EFFICIENT SECURED ROUTING WITH MOBILE SINKS (EESRMS) : AN EFFECTIVE METHOD TO MINIMIZE ENERGY UTILIZATION IN UNDER WATER SENSOR NETWORKS

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ABSTRACT

Underwater Wireless Sensor Networks (UWSNs) are specialized wireless sensor networks (WSNs) that monitor and communicate in underwater environments. Environmental monitoring, underwater exploration, disaster relief, military surveillance, and offshore industry activities are just a few of the many uses for them. High propagation delays, constrained bandwidth, changeable topology, and energy constraints make routing in UWSNs difficult. Underwater routing systems have to adjust to high bit error rates, signal attenuation, and node mobility, unlike terrestrial WSNs. Because underwater sensor nodes have limited battery power and are difficult to replace or recharge, energy efficiency is a major concern in UWSNs. Optimizing energy consumption is critical for extending network life and guaranteeing consistent data delivery. Optimization strategies are critical to improve routing performance in UWSNs. Given the constraints of underwater environments such as high energy consumption, long propagation delays, changeable topology, and restricted bandwidth, optimization approaches aid in determining the optimum routing paths, reducing energy consumption, and improving data delivery dependability. The proposed approach, "Energy-Efficient Secured Routing with Mobile Sinks (EESRMS)" includes PSO to discover the ideal path to route data while minimizing energy during transmission, and the results demonstrate that it performs well in characteristics such as PLR, latency, security, and energy usage.

Keywords: Routing, UWSN, Security, WSN, Energy efficiency.

1. INTRODUCTION

Wireless Sensor Networks' ability to collect and analyse data in real time is revolutionizing a variety of sectors. WSNs will continue to expand into smart cities, healthcare, defence, and industrial IoT due to advances in low-power technology, AI-driven analytics, and 5G connectivity. Energy efficiency is critical for extending WSN lifespan. Energy harvesting, duty cycling, data aggregation, and efficient routing are all effective power-saving strategies. Future advancements in wireless energy transfer and AI-driven optimization could boost WSN energy efficiency even further. In Wireless Sensor Networks (WSNs), routing refers to the process of selecting data transmission routes between sensor nodes and the base station (sink).

Sensor nodes have a limited battery life, thus energy-efficient routing is necessary. Frequent data transfer depletes energy rapidly. Large-scale WSNs require efficient routing to reduce congestion. Moving nodes (such as in warfare applications) result in frequent topology changes. Repeated broadcasts use both energy and bandwidth. Some applications require low latency and great reliability (for example, healthcare and catastrophe response). Node performance is impacted by harsh environments (for example, underwater or underground). WSNs require specialized routing algorithms due to their unique constraints, which include limited energy, bandwidth, and processing capability. Various protocols, such as flat, hierarchical, or location-based routing, are developed to meet the network's needs.

A variety of factors, including network scalability, data accuracy, and energy usage, influence protocol selection. Sensor nodes rely on batteries, which may be difficult to repair in remote areas. Effective routing algorithms optimize data transmission paths to save energy. The lifespan of a WSN is determined by the effectiveness with which nodes manage their energy. The application requirements of a Wireless Sensor Network (WSN), as well as scalability, energy efficiency, and dependability, all contribute to the ideal routing protocol selection. Optimization strategies are crucial for increasing the effectiveness of routing protocols in Wireless Sensor Networks (WSN).

These algorithms help to reduce energy consumption, balance network traffic, eliminate delays, and increase data transmission reliability. Particle Swarm Optimization (PSO) is a nature-inspired optimization technique that replicates the social behaviour of birds and fish. It is widely used in Wireless Sensor Network (WSN) routing to boost energy efficiency, path selection, and load balancing. This work focuses on developing a routing system called Energy-Efficient Secured Routing with Mobile Sinks (EESRMS), which combines shortest path routing via hop tree construction with PSO and improves data security by adding the AES encryption standard.

2. RELATED WORK

[1] The suggested energy-efficient routing protocol is built on an improved evolutionary algorithm and data fusion method. The proposed energy-efficient routing protocol improves on an existing genetic algorithm by incorporating an encoding method, a crossover procedure, and an improved mutation operation that aids in node identification. The proposed model also used an enhanced back propagation neural network for data fusion operation, which is based on a multi-hop system and operates a highly optimized momentum technique, which helps to choose only the best energy nodes and avoid duplicate selections, thereby improving overall energy and reducing the amount of data transmitted. The suggested energy-efficient routing protocol employs an upgraded cluster head node to select a strategy that can analyse the remaining energy. [2] In this study, when a node needs to decide on the routing path, they take into account the degrees of potential data aggregation of neighbour nodes. They suggest a brand-new data-aggregation-aware, energy-efficient routing method based on Q-learning. In order to find the best path, the suggested approach leverages reinforcement learning to maximize the rewards at each sensor node, which are specified in terms of the effectiveness of the sensor type-dependent data aggregation, communication energy, and node residual energy. They employed aggregation rewards that depended on the type of sensor. The performance of the suggested

routing technique was then assessed through simulations, and it was contrasted with that of the traditional energy-conscious routing algorithms. Their findings show that the proposed methodology can successfully lower the amount of data and extend the life of the WSN. [3] In this paper, the Particle Swarm Optimization (PSO) method is used to form the cluster in WSN, and a Fuzzy based Energy Efficient Routing Protocol (E-FEERP) is proposed that uses battery energy, average SN distance from BS, node density, and communication quality to optimally transmit data from Cluster Head (CH) to BS. The suggested E-FEERP's simulation results are compared to those of existing techniques, and they indicate an improvement in network performance-based measures such as throughput, residual energy (RE), load balancing ratio, packet delivery ratio, energy consumption, and network lifetime.

