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Energy Efficient Fuzzy Logic based Stable Election Protocol in Wireless Sensor Networks

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Abstract – **Wireless Sensor Networks (WSNs) are used to monitor/observe vast inaccessible regions through deployment of large number of sensor nodes in the sensing area. For majority of WSN applications, the collected data needs to be combined with geographic information of its origin to make it useful for the user; information received from remote Sensor Nodes (SNs) that are several hops away from base station/sink is meaningless without knowledge of its source. Furthermore, these sensor nodes are usually operated by the battery which is normally not easy to replace. Till now many routing protocols have been proposed for energy efficiency of both homogeneous and heterogeneous environments. This paper proposes a Fuzzy-based hybrid protocol for some nodes to transmit data directly to the base station. The proposed approach is based on fuzzy level information which minimizes the time for the selection of cluster head.**

Keywords – **Fuzzy Logic, SEP, Sensor Nodes, Wireless Sensor Networks.**

I. INTRODUCTION

Wireless sensor Network have stirred up the world of wireless communications. Figure 1 shows a WSN which uses high-frequency radio waves rather than wires to communicate between nodes, is another option for home or business networking. Individuals and organizations can use this option to expand their existing wired network or to go completely wireless. Wireless allows for devices to be shared without networking cable which increases mobility but decreases range. There are two main types of wireless networking [1]; peer to peer or ad-hoc and infrastructure. An ad-hoc or peer-to-peer wireless network consists of a number of computers each equipped with a wireless networking interface card. Each computer can communicate directly with all of the other wireless enabled computers. An infrastructure wireless network consists of an access point or a base station. In this type of network the access point acts like a hub, providing connectivity for the wireless computers.

Figure 1: Wireless Network [1]

Wireless Sensor Networks (WSNs) have emerged in the last few years providing a rich set of environmental information with a wide variety of useful applications. Hierarchical routing is to efficiently maintain the energy consumption of sensor nodes; by involving them in multihop communication within a particular cluster; and by performing data aggregation and fusion in order to decrease the number of transmitted messages to the sink. The paper has shown that the sensor networks that consist of identical sensors with equal capacity of sensing, computation, communication, and power is termed as Homogeneous. And if more than one type of sensors are used within a same network that is termed as Heterogeneous [2].

Wireless sensor networks are collection of several small, battery operated electronic devices known as sensors in order to monitor physical phenomenon such as temperature, pressure or humidity. With the technological advancements wireless sensor networks found enormous applications in various fields such as rescue operations, military fields etc. these networks are usually deployed in hostile areas

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or adverse environmental conditions where human involvement is not possible. Furthermore these sensor nodes are usually operated by battery which is normally not easy to replace. Hence energy efficiency is of prime need in wireless sensor networks [3]. Clustering is the key technique for diminishing energy dissipation in the network and enhancing the network stability. Nodes location may be far away from BS so direct communication is not feasible due to limited battery as this requires high energy. Many clustering protocols are designed in this regard. All the nodes belonging to cluster send their data to CH, where, CH aggregates data and sends the aggregated data to BS. Under aggregation, fewer messages are sent to BS and only few nodes have to transmit over large distance, so high energy is saved and over all lifetime of the network is prolonged. Energy consumption for aggregation of data is much less as compared to energy used in data transmission. Clustering can be done in two types of networks i.e. homogenous and heterogeneous networks. Nodes having same energy level are called homogenous networks and nodes having different energy levels called heterogeneous networks. Homogeneous protocols do not work efficiently under heterogeneous scenarios because these algorithms are unable to treat nodes differently in terms of their energy. For an energy efficient operation, optimal cluster formation is necessary to ensure that energy is consumed at a balanced rate. The operation of cluster based WSNs is broken into rounds. Each round is made up of cluster head selection, cluster formation and data transmission. The network lifetime is the number of rounds in which all nodes have non-zero energy. Most of the clustering algorithm relies on a random number generated by each sensor node in every round for the process of clusterhead election. If the generated random number is less than predefined threshold value then the current node will be elected as clusterhead node for current round. LEACH, DEEC and SEP are some of the algorithm which relies on this procedure of clusterhead election [4-7]. Recent studies shows that if parameters like residual energy, distance to base station, concentration and centrality are taken into account at the time of clusterhead election, network performance can further be improved [8-12]. In this context this paper is dedicated towards performance optimization of hybrid routing algorithm using fuzzy logic.

II. PROPOSED METHODOLOGY

We propose a Hybrid Routing protocol (HRP) with joint consideration of cluster head selection and routing discovery. The most important part of the proposed method is Fuzzy Inference System (FIS). The FIS has four parts and the architecture of the model is shown in Figure 2.

