

Fuzzy Logic Based Modified Stable Election Protocol: F-SEP

Ananya Saxena, Dr. Deepshikha Agarwal

Department of Computer Science & Engineering, ASET,
Amity University Lucknow
Lucknow, India

ananyasaxena94@gmail.com, dagarwal@lko.edu and Contact no.: 7376520650

Abstract— The Wireless Sensors based Networks are being widely used nowadays in many applications where the accessibility is remote or terrain is not approachable. Such fields include nuclear reactors, forest monitoring, farm surveillance, military surveillance etc. The electronic circuitry employed in designing these sensors has fixed power source mostly in the form of batteries. Thus, efficient use of the power source is an important concern in Wireless Sensor Networks. And it is no surprise that most of the research work going on these days, is focused at achieving an efficient energy usage, and thus to increase the usability of the network and its longevity. In this research work, the various heterogeneous network clustering algorithms have been studied and it is found that the computational intelligence if used in selecting the cluster heads in various rounds, can lead to a significant rise in the network longevity. This paper proposes fuzzy logic based clustering and routing algorithm to deal with the above mentioned problems. It has been implemented on MATLAB and results are compared against the Stable election Protocol (SEP) which is enhanced version of the standard Low Energy Adaptive Clustering Hierarchy (LEACH) protocol. The results confirm our belief that our proposed algorithm has better performance than SEP.

Keywords— Wireless Sensor Network, Energy efficiency, Network Lifetime, Fuzzy Logic, Sensor Node, Residual Energy, SEP.

I. INTRODUCTION

A typical wireless sensor network (WSN) consists of a large number of distributed embedded devices which can be used are to collect data of various kinds like temperature, pressure, humidity, pest count etc. depending on what kind of sensor they are embedded with. The development of electronics and the availability of less costly on-chip devices has led to the development of various kinds of exclusive sensor network paradigms, environmental or physical conditions [1-2]. In WSN, however due to the kind of areas where they are employed and the task they perform, such kinds of sensors are always constrained to various kinds of limitations in energy supply, computational capabilities and bandwidth. The energy limitation is the most important of them all because it is directly related to the lifetime of the whole network. A network lifetime is simply the measure of how long the sensors sustain. The longer the battery sustains, the better the network lifetime. Thus conserving power is always an important factor while designing any wireless sensor network protocol. In this paper a novel approach using fuzzy logic has been implemented for a heterogeneous network. The upcoming sections include a discussion on various methods proposed erstwhile by various researchers on methods for clustering, followed by a brief description of the proposed method and finally followed by analyzing the various results obtained after the simulation.

II. RELATED WORK

The typical representative dynamic clustering protocol is Low Energy Adaptive Clustering Hierarchy (LEACH) protocol, where randomized rotation of Cluster Head(CH) is done to distribute the energy dissipation evenly over the network [1], [7-8]. The main feature is that LEACH is fully distributed, which prolongs the network lifetime. However, it has also some drawbacks. One of the most important weaknesses of LEACH is load imbalance, i.e. as the CHs are selected randomly, some nodes may be selected as CHs, which are in close proximity of each other [1], [4]. This specifies the fact that the CHs are not evenly distributed over the network, which constrains to maximize the energy efficiency. . HEED [2] proposes a novel distributed clustering approach for long-lived ad hoc sensor networks. The proposed approach does not make any assumptions about the presence of infrastructure or about node capabilities, other than the availability of multiple power levels in sensor nodes. The protocol abbreviated as HEED i.e. Hybrid Energy-Efficient Distributed clustering, is a novel clustering based protocol that periodically selects cluster heads according to a hybrid of the node residual energy and a secondary parameter, such as node proximity to its neighbors or node degree. The authors have shown that the HEED protocol a significant increase in network scalability and lifetime. The protocol SEP improves the stable

region of the clustering hierarchy process using the characteristic parameters of heterogeneity, namely the fraction of advanced nodes (m) and the additional energy factor between advanced and normal nodes (α). To increase the stable region, SEP attempts to maintain the constraint of a well, balanced energy consumption. Advanced nodes have to become cluster heads more often than the normal nodes.

The new heterogeneous setting (with advanced and normal nodes) has no effect on the spatial density of the network [5]. The network energy distribution however changes considerably and it is found to show higher energy efficiency and network lifetime than the existing protocols.

A 2nd order radio model is as shown below in figure 1:

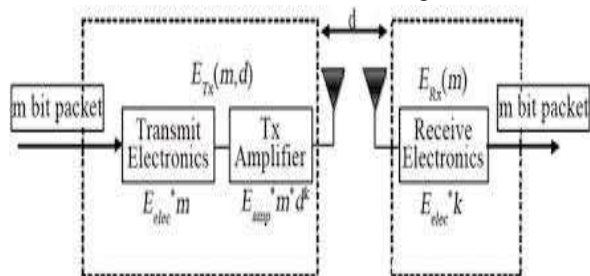


Figure 1: Radio Model [17]

The energy modeling of the above radio model is given by the following equations. The network being studied here is a two-level heterogeneous network, where we have two categories of nodes, a mN advanced nodes with initial energy $E_0(1+\alpha)$ and a $(1+m)N$ normal nodes, where the initial energy is equal to E_0 .

