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Energy Efficient Unequal Clustering Routing Algorithm Based on Neuro-Fuzzy Logic for Wireless Sensor Network

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Abstract:
Nowadays, Wireless Sensor Network (WSN) is used in large number of sectors like military surveillance, agriculture, health care and so on, because they are inexpensive, flexible and easy to use. Despite there are several benefits of WSNs, the major challenge faced by experts is their limited battery capacity which result in reduced lifespan. Over the years, numerous methods have been proposed by various researchers but these methods faced issues in uniform node deployment, complexity, clustering and cluster head (CH) selection which degraded their performance. In order to solve these issues, an enhanced model based on Neuro-Fuzzy system and unequal clustering is proposed in this paper. The process of clustering and CH selection is improved in the proposed Neuro-Fuzzy Energy Efficient Unequal Clustering (NFEEUC) model by utilizing the Neuro-Fuzzy system which takes node density and distance from the sink node as two input parameters so that the chances of a node to become a CH is determined. In addition to this, the proposed model is effective in detecting and eliminating the redundant data by comparing the sensed data with the previously sensed information. The performance of the suggested NFEEUC model is analyzed in the MATLAB software. The results from simulation are evaluated and compared with standard EEFUC model in terms dead nodes, node energy, first node death (FND), half node death (HND) and last node death (LND). The results obtained proved that the proposed NFEEUC model outperforms the traditional model in all parameters and has increased lifespan.
Keywords - Clustering Protocols, Fuzzy system, Network Lifetime, WSN.

1. Introduction

WSNs are becoming a critical component in a wide range of applications, including monitoring system, military, intelligence and medical by enabling seamless connectivity, assessment, and application execution [1]. WSNs are made up of small sensors that gather data from surroundings and transfer this data to the respective station. Nodes are small sensing devices in which a transceiver is used for sending and receiving signals or exchange information between nodes, battery for power, memory for data storage, and processor for data processing. The Sensor Nodes (SN) are cheap and their price is determined by various factors like battery size, processing speed, memory and capacity [2]. The WSN is a sub-category of ad-hoc networks. Unlike the traditional networks, the ad-hoc networks do not have any specific architecture and centralization and

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hence and their topologies are vulnerable to change when nodes relocate, die, or new nodes join [3]. The sensor networks comprises of nodes which are fitted with smart sensing units and have a special name, which is "Sensor"[4]. A SN is a system that transforms a detected attribute, such as pressure, vibrations, temperature, etc. into a type that consumers may recognize [5]. Fig. 1.1 shows the block diagram of a WSN network.

In WSN without any infrastructure, each node is equipped with smart SNs that interact with each other, resulting in lower communication overhead. WSNs are designed with multiple SN's that interact with one another and define multiple routes to multiple nodes. In multi-hop, the packet moves from one node to the other node, taking multiple paths to reach its destination [6]. The nodes in a WSN are dispersed over a wide geographical location. And since there are more nodes in a WSN, the network size is larger. A WSN is generally made up of homogeneous sensors, each of which has the same characteristics. All the neighbouring nodes gather similar information, if one node dies; it does not impact the network's process. Data collection quality suffers as a result.

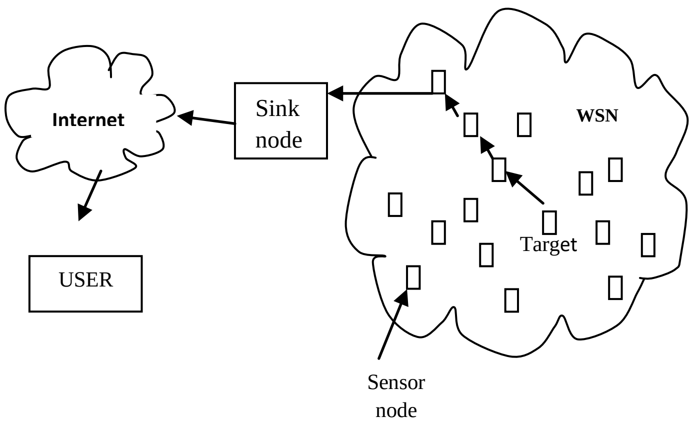

Figure 1.1 WSN architecture

Despite the fact that WSNs have huge number of features, there are some drawbacks of these networks which degrade the performance of entire network. WSN contains a huge number of SNs hence making it difficult to allocate bandwidth to each and every node with link [7]. Since the SN's are operate on the battery, they have less amount of energy and to process the information sensed by nodes in the sensing region a large amount of energy is utilized. Also SNs are minute computer embedded devices which have limited storage and processing abilities [8]. The nodes must be deployed in an effective way in the network as node deployment has a major impact on networks efficiency and lifespan [9].Some applications, such as tracking, monitoring, and event detection, needed the SNs' geographical location information. It is impossible to allow GPS in each node [10].In order to overcome these challenges, clustering is done in the WSN that effectively enhances the lifespan of the network.

