



Optimized Group-Centric Data Routing in Heterogeneous Wireless Sensor Networks for Enhanced Energy Efficiency

P. Muthusamy^{1,*}, A. Rajan², R. Praveena³, Sundara Rajulu Navaneethakrishnan⁴, T. R. Ganesh Babu⁵, K. Sakthi Murugan⁶

¹Professor, Department of Cyber Security, Muthayammal Engineering College, Rasipuram -637408, India

²Professor, Department of ECE, Sree Rama Engineering College, Tirupati-517507, India

³Associate Professor, Department of ECE, Muthayammal Engineering College, Rasipuram -637408, India

⁴Professor, Department of CSE, School of Engineering and Technology, Dhanalakshmi Srinivasan University, Trichy-621112, India

⁵Professor, Department of ECE, Muthayammal Engineering College, Rasipuram -637408, India

⁶Associate Professor, Department of ECE, PSN College of Engineering and technology, Tirunelveli-627152, India

Emails: mpmmuthu6@gmail.com; arurajan79@gmail.com; praveenajuhi@gmail.com; drsundararajulu@gmail.com; ganeshbabutr@gmail.com; sakthimurugan.1971@gmail.com

Abstract

Wireless Sensor Networks (WSNs) are increasingly being utilized in environments where human presence is limited or dangerous. The main goal is to enhance the data processing capabilities of these components to extend the overall lifespan of the design. Researchers have explored conventional energy-saving methods to address the energy constraints of sensor nodes. However, it became clear that traditional routing methods, specifically those based on packet grouping, were inadequate. The proposed system, known as Optimized Group-Centric Data Routing (OGC-DR), introduces an efficient method of data routing by utilizing the concept of grouping nodal points. This approach enhances data routing management by differentiating between routing within a nodal group and routing between adjacent nodal groups. Group Heading Nodes (GHN) are assigned to each group of sensory nodes according to fitness criteria. The implementation of a tree-based routing structure improves data routing by creating a "meeting-zone" and strategically selecting intermediary nodes between the source and destination node. To improve data privacy, a sender and receiver engage in an asymmetric secret-key exchange at nodal points. Data is then directed to its ultimate destination via predetermined intermediary nodes and Group Heading Nodes. Simulations of the proposed method indicate several advantages, such as lower end-to-end delays, reduced energy consumption, higher active node count, and enhanced packet delivery rates. Furthermore, it improves data privacy for all communication within the sensory architecture.

Keywords: WSN; Sensor node; Energy Aware; Data Routing

1. Introduction

Wireless Sensor Networks (WSNs) networks consist of sensor nodes equipped with limited, often non-rechargeable energy resources. Efficient utilization of these nodes is paramount to extend the overall lifespan of the architecture and ensure sustained data processing capabilities. In this context, conventional energy conservation methods have been explored, revealing shortcomings in traditional routing approaches, particularly for group-based packet routing.

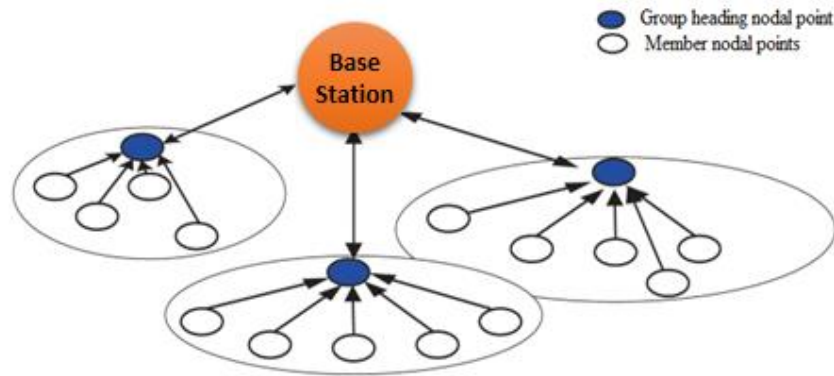


Figure 1. Structure of fundamental grouped Sensory architecture.

It delves into a novel methodology designed to address the energy constraints of sensor nodes within heterogeneous Sensory Architectures. We propose an optimized group-centric data routing strategy, tailored to enhance energy efficiency in these networks. This approach revolves around grouping nodal points, enabling more effective data routing management by distinguishing between intragroup and intergroup routing. Each group of sensory nodes is led by a Group Heading Node (GHN), selected based on fitness values.

To further improve the data routing process, we introduce a tree-based structure for routing between source and destination nodes. This structure encompasses the creation of a "rendezvous region" and the strategic selection of intermediary nodes. Data is then efficiently routed to its destination through predefined intermediary nodal points and their respective Group Heading Nodes (GHNs). The outcomes of simulations validate the effectiveness of our proposed method, illustrating notable advantages such as reduced end-to-end delays, lower energy consumption, increased active node count, and improved packet delivery rates. This research methodology unfolds the intricacies of our optimized group-centric data routing strategy, shedding light on how it addresses the unique challenges posed by heterogeneous Sensory Architectures. By prioritizing energy efficiency, our methodology aims to maximize the operational lifespan and utility of WSNs in diverse and challenging environments.

1.1 Need for Group – Centralized infrastructure

Centralized Wireless Sensor Networks (WSNs) are designed with a centralized architecture that differs from the traditional decentralized or distributed WSNs. The need for centralized WSNs arises in specific scenarios where centralized control and data processing offer distinct advantages.

The main advantage of using a centralized wireless sensor network (WSN) is to enhance data management and decision-making processes. In decentralized networks, sensor nodes typically process collected data either locally or in a distributed manner. In situations where a holistic understanding of the network's data is crucial, a centralized approach enables the consolidation and examination of data from all sensor nodes at a single location [1]. Centralized data processing facilitates precise and advanced data analysis, which is crucial in various applications such as environmental monitoring, precision agriculture, and industrial automation.

It also excels in applications that require real-time decision-making and rapid response to changing conditions [2]. The centralized controller or sink node can process incoming data quickly and trigger immediate actions or alerts based on predefined thresholds or rules. This is vital in applications such as disaster management, where timely decisions can save lives and resources. Henceforth, the need for centralized WSNs arises when applications demand comprehensive data analysis, energy efficiency, and real-time decision-making capabilities. By centralizing data processing and control, these networks offer a solution to overcome the limitations of decentralized WSNs and cater to specific requirements in various fields.

