Ameliorate the performance using soft computing approaches in wireless networks

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ABSTRACT

Wireless sensor networks are an innovative and rapidly advanced network occupying the broad spectrum of wireless networks. It works on the principle of "use with less expense, effort and with more comfort." In these networks, routing provides efficient and effective data transmission between different sources to access points using the clustering technique. This work addresses the low-energy adaptive clustering hierarchy (LEACH) protocol's main backdrop of choosing head nodes based on a random value. In this, the soft computing methods are used, namely the fuzzy approach, to overcome this barrier in LEACH. Our approach's primary goal is to extend the network lifetime with efficient energy consumption and by choosing the appropriate head node in each cluster based on the fuzzy parameters. The proposed clustering algorithm focused on two fuzzy inference structures, namely Mamdani and Sugeno fuzzy logic models in two scenarios, respectively. We compared our approach with four existing works, the conventional LEACH, LEACH using the fuzzy method, multicriteria cluster head delegation, and fuzzy-based energy efficient clustering approach (FEECA) in wireless sensor network. The proposed scenario based fuzzy LEACH protocol approaches are better than the four existing methods regarding stability, network survivability, and energy consumption.

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1. INTRODUCTION

Microcontrollers, networking technology, microelectromechanical systems, and nanotechnology have developed novel sensing and communication systems, referred to as wireless sensor networks. These new technologies have also contributed to the advancement of nanotechnology (WSNs). Figure 1 presents a schematic representation of a wireless sensor network.

They are skilled with opportunity providing technology which pings its role in a wide range of applications that bare minimum human intervention and play a critical function in making the future smarter. It uses spatially distributed self-governing nodes that use sensors to track any circumstance, either physical or environmental. WSN are continuing to be the most effective aid to sensing and monitoring tasks. The ability to work in uncertain environments, easy implementation, and high performances are among the many reasons for the popularity. Their primary benefit is the ability to be carried out to any discipline and in any surroundings. Unlike popular networks that, for their application, require extensively stringent conditions. In this mechanism, node energy, in conjunction with balancing glide, is the primary trouble in which sources are scarcely to claim approximately a way to reduce strength intake and prolong the network lifetime for the structure of WSNs using existing routing protocols.

In terms of productivity in WSNs, routing protocols [1], [2] play a vital role. Routing is one of the most challenging techniques on WSN. It is necessary to find the best path between the source node and the target node. This method is the mathematical portrayal of human concepts. The main motto of any network is the efficient and effective transmission of information between the source and the final destination. This routing is one of the best solutions to provide an efficient and best path for wireless sensor networks. In routing, in this work the clustering approach is chosen [3]–[9] for selecting the best way for intra-clustering and inter-clustering. The classification of routing protocols [10]–[12] relies upon two critical elements, i.e., first off, primarily based on network structure and secondly based on the protocol operation. The chore of discovering and retaining routes in WSNs is not minor, as energy restrictions and sudden changes in a node. WSN has attracted tremendous attention from academics and industry worldwide in the past, present, and future. The wide range of applications [13] of WSNs is flora and fauna, military, industrial, urban, environmental, health, education, entertainment [14]–[20]. WSN involve millions of nodes that operate together, detecting and transmitting ambient knowledge to the base station [21]. Apart from those have worked on multiple sink nodes in a WSN to increase the scalability and lifetime of the network [22]. Many cluster heads choose a specific sink node and try to send their data to the sink simultaneously. Sujith *et al.* [23] suggested an energy-efficient zone-based clustering algorithm for WSN. In their approach, they considered zones as clusters and zone monitor as cluster head. Bagga *et al.* [24] has initiated an fuzzy logic-based clustering routing (FLBCR) protocol as a routing scheme that applies fluctuating logic to determine the likelihood of selecting a node as a cluster head (CH) with a variable setting existence a network. For instance, an improved low-energy adaptive clustering hierarchy–mobile fuzzy (LEACH MF) protocol has been addressed to prolong lifetime of wireless sensor networks and they show in their results that the proposed modified parameter LEACH MF is better in performance and energy consumption [25]. This compared type1 and type2 fuzzy logic approach in choosing cluster head selection to increase the wireless sensor networks.

