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Self-Organization Based Clustering in MANETs Using Zone Based Group Mobility

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ABSTRACT The dynamic network topology and mobile nature of nodes can cause challenges regarding connectivity and routing. Clustering in mobile ad-hoc networks (MANETs) is one of the effective ways to organize a network according to the network topological changes. In this paper, we propose a self-organization-based clustering scheme in MANET using zone-based group mobility to improve scalability and stability of overall network. This proposed algorithm utilizes the bio-inspired behavioral study of birds flocking for the formation and maintenance of clusters in MANETs. A dynamic mechanism for cluster size management is taken into account to reduce network congestion and improve the performance of the MANETs in group mobility. For proper use of resources and to reduce extra energy consumption, an algorithm is also proposed to handle the isolated nodes. Simulation result shows that proposed algorithm reduces the energy consumption and improves the network lifetime along with more robustness.

INDEX TERMS Clustering, self-organization, group mobility, MANETs, bird-flocking.

I. INTRODUCTION

The recent advancement in network based wireless technologies has opened new doors for Mobile Ad-hoc Networks (MANETs) to achieve significant attention and popularity. MANET has a significant potential in multiple fields with numerous applications. It is rapidly improving and evolving for the practical implementation in several civilian and military real time scenarios. MANET has a potential to act as a backup network to facilitate users in case of failure of other networks in any disaster. The feature of data transmission at multiple hops through nodes with large coverage area makes it an ideal choice to be used in natural disaster and emergency situations. Furthermore, MANETs consists of mobile nodes capable of creating a network topology with dynamic environment. These mobile nodes can move freely without any use of centralized infrastructure [1].

Data transmission between mobile nodes is achieved by using routing protocols and performance of any network depends upon it [2]. Clustering is one of the types of routing and an effective way to transfer data between nodes in a network. It can improve the overall scalability of the network and provide stability by using hierarchical network environment. In clustering based MANETs, entire network is divided into small groups named as a clusters [3]. A cluster consists of cluster member nodes, gateway nodes and cluster head (CH) as shown in figure 1. A cluster design mechanism mainly consists of two stages, i.e. cluster formation stage and cluster management stage. In cluster formation a selection of CH takes place. A CH controls the overall performance of the cluster and it is elected among the member nodes of the cluster. A CH can access all the member nodes and it is responsible to manage the cluster in an effective and efficient manner. Therefore, the selection of CH is one of the main tasks in all clustering based algorithms and every cluster member can be a candidate to be elected as a CH at the time of CH election. The task of cluster organization is performed by CH. The cluster management stage controls the CH re-election procedure and manage the communication between nodes in an efficient manner [3]. The communication between the nodes of the same cluster is called intra-cluster communication while inter cluster communication takes place when a node of one cluster communicates with the node of other cluster through gateway nodes. Gateway nodes of each cluster are responsible to manage communication among clusters.

In MANETs, main challenges for clustering algorithms are optimal CH selection, network topology management and improvement of network performance in the presence of

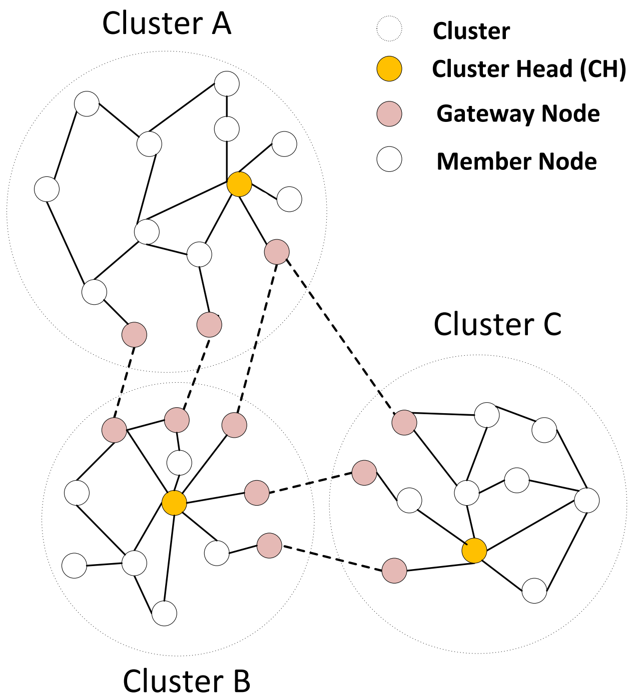

FIGURE 1. Clustering in MANETs.

mobility along with minimization of energy consumption at every node. Selection criteria of a CH are unique in every category of clustering scheme. In [4], the decision regarding the selection of CH among all member nodes takes place on the basis of weight value of a node. A weight value of each node is calculated based on the combined value of node degree, node energy and relative speed of a node. A CH is elected on the minimum weighted value of a node calculated by using a formula as mentioned in [4]. More number of overheads and transmission delays are the main drawbacks in this scheme which can degrade the performance of a network. In [5], the selection of CH is taken place based on the value of energy level of a node. A node with highest value has highest possibility to be a CH but this scheme needs extra steps to complete the cluster management phase, which causes traffic load on the network, produces delays and as a result affects the efficiency of overall network.

In [6], a unique identifier (ID) is assigned to every node based on the number of its neighborhood nodes. A node with the largest number of neighbor nodes will be assigned with lowest ID. Every node creates a neighbor node table which consists of two entries: neighbor node ID and neighbor node type. Each node broadcasts a Hello message within one hop distance. This hello message contains information about the total number of neighbor nodes, its ID and the smallest ID among the neighbor nodes. When a node receives this hello message, it will compare its ID with smallest ID. A node with smallest ID will declare itself as a CH [6]. This scheme improves scalability and ensures better transmission range of a cluster but it takes more exchange of control messages between nodes during CH selection. Schemes [7], [8] are designed to manage the topological changes in network and a CH is elected in these schemes by considering the node degree, energy level and neighborhood benchmark. These schemes improve the scalability, Quality of Service (QoS), and stability of the network with balancing the number of CHs but they are only suitable for small scale MANETs with low mobility. In large scale MANETs [7], it consumes more energy because a lot of computational power is needed to compute many parameters at CH and member nodes . This can cause congestion and end to end delays in both inter and intra cluster communication. There are also some hybrid schemes [9], [10] which are the combination of two or more algorithms to achieve the stability in the network but sometimes hybrid schemes cause more energy consumption on cluster member nodes as well as on CH in the presence of mobility [10].

A. OUR CONTRIBUTIONS

Keeping in mind the limitations of existing schemes, we propose a bio-inspired algorithm in MANETs which ensures Self-Organization based Clustering using Zone based group mobility Model (SOCZBM). In SOCZBM, our major contributions are:

1) Nodes are deployed in MANETs using zone based approach and behavioral study of bird flocking is utilized to achieve group mobility.
2) Selection of CH takes place by taking 3 different scenarios in MANET.
3) A dynamic mechanism for cluster size management is taken into account to control the network congestion hence improve the performance of cluster based MANETs in the presence of group mobility.
4) An algorithm to manage isolated nodes is proposed in SOCZBM to improve the use of resources and decrease the loss of energy.
5) Both Intra and inter cluster communications are considered for MANETs in SOCZBM.