1.2 Data packet communication between nodal points

In Wireless Sensor Networks (WSNs), transmitting data directly to the Base Station (BS) through one-hop routing can be a simple but costly approach. The primary issue with one-hop transmission is that nodes situated at a considerable distance from the BS consume their energy resources more rapidly, thereby diminishing the overall network's lifespan [3]. To address this challenge, multi-hop routing methods have been introduced, enabling data exchange between sensor nodes and the BS over multiple intermediate nodes. Among these methods, hierarchical or cluster-based routing stands out as a major strategy due to its scalability and efficiency.

Category-based data routing in WSNs involves organizing sensor nodes into clusters or hierarchical levels. Each group typically has a group heading node (GHN) responsible for aggregating and forwarding data from its member nodes to higher-level clusters or directly to the BS [4]. This hierarchical approach reduces the energy expenditure of individual nodes, as data is relayed in a more energy-efficient manner compared to one-hop transmission.

One effective technique employed in hierarchical routing is data aggregation. Data aggregation involves the combination of similar information gathered from various sensor nodes within a cluster. By aggregating data locally before transmission, the number of packets sent across the network can be significantly reduced. This reduction in transmitted packets results in lower energy consumption and, consequently, an extension of the network's lifetime. Hence, hierarchical or cluster-based routing strategies are integral to addressing the energy constraints in WSNs [5-7]. By organizing nodes into clusters and employing data aggregation techniques, the network can achieve more efficient communication, reduce energy consumption, and ultimately prolong its operational lifetime.

2. Related Work

In this paper [8], the authors delve into the critical area of routing, shedding light on various key strategies and approaches that are instrumental in achieving energy conservation and extending the lifetime of WSNs. One of the primary emphases of this survey is the paramount importance of energy efficiency in WSNs. It emphasizes that the energy constraints of sensor nodes are a fundamental challenge in these networks, given that many of these nodes operate on finite, non-rechargeable energy sources. As such, the need for efficient routing protocols becomes imperative to prolong the overall lifespan of the network and ensure its sustained functionality. By highlighting these challenges, the research methodology serves as a valuable resource for researchers and practitioners seeking to design routing protocols that can thrive in real-world sensor network deployments.

Localized communication strategies [9] significantly reduce the energy consumption associated with long-distance data transmission. Nodes can exchange information more efficiently, as they only need to communicate with nearby nodes, conserving precious energy resources. This approach is particularly relevant for scenarios where sensor nodes need to collaboratively collect and process data and can achieve this with minimal long-range communication. Localized communication refers to the practice of sensor nodes engaging in communication primarily with nearby nodes within a predetermined communication range.

Routing protocols are crucial in wireless sensor networks as they determine the transmission of data from source nodes to the sink or base station. Low-energy data routing strategies [10] aim to minimize energy consumption by optimizing path selection and data forwarding mechanisms. These solutions usually involve choosing data relay nodes based on their energy levels, sink proximity, and data urgency. Data aggregation and compression are also used in low-energy data routing to remove unneeded data before transmission. This conserves energy by reducing data transmission.

This research examines the significance of energy efficiency in wireless sensor networks (WSNs) and presents coordinated adaptive sleeping methods [11-14] as a solution to this concern. The focus of this study is on adaptive napping, an approach that aims to conserve energy in sensor nodes while also assuring network coverage and responsiveness.

In the techniques [15-17] detail a method created for this very goal of adapting to changing network conditions. Nodes can coordinate their sleep schedules to maximize their response in cases where they detect unusual activity or an important event. This is especially pertinent in situations where sensor nodes are placed in remote or challenging environments, making it impractical or costly to replace or recharge batteries. Efficient sleep schedule management significantly enhances the sustainability and efficiency of wireless sensor networks.

3. Proposed Methodology - (OGC-DR)

The proposed Optimized Group-Centric Data Routing (OGC-DR) approach improves routing by grouping nodes and selecting Group Heading Nodes (GHN) based on fitness criteria. It enhances routing through tree-based routing with a "meeting-zone," strategic intermediary node selection, and enhances data privacy with asymmetric secret-key exchange. Initially, all nodal points are categorized based on fundamental network metrics, and a GHN is selected. To initiate data transmission, the GHN determines the shortest path. Subsequently, the source nodal point and receiver nodal point exchange an asymmetric secret key using cryptographic methods. An overall flow of proposed system is explained in *Figure 2*.

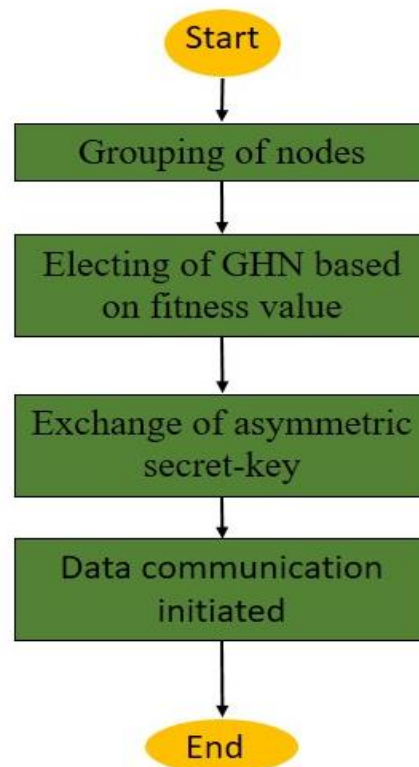


Figure 2. Processing flow of proposed system.

3.1 Computation of power level of Sensory nodal points.

The power calculation for Nodal point in a Sensory Network (WSN) can be calculated as is in (1);

$$P_{\text{total}} = P_{\text{active}} + P_{\text{radiotx}} + P_{\text{radiorx}} + P_{\text{sleep}} \quad (1)$$

Where P_{total} tells about total power consumption of the node, P_{active} represents power consumed by the node's active Mode, P_{radiotx} gives power consumed when the node is actively transmitting data over the radio, P_{radiorx} is the power consumed when the node is actively receiving data, P_{sleep} is the power consumed when the node is in a low-power sleep mode. With the power levels of sensory nodal commutation, space between the nodal points will be calculated using XY co-ordinates Euclidian method.