Clustering is an innovative strategy being used in WSNs so that energy can be effectively used particularly in large sensor networks with greater distances. During the clustering process, one node is selected as the CH and the remaining nodes are called as cluster members (CM). The CMs are the nodes which are responsible for sensing and collecting the information from the surroundings. It is responsible for sending information to the CH to which it belongs. CH are also called as the cluster leaders and their main job is to collect and aggregate the information from CMs before transmitted or received by the Base station(BS) or sink node. BS is also referred as sink node which acts as a bridge between the communication channel and end user During clustering, it is critical to consider various factors like size of clusters and the method for determining the CH, as well as the process for avoiding inter-cluster and intra-cluster collisions. Basically, clustering is done in three stages, in the first stage the selection of CH is done, in the next stage, clusters are formed in the network and finally, the process of communication is started in the network.. The data collected by WSNs can be used for a variety of purposes and can be accessed through internet, computer etc. Clustering is done in the WSN for balancing the loads, to avoid data loss, to make system efficient and reliable with enhanced security and decreased delays. In addition to this, clustering is done to increase the lifespan of WSN network [11]. Over the years, a lot of clustering protocols that were based on fuzzy system were developed by experts in order to enhance the lifetime of the network which are described in the next section of this paper. And in the further sections, the related work, proposed work, methodology, pseudo code and results are discussed. Finally the paper will be finished with the conclusion and future work.

2. Literature Review

A number of clustering and energy efficient routing protocols were proposed in the past by various researchers. An energy-efficient unequal fuzzy-based protocol for multi-hop clustering in WSNs (EEFUC) [12] is a four-stage Fuzzy Logic (FL)-based clustering architecture that includes determining the CH election, competition radius (CR), CM joining, and determining the next CH (relaying) for path selection. Firstly each node calculates its CR and competes to become a CH. After a node is elected as CH, the nodes in its CR join it and form a cluster. If a node comes in radius of more than one CH then FL system made the proper decision. After formation of clusters the routing paths are found and the best suited path is selected and the data is sent through multi hops in their respective slots allocated through TDMA technique. This algorithm showed good results as compared to previous algorithms. Distributed unequal clustering algorithm using FL [13], proposed an algorithm based on clustering in which CH selection is a two step process that chooses node with the maximum residual power as candidate CHs, from which the best nodes are chosen as final CH. Moreover, FL is used to change the cluster radius of CH nodes by considering BS distance and density as fuzzy Parameters. A FL based Multi-hop Routing for Unequal Clustering for WSNs [14], used a FL-based clustering method for determining Competition Radius with multi-hop communication in order to achieve load balancing, power usage reduction, and network lifespan extension.

Energy Aware Fuzzy Based Multi-Hop Routing Protocol Using Unequal Clustering [15] suggested an energy-efficient cluster-based routing procedure utilizing FL and a multi-hop routing strategy to resolve the hot spot issues, where even the cluster size has dynamic nature. The cluster radius is calculated by FL system whereas CH probability is calculated mathematically. A Clustering Technique for Hierarchical Routing Protocols based on Energy-Efficient Fuzzy-Logic in WSNs [16], established a model based on FL for selecting CH and to evaluate the likelihood of each node being a CH using five descriptors i.e., position suitability, remaining power, density, compacting, and distance from the base station. Distributed fuzzy approach to unequal clustering and routing algorithm for WSNs [17], proposed a distributed FL-based unequal clustering strategy and routing algorithm to eliminate the hot spot issues. An unequal clustering algorithm based on fuzzy to prolong the lifetime of WSNs [18], developed unequal clustering algorithm through fuzzy system to extend the network's lifespan. The clusters created in this model are unequal in size. Secure authentication and clustering algorithm based on fuzzy system for better energy efficiency in WSNs [19], proposed the FSAC and Fuzzy-based Secured Authentication Algorithm to identify the distinct types of data packets transferred via sensors to prevent attacks. The CH is done using FL and a secret key is used for encryption of data for better security**.** The decryption is done at the BS having the key. In fuzzy based unequal clustering using load balancing for WSNs assisted Internet of Things [20], fuzzy-based uneven clustering method was introduced that technique not only extends the network's lifespan, but it also stabilizes the load between networks. The fuzzy based system is used for calculating both CH and CR. The algorithm is performed for different scenarios where the number of nodes is varied along with the position of the BS.

