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Efficient Clumping of Wireless Sensor Networks using Mobile Data Collector Built on Firefly Maximisation Model

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***Abstract*—An effective transmission method is crucial to the long-term network life of a wireless sensor network. Energy constraints in sensor networks are critical since sensor nodes are often battery-powered and it is either impossible or extremely expensive to replenish them in most implementations. The early mortality of sensor nodes and indeed the network's lifespan are commonly caused by an imbalance in data flow in the communication channel. Proposed solutions address this issue and increase network longevity by altering transmission range based on distances between cluster chiefs and their members. In addition, a firefly optimization algorithm-based mobile data collector is used to extend the network's lifespan. For each case, the new method is compared against existing benchmark algorithms. Simulated findings show that the proposed technique beats current ones in terms of network lifespan.**

***Index Terms*— firefly, network delay, optimization, mobile data, wireless sensor networks.**

I. INTRODUCTION

Regarding real-time monitoring in a wide range of applications, from military and environmental to agriculture and psychiatric and health monitoring, a wide variety of sensors are utilised. A sensor node is a device that collects data from its surrounding environment. For further processing, these data are sent to the server through a data forwarding mechanism. Ad hoc communication between sensor nodes is possible [1]. Sensor nodes are now smaller and cheaper to meet real-time demands due to technological breakthroughs in wireless embedded sensors and integrated circuits.

A wide range of elements, such as the deployment, scope of sensors, clustering and routing, energy utilisation, adjusting to internal malfunctions, transmission synchronization, and system security, must be considered for the implementation of effective wireless sensor networks (WSNs). The WSN, on the other hand, suffers from the limitation of sensor battery life. Battery replacement is challenging because of the usual sensor application environment and the WSN is activated [2]. The network comprises of sensors, a sink, and the central node.

Multi-hop transmission is used to either send or route the gathered data to sinks. For each data transaction, the sensors draw energy from the power supply.

In comparison to other sensor nodes, those located near the sink should be able to manage greater data flow. Due to the amount of data they process, their batteries run out more quickly, resulting in the so-called "energy hole."

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Data can't be sent to the source node if there's an energy hole. Premature sensor death and data loss result from this condition. In addition, the network is disrupted, despite the fact that the other detectors have sufficient power to continue working. Sensor deployment, routing, and other methods have been used to extend the network's life and prevent the above WSN concerns. Aggregation, energy management, sequencing, and transmission range adjustment of WSNs have been utilised in a number of studies [3].
Clusters are the smallest units in the sensor network. Each cluster has a cluster head, and the head is rotated dependent on the remaining energy of the sensor nodes in the cluster. Sending and receiving data are the responsibility of the cluster leader. A well-balanced network has a longer lifespan when clustering and routing are properly utilised. The WSN's radio transmission is the primary energy user during the transmission and reception of information [4]. In recent years, the transmission range modification approach has garnered a lot of attention. The transmission distance and data size have the greatest impact on the overall amount of WSN energy consumed.

