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Performance Analysis of Deterministic Stable Election Protocol Using Fuzzy Logic in Wireless Sensor Network

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***Abstract*—**In Wireless Sensor Network (WSN), the sensor containing motes (nodes) incorporate batteries that can lament at some extent. To upgrade the energy utilization, clustering is one of the prototypical approaches for split sensor motes into a number of clusters where one mote (also called as node) proceeds as a Cluster Head (CH). CH selection is one of the optimization techniques for enlarging stability and network lifespan. Deterministic Stable Election Protocol (DSEP) is an effectual clustering protocol that makes use of three kinds of nodes with dissimilar residual energy for CH election. Fuzzy Logic technology is used to expand energy level of DSEP protocol by using fuzzy inference system. This paper presents protocol DSEP using Fuzzy Logic (DSEP-FL) CH by taking into account four linguistic variables such as energy, concentration, centrality and distance to base station. Simulation results show that our proposed method gives more effective results in term of a lifespan of network and stability as compared to the performance of other clustering protocols.

***Keywords*—**Deterministic stable election protocol, energy model, fuzzy logic, wireless sensor network.

I. Introduction

TODAY, WSN is an emerging technique with day by day advancement in their protocols. WSN is an implant system that is used to sense environmental conditions like humidity, temperature, pressure, pollution, etc. Various applications of WSNs, like environment, industries, home, military, Vehicular movement, etc., which use sensors, exist [1]. WSNs consist of many portable nodes with limited power, memory, capabilities, etc. When the whole network is deployed, nodes keep on sense any environmental change and send the updates to the base station. It is noted that, data aggregation and synthesis is necessary for well-organized data and relevant data communication between the motes. Nodes can send only precise and accurate information to sink.

One of the major constraints is the energy consumption during the sensing, receiving and transmitting data to base station [2]. At some extend network is depleted due to low energy. Cluster based routing protocol is one of the well organized ideas in which sensor nodes are divided into a number of groups, and these groups are known as clusters. From the cluster nodes, only one node is elected as CH in one round which performs sensing and sending data. CH aggregates data and sends it to the base station. In this way, at some extend, nodes can save their energy and improve the lifespan of then network. Variety of clustering routing protocols has been projected with the CH election using fuzzy logic. Abbas et al. [3] enhance Low Energy Adaptive Clustering Hierarchy (LEACH) protocol using fuzzy logic in addition to genetic algorithm to improve the performance of the network. Three parameters are used such as energy, density, and centrality to elect best candidate CH. Proposed protocol increases performance and stability than that of LEACH, DEEC protocols. Baghouri et al. [4] enhance SEP Stable Election Protocol (SEP) performance with SEP-FL Stable Election Protocol using Fuzzy Logic (SEP-FL) by taking into account distance to BS and energy level. These parameters are divided into linguistic variables to make decision regarding CH election. Fuzzy Inference System (FIS) is divided into two parts, one for normal nodes and another one for intermediate nodes, where both are increasing the lifespan, stability of the network and consume less energy. Haifeng et al. [5] worked on inequality of energy consumption by using fuzzy logic. Based on analysis of consumption of energy, single hop message forwarding consumes energy lesser than that of multihop forwarding schema. Parameters to elect CH are: degree of closeness from CH and BS and degree of energy balance. The proposed protocol gave good energy balance and consumption. Raju et al. [6] proposed an advanced version of SEP protocol as Enhanced Stable Election Protocol with Fuzzy Logic (F-SEP). Three linguistic variables for fuzzy expert that are: density of nodes, threshold, and distance from BS. Stability was increased by 16%, whereas stability was increased by 30%. Sachin et al. [7] planned CH Election mechanism using Fuzzy Logic (CHUFL) using parameters like reach ability, energy, quality of link and distance to BS. The proposed protocol is 20% enhancement in energy efficient and 72% more data packets sent to destination. Mritunjayet al. [8] enhanced network performance using fuzzy logic technique. Three descriptors are used for CH election as: energy, distance and density of nodes. Simulation comparison shows increase in network lifespan and stability with other protocols.

