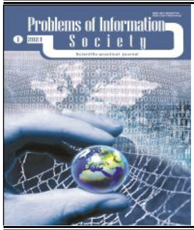

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Clustering protocols for energy efficiency analysis in WSNS and the IOT

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ABSTRACT

Throughout the development of energy efficient routing protocol for wireless sensor network clustering technique has been widely adopted approach. The Selection of cluster heads is also very important for the energy efficiency of the network. In the past, researchers have proposed multiple routing protocols; however, problems are still alive and need to be resolved because of the diversity of WSN applications. This article presents an energy-efficient routing protocol using the advanced approaches of Artificial Intelligence, the most promising field of computer science currently providing the best solutions. The proposed model uses the Deep Q-network to select the cluster head. Moreover, collected data at the cluster head is generalized as low, moderate, and high values using the fuzzy logic technique. After that, the Predictive coding theory algorithm is used for the data compression, and the lossy compression technique is applied to the data. Its compressed form also gives complete information of the data in small size and is delivered to the base station. Again, the transmitted data is reconstructed into its actual format. In the end, to justify the performance of the newly designed routing protocol, simulations are performed using the Matlab tool, and its results are evaluated in quality of service matrices and compared with well-known routing protocols.

1. Introduction

Sensor nodes (SNs) are tiny electromagnetic devices that can provide data storage, transmission, receiving, and energy resources with limited energy resources. The wireless sensor network is a combination of hundreds of small devices called nodes installed in the presided region with a central system called a base station. Wireless sensor network allocations are applied in different areas of life for monitoring and tracking purposes in health, agriculture, the military, the environment, and industries (Dionisis Kandris et al., 2020). WSN applications have benefits, as well as some drawbacks for its users. The significant problems related to its utilization are the energy efficiency of nodes, node localization, data aggregation, routing, scalability, security, and quality of service (Dheyab Salman Ibrahim et al., 2021). Energy efficiency is one of the most critical considered problems and is constantly encouraged to be resolved. Multiple efforts have been made to solve this problem; however, it's still alive. However, most efforts to resolve the issue are related to developing power-efficient routing protocols. Primarily, clustering is a highly adopted approach in developing energy-efficient routing protocols. The clustering procedure is based on grouping SNs based on similarities, and SNs in each cluster select their cluster head. After choosing the CHs, SNs in the cluster broadcast readings to the appropriate cluster heads and then aggregate them to broadcast toward the base station. The proposed model in this study uses the Deep Q network algorithm to select the cluster heads, a fuzzy logic algorithm to generalize the collected data at cluster heads, and performs data compression using the predictive coding theory.

These advanced approaches enable the proposed routing protocol to save extra energy resources and significantly enhance the network life span. This article is structured as described here. In section 2, the literature review of the study is briefly described. Section 3 gives details of the proposed methodology to be explained. In section 4, the simulations and the results are described. Section 5 is based on the study's conclusion and future work. In the end, the references of the study.

