMA slot is fed into each SN so that collision free broadcast can take place.

4.3 CH Selection Stage

CHs selection comes into existence after completion of deployment of SNs. The role of CH is very important for transmitting data to BS. Fuzzy logic systems are used to solve the uncertainty problem in any system. The choice of CH is based on several parameters such as residual energy, communication quality, average distance of BS, etc. Not all SNs know the location of BS, all SNs send sensory information to CHs with the help of TDMA slots. Each input node is aware of the input parameters (residual energy, communication quality, average distance of BS). The selection of CHs candidacy based on this input parameter starts in each SN. A Fuzzy inference system (FIS) has been designed for computing the Fuzzy likelihood values of SNs as shown in Fig. 5.

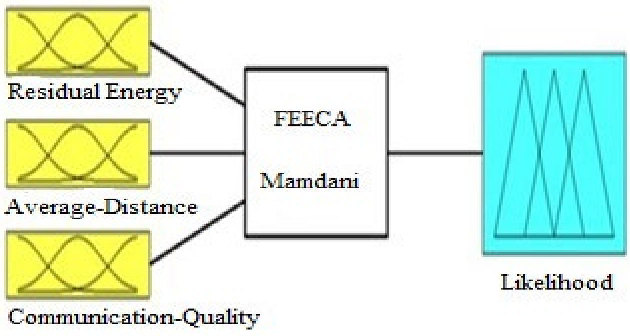

Figure 5. FIS for computing Fuzzy likelihood value

Algorithm 1. Proposed Cluster Head election Algorithm

```
N= total number of SN
CH= Cluster Head
J=A SN lie in the network
j. state= Provisional CH
This= Pointer point to the current Node
For z= 1: N
        z.AV_DBS = Average Distance of the node with BS
        z.RE = Remaining Energy of  SN
        z.CQ= Communication Quality
    Likelihood. Size=calculate fuzzy (z.AV_DBS, z.RE, z.CQ)
End For
    For k =1:N
        Send CH_Node to all neighbour node
Y= list of all CH_Node from neighbour node
If (this. likelihood > likelihood (Y))
        Advertise CH_message
            this. State = final _CH Node
    If receiving all CH_message
                My_CH= nearest CH
 SEND JOIN_CH message(ID) to the closest CH
Forward CH join_message(ID) to CH
 keep node_ID to cluster member record
            End if
     End if
End for
   F_CH= list of CH
   F_CM= list of cluster member
  If count(F_CH)j< (Size)j
        F_CH sends CM_Acceptance
     Else
        F_CH sends CM_Rejectance
  End if
For m=1: Size (F_CM)
if
on receiving CM_Acceptance
Join CH which concern CH_message
 m.state= Member Node
Else
Declare itself as CH
            m.state = final_CH
     End if
End for
```

4.4 Cluster Formation Stage

Cluster formation comes into existence after the CH selection process is completed, i.e. $p\%$ CHs are elected, once the CHs are finalized they disseminate their candidature and all non-CH members decide to elect them is needed. Based on the proximity of the CHS, all SNs send requests to join the CHS. After that the formation of the cluster begins.

It is very important to decide that after the selection of CHs, the intra clustering communication that is happening in the network does not involve more cluster members in the CH, otherwise the CH will start to spend energy due to overburden. For supporting the decision of choosing the CH by the non-CH nodes, Fuzzy logic is used. We have designed a FIS for computing likelihood of each CH as shown in Fig. 5. The fuzzy linguistic variables are depicted in Table 1. The membership functions of the input and output variables are indicated in Figure 6 (a – d). For defuzzification, we have used Center of Area (COA) method which is most commonly used in recent literature [29], [31].

Table 1. Fuzzifier linguistic variables

Variable Name	Linguistic Variables
Remaining Energy	Substantial , Sufficient , Deficient
Average Distance	Meagre, Medial, Huge
Communication quality	Superior, Modest, Inferior