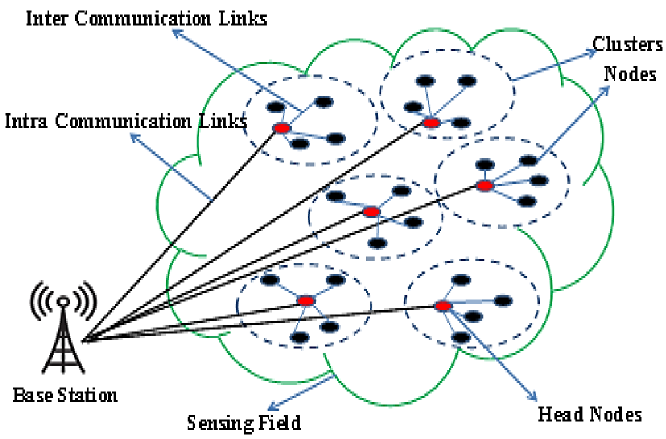

Figure 1. Layout of the wireless sensor network

2. METHOD

The main steps of our proposed fuzzy based LEACH approach are discussed in this section. In proposed algorithm, optimum number of head nodes are chosen using *Kopt* from (1).

$$Kopt = \frac{\sqrt{b}}{\sqrt{2*Th}} * \theta_0 * \frac{M}{dBS^2} \quad (1)$$

where b is the number of nodes, Th is the user defined threshold value, θ_0 is the computed ratio of energy dissipated in the free space (μ) by the energy dissipated in multi path (ϑ), M is the product of area of the network and sink coordinates, and dBS^2 is the first form of Euclidean distance of respective node to the sink node. The current heads of nodes calculate their $W\ i$ (output fuzzy parameter) value using the fuzzy method and broadcast the current head node (HN) message to all nodes coming under the communication range. The member nodes choose the nearest HN and join it to form clusters, respectively using dBS (2):

$$Distance = \min(\sqrt{(S_p - S_q)^2, (S_q - S_{bj})^2}) \quad (2)$$

where S_p and S_q are the length and width of the area of the network, respectively, and S_{bi} and S_{bj} are the sink coordinates. The residual energy *γRe* is calculated based on node coordinates Bb_{ij} and user defined threshold value *ψ*:

$$\Upsilon_{Re} = \Psi * \left(\sum_{i=1}^{b} H_i\right) - \left(\sum_{j=1}^{b} C_j\right) \quad (3)$$

where *i,j* are the coordinating positions of the node deployed in the network, *b* is the total number of nodes in the area, H is *x* coordinate of the node, and *C* is the *y* coordinate of the node. The calculations of *Dist* and *d* are shown in (4).

$$Dist_{min} = \sqrt{\sum_{q_{i,j=1}}^{b}((H_i - j)^2 + (C_i - C_j)^2)} \quad (4)$$

Initially, the cluster range will be considered as a value. Based on the calculated distance of the nodes with respect to the mote is checked. Whether the distance is less than the range of the cluster ℧*Clusterrange* in the network is calculated as (5):

$$\mho_{ClusterRange} = Dist \leq \mho_{ClusterRange} \quad (5)$$

$$d = \sqrt{\sum_{q_{i,j=1}}^{b}((S_{pi} - (H_i)^2) + (S_{qj} - (C_j)^2))} \quad (6)$$

where S_p and S_q are the length and width of the area of the network, respectively, and S_{bi} and S_{bj} are the sink coordinates.

$$Cost = \frac{Dist(T_{hn})}{((T_{hn}) - 1) + d} \quad (7)$$

where T_{hn} is the tentative head node, *d* is the minimum distance. The CH generates a time division multiple access (TDMA) schedule and sends it to its members until the CH and its members are fixed. The method of choosing a head node by the use of fuzzy procedure is done in 4 steps for Scenario 1.

a. Input and fuzzification: We fetch the three input values to the fuzzy inference system using (3), (2) and (7). Those input fuzzy parameters determine the cost of each enter based on the respective membership feature µ.
b. Fuzzy inferences: We offer the membership values acquired to our if then rules to acquire to our new fuzzy set output. Our fuzzy if then rules have more than one input and the bushy and operator which selects the minimal of our 3 membership values.
c. Aggregation: The aggregation is a unity of all the results from the implementation of all rules received. We use an OR fuzzy logic operator when we aggregate all our rules in our FIS as shown in Table 1. To produce a new aggregate fuzzy set which will be used in the defuzzification stage, this operator chooses the limit of the rule evaluation values.
d. Defuzzification: With a purpose to calculate the chance of each node, we mixture the effects of every rule the usage of Mamdani technique. This manner is known as defuzzification which unearths the threat price of each node to choose head node. In our proposed we use centroid method has been used for defuzzification.

