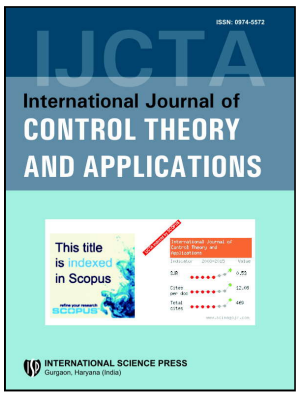

International Journal of Control Theory and Applications

ISSN : 0974-5572

Volume 10 • Number 13 • 2017

Efficient Cluster Head Selection in WSN using Fuzzy Logic

Ashwini Kumar Singh[1] and Santosh Kumar[2]

[1] Department of Computer Science and Engineering Graphic Era University, Dehradun, Uttrakhand, India, Email: ashwini.21mar@gmail.com
[2] Department of Computer Science and Engineering Graphic Era University, Dehradun, Uttrakhand, India, Email: amu.santosh@gmail.com

Abstract: Energy consumption in Wireless Sensor Network (WSN) is one of the major issues which facilitate a vast area of research. Grouping together of sensor nodes to form clustersare broadly embraced by the research group to gain flexibility, high energy efficiency for increasing lifespan of entire network in large-scale WSN environments. The WSN uses clustering phenomenon for combining various clustering parameters using fuzzy logic predefined rules. Appropriateselection of CH can exceedingly reduce the energy consumption hence enhancing the lifetime. This paper illustrates selection of cluster head using fuzzy rules based on parameters like energy, distance and bandwidth.Simulation results validate the improvement in energy efficiency and network lifespan of our proposed approach comparing with existing one.

Keywords: Clustering,Cluster Head, Fuzzy Logic, Network Lifetime

1. INTRODUCTION

The Wireless Sensor Networks (WSNs) are spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. and to cooperatively pass their data through the network to a main location [4].Nodes are arranged haphazardly by their own transmitting along themselves that are deployed in large count and uses radio signals [14]. Energy is one of the major issues in WSN. A large amount of energy is wasted while sensor nodes activated, participated in data transmission and communicate with each other.The unreliable communication, latency rate network lifespan and physical attacks are the issues associated with WSNs. The network nodes have low power capabilities with limited computational and storage. The network's lifetime is most significant issue. For resolving these issuesit is essential to consider anenergy efficient protocol.There exists various probability based protocols like LEACH, HEED etc. These techniques are also suitable and offer probability based solution

As Fuzzy logic offers various advantages over probabilistically selecting the nodes as CHs by using local information. It is used in clustering for combining various factors depending upon well-defined rules and then selecting CH [1, 2]. Fuzzy logicpossesses partial truth values, values lying in between true and false. It has anefficacy to step on partial data by taking into account multiple fuzzy as inputs as well as multiple combinations

of them and finally generating the outputs [3]. Fuzzy system consists of four important Modules:Fuzzification, Rules, Inference mechanism and Defuzzificationas shown in figure 1.

General observations concerning fuzzy logic include that it is simple to realize, scalable, consists of comprehensive and imprecise information.It can duplicate nonlinear functions of unsupported complexity. We prepare fuzzy logic (FL) to match any collection of input output information.

In clustering, CH acts as a master for the rest of its cluster members and thus performs tasks like: it set up intra-cluster scheduling for transmission, it collects required information from its members, it collects and compacts the correlated data signals and finally forwards the collected data to the sink.

In clustering, fuzzy logic offers many advantages such as: it offers scalability and spatial reuse, it improves network's lifespan, reduces communication transmission capacity, increases strength of the network, reduces collisions during intra-cluster communication and the rotation of CHs leads to load balancing in network.

It focuses energy efficient clustering issues like lower dissipation of energy during clustering process, evenly dispersion of CH and less count of free nodes in network.