2. Literature Review

Multiple research efforts have been made in the past related to the energy efficiency of the WSNs by developing the energy efficiency routing protocol to increase the WSN's life span reviewed in the literature. These are the following well-known studies shortly explained here. This cluster-based scheme selects the cluster heads and saves energy by randomly rotating cluster heads to share the power load. It performs data fusion to decrease the data, reduce energy expenditure, and enhance network lifetime (Chunyao FU et al., 2013*)*. This study is based on equalized clustering that selects the CHs using the Gaussian elimination method by considering the residual energy of nodes (Nikolidakis et al., 2013). This study proposed an energy-efficient routing protocol that selects the CHs using the Bubble sort algorithm by organizing data of CHs in matrices and uses the distance among nodes and the remaining energy to choose the cluster heads by considering the energy thresholds for the routing mechanism to ensure the energy efficiency of the network. This study uses the improved version of the grey wolf optimization algorithm that decreases the imbalance among exploration and exploitation, lack of inhabitants' variety, and untimely convergence of the basics of the algorithm for the energy efficiency of the wireless sensor networks. The basic task of this study is to boost the network's energy efficiency and throughput by optimal selection for the cluster head in the network; it is identified as the EECHIGWO (M. R. Reddy et al., 2023). This study is based on the well-known Leach routing protocol models the leach-C and leach-R, identified as leach-CR. The Leach-CR concept is concerned with signal strength and node distance. The process of this scheme is based on choosing CH and relay nodes, data aggregation, and data transmission (Nurfazrina Mohd Zamry et al., 2021*)*. This study proposed a fast and straightforward flooding strategy (FSFS). This study's key intention is to save energy resources and the crucial design objectives of the routing protocol, which are used in the WSNs without the overhead of the other designed factors and minimize the end-to-end delay and latency (Maha Salih Abdulridhaa et al., 2020*)*. This study chooses the supercluster head from the different cluster heads that can only transmit the data to the mobile sink by electing suitable fuzzy descriptors, such as the nodes' remaining energy, the base station's mobility, and the cluster head's centrality. The supercluster heads are elected by the fuzzy inference engine (the Mandeni rule) (Padmalaya Nayak et al., 2016). This study selects the cluster head by applying the fuzzy logic algorithm with radius competition from the dissimilar clusters. The study considered distance and residual energy factors as input variables to optimize efficient results (MOHD ADNAN et al., 2021). Using the fuzzy inferences system, this model chooses the cluster heads by considering node distance, degree, remaining energy, and radius competition with the two fuzzy output variables size. The SNs are allocated to the nearby, available CHs size (Amruta Lipare et al., 2019). This study uses the Bayesian predictive coding theory for lossy compression, which is based on sending the predicated signals instead of the actual signal to the receiver end. The Bayesian predictive coding model integrates the Bayesian inference with the predictive coding (Chen Chen et al., 2020). This study presents the lossless data compression approaches practiced through different datasets to defend their performance (Yao Liang et al., 2014). This study uses the packet scheduling approach using the deep Q network method for multiple Internet of Things devices. The schedulers alter the connection intervals and packages delivered by every node in the interval (Xing Fu et al., 2023). An approach designed for the Bluetooth low energy problem using the Q learning-based scheduling, the developed model schedule dynamically adjusts the key parameters, such as the distance and the data packets, for a specific interval that governs the operations of the BLE transmission scheme (Fu, X. Lopez-Estrada et al., 2021). This study presents the K medoid clustering approach, and the CHs are selected with the hybrid interval type-2 fuzzy method, which uses the residual energy of the node's centrality and neighborhood (I. Adumbabul et al., 2023).

3. DQN fuzzy hybrid approach with predictive coding theory

The proposed Deep Q-network fuzzy approach with predictive coding theory is based on the integrated techniques of artificial intelligence, which is used for energy-efficient routing in wireless sensor networks. The proposed model initially performs clustering of the nodes based on the equalized area of the network. A deep Q network algorithm chooses the cluster heads by considering the sensor nodes' highest transmission value, which is calculated by the sensor nodes' current energy and data transmission energy. Transmission values of the SNs are the ability of data packet transmission. After that, normal nodes broadcast their data packet to the cluster heads, and the fuzzy logic approach is applied to the collected data at cluster heads to make it a more generalized form, such as high, average, and low values. Furthermore, the predictive coding theory is applied to reduce the data size before communication between cluster heads and base stations in each round. Moreover, transmitted data reconstructs the shared information into its original shape after transmission, but energy consumption is reduced because of compression. By utilizing these advanced approaches, this routing protocol will provide a comprehensive solution to the wireless sensor networks and make them sustainable and more energy efficient.