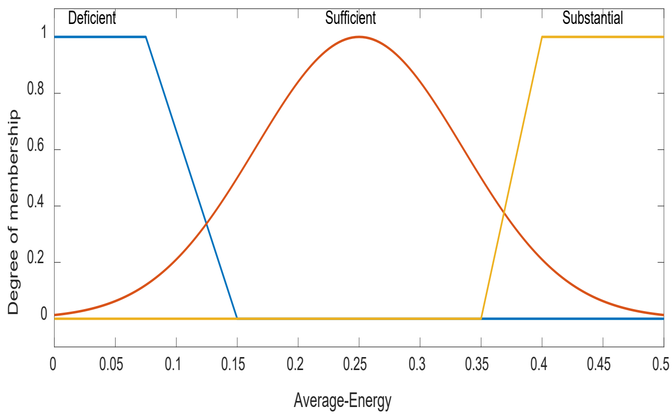

Figure 6(a). MF for Average Energy

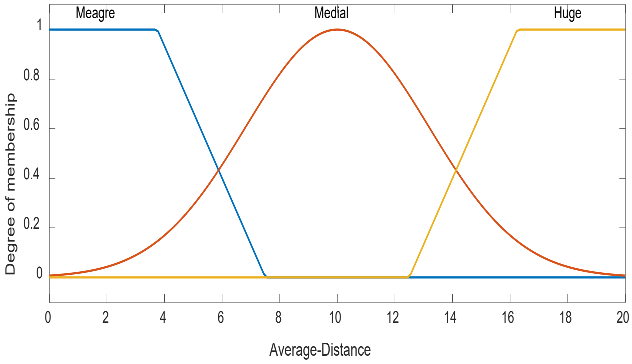

Figure 6(b). MF for Average Distance

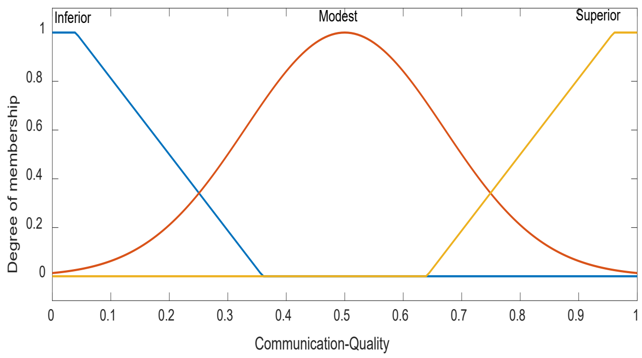

Figure 6(c). MF for Communication Quality

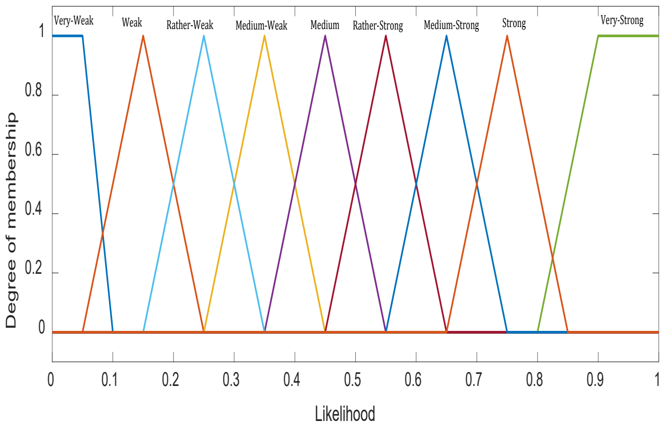

Figure 6(d). MF for Likelihood

The rules for mapping IF-then output variables are shown in Table 2. Each non-CH SN calculates the probability of CH candidates and the CH candidate with the maximum likelihood is chosen the optimal CH. The non-CH node sends a join request to the optimal CH node and receives an acknowledgment from the CH node with a TDMA slot for data collection during the round. The process of creating a cluster is illustrated in Algorithm 2.

Algorithm 2. Proposed Cluster formation Algorithm

1. *Tn = Total Nodes;*
2. *TN_CH ← Total CH nodes in a round;*
3. *m ← ID of SN;*
4. *For each Node in TN_CH do ;*
5. *Broadcast CH_MSG from CHs*
6. *Every node receive message (JOIN_CH message,m) from all CHs*
7. *for each node Tn*
8. *Fuzzy logic (E.residual, nearest to CH.m);*
   */*each node n calculates chance value of CH based on residual energy of CH and closeness to CH */*
9. *Likelihood (CH) = fuzzy logic (E.residual, closeness to CH.m)*
10. *If (Tn.ID = Max(likelihood (CH))*
11. *Send JOIN_REQ message to the CH chosen; /* node n join CH based on maximum likelihood value of CH */*
12. *End If*
13. *Cluster member (n) send sensed data to their CHs*
14. *End for*
15. *Sink collect the data from CHs;*
16. *End for*

4.5 Data Dissemination Stage

In this step, the proposed protocol describes how data from the source is sent to the sink after the CHS is selected and the cluster is created. TDMA plays a very important role in collision-free communication. SN sends data from target area to CH according to TDMA slot. Algorithm 3 states that data is sent to BS with the help of master node if it is close to BS or else if CH is close then data is sent directly to BS through it. The role of the cluster head changes dynamically after each round of data communication.

