

A NOVEL IOT BASED WSN USING MOPSO ROUTING ALGORITHM AND IAVOA CLUSTERING TECHNIQUE

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Abstract: *The Internet of Things (IoT) has a wide range of uses today, including weather systems, traffic management, intelligent infrastructure, security systems, and more, that generates a lot of data that provides issues like control clustering and routing protocols. It addresses the management of data transfers. In order to improve the energy efficiency of the network, various mechanisms like energy-based clustering and sleep schedules are incorporated into routing protocols because, in general, IoT devices have limited performance in terms of battery life and energy efficiency. The majority of designs are complex and difficult to implement in real-world situations, according to current research. In this regard, this study proposes a clustering algorithm-based routing technique. By identifying both the clusters and the network, the proposed strategy first applies the Improved African Vulture optimization algorithm (IAVOA) clustering technique to group the members of the network. The multi-objective particle swarm evolution (MOPSO) algorithm then selects the interface nodes to send packets to the base station as the routing time increases. The proposed strategy is evaluated with the help of the MATLAB programming language. The total energy consumption, normalized average energy and residual energy of proposed system are used to calculate the evaluations' outcomes, which are then presented in different distinct scenarios. The evaluations show that the proposed approach performed better than the comparable approach in both evaluation criteria, resulting in increased efficiency.*

INTRODUCTION

Due to the wireless nature of IoT networks and the wireless sensor network (WSN) as a technology, the process of data transfer between devices and data centers is a very important issue in today's topics related to IoT networks. The IoT hardware layer takes into account in corresponding with a lot of small integrated sensors with recording, processing, and data transmission units that make up the network. These nodes can talk to each other, sense and detect events, and send measured data like temperature, humidity, and motion, among other things. Relay nodes, which require routing algorithms, or directly connection to the base station [20]. Power limitation, bandwidth, dynamic topology (due to node failure, addition or deletion, or mobility), data traffic density, and network scale are some of the characteristics that distinguish WSNs from other common networks. As a result, these networks face a number of difficulties that necessitate the creation of robust and energy-aware protocols across all architecture layers [15].

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Keywords: *Improved African Vulture Optimization Algorithm (IAVOA), Multi-Objective Particle Swarm Optimization (MOPSO), Swarm Intelligence, Clustering, Routing, IOT, WSN*

The most important design considerations for the majority of WSN routing protocols are maximizing network life and making effective use of energy resources. The routing load processing must be evenly distributed among all network devices and intermediate nodes for a sensor network to be energy efficient. This guarantees that more gadgets work for a more extended timeframe. On the other hand, if this load processing is routing and only a subset of the network's devices are taken into consideration, and then this subset of devices uses energy more quickly and runs out of battery faster than the rest of the network [19]. As a result, the majority of research is devoted to the creation of effective routing protocols, clustering, and other energy-saving strategies, including the application of optimization techniques [13].

Numerous real-world issues can typically be formulated as multi-purpose optimization issues. Multi-objective evolution algorithms (MOEA) have received a lot of attention ever since the first attempt to use evolutionary algorithms to solve multi-objective optimization problems. In recent years, they have been widely used to solve a variety of problems. MOEA makes use of an evolutionary algorithm's capacity to generate multiple solutions simultaneously in a single run. In such manner, a mix of multi-objective particle swarm optimization (MOPSO) calculation, which is an imaginative multi-objective savvy improvement calculation, alongside African Vulture -based grouping (IAV) to find ideal ways between hubs in IoT and stations Determination of dependable variables in view of the heaviness of every way in the organization utilizes it to track down help ways [7].

The proposed approach improves the network's primary objectives by employing a multi-criteria objective function in the MOPSO algorithm. The proposed method uses distance between objects, distance from node to destination, link quality, and degree of reliability as evaluation criteria for performance. In fact, in each jump, the optimal and reliable node is the one with the fewest jumps to the source node, the shortest direct distance to the access point, the highest link quality, and the highest degree of reliability. As a reliable factor in the backup path, the backup node is also chosen as the second optimal node among adjacent nodes whose values meet the second category of evaluation criteria. The global optimization of reliable IoT routing is achieved by selecting the best nodes at each step [17].