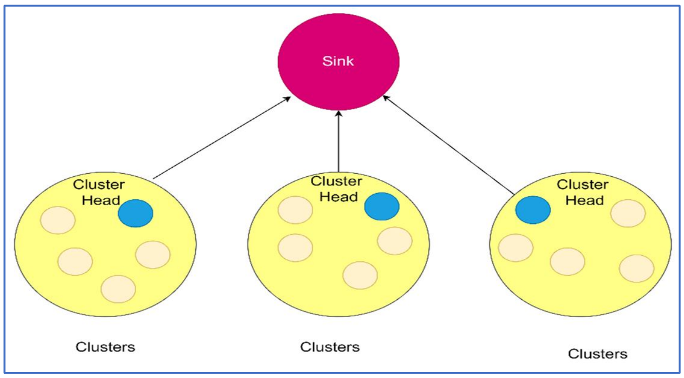

Figure 1. Wireless sensor Cluster formation

Consequently, it is possible to reduce energy consumption and increase network lifespan by adjusting the transmission distance and data traffic distribution. To go from a source node to a base station over long distances and with several hops, most present solutions rely on multi-hop communication. However, the sensor node uses more power while travelling a long distance [5]. The radio transceiver's transmission distance can be lowered to cut down on overall transmission energy usage. Despite this, transmission range modification for clusters is not an acceptable strategy for reducing energy use. In Figure 1, wireless sensor cluster formation is depicted.
As a result, the cluster-based technique necessitates an appropriate communication range modification mechanism. Researchers are increasingly interested in collecting data that used such mobile data collector (MDC). Sink mobility may be achieved in a variety of ways. The MDC is used to minimise the cost of communication between sensor nodes and to extend the network's lifespan. There are two types of MDCs: those that move at random and those that move under control [6]. If the MDC has random mobility, it can roam throughout a particular territory at will, gathering data in the process as it goes. When it comes to this sort of strategy, stochastic movement is the simplest and most straightforward to adopt. Sadly, the results are less than impressive [7].
A large portion of current research is focused on the use of complex software and statistical models to achieve a high degree of control over mobile systems. Controlled mobility's primary goal is to ensure that all cluster heads get visited in an efficient manner without losing any data. The WSN lifetime and energy hole problem can be improved by using an appropriate optimization method to gather data again from cluster heads using MDC. The fundamental goal of this study is to enhance the network's lifespan in light of the above challenges and factors [9].
Before beginning data collection, then use our altered slightly dynamic clustering hierarchy approach to "elect" cluster heads. The suggested range adjustment technique is used by all sensor nodes excluding the cluster heads to automatically modify the transmission range. MDC also uses the firefly-based fastest routing approach to efficiently collect data from all cluster heads. When these strategies are used together, the network's lifespan is greatly increased while eliminating the power gap concern and sensors' untimely expiration [10].
As a result, the following are the article has examined contributions:

- A method for grouping the sensor nodes based on the suggested technique is provided.
- Using a dynamic range modification strategy, the sensor network lifespan may be greatly

increased.

- Using a mobile data collector based on the firefly optimization technique, WSN network lifespan is significantly increased.
- The usefulness of the suggested strategy is demonstrated through comparisons of simulation results with those of existing techniques in a variety of circumstances.

II. LITERATURE SURVEY

We suggest an ACO-based transmission technique for extending the life of a network as much as possible. An energy-efficient and just a balanced distance are the two facets of a local optimal separation system. This method results in high energy efficiency and a satisfying WSN energy balance. Sensor nodes with high power consumption can be kept as low-power as possible by using an optimal solutions acquisition approach. In many real-world applications, sensors are not distributed in a uniform fashion, which is contrary to the work's underlying assumption. Radio interference is reduced by modifying the signal strength of nodes. This enhances traffic-carrying capacity [11]. Figure 2 depicts a simple WSN architecture.

