MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 693-707

Secure and Trust-Enhanced GPSR-IMST Routing for Reliable Data Transmission in IoT-Enabled WSNs

[1]S.Deepa, Assistant professor, Department Of Computer science, Gobi arts and science college, Gobichettipalayam
[2]Dr.B.Srinivasan, Associate Professor, Department of Computer Science, Gobi Arts and Science College, Erode, Tamilnadu
[3]Dr.P.Sakthi Murugan, Associate Professor, Department of Data Analytics and Mathematical Sciences, School of Sciences, Jain (Deemed-to-be) University, Bangalore 560027
[4]Dr.M.Sangeetha, Professor, Department of Computer Science, Dr.N.G.P Arts and Science College, Kalapatti Road, Coimbatore

Abstract

Wireless Sensor Networks play a crucial role in modern applications such as industrial automation, healthcare monitoring, environmental sensing, and IoT systems. However, energy restrictions and scalability issues lead to the importance of efficient routing as a design problem. Geographic routing protocols such as Greedy Perimeter Stateless Routing are enticing because they are localized and stateless, but the regular version of GPSR has been demonstrated to consume unevenly and often local minimums with respect to its energy use and routing overheads. In order to handle these shortcomings, this phaseproposes GPSR-IMST, a hybrid geographic routing protocol which is a hybrid of GPSR and an IMST. The main task is to attain energy efficient, reliable, and scalable data transmission of large-scale WSNs. The IMST is built based on composite link weights that include distance, residual energy and cost of communication creating a stable and energy stable routing backbone. IMST edges restrict greedy and perimeter routing choices and minimize redundant transmissions and enhance routing stability. The simulations that were done in large scale were used to test performance based on the latency, the ratio of packet delivery, energy consumption and network lifetime. The outcomes indicate that GPSR-IMST significantly works better than anexisting GPSR and energy-aware versions, with lower delay, better delivery dependability, less energy consumption and longer network life. The above-proposed approach stands out well in balancing energy usage and at the same time, it is scalable thus appropriate in resource-limited WSN and IoT applications.

Keywords: Better Minimum Spanning Tree, Energy Efficiency, Geographic Routing, GPSR, Network Lifetime, WSNs.

1. Introduction

Wireless Sensor Networks have now become an enabling technology fundamental to an incredibly broad set of uses such as industrial automation, environmental scanning, healthcare surveillance, and Internet of Things (IoT) systems [1]. In these networks, the sensor nodes are normally densely distributed and have strong energy constraints and therefore energy efficient and scalable routing is a critical design consideration [2]. Greedy Perimeter Stateless Routing and geographic route determination protocols, especially GPSR, have attracted a lot of attention because of their localized routing choices, minimal routing overhead as well as scalability [3]. Using the information pertaining to node position, GPSR does not need global route discovery, and it is therefore applicable in large scale implementations of WSN [4].

Although these benefits are achieved, conventional GPSR has a number of limitations that affect the performance of the network negatively [5]. Shortest path forwarding that is entirely distance driven frequently results in uneven energy use, erratic link choice and premature node crashing [6]. Moreover, the frequent presence of local minima makes GPSR use perimeter routing which adds delay, energy and routing overhead, particularly when the network is dense [7]. The recent research has tried to resolve these concerns by integrating energy consciousness, link-quality forecasting, fuzzy logic, deep learning, and optimization methods into geographic routing [8]. Despite these methods enhancing reliability and energy conservation, they create a high level of computational complexity, control overhead or reliance on large amounts of training data rendering them unsuitable in resource-constrained WSN settings [9].

To resolve the aforementioned problems, this worksuggests GPSR-IMST, a hybrid geographic routing protocol, which combines GPSR with an IMST that can support energy efficient and reliable data transmission. Such IMST is built with composite link weights that incorporate distance, residual energy and communication cost and this result in a stable and energy balanced routing backbone [11]. IMST routes are greedy and perimeter routing decisions and restricts unnecessary transmissions as well as evenly use energy [12]. The massive simulation-based analysis indicates that the latency, the percentage of packet delivery, the power usage, and the network lifetime have been enhanced significantly [13].

The rest of the paper is structured as follows: Section 2 provides a **background study**, Section 3 will involve the proposed GPSR-IMST methodology, Section 4 will involve a discussion of the simulation results and performance analysis and finally, Section 5 will be a conclusion of the paper [14].

2. Background study

According to Sangaiah et al. (2021) [1], this is an energy-conscious geographic routing scheme of real-time monitoring of the workforce within the industrial IoT. The principle aims at balancing energy usage and latency with location based forwarding. The gap in the research is ineffective energy consumption in real time industrial monitoring networks. It combines the geographic routing and energy metrics but is constrained by the necessary localization precision, whereas localization has been demonstrated to be more precise leading to the achievement of better network lifetime and decreased delay.

Hussein et al. (2022) [2] proposed a smart geographic routing protocol to improve energy efficiency and quality of service in wireless multimedia sensor networks. The research resolves the dilemma that exists in the area between high data rate multimedia transmission and energy restrictions. The protocol relies on adaptive geographic decisions when using QoS parameters. It is however limited in the case of high node mobility and performance results have been reported to indicate improved throughput and energy conservation.

Singh et al. (2021) [3] created W-GeoR, a weighted geographic routing algorithm used in VANET based health monitoring in city traffic applications. The idea incorporates the density of vehicles, distance and integration of link quality into routingdecisions. The fault is the inability to deliver reliable data on the dense urban VANETs. It employed simulation-based approaches but the results are worse with sparse networks but the ratio of packet delivery is high.

The article by Pandith et al. (2023) [4] was a proposal of anadaptive Location-Based Routing and Congestion Management Algorithm for Wireless Sensor Networks. The work is aimed at reducing the congestion and preserving energy efficiency. The gap of the research solution is the case observed with similar traffic loads in terms of routing behavior. It uses route reconfigurations, which is dynamically calculated by the algorithm, yet it increases computational load, and outcomes show a decrease of packet losses and delay.

The research by Wang et al. (2024) [5] introduced Energy-aware and dependable location-based routing using link detection collaboration of the Pointin WSNs. The concept focuses on forwarding choices that are reliability conscious. The gap relates to the frequent breakages in traditional geographic routing. The approach integrates the estimation of the link quality and collaborative scheduling, albeit at the cost of a greater control overhead, and its outcomes demonstrates higher reliability and improved lifespan of the network.

Sen et al. (2021) [6] designed an IoT-enabled GPS-supported surveillance framework utilizing inter-WBAN geographic routing in monitoring the Global epidemic. The paper is concerned with location-aware health surveillance in real time. The gap in the research results is scalable routing between two or more WBANs. It used GPS-assisted geographic routing; however, the energy used by GPS is a constraint whereas findings reveal better monitoring accuracy.

Bairagi et al. (2024) [7] proposed a routing protocol, which exhibits low energy consumption and utilizes principle of recursive geographic forwarding of WSNs. The idea enhances routing performance, in that it reduces unnecessary transmissions. The gap that is to be filled is that it is overly costly in terms of energy drain in multi-hop forwarding. Recursive forwarding mechanisms were utilized with performance depending on node density with results better than previous reports on improved packet delivery and energy efficiency.

Aravind (2024) [8] suggested an energy-efficient geographical routing scheme of IoT networks using optimized fuzzy logic. The idea of fuzzy decision-making, coupled with geographic routing, is to maximize energy consumption. The disconnection is the inflexible routing choices in dynamic IoT setting. Fuzzy inference systems can be applied to make forwarding decisions, but the complexity of the rules is restricted, and the results show that less energy is used and the delay is less.

Movable platform-based topology detection Li et al. (2020) [9] proposed to assist in geographic routing in WSNs was introduced. The idea uses the mobile platforms to enhance the topology awareness. The gap in the research is related to unfavorable node localization that influences routing efficiency. Topology detection was done through experimentation but there is the limitation of mobility cost and the results exhibit better routing accuracy.