B. ORGANIZATION

In this paper, we propose a self-organization based clustering algorithm which manages the topology of a cluster using zone based node deployment. This paper is organized as follows: Section 2 covers the related research work regarding our scheme. Section 3 explains the system models and some of the requirements of clustering based schemes in the presence of mobility. Section 4 consists of our proposed SOCZBM. In this section we discuss different phases of our schemes with multiple algorithms for formation and maintenance of clusters. Section 5 contains performance evaluation and section 6 concludes this paper.

II. RELATED WORK

A genetic algorithm based on hyper-mutation is proposed [11] for dynamic load balancing in the presence of changing environment. In this scheme a genetic method is used to perform clustering in MANETs. The rate of mutation is adaptive at every generation so that the diversity of population can be easily controlled. The mutation rate is directly related with change in the network topology which helps to find a good solution in the presence of changing environment. Load balancing is achieved by considering the standard deviation of CH degree. In [12] a mechanism to control the transmission power in a cluster is proposed. The rate of transmission power is adjustable in a cluster according to the density of a node. Self-organization of power in every cluster will decrease the interference among clusters and the power consumption at every node. Blough *et al.* [13] propose a scheme in which topology of a network is adjusted dynamically according to the change in environment. The main objective of this algorithm is to maintain the topology of a MANET in an effective and stable manner by using the coordination between neighborhood nodes. This algorithm is only suitable to deal with small clusters having less number of member nodes.

In [14] every node is assigned an ID based on the weight value of power consumption and mobility pattern. A node with lowest ID is elected as a CH. Each node broadcast a Hello message to its neighborhood node along with its ID. After receiving a Hello message from all neighborhoods, a node will compare its ID with the one received in Hello message. If a node has a lowest ID as compare to all neighborhood nodes, it can claim itself as a CH. This algorithm improves the stability and balance the load in clustering environment. More exchange of control messages among nodes can cause more power consumption and reduce the efficiency of CH. In [15] every node broadcasts a packet which contains its ID to the neighboring node. After receiving this packet each node estimate the distance between each other from received signal strength. The CH election takes place on a special attribute called quality of node. The quality of node depends on metrics of the highest node degree, the lowest node mobility, the highest battery energy and the best transmission range of the node which ensures stability in MANET. Every node selects a suitable transmission range that ensures connectivity between neighborhood nodes and save power consumption. In this algorithm as the transmission range of a node adjusts itself according to the number of neighbors therefore in some scenarios the node speed can influence the connectivity.

In [16] the nodes are grouped according to their pattern of mobility. A selection of CH takes place on the relative mobility level of a node. A node with lowest change in its mobility pattern as compare to neighborhood nodes is a suitable candidate to be elected as CH. The mobility pattern is the metric used for the cluster maintenance and fault identification. This algorithm improves network stability but rapid change in mobility pattern can cause issues in CH selection and cluster maintenance procedure. Mobility prediction based clustering algorithm (MPBC) [17] consists of cluster formation stage and cluster maintenance stage. In clustering formation stage, every node broadcast a Hello packet to its neighbor to organize a neighbors list. The exchange of Hello packets between neighborhood nodes is used to calculate the average relative speed of a node. The relative mobility level is used for the selection of CH and a node with lowest relative mobility level is considered as a best candidate for CH. A prediction based mechanism is used in cluster maintenance stage to handle the problem related with relative movement of a member node. MPBC provides cluster stability because mobility prediction can control some needless merge of cluster but long lifetime of CH can cause a lot of energy consumption due to exchange of multiple message packets.

An ant colony [18] based optimization algorithm is used to balance the number of member nodes in each cluster and decrease the hop counts for both inter and intra cluster communication in MANETs. This algorithm also improves the power efficiency of nodes. The main drawback is in the selection of best solution because it only considers those functions which have same weighted sum and performance of algorithm is sensitive to weight settings. A bio-inspired low complexity clustering (B-LCC) [19] is proposed for Wireless sensor network (WSN). This algorithm is inspired from the bird flocking behavior. B-LCC is a simple and well distributed clustering mechanism in WSN because it does not require information regarding number of neighborhood nodes, time synchronization between nodes and topology of a network. It has an advantage of network scalability and stability of connection between member nodes and CH. The main disadvantage is CH transmits more message packets in clustering stage. Cluster members also transmit at constant level of power regardless of their distance from CH which can cause wastage of energy. Self-organized approaches have been used not only in cognitive radios [20]–[22] but also in small cell clusters [23] and vehicular ad-hoc networks [24]. Introduction of this approach in cluster based MANET is a good idea to improve overall performance.

III. PROBLEM STATEMENT

A. NETWORK MODEL

In MANETs we consider a network model which consists of multiple nodes. These nodes possess some properties which are as follow:

1) Nodes are not static and they are changing their place dynamically.
2) The network topology, total number of nodes and number of neighbors in a network are unknown to every node initially.
3) Nodes are not equipped with GPS facility.
4) Every node possesses same capability in term of data processing, computational power and data storage.

B. REQUIREMENT OF CLUSTERING

In MANETs the nodes are not always static and they possess the ability to move freely. The mobility factor is an important parameter. For mobility based MANET, it is more essential to fulfill the basic characteristics and main requirements of clustering in the presence of mobility. Therefore in case of mobility it is a challenging task to manage a stable and efficient clustering environment in MANET and researchers need to focus more on these requirements while designing clustering based schemes. These main requirements are as follows:

1) Optimal Cluster head selection.
2) Neighborhood detection.
3) Node alignment with their neighborhood.
4) Minimum and maximum threshold distance between nodes for node connectivity.

IV. PROPOSED SCHEME

In our scheme we use the behavioral study of bird flocking for formation and maintenance of clusters in MANETs. The behavioral studies about bird flocking [25], [26] suggest some rules for group formation:

Rule 1: Every bird needs to avoid the isolation by attracting towards others.

Rule 2: Every bird needs to align themselves with their neighbors.

Rule 3: Every bird always tries to keep a little distance between its neighbors in a group to avoid collision.

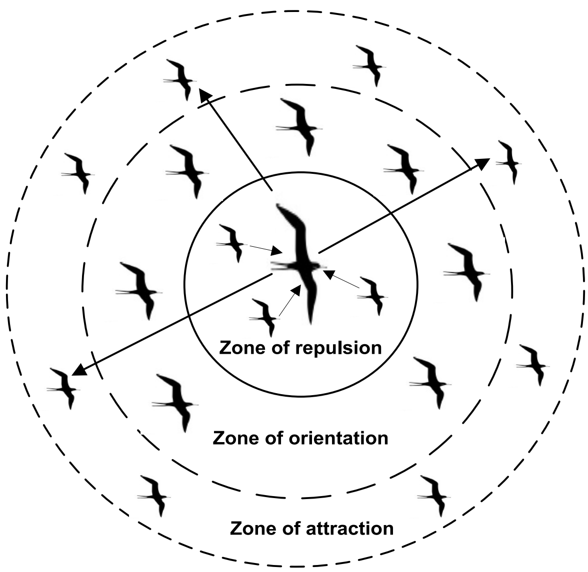

FIGURE 2. Zone based group mobility approach of flocking birds.

