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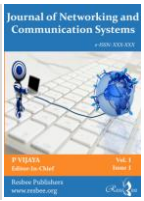

Energy Efficient Genetic Algorithm Based Clustering Technique for Prolonging the Life Time of Wireless Sensor Network

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Abstract: Wireless Sensor network plays a vital role in most of the real world applications and has gained a lot of interest in terms of research. In a WSN, the nodes are found to be positioned in remote area to observe, detect or gather data from that location and send the collected data to the receiver at another location. The main concern in this process is that a lot of energy is wasted during the process of data transmission from the source node to the destination. Since each node is provided with a limited power supply this cause the node to discharge its battery completely and thereby making the node to dead state. By adopting the suitable cluster head selection technique for data transmission this issue of energy dissipation can be reduced. In this paper we propose a concept of Primary Cluster Head (PCH), along with a genetic algorithm based selection process. The overall process includes a process of cluster formation, Cluster Head (CH) selection and Primary Cluster Head (PCH) selection among the CH using genetic algorithm. The complete process is simulated using NS-2 simulator and the results are compared with similar existing techniques for evaluating our better performance.

Keywords: *WSN, PCH, CH, Genetic algorithm, clustering.*

1. Introduction

Wireless sensor networks are widely adopted in most in real world scenario for monitoring or sensing environmental activities like forest fire, enemy intrusion detection in military etc. WSN consist of a number of sensor nodes that are deployed densely in an area based on the application requirement. Because of their wide application along with some special feature, a lot of researchers were attracted during the past years. One of the main features of the sensor nodes is that they are mostly deployed in hazardous area with a particular battery power, where human entry is not feasible or dangerous. Among number of issues, available battery charge, open environment and limited availability of computing components mostly makes the sensor nodes faulty. As soon as a sensor node is deployed or activated in an area, the node starts monitoring and hence its battery power reduces exponentially. When a sensor node sense an event occurrence, it immediately collect the required data and then send the data packets to the base station for further process and wait for the response from the Base station(BS). There are also chances that two or more neighboring nodes detect and collect the same information and send to the base station, making the nodes dissipate energy quickly.

Some of the techniques in literatures to eradicate this data redundancy and make the network more energy efficient are to adopt sensor fusion and data aggregation techniques [1]. In the past years numerous researches has been done in this area for energy dissipation reduction in WSN and came up with a lot of new routing protocols incorporating new ideas [4]. One among this is the clustering based routing protocols, in which the deployed sensor nodes are grouped into number of groups known as 'Clusters' and the group leader or group head is known as the 'Cluster Head'. Unlike other routing protocols, the nodes are not allowed to communicate directly with the BS. Instead, the selected CHs collect and send the data from the corresponding nodes and send to the BS. The schematic diagram representing the above mentioned clustering based WSN is depicted in figure 1.

