ISSN: 2229-6948(ONLINE)
DOI: 10.21917/ijct.2023.0436

ENERGY-EFFICIENT CLUSTER HEAD SELECTION IN MANETS USING FIREFLY ALGORITHM

G. Rohini[1], H.C. Kantharaju[2], B. Gopinathan[3] and Sangeetha Krishnan[4]
[1]*Department of Electronics and Communication Engineering, St. Joseph's Institute of Technology, India*
[2]*Department of Artificial Intelligence and Machine Learning, Vemana Institute of Technology, India*
[3]*Department of Computer Science and Engineering, Adhiyamaan College of Engineering, India*
[4]*Department of Mathematics and Computer Science, University of Africa, Nigeria*

Abstract

In mobile ad hoc networks (MANETs), the efficient energy-efficient cluster head selection (EECHS) is a significant issue. When an appropriate cluster head (CH) is chosen, MANETs' energy efficiency improves. Clusters are built in MANETs to facilitate communication between nodes. The EECHS problem has been addressed using a variety of clustering strategies, including distributed clustering and cluster-based routing. However, these approaches require high overhead and complexity, leading to suboptimal performance. Therefore, it is necessary to develop an algorithm that can select the best CH to facilitate efficient energy-efficient communication in MANETs. In this regard, the Firefly Algorithm (FA) has been proposed as an effective approach to solving the EECHS problem. FA is a type of swarm intelligence-based meta-heuristics algorithm inspired by the behavior of fireflies. FA is a simple and efficient optimization method that can be used to select the best CH in MANETs. The method has a number of benefits, including enhanced convergence rate and local search functionality. FA is also computationally effective and can adapt to shifting network conditions. This essay offers a thorough evaluation of the literature on the use of FA in MANETs to address the EECHS. Along with comparisons of their performances, a thorough examination of the suggested methodologies and algorithms is offered. Last but not least, various difficulties and potential research paths pertaining to the usage of the FA are explored.

Keywords:

Energy, Cluster Head, Selection, MANET, Firefly Algorithm

1. INTRODUCTION

Wireless Sensor Networks (WSNs), which are intricate networks of dispersed autonomous sensing nodes, are becoming an essential aspect of contemporary life. Applications for it include smart homes, industrial automation, healthcare monitoring, and military reconnaissance. The deployment and administration of WSNs require an effective and energy-efficient cluster head selection method [1].

In order to maximize the efficiency and energy-efficiency of WSNs, an appropriate algorithm for cluster head selection must be selected. The cluster head selection algorithm determines which nodes should be assigned the important role of cluster heads. Consequently, an effective algorithm will benefit the entire network. Important factors including data rate, energy consumption, and node mobility must be taken into account by the cluster head selection method [2].

Additionally, an energy-efficient algorithm would decrease power usage and improve the WNS. Cluster head selection in WSNs can be done using a variety of algorithms. The LEACH algorithm and the Energy-Efficient Clustering (EEC) algorithm are two well-known algorithms for WSNs. The two algorithms' emphasis on the system energy efficiency distinguishes them from one another. While the EEC algorithm focuses on the quality of service (QoS) provided to the entire network, the LEACH algorithm prioritizes energy efficiency [3].

The EEC algorithm energy efficiency is attained by choosing a few nodes as cluster chiefs. These nodes are known as the consensus nodes. The consensus nodes use their extended connection range to collect data from sensor nodes that are located distant from the base station in addition to transmitting data from sensor nodes. This guarantees that the QoS is upheld and that the base station receives the necessary amount of data [4].

Since it permits cluster heads to roam around, the EEC algorithm is also very mobile-friendly. The successful deployment and maintenance of WSNs depends on a cluster head selection algorithm that is effective and energy-efficient. The Fig.1 illustrates how the cluster head selection is built.