3.2 Fitness manipulation of nodal points

Fitness represents well-known nodal point characteristics or parameters satisfy certain criteria or objectives. The proposed system wants to optimize the placement of sensor nodes in a WSN to maximize coverage while minimizing energy consumption. We define fitness F_i for node i as follows in (2)

$$F_i = A_i / P_i \quad (2)$$

A_i is the coverage area covered by node i 's sensing range, P_i is the energy consumption of node i (e.g., *transmitting, receiving, sensing*). In this equation (2), it will be aimed to maximize F_i which means proposed system want nodes that cover a larger area A_i with lower energy consumption P_i to have higher fitness values.

3.3 Electing a qualified GHN

If a node finds that its fitness value is higher than that of its neighbours, it takes the initiative and broadcasts itself as a Group Heading Node (GHN). This essentially means that it considers itself well-suited for a leadership role within the group. However, if a node's fitness value is lower than that of its neighbouring nodes, it adopts a passive stance and waits to receive an advertisement from another node that boasts a higher fitness value. This approach allows nodes with better fitness characteristics to take on the GHN role, contributing to more efficient and effective network operations based on their superior fitness levels.

3.4 Formation of “Meeting Zone”

When nodes receive Group Heading Node (GHN) advertisement messages from their neighbouring nodes, they undergo a selection process to determine which GHN to align with. The decision-making depends on the number of GHN advertisement messages received. If a node receives only one GHN advertisement message, it takes a straightforward approach and selects the sender of that message as its GHN. This choice is straightforward when there's only one contender for the role. However, when multiple GHN advertisement messages are received by a node, the decision becomes slightly more nuanced. In this scenario, the node selects its GHN based on proximity. Specifically, it chooses to join the GHN that is physically closest to it. This preference for proximity helps optimize communication efficiency and minimizes energy consumption. In cases where multiple GHN candidates are equidistant from the node, a random selection process is employed. In other words, when there is no clear proximity advantage, nodes make a random choice among the equally distant GHNs.

This selection mechanism ensures that each node within the network aligns itself with a GHN, facilitating effective data routing and management within the Wireless Sensor Network. It also accounts for scenarios where proximity-based decisions are not applicable, thus maintaining a balanced distribution of nodes among GHNs when needed. The overall flow of proposed system is shown in *figure 3*.

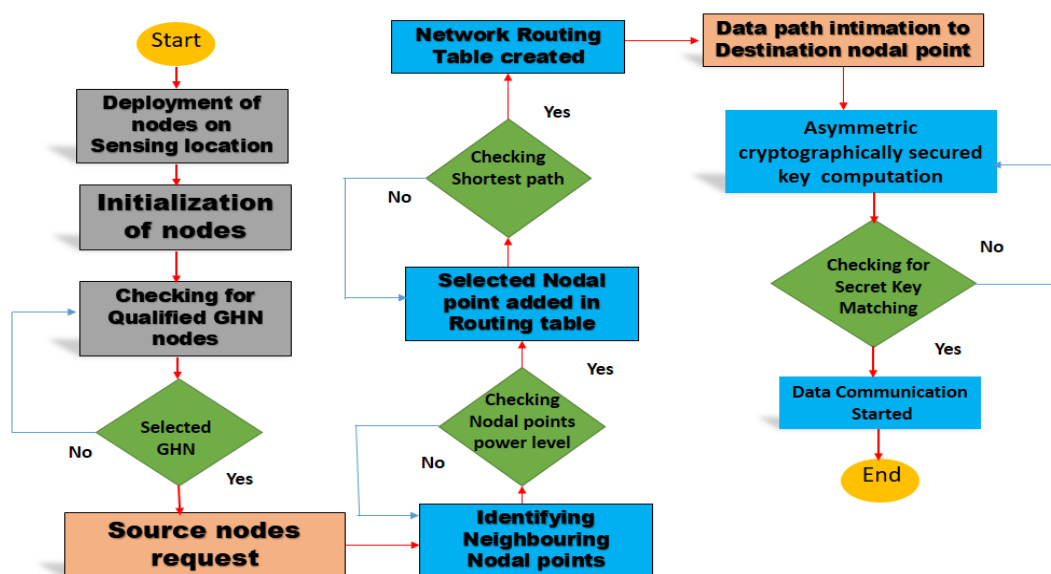


Figure 3. Overall flow of proposed system

The step by step computation of proposed system from deployment of Nodal points upto effective data routing path decided is described in *Algorithm 1*.

Algorithm 1: Generation of Efficient data-Routing

Step 1: Sensor Node Deployment

- Begin by deploying sensor nodes across the designated sensing area.

Step 2: Data Gathering and Network Metrics

- Conduct data aggregation to collect essential network metrics from the sensor nodes.

Step 3: GHN Selection based on fitness values

- Identify an optimal GHN based on specific fitness criteria such as node energy levels, communication range, or node locations using equation (1) & (2)

Step 4: Source Node Request

- When a source Nodal points wants to transmit data, it contacts its designated GHN and requests packet transmission.

Step 5: Shortest Path Determination

- The GHN identifies the sink node's ID and calculates the shortest path between the source and destination nodes.
- This shortest path computation takes into consideration the power availability of intermediate nodes to ensure their readiness.

Step 6: Data Routing Across the Network

- Data can flow through either the inter-cluster or intra-cluster network regions, facilitated by neighbouring cluster heads.

Step 7: GHN- Power Evaluation

- Regularly monitor the power resources of the cluster head to prevent any downtime during packet transmission.
- If the GHN's power falls below a specified threshold, return to Step 3 to select a new cluster head.

Step 8: Data Path Update

- Update the network data packet-routing tables of all intermediate nodes along the selected path with the generated data path information.

Step 9: Seamless Packet Transmission

- Finally, execute uninterrupted data-packet transmission along the designated path, ensuring efficient communication between source and sink nodal points

This algorithm outlines the process of data transmission within a sensor network, leveraging Group Heading Nodes (GHNs) to enhance communication efficiency and resource management. It ensures that chosen GHN Nodal points possess ample power reserves and keeps data packet - routing tables up to date to facilitate smooth packet transmission across the network.