The total initial energy of the heterogeneous networks is given by:

$$E_{total} = N(1+m)E_0 + NmE_0(1+\alpha) = NE_0(1+\alpha m) \quad (1)$$

According to the radio energy dissipation model illustrated in figure and in order to achieve an acceptable Signal-to-Noise Ratio (SNR) in transmitting an L -bit message over a distance d , the energy expended by the radio is given by:

$$E_{tx}(L,d) = \begin{cases} LE_{elec} + LE_{fs}d^2 & \text{if } d < d_0 \\ LE_{elec} + LE_{mp}d^4 & \text{if } d > d_0 \end{cases} \quad (2)$$

Where E_{elec} is the energy dissipated per bit to run the transmitter (ETX) or the receiver circuit (ERX).

The value of E_{elec} depends on many factors such as the digital coding, the modulation, the filtering, and the spreading of the signal. E_{fs} and E_{mp} depend on the transmitter amplifier model used, and d is the distance between the sender and the receiver. For the experiments described here, both the free space (d^2 power loss) and the multi path fading (d^4 power loss) channel models were used, depending on the distance between the transmitter and the receiver. If the distance is less than a threshold, the free space (fs) model is used; otherwise, the multi path (mp) model is used, we have fixed the value of d_0 .

The various equations for estimating average energy of networks and the cluster head selection algorithm which is based on residual energy where:

The average energy of r th round is set as follow

$$E(t) = \frac{1}{N} E_{total} (1 - \frac{r}{R}) \quad (3)$$

where R denote the total rounds of the network lifetime and is defined as:

$$R = \frac{E_{total}}{E_{round}} \quad (4)$$

E_{round} is the total energy dissipated in the network during a round, is equal to:

$$E_{\text{Round}} = L(2NE_{\text{elec}} + NE_{\text{DA}} + kE_{\text{mp}} d_{\text{toBS}}^4 + NE_{\text{fs}} d_{\text{toCH}}^2) \quad (5)$$

where k is the number of clusters, E_{DA} is the data aggregation cost expended in the cluster heads, d_{toBS} is the average distance between the cluster head and the base station, and d_{toCH} is the average distance between the cluster members and the cluster head.

III. FSEP PROTOCOL

In this research work, we have used the fuzzy logic technology to enhance the performance of the Stable Election Protocol. The fuzzy logic rule base is made up taking two input parameters and one output parameter as shown in the below table 1:

Table 1: Fuzzy Logic Parameters

Parameter	Type
Residual Energy	Input
Distance to Base Station	Input
Selection Probability	Output

The method extends the capability of the SEP protocol by using the fuzzy logic architecture to improve the decision making in selection of an optimal cluster head. The residual energy and the distance of various nodes from the base station is evaluated at each round and based on it the fuzzy logic engine comes to a decision of whether a particular nodes qualifies for becoming a cluster head or not. The use of fuzzy logic makes the decision more exclusive by clearly defining the relationship between the inputs and output as given in table 1. These rules are known as fuzzy inference rules, on the basis of which the fuzzy engine makes its decision.

IV. THE FUZZY MODEL

The Fuzzy logic Toolbox, in MATLAB software tool has been used to model the fuzzy logic inference engine for this research work. The Fuzzy Logic Toolbox contains several functions, which can be used to model the fuzzy inference engine. As described earlier, we have taken two input functions, the membership graphs show the relationship between these functions and the degree of membership. The Figure 2 shows the Fuzzy Inference System used in this paper, followed by the membership function plots of input and output functions in figure 3, 4 and 5.

