International Journal of Computer Networks and Applications (IJCNA)
DOI: 10.22247/ijcna/2020/196041 Volume 7, Issue 4, July – August (2020)

**RESEARCH ARTICLE**

# Taylor Based Grey Wolf Optimization Algorithm (TGWOA) For Energy Aware Secure Routing Protocol

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Published online: 04 August 2020

**Abstract – Wireless Sensor Network (WSN) design to be efficient expects better energy optimization methods as nodes in WSN are operated only through batteries. In WSN, energy is a challenging one in the network during transmission of data. To overcome the energy issue in WSN, Taylor based Grey Wolf Optimization algorithm proposed, which is the integration of the Taylor series with Grey Wolf Optimization approach finding optimal hops to accomplish multi-hop routing. This paper shows the multiple objective-based approaches developed to achieve secure energy-aware multi-hop routing. Moreover, secure routing is to conserve energy efficiently during routing. The proposed method achieves 23.8% of energy, 75% of Packet Delivery Ratio, 35.8% of delay, 53.2% of network lifetime, and 84.8% of scalability**.

**Index Terms – Taylor Series, Grey Wolf Optimization, Multi-hop Routing, Energy Efficiency, Security.**

## 1. INTRODUCTION

Wireless Sensor Network (WSN) is a group of devices. Every device is a sensor node (SN) in the network as they installed in a sensing environment. These nodes collect the environment information which, is then transmitted to the Base Station (BS) or intermediate gateway directly through wireless links [1]. WSNs are involved in national border surveillance, environmental monitoring, health care, and predicting disasters. WSNs are like Wireless ad hoc networks by their relation with an automatic network structure and wireless connectivity such that wireless transmission of sensor data is performed [2].When the sensor nodes directly communicate with BS, communication overhead caused, which avoided when these sensor nodes form clusters. One node in every cluster is known as a cluster head (CH) which acts as an intermediate terminal to communicate between SNs and BS.CH gathers information from SNs of the same cluster and then transfers to BS.

WSN which adopts this process termed as cluster-based WSN [3].First sensor location is determined by dividing the network into closer multi-node clustering. After then, in every cluster, the cluster head is selected by employing a practical selection approach [4]. These cluster heads then transmit their data as well as the data of the sub-clusters to the destination sensor. As sensors have limitations in energy, environment monitoring by the sensor nodes is based on its lifetime, and the information obtained within the intermediate nodes transferred to the destination [5]. When the node has energy deficiency, it becomes difficult to transmit data over the network. Hence, to improve the node lifetime, clustering techniques are involved. Numerous clustering approaches developed for improving the energy of the WSN's as energy plays a significant role during data transmission in WSNs [6]. CH collects data from the other nodes and then transfers to BS, which completes until the network is alive. The network lifetime relates directly to the battery. Hence, the energy of the node has to be saved. CHs exhausts energy when receiving, aggregating and transmitting data. Thus, the node with higher energy is considered as CH since it is responsible for receiving and transmitting data. When CH exhausts quickly, then it will be disconnected from the network causing, event loss [7].

WSNs employed in several fields despite some limitations like low energy, limited battery capacity, communication and computation abilities. While designing WSN protocols, these issues are to be considered [8].Routing helps in transmitting the packets among SNs and BS of WSN via a wireless communication medium. The protocols designed for routing falls under two major categories namely single and multiple path routing protocols. Source nodes pass data packets through intermediate nodes to the sink node inside WSN. Packets distributed over multiple hops, depending on the energy capacity of the network [9] and the balance of load [10]. For routing to be efficient, routing protocols estimate the tradeoff between the network factors like delay, energy cost, and load balancing [11].

The routing protocols performs a momentous role in WSN because it helps to achieve low energy consumption, less latency and produces Quality of Service (QoS) with high throughput. For application-specific WSN, several protocols designed to overcome the limitations caused while transferring data packets which require the information of node location for further processing [12]. This location information helps to estimate the distance of two nodes as well as energy consumed. Multi-hop routing helps rout the network out of the energy-constrained communication range. At this juncture, the delay has been reduced with higher energy consumption and therefore routing protocols have to be designed to save energy as well [13].

This research work focuses on enhancing energy efficiency by using optimal CH selection which thereby increasing the network lifetime. The other sections in this paper are arranged as: Section 2 briefs the survey related to this research; section 3 explains the contributed method; section 4 presents the achieved results and finally concludes with section 5.