3. Proposed Work

The biggest challenge that the researchers face while dealing with WSN is their limited battery capacity. A lot of methods have been already proposed by various experts, however, these systems were not efficient enough in enhancing the lifespan of network. So, in order to enhance the lifetime of the WSN network an enhanced approach is developed in this paper that is based on Neuro-fuzzy system. The main contribution of this work is that the process of CH selection is improved by using neuro-fuzzy model. Also, we have focused on developing an energy efficient routing algorithm based on Neuro-fuzzy for unequal multi-hopping clustering so that objectives such as to increase the total no. of alive nodes and lifespan of network can be achieved.

The proposed model is implemented under four scenarios. In the first scenario a total of 100 nodes are deployed with location of BS set at center (100,100). In the second scenario, again only 100 nodes are deployed in the network but the location of BS is changed to (100,250). In the third and fourth scenarios, a total of 1000 nodes are deployed in the given area and the location of sink node is set at (100,100) and (100,250) respectively. Fig. 1.2 shows the block diagram of the proposed ANFIS model in which two membership variables i.e. distance and node density serve as two inputs which are processed to obtain a single output as CH.

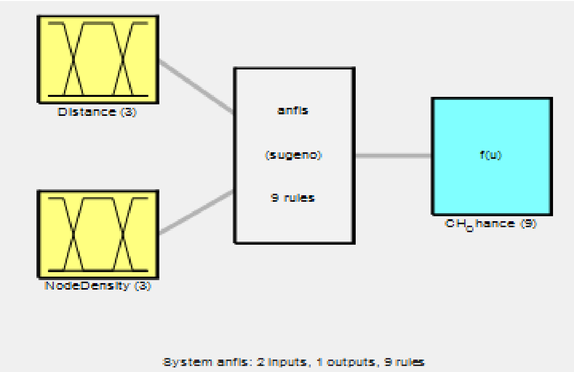

Figure 1.2 Proposed Neuro-Fuzzy System.

Fig. 1.2 illustrates the block diagram of the proposed fuzzy model with two distance and node density as two inputs. These inputs are then processed by the 9 defined rules so that a single output can be generated in the form of CHs, which determine the possibility of a node to become a CH in a particular cluster.

The neural networks get trained by utilizing a training algorithm which analyzes a large number of labelled samples provided as the input while training and then by utilizes this answer key to determine which input properties are required to produce the correct output. The Anfis in MATLAB is used for this purpose. It uses a back propagation method in which multiple layers are used. Two layers will be output and input and other layers will be hidden layers, that can be used for processing the data. After a significant set of characteristics were analyzed, the neural net can start to handle new, unknown inputs and accurately deliver results. Also, because computer learns from practice, more and more instances and types of inputs it sees, the more precise the outputs become.

In addition to this, the proposed scheme works on handling the data by eliminating the data redundancy. To achieve this, the proposed model will initially generate the data packet on random basis and track the values generated in a sequence. It will be capable to remove the similar values of the sensors if those will be in sequence and are repeated for number of times. The working of the model is given in the next section of this paper.

4. Method

This section describes working of the proposed model works. The complete flow diagram of the suggested model has also been given in Fig. 1.3.

1. The first and foremost step that is opted in the proposed scheme is initialization in which various parameters such as, area, total number of nodes, their initial energy, location of BS etc. other than this, there are several other attributes that are defined in the proposed model and are mentioned in table 1.
2. After the network is initialized, the next step is to deploy the given number of nodes in the sensing area. Based on the EEFUC[12], the proposed model works in four scenarios, in the first two scenarios, only 100 nodes are deployed with location of BS at (100,100) and (100,250). In the next two scenarios, 1000 nodes are deployed in the given sensing region with location of BS at (100,100) and (100,250). The network parameters are also selected from the EEFUC [12] protocol.

