

A Fuzzy Logic Based Clustering Algorithm for WSN to Extend the Network Lifetime

Priyanka Sood ^{#1}, Manpreet Kaur ^{#2}
 Research fellow^{#1}, Assistant Professor^{#2}

Department of ECE, Surya World Group of Institutions, Bapror, Punjab, India

Abstract

A mobile sensor network is a set of physically distributed sensor nodes. Sensor node is a small wireless device with limited battery life, radio transmission range and storage size. Sensor nodes perform the task of collecting data, processing of data, monitoring of environment etc. Mobility of sensors can be effectively used to improve the target coverage quality and network connectivity in randomly deployed mobile sensor networks. Appropriate cluster head (CH) selection can reduce the energy consumption. Most famous hierarchical routing protocol is Low energy adaptive clustering hierarchical (LEACH), in which CH is selected on rotation basis based on a probabilistic threshold value. In this process only CH are allowed to send information to base stations (BS). But in this method a SCH i.e. super cluster head is chosen among the CHs who can send the information to mobile base stations by choosing suitable fuzzy descriptors like base station mobility, clusters centrality and remaining battery power.

Fuzzy inference engine is used to select the chance of CHs to be SCH. We have derived the results from NS-2 simulator and show that the proposed protocol performs better than the LEACH protocol as it provides better stability and better lifetime to network.

Keywords - Wireless Sensor Network (WSN), Super Cluster Head (SCH), Fuzzy Logic

I. INTRODUCTION

Wireless sensor network is a real time embedded system deployed in a particular region and is used to sense various parameters like temperature, pressure, gas, humidity etc. with limited energy and memory. The applications of WSN involve habitat monitoring, forest fire detection, transport monitoring, whether monitoring etc. Typically WSNs are deployed in dangerous areas where battery recharge or restoration is almost impossible and human monitoring scheme is risky. Sometimes power constraints, limited computing capacity, radio connectivity, open environment creates faults in the sensor nodes. Once network is established sensing is started in nodes. Thus battery power decreases exponentially. Whenever an event occurs

nodes sense the information and start sending the information to other node as well as to the base station. In this way same information is received by the adjacent nodes as well as by the base station. This makes the network inefficient because energy of nodes is being wasted.

In order to avoid this data redundancy and to conserve energy data aggregation and sensor fusion have been listed in literature [1]. Many protocols have been proposed but cluster based routing protocol is best idea. In this process sensor nodes are divided into number of groups and each group is called a cluster. One group leader is selected called Cluster head. Leader node or cluster head is only responsible for sending information to base station. Figure 1 shows cluster based WSNs system model.

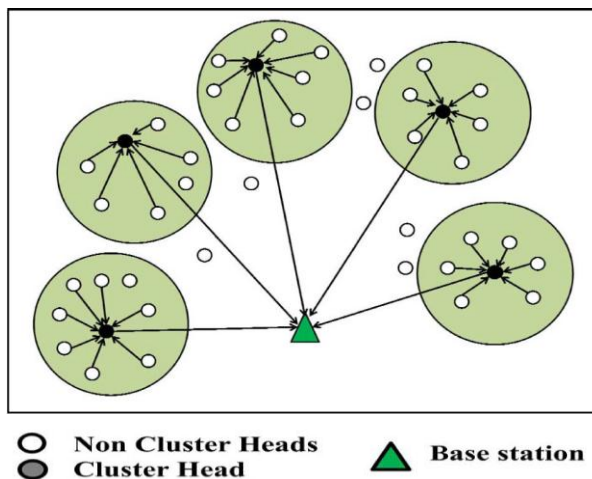


Fig 1. General model for Clustered WSN

LEACH is first and one of the best energy efficient hierarchical clustering based routing algorithm for WSN that was proposed for reducing power consumption thus increasing network lifetime. In LEACH clustering task is rotated among all sensor nodes based on duration. Nodes select their cluster head by some criteria. Direct communication is used by each cluster head of the network to forward the data directly to the base station.

There are certain pitfalls in LEACH algorithm. LEACH relies on probabilistic value, it can happen that in one round only one cluster head is selected or no cluster head is selected. Also sometimes cluster heads are selected at the boundary of the network, thus results in improper energy distribution. Also, after completion of round LEACH does not consider distribution of sensor nodes and remaining energy of each node. LEACH C is next protocol which follows a centralized method to select CH by using location information of BS and location information obtained from each node. In this way it produces better number of clusters and also it distributes cluster heads evenly between the clusters. Since all the sensor nodes need to send their location information to BS at a time in every set up phase so it increases overall network overhead.

