IIETA International Information and Engineering Technology Association
Advancing the World of Information and Engineering

Revue d'Intelligence Artificielle
Vol. 38, No. 3, June, 2024, pp. 1027-1034
Journal homepage: http://iieta.org/journals/ria

Hierarchical Routing with Optimization Algorithm for SDN: Enhancing Network Lifetime and QoS

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https://doi.org/10.18280/ria.380328

Received: 30 October 2023
Revised: 1 January 2024
Accepted: 14 February 2024
Available online: 21 June 2024

Keywords:
wireless sensor networks, routing, improved lion optimization, energy saving, quality of service

ABSTRACT

In many fields, such as monitoring the environment, health care, and surveillance, Software Defined Networking (SDN) was essential. The system performance of SDN remains severely constrained by the restricted electrical sources available. Most of the applications being developed in such networks are meant for critical a service which requires high computation leading to power dissipation and energy consumption. In such constraint networks, energy consumption is a significant cost factor for computing resources. Formation of cluster, Route establishment and transmission of data are the three aspects of the proposed technique. This paper offers a hierarchical navigation method for SDN, depending on the Improved Lion Optimization (ILO) method to handle this problem while improving the network's lifespan and Quality of Service (QoS) by using less power. The ILO method is used to create sensor node clusters according to an organizational framework during the cluster-formation phase. Simulations on computers have been employed to examine the proposed strategy, and several protocols for routing in use. Evaluated for their potential to improve SDN, efficiency and lengthen the lifespan of the network. The outcomes show that the proposed method can locate the shortest way, reduce expenditures, and minimize the use of energy. In addition, in comparison with existing methodologies, the proposed strategy delivers a longer network lifespan and higher QoS.

1. INTRODUCTION

A typical SDN is made up of an assortment of sensor gadgets that work together to complete a shared purpose and transmit the information they gather to a centralized node securely. The use of SDNs ranges from civic, medical care, and ecological to military use [1]. However, the development and administration of networked sensors have faced numerous difficulties due to the specialized attention to the special characteristics of networks of sensors, such as power constraints, strict capacity requirements, dynamic structure, high system density, in addition, massive deployments [2]. At all stages of the communication standard system, these difficulties have required consciousness of energy and strong standard implementations. On the other hand, any data collected that contains an indicator of a fire should be transmitted to the processor center within a particular period for a network of sensors used for identifying fires in a wooded area [3]. Additionally, strict limitations on speed and also delay have been imposed by the development of multimedia sensor networks and the rise in popularity of real-time applications to report time-sensitive information to the analyzing center or sink within predetermined time frames and also needs for bandwidth without any loss. The QoS needs is the common name for these evaluations of performance [4, 5]. As a result, for users to have appropriate utilization of data from sensors and optimal resource utilization, actual time applications that utilize networks of sensors require energy and QoS awareness in various tiers of the protocol hierarchy [6].

The capacity of SDN to perceive, compute, and transmit information has made them a potential technology for a variety of uses [7]. Power constraints, however, are a serious problem in SDNs that impact network lifetime and QoS. Numerous academics have proposed different hierarchical routing strategies with optimization algorithms in the research to increase network lifetime and QoS. The optimization method is one such technique that has been utilized in numerous researches to enhance the functionality of SDNs. For instance, a hierarchical routing method based on LO was proposed to save power consumption and increase network lifetime in a study by Lenka et al. [8]. Computer simulations were used to assess the proposed strategy; in addition, outcomes demonstrated that it surpassed existing plans in terms of network lifetime and energy consumption. A hierarchical navigation strategy based on LO was proposed for large-scale SDNs in a separate study by Al-Sadoon and Jedidi [9]. The proposed strategy was tested using simulations and field tests, and outcomes showed that it outperformed previous methods in terms of network lifetime and QoS. A hierarchical navigation method based on LO was proposed for SDNs in an examination [10] to extend the network's lifespan and consume less power.

Using computer models to analyze the proposed strategy, the findings revealed that it surpassed previous strategies in the areas of network lifetime and efficiency of energy [11]. Hierarchical routing techniques, which involve clustering the network into clusters and employing cluster leaders to connect with the base facility, is one such method. The cluster heads are used to decrease the power use for detector modules while extending a lifespan for a network [12]. Line Optimization (LO) method has also been put up as an environmentally friendly navigation method that may extend the network lifetime and consume fewer watts of energy. Hierarchical routing and the LO algorithm have both been studied about SDN [13].