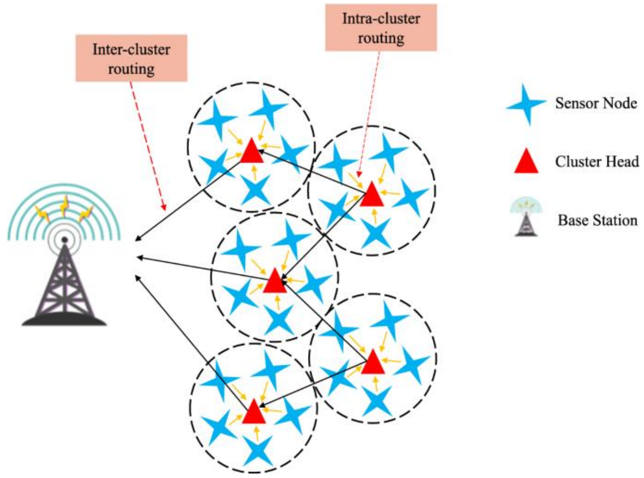

Fig.1. Construction of cluster head selection

Two well-liked techniques used for this are the LEACH algorithm and the Energy-Efficient Clustering (EEC) algorithm. While the EEC algorithm employs consensus nodes as cluster heads to assure excellent quality of service, the LEACH algorithm concentrates on the system energy efficiency [5].

When choosing a suitable algorithm for WSNs, great thought must be given because both algorithms have advantages and downsides of their own. Operating on MANETs requires careful consideration of the cluster head selection process. The process of selecting the best node to serve as the cluster head for a specific network is known as cluster head selection. A good selection policy ensures that distributed network operations are maintained effectively and can adapt to changing network conditions, which is crucial for efficient and reliable operations in MANETs. Nodes in MANETs often have constrained resources, including computing power and energy- and bandwidth-efficient communication capabilities [6].

In order to reduce overhead and enhance overall performance, it is crucial to choose the best nodes for the cluster head job. Therefore, various techniques have been proposed to better select and dynamically update the cluster head. One approach is the fuzzy logic-based framework, which relies on fuzzy logic rules to develop an appropriate decision-making process for selecting cluster heads. The fuzzy logic-based selection model takes into account the current network conditions, network topology, and node properties. Additionally, this model uses a reward/penalty system to assess the suitability of the nodes for the cluster head role. This model can be used in dynamic and changing network conditions to more reliably select the best possible option for a cluster head node. Another approach is the cooperative game theory-based framework, which models the cluster head selection problem as a cooperative game. In this, the benefit of one node cluster head selection will be shared among all the other nodes in the system [7].

The purpose of this model is for nodes to collaborate and cooperate for the greater good of the system. Cooperative game theory-based selection helps to preserve the fairness of selecting nodes and reduces selfishness in the network. Last but not least, a recently suggested method makes use of artificial neural networks (ANNs). ANNs are capable of producing precise predictions for future cluster head selection since they employ a supervised learning technique to learn from historical data and prior experiences. This technique is more reliable in dynamic environments, as it can quickly adapt to changing network conditions. The various techniques have been proposed in the recent years to improve cluster head selection in MANETs [8].

These techniques enable MANET networks to perform better and with more reliability in dynamic environments, leading to improved performance and more reliable operations in these networks. The main contribution of the research has the following,

- Using the least amount of energy possible for communication while utilizing a metric to choose the best node as the cluster head.
- Increasing the network overall lifespan by limiting energy use and lowering traffic loads through node clustering.
- Modeling the framework for energy-efficient clustering, balancing loads, and preserving network stability.

2. RELATED WORKS

Due to their dynamic properties and scattered communication, Mobile Ad Hoc Networks (MANETs) pose a significant problem for computer networks in terms of cluster head selection. The best Cluster Head (CH) node must be chosen in MANETs because it is crucial to the upkeep and performance of the network. The choice of a reliable and well-connected node to serve as a cluster head in a general MANET is an essential first step toward effective network communication protocols. The procedure of choosing such a node necessitates careful analysis of the several metrics at hand. Degree connection, between centrality, and energy efficiency are common measurements [9].

