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# Cluster Head Selection Algorithm for MANETs Using Hybrid Particle Swarm Optimization-Genetic Algorithm

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**Abstract – The Mobile Ad-hoc Network (MANET) is a decentralized system that consists of mobile nodes. Wireless connections are used to connect these nodes. The primary issues of concern of MANETs are mobility and limited battery lifetime. Advanced techniques for improving MANET energy efficiency and extending network lifespan are critical. Clustering is one of the tried-and-true methods for increasing network lifetime by lowering and balancing energy consumption. Choosing a suitable cluster head from the cluster improves the network's energy efficiency even further. Because of the additional workloads, the cluster heads (CHs) utilize more energy than non-cluster heads. A novel algorithm for CH selection with a Hybrid Particle Swarm Optimization-Genetic Algorithm (PSO-GA) is proposed to improve the MANET network's energy efficiency and lifetime. The proposed method is implemented using the NS-2 platform for the analysis. The proposed model outperforms the existing OSCA, EP-MBO, GBTC, SM-WCA, CM-BCA, and FCO methods in terms of network performance. The model's performance has achieved a low Bit Error Rate (BER) of 7% for 100 nodes with 99.38% Packet Delivery Ratio (PDR) with minimized delay in the range 2.01sec with the energy efficiency of 99.03%. The validation indicates that the Hybrid PSO-GA approach is more efficient than the other methods.**

**Index Terms – Mobile Ad-hoc Network, Clustering, Soft k-Means, Cluster Head Selection, PSO-GA Optimization Algorithm.**

## 1. INTRODUCTION

MANETs are network-based architectures made up of communication devices such as cell phones and laptop computers. MANET communication is decentralized, with connected devices communicating through a point-to-point strategy. Ad-hoc networks are instrumental during various emergency or relief operations when existing network infrastructure fails and when people performing relief operations require a rapid deployment mechanism that requires less effort and time. MANETs are also used in situations where fixed networks are impractical, such as military monitoring, medical care, tracking of endangered species, environmental monitoring, disaster relief, and so on [1]. Each node in a MANET works as a router and host. Nodes need to cooperate in route establishment, packet forwarding, and reliable data transmission process of MANETs. MANET's routing process is a complicated task due to the nodes' mobility which often causes topology changes [2]. So, MANETs need reliable routing for the best performance. In general, Routing protocols of MANETs fall into three categories: reactive, proactive, and hybrid [3]. MANET architecture offers better coverage, lower operating costs, and greater flexibility. MANET can be applied for IoT-related [4], Cloud Computing [5], and Edge computing [6] systems where reliable, secure, and energy-efficient data transmission is performed without losing PDR. However, there is still a need for energy management in mobile nodes [7].

One of the most severe threats that MANETs still face is security. MANET's significant security challenges are integrity, confidentiality, authentication, and non-repudiation [8]. Several studies on security issues and solutions in MANETs have been conducted [9]. MANETs significant challenge is dealing with routing issues caused by the nodes' mobility [10]. The nodes' movement alters the network's topology, resulting in broken, unstable, and unreliable communication links that increase the possibility of packet drops and force a CH (Cluster Head) to retransmit data, affecting the energy performance of the network [11]. We require an optimized routing algorithm that addresses MANET node mobility, topology, and retransmission issues.

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Clustering-based routing is a tried-and-true technique for more efficient and effective routing in MANETs. The cluster-based approaches are utilized to balance the network energy and prolong its lifetime while decreasing communication overhead. There are several algorithms available for developing clusters and cluster heads [12].

A Clustering algorithm groups nodes together to form a cluster. Each node in the cluster group exclusively belongs to the identified single cluster. Each MANET node acts as a router, sending a "hello" message with their ID [13]. There are two types of Clustering: secure Clustering and insecure Clustering. Secure Clustering is divided into three subcategories: hybrid schemes, trust-based schemes, and cryptographic-based schemes. The six types of insecure clustering approaches are flooding-based, weight-based, channel-based, connectivity-based, low maintenance, and mobility-based. The clustering approach contributes to the network's longevity and energy efficiency [14].

Clustering entails selecting cluster heads (CHs) for each cluster. The CH (Cluster Head) is chosen based on a range of variables and factors, including node mobility and density. The role of CH is to provide communication between clusters and coordination among nodes. CH will also be in charge of cluster member maintenance, data collection and aggregation from mobile nodes, topology details maintenance, resource allocation, routing, and packet transfer [15]. Furthermore, the Cluster head also works as a local coordinator and manages the IDS to monitor various functions and attacks [16]. There are five types of CH selection algorithms that are introduced and categorized. They are mobility-based, identifier-based, connectivity-based, power-based, and cost-based [17]. During the energy-efficient clustering approach, CH is selected based on less mobility and higher energy. After the selection of CH, an energy-efficient path for data transmission is also selected [18].

The main issues that MANETs face are energy efficiency and mobility awareness. Because of mobility unawareness, MANET nodes have the potential to move in the wrong direction. This process reduces the node's battery capacity and impacts the overall topology of the network. The CH node dissipates most of its energy due to MANET's node mobility and topological change issues. Therefore, an energy-efficient CH selection is necessary to take action against the network problem.

This paper's contribution is to create an energy-efficient clustering scheme for MANET and to combine it with a hybrid approach for selecting the best node as CH. The proposed methodology consists of several mobile nodes that are responsible for the routing. The MANET topology does not involve any auxiliary system (switch, router). For generating clustering Soft k-means method is used, and the

Hybrid PSO-GA approach is developed for selecting CH of MANET.

The main contribution of the work is:

- To design an energy-efficient CH selection algorithm to improve the overall performance and lifetime of MANET.

- Efficient cluster formation by soft K means fuzzy clustering algorithm that aims to improve CH selection algorithms' effectiveness in the energy-efficient CH selection process.

