Clustering algorithm for AODV Routing Protocol based on Artificial Bee Colony in MANET

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ABSTRACT

One of the most important challenges that MANET face is how to connect nodes together also how to adapt the dynamically changes in the network topology. A novel clustering algorithm that ensures an increase in stability and adaptability of MANET has been proposed, it depends on the Artificial Bee Colony (ABC) to determine the Cluster Head (CH) in each cluster taking into consideration a group of parameters to calculate the proposed fitness function also to manage control traffic messages.

CCS CONCEPTS

• **Networks → Mobile ad hoc networks**

KEYWORDS

Mobile Ad-hoc Network, Artificial Bee Colony, AODV, mobility, Energy, Cluster.

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1 INTRODUCTION

MANET "Mobile Ad-Hoc Network" is a type of ad-hoc network that connects a set of mobile nodes to each other, it has a continuously changing topology because of the randomized movement of mobile nodes. .MANET is a point-to-point network that connects nodes to each other using wireless links. Nodes in the network have limited resources such as battery, processing speed, and storage. They may connect directly when they are in the range of each other or may connect indirectly by an intermediate node when the nodes are out of the range. MANET has different types of routing protocols, like reactive, and proactive routing protocols. The main difference between these two types is that the nodes in proactive routing protocols have information about other nodes and how to reach them before the need for a route. Unlike the reactive routing protocols, nodes can only detect other nodes just when a route is needed. There is a type of routing protocol that combines both techniques of reactive, and proactive called hybrid routing protocols [1]. Fig. 1 shows some of MANET protocols.

MANET faces many important challenges because of the dynamic nature of nodes. There is no centralize unites to manage the nodes, and facilities the communication between them. That is why clustering techniques have been used to control the routing between nodes. Clustering is a technique that divides the network into groups called Clusters, each Cluster contains a set of nodes, in each Cluster, there are three types of nodes, Cluster Head (CH) node, Gateway node (GN), and normal nodes. CH is responsible for providing connections for normal nodes under his range.

GN is responsible for connecting CHs with each other, many clustering algorithms have been proposed to overcome some problems that MANET face.. These algorithms mainly depend on various parameters like mobility, connectivity, energy, and other parameters. Clustering in MANET used to increase the stability of the network and to reduce routing overheads especially in route discovery [2].Fig. 2 shows an example of clustering in MANET.

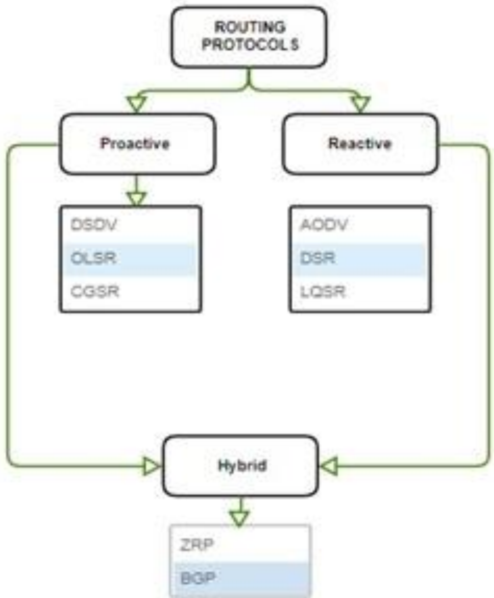

Figure 1: MANET routing protocols.

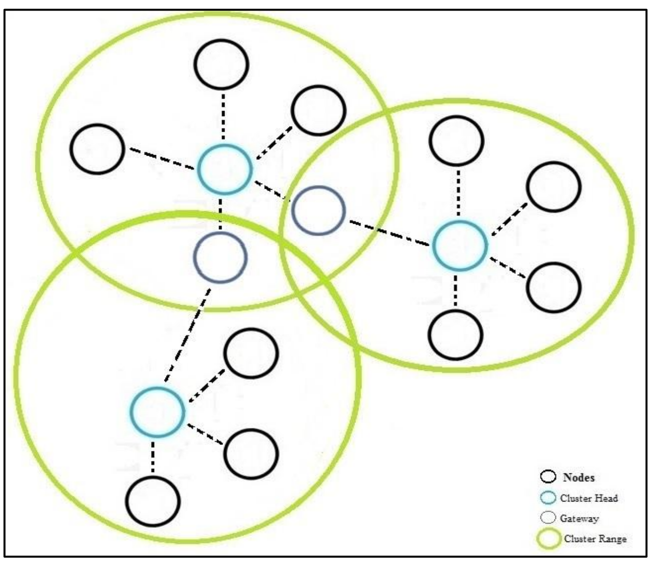

Figure 2: An example of Clustering in MANET.