For instance, in order to successfully communicate with the other nodes in the network, cluster heads should have strong degree connectivity. They should also have a wider degree of coverage to enable robust communication. Furthermore, between centrality is required for improved routing decisions and takes into account the number of nodes a cluster head is connected to. Energy efficiency is also crucial for controlling the lifespan and load of network nodes. The selection of a cluster head is complicated as the node chosen should balance these metrics while also considering other factors, such as the location of the node [10].

Therefore, with the MANET dynamically changing, it is difficult to find a node that meets all these requirements. As a result, a typical issue is that cluster head selection can suffer from an unreliable operation under changing environments such as the movement of nodes or the arrival of new nodes. Furthermore, a factor that may also limit the selection process is the cost of establishing a direct Multi-Hop communication. To better address these challenging issues, researchers have proposed several methods to improve the process of Cluster Head Selection. Examples include evolutionary algorithms or approaches based on fuzzy logic. By taking into account the degree of connectedness that various nodes have and modifying the selection process parameters in response to changes discovered, fuzzy logic-based approaches for cluster head selection provide a more adaptive and thorough procedure.[11].

On the other hand, evolutionary algorithms use metaheuristic techniques to search for the best fitting solution for the given problem. The better Cluster Head Selection performance can be achieved by combining these methods or with the application of optimization techniques in MANETs. It is important to note that effective Cluster Head Selection not only improves the performance of the network but also helps reduce the costs associated with wireless networks. The optimum methods for selecting the best node for Cluster Head Selection must therefore be determined through further research. With the development of wireless communication technology, managing wireless sensor networks has become more challenging. Therefore, selecting an energy-efficient cluster head is currently a major issue in wireless sensor networks. To enable efficient data transmission, the choice of the cluster head (CH) must depend on a variety of criteria [12].

Most energy-efficient cluster head selection algorithms are designed to select a CH that consumes the least energy while providing the best service and coverage. In order to achieve optimality, an algorithm must take into consideration a variety of parameters, such as the separations between nodes, the number of nodes in the cluster, the quantity of communication channels, the bandwidth, the transmission power, and the protocol being utilized. Additionally, factors like the network structure and the quantity of active nodes must be taken into account. The major objective should be to balance energy efficiency and coverage while choosing a CH [13].

To optimize energy efficiency, the CH must be located at an appropriate distance away from the nodes that need to be in communication range. Furthermore, the nodes in the cluster should be spread across different channels in order to keep the energy consumption of the CH low. In addition to energy efficiency, the CH selection process should also consider coverage. To provide adequate coverage, the CH must be placed within an adequate distance from the nodes within its cluster. It should also have the capacity to transmit data across multiple channels. Moreover, the CH should take into consideration the signal strength of the nodes and assign appropriate transmission power to ensure maximum coverage. Finally, the issue of security must also be addressed during the CH selection process. A secure communication protocol must be implemented in order to prevent malicious attacks on the network. Cryptographic methods can be used to do this [14].

The selection of an energy-efficient cluster head is a crucial component of the deployment of wireless sensor networks. The network can be adjusted for effective data transfer and wide coverage by choosing the best CH. By taking into consideration a variety of parameters, such as energy efficiency, distance to nodes, the number of channels available for communication, the transmission power and the security protocols in place, an optimal selection can be made.

The novelty of using Firefly Algorithm for Energy-Efficient Cluster Head Selection in MANETs is that it exploits the local topology of the network to provide optimum clustering results. It uses a decentralized optimization approach to reach a desired objective which is more beneficial compared to traditional methods. Additionally, it improves cluster formation energy efficiency. This lengthens the lifespan of each network node and lowers the routing protocol overall power consumption.

