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Performance Comparison of LEACH, SEP and Fuzzy Logic based Cluster Head Selection in WSN

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Abstract –**Thanks to the great steps taken in recent years in technological development, and in particular microelectronics and wireless communication techniques, wireless sensor networks (WSN) are increasingly being used in industrial applications and observation of the environment. However, the use of wireless sensor networks in such applications has to face several limitations imposed by sensors such as processing capacity, small memory size and energy. The limits imposed by the network itself, such as the narrow bandwidth, the network dynamics due to the topological variation of the network and the appropriate communication protocols adapted to this type of network. In this paper, we test, Low-Energy Adaptive Clustering Hierarchy (LEACH), Stable Election Protocol (SEP) and Fuzzy Logic based cluster-head election under the input variables; residual energy, neighbourhood index (Node centrality) and distance to BS.**

Keywords –**Clustering, Fuzzy Logic, LEACH, SEP, WSN.**

I. INTRODUCTION

Now-a-days the whole life of any person becomes mobile. It also proves a remarkable power of mobility in global development. In past only money was the important thing in life of every person without which nobody left the home. But at present, most of us don't take wallet to us while sleeping and even don't check it after few minutes. Apart from this, the popularity of laptops, GPS devices and intelligent computing devices is increasing day-by-day. Hence wireless network become a crucial part in our daily life. Recent advances in semiconductor networking and material science technologies are driving the ubiquitous deployment of large-scale wireless sensor networks (WSNs).These technologies all together form a new version of wireless network named as Wireless Sensor Networks (WSNs) which were developed about 5 to 10 years ago. It helps us to manage our lives with lower preparation and maintenance cost, contributing modern root ages of easily accessible information [1].

Wireless sensor network composed of numerous of sensor nodes which communicate with each other through wireless network. Each sensor node is required to be capable of sensing, processing and communicating the processed data to the neighbouring nodes to form a network. The data packets travel through these sensors nodes from source node to destination node via several intermediate nodes. The data packets can uses long as well as short route to reach to the destination node. The long route may results in network delay and can take larger time while simulating it. On the other hand short route results in better network performance by consuming lesser energy and lowest network delay. Finally, the routing targets are oriented by the application, therefore different routing protocols have been offered for easily accessibility of those applications.

Wireless sensor network also termed as distributed sensor nodes network in which each node are independent of each other and can perform transferring of data packets individually. A wireless sensor network is an accumulation of small randomly dispersed devices. Moreover in WSN, each node communicates with their neighbour node for transferring data from source node to sink node. The size of sensor nodes may change from small grain size to large box according to the requirement of application. Networking topologies may also vary. In WSN assumption, a user may retrieve the information by sending query to the system and then getting the results accordingly.

II. LOW-ENERGY ADAPTIVE CLUSTERING HIERARCHY (LEACH)

LEACH [2] is one of the most popular hierarchical routing algorithms for sensor networks. The idea is to form groups of sensor nodes based on the strength of the received signal and use the local clusters heads (CHs) as routers to the sink. This will save energy because the transmissions will only be made by CHs rather than all sensor nodes. The optimal number of CHs is estimated to be 5% of the total number of nodes.

All data processing such as merge and aggregate data is local to the cluster. The CHs change randomly over time in order to balance the energy dissipation of the nodes. This decision is taken by the node by choosing a random number between 0 and 1. The node becomes a CH for the current cycle if the chosen number is less than the following threshold:

$$T(n) = \begin{cases} \frac{p}{1-p^*(r \bmod \frac{1}{p})} & if\ n \in G \\ 0 & otherwise \end{cases} \quad (1)$$

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III. Stable Election Protocol (SEP)

Smaragdakis G. et al. [3] described the impact of heterogeneity on the heterogeneous-oblivious protocols and instability of the protocols like LEACH, in the presence of heterogeneity, once some nodes die. The authors of [3] describe the problems that can occur due to heterogeneity of nodes. They propose Stable Election Protocol (SEP) [3], a heterogeneity-aware protocol. It does not require energy knowledge sharing but is based on assigning weighted election probabilities of each node to be elected cluster head according to their respective energy. By using this approach, authors ensure that the cluster head is randomly selected based on the fraction of energy of each node; this assures that each node's energy is uniformly used. In SEP, two types of nodes (normal and advanced) are considered. It is based on weighted election probabilities of each node to become cluster head according to the remaining energy in each node. This prolongs the stability period i.e. the time interval before the death of the first node.