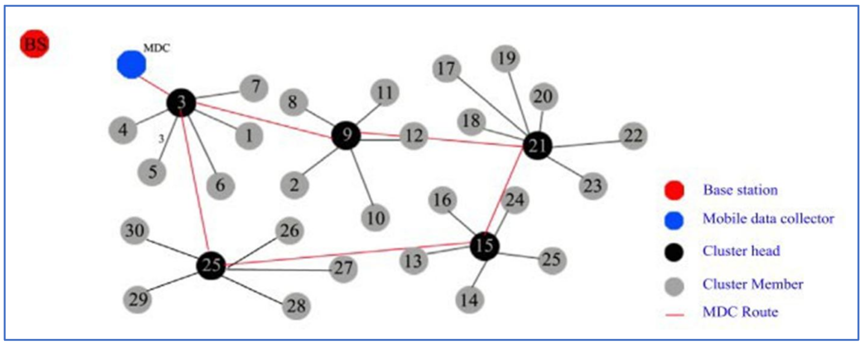

Figure 2. A WSN architecture

A method to improve the WSN's performance and extend its lifespan was proposed by Torkestani, altering transmission power. Individual nodes' transmission power can be dynamically adjusted using a training automaton predicated on a Gaussian distribution. The network's coverage and connection are guaranteed. Despite this, each node has a significant processing burden. As a result, the network's lifespan is reduced. WSN group sizes and broadcast ranges may be set using a cluster-based scheduling algorithm developed by Lai et al. Cluster members near the middle station transmit more data, therefore their batteries run out faster. It's a goal of the cluster head to utilise roughly the same amount of energy as the base station [12].

As a result, the network topology is divided into numerous hierarchical layers, which minimises the size of the clusters around the base station. When it comes to adjusting transmission ranges, the strategy ignores this possibility in favour of concentrating on cluster sizes and hierarchical structures. An enhanced corona model with customizable transmission ranges in WSN and circular multi-hop deployment was presented by Song et al. to avoid the WSN energy hole problem [13]. Node transmission range is an NP-Hard issue; hence two techniques are provided that assign the communication range of sensors within every coronal based on the distribution of nodes. However, this strategy is only appropriate for spiral or circular networks and not for all WSNs.

Here, the issue of a power gap is raised. WSNs may avoid the energy hole and extend their network lifespan by using a communication range control technique that considers both energy consumption reduction and consumption balancing. A short-trip movement technique for ACO has been proposed to reduce the complexity of the algorithm and increase the convergence speed. In spite of this, the resource hole problem continues, and the overall energy usage to compute and modify the range is significant [14]. As previously indicated, a commonly used cluster-based routing protocol, the LEACH algorithm, is designed to increase the lifespan of a network [15]. Despite the fact that LEACH offers intelligent solutions for WSNs, the randomised cluster head selection technique means that there is still a chance of imbalanced cluster formation and the power hole problem arising. Because of this, LEACH has a hard time in real-world use cases [16].

The evolutionary algorithm-based clustering method has been presented to keep the network's energy balance in check. There is a relay node idea applied in the network as an intermediate node among the cluster head and the base station in order to carry out the data transfer procedure." As a result of this algorithm's superiority over

LEACH, it must carry out all of the essential genetic algorithm operations. As a result, these activities have an impact on the network's performance [17]. The sensor nodes use control messages to locate the next best hop to transmit their information to the base station. This has an impact on the network's lifespan. Particle swarm optimization-based clustering for WSNs might help solve this problem (PSO). A supporting node is selected for each cluster head during the cluster building process in order to decrease the cluster head's overhead.

GSA is also used to locate the next optimum hop utilising characteristics such as range and pressure among the sensor's nodes. When gathering data, MDC might take the place of the supporting node technique. Various strategies, including as grouping, forwarding, data gathering, and energy scheduling, were used to increase the network lives of WSNs. To extend the life of the network, smart phones are also used for data collection from cluster heads. A fleet of autonomous robots that can cover the whole network in a short period of time [18]. A travelling salesman problem (TSP), MDC traversal may be handled using nature-inspired algorithms to increase the network lifespan. However, all of these current literatures only talk about the problems of routing pathways, ignoring the possible issues of grouping, transmission range modification, and mobile sink method.

Clustering, transmission range modification, and mobile sinks are effectively addressed in these researches. These works presume that all implementations perform well in every case, and no other techniques examine the conjunction of swarming, communication range modification, and routing with MDC. As a result of our focus on transmission range optimization, the needed transmission ranges for cluster members are automatically modified during data transfer. Firefly MDC installation also helps to move MDC throughout the whole region by utilising the quickest path to gather data, which dramatically enhances network life [19].