So now we lead to select a Super cluster head (SCH) among all CHs by using fuzzy descriptors. SCH is allowed to send messages to BS thus reducing the number of retransmissions performed by Cluster heads.

II. RELATED WORK

In this section hierarchical routing protocols have been discussed where we select cluster heads in an energy efficient manner even there are many protocols with fuzzy descriptors or without fuzzy descriptors but some important are discussed here.

A. Hierarchical Routing protocols Based on clustering

1) **LEACH:** LEACH is a hierarchal routing protocol which selects CHs by probabilistic model so each cluster head has equal probability to be selected as CH. Operation of this protocol occurs in two phases namely setup phase and steady phase. In set up phase actual data and nodes from clusters are transmitted in steady state phase. Selection of CH is done by choosing a number between 0 and 1 randomly. A node will get a chance to become a cluster head for current round if the chosen value is less than threshold value and vice versa.

Pitfalls in LEACH protocol:

- It gives no guarantee that preferred numbers of cluster heads are chosen in each round.
- In LEACH CHs are selected probabilistically so there are chances that two CHs chosen are too close to each other. In this way there is loss of energy.
- In this process in every round there is generation of one random number and its threshold value is calculated.
- Sometimes the selected node is at the boundary of the network so rests of the nodes need more energy to transfer information and hence energy wastage is there.

B. Clustering protocol using Fuzzy Logic:

Some of the Fuzzy logic based algorithms are discussed as follows:

1) **CHEF:** In CHEF cluster head is selected based on parameters, namely proximity distance and energy. This approach selects a node as CH which has high energy. CHEF is 22.7% highly efficient than Leach. Three fuzzy parameters namely energy label (energy available at each node), concentration (total number of neighboring nodes) and centrality (how central is the node to the cluster) are the key points to choose CH which can increase network lifetime. Main drawback of this protocol is that all the nodes are not equipped with GPS receivers and they cannot provide their location information in some places.

2) **FMCHEL:** In FMCHEL CH is elected by applying Fuzzy rules based on proximity distance and energy. The node which has maximum residual energy among all cluster heads is selected as master cluster head (MCH). MCH sends collected data to the base station. FMCHEL provides better network stability than CHEF. Major drawback of this model is that when mobility increases or decreases lifetime of the network remains constant. As mobility is directly proportional to distance to base station, to overcome this centrality has been considered as third input parameter for fuzzification in this module. Simulation results show that proposed model is better than the earlier protocols.

III. PROPOSED MODEL

Proposed model can handle real time application more accurately than other probabilistic model. FL (Fuzzy Logic) is used in this technique for handling uncertainties which can occur during electing SCH. FL is used to collect and calculate energy and information of each node. In FL based clustering algorithm sink node or BS is considered as static. Through simulation results we can see that proposed model performs better than LEACH protocol.

A. System Assumptions

In this proposed model sensor nodes are deployed randomly to monitor environment continuously.

- 1) All the sensor nodes are static rather than base station.
- 2) Base station is mobile.
- 3) It is considered that all the nodes have same initial energy.
- 4) With the help of received signal strength, the distance between base station and node is computed.

B. System Model

This method follows basic principle of LEACH. Clusters are formed in every round and in every clustering round each node generates a number in between 0 and 1. If the number selected is less than threshold value $T(n)$ then the node will become a CH otherwise not.

In LEACH, cluster formation algorithm was defined to ensure that number of clusters per round is k , where k is a system parameter. The value of k is determined by computational and communication energy models. It is assumed that after detecting an event, sensor node sends data. Cluster head receives data, collects it and sends it to the base station. To save energy we can think of SCHs among CHs that can send data to base station so that bandwidth can be utilized efficiently. Instead of using multiple CHs we can use one SCH to conserve energy. This model is shown in figure 2.

One more assumption is made that BS are mobile and all the CHs and SCHs are remain static. So BSs can adopt many different paths to move to the SCHs and can collect information as shown I figure 3. Further it is assumed that remaining power, centrality and mobility are three parameters used to select chance to be a SCH.