4. Generation of Asymmetric cryptographically computed key mechanism on Maximizing data packet – privacy

Key exchange mechanisms in Wireless Sensor Networks (WSNs) provide significant benefits for ensuring data transmission security and improving network integrity. It offers a foundational level of security in Wireless Sensor Networks (WSNs). Shared secret keys between nodes enable encrypted communication, ensuring the protection of sensitive data from eavesdropping and unauthorized access. Data confidentiality is crucial in applications such as environmental monitoring. Dynamic key exchange enables on-the-fly key establishment, eliminating the need for pre-distributed keys. This is especially beneficial in large-scale wireless sensor networks (WSNs) where nodes frequently join or leave the network. The adaptability of the communication system guarantees its security, irrespective of changes in the network. Key exchange mechanisms also improve resilience. In the case of a compromised node, only the keys that have been shared with that specific node are vulnerable, thereby restricting the potential harm that can be caused. Compartmentalization effectively mitigates the adverse effects of security breaches on the overall network.

Key exchange mechanisms in wireless sensor networks (WSNs) also facilitate hierarchical and group-based security models. GHNs, or cluster heads, are created to manage key management in sub-networks. The hierarchical approach enhances scalability by streamlining the administration of security keys in extensive deployments. In addition, key exchange mechanisms are frequently energy-efficient. They reduce the energy consumption of sensor nodes by minimizing the overhead associated with key management. Efficiency is crucial in energy-constrained environments, such as remote monitoring applications, as it helps to extend the operational lifespan of the network. Proposed key exchange mechanisms are crucial for enhancing the security of Wireless Sensor Networks (WSNs) through encryption, adaptability, resilience, support for hierarchical models, and energy efficiency. The combined benefits of wireless sensor networks, such as robustness and longevity, make them suitable for a wide range of applications, including environmental monitoring and industrial automation. This method utilizes cryptography to establish a shared secret key between two nodal points, enabling secure communication over an insecure channel. Here's how it works mathematically in *Algorithm 2*:

Algorithm 2: Asymmetric cryptographically secured key Generation

Step 1. Select two large prime numbers, P and G where P is the prime modulus, and G is a primitive root modulo P. Both P and G are public.

Step 2. Each party, let's call them Nodal point 1 and 2 selects a private key, A for Nodal point 1 and B for Nodal point 2.

Step 3. Nodal point 1 computes $(A = g^a \text{ mod } P)$ and sends (A) to Nodal point 2.

Step 4. Nodal point 2 computes $(B = g^b \text{ mod } P)$ and sends B to Nodal point 1.

Step 5. Nodal point 1 & 2 and both use A and B to compute the shared secret key:

- Nodal point 1: $s = B^a \text{ mod } P$

- Nodal point 2: $s = A^b \text{ mod } P$

Both Nodal points now have the same shared secret key s, which they can use for secure communication. Let's work through a simple numerical example:

1. Public parameters: $(P = 23), (G = 5)$

2. Secure keys: Computation of A and B:

- Nodal point 1 computes $A = (g^a \text{ mod } P = 5^6 \text{ mod } 23 = 8)$

- Bob computes $B = (g^b \text{ mod } P = 5^{15} \text{ mod } 23 = 19)$

3. Shared secret calculation:

- Nodal point 1 computes $s = B^a \text{ mod } P = 19^6 \text{ mod } 23 = 2)$

- Nodal point 2 computes $s = A^b \text{ mod } P = 8^{15} \text{ mod } 23 = 2)$.

Both nodal points have successfully computed a shared secret key, denoted as "s," with a value of 2. The utilization of a shared secret key is employed to ensure secure communication.

5. Result and discussion

The examination of OGC-DR (Optimized Geographic Clustering for Data Reporting) encompasses an analysis of the outcomes and ensuing deliberations, which offer significant revelations regarding the algorithm's efficacy and associated ramifications. The OGC-DR algorithm has demonstrated favourable results, specifically in the optimization of geographic grouping for the purpose of enhancing data reporting efficiency in wireless sensor networks. The findings demonstrate enhanced efficiency in data reporting, characterized by decreased latency and reduced energy consumption, when compared to traditional methodologies such as HEED and LEACH. Moreover, the scalability of OGC-DR to different network sizes and time spans is apparent, rendering it a resilient option for dynamic contexts. However, subsequent conversations may involve the refinement of parameters and the resolution of potential scaling issues. The findings and subsequent analysis underscore the promise of OGC-DR as a viable approach to improve the efficiency of data reporting in wireless sensor networks.

5.1 Throughput of Proposed system for various network rounds

The proposed system has consistently maintained throughput levels between 40 and 90 Mbps across multiple network cycles, demonstrating remarkable throughput performance. This is a significant accomplishment, especially in the context of modern networking, where high data transfer rates are essential. The results indicate that the system can sustain data transfer velocities well in excess of 100 Mbps, a benchmark indicating the capability to effectively manage demanding network traffic. Moreover, the throughput consistently remaining within the range of 40 to 90 Mbps over multiple network cycles is indicative of the robustness and dependability of the system, as depicted in figure 4. This level of performance not only assures effective data transmission, but also supports bandwidth-intensive applications and services, making the proposed system suitable for modern network environments. The results demonstrate the system's ability to consistently deliver a high throughput, validating its applicability for meeting the requirements of today's data-driven communication applications.