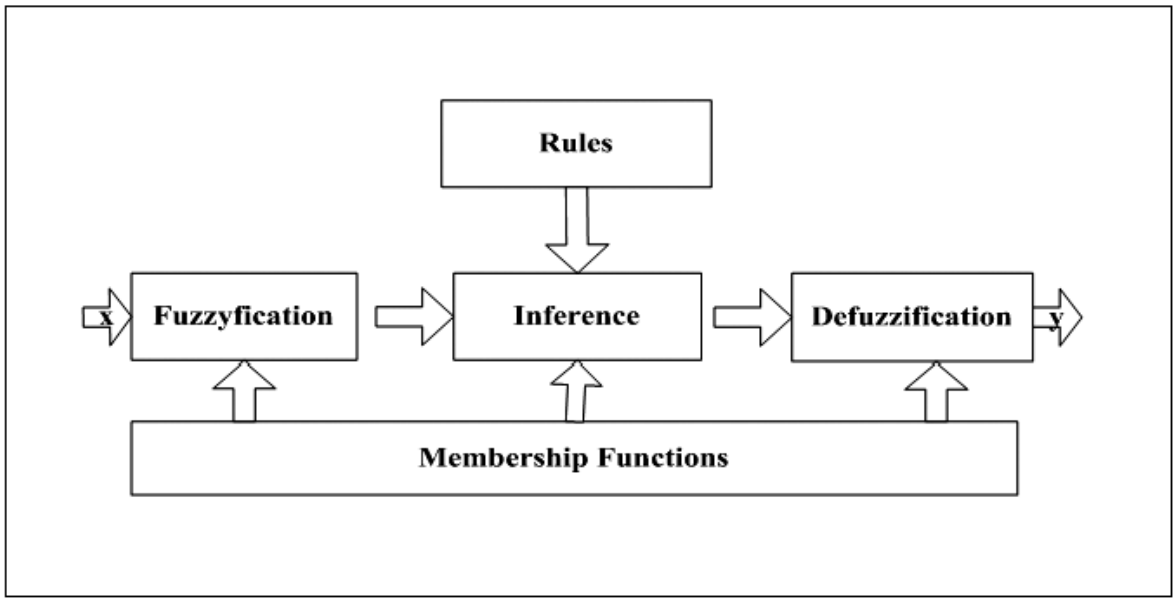

Figure 1: Fuzzy logic Controller

This paper introduces a novel clustering method using fuzzy logic. It measures the chance to become a CH using parameters such as node energy, bandwidth and distance of each node with respect to CH. The simulation results validates the optimization of energy depletion in cluster head selection and time consumed. A comparison based study is performed with the existing protocol by Maryam Mirsadeghi et al.

Rest of the paper is organized as: in section 2, related work for WSNs cluster based protocols are given,in section 3 system model is described. In section 4, the proposed approach of clustering method is defined. The simulation results and comparisons with existing techniques is presented in section 5. Finally the conclusionis presented in section 6.

2. LITERATURE REVIEW

In this section, we review some well-known clustering protocols in WSNs.In LEACH [13], construction of clustersdecreases energy dissipation in sensor networks. LEACH is completed in two stages: a setup stage and

a steady state stage. In set up stage, a random number between 1 and 0 is selected by the sensor node. This numberis compared with the threshold $T(n)$, and it is less than the threshold, the node turns out to be a Cluster Head. $T(n)$, defined as [11]:

$$T(n)=\begin{cases}\dfrac{p}{1-p\times\left(r \bmod \dfrac{1}{p}\right)} & if\ n\in G\\ 0 & \text{otherwise}\end{cases} \tag{1}$$

Here, p $\rightarrow$ cluster-head probability, r $\rightarrow$ current round and $G \rightarrow$ set of not CH nodes in the last $\frac{1}{p}$ rounds.

Every candidate CH is matched with the value calculated by eq.1 to some random numbers between 0 and 1. The node will become CH if the threshold is less than the random number.

The limitations of the LEACH protocol comprise: the remaining energy of a node is not conceded for CHs selection and lack of uniformed distribution of CHs. Therefore, these limitation leads to a chance of becoming CH for a node with very low energy which is not desirable for network lifespan. Thus, for networks deployed in large area, LEACH is not relevant.