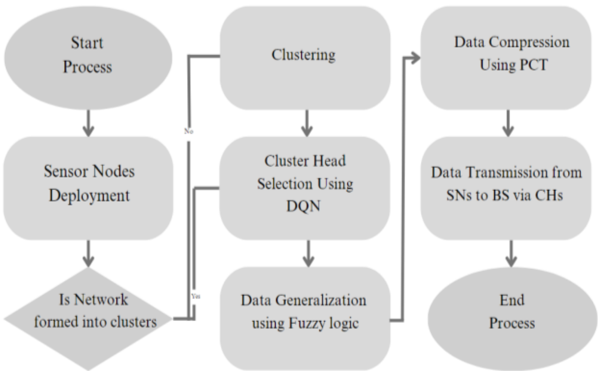


Fig. 1. Flow Chart

Fig. 1 illustrates the flow charts of the proposed models, which starts from working on node deployment and clustering formation and, after that chooses the cluster head using the deep Q-network. After cluster head selection, sensor nodes transmit their data to the cluster heads using the fuzzy logic approach to make the data generalized. The next step is the predictive coding theory for data compression and transmission to the base station and end process if all nodes lose their total energy.

Algorithm 1: DQN cluster head selection algorithm
Input :Cluster of SNs Output : Cluster Heads

1. Initialize the Variables with Deployed SNs data (coordinates, energy, etc)
2. Initialize the Q_tables with random weights Q1=Q1(S, A). {S=state, A=action}
3. for episodes
4. for steps
5. Exploration and Exploitation Process
If (rand less or equal to epsilon) Then action is rand
Else action will be maximum value from the Q table End If
6. Optimization of the Reward
If (action is 1) then reward will be 1
Else reward is 0 End If
7. Update the S' (new_state)
8. Update Q(S, A) in the Q table.
End for
End for

Algorithm 2: Fuzzy Logic
Input : stored data at CHs Output : Generalized data form 1. Initialization with CH's data 2. for Nodes_readings 3. define fuzzy sets values for (High, Moderate, Low) with trimf function to define values ranges 4. define membership functions (High, Moderate, Low) 5. fuzzy rules to optimize the generalized values End for

Algorithm 3: Predictive Coding Theory for data compression

Input : Generalized data of CHs
Output : Compressed & Reconstructed data
1. Initialization with generalized data of CH's optimized through fuzzy logic algorithm
2. Supposed first data value as Current Value
3. For # data compression
If (Next_Value is equal with Current _Value) Then Current_Value repetition is counted
Else Update the compressed data array
End if
End for
4. While # Reconstruction loop until the numbers of compressed data length
Update reconstructed data array
End while

Adopted Energy Model

In the proposed model 1st order radio energy model is adopted to compute the power consumption. The energy consumption in the designed model for each SN is determined with the symbol of Etx (k, d), in which the Etx indicates the transmission energy, k is for the packet size of data, and d is for the distance between communication devices in the network. Here is the equation used to calculate the energy used in data packets broadcasting between communication nodes.

$$((Etx*k)*(Efs*k))*d2,d<=do, \quad (1)$$

$$((Etx*k)*(Emp*k))*d4,d>=do, \quad (2)$$

As illustrated in equation in (1), the energy calculated which consumed in sending a data packet from a SN in WSNs. Efs in equation (1) denotes the amplification coefficients for the free space signal, and the Emp in the equation is multipath fading signal amplification. However, the value of the do is evaluated by this formula. Moreover, the below-stated equation 3 estimates energy expenditure to receive a data packet for a node in the network. Erx in the equation 3 represents the energy expenditure in receiving data packet.

$$(Erx*k) \quad (3)$$

4. Simulations and Results

Simulations

Simulations are designed using the Matlab tool to evaluate the performance of the developed deep Q-network fuzzy model using predictive coding theory. The proposed model simulation is performed using simulation parameters for the baseline and proposed model. The network area is 100 by 100 meters. These parameters are used to simulate the proposed and baseline models for the wireless sensor network listed in the following table with values.