III. PROPOSED SYSTEM

All of the components of a sensor node are contained within a single unit. Data is sent and received using a simple radio concept. Power is needed to run the radio and the power amplifier in the transmitter. B bits message transmission across the distance d is estimated using energy consumption by the radio device.

The following features characterise the sensor nodes that are dispersed at random over area R: They are all identical in appearance. Once sensors have been installed in a certain area, they are unable to relocate. All sensors can sense, process, and communicate in the same way. Each sensor's transmission power level may be adjusted to match the communication distance, but the energy it uses is not regenerative. In order to gather data, a mobile sink and mobile gadget with adequate energy can go around the network and examine together all cluster heads inside the area.

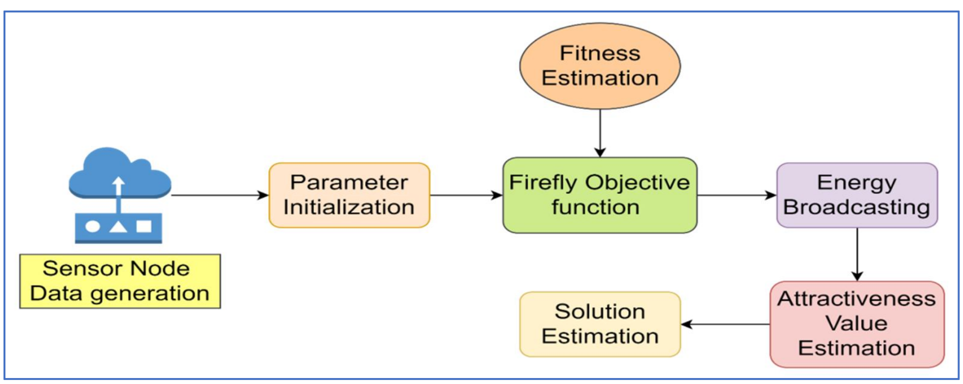

Figure 3. Proposed model architecture

Additionally, there is a maximum transmission range for each sensor. Clusters are sub- networks that make up the complete network. A modified approach is used to cluster the data. The sensor node with the largest residual energy is chosen as the cluster leader for each cluster. Cluster members include the remaining sensors. The remaining energy of the cluster members determines the rotational selection of the cluster head. Sensor nodes inside the cluster send their data from the smart sink via the cluster head. Proposed model architecture and process flow has been depicted in Figure 3.

In terms of the overall network's lifespan, sensor clustering, routing, and communication range adjustment have a significant impact. An efficient network may be achieved by correct clustering, precise range modifications, and optimum routing. There have been a few earlier researches that combined the grouping and transportation without making any range changes, but these studies were few in number. We have made a ground-breaking attempt to extend the life of a sensor network by combining clustering, routing, and transmission range modification. There are three stages to the strategy being presented.

$$E_{tx}(b,d) = \begin{cases} E_{elec} \cdot b + \epsilon_{fs} \cdot b \cdot d^2, & \text{for } d \leqslant d_0 \\ E_{elec} \cdot b + \epsilon_{mp} \cdot b \cdot d^4, & \text{for } d > d_0 \end{cases}$$

Cluster heads and members are selected using a modified clustering technique. Second, the communication range of each member of the cluster is automatically changed in accordance with the distance to the appropriate head of the cluster it corresponds with. To complete the data collection, a firefly-based shortest path routing algorithm is used. There are a lot of clusters that make up the complete network. Each cluster has a cluster head, and the rest of the sensors are members of the cluster. The clustering technique used in this approach has been updated. Random numbers around 0 and 1 are generated by each sensor at the beginning of each cycle.

Each sensor's output is compared to a specified threshold value Th. This means that the sensor node with the lowest value is chosen as the cluster head for the current round if the acquired value is less than Th and no other nodes are available to serve in this capacity within the transmission range. As long as there are two or more sensors available to act as a cluster head, one of the sensors will be designated as a cluster head and all other sensors will be designated as cluster members. The broadcast message is sent to all sensor nodes once the root node has been elected. The remainder of the sensor nodes connect the cluster head based on the sensor's control processes or developed as a consequence.