Thein and Thein in [15] prolonged the probabilistic CH selection algorithm for LEACH. They tuned the threshold $T(n)$ defend in eq. 1, relative to the residual energy of the nodes. Byrelating this threshold each node chooses whether to becomea CH or not in the next round and defined by eq. 2.

$$T(n)=\begin{cases}\dfrac{p}{1-p\times\left(r \bmod \dfrac{1}{p}\right)}\times\dfrac{E_{residual}}{E_{initial}}\times K_{opt} & if\ n\in G\\ 0 & \text{otherwise}\end{cases} \tag{2}$$

Here, $E_{initial}$ is the initial energy of the node before transmission and $E_{residual}$ is the remaining energy of the node.The Optimal number of CHs is given by eq. 3.

$$K_{opt}=\frac{\sqrt{N}}{\sqrt{2\pi}}\sqrt{\frac{E_{fs}}{E_{mp}}}*\frac{M}{d_{toBS}^2}. \tag{3}$$

Here,

$N \rightarrow$ Number of sensor nodes,

$M \rightarrow$ Length of nodes distributing fields and

$d_{toBS} \rightarrow$ Distance between nodes and the BS.

Al-Ma'aqbeh et al. [18] determined the expected number of CHs in LEACH protocol. The proposed approach is a pre deployment phase assuming the evenly deployed sensorsin the sensor field. This approach uses only two elements: the expected number of nodes to be deployed and density of network.Before the network deployment the number of CHs is calculated for the network.

In SCP [5], an alternative protocol for clustering is proposed which selects cluster-heads that have high energy with low communication cost while considering load balancing. In [6]Authors introduced demand clustering based on fuzzy logic, that considered node's residual energy for non-probabilistic election of CH. In this, communication is done in a multi-hop fashion between CHs and BS. In [7] authors proposed a new protocol i.e., UCFIA which took into consideration local information of CH that varies frequently, that includes associated residual energy, local density and distance to BS. Authors in [8] proposed a novel method of clustering using fuzzy logic, considering input parameters such as energy, centrality, and density for selecting a CH. These techniques define how it has improved performance in respect of consumption of energy, coverage of network and life expectancy of network.In this [9] node parameters such as its remaining energy, its reach ability from the nodes surrounding it (to lessen the intra-cluster cost of communication), quality of transmission medium with its surrounding nodes (for increasing reliability) and distance of node to BS are taken as fuzzy input variables for CH selection. Authors in [12] proposed a FL based upon energy-aware dynamic clustering that maximizes the network's lifespan on the basis of "Last node dies". Node can be selected as CH to the fuzzy cost, as it uses two inputs variables in the fuzzy inference system (FIS), the main merit of this protocol is that it describes how an optimum amount of cluster is maintained in each round, which is quite unmanageable in case of LEACH.

The literature survey concludes that protocols in WSN are required to be reliable and energy efficient. These features headed to offer a protocol as proposed; selection of cluster head based on fuzzy rules. Although selection of cluster head can be done by genetic algorithm or even by neural networks but fuzzy logic offers many advantages over others. Classical techniques can consider only values in the form of true or false. Fuzzy Logic(FL)considers partial truth values of parameters. Fuzzy systems can reach real time decisions even when the data is incomplete. Various other descriptors (apart from the variables we have considered) can be used in FL for the selection process.

3. SYSTEM MODEL

In our proposed scheme the following assumptions [8] are considered about our network:

- The architecture of a cluster based network
- All nodes have the same initial energy
- Fixed Base Station
- Static Sensor Nodes and Cluster Heads
- Random deployment of Sensor Nodes in area of interest
- 10 mbps Maximum bandwidth associated with the network
- Base Station is acknowledged with the size of environment.
- Base Station knows the count of nodes initially present inside the considered network.

4. PROPOSED METHOD

For the selection of CH using fuzzy logic, three inputs are considered which includes energy of the sensor node, distance between sensor node and base station and bandwidth associated to the sensor node for communication in the network.