[4] In order to extend the network lifetime of software-defined multihop wireless sensor networks (SDWSNs), the authors of this research suggest an energy-aware routing algorithm and a control overhead reduction technique. WSNs that supply services to the Industrial Internet of Things (IIoT) are being optimized in terms of energy consumption. By adding additional control overhead to the network, a centralized controller provides a worldwide perspective of the sensor network; however, this results in increased energy expenses. By choosing the paths with the highest residual energy level among several paths for every sensor node, the new algorithm, however, makes use of this global perspective and balances the network energy. Additionally, by creating a data packet aggregation function and monitoring the sensor nodes' routing tables with a basic checksum function, they limit the influence of critical functions that drain energy from the SDWSN. [5] An energy-efficient layered routing protocol (EELRP) is suggested in this research. The network is divided into a number of concentric circles with varying radii using the suggested method. Eight equal sections make up the circles. Crossovers between layers and sectors result in sections. There are several nodes in each part, and the best one is chosen to be the agent. Each section's nodes communicate the sensed data to their agent. The agent then sends information to the agent of the lower portion of the same sector after aggregating the data and providing error detection and correction based on the redundant residue number method. Until the data reaches the base station, the process is repeated. One may observe that EELRP improves network lifetime, energy usage, packet delivery rate, and path hop count when comparing its performance to that of traditional approaches.

[6] The energy-efficient hierarchical routing protocol for wireless sensor networks based on fog computing is the name of the effective routing protocol that is proposed in this article for data transfer in WSNs. Because fog computing may scale up to meet the demands of Internet of Things applications and optimize the constrained power source of WSNs, it is incorporated into the suggested system. Furthermore, they suggest an enhanced ant colony optimization technique that can be applied to build the best possible path for sensor nodes to transmit data efficiently. The suggested scheme's performance is assessed in relation to the P-SEP, EDCF, and RABACO schemes. The simulations' outcomes demonstrate that the suggested strategy can reduce the energy usage of sensor nodes, reduce data packet losses, and increase network lifetime. They are aware that a variety of circumstances, including hardware malfunctions, ambient influences, and depleted energy, might affect the certainty of the sensed data gathered by a sensor node in a wireless sensor network (WSN). [7] To solve issues like as power consumption, network lifetime, node deployment, topology, and

propagation delays, cooperative transmission protocols such as co-operative (Co-UWSN) and co-operative energy-efficient routing (CEER) have been developed. These protocols use broadcast capabilities and neighbor head node (NHN) selection to enable cooperative routing. This study introduces NBEER, a unique neighbor-based energy-efficient routing strategy designed specifically for UWSNs. NBEER attempts to overcome the constraints of Co-UWSN and CEER by optimizing NHNS and cooperative techniques for load balancing and improving network performance. We conducted extensive MATLAB simulations to compare NBEER against Co-UWSN and CEER, revealing its superior performance across a variety of measures. NBEER considerably boosts end-to-end latency, reduces energy consumption, improves packet delivery ratio, extends network lifetime, and enhances total received packets analysis when compared to existing protocols. [8] In order to prevent numerous retransmissions that could impair the network's overall performance, the routing strategy proposed in this study adjusts to changes in the network topology. In order to create an intelligent routing decision based on objectives, criteria, and alternatives, this protocol uses a fuzzy analytical hierarchical process (FAHP) under multi-criteria decision making (MCDM). It is energy-efficient. The number of hops, the distance to the sink node, and the number of neighbors is comparison matrices that are used to choose the next node on the route. Based on fuzzy techniques like SPRINT, the results demonstrate that the suggested configuration performs comparable to other known underwater sensor network routing schemes.

[9] This study focuses on developing the metaheuristics-based clustering with a routing protocol for UWSN, called MCR-UWSN, in order to address these problems and accomplish energy efficiency in UWSN. The MCR-UWSN technique aims to route to the target and elect an effective group of cluster heads (CHs). In order to create clusters, the MCR-UWSN approach uses cultural emperor penguin optimizer-based clustering (CEPOC) techniques. Additionally, the grasshopper optimization (MHR-GOA) and multi-hop routing techniques are derived using a number of input factors. The MCR-UWSN technique's performance was verified, and the outcomes are examined using a variety of metrics. The experimental findings demonstrated that the MCR-UWSN technique outperformed the most recent state-of-the-art methods. [10] This paper presents the IMCMR-UWSN approach, an enhanced metaheuristics-based clustering with multihop routing protocol for underwater wireless sensor networks. The selection of cluster heads (CHs) and the best paths to a destination are the main goals of the IMCMR-UWSN approach. The IMCMR-UWSN technique consists of two main processes: multihop routing based on the self-adaptive glow worm swarm optimization algorithm (SA-GSO) and clustering based on the chaotic krill head algorithm (CKHA). Based on a variety of factors, including residual energy, intra-cluster distance, and inter-cluster distance, the CKHA approach chooses CHs and arranges clusters. A fitness function comprising four parameters—remaining energy, delay, distance, and trust—is also derived by the SA-GSO algorithm. By using the IMCMR-UWSN technology, the UWSN's lifetime and energy efficiency are greatly increased. A number of simulations were conducted to guarantee the enhanced performance of the IMCMR-UWSN technique, and the comparative findings demonstrated the technique's superiority across several metrics. [11] To address the current issues, the Energy Optimization utilizing Routing Optimization (EORO) protocol is suggested. In order to select the best forwarder node for UWSN data delivery, we create Effective Fitness Function-based Particle Swarm Optimization (EFF-PSO). In

EORO, the intended source node uses location information to find forwarding relay nodes first. The best relay node is then chosen using the EFF-PSO algorithm, taking into account a wide range of factors. Each forwarder node's four parameters—remaining energy, packet transmission capability, node connectedness, and distance—are utilized to calculate fitness. By preventing packet collisions, these settings are specifically selected to lower throughput, delay, and energy consumption. In terms of throughput, energy consumption, latency, and Packet Delivery Ratio (PDR), EORO outperformed underlying routing technologies.

