International Journal of
Intelligent Engineering & Systems

http://www.inass.org/

Fuzzy C Means Clustering and Sea Lion Optimized Routing for Mobile Adhoc Networks

K. Paul Joshua[1]* **D. Srinivasa Rao[2]** **D. Madhivadhani[3]** **Lily saron grace[3]**

[1]*Department of Electronics and Communication Engineering, St. Peter's College of Engineering and Technology, Chennai-600054, Tamil Nadu, India*
[2]*Department of Computer science and Engineering, Medi- Caps University, Indore, Madhya Pradesh, India*
[3]*Faculty of Electronics & Communication Engineering, Kings Engineering College, Chennai-602117, India*
* Corresponding author's Email: kpauljoshua06@gmail.com

Abstract: Mobile ad hoc networks (MANET) are self-launching and self-building multichip wireless networks in which the system's construction deviates significantly owing to the mobility of the nodes. Network nodes serve as both hosts and routers, transferring data from other network nodes. MANETs necessitate an efficient routing protocol with a quality of service (QoS) component. They do not consider mobility as a potential restriction for routing concerns. It is challenging to maintain the necessary QoS in the network due to node mobility, which frequently causes connection failures and high error rates. The aim of the proposed study is to develop an effective MANET framework with dynamic routing and enhanced clustering. In this work, Fuzzy C means clustering is utilized to form the clusters identifying communities or groups of nodes with similar characteristics or behavior, whereas sea lion optimization (SLnO) is utilized to attain the best routing path for data transmission. The proposed model is empirically tested and compared with particle swarm optimization (PSO), ant colony optimization (ACO), grey wolf optimization (GWO), and genetic algorithm (GA) in terms of factors such as throughput, packet loss, energy consumed and end to end delay. The findings demonstrate that SLnO algorithm outperforms other protocols in terms of efficient routing generating a throughput of 680Mb/s and a packet delivery ratio (PDR) of 93.6%.

Keywords: Fuzzy C means clustering, Sea lion optimization, MANET, Multimedia services.

1. Introduction

A mobile Ad Hoc network (MANET) is a decentralized and self-configuring wireless network comprising numerous nodes that are capable of dynamic movement, leading to a constantly changing network topology. MANET facilitates communication without the need for centralized administration and operates using wireless technologies like WiFi, ZigBee, and WiMAX. The primary application of MANET is in scenarios where establishing a fixed infrastructure is impractical, such as battlefields, vehicles, disaster areas, military operations, ships, and aircraft. In these situations, MANET enables devices to create temporary networks, allowing seamless communication both within and beyond the network coverage area [1]. The MANET, however, might make the system more vulnerable to attacks because of its decentralised control, resource limitations and poor connectivity. To increase network's resilience to purposeful attacks, it is vital to first identify and then protect the critical nodes in a MANET network. As a result, the connection between MANET and IoT generates a new MANET network that increases end users' mobility and lowers the network's development costs [2].

MANET is a collection of self-governing nodes that can dynamically learn and update their network topology, allowing them to route packets between nodes. In this network, packets are transmitted in a multi-hop manner from source to destination. However, due to the mobility of nodes in MANETs, routing path frequently changes, leading to packet drops. Consequently, the packet delivery rate in MANETs tends to be low [3].The routing protocol plays a vital role in MANETs due to the numerous constraints posed by the network and node conditions[4]. MANET suffers from fast network fluctuating mobile density, topology change and frequent connection ruptures, all of which lead to unpredictable network connectivity. In order to tackle this issue and to attain efficient routing, various optimization algorithm and clustering techniques are employed [5]. Because of the enormous traffic created by comprehensive access and multimedia applications with QoS needs, MANETs consume a significant amount of energy. The continuous high volume of traffic in mobile ad hoc networks not only depletes energy but also leads to network congestion and potential data loss, thereby impacting network performance negatively [6].

MANETs can have a huge number of nodes, and typical flat routing techniques may become inefficient as the network increases. Hence, clustering is used which divides the network into smaller, more manageable groups, reducing the overhead associated with routing and maintaining neighbor information. The unlabeled dataset is separated into various groups using an unsupervised learning technique called K-Means clustering. In order to facilitate efficient routing, the K-means clustering structure groups and shares routing information [7, 8]. However, it is significantly dependent on the original positioning of centroids. Varied initializations may result in varied final cluster assignments, resulting in suboptimal or inconsistent clustering results. K-means clustering is also ineffective in detecting clusters with non-convex forms [9, 10]. The network's lifetime is also maximized by employing a cluster head selection and formation approach based on fuzzy logic. As the network size grows, the algorithm's scalability may be limited, and it may struggle to handle large scale networks effectively. Moreover, they may not necessarily consider global optimization criteria. Hence, this work uses Fuzzy C means approach for clustering which provides soft clustering, meaning that data points can belong to multiple clusters simultaneously with different membership degrees.