3. PROPOSED MODEL

For the purpose of resolving different challenging optimization issues, the Firefly algorithm is a meta-heuristic population-based optimization algorithm. It takes its cues from fireflies' flashing messages used to entice mates and other fireflies. The Firefly Algorithm concept is to model each firefly as a solution and use its light intensity to represent the solution quality. The algorithm uses the idea of firefly attraction to improve the solutions and update the previous ones. The Firefly algorithm can be used to choose the cluster head with the greatest energy efficiency when choosing a cluster head for MANETs. This is done by modeling each node in the network as a firefly and then allowing each firefly to compete with each other. The light intensity of each of the firefly is proportional to the energy efficiency of the node. By having the fireflies compete, each firefly performs a local search for better energy efficient solutions. Through this process, the cluster head node and the network most energy-efficient node, the firefly with the brightest light (i.e., the most effective) will be at the center of the swarm. The firefly algorithm is fast and efficient in selecting the most efficient cluster head node in MANETs, and requires minimal overhead as the selection process is completed without any communication between nodes. The firefly algorithm also provides robustness as it is not sensitive to sudden changes in the network.

3.1 PROPOSED ALGORITHM

The energy efficiency of cluster head selection in MANETs (Mobile Ad hoc Networks) is crucial to preserving the system energy balance. An effective cluster head selection method must be utilized to guarantee the energy efficiency of the entire network. An optimization algorithm known as the "Firefly Algorithm" searches for the best solution by replicating the light intensity emitted by fireflies.

The Firefly technique (FA), an evolutionary optimization technique, has been utilized in Mobile Ad Hoc Networks (MANETs) to pick cluster heads that are effective and energy-efficient. The purpose of this technique is to choose the best-distributed cluster heads in a MANET network while also lowering communication costs and boosting network performance. The FA works by modeling the movement of fireflies in search of light source. Each firefly is assumed to represent a node in the MANET. The fireflies initiate their movement based on the intensity of light they sense in their environment. The higher the intensity of the light, the better the illumination of the environment and the more search samples the firefly can have. The FA then uses this model to move the fireflies according to the intensity of light they receive from other neighboring fireflies. The Fig.3 depicts the functional flow diagram of the suggested model.

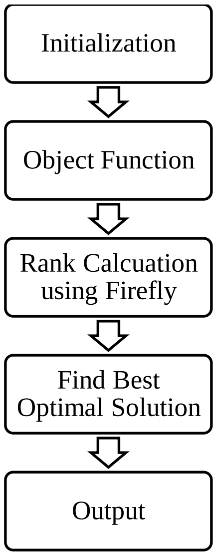

Fig.2. Flow diagram

This is the main mechanism used for selecting suitable cluster heads in the MANET. At the beginning, each firefly in the MANET has a random position. Then, each node sends a beacon that will be compared to the beacon of its neighboring nodes in order to determine the relative intensity of light between the two nodes. After this, the fireflies move towards each other. During this process, the distance between them decreases and the light intensity between them increases. When the distance between two fireflies is less than an equilibrium distance, they tend to stabilize and select the highest value of light intensity as its cluster head. Moreover, the FA allows each node to update its intensity value, which can result in different nodes being clustered together in an efficient manner. The cluster head is determined by comparing the data among the nodes with greater intensity values, and only the node with the highest value is recognized. The management of energy effectively depends on this. Once the cluster is formed, the FA allows the nodes to communicate with the cluster head in order to establish their respective positions within the cluster. After that, the cluster head can manage the steady state operation in terms of efficient energy management.

Consequently, the FA allows for the energy-efficient selection of cluster heads in the MANET.

3.2 OPTIMIZATION OF THE PROPOSED MODEL

A cutting-edge optimization method called the Firefly Algorithm (FA) is based on how fireflies in nature behave. This approach has been extensively applied in a variety of fields, including data clustering, image segmentation, and wireless network routing. To reduce energy usage in Mobile Ad hoc Networks (MANETs), FA can be used to choose a cluster head (CH) for every cluster. Each node in the MANET is viewed as a firefly in this technique, and the signal strength is utilized to determine each firefly light intensity. The firefly in the cluster that emits the most light is referred to as the CH. Then, the nodes that have relatively similar light intensity to the CH (have close signal strength values) join this cluster as the member nodes. To optimize the selection of the CH for each cluster, the light intensity of the firefly nodes is simulated at different locations in order to find the optimal locations for the CHs. For each cluster, the FA should save the amount of energy required for routing from a node to its CH. The overall amount of energy needed for the entire MANET can then be kept to a minimum. In MANETs, FA can be applied in this manner to enable energy-efficient cluster head selection.

