# Energy Efficient Multi-hop routing scheme using Taylor based Gravitational Search Algorithm in Wireless Sensor Networks

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***Abstract*** *– A group of small sensors can participate in the wireless network infrastructure and make appropriate transmission and communication sensor networks. There are numerous uses for drones, including military, medical, agricultural, and atmospheric monitoring. The power sources available to nodes in WSNs are restricted. Furthermore, because of this, a diverse method of energy availability is required, primarily for communication over a vast distance, for which Multi-Hop (MH) systems are used. Obtaining the optimum routing path between nodes is still a significant problem, even when multi-hop systems reduce the cost of energy needed by every node along the way. As a result, the number of transmissions must be kept to a minimum to provide effective routing and extend the system's lifetime. To solve the energy problem in WSN, Taylor based Gravitational Search Algorithm (TBGSA) is proposed, which combines the Taylor series with a Gravitational search algorithm to discover the best hops for multi-hop routing. Initially, the sensor nodes are categorised as groups or clusters and the maximum capable node can access the cluster head the next action is switching between multiple nodes via a multi-hop manner. Initially, the best (CH) Cluster Head is chosen using the Artificial Bee Colony (ABC) algorithm, and then the data is transmitted utilizing multi-hop routing. The comparison result shows out the extension of networks longevity of the proposed method with the existing EBMRS, MOGA, and DMEERP methods. The network lifetime of the proposed method increased by 13.2%, 21.9% and 29.2% better than DMEERP, MOGA, and EBMRS respectively.*

***Keywords***: *ABC algorithm, Energy efficiency, Multihop routing, WSN, Taylor series*

## 1. INTRODUCTION

WSNs offer a wide range of uses, including disaster management, environmental control, and surveillance. They are most commonly utilized in regions where humans cannot access them. A WSN [1] is a group of several small nodes linked wirelessly for smooth transmission. These sensors' processing capacity, memory, energy, and data communication range are all constrained. Furthermore, these sensor nodes often send data via wireless radio transmission [2]. The sensors achieve their goal of autonomous event detection and data collection. A WSN's backbone is made up of low-cost sensors. A multi-hop short-distance route may be a more energy-efficient method for transmitting a message than a single-hop long-distance route [3]. The lifetime of a WSN is one of the most critical elements in determining its efficacy.

The lifespan of a network can be effectively extended by balancing the node's energy usage and enhancing energy efficacy [4]. The CH is the vital node in the clustering protocol, and it is in charge of gathering the data experienced by the node members and relaying it to the sink node. Node members only have to interact with their cluster leaders over a small distance, saving energy [5,6]. There are various options for connecting the CH to the base station, including sending data directly to the base station (BS) or using additional nodes as a next-hop. [7].

Clustering protocols strive to identify the best CH set and interchange the function of CH across all nodes to balance the node's energy consumption. Metaheuristic and heuristic algorithms are commonly utilized in optimal CH selection as efficient techniques to obtain workable solutions with variable degrees of success. The ABC algorithm is an intelligent swarm technique based on metaheuristics stimulated by bees' natural honey-gathering behavior [8,9]. In contrast to other forms of swarm intelligence, the ABC algorithm may obtain good optimization results by balancing local exploration and global development. It has a small No. of parameters and is simple to implement simultaneously.

In the hierarchical clustering technique, the secure transmission phase is the last phase of each round. The node members communicate data that has been perceived to the associated CH in this phase, and the CH subsequently transmits the acquired data to the BS [10, 11]. There is a narrow gap between node members and their CHs, and intra-cluster communication is achieved with a single hop. The distance between the CHs and the BS, on the other hand, is usually quite large. If only a single hop is used for communication, the cluster heads' unnecessary energy consumption will be exacerbated [12, 13]. Therefore, hierarchical clustering protocols often necessitate a routing algorithm to determine the optimum path amongst each CH and the BS, data can be transmitted to it. When the CH is far away from the BS, it can avoid consuming too much energy. Multi-hop routing [14] aids network routing over the range of communication, and the energy factor governs that. The latency has been reduced, but the consumption of energy is immense. Thus, the routing must conserve energy. As a result, academics are working on an energy-aware routing strategy.

The major contribution of this paper are as follows:

- The main objective of this research project is to use hybrid optimization techniques to create a WSN multi-hop routing protocol with less energy consumption.
- For CH selection, an innovative and energy-efficient ABC algorithm is used.
- An energy-efficient routing method that relies on the Taylor-based Gravitational search algorithm is proposed to identify the best path from each cluster head and base station.
- The proposed strategy can successfully lower network energy consumption, increase throughput, and lengthen network lifetime, according to simulation results.

The remaining paper is ordered in a resulting manner. The concepts of various multipath routing protocols are discussed in Section 2, and the assumptions underlying the System model are presented in Section 3. The proposed TBGSA's many phases are discussed in Section 4. Section 5 examines the suggested method's performance and compares it to existing protocols. Finally, Sect. 6 brings the paper to a conclusion.

## 2. RELATED WORK

A Secure Energy-Aware Routing (SEAR) technique was proposed by Singh et al. [15]. SEAR discovered malicious nodes based on trust evaluation. For this routing, a multi-factor technique was evaluated, including node trust value, hop length, and residual energy. Using trust nodes, SEAR managed the network's energy consumption and data transmission. The protocol is not designed to be scalable.