According to these rules the geographical space around each bird can be distributed as three zones as shown in figure 2. The attractiveness behavior between birds can be represented as attractive zone, the ability to repel each other in order to avoid collision can be summarized as repulsive zone and bird's alignment with neighbors can be considered as orientation zone.

MANET consists of arbitrary distributed movable nodes. These nodes can communicate with their neighborhood nodes and routing scheme plays a vital role for effective communication between two nodes. In a clustering based MANET, network is divided into random number of clusters and its member nodes. A CH is elected among the member nodes of a cluster. Applying the behavioral study of bird flocking in clustering based MANET will divide the structure of a cluster into three different types of zones as follows: Cluster head (CH) Zone, Node attraction (NA) Zone and Node repulsion (NR) Zone. These zones are illustrated in figure 3.

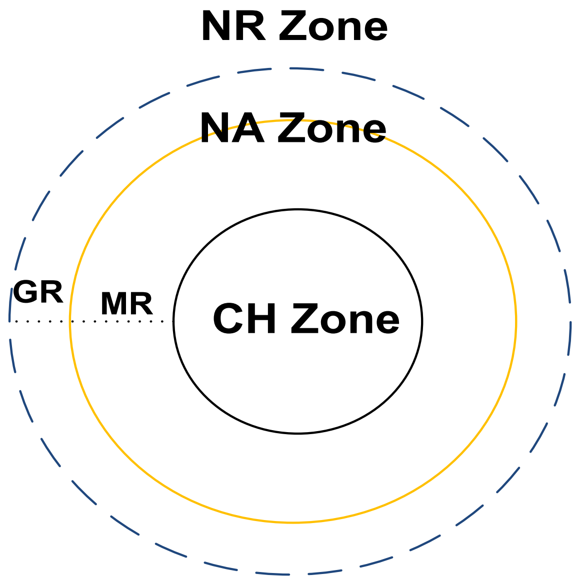

FIGURE 3. Zone based deployment of nodes using birds flocking approach of group mobility.

CH Zone: Nodes existing in CH zone are eligible candidates for the selection of CH. A CH will only be selected among the nodes existing in CH Zone.

NA Zone: Node attraction zone is divided into two regions, Gateway Region (GR) and Member Region (MR). A node near to the boundary of a NA zone will exist in GR and those nodes can act as a gateway node to connect cluster A with cluster B. Nodes existing in MR are the member nodes of a cluster. These nodes can communicate with other member nodes of this cluster as well as with the nodes of other clusters by using the nodes of GR.

NR Zone: Nodes existing in NR zone are not members of this cluster because they are not in the range of communication with CH and cluster member nodes. Therefore, they are free to join any cluster. The relationship between these three zones is illustrated in figure 3.

Nodes in MANETs can be divided in to three states; Idle state, Cluster member state and Gateway state [27]. The transitions between these states are shown in figure 4.

Idle state – when a node is not a member of any cluster it exists in idle state.

Cluster member state – when a node becomes a member of a cluster it exists in cluster member state.

Gateway state – A node becomes a gateway node if it causes connectivity with the member nodes of other clusters.

Based on different states of the nodes and zone based model, the SOCZBM is divided into following phases:

A. NODE STATUS IDENTIFICATION PHASE

Nodes in a cluster based MANET can be a CH, gateway node, a cluster member node and non- cluster member node based

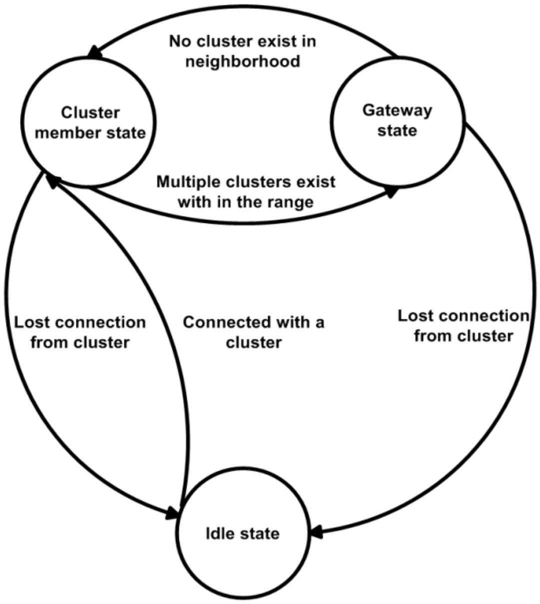

FIGURE 4. Node Transitions between the three different states in MANETs.

Algorithm 1 Identify the Node Affiliation in SOCZBM

1 **For** each *Node (z) in the network*;
2 **L= low value of RSSI;**
3 **H= High value of RSSI;**
4 **M=Medium value of RSSI;**
5 **If** (Receive an invitation message from CH);
6 **Do** (Identify RSSI value based on message received from CH);
7 **if** (RSSI = L) **then**
8 Indicates Idle state of a node ;
9 **return node status** (Node belongs to a NR zone);
10 **if** (RSSI = M) **then**
11 Indicates a node is a cluster member;
12 **return node status** (Node belongs to a NA zone) ;
13 **if** (RSSI = H) **then**
14 Indicates a node is a candidate to become a CH;
15 **return node status** (Node belongs to a CH zone);
end

on its status. The current status of a node in SOCZBM can be detected by using an approach of node affiliation as shown in algorithm 1. Node affilation is dependent on Received Signal Strength Indicator (RSSI) which is a useful parameter to identify the distance between source and destination [28]. Low value of RSSI indicates that receiver is located far away from the sender and high value of RSSI shows that distance between sender and receiver is not very far [28]. Each node identifies its status in SOCZBM from the level of RSSI value which is explained in detail by using algorithm 1.

Step (1)–(6): If a node in a network receives an invitation message from a CH, identify RSSI value from the receive message. RSSI value is divided in to 3 levels of strengths. L indicates low level, H indicates high level and M indicates medium level.

Step (7)–(9): Based on the value of RSSI, node affiliation will be identified. If the strength of RSSI value is L it means a node cannot connect to this cluster and it must continue as a non-cluster member and be in idle state. In this case the status is return as a node belongs to a NR zone.

Step (10)–(15): If the strength of RSSI value is M, it means a node belongs to a zone of cluster member. The return status in this case is a node belongs to a NA zone. If the strength of RSSI value is H it means a node belongs to a zone of nodes which are tentative members to be elected as a CH. The return status in this case is equal to node belongs to a CH zone.