IV. Cluster-Head Selection using Fuzzy Logic

Proposed approach takes various parameters to elect CH as a random value, which causes poor balancing of energy in the network. The Fuzzy logic approach is used to make energy level stable (improve balancing of energy) in the network [4, 5]. The proposed protocol is a fuzzy logic based protocol for the selection of cluster head. Hence we call it as Fuzzy based hybrid routing protocol [6, 7]. In the process of cluster head selection, two input functions such as distance and residual energy of sensor node are transformed into fuzzy sets. A fuzzy set consists of degree of membership. The distance and residual energy Fuzzy sets are defined as:

$$A = \{(d, \mu_A(d))\},\ d \in D$$
$$B = \{(e, \mu_B(e))\},\ e \in E \qquad (2)$$

Where, D is a universe of discourse for Distance and E is a universe of discourse for residual Energy, d and e are particular element of D and E respectively. $\mu_A(d)$, $\mu_B(e)$ are membership functions, the degree of membership of the element in a given set. Membership functions for distance and residual energy are as follows.

$$\mu_A(d) = \begin{cases} 1 & if d \leq TH_1 \\ (TH_1 - d)/TH_1 - TH_2 & if TH_1 < d < TH_2 \\ 0 & if d \geq TH_2 \end{cases} \qquad (3)$$

$$\mu_B(e) = \begin{cases} 0 & if e \leq TH_1 \\ (e - TH_1)/TH_2 - TH_1 & if TH_1 < e < TH_2 \\ 1 & if e \geq TH_2 \end{cases} \qquad (4)$$

Where,
TH_1= Threshold to activate system
TH_2 = Threshold which identifies the level of activeness

A fuzzy relation is a relationship between elements of D and elements of E, described by a membership function, $\mu_{D\times E}(d,e)$, $d \in D$ and $e \in E$.
The fuzzy operator AND (□) is used to find the fuzzy relation,

$$\mu_A(d) \wedge \mu_B(e) = \min(\mu_A(d), \mu_B(e)) = \begin{cases} \mu_A(d), & if\ and\ only\ if\ \mu_A(d) \leq \mu_B(e) \\ \mu_B(e), & if\ and\ only\ if\ \mu_A(d) \geq \mu_B(e) \end{cases} \qquad (5)$$

The maximization of lifetime can be formulated as an optimization problem. The variables of this optimization problem are routing parameters at nodes. When having sensed or asked to relay a data packet, each node needs to transmit this packet to a sink. However, it cannot send the packet directly to sinks except that it is a sink's neighbour. So normally a node needs to choose a neighbouring sensor as its next hop. When nodes are chosen as the next hops they will influence the energy consumption of the network as well as the lifetime. The process of Cluster Head selection consists of residual energy, neighbourhood index (Node centrality)and distance to BS as the input variables:

Residual Energy: It is an important factor for electing a node as CH since a CH node has to spend more energy than a member node. A CH node collects data from members, aggregates the collected data, and communicates it to BS.So, competent energy level is required for a CH for executing the above-mentioned activities.

Neighbourhood Index (N_C):Total number of one-hop adjacent nodes within R_c of a node is called node degree. $N_C$is a factor which determines how a node is located in the middle among its neighbours. Lower N_C value gives more chance of electing a node as CH:

$$N_C = \frac{\sqrt{\sum_{i=1}^{N_D} dist_i^2 / N_D}}{N_{tk_{dimension}}} \qquad (6)$$

In (5) N_D (node degree) corresponds to number of neighbours within the communication radius R_c of a node and $N_{tk_{dimension}}$ value is "M"in$M \times M$ field area and $dist_i^2$ represents distance with the i^{th}neighbour node. That is, in 100 m×100 m field area, $N_{tk_{dimension}}$ is 100 and 200 m×200 m field area and $N_{tk_{dimension}}$ is 200.

Distance to BS: The energy consumption for transmit-ting data increases with the increase in distance between transmitter and receiver nodes. From an energy conservation perspective, the distance between CH and BS should be minimized:

$$Distance\ to\ BS = \frac{d_i}{\propto . N_{tk_{dimension}}}$$
$$\propto = \frac{d_{max}}{N_{tk_{dimension}}} \qquad (7)$$

In (7) d_i is the distance between node i and the BS, d_{max} is the maximum distance between a node in the network and the BS, and ∝ is the network dimension specific constant.

Fuzzy Rule Set

The rules are designed as follows:

Table 1: Fuzzy Rule Set

S. NO	Residual Energy	Neighbour Index	Distance-to-BS	Output
1	Low	Low	Close	Small
2	Low	Low	Adequate	Small
3	Low	Low	Far	Small
4	Low	Med	Close	Small
5	Low	Med	Adequate	Small
6	Low	Med	Far	Small
7	Low	High	Close	Medium-Small
8	Low	High	Adequate	Small
9	Low	High	Far	Very-Small
10	Medium	Low	Close	Medium-Large
11	Medium	Low	Adequate	Medium
12	Medium	Low	Far	Small
13	Medium	Med	Close	Large
14	Medium	Med	Adequate	Medium
15	Medium	Med	Far	Medium Small
16	Medium	High	Close	Large
17	Medium	High	Adequate	Medium Large
18	Medium	High	Far	Medium Small
19	High	Low	Close	Medium Large
20	High	Low	Adequate	Medium
21	High	Low	Far	Medium Small
22	High	Med	Close	Large
23	High	Med	Adequate	Medium Large
24	High	Med	Far	Medium
25	High	High	Close	Very Large
26	High	High	Adequate	Medium Large
27	High	High	Far	Medium