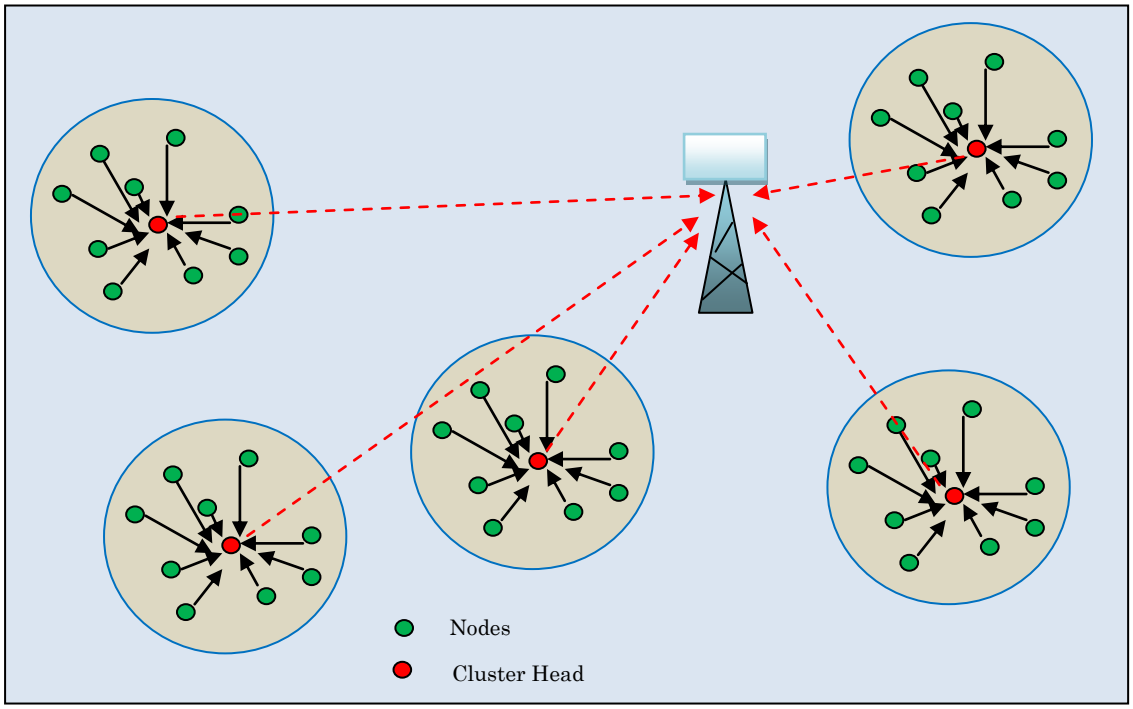

Figure 1*.Clustering based WSN*

The LEACH [1], [2] protocol is a well known and efficient hierarchical routing protocol among the traditional routing protocols. In the case of LEACH protocol, the available load is balanced among the available nodes in a rotation manner and the cluster head is selected based on probability. The main drawback of this protocol is the selection of CH along the boundary of the network which leads to a misbalanced energy distribution. Also the LEECH protocol parameters like residual energy and sensor distribution are left unnoticed after completing each round. An advanced version of LEACH is LEACH-C [2], in which a centralized approach is followed to select and CH using the location and BS information of each individual node. This technique is adopted in order to obtain an adequate number of clusters which in turn are evenly distributed among the CHs. Along with the above mentioned advantages; this technique also has its drawbacks like, updating of location information with the BS in each round leads to overhead in the network.

In our proposed technique, initially the cluster formation technique is as same as that of the LEACH protocol. Along with we have included a concept of optimal PCH selection using genetic algorithm from the available CHs. Unlike other protocols, only the PCH are provided with the authority to communicate with the BS, thereby reducing the number of retransmission of data by the CHs.

The continuation of the paper is organized as follows. Section 2 provides an overview of related works based on our work. Problem identification and solution for the proposed work is discussed in section 3. Section 4 presents the proposed clustering based routing technique for WSN along with PCH selection process. Results and discussions are provided in Section 5. An analysis and discussion of our proposed work in terms of obtained results is done in section5 and the work concludes in section 6.

2. Literature Review

Wide ranges of literatures featuring the clustering based WSN are available in the literatures. The main feature of a clustering scheme is its intracluster routing and topological management. AbdulAlim *et al.* [5] proposed a WSN based clustering protocol in which, the CH is based on fuzzy logic. Their proposed scheme came up with an adequate energy dissipation output. The main drawback of their research is that the mobility sensor nodes are left unnoticed. An energy prediction technique for clustering in WSN using fuzzy logic is presented by Lee and Cheng [6]. Apart from this, researchers also contributed to energy efficiency clustering schemes by adopting schemes such as multi objective fuzzy clustering [7], genetic algorithm [8], fuzzy logic for combining particle swarm optimization and genetic algorithms [9], energy efficient routing protocol with data aggregation [10], and interval type-2 fuzzy logic systems [11]. A soft computing technique for addressing this issue has been proposed by Nekooei and Manzuri-Shalmani [12].

