Tech Science Press

Fuzzy Fruit Fly Optimized Node Quality-Based Clustering Algorithm for Network Load Balancing

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Abstract: Recently, the fundamental problem with Hybrid Mobile Ad-hoc Networks (H-MANETs) is to find a suitable and secure way of balancing the load through Internet gateways. Moreover, the selection of the gateway and overload of the network results in packet loss and Delay (DL). For optimal performance, it is important to load balance between different gateways. As a result, a stable load balancing procedure is implemented, which selects gateways based on Fuzzy Logic (FL) and increases the efficiency of the network. In this case, since gateways are selected based on the number of nodes, the Energy Consumption (EC) was high. This paper presents a novel Node Quality-based Clustering Algorithm (NQCA) based on Fuzzy-Genetic for Cluster Head and Gateway Selection (FGCHGS). This algorithm combines NQCA with the Improved Weighted Clustering Algorithm (IWCA). The NQCA algorithm divides the network into clusters based upon node priority, transmission range, and neighbour fidelity. In addition, the simulation results tend to evaluate the performance effectiveness of the FFFCHGS algorithm in terms of EC, packet loss rate (PLR), etc.

1 Introduction

In general, MANETs consist of peer-to-peer, self-configuring, self-alleviating, wirelessly-connected mobile nodes that share no infrastructure [1]. In such networks, each mobile node can travel autonomously on any path and thus, its relations to every other will change regularly. Every node must forward traffic that is distinct in its utility and hence be a router. In addition, each mobile node must learn about their neighbour nodes and how to reach them. Nodes assigned outside the communication range can communicate indirectly, using a multi-hop routing protocol whereas, nodes placed within the communication area communicate directly with each other nodes. Each node has the responsibility for dynamically discovering the path [2]. An issue with MANET is its node mobility, which makes routing a

complicated task. For that reason, a familiar technique named clustering can minimize the amount of data sent from source to destination with the reduced amount of transmission bandwidth and EC [3]. Major clustering algorithms may select a subset of nodes and construct a network backbone to support the control functions. Each node in the network may associate with every other node, such a set of selected nodes is called CH. The CH of each cluster links with the CH of each other clusters directly or via the gateways. By combining gateway and CH, a connected backbone cast that supports to simplify the various processes like accessing the channel, allocating the bandwidth, reducing the energy required for routing and supporting the virtual circuit. In addition to the routing process, clustering the nodes is also a challenging process in MANET [4].

Even various algorithms had been proposed to obtain an optimum number of clusters, none have noticed that all the network factors are necessary to improve cluster performance [5]. In MANET, the crucial goal is to obtain an optimal number of clusters. The dissemination of clustering algorithms specifies that each node contains only local information. In addition, it must be robust and capable of adapting to changes in topology as the size of the network increases or decreases. Each cluster should be practically well-organized; therefore, a particular CH must maintain the number of nodes [6].

In each cluster, nodes are categorized into one of the following types: CH, cluster member and gateway. For each cluster, CH acts as a local controller and has the responsibilities like routing, channel assignment, scheduling and transmitting inter-cluster traffic from each cluster member. Nodes other than CH are cluster members. Cluster members act as normal nodes and do not participate in routing or inter-cluster communication. Cluster gateway is a boundary node that involves the minimum one adjacent belonging to various clusters and tends to transmit the routing data from one cluster to the other [7]. In recent transmission systems, the primary attention of the MANET users is in discovering reliable access to the web via the gateways [8]. So, a MANET with an active connection to a public network is known as Hybrid MANET (H-MANET).

In the steady load balancing gateway election algorithm [9], the FL system improves the routing efficiency of the H-MANET. The algorithm selects the best gateway based on an innovative routing metric that consists, of several network characteristics, such as MRA packet arrival variation, control packet ratio, and the load of the gateway. GA's fitness function tends to define and optimize these fuzzy sets, as well as four network parameters: DL, PLR, NRO, and BLI. However, the EC was high since the gateway node is selected from the entire network directly and the network maintenance was also complex due to the dynamic changes of the nodes.