Bio-inspired algorithms are computational techniques that mimic the behavior and principles found in nature, where various organisms react to different situations either as individuals or as a group. These algorithms have proven to be more efficient and autonomous in the setting of MANETs than conventional Artificial Intelligence algorithms, particularly in new and dynamic contexts. As a result, there have been numerous research studies exploring the use of these bio-inspired algorithms as routing protocols in MANETs [11, 12]. The GA possess a best solution and a feasible solution for routing. Both solutions result in a string of nodes connecting source and destination nodes. The operators of GA involve selection, crossover and mutation and it works on its own internal rules. However, for dynamic data sets the rules of GA are not applicableand the algorithm may converge too slowly, leading to longer optimization times and potentially getting stuck in suboptimal solutions [13, 14]. In such condition, improved GA is introduced for routing. The effectiveness of improved genetic algorithms can heavily depend on how the routing problem is represented. Selecting an appropriate representation that captures the problem's characteristics is essential for achieving good results. It also fails to yield local optima when the fitness function isn't precise [15].In PSO, the swarm simultaneously searches and analyses alternative locations based on survival criteria. Once the best location has been identified, it is shared with other members to gather at a suitable spot at the same time [16, 17]. In PSO algorithm, dealing with circumstances such as out of bounds is extremely challenging. PSO's performance is sensitive to the values of its parameters, such as the acceleration coefficients, inertia weight, and population size. Also, it lacks the capacity to extract ideas into mathematical calculations and it necessitates a thorough understanding of the issues [18, 19].The ACO is introduced to identify the most efficient routing path in MANET. In ACO, multiple travel paths are stored in routing table based on the pheromone information. The ACO possess low communication cost and it supports both wired and wireless network. [20, 21]. Anyway, it relies on exploration and exploitation, making it susceptible to getting trapped in local optima and not exploring other potentially better solutions.In the event of a network loss, planned path becomes unsuitable and the ideal way becomes unavailable. In addition, the option of choosing an alternate path is limited in ACO [22, 23]. Grey Wolf Optimization (GWO) is a promising algorithm that has been applied to various optimization problems, including routing in MANETs. GWO can converge prematurely, meaning that it might settle on suboptimal routing paths before exploring the entire solution space thoroughly. This can result in suboptimal or inefficient routing decisions in MANETs [24]. Whale optimization algorithm (WOA) is another bio-inspired optimization technique for solving various optimization problems. In spite of its numerous merits, it may take longer to adapt to new network

Received: May 19, 2023. Revised: September 12, 2023.

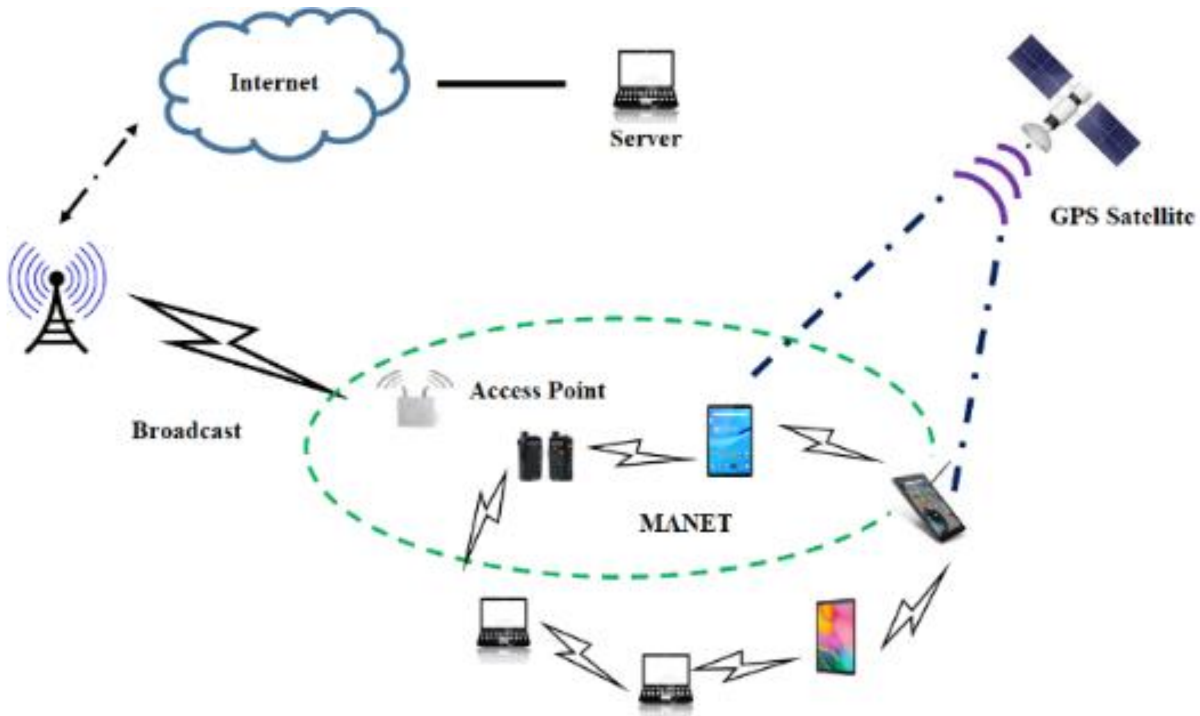

Figure. 1 MANET structure

topologies, leading to potential inefficiencies in routing decisions. [25].

To tackle all the above mentioned issues, Fuzzy C means clustering and sea lion optimization (SLnO) algorithm are utilized for attaining best path in multimedia network access. The Fuzzy C meansclusters the sensor nodes based on their characteristics such as sensor readings or energy levels. This facilitates data aggregation, routing and energy management in the network.The SLnO aids in finding more optimal routes in large and complex MANETs, leading to reduced latency and better resource utilization. The simulation of the suggested technique is implemented using NS2 software. Finally, the suggested technique is compared with GWO, GA, PSO and ACO in terms of factors such as throughput, packet loss, energy consumption, and end to end delay. When compared with these existing literatures the proposed one offers better results for clustering and routing with improved convergence outputs.

The structure of the paper is given as follows: Methodology of proposed model in section 2, results and discussion in section 3 and conclusion in section 4.

2. Methodology of proposed model

2.1 MANET

The wireless network known as a MANET is infrastructure free, self-organizing and quick to construct, making it particularly suitable during special communications in areas lacking radio infrastructure, outdoor events, crises, natural catastrophes and military operations. The IEEE 802.11 MANET swarm for mobile hydropower plant monitoring, under SDN control. Cameras, different sensors and other components are included in the affordable wheeled mobile hardware. To build the MANET node and provide sensitivity and mobility. Fig. 1 depicts the structure of a MANET.

The network design of MANET becomes more dynamic as multimedia wireless networks become more mobile, causing network congestion. Congestion occurs when there is an excess of communications within a network. As a result, enhancing dynamic routing algorithms for multimedia wireless networks is critical, since routing is directly related to network and user service quality. Hence, Fuzzy C means clustering and SLnO is utilized for attaining effective dynamic routing approach in multimedia networks.