This paper proposes a new protocol DSEP-FL that improves DSEP by using the Fuzzy Logic technique. Fuzzy logic makes real-time decision with the incorrect information. The BS selects the node as CH having maximum energy using four parameters that are energy level, distance from base station, the concentration of nodes, and centrality with respect to the

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entire CH. We can compare the proposed protocol with the previous clustering protocols.

II. Network Model

A prototypical WSN architecture in Fig. 1 consists of a number of sensor nodes, base station, and CH which are elected in each round. The node which has maximum energy than the other nodes is elected as a CH. Base station elects CH based on maximum energy. In every round, base station changes CH through which it can increases the lifetime of network and balance energy.

The WSN is serene of:

1. All the nodes are not stationary.
2. The base station is located far away from the sensor node and is immobile.
3. All the nodes in the network are energy constraint and are heterogeneous.
4. The base station performs CH selection and acts as coordinate.
5. Location finding system is operational with the sensor nodes [8].
6. Each node has GPS system to find their place and position.

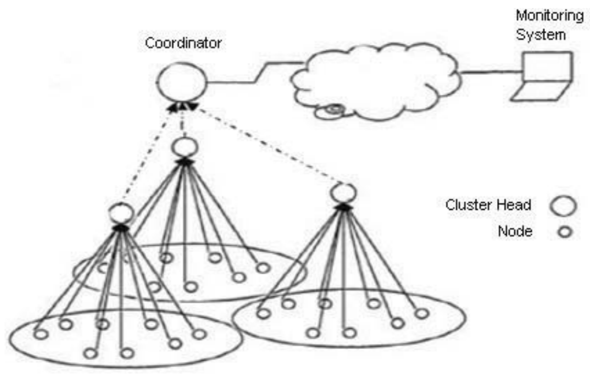

Fig. 1 WSN architecture [9]

III. DSEP

DSEP is advancement over Threshold Sensitive Energy Efficient Routing Protocol (TSEP) with the modified threshold formula which is depending on optimal probability of the nodes. DSEP increases the stability and network lifespan in the presence of heterogeneous network. DSEP is a heterogeneous protocol which uses three kinds of nodes that are normal nodes, intermediate nodes, and advanced nodes. Intermediate nodes have energy which lies between normal and advanced nodes, whereas advanced nodes have extra energy than that of intermediate nodes. Every type of nodes has different energy. CH consumes additional energy than cluster members for receiving, transmitting, and aggregated data. That is why CH selection always works in rounds. By rotating the CH, energy is balanced at some extend. Every cluster member elects optimal probability within 0 and 1, if that produced value is less than thresholds after that, node becomes CH. Threshold formula is shown in (1) [2]

$$T(Si) = \left\{\frac{pi}{1-\left(pi*rmod\frac{1}{pi}\right)}\right\} * \left\{Eresidual + \left(rsdiv\frac{1}{pi}\right) * \left(1 - Eresidual\right)\right\} \quad (1)$$

whereas pi is the optimal probability of the node to become CH.$r$is the round number. $E_{residual}$ is the remaining energy of the node. rs is the number of rounds in which a node has not become CH. If node becomes CH, then 'rs' is set to zero. Threshold value always depends upon the optimal probability of the nodes. DSEP has reference value of 'pi' which is different for the nodes. In [2], probability values are shown in (2)-(4):

$$pnrm = \frac{p}{(1+mA+xn)} * \frac{Eresidual}{Eaverage} \quad (2)$$

$$pin = \frac{p(1+\mu)}{(1+mA+xn)} * \frac{Eresidual}{Eaverage} \quad (3)$$

$$padv = \frac{p(1+A)}{(1+mA+xn)} * \frac{Eresidual}{Eaverage} \quad (4)$$

where m is the fraction of advanced nodes, A is the extra energy, x is the fraction of intermediate nodes, n is the total number of nodes, and $E_{average}$ is the average energy of the network.

