Fuzzy Rule Based Heterogeneous LEACH in WSNs

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ABSTRACT

Lifetime enhancement of a wireless sensor network is always an issue for network designers. To obtain this goal number of energy efficient protocols has been developed. Most of these protocols are based on hierarchical approach using clustering. LEACH (Low Energy Adaptive Clustering Hierarchy) was the first hierarchical based clustering algorithm in which cluster heads are determined using probabilistic approach in a dispersed manner. Then many protocols had been proposed but very few of them utilized the concept of energy prediction. In this paper, we introduced FRBHCP (Fuzzy Rule based Energy Efficient Heterogeneous Clustering Protocol) , which work for minimum energy consumption with farthest distance threshold due to maximum 3 transmission would be considered after that packet would not transmitted . And here the base station is at centre position, each and every node situated with equal distance form base station. Heterogeneity considered in this work on the basis of energy, we classify three groups of sensor nodes in the network. The simulation results of FRBHCP shows a significant perfection in terms of FND (First Node Dead), HND (Half Node Dead) compared to base LEACH algorithm.

Keywords: clustering, fuzzy Rule base logic, problistic wireless sensor network.

I INTRODUCTION

Wireless Sensor Networks (WSN) have emerged like promising tool for monitoring and actuating the physical world , utilizing self – organizing networks of battery powered wireless sensors that can sense the environmental conditions .It process the information and then communicate with the sink. A WSN typically consists of a large number of low powers, low cost and multifunctional wireless sensor nodes, with sensing, wireless communication and computation abilities. These small sensing devices are called sensor nodes and consist of CPU for data processing, memory for data storage, battery for energy and transceiver for receiving and sending signals and data from one node to another. These nodes form a network by communicating with each other directly or through other nodes. The primary component of the network is the sensor, essential for monitoring real world physical conditions such as sound, temperature, humidity, vibration, pressure, motion, intensity, pollutants etc. at different locations. The basic philosophy behind WSNs is that, while the capability of each individual sensor node is limited, the aggregate power of the entire network is sufficient for the required mission.

CLUSTERING SCHEMEAS

Sensor nodes have limited and non-rechargeable energy resources, energy is a very scarce resource and has to be managed carefully in order to extend the lifetime of the sensor networks. In recent years, researchers have done a lot of studies and proved that clustering is an effective scheme in increasing the scalability and lifetime of wireless sensor networks. In clustering schemes, there are two kinds of nodes in one cluster, one cluster head (CH) and several cluster members (CMs). Cluster members gather data from the environment periodically and send the data to cluster heads. Cluster heads aggregate the data from their cluster members, and send the aggregated data to the base station (BS). There are two kinds of communications between cluster heads and the BS, single-hop communication and multi-hop communication. In multi-hop communication clustering algorithms. the energy consumption of cluster heads consists of the energy for receiving, aggregating and sending the data from their cluster members (intra-cluster energy consumption) and the energy for forwarding data for their neighbour cluster heads (inter-cluster energy consumption). In these protocols, creation of clusters and assigning special tasks to cluster heads can greatly contribute to overall system scalability, lifetime, and bandwidth efficiency.

II RELATED WORK

LEACH (Low Energy Adaptive Clustering Hierarchy)

LEACH is a self organizing, low power and adaptive clustering protocol. It uses randomization for distributing the energy load among the sensors in the network. According to this protocol, the base station is fixed and located far from the sensor nodes and the nodes are homogenous and energy constrained. Here, one node called cluster head (CH) acts as local base station. LEACH randomly rotates the high energy cluster head so that the activities are equally shared among the sensors and the sensors consume battery power equally. Leach also performs data fusion, i.e. compression of data when data is sent from the clusters to the base station thus reducing energy dissipation and enhancing system lifetime. It divides the total operation into rounds – each round consisting of two phases: set-up phase and steady phase.

The following assumptions are made in LEACH protocol:

1. All nodes transmit with enough power to reach the base station.
2. Nodes located close to each other have correlated data.
3. Each node has enough computational power to support different MAC protocols.

SET- UP PHASE:

In this phase, cluster formation process takes place after electing the cluster heads. Sensor node generates a random number range 0-1. If this random number is less than the threshold T (n), then it releases the information that he is the cluster head node to the nodes within the cluster. In each round of circulation, if the node has been elected as cluster head, then put the T (n) to 0, so that the node will not be elected as cluster head in the next round of re-election. For the nodes, which had not elected as cluster head node, it will be elect as the cluster head node by the probability of T (n). As the number of elected cluster head nodes increased, the threshold T (n) is even greater for the remaining node which had not be elected as the cluster head node, the probability of generating the random number which is less than T (n) is greater, therefore, the probability of one node to be cluster head node is greater[8]. When only a node is not elected, T(n) = 1, so this node will be elected. T (n) formula can be expressed as:

$$T(n) = \begin{cases} \dfrac{P}{1-P*(r \bmod (1/P))} & \text{if } n \in G \\ 0 & \text{otherwise} \end{cases}$$

where P is the percentage of cluster head node in all nodes, r is an election rounds, r mod (1 / P) is on behalf of the number of node which was elected as cluster head nodes in the cycle, G is the node set which is not elected as a cluster head node in this cycle. Figure 1 shows communication between cluster head and base station.