Benkhelifa et al. (2020) [10] suggested an error-resilient and localized geographic routing protocol of mobile WSNs. Localization and routing are combined in the concept to manage errors caused by mobility. The distance between the localization and routing failures is in their independent treatment. Joint optimization algorithms were implemented, and the complexity is greater, and the results are higher in robustness and rates of deliveries.

Al-Essa et al. (2023) [11] introduced a fuzzy logic adaptive beaconing geographic routing protocol known as the AFB-GPSR that works with MANETs. The construction minimizes the beacon overload and preserves accuracy of the routes. The research gap is that of excessive beaconing in mobile case. Fuzzy logic adjusts the beacon intervals, but tuning of Selection of fuzzy parameters is challenging and affects performanceis energy saving and stable routing.

Nguyen et al. (2021) [12] suggested a routing strategy, which is energy efficient during geographic routing around complex holes in WSNs. The notion takes care of routing void issues. The discontinuity is seen in the ineffective detour routing by non-uniform holes. Hole-aware forwarding was specific to it, and scaling is less than ideal, with results indicating decrease in path length and energy consumption.

The paper by Mazouzi et al. (2023) [13] presented an agent-driven reactive geographic routing protocol for the Internet of Vehicles. The theory uses intelligent agents to make routing decisions dynamically. The gap in the research is the slow process of adapting to the change of the topology. The agent-based approaches were reactive, but the overhead of communication is higher, and the outcomes imply the enhanced adaptability and delivery ratio.

Kumar et al. (2022) [14] suggested a better reliable and power-efficient GPSR-based routing scheme in large-scale deployments WSNs. The idea combines the assessment of trust and geographic routing. This gap fills the malicious or unreliable nodes in GPSR. Trust metrics are used to make forwarding decisions, but trust computation increases overhead, and results are obtained which have better reliability and use less energy.

A mobility-aware geographic routing approach was suggested by Baba-Ahmed (2022) [15] to use in underwater acoustic networks. The concept detects routing to mobility of nodes and severe underwater conditions. The gap in the research is related to unstable connections in the underwater conditions. Mobility-conscious geographic forwarding was used, however, acoustic delays constrain performance, and performance is seen to be better with mobility.

Table: 1*Comparative Analysis of Related Works on Routing, Energy Efficiency, and Secure Data Transmission in WSN and IoT Networks*

Reference	Concept	Research Gap	Methods	Limitations	Result
Zhang et al. (2023) [16]	Delay-aware and link-quality-aware geographical routing for UANET	High computational overhead of deep RL in dynamic underwater environments	Dueling Deep Q-Network integrating delay and link quality metrics	Increased energy consumption and training complexity	Improved packet delivery ratio and reduced end-to-end delay
Panahi*et al.* (2023) [17]	Secure data transmission framework for IoT-enabled WSNs	Limited adaptability to heterogeneous attack models	Lightweight cryptographic mechanisms and secure routing	Security overhead impacts network lifetime	Enhanced data confidentiality and transmission reliability
Khalaf*et al.* (2020) [18]	Energy-efficient and reliable routing in WSN	Lack of scalability analysis for large-scale networks	Energy-aware routing with reliability-based link selection	Performance degrades with increasing node density	Reduced energy consumption and improved throughput
Arya*et al.* (2022) [19]	Deep learning–based routing for 5G-enabled WSNs	High training time and resource dependency	Neural-network-based routing decision model	Requires powerful computational infrastructure	Achieved higher data transmission efficiency and lower latency
Tripathi*et al.* (2022) [20]	Duty-cycle based slot scheduling for data transmission	Does not address security or fault tolerance	Novel slot scheduling algorithm for sleep–wake cycles	Limited adaptability to dynamic traffic loads	Significant energy savings and improved network lifetime
Surenther*et al.* (2023) [21]	Deep learning–based node grouping for energy efficiency	Model generalization under varying network conditions	DL-based clustering and grouping model	Computational overhead at cluster head	Enhanced energy efficiency and balanced load distribution
Seyyedabbasiet al. (2023) [22]	Optimal pathfinding and data transmission in WSN/IoT	Real-time adaptability not fully addressed	Improved Grey Wolf Optimizer (I-GWO, Ex-GWO)	Higher convergence time for large networks	Optimized routing paths and reduced transmission cost
Abualkishiket al. (2022) [23]	Trust-aware secure data transmission	Trust computation increases processing cost	Aquila Optimizer with trust evaluation mechanism	Scalability issues in dense networks	Improved secure data delivery and attack resistance
Sathishet al. (2023) [24]	Reliable data transmission in UWSN using clustering	Cluster maintenance overhead in harsh underwater conditions	Cluster-based routing endorsed by member nodes	Limited evaluation under high mobility	Enhanced reliability and packet delivery ratio
Sefatiet al. (2021) [25]	Cluster-based data transmission using hybrid optimization	Energy efficiency not optimized holistically	Black Hole and Ant Colony Optimization algorithms	Increased algorithmic complexity	Improved clustering stability and reduced energy usage
Anuradhaet al. (2022) [26]	Multi-hop data transmission in UWSN	Security aspects not explicitly considered	Chaotic Search-and-Rescue Optimization algorithm	Sensitive to parameter tuning	Lower delay and improved energy efficiency
Babaeeret al. (2020) [27]	Secure data transmission and sinkhole detection	High encryption and watermarking overhead	Homomorphic encryption with watermark-based detection	Increased computation and communication cost	Enhanced security and effective sinkhole attack detection
Harnet al. (2021) [28]	Lightweight aggregated data encryption	Limited resilience against advanced attacks	Lightweight aggregation-friendly encryption scheme	Focused mainly on static WSN scenarios	Reduced communication overhead with secure aggregation
Kuthadiet al. (2022) [29]	Energy management and data distribution in IoT-based WSN	Lack of integrated security consideration	Optimized energy management and data distribution framework	Performance affected by node mobility	Improved energy utilization and prolonged network lifetime

The table 1 provides an overview of recent studies on routing and data transmission in WSNs and UWSNs, including the concepts, research gaps, methods, limitations, and results of each research. The majority of these strategies aim at enhancing energy use, dependability, safety, and data transfer but tend to have such drawbacks as excessive computational load, loss of scalability, or inability to deal with dynamism. Taken together, these works indicate that advanced methods, including deep

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 693-707

learning, optimization algorithms, and trust-aware frameworks, can improve performance, but still lightweight and scalable and secure systems, applicable to heterogeneous networks in the real world, are required.

3. Proposed Methods

The suggested GPSR-IMST routing algorithm is a combination of Greedy Perimeter Stateless Routing and Improved Minimum Spanning Tree that enables scaling and Low-power data communication in wireless sensor networks. The protocol by design can make sure that greedy and perimeter forwarding choices are limited to IMST edges, which prevents unreliable, low-cost, and energy-unbalanced routing and unnecessary transmissions across long-distance routes. The hybrid design efficiently minimizes routing overhead, enhances reliability of packet delivery and increases the total lifetime of a network to a considerable extent.