In [16] author presented an Energy-Efficient Routing Protocol (EERP) for WSN, named an A-star algorithm. This routing approach increased network lifetime via passing data packets along the shortest route. According to the next-hop sensor node's highest remaining energy, buffer occupancy, a high level of connection quality, and a minimal number of hops, the optimum path was identified. However, when a network is enormous, its performance decreases.

In [17] author proposed an energy-saving routing strategy that included clustering and sink mobility. The entire sensor field was first divided into sectors, with each sector electing a CH depending on the weight of its members. To determine the optimal scenario, node members calculated the energy consumption of several routing paths. The most significant disadvantage is that the MS location must be transmitted regularly via sensors, which may increase the network load.

In [18] author presented a multi-hop routing protocol for data routing in wireless sensor networks. The high overhead was reduced by designing a green routing protocol. The lifespan of the network can be greatly extended and its overhead decreased by using an energy-efficient protocol. Utilizing relay nodes, inter-cluster broadcasts were used in this approach to distributing accumulated cluster data. As a result, the WSN's scalability was increased, and the employment of relay nodes had a favorable influence while dissolving energy in the WSN. This strategy did not perform well with massive networks.

In [19] author presented the Balanced and Energy Efficient Multi-Hop (BEEMH) algorithm for multi-hop routing in WSN. The Dijkstra algorithm was used to create this approach. This method sparked much interest in the residual energy of nodes. Thus, the transmitter and receiver nodes were chosen among the nodes with the highest energy. The method offered a useful framework for maximizing the choice of cluster heads based on several criteria, including location and energy. Low performance was the result since the technique did not optimize the grid regions and affected the nodes' dependability of connection.

In [20] author presented an energy-aware routing scheme to conserve the energy of networks. Initial energy, total network energy, and residual energy were all considered. Nodes closer to the base station were precluded from creating a cluster and were segregated.

Throughout the data transmission process, by comparing and evaluating different metrics, the energy usage of a single-hop route was compared to a multi-hop route. Mostly the approach that conserved the least quantity of energy was chosen. The network's longevity was prolonged while the cost of communication was cut.

In [21] author presented a new multicast routing technique that reduces time while increasing packet delivery ratio and bandwidth. Nodes were established in the network environment using multi-hop pathways to efficiently forward packets without incurring an additional loss. The most critical parameters are the bandwidth and multi-hop distance between CH and cluster members. Multi-path transmission removed collisions and false detections via Clear to Send (CTS) and Request to Send (RTS) mechanisms. The pathways were stabilized to reduce crashes.

In [22] author presented an Energy Balanced Multi-hop Routing Scheme (EBMRS) to find the best path to the BS, while increasing energy efficiency at the inter and intra-clustering levels equally. It chooses the essential no of sensor nodes as CHs depending on PS parameters such as residual energy, n.o of hops, and BS's distance. In respect of network throughput and transmission delay, it improves WSN performance. The protocol is not designed to scale.

In [23] author introduced a CS-based system that uses Multiple Objective Genetic Algorithms (MOGA) to optimize the number of measurements, the sensing matrix, and the transmission range in order to transfer data efficiently between WSNs. The program seeks to achieve the best possible energy efficacy and precision balance. It creates a multi-hop path depending on the optimum values. The simulation findings showed that, while MOGA improves network coverage quality, it also efficiently decreases the depletion of node energy, effectively extending the network's life cycle.

In [24] author presented a multipath routing protocol that is QoS sensitive and uses a hybrid particle swarm optimization-cuckoo search technique to cluster sensor nodes. The protocol then chose multiple trustworthy paths for data transfer based on multi-hop communication using the Cluster Heads (optimal network routing). In contrast to standard protocols, it relies on fast data transit over channels that do not affect QoS (Quality of Service). In contrast to conventional QoS Centric protocols, it also extended the network lifetime by switching CHs regularly depending on residual energy and using the optimal channels for data transmission.

In [25] author presented a Multi-hop Energy Efficient Routing Protocol (DMEERP). It is divided into three pieces. Each record of the CH and members of the cluster were held and maintained by the Super Cluster Head (SCH). If the present CH fails, the activation node and weight factor are approximated to get a new CH. The path reliability ratio is calculated to route packets swiftly while minimizing packet loss. The energy model is founded on the capacity of the channel concept. DMEERP delivered a high data delivery ratio, low overhead, the ratio of the path reliability, minor delay, extended network longevity, and low consumption of energy, according to simulation results. The computational time of this method was high.

Recent techniques have shown that sink mobility in a regulated path can improve energy efficiency in WSNs, but the path limits make routing more difficult. As a result, the sink with a set speed takes less time to collect data through sensor nodes that are randomly placed. This constraint has severe implications for improving data collection and reducing energy consumption. Furthermore, these research limits influenced the development of WSN's design proficient path optimization technique.