Table 2. Rules for FIS

Rule	Remnant Energy	Average Distance	Communication Quality	Likelihood for CH
1	Substantial	Meagre	Superior	Very Strong
2	Substantial	Meagre	Modest	Very Strong
3	Substantial	Meagre	Inferior	Strong
4	Substantial	Medial	Superior	Very Strong
5	Substantial	Medial	Modest	Strong
6	Substantial	Medial	Inferior	Strong
7	Substantial	Huge	Superior	Rather Strong
8	Substantial	Huge	Modest	Rather Strong
9	Sufficient	Huge	Inferior	Medium
10	Sufficient	Meagre	Superior	Medium Strong
11	Sufficient	Meagre	Modest	Medium Strong
12	Sufficient	Meagre	Inferior	Rather Strong
13	Sufficient	Medial	Superior	Medium

				Strong
14	Sufficient	Medial	Modest	Medium
15	Sufficient	Medial	Inferior	Medium Weak
16	Sufficient	Huge	Superior	Medium
17	Sufficient	Huge	Modest	Medium Weak
18	Sufficient	Huge	Inferior	Rather Weak
19	Deficient	Meagre	Superior	Medium Weak
20	Deficient	Meagre	Modest	Rather Weak
21	Deficient	Meagre	Inferior	Rather Weak
22	Deficient	Medial	Superior	Weak
23	Deficient	Medial	Modest	Weak
24	Deficient	Medial	Inferior	Very Weak
25	Deficient	Huge	Superior	Weak
26	Deficient	Huge	Modest	Very Weak
27	Deficient	Huge	Inferior	Very Weak

4.6 Data Routing

In the proposed protocol, data is forward to the sink with the help of the CHs and master nodes. Master nodes (super cluster head) have been selected from the CH based on the remaining energy and distance to sink. After cluster formation and cluster head selection stage, the sensed data transmit to the sink with the help of the master node or with the help of the cluster head as depict in Figure (7 -8). Suppose that if the farness from the sink to the CH is less than the master node. Then the cluster head will not send information to the master node. That information will be sent directly to the sink, and residual energy of the cluster head and master node may be same. These are the main differences between the proposed protocol and compared protocol.