[12] They provide an energy-efficient clustering multi-hop routing protocol (EECMR) in the study that can balance these nodes' energy usage and lengthen the network's lifespan. Depending on the depth level, the network area is separated into layers. Through a multi-hop routing path, the nodes' sensed data is sent to a sink. The cluster head is chosen based on the node's depth and remaining energy. The cluster head gathers all cluster members' data packets and sends them to the higher layer of the sink node in order to send data from the node to the sink. The outcomes of the simulation demonstrate that EECMR works well in terms of both network lifetime and node energy consumption. [13] Using the sense of butterflies, the Multilayer Clustering-based Butterfly Optimization Routing (MCBOR) algorithm has been developed to send data packets to their destination without any loss. Reducing transmission loss and raising PDR are the goals of the proposed study. The suggested MCBOR's performance is assessed by contrasting it with those of cutting-edge techniques. According to the evaluation report, the suggested MCBOR yields a residual energy of 0.47 J, an end-to-end delay of 6.3 s, and a packet delivery ratio of 0.98%. Therefore, it has been demonstrated that MCBOR is more effective in PDR and lowers transmission loss. [14] This research presents a Hierarchical Adaptive Energy-efficient Clustering Routing (HAECR) approach. First, this technique splits hierarchical zones based on the depth of the sensor node in a three-dimensional space. Second, sensor nodes create distinct competition radii based on their relevant features and remaining energy. Nodes in the same layer compete openly to create clusters of varying sizes. Finally, the transmission path between clusters is established using comprehensive parameters such as link quality, and the best route is planned. The simulation experiment is carried out inside the monitoring range of the 3D space. The simulation findings show that the HAECR clustering method outperforms LEACH and UCUBB in terms of balancing and decreasing energy consumption, prolonging network lifetime, and enhancing the number of data transmissions.

[15] Anchor Nodes helped Cluster-based Routing Protocol (ANCRP) establish consistent data transmission metrics, while the Void Handling approach in ANCRP (VH-ANCRP) dealt with the local maximum nodes. To achieve this, the network space is partitioned into little cubes called clusters. Then, each cube is assigned an anchor node to serve as the cluster head (CH). All cluster heads are expected to be tied to the centroid of a cube via a string, whereas source nodes are randomly distributed. In ANCRP, the source nodes are responsible for sending the detected data to their designated CH. The CH transmits the sensed data to the next-hop CH and repeats this process until the data packets are successfully delivered to the surface sinks. To reconnect with network operations in VH-ANCRP, void nodes adopt a void handling mechanism that involves creating an ad-hoc CH. We do extensive simulations in NS3 to validate our approaches. The simulation results show that both proposed schemes enhanced network performance when compared to the baseline methods. [16] This study describes an energy-efficient routing system dubbed the Energy-aware

Proportional Fairness Multi-user Routing (EPFMR) framework for WSN. EPFMR is deployed in a WSN context using instance time. The request time submitted for route finding is the first step developed in the EPFMR framework to reduce energy usage. In WSN, proportional fairness routing finds the best route path for packet flow based on the relationship between request times from distinct SN. The Greedy Instance Fair Method (GIFM) is used to quantify energy on multi-user route paths uncovered via packet flow analysis. The GIFM in EPFMR generates node-dependent energy-efficient localized route paths, increasing throughput. The energy-aware framework optimizes throughput rates and conducts experimental evaluations on aspects such as energy consumption rate during routing, throughput, RST, node density, and average energy per packet in WSN. The Boltzmann Distribution (BD) is used to reduce the Route Searching Time (RST), resulting in the minimization of energy on multi-user WSN. Finally, GIFM uses an instance time difference-based route search on WSN to achieve an optimal energy minimization system. [17] The suggested solution consists of four subsequent procedures: first, the sensing field is divided into equal sections based on the number of deployed mobile sinks, which eliminates the energy-hole problem. A new heuristic clustering approach, the stable election algorithm (SEA), is developed to reduce message transmission between sensor nodes and prevent frequent cluster head movement. A sojourn location determination approach is proposed that uses the minimal weighted vertex cover problem (MWVCP) to determine the ideal spot for sinks to pause and gather data from cluster heads. Finally, three optimization strategies are used to evaluate the optimized mobile sink trajectories via multi-objective evolutionary algorithms (MOEAs). The performance of the created work was assessed in terms of cluster head count, network lifetime, execution time of the sinks' sojourn location determination algorithm, convergence rate of optimization techniques, and data delivery. The simulation scenarios ran in MATLAB, and the results revealed that the proposed approach outperformed equivalent existing schemes. It was successful in increasing the network lifetime by up to 66% when compared to traditional routing methods.

[18] They present the Geographic and Cooperative Opportunistic Routing system (GCORP), a novel routing system. GCORP uses intermediary relay nodes to coordinate the routing of packets from the source node to the surface sinks. The GCORP protocol first establishes a network topology based on many sinks. The source node then uses the depth fitness factor to determine a relay forwarding set. Lastly, the relay forwarding set's weight calculation scheme is used to identify the optimal relay. To verify the suggested GCORP routing protocol in relation to various network parameters, they run simulations in NS3. According to the simulations, the GCORP protocol performs better than current methods. [19] In order to create a multipath protocol known as the Particle Swarm Optimization Routing Protocol (MPSORP), an optimization strategy utilizing the Particle Swarm Optimization (PSO) algorithm is suggested in this study. For WSN-based Internet of Things applications with high traffic loads and unjust network flow, the MPSORP is utilized. An experiment is carried out utilizing the NS-2 simulator with various configurations and settings in order to assess the created methodology. Additionally, AODV and DSDV routing protocols are compared with MPSORP's performance. The comparison's testing findings showed that the suggested method saves energy and has low end-to-end delay, high packet delivery ratio, high throughput, and low normalization load, among other benefits. [20] Particle Swam Optimization (PSO) and Water Wave Optimization (WWO) are combined to create the

suggested P-WWO algorithm. Using PSO-based cellular automata with fitness measure, the Cluster Head is chosen to identify the secure path required to broadcast the data packets. However, the fitness measure is computed by considering the factors, like energy, delay, trust, consistency factor, and maintainability factor. Therefore, utilizing the suggested P-WWO based on the fitness value, the routing path with the smallest distance and the least time is acknowledged as the ideal way. The suggested optimization can determine if the packets can be sent over the chosen path or if the data needs to be rerouted thanks to the route maintenance procedure. Furthermore, when utilizing criteria like the energy balancing index, coverage, number of alive nodes, and average energy left, the suggested P-WWO performed better.