## 2. RELATED WORK

Shende, D. K et al., 2020 defeated the challenges by developing an energy-aware multicast routing protocol based on Crow Whale-ETR optimization which combined WOA and CSA based on the energy and trust factors [14]. Trust and energy were estimated to establish the routes which were selected chosen optimally with CWOA. This selected optimal route employed for data transmission. At the end of every transmission, trusts and energy of every node updated, such that selected secure nodes increases the secure communication over the network. The experiment conducted with 50 and 100 nodes with or without attacks resulting in the minimum delay and maximum energy throughput.

Sampathkumar A., 2020 designed an algorithm which was useful in load balancing along with routing called Glowworm swarm optimization algorithm (LBR-GSO) [15]. This approach integrated pseudo-random route discovery approach with enhanced pheromone trail-based updating method for dealing with energy consumption of nodes. Moreover, practical heuristic updating approach with cost-effective energy measure involved for the optimization of route establishment. Finally, LBR-GSO cast-off energy-based broadcasting algorithm reduced the energy consumption caused by control overhead. LBR-GSO were evaluated for various scenarios with measures like energy consumption, energy efficiency and improving network lifetime and achieved better results

Mohan R et al., 2018 used the whale optimization algorithm (WOA) to pick MANET's optimally secured routing [16].Trust factor and distance of nodes evaluated to measure the fitness of routing. After then, the k-disjoint path discovered followed by optimal path determination depending on the evaluated trust and distance measures. Energy, throughput, and packet delivery ratio (PDR) were the performance measures considered to evaluate WOA and achieved improved results.

Ch, Ram et al., 2018 designed a novel hybrid M-Lion Whale optimization model [17], which incorporated lion algorithm (LA) and whale optimization algorithm (WOA) to find the optimal path for secure routing in MANET. This multi-objective model evaluated with various quality of service (QoS) measures like distance, energy, lifetime, trust and delay. With these parameters, fitness function defined to select the best route. This proposed M-Lion Whale approach obtained maximum residual energy, throughput and PDR.

Kumar R et al., 2017 developed a novel exponential ant colony optimization (EACO) approach to discover routing in WSNs after selecting CHs utilizing fractional artificial bee colony (FABC) technique [18]. At first, CHs selected with fitness function by taking distance, delay and energy into account. Next, ACO approach modified with exponential smoothing model for discovering multi-path route. EACO discovered optimal routes for data transmission from any node to BS by considering multiple objectives like energy, distance, an inter-cluster and intra-cluster delay estimated with a modified fitness function.

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Rajeev Kumar et al., 2016 integrated ABC with ACO approach and introduced a novel hybrid ABC-ACO approach [19] which solved Nondeterministic Polynomial (NP) limitations of WSNs. The primary operations of this algorithm are selecting optimal number of sub-regions followed by selecting CH by ABC algorithm and then transmitting data efficiently with ACO approach. Hierarchical clustering method employed for transmitting data based on the threshold. Using ACO approach, CH discovered the best route to transmit data to BS. This method assisted in designing the structure of forest fire monitoring and detection. The results proved that this ABCACO method enhanced stability and throughput.

Kuila P et al., 2014 coined Linear/Nonlinear Programming (LP/NLP) and developed routing algorithms which integrated the principles of particle swarm optimization (PSO) approach and multi-objective fitness function [20]. Clustering approach focuses on conserving the node energy via load balancing. The experimental results proved the superiority of this approach by considering energy consumption, network lifetime (NL), dead sensor nodes and packet delivery.

Pachlor and Shrimankaret al., 2017 [21] developed a Base-station controlled dynamic clustering protocol (BCDCP) which was a centralized routing protocol where the energy dissipation was distributed evenly among all nodes thereby saving energy and improving network lifetime.

Srbinovska et al., 2019 [22] contribution stochastic optimization approach which used genetic algorithm for minimizing the energy consumption based on the frequency and duration of the transmission. This optimization technique tested in various scenarios which increased the transmission frequency.

