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Article Title: Novel Butterfly Optimization Algorithm-Based Secure Node Selection Strategy for Wireless Sensor Network

Novel Butterfly Optimization Algorithm-Based Secure Node Selection Strategy for Wireless Sensor Network

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ABSTRACT

Wireless Sensor Networks (WSNs) allow new applications and necessitate non-traditional routing design paradigms due to several constraints. A long network lifetime requires minimal device complexity and low energy consumption, which requires a proper balance between communication and signal/data processing capabilities. The objective of this paper is to increase the network lifetime while minimizing overall energy. Currently, clustering and routing algorithms are widely used in WSNs to increase the network lifetime. The Butterfly Optimization Algorithm (BOA) is used in this work to select the best cluster head from a set of nodes. The cluster head is chosen based on the nodes residual energy, node degree, node centrality and space to the base station and neighbours. Comparing the existing methodology to current algorithms BOA, BOA exposures that it outperformed LEACH-PRO and EECHIGWO in terms of network lifetime, throughput, delay and energy consumption.

Keywords: Wireless Sensor Network (WSN), Butterfly Optimization Algorithm (BOA), Energy Consumption, Network lifetime, Throughput, Delay

I Introduction

The primary tool in a Wireless Sensor Network is a sensor. In order to satisfy user needs, a sensor is used to perceive the outside world efficiently. A wireless network is used to transmit information. [1] Its capabilities in the military include the ability to detect nuclear radiation, chemical and biological contamination, and the deployment of troops in hostile territory, among other scenarios. [2] It is used to collect data in the arena, monitor animal footprints, analyze pollution levels, and forecast the occurrence of forest fires and debris flows, among other environmental monitoring and protection tasks. [3] Intellectual creation in industry and agriculture involves tracking crop growth and product flow. The situation perform the tasks of collecting physiological data from patients, assessing their problems, and ensuring prompt medical treatment in the sphere of health and medical care [4].

Furthermore, wireless sensor networks are important for smart cities, smart homes, smart transportation, business, and the preservation of cultural artifacts, among other areas. People's lives are being transformed by wireless sensor networks to simulates the communication scenario of a WSN. [5] Because it guarantees important performance indicators and enhances the end-user experience, QoS is essential in contemporary networks. Each client chooses the best access devices in an effort to meet QoS access requirements. One of the most crucial

elements of wireless communications is QoS-aware delivery [6]. To address these problems, WSN introduces the Quality of Service Factor based Unfailing Route (QFUR) Construction. This method determines whether the sensor node is normal by verifying QoS characteristics such as packet drop, residual energy, and sensor node latency. The QoS factor value is below what is required for that node to be considered a typical sensor node in the WSN. [7]
To ensure a destination track in a routing list, an efficient MANET protocol is employed. For this tracking purpose an Optimized Link State Routing (OLSR) is used. [8] Then two protocols: OLSR, which is a proactive protocol for industry networks, and Ad hoc On-demand Distance Vector (AODV) [9], which is a responsive protocol. The main goal of Smart Grid (SG) industry 4.0 is to create a smart electrical standard through the use of cutting-edge IoT technologies to give a number of advantages in the developing domains, such as industry economy, limited energy sources, dependability, network stability, security, etc.[10] The standard OLSR protocol for SGs is utilized to better regulate control intervals that increase the regular OLSR protocol's efficiency without compromising its dependability. By minimizing simple flooding and assessing an optimal clusters head, the node grouping procedure helps manage the overall network cost. [11]
The hybrid optimization method known as Particle Swan Optimization Algorithm-Ant Colony (PSO-ACO) determines the quickest route for data transfer between the base station and the cluster head. [12] By checking PSO from entering local minima, the Particle Swan Optimization Algorithm – Grey Wolf Optimization (PSO-GWO) technique has improved the capacity for consideration [13]. To effectively choose the CH in each location, the sink node uses the particle swarm optimization technique. [14] An optimization method that combines Particle Swarm Optimization Algorithm with Lightning Search Algorithm (LSA) and simulated hardening with SA-LSA.[15]