2 BACKGROUND

2.1 AODV

Ad hoc On-Demand Distance Vector (AODV) is a reactive routing protocol that creates a route between nodes only when it is needed. AODV has a better performance than other reactive routing protocol according to [3]. In AODV each node periodically broadcasts a Hello message to notify neighbor nodes about its existence. AODV protocol uses two types of messages in order to find a route between nodes, Route Requests (RREQ) message, and Route Replies (RREP) message. When a node needs to establish a connection to any node in the network, it first broadcasts an RREQ to all its neighbors, then neighbor nodes checks if they have a route to the desired node if none of them has a route they rebroadcast RREQ. The rebroadcast process continues until the desired node receives the RREQ or an intermediate node has a route to the desired node receives the RREQ. An RREP message is sent back to the source node through the intermediate node using the same path that RREQ used. When the source node receives RREP, it starts the connection with the desired node using that path. If there is a link break between nodes a Route Error (RERR) message is propagated to all adjacent nodes, then source node reinitiate the route discovery [4]. Fig. 3 shows an example of MANET.

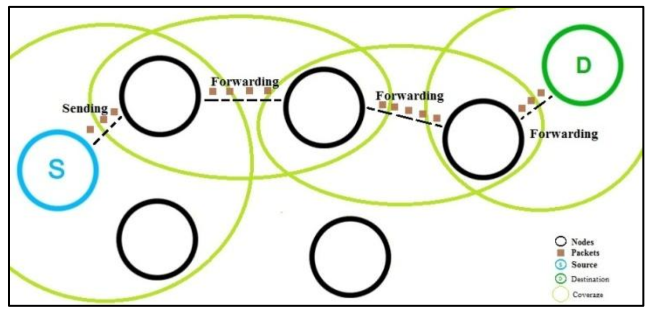

Figure 3: An example of MANET.

2.2 SWARM INTELLIGENCE (SI)

Gerardo and Jing introduced the concept of swarm intelligence in 1989[5]. SI means coordination between individuals by using decentralized and self-organization. The collective behaviors show a discipline that is a result of the local interaction between individual agents with each other using direct or indirect communication in the environment. Each agent has a simple task, where no cartelized control that determines how each individual agent is should act. Examples of systems in the nature that follows the Swarm intelligence includes Ant colony, Bee colony, Firefly colony, and Dolphin colony. The concept of SI used in MANET to enhance the performance of the network [6].

2.2.1 MULTI-AGENT SYSTEM

Multi-Agent System (MAS) is a group of autonomous agents, that acts and interacts in a shared environment in order to reach a specific goal. MAS is used to build strong, scalable, and decision-making systems that are capable of processing complex activate in a dynamic and non-deterministic environment. Properties of agents in MAS describe how an agent acts in the environment. Agents are autonomous, which means that each agent control and take responsibility for their action and their internal state. They are also social, they can communicate with each other in order to manage their actions. The final property agents are reactive they react to the changes in the environment.

In order to reach their goal, each agent in MAS has to know some information about the existing environment, interact, and collaborate with other agents to reach their goal. Information can be transmitted between agents, to facilitate the information gathering process. This information can be used as an input to produce different outputs to reach the determined goal [7]. MAS proved its efficiency in MANET like in [8], also improved the process of finding an optimal path in the route discovery process and in recovery from failure.

2.2.2 ARTIFICIAL BEE COLONY (ABC)

Artificial bee colony algorithm (ABC) developed for solving the non-linear Optimization problems. ABC algorithm consists of three types of bees: Scout bees, Onlookers, and Employed. The Scout bees leave the nest to search for a food source. When they find any source of food, they go back to their nest and become an Employed Bees, and then they start to dance. Onlooker bees in nests start to watch the dance of the Employed bees, in order to determine the best food source depending on the dance of the Employed bee. If the source food of the Employed bee is abandoned then the Employed bee becomes a Scout Bee and starts to search for food source again.