2.2Fuzzy C means clustering

The clustering of nodes by Fuzzy C means algorithm is represented in Fig. 2.

2.2.1. Collision detection

A formal measurement based technique is employed to determine the occurrence of collision in the channel path during the collision detection phase.

Received: May 19, 2023. Revised: September 12, 2023.

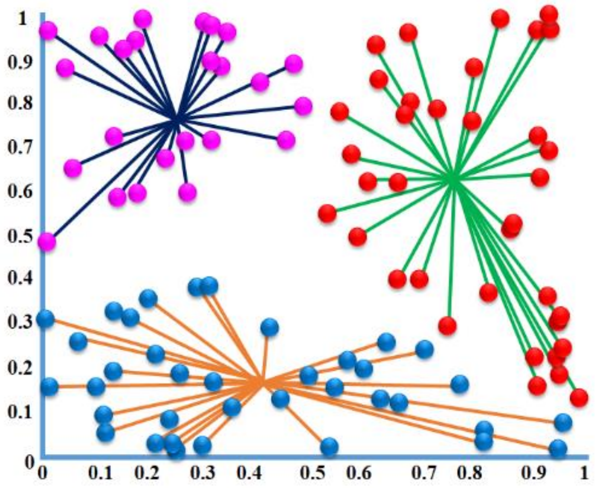

Figure. 2 Clustering by Fuzzy C means algorithm

In general, a measurement based technique uses characteristics such as the channel occupancy duration, the amount of messages in the queue and the amount of channel utilisation to identify collisions. In the proposed study, the amount of messages in the queue waiting to be delivered to the automobiles are examined. When the amount of messages in the queue exceeds the number of messages transferred per second, the detector identifies a collision and reports it to the data control unit, which takes appropriate action.

2.2.2. Data control phase

Gathering of data, filtering of data and clustering of data are used in the data control phase. The communications sent between mobiles are collected in the data gathering sub-phase. In our collision avoidance technique, data collection has been handled in two ways. After the identification of congestion, the data to be shared among the automobiles is gathered for filtering and clustering in the first technique. The data previously transferred between the automobiles are collected in RSU in the second approach, allowing the training process to be handled. The redundancy in the gathered data is removed during the filtering process to reduce the computing time. The filtered data from both approaches is forwarded in the data clustering step.

When there is a chaotic state, Fuzzy logic is one of the most current advances in clustering and decision making. A real number between the binary values 0 and 1 has been defined as Fuzzy logic by definition. The Fuzzy c-means clustering technique divides unlabelled data into a number of predetermined clusters, allowing the priority of messages to be defined and processed for communication. Since the messages in MANET are different in their categories and also unlabelled, Fuzzy logic has been utilised to cluster them.

The Fuzzy C-means clustering technique is utilized to cluster MANET signals in this study. The Fuzzy technique differs from other standard clustering algorithms, which group messages according to their degree of truth. The goal of clustering method is to reduce distance between the cluster's centroid c_j and the message x_i.Mathematically, the goal is expressed as follows:

$$O_{FCM} = \sum_{i=1}^{P}\sum_{j=1}^{N} U_{i,j}^{m} \times d\,(x_i, c_j) \qquad (1)$$

Such that $\forall i \epsilon P, \forall i \epsilon N$

Here, O_{FCM} denotes the objective function, the number of messages to be clustered is denoted byP, $U_{i,j}^{m}$ represents the membership value, the number of clusters is denoted by N , $d(x_i, c_j)$ indicates the distance between x_i and c_j and the coefficient each element in matrix $U_{N\times P}$ is denoted by$m$.

$$U_{i,j} = \begin{cases} 1, & if\ x_i \in 0 \\ 0, & otherwise \end{cases} \qquad (2)$$

$$U_{I,j}^{m} = \begin{bmatrix} U_{1,1} & U_{1,2} & .\,U_{i,j} \\ U_{2,1} & . & .\ \ . \\ U_{I,1} & . & .\,U_{i,j} \end{bmatrix} | U_{i,j}^{m} \in \mathbb{R} \qquad (3)$$

The Euclidean distance between the messages x_i to c_j is given by $d\,(x_i, c_j)$ and it is determined as follows,

$$d\,(x_i, c_j) = \sqrt{(x_{i,1} - C_{j,1})^2 + (x_{i,2} - C_{j,2})^2 + \cdots + (x_{i,z} - C_{j,z})^2} \qquad (4)$$

Here,

The number of characteristics that constitute the message $x_i$isz and c_j is the centroid of each cluster. Each coefficient is computed in the following way:

$$U_{(i,j)k}^{m} = \frac{1}{\sum_{k=1}^{N}\left(\frac{d(x_{ik}, c_{jk})}{d(x_{ik}, c_{jk})}\right)} \qquad (5)$$

Every cluster's centroid is modified at each iteration to minimize the aim of the function specified in Eq. 1 as follows:

$$C_{jk} = \frac{\sum_{i=1}^{P}(U_{(i,j)k}^{m} \times x_i)}{\sum_{i=1}^{P} U_{(i,j)k}^{m}} \qquad (6)$$

Received: May 19, 2023. Revised: September 12, 2023.

