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Achieving Energy Efficiency Using Fuzzy Logic-Based Cluster Algorithms in Wireless Sensor Networks

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Abstract: **-** Now a days Wireless Sensor Network (WSN) [1, 2] is an emerging and challenging aspect in the field of communication research. It is a type of infrastructure-less wireless networks, which have the capability of self-configuration. These nodes are deployed for environmental data collection by measuring different environmental condition like moisture, pressure and temperature etc. The nodes are working continuous or waiting for event happening to send information. Energy consumption is a major issue in WSN. In this thesis, our proposed approach Fuzzy Based Energy Efficient Clustering in which cluster head is selected based on the distance to BS, remaining energy of node and node density. The non-head nodes join with the cluster head node based on the distance to CH, remaining energy of CH and CH density. The simulation results show that the proposed approach gives better performance than that of LEACH in terms of energy consumption and lifetime of the network for first node death and half of node death.

Keywords: **-** *Fuzzy Logic, Clustering, WSN, Network Density, Network Energy Efficiency.*

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1. INTRODUCTION

There are numerous tiny nodes in WSN in the range of few hundreds to thousands. They have limited processing speed, low battery power and, limited memory, and slow processing speed. With the help of radio transceivers component, the sensor nodes communicate information to other nodes in their radio frequency range [3]. Here there is a schematic diagram of wireless sensor network architecture given below in Figure 1.

These nodes are deployed for environmental data collection by measuring different environmental condition like moisture, pressure and temperature etc. The nodes are working continuous or waiting for event happening to send information. Then the data is proceeded at the base station, termed as sink, which performs as an user-network interface [4].

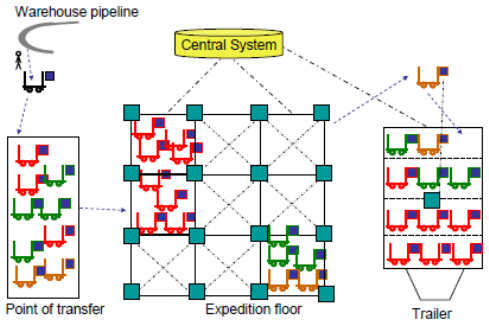

Figure 1: Case study on transport and logistics

So in this scenario by the employment of WSN, the process can be monitored efficiently. Each container attached with a WSN node, to facilitate better communication. All the nodes send their status to a central system. It is the duty of the central system to coordinate all the activities. Here is a process diagram is given in Figure 1.

Literature Survey

In WSN, clustering is used for increasing the longevity of the network. Clusters are formed by grouping sensor nodes and one node is selected as cluster head (CH) to represent cluster. Rest of the nodes except CH are called as member nodes of corresponding cluster. In WSN the member nodes in a cluster send sensed data to the CH.

In Wireless Sensor Networks (WSN), multiple sensors nodes continuously record values to share with sink node via either node-to-node communication or cluster heads. The data is sent from sensor node to cluster head node which are then forwarded to BS for further communication [10-11]. During this process, energy efficient routing is a major concern. It is very difficult to change battery of sensor nodes once activated in the critical environments in remote areas where nodes are deployed using small airplanes. Routing becomes more challenging in such scenarios when a number of nodes are expired due to excessive energy consumption [12].

Several clustering algorithms in WSN have been proposed to achieve energy efficiency. In this section, we give an overview of some of them.

Energy efficiency is a challenging area of research where the packets are sent over an unreliable network. Numerous approaches have been proposed for the consumption of energy. However, clustering routing protocols are one of the most dependable protocols that are used for the efficiency of energy, load balancing, communication cost and used to send the packets from the sink node to the base station (BS) [13].

In WSN, energy efficiency is very important, many energy efficient algorithm have been proposed. However, all of these are not efficient enough. There have been many routing algorithms provided in order to overcome multiple problems, such as load balancing [14], consumption of energy [15] and transmission cost [12].