In wireless sensor networks, clustering is the process of dividing the network into categories to balance the load and accomplish other objectives like scalability, longevity, and energy efficiency. Increasing network life and influencing the network's overall performance can be accomplished in a very effective and cost-effective manner. Member nodes (MNs) and clusters (CLH) are the two subsets of cluster-based routing protocols. The CLH that is selected is determined by crucial factors like residual energy and the distance to the node (SN). The weight and score of the nodes determine the function of CLH. Increasing or decreasing important parameters (different parameters are introduced in various algorithms) define node scores. As a leader or coordinator, the cluster head collects and transmits data from cluster members (CMs) to the base station (BS) or SN. The majority of research focuses on clustering, energy-saving strategies, and the design of sensor network routing protocols [2].

Anand and others [3] employs a concept-based clustering genetic algorithm (GA) and suggests particle swarm optimization (PSO) routing in a WSN in their approach. They select selective cluster heads (CH) based on distance and energy, which collect data from all parameter node parameters. At the relay node the collection for data depends on routing paths from the base station to the sink based on PSO algorithm. The traffic load between CH and BS always carried by relay node, the proposed method shows enhancement in the efficiency of energy by utilizing the

proper relay nodes between the CH and destination nodes which will support and facilitate the traffic flow in the network. Finally, the network lifetime will be extended, and the service quality will be improved. The simulation for the proposed algorithm shows successful results in energy consumption reduction and network lifetime expansion as compared with other traditional protocols.

In paper [9] the researchers proposed a new routing protocol (EEG) depending on overall network power consumption and dissipation of energy at each sensor node within the network. This algorithm shrinks the hole between the level of energy dissipation at each sensor node inside the network which ensures the network life extension and successful transmission. The main problem for the proposed method is the probability of errors in the location of sensor node which can be solved by considering the mean square error algorithm to overcome the problem and efficiently utilize the geo routing technique (EEG).

The proposed residual energy scheme takes into account the next carrier node to balance the energy consumption of the sensor nodes while they are in use. The EEG uses information from a neighbor about eligible carrier nodes to avoid voids. Consequently, communication overhead, which is relatively higher in existing GIS protocols, is reduced and the likelihood of location error is reduced. Broad reproductions show that the proposed conspire oversees energy utilization and bundle sending proportion more effectively than a high level geo-steering convention.

Problem Statement

In this section, which is the most important part of the research, we will discuss and find the research issue in relation to its important details and present and in-depth discussions. There are five sections to these topics: dimensions and limitations of the problem, the purpose of the research, the expression of unknown aspects, and the introduction of the research variables are all included in this section.

The proposed method consists of two steps of Improved_African_Vulture-based clustering and then MOPSO-based routing. The first step is to choose the most suitable beanie. These include various constraints and parameters such as the candidate node's energy consumption, the number of nodes in the cluster and the total energy of all nodes, the candidate node's distance from the associated nodes, number of headers formed and distance from BS to all. The next step is MOPSO-based routing, where a relay node is placed between the sink and the cluster head. Data is exchanged when the sink and eclipse are far from the transition node. Relay nodes are used to minimize the overhead power consumption when aggregating data and transmitting to the BS. To do this, the header first finds the nearest relay nodes, or the BS sends the collected data depending on which node is closest. This reduces the energy consumption of nodes when transmitting data, which increases their lifespan.

The primary goals are:

- 1- In order to share messages and extend the life of the network, sensor nodes need to be effectively clustered together.
- 2-Both sending and receiving messages between sensor nodes ought to use as little energy as possible.
- 3-Compared to previous tasks, the MOPSO-based routing protocol with clustering proposed for the IoT comprehension layer ought to perform better in terms of network life and power consumption.
- 4-Clustering is performed much more effectively and with a much faster convergence rate by the proposed (IAVO) algorithm than by methods that have been used before.
- 5- Use a variety of wireless sensor network applications.

Objectives in science:

1- Presenting research articles that are the result of research successes.