- A Hybrid approach of PSO-GA is used for selecting the best node as CH for MANET.

The remaining portion of this paper is structured as follows. Section 2 describes the related works as well as the problem statement. The proposed methodology of CH selection is described in Section 3. Section 4 contains the findings and discussion of the proposed work following its validation in NS-2. Finally, Section 5 contains the conclusion.

## 2. RELATED WORK

In this part, we will go through some of the research that has been done so far using energy-efficient clustering-based routing.

To reduce the number of clusters formed on the network along with the traffic and number of nodes involved in the routing, Hamid Ali et al. [19] used the multi-objective particle swarm optimization (MOPSO) algorithm. CH managed traffic flow within each cluster and intra-clusters and provided several solutions simultaneously. The optimal Pareto front method was used to obtain the implemented results. The introduced approach results were compared with WCA and CLPSO-based clustering schemes based on various parameters, and the designed strategy outperforms the other two approaches. The clustering model failed to provide an energy-efficient solution because the CH maintained both inter-and intra-clusters, causing cluster complication. Furthermore, the experiments were carried out solely with the fixed nodes, with no consideration given to the dynamic node environment.

To replace the expensive direct links for routing among the CHs along with the non-guaranteed coverage, Syed Zohaib Hussain Zahidi et al. [20] developed an upgraded ILP formulation. Here, multi-hop links replaced expensive direct links, and coverage enforcements to restrict the nodes were within each other's radius. Choosing the best fit node as CH was a critical issue in that scheme. Network lifetime enhancement was the foremost goal considered in that scheme. The enhanced ILP formulation resolved the clustering problems in MANET with the star-ring topological design. For a small-scale network, the generation of complex

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network solutions was enabled by those enhanced formulations. The time required by this algorithm to produce a specific result does not meet the stringent requirements of the practical environment. Furthermore, this model's earnest attempt to provide an inexpensive and high-coverage data transmission connection comes at the expense of the model's reduced lifespan, making it an unsuitable option.

To reduce the data replication on the MANET during the transmission at CH, Daichi Amagata et al. [21] have proposed the CTR model that uses an efficient top-k cluster query routing. According to the implemented framework, Cluster heads (CHs) were chosen from nodes that possess high-ranking data elements, and top-k queries were passed amongst CHs across gateway nodes belonging to multiple clusters. The authors then improved the CTR framework by incorporating a data de-replication methodology by employing the CTR2 framework. CTR2 performance was improved by recovering the top-k records from adjacent nodes. Extensive testing has revealed that the proposed systems perform admirably in query result accuracy, traffic, and delay. The model contributed to the reduction of network data replication issues. However, due to the high energy drainage caused by the additional query transmission of cluster heads, the network's lifespan was affected.

To solve of Clustering overhead problem due to continuous change of CH, Sunil Pathak and Sonal Jain have introduced an Optimized Stable Clustering Algorithm (OSCA) [22] that provided high stability to the network. The network topology of MANET was unstable due to noticeable changes such as overhead and retransmission. In that approach, a new node named backup node was introduced into the cluster, which served as the cluster's CH when the original CH died. The OSCA algorithm had the advantage of lowering clustering overhead and making the network more stable. The model's complexity has increased as a result of having a secure and congestion-free network. The use of a virtual or backup CH makes more confusion for the nodes during the data transmission process. The best load distribution framework in CH and cluster member nodes was introduced by D.Sundaranarayana and K.Venkatachalapathy [23]. The problem under consideration here was energy exhaustion. The cluster is created by the Modified Butterfly Optimization (EP-MBO) algorithm. The suggested load distribution framework focuses on associative Clustering, which was determined by the mobile nodes' load factors and the remaining energy in the cluster. The multi-hop communication by the load-balancing method was then used to transmit data from cluster member nodes. The load distribution in the clusters prevented energy waste. The simulation outcomes demonstrated that the proposed framework achieved maximum network lifespan with high energy efficiency. However, this model's distributed network is unsuitable for certain applications, and the load-based clustering method used in the method can

cause network congestion, which reduces the model's overall efficiency.

By focusing on the cluster formation problem bio-inspired clustering technique based on honey bee and GA (GBTC) was introduced by Masood Ahmad et al. [24]. Cluster formation was a significant issue considered in that approach. The cluster-based structure reduced the topology maintenance overhead. The combination of GA and Honey bee is used for providing dynamic solutions with improved quality. The balance and stable clusters were formed in the proposed scheme, which was demonstrated by the simulation outcomes. With regard to clustering overhead and network lifetime, the proposed scheme outperforms than the others. The model reduced the problem of overhead. However, this model drained a considerable amount of the node's energy to maintain the network's topology.

A SM-WCA (Stability-based Multi-metric Weighted Clustering Algorithm) was introduced by Naghma Khatoon and Amritanjali for MANET [25]. For selecting a CH, the emphasis was placed on individual parameters and the combined weight. A non-periodic re-clustering procedure was utilized in that proposed scheme when the CH's current dominance set was not covering the network nodes. The eligibility criteria process prevented inferior nodes from participating in the CH election process. The proposed plan provided enhanced network lifespan and reduced redundant communication and computation. The work had focused on the homogenous network; hence the mobility of the node is zero. Furthermore, this model's re-clustering process causes a delay in data transmission and could lead to higher data loss.

Amutha S et al. [26] introduced a Cluster Manager-Based CH (CMBCH) selection scheme for eliminating the leverage CH workload and energy issues. CM and CH were the two constraints utilized in the proposed method. The nodes' activities were observed and controlled by the CM. In the network, packet transmission between the nodes was executed by the CH. When the present CH energy level was exhausted, the equivalent node with maximum energy level and past CH activities was elected by the CM then simultaneously stored the data. By stable routing, the CMBCH provides low bandwidth, low energy and reliable throughput. The use of extra load (mechanism) puts a considerable burden on the network, and also, the bandwidth of this model is low, thus creating a problem in PDR.