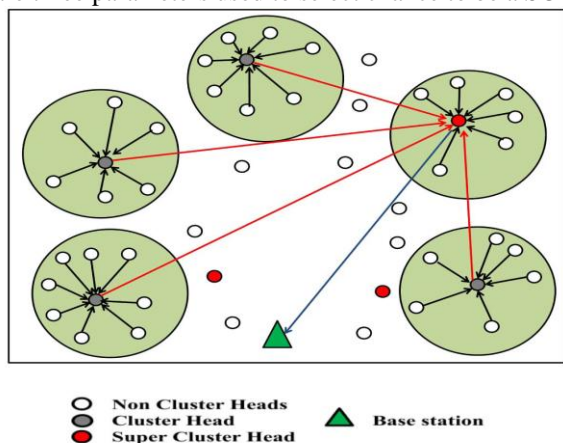


Fig 2. Proposed model

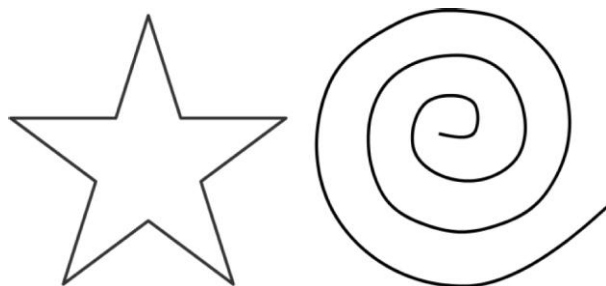


Fig 3. Paths taken by Base Station

The Proposed Algorithm

```

/*for every round */
1) Select CHs based on threshold value.
2) Select  $k_{optimal}$  CHs in each round
3) Select SCH based on fuzzy algorithm using if-then rules from the CHs
   /* for  $k_{optimal}$ CHs */
1) All CHs send collected data to SCHs.
   /* end of for */
1) BS collects the information from SCHs.
   /* end of rounds*/
    
```

C. Fuzzy Logic Model

This model consists of four modules named as a fuzzifier, fuzzy inference engine, fuzzy rules and a defuzzifier. Here Mamdani’s method is used. Block diagram of Fuzzy inference system is shown in fig 4.

Steps involved in this process are:

1. Fuzzification
2. Rule evaluation
3. Fuzzy inference engine.
4. Defuzzification

Explanation:

Fuzzification Module: In this method we make use of Mamdani’s Fuzzy inference method to select SCH. This is shown in figure 5. Three input variables are taken to elect tentative SCH. All the three input variables have three input function each. Now first input variable of fuzzy set i.e. remaining battery power is depicted in figure 6a. Less, medium and high are the linguistic variables for fuzzy set. For less and high trapezoidal membership function is considered and for medium triangular membership function has been considered. Mobility of base station is the second fuzzy input variable. In this protocol base station is considered as mobile. Low, moderate and frequent are the linguistic variables for mobility. Fuzzy set for mobility is drawn in fig 6b. Centrality is the third fuzzy input variable which means how much SCH is centralized to rest of clusters.

