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SIBCSRP: Swarm Intelligence based Cluster Supported Routing Technique for MANET

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Abstract: ***In a mobile ad hoc network (MANET), the mobile nodes travel at random and are not constrained by any infrastructure. Clustering is a crucial model in MANET to improve the efficiency of routing. In a MANET, choosing a Cluster Head (CH) necessitates producing resiliency in the face of topology changes brought on by node movement, connection failure, and the insertion or removal of nodes. On the other hand, some malicious nodes intentionally drop data during network transmission, which results in ineffective routing and security for reaching the destination node. In order to increase throughput and network lifetime during multipath transmission, the proposed work is focused on increasing the stability in routing and secure data delivery with minimal end - to - end delay and energy consumption for MANET. This paper propose the Swarm Intelligence Based Cluster Supported Routing Protocol (SIBCSRP) to address these problems by improving cluster accuracy and routing efficiency to find the best route in MANET. Cluster Aided Routing Algorithm (CARA) and Trusted Path Selection Using Swarm Intelligence (TPSUSI) are the two components of the SIBCSRP. MANET problems including cluster head selection, multipath routing, data collecting, and localization are dealt with by CARA. To determine the best way for transmitting data packets, the ant feeding behavior created the meta - heuristic technique TPSUSI. By reducing End to End latency and Routing Control Overhead in the network, the proposed SIBCSRP protocol improves data packet delivery ratio.***

Keywords: Routing, Meta - heuristic, Fuzzy, MANET, Security and Cluster

1. Introduction

Mobile nodes work together in a mobile ad hoc network to forward data packets from source to destination. Intermediary nodes communicate with nodes outside of their communication range. Because of the dynamic mobility of mobile nodes and communication management, the Mobile Ad hoc network infrastructure - less nature frequently causes changes in the topology of the network. One of the main problems with MANET is the stability of the network [1, 2]. For the creation of stable networks, clustering is a solution. Nodes are separated into numerous groups through clustering, which make the network more stable, long - lasting, and scalable.

Security in MANET is another problem that receives significant attention in addition to protecting routing protocols and intrusion detection [3]. Lack of a defined line defense is the main security feature of MANET. In wired networks, dedicated routers carry out the device routing functions. Every mobile node serves as a router, sending packets to other nodes. Wireless channels are available to both network users and attackers [4, 5]. There is no regulation requiring the monitoring of traffic from various nodes when imposing access control measures.

The major goal of the paper is to increase data transmission security and clustering accuracy in MANET. MANET relies on **clustering - based routing to provide safe data transmission along the best route.** The performance of the network is impacted by the reduction in routing stability caused by data transfer across mobile ad hoc networks. For improving network performance, a lot of literature on secure cluster - based routing is available [6, 7]. In addition, there are energy - efficient methods, trust based routing, multi - hop routing, secured routing, and clustering techniques available to perform efficient routing in MANET [8], however efficient clustering and secure data transmission techniques are needed. **A cluster - based secure routing solution is proposed to address the problems with efficient routing.**

A Swarm Intelligence Based Cluster Supported Routing Protocol is proposed in this paper (SIBCSRP). Cluster Aided Routing Algorithm (CARA) and Trusted Path Selection Using Swarm Intelligence (TPSUSI) are the two components of the SIBCSRP. The Trusted Path Selection Using Swarm Intelligence (TPSUSI) protocol is developed to improve cluster accuracy and routing efficiency in MANET. MANET problems including cluster head selection, multipath routing, data collecting, and localization are dealt with by CARA. A meta - heuristic method called Ant Colony Optimization (ACO) is created by ant feeding behavior. The TPSUSI protocol is used in combination with the ACO algorithm to determine the best path for transmitting data packets. The cluster CH is then chosen based on its lower weight value. Using fuzzy values in MANET, the weight value of CH is determined based on Energy, Speed, Buffer size, and Node Degree. Data from every cluster node within a certain cluster group is gathered during the selection of CH and sent to the base station. For the best route discovery based on the proposed TPSUSI protocol, the cluster gateway is completed while disjoining the sets of two cluster nodes. As a result, data packets are successfully routed in MANET from source to destination node while using less energy. As a result, assessing the fuzzy rule with a longer network lifetime improves cluster accuracy. By reducing end - to - end delay and network routing control overhead, the proposed TPSUSI protocol improves data packet delivery ratio.

2. Clustering in MANET

Mobile nodes work together in a mobile ad hoc network to forward data packets from source to destination. Intermediary nodes communicate with nodes outside of their communication range. Because of the dynamic mobility of mobile nodes and communication management, the Mobile Ad hoc network's infrastructure - less nature frequently causes changes in the topology of the network. For the establishment of stable networks, clustering is a solution [9]. Nodes are separated into numerous groups through clustering, which make the network more stable, long - lasting, and scalable. Clustering is a method that divides a network into cluster - like substructures. Each cluster has a specific node selected as the CH relies on a specific statistic or combination of metrics such as degree, weight, density, and so on. Within the substructure, Cluster Head serves as a crucial coordinator. Within the cluster, each CH functions as a temporary base station and interacts with another cluster head.

