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An Energy-Saving Routing Protocol for Wireless Sensor Network Communication

Mohammad Jeelani[1], Mohd Muqeem[2], Abhishek Saxena[3], Moh. Akif[4], Madhuresh Yadav[5]

[1,3,4,5]Department of Computer Application, Future University, Bareilly, U.P., India

[2]Department of Computer Sciences and Engineering, Sandip University, Nashik, India

jeelani.0018@gmail.com, muqeem.79@gmail.com, abhisheksaxena@futureuniversity.in,
akifmjpru@gmial.com

ABSTRACT

In wireless sensor networks (WSNs), routing algorithms play a crucial role in managing sensor devices and enabling communication between wireless sensor nodes. Designing a reliable routing algorithm remains challenging due to sink nodes' limited resources and their unstable, low-power connectivity. This paper proposes an energy-efficient routing protocol aimed at selecting optimal cluster heads. Sensor nodes are grouped into clusters by associating with the most suitable cluster heads, thereby enhancing energy utilization. To prevent cluster heads far from the base station from depleting excessive energy, an effective routing strategy is introduced to determine the optimal path between the cluster heads and the base station. Furthermore, a real-time, energy-efficient routing framework is presented for core network design, utilizing fixed slot allocations within the WSN. The approach also explores reducing data transmission overhead by leveraging the relationship between single-hop and multi-hop routing strategies. Simulation results demonstrate that the proposed protocol significantly outperforms existing related protocols in terms of energy efficiency and network performance.

Keywords: Wireless sensor networks, routing protocols, energy efficiency, cluster heads, sensor nodes.

1. Introduction

Recent advancements in wireless technologies have enabled the development of low-cost devices known as sensor nodes or motes. These devices communicate through radio waves and cooperate to form a wireless sensor network (WSN). A WSN can monitor physical or environmental conditions, such as temperature, sound, and humidity, using self-organising, distributed sensor nodes (SNs). One of the major challenges in WSNs is energy management, as it is often not possible to replace or recharge thousands of sensor nodes deployed in remote areas. This limitation affects both the node's computational processes and its communication mechanisms. Therefore, designing energy-efficient techniques is essential to extend network lifetime. Data aggregation and routing have proven effective strategies for reducing redundancy, minimising energy consumption, and lowering infrastructure costs [7].

In this work, we propose an energy-efficient routing protocol that organises the network into multiple clusters. Each sensor node is associated with a selected cluster head (CH) by the proposed routing algorithm. To avoid excessive energy consumption by CHs located far from the base station, the protocol determines an optimal multi-hop path between cluster heads and the base station. Many clustering protocols use Time Division Multiple Access (TDMA) for intra-cluster communication. While TDMA ensures efficient scheduling in ideal conditions, it often results in unnecessary energy waste when nodes wake up during their slots without having meaningful data to transmit [11]. To overcome this issue, our protocol incorporates an idle-node polling control mechanism during the steady-state transmission phase. This approach

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reduces unnecessary transmissions, improves energy utilisation, and increases overall network throughput. The cluster head collects data from its member nodes, aggregates it, and forwards the processed information to the base station through multi-hop communication, as shown in Figure 1.

In summary, this paper presents an energy-efficient routing protocol that focuses on optimal cluster head selection and effective routing paths between cluster heads and the base station. By combining clustering, multi-hop communication, and polling control, the proposed protocol aims to enhance energy efficiency, extend network lifetime, and improve the stability of WSNs.