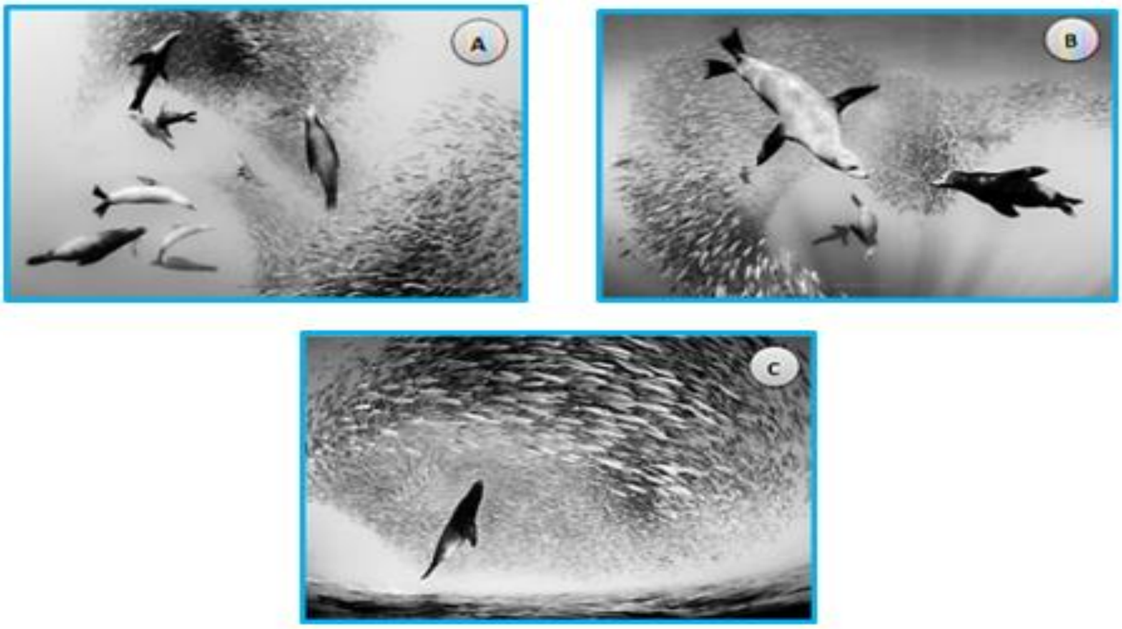

Figure. 3 Sea lion hunting behaviour

C_{jk} denotes the $k-$th component of the cluster center of cluster j. The pseudocode for clustering MANET messages using the Fuzzy C means technique is presented in Algorithm 1 based on the previously mentioned equations.

2.2.3. FCM-MANET clustering

When choosing cluster heads, it's necessary to seek the fastest way for transferring data between the automobiles or servers. For this process, the Sea Lion Optimized algorithm is utilized in the proposed model.

Input: $X \leftarrow \{X_1, X_2, \dots, X_i, \dots, . X_p\}$ Where P is the number of messages to be clustered
$X_i \leftarrow [X_{i,1}, X_{i,2}, \dots, X_{i,z}]$ Where z is the number of features of message
$C \leftarrow \{c_1, c_2, \dots, c_j, \dots, . c_N\}$Where N represents the number of Clusters.
$c_j \leftarrow [c_{j,1}, c_{j,2}, \dots, c_{j,z}]$Where z is the number of features of cluster center
c_j
Max_IT represents the maximum number of iterations
Assign values for m,c,z,N
begin
Initialize U_{NXp}
Repeat
For each j∈N do
Compute mean value of each cluster for c_j using Eq. (1)
End for
Compute $U_{i,j}$∀i ∈ P, ∀j ∈ N using Eq. (2)
Until (termination condition not satisfied)
Compute $U_{i,j}$∀i ∈ P, ∀j ∈ N using Eq. (2)
Until (termination condition not satisfied)
End
Output: C

2.3 Sea lion optimization (SLnO) algorithm

One of the most intellectual creatures on the planet is sea lion. Sea lions exist in massive colonies with 1000 of associates. Sea lions manoeuvre their way around their groups various times throughout their lifetimes. They lions have the capacity to detect fish and respond quickly, gathering them in deep water along the coast. The mathematical models for tracking, social hierarchy, attacking prey and surrounding is described below.

2.3.1. Detecting and tracking phase

The most distinguishing feature of sea lions is their highly intricate whiskers. These whiskers let them identify prey placements, shape, and size more precisely. The preys produce wakes or waves behind them as they swim around them. As a result, sea lions tracks them with their whiskers. Whenever the position of whiskers is in an opposite direction of the water waves, it aids at sea lion in sensing and detecting prey. On the other hand, the low vibration occurs in whiskers when they were in the same direction. The hunting behaviour of sea lion includes encircling, chasing, tracking prey, approaching, attack and stationary situation are represented in Fig. 3.

The sea lion detects the presence of target and summon other followers to pursue and attack the target. The hunting mechanism's leader is this sea lion and the other members adjust their locations in relation to the intended prey. According to the SLnO algorithm the target prey is now the finest or nearly optimum option. This behavior is mathematically represented by Eq. (7).

$$\overrightarrow{D_{lst}} = \left|\overrightarrow{2B}.\overrightarrow{P(t)} - \overrightarrow{SL(t)}\right| \quad (7)$$

Here, a target prey and sea lion distance is given by $\overrightarrow{D_{lst}}$, the sea lion and target prey position vectors are given by $\overrightarrow{P(t)}$ and $\overrightarrow{SL(t)}$, t is the present iteration and the random vector in [0, 1] is $\vec{B}$ that is multiplied by two to expand a search space, allowing search agents to identify the best or near best solution.

On each additional iteration, the sea lion gets closer to the desired target. The tendency is numerically characterized in Eq. (8).

$$\overrightarrow{SL(t+1)} = \overrightarrow{P(t)} - \overrightarrow{D_{lst}}\,.\vec{C} \quad (8)$$

Here, the next iteration is denoted by $(t+1)$ and over the course of repetitions, $\vec{C}$ is reduced linearly from two to zero since this forces a sea lion's leader to approach towards and encircle current target.

2.3.2. Vocalization phase

Sea lion sounds travel four times as quickly in water as they do in the air. When sea lions are rushing and attacking as a subgroup, they utilize a variety of vocalizations to communicate with one another. They also utilize their voice to summon other members who remain on the beach. As a result, sea lions hunt and constrain prey in order to get near to the ocean's surface. They also have tiny ears that is able to sense noises both above and below water. When it spots a prey, it calls on other sea lions to surround and attack it. The behavior is numerically described in Eqs. (9), (10) and (11) respectively.

$$\overrightarrow{SP_{leader}} = \left|(\overrightarrow{V_1}(1+\overrightarrow{V_2}))/\overrightarrow{V_2}\right| \quad (9)$$

$$\overrightarrow{V_1} = sin\,\theta \quad (10)$$

$$\overrightarrow{V_2} = sin\,\emptyset \quad (11)$$

Here, sound speed of sea lion leader is given by $\overrightarrow{SP_{leader}}$, a sound speed in water and air is denoted by $\overrightarrow{V_1}$ and $\overrightarrow{V_2}$ respectively. When a sea lion produces a sound, it is reflected by another medium, such as air, and used to call members who are submerged. As a result, the first instance is represented by $(\sin\theta)$, whereas the second instance is represented by $(\sin\emptyset)$.