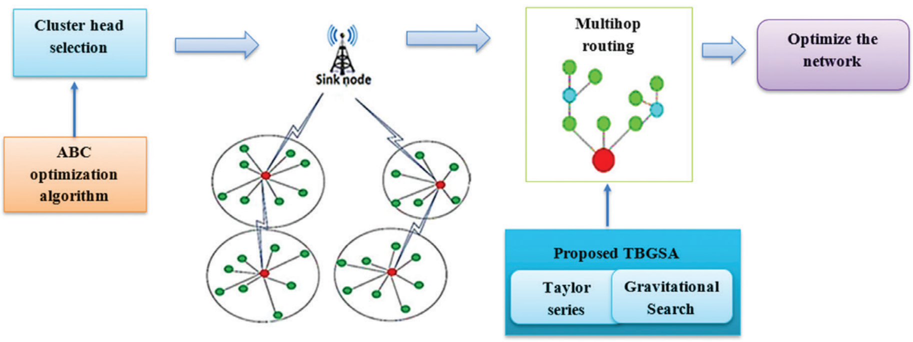


**Fig. 1.** Framework of TBGSA Model

## 3. SYSTEM MODEL

The sensor nodes are designated as $\{a_1, a_2 \ldots a_N\}$ in the network topology. In a WSN, nodes are arbitrarily distributed in an area $x\ M\ m^2$. $M = 100$ and $N = 100$ are used in this paper. All nodes have a limited radio range, and each has a sensor radius of d0 meters. Normal nodes, sink nodes (SN), and CH nodes are the three types of nodes found here. A clustering strategy is used in network communications, where a No. of nodes is chosen as CHs to gather data from ordinary nodes and transfer it to the SN. Fig. 1 shows an, e.g., of a WSN topology with 3 kinds of nodes. The SN is supposed to be in the middle of the area and have a limitless energy supply, whereas the sensor node's energy is inadequate in this paper. Positions of every node are considered to be static, & their beginning energy is equal. Furthermore, every node is GPS-enabled, and its locations are known every time.

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### 3.2. ENERGY MODEL

The energy required to send $E_{Ty}$ and receive $E_{Ry}$ of an m-bit message across a distance of $x$ is computed using equation (1) and equation (2).

$$E_{Ty}(m,x) = E_{el} * m + \varepsilon_{amp} * m * x^{i} \quad (1)$$

$$E_{Ry}(m,x) = E_{el} * m \quad (2)$$

Where $i = \begin{Bmatrix} 2, & if\ x < x_0 \\ 4, & else \end{Bmatrix}$ and $\varepsilon_{amp}$ is the amplified energy, $E_{el}$ is the required energy to operate the transmitting and receiving circuits, and the value of $x_0$ is computed as equation (3).

$$x_0 = \sqrt{\frac{\varepsilon_f}{\varepsilon_m}} \quad (3)$$

where $\varepsilon_m$ and $\varepsilon_f$ stand for multi-path amplification and free space energy, respectively. Furthermore, each nominated parent node expends energy $E_p$ to forward the m-bit long aggregated data of their '$n$' child nodes to its parent node, which is worked out as following equation (4).

$$E_p = n * m * E_{el} + n * E_a * m + m * E_{Ty} \quad (4)$$

where $E_a$ is the amount of energy spent on data aggregation by each parent node. In addition, each path uses $E\ (Pa)\ energy$, which is computed as following equation (5).

$$E(Pa) = \sum_{i=1}^{p} E_{i,n_{p(i)}}\ (m_i, x_i) \quad (5)$$

where $n_{p(i)}$ is node i's next hop on path $P$, and $E_{i,n\_p(i)}$ is the energy between node i and node $n_{p(i)}$ .

### 3.3. PROBLEM STATEMENT

Many researchers in wireless sensor networks regard data transfer from one sensor node to another as a critical difficulty. Finding the shortest path improves data transmission speed and node consumption of energy, which is a crucial matter in wireless sensor networks. As a result, the main issue is to transport data utilizing the shortest path possible and a better routing system. Because the energy consumption of nodes varies depending on their functions and network placements, the routing protocol must be capable of balancing the energy consumption of the nodes. The distances between nodes and base stations are typically large in a WSN. Data transmission over a vast distance will devour a significant amount of energy. The routing protocol must reduce the amount of energy used by nodes transmitting data to the base station. How to effectively form many network nodes to decrease node energy indulgence, keep node energy consumption in check, and decrease the energy dissolution of data transmission from sensor nodes to the BS. These are all issues that must be discussed in implementing an energy-efficient routing protocol for WSNs. This research work is to use a hybrid optimization approach to design an energy-aware multi-hop routing protocol for a wireless sensor network.

## 4. TAYLOR SERIES BASED GRAVITATIONAL SEARCH ALGORITHM (TBGSA)

The primary goal of this research work is to use optimization in a hybrid way to design a WSN multi-hop routing protocol with less energy consumption. Two actions are performed in this work: selecting the CH and multi-hop routing. For the selection of CH, the best CH is selected using the ABC algorithm [5], and then the data is transmitted utilizing multi-hop routing. Therefore, the optimal hop for broadcasting data begins with the optimal placement of hops, which is accomplished by the suggested Taylor-based Gravitational search algorithm.

### 4.1. CH SELECTION USING THE ABC ALGORITHM

The ABC algorithm is a swarm-based AI algorithm that stimulates honey bees' smart searching activity. The artificial colony of the bees of the ABC algorithm has 3 types of bees: onlookers, scouts, and worker bees, each of which denotes a location in the searching pane. The honeybees fly in the searching panel depending on the 'n' dimensions if the WSN comprises n' CH sensors. The ABC uses the bee population to locate the CHs. In the area for dance, an onlooker is a bee that stays there and chooses a food source, whereas an employed bee travels to the source of food that it previously visited. The scout is a bee that is responsible for our random search. The presence of food suggests that there may be a solution to the optimization process. The quality (fitness) of the related solution is proportional to the amount of honey in the food supply.