Figure 1 shows the components of a cluster, including the cluster head, gateways, and cluster member nodes. The coordinator of the cluster is the Cluster Head. A node that connects two or more clusters is a gateway. Member Node is neither a CH nor a gateway node [10]. Each node has a cluster to which it belongs, regardless of any neighbors it may have in other clusters. A cluster node is elected as the leader node for data transmission using the cluster head election process [11]. The Cluster Head keeps track of information about its cluster. The data includes a list of the cluster's nodes as well as the paths to each one. To communicate with every node in its own cluster, CH is utilized. The CH connects with the nodes of other clusters either directly, via another CH that is pertinent, or via gateways. The process of communication involves three steps. Data sent by members of the cluster are received by the cluster head, which then compresses and sends the data to the base station or another CH. The Cluster Head prolongs network lifetime and reduces energy consumption.

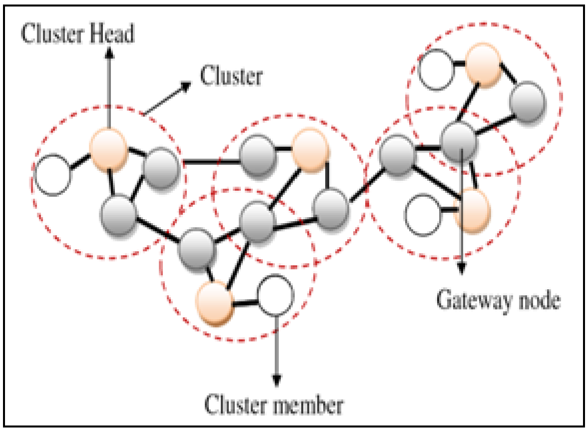

Figure 1: Cluster Structure in MANET

3. Fuzzy Logic System

The fuzzy set theory models describe erroneous and incomplete sensory data that the human brain imagines. The membership functions and set of fuzzy rules are used to characterize and mathematically manipulate such linguistic material in a natural way. In order to handle routing problems without using a mathematical model, the proposed algorithm tends to employ fuzzy logic to evaluates the best CH selection and optimal routing algorithm to select a route that may provide multi - hop reliability and efficiency while also taking into account node mobility, energy, buffer size, and degree when choosing a route. The final fuzzy value is efficiently defined using fuzzy rules [12]. It is possible to customize the fuzzy membership functions and associated fuzzy rules to guarantee a particular situation. **Defuzzification also converts the final fuzzy values into a numerical value.**

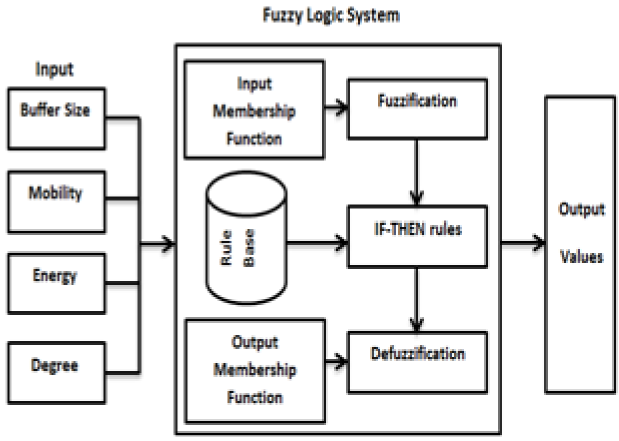

Figure 2: Fuzzy System

- **Fuzzification of Inputs/Outputs**

Fuzzification is the process of transforming several forms of input data into a single output in an inference system. All four input metrics, Residual Energy (RE), Mobility (M), Buffer Size (BS), and Node Degree (ND), must be fuzzified. The fuzzy logic obtains the study of information with the fuzzy set for each set of values representing the linguistic term to satisfy 'True' or 'False' and 'Low' or 'High' and so on.

Inference Engine and Knowledge Base System

The fuzzy inference system is a collection of instructions created with the assistance of experts. Fuzzy set theory models represent the human mind's perceived inaccurate and incomplete information [13]. Furthermore, it shows linguistic information in a simple manner using membership functions and fuzzy rules. The fuzzy rules are well established for obtaining the final fuzzy value. The IF - THEN pattern of the fuzzy set rules is utilized to infer output fuzzy values. The IF element is used to build conditions with predicates and logical links, whereas the THEN element is used to determine the degree of membership. To ensure an explicit scenario, fuzzy membership functions and fuzzy rules are used efficiently [14]. Furthermore, **the final fuzzy value is converted to a numerical number throughout the defuzzification process.** Table 1 summarizes the proposed fuzzy - based algorithm rules.

- **Defuzzification**

The process of converting fuzzy output into a single value is known as defuzzification [15], and the **defuzzification technique used in our proposed approach is the Centre of Gravity (CoG).** The fuzzy sets are fed into the defuzzification algorithm. The fuzzy inference system provides a series of output values that must be ***defuzzified in***

order to derive a single yield value from the fuzzy inference system, as shown in the above Figure 2.

