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Fuzzy Based Stable Election Protocol for Heterogeneous Wireless Sensor Networks

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Abstract: Wireless Sensor Networks have been increasing with the use of advanced methods to develop these kinds of networks in various fields like biometrics, weather monitoring, military applications etc. Wireless Networks are deployed in various regions and one of the key issues is that the sensor nodes are largely dependent on the batteries which are fitted in them at the time of installation. In most of the cases, the sensor nodes have to be largely dependent on the fixed non-rechargeable batteries. Thus it is for utmost importance to save the energy as much as possible and preserve the network energy and hence its lifetime. There have been several routing protocols designed and all are primarily focused on providing maximum network lifetime by ensuring the efficient use of sensor node energy. Among these protocols, the clustering based protocols are the most widely used and are extensively researched to devise new routing protocols to preserve the network energy. In this research work, the main focus is to study the various available clustering based routing protocols and observe their rules and features. An attempt is also made to devise a new protocol based on Fuzzy Based Stable Election Protocol for heterogeneous networks. A simulated virtual environment is envisaged to be built in MATLAB to understand the network setup and implement the algorithm for an energy efficient routing. A number of protocols have been studied in depth in this research work. The proposed protocol have shown improvement in a number of dead nodes and average energy per node as compared to the existing SEP protocol when a comparative study was done on similar simulation parameters on both the methods.

Keywords: Wireless Sensor Network, Energy Efficiency, Network Lifetime, Fuzzy Logic, 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 unbalance, i.e. as the CHs are selected randomly, some nodes may be selected as CHs, which are in close proximity to each other [1], [4]. This specifies the fact that the CHs are not evenly distributed over the network, which constraints 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:

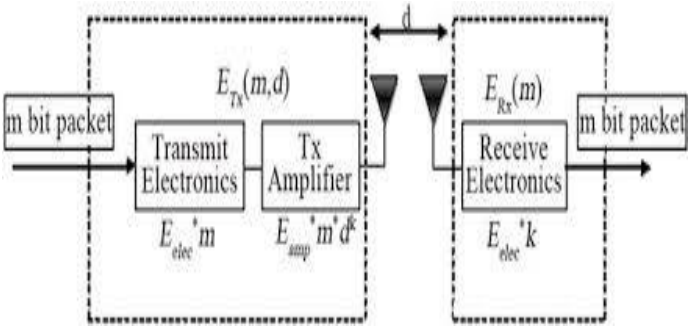

Figure 1: Radio Model [17]

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 Eo(1+a) and a (1 + m) N normal nodes, where the initial energy is equal to Eo.

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

$E_{total}=N(1+m)E_o+NmE_o(1+a)=NE_o(1+am)$ (1)

According to the radio, energy dissipation model illustrated in the 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:

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

Where Eelec is the energy dissipated per bit to run the transmitter (ETX) or the receiver circuit (ERX).

The value of Eelec depends on many factors such as the digital coding, the modulation, the filtering, and the spreading of the signal. Efs and Emp 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 rth round is set as follow

$$E(t) = \frac{1}{N} Etotal\left(1 - \frac{r}{R}\right) \quad (3)$$

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

$$R = \frac{Etotal}{Eround} \quad (4)$$

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

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

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. PROPOSED WORK

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 the selection of an optimal cluster head. The residual energy and the distance of various nodes from the base station are evaluated at each round and based on it the fuzzy logic engine comes to a decision of whether a particular node 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. 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.

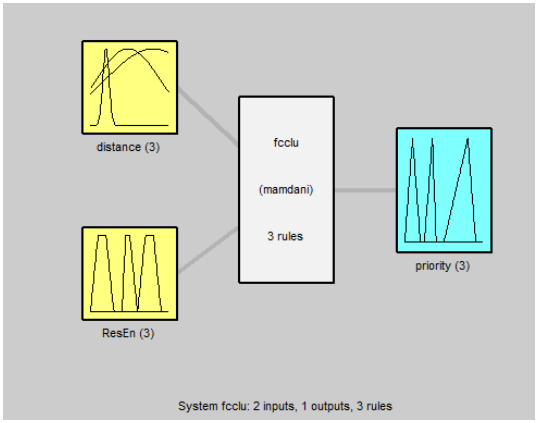

Figure 2: The Fuzzy Inference System Plot

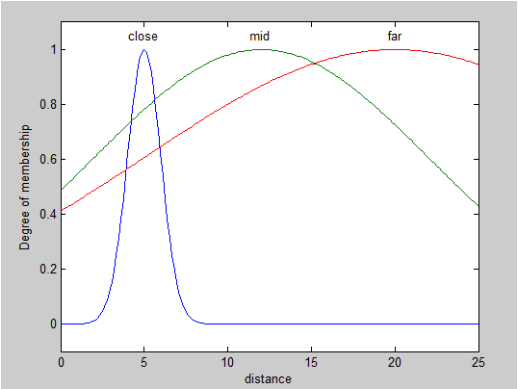

Figure 3: Degree of membership for Input 1(Distance)