A new algorithm in which genetic algorithm along with elitism technique is adopted during the iteration in tracking weights is developed by Cheng et al. [13]. An improved version of LEACH is Power efficient gathering in sensor information systems (PEGASIS) [10], in which chains of sensor nodes are formed for transmitting and receiving nodes. The disadvantage of this scheme is that, this approach can't be adopted for large networks and consume a more energy for clustering process. Unsupervised learning schemes along with fuzzy logic for clustering is applied for sensing changes in remote sensing images by Ghosh et al. [15] Tsekouras and Tsimikas [16]. They left out the group redundancy in WSN in their works. In Hybrid energy efficient distributed clustering (HEED) [14] intracluster communication cost and residual energy are considered as the main parameters for determining the cluster and cluster head nodes. Another challenging issue in WSN is hotspot issue. A solution using multiobjective fuzzy logic is presented by Sert et al. [7]. Although it is efficient, it is not suitable in the case of networks with mobile sensors as this consume a lot of power. Attacks like energy exhaustion attacks also leads to power dissipation in WSN .Alrajeh et al. [17] developed a solution for this by using artificial neural network technique. In this case mobility of sensor nodes are not considered.

3. Problem Identification and Solution

The clustering based routing approach proposed in [20] is developed with an objective of increasing the performance of the network with decrease in energy dissipation. In order to fulfill the objective concept of selection Super Cluster Head (SCH) among the preselected cluster heads using suitable fuzzy descriptors is proposed. The SCH is the only CH among the available CH that has the authority to receive and transmit data from the mobile BS. By doing so the researcher confirmed that the power dissipation in transmission of data to the BS by each CH as proposed earlier in most of the similar researches. Even though this approach seems to be more appropriate in terms of energy efficient clustering based routing in WSN it still has its pitfalls. In order to address those issues in SCH selection process we utilize the GA based technique for optimally selecting the SCH (for our work we have used the abbreviation PCH).

GA is a widely preferred optimal technique for deriving solution for any kind of real world problems. It is a kind of evolutionary algorithm inspired from human gene formation.GA can perform well even the available data is insufficient. This is one among the features that make GA more preferable than that in the similar category. A vast number of researchers have contributed much using GA in the field of WSN. Most of them available in the literatures make use of node parameters like transmission count, network density, field coverage etc. In our work with an objective to decrease the energy dissipation during data transmission further, we have opted the GA based approach for selecting the PCH. CH parameters like Residual Energy (RE), Centrality with respect to all CH (C) and the Distance from CH to BS (D) are considered for forming fitness function, so as to select an optimal CH as a PCH. The main advantages of using the GA for selecting the PCH is because of the capability of solving any kind of real time problems by the evolutionary algorithms. The GA is made available in BS and the BS initially based on the threshold value selects the CHs and by using the GA it selects the optimal CH as PCH for each round. The BS sends the network details to the PCH and then the PCH broadcast it to the CHs and the CHs to the sensor nodes in their cluster. The proposed approach exhibits better performance in terms of energy efficiency and stability as compared to its counterparts.

4. Proposed Method

The following assumptions are made in the case of our proposed clustering based WSN.

- The sensor nodes deployed are considered to be homogeneous in nature.
- The sensor nodes do not habitat mobility property and hence when deployed in an environment will remains stationary.
- All the sensor nodes have their own location information.
- The base station is considered to be located somewhere outside the sensor deployed area.
- When there is energy then the nodes are considered to be active nodes and when the energy completely drains then it is said to be in dead state.