After node is selected as cluster head, it will broadcast the information that he is the cluster head to the rest of the nodes in the same cluster. The remaining nodes decide to join the cluster according to the size of the received signal, and return the join signal. When the cluster head receives all join messages, it will allocate TDMA time slot information to all the nodes in the same cluster, notice nodes within the same cluster to send a TDMA message to the cluster head in its own time slot. In order to avoid signal interference near the cluster, cluster head can determine the CDMA codes which all nodes used. The CDMA codes which is used in the current phase and TDMA timing information will be sent together. When nodes within the cluster receive the message, they will send data to the cluster head in their own time slot. Algorithm will enter a stable phase.

STEADY PHASE:

Work in a stable phase, member nodes continuous collected monitoring data, and send data to the cluster head node in their own time slots. While the other time, it can turn off the radio module, into hibernation, and it is one of the main ways to save energy for LEACH. After the cluster head node received the data which is from its member, it will do the necessary processing of data fusion. Then the information is sent to the sink node. After a period of time of data transmission, nodes enter to a new work round, to re-select a new cluster head, and constantly circulating.

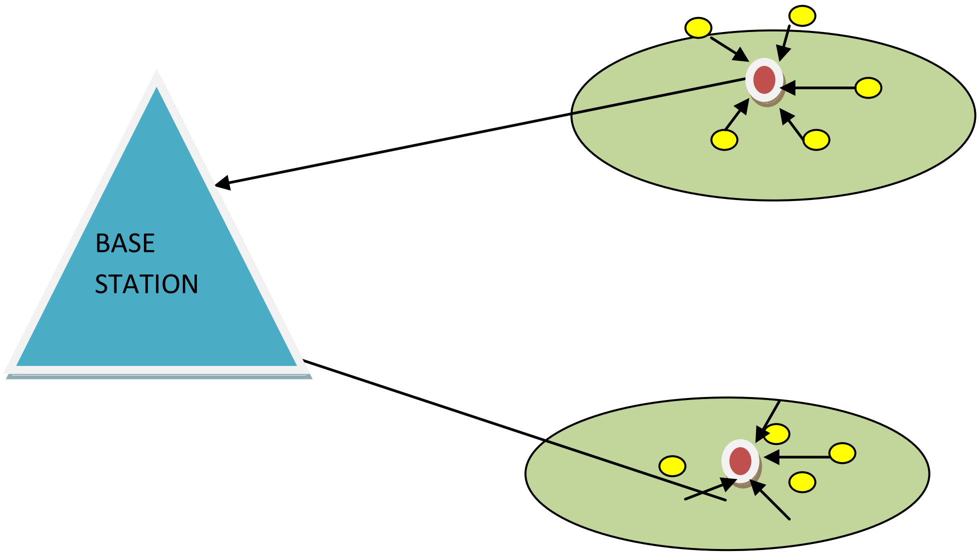


Figure 1: Communication between cluster head and Base station.

SENSOR NODE
CLUSTER

What is Rule Base Logic?

Fuzzy rules are linguistic IF-THEN- constructions that have the general form "IF A THEN B" where A and B are (collections of) propositions containing linguistic variables. A is called the premise and B is the consequence of the rule. In effect, the use of linguistic variables and fuzzy IF-THEN- rules exploits the tolerance for imprecision and uncertainty. In this respect, fuzzy logic mimics the crucial ability of the human mind to summarize data and focus on decision-relevant information. In a more explicit form, if there are I rules each with K premises in a system, the ith rule has the following form.

$$If \quad a_1 \; is \; A_{i,1} \; \Theta \; a_2 \; is \; A_{i,2} \; \Theta \ldots \Theta \; a_k \; is \; A_{i,k} \quad then \quad B_i$$

In the above equation a represents the crisp inputs to the rule and A and B are linguistic variables. The operator 1 can be AND or OR or XOR.

III PROPOSED SCHEME OF CLUSTER HEAD SELECTION

The work as also defined the reserved area for the base station. The nodes defined in this reserve area can perform direct communication with base station without the involvement of cluster head. These nodes can use single hop or multi hop communication with base station. The sensing range based path will be constructed to the base station to perform effective communication. Once the reserve area and reserve nodes are specified, the next work is to divide the rest network in clusters. While generating the clusters over the network, a rule based scheme is adopted under the following constraints. The cluster head will not be defined on boundary line area. The boundary line area is restricted to avoid the earlier failure for cluster head. While performing the cluster head selection, the node strength analysis will be performed under the energy constraint. A high energy node can be considered as the cluster head. A threshold limit is defined to set the minimum energy requirement for cluster head specification. While performing the cluster head selection, the connectivity analysis is defined. A node having the minimum number of sensor nodes in sensing limit, can be set as the cluster head. The number of clusters over the network is also restricted.

Fuzzy Rule Based Energy Efficient Heterogeneous Clustering Protocol (FEEHCP)

The power attenuation is dependent on the distance between transmitter and receiver. For short distances (single hop), the propagation loss is inversely proportional to square of the distance (d2) between transmitter and receiver, whereas for longer distances (multi hop), it is inversely proportional to d4. In this case, the received signal comes from both the direct path and a ground-refection path. Due to destructive interference when there is more than one path through which the signal arrives, the signal is attenuated as d4. The radio model used is shown in Fig.2.