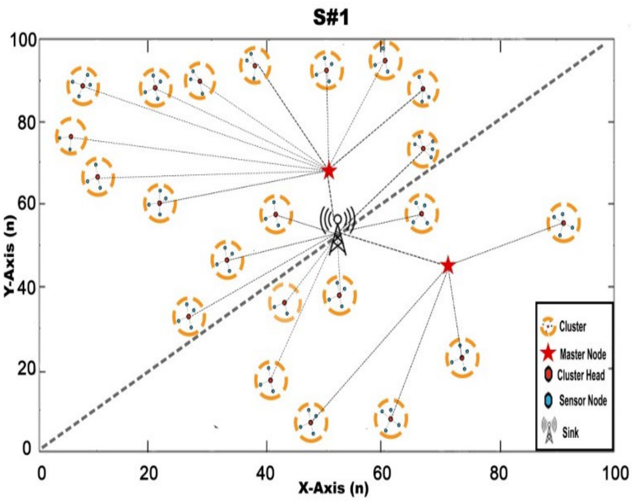

Figure 7. Network Layout of data route S#1

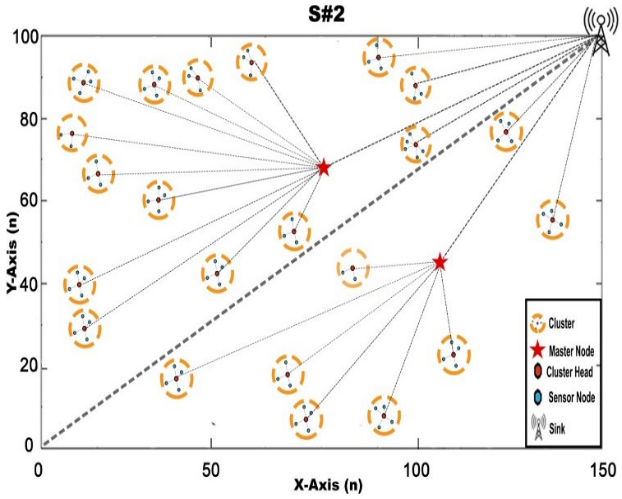

Figure 8. Network Layout of data route S#2

Algorithm 3. Data Routing in FEECA

1. *TN_CH = Total CH nodes in a round*
2. *MN = Master Node*
3. *BS= Base Station*
4. *If (distance of CH.ID> distance From BS)as compare to MN*
5. *Send Aggregate message_CH.ID to BS via MN.*
6. *Else*
7. *CH.ID send aggregate message directly to BS*
8. *End if*
9. *End for*

4.7 Simulation Results & Analysis

The simulation experiments of FEECA protocol is carried out in MATLAB along with two competent recent protocols SCHFTL and DFCR. In FEECA, we have considered two situations wherein some parameters of the simulation experiment are altered so that FEECA validates its applicability to diverse domain. In situation 1 (S#1), the BS is placed at the centre of the field with 100 SNs possessing initial energy as 0.5J. In situation 2 (S#2), sink is kept aloof from target area with 200 SNs having 1J initial energy each. The simulation parameters are listed in Table 3. The performance metrics chosen for comparative study are Stability period, Quarter Node death, All Dead, rate of Dead SNs per round, Throughput in terms of packet delivery to sink network's average energy per round.

Table 3. Network Parameters

Parameters	*Values for S#1*	*Values for S#2*
Total SN	200	100
ε_{fs}	10pJ/bit/m^2	10pJ/bit/m^2
ε_{mp}	0.0013pJ/bit/m^4	0.0013pJ/bit/m^4
E_o	0.5J	1J
Data packet	3000bits	3000bits

Parameters	*Values for S#1*	*Values for S#2*
E_{DA}	5nJ/bit/report	5nJ/bit/report
E_{elec}	50nJ/bit	50nJ/bit
Sink Position	(50,50)	(150,100)

4.8 Stability period, QND and All Dead

Stability period determines the reliability of the protocol as all the SN are performing their sensing task till that time [37]. All dead and QND are two parameters to determine how the energy is dissipated by the network. From Fig.9, we can see that for S#1, FEECA has shown improvement of 592.36%, 87.23% for Stability period, 304.87%, 104.61% for QND and 36.9%, 83.26% for all SN dead in comparison to SCHFTL and DFCR respectively. In Fig. 10, for S#2, FEECA outperforms SCHFTL and DFCR with 152.33%,68.75% improvement in Stability period, 135.85%, 76.88% in QND, 94.57%, 77.53% for all Dead respectively.

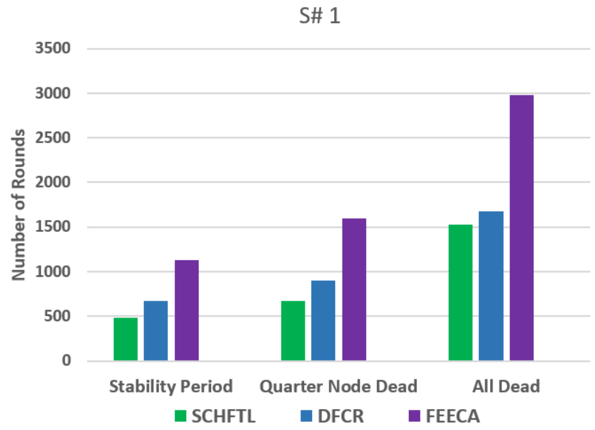

Figure 9. Stability, QND and All Dead for S#1

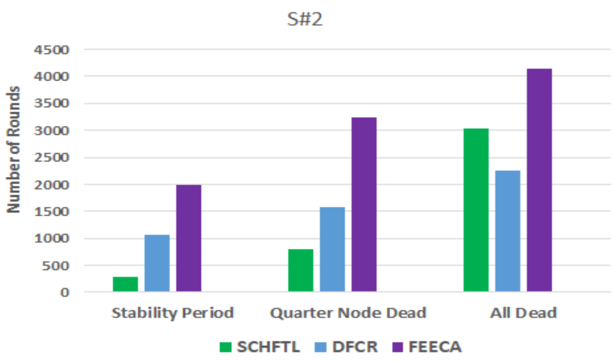

Figure 10. Stability, QND and All Dead for S#2

4.9 Dead Nodes per Round

There is a graph for dead nodes per round for both the graphs(S#1, S#2) as shown in Fig. (11-12) early death of SN makes the network unbalanced and changeable. It displays the life span of the network after the network is set (i.e. the beginning of the clustering process). That FEECA successfully balances the network's energy shortages for both graphs (S#1, S#2).