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Table 1: Network initialization parameters

Parameter	Value
Initial Energy	0.25J
Number of Node	100 and 1000
BS location	(X=100 & Y=100) and
Data Packet Size	127 Byte
Control Packet	25 Byte
Area	200 x 200 m^2

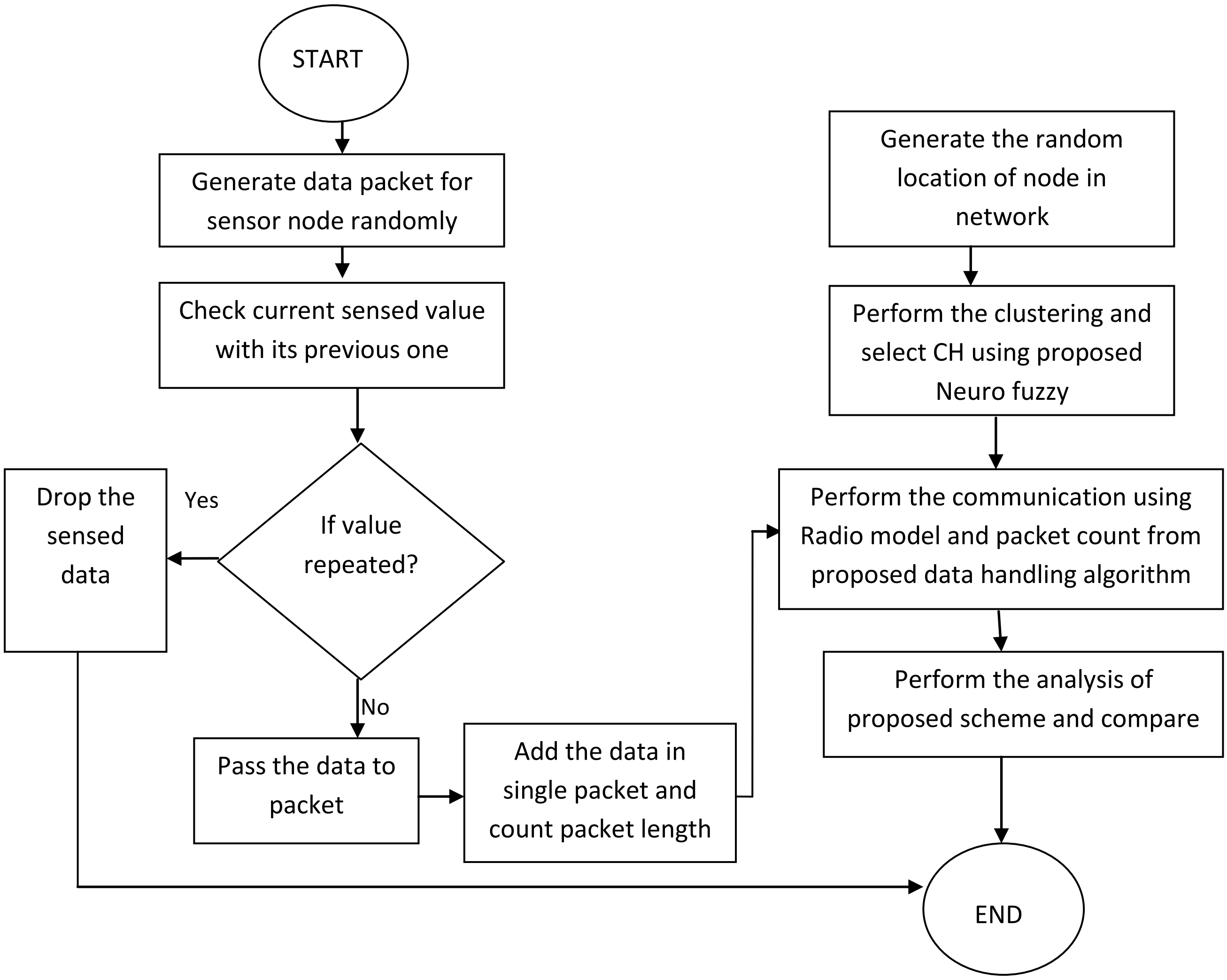

Fig. 1.3 Flowchart of proposed model

3. After this, temporary CHs are formed in the network and the distance between the temporary CHs and the remaining SNs is evaluated. The nodes whose distances are minimum to the selected temporary CH

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will be put together to form clusters in the network.