Worker bees would be in the first part of the colony in this algorithm, whereas spectator bees are in the second quarter. The first placements for food sources are generated at random, all employed bees are assigned to a specific source of food. Every employed bee finds a new nearby source of food from the previously related source of food, and the amount of nectar from the new source of food is calculated for each round, using equation (6).

$$S_{ij} = C_{ij} + \theta(C_{ij} - C_{kj}) \quad (6)$$

where the random number is denoted as θ∈ [1, 1], the candidate solution is denoted as $S_i$, the present solution is denoted as $C_i$, and $C_k$ is a neighbor solution, and $j$ ∈{1, 2,..., $d$} is an index picked at random, and the letter d denotes the solution vector's dimension. When all of the employed bees & onlooker bees have completed the search procedure, they share data about their food sources. The onlooker bee analyses information about nectar from all employed bees. It then selects a food sourced using the roulette wheel selection approach, based on a probability connected to its amount of nectar by equation (7), which gives the best candidates a higher chance of being chosen.

$$p_i = \frac{fi_i}{\sum_{n=1}^{A} fi_n} \quad (7)$$

where $fi_i$ is the fitness value of solution $i$, and $A$ is the No. of sources of food corresponding to the employed bees.

When all food sources have been chosen, each onlooker creates a new nearby source of food is chosen, and the amount of nectar is determined. If nectar levels are higher, the bee does not memorize the old location and does not remember the new one; otherwise, it keeps it. Both employed and onlooker bees use the same food source. The employed bee is transformed into a scout. As abandoned the food supply is allotted, the employed bee of that source seems to be a scout, and any location cannot be improved by more than a specific number of cycles, known as the limit parameter. The scout, mentioned in equation (8), produces a new solution in that position at random, where the abandoned source is denoted by $C_i$ in addition to $j \in \{1, 2,..., d\}$.

$$C_i^j = C_{min}^j + Rand(0,1)(C_{max}^j - C_{min}^j) \quad (8)$$

During the cluster setup stage, the ABC is utilized to select the CHs depending on the dependability of clusters being reduced to improve the network's longevity and period of stability. The work begins, and many clusters emerge around the base station considered a base station. The suggested work selects the nodes by taking into account their distance from the BS and their alignment with the numerous CHs. When the base detects a node with sufficient energy, it transmits the resultant data to the remaining no of nodes. The network's quality is calculated using a fitness function. The fitness function is derived using equation (9).

$$f = \sum_i \alpha(w_i, f_i) \forall f_i \in \{N_H, \lambda_o, E_{Rq}\} \quad (9)$$

where $N_H$ denotes the n.o of hops to the sink, and $\lambda_o$ denotes the total amount of traffic transmitted. $E_{Rq}$ is the required energy.

$$\lambda_o^i = \lambda_1^i + \lambda_g^i \quad (10)$$

In the above equation (10), the number of random nodes that make up one cluster represents the size of the hired hive. The fitness function $f_{im}$ is used to assess the nectar (network) quality using equation (11).

$$fi_m = \left\{ \begin{matrix} \frac{1}{1+f_m(x_m)} & , f_m(x_m) > 0 \\ 1 + |f_m(x_m)| & , \quad f_m(x_m) < 0 \end{matrix} \right\} \quad (11)$$

ABC, which follows the natural evolution process, assesses an individual's fitness. The ABC uses a search technique in which an arbitrary option guides the search depending on a parameter approach. Algorithm 1 discusses [26] how CHs are selected using the ABC algorithm. The management information system [6] includes significant elements related to ethics and information security [3-5], as well as computer security and computer ethics.

**Algorithm 1. CH Selection using ABC**

For each CH 'h' do

For all node 'j' do

Broadcast "hello" message

Obtain degree

e= {(p.s)⊂ S/D (p, s)≤R}

deg(p)=|e|

obtain consumed energy 0.05j<E(j)/E_0≤0.5j

calculate the distance to BS

$$p = \sqrt{(x - x_{bs})^2 + (y - y_{bs})^2}$$

calculate weight

wt=1/(Deg(wt)+0.05<E(wt)/E_0 ≤0.5j+p/max)-dist

end

if wt==min_wt(wt) then

state=h

broadcast" CH accepted"

else

state(wt)=on

end

end

### 4.2. PROPOSED TBGSA

WSN's multi-hop routing has improved communication across the network. For efficient data transmission, multi-hop routing is commonly used. However, with multi-hop routing, energy is the most significant barrier. As a result, the proposed Taylor-based gravitational search algorithm uses multi-hop routing to resolve energy issues. To reduce transmission energy, each cluster source node distributes its data to its neighbor node. The suggested TBGSA calculates the best hops for WSN routing progression using a newly created fitness function. Predicting the linear element of the equation is done by using the Taylor series to characterize previously recorded data. The Taylor series has the benefit of being a simpler and easier way to compute solutions, even in the presence of complex functions. The Taylor series provides a number of benefits, including straightforward convergence and reliable assessment of mutual functions.