[21] This study suggests a dependable and energy-efficient framework for an enhanced high-performance cluster-based secure routing protocol. This protocol's main characteristic is that it improves the quality of data management by taking into account factors like energy, packet mitigation, congestion management, encrypted data transfer, and attacker node monitoring. The wireless sensor nodes may eventually lose their ability to communicate with the base station and go dead due to network separation segmentation issues. The effectiveness of the suggested method has been shown using metrics such as ransomware attack detection rate, ergodic residual energy over rounds, early detection of clone attack throughput maximization, latency, capacity maximization, and network lifespan. [22] This study proposes a binomial distribution-based lightweight trust management strategy (LTMS) to protect against internal threats. In order to provide a multidimensional secure clustered routing (MSCR) system using dynamic dimension weight in hierarchical WSNs, the distance, energy, security, and environment domains are all taken into consideration and introduced simultaneously. According to the simulation results, MSCR can successfully strike a balance between security, transmission performance, and energy efficiency while meeting the demands of environmental applications, and LTMS can successfully stop a malicious node from being chosen as the cluster head. [23] A new chaotic search-and-rescue-optimization-based multi-hop data transmission protocol (CSRO-MHDT) for UWSNs is presented in this research. The CSRO-MHDT technique renders a variety of properties, such as remaining energy, intra-cluster distance, and inter-cluster detachment, by selecting cluster headers (CHs) and prearranging clusters. It is also detailed how the original search and rescue optimization (SRO) algorithm was modified to incorporate chaotic concepts, resulting in the chaotic search and rescue optimization (CSRO) algorithm. Furthermore, the CSRO-MHDT method computes a fitness function that considers a number of variables, including node degree, distance, and residual energy. The creation of the CSRO algorithm for route optimization, which was done internally, is one of the paper's unique features. The results of a series of tests conducted to verify the effectiveness of the CSRO-MHDT method revealed that it had an 88% packet delivery ratio (PDR), while the energy-efficient clustering routing protocol (EECRP), fuzzy C-means and moth-flame optimization (FCMMFO), fuzzy scheme and particle swarm optimization (FBCPSO), energy-efficient grid routing based on 3D cubes (EGRC), and low-energy adaptive clustering hierarchy based on expected residual energy (LEACH-ERE) reached lower PDR.

[24] Taking into account the optimization of multiple long-term global performance measures, we examine the routing problem in such a network with novel features including centralized route decision, global network-state awareness, and seamless route discovery in this research. Taking into account the

interference phenomenon of ad hoc scenarios and a few long-term global performance indicators of an ideal routing protocol, we define the complete routing problem of a multi-modal UWSN as an optimization problem. Regardless of whether a sensor node has full-duplex or half-duplex functionality, our issue formulation effectively captures all potential flexibilities. We identify the problem's NP-hardness upon formulation for every situation that could arise. The formulated routing problem that takes into account full-duplex scenarios is solved using a rounding technique based on the convex programming relaxation concept, while the problem for half-duplex scenarios is solved using a greedy method after being interpreted as a submodular function maximization problem. [25] This research proposes a Q-learning based energy-efficient and balanced data gathering (QL-EEBDG) routing protocol. The FNs in QL-EEBDG are grouped based on the energies of their nearby nodes and chosen based on their leftover energy. Efficient energy usage in the network is ensured by using energy as the primary selection parameter. Additionally, the network's lifetime is increased via effective FN selection. However, when the network topology is altered, the void node recovery procedure is unsuccessful. Consequently, a QL-EEBDG adjacent node (QL-EEBDG-ADN) method is suggested in order to prevent void holes in QL-EEBDG. It maintains constant network communication by identifying alternative neighbour routes for packet transport. The effectiveness of the suggested technique is evaluated by extensive simulations using the current baseline protocols, which are QELAR, enhanced EBDG (EEBDG), and efficient balanced energy consumption-based data collecting (EBDG). Network lifetime, energy tax, network stability period, and packet delivery ratio (PDR) are the performance metrics that are employed in the simulations.

3. PROPOSED WORK

Routing for mobile sinks with Particle Swarm Optimization (PSO) is an effective method for improving movement and data collection paths in Wireless Sensor Networks. This method seeks to maximise network lifetime, reduce energy consumption, and assure efficient data gathering by finding the ideal trajectory and scheduling of mobile sinks. Mobile sinks are devices that move through the network collecting data from sensor nodes. Their movement patterns have a substantial impact on energy consumption, network longevity, and data delay. PSO is a metaheuristic derived from the social behaviour of birds and fish. It efficiently examines the solution space for optimization issues by balancing exploitation (using well-known solutions) and exploration (looking for new ones). PSO can adapt to dynamic surroundings, making it ideal for scenarios such as WSNs with fluctuating energy levels and traffic conditions. The suggested routing methodology, Energy Efficient Secured Routing using Mobile Sinks (EESRMS), includes the use of mobile sinks to collect data from cluster heads deployed underwater and optimize the way to the base station using Particle Swarm Optimization. The mobile sinks take data from the cluster heads and send it to a base station on land. Initially, a hop tree is built from the cluster heads so that data can be transferred via single hops. The mobile sinks get the position of the cluster heads from the base station and use PSO to identify the route to collect data. Particles are represented by the trajectories or paths of mobile sinks. Each particle can represent a set of nodes that a data packet will pass through, including its source and destination. The fitness function is specified in terms of energy, network lifetime, and data delay. The fitness function is defined by the equation below:

$$F = \alpha.E + \beta.L + \gamma.D + \delta.C \qquad (1)$$

Where E is the Total energy consumption, L is the network lifetime, D is the data latency, C is the encryption overhead and $\alpha, \beta, \gamma, \delta$ are weight coefficients. The source node encrypts the data with the shared AES key. The encryption assures that even if the data is intercepted by an enemy, it cannot be accessed without the key. The particle representation defines the position of the sink, the data collection schedule, and the speed. Particles modify their positions based on the best known solution and the swarm's solution. The velocity of a particle signifies a change in the sequence of hops or nodes, which will be used to steer the search for optimal pathways. Update rules with velocity and position adjustments as shown in the equation below:

$$v_i(t+1) = w.v_i(t) + c_1.r_1(p_i - x_i) + c_2.r_2(g - x_i) + x_i(t+1) = x_i(t) + v_i(t+1) \qquad (2)$$

Where v_i is the velocity of the particle, x_i is the position of the parcticle, p_i is the best position found by the particle, g is the best position found by the swarm, w, c_1, c_2 are weighing factors and r_1, r_2 are random numbers in [0,1].

Once the particles have converged (i.e., the fitness values have stabilized), the best path (gbest) discovered by the swarm is chosen as the ideal route for delivering data packets from the source to destination. The selected path can be used to route packets across the network. The sink (or destination) node can send feedback to the source node in real time to confirm that the path chosen is optimal and valid. When Particle Swarm Optimization (PSO) and Advanced Encryption Standard (AES) are combined, Wireless Sensor Network (WSN) routing improves security and energy efficiency. AES ensures secure data transmission, whilst PSO optimizes the routing path. AES encryption is used between the cluster heads and base station, where the mobile sinks serve as intermediaries to transfer data to the base station, since the clustering process provides the cluster heads' location and energy level in advance. Sensor data should be encrypted using AES (128-bit, 192-bit, or 256-bit) before transmission to cluster heads, and decoded only at the base station. The mobile sinks are unable to decode the data collected from the cluster heads. The source and destination nodes establish a shared AES key. This key is used for encryption as well as decryption. Prior to transmission, the sensor data is divided into 128-bit blocks. Using the shared AES key, each data block is encrypted with AES.

$$C_{data} = AES_K(P_{data}) \qquad (3)$$

Where C_{data} is the ciphered data, AES_K is the key and P_{data} is the data before encryption.Cluster heads are used to send the encrypted data to the mobile sink node. The same AES key is used to decrypt the data once it arrives at the destination node. The following is an expression for the decryption process:

$$P_{data} = AES_K{}^{-1}(C_{data}) \qquad (4)$$

The PSO-selected optimal path is used to deliver encrypted data. PSO dynamically reroutes data through alternate secure channels in the event that a node is hacked.

Algorithm : Optimal Path Selection

Objective: Minimize energy consumption, enhance network lifetime, minimize data latency

Input

Network area Net_{area} *and Network topology* Net_t

Positions of nodes $N_{(x,y)}$ *and Initial energy* E_i

Communication range N_c *and number of mobile sinks* S_i

Start

Assess the sequence sink positions $S_{(x1,y1)}$, $S_{(x2,y2)}$,, $S_{(x3,y3)}$……….. $S_{(xn,yn)}$

Define speed of the Sink

Define Fitness Function

Initialize

Sink Trajectories

Initial Velocities

Define personal best solution p_{best} *and global best solution* g_{best}

For each particle

Evaluate fitness of current particle

Update p_{best} *and* g_{best}

Update particle velocity and position

Stop

When fitness function is below threshold

End

Algorithm : Data Security

Objective: Secure data transmission

Input

Energy level of cluster head E_{ch} *and position of cluster head* $CH(i)_{(x,y)}$

Encryption key AES_k

Start

Construct AES key with 128 bit

Divide sensor data into 128 bit blocks

For each cluster head

Encrypt data using key

For each mobile sink

Choose optimal path to reach CH(i)

Collect aggregated data from CH(i)

For Base Station

Decrypt data using key

Repeat for every round

End

4. RESULTS AND DISCUSSION

Simulation Parameters		
1	Simulation area	100 m x 100 m
2	Number of nodes	200
3	Deployment	Random
4	Node Mobility	Fixed
5	Initial energy	1000 J
6	E_{fs}	$10 * 10^{-2}$ J
7	E_{tx}	$50 * 10^{-9}$ J
8	E_{rx}	$50 * 10^{-9}$ J
9	E_{agg}	$50 * 10^{-9}$ J
10	Radio propagation range	300 m
11	Channel capacity	2 M bits/s
12	Data packets	3200 bits
13	Simulation time	180 s

Table 4.1. Simulation Parameters

AES encryption is used to increase data security and PSO is used to determine the best path in the suggested Energy Efficient Secured Routing using Mobile Sinks (EESRMS) approach. Randomly placed underwater, the nodes are localized such that the base station knows where they are. On the land, the base station is fixed. Clusters are created inside the hop tree, which is built from the base station. After a certain amount of time, the cluster heads are rotated and chosen based on their remaining energy. It is the cluster heads who aggregate the data. To gather information from the cluster heads and send it to the base station, two mobile sinks are set up. The suggested routing method finds the best way for the mobile sinks to provide data to the base station and to connect with the cluster heads. To compare the outcomes of the current approaches to the suggested one, PDR, PLR, latency, rate of tampered packets, and energy usage are calculated. [7] Neighbour-Based Energy-Efficient Routing (NBEER) and [19] Multipath Particle Swarm Optimization Routing Protocol (MPSORP) are used to compare the outcomes of the suggested methodology.