4. The next step that is followed in the proposed model is to select the final CHs in the network. For this, the proposed model utilizes the neuro-fuzzy system which calculates the distance to the BS and node density of every node present in that particular cluster.
5. The node with best fitness value in terms of distance and node density is selected as the final CH in the network.
6. After this, the communication phase starts in which the SNs sense the information from surroundings. This data is then cross checked with the previously transmitted data in order to remove data redundancy. If same data is sensed in the second iteration then this data is dropped otherwise it is passed to the packet to perform communication.
7. In order to evaluate the total amount of energy transmission in the network, the proposed system utilizes the energy model through which the energy consumed by nodes to transfer '*l* ' bits of data over distance d. The equation of energy model is given below.

$$E_{Tx}(l, sr, des) = \begin{cases} l \times E_{elec} + l \times \varepsilon_{fs} \times d^2, d \le d_o \\ l \times E_{elec} + l \times \varepsilon_{mp} \times d^4, d > d_o \end{cases} \quad (1)$$

8. Finally, the performance of the proposed model is evaluated for the given four scenarios in terms of dead nodes, remaining energy and FND, HND and LND as explained briefly in the next section.

5. Pseudo Code

The pseudo code of the algorithm is shown below:

r = No of rounds
n = number of nodes
T = random threshold
CRfis= fuzzy file for CR determination
RE =Residual Energy
ND= Node Density
SN= Select Node in CR range
NE =Node Residual Energy
CH_Chance= Calculate Chance for CH selection under threshold
N_Chance = Calculate Chance for CH selection of Nodes
CH=Cluster Head
CHfis = fuzzy system for CH selection
CMfis = fuzzy system for Cluster member selection
CM_Chance= Calculate Chance for Cluster member selection
SNode = Selected Node for Cluster member
CH_Relay = Chance for Cluster head used for relay node
CHRelayfis = fuzzy system for Cluster head relaying selection
DN2CH = distance Node to Cluster head
DCH2CH= distance Cluster head to Cluster head
SCH = Selected Cluster head for relaying

```
    for  i=1 to r
%%%% Calculate CR and Selection of Cluster Head
 for  j=1 to n
   T=rand;
    If T<Threshold
     CR=evalfis([RE,D2BS,ND],CRfis);
     SN=Find nodes in CR Range
      for k=1 to sn
          N_Chance=evalfis([N2BS, ND],CHfis);
          if (RE<NE)
              Status=true;
```

