Energy Efficient Sleep and Wakeup Clustering Protocol for Packet Transmission in Wireless Sensor Networks

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Abstract: **Fuzzy clustering techniques-guided sleep and wakeup protocol integration offers a revolutionary method for addressing energy efficiency in wireless sensor networks (WSNs). Based on fuzzy clustering criteria, sensor nodes in the protocol dynamically switch between energy-saving sleep and active wakeup modes. Fuzzy clustering enhances the sleep and wakeup protocol, which optimizes transitions by taking node energy levels, network traffic, and neighbor proximity into account. The proposed protocol not only impacts immediate energy savings but also enhances the stability, reliability, and adaptability of WSNs. In this paper, Sleep and Wakeup protocol has been proposed which has overcome the metrics which are improved using the fuzzy based mechanism and metrics include Lifetime, Packet drop ratio, Energy Efficiency, Dead Nodes, Alive Nodes, Packets sent to Base Station and Throughput.**

Keywords: **Wireless Sensor Networks, Fuzzy Clustering, Sleep and Wakeup Protocol, Energy Efficiency, Adaptive Node Organization.**

1. INTRODUCTION

Applications for Wireless Sensor Networks (WSNs) range from industrial automation to environmental monitoring. WSNs have become a disruptive technology. These networks are made up of spatially dispersed sensor nodes that work together to gather and send data to a sink or central processing unit. Nevertheless, since individual sensor nodes are frequently powered by limited energy sources, the energy management of each one is closely linked to the operational efficiency of WSNs(D.-S. Kim & Tran-Dang, 2019)[7]. The need for energy-efficient protocols grows as WSNs become more and more embedded in various domains. The integration of sleep and wakeup protocols driven by fuzzy clustering techniques is the main topic of this introduction, which highlighted a cutting-edge strategy for energy conservation within WSNs. Given the constrained power sources of sensor nodes, the main issue of method attempts to solve is the prudent use of energy resources(Indhumathi & Sivakumar, 2015)[4]. It is frequently not possible for traditional protocols to adapt dynamically to changing environmental conditions and energy demands, which calls for a paradigm shift in energy management techniques.

II BACKGROUND

Fuzzy Clustering in WSNs

With its foundation in fuzzy logic, fuzzy clustering offers a sophisticated method of addressing ambiguity and imprecision. Fuzzy clustering provides a more adaptable and flexible arrangement of sensor nodes in the context of wireless sensor networks (WSNs), where conditions are intrinsically uncertain and dynamic. In contrast to conventional clustering techniques, fuzzy clustering recognizes the dynamic and intricate nature of real-world sensor deployments by permitting nodes to have partial membership in multiple clusters(Baradaran & Navi, 2020)[1].

Sleep and Wakeup Protocol

Introducing a sleep and wakeup mechanism is a strategic response to the problem of energy conservation in wireless sensor networks (WSNs). Based on predetermined criteria, sensor nodes switch between an active wakeup mode and an energy-saving sleep mode. The protocol is unique that it uses fuzzy clustering to inform the decisions made during these transitions(Ye & Au, 2018)[17]. Sensor nodes reduce their activity to save energy during the sleep phase, which occurs when network demand is low. An important factor in figuring out the best time and circumstances to switch between sleep and wakeup mode is fuzzy clustering. The fuzzy logic system considers variables like the nodes current energy levels, network traffic patterns, and the distance between adjacent nodes.

Objective and Potential Impacts

The main objective of the protocol's used here is to drastically cut down on energy usage across WSNs. The protocol matches energy consumption with the real needs of the network by enabling nodes to intelligently sleep during idle times and wake up when their contributions are critical. These choices are made with a degree of flexibility and responsiveness made possible by fuzzy clustering that was previously impossible with traditional protocols. The suggested sleep and wakefulness protocol with fuzzy clustering has benefits that go beyond short-term energy savings. It establishes itself as a crucial facilitator of continuous and effective sensor network operation by influencing the general stability, dependability, and adaptability of WSNs. The algorithm describes how clusters are formed, how cluster heads are chosen, and how sleep and wakeup protocols work.

