Fuzzy Logic based Load Balanced Clustering for Network Lifetime Enhancement in WSN's

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Abstract **-** Large number of small sensor nodes exists in WSN's for sensing and collecting information from the environment. In today's time, these sensor nodes were applied in under water, military area, health care, earthquake sensing and in dedicated areas with recent technologies. Sensor nodes have limited life time and have supplementary network life. Network lifecycle depends on many factors such as connectivity, residual energy, topology types, single hop, multi hop, distance from base station, distance to cluster heads and much more. Among the various solutions given, clustering is considered to be good solution and optimal cluster head selection leads to efficient energy consumption. This paper proposes fuzzy based multi-attributes clustering that balances load among sensor nodes and also gives energy efficient clustering. Here we have used some attributes such as delay, residual energy, distance to CH, standard deviation to average network lifetime and standard deviation to residual energy. Results and experimental analysis validates that the proposed methods outperforms other compared algorithms.

Index Terms – Fuzzy Rules, Clustering, MADM, Load-Balance, Network Lifetime.

I. INTRODUCTION

In wireless sensor network large number of sensor nodes senses the environment and collects data [1]. Sensors have limited battery power thus efficient energy consumption is an important issue [2] in wireless sensor networks. Here many researchers have given solutions, clustering is considered to be good among others. In clustering, sensor networks is divided into clusters, each cluster consists of cluster head and member nodes. Each cluster head collects data from its member nodes and aggregates these data for sensing it to base station [3, 4]. Clustering makes efficient use energy consumption by making clusters and cluster heads for sending data to the base station. Selection of cluster heads plays an important role in clustering thus optimal cluster heads selection will enhance network lifetime with efficient energy consumption. Cluster heads selection basically depends on various attributes which are conflicting in nature. In this paper we have applied hybrid method where multi-attributes decision making (MADM) TOPSIS is applied by considering four attributes and after that fuzzy rules has been applied for automatic weight assignment. The attributes considered in this paper are standard deviation of lifetime, Average residual energy of connected CHs, Average residual energy of disconnected CHs and Average distance to CHs, these are conflicting in nature thus proper co-ordination among them is made and fuzzy rules were applied for optimal cluster heads selection. Earlier classical methods such as LEACH [1], LEACH-C [5], HEED [6], EECS [7], EEHC [8] and much were only considering one attributes due to which optimal cluster heads selection is difficult. Thus for enhancing network lifetime and balancing load among sensor nodes proper co-ordination among sensor nodes should be made. Thus in paper we have applied hybrid approach of TOPSIS [9, 10] and Fuzzy rules for enhancing network performance.

In today's era where everything is based on technologies and connected to internet sensor nodes plays an important role. Thus optimal cluster heads will not only make efficient use energy consumption but also increase network lifetime while balancing load among sensor nodes. The rest of the paper is organized as: in section related work has been discussed where earlier work done has been presented. In third section we have discussed the proposed work where we have discussed proposed methodology. In section 4 result and experimental analysis has been discussed where experimental results has been shown and lastly we have concluded our results and focus on future work.

II. RELATED WORK

In the modern era many research works were done in clustering for enhancing network lifetime, balancing load among sensor nodes and energy efficient consumption. In [11] author has proposed fuzzy clustering approach for energy efficiency. In this approach the algorithm works in two part, in first part balanced clustering with self-organizing is focused and in second part by using firefly with differential evolution algorithm cluster head selection is done. In [12] author has calculated network lifetime using linear optimization problem to outspread dead of the first node as much as possible and uniform distribution of CH has also been applied for efficient energy consumption. In [13] author has deal with congestion control problem by using two fuzzy logic controllers (FLCs) for clusters organization. In this [14] author has proposed energy efficient fuzzy based cluster head selection for enhancing network lifetime where k mean clustering method is used and fuzzy logic has been used for efficient selection of cluster head. But all these works consider one attributes for cluster head selection thus for enhancing network lifetime we need to consider more attributes for optimal cluster head selection. Some of the works were also done by considering multi-attributes or multi-criteria in clustering. In [15] author has proposed multi-criteria based cluster heads selection were introduced considering seven attributes and among them all are contradictory to each other thus by using VIKOR (Visekriterijumsko KOmpromise Rangirange) co-ordination

among them is achieved. All seven attributes were used for optimal cluster heads were selected and proposed method enhances network lifetime. In [16] author has proposed hybrid meta-heuristics algorithms based clustering with multi-hop routing. Here quantum harmony search algorithms has been used to select optimal cluster heads and improved cuckoo search has been used for optimal route selection. Proposed method outperforms with other compared algorithms.