V SIMULATION PARAMETER TABLE

Field Area	100×100 meter squares
Number of nodes in the field	100
Optimal Election Probability	0.1
Initial Energy of Node	0.5 J
Maximum Number of Round	4000
Energy Consumption of transmit and receive amplifier	500 nano joules per Round

V1. Proposed FIS Structure

The performance of proposed algorithms has been studied by means of MATLAB simulation. Figure 1 shows the proposed fuzzy inference system.

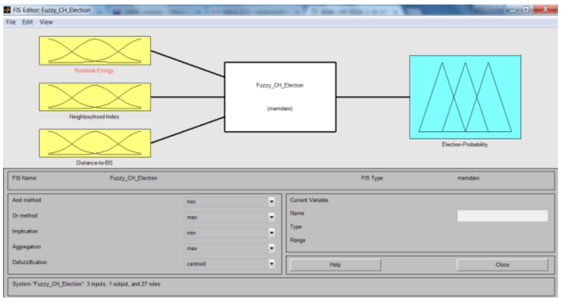

Figure 1: Proposed FIS structure

A fuzzy relation is a relationship between input variables, described by a membership function. Triangle and Trapezoidal membership functions are used because their degree is more easily determined. When we double click on any of the input (yellow plot) of FIS variables, the membership function opens up.

The decision will depend on the input values for the system.

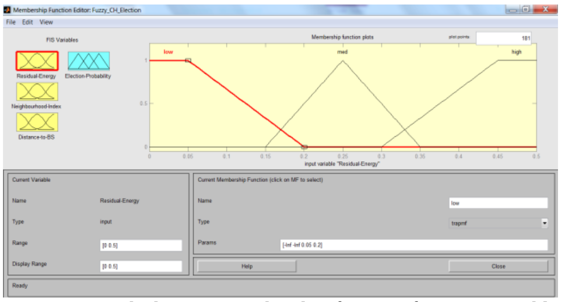

Figure 2: Graph showing membership function for input variable “Residual Energy”

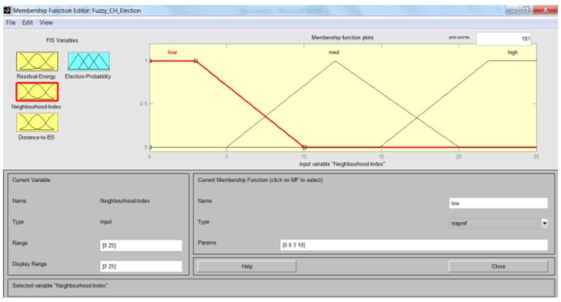

Figure 3: Graph showing membership function for input variable “Neighborhood Index”

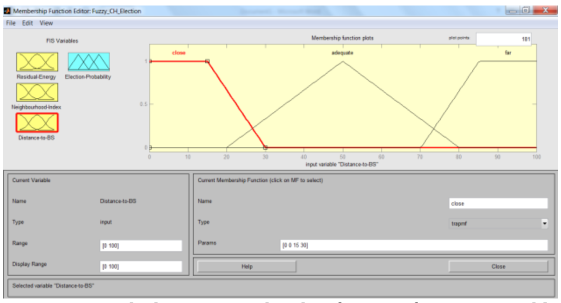

Figure 4: Graph showing membership function for input variable “Distance to BS”

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We can adjust the desired input by clicking anywhere in the plot. This will let changed value be highlighted with red index line. Same procedure is followed to modify other input values. When we release the line, a new calculation is performed and we can see the fuzzy process takes place.

The graph of various probabilities of output functions are shown in Figure 5.