In the ABC algorithm, the location of the source food represents the possible solutions of the problem. Each Onlooker Bee evaluates the source food to determine the nectar amount depending on the information form the Employed Bee dance using the fitness function. The onlooker Bee selects the source food based on a probability that calculated using equation (1) as in [9]:

$$p_i = \frac{fit_i}{\sum_{n=1}^{SN} fit_n} \qquad (1)$$

Where Pi: the probability of selecting source food i, fit_i is the fitness value of the solution i, and SN is the number of the food sources.

3 RELATED WORK

As mentioned above cluster techniques help in increasing the stability of the network, and avoid the flooding of the network in route discovery phase. This section describes used clustering techniques, and how some of them depend on SI to improve these techniques.

Adwan Yasin et. al. [10] developed a new algorithm used in clustering MANET. The developed algorithm depends on three parameters to decide which node will be the cluster head battery power, connectivity, and power consumption are calculated and the node that has the best value among these three parameters is assigned to be the cluster head. The algorithm tried to divide the network into clusters that are balanced loaded. The proposed algorithm can handle networks with many numbers of nodes that have a high rate of changing their topology.

Sasmita Mohapatra et. al. [11] proposed a new algorithm for improving routing, not just within one cluster but also between the clusters themselves to facilitate transferring data using the bee colony techniques. This is done by using a special scout bee named border cluster node (BCN) that is responsible for various tasks like helping the cluster head to communicate with their destination, minimizing energy consumption, redundancy, and delay, also to control traffic among the nodes. Paper results showed that the proposed algorithm" Improvised Bee-Ad Hoc-C" has better energy efficiency, end to end delay, throughput, packet delivery ratio than the" Bee-Ad Hoc-C".

Hamid Ali et. al. [12] developed a new algorithm for clustering in MANET that takes into consideration energy consumption, since battery power limitation is one of the important challenges that MANET face, especially during clusters arrangement. A multi-objective particle swarm optimization (MOPSO) algorithm is used to enhance cluster number in MANET, also to optimize power consumption in nodes, in order to minimize network traffic. Three main parameters were taken into consideration, the transmission power, battery power, and the degree of nodes. The results showed the effectiveness and flexibility of the proposed algorithm.

Imane M. A. Fahrnv et. al. [13] proposed a new approach using swarm intelligent routing algorithm that is inspired by bees, the model choose the best routing path between multiple possible paths based on energy consumption and the delay for all existing nodes within the path from the source to destination, the approach uses two bee agents types to collect information then calculate their efficiency.

P. Visu et. al. [14] introduced routing protocol based on the ABC algorithm in Ad Hoc networks. This paper proposed energy models that manage routing process between nodes, based on selecting a Queen among the bee population based on some parameters. The queen is responsible for choosing best nodes to be selected in the routing path.

Harmanjot Singh et. al. [15] represents new clustering model based on Ant Colony Optimization, in order to optimize AODV routing protocol. The proposed model was built to remove congestion during finding the shortest path between source and destination. The model also suggests that each board unit will transmit its data to only the closest authentication on-board unit, this is done in order to minimize transmission energy, link failures, and delay.

Mustafa Tareq et. al. [16] proposed an algorithm for optimizing energy consumption in the dynamic source routing protocol. The proposed algorithm uses bee colony algorithm to identify the best path between the source node and the destination node, in order to overcome energy consumption problem. The combination of the bee algorithm and the dynamic source routing protocol showed improvements in wide network parameter settings, like node speed and packet size. The proposed algorithm uses employee bee to search the network, and onlooker bee type to evaluate the energy information from employed bees.

K.G.SANTHIYA et. al. [17] studied ABC algorithm combined with clustering technique in order to achieve QoS. This paper also discussed ABC applications in ad hoc networks. The study was made to show that ABC algorithm can be used to provide the best path between source and destination, depending on some chosen variables like energy and delay, this is done to ensure QoS and minimize cluster overheads.

Naghma Khatoon et. al. [18] introduced new clustering algorithm for MANET using multi-agent stochastic parallel search technique. The cluster head election is based on mobility, connectivity, and energy, in order to keep managing the nodes for long period. The algorithm uses multi-objective fitness function enhanced based on the distance between nodes to their own cluster head, and the strength of the cluster head that depends on the energy. Fitness function taking consideration of those two parameters will enhance the CH lifetime.