Amin Salih Mohammed et al. [27] proposed a Fuzzy constraint-based Cluster Optimization (FCO). The use of efficient energy was an unresolved issue in ad-hoc networks. The fuzzy parameters considered in that scheme to evaluate the node's fitness value were the device position, device energy, device hop-count, and device movement/speed. Next, the CH selection process was activated depending on the fitness value. But this method did not address uncertainty

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conditions such as CH energy depletion, CH failure, and topology variation.

## 2.1. Problem Statements and Motivation

The most severe issue confronting ad hoc networks is energy consumption. Energy utilization and network lifetime have a strong relationship in ad-hoc networks. Existing research has concentrated on improving network lifetime, energy consumption rate, overhead issues, and so on. None of the methods had provided a comprehensive solution to all of the problems. Furthermore, the majority of low-energy techniques employed a large number of CHs, resulting in unreliable data delivery. Some works have reduced the number of CHs, but the received signal's signal strength is feeble. So, while every technique has an advantage, it also has a disadvantage. However, the introduced technologies do not significantly improve the overall performance of the MANET. We have focused on the optimization techniques that provide a better solution to these issues to resolve this problem.

The optimized CH selection will deal with the identified problem. A well-defined CH can be selected using several CH parameters such as node density, node mobility, node degree, energy level, position, and so on. To ensure reachability and reliability for the CH to aggregate data, the network is first divided into a number of clusters, allowing the optimized CH to recognize relevant area with high signal strength.

## 3. PROPOSED METHODOLOGY

A practical PSO-GA approach with Soft k-means clustering is employed in MANET to strengthen its energy efficiency. With the Support of the Soft-k means algorithm, the clustering process can be achieved. Different parameters like speed, position and direction are considered to generate Clustering, and the minimization process helps estimate the Cluster center. The Particle swarm optimization and genetic algorithm combination (GA) [27] have been utilized to determine the Cluster Head (CH) depending upon the cluster formed. For the selection of CH, factors like energy, degree and mobility are estimated. Further, estimating the location of selected CH using GA algorithm. After the selection process, the selected CH location is calculated using the cluster center-based GA method. The placement process depends on the energy value of CH. The schematic Diagram of Energy Efficient CH selection in MANET is shown in Figure 1.

The proposed architecture model has three stages: data generation, soft k-mean Clustering, and a hybrid PSO-GA method for CH selection. The initial step is data generation, composed of determining the number of nodes, the range of transmission, and the grid's size. The second stage is Soft k-mean based Clustering. For the Clustering process, factors like speed, distance, and position are considered. The Final Stage is Hybrid PSO-GA based CH Selection which used

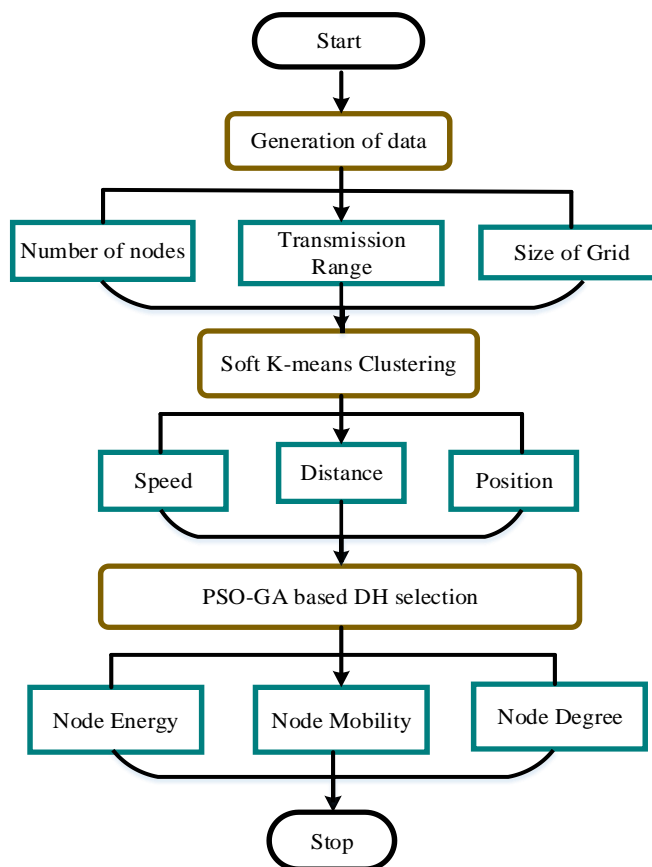Node Energy, Node Mobility and Node Degree for selecting the CH.



Figure 1 Schematic Diagram for Energy Efficient CH Selection in MANET
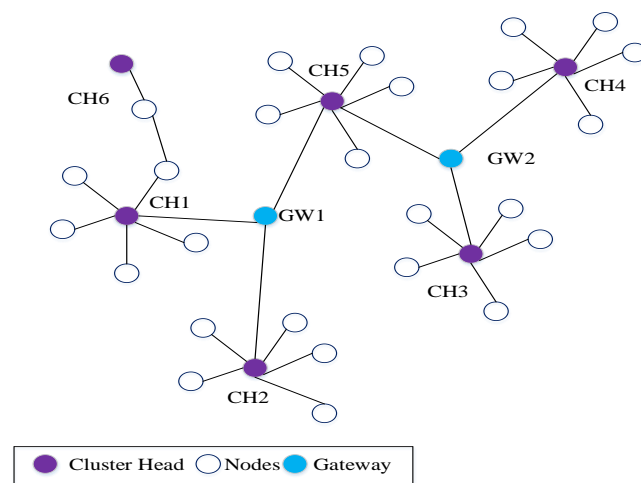
## 3.1. Clustering Model of MANET



Figure 2 Clustering Model of MANET

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The issue of mobility and limited battery lifetime is MANET's fundamental concern, and nodes of Ad-hoc networks have complete control over-processing.