III. LITERATURE SURVEY

The literature surrounding wireless sensor networks (WSNs) and energy-efficient protocols is extensive, reflecting the ongoing efforts to enhance the operational lifetimes and reliability of these networks. A comprehensive review of existing literature reveals key advancements and innovative approaches in the field.

Narayan & Daniel, 2022[13]introduced the CHHP protocol, focused on coverage optimization and hole healing in WSNs. The CHHP protocol employed a sleep and wakeup concept to enhance stability and network lifetime. Their work emphasized the importance of addressing coverage and hole issues, showcasing the significance of sleep and wakeup protocols in optimizing network performance.

Verma et al., 2020[15]proposed the Fuzzy Logic-based Effective Clustering (FLEC) for homogeneous WSNs with a mobile sink. The protocol addressed issues in existing clustering protocols like LEACH and EDEEC. FLEC employed fuzzy logic for improved cluster head selection, demonstrating superior performance in terms of stability period and network lifetime.

Wu et al., 2017[16]contributed to the literature with an improved clustering algorithm based on energy consumption in WSNs. Their algorithm enhanced the energy efficiency of the LEACH clustering algorithm, considering factors like residual energy and long-distance nodes. The proposed algorithm aimed to prevent excessive energy consumption through the adoption of free-space and multi-path fading models.

Tabatabaei et al., 2015[14]proposed a reward-based routing protocol (RBRP) for Mobile Ad Hoc Networks (MANETs). RBRP utilized a Q-learning route strategy based on factors such as hop count, bandwidth, battery power, and speed of mobile nodes. The protocol focused on selecting stable routes, showcasing superiority over the well-known AODV protocol.

Mao & Zhao, 2011[10]presented a novel unequal clustering algorithm for large-scale WSNs, incorporating fuzzy logic and adaptive max-min ant colony optimization. The algorithm balanced node power consumption and prolonged network lifetime, considering factors like energy level, distance to the base station, and local density for cluster head selection.

Mhemed et al., 2012[12]introduced the Fuzzy Logic Cluster Formation Protocol (FLCFP). FLCFP utilized fuzzy logic inference in the cluster formation process, demonstrating that using multiple parameters in cluster formation can reduce energy consumption. Comparative analysis with the LEACH protocol highlights FLCFP's ability to enhanced network lifetime significantly.

IV. METHODOLOGY

The proposed sleep and wakeup protocol using fuzzy clustering aims to optimize energy consumption in wireless sensor networks (WSNs). The algorithm initializes by setting cluster centers, facilitating the formation of clusters among sensor nodes. In each iteration, the membership degree of each node to each cluster is calculated based on fuzzy logic, allowing a flexible and adaptive clustering approach. Sensor nodes are assigned to the cluster with the highest membership degree, and cluster heads are selected for each cluster. The unique feature of the protocol lies in its efficient sleep and wakeup mechanism. Non-cluster head nodes are periodically put to sleep, conserving energy, and are awakened to transmit data to their respective cluster heads. The cluster heads, in turn, aggregate the data and forward it to the base station.

The subprocess 'Sleep and Wakeup Protocol' outlines the energy-aware sleep duration calculation based on residual energy and distance to the cluster head. Nodes follow the protocol, periodically waking up to check for incoming messages. If data needs to be sent, they communicate with the cluster head; otherwise, they go back to sleep.

This iterative process repeats until the end of the network lifetime, effectively balancing energy consumption and extending the overall network lifespan. The fuzzy clustering approach adds adaptability to cluster formation, optimizing the network's performance in dynamic conditions.The flow chart of proposed work is given in figure 1.