2. RELATED WORKS

A hierarchical route protocol constructed around the LEACH and LO method, for example, has been proposed in "An Energy-efficient Hierarchical Routing Protocol based on LEACH for SDN" [14]. This protocol aims to decrease the use of energy and extend the lifespan of networks. In terms of the network's lifespan and the delivery of packets ratio, the proposed method performs better than the protocols that are already in use. It is proposed to use a novel hierarchical routing method depending on the LO and genetic algorithms. The proposed approach outperforms existing protocols in terms of efficiency while consuming less energy and extending network lifetime. Based on the LO method [15], the model proposes a hierarchical routing method to cut down on power consumption and increase network lifetime. Simulations are used to test the proposed approach, and outcomes show that it performs better than existing techniques in terms of both power usage and lifetime of the network.

Overall, the research points to hierarchical routing using the LO algorithm as a potentially effective method for extending network lifetime and improving QoS in SDN [16]. Following simulated evaluation, the proposed method was determined to perform better than existing techniques. The impact of various network factors and topology on the proposed strategy can be investigated in more detail and it can be expanded to solve security issues in SDN.

The following is how the work is organized:

It briefly describes the issue of finite power supplies along with SDN. Mention how enhancing network lifetime and performance requires energy-efficient routing strategies. Introduce the ILO method and hierarchical sequencing as a potential solution to this problem [17].

The proposed method is to describe the ILO-based hierarchical routing strategy. Describe the cluster creation, route establishment, and information transmission stages of the method. Describe how the proposed method lowers consumption of energy and routing overhead, enhancing system lifetime and QoS.

The links between OpenFlow switches and virtual host devices are achieved using virtual ethernet pairs in Linux. Virtual switches set up TCP connections to the SDN-assisted controller in Mininet. Sending a packet from one application on host device 1 to another application on host device 2 will be processed by the network protocol stack in Linux kernel [18].

Computer simulation outcomes for the proposed technique should be shown. Analyze the effectiveness of various routing protocols that have been established using the proposed method. Show how the proposed strategy can locate the most efficient way, use less energy, and spend less cost. Give a summary of the proposed ILO algorithm-based hierarchical routing scheme for SDN. Emphasize how the proposed technique will improve network lifetime and QoS. Highlight the possibilities of the proposed strategy for upcoming SDN studies and research.

3. PROPOSED HIERARCHICAL ROUTING

SDN technology is a method of managing networks that allows for flexible, programmatically effective network setup to enhance effectiveness of networks. The nodes of sensors typically carry out sensing, data transfer tasks and processing. Figure 1 shows how this work has generally progressed. Transferring information uses the most power out of all of these fundamental tasks. Consequently, a smart routing strategy can prevent the network of sensors from using too much power. This promotes conserving energy, which lengthens the network's lifespan. The purpose of the research is an offer the hierarchical routing approach for SDNs depends on ILO. A leader node evenly distributes the electrical power of the detectors; hierarchy routing strategies work [19]. A cluster's leader node acts as a governing body to provide scalability and management. The present study, which was informed by the underlying concept of bio-inspired structures, selected ILO and assesses the path selection effectiveness of this strategy. The advantages of ILO include faster convergence and better exploring speed. This method effectively manages the stages of exploration and extraction by including a mechanism for adaptation shown in Figure 1. By simplifying the algorithm's mathematical computations, this concept promotes the conservation of energy.