The communication paths between clusters and the SN are set during this stage taking the chosen CHs into account. Each cluster's CHs are regarded as particles in a gravitational search algorithm. Due to gravitational search, the particles in the packet are balanced at each stage of transmission. It discards those of poor quality while other particles are chosen as suitable solutions. Based on the objectives, the selected particles' weight is established. According to the proposed approach, TBGSA determines whether the route between the sensor nodes and sink nodes, which call for information transmission, decreases energy consumption and ETE delay while increasing data delivery speed and network throughput. The ideal routes improve even one of these criteria, whereas the abandoned routes are those that deteriorate even one of these measures. As a result, the suggested TBGSA's fitness function is given in equation (12).

$$f_{gr} = \min\left(\sum_{i=1}^{n}\sum_{j=1}^{n} de_{i,j} + \sum_{i=1}^{n} E_{co} - \sum_{i=1}^{n} dd - \sum_{i=1}^{n} tput\right)$$

Where, $\sum_{i=1}^{n}\sum_{j=1}^{n} de_{i,j} > 0, \sum_{i=1}^{n} E_{co} < E_{in}, \sum_{i=1}^{n} dd > 0, \sum_{i=1}^{n} tput > 0$ (12)

where $f_{gr}$ is the fitness function of TBGSA, $de_{i,j}$ is the network's ETE delay, $E_{co}$ is the network's total consumption of energy, $E_{in}$ is the network's beginning energy, dd denotes the delivery rate of data at every node, and tput denotes the throughput of the network. Every population with a minimal fitness value can be chosen as a feasible information transmission solution based on the fitness function. The proposed TBGSA workflow shows in Fig. 2.

**Algorithm 2. TBGSA for optimal route selection**

Input: Nodes (N=N1, N2, ...Nn)

Output: Optimal route (R)

Start

Initialise the random number of nodes

{Ni==N1, N2, ...Nn}

for (i=1,2,...n iterations)

{

Clustering and cluster head using ABC

Transmit data to optimal CHs

Calculate G

$G(r)=G_0 e^{(-\frac{\beta r}{T})}$

Update the Route

if G(r)=R

{

Route identified by TBGSA

Choose optimal route

}

Else

Discard solution

}

End

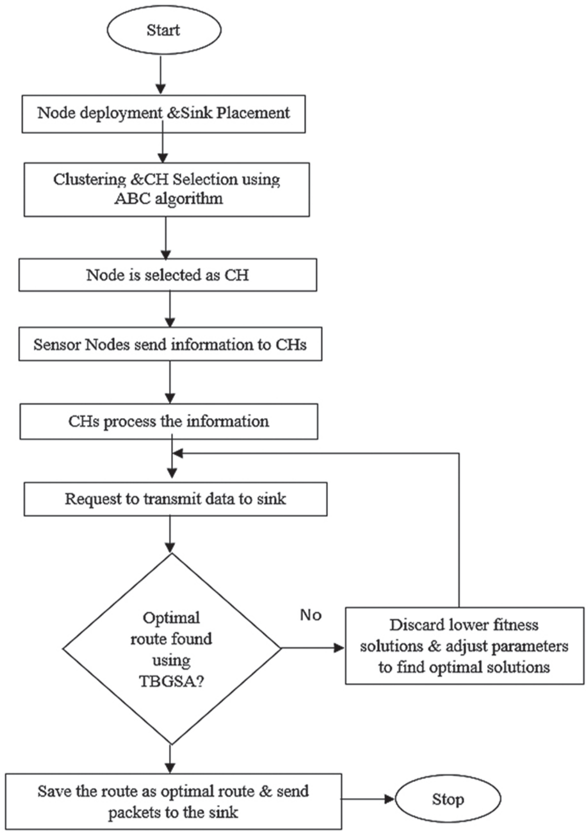


**Fig. 2.** Flowchart for Proposed TBGSA

## 5. RESULTS AND DISCUSSION

The WSN must first be configured using conventional parameters to use the proposed method. The suggested network is put into action in a real-world setting. MATLAB 2021a is used to implement this situation.

**Table 1**. Initial Parameters

| Parameters | value |
|---|---|
| Dimension of the network | 100 x 100 m |
| No of nodes | 100 |
| Initial node energy | 0.5J |
| Consumption of energy for transmitting data | 5 x$10^8$ J |
| Consumption of energy for receiving data | 5 x $10^8$ J |
| Consumption of energy for routing packet transmission | 1 x $10^{10}$ J |
| Consumption of energy for routing packet reception | 13 x$10^{13}$ J |
| Consumption of energy for aggregation of data | 5 x $10^9$ J |
| Maximum n.o of iterations | 3500 rounds |
| Length of the data packet | 4000 bits |
| N.o of transmissions at each hop | 10 |
| Packet length for routing | 100 bits |
| Radio range | 5000 m |

The WSN is simulated using the primary parameters, as indicated in Table 1 and Fig. 3. The WSN is made up of 100 nodes which are dispersed throughout the n/w at random. The SN is located near the heart of the network, making it easy to reach it.

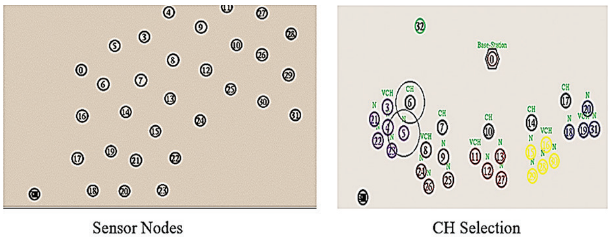


**Fig. 3.** Sensor Nodes and CH Selection

Equation 9 describes the fitness function, TBGSA evaluates a route's quality, and the routes that better the n/w goals are responded with their fitness value. Fig. 4 depicts the TBGSA's convergence to the optimal point. Because the fitness function used is a minimization function, the TBGSA decreases the value of the objective function at every step to converge to the ideal point, as shown in Fig. 4.