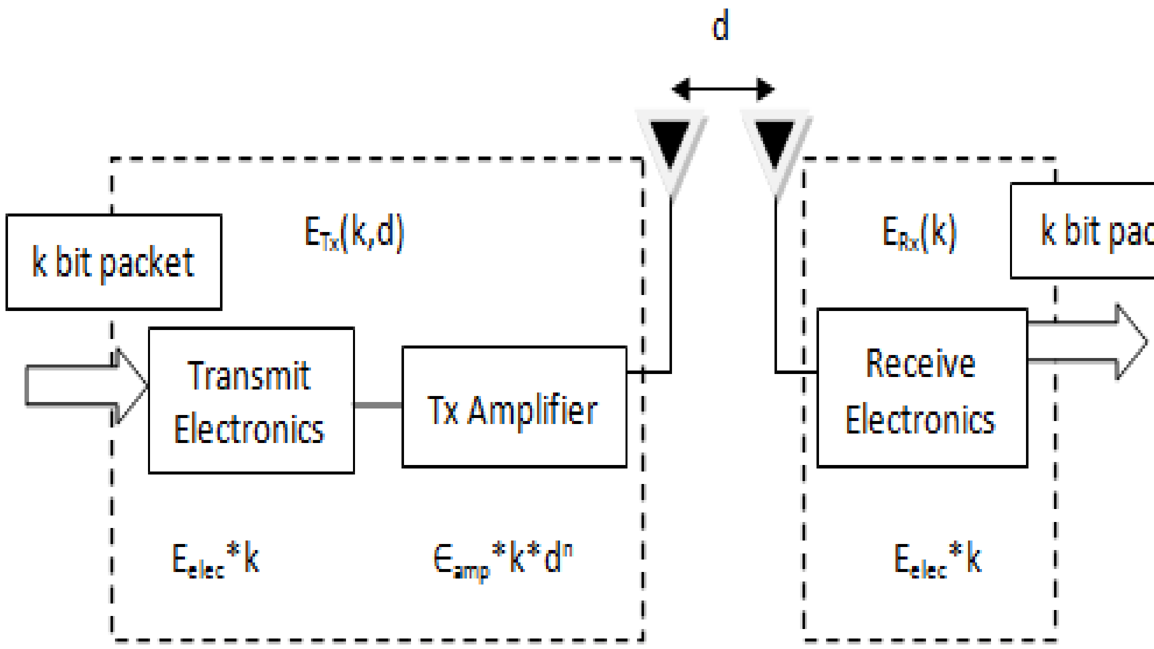


Figure 2: Radio Model

Thus to transmit a k bit message to distance d, the radios consume energy.

$$E_{Tx}(k,d) = \begin{cases} k * E_{elec} + k * \varepsilon_{fs} * d^2, & d < d_0 \\ k * E_{elec} + k * \varepsilon_{mp} * d^4, & d \geq d_0 \end{cases}$$

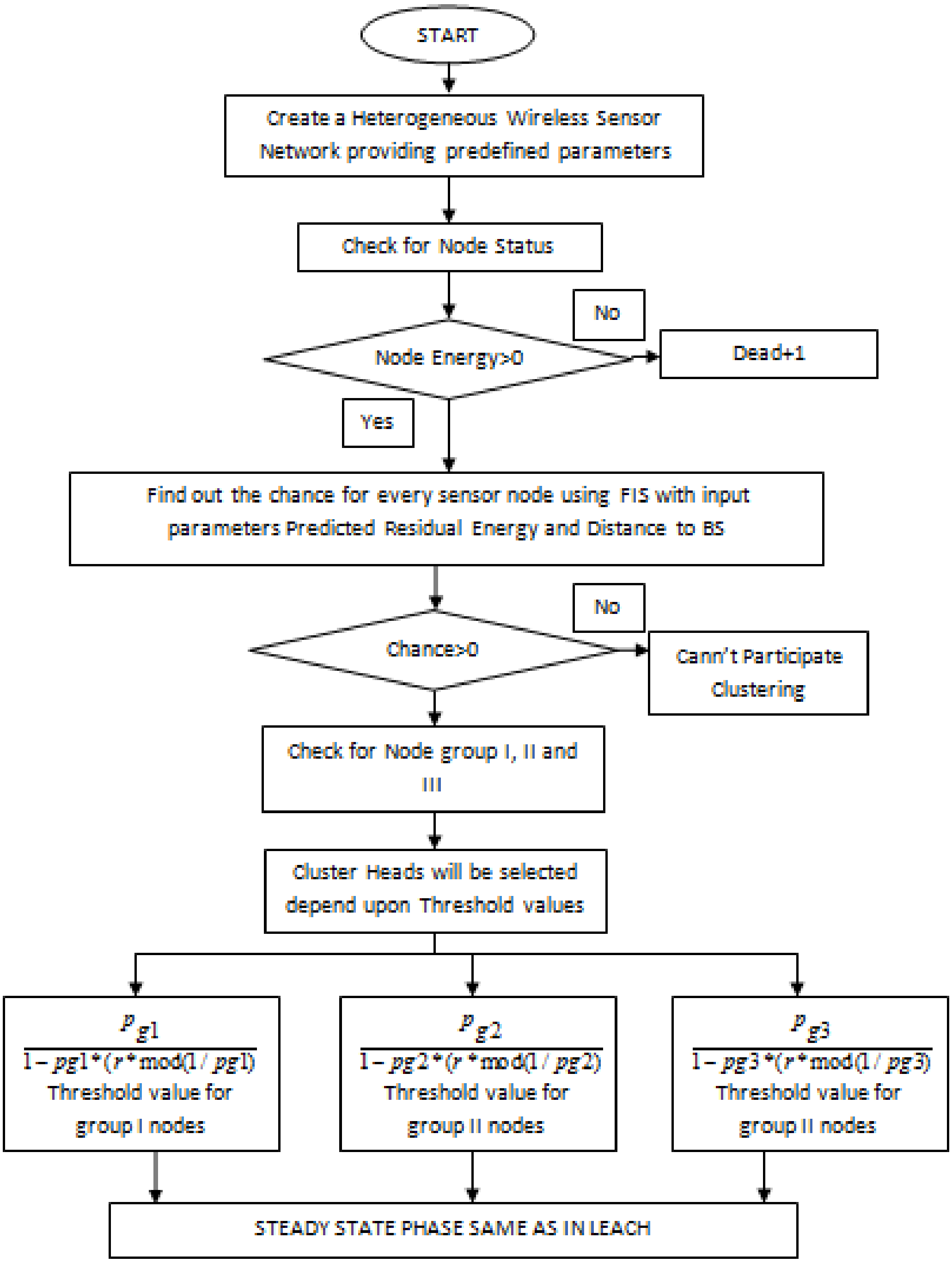
Energy consumption :

