IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

OPTIMIZING ENERGY EFFICIENCY IN WIRELESS SENSOR NETWORKS USING A HYBRID ARTIFICIAL BEE COLONY AND GRASSHOPPER OPTIMIZATION ALGORITHM

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Abstract: In this paper, we present an effective Wireless technique in which two optimization algorithms i.e., Artificial Bee Colony (ABC) and Grasshopper Optimization algorithm (GOA) has been hybridized. The key motive of the proposed HABCGOA model is to improve the lifespan of the network by reducing its energy consumption. To combat this task, nodes are deployed in the network upon which HABCGOA technique is implemented. In order to select the optimum CH in the network, the proposed model analyzes four parameters i.e., node density, residual energy, distance from CH to BS and average distance between two nearby nodes to calculate fitness value. The node with the best fitness value is selected as CH in the network for a particular cluster on iteration. Additionally, we have also introduced the range-based communication in the proposed work by virtue of which non cluster member nodes transfer their data to the nearest CH node instead of transferring it directly to Base Station (BS). The effectiveness or proposed HABCGOA model is analyzed and validated by comparing it with similar approaches in MATLAB Software using various dependency factors.

Index Terms **– WSN, Energy Consumption, Routing protocols etc.**

I. INTRODUCTION

In many commercialized corporate automated processes and numerous other real-world applications, wireless sensing technology is essential [1]. It is especially useful for applications requiring extreme environments wherein building alternative network infrastructure is challenging and/or extremely difficult, such as in dangerous chemical plants, high-temperature environments, and battlefields. It is typical to observe that the majority of important surveillance and safety systems rely on sensor-based software as well. Small, inexpensive sensors can be used in a wide range of situations because of their versatility [2]. Almost all sensor networks have some sort of sensing component that gathers data from a targeted physical surroundings using either a time-driven or an event-triggered method. With the help of some types of routing protocol, such as cluster-based routing protocols, a sensor can transmit the detected data to a target or sink (many destinations/sinks are also feasible). Because they are so tiny, sensor nodes have a limited amount of computing capability, little storage memory, and a finite amount of battery power [3]. Memory, CPUs, sensing components, batteries, and a transceiver are all parts of a sensor node. Huge numbers of these sensor nodes can be placed in the sensing region, producing a bunch of data that is sent to the base station for analysis. However, because sensor nodes are so small, they have some limits in terms of memory, bandwidth, computing power, and battery life. Energy management is unquestionably the top priority when creating a dependable and effective WSN. Typically, a long lifespan of the sensor network ensures the overall effectiveness and dependability of the monitoring program whenever WSN is employed for remote monitoring systems. This even retains a significant amount of human effort to ensure the sensor network's operation. When considering all the elements that go into consuming energy to maintain all WSN activities, communication typically consumes a significant amount of energy. Through reducing the number of transmission hops and associated average length, energy consumption could be reduced. The WSN's lifespan will eventually be increased as expected [4-5].

The routing strategy plays a crucial role in extending the network's life. Many WSN routing protocols fall into one of many categories, including flat, location-based, and hierarchical approaches [6]. The initial energy dissipation issue has been solved by a number of energy-efficient routing protocols that are likely to be successful. Based on their interaction with the BS or sink, the three distinct types of hierarchical routing in sensor networks are tree-based method, chain-based method, and cluster-based method [7]. The cluster-based strategy is a major contender for extending the life of the network. The cluster creation method, in which sensor nodes are divided into distinct regions, is an efficient method for data collecting, and cluster-based routing has achieved this with the least amount of overhead (Fig 1).