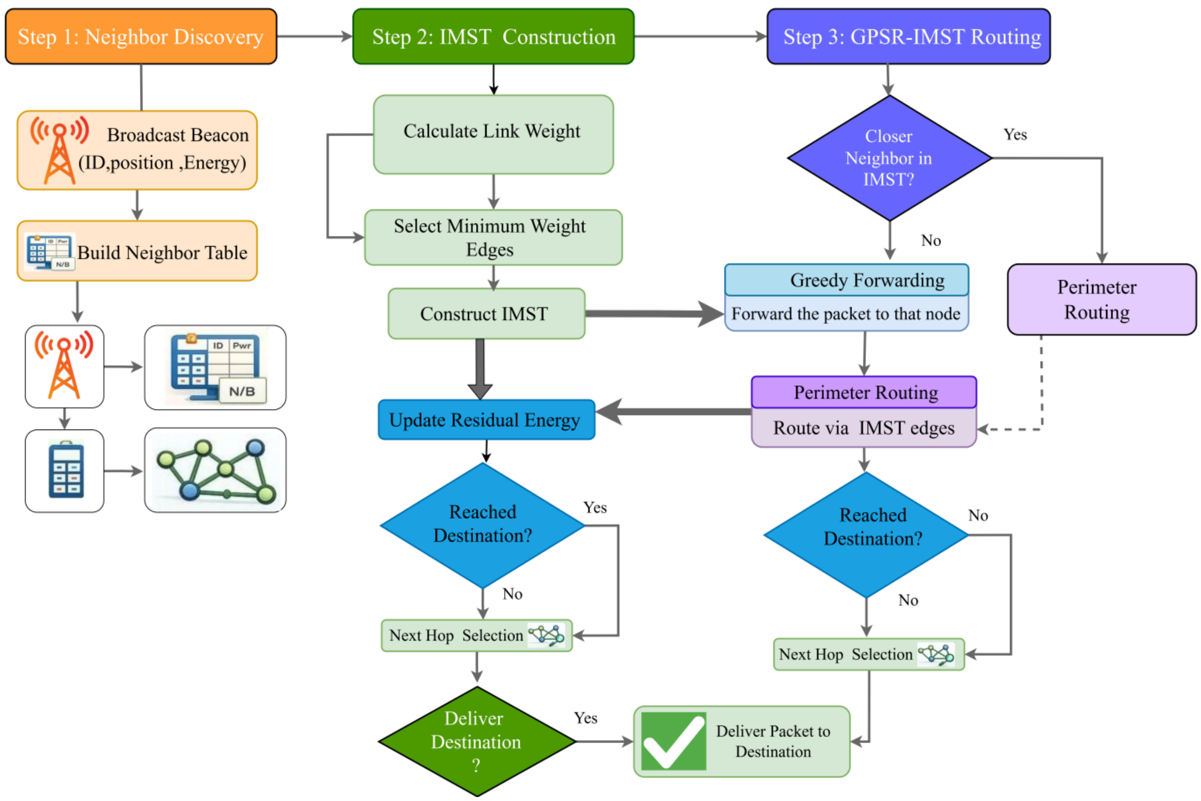

Figure3: ***Workflow Diagram of the Proposed GPSR-IMST Routing Algorithm in Wireless Sensor Networks***

Figure 3 exemplifies the working of GPSR-IMST in three stages which are neighbor discovery, IMST building, and GPSR based routing. The beacons are exchanged first between nodes to generate neighbor tables and create an energy-efficient IMST based on composite link weights. Greedy routing or perimeter routing is then used on IMST edges to forward data packets, which is reliable and with balanced energy consumption and long network lifetime.

3.1 Greedy Perimeter Stateless Routing (GPSR)

Greedy Perimeter Stateless Routing in the proposed GPSR-IMST algorithmoperates by exploiting the spatial positions for sensor nodes to createlocalized, energy-aware Route determination. Each node periodically exchanges beacon messages to maintain an updated neighbor table containing IDs, locations, and residual energy of nearby nodes. When a source node **needs to send data**, it applies **greedy forwarding**, selecting the neighbor**with the shortest distance to the destination** while satisfying IMST edge constraint. If greedy forwarding fails due upon reaching a local minimum, the algorithm transitions to**perimeter routing**, forwarding packets along planar graph edges derived from the IMST structure. The improved MST limits routing choices to low-cost, stable links, preventing unnecessary long hops. At every hop, GPSR decisions are made statelessly, relying only on local information. This integration ensures loop-free forwarding with reduced overhead. Consequently, the proposed GPSR-IMST algorithm achieves efficient, scalable, and energy-balanced data transmission in WSNs.

$$d(i,D) = \sqrt{(x_i - x_D)^2 + (y_i - y_D)^2} \quad (1)$$

In equation (1), $d(i,D)$ is the Euclidean distance of point i and point D on a two-dimensional plane. x_i and y_i denote the x- and y -coordinate of point i, while x_D and y_D denote the x - and y -coordinate of point D. Horizontal and vertical separation is then measured by the squared distances, then squared root of the difference will give the direct distance between the two points.

$$NH = arg \max_{j \in N_i} (\alpha \frac{1}{d(j,D)} + \beta \frac{E_j}{E_{max}} + \gamma LQ_{ij} \quad (2)$$

In equation (2), uses a neighboring node to the node i that scores most in the form of a weight to select the next-hop node (NH). The score is a product of distance efficiency $\frac{1}{d(j,D)}$, energy awareness $\frac{E_j}{E_{max}}$max, energy remaining in node, and link quality γLQ_{ij}, more reliable connections. The weights are α, β, and γ which determine the relative significance of distance, energy and quality of links in the routing decision.

$$LQ_{ij} = \frac{P_{success}}{P_{sent}} \quad (3)$$

In the equation (3) LQ_{ij} is the reliability for the communication channel connecting node i and node j, $P_{success}$ refers to the count of packets that node j receives correctly, and P_{sent} denotes the total packets sent from node i. The value of LQ will be higher which implies that the two nodes are linked more reliably and are more steady.

$$E_i(t+1) = E_i(t) - E_{tx}(i,j) - E_{rx}(i,j) \quad (4)$$

In equation (4), $E_i(t+1)$ represents the variation in the energy of node i within the communication system over time. Here, $E_i(t)$ denotes the remaining energy of node i at time t while $E_i(t+1)$ indicates the energy level of node i at the next time step after a communication event. $E_{tx}(i,j)$ is the amount of energy that node i uses to send data to node j and $E_{rx}(i,j)$ refers to the energy consumed by node i when transmitting data to node j.

$$PDR = \frac{P_{received}}{P_{sent}} \quad (5)$$

The equation (5) defines PDR the ratio of packets successfully received at the destination to the total packets transmitted by the source. In this case, the value of $P_{received}$ is the number of packets that were received without loss and that of P_{sent} is the total number of packets sent across. PDR is a major performance measure in networking that reveals the dependability and effectiveness of the transmission of the data.

```
Algorithm: GPSR-IMST Routing
Input:
  Network nodes N with positions (x, y)
  Destination node D
  IMST edge set E_imst
Output:
  Forward data packet from source S to destination D
for each node i ∈ N do
    Broadcast beacon ⟨IDi, positioni, residual_energyi⟩
    Build Neighbor_Tablei from received beacons
end for
Current_Node ← S
 Mode ← GREEDY
whileCurrent_Node ≠ D do
if Mode = GREEDY then
        Select neighbor j ∈Neighbor_TableCurrent
such that dist(j, D) is minimum
and (Current_Node, j) ∈E_imst
if j exists then
          Forward packet to j
Current_Node ← j
else
          Mode ← PERIMETER   // local minimum reached
end if
end if
if Mode = PERIMETER then
      Construct planar subgraph using IMST edges
      Select next hop k using right-hand rule
      Forward packet to k
Current_Node ← k
ifdist(Current_Node, D) <dist(previous_node, D) then
          Mode ← GREEDY
end if
end if
end while
 Packet successfully delivered to destination D
```

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 693-707

GPSR-IMST routing relays on the basis of the position of the nodes, but limits forwarding actions to IMST edges in order to conserve energy. In the greedy mode, each node chooses the nearest IMST connected node to the destination, and when the algorithm converges to a local minimum the perimeter mode. Perimeter routing takes a planar IMST sub graph and the right-hand rule to avoid voids and then gets back to greedy mode when progress toward the destination has been regained so that packet delivery is successful.