$$ECE = CH(r) * [E_{Tx}(k, d_{toBS}) + \{((alive(r+1) / CH(r)) - 1\} * E_{Rx}(k)]$$

Predicted residual energy (PRE): PRE = RE- ECE

This is the leftover energy of a sensor node after running a complete round. Because most of energy of a sensor node get consumed when it become Cluster Head (CH) because as a CH a sensor node has to receive data from its cluster members, aggregate these data packets into one and then send this packet to Base Station (BS). Thus, if number of cluster heads in previous round known then we can easily calculate the energy consumption where CH(r) is the number of cluster heads in round r, k is the message length in bits, d to BS is distance to the base station can be calculated via received signal strength, alive(r+1) are number of alive nodes in current round. It is believed that all cluster members send their data to CH and then aggregated message will be sent to the BS. So, for calculating expected consumed energy and the cluster members can be calculate through number of alive nodes in current round divided by the number of CHs.

Flow Chart for Cluster Head Selection



Network parameters:

Network size	100 * 100 m^2
Number of nodes	100
Base Station location	(200,100)
Initial network energy	50J
Initial Energy of each node	2 J
Max no.of round (r max)	1000
ETX(transmission energy)	50nj/bit
ERX(receiving energy)	50nj/bit

IV SIMULATIONS RESULTS OF LEACH & PROPOSED SCHEME

We are using a 100 * 100 network of 100 sensor nodes for simulation using MATLAB. The base station is present at centre.. The nodes are randomly chosen in each simulation. The initial position of nodes in the field is given below:

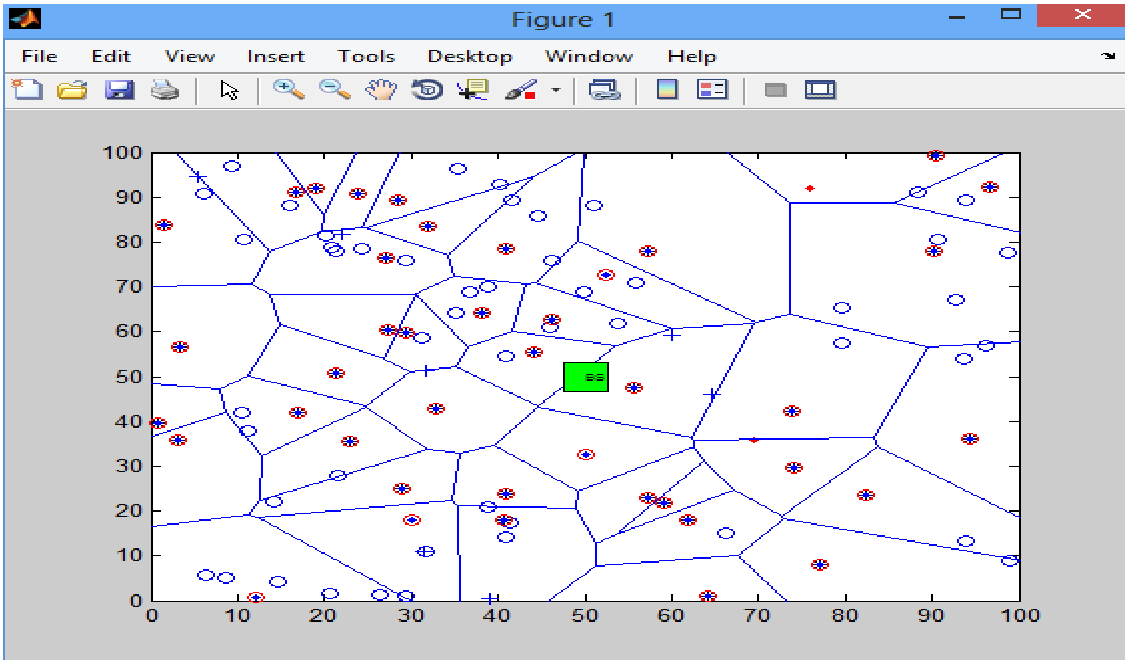


Figure 3: Initial Positions Of The Nodes And Base Station

Here, Normal Circles represent the simple nodes. Blinking Stars represent the cluster heads in the current round. Red dots are the dead nodes. Star at (50, 50) represent the base station. Fig 4 -Now, the below simulation shows the network after the death of first nodes and the comparison of alive nodes between LEACH and PROPOSED model.