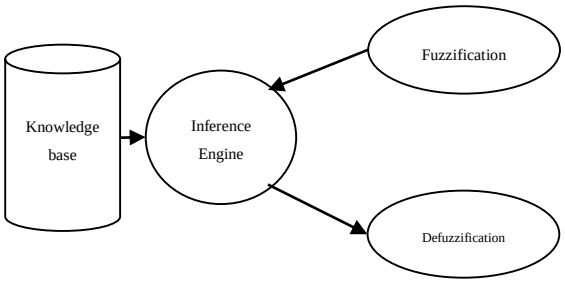

Figure 2: FIS Architecture

1. Fuzzification module: System inputs, which are crisp numbers, are transformed into fuzzy sets by applying a fuzzification function.
2. Knowledge base: It stores IF-THEN rules.
3. Inference Engine: By making fuzzy inference on the inputs and IF-THEN rules it simulates the human reasoning process.
4. Defuzzification module: The fuzzy set obtained by the inference engine is transformed into a crisp value.

Here in HRP protocol two types of heterogeneous nodes are used with clustering technique. Where n is the total no. of nodes in the network, m is the fraction of n having α time more energy than the normal node called super nodes. To increase the stable region, HRP attempts to maintain the constraint of well-balanced energy consumption. Super nodes have to become cluster heads more often than the normal nodes. The new heterogeneous setting (with super and normal nodes) has no effect on the spatial density of the network.

Suppose, Initial energy of each normal node=E_0

And the initial energy of each super node= $E_0(1+\alpha)$.

Total initial energy of super nodes=$n.m.E_0(1+\alpha)$

The total (initial) energy of the new heterogeneous network=$n.(1-m).E_0+n.m.E_0.(1+\alpha)=n.E_0.(1+\alpha.m)$ (1)

Total energy of the system is increased by a factor=$(1+\alpha.m)$

Specifically, the design goals are given as follows:

- Region-based clustering
- Hybrid Routing in Heterogeneous Sensor Network
- Cluster-Head Selection using Fuzzy Logic

In HRP, Cluster Head (CH) selection is based on fuzzy level information which minimizes the time for the selection of cluster head.

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Consider M × M region where base station is located nearly at the center. The total area is divided into fixed regions. The two types of sensor nodes (normal node and super node) are considered for data collection and transmission. Normal nodes are placed near the base station region and Super nodes having energy more than the Normal nodes are placed far away from the base station. The sensor nodes are uniformly distributed within the fixed regions. All sensors nodes and BS are stationary after deployment. The total energy of the heterogeneous network is calculated by equation (1). The proposed protocol has following sections:

A. Region-Based Clustering

An efficient routing protocol is one which consumes minimum energy and provides large coverage area. Minimum consumption of energy leads towards better network lifetime and stability. Where large coverage area is useful for gathering information from the whole network if the coverage area is not large, then there would be some smaller areas left unattended in the network. These unattended areas are referred to as coverage hole. To overcome this total area is divided into small regions and these regions are treated separately for the nodes distribution.

B. Region wise Routing in Heterogeneous Sensor Network

Two types of node are considered in the network. Normal nodes are placed near the base station and they transmit their data directly to base station. Super nodes having energy more than the normal nodes are deplore far away from base station [13].
The hybrid approach is used for transmitting data from normal nodes by direct and super nodes by using cluster head transmission. This leads efficient utilization of energy and improving lifetime of the network [14].

C. Cluster-Head Selection using Fuzzy Logic

The Hybrid Routing Protocol (HRP) takes various parameter 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. The proposed protocol is a fuzzy logic based protocol for the selection of cluster head. Hence we call it as Fuzzy-SEP i.e. Fuzzy stable election protocol. 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:

$$A = \{(d, \mu_A(d))\}, d \in D \quad (2)$$

$$B = \{(e, \mu_B(e))\}, e \in E \quad (3)$$

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. μ_A (d), μ_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:

$$\mu_A(d) = \begin{cases} 1 & if\ d \le TH_1 \\ (TH_1 - d)/TH_1 - TH_2 & if\ TH_1 < d < TH_2 \\ 0 & if\ d \ge TH_2 \end{cases} \quad (4)$$

$$\mu_B(e) = \begin{cases} 0 & if\ e \le TH_1 \\ (e - TH_1)/TH_2 - TH_1 & if\ TH_1 < e < TH_2 \\ 1 & if\ e \ge TH_2 \end{cases} \quad (5)$$

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 € D and e € E.
The fuzzy operator AND (∧) is used to find the fuzzy relation:

$$\mu_A(d) \wedge \mu_B(e) = \min\left(\mu_A(d), \mu_B(e)\right) = \begin{cases} \mu_A(d), \text{if and only if } \mu_A(d) \le \mu_B(e) \\ \mu_B(e), \text{if and only if } \mu_A(d) \ge \mu_B(e) \end{cases} \quad (6)$$

The maximization of lifetime can be formulated as an optimization problem.