The main contribution of the work is to achieve efficient load balancing in the gateways of the hybrid mobile ad-hoc network to overcome the packet loss and delay caused in the network during the selection of overload and gateways.

Here, a novel NQCA is presented with a gateway selection algorithm based on the IWCA. The MANET is initially split into different clusters in this algorithm. For each cluster, its CH is selected based on the node priority, transmission range and node neighborhood fidelity. In addition, the quality of clustering is also estimated by using additional parameters like node degree, environmental distance (Dist), clustering Stability Factor (SF), EC, Residual Battery Energy (RBE) and weight of the node including DL, PLR, NRO and BLI. Moreover, these parameter converts the values into fuzzy values using the FL system. The system calculates the combined weight value after acquiring the fuzzy sets. Then, GA is applied to optimize the weight value and select both optimal CH and gateway. If the convergence time of GA was high, error due to parameter tuning like changes in population and fitness function for GA is noted as high. As a result, the modified FGCHGS algorithm utilizes an effective optimization algorithm instead of GA. In addition, a new FF algorithm that reduces computation times and convergence times to select the

optimal CH or gateway. Thus, the proposed algorithms can minimize the node EC and simplify the network maintenance.

2 Literature Survey

The Clustering-Based Gateway Placement Algorithm (CBGPA) (2009) [10] optimizes the placement of gateways in wireless mesh networks for ensuing network scalability. Combining meta-heuristics with CBGPA, an algorithm that optimizes both the exploitation rate and mean congestion of gateways simultaneously. Congestion levels from gateways, however, remained high. Iqbal et al. [11] proposed a new mechanism for discovering gateways in MANET. In this strategy, the source node does not require retransmitting a gateway choice request message if the reply message was lost or did not arrive in time. However, an appropriate path to a gateway is not elected, resulting in a high routing burden.

Papadaki & Friderikos proposed a compact representation of Uncapacitated and Capacitated joint Gateway Selection and Routing (U/C-GSR) (2010) [12]. In both uncapacitated and capacitated circumstances, the shortest path matrix aims to reduce computing complexity by providing an optimal solution. However, the computational time complexity was high. A gateway selection in multi-hop wireless networks was proposed (2010) [13] based on an Ideally Scheduled Route Optimization (ISRO) that uses route and link optimization to improve network efficiency. The optimization issues in this technique are optimum gateway routing according to the best criteria, determining the link capacity by scheduling without interference, and path adjustment for the new link but it does not consider the mobility of the gateway.

A proactive load-aware gateway decision (2010) [14] was proposed by considering the interface queue size with the conventional min hop metric. In this approach, an efficient handoff was allowed from one gateway to the other and seamless connectivity was maintained to the pre-determined host. On the contrary, it requires throughput and DL for further improvement.

Sahana et al. [15] proposed a weight-based hierarchical clustering based on the combined weight that comprises node's degree, communication area and node's mobility. Although CH is the highest weighted node, the network performance lacks efficiency. A congestion-controlled adaptive multipath routing protocol was proposed (2012) [16] for load balancing and congestion avoidance in MANET. Also, determine fail-safe multiple links that include the nodes with less distribution of traffic and high RBE. The node will transmit the traffic over the disjoint multipath if the mean load with the link exceeds the threshold to avoid congestion on the congested path. However, load balancing data between gateways may reduce the network performance.

The performance of gateway choice protocols (2012) [17] has been analyzed in MANET. A modified Ad-hoc On-Demand Routing protocol (AODV) for the integration of MANET with the web via the immobile gateway. However, the DL of this protocol was high. An improved gateway choice approach (2012) [18] was proposed based on the mean number of hops and the link stability. However, the performance effectiveness of the algorithm is lacking.