METHODOLOGY

Power consumption, network life, network throughput, wireless routing protocols, and network security are all aspects of WSNs that have been the subject of numerous studies. The use of energy is a major issue in WSN communications, and the development of a green routing protocol—also known as an energy-efficient routing protocol—has a significant impact on the performance of the entire network as well as the sensor node's lifespan. The process of determining the best route for the transfer and exchange of information between sensor nodes via other nodes is known as routing, and its operation is influenced by the topology of the network. To put it another way, the performance, quality of service, and power consumption of the nodes are affected by whether the locations of the nodes are predetermined or distributed at random. Due to the limited resources of sensors—such as limited energy, limited processing, and short communication distances—routing has always been a major obstacle for researchers [14].

It is essential that the routing load processing be evenly distributed among all network devices for an energy-efficient network, particularly one with sensor devices. This guarantees that more gadgets work for a more extended timeframe. On the other hand, if load processing is related to routing and only a subset of network devices is taken into consideration, this subset of devices uses energy more quickly and exhausts its battery faster than the rest of the network. As a result, other approaches to lowering energy consumption are utilized in addition to routing, such as clustering, which is utilized in some routing algorithms for the following reasons [10]:

- Data collection in Cluster Heads (CH) results in energy savings for sensor nodes. As a result, irrelevant and additional data are deleted. Due to the shorter transmission range in the clusters, the transmission energy can also be reduced in nodes with the ability to adjust the transmission power.
- Because only CHs should be involved in routing to the final destination, routing can be simplified. Additionally, it substantially enhances network scalability.
- Maintains communication bandwidth because sensor nodes, which typically have limited energy and communication range, only communicate with CHs and do not send any additional messages to one another.

Proposed System Model

As a result of the effortlessness of the calculation, we utilized the Improved_African_Vulture (IAV) for bunching and the multi-objective particle swarm optimization (MOPSO) calculation for steering. As a result, we'll go over this approach in detail below. In order to accomplish this, we will first examine the clustering structure, objective function, and proposed clustering algorithm.

The Structure of Clustering

To group a set with n nodes into k clusters, we use an array with length n and the contents of each numeric cell will be between 1 and k . The amount of data in cell i actually represent the cluster in which cell i is located. To better illustrate this, let's say we have a data set with 10 wake nodes that we want to divide into three clusters.

This data set can be clustered as shown in Figure 1.

10	9	8	7	6	5	4	3	2	1
1	2	3	1	3	3	2	2	2	1

Figure 1: An Example of 10 Data Clustering.

Data samples 1, 7, and 10 are shown as being in cluster 1, while samples 2, 3, 4, and 9 are shown as being in cluster 2 and samples 5, 6, and 8 are shown as being in cluster 3. It is abundantly clear that this structure permits the formation of various clusters.

Objective Function

Three issues are addressed in the presentation of the clustering objective function. Some of these topics are:

- 1- The distance between cluster members: The objective function tries to minimize the distance between cluster members.
- 2- The energy disparity between members of various clusters: In order to avoid having one cluster's energy too high and the other cluster's energy too low, the objective function tries to minimize the energy difference between the clusters.
- 3- How many clusters can be adopted: the clustering tries to minimize the number of clusters, but keeping the facility for traffic flow from the source to the sink with minimum number of transition?

The desired objective function is depicted in Equation (1)

$$fitness = ClusterCount \times EnergyDifference \times InClusterDistace \quad (1)$$

Clustering Algorithm Using (Iavoa)

An optimization problem that needs an optimal solution can be simulated using one of the meta-heuristic algorithms inspired by the behaviour of an animal such as African Vulture. The similarity between seeking for food and looking for optimal solution is the key for the problem solution [8].

In AVO algorithm, the set of vultures which are flying around seeking for the nominal prey may represent the problem search space. The African vulture's movement can be controlled by four aspects: (1) exploration randomly, (2) local search randomly, (3) social learning, and (4) search globally [4].

The basic behavior of vultures is exploration randomly, where they flying randomly in the space in order to search for their prey. Based on the local search behaviour, the vultures try to restrict their search in some regions where they found their prey previously. While based on social learning behaviour, the vultures try to acquire experiences from other vultures and adapt their search continuously. Based on globally search behaviour the vultures try to expand the search space out of their locally regions and seeking new regions [22].