Table 1: Linguistic Variables with Fuzzy

Rules	Residual Energy	Mobility	Buffer size	Degree	Cluster Efficiency	CH_Selection
R	R1	R2	R3	R4	Weight	CH-SL
1.	VLow	High	Small	Short	VLarge	CH
2.	VLow	Medium	Small	Short	VLarge	CH
3.	Low	Medium	Small	Sht-med	Large	CH
4.	Low	High	Small	Sht-med	Large	CH
5.	Low	High	Large	Med-L	Medium	CH
6.	Medium	Medium	Small	Med-L	Medium	CH
7.	Medium	Medium	Small	Large	Medium	CH
8.	Medium	High	Small	Large	Medium	CH
9.	Medium	High	Large	Large	Small	CG
10.	Medium	Medium	Large	Large	Small	CG
11.	High	Medium	Large	VLarge	Small	CG
12.	High	Medium	Large	VLarge	Small	CM
13.	High	Low	Small	Short	Large	CM
14.	VHigh	Low	Small	Short	Large	CM
15.	VHigh	Low	Small	Short	small	CM

4. Fuzzy Aided Ant Colony Optimization (ACO) Technique

Path selection is a critical challenge in routing algorithms, and the **proposed technical work addresses this issue** by creating the routing algorithm using Ant Colony Optimization [16] and Fuzzy logic approaches. The path information produced by ants is provided to FIS (Fuzzy Interference system) for computing the score values of the various paths, and the optimal paths are determined based on the FIS system score value.

$$P_{xy}^{\alpha} = \frac{T_{xy}^{\alpha}\,\eta_{xy}^{\beta}}{T_{xy}^{\alpha}\,\eta_{xy}^{\beta}} \text{ - - - - - - - - - - - - (1)}$$

T_{xy}^{α} , is the amount of deposited pheromone during transition from x to y and η_{xy}^{β}, is the desirability of the transition xy. Considering N as the number of nodes, x as the source point and y as the destination point, the limit for x and y is given as: $1 \leq x \leq N$ and $1 \leq y \leq N$. The calculation of the probability of each path connecting the source and destination is done with the help of equation 1. The key step required for delivering fuzzy intelligence to the ants is the formulation of rules for the hybrid fuzzy approach based on the fuzzy integrated ACO. In the instance of FIS, the specified input parameters, such as energy, buffer size, mobility, and degree, are trained using a Quadruplet membership function as the membership grade to produce the FL and a fuzzy weight matrix as the output. The specified FL inputs are fuzzy divided into two sets, high and low, meanwhile the output is **fuzzy divided into three sets, high, low, and medium,** and the hybrid fuzzy rules are constructed based on such input and output variables.

The shortest path between the source and destination is discovered using fuzzy weight values in ACO. The ant pheromone [16] deposition and updating are presented in the following series. After all successful iterations, the deposited ant pheromone is updated by travelling from one node to another. The equation (2) is used to calculate the amount of deposited pheromone.

L_k denotes the cost of Kth ants tour and Q is kept constant

$$\nabla T_{xy}^{k} = \begin{cases} \frac{Q}{L_k}\, if\ any\ ants\ uses\ curve \\ 0 \qquad otherwise \end{cases} \text{--------------(2)}$$

The formula for calculating the Pheromone update is given in equation (3), and it is based primarily on both the pheromone evaporation coefficient and the amount of pheromone deposited. ρ - Pheromone Evaporation coefficient in the preceding equation (2).

$$T_{xy} = (1-\rho)T_{xy} + \textstyle\sum_k \nabla T_{xy}^{k} \text{-----------------(3)}$$

The procedure is repeated by updating the pheromone, and the results are collected by probability computation for each conceivable path to discover the shortest path for the respective route. The cost function for the shortest path is calculated using the numbers energy (θ), mobility (φ), buffer size (φ), and degree (α), which are expressed in equation (4) as follows:

$$\xi = 0.25\,\frac{1+\sum_{i=1}^{n}\varphi_i(\varphi_i+\theta+\alpha)}{\sum_{i=1}^{n}\varphi_i} \text{------------(4)}$$

$$\alpha = \alpha_1 + \alpha_2 + \cdots + \alpha_n$$

$$\alpha_1 = \varphi_1\lambda\alpha_2 = \varphi_2\lambda + \varphi_1\tau$$

$$\alpha_2 = \varphi_3\lambda = \varphi_2\tau$$

$$\alpha_n = \varphi_{n-1}\tau$$

5. Proposed Swarm Intelligence Based Cluster Supported Routing Protocol (SIBCSRP)

The proposed Swarm Intelligence Based Cluster Supported Routing Protocol (**SIBCSRP) is intended to improve routing efficiency** while consuming less energy in mobile networks. As shown in Figure 3, the proposed SIBCSRP protocol in MANET contains three distinct stages. To begin, the TPSUSI algorithm is used to determine the best path for routing in the network. Following that, the CARA algorithm is implemented in the proposed SIBCSRP protocol using a weight factor and a fuzzy rule. Thus, a lower weight value is acquired from all other cluster nodes inside a certain cluster group and then broadcast to the base station with the minimal end - to - end delay achievable using the proposed TPSUSI protocol. Finally, utilizing fuzzy rules, the route discovery process is accomplished within the cluster for determining the optimum route from source to destination node in MANET. ***This, in turn, increases network lifetime while consuming less energy*** for efficient routing during transmission using the proposed SIBCSRP protocol. As a result, the proposed SIBCSRP protocol achieves much greater Cluster Accuracy and Packet Delivery Ratio with minimal end - to - end delay.