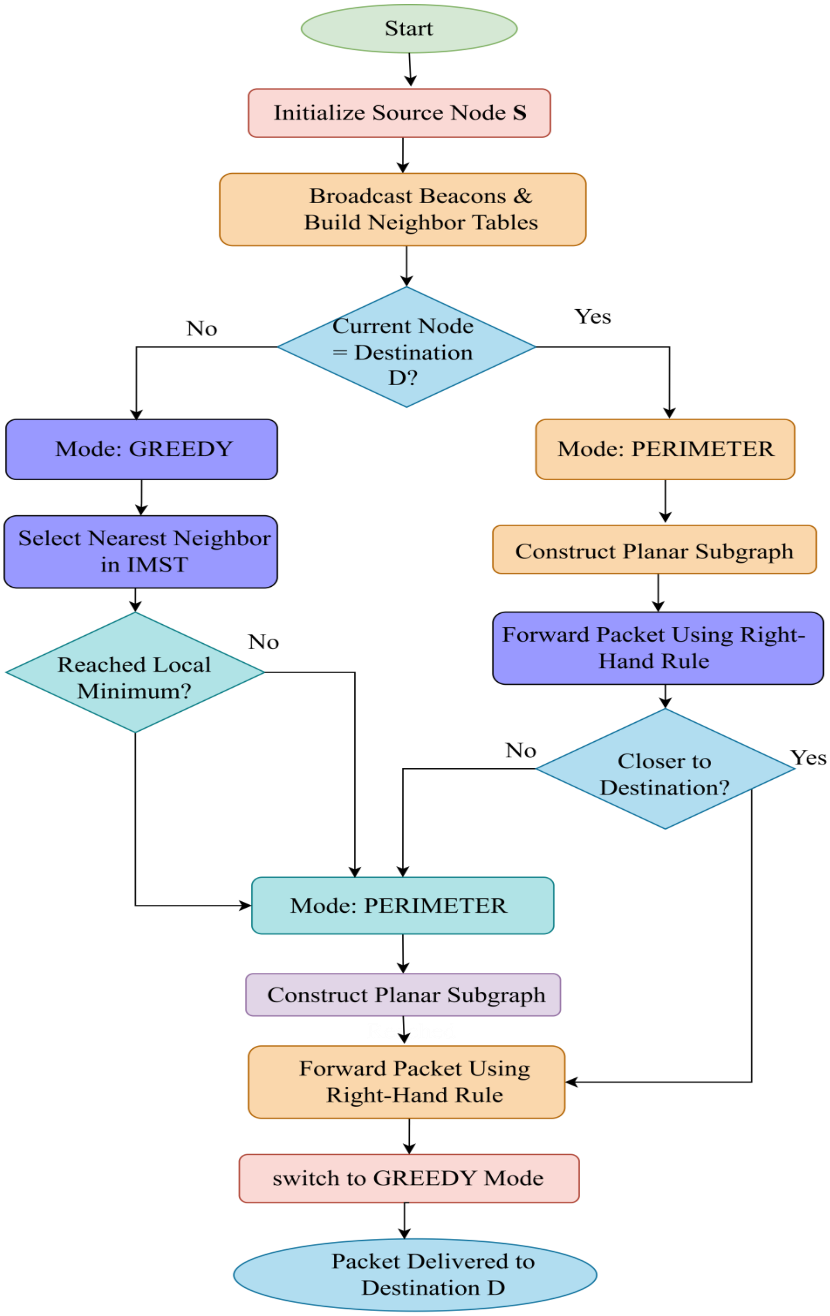

Figure 1:*Flowchart of GPSR Routing Process with Greedy and Perimeter Modes Based on IMST Constraints*

The Figure 1 outlines the packet forwarding based on IMST based geographic routing in a greedy and perimeter mode. The packets are then sent greedily to the nearest IMST neighbor until a local minimum is achieved where perimeter routing is called upon. Without traversing voids, planar sub graphs are used alongside right-hand strategy to return the packet to the greedy mode until it reaches its destination.

3.2 Improved Minimum Spanning Tree (IMST)

Improved Minimum Spanning Tree in the proposed GPSR-IMST algorithm is designed to construct a power-conscious and reliable routing framework for wireless sensor networks. Initially, each node computes link weights using a combination of distance, residual energy, and communication cost rather than distance alone. A distributed IMST construction process then selects edges with minimum composite weight to connect all nodes without forming cycles. Unlike conventional MST, the

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 693-707

IMST periodically updates its structure to adapt to node energy depletion and topology changes. Only reliable and low-cost links are retained, reducing transmission failures. The resulting IMST restricts routing to energy-balanced paths. This minimizes long-range transmissions and uneven energy usage. Consequently, the proposed IMST enhances network lifetime and supports efficient geographic routing decisions.

$$W_{ij} = \alpha d_{ij} + \beta\left(\frac{1}{E_j^{res}}\right) + \gamma C_{ij} \quad (6)$$

In equation (6), W_{ij} is a composite measure, which depends on three factors. The αd_{ij} is the contribution of the distance between two nodes i and$j$, multiplied by a coefficient, which is referred to asα. The $\beta\left(\frac{1}{E_j^{res}}\right)$ is used to penalize low-energy nodes, and γC_{ij} is known as the cost or congestion factor connecting nodes$i$and j, which is weighted by γ.

$$d_{ij} = \sqrt{(x_i - x_j)^2 + (y_i - y_j)^2} \quad (7)$$

In the equation (7), the d_{ij} is the Euclidean distance between node $i$and j. It is calculated based on their coordinates, $(x_i, y_i)$and (x_j, y_j), that is the straight-line distance between them. This measure assists in measuring the spatial proximity which directly affects the cost of communication or signal attenuation.

$$\min \sum_{(i,j)\in E_{IMST}} W_{ij} \quad (8)$$

In equation (8), $\min \sum_{(i,j)\in E_{IMST}} W_{ij}$ is intended to decrease the total weight of all the edges chosen in the enhanced minimum spanning tree (IMST). The weight W_{ij} of each edge is an achievement of combined factors of distance, energy, and cost. The model is able to reduce this amount thereby resulting in optimal, efficient and energy conscious network structure.

$$E_{ij}^{tx} = E_{elec} \cdot k + E_{amp} \cdot k \cdot d_{ij}^{n} \quad (9)$$

In equation (9), E_{ij}^{tx} is the amount of energy needed to transmit a k -bit message between node i and node j. The acronym $E_{elec} \cdot k$ takes into consideration the amount of power consumed by the electronic circuitry, whereas $E_{amp} \cdot k \cdot d_{ij}^{n}$is the amount of power consumed by the power amplifier, which rises with distance. Path-loss exponent n is a model that is used in wireless channel attenuation.

$$E_i^{res}(t+1) = E_i^{res}(t) - E_{ij}^{tx} - E_i^{rx} \quad (10)$$

In the equation (10), the new $E_i^{res}(t+1)$for node $i$at the next time step$t+1$is evaluated based on the existing energy of node i minus the communication energy state. E_{ij}^{tx}means the energy used in transmitting data and E_i^{rx} is the energy used in receiving data. This equation is a model that shows the way the available energy of a node depreciates with time as a result of network activities.

```
Algorithm: Improved Minimum Spanning Tree (IMST) Construction
Input:
  Set of sensor nodes N with positions (x, y)
  Initial energy E_init for each node
Output:
  Energy-efficient IMST edge set E_IMST
for each node i ∈ N do
    Discover neighboring nodes within communication range
    Compute distance d_ij to each neighbor j
    Estimate communication cost C_ij
                Calculate composite link weight:
W_ij = α·d_ij + β·(1 / E_j^res) + γ·C_ij
end for
 Initialize E_IMST ← ∅
 Mark all nodes as unconnected
 Select node with maximum residual energy as root
 Add root node to IMST
while not all nodes are connected do
    Select edge (u, v) with minimum W_uv
such that u ∈ IMST and v ∉ IMST
    Add edge (u, v) to E_IMST
    Mark v as connected
end while
 Periodically do
    Update residual energy of each node
RecomputeW_ij for affected links
    Prune high-cost or unstable edges
    Reconstruct IMST if energy drops below threshold
end periodically
 Return E_IMST
```

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 693-707

The IMST algorithm constructs a sparse routing topology by placing composite weights on the links in terms of distance, remaining energy and cost of communication. It stepwise links the nodes beginning with the most energetic root, and maintains minimal cumulative energy consumption. The periodic updates enable the tree to react to the loss of energy and associate instability to increase the lifetime of networks.