Initialization for a population of vultures randomly in a search space in the first step in the IAVO algorithm. The second step is the vulture's movement along the nominated search space and implementing the behaviour rules for optimal solution seeking for the optimal solution. Each vulture has its fitness value; this value is calculated according to an objective function within the optimization problem under study. The success vultures with most large fitness values are chosed to construct the next vultures generation [12].

The best solution which was found by the adopted algorithm is considered as the optimal solution for the problem. Each iterative algorithm has its own stopping

criterion, the iterations are continued till one of the stopping criterions have been occurred, and the most popular stopping criterion for iterative methods is: maximum number of iteration was reached, or fitness achieved with satisfied level [5].

Many optimization problems were solved successfully using AVO algorithm, including minimization or maximization function-based optimization problems, selected features problems, and training for artificial neural network. However, like any other optimization algorithm, AVO has its limitations and weaknesses, and there is still ongoing research on how to improve its performance [1].

As previously stated, the Improved_African_Vulture algorithm is utilized for multiple clustering purposes in the proposed approach. The algorithm that follows is visible.

Positive outcomes can be expected when the Improved_African_Vulture algorithm is used to cluster the WSN's waking nodes and increase routing protocol energy efficiency. Any device that has an average value that is closest to the current device specifications is added to the cluster during the clustering process. After clusters are formed during the clustering stage, each cluster chooses a cluster head. It is the responsibility of the cluster head to send messages to the base station from all of the devices in her cluster. As a result, clusters participate in shaping the routing path and do a lot of heavy lifting for their clusters in terms of energy and processing costs. However, as a result, the nodes quickly run out of energy. The proposed method selects a new cluster head after some time to prevent damage to the nodes from battery power loss. The spark plugs are chosen based on how much battery is left at the beginning of each cycle. The network's operational life is extended as a result of the uniform distribution of routing requests caused by the rotation of the nodes. The branches are chosen at random in the first round because each device will have the same amount of energy.

The IAVOA algorithm's main steps can be summarized as follows:

1. Set the maximum number of iterations and the population size at initial.
2. Determine the vulture's fitness value.
3. For every vulture, select $R(i)$ the appropriate methodology.
4. perch foundation for the ideal vulture.
5. update the position of vulture according to vulture's satiation rate (F),
6. keep the best position of vulture and update the ability of wellness till reaching the largest number of emphasizes.

Routing Algorithm Based Mopso

Some problems with multi-objective optimization can be solved by Multi-objective Particle Swarm Optimization algorithm (MOPSO) which can be defined as a meta-heuristic algorithm formulated to seek a solution for multi-objective optimization problems. It is an extended version of the well-known Particle Swarm Optimization (PSO) algorithm, which simulates the social birds flocking behavior as a population-based optimization algorithm [6].

In MOPSO, the set of moved particles around the search space represents the search space to find the optimal solutions. A potential solution to the optimization problem can be represented by each particle within the population. Each particle has a velocity vector that defines its movement in the search space. Each particle's position can represent a candidate solution that is calculated using fitness and multiple objective functions [18].

Population is classified into dominant and non-dominated particles, in MOPSO algorithm, a set of non-dominated particles represent multi-objective optimization

problem optimal solutions, which are also known as the Pareto front. So, in terms of all the objective functions the Pareto front represents a set of solutions that are non-dominated by any other solution. The main goal of MOPSO algorithm is covering the Pareto front, such that different objectives can be represented by the optimal trade-offs [11].

By random initialization of particles within a population in the search space, The MOPSO algorithm can be started with a first step. Then each particle fitness is calculated using a dominance Pareto operator, also all particles objective functions are evaluated. Based on particles velocities the positions for each particle is updated and the best solutions are found by the algorithm. Till reaching a stopping criterion by convergence satisfaction or maximum number of iterations, the algorithm continues to iterate. The algorithm found the best solutions known as the Pareto front which represent the optimal solutions to the multi-objective optimization problem [16].