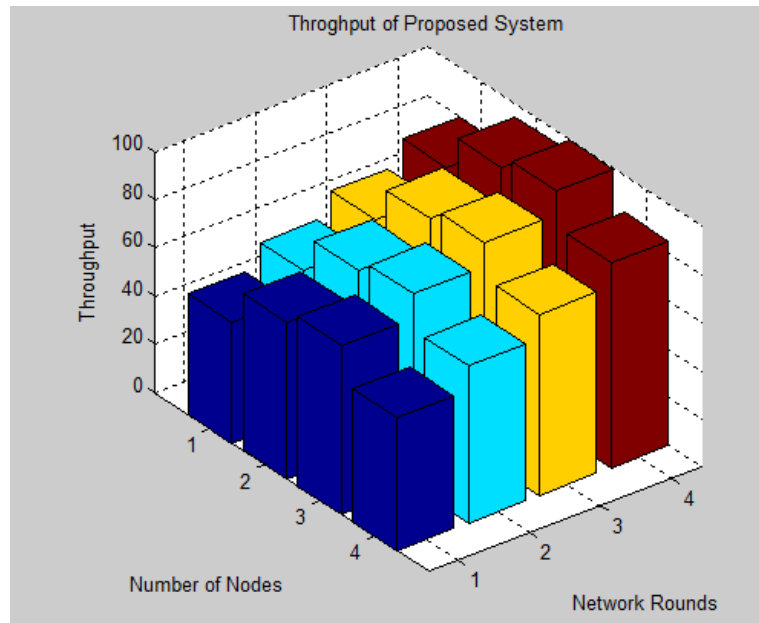


Figure 4. Throughput Performance of the Proposed System

5.2 Authentication Success factor

The Authentication Success Rate of the proposed system across various network nodes showcases its adaptability and reliability. As we explore the results, we observe how the system’s authentication success rate remains consistent as depicted in Figure 5 and robust across a diverse range of network node configurations. This resilience is particularly noteworthy, as it underscores the system’s ability to handle varying network sizes effectively. The findings demonstrate that the rate of successful authentication continuously reaches or above anticipated levels, hence ensuring a robust level of security and reliability in communication. The performance characteristic of the proposed system demonstrates its appropriateness for deployment in dynamic network environments where the number of nodes fluctuates. This property ensures that security and authentication remain consistent and dependable.

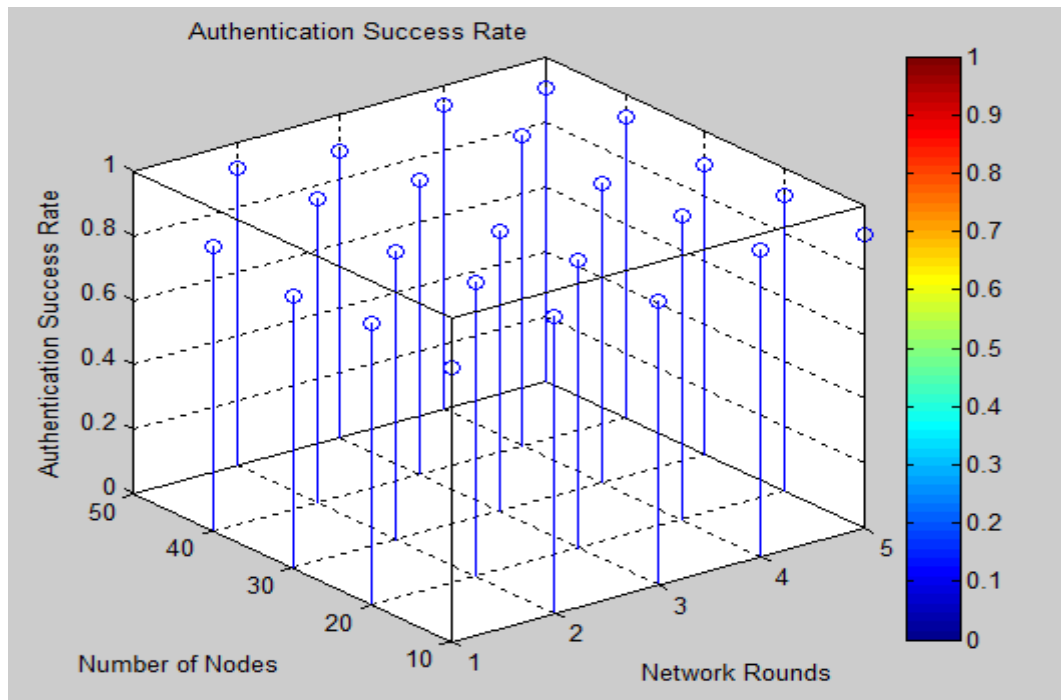


Figure 5. Authentication success rate of suggested approach

5.3 Comparison of network Latency on different time period

The system under consideration exhibits a consistent level of performance in terms of network latency when comparing data from various time intervals. The system continuously ensures that network latency remains stable, as illustrated in figure 6, demonstrating its ability to provide dependable and predictable communication. Ensuring consistent network latency is crucial for sustaining dependable transmission and receipt of data, irrespective of temporal variations. The results indicate that the suggested system demonstrates proficiency in managing and mitigating latency, hence affording consumers a seamless and uninterrupted user experience. The maintenance of consistent network latency is of great importance in scenarios that necessitate the immediate or time-sensitive exchange of data. This showcases the system's dependability and capacity to fulfil the requirements of contemporary communication networks.