Vijaya et. al. [19] proposed clustering technique for mobile ad hoc network that tried to reach a stable and easily reached network topology. The proposed technique depends on two phases, the clustering setup phase, and the clustering maintenance phase. In the first phase, the cluster head is selected using a fitness function that depends on the following parameters; mobility, power, transmission rate, and transmission range. Each parameter is assigned with a specific weight. After calculating the fitness function for each node the one with the highest value is treated as a cluster head. In the second phase, the clusters are rearranged in case that some nodes including cluster heads moved outside the range of a cluster, this phase depends on the following parameters; the degree of the node, stability, power of battery, and battery remaining. Those parameters are used to re-elect the cluster head. The results showed that the algorithm gives a steady cluster group and accessible.

D.Srinivasa Rao et. al. [20] introduced a new cluster based routing protocol (PMRP), which was built to minimize overheads and increase the throughput, energy consumption, end to end delay and packet delivery ratio performance in a dynamic environment. The proposed protocol is divided into two parts, the first is cluster formation and the second is routing. In the first part, nodes organize themselves into groups and elect a cluster head. The node with the highest degree of neighbors is elected as a cluster head. The second part "routing" is for communications between clusters by maintaining a routing table. The results showed some advantages compared to AODV protocol.

Mrinal Kanti Deb Barma et. al. [21] proposed an energy efficient weighted clustering algorithm. The proposed algorithm prevents re-clustering in the network by making the least second minimum weight node to be a cluster head. All nodes weights are stored in a special table called weight list inside the cluster head. When there is a need to change the cluster head, then the cluster head node selects the least minimum weight node from its table to avoid re-clustering process overheads. This algorithm tried to minimize power consumption by keeping away from flooding messages during the cluster formulation. Table 1 summarizes and compares the proposed clustering models in related work section.

Table 1: Comparison between Clustering Models in MANET.

Clustering Model	Cluster head Selection Criteria	Characteristics
AWCAMAN [10]	Battery power, Connectivity, and Power Consumption.	Capability of Handling networks with many numbers of nodes that have a high rate of changing in their topology.
IBAC [11]	RSS(Received signal strength).	Extend model from BAC has a Better Energy Efficiency, End to End Delay, Throughput, and PDR.
MOPSO [12]	Transmission Power, Battery Power, and the Degree of nodes.	Energy-Efficient clustering technique also provides flexibility in the network by finding multiple optimal paths to the desired node.
PEEBR [13]	Energy Consumption, and Delay.	Selects the optimal route between nodes based on goodness ratio.
ABC [14]	Speed, and Energy.	Provides an energy management technique, to increase the energy efficiency of the protocol.
AODV-R [15]	Nearest neighbor, and Transmission Energy.	Avoid link breakage by selecting the most reliable path.
BEEDSR [16]	Distance, and Energy.	The simplicity of the proposed model, selects an optimal path between nodes, and overcomes the energy consumption resulted from

		overload packets.
ABICR [17]	Lowest ID , Higher Degree, and LCC (Least Cluster Change).	Ensures the Qos of the network, provides scalability and minimizes overhead resulted from cluster maintenance.
ME-PSO [18]	Mobility, Connectivity, and Energy.	Increases the cluster head lifetime.
CASRCG [19]	Combined weight from Mobility, Transmission Rate, and Transmission Range.	Provides stability to the network, and minimizes overhead resulted from the re-clustering process.
PMRP [20]	The highest degree of neighbors.	Improves routing discovery process, and reduces routing overhead.
EEWCA [21]	Combined weight from Degree, Distance between neighbors, Speed of nodes, and Battery Power Consumed.	Avoids re-election of cluster head, and reduces explicit flooding of messages among member nodes.

4 PROPOSED MODEL

The proposed model, which is called CEB_ADOV (Cluster Election using ABC in AODV) uses ABC to elect and select the optimal node within a set of mobile nodes to be a cluster head. CEB_ADOV depends on different parameters such as energy that each mobile node has, the delay time between mobile nodes, the relative speed of nodes, and connectivity of each node. Connectivity means the number of adjacent nodes that lay within each node coverage. The aim of the proposed model is to increase the stability and adaptability of the network by dividing it into clusters in an optimal way. The use of ABC algorithm provides a better path selection based on different parameters. In this model, we tried to simulate Bee Colony and how each Bee has its own job. We used six types of bees and the proposed model contains seven stages, Network Engagement, Distance Calculation, Fitness Calculation, Cluster head selection, Gateway selection, Splitting, and Route Discovery. Each stage is described using pseudo code.