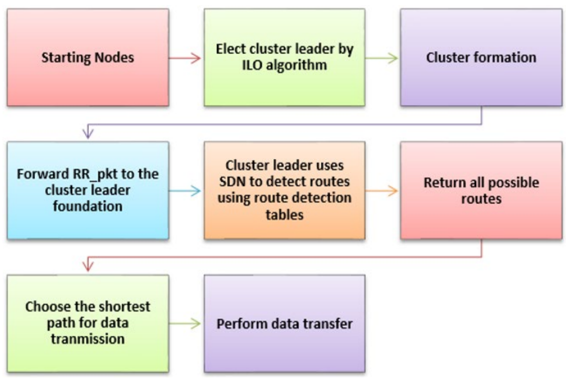

Figure 1. The overall flow of the proposed work

3.1 Energy efficient routing algorithm

One of the hot fields of study in SDN is preserving energy. For the network to last longer, there are many approaches to conserve power. For example, topological administration, duty cycle models, clustering, and route strategies. This work focuses on a power-efficient routing strategy because transmitting information requires more energy used. Figure 2 displays the planned work's flowchart. Connection of the detector closest for the BS serves as a cluster leader detect at first by broadcasting a pack for all of the sensor detector. Received signal strength identifies a node that is closest for a base station. However, the most effective node for sensors must be picked in order to perform the cluster supervisor's duties. Compared to the other cluster nodes in the head unit has a stronger sense of responsibility. Information Collection and transfer from the cluster's leader node's membership networks to the appropriate destinations is its primary responsibility. Therefore, a highly capable node has to be picked as the cluster leader, ensuring that all of the cluster leader's duties can be carried out without difficulty.

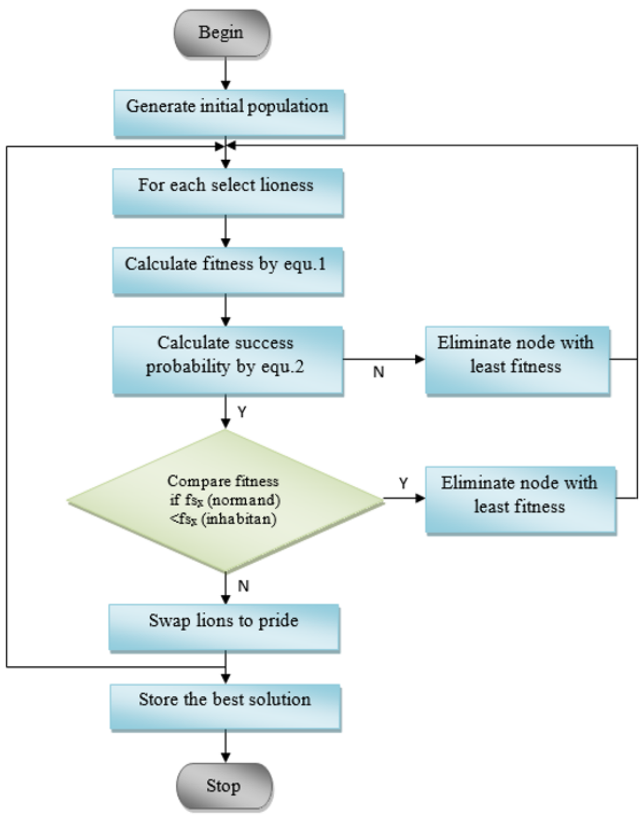

Figure 2. Improved Lion optimization method's structure

The ILO computational cost was usually based on three rules: answer introduction, fitness value calculation, & answer update. Assuming N represents the total of answers and O(N) would be the complexity of computational for the starting operations of answers. The complexity of computational for the update procedures for the answers was O(T/N*Dim) + O(T*N), which contains searching the optimal locations & upgrading the locations of all answers, where T seems to be the total current iteration & Dim seems to be the dimension size of the provided issue. As a result, the proposed ILO total computational complexity was O(N(DT + 1)).

Algorithm: ILO
Step 1: Population P initialized and parameters α, δ
Step 2: do while
Determine fitness function values Pbest (r)
Identify the best solution achieved
Step 3: for x ranges from 1 to N
Average value of the present solution Pm(r) is updated
Modify the value x, y, H_1, H_2, Levy(R)
if $r \leq \left(\frac{2}{3}\right)$ then
if random ≤0.5 then
Expanding (P1)
Current solution updated by using Eq. (1)
if Fitness (P1 (r+1)) < Fitness (P(r)) then

$$P(r) = (P1(r+1)) \tag{1}$$

if Fitness (P_1 (r+1)) < Fitness (Pbest(r)) then

$$Pbest\ (r) = P1(r+1) \tag{2}$$

end
end
else
Step 4: Narrow (P_2))
Current solution updated by using Eq. (2)
if Fitness (P2(r+1)) < Fitness (P(r)) then
P(r) = (P_2(r+1))
if Fitness (P_2(r+1)) < Fitness (Pbest(r)) then
Pbest(r) = P_2(r+1)
end
end
end
end
Step 5: Start the ILO Proceduer and set the input (a,P(r), Pbest(r))
Step 6: Set X =0 and Y=0
Step 7: for (a,t) ϵ Pbest(r) union do
set the VECTORIZE (a,t) to X append u(a,b) to Y
Set the gp= Gaussian Process (X,Y)
€*, δ* = POSTERIOR(gp,l*)
end for
Step 8: retun the value