Carolina Del-Valle-Soto et al., 2020 [23] designed an energy model to estimate the energy consumed by Multi-Parent Hierarchical (MPH) routing protocol and different extensively used network sensor routing protocols. Experiments carried out on a random layout topology with two collector nodes. Every node runs on various wireless technologies like Bluetooth, Zigbee, and LoRa through WiFi. This work achieved the objective of analyzing the performance of the energy model developed with the various routing protocols of different nature.

Trupti Mayee Behera et al., 2019 [24] concentrated on designing a method which efficiently selected CH and rotates the position of CH among the nodes with higher energy. Initial and residual energy along with the optimum value of CH considered choosing the subsequent CHs that works well for IoT applications.

## 3. PROPOSED TGWOA MODEL

The energy-aware, multi-objective secure routing protocol is newly developed with WSN optimization. The multi-hop routing achieved by implementing the proposed Taylor-based Grey Wolf Optimization algorithm (TGWOA) which integrated the Taylor series and Grey Wolf Optimization (GWO) methods. The proposed TGWOA with multiple objectives developed to achieve secure energy-aware multi-hop routing in WSN. Figure 1 represents the architecture of TGWOA method.

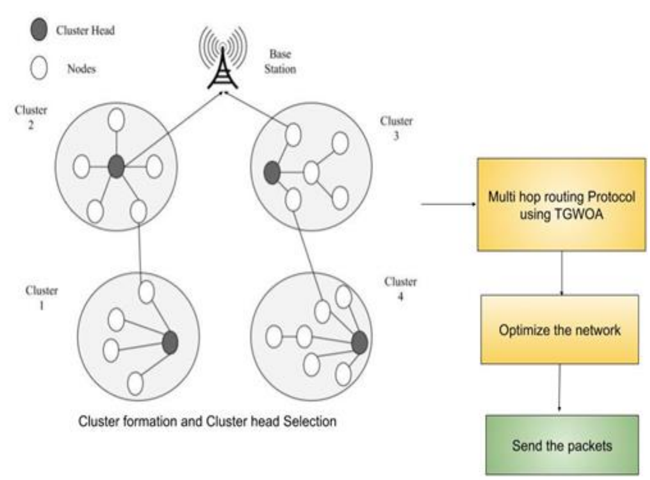


Figure 1: Architecture of the Proposed Model

Initially, the node discovered in the network, followed by cluster formation and selection of Cluster Head (CH).Then multi-hop routing is accomplished by using the proposed TGWOA. After that, the network evaluated by the metrics like energy, network lifetime (NL), packet delivery ratio (PDR), delay and scalability of the network.

### 3.1. Cluster Head Selection

Sensor nodes of the network are formed as clusters and the node having the highest energy efficiency (residual energy) in that cluster is termed as cluster head. The role of the CH is to manage all the remaining nodes of the cluster and to communicate with other CHs until the data has reached the sink node. CHs of the network periodically collect, aggregate, and transmit data to BS through optimal route. Moreover, also, all nodes in the cluster has an opportunity to be a CH thereby balancing the overall energy consumption over the network. So, a node with parameter (P) having the highest score than other nodes is qualified to be a CH. Thus, P is given by,

$$P = \frac{E_{current}}{E_{max}}$$

Where $E_{current}$ and $E_{max}$ represents the residual energy and total energy of a node when charged fully.

At every round node compromise detected, and such nodes prevented as a CH in the next round of CH selection, since these nodes cannot participate effectively in the network. Hence these compromising nodes are prevented from being a CH to optimize the network lifetime and increase the network performance.

Consider, a dense sensor network with nodes having equal energy. The task of the nodes is to transmit data to sink node [25]. For this, an optimal node called CH selected to collect and broadcast data. In cases where the sink is too far, CH consumes more energy to transmit data. As nodes distributed in the network, no control information from BS and global network information are not required. Location information of node is not necessary as the focus is on improving the network lifetime. MAC protocol considers a homogenous network of nodes to gather and transmit data to the sink node. As nodes consume enormous energy, energy is distributed evenly in the nodes to minimize the energy load. CH selection guarantees better data transmission and minimum energy consumption.

### 3.2. Proposed TGWOA

In WSN, multi-hop routing optimizes the network communication; hence utilized usually to transfer data effectively. Still, energy considered as a significant issue in multi-hop routing. Thus, to resolve this constraint, proposed TGWOA is developed for multi-hop routing where the data is transmitted from a source node to CH through intermediate nodes present in every cluster which minimizes the energy required for transmission.