Packet Delivery Ratio (PDR): It is an important performance indicator in Wireless Sensor Networks (WSN) that assesses the reliability of data transmission. It is defined as the ratio of packets successfully received at the destination to packets sent by the source.

$$PDR = \frac{Number\ of\ data\ packets\ received}{Number\ of\ data\ packets\ sent} * 100\% \qquad (5)$$

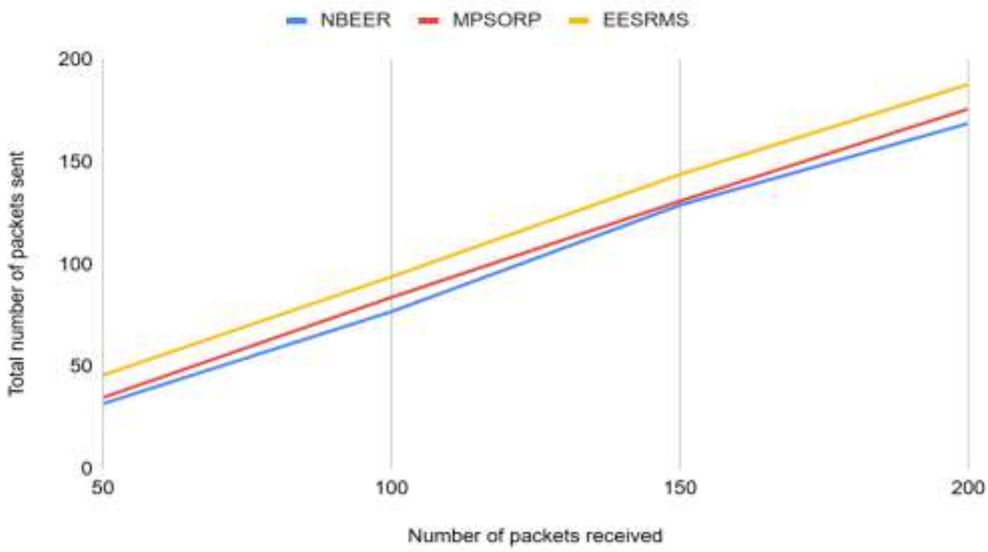


Figure 4.1. Ratio of number of packets sent to number of packets received

The above figure (Fig 4.1) shows that the suggested technique EESRMS delivers more packets than the other two methods, and PDR remains constant even as the number of packets sent varies.

Packet Loss Ratio (PLR): It is a critical performance parameter in Wireless Sensor Networks (WSN) that calculates the percentage of packets that do not reach their destination. It demonstrates the dependability and efficiency of data transfer.

$$PLR = 1 - PDR \quad (6)$$

Number of packets sent	NBEER	MPSORP	EESRMS
50	0.36	0.3	0.08
100	0.23	0.16	0.06
150	0.14	0.14	0.06
200	0.18	0.15	0.06

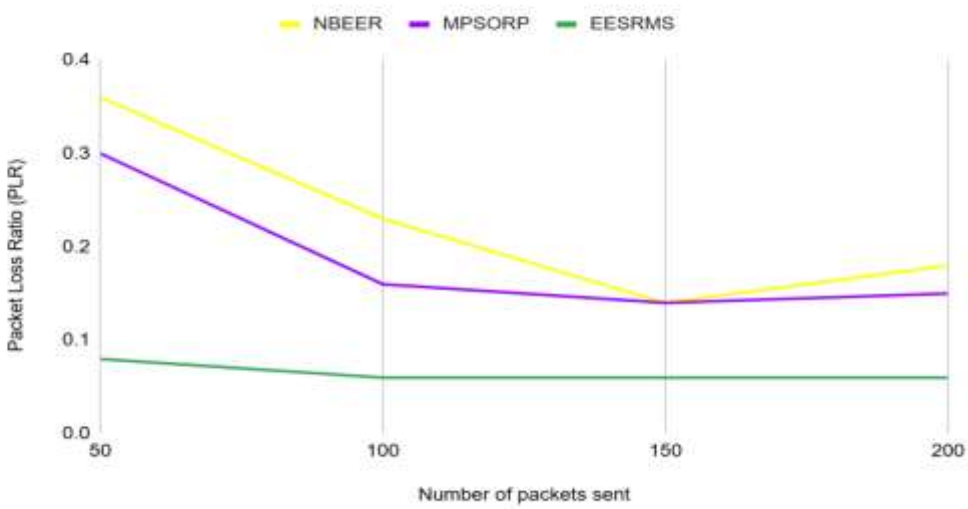


Figure 4.2. Comparison on Packet Loss Ratio among various methodologies

The above table and Figure 4.2 show that the suggested algorithm's Packet Loss ratio is exceptionally low when compared to existing approaches, and the proposed methodology maintains a consistent ratio even when the number of packets increases.

Latency : In Wireless Sensor Networks (WSN), delay is the amount of time it takes for a data packet to get from a sensor (the source node) to a sink or base station (the destination node). The following formula is used to measure the transmission delay:

$$T_t = \frac{Size\ of\ the\ data\ packet}{Transmission\ speed} \qquad (7)$$

The data packets are divided into 128-bit blocks after encryption, and the transmission delay for 128-bit data packets at 2 Mbps is 0.064 milliseconds, which is extremely small. As a result, the transmission delay for a 3200-bit data packet is only 1.6 milliseconds, demonstrating the effectiveness of the suggested method. The following formula is used to calculate the overall delay in data transmission from the source to the destination:

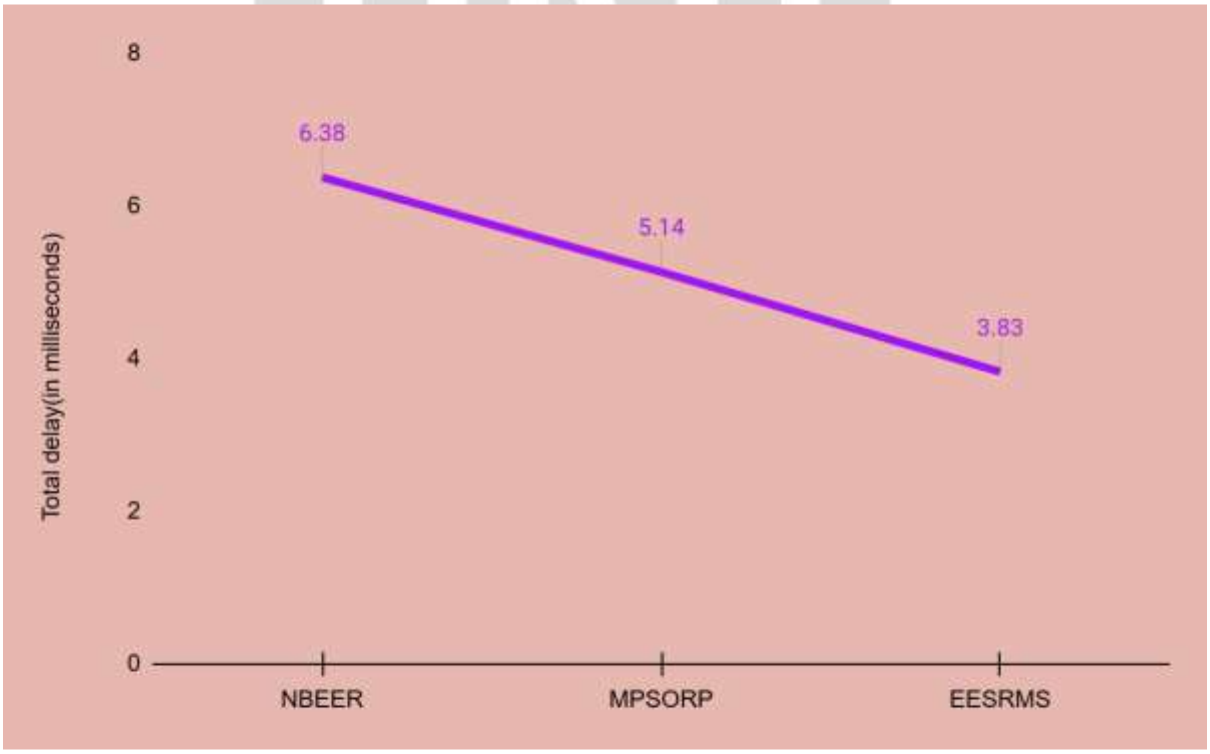
$$Total\ Delay = \sum_{i=1}^{N}(T_t + T_p + T_{pro} + T_q)_i \qquad (8)$$

Where T_t is the transmission delay, T_p is the propagation delay, T_{pro} is the processing delay, T_q is the queuing delay and N is the number of hops

Table 4.3 Parameters on Total Delay

Methodologies	T_t	T_p	T_{pro}	T_q	Total Delay
NBEER	3.78	1.33	0.12	1.2	6.38
MPSORP	2.13	1.33	0.08	1.6	5.14
EESRMS	1.6	1.33	0.03	0.6	3.83

Figure 4.3. Comparison on Total Delay among the proposed and existing methodologies



As can be observed from Figure 4.3, the computed latency is significantly lower than that of the current methods, indicating that the current approach processes and transmits data more quickly than the other two. The percentage of data packets that have been altered or corrupted (i.e., tampered with) during transmission is known as the rate of tampered data packets. The total number of packets sent or received over a specified time period and the number of modified packets are required to calculate this rate.

$$Rate\ of\ tampered\ data\ packets = \frac{Total\ number\ of\ data\ packets\ tampered}{Total\ number\ of\ packets\ sent} * 100\% \quad (8)$$

Figure 4.5 illustrates that the suggested approach has a very low rate of tampered data packets, and Figure 4.6 shows that the tampering rate is quite low in comparison to the other two methodologies. The figure below clearly shows that NBEER has a greater tampering rate.