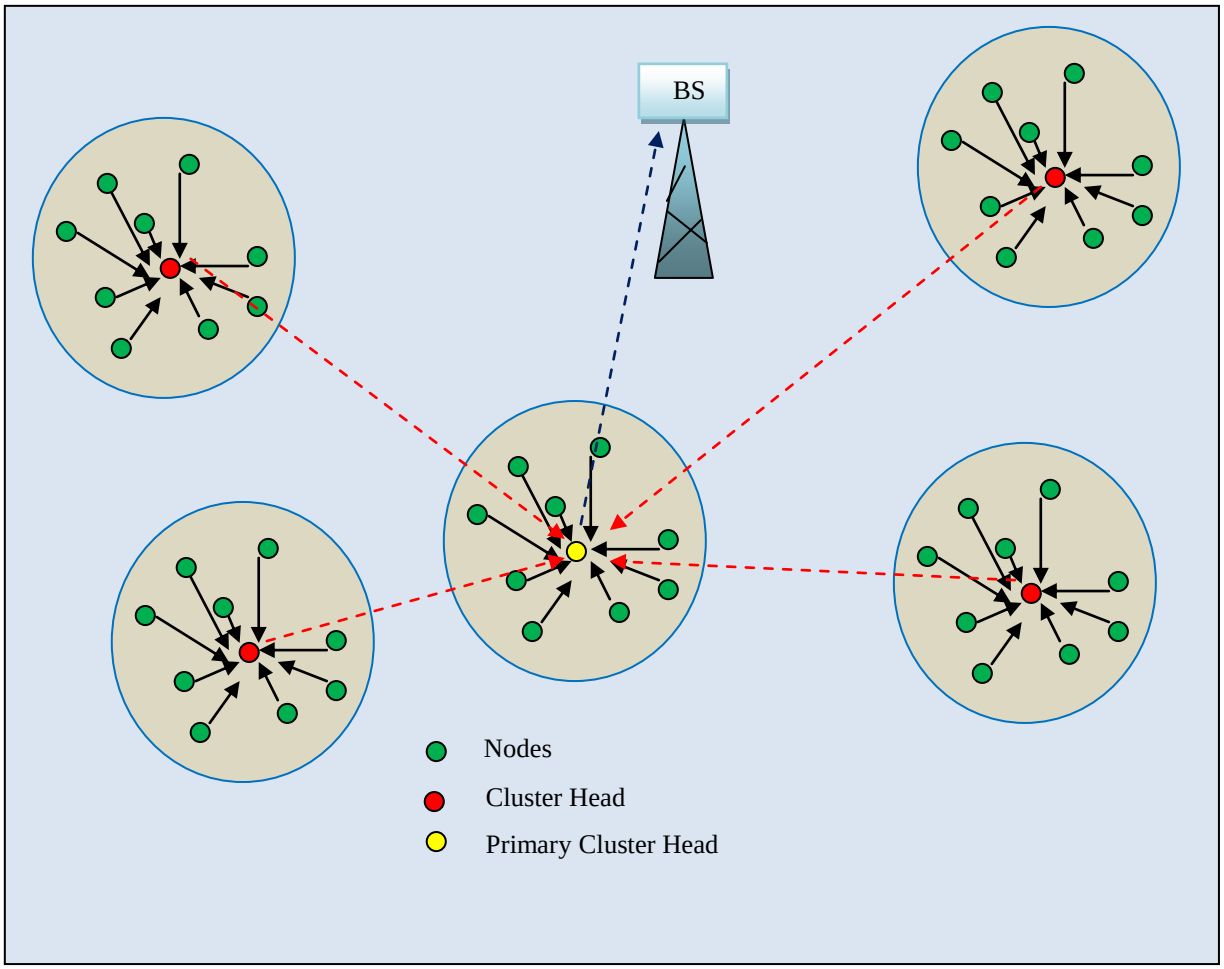

Figure 2: *Proposed clustering scheme for WSN*

4.1 The Proposed Routing Process

Step 1: Fix a threshold value and based on that select some CHs among available sensor nodes.
Step 2: From the selected CHs determine the optimal CH.
Step 3: Repeat step 1 and 2 for all available clusters.
Step 4: From the available CHs by using Genetic Algorithm determine the PCH.
Step 5: The sensor nodes collect the data and send to the corresponding CH.
Step 6: All the CH send the aggregated data to the PCH.
Step 7: The PCH communicate with the BS and send the responses to the CHs from the BS.
Step 8: Repeat Step 1 to 7 for each round till all the sensor nodes die.