In this proposed TGWOA, this achieved by deriving optimal hops with the help of revised multi-objective fitness function which processes the routing in WSN. Optimal hops are the selected CH with the ability to provide effective network routing by reducing information loss occurring during data transmission. Here, this proposed TGWOA determines the best path from the source node.

#### 3.2.1. Fitness Function with Multi-hop Routing

Fitness function is a maximization function which estimates the optimal solution with the set of parameters. Therefore, the solution which provides maximum fitness value considered for multi-hop routing. The Fitness function of TGWOA is given by,

$$F = W_1 \times NE + W_2 \times (1 - T) + W_3 \times (1 - D) + W_4 \times M$$

Where, W1, W2, W3, W4, represents the weights, NE refers the energy of the node, T represents the delay in transmission, D describes the distance of two hops, and M is the node-time.

The fitness function calculated to obtain the best solution for optimizing the network for which it utilizes the objectives like distance, delay, hop distance, network lifetime, and energy. The solution which provides the best fitness value is said to be optimal.

#### 3.2.2. Hop Distance

This is the total distance between two hops as given in the following equation. For multihop routing, hop distance must be minimal.

$$Hop\ distance = \frac{1}{p} \times \left( \frac{\sum_{k=1}^{b-1} X(N_n, N_{n+1})}{\beta} \right)$$

#### 3.2.3. Taylor Series

Taylor series states the historical values stored and predicts the linear part. The benefit id that this Taylor series is straightforward and the most natural approach for evaluating the solutions, even with complex functions by accurately estimating the standard functions and thereby achieves convergence more easily.

#### 3.2.4. Grey Wolf Optimization Algorithm (GWO)

GWO routing approach saves the node energy in the network. The three phases of this routing approach are wolf initialization, fitness estimation of every wolf and updating velocity as well as the position of wolves.

##### 3.2.4.1. Initialization of the Wolves

Representation of every solution by mapping one gateway to other gateway or base station BS. Solution size and the total gateways (M) are equal. Solutions in the network provide a route from every gateway to BS via subsequent gateways. Initialization of every gateway done with a random number (Xi,d) = Rand(0, 1) where 1 ≤ i≤ Ns, 1 ≤ d ≤ M. Ns denotes the number of initial solutions. Where d is the gateway number in the corresponding solution and this used to map the gateway gk with the next gateway in the route of BS from gd. Hence, this states that gd transmits data to gk. The route mapping given by the following indexing function returning the index of the $n^{th}$ gateway from SetNextG and n = Ceil(X(i,d) × |SetNextG(gd)|).

$$g_k = Index(SetNextG(g_d), n)$$

##### 3.2.4.2. Computation of Fitness for Every Wolf

Fitness function is employed to measure the quality of solution. It assists in updating α, β and δ solutions at every iteration. Here, the new fitness function is given to generate a route efficiently from every gateway to BS. Total distance (D) travelled by the gateways is given in the following equation

$$D = \sum_{i=1}^{m} dist(g_i, NextG(g_i))$$

Total gateway hops are evaluated by

$$H = \sum_{i=1}^{m} NextGCount(g_i)$$

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Minimum number of hops and minimum distance travelled considered while estimating the route. Hence, it provides a higher fitness value produces the best solution, and this clearly states that the parameters mentioned above inversely proportional to the fitness. The introduced fitness function is given as

$$Routing\ Fitness = \frac{K_1}{(w_1 * D + w_2 * H)}$$

Where (w1,w2) ϵ [0,1] such that, w1 + w2 = 1 and K1 denotes the proportionality constant. The overall distance, as well as whole hops efficiently balanced in the network.

3.2.4.3. Updating Position and Velocity of Wolves

Position of every wolf must be updated based on the positions of α, β and δ wolves in order to obtain the optimum solution. In GWO method, α wolf represents the global solution; β and δ wolves are the best solution from prior iteration and current iteration, respectively. Positions of ω wolf updated with the average of all the updated positions of α, β and δ wolves. By updating position, optimal solution obtained for the optimization problem. Now, updated positions may hold negative values or values>1 due to the algebraic addition and subtraction performed. Still, (Xi,d) is likely to be between 0 to 1. For avoiding negative values or values>1, positions selected using the following assumptions:

1. If (Xi,d≤ 0), then (Xi,d) = (n1 ≤ n2? (n1 ≤ n3? n1 :n3) : (n2 ≤ n3? n2 : n3)). n1, n2, and n3 are the numbers randomly selected to predict the positions of α, β and δ wolves respectively. (Xi,d) provides the minimal value among r1, r2, and r3.
2. If (Xi,d≥ 1), then (Xi,d) = 1.