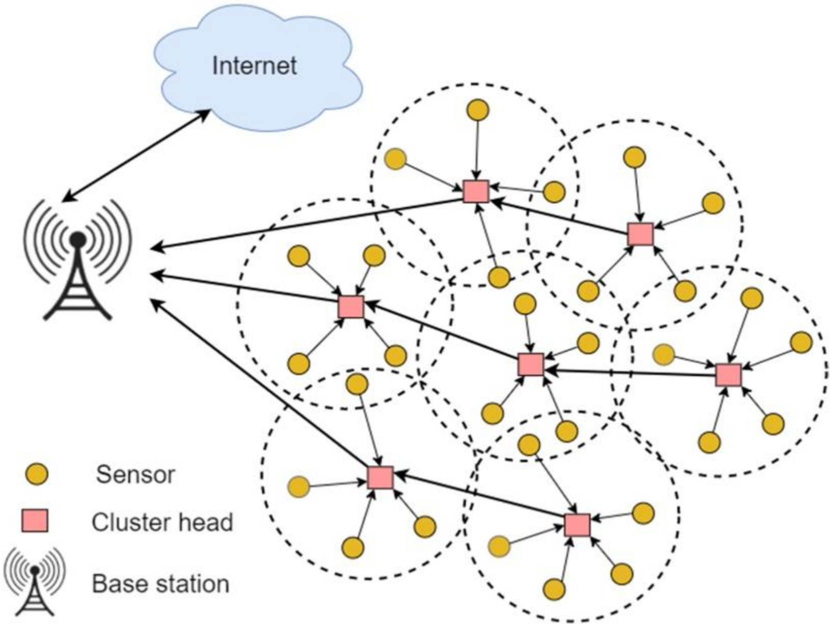

Figure 1: Cluster-based-WSN-topology

The order of the remaining text is as follows. The related work is described in Section 2. The network and energy-efficient model is introduced in Section 3. Section 4 discusses the improved results of the efficient routing protocol. The final Section concludes the entire paper.

2. Related Work

Ahmad et al. [1] proposed a supportive, energy-efficient routing protocol to enhance trustworthiness and extend the lifetime of wireless sensor networks (WSNs). They addressed the hotspot problem using sink mobility, which helps minimise energy usage. To simplify deployment, the authors divided the sensing area into several sections and placed sink nodes in each region. These sink nodes collected and processed data from sensor nodes, thereby conserving energy. Almazaideh and Levendovszky [2] improved energy efficiency by optimising routing paths to minimise residual energy while remaining within reliability limits. This approach enhances both lifetime and complexity compared to earlier methods. The protocol ensures that packets reach the base station with a defined success rate while balancing residual energy across nodes. Behera et al. [4] reviewed variations in cluster head (CH) selection thresholds. They highlighted the use of bio-inspired algorithms to improve CH selection by reflecting network behaviour. The study also provided an overview of LEACH-based and bio-inspired protocols, outlining their benefits, limitations, assumptions, and CH selection criteria. Elshrkawey et al. [5] introduced a routing scheme based on a fitness function using the Reposition Particle Swarm Optimisation (RPSO) algorithm. RPSO prevents particles from becoming trapped in local minima, thereby enhancing the routing process's efficiency. Their proposed method was tested against four other meta-heuristic algorithms, evaluating energy consumption, packets delivered, the number of dead nodes, and network lifetime. Gulda and Kuda [6] presented a learning automata-based routing technique to ensure reliable data transmission and energy efficiency in WSNs. Node selection for routing paths was determined using residual energy, link quality, buffer availability, and distance. This approach favoured routes with higher energy, good link stability, and shorter paths. Ibrahim et al. [7] proposed a routing solution that combines data aggregation and ant colony optimisation to lower communication costs and enhance energy efficiency. Their protocol demonstrated superior performance compared to recent schemes across energy consumption, lifetime, stability, and throughput. Kavra et al. [8] offered a detailed survey of hierarchical routing protocols, ant colony optimisation, and topology-aware particle swarm optimisation for both static and mobile networks. Their study also included graph-based methods and interference models, which were not covered in previous surveys. Khalaf et al. [9] utilised the bee algorithm to improve network coverage. Results showed it outperformed the genetic algorithm by achieving better coverage with less computational time and resource use. Khalaf and Sabbar [10] further analysed localisation challenges in WSNs, concluding that spontaneous structures allow for adaptive solutions to optimise node positioning. Lata et al. [11] proposed a clustering protocol using fuzzy logic to elect cluster heads and form clusters, thereby increasing the network lifetime. Unlike distributed approaches, they used a centralised method for cluster formation and introduced a vice-cluster-leader mechanism to improve stability. Lilhore et al. [12] developed an energy-efficient routing protocol based on an enhanced genetic algorithm combined with data fusion. Their model incorporated improved crossover, mutation, and encoding strategies, along with a neural network optimised for data fusion. This reduced redundant transmissions and conserved energy. Moussa et al. [13] proposed E-RARP, an ACO-based routing protocol for dependable and energy-efficient WSNs. The protocol ensured reliable communication for time-critical applications such as disaster detection, where timely data delivery is crucial. Rani et al. [14] enhanced the Optimised Link State Routing (OLSR) protocol for smart grids, focusing on better control interval management. Their fault-tolerant method minimised flooding, reduced network cost, and improved reliability for industrial systems. Rao and Reddy [15] presented clustering and routing techniques using an Improved Butterfly Optimisation (IBO) algorithm. This method selected cluster heads based on residual energy, distance, degree, and centrality, thereby increasing efficiency and extending lifetime. Robinson et al. [16] introduced the Enhanced Border and Hole Detection (EBHD) method to improve energy utilisation in WSNs. Simulation results using NS2 demonstrated that EBHD reduced delay, enhanced packet delivery, and increased residual energy compared to existing methods. Salman et al. [17] focused on smart home applications, where reliable sensor hubs were deployed to monitor temperature, humidity, gas, and light. Their system demonstrated how WSNs can improve home automation and energy management. Sreedevi and Venkateswarlu [18] proposed an optimisation model combining Particle Swarm Optimisation (PSO), Genetic Algorithm, and mobile agents for clustering and relay node selection. Their method reduced power usage, improved packet delivery, and optimised sink placement. Tabatabaei [19] proposed a clustering technique that considers both residual energy and sink distance to facilitate stable cluster formation. A mobile sink was used to balance energy consumption and maintain uniform load distribution. Wang et al. [20] improved clustering through a modified Artificial Bee Colony (ABC) algorithm. Their approach selected cluster heads based on factors such as energy, density, and location, resulting in more balanced clusters and more efficient communication.