4.1 Network Engagement

In this stage, each mobile node that engages to the network broadcasts an Employed Bee (EB) to all neighbor mobile nodes. EB contains node ID, Energy, connectivity, and timestamp that the EB has been broadcasted at. Each mobile node receives EB checks if it had EB source ID in its table then it updates its entry otherwise, it creates a new entry in the table, adds all information in EB, and calculates Delay between them using equation (2):

$$De_{i,j} = Rt - St \qquad (2)$$

Where $De_{i,j}$ is the Delay time between node i and j, Rt: is the received time of EB and St: is the send time of EB that is stored in EB. Mobile nodes have timer called EB_Timer, every time that EB_Timer reaches it's determined time it broadcasts EB, mobile nodes reset timers after sending EB. In this stage, each mobile node is aware of its neighbor nodes and has information about them, which helps in identifying and selecting cluster head. Fig. 4 shows how nodes broadcast EB to all other nodes within its coverage. Algorithm 1 below describes the Network Engagement stage using pseudo code.

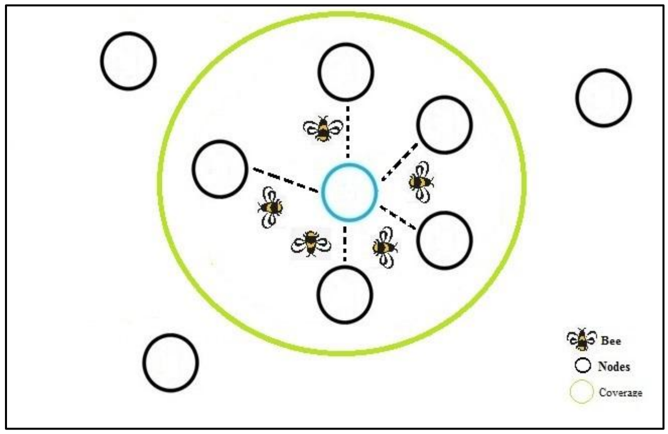

Figure 4: A node broadcasts EB.

Algorithm 1: *Network Engagement*

Sender Node

```
1 if CurrentTime ==EB_Time then
2   Initiate EB;
3   Broadcast EB to all neighbors;
4   Reset EB_Time;
5 end if
```

Receiver Node

```
1 search (EB Source ID in Table)
2 if ID exists then
3   Update the entry in the table;
4 else
5   Create a new entry in the table;
6   Add all information in EB;
7   Calculate the Delay between Sender and receiver node
    using equation (2);
8 end if
```

4.2 Distance Calculation

In this stage, each node keeps calculating the distance between the nodes within a determined time, which is set by the users based on the environment of the system. Distance is calculated by using the received radio signal from nodes using Received signal strength indication (RSSI) equation (3) which it is used in [22]:

$$P_r(i,j) = \frac{P_t*G_t*G_r*H^2{}_t*H^2{}_r}{D^4*L} \qquad (3)$$

Where $P_r(i,j)$: Receiving power between node i and j, P_t: transmitting Power, G_t: Gain of a transmitting antenna, G_r: Gain of a receiving antenna,$H^2{}_t$:height of the transmitter antenna , $H^2{}_r$:height of the receiver antenna, L: is system loss factor which has nothing to do with the transmission, and D: is the distance between the antennas. After calculating distance, node stores distance between them in the table (D), ΔD, and the time between recording of D, then node calculates the relative speed between nodes using the equation (4):

$$S_{i,j} = \frac{\Delta D}{T} \qquad (4)$$

Where $S_{i,j}$: is the relative speed between node i and j, ΔD is the difference between old distance and the new distance and T is the time between recording the distance. Algorithm 2 below describes the Distance Calculation stage using pseudo code.