After these now positions are assigned, every solution is determined again with the help of fitness function.

3.3. TGWOA Algorithm

The proposed Taylor based Grey Wolf Optimization Algorithm (TGWOA) is described in Algorithm 1.

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1: Initial hunt agents $G_i$are generated with I ranging from 1 to n

2: Factors of the vectors are initialized

3: Fitness value of every hunt agent is evaluated

Gα, Gβ and Gδ are the best, second best and next best hunt agents respectively

4: Iter=1

5: Do steps 6 to 10 until iter reaches maximum iterations (Terminating condition)

6: for i=1: Gs (pack size for grey wolf)

Location of the current hunt agent is renewed

End for

7: For all hunt agents, fitness value is evaluated

8: Gα, Gβ, Gδ are updated

9: Vectors factorsare updated

10: Iter=Iter+1

11: output Gα

12. End

---

Algorithm 1 Taylor based Grey Wolf Optimization Algorithm (TGWOA)

## 4. RESULTS AND DISCUSSIONS

The simulation carried out in NS2 platform, and the simulation parameters represented in Table 1. The performance analysis is carried out by the parameters, namely Energy, Network Lifetime (NL), Packet Delivery Ratio (PDR), Delay and scalability.

| Simulation Parameters | Values |
|---|---|
| Coverage area | 100m x 100m |
| Threshold distance | 70 meters |
| Number of nodes | 50 nodes |
| Packet size | 512 bytes |
| Node transmission range | 20 meters |
| Initial Energy | 2 Joules |

Table 1 Simulation Parameters

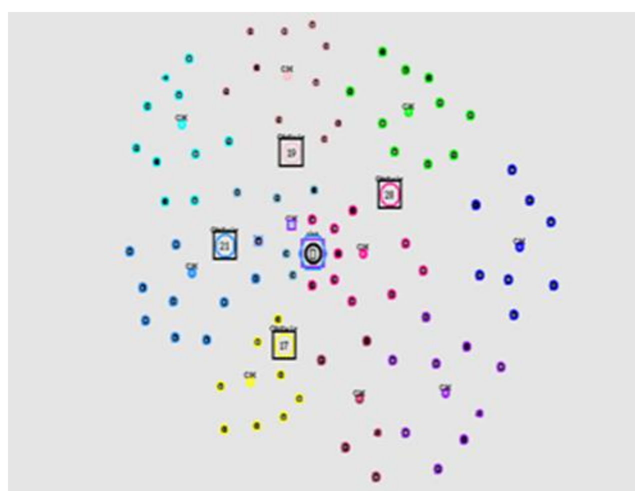

Figure 2 Cluster Formation and Cluster Head Selection by Proposed Method

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The Figure 2 illustrates the way the cluster is formed and the cluster head is selected in the network by the proposed TGWOA method. The center node of the cluster is the base station and the nodes transmit data among themselves. Nodes 17, 19, 21, and 29 are selected as cluster heads and the remaining nodes are the members of the cluster.

4.1. Energy

This is measured as the total energy of all hops and computed as:

$$Energy = \frac{1}{p}\sum_{n}^{p} E_n$$

Where p denotes the hops in multi-hop routing and $E_n$ is the energy of $n^{th}$ hop.

Table 2 presents the energy obtained with existing CWOA and Proposed TGWOA methods.

| No. of Nodes | Existing CWOA | Proposed TGWOA |
|---|---|---|
| 10 | 54 | 14 |
| 20 | 57 | 19 |
| 30 | 59 | 26 |
| 40 | 60 | 29 |
| 50 | 62 | 31 |