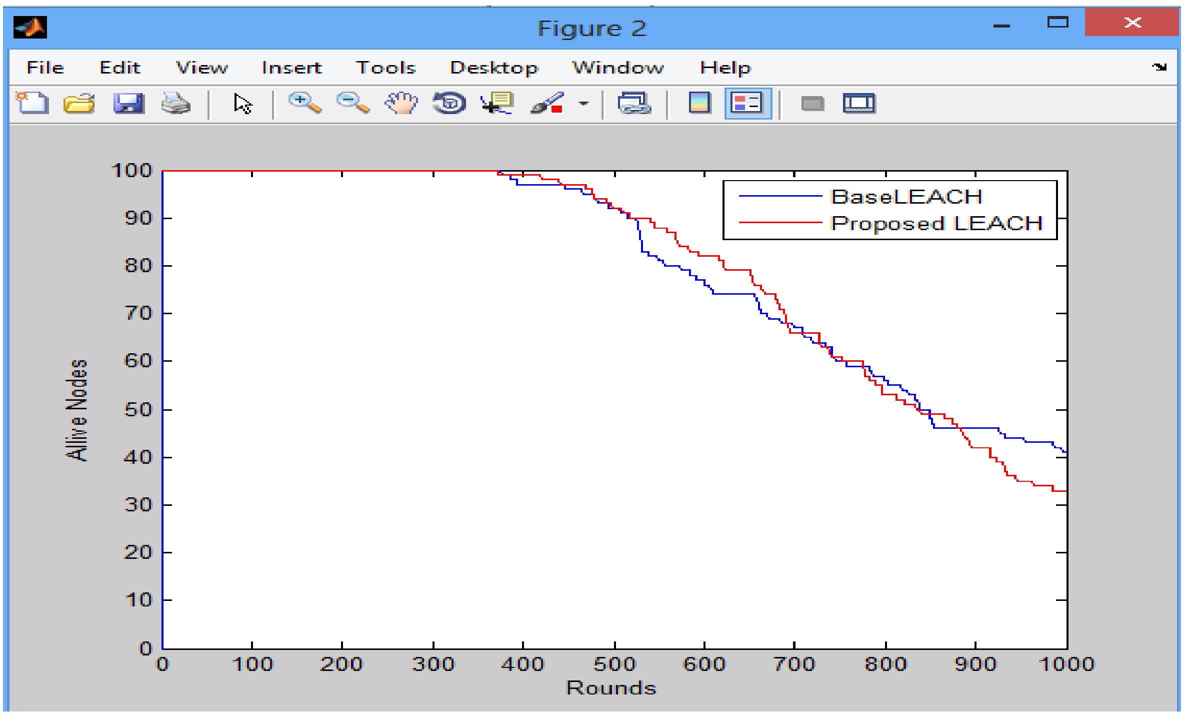


Figure 4: comparisons of alive nodes between LEACH and PROPOSED model

The below simulations show the status of the network at different moments when different number of nodes died.

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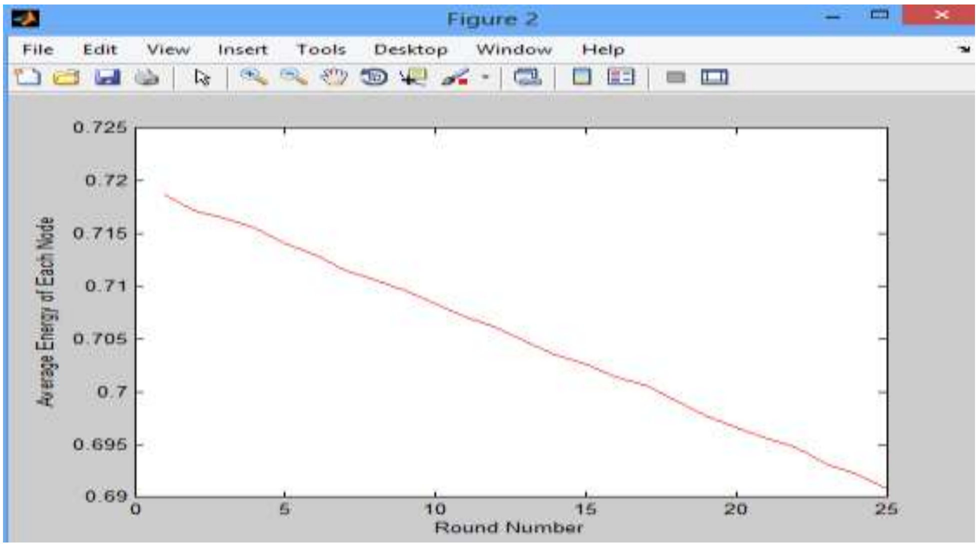

Figure 5: average energy of each advance nodes in 25 rounds

Fig. 5 shows the average energy of each advance nodes in 25 rounds .we can see that not so much energy get dissipated in 25 rounds.