In the WSN some of the routing protocols are of special types. These routing protocols are used for energy efficiency and to maximize the lifetime of the network. Many existing routing protocols are designed for WSN e.g. cluster based protocols, energy efficient protocols etc. In the efficient cluster based routing protocol the effective use of energy is require in the WSN. Sensor nodes designing in WSN with the different aspects like adaptability, small size, cost, security etc. [16]. In the past many techniques are proposed on clustering based routing

protocols. In the cluster head sensor nodes sends their sensed data that relates to the same clusters. Cluster head remove the two sets of data to overcome the final packet and combine the data from several measurements to the data sink. For this energy efficiency and lifetime of the network is improved. Clustering based protocols are used to transmit the data to the data sink. Secured- Scalable Energy Efficient Clustering Hierarchy Protocol for WSN (S-SEECH) [10] is the most recently introduced method that describe the distance is large between the cluster head and the sink node. According to the aspects of security authentication, availability, confidentiality and integrity of services are available [17]. For the security purpose many cryptographic and stenography methods are used. In the WSN many attacks occur with the respect of security and routing mechanisms. Some of the major attacks are DOS attacks, Sybil attacks, black hole attacks etc. In the WSN to improve the performance of security and to minimize the consumption of energy keys are used [18]. To fulfill the requirement of security authentication, integrity, secrecy is used and to fulfill the requirement of energy efficiency network connectivity, maximum supporting network size, minimum energy storage, and low computation overhead is used. More and less specific issue in the security mechanism and the solution exist in one of the problem. MAC protocol used in WSN, to improve the efficiency of energy. MAC protocol is already implemented in the WSN, however, no one protocol has accepted as a single standard [19]. Holistic approach is used to improve the performance of the network and lifetime of the network. This concerns all layers in the network to ensuring the security [20]. This provides security to all of the layer of WSN. The solution of security on a single layer is not the efficient solution whereas holistic approach is the best solution [21]. The drawback of holistic approach is that it takes a lot of time to execute the complex calculations [22]. In the terms of energy efficiency DEC and SEP are most important cluster based protocols. In the WSN limited energy is the major issue. To effect the lifetime of the network the power of the battery and the nodes of the inefficient energy expires rapidly. If we reduce the traffic of packets, then we improve the usage of energy. In the WSN two types of the network homogeneous and heterogeneous. With the perspective of hardware and energy efficiency the sensor nodes are arranged in the WSN. Whereas, in the heterogeneous network extra processing and additional vitality improves the lifetime of the network. When it compares to the sensor node additional battery cost is low. Due to the cause of the heavy traffic the nodes dies quickly when they surrounding the sink [23]. For two level clustering approach SEP protocol is energetic. The sensor nodes transmit the data when the network is energetic. For two level clustering approach Stable Election Protocol (SEP) is energetic. In the SEP protocols two level of heterogeneity is introduced in the WSN [24]. In the advanced nodes additional energy is allocated than the normal nodes.

2. Fuzzy Based Energy Efficient Clustering

The system model used in our work consists of network and energy models. Mainly sensor nodes are used for the network model. The following assumptions are made here:

1. Initially, all the sensor nodes have the same amount of energy.
2. The sensor network is homogeneous in nature. That means each node has the same amount of memory, processing speed, transmitting and receiving power.
3. Sensor nodes are deployed arbitrarily.
4. The distance of the node is calculated based on the received signal strength.
5. Node death is because of energy depletion only.

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In WSN different sizes of clusters are formed by sensor nodes. In a cluster the information collected by the cluster member nodes first transmitted to the cluster head.

The cluster head aggregates the data and then transmits the redundancy compressed data to the base station. The consumption of energy is mainly due to packet transmission and packet reception. The energy consumption model used for transmission and reception is similar to the model used in [12].