The following components constitute the type-2 fuzzy logic model is done in 6 steps for Scenario 2 used in this work.

a. Fuzzification module: This module maps the crisp input to a type-2 fuzzy set using the gaussian2 membership function.
b. Inference engine: This module evaluates the rules in the knowledge base against the type-2 fuzzy set gotten from the fuzzification module to produce another type-2 fuzzy set.
c. Type reducer: Type reducer uses Karnik-Mendel algorithm to reduce an interval type-2 fuzzy set to type-1 fuzzy set.
d. Defuzzification module: It maps the fuzzy set produced by the type of reducer to a crisp output using the center of gravity defuzzification method.
e. Fuzzy knowledge base: This is a database of rules to be used by the inference engine.
f. Membership function: This mathematical equation helps the fuzzification module convert the crisp input into a fuzzy set.

Figure 2 represents pseudocode for the proposed algorithm.

Table 1. The fuzzy if then rules

Rule no	Residual energy	Cost	Distance	Chance
1	High	High	Low	High
2	High	Medium	Medium	Very high
3	High	Low	High	Medium
4	High	High	Low	Medium
5	High	Medium	Medium	Very high
6	High	Low	High	Medium
7	High	High	Low	Medium
8	High	Medium	Medium	Very high
9	High	Low	High	Medium
10	Medium	High	Low	High
11	Medium	Medium	Medium	Medium
12	Medium	Low	High	High
13	Medium	High	Low	High
14	Medium	Medium	Medium	Medium
15	Medium	Low	High	High
16	Medium	High	Low	High
17	Medium	Medium	Medium	Medium
18	Medium	Low	High	High
19	Low	High	Low	Low
20	Low	Medium	Medium	Medium
21	Low	Low	High	Very low
22	Low	High	Low	Very low
23	Low	Medium	Medium	Medium
24	Low	Low	High	Very low
25	Low	High	Low	Very low
26	Low	Medium	Medium	High
27	Low	Low	High	Very low

Algorithm 1: The Pseudocode for the Proposed algorithm

```
Input: Initialization
B = Total number of nodes
p = the desired percentage of Concurrent NH
r = current round
b= sensor node
for allalivenodesinthenetwork do
    rand_number = rand(0, 1)
    if rand_number < Th then
        b = ConcurrentHN
        ResidualEnergy = remainingenergyofb
        Count = Neighborsaliveofb
        MinimumDistance = DistancefrombtoBS
        Wi = FuzzyLogic(MinimumDistance, ResidualEnergy, Count)
    else
        b = member
    end
    for alltheConcurrentHNnodes do
        bcurrent = ConcurrentHNwithhighResidualEnergy
        ElectbcurrentasHN
        SendbcurrentisaHNtoallneighborConcurrentHNnodes
        SendConcurrentHNtoallneighborConcurrentHNnodes
        CHN_list = listofallConcurrentHNfromneighbornodes
        if bcurrent.chance¿ CHN.chance then
            advertiseElectedHN
        else
            broadcastsQuitHN
        end
    end
    for allaliveclustermembers do
        JointheclosestHN
    end
end
```

Figure 2. The pseudocode for the proposed approach

3. RESULTS AND DISCUSSION

All the following results in this paper are executed using MATLAB R2018a, which system configuration is Intel i5 processor (2.7 GHz) with 16 GB memory running on Windows 10 operating system. During the simulation process of data transmission between nodes from the source, through intermediate nodes and to the final destination nodes, each node uses its limited power, causing depletion. Any node which has reached a specific limit value of user choice is considered dead. The simulation parameters for performing our experiment are shown in Table 2.