IV. DSEP-FL: The Proposed Scheme

The proposed clustering heterogeneous method used the central principle of Fuzzy Logic that enhances the benchmark is used to select CH as it evaluates the parameters efficiently. Fuzzy Logic can handle uncertainties associated with human thinking, perception, cognition, etc. Fuzzy Logic can make the decision even when there are insufficient data for CH selection. In the Fuzzy Logic environment, we can express numeric data into language, that are known as linguistic variables. It can overcome the overheads of location information and calculate energy. Higher output means higher the chance of the sensor nodes to become a CH [10]. DSEP-FL using FIS, i.e. Mamdani model, is utilised for mapping the given inputs to an output [11]. Linguistic variables are the variables where values are words in the artificial and natural language. We have four types of linguistic variables as energy, distance to base station, the concentration of nodes and centrality. This proposed scheme can enhance the lifetime of the network by improving DSEP CH selection by using Fuzzy Logic.

A. FIS

FIS is mapped from the specified inputs to an output using Fuzzy Logic model. Two types of FIS are Mamdani-type FIS and Sugeno-type FIS. We use Mamdani method because it is well suited to human inputs, whereas Sugeno method is well suited for mathematical analysis (like linear mathematical expressions). Our FIS model for DSEP-FL is illustrated in Fig. 2. FIS consists of four parts denoted as Fuzzification, Rule Evaluation, Fuzzy Inference Engine, and De-fuzzification. Fuzzifier accepts crisp values as an input change into a fuzzy set. These results are transferred to de-fuzzifier through fuzzy inference engine and fuzzy rule evaluation. De-fuzzifier changes that fuzzy set into the crisp values for human understanding. Rule evaluation has simply a series of IF ELSE rules. Four parts of FIS are as follow [11]:

1. Fuzzification**:** Fuzzifier always accepts crisp values (understand by the human being) and converted into fuzzy values. These values are accepted by Defuzzification.
2. Rule Evaluation**:** Only IF ELSE rules are used to evaluate the results. IF use as the premise and THAN used as consequent. To find the highest value from the fuzzy inputs, we can use the inference (9) [12]:

$$Inference = 2e + ds + 1 - dt \qquad (5)$$

where e is the energy of the sensor node, ds is the density of sensor node within cluster and dt is the distance from the BS.

3. Fuzzy Inference Engine**:** Inference engine accepts both the inputs variables and IF-ELSE condition evaluate them and produce fuzzy inference.
4. Defuzzification**:** It can aggregate all the data from inference engine and transfer fuzzy set into crisp outputs which can be understood by human. Centroid technique is used to find the maximum value among the input values. The membership function for centroid is given in (10) [12]

$$Z^* = \frac{\int \mu Z(x)^* \, x \, dx}{\int \mu Z(x) \, dx} \qquad (6)$$

where μZ is the degree of membership.

B. Handling Uncertainties Using FIS

FIS handle with uncertainties by computing the chance for each node. As shown in Fig. 4, four linguistic variables for the FIS are energy, distance to the BS, concentration of nodes, and centrality with one output parameter which is the possibility of the node to become CH.

Energy: Energy of the node is the remaining energy of the node in proportion to total network energy.

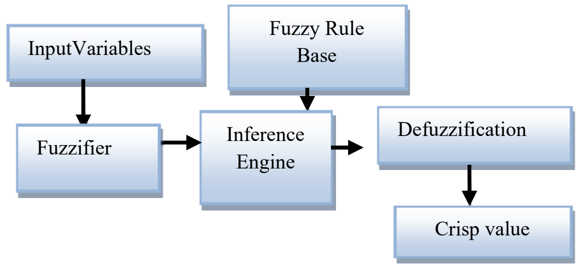

Fig. 2 DSEP-FL FIS [12]

1. Max energy= initial energy
2. Distance: Distance of the node from the BS.
3. Centrality: This variable shows how close a node is from the cluster.
4. Concentration: Number of nodes connected to the CH.