Many multi-objective optimization problems can be solved effectively by MOPSO, including portfolio optimization, design and implementation engineering, and scheduling problems. However, MOPSO, like any other optimization algorithm, has its limitations, and there is still ongoing research on how to improve its performance and scalability [21].

The proposed approach employs the multi-objective particle swarm optimization (MOPSO) algorithm following K-means clustering to route and select the appropriate cluster heads for directing packets to their destination (where more than one header per jump is a candidate for packet navigation). The proposed approach's objective function for MOPSO is to reduce energy and distance as much as possible. Because we value energy more than jumping (that is, we want to have less energy, not more jump).

The particle swarm algorithm is used to direct the packets to their final destination and select the appropriate headers and nodes in the path in the following section of the fundamental article. In the base article, the goal of PSO is to cut down on both the distance and the number of hops. To convert a multi-objective function into a single-objective one, a value of W_i weight is multiplied by each goal and then added together to get a single-objective value like this:

Fitness function (routing) = $W_1 \times \text{MaxDist} + W_2 \times \text{MaxHops} \dots$ (2)

Steps of the MOPSO algorithm for equation (2).

1. Beginning.
2. Set the particles' initial velocity to zero.
3. Compute the objective standards for all particles in the underlying populace.
4. Consider each particle's initial position to be its best personal memory.
5. For each P particle, repeat the steps above.
6. If there are no particles in the target pool that meet the criteria that are higher than the best personal memory P. Add P's best personal memory to the collection in the repository.

P's best personal memory must be used to eliminate any particles that remain in the tank. For the specified number of times, perform the following.

10. To lead a crash out of the tank, select a particle. For each 11, do the following: within the populace.
12. Speed up the particles.
13. Refresh the particle's position.
14. Determine the new position's desired qualifications.
15. Replace the best personal memory with a new one if the new circumstance overwhelms it.
16. Otherwise, in the event that neither of the new situations nor the best personal

memory can overcome the other, choose one of them by accident as the best personal memory.

17. For each P particle, repeat the steps above.

18. In the event that there isn't more than the best private memory P in the molecule set with the objective rules.

19. Add P's best personal memory to the collection in the repository.

20. P's best personal memory must be used to eliminate any particles that remain in the tank.

21. The end.

Experiments and Results

The energy constraint is the most important issue in the wireless sensor networks, although there are other considered parameters such as bandwidth, processing time and memory. Each node has a battery to drive the sensor. Due to location of node sometimes the battery cannot be replaced. Therefore, energy is the main factor for specifying the node lifetime. So many proposed algorithms in WSN consider the consumption of energy at each node. In fact, loss of energy leads to loss of the node. Many proposed algorithms for WSN considered the network lifetime to be the interval between the simulation starting instance and the time at which the losing for the first node occurred. In addition to the energy. In addition to the majority importance for energy parameter, the number of nodes that have remained live in the network is also an important factor in algorithm's evaluations. In this paper, the remained energy and the number of remaining alive nodes are used for algorithm evaluation.

Scenario I

The objective for this scenario is to demonstrate the effect of nodes number on both methods (proposed and compared). The performance of both methods will be discussed based on Figures 2 and 3.