Table 2 Analysis of Energy

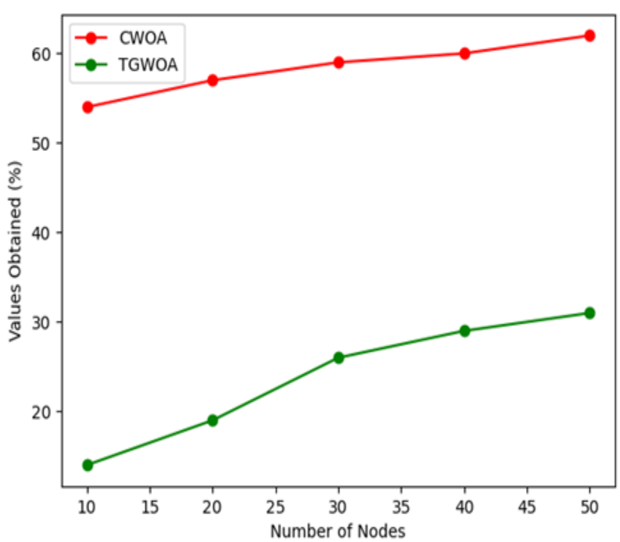


Figure 3 Comparison of Energy between Existing and Proposed Methods

Figure 3 depicts the energy comparison of existing CWOA and Proposed TGWOA methods. The X axis and Y axis shows that number of nodes and the values obtained in percentage respectively. The red and green color indicates existing CWOA and Proposed TGWOA methods, respectively. When compared to existing method, Energy consumed by the proposed method achieves 35%.

4.2. Packet Delivery Ratio (PDR)

The ratio of a packet transferred from the source node to the destination in the network successfully.

$$PDR = \frac{number\ of\ packet\ received\ succesfully}{Total\ number\ of\ packets\ forwarded}$$

The Table 3 presents the analysis of the PDR with existing CWOA and Proposed TGWOA methods.

| No. of Nodes | Existing CWOA | Proposed TGWOA |
|---|---|---|
| 10 | 46 | 57 |
| 20 | 53 | 69 |
| 30 | 62 | 78 |
| 40 | 74 | 82 |
| 50 | 81 | 91 |

Table 3: Analysis of PDR

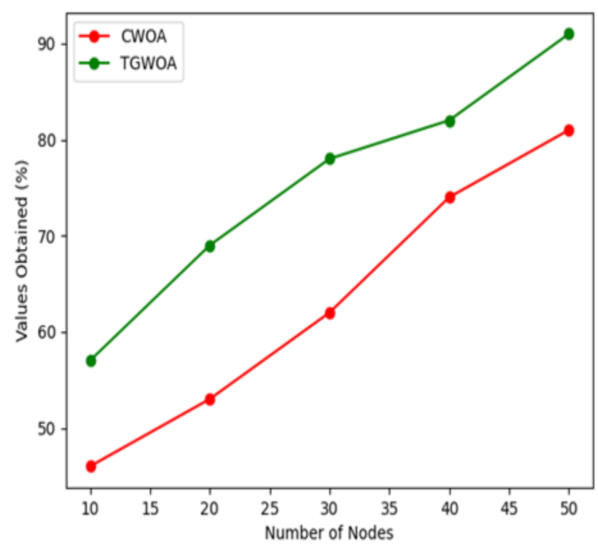


Figure 4 Comparison of PDR between Existing and Proposed Methods

Figure 4 compares the PDR of existing CWOA and Proposed TGWOA methods. The X axis and Y axis shows that number of nodes and the values obtained in percentage respectively.

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The red and green color indicates existing CWOA and Proposed TGWOA methods. Packet delivery ratio of proposed method achieved is 75% against the existing method.

### 4.3. Delay

This is the ratio of total hops (p) essential for routing to the total nodes (tn) in the network which is given by

$$Delay = \frac{p}{tn}$$

Less delay provides effective network routing. Table 4 presents the analysis of Delay with existing CWOA and Proposed TGWOA methods.

| No. of Nodes | Existing CWOA | Proposed TGWOA |
|---|---|---|
| 10 | 35 | 18 |
| 20 | 54 | 23 |
| 30 | 63 | 39 |
| 40 | 75 | 42 |
| 50 | 84 | 57 |