Based on the behavioral knowledge of bird flocking, we apply here some rules on nodes in the presence of mobility. Group mobility rules a CH needs to follow are given below:

1) The nodes in the CH zones are the candidates to become a CH and will be assigned a selection index. A node which has the highest selection index will become a CH.
2) A CH will define a Cluster Mobility range (MR) for the respective cluster.
3) CH needs to maintain a minimum distance between itself and other member nodes regardless from which zone they belong.
4) A node whose speed is in MR will continue to be a member of CH, slower or faster moving nodes will become a dead node for a cluster and will be in idle state.
5) The CH will ensure the connectivity between each node in NA zone after every time interval Tcheck to identify dead nodes.

Group mobility rules assigned to cluster member nodes in SOCZBM are following:

1) A cluster member needs to maintain a minimum distance between itself and other member nodes regardless from which zone they belong.
2) Every node in NA zone needs to align itself with the CH after time duration Tmob.
3) If some nodes are neither in the range of CH zone nor in NA zone but exist in NR zone then such nodes are in idle state because they are not a member of any cluster.
4) When a node is in idle state and two groups of nodes are surrounding it. Idle node will follow such a group of nodes which has limited number of members regardless of its group mobility.

Based on the above mentioned rules, a zone based node deployment can be used in MANETs to ensure group mobility. The algorithm 2 describes a mechanism for SOCZBM to ensure zone based deployment of nodes in cluster based MANET. In this mechanism the results of node affiliation from algorithm 1 will be used to deploy the nodes in cluster after identifying their status. A node can be a CH, cluster member or a gateway node based on its zone affiliation. The zone based deployment of nodes is explained in detailed by using Algorithm 2. The steps of algorithm 2 are given below:

Algorithm 2 Zone Based Node Deployment in SOCZBM

```
1  For each Node (z) in the network do
2      Identify the affiliation of each node with respect to
       zone ( Algorithm 1) ;
3      Check ( node status( ));
4      if ( node status = Node belong to a NA zone ); then
5          Identify ( Node region in NA zone);
6              If ( node region=MR)
7              return ( node is a member of a cluster);
8              If (node region=GR)
9              return ( node is a gateway node );
10     else if ( node status = Node belong to a CHzone );
11         Node is a tentative candidate to become a CH;
12         Assign CH priority index to the node in CH
           zone;
13     else
14         Indicates Node is in idle state;
15     end
16 end
```

Algorithm 3 CH Selection for Scenario 1 in SOCZBM

```
1  NRR= 0;
2  Node X;
3  Node Y;
4  Rex=Residual energy of Node X;
5  Rey=Residual energy of Node Y;
6  While (NodeX&Node Y exist in a NR zone) then;
7      Check(NRR);
8      if( NRR=1 & RSSI = H)
9      Transmit IDF message to Node Y ;
10     While(Node Y receive IDF message)
11         Compare (Rex & Rey );
12         if (Rex < Rey)
13         return (Node Y become CH);
14         else if (Rex >Rey)
15         return ( Node Y become CH);
16         else
17         return (Node Y become CH);
18     end
19 end
```

Step (1)–(4): For every node in the network check its affiliation with respect to zone by using algorithm 1. The status of every node is checked to identify a node belongs to which zone.

Step (5)–(9): If a node belongs to NA zone, it means a node is a member node of a cluster. The region of a node is used to classify either a node is a member node or a gateway node. If node region is equal to MR it means a node is a member of a cluster and if node region is equal to GR, it identifies a node is a gateway node.

Step (10)–(16): If a node belongs to CH zone, it means a node is a tentative candidate to become a CH. A CH priority index is assign to every node in the CH zone. If a node does not belong to NA and CH zone, it means it exists in NR zone and it is in idle state.

B. CLUSTER HEAD SELECTION PHASE

1) SCENARIO 1: ALL NODES ARE RANDOMLY MOVING AND CLUSTER DOES NOT EXIST

In the scenario where all nodes are moving randomly and no clusters exist, we perform node identification procedure for cluster formation in which nodes can identify other nodes located in nearby distance as shown in algorithm 3. For node identification we define here a node recognition range (NRR). A node will detect another node only when other node exists in its NRR. RSSI is used here to determine the distance between node 1 and node 2 by measuring the received signal strength of node 1 at node 2. The higher value of RSSI indicates that node 1 is located near to node 2. Whereas smaller value indicates node 1 is located faraway from node 2. If a node 1 recognizes a node 2 within its NRR, node 1 will transmit an identification (IDF) message to node 2. This IDF message will contain node ID and residual energy level of node. Node 2 will compare its value with the received message. Based on its value of residual energy level decision will be taken place either to declare itself a CH or accept other node as a CH.

Step (1)–(3): Scenario 1 explains a situation when no cluster exists in a network. N numbers of nodes are moving freely in arbitrary direction. Node X and Node Y are among these freely moving nodes.

Step (4)–(9): Suppose two nodes, Node X and Node Y exist in NR zone. Node X will check its NRR. If a Node X has identified Node Y in its NRR and RSSI = H then in this case Node X will Transmit an IDF message toward Node Y.

Step (10)–(19): When node Y will receive the IDF message, it will compare its residual energy Rey with the residual energy of Node X Rex. If the value of Rex is less than Rey it means node Y becomes CH. If the value of Rex is greater than Rey it means node X becomes CH. If both nodes have same value of residual energy Rex is equal to Rey, then node Y will declare itself as a CH in order to avoid more number of packet exchange.

According to the flocking behavior of birds, if two birds are within the distance of collision, they will repel each other. Applying this behavior in node mobility of MANETs, we define here Node distance separation (NDS) which is a threshold distance a node must maintain between its nearby nodes to avoid collision. Therefore if two nodes are within the range of NDS, they will adjust their direction to avoid the dis-connectivity between nodes.

2) SCENARIO 2: A CLUSTER ALREADY EXISTS AND NEW NODES JOIN THE CLUSTER

In this scenario CH already exists and it will transmit an Invitation message which contains node ID and hop count. After receiving this message, a node will identify it belongs

Algorithm 4 CH Selection for Scenario 2 in SOCZBM

```
1  For each Node (z) in the networkdo
2      Check ( invitation message);
3      While (invitation message receive)
4          Identify the affiliation by using ( Algorithm 1) ;
5          Check node status from ( Algorithm 2);
6          if ( node status = Node belong to a CH zone)
7          return (Transmit a CM to CH with zone info );
8          if ( CH receive a CM && node index in
           message =1)
9          Assign (CH priority index) to the node;
10         Transmit (connectivity message to a node );
11         Check (CH priority index);
12         if (New member CH priority index =2)
13          if (Wait Timer expires && CM from
            CH not received)
14             return (current CH expires);
15             New memberBroadcast CH claim
               message to CH zone;
16         end
       end
```

Algorithm 5 CH Selection for Scenario 3 in SOCZBM

```
1   CH TIMER= 0;
2   Nodes in CH zone = n where (n=1,2,3,.....,N)
3   N = Maximum number of nodes in CH Zone;
4   Ren=Residual energy of nth Node;
5   For (n=1; n<=N; n++)
6   Check (Ren);
7   Assign (CH priority index);
8    While (CH TIMER = ET) then;
9       Run (Wait Timer);
10       If (Wait Timer expires && CM not received)
11          Broadcast CH claim message to CH zone;
12      end
13  end
```

to which zone based on the value of RSSI of the invitation message. If a node belongs to NR zone it indicates value of RSSI is very low and node cannot connect to CH so it will continue to be in idle state. As shown in algorithm 4, if a node belongs to NA zone or CH zone it will transmit a confirmation message with its node ID, hop count, residual energy and zone association. On receiving the confirmation message, CH will recognize the role of the node. If a node is in NA zone, CH will identify based on the value of RSSI either it is a gateway node or not. If a node exists in CH zone it will allocate a CH priority index. CH will assign a new cluster ID to the node and forward a connectivity message which will contain Cluster ID, hop count, node role specification, mobility factor.