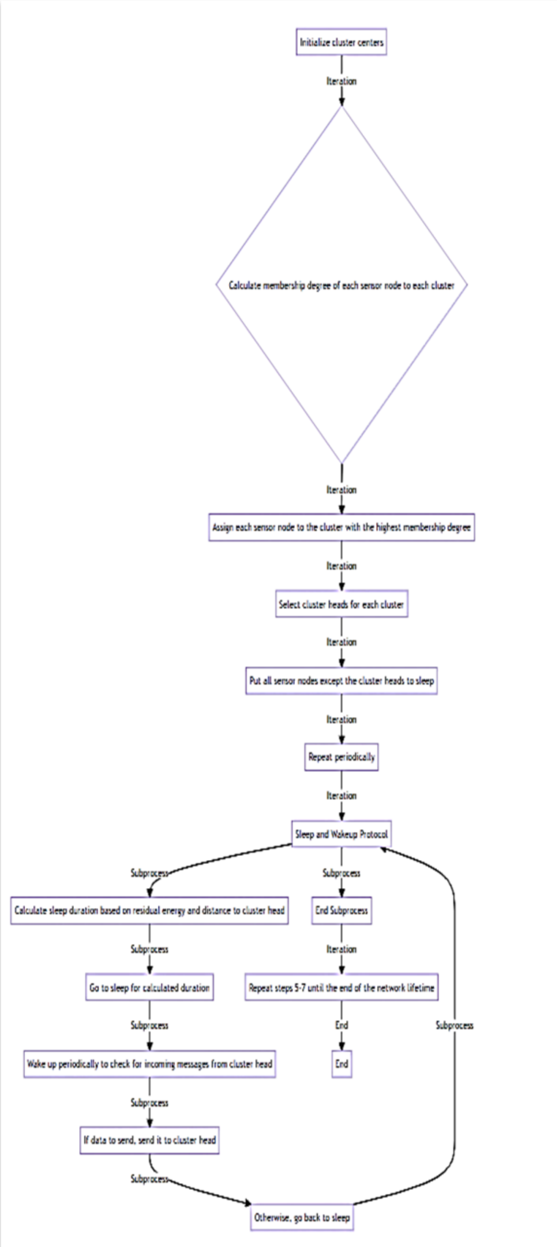

Figure 1: Flow chart of proposed Work

V. PERFORMANCE ANALYSIS

a. Energy Efficiency: The energy efficiency results indicate a progressive reduction in energy utilization across the evaluated algorithms over successive rounds. LEACH consistently demonstrates the lowest energy efficiency, and Proposed work has high energy efficiency. SEP and EDEEC exhibit higher energy usage, with EDEEC consistently surpassing SEP. This implies the efficiency of the proposed approach in optimizing energy utilization, potentially contributing to prolonged network lifespan. The energy efficiency is represented in figure 2

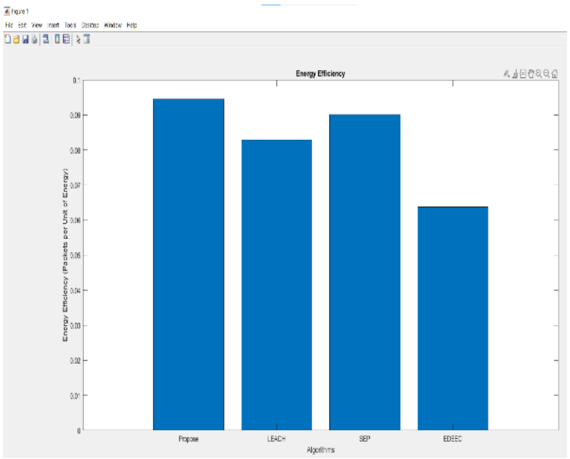

Figure 2: Energy Efficiency comparison with PROPOSED, LEACH, SEP and EDEEC

The figure shows that it keeps the balance between saving energy and improving network performance. These results show how important it is to choose the right algorithm to reduce energy use, which is necessary for wireless sensor networks to last for a long time.

Rounds	*PROPOSED (Joules)*	*LEACH (Joules)*	*SEP (Joules)*	*EDEEC (Joules)*
1000	0.094	0.08	0.090	0.06
2000	0.05	0.03	0.04	0.03
3000	0.03	0.02	0.02	0.02
4000	0.023	0.01	0.022	0.017
5000	0.019	0.014	0.017	0.013

Table 1: Comparison table of Energy Efficiency for PROPOSED, LEACH, SEP and EDEEC at different rounds

*b. Throughput***:** Throughput is typically measured as the amount of data successfully transmitted over the network. Assuming that throughput is represented in bits, we can use the formula:

Throughput(bits)=Data transmitted/Time

The throughput results reveal varying data transmission efficiencies among algorithms across rounds. Proposed work consistently achieves the highest throughput, indicating superior data transmission rates. Proposed work closely follows, demonstrating competitive performance. LEACH, SEP and EDEEC exhibit lower throughput, suggesting potential challenges in data transmission efficiency. The graphical representation of the result is given in figure 3.