As a last step, the cluster head broadcasts a TDMA message to its members containing scheduling information for data communication with no network collisions. It is determined how far apart each cluster member is from its head. Base station gathers distances between sensor nodes and cluster heads. If a sensor node's communication distance falls below the high bandwidth level, the node's transmission level is modified accordingly. In order to alter the power level of regular sensor nodes, the base station transmits a control signal. The base station transmits a power level reset signal to all sensor nodes at the conclusion of each round.

A WSN containing 20 sensor nodes and a cluster head of three nodes is an example of this. Once a cluster has formed, the distances between its central node C and each of its members may be computed. As a result of their proximity, cluster leaders and members are linked. It's clear from the distance between them. In addition, the devices are made of a range of transmission levels, from level 1 to level 5, while in operation. When it comes to transmitting distances, there are five levels as Level 1 to 5. Formation of sensor network and their clusters.

Each round, the control signals are used to alter the sensor communication range levels before the communication process begins. Since the distances vary, the transmission levels are set accordingly. Similarly, all sensor nodes' transmission ranges are changed. All sensors' transmission ranges are reset at the completion of each round. All of the cluster heads in R must be collected in a minimal period of time in order for MS to achieve its purpose. As in the TSP, a traveller sees all the cities and returns to their starting point without re-visitation. The ideal solution to the routing problem may be found by finding the least expensive and most complicated permutation of cluster heads. Meta-heuristic algorithms are used since current methods do not deliver the best result.

$$\sum_{i=1}^{n} W_{ij} = 1, j = 1, 2, \ldots, n, i \neq j$$

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Firefly is an algorithm that takes inspiration from the natural world. The bioluminescence feature of the firefly is used to produce brief and pulsating flashes. In order to mate, fireflies use their flash to attract other fireflies. Based on the properties of the firefly, the simulation is conducted in order to apply the firefly method in a continuous domain issue. The purpose of all fireflies is to attract all other fireflies, which is why they are all unisex. For whatever reason, the brighter the firefly is, the less likely it is to fly away from the darker one. Random movement occurs when a firefly can't find a brighter firefly.

$$\min \sum_{i=1}^{n} \sum_{j=1}^{n} C_{ij} W_{ij}$$

$$C_i^{t+1} = C_i^t + \beta_0 e^{\gamma d^2} ij (C_j^t - C_i^t) + \alpha_t \epsilon_t.$$

The objective function determines how brilliant a light is. Early populations of fireflies are generated, and characteristics such as luminosity l, attraction b0, and light optical absorption c values are established in the algorithm's initial stage. One by one, each of these fireflies locates the most dazzling specimen. There is always a firefly that travels toward the brighter one, regardless of its own brightness. The motion of the firefly affects the intensity and beauty of their light. The brightest fireflies will be chosen in the following iteration depending on the goal function. Once the optimal solution has been found, the procedure is repeated until it reaches its convergence rate.

IV. RESULTS AND DISCUSSION

LEACH, PSO, and ACO methods are tested against the suggested technique in this part using MATLAB. Model1 is based on the system grouping and conventional routing algorithms, whereas Model2 is a newer approach that combines the best of both worlds. This model explains how transmission range adjustment is put into action. Model 3 depicts the recommended strategy, which is a combination of clustering and MDC. A 200-by-200-sqm space is home to anything from 500 to 1000 sensor nodes. Initially, all nodes are presumed to have had the same amount of starting energy, and they are placed at random. To evaluate WSN performance, network lifespan is among the most important aspects. The term "network lifespan" has been used variously in the scientific literature. Here, we focus on the final node's lifespan, which is what we're interested in studying for this project.
Minimizing energy usage for data collecting improves the life expectancy of MDC. This MDC visits to each cluster head to gather their data at this stage. While many data passing procedures may be avoided, only one-hop communication collects the information. Like a consequence, the network as a whole utilises very little energy. Show how the proposed strategy and current clustering approaches stack up against the standard routing technique in terms of the time it takes for the first and final nodes to die. As the network size increases, so do the examples. The suggested method is clearly shown to have a longer network lifespan than the current techniques. There are fewer dead nodes if the current clustering and blind packet transmission methods are substituted with the suggested segmentation and MDC data gathering. Energy consumption outcomes are listed in Table I.