2 Related Work

Singh *et al* (2021) [16] have proposed a Multi-Objective Optimization (MOO) to improve optimizing metric. In WSN the conflicting goals is comprise using the multi-objective optimization (MOO) technique to find the routing between sources to destination. First, the main optimization goal in WSNs is to find the secure routing, which includes current problems like routing, rate control and power control. Later, a MOO method is used for enhancing the optimization metric. It encountered issues with more network overhead, excessive cost consumption, and reduced QoS.
Banerjee, A. *et al.* (2022) [17] have developed a modified Ant Colony Optimization (ACO) technique has been used to build effective WSN. The ACO is a probabilistic method for resolving computing issues with the selection of a graph's minimized path. The total number of nodes needed to effectively cover the area is determined after the WSN network is constructed. The lifetime of the WSN is easily measurable by everyone, and the distance among each node and the distance among sink nodes and WSN nodes is calculated to determine the

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 03 (10), October 2024, pp. 61-74

energy consumed for the network. It has low network lifetime and energy consumption using ant colony optimization technique.

Wang *et al* (2022) [18] have invented a Firefly Algorithm (FA) as well as Ant Colony Optimization (ACO) to improve the inter cluster routing stage. To maximize network clustering, it was added to the firefly method. Moreover, an enhanced ACO establishes the inter-cluster routing in addition to that for the inter-cluster routing stage. Furthermore, energy and distance are incorporated to improve the path, and incorporates the coefficient of variation in statistics.

Obaid *et al* (2021) [19] have developed a Fuzzy logic as well as Ant Colony Optimization Algorithm (FACO) it is used to find the nodes in the routing. Similarly, the constraint is to find and determine the shortest distances between the sources and the destination sensor nodes. The shortest distances is for evaluating system performance and drawing conclusions informed the implementation of ACO. To find the shortest path between the nodes the optimization technique is used. It improved the system performance, particularly in terms of energy conservation. It takes more time to discover the shortest path between the nodes.

Shahryari *et al* (2023) [20] have proposed a Genetic Algorithm (GA) to find a super nodes from cluster head to base station. A GA builds a spanning tree over super nodes and assigns the right radio channels to them. A unique multi-objective cost function is advised that significantly extends network lifetime. The appropriate Cluster Head (CH) and channel for each typical node are identified in the second stage of the suggested procedure. The systematic simulations show that the suggested technique uses many channels to achieve high throughput. Whereas using a single algorithm to find the throughput easily.

The major contributions of the proposed work involves

- Introduction of a secure node selection process that evaluates trust, connectivity, and QoS, ensuring the consistency and security of nodes in the network.
- Incorporates the Butterfly Optimization Algorithm to enhance routing efficiency, optimizing path selection for better resource utilization.
- By combining secure node selection with an advanced optimization technique, the proposed work provides a hybrid approach that ensures both security and performance in routing.
- The research delivers a scalable and adaptable routing mechanism suitable for dynamic network environments.

3 Proposed System

By using the Butterfly Optimization Algorithm (BOA) for secure node selection, this study offers a unique technique for improving the security and effectiveness of WSNs. The proposed approach optimizes network performance indicators although creating dependable and secure communication channels from the source to the destination. Secure node selection is the first step in the process, which finds the best nodes based on three crucial factors: connectivity,

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 03 (10), October 2024, pp. 61-74

trust, and QoS. Assuring the dependability and integrity of chosen nodes while optimizing node lifetime and reducing communication delays is how trust is measured. Connectivity ensures strong links throughout the network, facilitating smooth communication. QoS places a higher priority on performance requirements like bandwidth, dependability, and responsiveness.

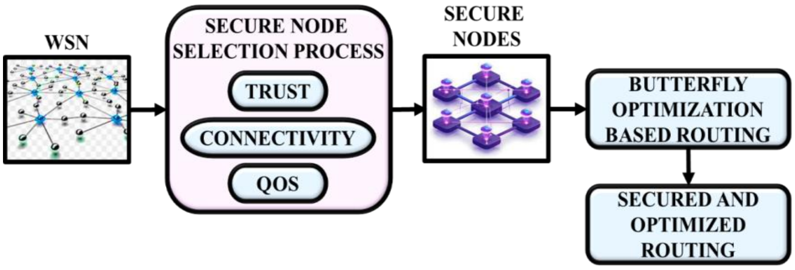

Figure 1: *Block diagram of BOA*

The BOA is used to optimize path selection after secure nodes have been chosen, increasing throughput and reducing energy usage. This strategy strikes a balance between security, effectiveness, and longevity while strengthening the network against possible threats and enhancing overall performance. The proposed approach shows important gains in throughput, energy efficiency, and secure communication within WSNs by utilizing BOA and including trust, connection, and QoS into the secure node selection process.