For transmitting k-bit message for distance d the energy required is given as follows:

$$E_r(k,d) = \begin{cases} kE_{elec} + k \in_{fs} d^2 \; for \; d < d_0 \\ kE_{elec} + k \in_{fs} d^4 \; for \; d < d_0 \end{cases} \quad (3.1)$$

where d_0 is cross over distance *i.e* if distance d is less than d_0 free space propagation mode is applied, otherwise multi path model is applied. For receiving k-bit message energy required is given as follows:

$$E_R(k) = k\, E_{elec} \quad (3.2)$$

Table 1. Fuzzy input variables and their minimum and maximum values for CH priority

Input Variables	Min. Values	Max. Values
Distance to BS	0	140
Remaining Energy	0	0.5
Node Density	0	50

In our proposed approach FBEEC, first by using three fuzzy parameters that are the distance to BS, the remaining energy of nodes and node density, the CH priority of each node is calculated for selecting cluster heads. After that, the noncluster head nodes are joined with the cluster head to form a cluster. For this cluster formation, the noncluster head nodes choose the cluster head by taking the fuzzy parameter distance to CH, remaining energy of CH and density of CH.

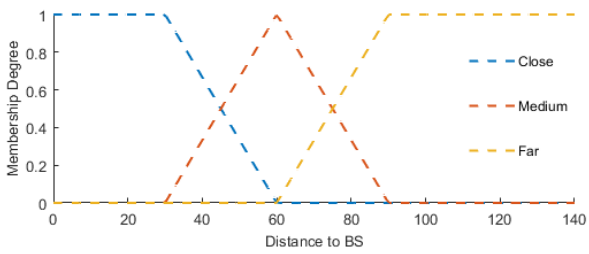

Figure 3: Fuzzy membership for Distance to BS

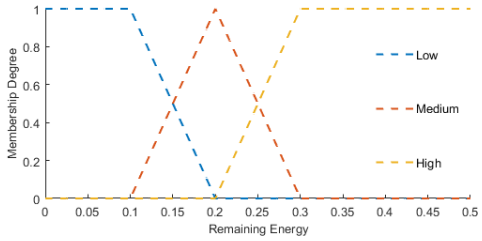

Figure 4: Fuzzy membership for Remaining Energy

FBEEC is centralized in nature and the clusters formed in this method are unequal in size. The main steps of the FBEEC algorithm are given in Algorithm 1.

Algorithm 1: Fuzzy Based Energy Efficient Clustering

1. **Initially, all nodes have the same amount of energy**
2. **For each round calculate the remaining energy, distance to BS and node density**
3. **Calculate CH priority using fuzzy if-then rules given in Table 3.5 CH priority = Fuzzy Logic (distance to BS, remaining energy, node density)**
4. **From Step 3, select those nodes which have a high value of CH prority and assign those nodes as CHs**
5. **Calculate the CH choice using fuzzy if-then rules given in Table 3.6 CH choice = Fuzzy Logic (distance to CH, remaining energy, CH density)**
6. **Join the noncluster head nodes with CH having a high value of CH choice form Step 5 to form a cluster**

For fuzzy rule evaluation Mamdani inference method [18] has been used and the center of area(COA) method has been used for defuzzification.

3. Simulation Results and Analysis

The proposed Fuzzy Based Energy Efficient Clustering (FBEEC) approach has been simulated using MATLAB. In our work 100 sensor nodes are considered in an area of (100*100) m^2. The initial amount of energy assumed as 0:5Joules for each sensor node. The simulation parameters are given in Table 4.1.

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In our simulation 100 different runs are taken. The average of these different runs has been considered for result analysis to resolve the random nature of the proposed approach. FBEEC is compared with LEACH and the experimental results show that the proposed FBEEC gives better results than LEACH in terms of network lifetime and energy consumption. Here network lifetime considered for first node death (FND) and half of the node death (HND). In Figure 4.1. the comparative analysis of both FBEEC and LEACH is given for the number of nodes alive for the different number of rounds.