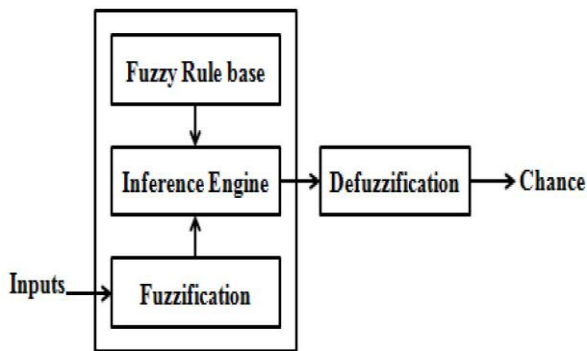


Fig 4. Block diagram of Fuzzy inference system

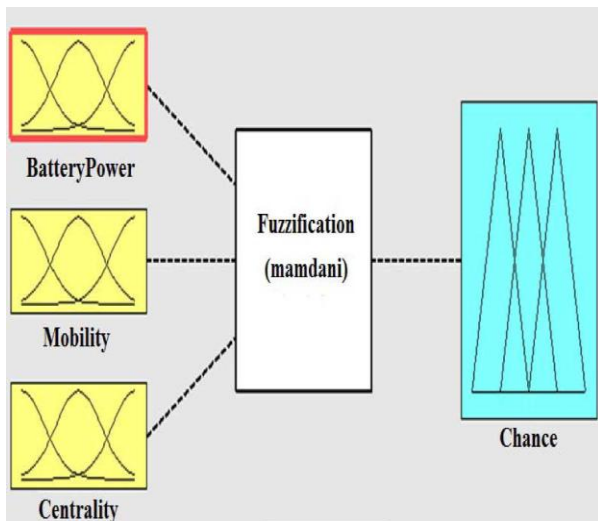


Fig 5. Fuzzy system for proposed model

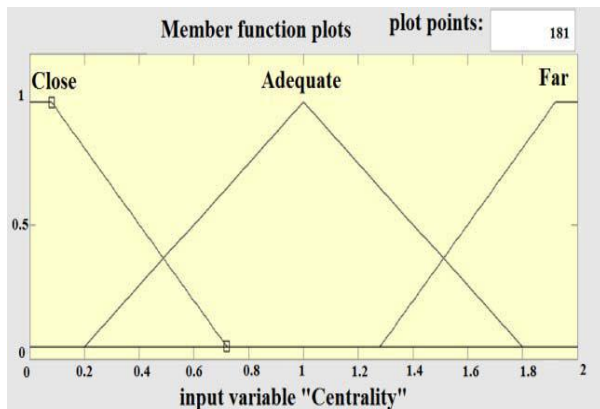


Fig 6c

IV. SIMULATION RESULTS AND ANALYSIS

To check if the proposed model is valid or not NS-2 simulator has been used as a tool to compare the performance matrix with LEACH protocol which give us increased lifetime of WSN for proposed protocol.

In this experiment we have taken 40 nodes that are deployed over area In between (x=0, y=0) to (x=100, y=100) and base station location is at (x=50, y=50).Number of clusters are four that are used here and duration of each round is 20s.Bandwidth of channel is taken as 1Mbps.Each data message is 500 bytes long, length of packet header is 25 bytes. Thus the required parameter of interest and communication parameters are given in table I. After simulation it is found that the proposed protocol performs better than LEACH.

Table1. Simulation Parameters

Network Topology	Network Size No of Nodes Expected No of clusters BS Location Node distribution BS mobility Channel Channel Type	100x100m 40 5 50x50m Random Random Walk Wireless Bidirectional
Radio Model	Energy model Start up Energy E_{elec}	Battery 2J 50nJ per bit
Application	Sim Time Round Time Packet Header Size Data packet size Bandwidth	20000s 20s 25 bytes 500 bytes 1Mbps