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```
        else if (RE==NE && CH_Chance< N_Chance)
            Status=true;
          end
      if (Status=true)
         CH= Node selected for CH;
      end
    end
 end
%%%% Communication Phase Node to CH
for i=1 to n
   for j=1 to nCH
      CM_Chance=evalfis([DN2CH, RE ],CMfis);
   end
 SNode=max(CM_Chance); become node as cluster memeber
 if r==1
   Pattern=randi(10) generate pattern
   Do communication with node to cluster head
else
   temp==randi(10) generate pattern again
  if Pattern==temp
       do nothing
  else
    Do communication with node to cluster head
   end
  end
end
%%%% Communication Phase CH to CH and sink
for i=1 to nCH
   for j=1 to nCH
      CH_Relay=evalfis([DCH2CH, RE ,OptimalD],CHRelayfis);
   end
  SCH=max(CH_Relay) Selected Cluster Head for CH to CH communication
end
if SCH is Selected
   Do communication with cluster head to cluster head
else
 Do communication with cluster head to sink
end
end
```

6. Results and Discussion

The effectiveness of the suggested NFEEUC approach is simulated and compared with conventional EEFUC approaches in the MATLAB software. The simulated outcomes were determined in terms of various factors which include node deaths, remaining energy, FND, HND and LND and are explained in this section. The node will be considered as dead when its remaining energy becomes less than a threshold value. The threshold value will be equal to transmission energy calculated through eq (1). The remaining energy is calculated after each round by subtracting the energy consumed from initial energy based on whether the selected node is a CM or a CH.

The performance of the proposed NFEEUC model is firstly evaluated for the scenario when 100 nodes are deployed in the sensing area and the location of base station is (100,100) in terms of dead nodes and remaining energy. Fig. 1.3 and 1.4 shows the comparison graph of the proposed NFEEUC model and conventional EEFUC model with respect to their node death and remaining energy.

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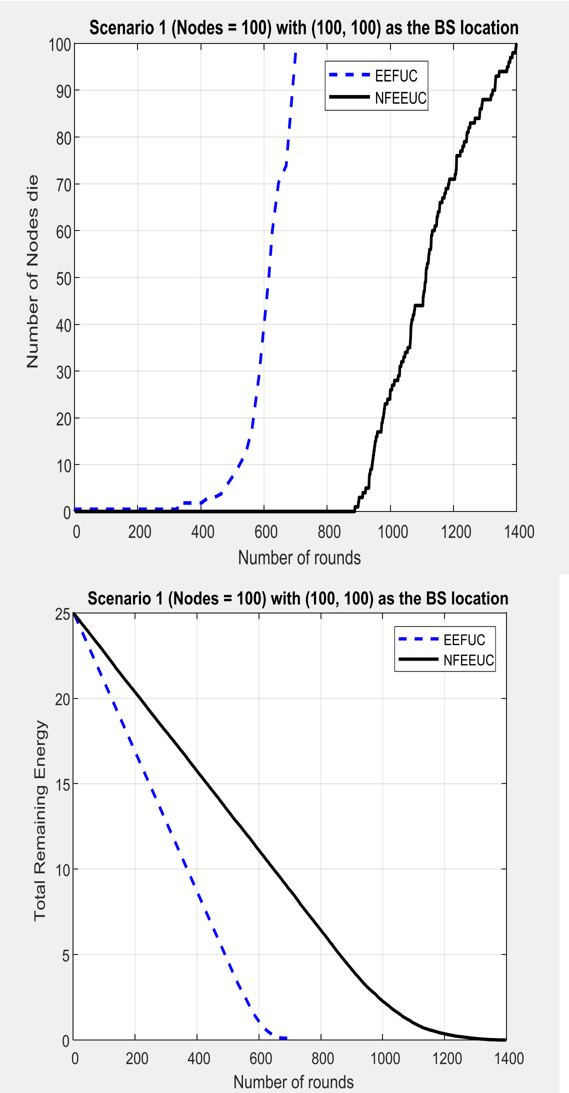

Figure1.3 (a) Comparison graph for dead nodes (b) Comparison graph for total remaining energy

Fig. 1.3(a) represents the simulation graph of traditional EEFUC model and proposed NFEEUC model in terms of the death of nodes. From the graph it is observed that, with the increase in the number of rounds, the no. of node die also increases. Like in conventional EEFUC model the first nodes dies after performing just 339 rounds and after 718 simulation rounds all the nodes die. While as, in proposed NFEEUC model the first node dies after performing 888 rounds and the model lasts up to 1400th simulation rounds. Also, from Fig. 1.3(b), it is observed that in EEFUC the energy of all nodes is vanished after performing just 700 rounds whereas, in proposed NFEEUC model energy of nodes is draining slowly and lasts up to 1400 round which results in increasing the lifetime of the entire WSN network.

Likewise, the performance of the proposed model is analyzed in terms of death of nodes and remaining energy, when the nodes deployed are 100 and BS location is (100,250). Fig. 1.4(a) and (b) shows the comparison graph for death of nodes and energy.