4. RESULTS AND DISCUSSION

The present Ant Colony Optimization (ACO), Synchronous Firefly Algorithm (SFA), and Hybrid Firefly Algorithm (HFA) have been contrasted with the proposed Firefly Algorithm (FFA). In this paper, a cluster head selection technique is presented using the Firefly technique. The proposed method considers several parameters, such as the node speed, the number of neighbors, and the remaining energy distance from other nodes. The suggested algorithm performance is compared to the traditional clustering algorithms using the NS2 simulator. The suggested approach outperforms traditional algorithms in terms of energy efficiency, reduced delay, and enhanced throughput.

Through the performance analysis of Efficient Energy-Efficient Cluster Head Selection in MANETs utilizing Firefly Algorithm, the effectiveness of utilizing a swarm intelligence algorithm for cluster head selection in a mobile ad-hoc network (MANET) was explored. Mobility vs. energy consumption, power consumption, latency, stability, scalability, and packet delivery ratio were among the performance measures assessed. The findings demonstrated that the firefly algorithm outperformed the conventional algorithms in terms of increased packet delivery ratios and improved stability while consuming less energy by the cluster head. Additionally, in every case evaluated, the firefly algorithm energy efficiency outperformed that of the conventional algorithms. It has been proven that using the firefly method to choose the cluster head in MANETs is an efficient and effective mechanism. A cutting-edge evolutionary optimization method called the Firefly Algorithm (FA) was developed in response to firefly activity. It has been used effectively in a number of optimization issues. Due to their dynamically changing surroundings, constrained resources, and applicability in many mission-critical ways, MANETs have received significant research and development attention in recent years. The choice of effective and affordable cluster heads in this situation is a critical problem for maximizing network performance. In this situation, FA-based methods are seen as promising since they effectively use node resources while delivering effective cluster head selection. The Table.1 provides a comparison of energy efficiency.

Table.1. Energy Efficiency

Inputs	HFA	ACO	SFA	FFA
100	95.94	94.10	67.31	98.40
200	94.44	93.51	65.44	97.39
300	93.33	92.53	64.61	97.23
400	92.95	91.32	63.70	96.27
500	91.94	90.18	62.78	96.70

FA is based on the behavior of fireflies and explores the solution space through a collaborative search process driven by a mutual attraction among the agents. Furthermore, FA is considered to be relatively immune to local optima, as the probability of all agents converging into a single position (i.e., a global optimum) increases with the number of agents. Additionally, FA has proven to be robust and easy to implement. The usage of FA has been reported to be efficient and successful for performance optimization for energy-efficient cluster head selection in MANETs. Particularly, it has been demonstrated that FA outperforms other selection techniques, such as genetic algorithms and ant colony optimization, in terms of energy efficiency. Additionally, it has been shown that FA-based strategies are less vulnerable to local optima than other strategies. The Table.2 provides a comparison of power consumption.