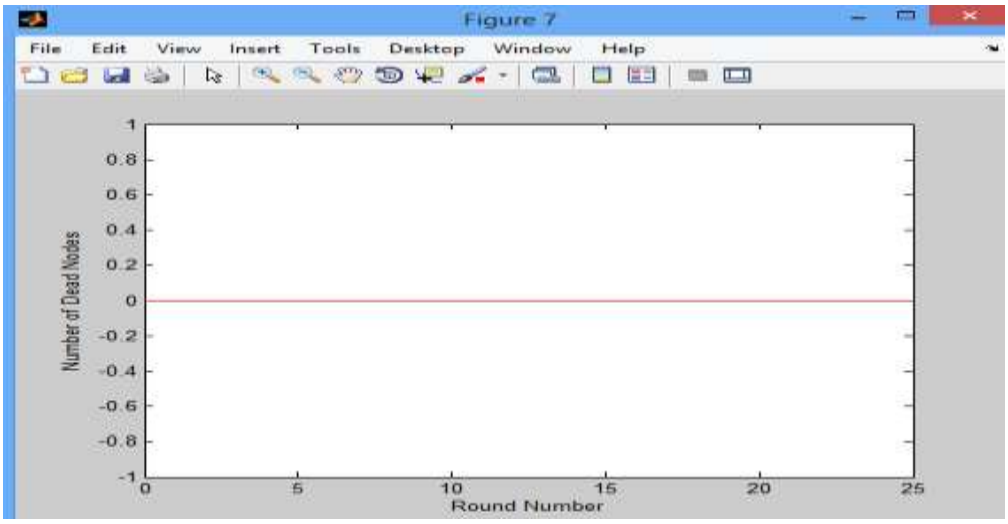

Figure 6: dead nodes after 25 rounds

Figure 6 no of dead nodes after 25 rounds and from fig we can see that .no one node get died in 25 rounds.

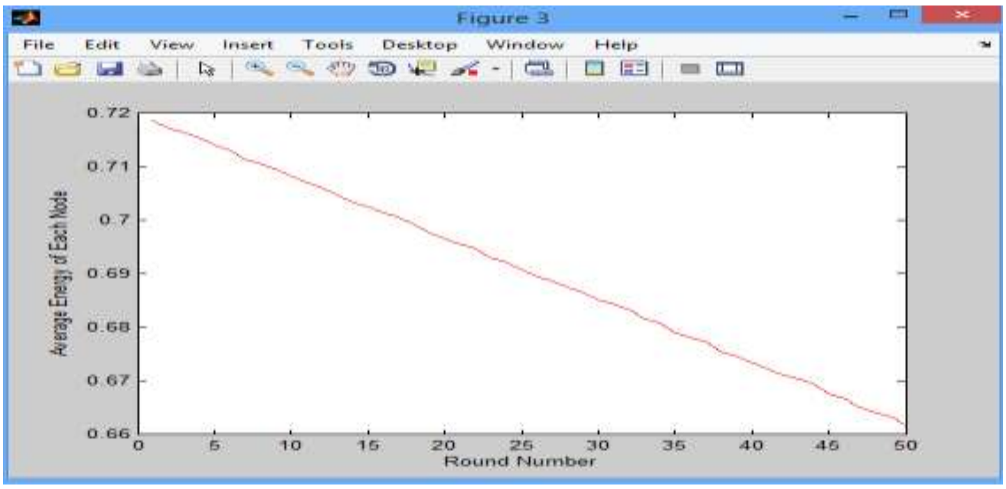

Figure 7: Energy of network in 50 rounds

Figure 7 energy of network in 50 rounds. after 5o rounds not so much energy get consumed.

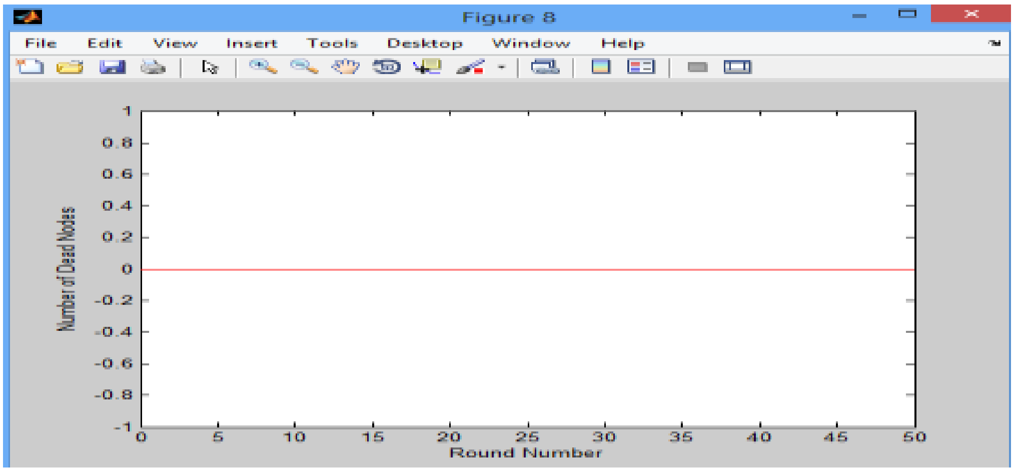

Figure 8 dead nodes after 50 rounds

Figure 8 no of dead nodes after 50 rounds. No node gets died after 50 rounds.