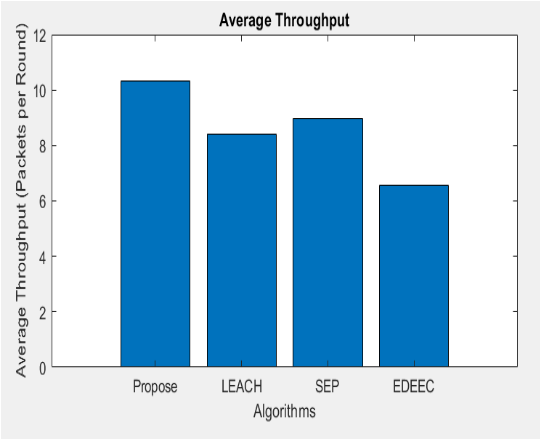

Figure 3: Average Throughput of different protocols

The impact of algorithm choice on network data transfer capabilities. The proposed method stands out for their ability to maintain robust and efficient data throughput, emphasizing their potential in enhancing overall network communication and data transfer performance in wireless sensor networks.

Rounds	PROPOSED (Through put bits)	LEACH (Through put bits)	SEP (Through put bits)	EDEEC (Through put bits)
1000	10.309	8.414	8.954	6.565
2000	5.00	3.98	4.28	3.59
3000	3.120	2.683	2.928	2.459
4000	2.396	1.993	2.234	1.789
5000	1.968	1.485	1.708	1.379

Table 2: Comparison table of Throughput with PROPOSED, LEACH, SEP and EDEEC

c. *Alive Nodes*

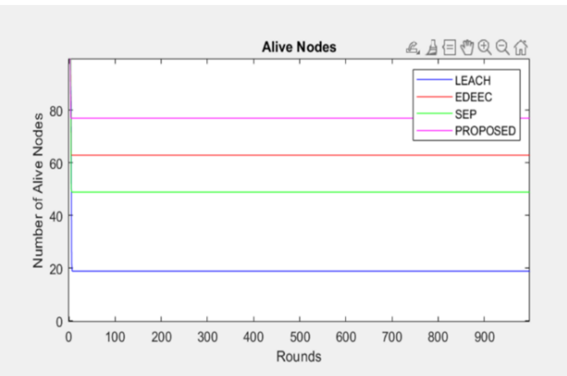

Figure 4: Alive nodes comparison with LEACH, SEP, EDEEC and PROPOSED

The analysis of alive nodes unveils dynamic fluctuations in node vitality throughout the rounds. Proposed work consistently maintains a higher number of alive nodes, showcasing its effectiveness in preserving network nodes. Proposed Work closely follows, indicating its ability to sustain a significant node population. LEACH, SEP and EDEEC exhibit a gradual decline in the number of alive nodes, potentially pointing to challenges in node longevity. These outcomes emphasize the importance of algorithm selection in influencing the resilience and sustainability of nodes within the network. The proposed approach emerges as promising solutions for fostering a robust and enduring network infrastructure by preserving a larger number of active nodes.

ROUNDS	PROPOSED (Alive Nodes)	SEP (Alive Nodes)	EDEEC (Alive Nodes)	LEACH (Alive Nodes)
1000	77	49	63	19
2000	71	57	61	
3000	71	55	64	41
4000	74	52	60	43
5000	70	59	68	35

Table 3: Comparison table of Alive Nodes with PROPOSED, SEP, EDEEC and LEACH at each rounds

The analysis of alive nodes across rounds reveals notable variations in node vitality. Propose work consistently outperforms other algorithms, maintaining a higher number of alive nodes throughout the evaluated rounds. Proposed Work closely follows, demonstrating its effectiveness in sustaining a significant population of active nodes.