4.2 Cluster Formation Phase

The cluster formation phase in our proposed approach is based on the LEACH protocol we have discussed earlier. The cluster formation process takes place for all rounds. According to this process, in each round based on certain criteria each sensor nodes generates values ranging between 0 and 1 randomly. A threshold value T will be determined and fixed during the initialization phase and the nodes with the value smaller than T will be selected for the next step of CH selection. In the case of LEACH protocol [2], the number of clusters for each round is defined to be l , which is a system parameter. The value of *loptimal* can be determined by adopting suitable computation and communication models. For better clarification, let us consider *Ns* be the number of sensor nodes deployed in an area of A x A randomly. The number of nodes in each cluster *Nc* can be determined as,

$$Nc = \frac{Ns}{l} \tag{1}$$

Nc includes 1 CH and Nc-1 non-CH nodes. Most of the energy dissipation occurs because of the process of aggregating data from the non-CH nodes by the CH and sending and receiving the data to the

BS. In order to overcome this issue we have decided to design a concept of selecting PCH among the previously selected CHs.The PCH is the only node that is responsible for sending and receiving data from the BS. By adopting this approach, we can reduce the data transmission and reception point of contact with the BS to be one there by reducing the energy dissipation efficiently. The PCH selection process should be an effective one, because in most case all the CHs pocess the similar metrics and general computation is in vain. So for our proposed technique we adopt the most famous and effective genetic algorithm for selecting the optimal PCH among the CH. The proposed clustering scheme is depicted in figure 2.

4.3 Primary Cluster Head selection phase

The optimal PCH among the available CHs is selected using GA based on parameters like Residual Energy (RE), Centrality with respect to all CH (C) and the Distance from CH to BS (D). The basic definition for the above parameters is,

The steps involved in the selection process by GA are as follows.

1. Population

In GA population represents the solution space for the problem identified. The accuracy of the algorithm is directly propositional to the number of solutions. In our case the solution space includes all the pre-selected CH parameter values.

2. Fitness

The fitness function helps in identifying the survivability of each individual based on the computed fitness value. In our approach, the fitness value is computed based on three main parameters of each CH as follows,

- Residual Energy (RE)
- Centrality with respect to all CH (C)
- Distance from CH to BS (D).

Here the residual energy is given as,

$$RE_i = RE_{(i-1)} - 1 \quad (2)$$

The RE is represented by such a notation because of some dissipation in energy in each round among the sensor nodes. Hence some amount of energy from the before round is reduced and represented in the next round. The centrality of each CH is defined as how central the CH is to other CH to receive and transmit data to the BS and CHs. The distance between CH and BS is also an important parameter for PCH selection. Hence the fitness function to determine the best suitable CH to be selected as an PCH is given as,

$$\text{Fitness} = RE + C + D \quad (3)$$

3. Selection

The process of selecting the individuals among the current population to form the new population is known as selection. The main objective of the selection process in a GA is to reproduce new off springs that pocess better fitness value. A numerous techniques like Random selection, Tournament selection, Roulette Wheel selection, Rank selection, Boltzmann selection, etc. are available in the literature. For our work we use the Roulette Wheel selection to choose the best suit chromosomes so as to generate new population.

4. Crossover

We prefer the one point cross over technique in our approach. The process of cross over performs between any two chromosomes with probability specified by crossover rate. The considered two chromosomes interchange their portion with respect to their cross over point. Let us consider an example for one point cross over process.

Individual-1	1	1	1	0	0	1	1	1	0
Individual-2	0	1	0	1	1	0	0	1	0

After crossover, two off spring are created as below:

Individual-1	1	1	1	0	1	0	0	1	0
Individual-2	0	1	0	1	0	1	1	1	0

5. Mutation-

In the process of mutation, based on the chance of high mutation rate the mutation operation is performed over each bit in an individual chromosome. As shown in the example below after performing the mutation process a bit value of 1 changes to 0 and vice versa.