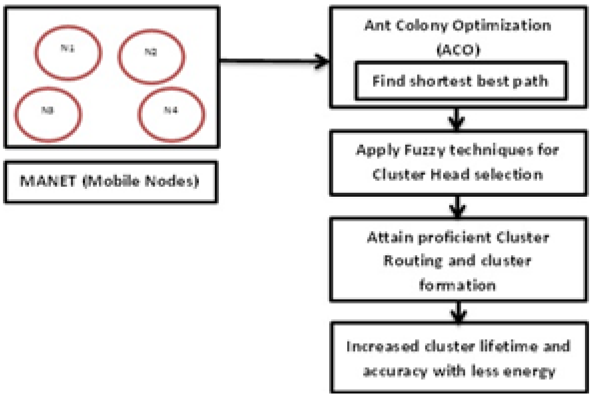

Figure 3: Block Diagram of SIBCSRP

According to Figure 4, the proposed SIBCSRP protocol first constructs the cluster node deployment for effective routing from source to destination node in MANET. The cluster head selection for each node operation is then performed in order to evaluate the weight value utilising fuzzy rules. If the weight value is the minimum, the CH selection process is achieved with less energy utilisation based on the proposed SIBCSRP protocol, or the cluster head process is reelect. The route discovery process is then finished in order to choose the CH with the best fuzzy value by comparing two cluster nodes. Fuzzy rules are used in the early stages of a disjoining set of two clusters to achieve efficient optimal route discovery utilising ACO with reduced delay and routing control overhead during transmission in MANET. The ACO method is used to successfully route data packets from source to destination nodes while consuming less energy and extending network lifetime over a wireless network. As a result, **the proposed SIBCSRP protocol improves cluster accuracy and packet delivery ratio** in MANET while also being more efficient.

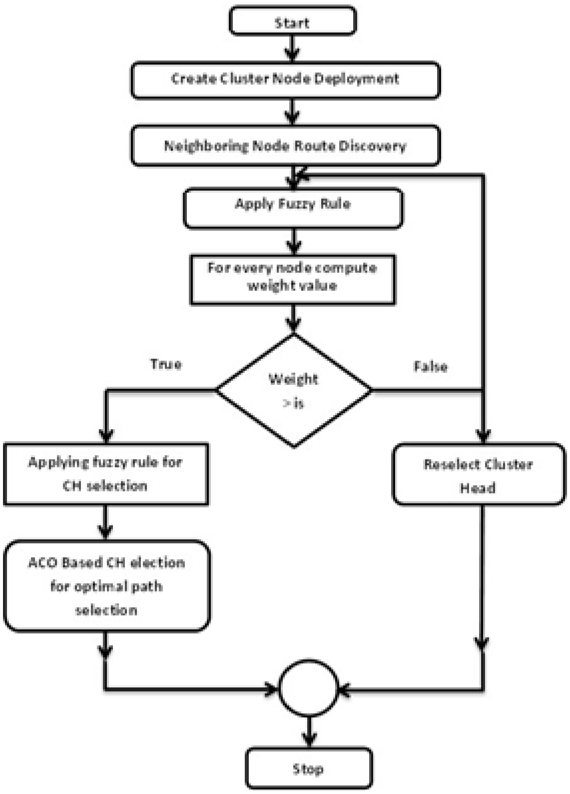

Figure 4: Flow Diagram of Proposed SIBCSRP

Consider that 'i' refers to the cluster node in the network and n(i) is the number of cluster nodes. In a MANET, a cluster consists of 'n' mobile nodes '$MN_i = MN_1$, MN2 ...MNn'. By analyzing node weights, any node in a cluster can become the cluster head. **The weight is calculated using four factors: energy, speed, buffer size, and node degree.** The following is the mathematical calculation for the weight associated with a node in relation to fuzzy rules when utilizing the proposed SIBCSRP protocol.

Weight=(WF1*nE)+(WF2*nB)+(WF3*nM)+(WF4*nD) (5)

According to Equation (5), the node with the lowest weight is chosen as the cluster head node for efficient MANET routing. The energy is represented by 'nE, ' the difference between degree and its ideal degree is represented by 'nD, ' the buffer size of each node is represented by 'nB, ' and the node mobility or speed of movement is represented by 'nM. ' The weighting factors are denoted by WF1, WF2, WF3, and WF4. When the weighting factors are increased, the fuzzy values can be written as WFl + WF2 + WF3 + WF4 = l. The weight of node determines the cluster head based on the weight value of each node. If the node sends or receives packets to or from the header, the parameter may change.