In clustering much work has also done using multi-attributes decision making where conflicting attributes were considered and proper co-ordination among them has been made but there is drawback of weight assignment. Thus in this paper we have taken the advantage of both methods where multi-attributes of sensor nodes were considered and fuzzy rules were applied for automatic weight assignments.

III. SYSTEM MODEL AND METHODOLOGY

A. *System Model*

In sensor network, sensor nodes transfer the data to cluster heads and cluster heads aggregate data for transferring it to base station. For transmission of collected data energy model is required, in this paper we have used energy model [2]. The energy model is depicted below and parameters used in our simulation is presented in table 1.

$$E_{tra} = E_{(tra-el)}(l) + E_{(tra-amp)}(l,d)$$

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(1)

$$E_{tra} = \begin{cases} l * E_{el} + l * \varepsilon_{fs} d^2, & if\ d < d_0 \\ l * E_{el} + l * \varepsilon_{amp} d^4, & if\ d \geq d_0 \end{cases}$$

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(2)

$$E_{rec} = E_{(rec-el)}(l) = lE_{el}\, E_{rec} = E_{(rec-el)}(l) = lE_{el}$$

(3)

Table 1: **Simulation values**

Name of the Parameters	**Value**
Origin	(0,0)
Area of Deployment	200*200
Base Station position	(75,125)
Sensor Nodes	100, 500
Initial energy of Nodes	.4 J

B. *Methodology*

In this section, proposed work will be described. In this paper, we have applied hybrid approach of MADM and Fuzzy rules for load balanced energy efficient cluster heads selection. Four attributes has been taken for cluster heads and their proper co-ordination has been made. After this fuzzy rules is applied to automate the weight of attributes. MATLAB is used for simulation and proposed algorithm has been deliberated in ALGORITHM. As in sensor networks there are much issues and choosing optimal cluster head is important for efficient energy consumption. As cluster head selection depends on various attributes thus we need consider it and in this paper we have considered four attributes. Attributes are conflicting in nature, proper co-ordination among is necessary thus by using MADM method proper co-ordination among has been made and after this we have applied fuzzy rules for automatic weight assignment so that performance of network has enhanced.

Attributes taken for cluster head selection explained below.

1) Residual energy of connected CHs (Avg_Eres_Con): Connected CHs are the CHs having distance to Base Station (BS) less than 'd_0' and it is useful because we are using hierarchical topology in which all the data passes through nearest CHs. So, nearest CHs should have higher energy than the nodes far away, Whereas, if the transmission is single hop then the nodes at higher distance should have higher energy than the nearer nodes.
2) Residual energy of disconnected CHs (Avg_Eres_Discon): Disconnected CHs are the CHs having distance to Base Station (BS) greater than or equal to 'd_0'. It shows the average residual energy of such CHs.
3) Average distance to CHs (Avg_Dist_CH): It shows the average distance of nodes to respective CHs.
4) Standard deviation of lifetime of CHs (Std_Life): It shows the standard deviation of lifetime of CHs if it collects and send the data to the sink.

Proposed methodology of our work has been explained below:

- Step1: We have randomly generated sensor nodes and evaluated their values.
- Step 2: TOPSIS method is applied for multi-attributes selection of cluster heads.
- Step 4: Fuzzy based rules were applied for automatic weight assignment of attributes.
- Step 5: Ranking of cluster heads.
- Step 6: Data aggregation and transfer of data were done.

TOPSIS method is applied for multi-attributes cluster heads selection and after that dragon fly algorithm is applied on it for optimal cluster heads selection that increases network lifetime with efficient energy consumption. The methodology has been given below mathematically:

First we have randomly generated twenty population and their values is calculated. After this we have applied TOPSIS based FUZZY RULE applied for optimal cluster heads selection.