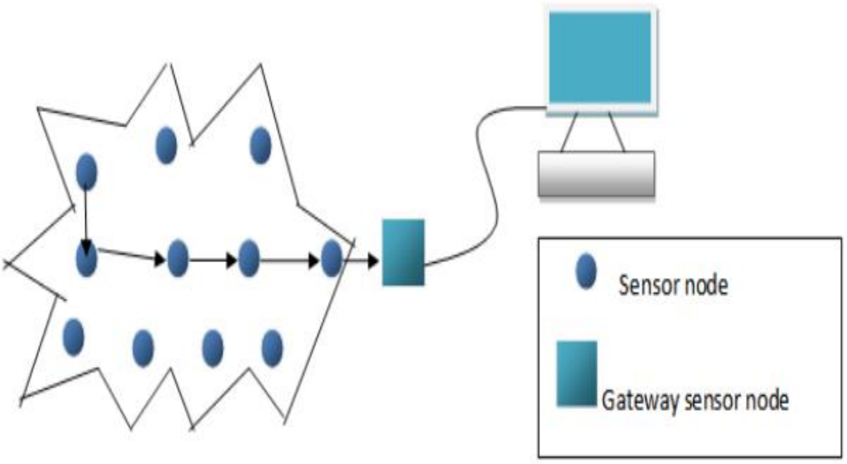

Figure 1. Typical example of WSN

Each unit in a cluster has a leader node called a Cluster Head (CH), that is tasked with communicating with cluster members (CMs) and gathering data from these. Data aggregation, where the CH eliminates duplicate and pointless data packets to save delay and complexity, is one of its key functions. By reducing the size and total number of nodes in the routing channel, clustering reduces the complexity of routing and improves the effective use of memory and bandwidth [8]. Data packet transfer and receptions are regarded as the main causes of energy usage in WSNs [9]. As a result, one should effectively manage and regulate energy usage in order to create routing algorithms for WSNs that are energy-aware. Lack of energy consumption management will cause the rapid depletion and degradation of the energy resource of the nodes close to the sink as a consequence of the many-to-one traffic pattern; this is known as the energy hole issue. The energy hole challenge and the periodic selection of the ideal path have an effect on WSN lifespan in most routing protocols. These two issues will cause the system to be divided and prevent the WSN from performing its planned crucial purpose [10]. These routing techniques' main drawback is that they reduce overall energy use at the price of uneven energy loss throughout the network. Improving network longevity is regarded as one of the most significant difficulties facing WSNs, and as such, it must unquestionably be taken into consideration when designing the routing protocol.

The remaining section of the paper is categorized as; Section 2 discusses literature proposed by various authors for enhancing the network lifespan followed by a problem statement. Section 3 discusses proposed work and its working methodology. Section 4 discusses various results that are obtained for the proposed model and finally a conclusion is given in section 5.

II. LITERATURE REVIEW

In the past few years, a significant number of researchers and academic scholars are working on enhancing the lifespan of wireless network. There is a considerable improvement in network lifespan, therefore it is vital to thoroughly study some of the recently proposed WSN technologies in order to have better insights. **S Pathaket al. [11],** proposed the PBC-CP, a protocol for proficient bee colony clustering that is based on the artificial bee colony algorithm. Moreover, they considered crucial elements in the PBC-CP strategy, like node energy, node degree, and node distance from the base station. Moreover, they also introduced energy efficient channel for transmitting data from CH to BS. **O Buyanjargal, et al. [12],** proposed Adaptive and Energy Efficient Clustering Algorithm for Event-Driven Application in WSN in which equilibrium of nodes energy was achieved. Moreover, they utilized nodes remaining energy for selecting the CH in the network. **G Molina, et al. [13],** adopted a multi-objective method to accomplish the goals of decreasing network costs, extending network lifetime, and taking into account the constraint of sensor area coverage. Furthermore, Energy efficiency and the number of nodes were two separate optimization goals that were achieved using multi-objective optimization methods for this task. **S A. B. Awwad, et al. [14],** developed a cluster-based routing protocol especially for mobile sensor nodes (CBR-Mobile). Additionally, this protocol dealt with mobility and traffic management. Moreover, the sensor nodes that leave the cluster or didn't have any data packets to send were given a specific, limited time slot that was then given to newly arriving sensor nodes inside the cluster. **N Zaman, et al. [15],** developed "Position Responsive Routing Protocol" (PRRP) that used a cross-layer design methodology. PRRP was intended to reduce the amount of energy utilized by every node by decreasing the amount of time a sensor node was in an idle listening mode and lowering the network's average communication distance. **Y. Xu, et al. [16],** proposed an approach that made use of an improved genetic algorithm to identify the bare minimum number of sensor nodes necessary to assure complete DPOI coverage. **P Maheshwari, et al. [17],** utilized Butterfly Optimization Algorithm (BOA) in this work to select the best cluster head from a set of nodes. The cluster head selection was optimized by the node residual energy, distance to neighbors, distance to the base station, node degree, and node centrality. Ant Colony Optimization (ACO) was used to determine the path between the cluster head and the base station; it chooses the best course based on the node degree, distance, and residual energy. **W. Zhang, et al. [18],** On the basis of the cross-layer optimization model, a new routing technique based on Leach-Cross-Layer Optimization (CLO) was proposed for a ring monitoring domain, along with an energy-efficient ring cross-layer optimization technique. Based on the standard Leach method, this Leach-CLO routing algorithm was developed. **V Sharma, et al. [19],** modified an ant colony optimization method and applied it to the issue of identifying the most energy-efficient path for the recruitment of sensor nodes for signal transmission in order to increase the network lifetime. The intra-node spatial distance and the rate of battery drain out/recovery with regard to signal transmission were combined in the suggested method. **J. -W. Lee et al. [20],** suggested an ant-colony-based scheduling algorithm (ACB-SA) for solving efficient-energy coverage (EEC) issue.