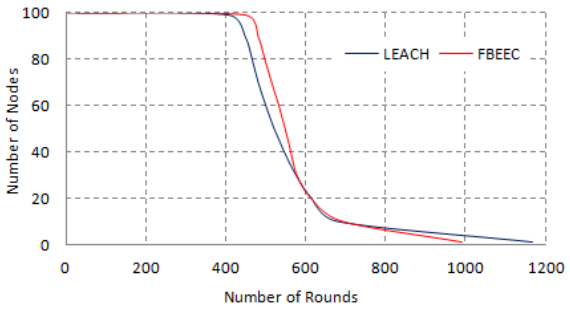

Figure 5 Nodes alive in Rounds

Table 2 : Network Parameters

Parameters	Values
Network Size	(100 * 100) m^2
Number of Nodes	100
E_0	0.5 Joules
ETX	50 * 10 $^{-9}$ J
ERX	50 * 10 $^{-9}$ J
E_{fs}	10 * 10 $^{-12}$ J
E_{mp}	0.0013 * 10 $^{-12}$ J

From the Figure 4.1 and Figure 4.2, it can be observed that in LEACH, the first node died in 406 round and half of the nodes die in 520 round. But in our proposed approach node die in 448 round and half of the nodes die in 547 round. This is because of LEACH follows the probabilistic approach while our approach follows the fuzzy parameter for cluster head selection. The last node death occurs in 1166 round in LEACH and 989 round in FBEEC, because in the proposed FBEEC approach most of the nodes have consumed energy in early rounds for better load balancing as shown in figure 4.3.

In Figure 4.2 comparative analysis of bar graph for both protocol is given for the number of rounds for FND, HND, and LND. From the experiment result, it is shown that our proposed approach is 10.5% efficient with respect to FND and 5.2% efficient with respect to HND as compared to LEACH.

Figure 4.3 shows a comparative study of the energy consumption of both protocols. It is shown from the graph that FBEEC gives better performance.

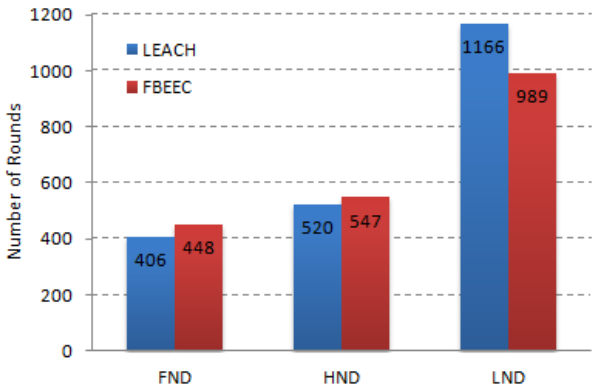

Figure 6: Network life time

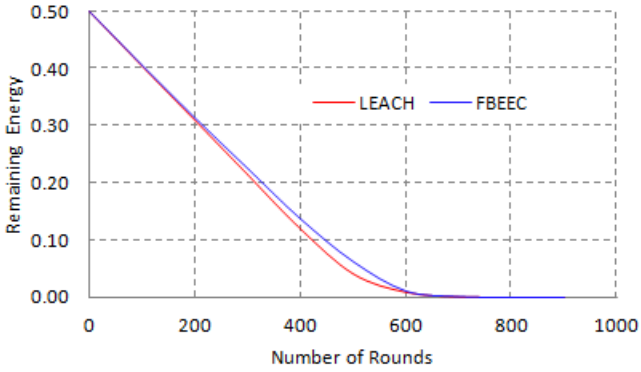

Figure 7: Energy consumption in Rounds

4. Conclusions

Energy consumption is a major issue in WSN. In this thesis, our proposed approach Fuzzy Based Energy Efficient Clustering in which cluster head is selected based on the distance to BS, remaining energy of node and node density. The non-head nodes join with the cluster head node based on the distance to CH, remaining energy of CH and CH density. The simulation results show that the proposed approach gives better performance than that of LEACH in terms of energy consumption and lifetime of the network for first node death and half of node death.

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