3. Proposed Work

To transfer data to the base station, this method uses a protocol to establish and maintain multiple pathways for all sensor nodes (SNs) in the energy-efficient routing protocol, EERPR. The EERPR protocol extends the life of the network by using an improved energy routing mechanism. A number of measures, such as the main exchange mechanism, MAC, are closely related to the suggested routing protocol, which aims to lessen the major problems by establishing a reliable channel between two nodes. It is also advised to install a sensor node monitoring system to prevent compromised-node attacks in EERPR. Additionally, the results are measured in a simulator and contrasted with the current routing systems. Three factors are the key reasons why WSNs are frequently seen as being comparably unreliable:

(i). To reduce costs and extend network life, the longevity of single routes and movable sink multi-path routing protocols can be assessed through the design of simulation solutions. This work addresses the issue of uneven clustering in WSNs.
(ii). It suggests a Wireless Sensor Network (WSN) Energy Efficient Routing (EERPR).

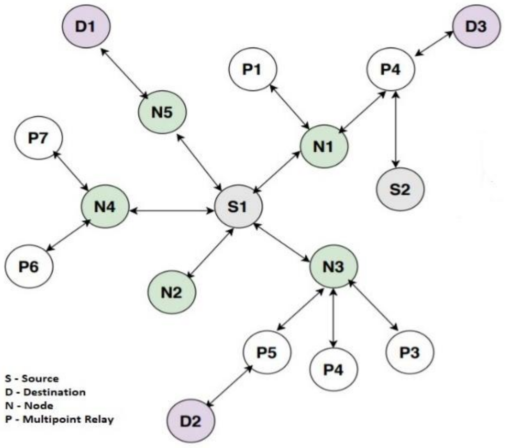

Figure 2: Network setup for communication

We can see in Figure 2 that a network communication setup is used to find the best path. Here, a number of nodes are deployed for communication, and some nodes have source and destination paths, as well as multiple relays, in this network setup.

3.1 Proposed Work Flow Chat

We propose using random clustering as the basis for our strategy for the first criterion. The clustering method is employed in the subsequent steps to define the basic network architecture. Two crucial stages make up our suggested strategy in Figure 3:

Stage I: The goal is divided into two subjects for our suggested strategy. The initial goal is to create a successful method for choosing the best clusters. Second, it is possible to access the configuration that uses the fewest resources. For condition one (condition=1), CHs are chosen at random.[3][7][11]. The setup then occurs within the context of cluster creation and determines the cluster's health (Ha). BS is used to determine the configuration's healthy function (Hb).

Stage II: The results are transmitted, along with the sensor node data, from the cluster heads (CHs) to the base station (BS). Based on the principles of the TDMA scheduling system, member nodes within each cluster send their sensed data to the designated controllers, which then forward it through the relay nodes (CHs) to the BS. After transmission, the nodes remain inactive until their next allocated time slot. In scenarios where only a single node is detected, the data is sent directly to the base station, which serves as the central point for covering the entire communication network.