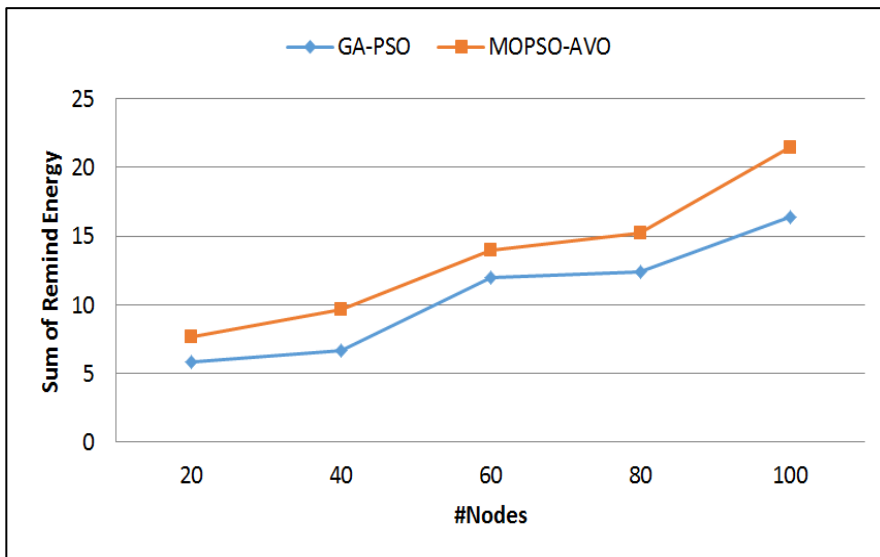


Figure 2: Average Remained Energy Versus Various Numbers of Network Nodes.

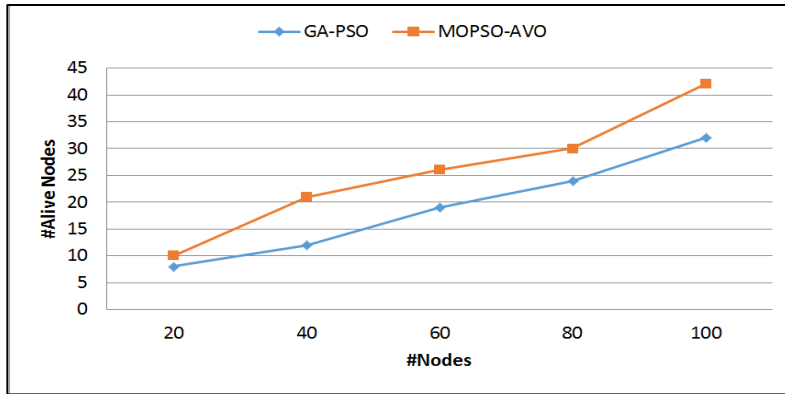


Figure 3: Number of Remained Alive Nodes for Various Number of Network Nodes.

Referring to Figures (2) and (3), as the number of nodes increasing then the remaining energy has increased too, for both methods and also the number of remaining alive nodes has increased till the simulation time elapsed. This is clear because increasing the number of nodes in the network will support each node with more neighbors. Hence, increase in neighbor's node number will give the sending node more options for sink selectivity. In other words, increasing the neighboring number for the node, lead to different routes is created toward the destination, which means reduction in the neighbors traffic loading, which yield to increase the remained energy in the nodes, and thus more alive nodes will be remained. In both criteria (remained energy and alive node), the evaluation of the proposed approach (MOPSO-AVO) performs better than the compared method (GA-PSO) because both factors (the remaining energy and the number of alive nodes) showed better values than the compared method.

Scenario II

In the 2nd scenario, the performances of both methods (proposed and compared) are evaluated over a specified period of time. The results of 2nd scenario are summarized in figures (4) and (5).

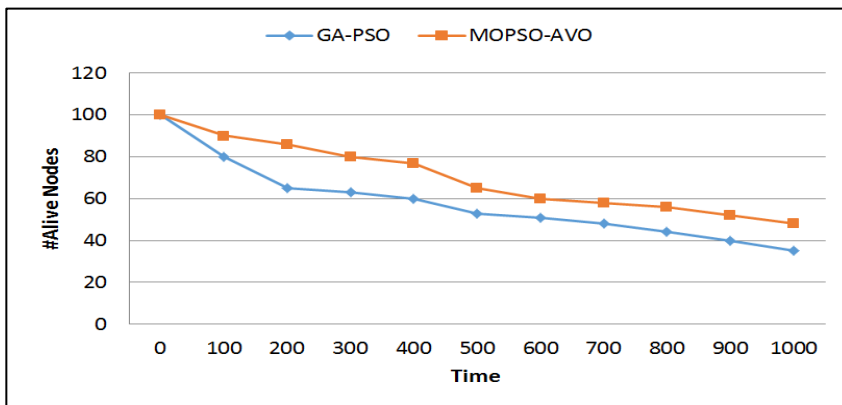


Figure 4: Average Residual Energy During the Simulation Period.