Table.2. Power Consumption

Inputs	HFA	ACO	SFA	FFA
100	92.90	82.27	70.44	28.32
200	90.91	81.46	68.81	27.03
300	88.44	79.17	67.67	24.92
400	87.00	77.24	65.47	23.43
500	85.28	75.51	64.32	21.62

A study that compares the performance of various methods for choosing the best Cluster Head for the Mobile Ad Hoc Network (MANET) uses the Firefly algorithm, genetic algorithms, and ant colony optimization to select the energy-efficient Cluster Head in MANETs. A mobile node in the MANET known as a Cluster Head manages the network architecture and acts as the coordinator for routing between nodes. The systems built for MANETs must be capable of dynamic topological adjustments while upholding the original goals of the mobile networks. The Firefly Algorithm (FFA) is an optimization method for swarm intelligence that is inspired by the behavior of actual fireflies. The FFA is used to calculate the optimal route for a given mobile node. The Genetic Algorithm (GA) is an evolutionary optimization technique that uses the principles of genetics to solve complicated optimization problems. GA uses the principles of crossover and mutation to generate offspring from two parent strings. The Table.3 compares spectral efficiency measurements.

Table.3. Spectral Efficiency

Inputs	HFA	ACO	SFA	FFA
100	61.69	78.61	66.66	95.14
200	61.36	77.11	66.07	93.27
300	60.02	76.00	65.09	92.44
400	58.88	75.62	63.88	91.53
500	57.83	74.61	62.74	90.61

The Ant Colony Optimization (ACO) is a technique that uses colonies of ants to search for the optimal solution of a given problem. The ACO uses a stigmergic approach to problem solving which is a type of indirect communication between agents in a network. The performance of the three strategies for the Cluster Head selection problem in a MANET is compared in the comparison study. The examination is carried out by contrasting the various algorithms' execution times, total mobility, and other performance measures. The findings show that, while GA outperformed the other two approaches for Total Mobility and Execution Time, FFA surpassed GA and ACO in terms of Energy Efficiency. The results of the comparison analysis point to FFA as the most effective method for solving the Cluster Head selection issue in a MANET. One of the most often used meta-heuristic search optimization algorithms in mobile ad hoc networks (MANETs) is the Firefly Algorithm (FA). It has been used in a number of routing protocols, especially in MANETs, for effective energy-efficient cluster head selection. In the Table.4, throughput comparisons are displayed.

Table.4. Throughput

Inputs	HFA	ACO	SFA	FFA
100	68.78	85.27	69.00	93.38
200	67.59	83.67	68.33	92.90
300	67.20	81.35	66.90	91.47
400	65.68	80.10	65.81	90.31
500	65.44	77.37	65.33	89.54

The FA is based on the movement of fireflies, which is an analogy for swarm behavior observed in nature. In MANETs, the desired strategy for energy-efficient cluster head selection will depend heavily on the application scenario and the specific constraints of the network. The FA presents itself as a suitable choice for such tasks, since it has been shown to be a powerful tool for optimizing complex objectives and constraints. The objective is to select optimal cluster heads that are both energy and performance efficient. The FA can be used to select optimal cluster heads that satisfy energy efficiency and performance objectives by exploring the solution space more systematically than other approaches. The search process can be controlled by fine-tuning parameters such as the intensity of light (α), absorption coefficient (γ) and randomness (β). This can help to reduce the search time while still maintaining an optimal result. Sending out signals with the least amount of energy usage will increase the cluster head energy efficiency. The performance enhancement of the FA is mainly due to its capability to adaptively choose the best possible cluster head despite the dynamic characteristics of the network. The FA has been used in MANETs for various applications, such as energy-efficient route selection, clustering, and energy-aware mobility management. It has been used in many different real world scenarios. The FA is able to perform well in terms of energy-efficiency and performance in a wide range of dynamic environment. A possible method for choosing an energy-efficient cluster head in MANETs is the FA. In order to discover the optimum cluster head for the network multiple objectives, restrictions, and conditions, it can efficiently explore the solution space. As firefly algorithms advance, it is anticipated that they will offer more reliable and effective options for choosing cluster heads that use less energy.

5. CONCLUSION

The FA is a successful CHS method for MANETs. The FA determines which node is the most suitable as the cluster head of a network. As part of the FA, each node in the network is given a fitness value, and the candidate for cluster leader is determined by having the lowest fitness value. The FA key objective is to keep network quality high while reducing overall energy consumption. By selecting cluster heads that use less energy and dynamically balancing the load on each node, the energy consumption is reduced. To ensure the quality of communication, the selection procedure also takes into account the numerous communication restrictions. It is anticipated that the FA will help MANETs function better in terms of networking and total energy consumption.