Here, Mamdani is used as an inference technique in fuzzy logic system. It is a modest rule-base method as it does not involve complex calculations moreover, IF __THEN__ rules can be employed wherever needed.

The parameters taken as input variables are described:Remaining energy possessed by each sensor node (represented by energy) which is defined by eq. 4.

$$RE = \sum_{i=0}^{100} \left(E_i - \mu / n \right) \tag{4}$$

$\mu \rightarrow$ required energy by node.

Distance of each node with respect to user is calculated by eq. 5:

$$d = \sum_{i=0}^{100} \left(lt,\ i \right) \tag{5}$$

$lt \rightarrow$ Look up table i.e., linear array of distances

Bandwidth associated with each node is defined by eq. 6:

$$RBW = \sum_{i=0}^{100} \left(BW_i - \ rb \right) \tag{6}$$

$$rb = \left(BW_i / N \right) \times d\left(i \right) \tag{7}$$

Where: $rb \rightarrow$ required bandwidth for communication, $N \ \rightarrow$ total number of nodes and $BW \rightarrow$ total Bandwidth allocated to the network.

For complete number of nodes inside a network, linguistic variables (descriptors) used which are categorized into three levels. Levels for energy are defined as:Low, Medium and High, Levels for distance are defined as:Close, Adequate andFar, and Levels for bandwidth are defined as:High,Medium and Low. To elect CHs based on these input variables cluster-head election, levels of chances can be seen from the table 1. Considering a case for example, if the energy is Low, distance is *Far* and bandwidth is *High*then the node's CH chance is *Very Low*.There are total nine rules as we have taken only the extreme conditions. Fuzzy Rules are defined below on the basis of which chance of being elected as CH.

Table 1
Defined Fuzzy Rules

Bandwidth	*Distance*	*Energy*	*Chance*
Low	Far	Low	VL(Very Low)
High	Close	High	VH(Very High)
Low	Adequate	Low	Low
Medium	Far	Low	RL(Rather Low)
Low	Adequate	Medium	ML(Medium Low)
High	Far	Medium	MH(Medium High)
High	Close	Medium	High
Medium	Adequate	High	RH(Rather High)
Medium	Adequate	Medium	Medium

The energy consumption model (radio model) for communication [10] whereenergyconsumed at transmitter node isdefined by eq. 8.

$$E_{TX(L,d)} = \begin{cases} L * E_{ele} + L * \in_{fs} * d^2 & if\left(d < d_0 \right) \\ L * E_{ele} + L * \in_{fmp} * d^4 & if\left(d \geq d_0 \right) \end{cases} \tag{8}$$

Where;

$$d_0 = \sqrt{\frac{\in_{fs}}{\in_{mp}}}$$

Both free space and the multipath fading channel model are taken that depends upon the distance between the sensor and receiver and E_{ele} is electricity consumed however $\in_{mp}$ and $\in_{fs}$ is the consumed energy per bit in the distance based radio frequency amplifier. The Proposed algorithm is discussed here.

Proposed Algorithm

FLCHS Algorithm

Begin

Start clock to record time

Step 1. Loop through the nodes

Step 2. Calculate required bandwidth

rb/N

Step 3. Calculate required energy

Re/N

Step 4. Get distance from distance table

Step 5. Evaluate Fuzzy using distance, bandwidth and energy as parameter

Step 6. If probability returned is more than 0.5 then

Select node as the channel head

Accept request

Otherwise

Pass the request to next node and repeat step 4 through step 6

end if

Step 7. Record time

Step 8. End loop

5. SIMULATION AND ANALYSIS

The proposed algorithm is simulated having consideration of scenario followed by parameters discussed in table 2.