3.2 SDN-based route

A node transmits a data packet containing an inquiry to the cluster leader network each time it needs to communicate with a different node. The history of transmitted information is checked in the cluster's leader node's storage. The message in the request packet includes both the requester's and the intended node's distinctive IDs [20]. A routing request packet with the clusters identifier, clusters leader, hop count, nodes type, and identification of the existing and prior sensor nodes is transmitted around by the cluster leader nodes.

$$RR_{pkt} < C_{id}, CL_{id}, HC, NN, PN_{id}, PR_{id} > \tag{3}$$

C_{id} is the cluster's identifier, CLid is the leader's unique identifier, C is the hop count that increases with each step forward, NN is the type of node, PN_{id} is an identifier of a existing nodes, and PR_{id} is an identifier for a previous sensor nodes. Let's say that node with ID 5 wants to send an alert for node 10. All nodes belong to separate clusters. The Table 1 shows the routes keeps track of all the developments associated with this procedure as follows.

The cluster leader node oversees and updates this table at each stage. Depending on the defined routing table, the nodes that got RRpkt to respond to the cluster master with an acknowledgment. The node identification is the only thing in the sensor's nodes' acknowledgment. A sample Table 2 is provided the cluster's leader node receives a list of all feasible connections.

Table 1. Lists routes based on SDN

C_{id}	CL_{id}	HC	NN	PN_{id}	PR_{id}
1	CL 1	0	0	6	-
1	CL 1	1	1	7	6
1	CL 1	2	0	5	7
1	CL 1	3	0	9	5
1	CL 1	4	1	2	9
2	CL 2	5	0	4	2
2	CL 2	6	0	8	4

Table 2. Possibly detecting the path

Source	Route					Destination
6	7	5	9	2	4	9
6	9	2	-	-	-	9
6	10	8	2	4	-	9

The route table is taken into account while creating the list for potential path identification, which comprises total potential routes from a source node. All of the discovered routes have been fixed and are being used for the duration of the network. Multiple nodes send acknowledgments for a cluster head node. Every phase of a data transmission procedure is completed one after the other after it has begun. The initial setup of node clusters and the establishment of the data transmission path [21] are equally necessary. All potential routes connecting the source and final nodes are returned by the route creation procedure.

3.3 Total energy consumption and network lifetime

The median amount of overall power required an interact including CHs and median quantity of overall power required by CHs to receive data sink is supplied in Eqs. (4) and (5). This information is used to analyze the overall use of energy.

$$e(C1) = e[e(C1)|N = N_0] \tag{4}$$

Given **below** is the average overall energy usage as determined by the aforementioned formulas.

$$e(C_t) = e(C1) + e(C2) \tag{5}$$

The equation provides the mean power usage of each node as CH and then membership connections. The mean electricity usage while travelling by CH or a regular network to a target is provided by Eqs. (6) and (7). By using the least amount of electrical power possible when electing CHs, the system's lifespan is increased.

$$E_{in} = (1 - p) \sum_{k=0}^{N} R_{net} R_{exp}(-\gamma\pi[RK]) \tag{6}$$

$$E_{out}(r) = pe\big(R_D(c_x)\big)e_c(r) \tag{7}$$

Combining each of the equations previously yields Eqs. (8) and (9) and, according to the definition, the lifespan of a network is inversely related to the greatest usage of energy.

$$E_t(s) = E_{ch,mn} + E_r \tag{8}$$

$$E_{(Lifetime)\alpha min\left(\frac{1}{E_t}\right)=\left(\frac{1}{E_t}(1)\right)} \tag{9}$$

4. RESULTS AND DISCUSSIONS

By implementing the proposed clustering and transportation method in the Network Simulator (NS2) surroundings, its efficacy is assessed. The experiment will take place in a 100 × 100 m^2 space. The placement of the clusters is random, while the sensor nodes' range for transmission is set to 100 meters. The proposed approach is evaluated in terms of the delivery of packets percentage, median latency, median power use, and network lifespan versus cooperative PSO, ACO and Cat Swarm Optimization CSO. The work's packet speed of delivery is examined by adjusting a number for sensor nodes from 25 to 250.A primary goal for a routing system is to increase the packing transfer rate for a routing algorithm. The route selection strategy is ineffective in forwarding packets when the packet's speed of delivery is low. Following a comparison of the results of the experiment between the proposed strategy and the already used gets closer, the findings are provided. Table 3 provides the calculated ratio of package deliveries using a sensor node sequencing.