Proposed Algorithm
1. Generation of sensor nodes.
n = denotes sensor nodes n
CH's= denotes cluster heads
2. Partition of network in clusters
3. TOPSIS based

FIGURE 1: PROPOSED ALGORITHM

IV. SIMULATION RESULTS AND EXPERIMENTAL ANALYSIS

For simulation and experimental analysis MATLAB software is used, where 20 alternatives were taken for cluster heads selection. In this we have taken four attributes of sensor nodes using MADM approach where fuzzy us applied for automatic weight assignment. Energy model [1] has been used in our simulation and runs for several rounds. Here, proposer co-ordination among conflicting attributes has been made and then fuzzy is applied for automatic weight assignment. In figure 2 we have represented fuzzy rule taken in our experiment and figure 3, 4 represents the results of our proposed algorithm. The results has been evaluated in terms of First_Node_Dead and Last_Node_Dead where our proposed algorithm outperforms LEACH, eeFA/DA, and LEACH-C. In energy consumption our proposed algorithm also perform better than the compared algorithms.

From result, it has been validated that our proposed algorithm performs better in energy consumption which enhance network lifetime and also balances the load among sensor nodes. We have taken, four scenario where we number rounds and number of sensor nodes has been changed giving same results in either case. In first scenario we have 100100 rounds and 150150 nodes and energy consumption also of proposed algorithm is better than the other. In second scenario we have increase number of rounds and sensor nodes i.e. 500 & 250500 & 250 and similarly we have taken in third, fourth scenario as well. Our proposed algorithm performs better than other compared algorithms. In proposed method we have applied MADM based fuzzy cluster heads selection where we have considered four attributes, as they are conflicting in nature proper co-ordination among them is done using MADM and after fuzzy is applied. The performance of network has increased by 27% percent and load among sensor nodes is also balance.
In fuzzy rules were made by automatic weight assignment by giving low, average and high value to the attributes and after that optimal cluster heads were selected. In figure 1 we have presented the membership function and also in figure 2 fuzzy rules were applied in simulation has been presented.

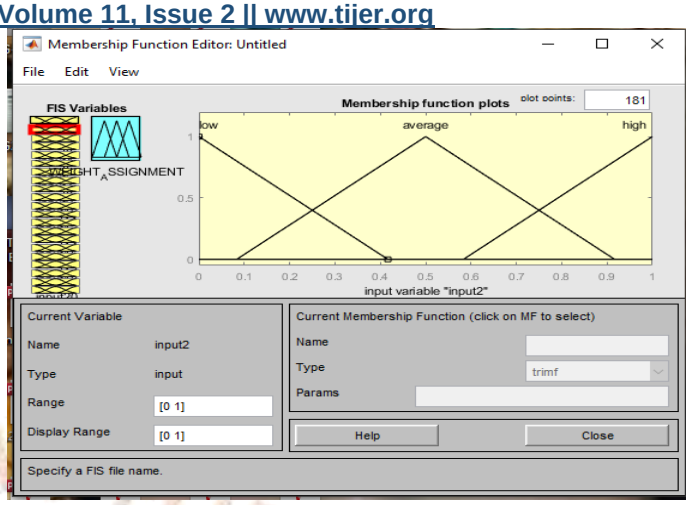
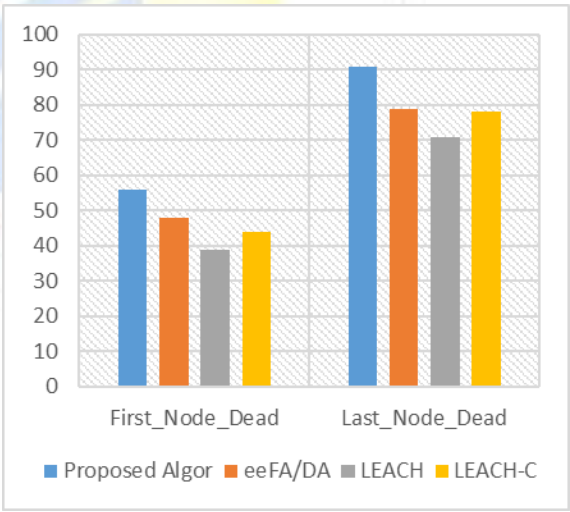
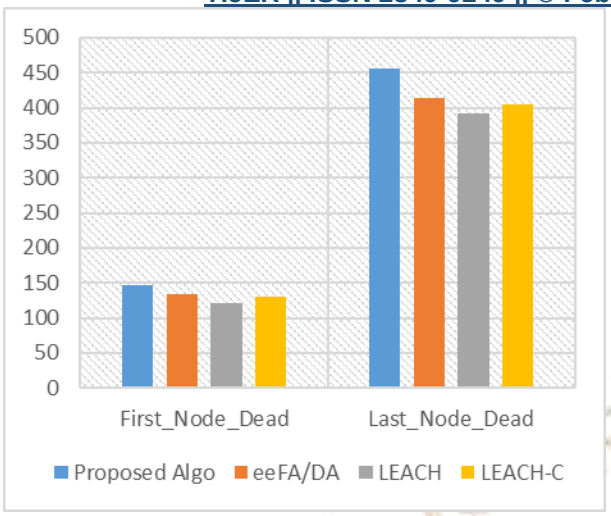