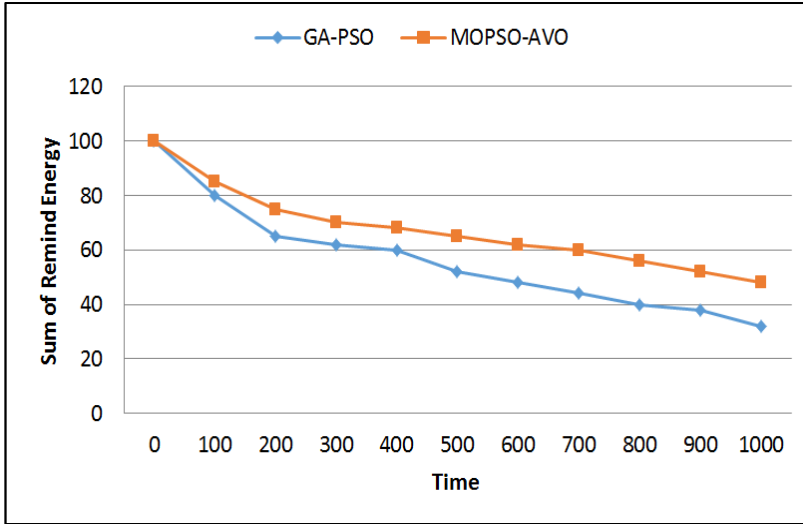


Figure 5: Number of Nodes Remaining During the Simulation Period.

Referring to figures (4) and (5), as the simulation time increased the average of remaining energy as well as the number of alive nodes of the WSN will be decreased. It is obvious that as the simulation time increases the number of messages sent increased in the network, and hence more energy consumed. By comparing both methods, the proposed method results in better performance than the compared method. Based on the 2nd scenario, it can be demonstrated how long the network can be operated during certain simulation time. The remaining energy and the number of alive nodes are inversely proportional to the simulation time period. So, the proposed method shows more network reliability than the compared method.

CONCLUSIONS

In this paper, a proposed new clustering-based algorithm to manage a technique for routing in IoT wireless sensor networks. This was achieved in light of the advantages that clustering of IoT sensor networks has provided thus far. At The improved African Vulture evolution algorithm is utilized for network clustering. After network clustering and eclipses selection each node connects to minimum distant eclipse. After cluster identification the packet routing starts based on proposed multi-objective particle swarm optimization (MOPSO) algorithm. MOPSO is adopted to select the best path for transmission according to criteria based on minimum dissipated energy and shortest path from source to sink nodes.

The proposed algorithms implemented and evaluated using MATLAB program. For comparison purposes, the results of a research paper with different algorithms in the field of research have been implemented also, and both methods are compared in one graph. The current work adopts Two scenarios have been used to explain how the proposed method evaluated well. In the earlier scenario the number of nodes is varied, while in the latter scenario the aim is concentrated in comparison with the stability of adopting methods during an interval of simulation time. The evaluations' results for the remaining energy and number of alive nodes for the proposed methods showed that it outperformed the other compared method.