3.1 Intention of trust and opportunity based on routing in WSN

To control optimal path in WSNs a routing protocol is used and to assure the secure routing many different routing protocols have been created. In WSNs the trust and energy features are the important limitations, it allow secure and actual routing. Furthermore the existing method of computational densities remains high. A technique is created to reduce overhead and the capacity to contract with the compound attacks. The routing structure using a recently designed Butterfly Optimization Algorithm (BOA) is planned and is to allow both network security and optimization.

Using two key parts the proposed method is operated to find the secure nodes from source to destination. First, among the initialized nodes in WSNs, a subset of secure nodes is concentrated. The network's parameters, trust, connection, and quality of service are used to activate and display the secure nodes by tolerant constant selection. In the sensor environment, the network is first simulated with M nodes, and secure nodes are selected depending on tolerance.

3.1.1 Collection of the secure nodes using the tolerant constant

The tolerance constant is stated for selecting the network's secure nodes in order to allow true security. Based on the tolerant constants the nodes are selected and it is calculated using the nodes must be maximum. TC is expressed as

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International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 03 (10), October 2024, pp. 61-74

$$TC = \frac{1}{3}[T_j + C_j + QoS_j] \tag{1}$$

Where, T_j denotes as the trust of j^{th}node, C_j designed the connectivity of j. If $(N < M)$ of the M nodes in the environment, N secure nodes are certain. The highest value of the trust, highest vale of connectivity are obtained on the nodes in the environment. Following environment communication, the secure nodes with the highest QoS are chosen, and the remaining nodes are eliminated. The network's maximum link lifetime, minimal node delay, and maximal QoS are all provided.

Trust

The degree of satisfaction that occurs between node interfaces is the basis of direct trust, is identified as local trust. Direct trust among nodes i and j is founded on how satisfied each node is with the others. The amount of satisfaction sat_{ij}between nodes j and i is determined by the number of nodes and successful transactions. Are calculated as

$$sat_{ij} = \frac{\$_{ij}}{M} \tag{2}$$

Where the degree of satisfaction sat_{ij} among the nodes i and j are written as, $\$_{ij}$ and the overall quantity of nodes is denoted by M

Connectivity

Connectivity is the link that exists among the nodes and the link that is mentioned in the two-way connection, joining the nodes. The node's connectivity is expressed as,

$$Cj = \frac{1}{M}\sum_{i=1}^{M}\frac{Ci}{e} \tag{3}$$

Where C_i indicates connectivity of i^{th}node, and e denotes entire connections.

QoS

The network's delay and link lifetime, which are used to compute QoS: The nodes' link lifetime is dictated by the connections that exist between them, and the link lifetime is connected to the network's. Link breakage is a serious problem in WSNs because of the dynamic nature of the network, which necessitates assessing the nodes link lifetimes. Simultaneously, link breaks must be kept to a minimum and constitute a major need in the path selection procedure. Examine the network's nodes n_i, and n_j, which are located at$(y_1, z,)$ and(y_2, z_2) individually. The Link Life Time (LLT) of the nodes is given as

$$LT_j = \frac{-(WX+YZ)+\sqrt{(W^2+Z^2)V^2}-(WZ-YX)}{(W^2+Z^2)} \tag{4}$$

Where LLT_jcharacterizes the link life time j^{th}node, Vdenotes the array of transmission, $W, X, Y and\ Z$ are the factors stated by way of:

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 03 (10), October 2024, pp. 61-74

$$W = S_i \cos \varphi_i - S_j cos\varphi_j \tag{5}$$

$$X = y_i - y_j \tag{6}$$

$$Y = S_i \sin \varphi_i - S_j \sin \varphi_j \tag{7}$$

$$Z = z_i - z_j \tag{8}$$

The delay $d_j$of thej^{th} node on the transmission. Thus, QoS of the j^{th} node is given as,

$$QoS_j = LLT_j + d_j \tag{9}$$

The Quality of service is derived using the above formula to get better throughput and energy consumption.