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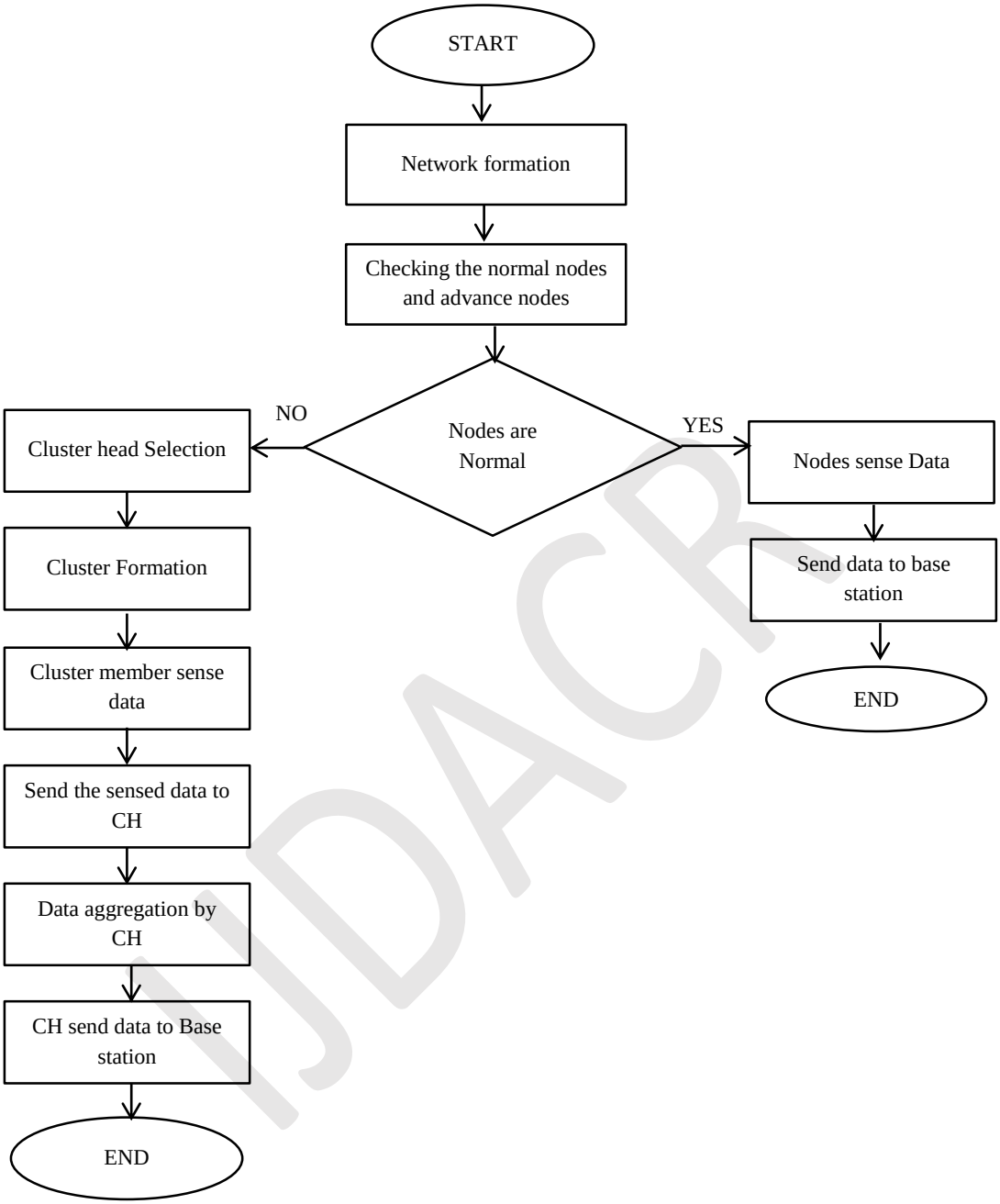

Figure 3: Flowchart of proposed Fuzzy-SEP

CH= Cluster Head; CM= Cluster Member; BS= Base Station
Start
Total Area = M X M meter
Total No. of Nodes = n
m = fraction of total no. of nodes (no. of Super Node
having α time more energy and)
n X (1-m) = no. of Normal Node
if node = normal
node sense data
data → BS
end if
else node = super
Cluster formation
CH selection using Fuzzy logic rule
CM sense data
data → CH
data aggregation by CH
CH → BS
end else
End