Step (1)–(5): Scenario 2 explains a situation of CH selection when a cluster already exists in a network. A CH will transmit an Invitation message. When an idle node receives this message, it will identify its affiliation with respect to zone based on algorithm 1 and a status of each node will be checked according to the algorithm 2.

Step (6)–(11): If the node belongs from a CH zone, it will transmit a Confirmation message (CM) to CH with node index = 1. When a CH will receive this confirmation message it will check the node index. If node index = 1 CH will assign a CH priority index to this node and transmit a connectivity message to ensure connection.

Step (12)–(16): If a new member has a CH priority index = 2 and after a wait timer if a node has not received a continuation message from CH it means that current CH has expired or lost the cluster connectivity. In such case the node with CH priority index = 2 will broadcast a CH claim message to CH zone.

3) SCENARIO 3: CH RE-ELECTION TAKES PLACE

CH re-election procedure will take place between the nodes in CH zone when a CH TIMER reaches a time Election Time (ET) as shown in algorithm 5. All nodes in CH zone will be assigned a CH priority index based on better value of residual energy. A node with highest priority index will be elected as a CH. Based on the value of this index, nodes will know about tentative candidate to become a new CH. At a time ET, every node in CH zone will run Wait Timer, if a node does not receives a Continuation Message (CM) from CH within the limit of Wait Timer, the node with highest CH priority index will broadcast a CH claim message within a CH zone.

Step (1)–(7): Scenario 3 explains a situation of CH re-selection procedure. Nodes in CH zone are represents by n where (n = 1, 2, 3, ..., N) whereas N represents maximum number of nodes in CH Zone . A CH priority index is assigned to nodes in CH zone based on the value of residual energy.

Step (6)–(14): At a time ET, every node in CH zone will run Wait Timer. After wait timer expires, if a node has not received a CM from CH it means that current CH has expired or lost the cluster connectivity. In such case the node with CH priority index = 2 will broadcast a CH claim message to CH Zone.

C. DYNAMIC CLUSTER SIZE MANAGEMENT PHASE

In SOCZBM clusters with few numbers of nodes can merge with other clusters in order to achieve a stable networking environment. Figure 5 explains in detail about the cluster size management phase of SOCZBM. If a CH identifies its total number of member nodes is less than the threshold minimum nodes limit for the cluster, then by using the behavioral study of bird flocking the group of nodes can be merged together by following the rule of cohesion [29]. After locating the nearby cluster and receiving the merge confirmation reply for the CH, nodes can reconfigure with new CH to form group mobility. Similarly if a CH identifies its total number of member nodes is greater than the threshold maximum nodes

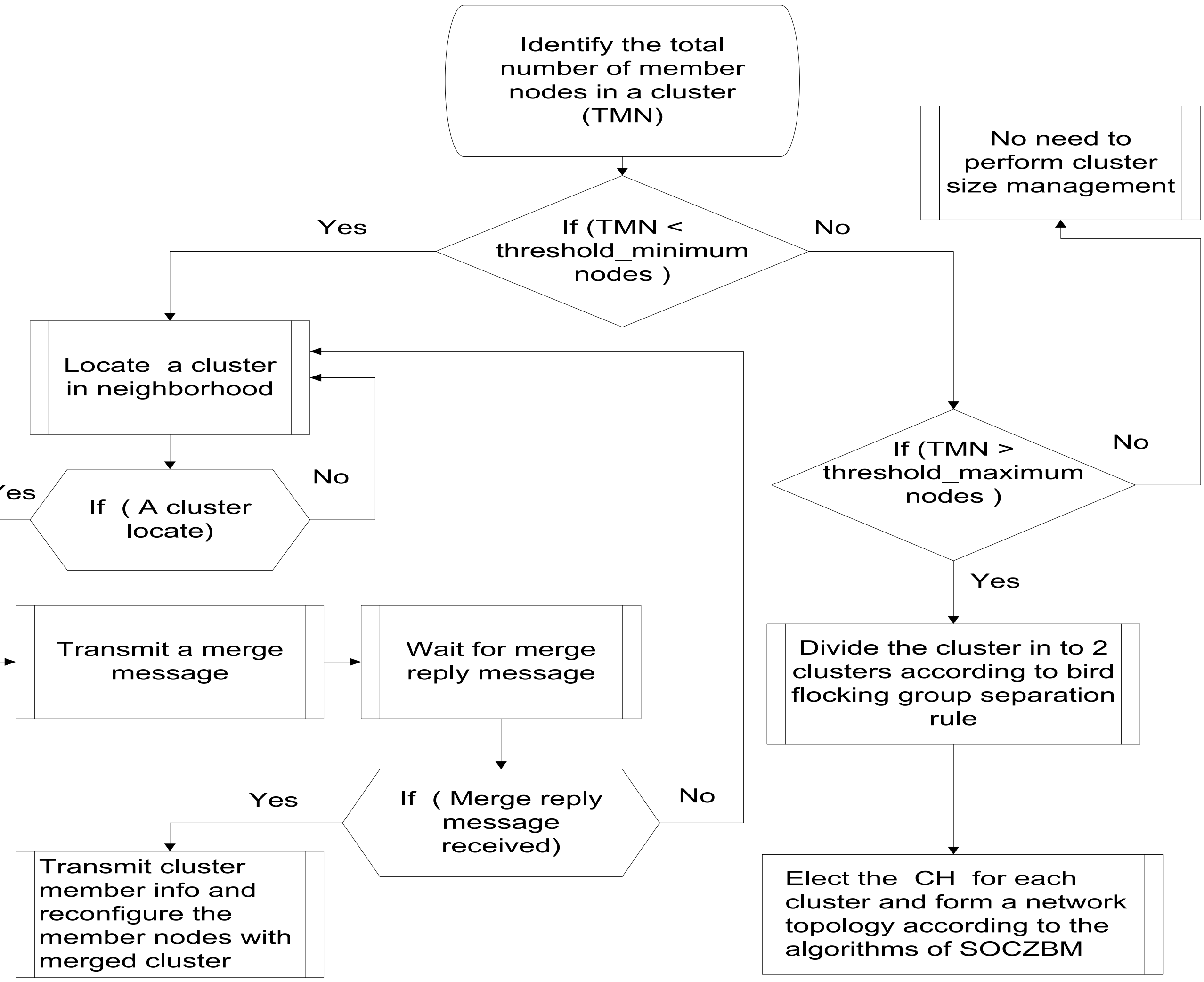

FIGURE 5. Dynamic cluster size management in SOCZBM.

limit for the cluster, then to avoid over crowded cluster in SOCZBM cluster splitting mechanism is used. Separation rule of behavioral study of bird flocking [29] is used to split one group in to two small groups to avoid congestion. CH is elected in the both new formed clusters according to the CH selection mechanism of SOCZBM.