Before Mutation	1	1	1	0	0	1	1	1	0
After Mutation	1	1	1	1	0	1	1	1	0

Algorithm 1: PCH selection process by GA

1. *Generate the initial solution (Population) for the individuals using random chromosomes.*
2. *Compute the fitness for each solution and rank them according to their obtained fitness value.*
3. *While (No. of CHs< 0.1×Node Density)*
4. *{*
5. *Do*
6. *Select the topmost individual in the fitness ranking for reproduction.*
7. *Eliminate certain unfit solutions from the population.*
8. *Perform crossover between best individuals.*
9. *Perform mutation in the best individual*
10. *Evaluate the fitness of the modified individuals*
11. *Compute the fitness value for the new individuals.*
12. *Update the initial solution list.*
13. *}*
14. *End while*

Our proposed GA based PCH selection process along with the clustering based approach for obtaining energy efficiency is a BS dependent approach. In this approach each node initially sends the random values to the BS and based on the threshold value the BS determine the CH for each cluster. Similarly during the process of PCH selection each CH send their RE,C and D values and by using the GA technique the BS determine the optimal PCH for each round. TDMA based scheduling is done for each cluster is done by the BS and the entire information is broadcasted to the whole network. Since all the operations are performed in the BS itself most of the energy dissipation by the sensor node is prevented. In each round, based on the provided time slot the respective nodes in the cluster and CH wake up and send and receive data from the CH and PCH and then sleeps. After completing each round re-clustering process takes place.

5. Results and Discussion

In order to evaluate the efficiency of the proposed protocol, we use the NS-2 simulator (2.34) for simulating the working process and compare certain performance metric with the LEACH [2], LEACH with Fuzzy Descriptor [20]. The simulation setup for the experiment is tabulated in table.1 below.

Parameter	Value
No. of Nodes	40
Area Size	100 X 100m
Simulation Time	20000 sec
Traffic Source	CBR and Video
Packet Size	500 bytes
BS Mobility Model	Random Walk
Bandwidth	1Mbps
No. of clusters	5