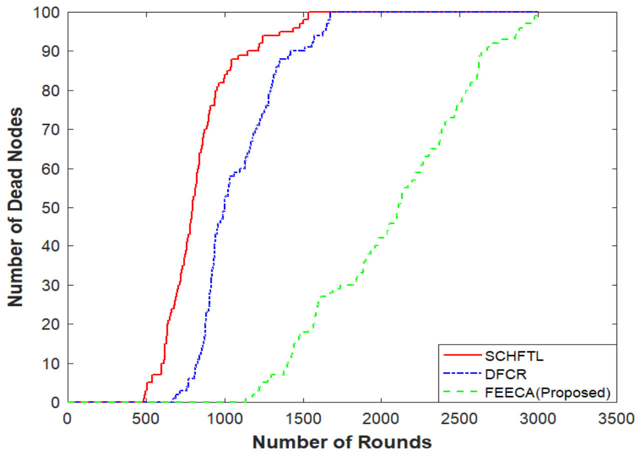

Figure 11. Dead SN per round for S#1

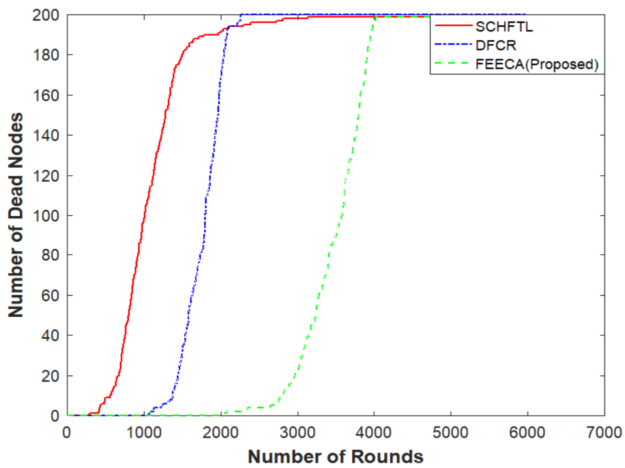

Figure 12. Dead SN per round for S#2

4.10 Throughput

Throughput of WSN estimates the effectively transmitted packet to BS. If a lot of varieties of packets are delivered to BS then more data is collected fulfilling the target of WSN. Figure (13-14) depicts the total packets forward to the BS per round. In order to consider the graph (S#1, S#2) the plot figure out that FEECA forward more packets as compare to SCHFTL & DFCR. The packet delivery is somewhat proportional to the energy consumption by the network. If more energy is there in the network, then more packet delivery will be there to BS.