Table 2. Simulation parameters

Type	Parameter	Value
Network topology	Number of nodes	100, 200, 500, 1000
	Number of clusters	20
	Network coverage	100, 100, 50, 175
	Deployment	Random
Radio model	Initial energy	2 J
	Energy consumption per bit	50 nJ/bit
	Energy loss in free space	100 pJ/bit/m2
	Energy loss in multipath	0.0013 pJ/bit/m4
Application	Simulation rounds	5000
	Packet header times	25 bytes
	Broadcast packet size	16 bytes
	Data packet size	3200
	Competition radius	25 m
	Bandwidth	1 Mb/s

Here we compared three protocols fuzzy LEACH, multi-criteria cluster head delegation based on fuzzy logic (MUCH) and the proposed fuzzy logic LEACH. Simulation was done in MATLAB simulator and initially a total of 100 nodes are randomly scattered in a 100 m–by–100 m square area. Depicts the number of sensor nodes alive in the network.

3.1. First node die

Figure 3 illustrates the point in time at which the first node is removed from the graph (FND). Based on the findings of the study, we are able to conclude that the FND can be found using the existing approaches even at the early rounds when compared with the methods that we have provided.

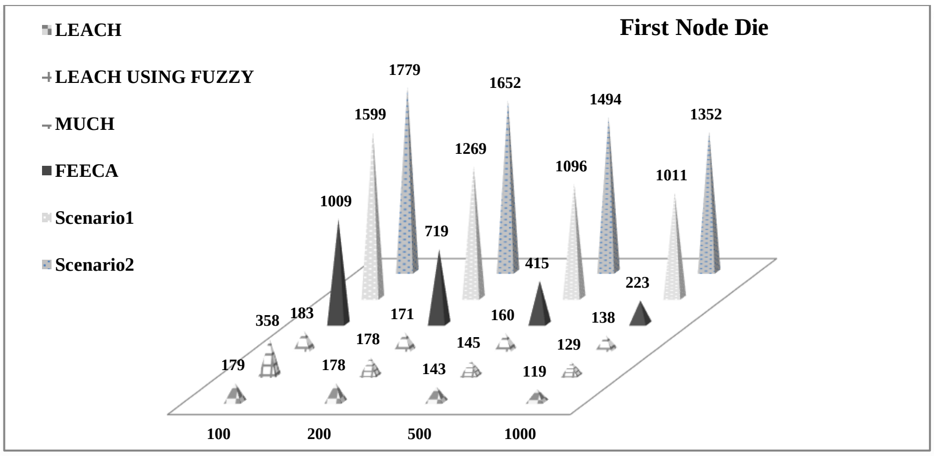

Figure 3. First node die

3.2. Quarter node die

Figure 4 illustrates the round at which a quarter of the nodes are removed from the graph (QND). Based on the findings of the investigation, we can conclude that, in comparison to our suggested technique, the existing methods produce at earlier rounds.

3.3. Half-node die

Figure 5 illustrates the round at which the half nodes are considered dead (HND). The findings of the study allow us to conclude that, in comparison to the way that we have presented, the existing methods produce HNDs at earlier rounds.