d. *Dead Nodes*

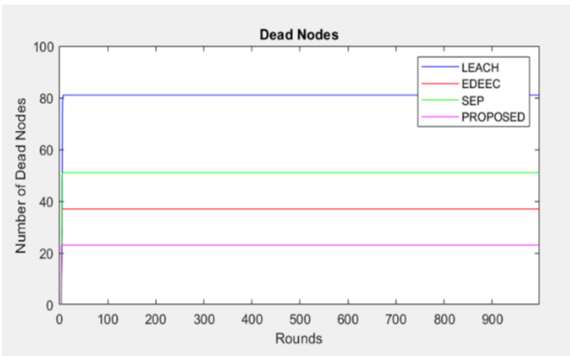

Figure 5: Dead nodes comparison with LEACH, EDEEC, SEP and PROPOSED

The performance of the proposed work is consistently better than LEACH, SEP and EDEEC.

Rounds	LEACH (Dead Nodes)	EDEEC (Dead Nodes)	SEP (Dead Nodes)	PROPOSED (Dead Nodes)
1000	81	37	51	23
2000	76	39	43	29
3000	59	36	45	29
4000	57	40	48	26
5000	65	32	41	30

Table 4: Comparison table of Dead Nodes with LEACH, EDEEC, SEP and PROPOSED at each rounds

The analysis of dead nodes across rounds reveals notable variations in node vitality. Proposed work consistently outperforms other algorithms, maintaining a higher number of alive nodes throughout the evaluated rounds.

e. Packets sent to Base Station

Rounds	PROPOSED (Packets sent to Base Station)	LEACH (Packets sent to Base Station)	SEP (Packets sent to Base Station)	EDEEC (Packets sent to Base Station)
1000	10309	8414	8954	6565
2000	10015	7967	8567	7180
3000	9362	8051	8786	7378
4000	9587	7975	8936	7158
5000	9844	7426	8540	6896

Figure 6: Comparison of Packets Sent to Base Station with PROPOSED, LEACH, SEP and EDEEC

In a Wireless Sensor Network (WSN), sensor data from different nodes in the network is usually sent to the base station in a packet. These nodes could be put in hard-to-reach or remote places to keep an eye on the environment and collect data about it. Usually, the packet has readings from sensors that show things like temperature, humidity, pressure, or anything else that the nodes are supposed to measure.

The base station is where all the data that has been collected comes together so that it can be processed or analyzed further. Communication like this is very important for tasks that need real-time or regular data from different places, like monitoring the environment, automating factories, or keeping an eye on things. In the figure 6 it clearly shows that Proposed work is better than LEACH, SEP and EDEEC as it transfers more Packets to the Base Station.

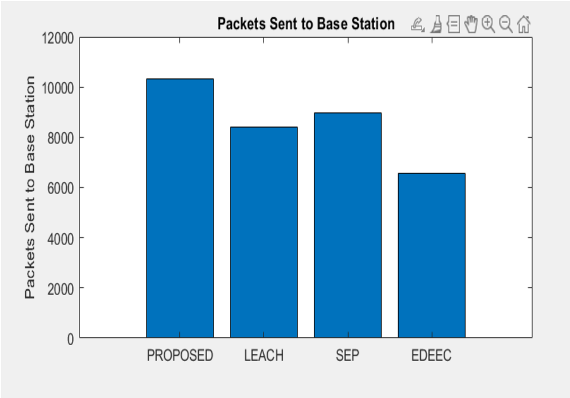

Table 5: Comparison table of Packets Sent to Base Station with PROPOSED, LEACH, SEP and EDEEC

VI. CONCLUSION

In conclusion, the research journey through the intricacies of wireless sensor network algorithms has revealed the Fuzzy-based protocol as a consistent frontrunner, showcasing unparalleled energy efficiency, high throughput, and a remarkable ability to maintain a robust population of active nodes while minimizing the number of inactive ones. The Proposed Work, emerging as a promising protocol, demonstrated competitive performance across critical metrics, positioning it as a noteworthy solution. Despite certain challenges observed in SEP and EDEEC, particularly in terms of energy consumption and node longevity, the study's implications extend far beyond the immediate context of wireless sensor networks.

The findings hold significant relevance for the design and deployment of sensor networks in diverse applications, from environmental monitoring to healthcare. The excellence of the Proposed Work suggests its applicability in scenarios where energy conservation and prolonged network operation are paramount. Furthermore, the competitive performance of the Proposed Work opens avenues for hybrid approaches, combining the strengths of different algorithms to address specific challenges in various network environments.