REFERENCES

- [1] B. Abdollahzadeh, F. S. Gharehchopogh, S. Mirjalili, *African vultures optimization algorithm: A new nature-inspired metaheuristic algorithm for global optimization problems*, Computers & Industrial Engineering **158** (2021), 107408.
- [2] M. B. Agbaje, A. E. Ezugwu, R. Els, *Automatic Data Clustering Using Hybrid Firefly Particle Swarm Optimization Algorithm*, IEEE Access **7** (2019), 184963-184984.
- [3] V. Anand, S. Pandey, *New approach of GA-PSO-based clustering and routing in wireless sensor networks*, Int. J. Commun. Syst. **33** (2020), e4571.
- [4] H. A. Bagal, Y. N. Soltanabad, M. Dadjuo, K. Wakil, M. Zare, A. S. Mohammed, *SOFC model parameter identification by means of Modified African Vulture Optimization algorithm*, Energy Reports **7** (2021), 7251-7260.
- [5] Y. Chen, G. Zhang, *New parameters identification of Proton exchange membrane fuel cell stacks based on an improved version of African vulture optimization algorithm*, Energy Reports **8** (2022), 3030-3040.
- [6] R. Cheraghi, M. Hossein Jahangir, *Multi-objective optimization of a hybrid renewable energy system supplying a residential building using NSGA-II and MOPSO algorithms*, Energy Conversion and Management **294** (2023), 117515.
- [7] C. C. Coello, M. S. Lechuga, *MOPSO: A proposal for multiple objective particle swarm optimization*, in: Proceedings of the 2002 Congress on Evolutionary Computation. CEC'02 (Cat. No. 02TH8600), IEEE, 2002, 1051-1056.
- [8] J. Fan, Y. Li, T. Wang, *An improved African vultures optimization algorithm based on tent chaotic mapping and time-varying mechanism*, PLOS ONE **16** (2021), e0260725.
- [9] A. R. Hameed, S. u. Islam, M. Raza, H. A. Khattak, *Towards Energy and Performance-aware Geographic Routing for IoT-enabled Sensor Networks*, Comput. Electr. Eng. **85** (2020), 106643.
- [10] M. Ilyas, Z. Ullah, F. A. Khan, M. H. Chaudary, M. S. A. Malik, Z. Zaheer, H. U. R. Durrani, *Trust-based energy-efficient routing protocol for Internet of things-based sensor networks*, International Journal of Distributed Sensor Networks **16** (2020), 1550147720964358.
- [11] M. Jamalzadeh, M. Maadani, M. Mahdavi, *EC-MOPSO: an edge computing-assisted hybrid cluster and MOPSO-based routing protocol for the Internet of Vehicles*, Annals of Telecommunications **77** (2022), 491-503.
- [12] C. Kumar, D. M. Mary, *Parameter estimation of three-diode solar photovoltaic model using an Improved-African Vultures optimization algorithm with Newton-Raphson method*, Journal of Computational Electronics **20** (2021), 2563-2593.
- [13] N. Kumar, D. P. Vidyarthi, *A Green Routing Algorithm for IoT-Enabled Software Defined Wireless Sensor Network*, IEEE Sensors Journal **18** (2018), 9449-9460.
- [14] N. Mittal, U. Singh, B. S. Sohi, *A stable energy efficient clustering protocol for wireless sensor networks*, Wireless Networks **23** (2017), 1809-1821.
- [15] M. Norouzi Shad, M. Maadani, M. Nesari Moghadam, *GAPSO-SVM: An IDSS-based Energy-Aware Clustering Routing Algorithm for IoT Perception Layer*, Wireless Personal Communications **126** (2022), 2249-2268.
- [16] C. M. Pareek, V. K. Tewari, R. Machavaram, *Multi-objective optimization of seeding performance of a pneumatic precision seed metering device using integrated ANN-MOPSO approach*, Engineering Applications of Artificial Intelligence **117** (2023), 105559.

- [17] T. Qiuyun, S. Hongyan, G. Hengwei, W. Ping, *Improved Particle Swarm Optimization Algorithm for AGV Path Planning*, IEEE Access **9** (2021), 33522-33531.
- [18] R. Sellami, F. Sher, R. Neji, *An improved MOPSO algorithm for optimal sizing & placement of distributed generation: A case study of the Tunisian offshore distribution network (ASHTART)*, Energy Reports **8** (2022), 6960-6975.
- [19] M. Shafiq, H. Ashraf, A. Ullah, M. Masud, M. Azeem, N. Jhanjhi, M. Humayun, *Robust Cluster-Based Routing Protocol for IoT-Assisted Smart Devices in WSN*, CMC, Comput. Mater. Continua **67** (2021), 3505-3521.
- [20] A. Souri, A. Hussien, M. Hoseyninezhad, M. Norouzi, *A systematic review of IoT communication strategies for an efficient smart environment*, Transactions on Emerging Telecommunications Technologies **33** (2022), e3736.
- [21] H. Taghavifar, F. Mazari, *1D diesel engine cycle modeling integrated with MOPSO optimization for improved NOx control and pressure boost*, Energy **247** (2022), 123517.
- [22] Y. Wang, S. Li, H. Sun, C. Huang, N. Youssefi, *The utilization of adaptive African vulture optimizer for optimal parameter identification of SOFC*, Energy Reports **8** (2022), 551-560.