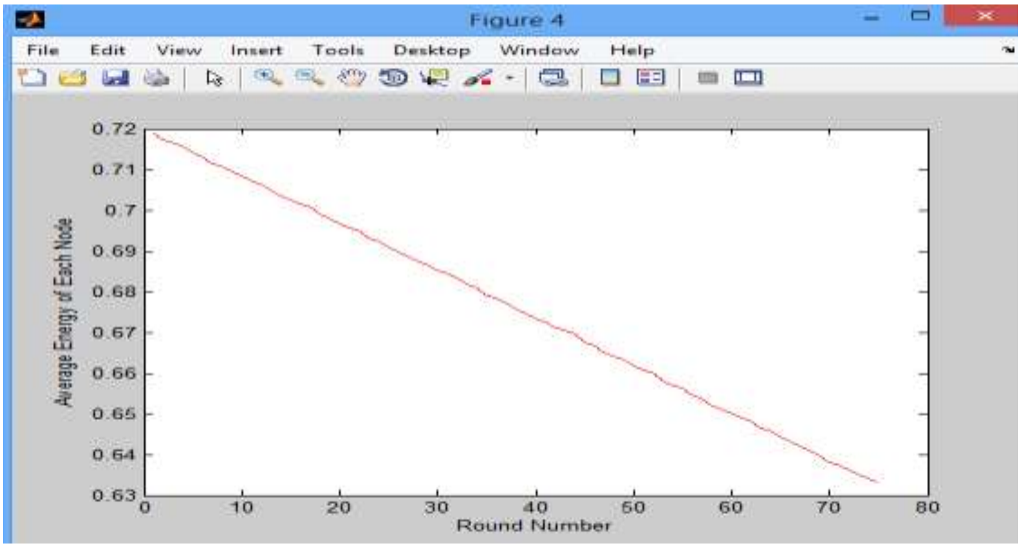

Figure 9 energy of each advance nodes after 80 rounds

Figure 9 energy of each advance nodes after 80 rounds. After 80 rounds we can see that energy consumption get Increase by 1 point.

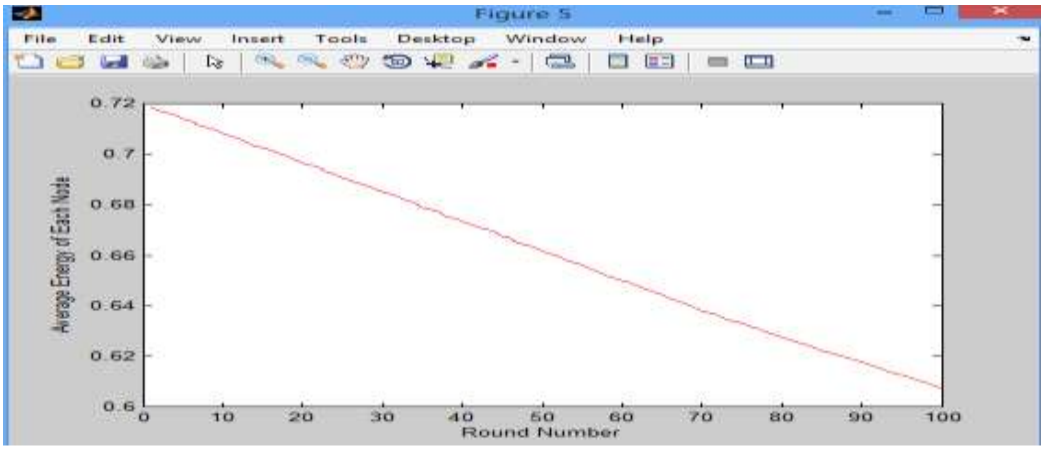

Fig 10 energy of each advanced nodes in 100 rounds.

Fig 10shows energy of each advanced nodes in 100 rounds. And after 100 rounds energy dissipation is very sharp at 0.72 and after that there will be very little inc in energy consumption.