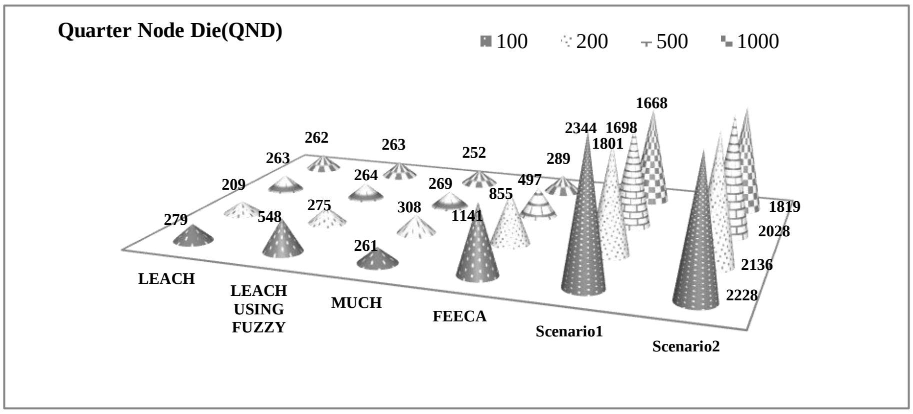

Figure 4. Quarter node die

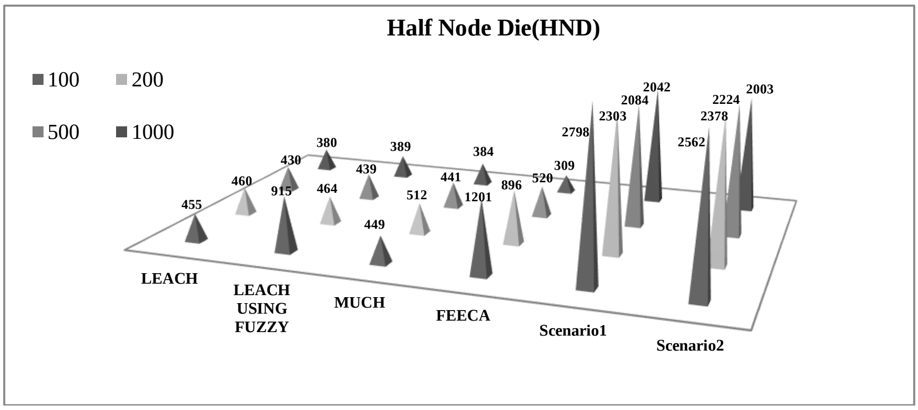

Figure 5. Half-node die

3.4. Number of nodes survived

Figure 6 shows the total number of nodes alive after completion of a certain number of simulation rounds. It is observed that in initial fuzzy LEACH and one of the improved fuzzy LEACHs termed MUCH, has 99% of nodes die after completing of 5000 rounds but in our proposed methods only 81% and 93% of nodes die these results better energy efficiency of the nodes as well as improved network lifetime. The comparison is made based on residual energy, lifetime of sensor nodes, and throughput. These three parameters are used as comparison parameters. Figures 7 to 9 show the comparative analysis in the following subsections, respectively.

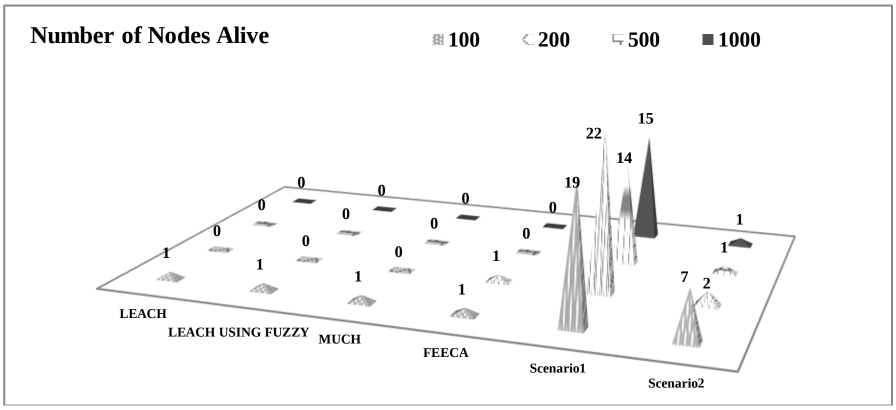

Figure 6. Nodes alive after completion of 5,000 rounds

3.5. Throughput

The term "universal performance" or "throughput" refers to the amount of packets that are received by the sink using its available resource. As can be seen in Figure 7, our suggested protocol has a higher throughput in comparison to LEACH, LEACH with fuzzy, MUCH, fuzzy-based energy efficient clustering approach (FEECA), and both of our proposed methods, which are Scenario 1 and Scenario 2, respectively.