Table 2
Summary of the Simulation scenario and parameters used

Parameters	*Value*
Field size($M \times M$)	$100m \times 100m$
Base Station Position	$d_{to\ BS} < 5\ KM$
No of nodes,	100 *nodes*
Cluster Head probability	0.5
Sensor Node's initial energy	0.0025 *I*
The data packet size()	4000 *bits*
Bandwidth	(0 -10) *mbps*

We have compared our work with the existing protocol by Maryam Mirsadeghi et al. via MATLAB software. The existing algorithm considers energy, density and centrality as three input parameters for CHs selection while the proposed one considers energy, distance and bandwidth as three parameters for CHs selection. The comparison is done on the basis of energy consumption, time consumed and balance bandwidth. The results are obtained after 100 rounds. Sensor nodes are pretended to be active in all rounds, therefore they senses and further forwards theinformation associated with them to their CHs. Finally all the CHs dispatch the data to BS.

Membership Function Schemes of energy, density and centrality are shown in figure 2 on the basis of which chance for the selection of CH can be calculated.

Membership Function Schemes of energy, distance and bandwidth are shown in figure 3based on which chance for the selection of CH can be calculated.

A comparison of energy consumption in cluster head selection is shown in figure 4. The comparison of time consumed in cluster head selection using proposed method is shown in figure 5.