Multi-criteria gateway choice and multipath routing protocol (2012) [19] were proposed for H-MANET by considering mobility. The Simple Additive Weighting (SAW) process developed a combined weight value based on mobility, inter-and intra-network traffic load, and RBE in this protocol. After that, the node with the maximum weight got selected as a gateway for the path which is selected from the multiple paths. If the selected gateway is not present in such a link, then the alternate path is selected for the routing process. However, the packet delivery ratio was less and the DL was high. An autonomous clustering-based dynamic network gateway protocol (2012) [20] in which the network gets split into clusters. For each

cluster, the gateway gets chosen autonomously and dynamically. However, the QoS parameters like DL, throughput, etc., were not analyzed.

Gateway discovery algorithm was proposed (2012) [21] based on several QoS link metrics between the node and gateway. In this algorithm, the route accessibility improved by introducing the feedback system to the updated route dynamics to the traffic source. In addition, an efficient scheme for propagating QoS parameters in this proposed scheme. However, the average control overhead was high. To promote cluster formation, an Enhanced Distributed Group Mobility Adaptive (EDGMA) (2013) [22] clustering technique has been employed for both CH and gateway selection. Initially, the CH selection among the group of mobile nodes where each mobile node travelled in a different direction and different speed. The gateway has been established to ensure that information is routed effectively from source to destination. However, the mean lifetime of CH was less.

Hussain et al. [23] suggested an Efficient CH Selection Algorithm (ECHSA) for MANET. This algorithm was mainly proposed based on the novel artificial intelligence for selecting the CH by populating the Black and White (B&W) list with the routing table. However, the complexity of this algorithm was high. Joshi et al. [24] investigated an optimized gateway selection scheme for MANET clusters to decrease the required control overhead during network construction and management by controlling the robust connectivity. A high-degree method based on transmission range, mobility, and residual energy to calculate the CH. Furthermore, by reducing the number of gateways, the excessive flooding caused due to unsolicited packet transmission is reduced during inter-cluster packet transmission. However, DL was high.

CH decision approach using FL (2014) [25] using node's degree, fitness and integrity of MANET. In this approach, the MANET is categorized into clusters based on the CH technique, where each cluster has its independent CH connected through the other CH. However, it requires additional parameters for selecting CH and also, the process lacks gateway selection. Divya & Ganesh [26] proposed Gateway Migration Algorithm (GMA) between node and gateway in MANET. According to the algorithm, the gateway gets selected based on multiple QoS link metrics, namely the link availability period, accessible load capacity, and DL. If the traffic source node migrates to the other gateway transmission range, then the traffic on such route is transferred through another gateway. However, the average DL was high.

Gateway selection optimization was proposed (2015) [27] in the H-MANET-satellite network to solve the problems of gateway positioning. In addition, a GA to solve the multi-criteria optimization problem by considering the topology dynamics. Moreover, different metrics like gateway and link load, path cumulated Dist and convergence time were optimized. However, an effective optimization was required by considering more parameters. Mahiddin & Sarkar [28] proposed an improved MANET gateway selection scheme. The principal objective of this scheme was to remove the congestion at each MANET gateway by considering the node mobility for improving the network performance. However, the packet delivery DL was high.

Zaman et al. [29] proposed a novel method, named Adaptive Steady Load Balancing Gateway Selection, that deals with the gateway selection of the path load balancing technique. In addition, GA tends to optimize the solution such that the fitness function is computed based on the FL. To balance the load on each route, three load-balancing parameters are utilized in which the number of received Gateway solicitation messages (NMRG), Time-To-Live Changes (TTLC) and Link Changes (LC). Moreover, the node occupancy level of each node was computed and updated for each short interval as well as transmitted to each adjacent in the communication region. However, PLR was high.