D. ISOLATED NODE MANAGEMENT PHASE

The isolated node in a MANET can cause loss of energy and resources. In case of group mobility more number of isolated nodes can affect the overall performance of the network and can cause issues in cluster management with respect to environmental changes. To decrease the number of isolated nodes we propose mechanism in SOCZBM. Algorithm 6 explains the idea of deceasing overall number of isolated nodes in MANET.

Step (1)–(7): A network consists of Xn isolated nodes where (n=1, 2, 3,. . . . . .) . Every isolated node in the network checks its NRR. If NRR = 1, it means a node exists in the range of an isolated node. If a condition of NRR=1 and RSSI = H satisfies, isolated node will transmit an IDF message. When an IDF message is received by the other

Algorithm 6 Isolated Node Management Phase in SOCZBM

```
1   NRR= 0;
2   Isolated Nodes Xn; where (n=1,2,3,. . . . . .)
3   While(Xn exist in a NR zone) then;
4       Check(NRR);
5       if( NRR=1 & RSSI = H)
6       Transmit IDF message to nearest isolated node;
7       Elect a CH by using Algorithm 3;
8       else if( NRR=1 & RSSI = M || RSSI = S)
9       Wait forIDF message from nearest node;
10      else
11      Wait for anInvitation message from the CH;
12  end
```

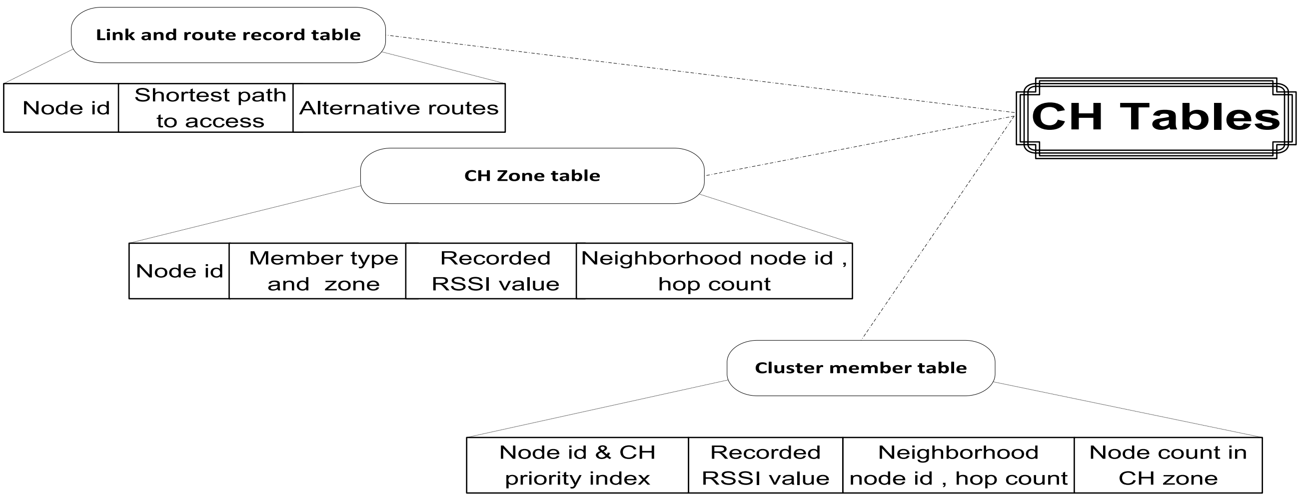

FIGURE 6. CH tables for inter and intra communication in SOCZBM.

isolated node, the procedure of CH selection will take place by using the algorithm 3.

Step (8)–(12): If a condition of NRR=1 and RSSI = M or RSSI = S satisfies it means the possibility to have a successful connectivity with the other isolated nodes is not very high so in this case this node needs to wait for an IDF message from a nearby isolated node which has a RSSI value of H or need to wait for an invitation message from the CH to join a cluster if it comes in the range of nearby cluster.

E. INTRA AND INTER CLUSTER COMMUNICATION PHASE

Intra cluster communication consists of communication between nodes inside the same cluster. In SOCZBM CH knows the information of its cluster members. This information includes the node ID, hop count and the calculated RSSI value. The CH generates a path selection for data communication based on the value of hop count. CH also keeps the record of alternative paths to achieve efficient data communication in case of path loss or dis-connectivity issue between nodes. The discovery of route and topology is the key role of CH for efficient communication. If source and destination node are within each other's range they can communicate directly and also can use CH as a relay to transfer data packet. If they are not in range, they must use a CH for the transfer of data packet. In SOCZBM, CH generates three tables to perform inter and intra communication; Cluster member table, CH Zone table and Link & route record table. These tables with their attributes are shown in figure 6.

Inter cluster communication includes communication between nodes from different clusters. Theorem 1 explains the routing pattern for inter cluster based communication between nodes [30].

Theorem 1: In SOCZBM, If two different cluster heads CH1 and CH2 in G= (V, E), then CH 1 will use the existing routing of CH2.

The proof of this theorem is justified by using the following cases [30]:

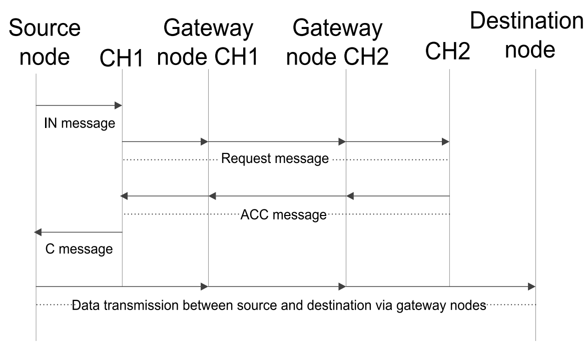

FIGURE 7. Handshaking between CHs for inter-cluster communication in SOCZBM.

Case 1: Suppose if CH1 and CH2 are located adjacent to each other. These neighboring CHs are connected through gateway nodes g1 and g2, where g1 exists in cluster 1 and g2 exists in cluster 2. The gateway nodes can be written as (g1, g2) ∈ E because both cluster 1 and cluster 2 are located adjacent to each other. As gateway nodes g1 and g2 can receive messages from both CHs therefore CH1 can use the existing routing of CH2.