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III. Simulation Results

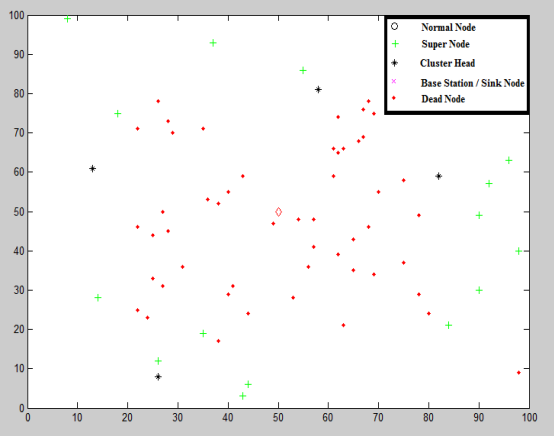

Figure 4: Network field at on completion of all rounds

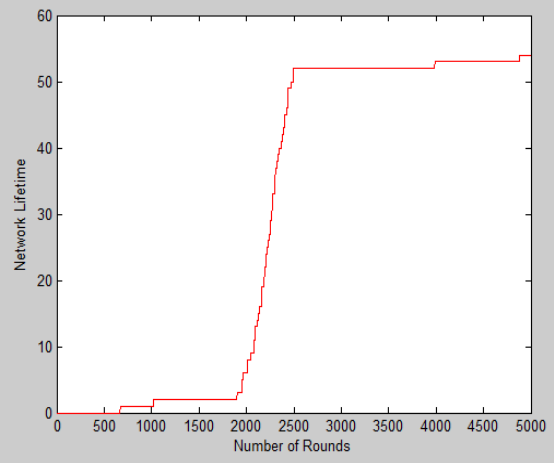

Figure 5: Graph between network lifetime and no. of rounds for Fuzzy SEP

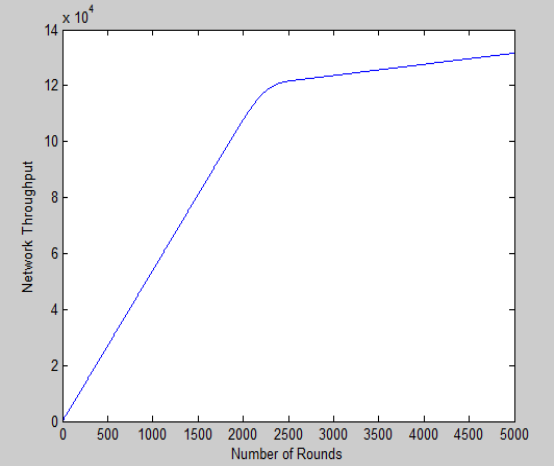

Figure 6: Graph between Network Throughput and no. of rounds for Fuzzy SEP

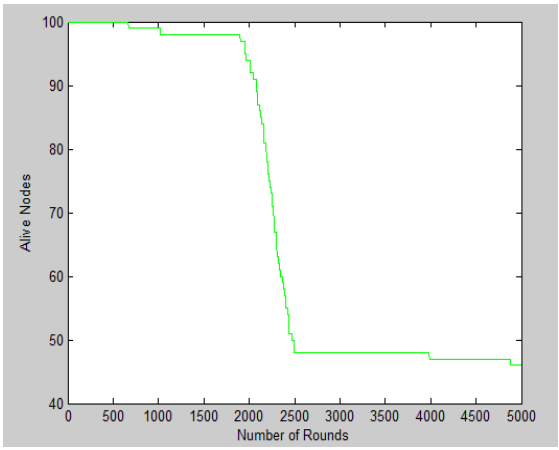

Figure 7: Graph between alive Nodes and no. of rounds for Fuzzy SEP

IV. Conclusion

In this paper, we propose a new routing scheme using fuzzy logic information for increasing network lifetime by improving energy efficiency and other performance parameters. We have thus implemented the proposed methodology and approach.

- The sensor nodes are usually operated by battery which is normally not easy to replace.
- Energy efficiency is of prime importance in wireless sensor networks.
- Clustering is the key technique for diminishing energy dissipation in the network and enhancing the network stability.
- But most of the clustering algorithm relies on a random number generated by each sensor node in every round for the process of clusterhead election.
- Recent studies shows that if parameters like residual energy, distance to base station, traffic load and centrality are taken into account at the time of clusterhead election, network performance can further be improved.
- Thus we propose a Fuzzy SEP protocol taking residual energy, traffic load and distance as input parameters and thus analyze and try to increase output parameters i.e. network lifetime and network throughput with respect to the number of rounds.

In future, the work can be extended by reducing the complexity of network further by optimizing the energy parameter along with the distance parameter or the nutrient function can be changed.

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