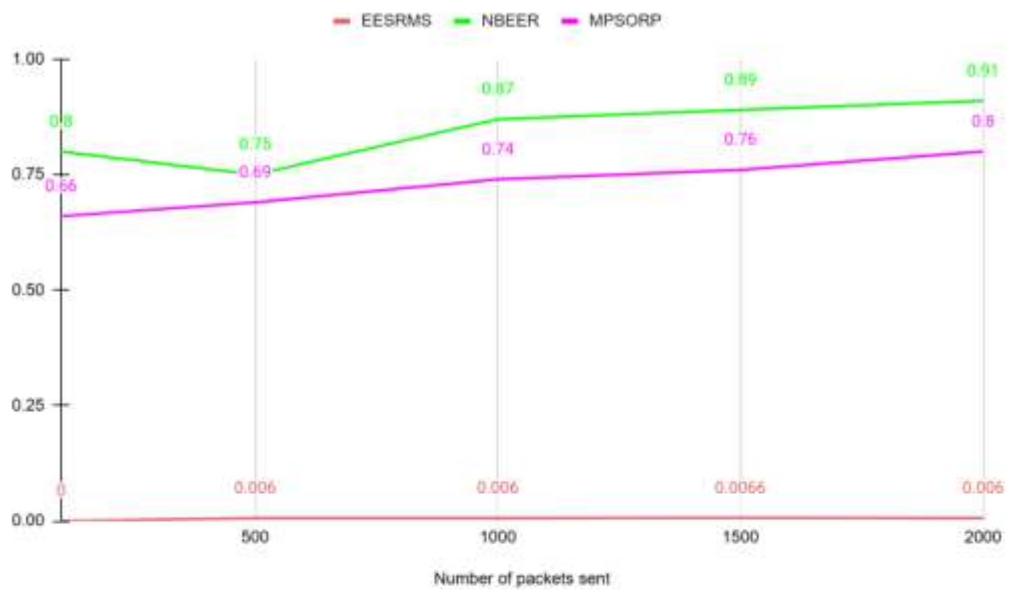


Figure 4.4. Comparison on data tampering rate among various methods

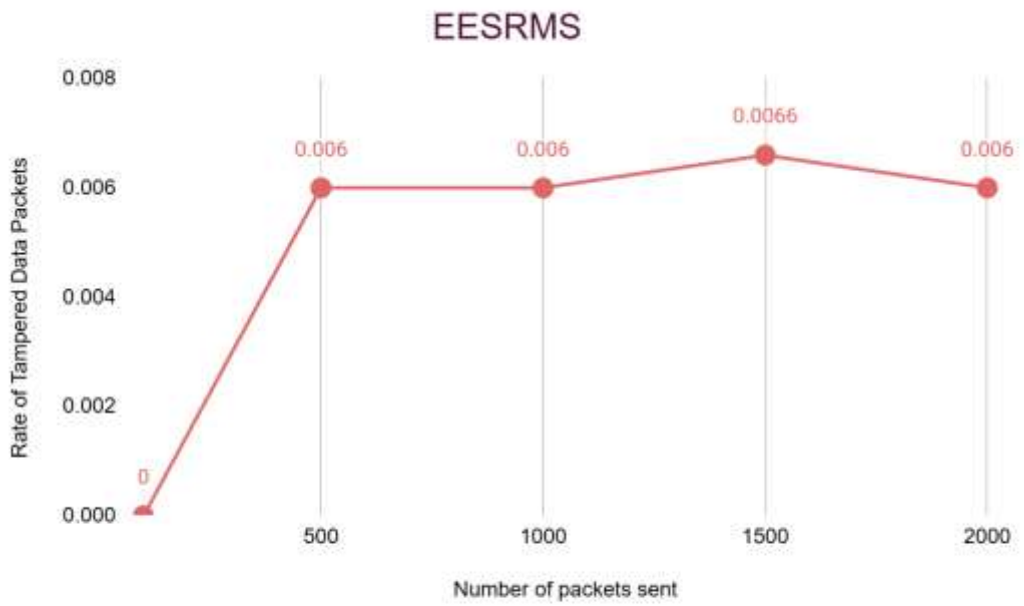


Figure 4.5. Data tampering rate of the proposed methodolgy

Energy Consumption: Numerous elements, including transmission power, reception power, node activity, and network parameters, must be taken into account when calculating energy usage during routing in a Wireless Sensor Network (WSN). The amount of energy needed to send data from the source is determined by

$$E_{tx}(d) = E_{elec}.k + E_{amp}.k.d^n \quad (9)$$

Where E_{elec} is consumed per bit for processing, E_{amp} is the energy consumed by the amplifier, k is the number of bits, and d is the distance between the nodes and n is the path loss exponent (n=2 for free space and n=4 for multipath). The energy required to receive data is given by

$$E_{rx} = E_{elec}.k \quad (10)$$

The total energy for transmission and reception is computed by the following equation:

$$E_{total} = \sum_{i=1}^{N}(E_{tx_i} + E_{rx_i}) \quad (11)$$

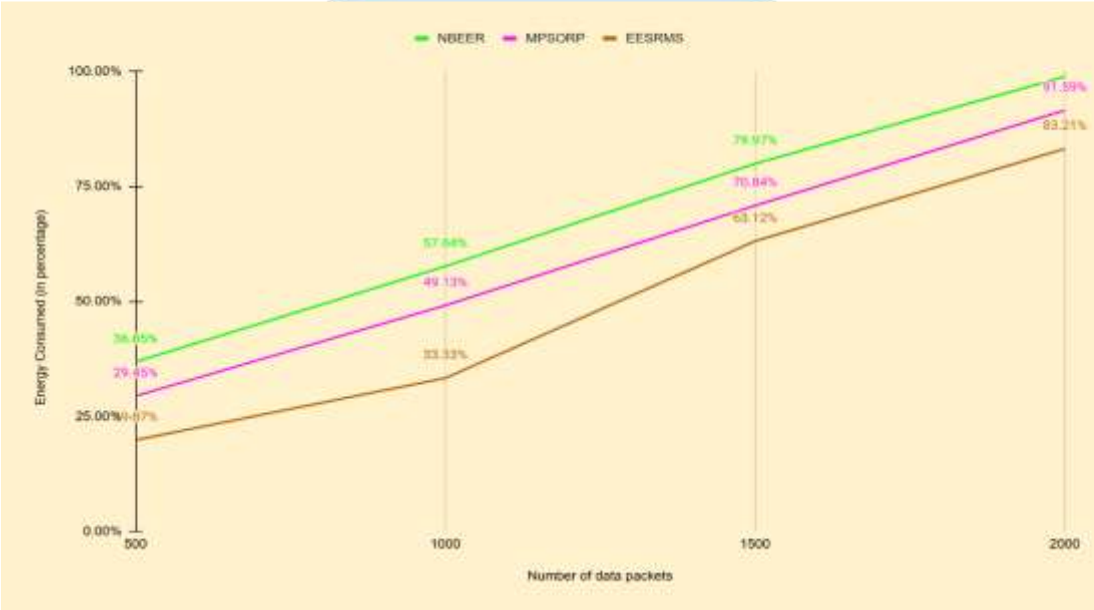


Figure 4.6. Comparison on energy consumption among various methods

The energy usage comparison of the suggested and current approaches is displayed in Figure 4.6. The suggested approach improves network longevity because it uses less energy than the other approaches.

5. CONCLUSION

In terms of packet delivery, latency, data security, and energy consumption, the suggested routing technique "Energy-Efficient Secured Routing with Mobile Sinks (EESRMS)" performs better, thereby extending the network lifetime. Large networks can use more mobile sinks to make data collection easier. Data confidentiality is preserved during transmission thanks to encryption, which also prevents needless security problems. Future studies can strengthen encryption standards to increase data security.

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