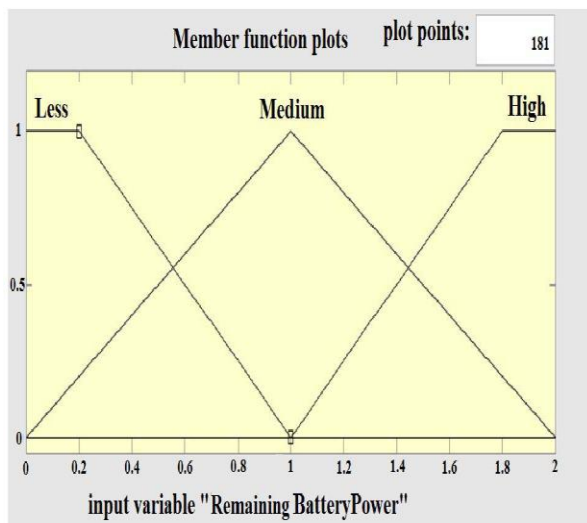


Fig 6a

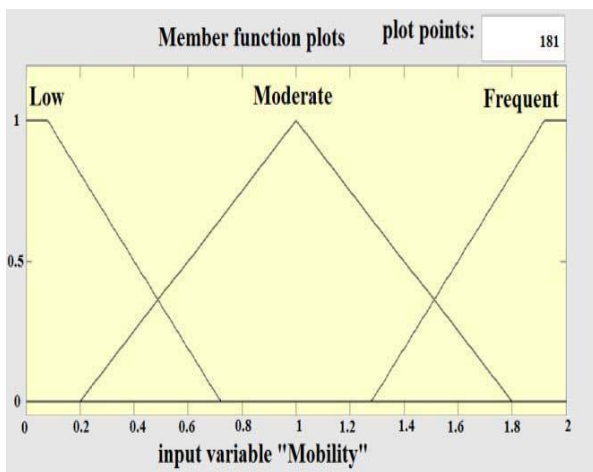


Fig 6b

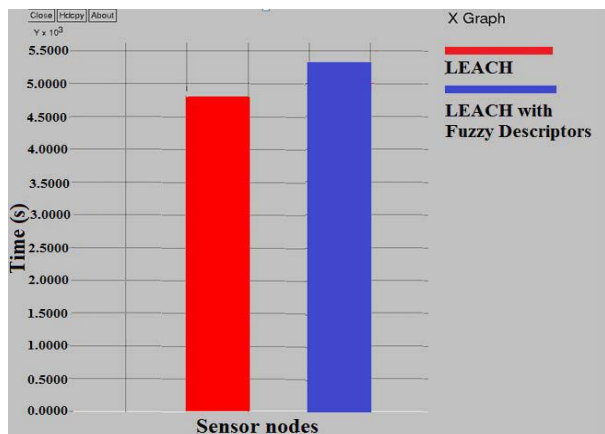


Fig 7. First node dies over time

Results: In fig 7 we can see the results of simulation which shows the time period when first node dies. From the figure we can see that first in LEACH first node dies very fast as compared to proposed model in which it survives for the double time. Here a matrix named half of nodes alive (HNA) used to calculate estimated value of round in which half of nodes die. Stability period of network is determined by time duration between the death of first node and half of the nodes. It is shown in figure 8 that half of the nodes die faster in LEACH rather than the proposed protocol. So network will be more stable in between time periods of first node death to the half of the nodes alive. In Fig 9 it is proved that proposed protocol is more stable than the LEACH protocol. Fig 10 represents end to end delay which means time taken by packets to travel from source to base station. This figure shows that end to end delay is reduced by 62% in proposed model. Fig 11 shows that sensor nodes survive for longer time i.e. for more number of rounds than LEACH protocol. Fig 12 shows that last node dies in LEACH very much before the proposed protocol. Finally simulation results shows that proposed protocol using Fuzzy model is more stable and they have 20% longer lifetime as compare to LEACH.