Table 1: Parametric values to perform simulation

Parameters	Values
Numbers of Nodes	50
Base station Location	Center, Away
Initial energy of SNs	0.02 joule
Etx	50 nJ/bit
Erx	50 nJ/bit
EDA	5*0.000000001
Emp	100 pJ/bit
Efs	10*0.000000000001
Data Packet Size	500 bits

5. Results

To justify the effectiveness of the newly designed deep Q-network fuzzy model using the predictive coding theory results are optimized and evaluated based on the energy efficiency and quality of service matrices such as total energy consumption, dead nodes, and throughput. All of these are obtained with the rounds, representing the network's lifetime. The results are generated with the center and away base station scenario to test the adoptability of the model. However, the results of the proposed model are compared with the leach-CR. The results are figured out to evaluate the performance with analysis.

Numbers of Dead nodes Versus Rounds

Fig. 2 illustrates the results based on the evaluation parameters of dead nodes versus rounds for the proposed and leach-CR models. The proposed model shows some significant improvements over the other models. The progress is approximately a hundred percent of the baseline model in enhancing the network lifetime. The first node depletion time is also more than the baseline model. So, the proposed model is more energy efficient than the baseline model.

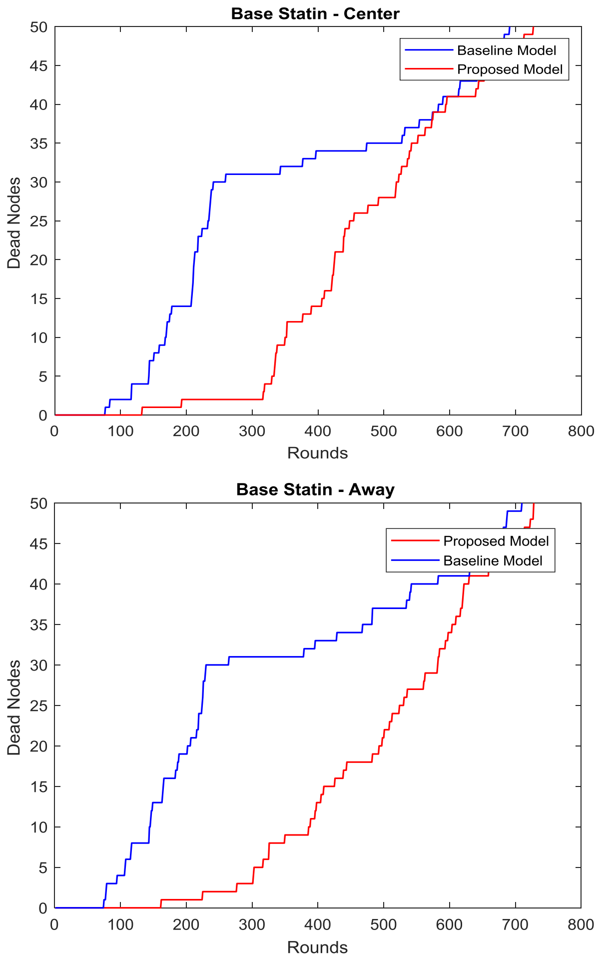
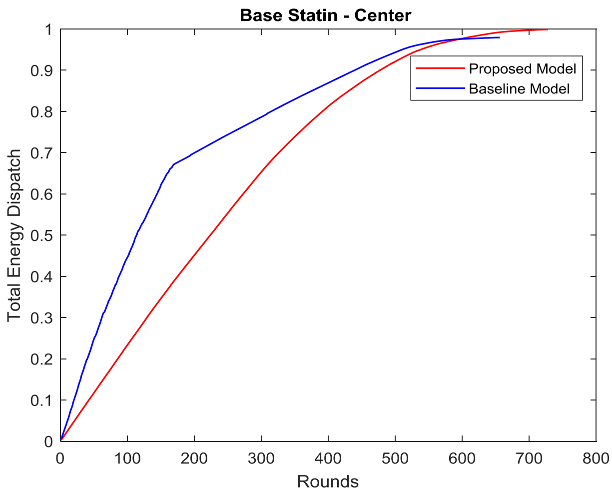