Figure 2 represents the MANET Clustering Model. It consists of CH, Nodes, and Gateway. The communication process is done with the help of Gateway, and CHs. Each node is connected with their CH and each CH is connected with Gateway. The node which ensures parameters (Node Energy, Node Degree and Node Mobility) in an effective manner is considered as CH. After the selection of CH from clusters, a routing process occurred for data transmission.

3.2.  Proposed Soft K-Mean Based Clustering

The Soft k-mean method is a fuzzy based clustering process, and clusters are created at the center. The traditional k-mean clustering process is inefficient because it causes overlapping issues between clusters. Hence, the Soft k-mean method is introduced. In this method, each node has various membership degree. The edge nodes of the cluster show a lower probability than nodes that are near the cluster center. Each node of Soft k-mean belongs to only one cluster. For the generation of Clustering, speed, position and distance are calculated. The membership degree has an essential role in the minimization process.

3.2.1. Generation of Cluster in MANET

The position of Cluster Members are represented by $N = \{n_1, n_2, ..., n_m\}$ in MANET, and these Cluster Members are grouped into $l$ sets $L = \{l_1, l_2, ..., l_i\}$. The generation of Clustering in MANET is explained in equation (1)

$$G(N,D,S) = \sum_{s=1}^{i}\sum_{q=1}^{m} d_{sq} \|n_q - \gamma_s\|^2 \qquad (1)$$

Where the speed between nodes (Cluster Member) are denoted by $S(\gamma_s; s=1,...,i)$, and the distance between nodes are represented by $D(d_{sq}; s=1,...,i; q=1,...,m)$. The $q^{th}$ membership degree to the $s^{th}$ cluster is described in equation (2)

$$\gamma_s = \frac{\sum_{q=1}^{h} d_{sq} n_q}{\sum_{q=1}^{h} d_{sq}} \qquad (2)$$

Where $\alpha$ represents the degree value of each node. Effective Clustering is formed by minimizing the value of $d_{sq}$, and the process of minimization must satisfy the following three conditions.

a)  The Cluster Member inside the MANET is assigned with a membership degree between zero and one.

$$d_{sq} \in [0,1], \quad s=1...i, \quad q=1,...,h. \qquad (3)$$

b)  The total value of all the membership degree for one Cluster Member must be one.

$$\sum_{s=1}^{i} d_{sq} = 1, \quad q=1,...,h. \qquad (4)$$

c)  There must be at least one Cluster Member who has a membership degree of non-zero value.

$$\sum_{q=1}^{h} d_{sq} > 0, \quad s = 1,...,i. \qquad (5)$$

After satisfying these conditions, the centres of clusters are estimated by equation (6).

$$d_{sq} = \frac{e^{-\alpha \|n_q - \gamma_s\|^2}}{\sum_{b=1}^{i} e^{-\alpha \|n_q - \gamma_s\|^2}} \qquad (6)$$

The overall process of the proposed Soft k-mean algorithm is summarized as follows: The value of membership degree and the location of the center of the cluster is estimated by equation (2) and equation (6). The generation of Clustering stops if the direction and speed of Cluster Member are below the threshold value.

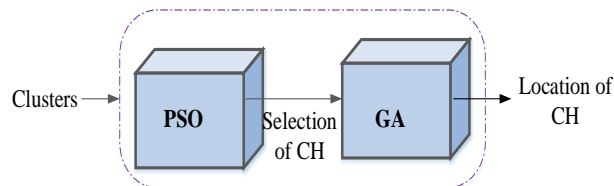3.3.  Selection of CH Using Effective PSO-GA Approach



Figure 3 PSO-GA Approach for CH Selection

One of the most popular meta-heuristic algorithms is PSO which resembles the flocking nature of birds. It is composed of a large number of particles. These particles are otherwise known as Agents. The population process of PSO is known as Swarm. The proposed method's primary goal is to develop energy-efficient CH selection for increasing the lifespan of MANET. Hence we are introducing a Hybrid PSO-GA approach for selecting the CH. The CH selection is made with the help of PSO, and the location of the selected CH is determined by GA [27] algorithm. For the CH selection, various factors are considered, like the mobility of the node, energy value and node degree. These parameters perform a

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significant impact on choosing the best node as CH. The workflow of Hybrid PSO-GA is shown in Figure 3.

The input of the PSO is clusters, which is formed with the help of the Soft k-mean method. After the formation clusters, the CH is selected with the help of the PSO algorithm, which depends on various factors like node mobility, node energy and node degree. Further, estimating the location of selected CH using GA algorithm. The proposed Hybrid approach of PSO-GA gives energy-efficient CH, which increases the lifespan of MANET.

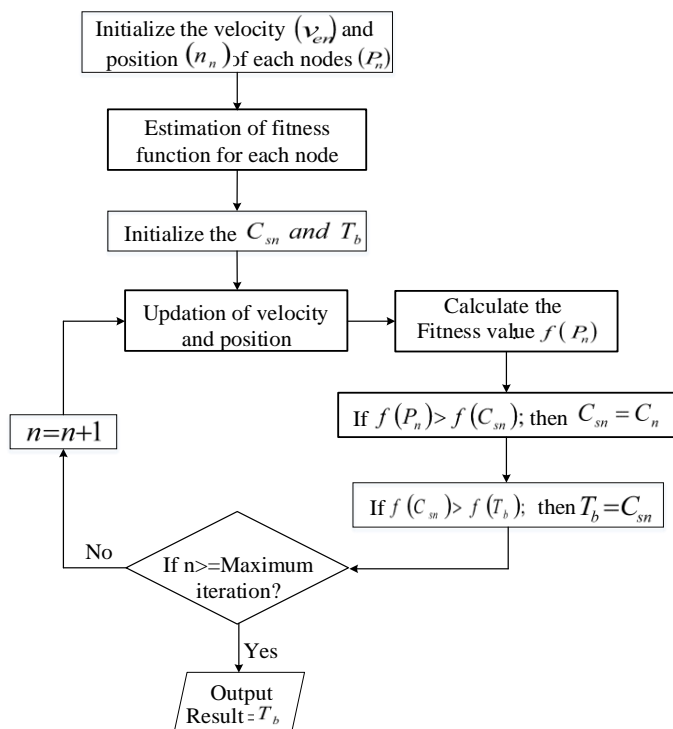3.3.1.   Selection Process of CH Using PSO