Table 3. Analysis of delivery rate of packets

No. of Nodes	ACO	PSO	CSO	Proposed
25	83	91	94	98
50	81	85	91	95
100	77	82	85	90
150	71	78	83	91
200	69	77	78	89
250	66	73	76	85

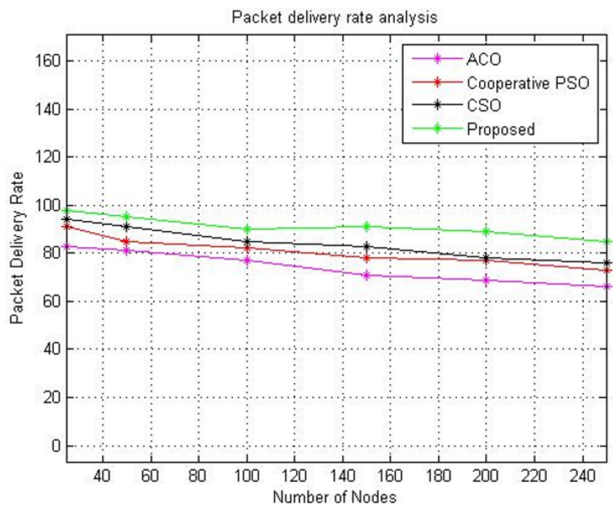

Figure 3. Packet delivery rate analysis

The amount of periods takes to send a communication for a source and the target node is measured by the delay in addition to which is another crucial efficiency indicator. To improve energy efficiency, the routing method's latency duration must be kept to a minimum. The single most crucial success parameter for assessing the efficiency of energy is the median consumption of energy. The routing strategy must use the less amount of power possible to lengthen a network's lifetime. The power consumption of the sensor nodes determines the network lifespan. Therefore, the emphasis of this study has been largely on improving the efficiency of energy and packet delivery rate. Following a comparison of the experimental findings between the proposed strategy and the already used approaches, the findings are provided. The outcomes of the transmission of packets rate assessment compared to the existing methods are shown in Figure 3. It is clear from the experimental results that the proposed routing strategy exhibits higher transmission of packet speeds. Table 4 provides an assessment of the simulation's typical delay.

Table 4. Analysis of the experiment's mean delay

No. of Nodes	ACO	PSO	CSO	Proposed
25	18	15.1	10.5	7.5
50	20	18	12.2	10
100	24.5	21	14.1	11
150	29.1	24	17	15
200	33.2	26.1	20.4	17
250	37	33.2	22	19

The use of the clustering idea and the selection of the shortest route for transmitting information are the primary causes of the higher packet delivery rate. With an increase in nodes, the packet transfer rate keeps falling. Figure 4 shows the average latency assessment of the proposed method.

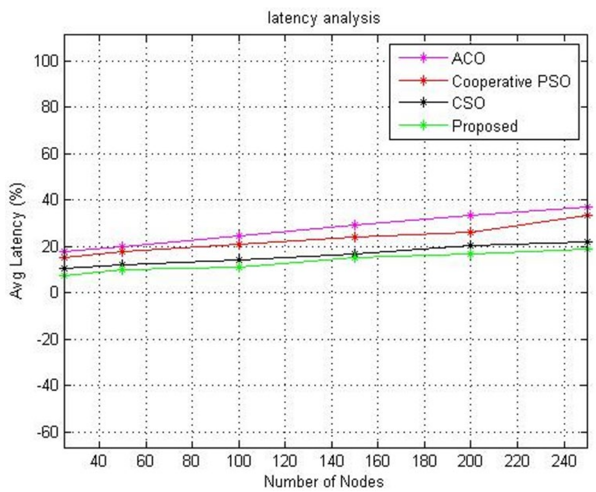

Figure 4. Average latency analysis

Figure 4 of the aforementioned graph shows that the proposed approach has the smallest average delay when compared to the other methods. The median length of time a packet spends traveling from the origin nodes to the target is referred to as latency. Efficiency is shown when there are 175 nodes, and the mean packet delivery time for the existing methods is 28.6, 23.6, and 18 seconds, correspondingly. The proposed method takes 14.6 seconds. It is undeniably true that the proposed solution has a shorter median delay. The successful choice of the cluster head and the quickest path selection are the causes of the extremely low latency level.