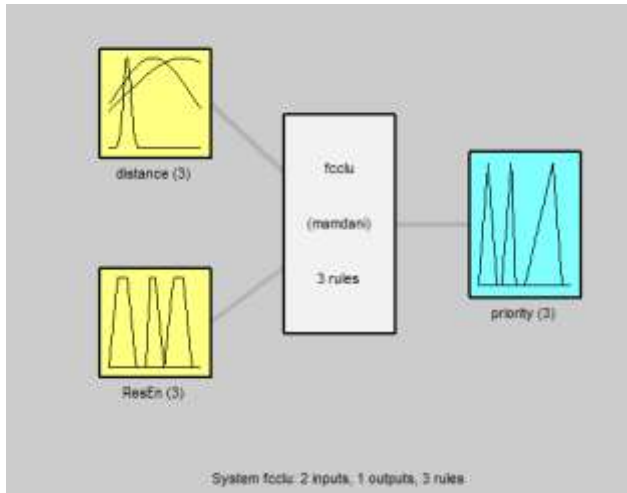


Figure 2: The Fuzzy Inference System Plot

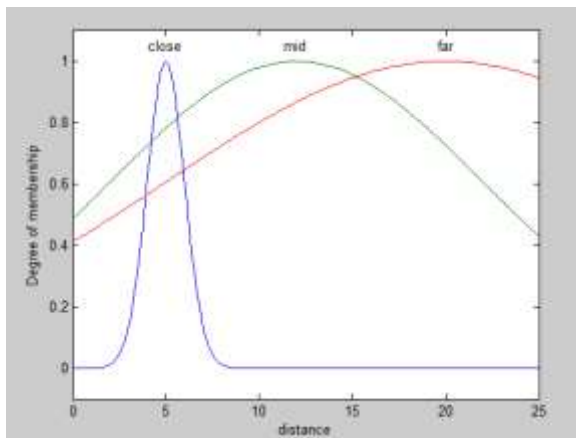


Figure 3: Degree of membership for Input 1(Distance)

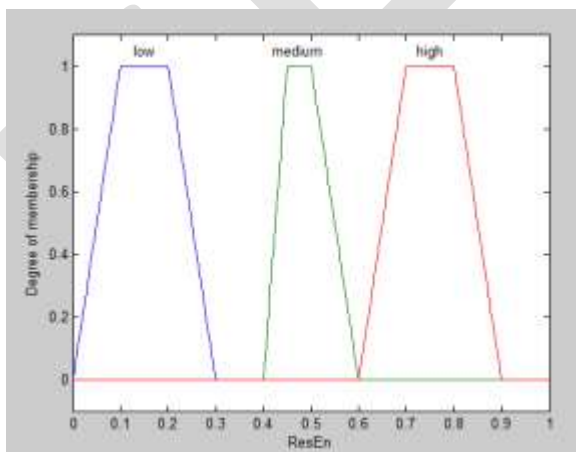


Figure 4: Degree of membership for Input 2
(Residual Energy)

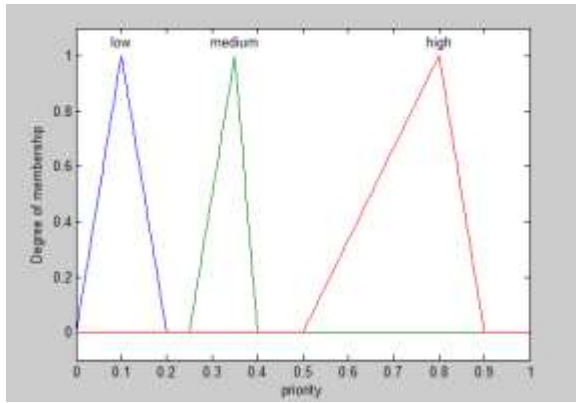


Figure 5: Degree of Membership for Output (Selection Probability)

The cluster head selection is based on the values of the residual energy and the distance of the nodes from base station. The threshold value for the selection is given by:

$$T(n) \begin{cases} \frac{P}{1-P*(r \bmod \frac{1}{P})} & \text{If } n \in G \\ 0 & \text{Otherwise} \end{cases} \quad (6)$$

where P is the optimal selection probability to become cluster head.

V. SIMULATION AND ANALYSIS

The network environment has been simulated using the simulation parameters in table 2:

Table 2: Simulation Parameters

Parameters	Values
Energy consumed in the electronics circuit to transmit in or receive the signal, E_{elec}	50 nJ/bit
Energy consumed by the amplifier to transmit at a short distance, E_{fs}	10 pJ/bit/m,
Energy consumed by the amplifier to transmit at a longer distance, E_{mp}	0.0013 pJ/bit/m,
Data Aggregation Energy, EDA	5 nJ/bit/signal
Message Size	4000 bits
Initial Energy, E_0	0.5 J

The following graphs show a comparison between the proposed work and SEP protocol.