Figure 4 Flowchart of CH Selection Using PSO

The generated Clusters are denoted by $A_x$, which is moving inside the $Y$ dimension search area, and mobile nodes belong to $N = \{n_1, n_2, ..., n_m\}$. Each node $N_n$ is employed to evaluate the fitness function. The fitness function is the sum of node features (energy, degree, and mobility). The position of each node in the search space is denoted by $N_{n,y}$, and the velocity of each node is represented by $VE_{n,y}$. The currently selected node is denoted by $C_{sn}$, and the neighboring node is represented by $T_b$. Each node of MANET updates its

velocity, mobility, energy, and degree values. This process is described in equation (7) and equation (8).

$$VE_{n,y}(\rho+1) = \varepsilon \times VE_{n,y}(\rho) + \alpha \times r_{an1} \times (NC_{sn,n,y} - N_{n,y}(\rho)) \\ + m_o \times r_{an2} \times (NT_{b,n,y} - N_{n,y}(\rho)) \quad (7)$$

$$N_{n,y}(\rho+1) = N_{n,y}(\rho) + VE_{n,y}(\rho) \quad (8)$$

Where the energy of node is represented by $\varepsilon$, mobility of node is denoted by $m_o$. The random numbers between zero and one are represented by $r_{an1}$ and $r_{an2}$. The flowchart of CH selection using PSO is given in Figure 4. At the starting stage, the node's velocity and position are initialized, and then each node's fitness function is calculated. The currently selected node $C_{sn}$ and neighboring nodes are initialized. Further, updating the velocity and position of the nodes with respect to each iteration $n$. Then again, calculating the fitness value of the nodes. Whichever node satisfy the conditions, is selected as CH.

3.3.2.  Placement of CH Using GA

After the selection of CH, determining the location of CH using the GA [30] Algorithm. Basically, the GA algorithm is utilized for producing high-quality solutions, and it is composed of three Stages-Selection, Crossover, and Mutation. The initial stage is the generation of chromosomes. The estimation of fitness value is based on the given problem. The second stage is the Crossover stage. During this stage, two parents exchanges their genetic traits. The final step is Mutation which is used for increasing the gene value and diversity of offspring.  The nodes of MANET are represented by using the chromosomes of GA, which is described as $X_N = \{r_\varepsilon, r_\alpha, r_{m_o}\}$ where $X_N$ represents the placement of nodes inside the clusters. Regularity factors of energy, degree, and mobility are represented by $r_\varepsilon, r_\alpha$ and $r_{m_o}$ respectively.

The three stages of estimating the CH location are the Calculation of the initial position of CHs. Estimating the energy value of selected CH and final stage is the Placement of CH based on lower energy consumption. During the first stage, each desired CH's initial position is estimated by using a fitness value from PSO. The energy value of selected CH is calculated using node membership degree, which is described in equation (2). After estimating CH's energy value, if the selected CH shows lower energy than the other neighboring nodes, it is positioned at the center of the corresponding MANET Cluster.

Step 1: Initialize the number of nodes in the network and the network area.
Step 2: Generate the velocity and position of nodes.
Step 3: For Maximum iteration condition is satisfied

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//PSO for CH selection

Step 4: Calculate the fitness for each node
Step 5: Based on maximum fitness, calculate the velocity by equation (7)
Step 6: Evaluate the position of the node by equation (8)

Step 7: Update the node having the best velocity
//GA for relocate the CH
Step 8: Update the position of the node to the GA algorithm
Step 9: Generate fitness as maximum node energy, node degree, and minimized node mobility.
Step 10: Iteratively, the fitness is calculated for every node.
Step 11: Update the best fitness evolving position of the node.
Step 12: Relocate the CH to that position.
Step 13: Stop

Pseudocode 1 Pseudocode for PSO-GA algorithm

Pseudocode 1 shows the Pseudocode for PSO-GA algorithm.

### 4. EXPERIMENTAL RESULTS AND DISCUSSION

NS-2 is used as a simulation tool in the research. In this work, we have used the area of $1000m \times 1000m$. The direction of the antenna for data transmission is omni-directional. 500 Nodes are selected, and $30m$ is the range of transmission. The size of the packet is 512 bytes, and the number of CH is 17. The value of bandwidth (BW) is $11Mbps$. Initial energy of the node is $0.65mJ$. The iteration value is 100, and packet rate is 35 *packets / s*. Constant bit rate is the used traffic type, and maximum speed is 20 *m / s*. Table 1 shows a summary of these parameters.

| Parameters | Value |
|---|---|
| Area | 1000m x 1000m |
| The direction of the antenna | Omni-directional |
| Number of nodes | 500 |
| Range of transmission | 30m |
| Size of packets | 512 bytes |
| Number of CH | 17 |
| BW | 11 Mbps |
| The initial energy of nodes | 0.65mJ |
| Simulation Time | 500 sec |
| Value of iteration | 100 |
| Rate of packet | 35 packets / s |
| Model of movement | random-way point |
| Model of radio propagation | two-ray ground |
| Type of traffic | constant bit rate |
| Maximum Speed | 20 m / s |

Table 1 Simulation Parameters

### 4.1. Performance Metrics and Measures

For evaluating the proposed method's performance, the parameters (End-to-End Delay, BER, PDR, Network Lifetime, PLR, Throughput, and Energy Consumption) are used.