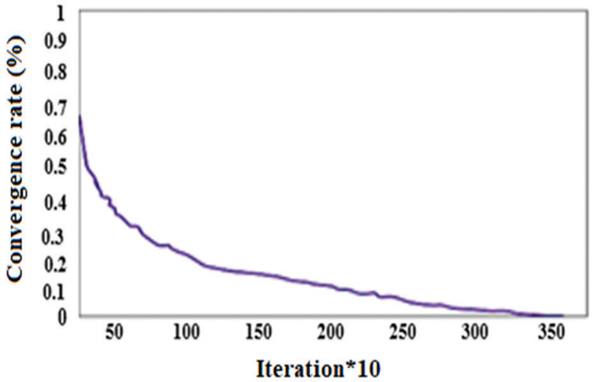


**Fig. 4.** TBGSA's Convergence to the Optimal Point

The effectiveness of a proposed approach is evaluated in order to raise performance in relation to the main issue. The literature, which is introduced in light of the study goals listed in the first section, offers a number of metrics for evaluating WSNs. Energy consumption, number of dead nodes, number of missed packets, End-to-End (ETE) delay, data delivery rate, & network throughput are all analyzed for the proposed technique.

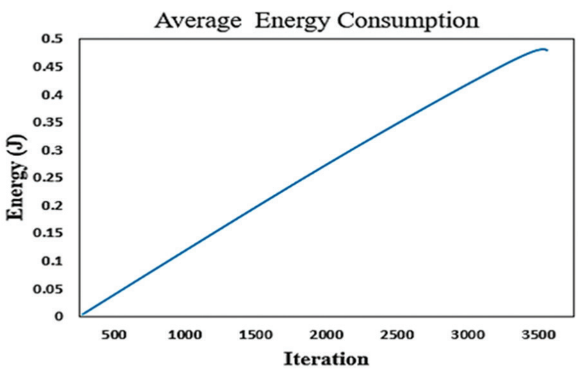


**Fig. 5.** Average Energy Consumption

The slope of energy used in the nodes is linear, as illustrated in Fig. 5, showing that the usage of energy used for all the nodes in the network during various iterations. As a result, specific nodes may not run out of energy before others, and at around the same time, all nodes run out of energy. As a result, all nodes progressively lose energy, showing that the network has a lengthy lifespan.

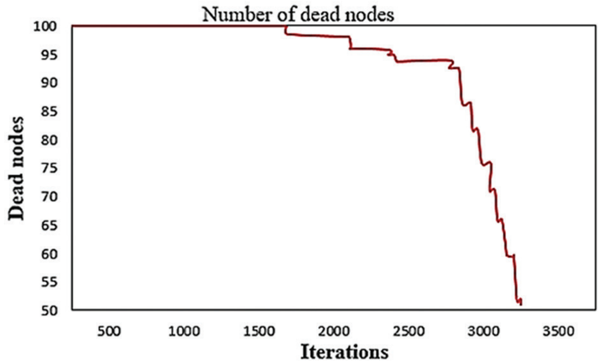


**Fig. 6.** Dead Nodes in the Network

Fig. 6 depicts the mortality procedure for sensor 500 nodes in the network. An alternate channel for information transmission may be established if a node fails, but the data from that area cannot be gathered. If the death of a node does not disrupt the network, it can be managed. It happened with the suggested technique in the 3020th iteration when nearly most of the nodes ran out of energy & the network was disrupted. This enhancement is because when CH selection is optimized under various characteristics, TBGSA achieves more remarkable energy preservation than other methods.

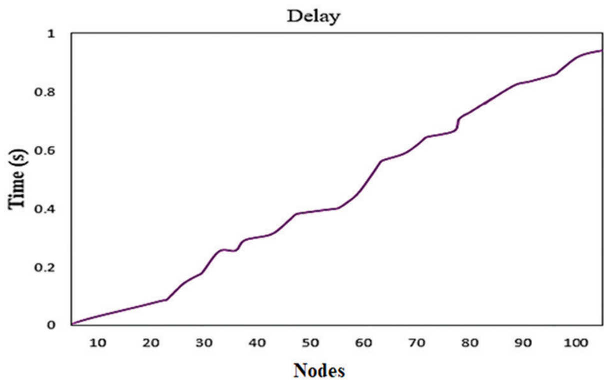


**Fig. 7.** ETE Delay of 100 Nodes

The network nodes' end-to-end (ETE) delay is the final metric to be assessed. The distance among the nodes is the primary cause of the ETE delay in transmission because the transmission time factor of a packet is static for the nodes. Because information is exchanged among nodes & the CH in the proposed method, the smaller mean intra-cluster distance and a shorter distance among the Cluster head and other nodes show accuracy in clustering, one of TBGSA's goals. Fig. 7 shows that the suggested technique has a 100 ms latency for hundred nodes & 3500 transmission iterations, proving a proposed method's high accuracy in clustering.

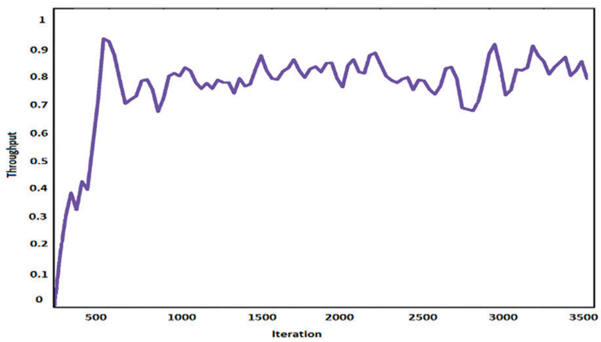


**Fig. 8.** Throughput of the Network

The throughput is calculated as the BW of the communication medium divided by the number of packets transferred per unit time. The network throughput increased in increasing order, reaching 100% at the end, as shown in Figure 8.