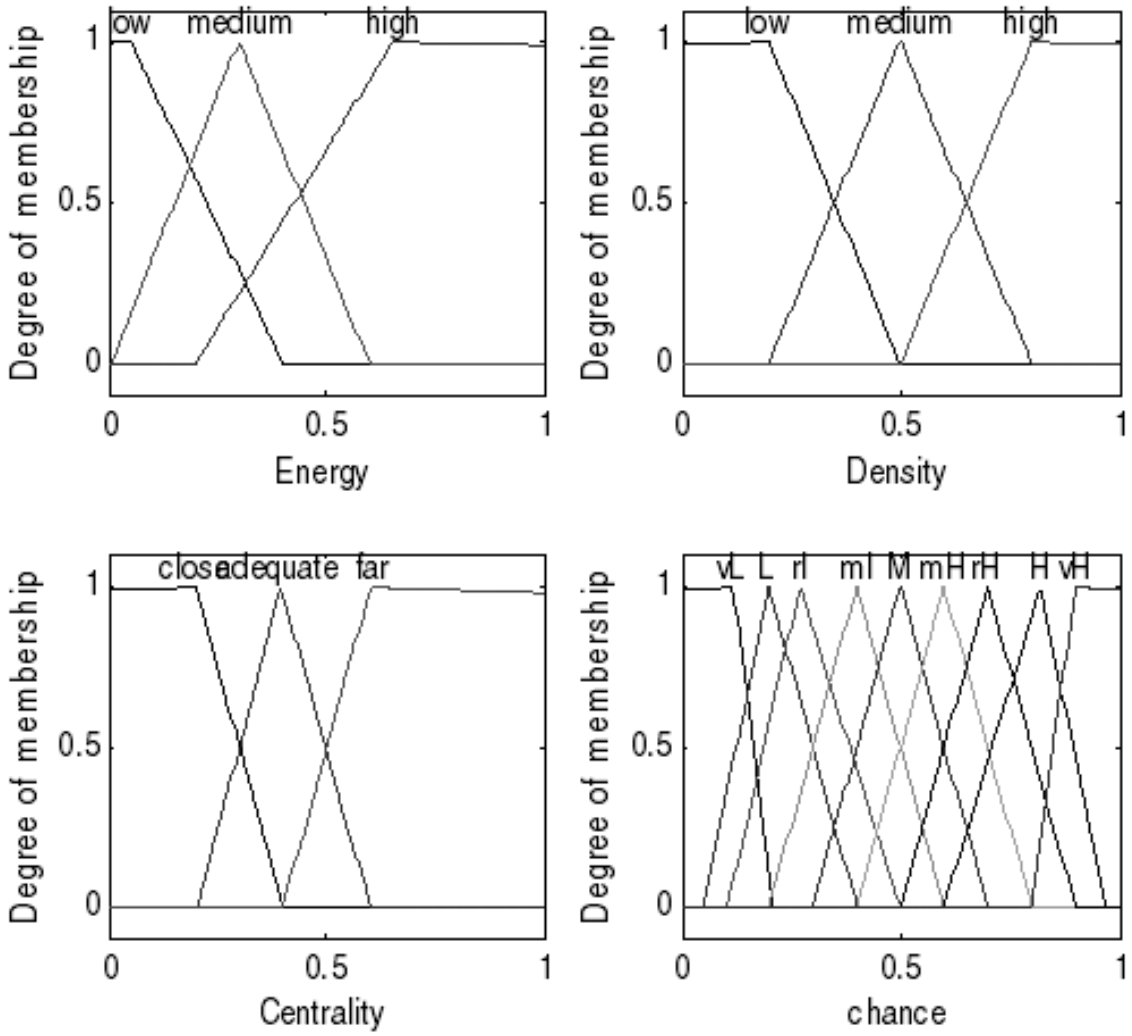

Figure 2: Result of Maryam Mirsadeghi's method.

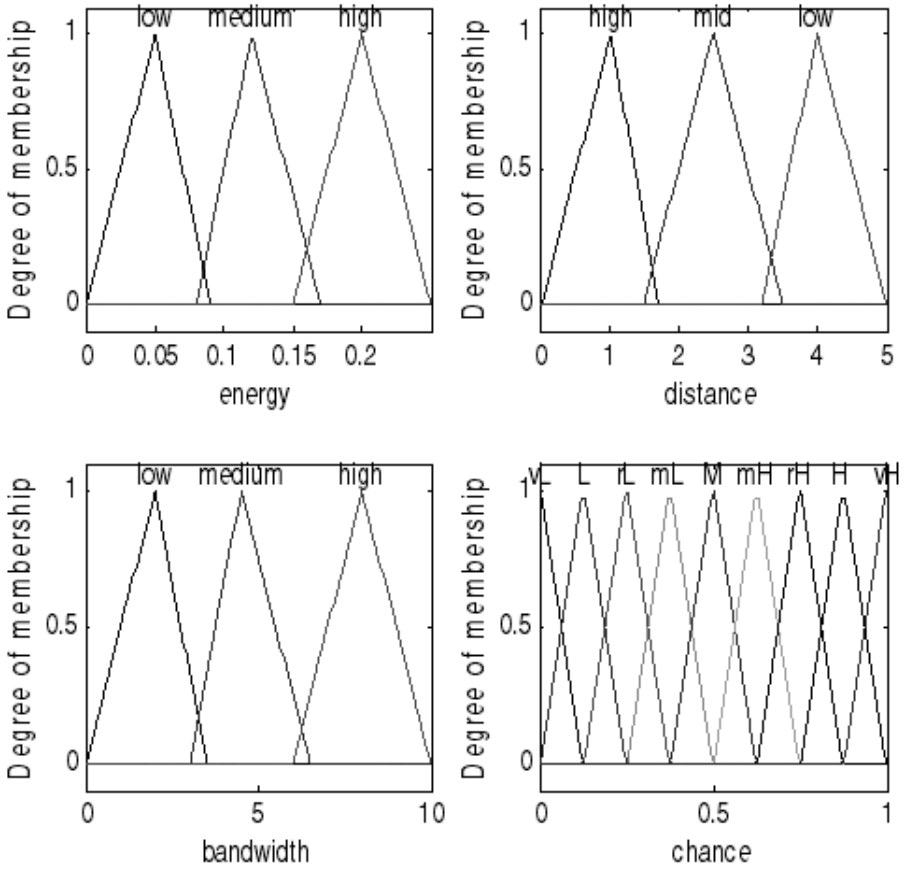

Figure 3: Result of proposed FLCHS method.