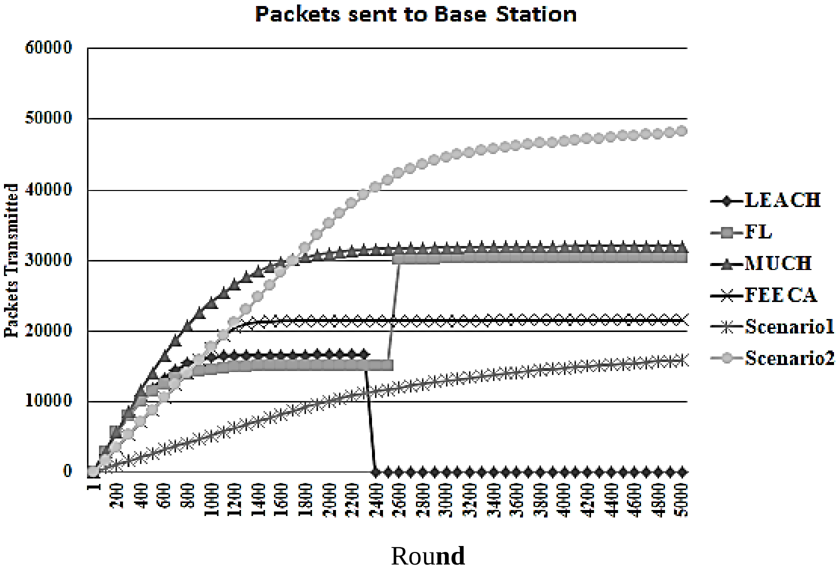

Figure 7. Performance of the node based on data transmission among nodes to mote

3.6. Lifetime of sensor nodes

The average network lifetime of the wireless network has been calculated using three mentioned routing protocols. Here, the forwarder node is regarded in each round to be the node with the most considerable rest energy. As Figure 8 shows, the average network life will be extended when the information is transferred from nodes to sinks through our suggested protocol routing. In other words, in terms of average network life, our proposed plan outperformed existing schemes.

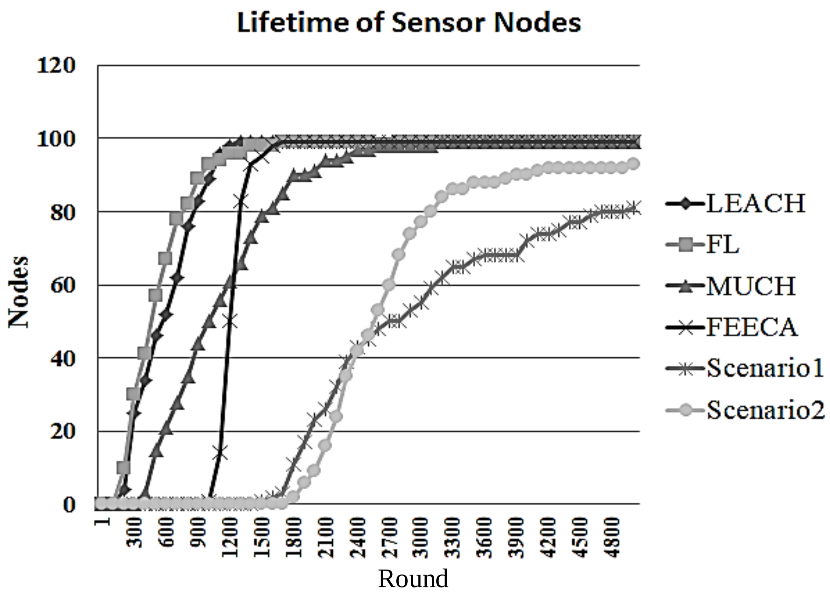

Figure 8. Lifetime of the sensor nodes in the network

3.7. Residual energy

In this experiment, we have considered the average residual energy of all the nodes as a measure of performance and compared our protocol to three others. Higher residual energy is essential to extend the network life. From Figure 9, we can see that this residual average power is above the three mentioned protocols.