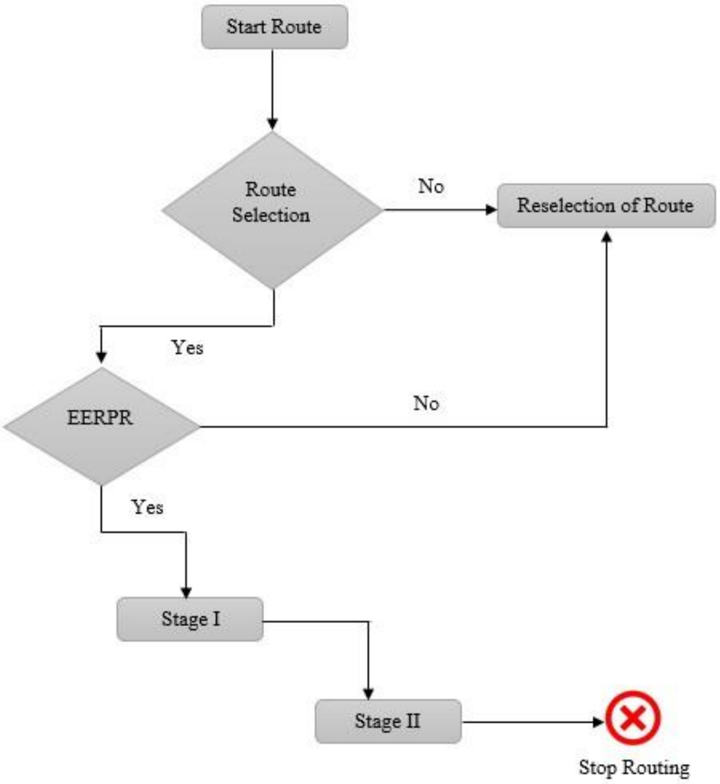

Figure 3: Flowchart of EERPR

4. Result and Discussion

This section presents the performance evaluation of the proposed protocol, conducted through simulation experiments in the Network Simulator-2 (NS-2). We begin with a brief description of the simulation environment, followed by an outline of the performance metrics employed to measure the protocol’s efficiency. Finally, the results of the proposed protocol are compared with those of the Cluster-Based Protocol for Dynamic Load Balancing (DLCP) to highlight its effectiveness.

4.1 Simulation Parameters

Table 1: Simulation parameter

Simulation Parameters	**Values**
Simulator version	NS2.35
Routing protocol	AODV
Network channel	Channel/Wireless
Channel frequency	2.4 GHz
Queue type	Droptail
Network interface type	Phy/Wireless MAC/802.11
MAC layer protocol	Antenna/OmniAntenna
Antenna model	50
Number of nodes	100m X 100m
Simulation area (Terrine)	Mica Motes Energy Model
Battery type	100 (Joule)
Initial energy	UDP
Transport layer	CBR
Type of traffic	1500
Packet size	0.5
Initial trust value	2
Seed value	Mobility Model
Random-way point	