The most crucial effectiveness parameter is the consumption of energy because it directly affects the network's lifespan. The sensors' electrical power consumption is expressed in the form of joules. The analysis is done on the proposed method's energy usage pattern for simulation times between 0 and 1.0 seconds.

The typical amount of power consumed rises over time. The proposed method has a maximum energy consumption of 0.36 J, which occurred at the 500th simulated second. The mean power usage of the proposed method is examined, and the findings are shown in Figure 5.

The mean power usage of the proposed method is examined, and the findings are shown in Figure 5 above. The most crucial performance parameter is energy consumption because it directly affects the network's lifespan. The sensors' energy usage is expressed in terms of joules. The analysis is done on the proposed approach's power consumption patterns for simulated times between 0 and 1 seconds. The average amount of power consumed rises over time. The proposed approach has a maximum energy consumption of 0.36 J, which occurred at the final simulation second. Table 5 displays a comparative comparison of the power used in different experimental procedures.

Table 5. Comparison of the consumption of energy during experiments

Simulation Time (s)	ACO	PSO	CSO	Proposed
0	0.3	0.21	0.1	0.08
0.2	0.38	0.21	0.18	0.1
0.4	0.39	0.3	0.2	0.1
0.6	0.4	0.31	0.28	0.18
0.8	0.48	0.32	0.29	0.2
1.0	0.5	0.39	0.3	0.22

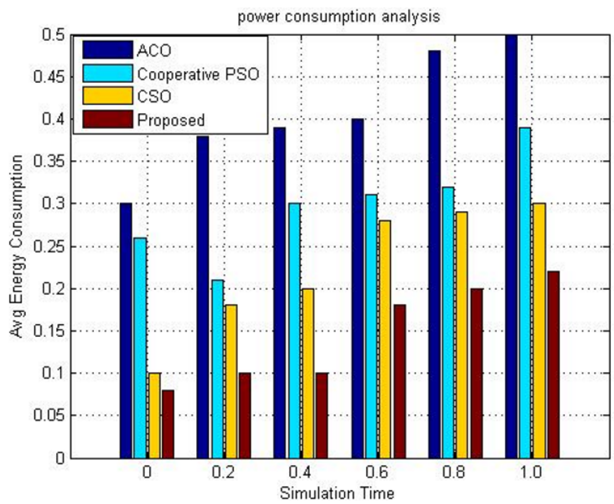

Figure 5. Analysis of typical power consumption

Table 6. Comparison of lifetime of networks during experiments

Simulation Time (s)	ACO	PSO	CSO	Proposed
0	239	239	240	250
0.2	200	239	240	250
0.4	190	220	235	249
0.6	150	200	205	249
0.8	0	159	200	249
1.0	0	0	100	240

In Table 6, the analysis and contrast between the network lifetimes of the proposed strategy during simulations are presented, and the outcomes are contrasted with those of the existing used methods.

The lifetime of a system is determined by the amount of functioning nodes in it. Figure 6 shows the Network lifespan of the proposed strategy.

Assessment reveals that the proposed strategy had more live nodes at the 500th-second mark of the experiment. There are 250 deployed nodes in total at the start of the experiment. The proposed technique has revealed 202 live nodes at a 500th second. ACO, on the other hand, shows the fewest living nodes, which are 146 at the 500th second. Two methods, cooperative

PSO and CSO, display 183 and 198 nodes, correspondingly, at the 500th second.