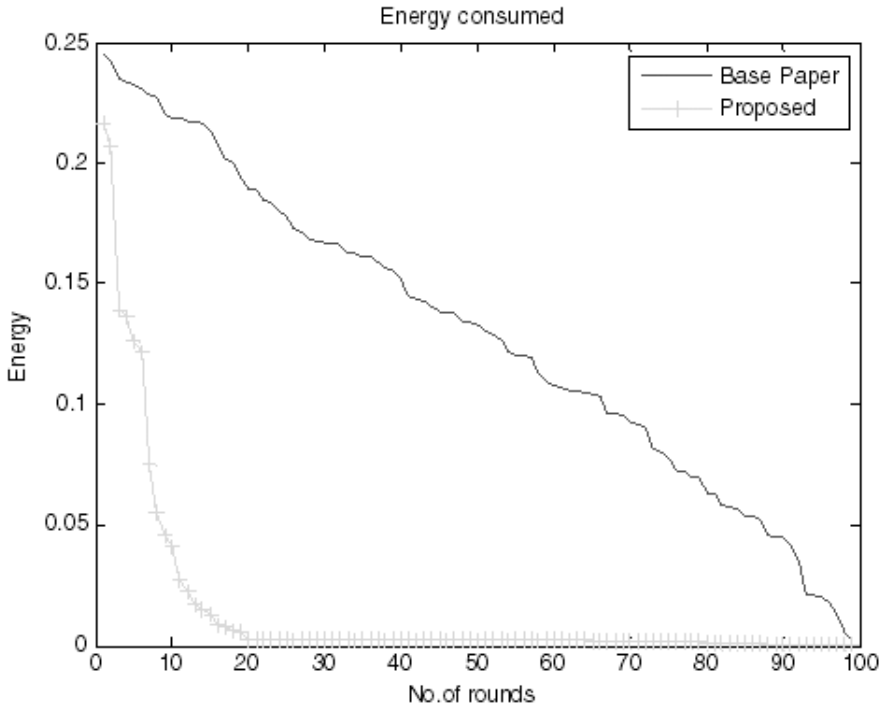

Figure 4: Energy Consumption in each technique

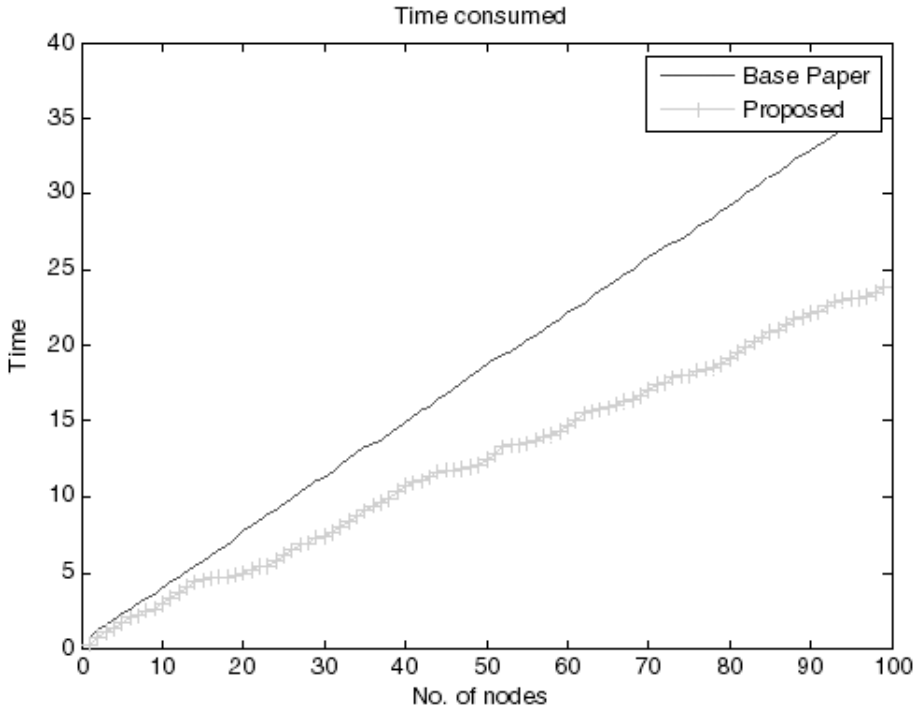

Figure 5: Time consumed in each technique

6. CONCLUSION

The proposed method has less computational complexity as it makes use of FL. All processes for group creation (cluster) are completed locally here; therefore a comparative quantity of energy is conserved. Simulation results illustrates that the proposed work has lower energy consumption, consumes lesser time and more balance bandwidth that prolong the network lifetime as compared to Maryam Mirsadeghi et al.