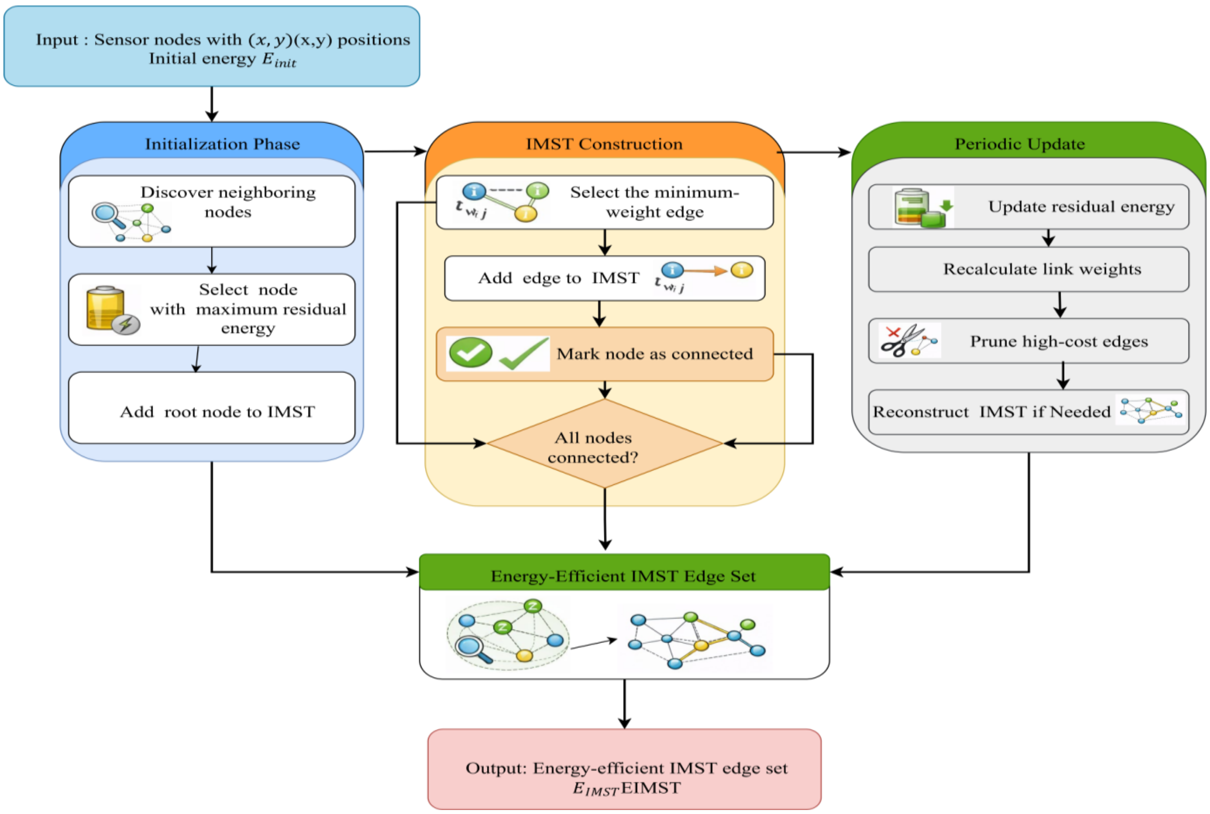

Figure 2: Flowchart of the Proposed Energy-Efficient Improved Minimum Spanning Tree (IMST) Construction Algorithm

Figure 2 demonstrates the IMST process as follows: first, it finds neighbors and a root node with the greatest residual energy is chosen. It grows the tree line with minimum-weight edges and minimizes its connectivity energy consumption in a progressive manner until every node is reached. Periodic updates update the weight of links, remove the expensive links and rebuild the IMST where necessary in order to increase network life.

3.3 GPSR-IMST: Geographic Routing Enhanced By Improved Minimum Spanning Tree

In the proposed GPSR-IMST algorithm, Greedy Perimeter Stateless Routing (GPSR) is integrated with an Improved Minimum Spanning Tree (IMST) to enable efficient and energy-aware data transmission in wireless sensor networks. Each sensor node periodically exchanges beacon messages to maintain local information about neighbor position, ID, and residual energy. During data forwarding, greedy routing chooses the neighbor nearest to the destination while satisfying IMST edge constraint, ensuring low-cost and stable links. When greedy forwarding encounters a local minimum, perimeter routing is applied over planar graph edges derived from the IMST structure. The IMST is constructed using composite link weights based on distance, residual energy, and communication cost, rather than distance alone. This distributed and adaptive IMST restricts routing to reliable, energy-balanced paths and avoids unnecessary long hops. All routing decisions are stateless and rely solely on local information, guaranteeing loop-free forwarding with minimal overhead. As a result, the GPSR-IMST algorithm improves scalability, balances energy consumption, and significantly enhances overall network lifetime.

$$W_{ij} = \alpha 1 d_{ij} + \alpha 2 \frac{1}{E_j^{res}} + \alpha 3 C_{ij} \quad (11)$$

In equation (11), W_{ij} is the total cost of node j being a next-hop neighbor of node i. It is a product of the distance between nodes d_{ij}, the inverse of the remaining energy of node $j \frac{1}{E_j^{res}}$, and the communication cost C_{ij} in which the $\alpha 1$, α 2, $\alpha 3$ are importance factors. This formulation rates shorter links, nodes with high energy and inexpensive communication routes which allow efficient routing on energy and reliability.

$$n^* = \arg \min_{j \in N_i \cap IMST} d(j, D) \quad (12)$$

$$d(j,D) < d(i,D) \quad (13)$$

In equation (12) picks the best next-hop node n^* in the neighbor set N_i that is also a node in the IMST structure. One of such candidates is selected as the node j whose distance to the destinationD is minimum and is denoted by$d(j,D)$. In the equation (13), $d(j,D) < d(i,D)$ is assuring that the chosen node moves geographically towards the destination positively. This ensures greedy forwarding and limits the routing decisions to energy efficient IMST links.

$$\forall j \in N_i : d(j,D) \geq d(i,D) \quad (14)$$

In equation (14), j of node i (i.e., j Nij in N i) distance between j and destination D, $d(j,D)$ is not less than or equal to distance between i and destination D, $d(i,D)$. It brings out a local minimum or void scenario in which there is no other node near the destination than the one. Greedy forwarding does not work in this scenario and other recovery mechanisms are needed such as perimeter routing.

$$E_{planar} \subseteq E_{IMST} \quad (15)$$

In equation (15), E_{planar} denotes the collection of edges which are utilized to create a planar sub graph of geographic routing. E_{IMST} Represents a collection of edges in the Improved Minimum Spanning Tree (IMST) of the network. E_{planar} is a term used to denote the fact that planar graph is built by the use of only IMST edges, which makes this graph to be energy-efficient and loop less.

$$T_{life} = \min\{t \mid \exists i, E_i^{res}(t) - 0\} \quad (16)$$

Equation (16) defines the network lifetime as $T_{life} = \min\{t \mid \exists i, E_i^{res}(t)$ which is the first time at which any node i is out of residual energy. It records the moment when the initial node fails, which usually restricts the general network performance. The metric is used in the determination of power optimization and operational lifespan of routing schemes in WSNs.

```
Algorithm: GPSR-IMST Routing

Input:
   N         → Set of sensor nodes with positions (x, y)
E_init    → Initial energy of each node
   S, D      → Source and Destination nodes
Output:
   Energy-efficient packet delivery from S to D
/* Step 1: Neighbor Discovery */
for each node i ∈ N do
    Broadcast beacon ⟨IDi, positioni, residual_energyi⟩
    Build Neighbor_Tablei from received beacons
end for
/* Step 2: IMST Construction */
for each node i ∈ N do
for each neighbor j ∈Neighbor_Tablei do
       Compute distance d_ij
       Estimate communication cost C_ij
       Compute composite weight
W_ij = α1·d_ij + α2·(1 / E_j^res) + α3·C_ij
end for
end for
 Construct IMST by selecting minimum-weight edges
   (no cycles, adaptive updates)

/* Step 3: GPSR-IMST Routing */
Current_Node ← S
whileCurrent_Node ≠ D do
if∃neighbor j ∈Neighbor_TableCurrent ∩ IMST
such that d(j,D) < d(Current_Node,D) then
       Select j* = argmind(j,D)
       Forward packet to j* (Greedy Mode)
else
       Switch to Perimeter Mode
      Forward packet along planar IMST edge
end if
    Update residual energy of Current_Node
Current_Node ← next hop
end while
 Packet successfully delivered to destination D
```

The GPSR-IMST algorithm proposed will be a hybrid of geographic routing and the energy-conscious IMST backbone to provide efficient delivery of data in a wireless sensor network. Neighbor discovery and IMST construction provide that the routing decisions are limited to stable and low-cost links as well as energy balanced links. The algorithm ensures that packets are delivered without loops by greedy forwarding with perimeter routing as a fall back and minimizes the overhead and increases network lifetime.