Algorithm 2: *Distance Calculation*

```
if CurrentTime ==DC_Time then
  for each neighbor node do
    Calculate D using RSSI (3);
    ΔD = new D minus old D;
    ΔT = new T minus old T;
    Update D, ΔD, ΔT values in the table entry;
    Calculate relative speed between nodes using (4);
  end for
Reset DC_Time;
end if
```

4.3 Fitness Calculation

In this stage, Onlooker Bees (OB) in each node watch the dance of each received EB and select the optimal node based on the value of fitness function. The fitness value can be calculated using equation (5):

$$F_{i,j} = \frac{C*E}{D_{ei,j}*S_{i,j}} \qquad (5)$$

Where $F_{i,j}$ is the fitness function value between node i and j, C: is connectivity, E: is the Energy and $D_{ei,j}$ is the Delay between node i and j, and $S_{i,j}$: is the relative speed between node i and j. Algorithm 3 below describes the Fitness Calculation stage using pseudo code.

Algorithm 3: *Fitness Calculation*

```
Initiate OB;
for each EB received do
  Watch dance of received EB;
  Calculate the value of the fitness function (5);
end for
OB Selects the optimal node; //highest fitness value
```

4.4 Cluster Head Selection

In this stage, after the selection of the optimal node by OB, nodes unicast a special type of scout bees called Cluster Head Election Scout Bee (CHESB) to the selected optimal node. Each node receives CHESB may accept the cluster head election or may reject it because it belongs to another cluster head. In case of accepting the cluster head, the elected node broadcasts another special type of scout bee called Cluster Head Scout Bee (CHSB), each mobile node receives CHSB considers CHSB source ID as a cluster head and uses that ID to communicate with other nodes. In case that the node rejected the CHESB then nodes send CHESB to the second highest fitness function value determined by OB. In case all nodes refused the election, then the same node that sent the elections may claim to be a cluster head for all other neighbor nodes. Each cluster head node has a timer when the timer reaches its determined value by the user the Cluster Head selection stage starts again. Algorithm 4 below describes the Cluster Head Selection stage using pseudo code.

Algorithm 4: *Cluster Head Selection*

Sender Node

```
if CurrentTime ==DHS_Time then
  Unicast CHESB to the selected optimal node;
  Reset DHS_Time;
end if
if the selected optimal node reject CHESB then
  Unicast CHESB to the second optimal node;
else
  Consider CHSB Source ID as Cluster Head;
end if
```

Receiver Node

```
for each received CHESB do
  if Receiver Node belongs to a Cluster then
    Reject CHESB;
  else
    Broadcast CHSB;
  end if
end for
```

4.5 Gateway Selection

In this stage, when a node receives a CHSB from two or more cluster head nodes. This node broadcasts a special type of scout bee called Gateway Scout Bee (GSB). Each Cluster head node receives GSB add source ID to its table in order to help him to reach out other cluster heads nodes.

In case there is an isolated, cluster and cannot reach other cluster heads a connection between gateways nodes is needed in order to connect the isolated cluster to the network. Cluster head knows that it is isolated from another network if it did not receive any GSB from any node. In this case, cluster head node broadcasts a special type of scout bee called Gateway to Gateway Scout Bee (GTGSB). Any node receives GTGSB try to find any node within its neighbors that connects it to another cluster when this happens both nodes broadcast GSB to cluster head. In this case, two gateway nodes communicate with each other to forwards packets between cluster heads Fig. 5 and Fig. 6 describe how to solve the isolated cluster problem. Algorithm 5 below describes the Gateway Selection stage using pseudo code.

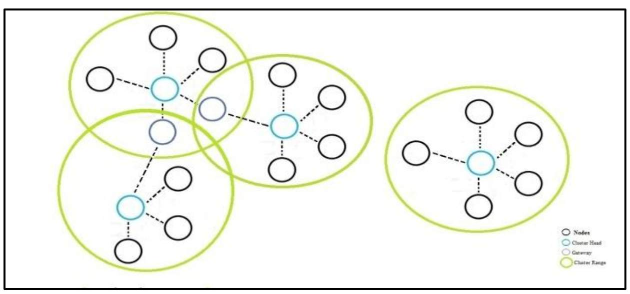

Figure 5: Isolated Cluster.

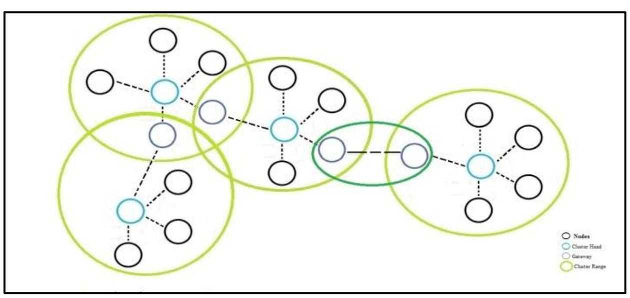

Figure 6: Connecting isolated Cluster to a network.

