J. Electrical Systems 20-3 (2024): 3302-3307

Rashmi Sonkar[1]

Dr. Shish Ahmad[2]

Smart Routing Protocol for WSN: An Energy and Load Balancing Platform

Journal of Electrical Systems

Abstract: - The longevity of a tuner sensor system is significantly impacted by three critical factors: node gathering, routing pattern determination, and collection maintenance. In addition to these three characteristics, this study presents a clustered routing protocol that uses fuzzy logic to improve network load balancing and energy efficiency. The routing algorithm chooses the best CHs and establishes the best routing paths by figuring out the most optimal route. Fuzzy logic rules founded on a distinct fitness purpose that takes load complementary, lowest energy consumption, and new determination conditions into account enable the algorithm to rapidly converge. In addition, an energy-efficient adaptive behavior is offered to maintain the clusters while reducing energy usage even more. The suggested approach outdoes LEACH, PEGASIS, and Q Learning-based steering techniques in terms of energy efficiency, load matching, meeting haste, and longevity, according to simulation data.

Keywords: WSNs, clustering, multi-hop routing, energy and load balancing CHs.

I. INTRODUCTION

Wireless sensor networks (WSNs) find extensive application in conservational monitoring, intellectual transportation, disaster prevention, and space examination, owing to the rapid advancements in information technology. WSNs comprise various sensors coordinated into hubs, with energy conservation being a critical concern to enhance network longevity, given the limited resources and energy of WSN nodes. Clustering of nodes and selection of cluster heads (CHs) to supervise clusters form the basis of energy-efficient clustering routing, which has proven to be efficient, reliable, and scalable. One of the pioneering protocols in WSN clustering routing is the LEACH, known for its advantages such as reduced overhead, balanced energy distribution, and prolonged network lifetime. However, LEACH suffers from issues such as random CH selection, fixed round time leading to increased control message overhead, and uneven energy consumption.

Substantial efforts have been made to improve LEACH's performance through various approaches, resulting in significant advancements in clustered routing techniques. The typical stages of clustering routing include gathering, routing, and gathering preservation. The selection of CHs and building of collections are fundamental steps in clustering, with multiple approaches available for CH selection categorized into probability-based, weight-based, and heuristic-based techniques. Probability-based methods designate nodes as CHs based on threshold values, while weight-based techniques choose nodes with large weights as CHs to address premature node death issues. However, both approaches may not effectively solve the NP-hard problem for clustering and can be challenging due to local decision-making and network dynamics.

On the other hand, NP-hard problems can be roughly solved using heuristic-based techniques such fuzzy logic derivation, PSO, bat algorithm, genetic algorithm, differential evolution, and consensus search. To find the best CHs, these heuristic algorithms use either local or global search techniques. The uniform and energy-efficient clusters are formed by each selected CH broadcasting an advertisement message; the normal nodes pick the CHs according to residual energy and received signal intensity. Routing pathways are generated using weight-based and heuristic-based techniques, which are similar to cluster selection techniques. These methods assign weights to potential relay nodes based on factors such as the distance to the next hop CHs and the remaining energy in the future hop CHs. However, because of network dynamics and local navigation, choosing the optimal routing paths is difficult. Therefore, to determine the best routing patterns for each CH and encourage balanced energy usage and an extended network lifetime, methods including fuzzy logic, PSO, ant colony optimization, and GA are used.To maintain balanced energy consumption among nodes, cluster maintenance involves rotating CHs

[1] [1*,2]Dept of Computer Science and Engineering, Integral University, Lucknow.

[1]rashmiso@student.iul.ac.in, [2]shish@iul.ac.in

periodically. Traditional approaches, such as LEACH, use fixed round times for cluster reformation, but determining the ideal round time poses challenges and can lead to untimely depletion of CHs with low residual energy, halting communication. Variable round time or CH substitution strategies are proposed to address this issue, preventing the premature depletion of CHs and ensuring normal network communication. These approaches significantly reduce the number of rotations, minimize energy ingesting, and prolong the network's generation.

Fuzzy Logic based directing procedure:

The recommended routing protocol, an energy-efficient fuzzy logic-based cluster-based routing system for wireless networks, is explained in this section. Within the network, devices can communicate locally to improve next-hop selection and optimize energy consumption. Every device in the vicinity that is capable of overhearing a packet uses the information included in the packet header to adjust its routing table. The packet header contains the sender's local data, including device ID, remaining energy, position coordinates, and hop count. This method has three parts, similar to previous cluster-based routing systems: network configuration (including cluster head election), data transmission, and cluster construction.