The node is then in charge of forwarding the packets to the nearby node even if there is no response if it is ideal. As a result, the weight varies depending on the node's characteristics. According to **the proposed SIBCSRP protocol, the MANET requires the cluster head to be re - elected** whenever the energy level of the cluster head becomes low while connecting with neighbouring nodes or cluster heads. Euclidean distance is one of the parameters used by the cluster formations to calculate the weight value. To transport the packet (i. e., created randomly) from source to destination nodes, the distance is determined using fuzzy rules. Within the MANET transmission range, the distance between the two nodes is calculated as follows.

$$Fuzzy\ Distance\ (FD) = \sqrt{(p_2 - p_1)^2 + (q_2 - q_1)^2} \quad (6)$$

'p' and 'q' are designated as the coordinates with respect to the movable node in Equation (6). Additionally, the cluster's radius or centre is established using the following formula.

$$Radius = Over\ fuzzy\ distance\ /\ 2\text{------------------}\ (7)$$

The cluster radius is calculated from Equation (7) using the proposed SIBCSRP protocol. Since the node distance from all other nodes is nearly equivalent and the fuzzy distance is smaller than the radius, the node might serve as the cluster head. The weight factors of each ant are then used to evaluate the fuzzy rule using the fuzzy interference system, where "WF=1 and i=1" is provided by,

Weight p (WF1) =F_ant_L / (Node Energy * WF1 * 100) - - - - - - - - - - - - - - - - - - (8)

Weight p (WF2) =F_ant_L / (Node Speed * WF2 * 100) - - - - - - - - - - - - - - - - (9)

Weight p (WF3) =F_ant_L / (Node Buffer Size * WF3 * 100) - (10)

Weight p (WF4) =F_ant_L / (Degree of Node * WF4 * 100) - - - - - - - - - - - - - - - (11)

Equations are used to calculate the weight value depending on factors including energy, node speed (mobility), buffer size, and node density utilizing the proposed SIBCSRP protocol. Where ‘i’ refers to the rule of optimization and "R" refers to the number of routines. The food value of Ant_Node is therefore given in the following form.

R=WF1+WF2+WF3+WF4 - - - - - - - - - (12)

According to the proposed SIBCSRP protocol, Equation (12) is used to estimate Ant Node food value. The difference between the maximum values of clusters and the food value of Ant_node in MANET is then used to measure fuzzy values.

F_value=Maximum cluster value – Food value of ant_node - - - - - - - - - - - - - - - - - - (13)

If the fuzzy value in the node is larger than or equal to F ant L, according to Equation (13), the new fuzzy value is set as the node. As a result, the cluster head node is selected approximately, and the header is chosen using the proposed SIBCSRP protocol to compute the parameter weights. Every cluster node packet information is included in F_ant_L. The cluster head should also be taken into account by the radius when choosing the most optimized cluster member using MANET's optimization rules and routines. Each node in the cluster is responsible for maintaining this information.

As a result, the cluster head node based on **the proposed SIBCSRP protocol is chosen as the best node with fuzzy value.** Considering that it gathers information from all other cluster nodes collected through a certain cluster group and sends it to the base station utilizing the proposed SIBCSRP protocol in the MANET within the cluster head. By performing CH selection with a lower weight factor during transmission over a mobile network, the proposed SIBCSRP protocol enhances cluster stability. According to Figure 5, the algorithm for cluster head selection uses a mobile data set and a weight factor with fuzzy rules.

```
Input: Mobile Nodes 'MNi =MN1, MN2,..., MNn ', Source Nodes 'S', Destination Nodes 'D', Cluster Node 'i'
Output: Achieve best cluster head
        Start
        For each mobile node
        Estimate the fuzzy distance using (2)
        Estimate the node radius using (3)
              For R=1; Routines
                  For i=1;
                      Estimate the weight factor based on ACO using fuzzy rule (4), (5), (6), (7), (8)
                      Measure the food value of the Ant_Node using (9)
                      Measure the fuzzy value using (10)
                      If "F_value>=F_ant_L in node", then
                          Set new Fuzzy value as the node
                      End If
                  End For
              End For
        If "F_ant_head (i, R)>F_ant_L (i, R)", then
              F_ant_Li (I, R) = F_ant_head (I, R)
        End If
        Perform Maximum Elimination criteria of half the F_ant_Li nodes clusters
        For i=1; Ant nods/2
              If (i. F_value > F_ant_L)
                      i. Role = Cluster Head
              Else
                      F_ant_Li. Role = Cluster Head
                      Select a node in F_ant_L values is higher than the cluster is CH
                      F_values (best) =F_ant_Li
              End if
        End For
        Obtain best node with the fuzzy value is elected has CH node
        End For
        End
```

Figure 5: SIBCSRP - CH Selection using CARA Algorithm

Following the cluster head selection, the proposed SIBCSRP protocol is used in the network to implement the route discovery process. The cluster node is first chosen as the cluster header by the proposed SIBCSRP protocol without any loss. The node "X" is then set while its cluster's neighbours are all segmented. After then, the node with the lowest weight is chosen from the remaining ungrouped nodes and is deemed to be one of cluster X nearby nodes; similarly, cluster Y neighbouring nodes have the least amount of generality loss. belongs to the neighbour node set of Y, however Z cannot be a member of the neighbour set of node X. All nodes are split into a cluster when the cluster node Z is selected as the cluster header of the following cluster. Thirdly, if the cluster headers are linked to one another, the cluster headers connect two clusters. After clustering in the network, two clusters won't be able to communicate with one another if their headers for the clusters don't have connections. The two clusters should include the link between two ordinary nodes because this is a connected graph, and then they should select both nodes as cluster headers. While partitioning the sets of two clusters, the nodes may act as a gateway between them.