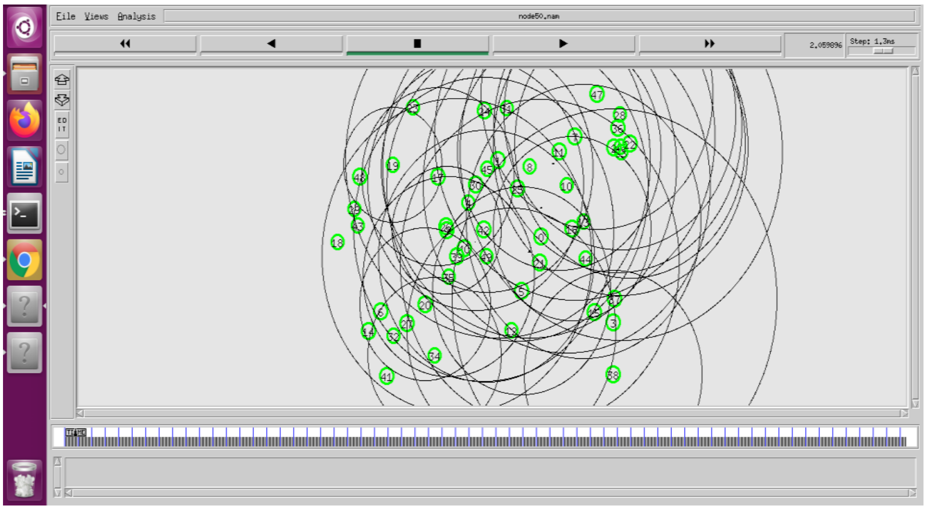

Figure 4: Simulation with 50 nodes

In Figure 4 and Table 1, the simulation was conducted using NS2.35 as the simulator, employing the AODV routing protocol over a wireless channel operating at 2.4 GHz. The utilized queue type was Droptail, along with the PHY/Wireless network interface type and MAC/802.11 protocol. An OmniAntenna model was employed, with a total of 50 nodes simulated within a 100m x 100m terrain. The energy model utilized the Mica Motes Energy Model, with an initial energy of 100 Joules per node. Transport layer traffic is generated using UDP with a Constant Bit Rate (CBR) traffic type, and a packet size of 1500 bytes. The initial trust value was set to 0.5, and a seed value of 2 was used for the random waypoint mobility model.

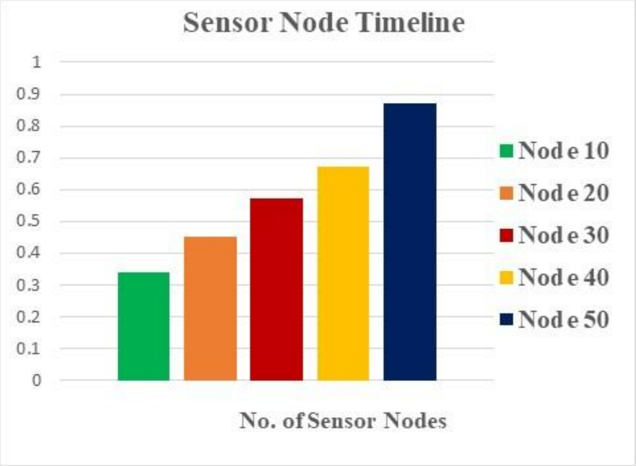

Figure 5: Node timeline

The nodes situated closer to the base station exhibit lower energy levels when contrasted with nodes located in isolated regions, as depicted in Figure 5. As the path length increases, the remaining lifespan of sensor nodes (SNs) also increases. However, it's worth noting that the enhancement in SNs' lifespan across various locations is not consistently predictable. This unpredictability may be attributed to factors such as extensive network access and collisions, which result in SNs positioned centrally within the network area consuming more energy compared to those at the periphery. Moreover, the study suggests that proximity to the base station correlates with lower energy consumption by SNs. As a result, the findings from the simulation validate the accuracy of the scientific model.

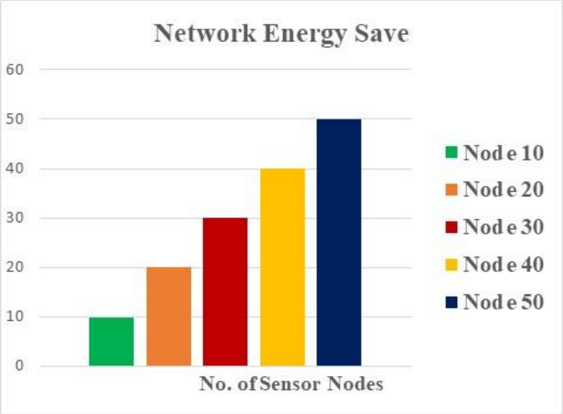

Figure 6: Network energy consumption

In figure 6, illustrates the simulation results of the network's power utilization over 100 rounds. It demonstrates the energy remaining in the network after transmitting or receiving data packets for a series of rounds. The energy consumption at the base station (0,0) is observed to be higher than the energy replenishment until three nodes becomes energy-efficient. This phenomenon is attributed to the substantial energy expenditure incurred as packets traverse a considerable distance towards the base station, thereby impacting the coverage and distribution of data packets.