4. Result and Discussion

In this section, an in-depth evaluation of the suggested GPSR-IMST routing protocol is done with deep simulations under typical wireless sensor network scenarios. The comparison of GPSR-IMST and current routing schemes based on the latency, the ratio of packet transmission efficiency, power usage, and operational lifespan are employed toanalyze the results. The discussion shows the importance of integration of IMST in improving the efficiency of routing, scalability of routing and energy balance as the density of networks grows.

4.1 Simulation Setup

In the simulation parameters, a definite wireless sensor network that is deployed on a large two-dimensional area is set up in a static environment to assess the scalability and energy efficiency of proposed GPSR-IMST protocol. The transmission and control overhead under steady-state traffic conditions are modeled in realistic energy and radio models to reflect accurate simulation of three models. The assessment of the performance is performed on the basis of the several runs with the help of standard measures like packet delivery ratio, Latency, Power usage and System operational duration to control the consistency and equitable comparison.

Table 2: Simulation Parameters and Network Configuration

Parameter	Value	Description
Simulation Area	1000 m × 1000 m	Two-dimensional square sensing field where sensor nodes are randomly deployed
Number of Nodes (N)	50 – 200	Total number of sensor nodes used to evaluate scalability
Node Deployment	Random	Nodes are randomly distributed across the sensing area
Node Mobility	Static	Sensor nodes remain stationary during the simulation
Initial Energy (E_init)	2 Joules	Initial battery energy assigned to each sensor node
Transmission Range	100 m	Maximum communication distance between neighboring nodes
Data Packet Size	512 bytes	Size of data packets transmitted from source to destination
Control Packet Size	32 bytes	Size of beacon and routing control messages
Traffic Type	Constant Bit Rate (CBR)	Data packets generated at fixed intervals
Packet Generation Rate	1 packet/sec	Rate at which source nodes generate data packets
Energy Model	First-order radio model	Considers electronic and amplifier energy consumption
E_elec	50 nJ/bit	Energy consumed by radio electronics
E_amp	100 pJ/bit/m²	Energy consumed by power amplifier
Path Loss Exponent (n)	2	Free-space propagation model
Routing Protocols Compared	GPSR, Energy-aware GPSR, GPSR-IMST	Baseline and proposed routing schemes
IMST Update Interval	Periodic	IMST is reconstructed based on residual energy threshold
Performance Metrics	PDR, Delay, Energy Consumption, Network Lifetime	Metrics used for performance evaluation
Network Lifetime Definition	First Node Death (FND)	Time until the first node depletes its energy
Simulation Time	2000 seconds	Total duration of each simulation run
Number of Runs	10	Results averaged over multiple runs for accuracy

This table 2 gives the settings of the simulation parameters used intesting the performance of the proposed GPSR-IMST routing protocol in realistic conditions of the wireless sensor network. The design includes energy limits, geographic vision, and multi-hop communications that provide equal opportunity of comparing with the baseline protocols. Various densities of nodes are used in multiple simulation runs to achieve consistent results which are reliable and statistically significant.

4.2 Performance

In this section, the performance of the proposed GPSR-IMST routing protocol is evaluated againstLSTM GPSR, CNN GPSR and Energy aware GPSR under different network sizes. The latency, the ratio of Packet delivery, energy consumption, and network longevity are primary performance indicators used to assess routing efficiency, the reliability of routing, and the energy sustainability. These findings are clearly indicative of the fact that GPSR-IMST is more effective and scalable in dense wireless

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 693-707

sensor network set-ups.

4.2.1 Latency

Latency is the mean total transmission latency from the source to the destination node. It involves Sending delay, Travel time delay, Computation delay and the Waiting delay that is incurred at the in-between nodes. Latency in a dense the performance of a wireless sensor network can generally be expected to **increase** as the number of nodes grows due toa greater number of contenders, longer routes and more control overhead.

$$Latency = \frac{1}{P_{received}} \sum_{k=1}^{P_{received}} (t_k^{receive} - t_k^{send}) \quad (17)$$

The $P_{received}$ is used to represent number of packets delivered successfully, t_k^{send} is the time that the kth packet was sent at the source and $t_k^{receive}$ is the receiving time at the destination. Reduced latency value means more efficient routing and faster delivery of information, which is obviously reached by the suggested GPSR-IMST protocol of all sizes of networks.

Table 3: Performance Comparison of Routing Protocols (Latency in ms)

Node Size	LSTM-GPSR	CNN-GPSR	Energy-Aware GPSR	GPSR-IMST (Proposed)
10	85	92	80	75
20	98	105	92	88
30	112	120	105	102
40	128	138	118	115
50	145	155	130	130

The table 3 indicates that the latency increases with node size across routing protocols since the network load and complexity of routing increases. The suggested GPSR-IMST has lower latency than LSTM GPSR, CNN GPSR, and Energy Aware GPSR, and it performs routing tasks more efficiently and faster.

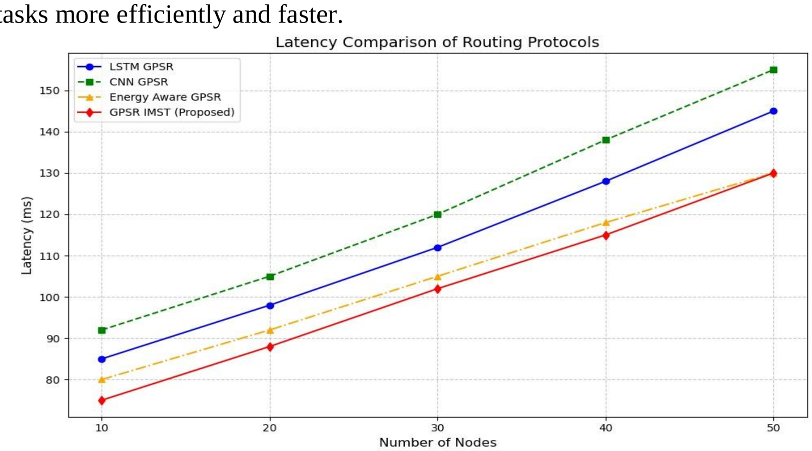

Figure 4: Latency Comparison of Routing Protocols for Different Node Sizes

The latency of figure 4 is dependent on the number of nodes of each routing protocol because with more nodes, there is more contention and routing overhead. The proposed GPSR-IMST always gives the lowest latency, which means that it will be more efficient and faster to forward packets than the current approaches.

4.2.2Packet Delivery Ratio

Packet Delivery Ratio is one of the performance metrics and it relates to the reliability of a routing protocol by determining proportion of successfully received packets. It indicates the efficiency of route choice and when there is congestion and the stability of links in the network.