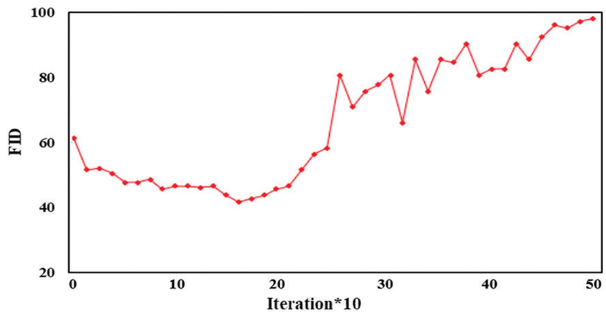


**Fig. 9.** Frechet Inception Distance

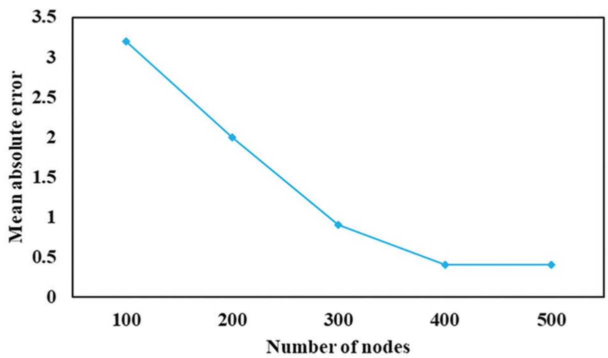


**Fig. 10.** Mean absolute error

Finally, we observe that the simulation results are most closely mateched with the analystical results for all distribition as the number of node increases. Acoording to the figure 9 FID improves up to 19k iterations. Figure 10 shows the results obtained for Mean absolute error. Mean absolute error (MAE) is a measure of errors between paired observations expressing the number of nodes.

### 5.2. COMPARISON WITH EXISTING METHODS

The effectiveness of the suggested strategies was demonstrated by comparing their performance to that of the current strategy. Performance is assessed using the following metrics: throughput, packet delivery rate, end-to-end delay, network lifetime, and energy efficiency. In a comparative study, the suggested model is compared against three existing approaches.

**Table 2.** Comparison of Energy Consumption

| Parameters | N.o of nodes | EBMRS | MOGA | DMEERP | TBGSA (proposed) |
|---|---|---|---|---|---|
| Energy Consumption (mJ) | 100 | 80 | 50 | 30 | 20 |
| | 200 | 110 | 75 | 55 | 46 |
| | 300 | 150 | 85 | 65 | 58 |
| | 400 | 165 | 120 | 80 | 76 |
| | 500 | 180 | 150 | 95 | 82 |

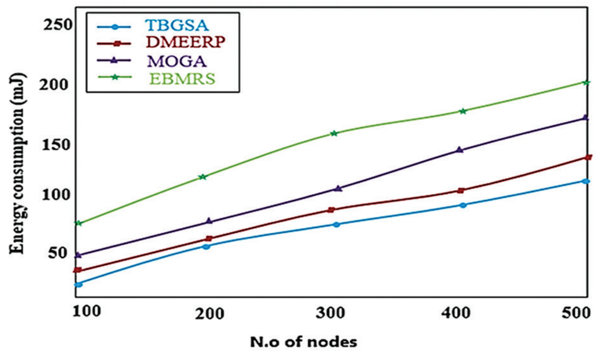


**Fig. 11.** Comparison of Energy Consumed

Concerning the average energy consumption, Fig. 11 compares the suggested method to existing methods. As a result, compared to all existing methods, the proposed TBGSA model has achieved the lowest energy use. The TBGSA model reduces the energy required to transfer data within the cluster. Because of the random selection of CH, EBMRS achieves a bad performance. These are some reasons why maximal energy dissipation is preferred over other models. The TBGSA model, for example, has a lower energy expenditure of 75mJ when the maximum node count is 500. In contrast, the EBMRS, MOGA, and DMEERP models are indicated in Table 2. The findings of the aforementioned experiment show that the computational complexity is significantly decreased by the suggested TBGSA approach.

**Table 3.** Comparison of Data Delivery Rate

| Parameters | N.o of nodes | EBMRS | MOGA | DMEERP | TBGSA (proposed) |
|---|---|---|---|---|---|
| Data delivery rate (%) | 100 | 97 | 97.5 | 98 | 99.3 |
| | 200 | 96 | 97 | 97.5 | 99 |
| | 300 | 95.5 | 96.8 | 97 | 98.9 |
| | 400 | 94 | 96.4 | 97.3 | 98.6 |
| | 500 | 93.3 | 96 | 96.8 | 98.8 |

As illustrated in Fig. 12, the suggested method has a greater delivery ratio than the existing methods. When the network size is expanded, the no of packets in TBGSA is always more than that of existing methods, as can be shown. This outcome is explained because the TB-

GSA protocol has a longer lifetime than other models, resulting in a substantial increase in data transmission to the sink node. Furthermore, the TBGSA protocol can expand network longevity and is appropriate for large-scale networks. For example, the TBGSA framework has a maximum DDR of 98.8 % when the node value is 500, but in the EBMRS, MOGA, and DMEERP approaches as indicated in Table 3, the least PDR of 93 %, 96 %, and 96.8 %, respectively.