2.3.3. Attacking phase or exploitation phase

The attacking in sea lion is led by the finest search agent, who spots the target and informs the other followers. Generally, the target prey is regarded as the best available option. However, a new search agent is introduced that finds and encircles better preys.Two phases, diminishing encircling technique and circle updating location, are used in mathematics to describe sea lion hunting behaviour.

Dwindling encircling method

This is determined by the $\vec{C}$ value in Equation (8).To be more precise throughout the period of rounds, $\vec{C}$ is lowered linearly from two to zero. Because of this reduction, the sea lion's leader approaches the prey and encircles it. Then a search agent approaching location might be in any place among the agent's best position and the current best agent's place.

Circle updating position

The sea lions pursue and hunt bait balls of fish, starting at the edges, as illustrated in Fig. 4.

Based on this, Eq. (6) is proposed,

$$\overrightarrow{SL}(t+1) = \left|\vec{P}(t) - \overrightarrow{SL}(t)\right|.cos(2\pi m) + \vec{P}(t) \quad (12)$$

Here, the best finest solution and search agent distance is denoted by $\left|\vec{P}(t) - \overrightarrow{SL}(t)\right|$, entire value is denoted by | | and m is a random number in [1, -1]. Sea lion swims in a circle around prey to begin a target that are near a bait ball's edge. Finally, $\cos(2\pi m)$ is used to numerically represent this phenomenon.

2.3.4. Searching phase or exploration phase

Generally, sea lions hunt for food by using their whiskers and swimming in zigzagging patterns. As a result, the random values are used with $\vec{C}$ in this investigation.If $\vec{C}$ is larger than 1 or < than negative 1, then the sea lions are compelled to flee from the targeted prey and the sea lion's leader. As a result, sea lions are forced to seek out alternative sources of food.

Throughout searching phase, the sea lions move into different locations in relation to a best search agent.In other words, an algorithm executes a global

Received: May 19, 2023. Revised: September 12, 2023.

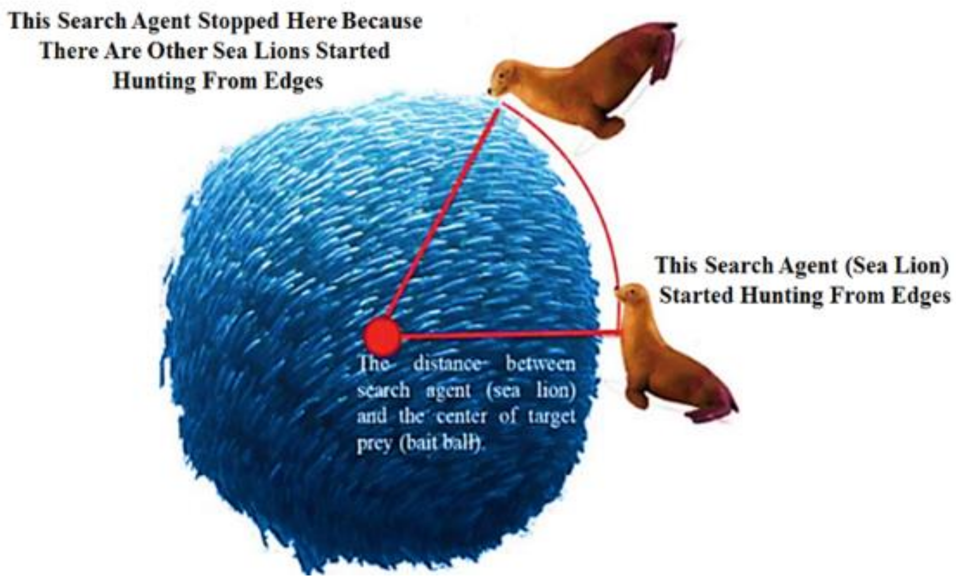

Figure. 4 Sea lion circle updating

Table. 1 Simulation parameters

S. No	Parameters	Values
1	Simulator	NS-2
2	Road length	3 Km
3	Number of Lanes	2
4	Number of nodes	25-50
5	Transmission range	300 m
6	Maximum node speed	35m/s

search agent as well as finds global best option when $\vec{C}$is larger than one. In this regard, Eqs. (13) and (14) are proposed.

$$\overrightarrow{D_{lst}} = \left|\overrightarrow{2B}.\overrightarrow{SL}_{rnd} - \overrightarrow{SL(t)}\right| \quad (13)$$

$$\overrightarrow{SL}(t+1) = \overrightarrow{SL}_{rnd}(t) - \overrightarrow{D_{lst}}.\vec{C} \quad (14)$$

Here, the random sea lion that is chosen from present population is denoted as$\overrightarrow{SL}_{rnd}(t)$.In Fig. 5 flowchart of SLnO algorithm is represented.

This optimization approach is used for the determination of an efficient path for routing among the clusters in MANET. The best solution obtained from the optimization algorithm indicates the finest routing path for the data transmission. The selected path provides improved data transfer with reduced packet loss delay and energy utilization indicating the efficacy of proposed optimization algorithm.

3. Result and discussion

The network architecture in MANET becomes more dynamic as a result of rising mobility in multimedia wireless networks, resulting in network congestion. As a result, because routing is closely tied to network and user service quality, establishing a better flexible routing method for multimedia wireless networks is crucial. Hence, Fuzzy C means clustering and SLnO is utilized for attaining effective dynamic routing approach in multimedia networks. The simulation is implemented using Network Simulator (NS2) software. The SLnO algorithm proposed is empirically tested and compared with different optimization algorithms in terms various factors which are discussed below. The parameter used for simulation in NS2 software is represented in Table 1.