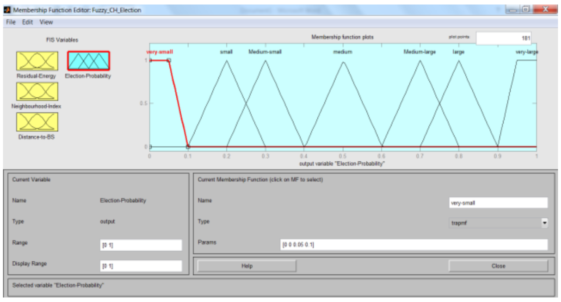

Figure 5: Membership Function plot for output

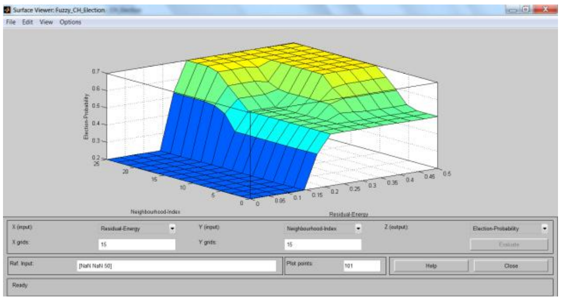

Figure 6: Graph for rule surface

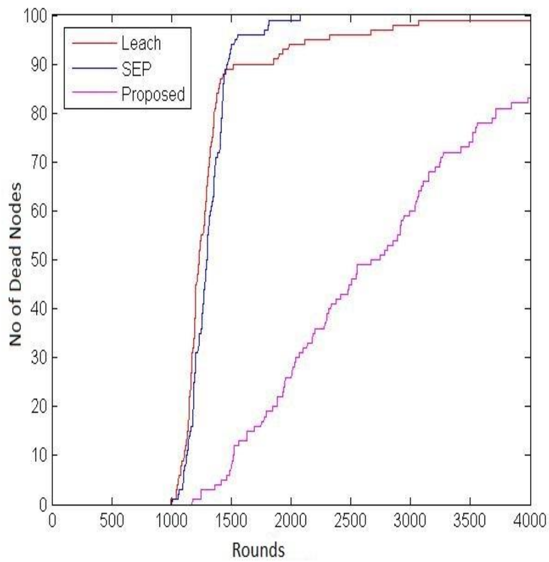

Figure 7: Comparative Analysis of Number of Dead Nodes

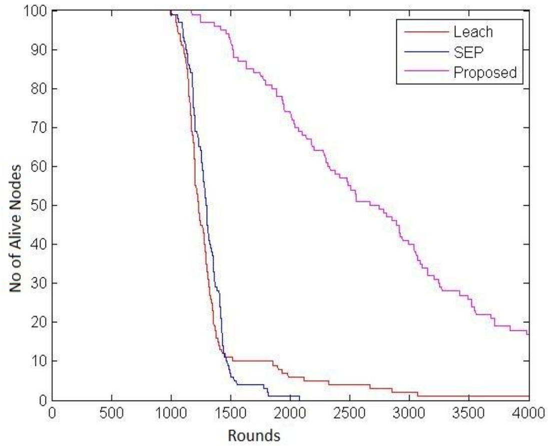

Figure 8: Comparative Analysis of Number of Alive Node

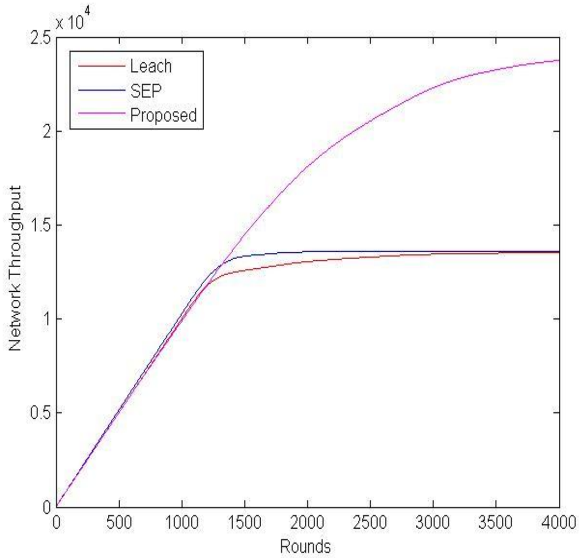

Figure 9: Throughput Comparison for different methods

V. CONCLUSION

As the wireless network do not have global addressing scheme so routing in sensor network has become a matter of attraction towards the wireless technology and it provide some unparalleled challenges as compared to traditional routing algorithm.

Under the conclusion of this work, several points were taken under consideration. For better understanding of our work that is evaluation of routing protocols for Wireless sensor network we have framed our work in two scenarios which consist of a simple WSN protocols, for now we have taken LEACH and SEP in consideration and performed a comparative study by implementing various topologies.

Fuzzy Logic has been a famous procedure used to take care of cluster head election in WSNs because of its straightforwardness, high calibre of result, quick joining and inconsequential computational complexity.

The proposed protocol uses the fuzzy data for the choice of cluster head to reduce the time consumed for cluster head election. To address problem of energy efficiency, we have designed FUZZY based cluster head election via a simulation study. This method minimizes overall utilization of energy in course while cluster head election process. So it prolongs the lifetime of system.

Comparative results shows that the proposed fuzzy based approach outperforms other methods.

Since the routing methods in WSNs are application specific, there is always scope for improvements. Moreover, future work can be carried out to improve the throughput of this method using other optimization algorithms.

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