TABLE I. ENERGY CONSUMPTION ANALYSIS

	Energy Consumption (J)			
No. of Sensors	**LEACH**	**GA**	**PSO**	**Proposed**
50	19.56	13.65	12.87	10.32
150	21.65	27.85	24.85	19.65
250	42	46.52	41.25	39.05
350	61.52	65.24	63.87	60.99
450	68.35	70.36	71.52	68.12

In addition, the frequent rotation of cluster heads increases network life and maintains network balance. For the following three cases, they compare the number of dead sensors and how many bullets were fired. This number of missing sensor nodes in the algorithms grows as the amount of iterations increase. However, as compared to the current methodologies, the suggested methodology results in a lesser number of dead sensors. Significantly, the network life expectancy is extended by the suggested method That technique is also more appropriate for data collecting in networking of mobile devices, as evidenced by the study. Once the first node dies, the energy usage of the algorithms is shown in Figure 4.

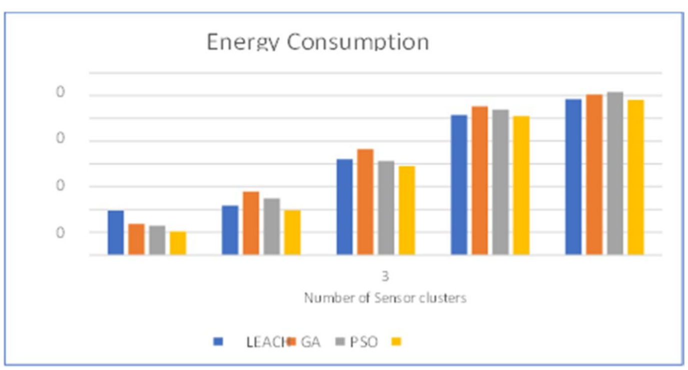

Figure 4. Energy consumption analysis

We can save a little power by sending data to MDC across a shorter distance and using largely one-hop communication in this technique. single or multi-hop transmission is used in the current techniques (GA, PSO, ACO) transfer of information from the member nodes to the sink. The suggested method uses MDCs with optimum routing as well as transmission range modifications for data collecting. A greater amount of leftover energy may be kept compared to the current methods. A typical LEACH sensor consumes 14.81 J of energy, but the suggested technique consumes 11.62 J in model 3. It is shown that the suggested strategy outperforms the currently used clustering and routing methods. The data is collected using MDC, and the network lifespan is extended using an optimization strategy based on fireflies. Table 2 lists the cost per unit analysis results.

TABLE II. COST ANALYSIS

	Cost unit (m)			
No. of Sensors	LEACH	GA	PSO	Proposed
10	785	685	745	589
20	854.23	871.52	814.52	785.58
30	342	346.52	341.25	339.05
40	561.52	565.24	563.87	560.99
50	768.35	770.36	771.52	768.12

Multi-hop communication is avoided because to the rotation of the cluster heads. There are no energy holes or data losses to deal with in this way. Also shown in models 1 and 2 is how the network's life expectancy improves when compared to the previous techniques. Small to large sensor networks can benefit from the suggested technique in terms of the first dead node, power consumption, and the number of dead sensors. According to other approaches now in use, Firefly provides a more optimum solution. Additionally, it can provide results in a short period of time and only require a few numbers of iterations to get to the desired result. Cost unit analysis is depicted in Figure 5. Table 3 contains execution time analysis.