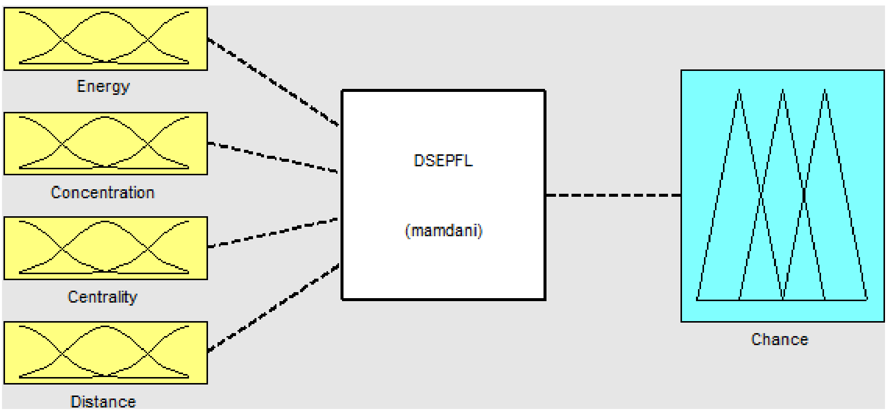

Fig. 3 DSEP-FL: four inputs, one output, 82 rules

The node with maximum value has become CH. Linguistic input variable is also known as membership function of the input variable. All the four input variables have different membership functions which depend upon value. It always depends upon the type of input variable. Membership functions for each input variable are divided into three parts because they are very flexible and improve the results. The mapping provides a common structure from which decisions can be made or patterns can be discerned [12]. Energy variable is separated into the low (L), medium (M) and high (H). Concentration is separated into the low (L), medium (M) and high (H). Centrality is divided into the close (C), adequate (A), and far (F). Distance is separated into the near (N), medium (M), and far (F). The output variable is the chance to become CH. Chance has seven linguistic variables that are: very small (vS), small (S), rare small (rS), medium (M), rare large (rL), large (L), very large (vL). Various membership functions exist in MATLAB tool. We can use Trapezoidal and Triangle membership function because their degree is determined easily. The Trapezoidal function is used for low and high, whereas Triangle function is used for medium. To get the chance to become CH, we can use Fuzzy IF-ELSE rules. From the Fuzzy IF-ELSE rules, we can get the chance to become CH. These Fuzzy variables have to be transferred into the crisp number by using De-fuzzification method. Fuzzy rules can be generated from either experimental data or heuristic.

V. Performance Evaluation

The proposed protocol is implemented and examined by using MATLAB tool. It presents the results of the proposed approach. Moreover, we can compare our DSEP-FL algorithm with the original DSEP. Results show that approach protocol performed better and increases the lifetime of the network.

A. Simulation Environment

We can consider 100 nodes randomly deployed over an area between (0, 0) and (100,100) with the BS deployed in the center (50, 50). This means horizontal and vertical coordinates of the sensor nodes. We run the simulation over 4999 s. Each data packet is 4000 bits. The simulation parameters are shown in Table I.

B. Results and Discussion

We use MATLAB tool for performance evaluation. This paper simulates and compares the results of SEP, DSEP, and DSEP-FL protocols on the basis of different performance metrics. Various performance metrics are:

1. Stability Period

This period is the time interval from the start of the network performance until the demise of initial node. We can simulate our results by considering various cases. Fig. 4 elucidates that lifespan of network for Eo=0.05 over 4999 rounds. We perceive that, in SEP protocol, all the nodes expire after 289 rounds. In DSEP protocol, all the nodes expire after 387 rounds, whereas in DSEP-FL protocol all the nodes expire after 563 rounds. From these results, it can be justified that DSEP-FL protocol can increase the network lifespan and stability of the network. Fig. 5 elucidates for Eo=0.3 where DSEP-FL protocol last node expires after 2364 rounds, but SEP and DSEP protocol last node expires after 1527 rounds and 2131 rounds. These results show that DSEP-FL increases the network stability.

2. Throughput of Network

Throughput of the network means CH active to receive and send data packets to sink. Figs. 6 and 7 illustrate that the existing DSEP protocol has three types of nodes, so throughput of the network is up to the round 295 for Eo=0.05 and 1688 for Eo=0.3, whereas the existing protocol SEP has two types of nodes with throughput of network which are up to round 213 for Eo=0.05, and 1413 for Eo=0.3. But, the DSEP-FL protocol increases the throughput of network up to round 387 for Eo=0.05 and 2129 for Eo=0.3.