Figure 2: Membership Function

Figure 3: Fuzzy Rules



(a)



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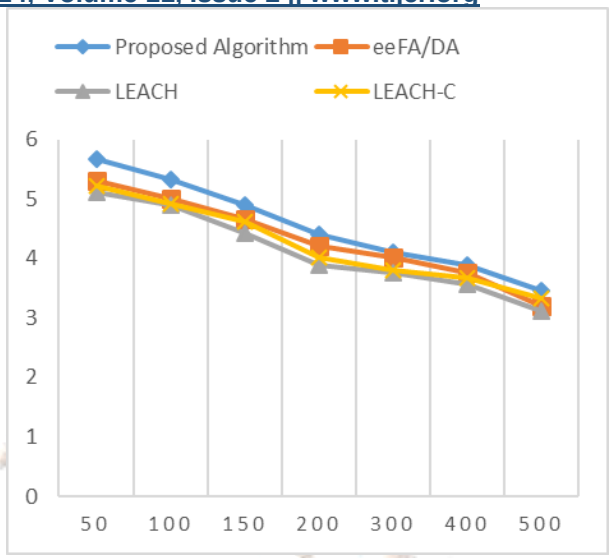
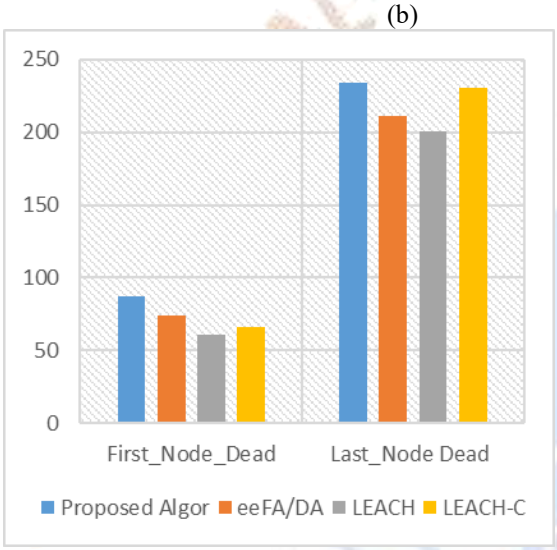


(a)