Fig. 2. Numbers of dead nodes versus Rounds

Total energy Consumption versus Rounds



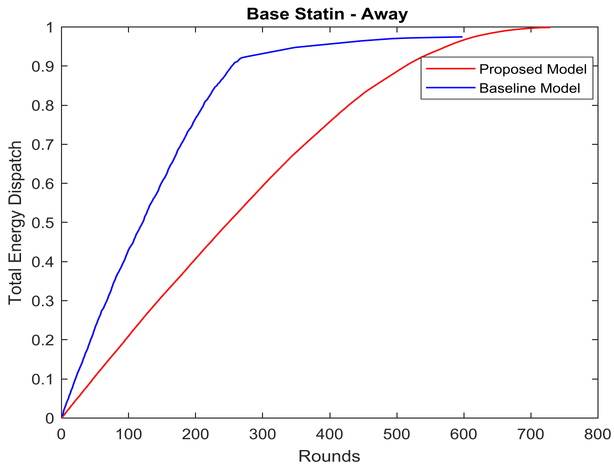
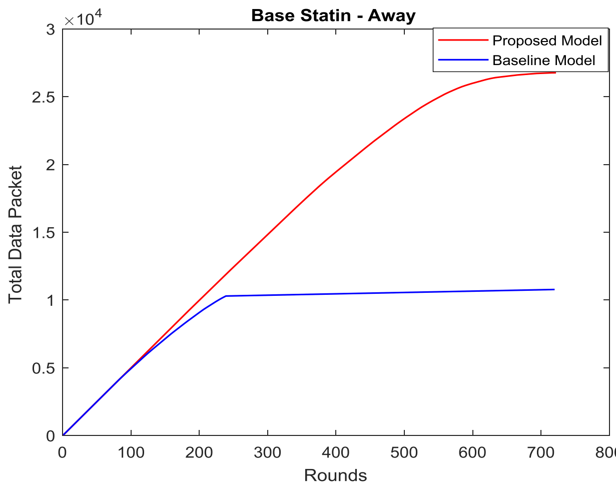


Fig. 3. Total Energy Dissipation versus Rounds

Fig. 3 shows the results obtained based on the total energy consumption versus rounds. The proposed model consumed 1 joule total energy in the more than 720, 729 rounds; however, the compared models, leach-CR model, consumed the same energy in the 651, 696 if base station is in center, away. In the scenario of total energy expenditure, the proposed model shows that it's more energy efficient and has an extended network lifetime the same initial energy resources as others.

Throughput versus Rounds

Fig. 4 shows the results for network throughput versus rounds. The proposed model can deliver around 24722, 26768 data packets with the 1-joule total energy resources for each sensor node, and comparison with the baseline, they transfer the 10156, 10778 if the base station is in the center and away from the network with similar initial energy resources, that is showing the enormous improvements in the performance so the proposed model justifies its performance for energy-efficient routing as compared to the existing compared routing protocol for WSNs.