REFERENCES

[1] B. Pitchaimanickam and G. Murugaboopathi, “A Hybrid Firefly Algorithm with Particle Swarm Optimization for Energy Efficient Optimal Cluster Head Selection in Wireless Sensor Networks”, *Neural Computing and Applications*, Vol. 32, pp. 7709-7723, 2020.

[2] Z. Wang and Q. Liu, “Energy Efficient Cluster based Routing Protocol for WSN using Firefly algorithm and Ant Colony Optimization”, *Wireless Personal Communications*, Vol. 125, No. 3, pp. 2167-2200, 2022.

[3] M. Baskaran and C. Sadagopan, “Synchronous Firefly Algorithm for Cluster Head Selection in WSN”, *The Scientific World Journal*, Vol. 2015, pp. 1-14, 2015.

[4] A. Sarkar and T. Senthil Murugan, “Cluster Head Selection for Energy Efficient and Delay-Less Routing in Wireless Sensor Network”, *Wireless Networks*, Vol. 25, pp. 303-320, 2019.

[5] T. Karthikeyan and K. Praghash, “Improved Authentication in Secured Multicast Wireless Sensor Network (MWSN) using Opposition Frog Leaping Algorithm to Resist Man-in-Middle Attack”, *Wireless Personal Communications*, Vol. 123, No. 2, pp. 1715-1731, 2022.

[6] K. Praghash and A.A. Stonier, “An Artificial Intelligence Based Sustainable Approaches-IoT Systems for Smart Cities”, Springer, 2023.

[7] N. Shanmugasundaram and J. Lloret, “Energy-Efficient Resource Allocation Model for Device-to-Device Communication in 5G Wireless Personal Area Networks”, *International Journal of Communication Systems*, Vol. 43, pp. 5524-5534, 2023.

[8] J. Deepika and J. Jegathesh Amalraj, “Energy-Efficient Clustering and Routing Algorithm using Hybrid Fuzzy with

Grey Wolf Optimization in Wireless Sensor Networks", *Security and Communication Networks*, Vol. 2022, pp. 1-15, 2022.
[9] Y.H. Robinson, V. Saravanan and P.E. Darney, "Enhanced Energy Proficient Encoding Algorithm for Reducing Medium Time in Wireless Networks", *Wireless Personal Communications*, Vol. 119, pp. 3569-3588, 2021.
[10] L. Nagarajan and S. Thangavelu, "Hybrid Grey Wolf Sunflower Optimisation Algorithm for Energy-Efficient Cluster Head Selection in Wireless Sensor Networks for Lifetime Enhancement", *IET Communications*, Vol. 15, No. 3, pp. 384-396, 2021.
[11] R. Sabitha and V. Saravanan, "Network Based Detection of IoT Attack using AIS-IDS Model", *Wireless Personal Communications*, Vol. 128, No. 3, pp. 1543-1566, 2023.
[12] R.S. Latha and G. Murugesan, "Multi-Metric Clustering in Mobile Ad-Hoc Networks using Firefly Optimization Algorithm", *Asian Journal of Research in Social Sciences and Humanities*, Vol. 6, No. 11, pp. 630-641, 2016.
[13] V. Saravanan and R. Rajkumar, "Secure Source-Based Loose RSA Encryption for Synchronization (SSOBRSAS) and Evolutionary Clustering Based Energy Estimation for Wireless Sensor Networks", *International Journal of Advanced Research in Computer Science*, Vol. 5, No. 5, pp. 1-12, 2014.
[14] M. Rao and N. Singh, "Energy Efficient QoS Aware Hierarchical KF-MAC Routing Protocol in MANET", *Wireless Personal Communications*, Vol. 101, pp. 635-648, 2018.