After analyzing the literature survey, it is observed that a number of techniques have been proposed in the past few years in order to enhance the lifespan of wireless networks. No doubt these methods were giving good results but we observed that there is a scope of improvement. It has been observed that traditionally the authors were taking energy, node degree and sensor node distance into considerations for selecting CH. However, there are some other factors that must be considered for selecting CH in the network. Moreover, some researchers also used optimization algorithms in their work, however, these methods undergo through slow convergence rate and often tend to be trapped in local minima. In practice, many nodes encountered larger communication distances, resulting in excessive energy consumption or even failure, which resulted in the loss of data. These findings highlight the need to improve the current algorithm in order to address these problems and increase the network's lifespan.

III. PROPOSED WORK

In order to overcome the shortcomings of traditional models, a new and effective method is proposed in this paper that is based on hybrid optimization algorithms. The key goal of the proposed model is to improve the lifespan of wireless network while minimizing the node energy. In a standard WSN, choosing the best CH for the network is vital for extending network lifespan; as a result, choosing CH for the network must be done using an efficient method. To accomplish this task, we have used a hybrid optimization algorithm in which Grasshopper optimization algorithm (GOA) and Artificial Bee colony (ABC) algorithm are hybridized. In the proposed study, two optimization approaches were merged mainly to solve problems with slow convergence rate and tendency to get stuck in local minima. We have also changed the network's CH selection standards. The prior approach just used the node density, residual energy, and distance factors for selecting the CH in the network, as was previously mentioned. However, after investigating the literature, we found that average distance between two adjacent nodes, are important in selecting the appropriate CH. As a result, we have taken this into account while recommending the best CH.

Furthermore, we also considered the fact that certain nodes in the sensing region were not connected to any cluster groups, despite communication in the usual design occurring from sink node to CH to node. Such nodes directly interface with the sink node to transmit data, which uses a lot of energy and eventually depletes the nodes. In the proposed study, we have chosen to adopt range-based communication as a solution, that means that non-cluster member nodes will seek out the closest node or CH while transmitting data. In the proposed study, we have chosen to adopt range-based communication as a solution, that means that non-cluster member nodes will seek out the closest node or CH while transmitting data. By doing this, the non-cluster member nodes can send information to a nearby node that will subsequently send them to the sink node. In this way, node energy usage is optimized, and network durability is increased. Consequently, the lifetime of the wireless sensor network can be greatly extended by employing the hybrid optimization method and range-based communication system. In the methodology section of this paper, the suggested HABCGOA model's step-by-step operation is described in depth.