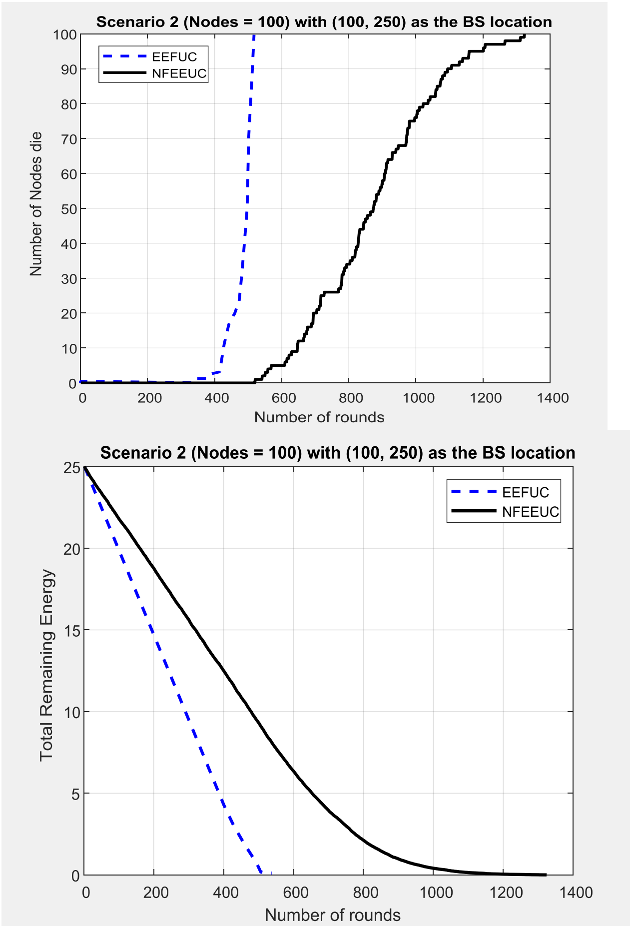

Figure 1.4(a) Comparison Graph for node deaths in scenario 2 (b) Graph for remaining energy in scenario 2

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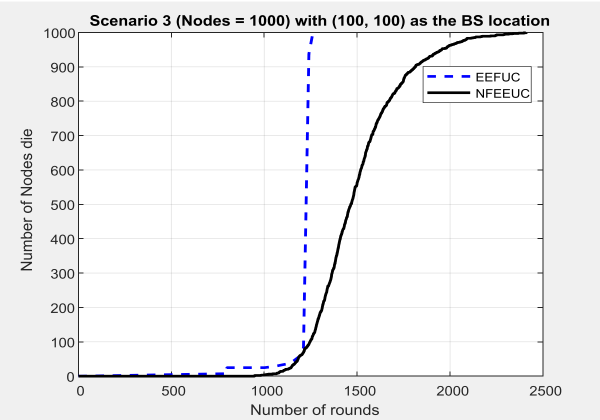
Fig. 1.4(a) represents the comparison graph for node death in traditional EEFUC and proposed NFEEUC method. From the graph it is observed that the nodes are dying very quickly in the traditional EEFUC model and network lifespan is only up to 455 simulation rounds. However, this is not the case in proposed NFEEUC model where nodes last up to 1324 rounds that is an improvement of 869 rounds. In addition to this, from Fig. 1.4(b), it is observed that the energy of all the nodes drains just after 500 rounds in standard EEFUC scheme whereas, the energy of nodes last up to 1310 simulation rounds in proposed NFEEUC scheme, which proves that the proposed NFEEUC model has larger lifespan than traditional EEFUC model.

Fig. 1.5(a) and (b) represents the simulation graph of the proposed NFEEUC model and conventional EEFUC model when nodes deployed are 1000 and location of BS is center (100,100).



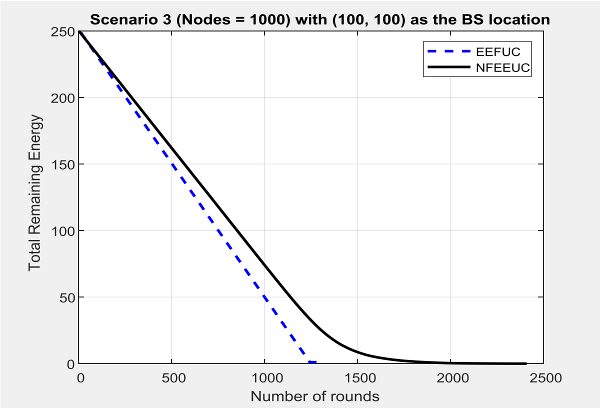


Figure 1.5(a) Comparison Graph for dead nodes (b) Comparison graph for remaining node energy

From the graph given in fig. 1.5(a), it is observed that the death of first node occurs in the conventional EEFUC model after performing just 614 rounds and with the increase in simulation rounds the nodes die more and death of last node occurs at 1221 rounds. However, in proposed NFEEUC model the death of first node occurs at 948 round and last node dies at 2411 round, which means that there is an improvement of around 1190 rounds. Likewise, the graph for remaining energy is obtained for both i.e. traditional EEFUC model and suggested NFEEUC model when number of deployed nodes is 1000 and BS location is at (100,100) and is shown in fig. 1.5(b). After analyzing the graph closely, it is observed that the energy is draining more quickly in conventional EEFUC approach and all energy is drained after performing 1300 round while as, in case of proposed NFEEUC approach the node energy lasts up to 2400 round, hence an improvement of 1100 rounds.

Finally, the performance of the suggested model is also analyzed for the last scenario

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when nodes to be deployed are 1000 but the location of sink node is changed to (100,250). The performance of proposed NFEEUC model is validated and compared with traditional EEFUC model in terms of node death and energy remaining and is shown in Fig. 1.6(a) and (b).

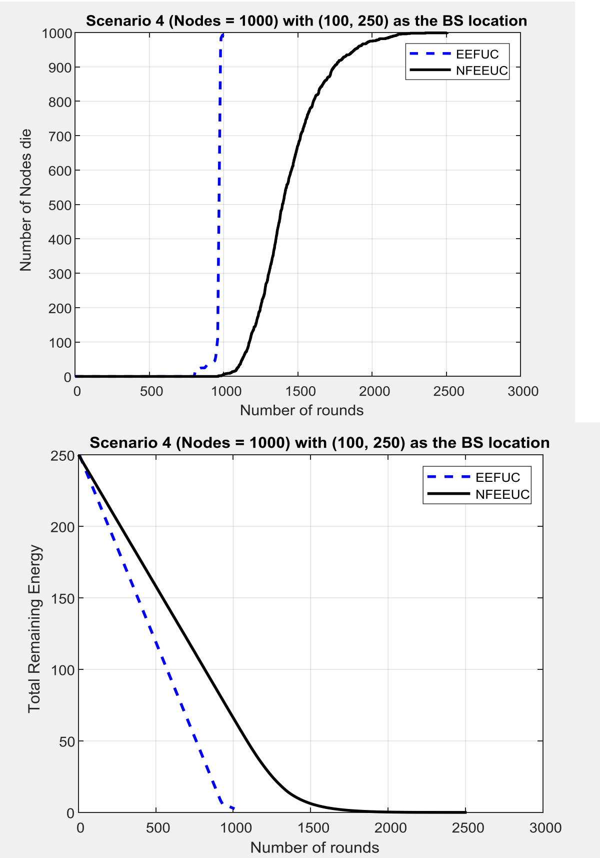

Figure 1.6(a) Comparison graph for dead nodes. (b) Comparison graph for remaining node energy

Fig. 1.6(a) depicts the comparison graph of traditional EEFUC model and proposed NFEEUC model in terms of their node deaths. From the graph, it is observed that the lifespan of standard EEFUC model is very small and lasts up to only 1021 round, which means all nodes are dead in the network and hence no data can be transferred further. On the other hand, the nodes in suggested NFEEUC approach works efficiently up to 2500 simulation round. Likewise, the energy remaining comparison is shown in fig. 1.6(b), and it was found entire energy is drained just after performing 1000 rounds in conventional EEFUC model. However, in case of proposed NFEEUC model the energy of SNs drains slowly and hence lasts longer than traditional model by around 1500 simulation rounds.