The topic of increasing lifetime in WSN is still a wide open area of research. Better solutions which take care of mobility constraints like power consumption, storage andbatterydesires to be concentrated. As a continuation of the research, more work is need to be done which particularly focuses upon energy consumption which will prolong the network lifespan. By changing the parameter sets, further improvement can be achieved in this direction.

REFERENCES

[1] L.A. Zadeh, "Fuzzy Sets, Information and Control",1965, pp. 338-353.

[2] L.A. Zadeh, "Outline of a new approach to the analysis of complexsystems and decision processes", IEEE Transactions on Systems, Man and Cybernetics, SMC-3 1,1973, pp. 28-44.

[3] Tarique Haider, Mariam Yusuf, "A Fuzzy Approach to Energy Optimized Routing for Wireless Sensor Networks", The International Arab Journal of Information Technology, 2009, Vol. 6, No. 2.

[4] Wikipedia.org., Retrieved September 27, 2016, from https://en.wikipedia.org/wiki/Wireless_sensor_network.

[5] A.K. Tripathy and S. Chinara,"Staggered Clustering Protocol: SCP an Efficient Clustering Approach for Wireless Sensor Network", World Congress on Information and Communication Technologies, IEEE, 2012.

[6] Hoda Taheri, P. Neamatollahi, O. M. Younis, S. Naghibzadeh and M. H. Yaghmaee, "An energy-aware distributed clustering protocol in wireless sensor networks using fuzzy logic", Ad Hoc Networks 10, 2012, 1469-1481.

[7] M. Song and Z. Cheng-lin,"Unequal clustering algorithm for WSN based on fuzzy logic and improved ACO", The Journal of China Universities of Posts and Telecommunications, 2011, pp.89-97.

[8] Maryam Mirsadeghi, Ali Mahani, Maryam Shojaee, "Novel distributed clustering protocol using fuzzy logic", Conference on Electronics, Telecommunications and Computers – CETC, 2013.

[9] SachinGajjar, Mohanchur Sarkar, and KankarDasgupta, "Cluster Head Selection Protocol using Fuzzy Logic for Wireless Sensor Networks",International Journal of Computer Applications, 2014, pp. (0975 – 8887), Volume 97– No.7.

[10] Smaragdakis G. Matta I. Bestavros A., "A Stable Election Protocol for Clustered Heterogeneous Wireless Sensor Networks", Proceedings of the 2nd International Workshop on SANPA,Massachusetts, U.S., 2004.

[11] F.Al-Ma'aqbeh, O. Banimelhem, E. Taqieddin, F. Awad and M. Mowafi, "Fuzzy Logic Based Energy Efficient Adaptive Clustering Protocol", ICICS-12, Irbid, Jordan, 2012.

[12] Md. A. Alim, Yucheng Wu, Wei Wang, "A Fuzzy Based Clustering Protocol for Energy-efficient Wireless Sensor Networks",Proceedings of the 2nd International Conference on Computer Science and Electronics Engineering (ICCSEE), 2013.

[13] K. Akkaya, M. Younis,"A survey on routing protocols for wireless sensor networks", Ad Hoc Networks 3 (3),2005, pp. 325–349.

[14] G. Ran, H. Zhang, S. Gong, "Improving on LEACH protocol of Wireless Sensor Networks Using Fuzzy Logic" Journal of Information and Computational Science, 2010, pp. 767–775.

[15] Thein, T. Thein,"An energy efficient cluster-head selection for wireless sensor networks", International Conference on Intelligent Systems, Modeling and Simulation, 2010, pp. 287–291.