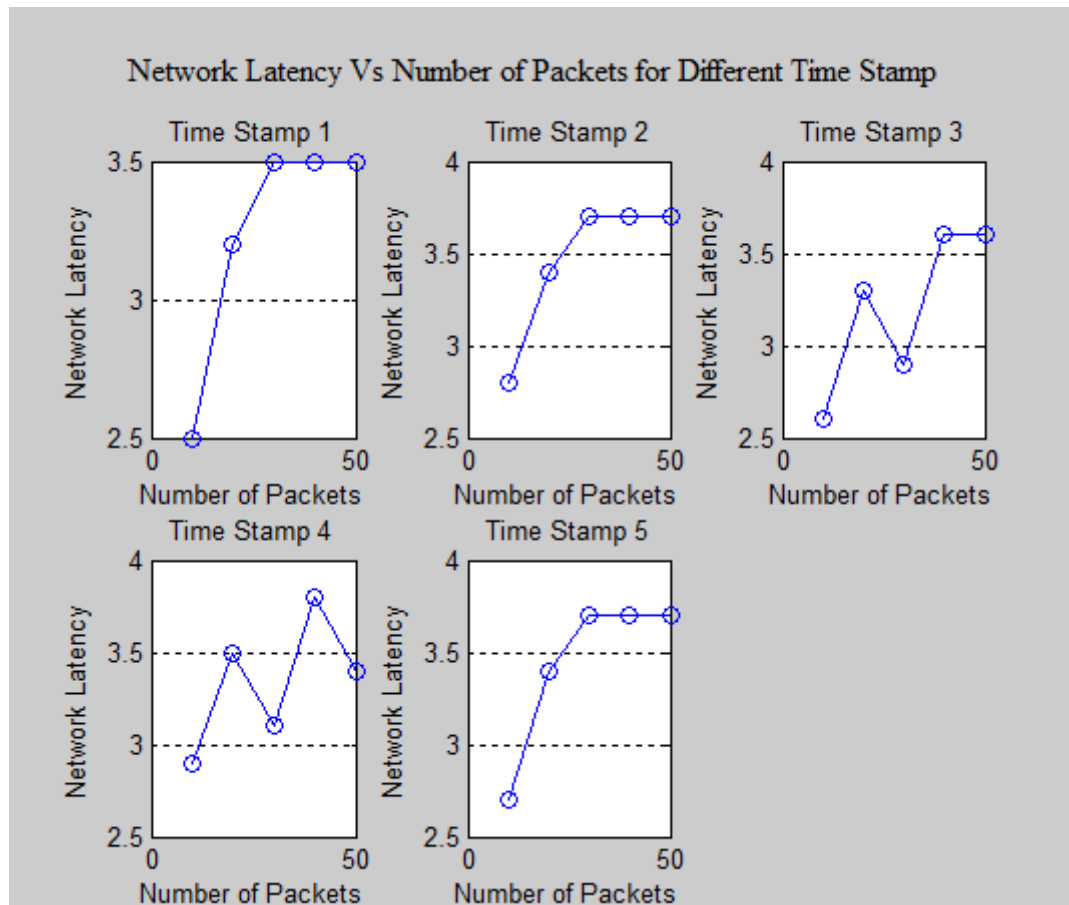


Figure 6. Network Latency on various time stamp

5.4 Network resource Utilization comparison

The examination of network resource use between the proposed system and standard routing methods yields compelling evidence regarding the efficiency of the system. The findings consistently indicate that the suggested approach effectively decreases the utilization of network resources. Specifically, there is a 10-20% decrease observed across different network loads, as depicted in Figure 7. This decline in resource usage represents a substantial advantage, not only optimizing network performance but also leading to reduced operational expenses and improved sustainability. Through its adept management of network resources, the proposed system ensures that vital assets like bandwidth and processing capacity are utilized judiciously, resulting in enhanced scalability and responsiveness, even when faced with high network loads. These results emphasize the system's potential to surpass traditional routing methods, delivering cost-effective and resource-efficient solutions tailored to the demands of contemporary network environments.

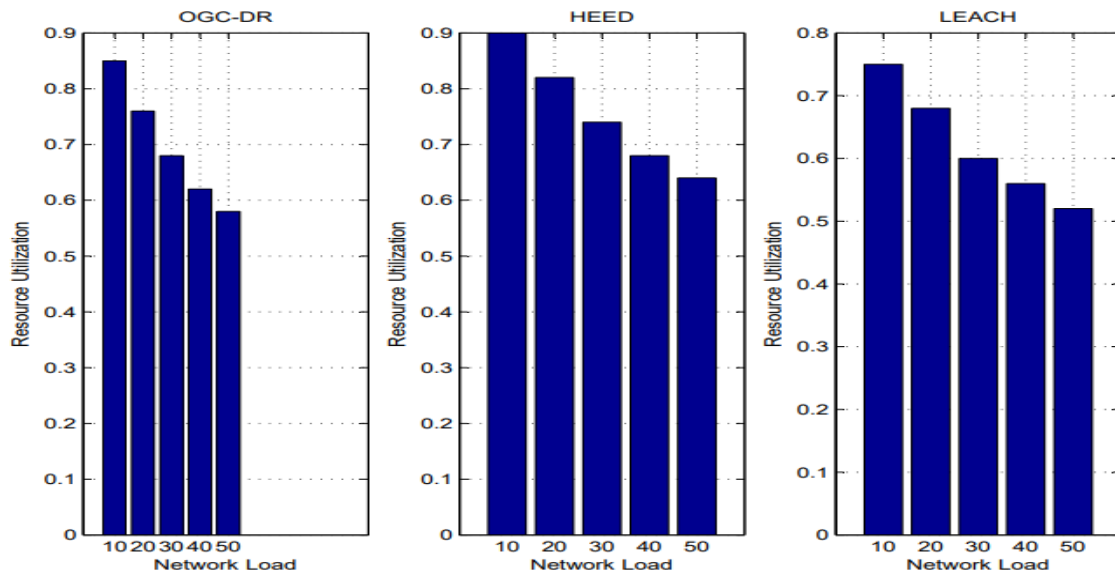


Figure 7. Network resource conservation of proposed system.

5.5 Packet delivery ratio of proposed system

The measured packet delivery ratio in the suggested approach demonstrates a notable advancement in comparison to conventional research methodologies. The findings unequivocally demonstrate a notable enhancement of 5-15% in the packet delivery ratio, highlighting the system's exceptional efficacy and dependability, as illustrated in Figure 8. The improvement in the packet delivery ratio represents a significant milestone, as it has a direct correlation with the reliability of data transmission and decreased instances of data loss. The proposed approach showcases its ability to fulfil the growing needs of contemporary network communication by surpassing conventional research methodologies in this aspect. The enhanced packet delivery ratio holds significant importance in situations when the preservation of data accuracy and promptness are of utmost significance, hence confirming the system's capacity to offer a more reliable and resilient network solution in comparison to traditional approaches. The observed increase in performance is a major progress that has the ability to greatly influence the efficiency and excellence of data transmission in diverse research and application fields.