In addition to this, the performance of the NFEEUC (proposed) model is analyzed and compared with traditional EEEUC, MOFCA and EEUC models in terms of their FND, HND and LND values in all the four scenarios. The values obtained are mentioned in table 2.

Table 2: Values of FND, HND and LND in all four scenarios.

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Parameters	Scenario 1				Scenario 2				Scenario 3				Scenario 4			
	EEUC	MOFCA	EEFUC	NFEEUC	EEUC	MOFCA	EEFUC	NFEEUC	EEUC	MOFCA	EEFUC	NFEEUC	EEUC	MOFCA	EEFUC	NFEEUC
FND	208	260	339	888	182	289	337	521	523	290	614	948	550	265	599	965
HND	509	580	617	1113	402	468	492	875	998	1112	1170	1466	878	945	975	1396
LND	570	670	718	1399	455	490	510	1324	1047	1162	1221	2411	926	991	1021	2507

After analyzing the graphs and the tables, it is observed that the proposed NFEEUC model works pretty well as compare to traditional models in all the four scenarios and hence is more effective and efficient in enhancing the network lifetime.

7. Conclusion & Future Scope

In this paper, an enhanced approach based on neuro fuzzy system and unequal clustering, namely as, neuro fuzzy energy efficient unequal clustering (NFEEUC) model is developed to enhance the lifespan of the WSN. The performance of the suggested NFEEUC model is simulated in the MATLAB software for small range and large-scale node deployments. The experimental outcomes were compared with several models in terms of their node death rate, remaining energy, FND, HND and LND. From the results, it is observed that the lifespan of traditional EEFUC model is less then proposed NFEEUC model by around 618 rounds when only 100 nodes are deployed and location of sink node is center (100,100). The location of BS is changes to (100,250) in the second scenario, and in that case the first node dies after 521 rounds and the last node dies at 1324th round in proposed NFEEUC model whereas, the traditional EEUC, MOFCA and EEFUC models the last node dies after performing just 455, 490 and 510 rounds. For large scale node deployment, 1000 nodes are deployed in the network with location of BS at (100,100) and (100,250) and the value of FND, HND and LND came out to be 948, 1466 and 2411 and 965, 1396 and 2507 in proposed NFEEUC approach. While as, the value of LND in standard EEUC is 926, followed by MOFCA and EEFUC with LND value 991 and 1021 rounds. Thus, the lifetime of the suggested WSN network is more and can be used in real world.

Current system is using FLs that are operated by user rules that can get effected by some human error and might be few conditions may get skipped. Therefore in future there is scope of improvement in reducing the complexity of system with automating the process of conditions in different phase of network performance control.

8. Acknowledgement

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