(a) Network Setup and Cluster Head Election: This phase involves two parts. Initially, devices compute their initial fitness value using local information obtained during network setup. The base station initiates this process by broadcasting its position coordinates in a heartbeat transmission. Equations (1), (2), and (3) are used by each device to determine the initial fitness value based on its early vigor level and hop count when it receives the packet from the base position. The device also records the position of the sender. CHs and the base position are unglued by a distance threshold in order to reduce network overhead and accommodate sensors located far from the station. It is also expected that the energy levels of each gadget fluctuate. Equation 1 represents the average deviation of the regular remaining power chosen to each load on a CH:

$$\boldsymbol{\sigma} = \sqrt{\frac{\sum_{i=1}^{r}\left(\frac{E_{residual}(h_i)}{n_L(h_i)} - \frac{\sum_{i=1}^{r}\frac{E_{residual}(h_i)}{n_L(h_i)}}{r}\right)^2}{r}}$$

where r is the amount of rounds enclosed, $E_{residual}(h_i)$ is the remaining power of CH h_i , and $n_L(h_i)$ is load on CH h_i

n_L= Load = Quantity of packets poised at the cluster head for distribution the base station.

NH=Number of hop counts = D_{link}/TX_{range} (2)

Dropping the broadcast distance amid nodes when they transmit information to the cluster head can lead to the clustering of WSN nodes into tight clusters, thereby decreasing communication energy consumption within each cluster. The clustering loss meaning is characterized by Equation (3):

$$J_m = \sum_{i=1}^{N}\sum_{j=1}^{C} u_{ij}^{m}\left\|x_i - c_j\right\|^2, \quad 1 \le m \le \infty$$

In Equation (3), xi signifies the ith model point, cj revenue the jthj^{th}jth cluster center, ||xi−cj|| signifies the distance amid the cluster center and example iii. The grade of model i's connotation in the jth cluster center is signified by uij. N signifies the amount of samples, CCC indicates the quantity of clusters, and mj, means the allowance factor with a value of 2.

The gathering technique involves continuous repetition aimed at minimizing the clustering loss purpose JmJ_mJm . Each iteration leads to an update of the association matrix.

Equation for choosing the best route is:

$$y = F(\sigma, NH, J_m)$$

In the fuzzy logic-based choice scheme for selecting cluster heads, the variable y represents whether a node is chosen as a cluster head or not. When y=1, it indicates that the node is not designated as a cluster head, whereas y=1, denotes that the node is chosen as a cluster head.

Results and discussion:

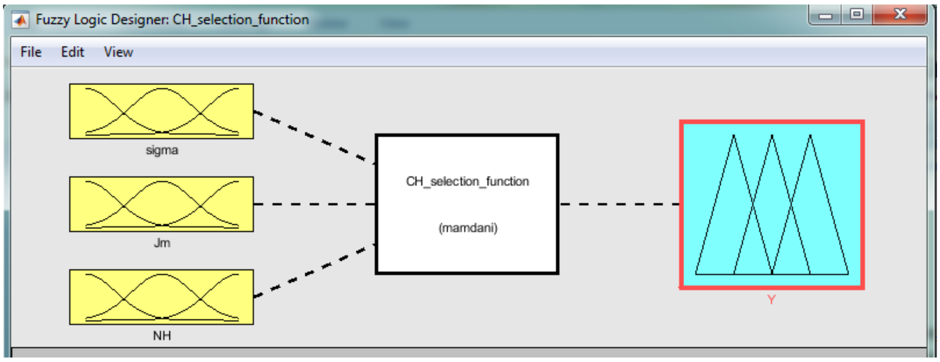

Fig 1: Planned fuzzy logic based choice model

Sensing field size 100.0 ×100.0 m

Number of devices [30.0–100.0]

Transmission range 20.0 m

Initial energy [1-2] joules

Data size 4000 bits

Eelec 50.0 ×10-9 joules/bit

E amp 100.0 ×10-12 joules/bit/m2

Routing Criteria:

The routing method for data transfer involves several rules. When a sensor node runs out of energy, it is first considered inactive and cannot provide any data. Conversely, devices within the transmission range of the base station and nodes with the highest degree of membership as potential cluster heads can communicate directly with the base station, negating the requirement for an intermediary node. When the cluster head is farther away, nodes farther from the base station may relay packets through the closest node in the same cluster.