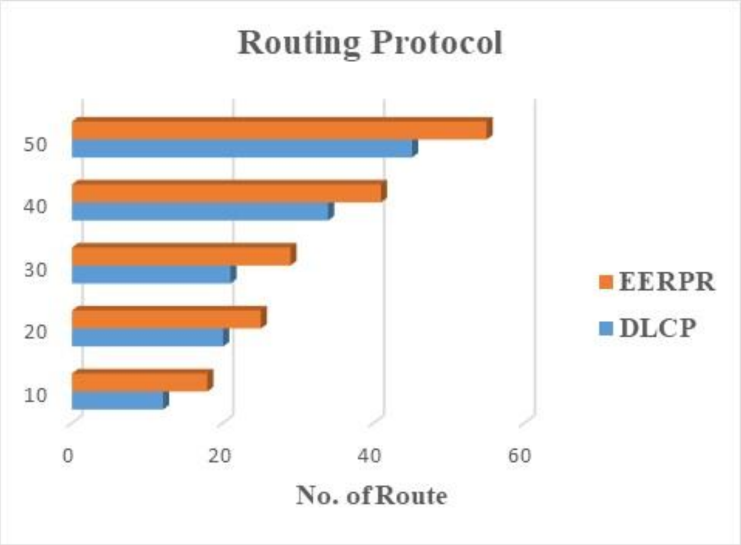

Figure 7: The Routing protocol uses the network lifetime

Figure 7 provides insight into the duration of rounds until the network becomes inoperative. The above figure depicts that while the network supports 100 rounds per minute for the hub, base stations at corner positions remain operational at 800 and 900 rounds per minute. Base stations situated at angles or boundaries are serviced by fewer sensor nodes compared to those in the centre, leading to their traversal. Consequently, if nearby nodes lack power, the network continues to deteriorate, contributing to network partitioning and significant energy wastage.

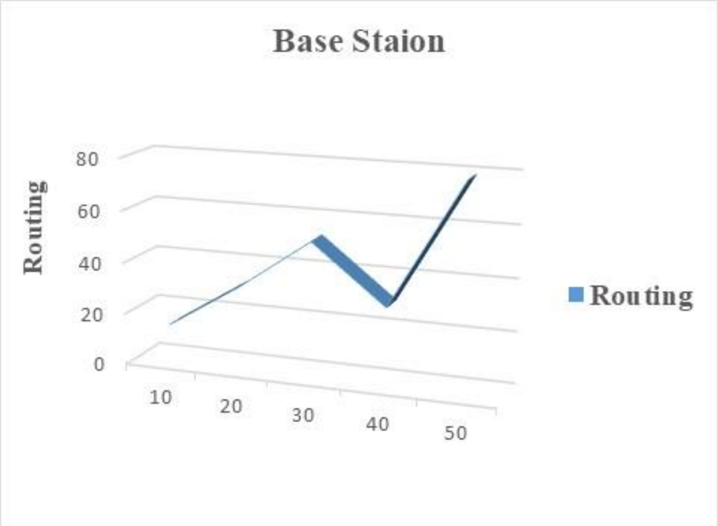

Figure 8: Comparative analysis for 100 nodes

A comparative analysis between the Dynamic Load-Balancing Cluster-Based Protocol (DLCP) and the EERPR protocol, as illustrated in Figure 8, evaluates the lifetime of a 100-node Wireless Sensor Network (WSN). The results indicate that the newly optimised HEESR protocol surpasses DLCP in efficiency by nearly 10%. However, the findings also highlight that EERPR is less cost-effective, as its sensor nodes are entirely depleted during operation. Additionally, the analysis shows that even after 850 rounds, the EEUC sensor hop does not achieve the longevity of DLCP, which continues to function for more than 950 rounds.

5. Conclusion

The wireless sensor network has advantages such as strong invulnerability, low power consumption, fast information transmission, and no wiring. WSN has become increasingly popular in large-scale applications as science and technology have advanced. However, the lack of a wire also makes it impossible to directly supply energy to sensor nodes; only batteries with a finite energy capacity can do so. The proposed energy-efficient routing strategy for WSNs is crucial for this reason. This research investigates minimizing WSNs' energy consumption. However, these findings also suggest that EERPR may be less cost-effective due to the complete depletion of its sensor nodes. Additionally, the EERPR gives better results against the existing model for WSN. Further, we will go for better results with other energy-efficient routing protocols in the future.

References

[1] Ahmad, I., Rahman, T., Zeb, A., Khan, I., Othman, M. T. B., & Hamam, H. (2022). Cooperative energy-efficient routing protocol for underwater wireless sensor networks. Sensors, 22(18), 6945.

[2] Aldergazly, A. (2020). Investigation of dispersion and nonlinear characteristics of liquid core optical fibre filled with olive oil. Sustainable Engineering and Innovation.