Thus, the fuzzy rulesfor interferences system and ACO are employed to achieve the selection of optimal route for efficient routing over the network communication by using proposed SIBCSRP protocol, Figure 6 demonstrates the algorithmic process of route discovery algorithm in MANET based on proposed SIBCSRP protocol as follows. In order to select the best route for effective routing over network communication using the proposed SIBCSRP protocol, the fuzzy rules for interferences system is used. Figure 6 shows the algorithmic process of the route discovery algorithm in MANET based on the proposed SIBCSRP protocol as follows.

```
Input: Mobile Nodes 'MNi = MN1, MN2,..., MNn', Source Nodes 'S', Destination Nodes 'D', Cluster Node 'i'
Output: Improved cluster accuracy with minimal energy consumption
    Begin
    For each mobile node
        Select two nearby nodes in a cluster say X, Y
        Cluster head is selected for best fuzzy value through comparing nearby nodes X and Y
        Sent Hello messages to every nodes within the cluster
        If "equal value is received for both nodes", then
            "Fuzzy rule is applied"
        Else "equal value is not received for both nodes", then
            "Fuzzy rule is not applied"
            Analyze other parameters 'Z' by fuzzy rule better cluster head is selected and another
            node performs the member node
        End If
    Sent Hello messages to every nodes within the cluster (Repeat this process)
    When disjoining sets of two clusters the nodes may act as gateway between the clusters
    End For
    End
```

Figure 6: SIBCSRP - Shortest path selection using TPSUSI

6. Performance Analysis of Proposed SIBCSRP Protocol

The proposed SIBCSRP protocol's results are compared with those of a previously proposed protocol called Secure Routing Algorithm Based on Differential Evolution (SRABDE), as well as those of existing techniques like Ad hoc On - Demand Multicast Distance - Vector Secure Adjacent Position Trust Verification Routing Protocol (AOMDV - SAPTV), Node Disjoint Energy Efficient Multipath Routing (NDE - MR), DE algorithm - based Ad hoc On - Demand. Following that, a performance study of **the proposed SIBCSRP protocol is done using the graph in order to provide better result analysis.**

Simulation Setting:

In NS2, this protocol is simulated. The network environment simulation settings are displayed in Table 2.

Table 2: Simulation Parameter

Parameter	Values
No. of Nodes	500
Area Size	1100 X 1100 m
Mac	802.11
Radio Range	250m
Simulation Time	60 sec
Traffic Source	CBR
Packet Size	80 bytes

1) Cluster Accuracy

According to the proposed SIBCSRP protocol, the cluster accuracy is calculated as the proportion of data packets segmented into appropriate clusters for each mobile node. The cluster accuracy is measured in terms of (%) percentage and scientifically represented using the equation below (14).

CA = Number segmentation are performed correctly in cluster / Total no of pckets * 100 - - - - (14)

When shown in figure 7, all of the proposed MANET approaches result in higher cluster accuracy as the number of packets is increased. However, the proposed SIBCSRP protocol gives the optimal performance in terms of enhancing cluster accuracy in MANET when compared to existing approaches. Figure 7 shows a graph that is plotted based on the expriment values. The proposed SIBCSRP protocol performs routing over communication between cluster nodes, choosing the path from the source node to assure routing optimization to reach the destination node.

As a result, the MANET minimum energy consumption is decreased, increasing the cluster accuracy**.** Comparing the proposed SIBCSRP protocol to the existing AOMDV - SAPTV, NDE - MR, DE - AOMDV, TPACO, and the previously proposed technique SRABDE, **the cluster accuracy of SIBCSRP is maximised in MANET.**

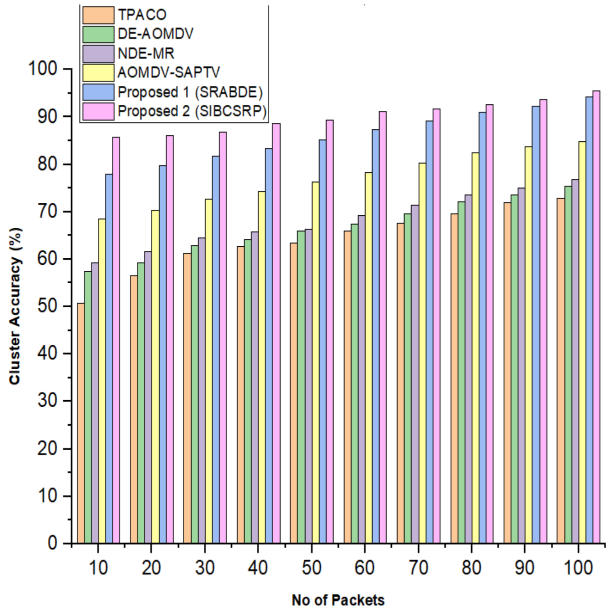

Figure 7: Performance of Cluster Accuracy (SIBCSRP)

2) Packet Delivery Ratio

The number of packets that correctly reach the destination node during transmission in a MANET is known as the packet delivery ratio. As shown in the following equation (15), the packet delivery ratio is calculated mathematically and expressed as a percentage (%).

PDR = Number of packets reached at destination / Total no of packets - - - - - - - (15)

The assessment of packet delivery ratio using the proposed SIBCSRP protocol in MANET is explained in Figure 8 and compared with the already existing methods, such as AOMDV - SAPTV, NDE - MR, DE - AOMDV, TPACO, and the previously proposed method SRABDE. When compared to existing techniques, **the proposed SIBCSRP protocol improves the packet delivery ratio in MANET**, as shown in Figure 8.