VI. Conclusion

One of the major pitfalls in WSN is the utilization of sensor energy which leads to network dead and falls off stability of the network. To increase network lifespan various clustering routing protocols are elaborated. DSEP is one of the techniques to enhance network performance with three elevations of nodes. The proposed protocol DSEP-FL distributes workload and extends the lifespan of the network by using Fuzzy Logic. Selection of CH depends upon four parameters such as energy, concentration, centrality, and distance to BS. Simulation results performed by MATLAB tool show considerable improvement in network lifespan of DSEP-FL protocol as compared to SEP and DSEP protocol with randomly strew sensor nodes

TABLE I
Parameters for Simulation

S.no	Parameters	Value
1.	Number of nodes	100 [13]
2.	Network Field	(100, 100) [13]
3.	Message size	4000 bits
4.	Eo (Initial energy)	0.5 J
5.	Eelec	50 nJ/bits
6.	Eamp	0.0013 pJ /bit/m^2
7.	Efs	10 nJ/bit/m^4
8.	EDA	5 nJ/bits/signal
9.	Do (Threshold)	70 m
10.	Bandwidth	1 Mbps

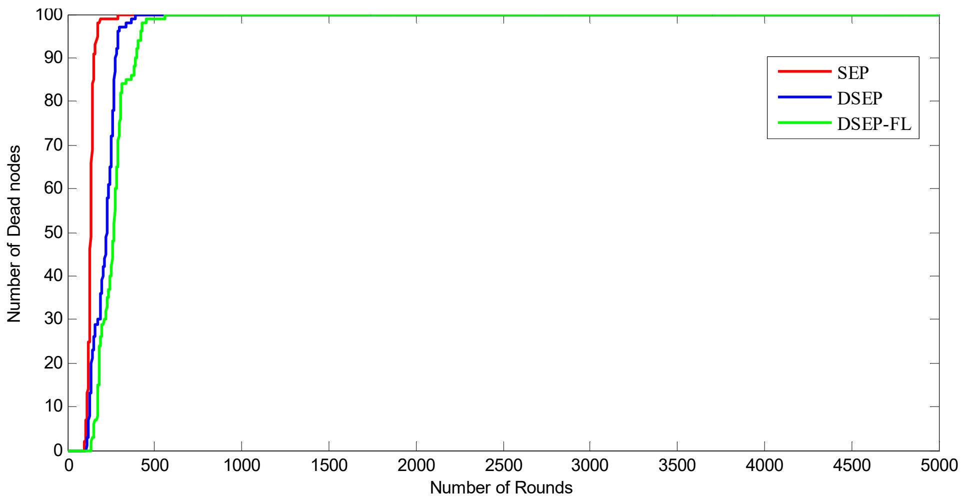

Fig. 4 Number of Dead node for Eo = 0.05

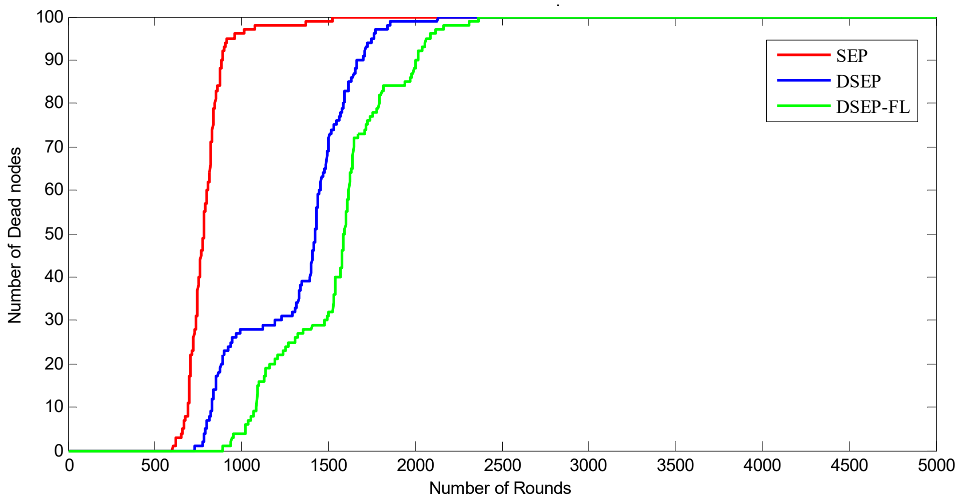

Fig. 5 Number of Dead node for Eo = 0.3

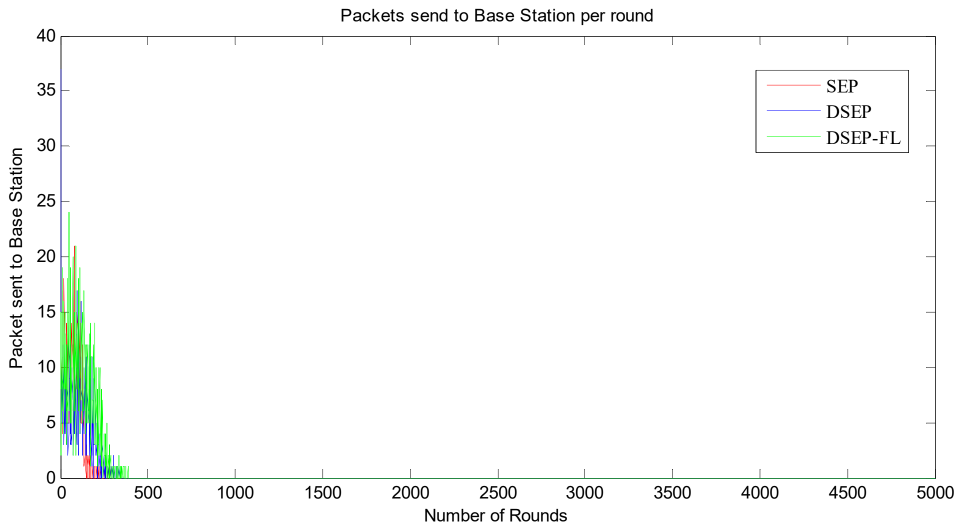

Fig. 6 Throughput of the network for Eo = 0.05

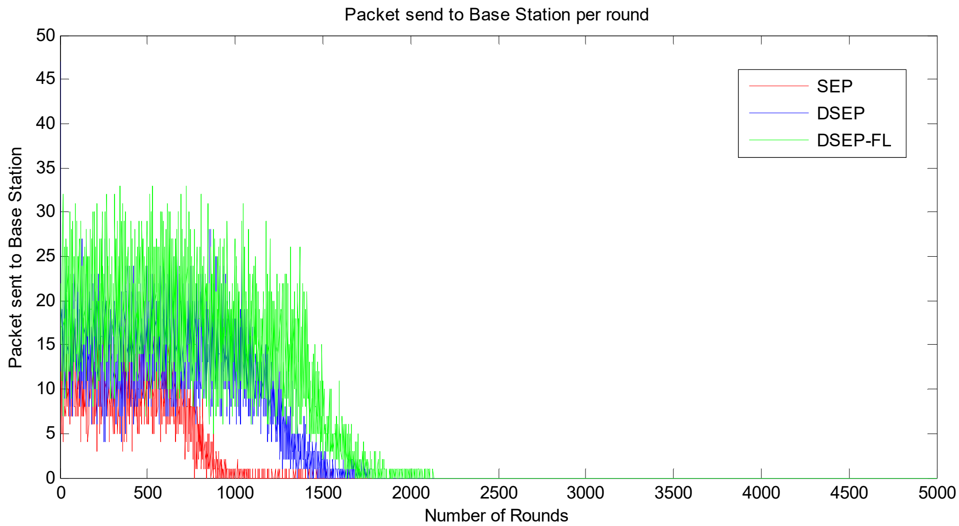

Fig. 7 Throughput of the network for Eo = 0.3

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