Case 2: Suppose a network consists of many clusters with CHs represented as CH1, CH2, CH3, ... , CHn. If CH1 and CH2 are not adjacent to each other so in this case other clusters exist in between them. From Case1, as the CH1 and CH2 are connected with each other through gateway g1 and g2. Therefore other clusters are also connected with their adjacent clusters via gateway nodes. Hence entire network forms a topology. Therefore due to routing topology between clusters, there is at least one existing route available between CH1 and CHn due to gateway nodes such as R= {CH1, g1, CH2, g2, CH3, g3, ..., CHn, gn}.

Gateway nodes play a critical role for efficient communication between member nodes of two different clusters. In SOCZBM a source node sends an Initialization (IN) message to its CH as shown in figure 7. CH1, after receiving an

IN message from its member node, will transmits a request message to the CH2 through gateway nodes. CH2 will send an Acceptance message (ACC) message in reply of request message. ACC message contains the information of shortest path to establish connectivity with destination node. CH1 will transmit this information to the source node through Confirmation (C) message. After receiving C message, a source node will directly transmit the data to the destination node using gateway nodes as shown in figure. As a result of frequent changes in topology it's very important to check the validity of the route in both inter and intra cluster communication. If a node identifies a failure in connectivity with the neighborhood node, it transfers a link Fault message to CH. A CH will use a fault management mechanism by utilizing the information from Link & route record table and use alternative paths for message packet delivery.

TABLE 1. Simulation parameters.

Parameter	Attributes
Simulator language and package	Python 3.6.1
Simulation time (Seconds)	3600
Number of nodes	1000
Field dimension	500 m x 500m
Transmission range of CH	100m
Range of zones	50m,80m and 100m
Message size	30bytes

V. SIMULATION EVALUATION AND ANAYSIS

This section illustrates the performance of SOCZBM by using evaluation based on simulation. Main objective of this evaluation is to demonstrate the stability, scalability, efficiency and performance of SOCZBM. The simulation is performed using Python and results are compared with the existing scheme of B-LCC. Network topology consists of 1000 nodes randomly distributed in 500 m times 500m field. Table 1 present's parameters of simulation environment along with its attributes. Energy consumption and network lifetime are the two main performance metrics used in our evaluation. Energy consumption is the energy of the nodes consumed during simulation to perform the procedures related with clustering. The energy consumption of a node can be explained as:

$$Energy\ Consumption = \sum_{i}^{n}(Initial\ energy\ level\ (i) - Current\ energy\ level(i)) \quad (1)$$

Whereas initial energy level represents the node energy at the start of simulation while current energy level represents the energy level of a node at the end of simulation.

Network lifetime is the time at which n nodes of the network became exhausted due to consumption of all energy from their batteries. Network lifetime can be expressed as:

$$Network\ Lifetime = \sum_{i}^{n}(Current\ energy\ level\ (i) = 0) \quad (2)$$

A. RESULT AND ANALYSIS

Figure 8 (a) presents CH advertisement messages with respect to number of nodes. SOCZBM broadcast smaller number of messages in a cluster as compare to B-LCC algorithm. In B-LCC the number of advertisement message per cluster is more because CH needs to broadcast advertisement message three times. These advertisement messages in B-LCC are transmitted until every node recognizes its role as a result increasing overall number of advertisement messages per cluster. The number of advertisement messages per cluster with respect to number of CH is shown in figure 8 (a).

In SOCZBM, role of every node in a cluster is determined based on the RSSI value of packet sent by a CH. Based on the value of RSSI every new node will identify its role and CH doesn't need to broadcast advertisement message three times as in B-LCC. Therefore the number of advertisement messages transmitted by CH is reduced by approximately 45% and number of advertisement messages per cluster is also decreased in SOCZBM as shown in figure 8 (b). In B-LCC with increase in number of CHs, the number of advertisement messages also increase. For 20 CHs in MANET, number of advertisement messages is around 60 which increases up to 108 for 35 CHs. While in SOCZBM number of advertisement message for 35 CHs are only around 40. The performance of SOCZBM is further evaluated by considering the hop count from source to destination node.

Figure 9 (a) illustrates that SOCZBM has a better performance in term of cluster management. The nodes in a cluster need lower number of hops to reach the destination as compared to B-LCC. In B-LCC more number of nodes are deployed at the hop distance of 4 and 5 as compared to SOCZBM. In SOCZBM most of the nodes can easily reach to its destination in 2 and 3 hops. The zone based model in SOCZBM allows a better cluster management in term of number of hops which ensures a stable network topology. Average energy consumption in a network is also related with the hop count. If hop count of intra cluster communication is one energy unit and that of inter cluster communication is four units of energy, then the average of total energy consumption of a cluster is demonstrated in figure 9 (b). The results from figure 9 (b) illustrate that SOCZBM energy consumption is 9% better as compare to B-LCC.

Figure 10 demonstrates the distribution of accessible next hops with respect to CH. From result it is clear that 96 % CHs can access the nearby CH with a next-hop of 2, 3 and 4 in SOCZBM as compare to B-LCC. This shows that SOCZBM algorithm is robust in nature and in case of node failure it provides resilience for efficient communication.

Figure 11 shows consumption of energy at a node with respect to the group mobility. Consumption of energy is more in B-LCC as compare to SOCZBM. B-LCC has an overall

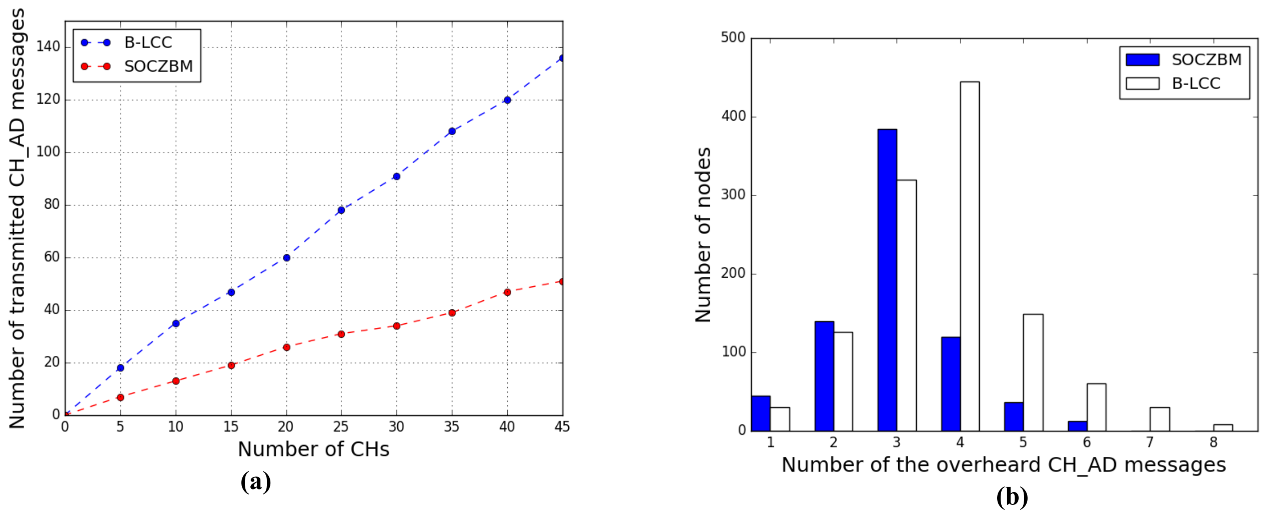

FIGURE 8. Overhead CH advertisement messages (a) For number of nodes. (b) For number of CHs.