3.1 End to end delay

In Fig. 6, the suggested SLnO algorithm's total latency is contrasted with that of GWO, GA, PSO and ACO. End-to-End Delay, also known as end-to-end latency, is a critical network performance indicator that counts the time it takes a data packet in a network to transit from the source node to the destination node.

The graph shows that alternative optimisation algorithms trail the SLnO method. The SLnO technique is more efficient than the remaining protocols because it requires less time to transfer packets to their destination.

3.2 Energy consumption

Energy consumption refers to the amount of electrical energy utilized by the individual nodes and the network infrastructure to perform their communication and routing functions. Fig. 7 shows a comparison of a proposed SLnO algorithm's energy

Received: May 19, 2023. Revised: September 12, 2023.

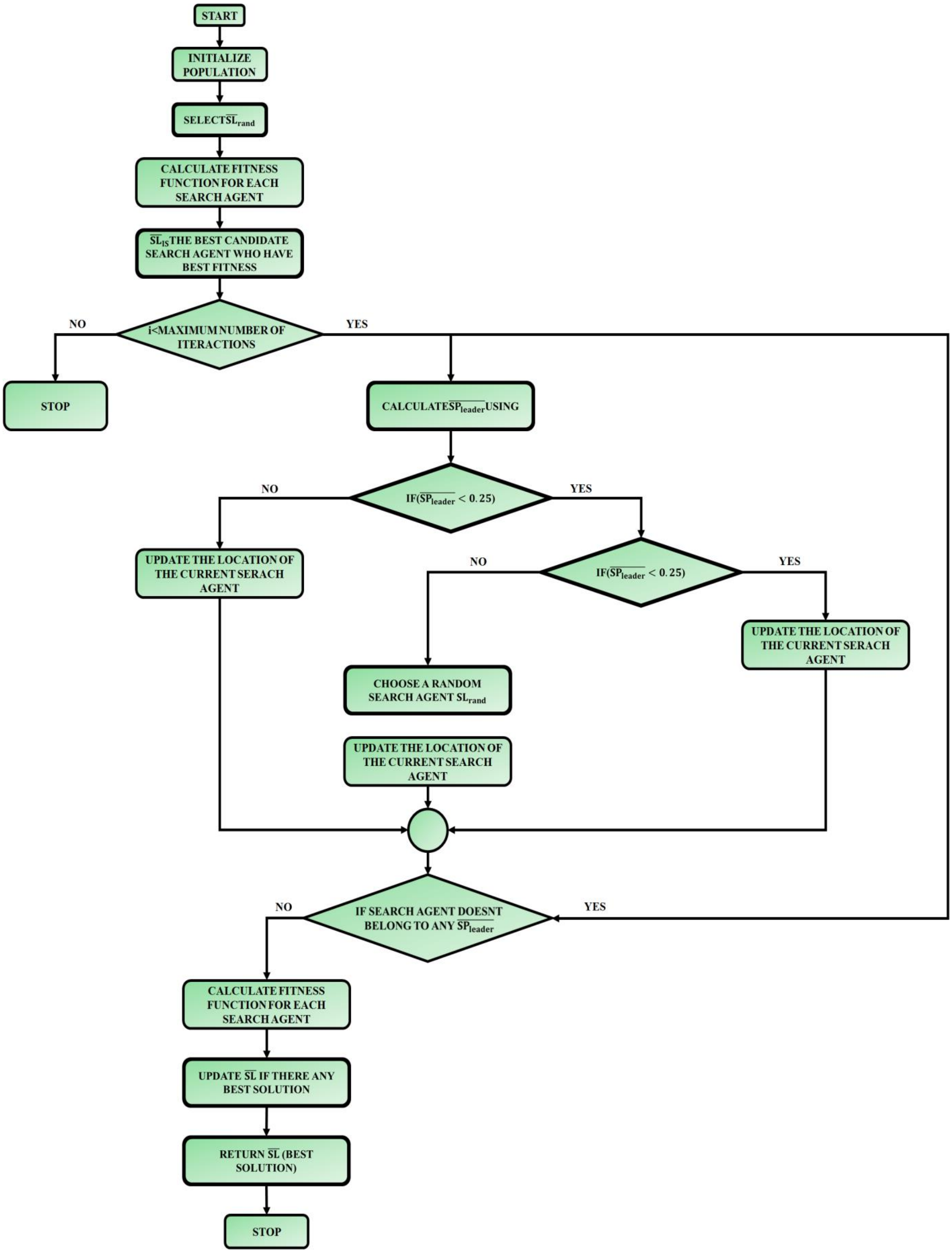

Figure. 5 Flow chart of SLnO Algorithm

usage with that of the GWO, GA, PSO and ACO algorithms.

The ACO algorithm uses more energy than the other algorithms, as seen in the graph. However, the

Received: May 19, 2023. Revised: September 12, 2023.