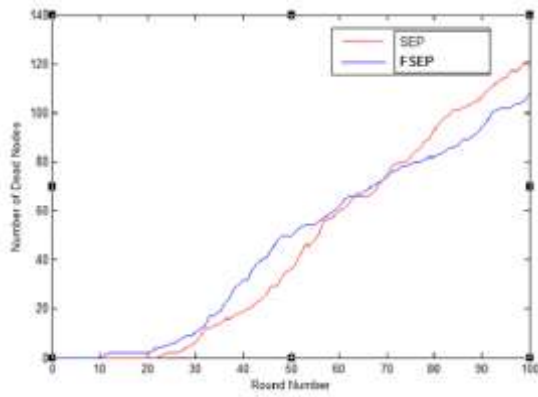


Figure 6: Number of Dead Nodes

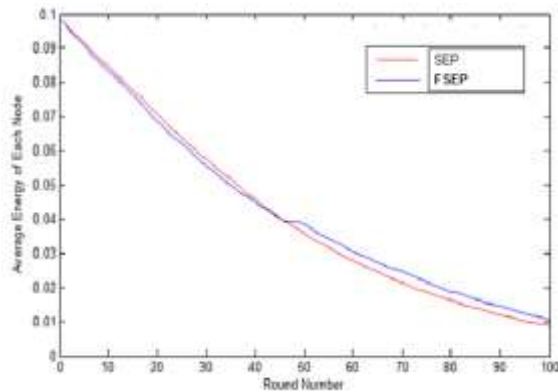


Figure 7: Average Energy of Nodes

Figure 6 and Figure 7 show the comparison between the SEP protocol and the fuzzy logic based SEP protocol, which we have proposed in this research work. The improvement in our method is clearly visible with lesser number of dead nodes and a better average energy as compared to SEP. the improvement leads to an increased network lifetime.

CONCLUSION & FUTURE SCOPE

The fuzzy logic optimization in the selection of cluster heads, improves the performance of the SEP protocol, as is clear in the simulation result. The residual energy of the nodes after each round and the distance from the base station are taken as the two input parameters for the fuzzy logic inference engine, while the output parameter is the selection probability to become a cluster head. The network radio model has been implemented using the MATLAB software tools and graphics environment.

The proposed fuzzy logic approach can be used further with other standard protocols. The feasibility of the proposed protocol can also be studied with varying network parameters to study its suitability in different network environments.

REFERENCES:

- [1] Abbasi A.A., Younis M. "A survey on clustering algorithms for wireless sensor networks". Elsevier 2007.
- [2] Malik M., Singh Y. Analysis of LEACH protocol in wireless sensor networks. International Journal of Advanced Research in Computer Science and Software Engineering, Feb. 2013.
- [3] Xuxun Liu 2012. A survey on clustering routing protocols in wireless sensor networks.

- [4] Heinzelman W.B., Chandrakasan A.P. An application specific protocol architecture for wireless microsensor networks. IEEE, 2002.
- [5] Kour H., Sharma A.K. Hybrid energy efficient distributed protocol for heterogeneous wireless sensor network. International Journal of Computer Applications, 2010.
- [6] Yun Li, Nan Yu, Weiyi Zhang, Weiliang Zhao, Xiaohu You, Daneshmand M. Enhancing the performance of LEACH protocol in wireless sensor networks. IEEE, 2011.
- [7] Demirbas M., Arora A., Mittal V., Kulathumani V., A fault-local self-stabilizing clustering service for wireless ad hoc networks. IEEE, 2006.
- [8] Demirbas M., Arora A., Mittal V. FLOC: A fast local clustering service for wireless sensor networks.
- [9] Demirbas M., Arora A., Mittal V., Kulathumani V. Design and analysis of a fast local clustering service for wireless sensor networks. IEEE.
- [10] Mamalis B., Gavalas D., Konstantopoulos C., Pantziou G. Clustering in wireless sensor networks.
- [11] U. Sajjanhar, P. Mitra, —Distributive Energy Efficient Adaptive Clustering Protocol for Wireless Sensor Networks, Proceedings of the 2007 International Conference on Mobile Data Management, pp. 326 - 330, 2007.
- [12] Elbhiri Brahim, Saadane Rachid, Alba-Pages Zamora, Dris Aboutajdine, —Stochastic Distributed Energy-Efficient Clustering (SDEEC) for heterogeneous wireless sensor networks, ICGST-CNIR Journal, Volume 9, Issue 2, December 2009.
- [13] Inbo Sim, Kyoung Jin Choi, Kyoung Jin Kwon and Jaiyong Lee, —Energy Efficient Cluster Header Selection Algorithm in WSN, International Conference on Complex, Intelligent and Software Intensive Systems, IEEE, 2009.
- [14] Ma Chaw Mon Thein, Thandar Thein —An Energy Efficient Cluster-Head Selection for Wireless Sensor Networks, International Conference on Intelligent Systems, Modeling and Simulation, IEEE 2009
- [15] Dilip Kumar, Trilok C. Aseri, R.B. Patel, —EEHC: Energy efficient heterogeneous clustered scheme for WSNs, ELSEVIER, Computer Communications, 32 (2009) 662–667
- [16] Yingchi Mao, Zhen Liu, Lili Zhang, Xiaofang Li, —An Effective Data Gathering Scheme in Heterogeneous Energy WSNs, International Conference on Computational Science and Engineering, 2009
- [17] Georgios Smaragdakis, Ibrahim Matta, Azer Bestavros, “SEP: A Stable Election Protocol for clustered heterogeneous wireless sensor network,” Boston University, Technical Report BUCS-TR-2004-002