The following equation is employed to calculate the Packet Delivery Ratio:

$$PDR = \frac{P_{received}}{P_{sent}} \times 100 \quad (18)$$

Where $P_{received}$ is the total number of packets that made it to their destination, and P_{sent} is the total number of packets sent on the source nodes. The high value of PDR represents better reliability and strength of routing protocol, which is obviously attained with the suggested GPSR-IMST protocol.

Table 4: Packet Delivery Ratio (PDR %)

Node Size	LSTM-GPSR	CNN-GPSR	Energy-Aware GPSR	GPSR-IMST (Proposed)
10	92	90	91	95
20	89	87	88	93
30	86	84	85	91
40	83	80	82	89
50	80	77	79	87

Table 4 also shows that the packet delivery ratio of all protocols tends to reduce with the node size because of the increased congestion and routing overhead. The proposed GPSR-IMST has the highest delivery ratio, which is more reliable

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 693-707

and scalable than LSTM GPSR, CNN GPSR and Energy-Aware GPSR.

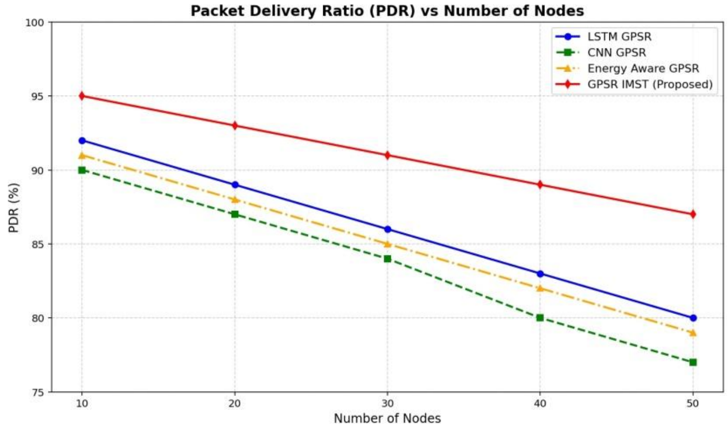

Figure 5: Packet Delivery Ratio (PDR) vs. Number of Nodes

In this figure 5, PDR declines with increased count of nodes in all routing strategies because of increased network congestion and complexity of routing. Nevertheless, the proposed GPSR-IMST consistently has the largest PDR and is more scalable and has a more efficient delivery of packets than LSTM, CNN, and Energy-Aware GPSR approaches.

4.2.3Energy Consumption

Energy usage serves as a critical performance metric for wireless sensor networksbecause sensor nodes have small batteries and must be used in conditions where changing batteries is not possible. The goals of efficient routing protocols are to reduce the energy consumption of communication and processing and ensure the safe delivery of data.

The mean consumption per node can be determined using the following equation:

$$E_{avg} = \frac{1}{N}\sum_{i=1}^{N}(E_i^{init} - E_i^{res}) \quad (19)$$

Where Nrepresents the total number of nodes in the network, andE_i^{init}denotes the initial energy of each node$i$ and E_i^{res} is the final energy of node i after the simulation. The lower the value of E_{avg} the higher the energy efficiency and the proposed GPSR-IMST protocol evidently achieves it.

Table 5: Energy Consumption

Node Size	LSTM-GPSR	CNN-GPSR	Energy-Aware GPSR	GPSR-IMST (Proposed)
10	1.25	1.30	1.20	1.15
20	1.48	1.50	1.40	1.35
30	1.72	1.75	1.65	1.58
40	1.95	1.98	1.85	1.75
50	2.18	2.20	2.05	1.95

The table 5 indicates that all the routing protocols increase energy consumption with node size because of increased communication and processing overheads. The suggested GPSR-IMST is always the most energy-efficient, which highlights its efficiency and better energy-conscious routing than the rest of the techniques.

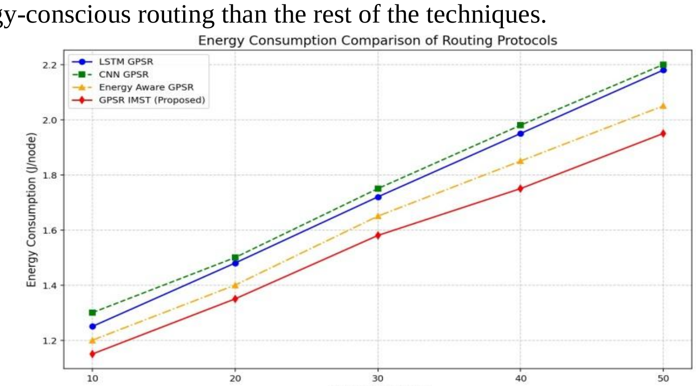

Figure 6: Energy Consumption Comparison of Routing Protocols vs. Number of Nodes

The graph indicates that the amount of energy used with the number of nodes in all the routing protocols also increases owing to the increased communication overhead and routing overhead. The suggested GPSR-IMST is the minimum energy consuming, which means that it is more efficient in the process of routing and more economical in energy usage as opposed to the current methods.

4.2.4Network Lifetime

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 693-707

The operational lifespan of a network is a key metric for evaluating the energy efficiency and long-term viability of routing protocols in wireless sensor networks. In this paper, the definition of network lifetime is the First Node Death time, which is the time in which the first sensor node runs out of energy. The longer network lifetime is a sign of the increased energy balancing and efficient routing decisions.

The equation below can be used to compute the network lifetime:

$$T_{life} = min\{t|\exists i \text{ such that } E_i^{res}(t) = 0\} \quad (20)$$

Where $E_i^{res}(t)$denotes the remaining energy of node$i$ at time t. The metric represents the moment where the initial node depletes its energy. The greater T_{life} value demonstrates a better energy management and the network operation which is obviously the result of the suggested GPSR-IMST protocol.

Table 6: Network Lifetime

Node Size	LSTM-GPSR	CNN-GPSR	Energy-Aware GPSR	GPSR-IMST (Proposed)
10	1550	1480	1600	1720
20	1380	1320	1450	1560
30	1250	1190	1320	1425
40	1120	1070	1200	1300
50	1020	995	1100	1185

The table 6 indicates that all the routing protocols have a negative relationship between the node size and the network lifetime or energy efficiency. The proposed GPSR-IMST is the most successful among them with excellent performance meaning that it has high efficiency in management of energy and data transmission than LSTM GPSR, CNN GPSR, and Energy Aware GPSR.

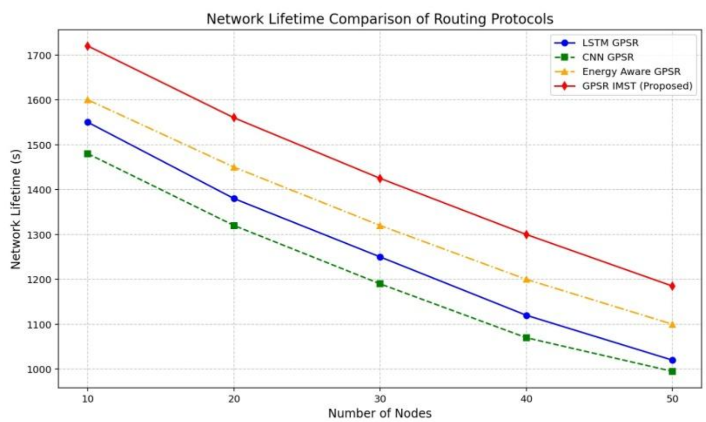

Figure 7:Network Lifetime Comparison of Routing Protocols vs. Number of Nodes

Network lifespan decreases as the number of nodes increasesbecause of the expenditure of more energy and communication overhead. The proposed GPSR-IMST is highly energy Effective with respect to network lifespan, which continues as thelongest among the rest of the protocols and offers balanced routing.