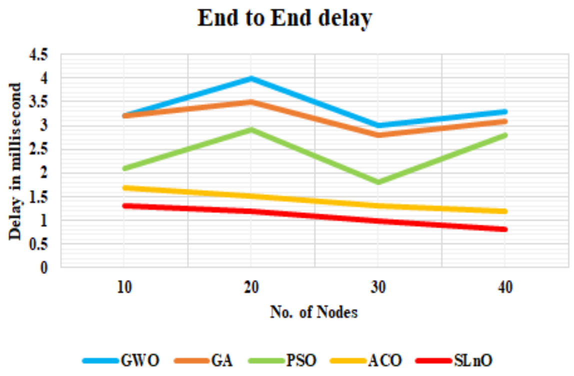

Figure. 6 End to end delay

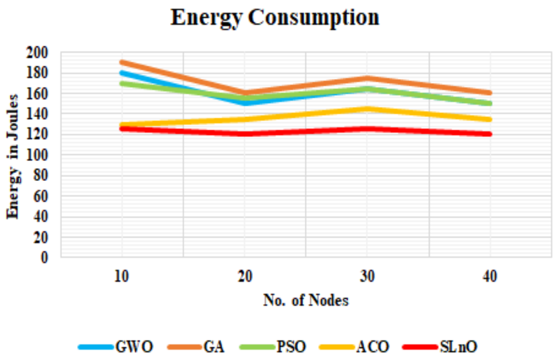

Figure.7 Energy consumption

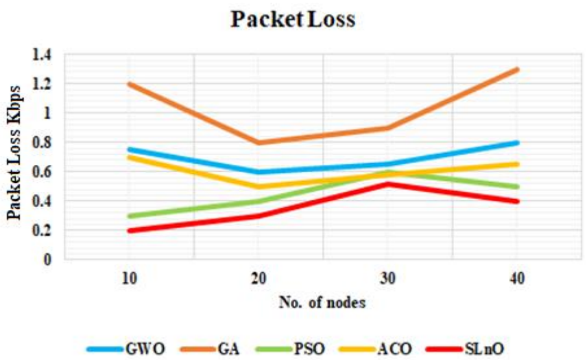

Figure. 8 Packet loss

routing protocol and energy consumption is decreased to a certain amount by using SLnO algorithm.The energy needed by SLnO algorithm is low when compared to all the other protocols. Hence, SLnO algorithm is more efficient than the other protocols.

3.3 Packet loss

Packet loss in MANETs refers to the situation where data packets transmitted between nodes within the network fail to reach their intended destinations successfully. Fig. 8 compares the packet loss of the proposed SLnO algorithm to that of GWO, GA, PSO, and ACO.

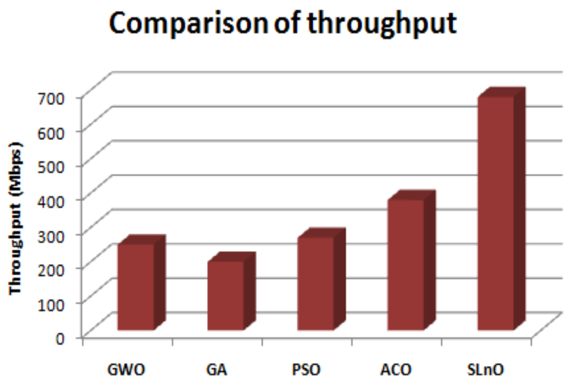

Figure. 9 Throughput

Table 2. Comparison with existing works

Methods	Packet Delivery Ratio	Delay
GA [14]	85%	-
PSO [18]	86.8%	4s
ACO [20]	88%	12s
GWO [24]	55%	-
Proposed SLnO	93.6%	1 ms

From the graph it is clear that, the GA experiences high packet loss as compared to all the other algorithms. However, the packet loss is decreased to a certain amount by using SLnO algorithm. Hence, SLnO algorithm is more efficient than the other protocols.

3.4 Throughput

Throughput refers to the amount of data that can be transmitted successfully over the network within a given period of time. The throughput analysis of the suggested SLnO algorithm is contrasted with conventional models like GWO, GA, PSO and ACO which is represented in Fig. 9.

The graph makes it clear that clustering behaviour of the recommended SLnO algorithm makes its throughput far more efficient than that of the other protocols.

Table 2 represents the comparison of the proposed work with existing works considering the packet delivery ratio and delay. The SLnO generates an enhanced delivery ratio of 93.6% and a delay of 1 ms. Thus the algorithm is effective in finding and maintaining reliable routes, leading to a high percentage of successful packet deliveries.

4. Conclusion

The goal of the proposed study is to develop an effective dynamic routing approach for multimedia networks. Fuzzy C means clustering is utilized to form the clusters and share routing information for efficient clustering, while sea lion optimization (SLnO) is utilized to attain the best path for multimedia access. The simulation is implemented using network simulator (NS2). The proposed model is empirically tested and compared with GWO, PSO, GA, and ACO in terms of various factors. The obtained results conclude that the proposed SLnO algorithm generates an enhanced PDR of 93.6% and a throughput of 680Mb/sthereby delivering most of the transmitted packets to their destinations. On comparing with other conventional ones, SLnO algorithm generates only a reduced delay of 1 ms and ensures that data packets reach their destination quickly, minimizing the time it takes for users to interact with applications and receive responses.

Conflicts of interest

The authors declare that they have no conflicts of interest to report regarding the present study.

Author contributions

- Conceptualization: K. Paul Joshua
- Data Curation: K. Paul Joshua
- Methodology: D. Srinivasa Rao, D. Madhivadhani, Lily saron grace & K. Paul Joshua
- Project administration: D. Srinivasa Rao, D. Madhivadhani, Lily saron grace
- Supervision: D. Srinivasa Rao, D. Madhivadhani, Lily saron grace.
- Validation: D. Srinivasa Rao, D. Madhivadhani, Lily saron grace.
- Writing-original draft: K. Paul Joshua
- Writing-review & editing: D. Srinivasa Rao, D. Madhivadhani, Lily saron grace &K. Paul Joshua

References

[1] T. K. Priyambodo, D. Wijayanto, and M. S. Gitakarma, "Performance optimization of MANET networks through routing protocol analysis", *Computers*, Vol. 10, No. 1, p. 2, 2020.

[2] Z. Niu, Q. Li, C. Ma, H. Li, H. Shan, and F. Yang, "Identification of Critical Nodes for Enhanced Network Defense in MANET-IoT Networks", *IEEE Access,* Vol. 8, pp. 183571-183582, 2020.

[3] N. S. S. Farheen and A. Jain, "Improved routing in MANET with optimized multi path routing fine-tuned with hybrid modelling", *Journal of King Saud University-Computer and Information Sciences*, Vol. 34, No. 6, pp. 2443-2450, 2022.