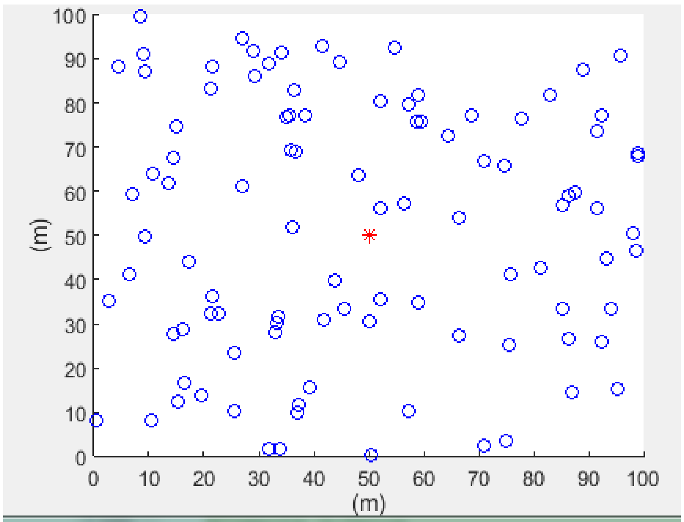

Figure 2: WSN under contemplation

Table: system lifetime enclosed under dissimilar structures and number of nodes

	Number of Nodes:			
	30	50	70	100
Scheme:				
Q learning	713	897	1321	1427
PEGASIS	584	635	655	672
LEACH	433	484	1237	792
PROPOSED	1871	1935	1776	1576

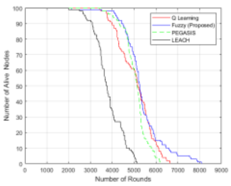

Figure 3: Difference of sum of alive bulges with respect to amount of rounds.

After more than 8000 rounds, all nodes in the suggested fuzzy-based routing technique are seen to be inactive. This shows how the number of active nodes varies with admiration to the number of circles.

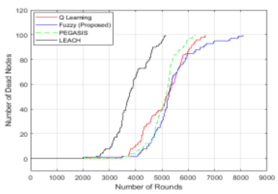

Figure 4: Difference of number of bulges with admiration to amount of rounds.

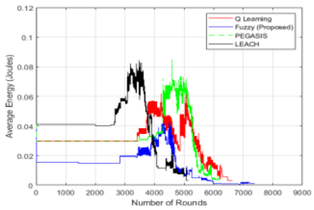

Figure 5: Difference of amount of average vitalities with approbation to amount of rounds.

The planned fuzzy-based steering method demonstrates a minimum vigor consumption per round associated to other algorithms. This trend is observed across varying numbers of rounds, highlighting the effectiveness of the fuzzy-based approach in conserving energy.

Conclusions and Future Considerations

In this study, we introduced a cluster-based energy-efficient routing approach using fuzzy logic, aiming to optimize data transmission channels and prolong network lifetime while minimizing energy consumption. Our proposed protocol demonstrated superior scalability compared to existing designs. The routing strategy involved three key steps: network setup, cluster head (CH) election, and optimization. Initially, the CH election phase utilized initial energy levels and hop count factors to calculate the fitness value. Subsequently, each CH invited nearby devices to form clusters, with remote devices joining the cluster of the nearest CH to the base station. Finally, learning-driven methods were used in the data transmission phase to determine energy-efficient routing paths that took into account both the amount of hops and the residual vigor of the device. Furthermore, a threshold for energy cutoff was established for CH substitution. The simulation results demonstrated our method's advantages over LEACH, Q knowledge, and PEGASIS in terms of network longevity and energy consumption. To further enhance the routing system, future work will incorporate additional factors and optimizations.

Acknowledgement

The authors gratefully acknowledge Integral University, Lucknow, for providing the article with the number IU/R&D/2024-MCN0002781, which supported this research work.

References

[1] J. A. Guerrero-ibanez, S. Zeadally, and J. Contreras-Castillo, “Integration challenges of intelligent transportation systems with connected vehicle, cloud computing, and internet of things technologies,” IEEE Wireless Communications, vol. 22, no. 6, pp. 122–128, 2015.

[2] Yaqoob, E. Ahmed, I. A. T. Hashem et al., “of things architecture: recent advances, taxonomy, requirements, and open challenges,” IEEE Wireless Communications, vol. 24, no. 3, pp. 10–16, 2017.

[3] [3] A. Imran, S. Sendra, J. Lloret, and A. Oumnad, “Internet of things for measuring human activities in ambient assisted living and e-health,” Network Protocols and Algorithms, vol. 8, no. 3, pp. 15–28, 2016.

[4] J. Liu, Y. Li, M. Chen, W. Dong, and D. Jin, “Software-defined internet of things for smart urban sensing,” IEEE Communications Magazine, vol. 53, no. 9, pp. 55–63, 2015.

[5] V. A. Dhtore, A. R. Verma, and S. B. *igale, “Energy efficient routing protocol for IoT based application,” in Proceedings of the 2nd International Conference on Advanced Technologies for Societal Applications, pp. 197–204, Maharashtra, India, November 2018.

[6] M. S. Obaidat and S. Misra, Inside a Wireless Device: Structure and Operations, Cambridge University Press, Cambridge, UK, 2014.

[7] C. A. Suescun and M. Cardei, “Anchor-based routing protocol with dynamic clustering for internet of things WSNs,”

[8] EURASIP Journal on Wireless Communications and Networking, vol. 2019, no. 130, pp. 1–12, 2019.