5. Conclusion

This paper has proposed GPSR-IMST as hybrid geographic routing protocol, which combines Greedy Perimeter Stateless Routing with an Improved Minimum Spanning Tree to deliver energy-efficient, dependable and expandable data transmission in wireless sensor networks. Through limiting greedy and perimeter routing selections to IMST edges built by composite link weights; the suggested strategy manages to balance energy utilization and decrease routing overhead expenses and the local minimum issue. The extensive simulation findings have proved GPSR-IMST to be better than the available GPSR-based schemes in terms of Delay, Data delivery efficiency, Power consumption, and Node lifespan with regard to network size. IMST is also adaptive which further increases routing stability during energy depletion conditions. Although these enhancements have taken place, the existing work presupposes stationary nodes and perfect localization preciseness. The further research should be aimed at the implementation of GPSR-IMST to enable node mobility and localization errors and dynamic flows. Also, the use of lightweight security implementations and test bed validation with real world will enhance the usability of the proposed protocol in real world implementation of IoT and WSNs.

Reference

MSW MANAGEMENT -Multidisciplinary, Scientific Work and Management Journal
ISSN: 1053-7899
Vol. 36 Issue 1, Jan-June 2026, Pages: 693-707

1. Sangaiah, A. K., Rostami, A. S., Hosseinabadi, A. A. R., Shareh, M. B., Javadpour, A., Bargh, S. H., & Hassan, M. M. (2021). Energy-aware geographic routing for real-time workforce monitoring in industrial informatics. *IEEE internet of things journal*, *8*(12), 9753-9762.
2. Hussein, W. A., Ali, B. M., Rasid, M. F. A., &Hashim, F. (2022). Smart geographical routing protocol achieving high QoS and energy efficiency based for wireless multimedia sensor networks. *Egyptian Informatics Journal*, *23*(2), 225-238.
3. Singh, P., Raw, R. S., Khan, S. A., Mohammed, M. A., Aly, A. A., & Le, D. N. (2021). W-GeoR: Weighted geographical routing for VANET's health monitoring applications in urban traffic networks. *IEEE Access*, *10*, 38850-38869.
4. Pandith, M. M., Ramaswamy, N. K., Srikantaswamy, M., &Ramaswamy, R. K. (2023). An efficient reconfigurable geographic routing congestion control algorithm for wireless sensor networks. *International Journal of Electrical & Computer Engineering (2088-8708)*, *13*(6).
5. Wang, M., Zhu, Z., Wang, Y., &Xie, S. (2024). Energy-Efficient and Highly Reliable Geographic Routing Based on Link Detection and Node Collaborative Scheduling in WSN. *Sensors*, *24*(11), 3263.
6. Şen, S. S., Cicioğlu, M., &Çalhan, A. (2021). IoT-based GPS assisted surveillance system with inter-WBAN geographic routing for pandemic situations. *Journal of Biomedical Informatics*, *116*, 103731.
7. Bairagi, P. P., Dutta, M., &Babulal, K. S. (2024). An energy-efficient protocol based on recursive geographic forwarding mechanisms for improving routing performance in WSN. *IETE Journal of Research*, *70*(3), 2212-2224.
8. Aravind, K. (2024). Optimized fuzzy logic based energy-efficient geographical data routing in internet of things. *IEEE Access*, *12*, 18913-18930.
9. Li, R., Wang, J., & Chen, J. (2020). Movable platform-based topology detection for a geographic routing wireless sensor network. *Sensors*, *20*(13), 3726.
10. Benkhelifa, I., Moussaoui, S., &Demirkol, I. (2020). Intertwined localization and error-resilient geographic routing for mobile wireless sensor networks. *Wireless Networks*, *26*(3), 1731-1753.
11. Al-Essa, R. I., & Al-Suhail, G. A. (2023). AFB-GPSR: Adaptive beaconing strategy based on fuzzy logic scheme for geographical routing in a mobile ad hoc network (MANET). *Computation*, *11*(9), 174.
12. Nguyen, K. V., Nguyen, C. H., Le Nguyen, P., Van Do, T., &Chlamtac, I. (2021). Energy-efficient routing in the proximity of a complicated hole in wireless sensor networks. *Wireless Networks*, *27*(4), 3073-3089.
13. Mazouzi, M., Mershad, K., Cheikhrouhou, O., &Hamdi, M. (2023). Agent-based reactive geographic routing protocol for internet of vehicles. *IEEE Access*, *11*, 79954-79973.
14. Kumar, M. P., &Hariharan, R. (2022). Improved trustworthy, speed, and energy-efficient GPSR routing algorithm in large-scale WSN. *Measurement: Sensors*, *24*, 100576.
15. Baba-Ahmed, M. (2022). Mobility aware strategy for geographical routing schemes in underwater acoustic networks. *International Journal of Wireless and Microwave Technologies (IJWMT)*, *12*, 33-53.
16. Zhang, Y., &Qiu, H. (2023). Delay-aware and link-quality-aware geographical routing protocol for UANET via dueling deep Q-network. *Sensors*, *23*(6), 3024.
17. Panahi, U., &Bayılmış, C. (2023). Enabling secure data transmission for wireless sensor networks based IoT applications. *Ain Shams Engineering Journal*, *14*(2), 101866.
18. Khalaf, O. I., &Abdulsahib, G. M. (2020). Energy efficient routing and reliable data transmission protocol in WSN. *Int. J. Advance Soft Compu. Appl*, *12*(3), 45-53.
19. Arya, G., Bagwari, A., &Chauhan, D. S. (2022). Performance analysis of deep learning-based routing protocol for an efficient data transmission in 5G WSN communication. *IEEE Access*, *10*, 9340-9356.
20. Tripathi, Y., Prakash, A., &Tripathi, R. (2022). A novel slot scheduling technique for duty-cycle based data transmission for wireless sensor network. *Digital Communications and Networks*, *8*(3), 351-358.
21. Surenther, I., Sridhar, K. P., & Roberts, M. K. (2023). Maximizing energy efficiency in wireless sensor networks for data transmission: A Deep Learning-Based Grouping Model approach. *Alexandria Engineering Journal*, *83*, 53-65.
22. Seyyedabbasi, A., Kiani, F., Allahviranloo, T., Fernandez-Gamiz, U., &Noeiaghdam, S. (2023). Optimal data transmission and pathfinding for WSN and decentralized IoTsystems using I-GWO and Ex-GWO algorithms. *Alexandria Engineering Journal*, *63*, 339-357.
23. Abualkishik, A. Z., &Alwan, A. A. (2022). Trust aware aquila optimizer based secure data transmission for information management in wireless sensor networks. *Journal of Cybersecurity and Information Management*, *9*(1), 40-51.
24. Sathish, K., Hamdi, M., Chinthaginjala, R., Pau, G., Ksibi, A., Anbazhagan, R., ...&Usman, M. (2023). Reliable data transmission in underwater wireless sensor networks using a cluster-based routing protocol endorsed by member nodes. *Electronics*, *12*(6), 1287.
25. Sefati, S., Abdi, M., &Ghaffari, A. (2021). Cluster-based data transmission scheme in wireless sensor networks using black hole and ant colony algorithms. *International Journal of Communication Systems*, *34*(9), e4768.

26. Anuradha, D., Subramani, N., Khalaf, O. I., Alotaibi, Y., Alghamdi, S., &Rajagopal, M. (2022). Chaotic search-and-rescue-optimization-based multi-hop data transmission protocol for underwater wireless sensor networks. *Sensors*, *22*(8), 2867.
27. Babaeer, H. A., & Al-Ahmadi, S. A. (2020). Efficient and secure data transmission and sinkhole detection in a multi-clustering wireless sensor network based on homomorphic encryption and watermarking. *IEEE Access*, *8*, 92098-92109.
28. Harn, L., Hsu, C. F., Xia, Z., & He, Z. (2021). Lightweight aggregated data encryption for wireless sensor networks (WSNs). *IEEE Sensors Letters*, *5*(4), 1-4.
29. Kuthadi, V. M., Selvaraj, R., Baskar, S., Shakeel, P. M., &Ranjan, A. (2022). Optimized energy management model on data distributing framework of wireless sensor network in IoT system. *Wireless Personal Communications*, *127*(2), 1377-1403.