[3] Almazaideh, M., & Levendovszky, J. (2020). Novel, reliable, and energy-efficient routing protocols for wireless sensor networks. Journal of Sensor and Actuator Networks, 9(1), 5.

[4] Behera, T. M., Samal, U. C., Mohapatra, S. K., Khan, M. S., Appasani, B., Bizon, N., & Thounthong, P. (2022). Energy-efficient routing protocols for wireless sensor networks: Architectures, strategies, and performance. Electronics, 11(15), 2282.

[5] Elshrkawey, M., Al-Mahdi, H., & Atwa, W. (2022). An enhanced routing algorithm based on a re-position particle swarm optimisation (RA-RPSO) for a wireless sensor network. Journal of King Saud University-Computer and Information Sciences, 34(10), 10304-10318.

[6] Gudla, S., & Kuda, N. R. (2022). Learning automata based energy efficient and reliable data delivery routing mechanism in wireless sensor networks. Journal of King Saud University-Computer and Information Sciences, 34(8), 5759-5765.

[7] Ibrahim, M. E., & Ahmed, A. E. (2022). Energy-aware intelligent hybrid routing protocol for wireless sensor networks. Concurrency and Computation: Practice and Experience, 34(3), e6601.

[8] Kavra, R., Gupta, A., & Kansal, S. (2022). Systematic study of topology control methods and routing techniques in wireless sensor networks. Peer-to-Peer Networking and Applications, 15(4), 1862-1922.

[9] Khalaf, O. I., Abdulsahib, G. M., & Sabbar, B. M. (2020). Optimisation of wireless sensor network coverage using the Bee Algorithm. J. Inf. Sci. Eng., 36(2), 377-386.

[10] Khalaf, O. I., & Sabbar, B. M. (2019). An overview of wireless sensor networks and finding the optimal location of nodes. Periodicals of Engineering and Natural Sciences, 7(3).

[11] Lata, S., Mehfuz, S., Urooj, S., & Alrowais, F. (2020). Fuzzy clustering algorithm for enhancing reliability and network lifetime of wireless sensor networks. IEE Access, 8, 66013-66024.

[12] Lilhore, U. K., Khalaf, O. I., Simaiya, S., Tavera Romero, C. A., Abdulsahib, G. M., M P., & Kumar, D. (2022). A depth-controlled and energy-efficient routing protocol for underwater wireless sensor networks. International Journal of Distributed Sensor Networks, 18(9), 15501329221117118.

[13] Moussa, N., Nurellari, E., & El Belrhiti El Alaoui, A. (2023). A novel energy-efficient and reliable ACO-based routing protocol for WSN-enabled forest fires detection. Journal of Ambient Intelligence and Humanised Computing, 14(9), 11639-11655.

[14] Rani, S., Koundal, D., Kavita, F., Ijaz, M. F., Elhoseny, M., & Alghamdi, M. I. (2021). An optimised framework for WSN routing in the context of Industry 4.0. Sensors, 21(19), 6474.

[15] Rao, S. S., & Reddy, K. C. K. (2022). An Energy Efficient Clustering-based Optimal Routing Mechanism using IBMFO in Wireless Sensor Networks. Int J Intell Syst Appl Eng, 10(4), 641-651.

[16] Robinson, Y. H., Lawrence, T. S., Julie, E. G., Kumar, R., Thong, P. H., & Son, L. H. (2022). Enhanced Border and Hole Detection for Energy utilization in wireless sensor networks. Arabian Journal for science and engineering, 47(8), 9601-9613.

[17] Miglani, A., Bhatia, T., Sharma, G., & Shrivastava, G. (2017). An energy efficient and trust aware framework for secure routing in LEACH for wireless sensor networks. Scalable Computing: Practice and Experience, 18(3).

[18] Sreedevi, P., & Venkateswarlu, S. (2022). Comparative analysis of energy-efficient routing protocols with optimisation in WSN. International Journal on Interactive Design and Manufacturing (IJIDeM), 1-16.

[19] Tabatabaei, S. (2022). Provide energy-aware routing protocol in wireless sensor networks using bacterial foraging optimization algorithm and mobile sink. Plos one, 17(3), e0265113.

[20] Wang, Z., Ding, H., Li, B., Bao, L., & Yang, Z. (2020). An energy-efficient routing protocol based on an improved artificial bee colony algorithm for wireless sensor networks. IEEE Access, 8, 133577-133596.