#### 4.1.1. End- to -End Delay

The total amount of time required to transmit packets across the network.

$$End - to - End\ Delay = \sum_{e_g=1}^{e_{g\,max}} \frac{E(W_u, W_v)}{A} \qquad (9)$$

Where the hop count of $u^{th}$ and $w^{th}$ nodes are represented by $e_g$. The speed of signal speed is denoted by $A$. The distance between $u^{th}$ and $v^{th}$ nodes are indicated by $E(W_u, W_v)$.

#### 4.1.2. Packet Delivery Ratio

The ratio of total packets arrived at the destination to the packets generated by the sensor node.

$$PDR = \frac{overall\ packets\ reached\ at\ destination}{total\ packets\ created\ at\ the\ sensor\ node} \times 100 \qquad (10)$$

#### 4.1.3. Packet Loss Ratio (PLR)

Total number of lost packets to the total packets transmitted from source to destination.

$$Packet\ Loss\ Ratio = \frac{total\ number\ of\ lose\ packets}{total\ number\ of\ packets\ transmitted} \times 100 \qquad (11)$$

#### 4.1.4. Throughput

It refers to the cumulative amount of information transmitted in a given period from source to destination.

$$Throughput = \frac{total\ number\ of\ delivered\ packets}{value\ of\ time\ taken} \qquad (12)$$

#### 4.1.5. Energy Consumption

It represents the total quantity of energy consumed by the nodes and the CH during successful communication.

$$E_C = \sum_{c=1}^{l}\left[ CH_E(C) + \sum_{r=1}^{zc} H_E(zc) \right] \qquad (13)$$

Where the overall energy consumption is denoted by $E_C$, and the energy consumption of CH is indicated by $CH_E(C)$. The node energy consumption is indicated by $S_E$.

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4.1.6.   Network Lifetime

It is the value of time that is taken by the initial sensor in the network for running out of energy.

$$N_t = \min(N_{ts}) \qquad (14)$$

Where the lifespan of the network is denoted by $N_t$ , and lifespan of sensor is represented by $N_{ts}$.

4.1.7.   Bit Error Rate

The total number of faults introduced in the network to the total number of bits transferred.

$$Bit\ Error\ Rate = \frac{total\ amount\ of\ errors\ across\ the\ network}{number\ of\ transmitte\ d\ bits} \qquad (15)$$

4.1.8.   Energy Efficiency

The proposed model's energy efficiency is calculated by the total available energy in the node after certain transmission to the total energy in the node before transmission.

$$Energy\ Efficiency = \frac{energy\ after\ certain\ transmission}{total\ available\ energy\ at\ initial\ stage} \qquad (16)$$

All of the above-mentioned parameters are measured and verified using OSCA, EP-MBO, GBTC, SM-WCA, CM-BCA, and FCO method.

4.2.   Simulation Result

The introduced model uses the area of $1000m \times 1000m$. The number of nodes used is 500. The packet size is 512 bytes. Initial node energy is 0.65mJ, and the number of CH is 17. The BW value is 11 Mbps. The value of iteration is 100. The rate of the packet is 35 packets / s, and the maximum speed is 20 m / s.
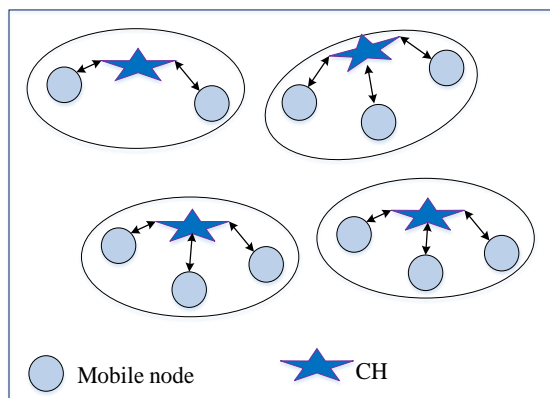


Figure 5 Representation of Proposed Model

In Figure 5, the small circles represent the mobile node, and the star symbol represents the CH. With the help of Hybrid PSO-GA approach, the CH is selected from the clusters. After

the selection of CH from each cluster, data packets are transmitted from source to destination.

4.2.1.   Performance Comparison

In terms of BER, PDR, PLR, Throughput, Energy Consumption, End-to-End Delay, and Network Lifetime, our proposed Hybrid PSO-GA method is analyzed and compared to the Optimized Stable Clustering Algorithm (OSCA)[22], Energy Preservation-Modified Butterfly Optimization (EP-MBO) [23], Genetic Bee and Tabu Clustering (GBTC)[24], SM-WCA [25], Cluster Manager-based CH selection (CM-BCA)[26] and Fuzzy constraints Cluster Optimization (FCO)[27].
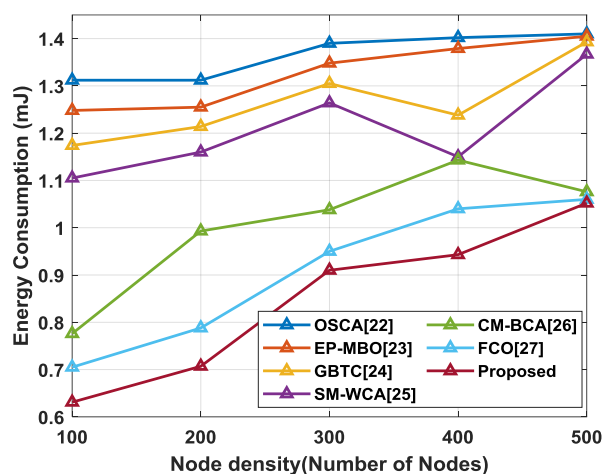