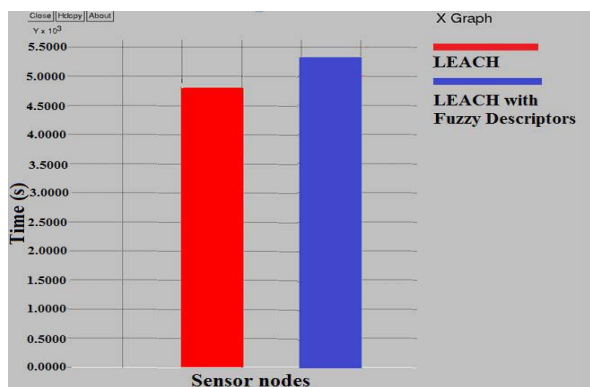


Fig 8. Half of the nodes alive over time

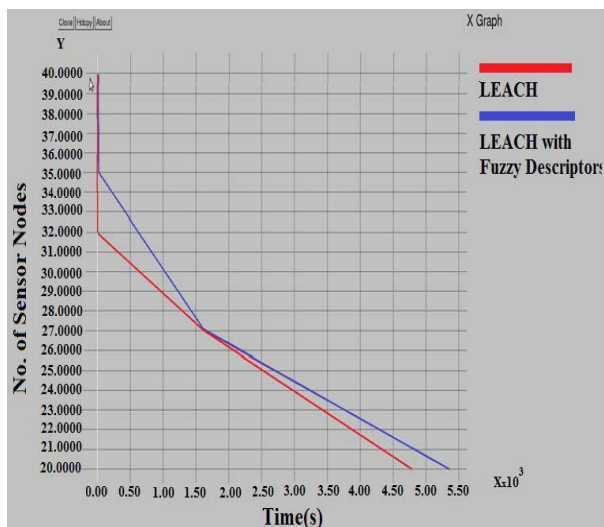


Fig 9. Network Stability Period

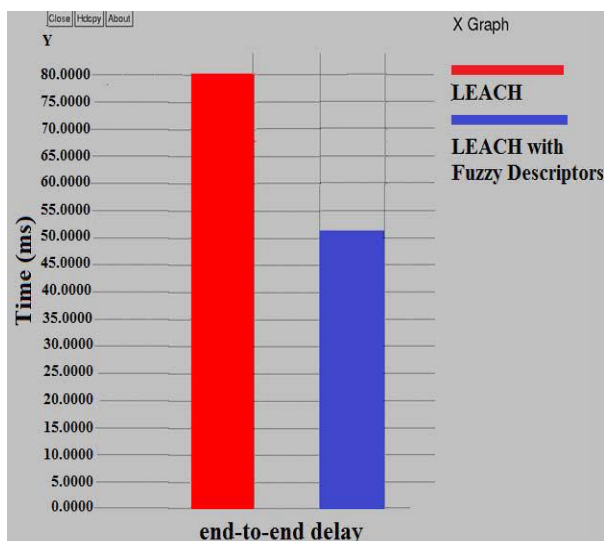


Fig 10. End to end delay

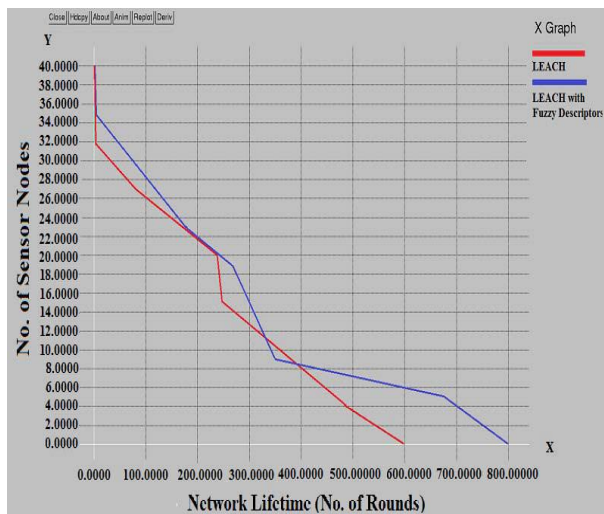


Fig 11. Network lifetime over time

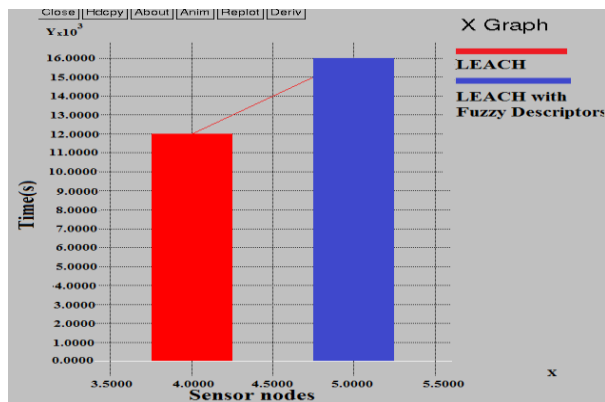


Fig 12. Last node dies over time

V. CONCLUSION

Although LEACH is a promising protocol but some improvements in LEACH makes it more useful. In this research paper a clustering algorithm which is more energy efficient has been proposed with Fuzzy logic concept. By selecting desirable fuzzy descriptors firstly one SCH is selected among cluster heads which transfers data to mobile base station. The idea of sink mobility using fuzzy logic increases network lifetime. It is expected that this protocol will be more useful in disaster areas, health care areas, agricultural field etc. Simulation results shows that the proposed protocol is better in performance in terms of first node dies, last node dies, half node alive, better stability and better network lifetime.

REFERENCES

- [1] W.R. Heinzelman, A Chandrakasan and H. Balakrishnan, "Energy Efficient Communication protocol for Wireless micro Sensor Network, "in proc IEEE computer soc 33rd Annual Hawaii international Conference System Sciences. Jan 2000, pp 1-10
- [2] E.P.Wigner,"Theory of travelling wave optical laser".
- [3] I.Gupta, D Riordan and S Sampali "cluster head election using fuzzy logic for wireless sensor networks" in proc.3rd Annu. Communication networking services Res. Conf. May 2005, pp 255-260
- [4] Pamalaya Nayak, Anurag Devulapalli," A fuzzy logic based clustering algorithm for WSN to extend network lifetime" IEEE sensors journal, Volume 16,No. 1,January 1,2016,pp 137-144
- [5] Heinzelman W,Chandrakasan A,Balakrishnan H,"Energy Efficient Communication Protocol for wireless micro sensor network," proceeding of 33 Hawaii international conference on system sciences held at Maui USA pp. 3005-3014
- [6] Murungnathan, F, Bhasin R I Fapojuwo A.O 2005,"A centralized energy efficient Routing protocol for wireless sensor Network,"IEEE Radio Communication pp S8-S13
- [7] M.J Handy, M Hasse, D Timmermann (2002),"Low Energy Adaptive Clustering Hierarchy with deterministic Cluster Head Selection," IEEE pp. 3

- [8] DV Pushpalatha ,Padmalaya Nayak(2015) A Clustering Algorithm for WSN to Optimize the Network Lifetime using Type 2 Fuzzy Logic Model," Modeling and Simulation Third International Conference on Artificial Intelligence,pp,53-58
- [9] Trupati Sharma¹, Brijesh Kumar²(2012),"FMCHEL: Fuzzy based Master Head Selection Leach protocol in Wireless Sensor Network, "international Journal of Computer Science and Telecommunication" (Volume 3.issue 10,October 2012) pp.8-13