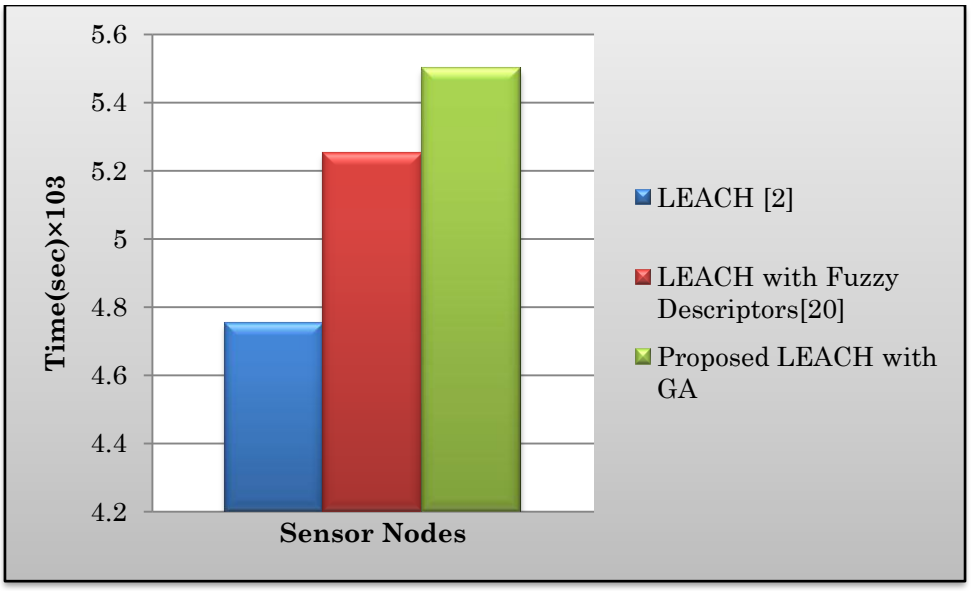

Figure3. *Time taken by first node to die*

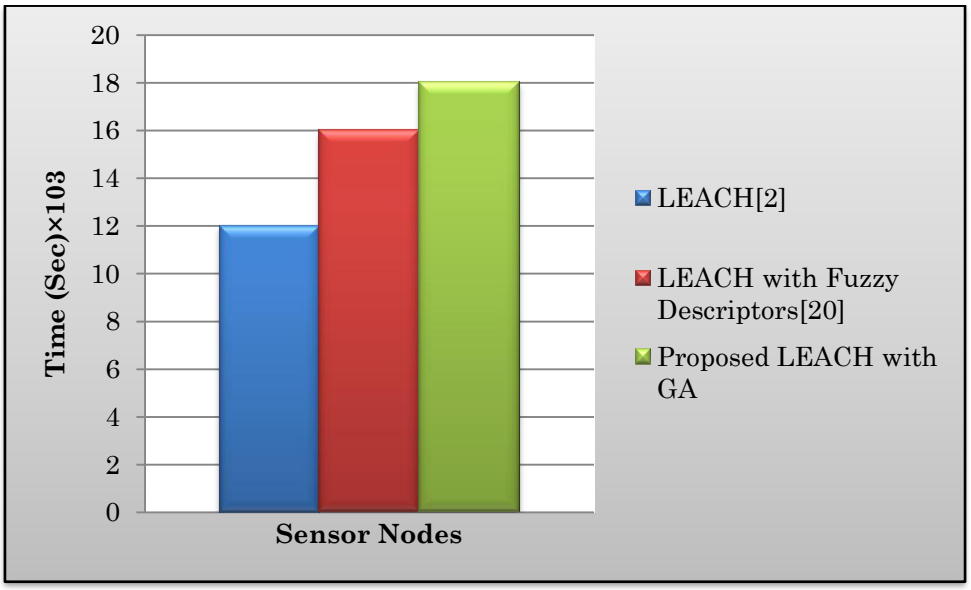

Figure4. *Time taken by last node to die*

Figure 3 depicts the bar chart plot for the time span of first node to die. In the case of LEACH the first node die earlier at 4.75 ms whereas the first node in LEACH with Fuzzy Descriptors die at the time of 5.25 ms. Out method out performs both the approach and it takes around 5.5ms for complete depletion of energy from the first node. The time taken for the last node to drain out for three techniques is plotted in figure 4. In this case also our approach shows a highest time of 18ms, whereas LEACH and LEACH with Fuzzy Descriptors lives for only 12ms and 16 ms respectively. This shows that our technique has high energy efficiency compared to that of the other two.