This is as a result of the proposed SIBCSRP protocol being used, in which the cluster nodes selected the cluster head node from among the mobile nodes to carry out network - optimized routing. This is done based on the weighting parameters in order to manage data packet enhancement and keep transmission sustainability.

In order to improve route discovery, network lifetime, and cluster accuracy, fuzzy rules are applied to a disjoining set of clusters. **This increases packet delivery ratio dramatically** while also enhancing network lifetime and cluster accuracy.

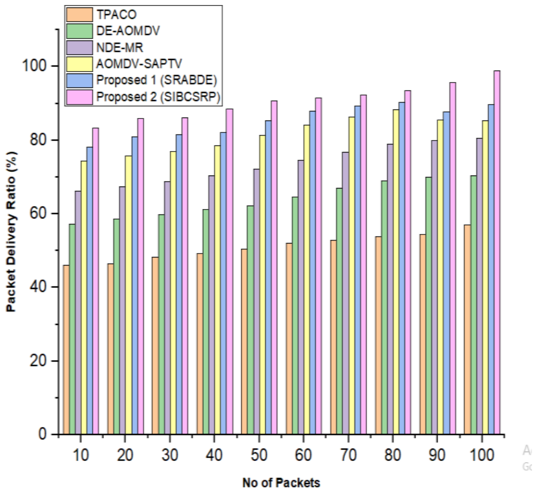

Figure 8: Packet Delivery Ratio

3) End to End Delay

Applying the proposed SIBCSRP protocol, the end - to - end delay is calculated as the amount of time needed to send data packets among the MANET nodes. The following equation (16) mathematically expresses the end - to - end delay in milliseconds (ms).

EED = Number of packets * 100 - - - - - - - - - (16)

Figure 9 compares the end - to - end delay measured using the proposed SIBCSRP protocol in MANET with the already existing methods, including AOMDV - SAPTV, NDE - MR, DE - AOMDV, TPACO, and the previously proposed approach, SRABDE. Figure 9 shows that when compared to existing techniques, the proposed **SIBCSRP protocol significantly reduces MANET end - to - end delay.** This is because the proposed SIBCSRP protocol uses the cluster head selection algorithm to determine which nodes have the best stability during clustering in order to preserve sustainability. In addition detecting the optimal path, any disjoint node is used for achieving efficient routing with minimum time in MANET. As a result, end - to - end transmission time is effectively decreased.

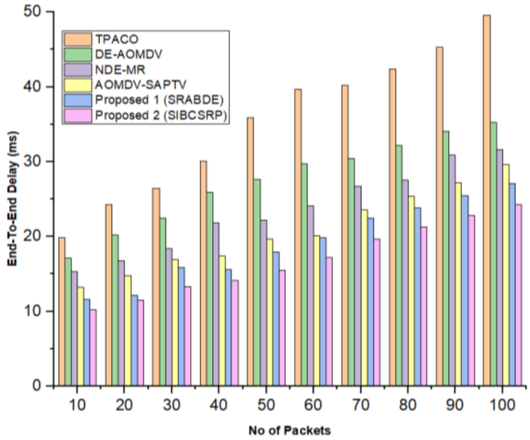

Figure 9: End – End Delay

4) Energy Consumption

When the proposed SIBCSRP protocol is used, energy consumption is the amount of energy used for data packet delivery in the network. It is represented mathematically using the following equation (17) and calculated in Joules (J).

EC = Number of nodes * Energy - - - - - - - - - - (17)

Figure 10 shows the comparison of the proposed SIBCSRP protocol's measurement of energy consumption in MANET with the existing methods AOMDV - SAPTV, NDE - MR, DE - AOMDV, TPACO, and the previously proposed method SRABDE. When compared to existing techniques, it is illustrated in Figure 10 that the **proposed SIBCSRP protocol uses less energy when executing routing in MANET.** This effective energy consumption reduction is accomplished using the proposed SIBCSRP protocol's MANET route discovery algorithm. In order to perform efficient routing and use less energy during data packet transmission, this is done by disjoining the set of clusters among the mobile nodes.

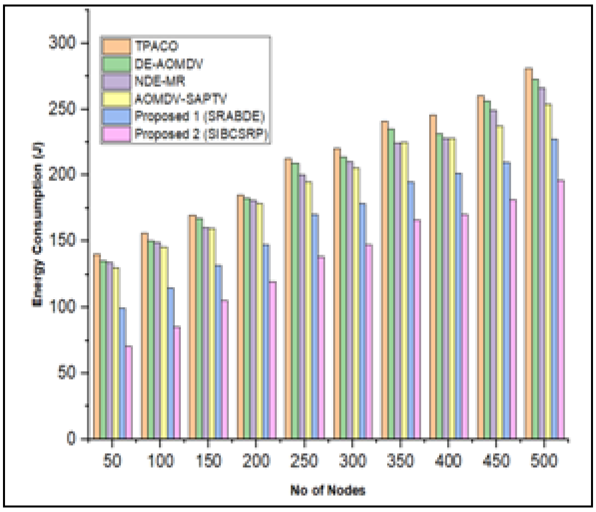

Figure 10: Energy Consumption

7. Routing Control Overhead

With the proposed SIBCSRP protocol design, routing control overhead is calculated as the proportion of control messages transmitted to the actual data received at each node during MANET transmission. The following equation (18) is the mathematical formula for control overhead expressed as a percentage (%).