3.2 Butterfly Optimization Algorithm

The two algorithms in the proposed method are one for network routing and one for selecting the Cluster Head (CH). The best sensors, such as CH and the BS, are chosen using BOA.

3.2.1 Cluster head selection using BOA

One of the metaheuristic algorithms influenced by nature is the Butterfly Optimization Algorithm. This BOA mimics the mating and food-seeking behaviours of butterflies. The search algorithm is used to characterize the behaviour of butterflies. In general, butterflies are drawn to one another by the fragrance that other butterflies generate. After then, butterflies either migrate randomly or in the direction of the butterfly that has the strongest fragrance. Additionally, the butterfly's stimulus intensity is ascertained using the objective function. Using node to the base station, and residual energy, the BOA selects the best CHs from all sensors.

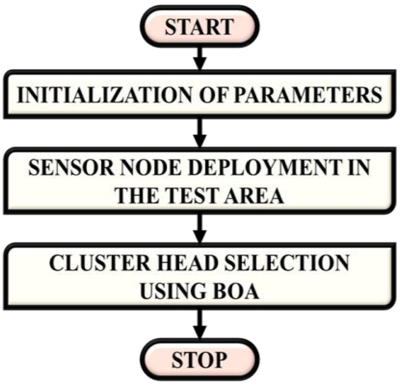

Figure 2: *Flowchart for BOA*

3.2.2 Butterfly representation and Initialization

The butterfly chooses a subset of network sensors to serve as CHs during the BOA CH selection phase. The amount of CHs in the network corresponds to every butterfly dimension. A unplanned node ID between 1 and m, which is the total number of nodes in the network, is used to initialize each butterfly's position.

Assume,$B_i = (B_{i,1}(t), B_{i,2}(t), \dots \dots, B_{i,m}\ (t))$ stand for butterfly and wherever butterfly station $B_{i,d,} \leq d \leq m$ that establishes the number of CHs in the network and provides the node ID among 1.

3.2.3 Butterfly position improvisation

The CH selection process takes into sketch the butterfly's ability to improvise their positions. The following is the procedure for updating the butterfly's positions:

a. Generation of new-fangled butterflies

The locations of the butterflies are restructured in BOA during either the local or global search phases. The random number in [0, 1] determines whether to use a local or global search phase. Equations (10) and (11) define the BOA's global and local search phases, respectively. This involves improvising new butterflies at random using node IDs from all of the network's nodes. In this instance, the fragrance of the butterflies is used to update the positions. Furthermore, when the butterfly is unable to detect any fragrance in the surroundings, the BOA initiates the local search. The butterfly mimics the finest butterfly's movements or clarification g^*at global search phase.

$$x_i^{t+1} = x_i^t + (r^2 \times g^* - x_i^t) \times f_i \tag{10}$$

$$x_i^{t+1} = x_i^t + (r^2 \times x_j^t - x_k^t) \times f_i \tag{11}$$

Where $j^{th}$and k^{th}butterfly is represented asx_j^t andx_k^t . The equation (10) acts as local random walk when bothx_j^t andx_k^t are from the same butterfly. The following is used to create the butterflies' fragrance in their appropriate locations equation (11).

$$f = cI^a \tag{12}$$

Where f stands for fragrance; $c$is sensory modality; I stands for stimulus intensity and a stands for power exponent.

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 03 (10), October 2024, pp. 61-74

Cluster head selection using BOA
Input: All Sensor Nodes N
Output: Cluster Head Node CH
Residual energy − RE
Node's traffic − NT
Distance to BS − DBS
Distance to the Sensor Nodes − DSN
Node Centrality − NC
Node Degree − ND
Produce a preliminary population of butterflies
    for p = highest amount of iteration
        for all butterfly in population
            calculate fragrance through eq. 12
        end
find the best butterfly population
for all butterfly in population
    Produce a random value from [0,1]
    if population found
Move on the way to an optimal node
else
Move arbitrarily
end
end
Update the value optimal node
end

4 Results and Discussion

The simulation configuration is designed for BOA in WSN. This section presents the effectiveness of the future procedure employing butterfly optimization algorithm, along with a discussion and comparative analysis.