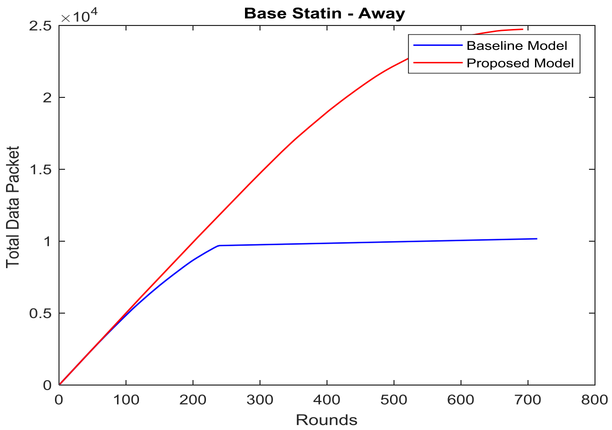


Fig. 4: Throughput of the network Versus Rounds

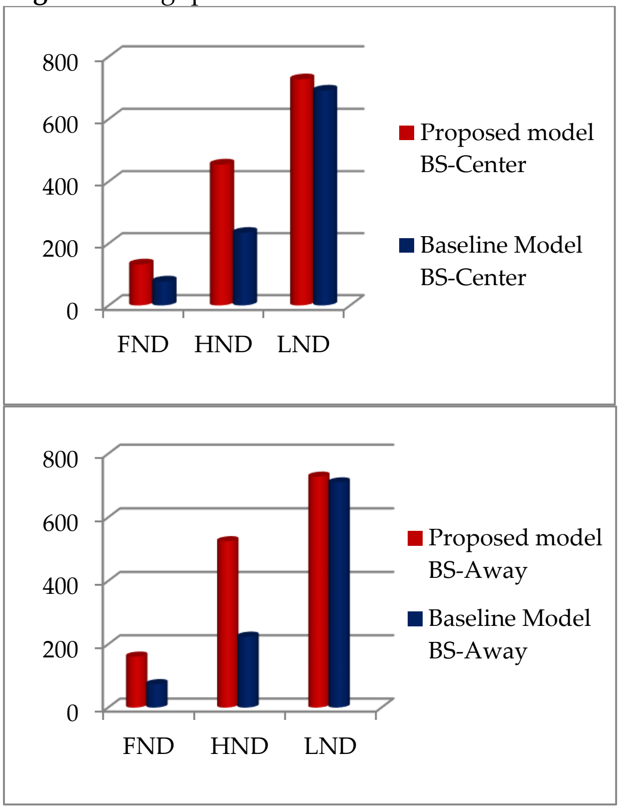


Fig. 5: Charts to illustrate FND, HND, LND values.

Fig. 5 illustrates the chart based findings of the results for the proposed and base line models for their first, half, last nodes depletion times with FND, HND, LND identities. This figure makes it clearer about the improvement of the newly designed model.

Table 2: Table for results comparison based on evaluation parameters

Protocol	Stability Period	Packet Sent to BS	Base station Location
Proposed Model	161	26768	Center
Baseline Model	75	10778	Center
Proposed Model	132	24722	Away
Baseline Model	77	10156	Away

Table 2 shows the results numbers based on the stability period and total packet sent for the proposed model and baseline model with exact numbers, it's better way to show the results.

6. Discussions

This article presents an energy-efficient routing protocol for the energy efficiency of wireless sensor networks by utilizing advanced artificial intelligence approaches. This study initiates by reviewing the existing relevant schemes and finds the research problem. After that, it proposes a novel, advanced artificial intelligence approach-based model that efficiently solves these problems. Simulations are designed to test the proposed model, and results are evaluated with the well-known routine protocol. The simulation experiments are conducted in multiple scenarios to test the proposed model's adaptability and potential. This study provides a more efficient routing protocol, which has more potential in the network lifetime context with better service quality.

7. Conclusion

This study was based on developing the energy-efficient routing protocol for WNs using advanced artificial intelligence approaches. It is a clusters-based network of randomly scattered nodes, and each cluster selected its cluster head using the Deep Q-network algorithm. SNs broadcasted the readings toward cluster heads, and then the fuzzy logic algorithm was applied to the collected data and generalized its value. After that, the Predictive coding theory approach was utilized with lossy compression to compress data. It reduced its size before transmission to save significant energy resources and reconstructed the data into its original form after transmission. The simulation was performed using the Matlab tool, and results were evaluated based on dead nodes, total energy consumption and the network's throughput and compared with the Leach-CR model. Results were obtained in 2 scenarios to judge the performance and compare with the base station center and away from the network. If the base station was located in the center, then the proposed model showed 115 percent improvement in the stability period and 148 percent improvement in throughput; however, if the base station was located away, then it showed 75 percent improvements in the stability period and 145 percent improvements in throughput. Hence, these statistics showed significant improvements in the Deep Q-network fuzzy model using predictive coding theory compared to the existing models. In the future, this study can be enhanced by utilizing advanced approaches to manage the delay of the network. Also, using some progressive approach to solve the energy problem is possible by developing the routing protocol for WSNs.