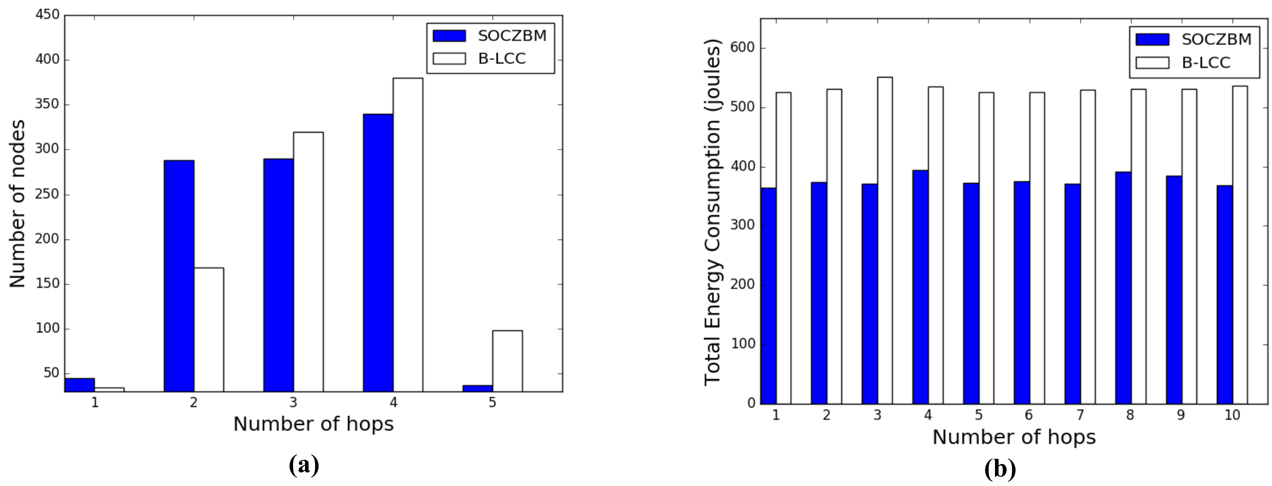

FIGURE 9. The distribution of number of hops. (a) With respect to nodes. (b) For energy consumption.

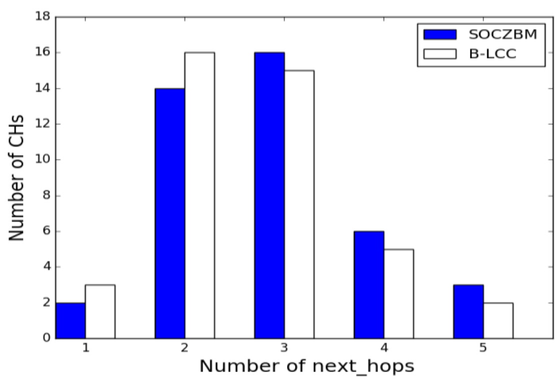

FIGURE 10. The distribution of next hops for number of CHs.

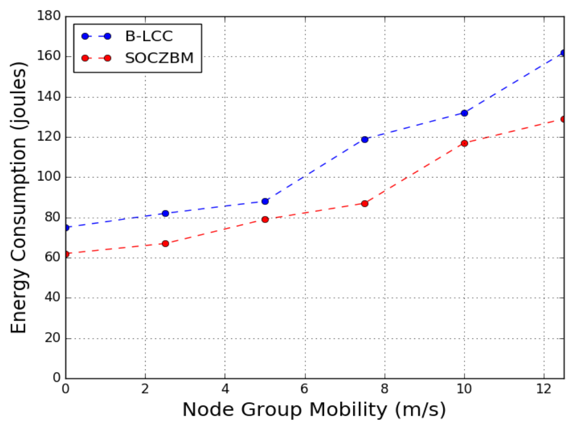

FIGURE 11. Effect of node group mobility on energy consumption.

node energy consumption of 82 joules at a group mobility of 5 m/s which increases up to 133 joules at 10m/s. While in SOCZBM overall node energy consumption remains up to 118 joules at a group mobility of 10 m/s. Figure 12 shows number of exhausted nodes with respect to the group mobility. As the speed of mobility increases more number of nodes becomes exhausted due to more consumption of power

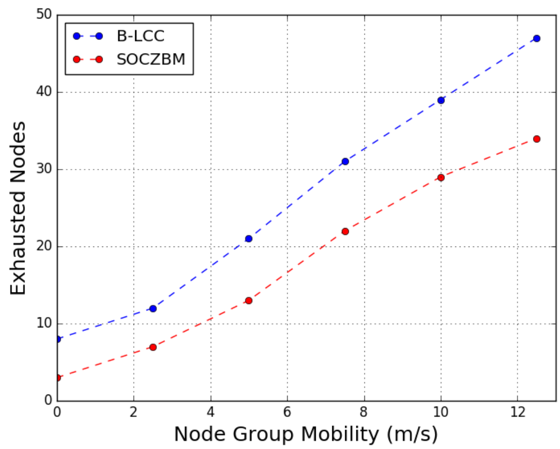

FIGURE 12. **Number of exhausted nodes vs. node group mobility.**

resources. SOCZBM shows better result as compared to B-LCC. As the value of group mobility increases more nodes become exhausted in B-LCC. At a group mobility of 4 m/s number of nodes become exhausted are 18 which reach 39 at a group mobility of 10 m/s. While in SOCZBM number of exhausted nodes at a group mobility of 10 m/s is 29.

VI. CONCLUSION

SOCZBM is a self-organization based bio-inspired clustering algorithm for MANET. SOCZBM algorithm ensures stability in cluster based topology due to its zone based node deployment mechanism. The simplicity in node deployment technique and CH selection based on bio-inspired bird flocking mechanism makes SOCZBM more effective in terms of its performance and efficiency. SOCZBM utilizes a dynamic mechanism for cluster size management which controls the network congestion and improves the performance of the MANETs in group mobility. Isolated node management algorithm is also proposed in SOCZBM to improve the use of resources and decrease the loss of energy. Simulation results indicate that SOCZBM has a better performance in term of energy consumption, network lifetime and CH advertisement messages. The network topology of SOCZBM is robust in nature and ensures resilience in case of failure in connectivity between CHs.

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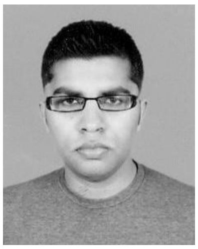

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