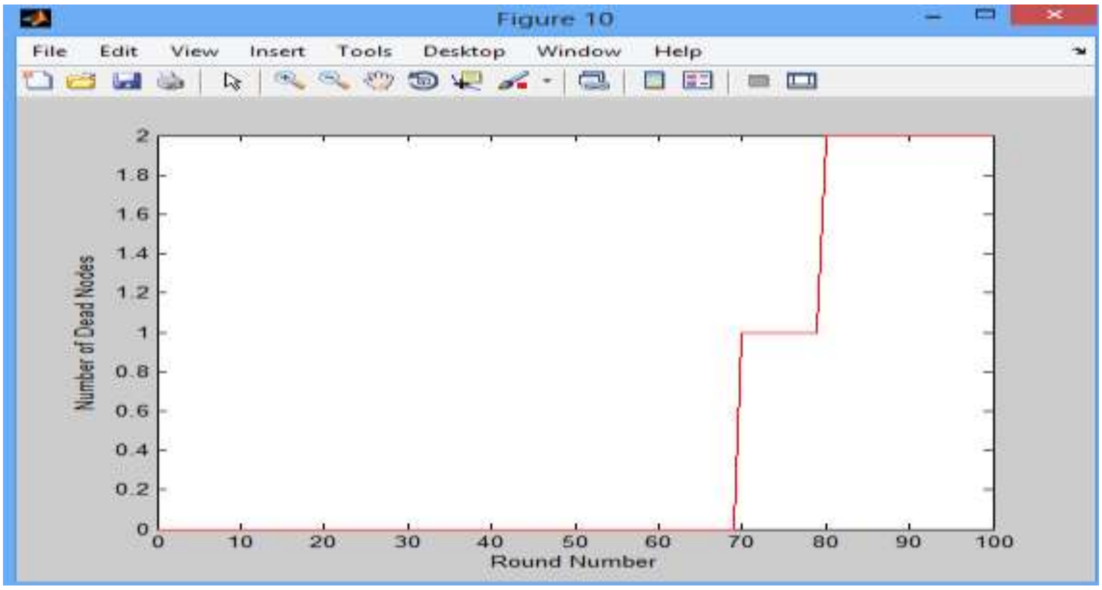

Fig 11: rate of dead nodes after 100 rounds

Fig 11 rate of dead nodes after 100 rounds. we can easily analyse that at round no 69 ,the first node get died and after that the second node died at near 8o rounds .

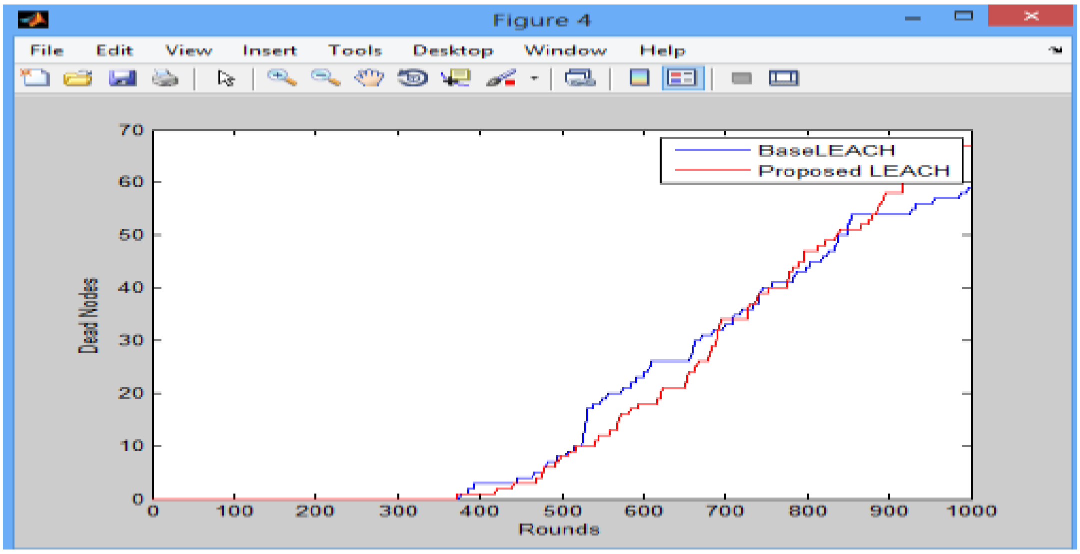

Figure 12: comparison of energy consumption of leach and proposed fuzzy rule based heterogeneous leach .in 400 rounds.

Fig 12 shows comparison of energy consumption of leach and proposed fuzzy rule based heterogeneous leach .in 400 rounds both contain the equal no of dead nodes ,we can easily see the difference of dead nodes in 20^{th} and 30th round. The no of dead nodes in our PROPOSED model is less than LEACH.

V CONCLUSIONS AND FUTURE SCOPE

Wireless Sensor Networks have a great importance in today's scenario due to their practical applications in research areas as well as in daily life. There is an inherent characteristic of limited energy resource in WSNs, therefore, main focus is to make them energy efficient with enhanced lifetime. Further advancement has been done with the inclusion of heterogeneity for prolonging the lifespan of sensor network. In this paper, Fuzzy based Energy Efficient Clustering Protocol has been proposed for WSN systems. The proposed protocol improved the stability period or FND (First Node Dead) period by a factor of 113.9% and 50.5% for different base station location (50, 50). In FRBHL the energy is consumed in a balanced fashion in the network. As a result, the proposed protocol does not suffer from an early node death problem that could happen in the case where some nodes consume energy at a higher rate than others. FRBHL operates in a distributed and centralized manner where decisions are made based on local information only as well as information available with canter BS. Another interesting issue is the consideration of node mobility. Most of the current protocols assume that the sensor nodes and the sink are stationary. One of the possible future works is to investigate how we can best control the number of associated cluster members in every cluster, to achieve a relative load balance in terms of number of nodes among all clusters formed. This would give better uniformity in their respective energy usage, eventually leading to further prolonged effective network lifetime.

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