I. RESEARCH METHODOLOGY

The proposed Hybrid ABCGOA model undergoes through various stages like network initialization, node deployment, CH selection, data collection and communication. The step by step working of the proposed model is explained briefly in this section.

3.1 Initialize Network

The very first step opted in the proposed model is to initialize the network in which different parameters are defined. In this phase, parameters like sensing region, number of nodes to be deployed, location of sink node, initial energy etc., are defined. The specific value of these parameters and other are given in table 1.

Table 1 Network Initialization Parameters

Parameter	**Values**
Sensor area	100*200m
Location of sink node	50, 150
Number of nodes (s)	100
Initial node energy (Eint)	0.5
Data packet length (L) bits	4096
Energy/bit absorbed in transceiver circuitry Ee (nJ/bit)	70
Energy/bit absorbed in power amplifier Efs and E tg (pJ/bit/m2)	120 & 0.0013
Energy data aggregation Eg (nJ)	5
Total iterations	3500

3.2 Deploying Nodes

After the network has been initialized, it is time to start deploying nodes in its sensing region. Here, the total sensing area is 100*200m in which a total of 100 nodes are deployed. The initial energy of these nodes is 0.5J and location of BS is (50, 150).

3.3 Cluster Formation

In this phase temporary clusters are formed by selecting temporary CH in the network. The CH nodes form clusters by grouping together the nodes whose distance to CH node is small.

3.4 HABCGOA Initialization

Immediately after this, HABCGOA model is initialized in which different parameters like population size, iterations and other parameters are defined. The specific value of these parameters and others are given in table 2.

Table 2 HABCGOA Initialization Parameters

Parameter	**Value**
Population (Colony Size)	20
Iteration	10
Onlooker Bees	20
Cmax	1
Cmin	0.00004

3.5 CH Selection

In the next phase of the proposed model, efficient and optimal CH must be selected. For this, we have analyzed four parameters like node density, residual energy, distance from CH to BS and average distance between two nodes for each node to calculate fitness value. The node whose fitness came out to be best is selected as CH in the network.

3.6 Cluster Member Recruitment

Once the CH node is selected, it broadcasts a signal to non-cluster members present in the network. Depending on the intensity of the signal, the non-cluster members decide whether they want to join the particular cluster are not to form final clusters.

3.7 Data Collection

Immediately after this, the CH node begins to sense data from sensing region which then combines it and sends it further to Base station (BS). Moreover, the CH nodes also analyze this data and remove any redundant data to make communication more effective.

3.8 Communication

The suggested work's communication phase comes next, during which all the data must be given to BS. Here, we've introduced the idea of range-based communication, in which any node that isn't a member of the cluster searches for the nearest CH node to send data to. By doing this, the energy of nodes that are not members of the cluster is used effectively, extending the lifespan of the network.

3.9 Rotation of CH

The same process is applied to select the new CH for the system once the information sharing is completed. The node with the highest fitness value is selected as the CH for the subsequent iteration, and this process is repeated a certain number of times.

3.10 Performance Analysis

Finally, the performance of proposed HABCGOA model is analyzed and validated by comparing it with traditional models in terms of various performance dependency factors. The results obtained for the proposed HABCGOA Model are discussed in the next section of this paper.

IV. RESULTS AND DISCUSSIONS

The efficacy and usefulness of proposed HABCGOA model is analyzed and examined in MATLAB software. The simulating outcomes were obtained and compared with traditional models like HSA-PSO and PBC-CP models in terms of dead nodes, alive nodes, throughput, residual energy and lifetime evaluating factors. The detailed description of results are discussed in this section of paper.

4.1 Performance Evaluation

Initially, we have examined the suggested HABCGOA approach's performance with the established HSA-PSO and PBC-CP models in terms of their dead nodes in order to demonstrate its efficacy and efficiency. The graph demonstrating the dead nodes graph is shown in Fig 2. It has been determined from the presented graph that node in the traditional HSA-PSO and PBC-CP models begin to die after finishing 1450 and 1642 rounds, respectively, whilst nodes in the suggested HABCGOA model begin to die after 1855 iterations. This demonstrates that the suggested HABCGOA model significantly outperforms the initial HSA-PSO and PBC-CP models by a factor of between 405 and 213. The suggested HABCGOA model can continue to operate properly for 4345 rounds despite nodes dying early on, whereas the HSA-PSO and PBC-CP conventional models only persist for 1760 and 2500 rounds, respectively.