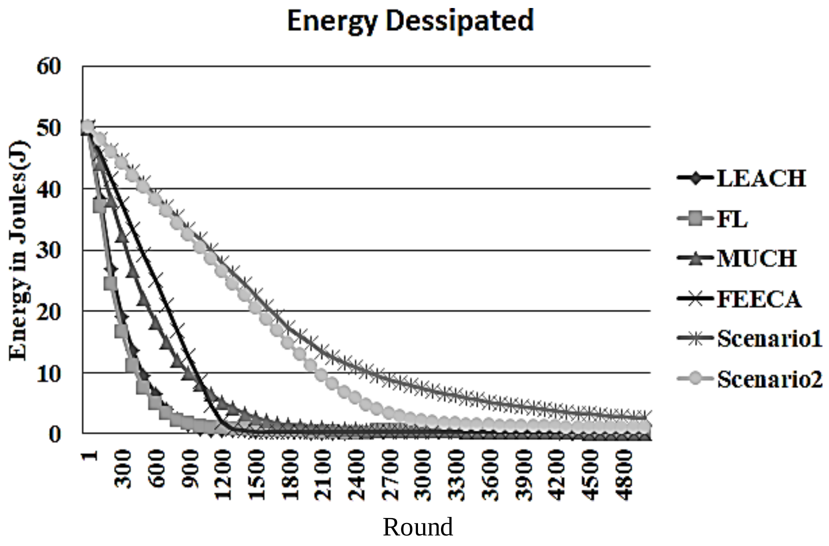

Figure 9. Total energy dissipated among the nodes during each round

4. CONCLUSION

Wireless sensor networks are becoming relevant in a broad range of emerging technologies. One of the challenges to WSNs is to reduce the use of resources and increase the networks' existence, for which routing may be a remedy. As the propagation energy is proportional to the distance between the sender and the receiver, the clustering mechanism minimizes energy use in routing. Using fuzzy reasoning, WSN can resist complicated mathematical models and provide considerable stability in the networks life to deal with uncertainty and interpretation. These suggested strategies described in both scenarios are a revision of the option of LEACH to select the optimal number of head node selection and select the best head node selection in any round during each cluster. The simulation findings indicate that our proposed solution delivers more robust results than four other existing state-of-the-art algorithms and proves to be more scalable after completing rounds in FND, QND, HND, and the number of nodes alive.

REFERENCES

[1] R. T. Ai-Zubi, N. Abedsalam, A. Atieh, and K. A. Darabkh, "Lifetime-improvement routing protocol for wireless sensor networks," in *2018 15th International Multi-Conference on Systems, Signals & Devices (SSD)*, Mar. 2018, pp. 683–687, doi: 10.1109/SSD.2018.8570628.

[2] J. N. Al-Karaki and A. E. Kamal, "Routing techniques in wireless sensor networks: a survey," *IEEE Wireless Communications*, vol. 11, no. 6, pp. 6–28, Dec. 2004, doi: 10.1109/MWC.2004.1368893.

[3] J. A. Patel and Y. Patel, "The clustering techniques for wireless sensor networks: a review," in *2018 Second International Conference on Inventive Communication and Computational Technologies (ICICCT)*, Apr. 2018, pp. 147–151, doi: 10.1109/ICICCT.2018.8473153.

[4] H. Yetgin, K. T. K. Cheung, M. El-Hajjar, and L. Hanzo, "A survey of network lifetime maximization techniques in wireless sensor networks," *IEEE Communications Surveys & Tutorials*, vol. 19, no. 2, pp. 828–854, 2017, doi: 10.1109/COMST.2017.2650979.

[5] K. A. Darabkh, W. S. Al-Rawashdeh, R. T. Al-Zubi, and S. H. Alnabelsi, "C-DTB-CHR: centralized density- and threshold-based cluster head replacement protocols for wireless sensor networks," *The Journal of Supercomputing*, vol. 73, no. 12, pp. 5332–5353, Dec. 2017, doi: 10.1007/s11227-017-2089-4.

[6] L. XingGuo, W. JunFeng, and B. LinLin, "LEACH protocol and its improved algorithm in wireless sensor network," in *2016 International Conference on Cyber-Enabled Distributed Computing and Knowledge Discovery (CyberC)*, Oct. 2016, pp. 418–422, doi: 10.1109/CyberC.2016.87.

[7] V. Kadrolli and J. Agarkhed, "Soft computing routing techniques in wireless sensor network," in *2016 2nd International Conference on Advances in Electrical, Electronics, Information, Communication and Bio-Informatics (AEEICB)*, Feb. 2016, pp. 748–751, doi: 10.1109/AEEICB.2016.7538395.

[8] B. Bhushan and G. Sahoo, "Routing protocols in wireless sensor networks," in *Computational intelligence in sensor networks*, 2019, pp. 215–248.

[9] M. F. S. Yagoub, J. J. P. C. Rodrigues, O. O. Khalifa, A. B. Mohammed, and V. Korotaev, “Service redundancy and cluster-based routing protocols for wireless sensor and mobile ad hoc networks: A survey,” *International Journal of Communication Systems*, vol. 33, no. 16, 2020, doi: 10.1002/dac.4471.

[10] H. S. Bazzi, A. M. Haidar, and A. Bilal, “Classification of routing protocols in wireless sensor network,” in *International Conference on Computer Vision and Image Analysis Applications*, Jan. 2015, pp. 1–5, doi: 10.1109/ICCVIA.2015.7351790.