[9] S. Hamrioui, C. A. M. Hamrioui, J. Lioret, and P. Lorenz, “Smart and self-organised routing algorithm for efficient IoT communications in smart cities,” IET Wireless Sensor Systems, vol. 8, no. 6, pp. 305–312, 2018.

[10] L. Atzori, A. Iera, and G. Morabito, “*e internet of things: a survey,” Computer Networks, vol. 54, no. 15, pp. 2787–2805, 2010.

[11] D. Kandris, A. Alexandridis, T. Dagiuklas, and E. Panaousis, “Applications multiobjective optimization algorithms for wireless sensor networks,” Wireless Communications and Mobile Computing, vol. 2020, no. 1, pp. 1–5, 2020.

[12] S.-H. Vergados, Hardware Design for WSNs, Springer, London, UK, 2014.

[13] Internet of *ings, Wireless Sensor Networks, IEC, Geneva, Switzerland, 2014.

[14] L. K. Ketshabetswe, A. M. Zungeru, M. Mangwala, J. M. Chuma, and B. Sigweni, “Communication protocols for wireless sensor networks: a survey and comparison,” Heliyon, vol. 5, no. 5, p. e01591, 2019.

[15] Shallari, S. Krug, and M. O’Nils, “Communication and computation inter-effects in people counting using intelligence partitioning,” Journal of Real-Time Image Processing, vol. 17, no. 6, pp. 1869–1882, 2020.

[16] M. Pavelic, V. Bajt, and M. Kusek, “Energy efficiency of machine-to-machine protocols,” in Proceedings of the 41st International Convention on Information and Communication Technology, pp. 361–366, Electronics and Microelectronics (MIPRO), Opatija, Croatia, May 2018.

[17] J. Shin and J. Hwang, “Intelligent energy information service based on a multihome environment,” in Proceedings of the 3rd International Conference on Ambient Systems, Networks and Technologies (ANT), pp. 197–204, Warsaw, Poland, December 2012.

[18] L. Xu, G. M. P. O’Hare, and R. Collier, “A smart and balanced energy-efficient multi-hop clustering algorithm (smartBEEM) for MIMO IoT systems in future networks,” Sensors, vol. 17, no. 7, p. 1574, 2018.

[19] R. S. Sutton and A. G. Barto, Reinforcement Learning: An Introduction, *e MIT Press, Cambridge, UK, 2nd edition, 2020.

[20] Z. Mammeri, “Reinforcement learning based routing in networks: review and classification of approaches,” IEEE Access, vol. 7, pp. 55916–55950, 2019.

[21] C. Savaglio, P. Pace, G. Aloi, A. Liotta, and G. Fortino, “Lightweight reinforcement learning for energy efficient communications in wireless sensor networks,” IEEE Access, vol. 7, pp. 29355–29364, 2019.

[22] D. A. Dugaev, I. G. Matveev, E. Siemens, and V. P. Shuvalov, “Adaptive reinforcement learning-based routing protocol for wireless multi-hop networks,” in Proceedings of the XIV International Scientific-Technical Conference on Actual Problems of Electronics Instrument Engineering (APEIE), pp. 209–218, Novosibirsk, Russia, October 2018.

[23] W. R. Heinzelman, A. Chandrakasan, and H. Balakrishnan, “Energy-efficient communication protocol for wireless microsensor networks,” in Proceedings of the 33rd Annual Hawaii International Conference on System Sciences, pp. 1–10, Maui, Hawaii, January 2000.

[24] S. Lindsey and C. Raghavendra, “PEGASIS: power-efficient gathering in sensor information systems,” in Proceedings of the IEEE Aerospace Conference, pp. 1125–1130, Big Sky, MA, USA, May 2002.

[25] M. Littman and J. Boyan, “A distributed reinforcement learning scheme for network routing,” in Proceedings of the International Workshop on Applications of Neural Networks to Telecommunications, pp. 1–6, Seattle, WA, USA, March 1993.

[26] Forster and A. L. Murphy, “FROMS: Feedback routing for optimizing multiple sinks in wsn with reinforcement learning,” in Proceedings of the 3rd. International Conference on Intelligent Sensors, pp. 371–376, Sensor Networks and Information, Melbourne, Australia, August 2007.

[27] [26] G. Oddi, A. Pietrabissa, and F. Liberati, “Energy balancing in multi-hop wireless sensor networks: an approach based on reinforcement learning,” in Proceedings of the NASA/ESA Conference on Adaptive Hardware and Systems (AHS), pp. 262–269, Leicester, UK, July 2014.

[28] S. Z. Jafarzadeh and M. H. Y. Moghaddam, “Design of energy-aware QoS routing algorithm in wireless sensor networks using reinforcement learning,” in Proceedings of the 4th International Conference on Computer and Knowledge Engineering (ICCKE), pp. 722–727, Mashhad, Iran, October 2014