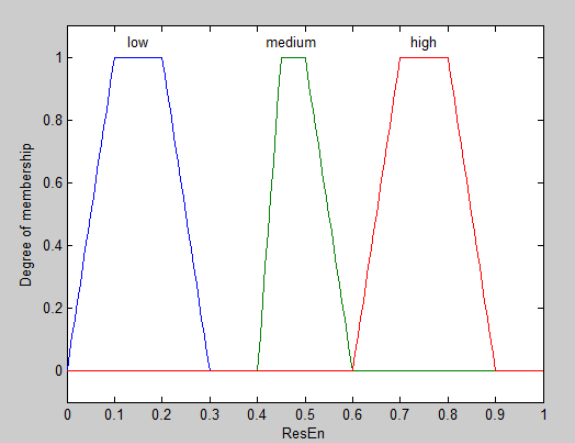

Figure 4: Degree of membership for Input 2(Residual Energy)

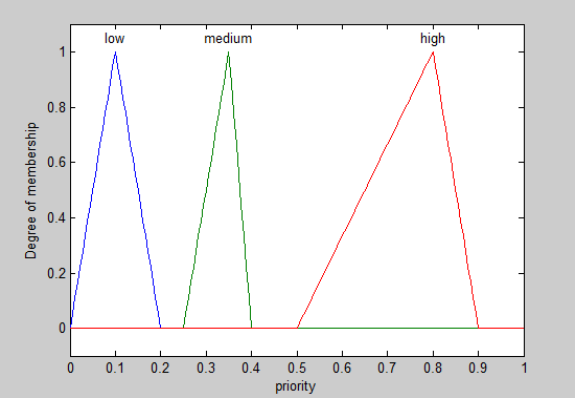

Figure 5: Degree of Membership for Output (Selection Probability)

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

$$T(n) = \begin{cases} \dfrac{P}{1 - P * (rmod\frac{1}{P})} & If\ n \epsilon G \\ 0 \quad Otherwise \end{cases} \quad (6)$$

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_2
Energy consumed by the amplifier to transmit at a longer distance, Emp	0.0013 pJ/bit/m_4
Data Aggregation Energy, EDA	5 nJ/bit/signal
Message Size	4000 bits
Initial Energy, E0	0.5 J

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

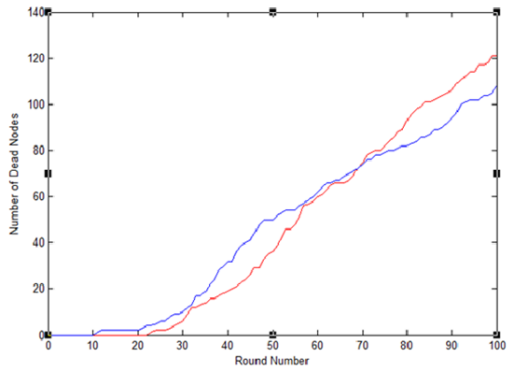

Figure 6: Number of Dead Nodes

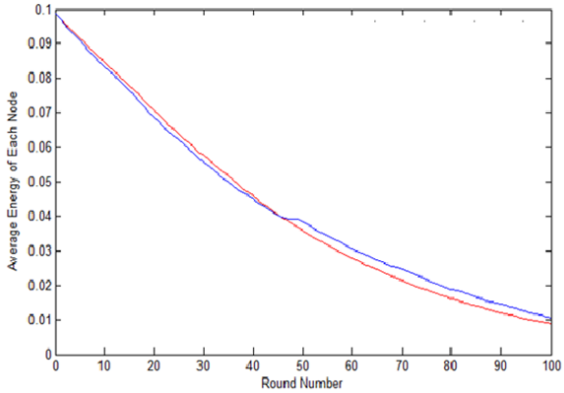

Figure 7: Average Energy of Nodes

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 a 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.

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BIOGRAPHY

Nimisha is a M.Tech Scholar pursuing her degree form AKTU Lucknow, in Electronics and Communication Engineering. She has received her B.Tech degree from Lingayas University, Faridabad. She has also worked as Electronics Engineer post her graduation. During her M.Tech she has also taken various teaching assignments.

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Dr. K.K.Sharma is working as a Professor in Electronics and Communication Department of Lingayas University.He has almost 20 years of vast experience in radar and communication systems. He has published research papers and 18 books in the field of communication engineering. He has been nominated and selected for representation of "RASHTRIYA VIDYA GAURAV PURASKAR" and "CERTIFACTE OF EDUCATION EXCELLENCE" by Indian Solidarity Council New Delhi 2016.