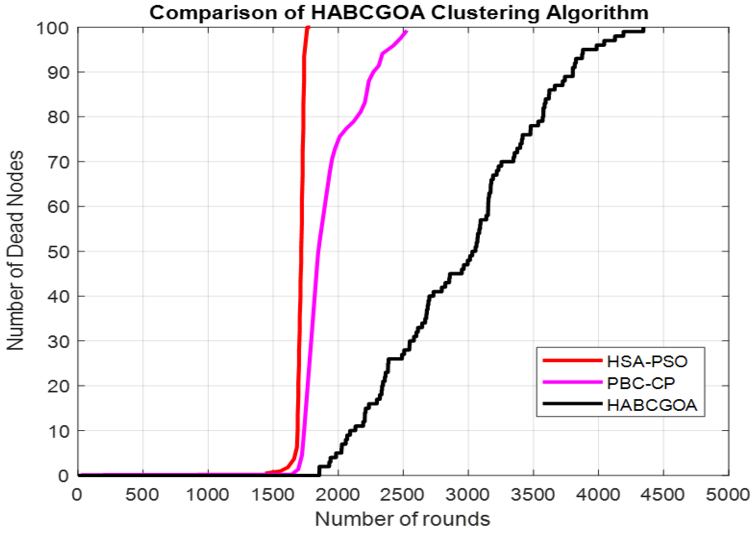

Fig 2. Comparison graph for dead nodes

In a similar way, we additionally assessed the effectiveness of our model in terms of alive nodes; the resulting comparative graph is given in Fig 3. In the classic HSA-PSO and PBC-CP models, all nodes remain active for 1450 and 1642 iterations, respectively, according to the shown graph. In contrast, all of the nodes in the proposed HABCGOA model are still alive and executing 1855 rounds. The nodes begin to die shortly after this, nevertheless the suggested framework is still able to prolong the network's longevity until 4345 rounds, while the classic HSA-PSO and PBC-CP models only have lifespans of 1760 and 2500 rounds, respectively.