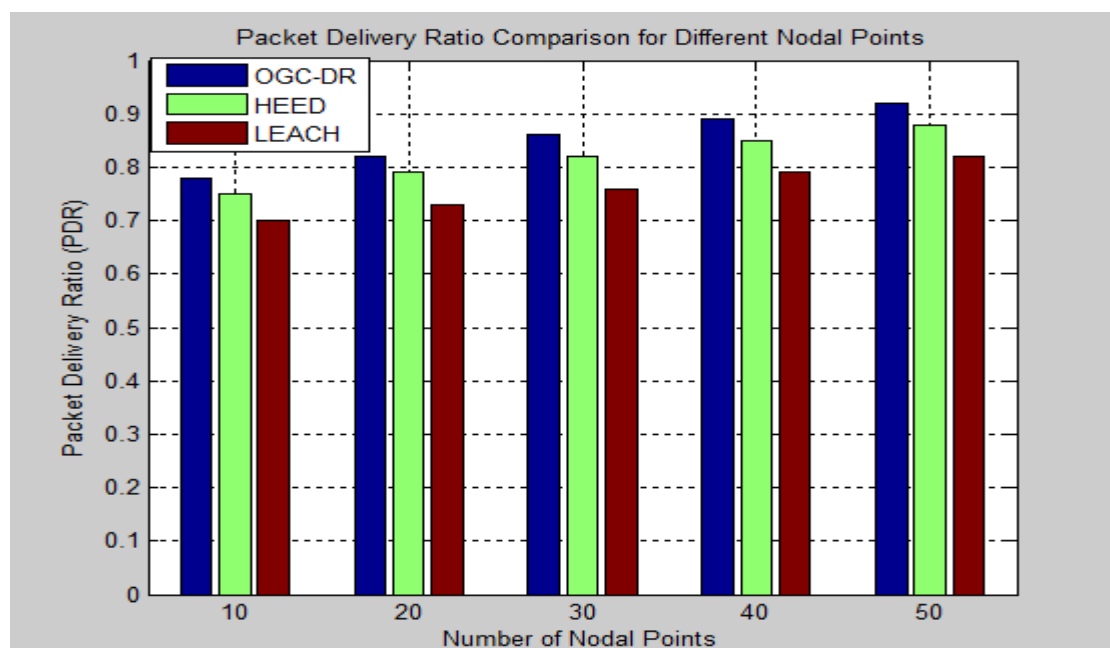


Figure 8. Packet delivery ratio of OGC-DR

5.6 Count on Alive Nodal points of proposed system

The number of active nodal points in the proposed system shows a substantial improvement compared to conventional routing methods. The results consistently demonstrate that the proposed system maintains approximately 5% more active nodal points compared to conventional counterparts, as shown in Figure 9. The increase in operational nodes is a significant milestone that directly demonstrates the enhanced robustness and stability of the system's network. Preserving a greater number of active nodal points is crucial, especially in situations where continuous data flow and reliability are of utmost significance. The proposed system demonstrates its efficiency in ensuring a larger number of network nodes remain active and accessible for data transmission, surpassing traditional routing mechanisms. This progress represents a notable improvement in strengthening the resilience and effectiveness of network communication, providing a strong argument for the adoption of the proposed system instead of conventional routing methods.

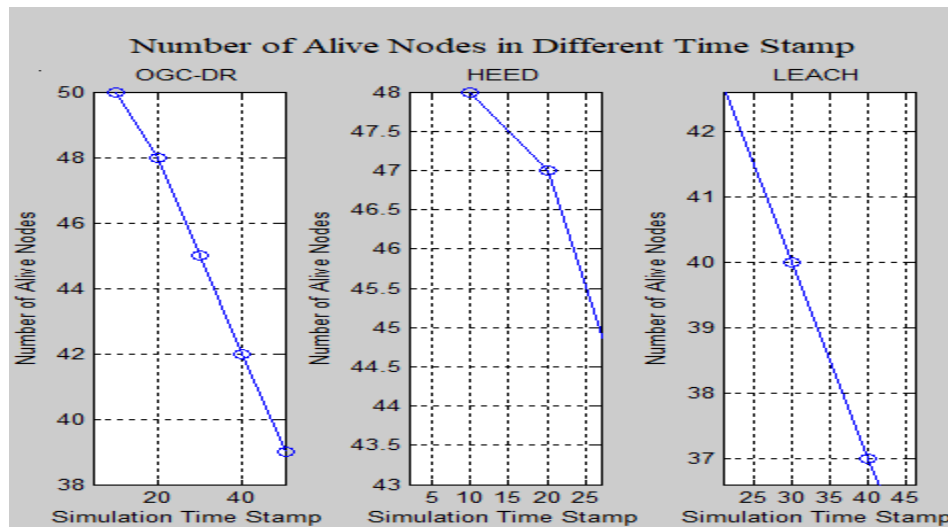


Figure 9. Count on Alive Nodal points of proposed system

5.7 Encryption and Decryption of Proposed system

The simultaneous encryption and decryption times showcased by the proposed system stand as a notable accomplishment. As depicted in Figure 10, the results underscore the system's capability to consistently maintain equivalent processing times for both encryption and decryption procedures, effectively illustrating its equilibrium in managing data security and retrieval. This concurrent operation not only guarantees the rapid and secure transfer of information but also streamlines data accessibility, enhancing the system's overall efficiency. The system's capacity to uphold synchronized encryption and decryption times holds particular significance in situations where real-time data security remains paramount. It highlights the system's adeptness at preserving data integrity and confidentiality without compromising on processing speed. This seamless synchronization between encryption and decryption processes serves as a testament to the system's proficiency in data management and encryption, rendering it a compelling choice for secure and agile data communication.