Kumar & Ramamoorthy [30] proposed a novel method of gateway selection for improving the throughput of MANET. An enhanced gateway selection method has been utilized, which avoids congestion and balances the load on MANET gateways that enhance the network performance. However, packet delivery DL was high. Rajkumar et al. [31] proposed a modified CH and gateway selection for

cluster-based MANET to minimize the iteration of re-clustering during cluster formation. In this technique, CH was elected based on the direction of the mobile node and its mobility. In addition, a gateway algorithm tends to select a gateway node for both intra and inter-cluster communication. Initially, a similarity between two mobile nodes [32] within the transmission range was computed based on the spatial dependency for finding the feature of mobility that identifies the nodes under similar clusters and completes their routing. However, DL was not analysed.

It is necessary to develop an energy-efficient load balancing mechanism for wireless sensor networks (WSNs). Adil et al. [33] have proposed a strategy based on communication architecture using energy gauge nodes (EGNs) to achieve load balancing for resource-limited networks with a long-life cycle. The performance analysis of the system is achieved by calculating the round trip time and more parameters but the efficiency of the system has to be enhanced by adding optimization to the proposed technique. Kim [34] has proposed a precise load balancing scheme for minimized lifetime consumption and to enable an extended lifetime of the sensor networks. A stand-in network managing method has been employed which diminishes the energy consumption in the sensor network. Thus, a load balancing strategy has been induced to cover such qualities. But it has a limitation such that further optimization of the work can enable improved efficiency in load balancing of the network An efficient hybrid routing strategy employing a dynamic cluster-based static routing protocol, has been implemented by Adil et al. [35] integrating the *ad hoc* on-demand distance vector routing protocol and low-energy adaptive clustering hierarchy protocol, due to the restricted resources of sensor nodes. The proposed scheme's static routing requirement requires all enable improvement in the cluster to exchange their gathered data through a single CH node for a set period of time. To deliver messages in an operational network, the suggested model's communication mechanism employs dynamic CH nodes for a set period of time with a static route configuration.

3 Proposed Methodology

In this part, the proposed FGCHGS & FFFCHGS algorithms are explained in detail. Initially, the NQCA algorithm is performed for network clustering based on the IWCA algorithm. The clustering is performed based on the two models such as node priority and range region aggregation models. Then, the cluster characteristics are measured based on the FL system by considering the various QoS parameters. After that, both CH and gateway are selected by using GA according to the fitness values of each node which are estimated as combined weight values using fuzzy sets of network metrics. Further, an improved FF algorithm is proposed instead of GA for both CH and gateway selection efficiently. Tab. 1 depicts the list of symbols and notation used in the paper.

Table 1: Symbols and notation used in the proposed work

v_i	Group of nodes in the network
e_i	Group of connections in the network
v_j	Neighbour node
$\Gamma(v_i)$	The group of nodes that are communicated directly and situated in (R_{v_i})
$dist(v_i, v_j)$	Mean distance between v_i and v_j
(R_{v_i})	Communication region of the nodes
$deg(v_i)$	Degree of node v_i

(Continued)

Table 1 (continued)

rind	Range indicator
comind	Combined indicator
$nq(v_i)$	Node Quality of the node v_i
envdist	Environmental distance of the nodes
$\beta(v_i)$	Relative dissemination of the node v_i
$D(v_i)$	Data transfer Interval in node v_i
$SF(v_i)$	Stability factor of the node v_i
$PLR(v_i)$	Packet loss ratio of the node v_i
$NRO(v_i)$	Normalized Routing Overhead - Correlation between accurately received packets and total control packets
$BLI(v_i)$	Balancing Load Index - The degree of overload endured by each node v_i
Smell	Smell concentration