Figure 6 Performance Analysis of Energy Consumption

Figure 6 represents the Energy Consumption analysis of the proposed method with various techniques. The number of nodes are in the range of 100 to 500. Our proposed method gives better energy consumption performance than other existing routing methods. The proposed PSO-GA consumes lower energy (0.63mJ) in 100 nodes. In the case of 100 nodes, other techniques obtained an Energy Consumption value of 0.71mJ (FCO), 0.79mJ (CM-BCA), 1.1mJ (SM-WCA), 1.18mJ (GBTC), 1.24mJ (EP-MBO) and 1.3mJ (OSCA). The value of Energy Consumption is increasing as the number of nodes grows.

Figure 7 illustrates the throughput analysis of proposed with other techniques. The proposed PSO-GA method gives a higher throughput performance than others. The throughput value for all methods decreases as the total node increases. Initially, the proposed Hybrid PSO-GA method acquires a Throughput value of 0. 95Mbps.The other methods gives Throughput value as 0.9Mbps (FCO), 0.89Mbps (CM-BCA), 0.88Mbps(SM-WCA), 0.6Mbps (GBTC), 0.5Mbps (EP-MBO) and 0.41Mbps (OSCA). After the analysis, we can see that the proposed Hybrid PSO-GA takes less time for data

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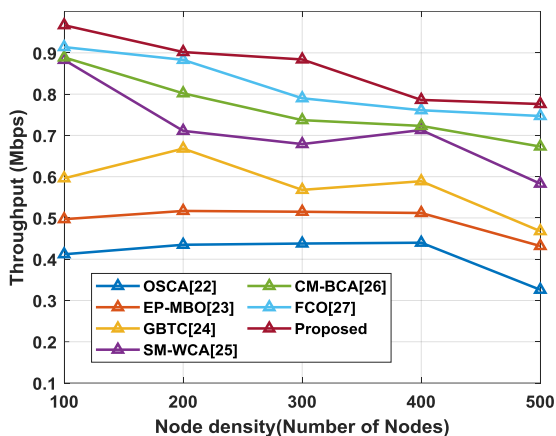transmission. The OSCA gives lower Throughput performance.

of PLR is incremented when the node number increases. FCO offers the highest PLR Performance.



Figure 7 Performance Analysis of Throughput



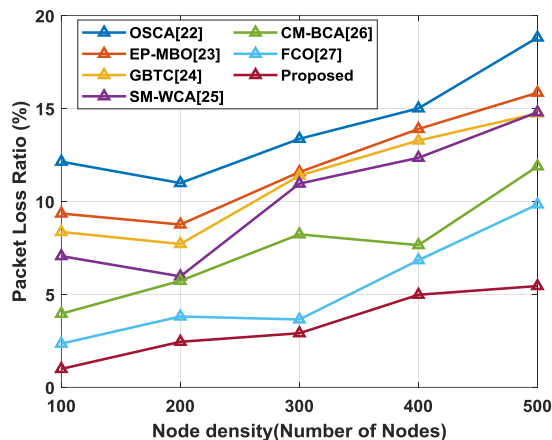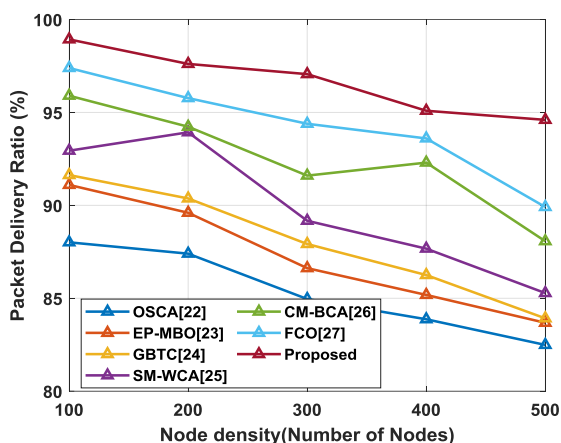Figure 9 Performance Analysis of PLR



Figure 8 Performance Analysis of PDR



Figure 10 Performance Analysis of Lifetime of Network

Figure 8 represents the PDR analysis of the proposed PSO-GA with other techniques. Our proposed method gives higher PDR performance (99.38%) at the initial stage. The initial PDR value of other techniques are 97%(FCO), 96%(CM-BCA), 93%(SM-WCA), 91.5%(GBTC), 91%(EP-MBO), and 88%(OSCA). The value of PDR rises as the node number grows. While the number of nodes is 500, all the methods give a lower PDR value. OSCA gives the lowest PDR performance.

Figure 9 represents the PLR analysis of the proposed method with other methods. Our proposed method gives a lower PLR value (1%) than other methods in the case of 100 nodes. The PLR value of other methods in the case of 100 nodes is 4%(FCO),2.5%(CM-BCA),7%(SM-WCA),8%(GBTC),9% (EP-MBO), and 12%(OSCA). All the methods show a gradual increase of PLR when the number of nodes is 300. The value
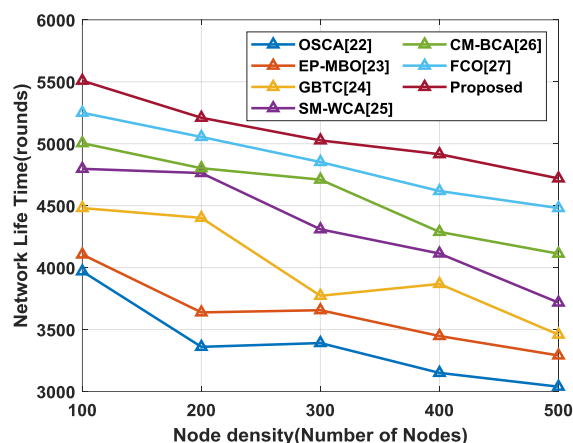
Figure 10 represents the performance analysis of the Network of PSO-GA with other methods. The proposed method achieved the highest Network Lifetime value (5500 rounds) than other approaches in 100 nodes. The other method shows Network Performance of 5250 rounds (FCO), 5000 rounds (CM-BCA), 4850 rounds (SM-WCA), 4500 rounds(GBTC), 4100 rounds(EP-MBO), and 4000 rounds(OSCA) respectively in 100 nodes. The Lifetime of the Network is reduced as the node number increases. After the analysis, OSCA shows poor lifetime Performance.