REFERENCES

[1] Baradaran, A. A., & Navi, K(2020), HQCA-WSN: High-quality clustering algorithm and optimal cluster head selection using fuzzy logic in wireless sensor networks. Fuzzy Sets and Systems, 389, 114–144.

[2] El Alami, H., & Najid. A(2016) , Energy-efficient fuzzy logic cluster head selection in wireless sensor networks. 2016 International

Conference on Information Technology for Organizations Development, IT4OD.

[3] Faris, M., Mahmud, M. N., Salleh, M. F. M., & Alnoor, A.(2023) , Wireless sensor network security: A recent review based on state-of-the-art works. International Journal of Engineering Business Management.

[4] Indhumathi,T. C., & Sivakumar, P.(2015), Comparison and performance analysis of clustering protocol using sleep & wakeup technique in WSN. Proceedings of 2014 IEEE International Conference on Advanced Communication, Control and Computing Technologies, ICACCCT 2014, 667–672.

[5] Kashaf, A., Javaid, N., Khan, Z. A., & Khan, I. A. (2012), TSEP: Threshold-sensitive stable election protocol for WSNs. Proceedings - 10th International Conference on Frontiers of Information Technology, FIT 2012,164–168.

[6] Kaur, S., Awasthi, L. K., Sangal, A. L., & Dhiman, G. (2020), Tunicate Swarm Algorithm: A new bio-inspired based metaheuristic paradigm for global optimization. Engineering Applications of Artificial Intelligence, 90.

[7] Kim, D.-S., & Tran-Dang, H. (2019). Wireless Sensor Networks for Industrial Applications. 127–140.

[8] Kim, J. M., Park, S. H., Han, Y. J., & Chung, T. M. (2008),CHEF: Cluster Head Election mechanism using Fuzzy logic in wireless sensor networks. International Conference on Advanced Communication Technology, ICACT, 1, 654–659.

[9] Lata, S., Mehfuz, S., Urooj, S., & Alrowais, F. (2020), Fuzzy Clustering Algorithm for Enhancing Reliability and Network Lifetime of Wireless Sensor Networks. IEEE Access, 8, 66013–66024.

[10] Mao, S., & Zhao, C. L. (2011), Unequal clustering algorithm for WSN based on fuzzy logic and improved ACO. The Journal of China Universities of Posts and Telecommunications, 18(6), 89–97.

[11] Mehra, P. S., Doja, M. N., & Alam, B. (2019), Enhanced clustering algorithm based on fuzzy logic (E-CAFL) for WSN. Scalable Computing, 20(1),41–54.

[12] Mhemed, R., Aslam, N., Phillips, W., & Comeau, F. (2012). An Energy Efficient Fuzzy Logic Cluster Formation Protocol in Wireless Sensor Networks. Procedia Computer Science, 10, 255–262.

[13] Narayan, V., & Daniel, A. K. (2022), CHHP: coverage optimization and hole healing protocol using sleep and wake-up concept for wireless sensor network. International Journal of System Assurance Engineering and Management, 13(1), 546–556.

[14] Tabatabaei, S., Teshnehlab, M., & Mirabedini, S. J. (2015),A New Routing Protocol to Increase Throughput in Mobile Ad Hoc Networks. Wireless Personal Communications 2015 83:3, 83(3), 1765–1778.

[15] Verma, A., Kumar, S., Gautam, P. R., Rashid, T., & Kumar, A. (2020). Fuzzy Logic Based Effective Clustering of Homogeneous Wireless Sensor Networks for Mobile Sink. IEEE Sensors Journal, 20(10), 5615–5623.

[16] Wu, W., Xiong, N., & Wu, C. (2017). Improved clustering algorithm based on energy consumption in wireless sensor networks. IET Networks, 6(3), 47–53.

[17] Ye, D., & Au, M. Z. (2018). A Self-Adaptive Sleep/Wake-Up Scheduling Approach for Wireless Sensor Networks. IEEE Transactions on Cybernetics, 48(3), 979–992.