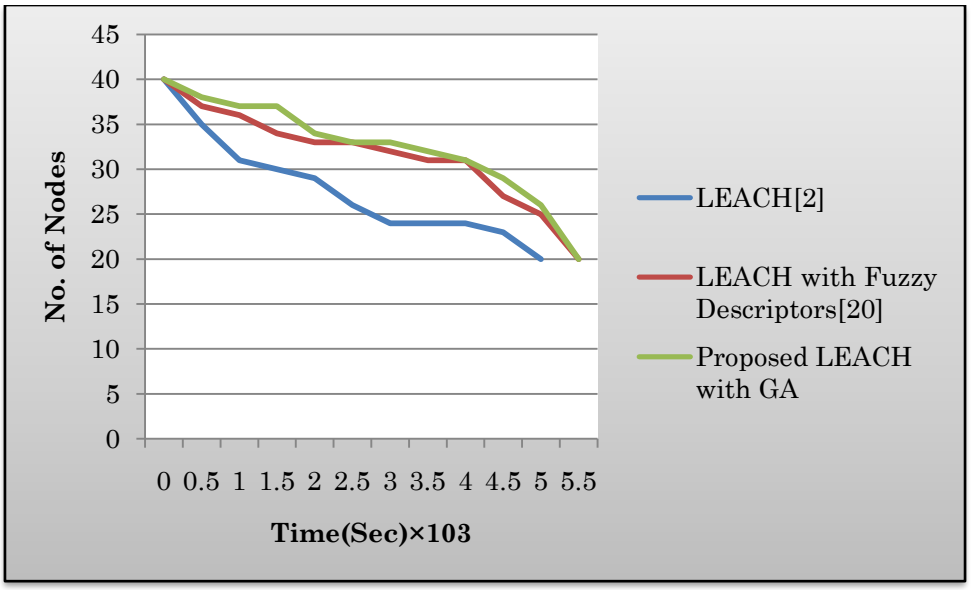

Figure5. *Stability of network with respect to time*

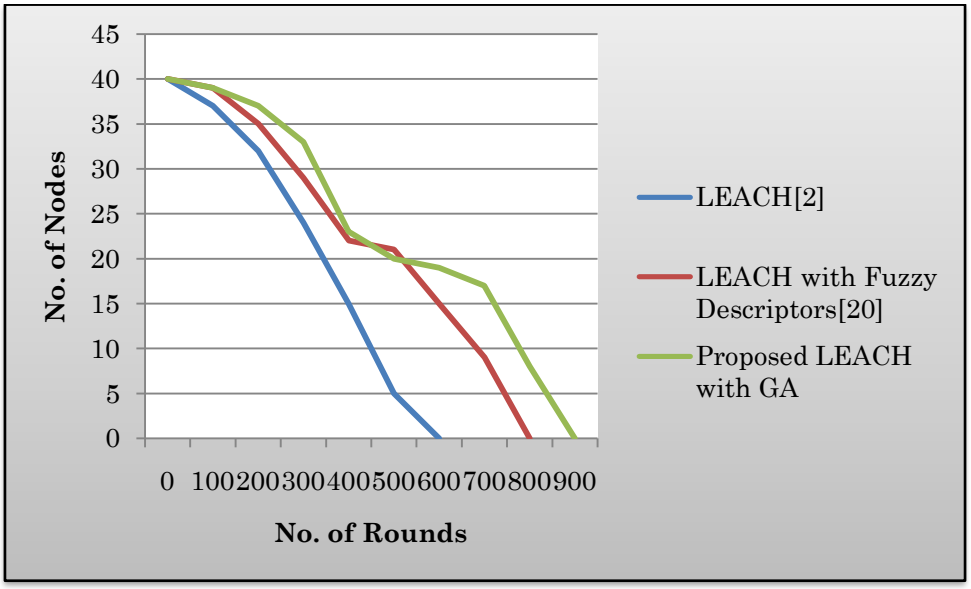

Figure6. *Life time of network*

In figure 5, the stability of nodes with respect to time for two techniques LEACH and LEACH with Fuzzy Descriptors are plotted. It is evident from the figure that the stability of our approach is much better than that of the other two. The life time comparison of the thee approaches is plotted in figure 6. Our approach has a prolonged life time of about 900 rounds whereas the other two remains active only for 600 and 800 respectively. Hence our approach has around 11% of high lifetime than that of and LEACH with Fuzzy Descriptors and around 33% than that of conventional LEACH protocol

6. Conclusion

In this paper we have proposed an energy efficient genetic algorithm based clustering technique for prolonging the life time of wireless sensor network. By using the GA technique an optimal CH known as PCH is selected among the available CHs and the PCH is the only node that is authorized to send and receive data from the mobile BS. The concept of mobile sink discussed in the earlier sections increases the life time the network considerably. We would like to suggest this approach will best suit for applications like agricultural field, health care, military applications, disaster heat areas etc. The results obtained from the simulation of our approach in comparison with that of LEACH and LEACH with Fuzzy Descriptors confirms that our approach outperforms the other two in terms of first to last node death time , stability of the node and network life time.

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