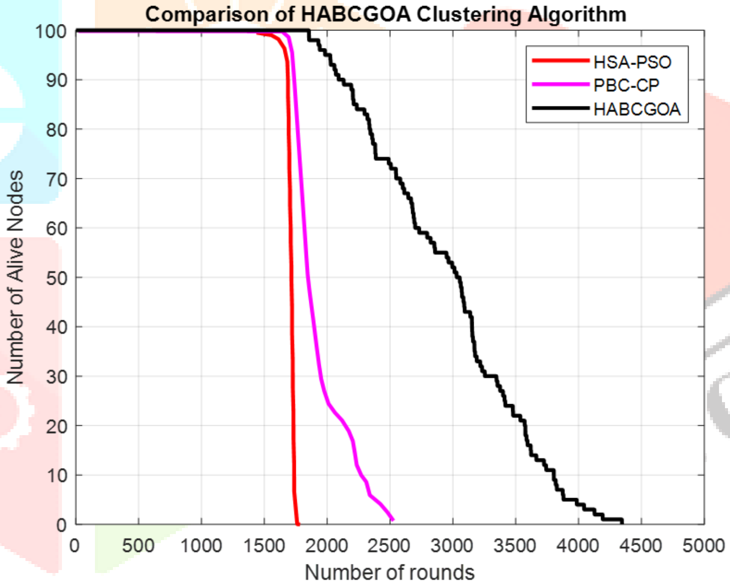

Fig 3. Comparison graph for alive nodes

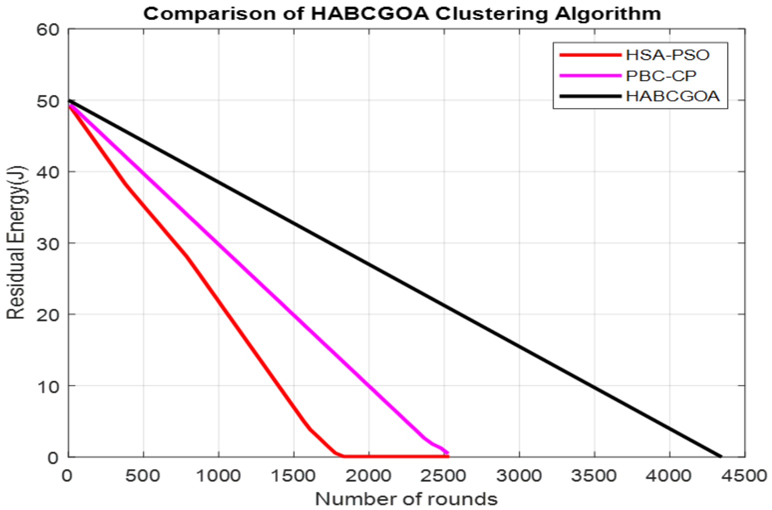

Fig 4. Comparison for residual energy

By comparing and contrasting the proposed energy-efficient strategy with standard approaches, we have also examined their remaining energy. The comparative graph obtained for the same is shown in Fig 4. It is evident from the analysis of the provided graph that all nodes have an initial energy of 50j in all categories. However, as iterations mount, nodes begin to lose energy, and in conventional HSA-PSO systems, all node energy is exhausted at the 1700th round. Similar to this, the PBC-CP model's nodes all run out of energy after only 2500 rounds. However, in the suggested HABCGOA Model, data is transmitted from nodes to the BS node until the 4300th round, to mark its supremacy.