Table 4 Analysis of Delay

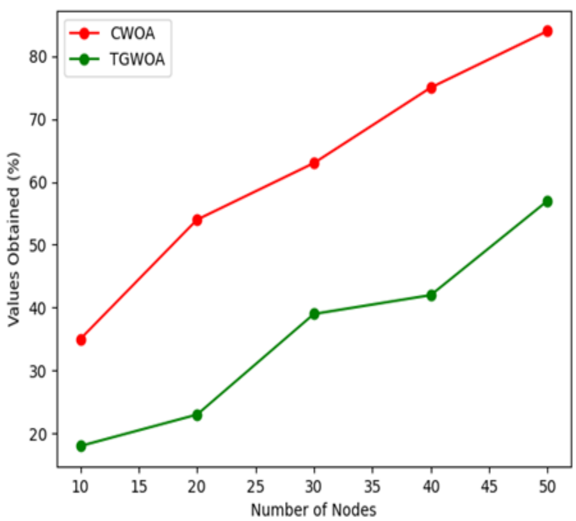


Figure 5 Comparison of Delay between Existing and Proposed Methods

Figure 5 depicts the delay comparison of existing CWOA and proposed TGWOA methods. X axis and the Y axis shows that number of nodes and the values obtained in percentage, respectively. The red and green color indicates existing CWOA and Proposed TGWOA methods respectively. When compared, the existing method achieves 62.2% while the proposed method achieves 23.8% delay.

### 4.4. Network Lifetime

This derived from the lifetime of the node which must be maximum to achieve effective routing which is given by

$$Network\ Lifetime = \frac{1}{p} \times \sum_{n=1}^{p-1} \frac{M(N_n, N_{n+1})}{\beta}$$

Table 5 presents the analysis of network lifetime with existing CWOA and Proposed TGWOA methods.

| No. of Nodes | Existing CWOA | Proposed TGWOA |
|---|---|---|
| 10 | 24 | 32 |
| 20 | 35 | 43 |
| 30 | 41 | 51 |
| 40 | 53 | 62 |
| 50 | 69 | 78 |

Table 5 Analysis of Network Lifetime

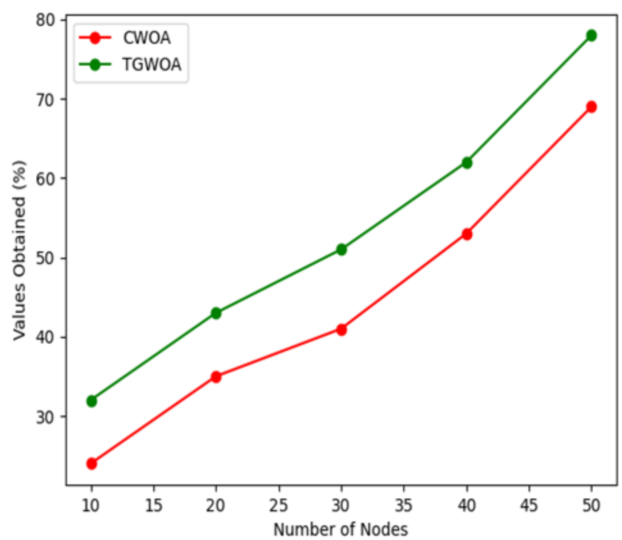


Figure 6 Comparison Plot for Network Lifetime between Existing and Proposed Methods

Figure 6 plots the Network lifetime of the existing CWOA and Proposed TGWOA methods. X axis and Y axis shows that number of nodes and the values obtained in percentage respectively. The red and green color indicates existing CWOA and Proposed TGWOA methods, respectively. When compared, the existing method achieves 44% while the

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proposed method achieves 53%, which is nearly 10% improved than the existing method.

4.5. Scalability

It ensures that regardless of the network size, the network performance well without any degradation.

$$Scalability = \frac{Performance\ of\ the\ network}{Network\ size}$$

Table 6 presents the analysis of Scalability of the network against the existing CWOA and Proposed TGWOA methods.

| No. of Nodes | Existing CWOA | Proposed TGWOA |
|---|---|---|
| 10 | 52 | 75 |
| 20 | 63 | 79 |
| 30 | 74 | 83 |
| 40 | 81 | 91 |
| 50 | 87 | 96 |

Table 6 Analysis of Scalability

Figure 7 compares the network scalability of existing CWOA and Proposed TGWOA methods. X axis and Y axis shows that number of nodes and the values obtained in percentage respectively. The red and green color indicates existing CWOA and Proposed TGWOA methods, respectively. When compared, the existing method achieves 71% while the proposed method achieves 84.8%.