Table 1: *Summary of simulation*

Parameters	Values
Node Region	$200m\ X\ 300m$
Network Sizes	$50, 100, 200, 500$
First Energy (J) of every node	$0.5\ J$

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 03 (10), October 2024, pp. 61-74

$E_{Tx-elec}$	50 nJ/bit
$E_{Rx-elec}$	50 nJ/bit
ϵ_{amp}	100 pJ/bit/m^2
Data Packet Length	4000 bits
Amount of nodes in Cluster	10
Possibility	0.1
Simulation rounds	6000
Location of base station	(100,300)

4.1 Experimental Setup

The outcomes for parameters such as throughput, detection rate, delay, and distance are used to assess the performance, and the results are compared to existing system.

Performance Metrics

The comparison's parameters include the approaches throughput, PDR, energy consumption, network lifetime and delay.

Energy consumption

The total power consumption of a system during data packet transmission is called power consumption.

$$E_c = \sum_{i=1}^{N} E_{i,L} \tag{13}$$

Thus, the total energy used by node *i* following *L* rounds of data collecting, and *N* symbolizes the number of nodes.

Throughput

A throughput measurement is expressed in bits per second. The bits transferred to the BS are known as the throughput.

$$T_p = \frac{Received\ packet\ size}{stop\ time - start\ time} \tag{14}$$

Delay

Duration of the sensor node's transmission of the data it has detected from the source to the destination.

Packet Delivery Ratio

PDR is the ratio of all packets transmitted to all packets sent from the origin node.

$$PDR = \frac{packet\ received\ at\ destination}{total\ number\ of\ packet\ send} \times 100 \tag{15}$$

4.2 Comparative analysis

Energy consumption

ISSN (Online): 2583-7052

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 03 (10), October 2024, pp. 61-74

The energy usage of the suggested Butterfly Optimization algorithm is analysed in the figure 3 using several alternative methodologies. When compared to other current routing techniques the suggested BOA methodology provides superior energy consumption performance. LEACH-PRO [21] and EECHIGWO [22] are the existing methods.

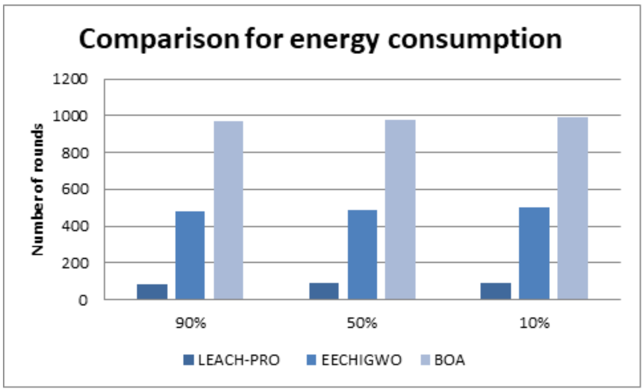

Figure 3: *Comparison for energy consumption*

Packet Delivery Ratio

The PDR for the proposed structure is displayed in figure 4 in combination that includes LEACH -PRO, EECHIGWO and BOA. The PDR has value ranges from 0 to 2500 for both x-axis and y-axis. The PDR value for BOA is high compared to the other technique.

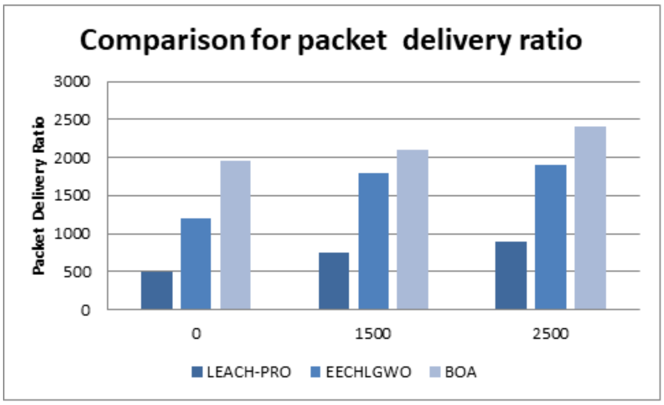

Figure 4: *Comparison of packet delivery ratio*

Through Put

Figure 5 compares the suggested BOA throughput analysis with alternative methods. In terms of throughput, the suggested BOA strategy outperforms other strategies. The evaluation indicates that the suggested BOA method provides data faster. BOA results in a drop in throughput performance.