Algorithm 5: *Gateway Selection*

Normal Node

__If__ received 2<=CHSB __then__
Broadcast GSB;
__end if__
__if__ GTGSB is received __then__ // Gateways communicate with each other
search (Gateway in neighbors table)
__if__ Gateway exists __then__
Broadcast GSB;
__end if__

Cluster Head Node

if CurrentTime ==GSB_Time then
for each received GSB
Add GSB source ID to the table;
end for
if received GSB==0 then //Cluster is isolated
Broadcast GTGSB;
end if
end if

4.6 Splitting

In this stage, each node will notify the head cluster node that it is going to leave the coverage. After computing the distance each node starts to calculate the distance between him and head cluster range by using equation (6):

$$DL = R - D_{i,j} \qquad (6)$$

Where DL: is the distance left between the node and the coverage of the cluster head node, R: is the coverage of the cluster head node, and $D_{i,j}$: is the distance between the node and the cluster head node using the RSSI equation. When the DL is lower than the threshold that is determined by the user depending on the environment of the system. Nodes unicast a special type of employed Bee called Split Bee (SB) when cluster head node receives SB it removes that source node ID from its table. This stage helps in reducing the link failure and reduces the false information in the cluster head node table. Algorithm 6 below describes the Splitting stage using pseudo code.

Algorithm 6: *Splitting*

Normal Node

Calculate the DL between the node and the cluster head using equation (6);
__if__ DL > threshold __then__
Unicast SB to cluster head;
__end if__

Cluster Head Node

__for each__ SB received __do__
Remove SB node ID form its table;
__end for__

4.7 Route Discovery

In this stage, when a node wants to communicate with another node in the network it sends a Path Scouts Bee (PSB) to the CH with the ID of the desired node. Then the CH search in its table if the desired node is in the same cluster or not. If the desired node is the same cluster, then a route is created between Source and desired node through the CH. Otherwise, CH sends PSB to gateway nodes to search for the desired node in other clusters. When PSB finds the desired node it go back to the CH in the same path, while PSB travels from the Destination node to the Source node PSB store the maximum relative speed within the nodes in the path, the sum of total energy of all nodes within the path, and the travel time from the destination node to the source node in its memory. If CH received multiple PSB, OB in CH calculates fitness value of each path to determine the optimal path using equation (7):

$$N = \frac{E_t}{M*T} \qquad (7)$$

Where N: is the nectar amount, Et: is the sum of total energy of the nodes in the path, M is the maximum relative speed, and T is the travel time from source to destination. After caluclating the nectar amount, CH selects the optimal path to start communication with the destination node through it. Algorithm 7 below describes the Route Discovery stage using pseudo code.

Algorithm 7: Route Discovery

- Sender Node
- Unicast PSB to the cluster head with the ID of the desired node;
- Start transmitting packets after receiving a reply from cluster head node;
-

Cluster Head Node

```
for each PSB received do
  if PSB from other Cluster head then
  Search  (PSB node ID in the table)
     if ID exists then
        set reply_flag in PSB
        Send a reply for cluster head node ;// a route
        between the two nodes is found
     else
        Unicast PSB to Gateway nodes // to search for the
        desired node in other clusters
     end if
  else // received a reply
     if PSB reply_flag is set then
        Calculate nectar amount using the equation (7);
     else
        Discard PSB;
     end if
  end if
end for
Use optimal path from the received PSB;
```

5 Conclusions and Future Work

Clustering in MANET helps to reduce network congestion resulted from the flooding. It also helps in increasing the stability of the network. Many factors may change the topology in MANET like Speed, Energy, and Coverage of nodes. An algorithm is needed to adapt the changes in the topology and to increase the stability of the network. Artificial Bee Colony is considered as one of the important optimization algorithms that help in adapt changing in the environment. In this research, we constructed a model that is based on ABC that helps in electing the head cluster in the network based on different parameters such as Speed and Energy. Because these parameters are considered as the main factors that affect the topology in MANET. In future, we consider implementing this model and compare the result of it with other different technique in electing cluster head, and compare the network performance after implementing this model under different parameters such as Packet Delivery Ratio, Jitter, and Energy consumption.

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