[4] T. A. Abdali, R. Hassan, R. C. Muniyandi, A. H. M. Aman, Q. N. Nguyen, and A. S. A. Khaleefa, "Optimized particle swarm optimization algorithm for the realization of an enhanced energy-aware location-aided routing protocol in manet", *Information*, Vol. 11, No. 11, p. 529, 2020.

[5] L. Deng, F. Liu, Y. Zhang and W. S. Wong, "Delay-Constrained Topology-Transparent Distributed Scheduling for MANETs", in *IEEE Transactions on Vehicular Technology,* Vol. 70, No. 1, pp. 1083-1088, 2021.

[6] A. Bhardwaj, and H. E. Ocla, "Multipath routing protocol using genetic algorithm in mobile ad hoc networks", *IEEE Access*, Vol. 8, pp. 177534-177548, 2020.

[7] M. Tahboush and M. Agoyi, "A hybrid wormhole attack detection in mobile ad-hoc network (MANET)", *IEEE Access,* Vol. 9, pp. 11872-11883, 2021.

[8] Y. Hamzaoui, M. Amnai, A. Choukri, and Y. Fakhri, "Enhancing OLSR routing protocol using K-means clustering in MANETs", *International Journal of Electrical and Computer Engineering,* Vol. 10, No. 4, p. 3715, 2020.

[9] C. G. Krishnan, A. H. Nishan, S. Gomathi, and G. A. Swaminathan, "Energy and trust management framework for MANET using clustering algorithm", *Wireless Personal Communications*, Vol. 122, No. 2, pp. 1267-1281, 2022.

[10] A. Pandey, P. Singh, P. Mani, S. Gupta, and J. N. Verma, "Message Ferry Route Calculation through K-means Clustering Algorithm for Partially-Connected MANET", *Webology,* Vol. 17, No. 2, 2020.

[11] S. Sarhan, and S. Sarhan, "Elephant herding optimization Ad Hoc on-demand multipath distance vector routing protocol for MANET", *IEEE Access*, Vol. 9, pp. 39489-39499, 2021.

[12] U. Srilakshmi, N. Veeraiah, Y. Alotaibi, S. A. Alghamdi, O. I. Khalaf, and B. V. Subbayamma, "An improved hybrid secure multipath routing protocol for MANET", *IEEE Access*, Vol. 9, pp. 163043-163053, 2021.

[13] N. Shah, H. E. Ocla, and P. Shah, "Adaptive Routing Protocol in Mobile Ad-Hoc Networks Using Genetic Algorithm", *IEEE Access*, Vol. 10 pp. 132949-132964, 2022.

[14] J. Patel and H. E. Ocla, "Energy efficient routing protocol in sensor networks using genetic algorithm", *Sensors,* Vol. 21, No. 21, p. 7060, 2021.

[15] K. B. Gurumoorthy, S. AllwinDevaraj, S. Gopinath, and T. Ali, "A novel clustering method for fault recovery and routing in mobile

ad-hoc networks", *International Journal of Communication Systems*, Vol. 34, No. 15, p. e4937, 2021.

[16] M. Z. Ghawy, G. A. Amran, H. A. Salman, E. Ghaleb, J. Khan, A. A. A. Bakhrani, A. M. Alziadi, A. Ali, and S. S. Ullah, "An Effective wireless sensor network routing protocol based on particle swarm optimization algorithm", *Wireless Communications and Mobile Computing*, 2022.

[17] A. W. Y. Khang, S. J. Elias, N. Zulkifli, W. A. Indra, J. A. J. Alsayaydeh, Z. Manap, and J. A. M. Gani, "Qualitative-based QoS performance study using hybrid ACO and PSO algorithm routing in MANET", *Journal of Physics: Conference Series*, Vol. 1502, No. 1, p. 012004, 2020.

[18] M. Ilayaraja, "Particle swarm optimization based multihop routing techniques in mobile ADHOC networks", *International Journal of Wireless and Ad Hoc Communication*, Vol. 1, No. 1, pp. 47-7, 2021.

[19] A. Mariadas, A. E. Peo, and R. Madhanmohan, "Hybrid PSO-DE algorithm-based trust and congestion aware cluster routing algorithm for MANET", *International Journal of Cloud Computing*, Vol. 9, No. 2-3, pp. 330-354, 2020.

[20] C. Kalaiselvi and S. Palaniammal, "Adaptive quality of service based routing and queue management for mobile ad hoc networks using hybrid ACO and GA", *Adv Math, SciJ*, Vol. 9, No. 5, pp. 2955-2976, 2020.

[21] D. Sinwar, N. Sharma, S. K. Maakar, and S. Kumar, "Analysis and comparison of ant colony optimization algorithm with DSDV, AODV, and AOMDV based on shortest path in MANET", *Journal of Information and Optimization Sciences*, Vol. 41, No. 2, pp. 621-632, 2020.

[22] K. Sumathi and D. V. Kumar, "Energy-Efficient Perspicacious Ant Colony Optimization Based Routing Protocol for Mobile Ad-Hoc Network", *International Journal of Computer Networks and Applications*, pp. 240-250, 2022.

[23] B. S. K. Anibrika, M. Asante, B. H. Aquash, and P. Ghann, "A Survey of Modern Ant Colony Optimization Algorithms for MANET: Routing Challenges, Perpectives and Paradigms", *Int. J. Eng. Res. Technol*, Vol. 9, pp. 952-959, 2020.

[24] S. Balaji, M. S. Obaidat, S. Suthir, M. Rajesh, and K. C. Suresh, "Retracted: Selection of intermediate routes for secure data communication systems using graph theory application and grey wolf optimization algorithm in MANETs", *IET Networks*, Vol. 10, No. 5, pp. 246-252, 2021.

[25] K. Saminathan, and R. Thangavel "Energy efficient and delay aware clustering in mobile adhoc network: A hybrid fruit fly optimization algorithm and whale optimization algorithm approach", *Concurrency and Computation: Practice and Experience*, Vol. 34, No. 11, p. e6867, 2022.