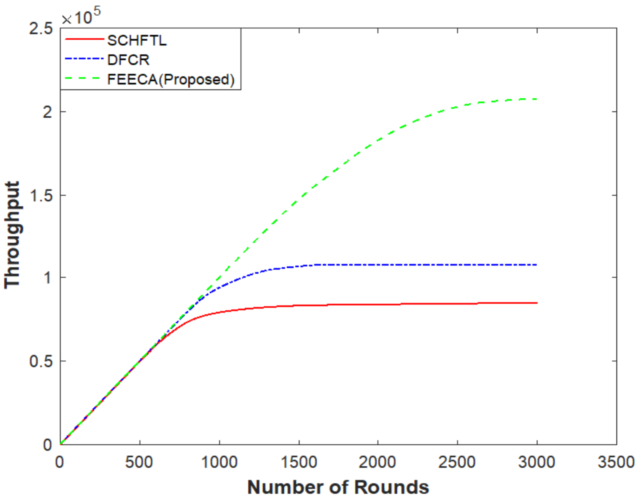

Figure 13. Througput of network for S#1

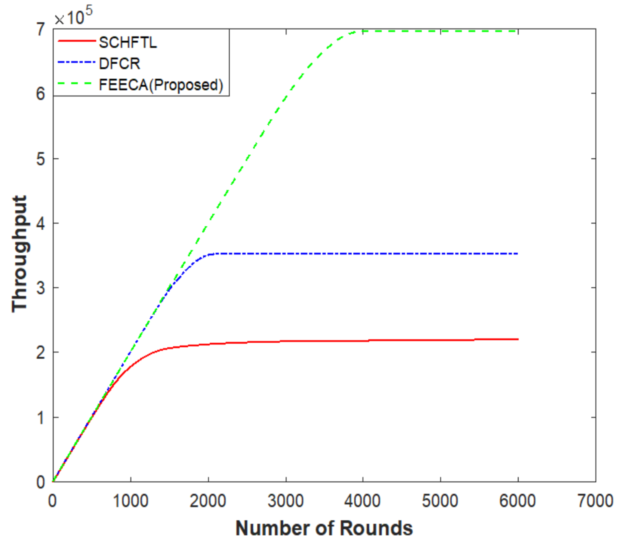

Figure 14. Throughput of network for S#2

4.11 Average Energy

In this metric, Energy of the network is dissipated mainly in sensing, processing and communication for any type of network. If the network is consuming more energy per round and depleting its average energy, then its lifetime of the network gets affected and that protocol will have poor stability region. Figure (15-16) shows that the average energy of FEECA is always greater than SCHFTL and DFCR protocols in both graph (S#1,S#2) and makes the protocol more reliable. This performance improves to select the best candidate for WSN called cluster head (CH) by considering the parameter which affects energy more.

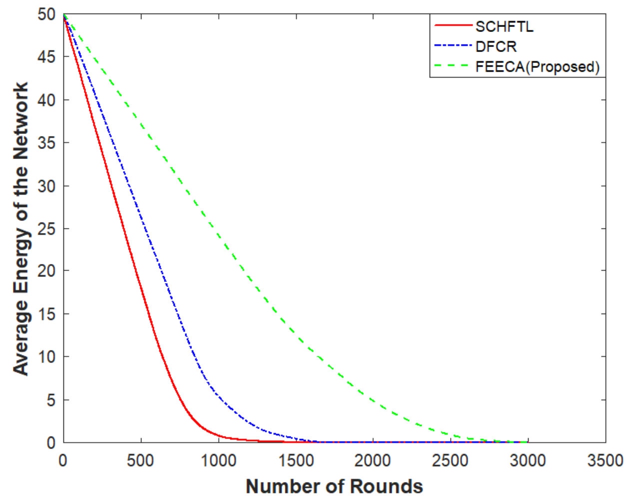

Figure 15. Network's average energy per round for S#1

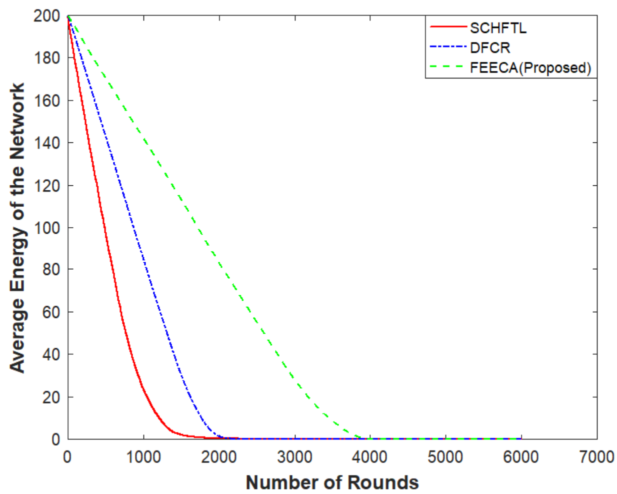

Figure 16. Network's average energy per round for S#2

5. Conclusion

Various clustering algorithms are proposed to achieve the energy efficiency in WSN, LEACH protocol is one of them. Basically LEACH uses probability model, on the basis of this model energy is not increased. To overcome the limitation of SCHFTL and DFCR protocol .FEECA protocol is proposed in this paper. FEECA select a best candidate to work as CH on the basis of four key parameters (Remnant energy, Average distance, communication quality, likelihood for CH). Energy level of a CH may increase or decrease it's depend on the distance between CH and BS. Initially when cluster are formed, then every non-CH node intelligently select their CH using FIS. This protocol uses a two pre-deployed diagram by changing the location of BS. Experimental result shows enhancement the longevity of network along with better throughput. In future, we will concern genetic algorithms for the election of membership function which is helpful for selection of CH and cluster formation to enhance the network lifetime.

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