Figure 11 indicates the End-to-End Delay analysis of Hybrid PSO-GA with other methods. After the analysis, we can see that our proposed work gives a lower End-to-End Delay than other methods. Initially, the End-to-End Delay of the suggested method is 2s for 100 nodes. The alternative methods provide initial End-to-End Delay value of 2.3s

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(FCO), 3s (CM-BCA), 4s(SM-WCA), 5s (GBTC), 6.3s (EP-MBO), and 7.5s (OSCA) for 100 nodes.
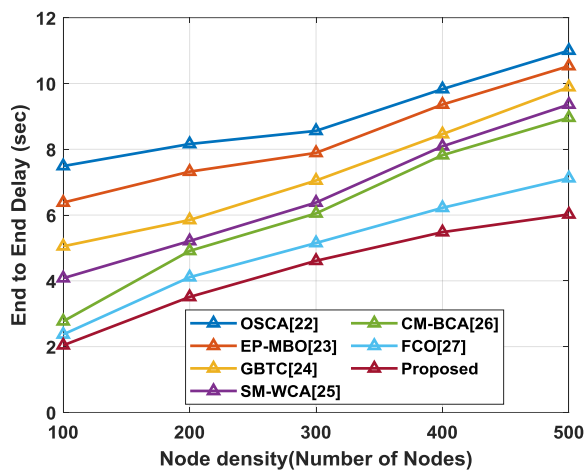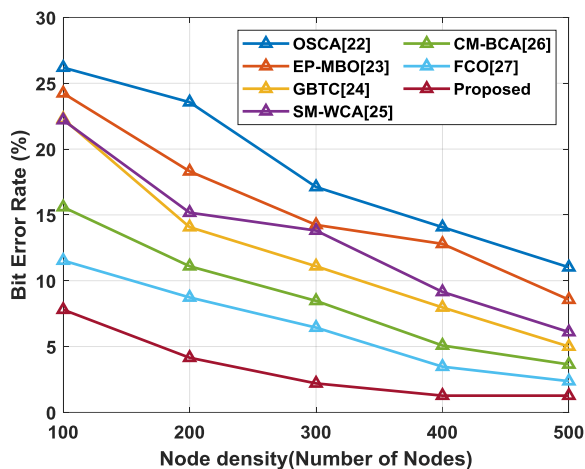


Figure 11 Performance Analysis of End-to-End Delay



Figure 12 Performance Analysis of BER

Figure 12 represents the BER analysis of the proposed work. The proposed Hybrid PSO-GA method gives the lowest BER than other methods. As the node increases, the value of BER reduced for all methods. At the initial stage, our proposed work shows a BER of 7%. The other methods show BER of 11%(FCO),15%(CM-BCA),22.5%(SM-WCA),24.9%(GBTC) and 26%(OSCA) for 100 nodes. At the starting stage of analysis, all the methods show their highest BER value. When the number of nodes is 500, all the methods give the lowest BER. The obtained energy efficiency is shown in the Table 2.

| Number of nodes | 100 | 200 | 300 | 400 | 500 |
|---|---|---|---|---|---|
| OSCA | 97.98 | 98.98 | 99.29 | 99.46 | 99.57 |
| EP-MBO | 98.06 | 99.02 | 99.3 | 99.47 | 99.57 |
| GBTC | 98.18 | 99.06 | 99.33 | 99.53 | 99.58 |
| SM-WCA | 98.3 | 99.1 | 99.35 | 99.56 | 99.58 |
| CM-BCA | 98.8 | 99.24 | 99.47 | 99.56 | 99.67 |
| FCO | 98.8 | 99.4 | 99.51 | 99.6 | 99.67 |
| Proposed | 99.03 | 99.46 | 99.53 | 99.64 | 99.68 |

Table 2 Energy Efficiency

## 5. CONCLUSION

An Energy-Efficient CH Selection method is introduced with the help of the Hybrid PSO-GA approach. The proposed work helps to overcome the energy consumption problem in MANET. The Soft k-means method is used for Clustering, which takes node distance, position, and speed into account for the best cluster formation. The Soft k-means method is utilized for clustering based on the factors such as node distance, position, and speed. After the cluster formation, the Hybrid PSO-GA method is used for selecting the CH from the nodes. The mobility of node, degree of node, and energy of nodes are used for CH selection. The performances are monitored by PDR, Energy Consumption, PLR, Energy Efficiency, Network Lifetime, Throughput, and End-to-End Delay. The simulation tool is the NS-2 platform. These performance metrics are compared with existing methods – CM-BCA, FCO, GBTC, OSCA, EP-MBO, OSCA, and SM-WCA. Simulation result verifies the performance of our proposed model with Higher PDR (99.38%), Lower Energy Consumption (0.6mJ), Minimum PLR (1%), Lower End-to-End Delay(2.01Sec), Network Lifetime (5500 rounds), throughput (0.95Mbps) and lowest BER (2%) than other methods. In future, the CH selection algorithm will be used with energy-efficient routing to evaluate the overall network performance and lifetime.

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