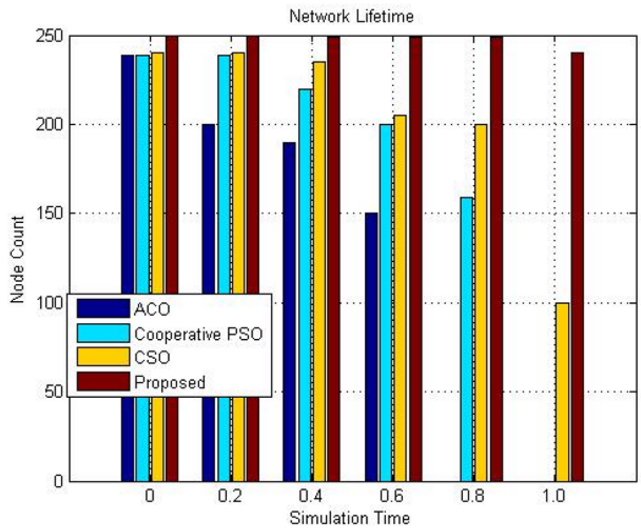

Figure 6. Network lifetime assessment comparing

Therefore, the proposed strategy has demonstrated a better lifetime by efficiently using power to achieve the process of data transfer. The analysis of Network Lifetime and Residual Power of various techniques is shown in Figure 7. There are 244 active nodes and 0.16 J of power consumed by the proposed method at the 1.0 second. As a result, the proposed approach has demonstrated more active nodes with greater levels of residual power for completing the information transfer operation.

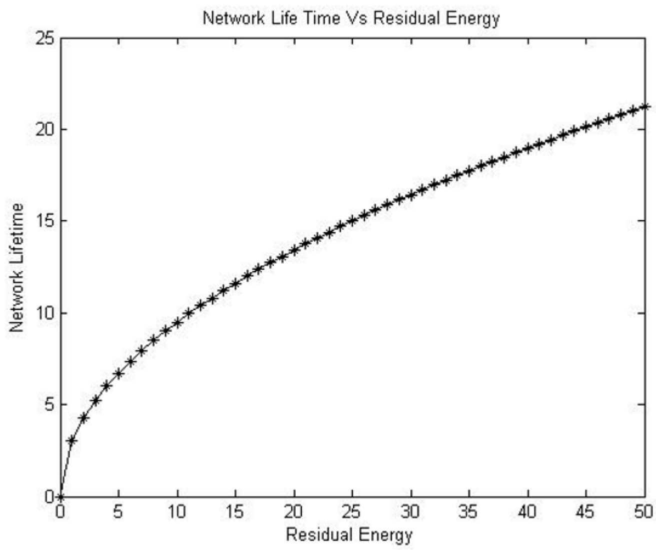

Figure 7. Network life time vs residual energy

5. SIMULATION STUDY

To check the efficacy and effectiveness of the rules, the ILO method, which was constructed using MatLab, served to analyze and validate the protocol simulations procedure. To compare the outcomes of the two processes, an algorithm for simulated annealing was also built in MatLab. 2000 nodes make up the process of simulation, which is uniformly dispersed across a detecting area. The power supply, recall, and processor unit of every sensor is the same. These nodes were all situated in the same surroundings outside. The implemented version of the procedure using the ILO method produced a shorter time to travel between every node than recreated annealing, as shown by the simulation outcomes of the two computations. This means that the ILO algorithm will decrease energy consumption, and cost savings, along with certain additional variables.

The ILO approach, which is implemented in MatLab, is used to depict the route between each of the nodes that have been scattered throughout the field of sensing. Figure 8 illustrates how Java was used to develop ILO and produce a commendable outcome.