The efficiency of an algorithm might be affected by the unique qualities of each optimization method. Using the firefly features of exploration and exploitation, a better solution is found. The number of movements between fireflies, the quantity of fireflies, and the intensity of the light are the major elements mostly in firefly

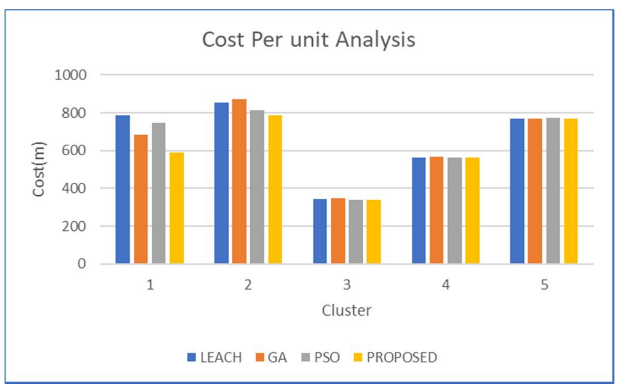

Figure 5. Cost unit analysis

TABLE III. EXECUTION TIME COMPARISON

	Execution Time(ms)			
No. of Sensors	LEACH	GA	PSO	Proposed
200	6.3578	6.12547	6.3254	5.9687
400	8.32547	8.9658	9.325447	8.02147
600	12.32547	13.2547	11.2547	11.03254
800	19.3254	18.3654	17.3682	15.325
1000	24.3654	22.3654	23.3654	21.0315

optimization model. There are a few advantages to using the firefly method over other metaheuristics including GA, PSO as well as ACO, including faster calculation times and easy alternatives in less iterations. Execution time comparative analysis is shown in Figure 6.

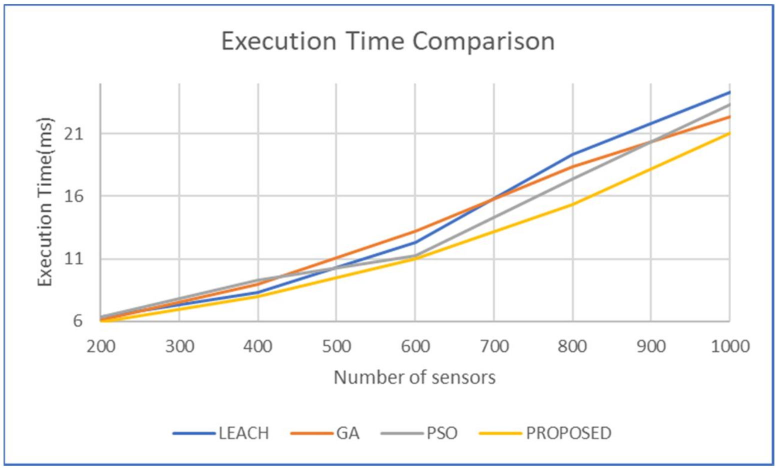

Figure 6. Execution time comparison

V. Conclusion

Clustering algorithms with automated transmission range modification and a firefly- based approach for data gathering are presented in this study to increase the sensor network's life span. In the proposed method, there are two steps. In the first place, the cluster head with each sub-region is dynamically chosen by the system. The broadcast range for other members of the cluster is automatically modified based on the distance they are from each other. In addition, the firefly method is used by MDC to select the ideal shortest route through the complete sensor network for data collection. For dynamic changes in WSN topology, the firefly-based MS method is more appropriate. This method may also be used for a wide range of sensor applications. Overall mean power consumption of endpoints is reduced as a result of the MS method being adopted. Partially linked sensor networks benefit greatly from the suggested strategy. The results of the simulations show that the proposed technique is superior to the already used algorithms. Other optimization techniques with many mobile sinks can be used in the future to achieve the suggested methodology, as well.

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