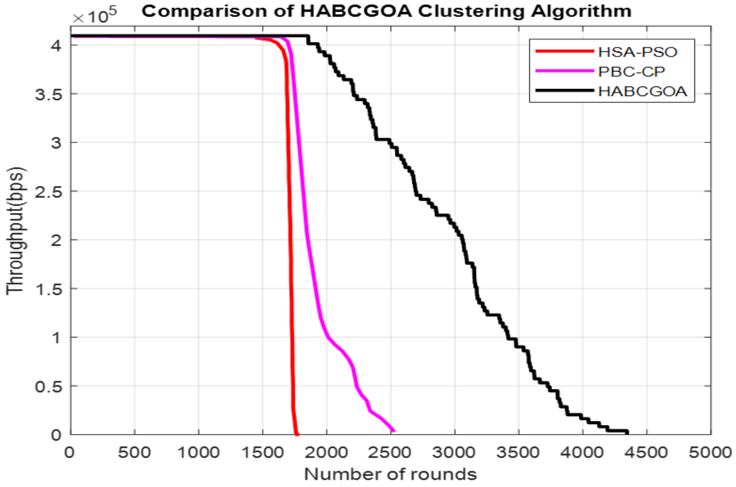

Fig 5. Comparative graph for Throughput

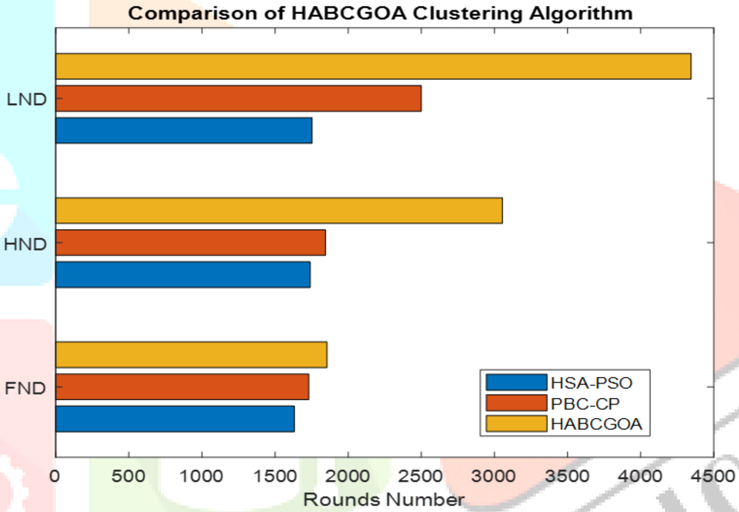

Fig 6. Comparative graph for lifetime evaluation

Additionally, we have examined and contrasted the effectiveness of the conventional HSA-PSO and PBC-CP approaches with that of the suggested HABCGOA model in terms of their throughput values. Fig 5. depicts the comparative chart that was created for the same. All models start out with large throughput values up to the 1500th round, however as soon as this happens, the typical HSA-PSO model's throughput rapidly drops until it reaches zero after 1750 rounds. Nevertheless, the standard PBC-CP model's throughput value has been slightly enhanced to 2500 rounds. On the contrary, under the suggested HABCGOA model, throughput is high until the 1800th round and then gradually declines as nodes exhaust themselves. The proposed HABCGOA model has a throughput value of 3×105 at the 2500th iteration, which is a very high figure.

Furthermore, we have examined and contrasted the effectiveness of the suggested HABCGOA model with that of the conventional HSA-PSO and PBC-CP models in terms of their lifetime evaluation metrics, such as FND, HND, and LND. Fig 6 shows the comparison graph that was produced for the same. In the HSA-PSO and PBC-CP models, it is noted that the values of FND are 1450 and 1642, respectively. Whereas FND in the suggested HABCGOA model has a value of 1855. The value of HND was also examined and determined to be 1710 and 1845 in the HSA-PSO and PBC-CP systems, respectively, and 3055 in the suggested HABCGOA model. Additionally, the value of LND, which was only 1760 in the conventional HSA-PSO model and 2500 in the conventional PBC-CP model, was examined. In contrast, the value of LND in the suggested HABCGOA model was 4345, which signifies that network lifespan is improved by up to 2490 and 1290 rounds than traditional HSA-PSO and PBC-CP models respectively. The specific values of lifetime evaluating parameters is recorded in tabular form and is shown in table 3.

Table 3 Specific Values for Lifetime Evaluation Parameters

Technique	**FND**	**HND**	**LND**
HSA-PSO	1450	1710	1760
PBC-CP	1642	1845	2500
HABCGOA	1855	3055	4345

From the above graphs and tables, it is observed that the proposed HABCGOA model is outperforming traditional HSA-PSO and PBC-CP models in terms of all parameters and hence is extending network lifespan significantly.

V. CONCLUSION

This paper presents an efficient WSN technique wherein two optimization algorithms i.e. ABC and GOA are hybridized. The usefulness of the proposed HABCGOA model is examined in MATLAB Software. Moreover, the simulating outcomes were also obtained and compared with traditional HSA-PSO and PBC-CP models in terms of FND, HND, LND, throughput, residual energy, dead and alive nodes respectively. The nodes in the conventional HSA-PSO and PBC-CP systems were still functional after 1450 and 1642 simulation iterations, respectively, according to the findings analysis. In contrast, all nodes in the suggested HABCGOA system were functional and alive up until 1855 cycles. A similar analysis of their HND (Half node death) values, that were determined to be 1710 in the HSA-PSO and 1845 in the PBC-CP models, validates the effectiveness of the suggested model. Nevertheless, the suggested HABCGOA paradigm has an HND value of 3055, that indicates that it has more cycles than the standard HSA-PSO and PBC-CP models by about 1345 and 1210 rounds, respectively. Additionally, the value of LND in the developed framework was around 4345 rounds, whereas it was only 1855 and 3055 rounds in the traditional HSA-PSO and PBC-CP systems. This indicates that the suggested HABCGOA model extends the network's longevity by about 2490 rounds compared to HSA-PSO and 1290 rounds compared to PBC-CP models. Furthermore, it has been noted that in terms of throughput and residual energy, the suggested HABCGOA model outperforms conventional HSA-PSO and PBC-CP models.

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