References

Amruta Lipare, Damodar Reddy Edla. (2019). Cluster Head Selection and Cluster Construction using Fuzzy Logic in WSNs. IEEE

Chunyao, FU, Zhifang JIANG, Wei WEI and Ang WEI. (2013). An Energy Balanced Algorithm of LEACH Protocol in WSN. IJCSI International Journal of Computer Science Issues, 10(1), 1694-0814 www.IJCSI.org

Chen Chen, Limao Zhan, Robert Lee Kong Tiong. (2020). A new lossy compression algorithm for wireless sensor networks using Bayesian predictive coding. Wireless Networks. Springers. https://doi.org/10.1007/s11276-020-02425-w.

Dionisis, Kandris, Christos Nakas, Dimitrios Vomvas and Grigorios Koulouras (2020). A pplications ofWireless Sensor Networks: An Up-to-Date Survey. Appl. Syst. Innov., 3(1), 14; doi:10.3390/asi3010014

Dheyab Salman Ibrahim, Abdullah Farhan Mahdi, Qahtan M. Yas. Challenges and Issues for Wireless Sensor Networks: A Survey (2021). Journal of Global Scientific Research (ISSN: 2523-9376), 6(1), 1079-1097.

Fu, X. Lopez-Estrada, L. Kim, J.G. (2021). A Q-learning-based approach for enhancing energy efficiency of Bluetooth Low Energy. IEEE. Access, 9, 21286–21295.

I. Adumbabul, and K. Selvakumar. An Improved Lifetime and Energy Consumption with Enhanced Clustering in WSNs. Intelligent Automation & Soft Computing
doi: 10.32604/iasc.2023.029489.

M.S. Ali, A. Alqahtani, A. M. Shah, A. Rajab and M. U. Hassan. (2023). Improved-equalized cluster head election routing protocol for wireless sensor networks, Computer Systems Science and Engineering, 44(1), 845–858.

M. R. Reddy, M. L. R. Chandra, P. Venkatramana, and R Dilli (2023). Energy-efficient cluster head selection in wireless sensor networks using an improved grey wolf optimization algorithm, Computers, 12(2), 1-17.
doi: 10.3390/computers12020035

Maha Salih Abdulridhaa, Ghaihab Hassan Addayb, Imad S. Alshawi. (2020). FSFS: Fast simple flooding strategy in wireless sensor networks. Xinan Jiaotong Daxue Xuebao/Journal of Southwest Jiaotong University.

Mohd Adnan, Liu Yang, Tazeem Ahmad, and Yang Tao. (2021). An Unequally Clustered Multi-hop Routing Protocol Based on Fuzzy Logic for Wireless Sensor Networks.
doi: 10.1109/ACCESS.2021.3063097

Nurfazrina Mohd Zamry , Anazida Zainal, Murad A. Rassam. LEACH-CR: Energy Saving Hierarchical Network Protocol Based on Low-Energy Adaptive Clustering Hierarchy for Wireless Sensor Networks. (2021) 3rd International Cyber Resilience Conference (CRC) | IEEE | doi: 10.1109/CRC50527.2021.9392488

Padmalaya Nayak. (2016). A Fuzzy Logic-Based Clustering Algorithm for WSN to Extend the Network Lifetime. IEEE sensors journal, 16(1).

S.A. Nikolidakis, D. Kandris, D. D. Vergados and C. Douligeris. (2013). Energy efficient routing in wireless sensor networks through balanced clustering, Algorithms, 6(4), 29–42.

Yao Liang, Yiemi Li. (2014). An Efficient and Robust Data Compression Algorithm in Wireless Sensor Networks. Article in IEEE Communications Letters.
doi: 10.1109/LCOMM.2014.011214.132319

Xing Fu and Jeong Geun Kim. (2023). Deep-Q-Network-Based Packet Scheduling in an IoT Environment. Sensors, 23, 1339. https:/doi.org/10.3390/s23031339