[11] A. Krishnamoorthy and V. Vijayarajan, “Energy aware routing technique based on Markov model in wireless sensor network,” *International Journal of Computers and Applications*, vol. 42, no. 1, pp. 23–29, 2020, doi: 10.1080/1206212X.2017.1396423.

[12] J. Tan *et al.*, “An adaptive collection scheme-based matrix completion for data gathering in energy-harvesting wireless sensor networks,” *IEEE Access*, vol. 7, pp. 6703–6723, 2019, doi: 10.1109/ACCESS.2019.2890862.

[13] D. Kandris, C. Nakas, D. Vomvas, and G. Koulouras, “Applications of wireless sensor networks: An up-to-date survey,” *Applied System Innovation*, vol. 3, no. 1, Feb. 2020, doi: 10.3390/asi3010014.

[14] K. A. Darabkh and J. N. Zomot, “An improved cluster head selection algorithm for wireless sensor networks,” in *2018 14th International Wireless Communications & Mobile Computing Conference (IWCMC)*, Jun. 2018, pp. 65–70, doi: 10.1109/IWCMC.2018.8450446.

[15] I. A. T. Hashem *et al.*, “The role of big data in smart city,” *International Journal of Information Management*, vol. 36, no. 5, pp. 748–758, Oct. 2016, doi: 10.1016/j.ijinfomgt.2016.05.002.

[16] D. P. Agrawal, “Applications of sensor networks,” in *Embedded Sensor Systems*, vol. 8, no. 9S3, Singapore: Springer Singapore, 2017, pp. 35–63.

[17] B. Rashid and M. H. Rehmani, “Applications of wireless sensor networks for urban areas: A survey,” *Journal of Network and Computer Applications*, vol. 60, pp. 192–219, Jan. 2016, doi: 10.1016/j.jnca.2015.09.008.

[18] S. R. Jino Ramson and D. J. Moni, “Applications of wireless sensor networks — A survey,” in *2017 International Conference on Innovations in Electrical, Electronics, Instrumentation and Media Technology (ICEEIMT)*, Feb. 2017, pp. 325–329, doi: 10.1109/ICIEEIMT.2017.8116858.

[19] T. Khan *et al.*, “A novel and comprehensive trust estimation clustering based approach for large scale wireless sensor networks,” *IEEE Access*, vol. 7, pp. 58221–58240, 2019, doi: 10.1109/ACCESS.2019.2914769.

[20] S. S. Desai and M. J. Nene, “Node-level trust evaluation in wireless sensor networks,” *IEEE Transactions on Information Forensics and Security*, vol. 14, no. 8, pp. 2139–2152, Aug. 2019, doi: 10.1109/TIFS.2019.2894027.

[21] D. Agrawal and S. Pandey, “Optimization of the selection of cluster-head using fuzzy logic and harmony search in wireless sensor networks,” *International Journal of Communication Systems*, vol. 34, no. 13, Sep. 2021, doi: 10.1002/dac.4391.

[22] A. Shahidinejad and S. Barshandeh, “Sink selection and clustering using fuzzy-based controller for wireless sensor networks,” *International Journal of Communication Systems*, vol. 33, no. 4, Aug. 2020, doi: 10.1002/dac.4557.

[23] A. Sujith, D. R. Dorai, and V. N. Kamalesh, “Energy efficient zone-based clustering algorithm using fuzzy inference system for wireless sensor networks,” *Engineering Reports*, vol. 3, no. 4, Apr. 2021, doi: 10.1002/eng2.12310.

[24] S. Bagga, A. Goyal, G. Gupta, and D. K. Sharma, “FLBCR: Fuzzy logic based clustering routing protocol,” in *2019 10th International Conference on Computing, Communication and Networking Technologies (ICCCNT)*, Jul. 2019, pp. 1–7, doi: 10.1109/ICCCNT45670.2019.8944547.

[25] S. Sharma and N. Mittal, “An improved LEACH-MF protocol to prolong lifetime of wireless sensor networks,” in *2018 IEEE 8th International Advance Computing Conference (IACC)*, Dec. 2018, pp. 174–179, doi: 10.1109/IADCC.2018.8692096.

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