**Table 4.** Comparison of ETE Delay

| Parameters | N.o of nodes | EBMRS | MOGA | DMEERP | TBGSA (proposed) |
|---|---|---|---|---|---|
| End to End delay(s) | 100 | 4 | 2.8 | 2 | 2 |
| | 200 | 5 | 4.5 | 2.4 | 2.2 |
| | 300 | 6.3 | 5.8 | 3.2 | 2.4 |
| | 400 | 7.5 | 7.3 | 3.8 | 2.9 |
| | 500 | 9.2 | 8.3 | 5.1 | 3.2 |

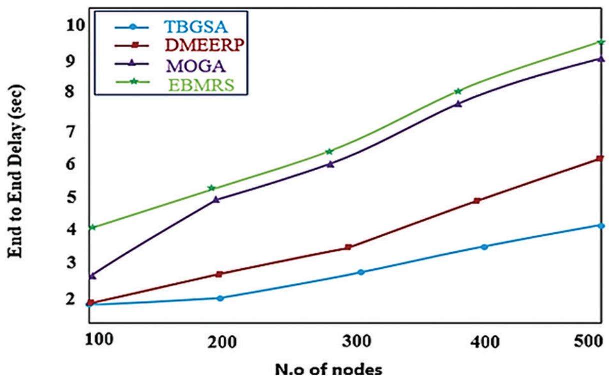


**Fig. 13.** End-to-End Delay

The ETE delay analysis of the TBGSA method is shown in Fig. 13 alongside a collection of prior approaches. E2E delay saves energy and ensures consistency. The E2E latency is calculated as the total time of data transmission, processing, and data delivery time. Minimum delay improves network reliability while also lowering energy consumption. For example, the TBGSA scheme achieved a minimum ETE delay of 3.2s under a higher node count of 500, the EBMRS, MOGA, and DMEERP frameworks as indicated in Table 4, achieved a maximum of 9.2s, 8.5s and 4.5s, respectively.

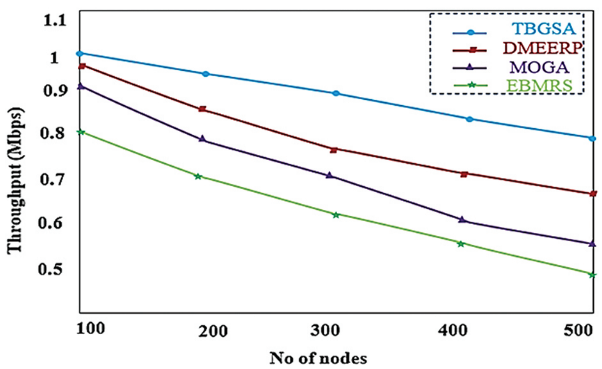


**Fig. 14.** Throughput

Fig. 14 compares the TBGSA model's throughput analysis to several earlier methodologies. The TBGSA method has shown qualified results with increased throughput. The TBGSA framework, for example, has reached a maximum throughput of 0.79Mbps with a node count of 500, whereas the EBMRS, MOGA, and DMEERP frameworks as indicated in Table 5, achieved low throughput of 0.65, 0.61, 0.53, 0.46, and 0.47 Mbps, respectively. As a result, data from cluster members cannot reach the base station, resulting in a sparse sensing field and limited network performance.

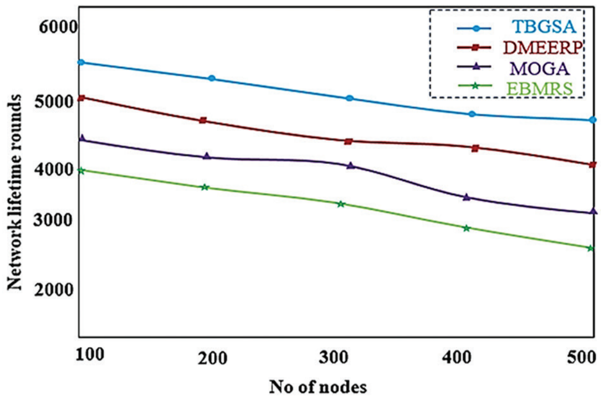


**Fig. 15.** Network Lifetime

Fig. 15 compares the TBGSA technique's network lifespan analysis to various existing approaches. The TBGSA model has shown superior outcomes with the highest network lifetime. The TBGSA, for example, has a longer network lifespan of 5300 rounds when the node count is 500. However, the EBMRS, MOGA, and DMEERP models have a minimum network lifetime of 3000, 4000, and 4600 rounds. The TBGSA concept aims to extend the network's longevity by boosting energy efficiency.

## 6. CONCLUSION

In this research present a low-energy multi-hop routing protocol that considers energy as a key factor in multi-hop routing. The technique went through two steps to achieve good multi-hop routing. The Cluster Head selection is done first, followed by the transmission of data. When selecting the CH, the best node is chosen as CH based on the ABC algorithm. Subsequently, data is communicated from one node to another utilizing various hops ideally chosen using the suggested Taylor GSA-based multiobjective fitness function. The improvement in extending the network's longevity was verified by making a comparison with the suggested technique to the findings of cutting-edge research. These results of the research appear to be extremely useful in the development of an energy-efficient multi-hop wireless sensor network, and they open the way for the expansion of commonly used applications in these networks. In the future, efforts should be made to strengthen the protocol's security features.

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