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 03 (10), October 2024, pp. 61-74

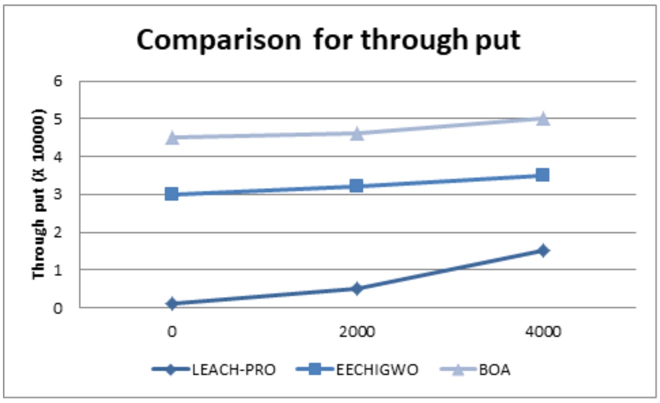

Figure 5: *Comparison for through put*

Network lifetime

Based on stable and unstable periods the network lifetime is well-defined. Figure 6 shows the comparison of network lifetime with the other networks

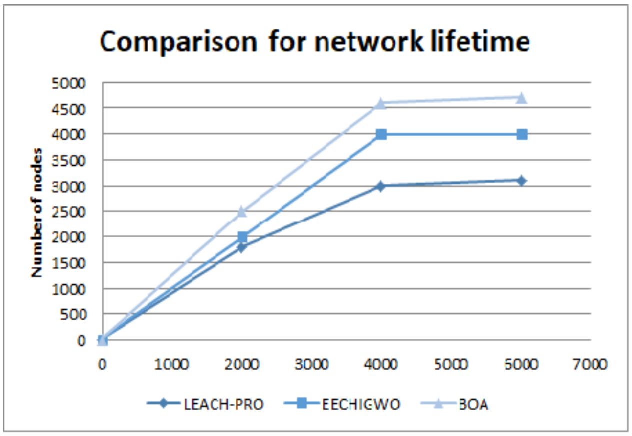

Figure 6: *Comparison for network lifetime*

Delay

The delay mechanism is going on decreasing for the proposed BOA method. When compared to the existing LEACH-PRO, EECHIGWO techniques.

International Journal of Advanced Trends in Engineering and Management (IJATEM)
Vol. 03 (10), October 2024, pp. 61-74

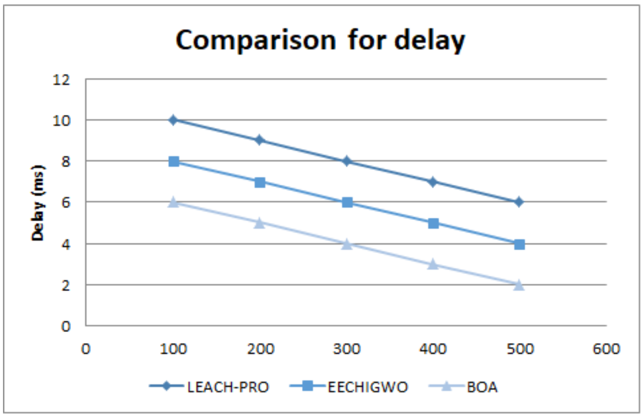

Figure 7: *Comparison for delay*

5 Conclusion

The paper presents a robust approach to achieving secure and optimized routing in network infrastructures. By incorporating a Secure Node Selection Process based on trust, connectivity, and QoS, it ensures reliable node identification for routing. The integration of the Butterfly Optimization Algorithm further enhances routing efficiency, providing optimal path selection while maintaining network security. This dual-layered framework effectively addresses challenges such as trust management and routing optimization, delivering a secured and high-performance routing mechanism. The proposed BOA's performance is contrasted with those of other optimization techniques, like EECHIGWO and LEACH-PRO. The results showed that the suggested BOA has a longer network lifetime, higher throughput, better energy consumption, and less delay.

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