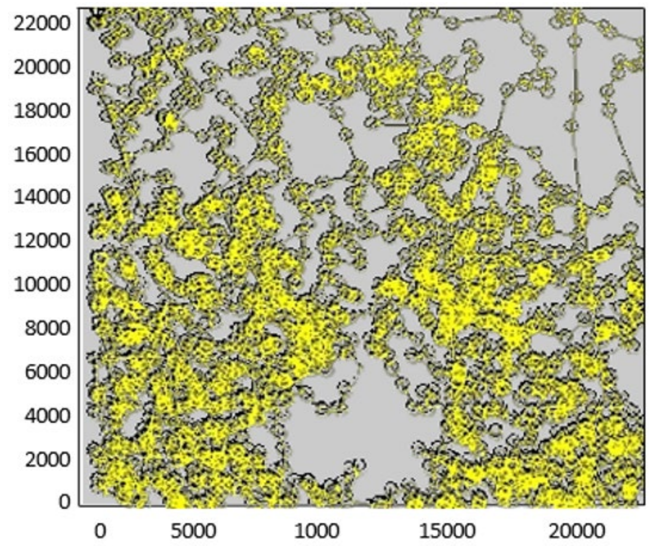

Figure 8. Implement ILO in Java

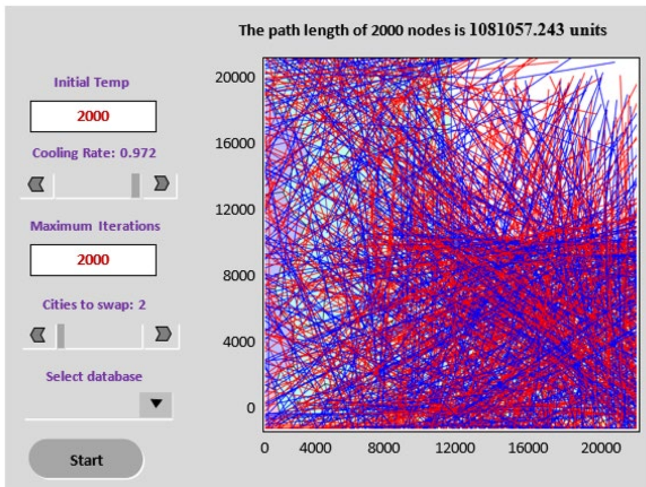

Figure 9. Implementation through MatLab

The ILO approach, which can be implemented in Java, is used to show the path among the points that are scattered throughout the field of sense in the preceding Figure 9. Table 7 displays the outcomes of the ILO method's execution in both PL.

Table 7. MatLab and Java results for ILO implementing

Algorithm	Programming language	Cost	Time
ILO	Java	734096	26.83 Sec
	MatLab	730241.4832	3.72 Min

The ILO method was executed in MatLab, and Figure 9 depicts the outcome of ILO MatLab implementation for SDN. The path connecting the nodes spread in the field of sensing is depicted in the Table 8 utilizing the MatLab-implemented simulation of the annealing process. Table 8: The ILO method's implementing outcomes for SDN.

The average length of the path of the Routing protocol utilizing both the ILO for SDN methods is shown in Figure 10. It is clear that the SDN has an extended path when the proposed method is implemented.

Table 8. MatLab implementing results for ILO

Algorithm	Programming Language	Cost	Time
ILO	MatLab	1081057.24341	Sec

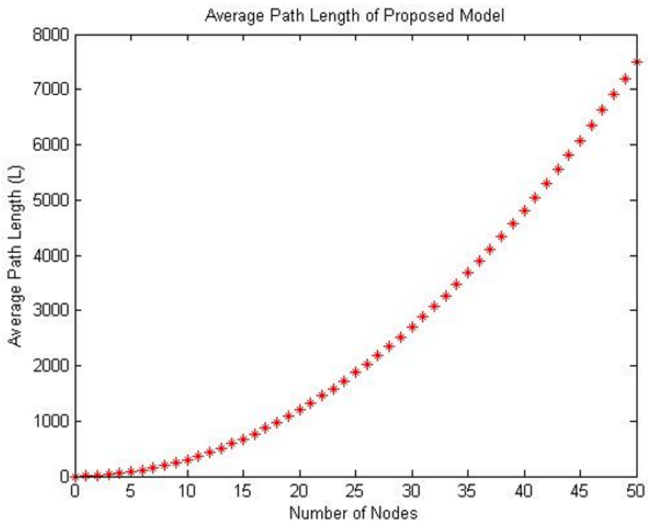

Figure 10. Average path-length

6. CONCLUSIONS

In this paper, the ILO algorithm-based hierarchical routing method for SDNs is presented. The major goal of this effort is to consume an acceptable amount of power, extending the network's lifespan and improving its QoS. The effort is divided into three phases—cluster creation, route company, and information transmission—to accomplish the purpose. A cluster of nodes with sensors is created by the ILO method and the straightforward technique is used to determine the route. This concept lowers routing overhead while also conserving power. The network's lifetime is improved by suitable energy consumption. This work will likely be expanded in the future to assure security routing. Numerous routing protocols have been implemented and tested through computer simulation, and all of them have demonstrated their capacity to increase SDN achievement along with network life using their capacity to find the smallest path, which lowers energy use and costs. Future research will examine standard effectiveness and efficiency, as well as the impact of network capacity, path length, and buffer size on key protocol performance parameters. Future studies will examine the effectiveness and efficacy of the proposed method. Mention the study that looked at the impact of network capacity, buffer size, and path length on protocol metrics for performance. Describe the goal of enhancing the routing protocol's safety.

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