RCO = Actual data received / no of control information sent * 100 - (18)

Figure 11 shows the comparison between the proposed SIBCSRP protocol and existing methods such as AOMDV - SAPTV, NDE - MR, DE - AOMDV, TPACO, and a previous proposed method SRABDE for measuring the routing control overhead in a MANET. According to Figure 11, when compared to existing techniques**, the routing control overhead of the proposed SIBCSRP protocol is reduced over the mobile network.** This is because the proposed SIBCSRP protocol makes use of the ACO algorithm and the CH selection process by using fuzzy rules in order to achieve the best route discovery in MANET. In turn, this enhances the reduction of the routing control overhead from source to destination node.

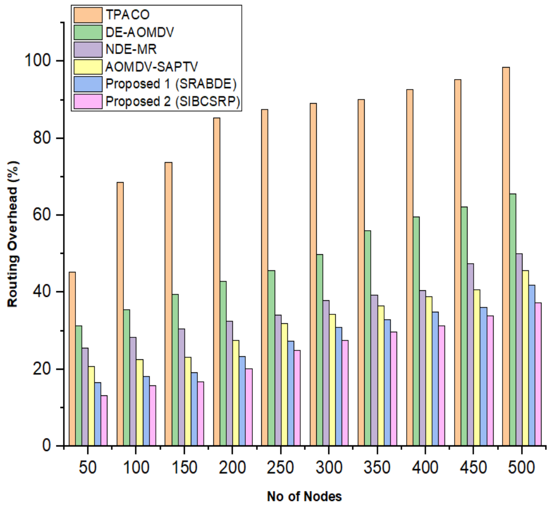

Figure 11: Routing Control Overhead

8. Intrusion Detection Rate

The proportion of normal and intruder nodes to all nodes in a mobile network is known as the intruder detection ratio, or IDR. It is determined in percentage (%) and shown in the equation below (19).

IDR = No of normal nodes – No of malicious nodes / total no of nodes * 100 - - - - - - - - - - - - - - - (19)

Figure 12 compares the proposed SIBCSRP protocol measurement of intrusion detection rate in MANET to the methods that are already in use, including AOMDV - SAPTV, NDE - MR, DE - AOMDV, TPACO, and the previously proposed method SRABDE. Figure 12 shows that when compared to existing techniques, **the proposed SIBCSRP protocol has a higher intrusion detection rate in the mobile network.** This is due to the node disjoint path model, which is used to divide data packets into a number of segments with improved security in the network.

The nodes may act as a gateway when separating a pair of clusters. In addition, a fuzzy rule for interferences system is employed to give optimal route path selection for effective routing in the network utilising the proposed SIBCSRP protocol. As a result, the intrusion detection rate across the network is enhanced in an efficient way.

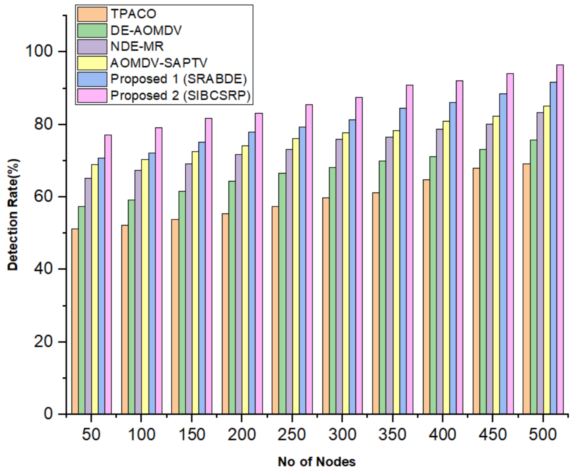

Figure 12: Intrusion Detection Rate

9. Conclusion

For better route discovery in MANET, **an effective SIBCSRP protocol is developed to improve cluster accuracy and routing efficiency.** First, the MANET's optimal path identification uses the ACO algorithm. The proposed SIBCSRP protocol then selects the cluster head with the lowest weight value. With the help of fuzzy value, the weight value is evaluated based on four variables, including energy, speed, buffer size, and degree of node. When choosing the best CH, it gathers information from every other cluster node found in the specific cluster group and sends it to the base station for effective routing. Finally, in MANET, ***fuzzy rule with disjoining set of two clusters takes place with optimised route discovery*** from a source node to a destination node, improving cluster accuracy and network lifetime. With decreased end - to - end delay and routing control overhead, the proposed SIBCSRP protocol increases packet delivery ratio for successful data transmission over wireless communication. Additionally, the proposed SIBCSRP protocol is evaluated in the MANET using the metrics of end - to - end delay, cluster accuracy, packet delivery ratio, energy consumption, and routing control overhead. **The simulation results show that the proposed SIBCSRP protocol offers higher performance** with improvements in cluster accuracy, packet delivery ratio, intrusion detection rate, and reductions in end - to - end delay, energy consumption, and routing control overhead.

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