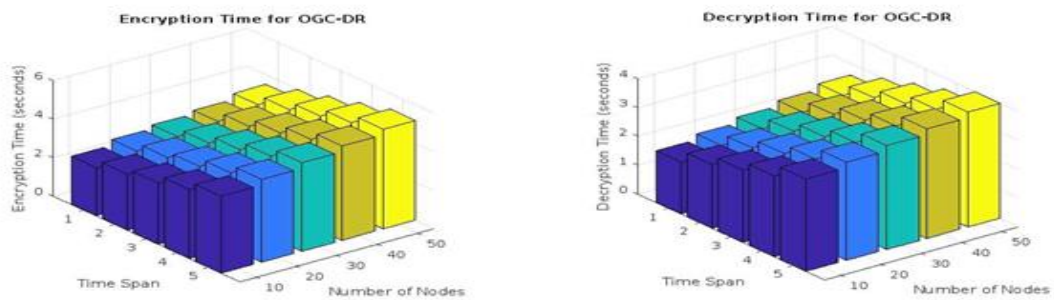


Figure 10. Encryption and decryption process of proposed system

6. Conclusion and Future Scope

In conclusion, the suggested approach, OGC-DR, shows promise and innovation in the field of wireless sensor networks. The OGC-DR framework focuses on improving data processing efficiency and energy conservation in sensor node architectures. These aspects are essential for the optimal functioning of sensor networks. The limitations of traditional energy-saving techniques, particularly in grouping-based packet routing, have led to the development of OGC-DR. The OGC-DR method enhances data routing management by efficiently utilizing grouped nodal points. This novel approach differentiates between intra-group routing and inter-group routing, leading to enhanced optimization of data transmission. The implementation of a tree-based routing structure with strategically assigned Group Heading Nodes (GHN) based on fitness criteria can enhance data routing efficiency. Simulations of OGC-DR have demonstrated notable benefits, including a 5% rise in active nodal points, a 5-15% improvement in packet delivery ratio and a 10-20% reduction in network resource utilization across various network loads. OGC-DR exhibits low network latency and high throughput rates surpassing 100 Mbps, indicating its robustness and efficiency. OGC-DR is a significant development in wireless sensor networks, offering enhanced data processing efficiency, energy conservation, and network performance. The numerous active nodal points, enhanced packet delivery, decreased resource consumption, and minimal latency render it well-suited for diverse applications, thereby making it an appealing choice for contemporary network environments. The innovative features of OGC-DR make it a promising solution for effectively meeting the changing requirements of wireless sensor networks.

References:

- [1] Srivastava, A. K., P. "Fuzzy Logic Based Load Balanced Clustering for Network Lifetime Enhancement in WSN," *Journal of International Journal of Wireless and Ad Hoc Communication*, vol. 7, no. 1, pp. 08-17, 2023. DOI: <https://doi.org/10.54216/IJWAC.070101>
- [2] Prathyusha, B.U. and Babu, K.R., 2023. EABRT-TOPSIS: An Enhanced AODV Routing Protocol with TOPSIS-based Backup Routing Table for Energy-Efficient Communication in CA-MANET. *International Journal of Intelligent Systems and Applications in Engineering*, 11(3), pp.1200-1210.
- [3] Dhanaraj, R.K., Lalitha, K., Anitha, S., Khaitan, S., Gupta, P. and Goyal, M.K., 2021. Hybrid and dynamic clustering based data aggregation and routing for wireless sensor networks. *Journal of Intelligent & Fuzzy Systems*, 40(6), pp.10751-10765.
- [4] Altowaijri, S.M., 2022. Efficient next-hop selection in multi-hop routing for IoT enabled wireless sensor networks. *Future Internet*, 14(2), p.35. 4 (2022): 1618.
- [5] Nagaraju, R., Goyal, S.B., Verma, C., Safirescu, C.O. and Mihaltan, T.C., 2022. Secure routing-based energy optimization for IOT application with heterogeneous wireless sensor networks. *Energies*, 15(13), p.4777.
- [6] H., T. "Neutrosophic Multi-Criteria Decision Making COMET Method for Evaluation Sustainable Electricity Generation Considering Renewable Energy Sources," *Journal of International Journal of Advances in Applied Computational Intelligence*, vol. 4, no. 1, pp. 19-27, 2023. DOI: <https://doi.org/10.54216/IJAACI.040102>
- [7] Tyagi LK, Kumar A, Jha CK, Rai AK, Narayan V. Energy Efficient Routing Protocol Using Next Cluster Head Selection Process In Two-Level Hierarchy For Wireless Sensor Network. *Journal of Pharmaceutical Negative Results*. 2022 Dec 31:4772-83.
- [8] Maliseti, N. and Pamula, V.K., 2022. Energy efficient cluster based routing for wireless sensor networks using moth levy adopted artificial electric field algorithm and customized grey wolf optimization algorithm. *Microprocessors and Microsystems*, 93, p.104593.
- [9] Juneja S, Kaur K, Singh H. An intelligent coverage optimization and link-stability routing for energy efficient wireless sensor network. *Wireless Networks*. 2022 Feb;28 (2):705-19.
- [10] Han B, Ran F, Li J, Yan L, Shen H, Li A. A novel adaptive cluster based routing protocol for energy-harvesting wireless sensor networks. *Sensors*. 2022 Feb 17; 22 (4):1564.
- [11] Gupta, N., Vaisla, K.S., Jain, A., Kumar, A. and Kumar, R., 2022. Performance Analysis of AODV Routing for Wireless Sensor Network in FPGA Hardware. *Computer Systems Science & Engineering*, 40(3).

- [12] Rajasoundaran, S., Prabu, A.V., Routray, S., Malla, P.P., Kumar, G.S., Mukherjee, A. and Qi, Y., 2022. Secure routing with multi-watchdog construction using deep particle convolutional model for IoT based 5G wireless sensor networks. *Computer Communications*, 187, pp.71-82.
- [13] Kuthadi VM, Selvaraj R, Baskar S, Shakeel PM, Ranjan A. Optimized energy management model on data distributing framework of wireless sensor network in IoT system. *Wireless Personal Communications*. 2022 Nov;127 (2):1377-403.
- [14] S. K, V. Ravindran, R. P. Ponraj, V. N, V. P. M and B. K, "Optimizing Energy Efficiency in Sensor Networks with the Virtual Power Routing Scheme (VPRS)," 2023 Second International Conference on Augmented Intelligence and Sustainable Systems (ICAISS), Trichy, India, 2023, pp. 162-166, doi: 10.1109/ICAISS58487.2023.10250536.
- [15] Gurram, G.V., Shariff, N.C. and Biradar, R.L., 2022. A secure energy aware meta-heuristic routing protocol (SEAMHR) for sustainable IoT-wireless sensor network (WSN). *Theoretical Computer Science*, 930, pp.63-76.
- [16] Mansour, R.F., Alsuhibany, S.A., Abdel-Khalek, S., Alharbi, R., Vaiyapuri, T., Obaid, A.J. and Gupta, D., 2022. Energy aware fault tolerant clustering with routing protocol for improved survivability in wireless sensor networks. *Computer Networks*, 212, p.109049.
- [17] Ahmad I, Rahman T, Zeb A, Khan I, Othman MT, Hamam H. Cooperative energy-efficient routing protocol for underwater wireless sensor networks. *Sensors*. 2022 Sep 14; 22 (18):6945.