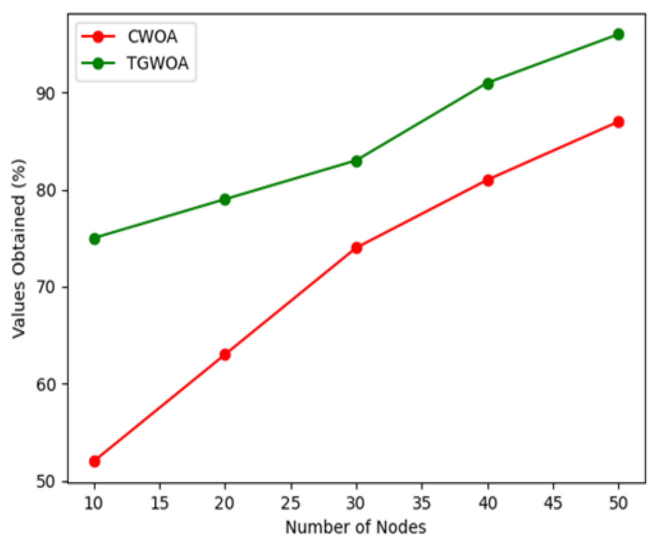


Figure 7: Comparison of Scalability between Existing and Proposed Methods

Table 7 shows the overall performance of analysis for existing Crow Whale Optimization Algorithm (CWOA) and proposed method Taylor based Grey Wolf Optimization Algorithm (TGWOA). The parameters considered for analysis are energy, packet delivery ratio, delay, network lifetime and scalability.

| Parameters | Existing CWOA (%) | Proposed TGWOA (%) |
|---|---|---|
| Energy | 58.4 | 35.8 |
| Packet Delivery Ratio | 63.2 | 75.4 |
| Delay | 62.2 | 23.8 |
| Network Lifetime | 44.4 | 53.2 |
| Scalability | 71.4 | 84.8 |

Table 7 Overall Performance Analysis

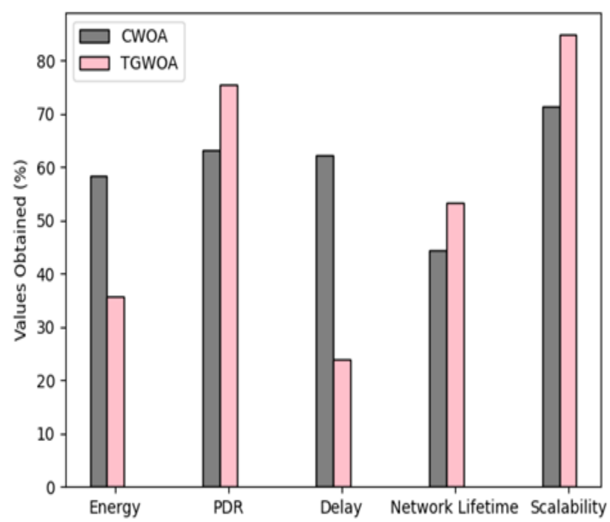


Figure 8 Comparison of Performance with Existing and Proposed Methods

Figure 8 compares the values achieved for the parameters. X axis and Y axis shows parameters considered for analysis and values obtained in percentage, respectively. The black and pink colors indicate existing CWOA and proposed TGWOA methods, respectively. The proposed method achieves 23.8% of energy, 75% of PDR, 35.8% of delay, 53.2% network lifetime, and 84.8% of scalability.

Finally, the above discussion implies that all the metrics considered for analyzing the proposed TGWOA method provides satisfactory results when compared to the existing CWOA method.

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## 5. CONCLUSION

This work concentrated on energy-aware multi-hop routing protocol which considered security as a significant concept to perform multi-hop routing. For selecting CH, the optimal node chosen using the routing protocol. Data transmitted from one node to others based on various hops that optimally chosen by proposed TGWO fitness function. The TGWOA proposed the combination of Taylor series with Grey Wolf Optimization (GWO) algorithm. This proposed method provided improved convergence, and this hybrid optimization achieved better energy, delay, hop distance and network lifetime. It observed that the proposed Taylor based GWO algorithm shows the best performance when compared with CWOA. The proposed method achieves 23.8% of energy, 75% of Packet Delivery Ratio, 35.8% of delay, 53.2% of network lifetime, and 84.8% of scalability.

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