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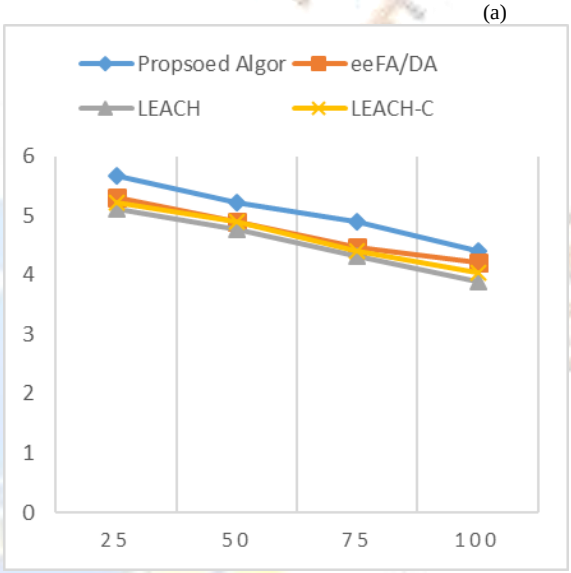
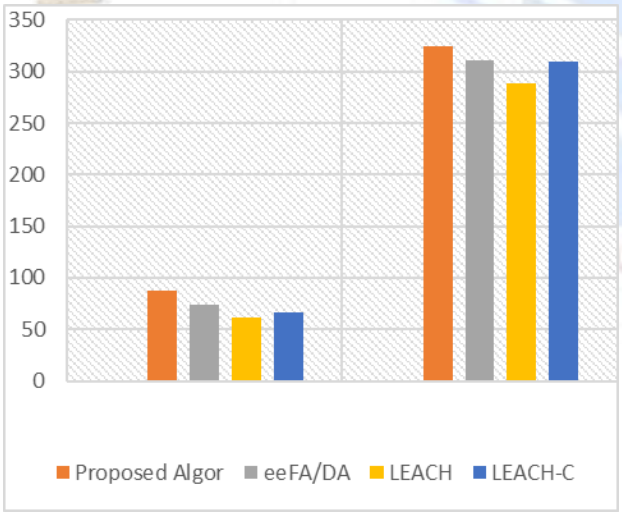
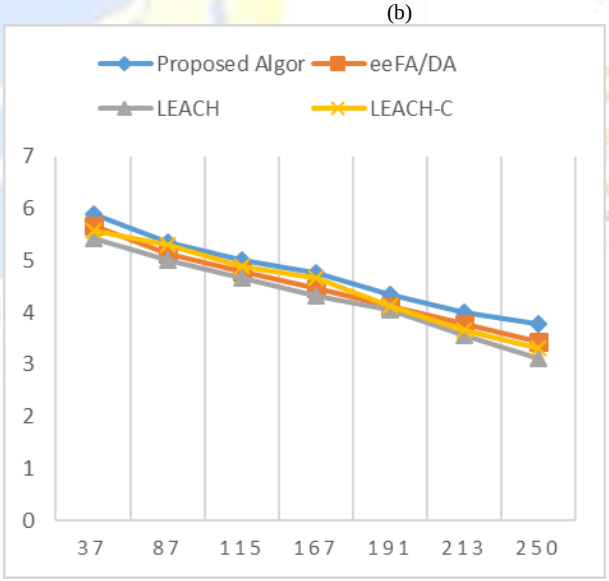


(b)

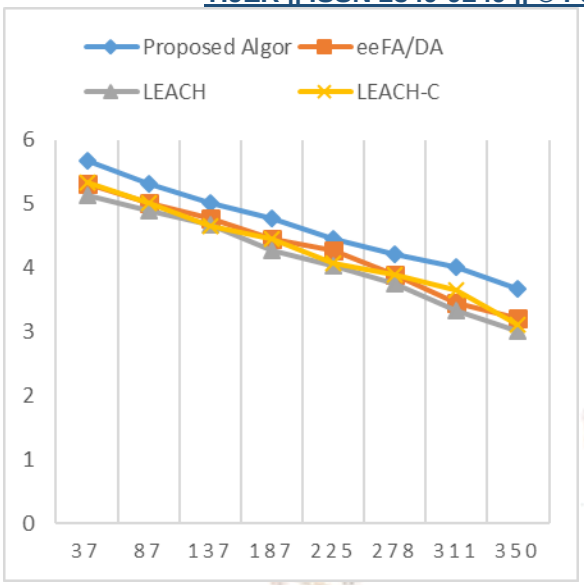


(d)



(c)

Figure 4: FND and LND of Proposed Algorithm (a, b, c, d)



(d)

Figure 5: Energy Consumption (a, b, c, d)

v. CONCLUSION

The proposed fuzzy based multi-attribute cluster head selection algorithm outperforms compared to other algorithms such as eeFA/DA, LEACH and LEACH-C. We have evaluate results in terms of FND, LND and Energy consumption. By considering multi-attributes for optimal cluster head selection using fuzzy rules it enhances network lifetime and balances load among sensor nodes because cluster heads selection depends on various attributes. Our proposed algorithm outperforms with other algorithms in terms of energy consumption, FND and LND. In future we will focus on meta-heuristics algorithms with multi-attributes for cluster heads selection which will enhance the performance of sensor network.

Declaration

Ethical Approval

Both Authors has given consent for publication.

Competing Interests

There is no conflict of interest between the Authors.

Authors' Contributions

Ankita Srivastava: Conceptualization, Methodology, Software Validation, Writing Original draft preparation.

P.K Mishra: Supervision, Methodology, resources, Validation, Investigation, Writing-Reviewing and Editing

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Availability of Data and Materials

No data was used for research described in the article.

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