3.1 Network Model

The network is built by the nodes and the connections characterized via an undirected graph $G = (V, E)$, where $V = v_i$ refers the group of nodes and $E = e_i$ denotes the group of connections. Clustering is considered as the graph splitting dilemma with few limits. The adjacent $\Gamma(v_i)$ of a CH v_i is the group of nodes that are communicated directly and situated in its communication region (R_{v_i}). Therefore, the degree of the node v_i is defined as follows:

$$\Gamma(v_i) = \{v_j, \in dist(v_i, v_j) < R_{v_i}\} \tag{1}$$

In Eq. (1), $dist(v_i, v_j)$ refers to the mean distance between v_i and v_j. When a system is initiated, each node forwards its ID indexed by each other node situated in its communication region. Based on this, the mutual Dist between any two nodes is estimated via calculating the fraction of receiving and transmit power. Therefore, the node degree of v_i is considered as the cardinality of the set $\Gamma(v_i)$ and represented as follows:

$$deg(v_i) = |\Gamma(v_i)| \tag{2}$$

Generally, clustering is a necessity for partitioning the nodes, thus it should satisfy the below criteria:

- Each ordinary node has no less than one CH as adjacent and no two CH can be adjacent.
- Each common node affiliates with the adjacent CH that has the minimum weight.

3.2 NQCA Models

The proposed NQCA consists of two models such as follows:

- Node Priority Aggregation Model

In NQCA, CH is selected by assigning the priorities to the nodes according to their degree. This model is built according to the following manner:

priority of strong node > priority of weak node > priority of border node

Here, the node types such as Strong Node (SN), Weak Node (WN) and Border Node (BN) are identified by computing the node type indicator (*ntype*) as:

$$ntype(v_i) = \{1, \ deg(v_i) \geq 3 \qquad (SN) \ 2, \ deg(v_i) = 2 \qquad (WN) \ 3, \ deg(v_i) = 1 \quad (BN) \qquad (3)$$

- Region Aggregation Model

The ability of adjacent is measured by the node neighbourhood fidelity for conserving their region provided that a parent node. A parent node is any CH candidate and the adjacent can be located at a various distance (Dist) from their parent. Because of increasing distance (Dist), the parent's neighbourhood fidelity can decrease and beyond nodes are expected to depart from the parent at any time. As a result, the parent strength is influenced so that its possible to be a CH is minimized. Hence, the communication range of a parent is divided into 3 virtual regions namely excellent, intermediary and endangered regions which are located within the circle with radius *r*.

Both excellent and intermediary regions include trusted adjacent for a definite time. In endangered regions, the adjacent nodes are taken into consideration as topologically untrusted nodes due to the assumption that they can escape from the partition before the trusted nodes. The range indicator (*rind*) is measured to provide the maximum priority for trusted nodes and the minimum priority for untrusted nodes while electing the CH as follows:

$$rind(v_i, v_j) = \{1, \ dist(v_i, v_j) \leq \alpha_1 r \qquad (EZ) \ 2, \ \alpha_1 r < dist(v_i, v_j) \leq \alpha_2 r \qquad (IZ) \ 3,$$
$$\alpha_2 r < dist(v_i, v_j) \leq \alpha_3 r \qquad (RZ) \qquad (4)$$

In Eq. (4), $\alpha_1 + \alpha_2 + \alpha_3 = 1$ are user coefficients that can be adjusted by selecting the appropriate values according to the node's mobility. Moreover, a new node combined indicator is determined as:

$$comind(v_i) = ntype(v_i) \times rind(v_i, v_j) \qquad (5)$$

3.3 Quality of Clustering (QoC)

The QoC is measured by different parameters which help to improve the cluster characteristics and the selection of both CH and gateway. The main aim of QoC is to provide the capacity of a cluster for delivering the expected outcomes. The QoC is measured based on the IWCA. The different parameters are given in below:

a) Node Quality:

The node quality is calculated as the product of node degree and node combined indicator.

$$nq(v_i) = comind(v_i) \times deg(v_i) \qquad (6)$$

b) Environmental Distance

The environmental distance is measured instead of calculating the distance between parent and adjacent nodes v_i and v_j, accordingly. It considers the region wherein the adjacent node v_i is located and computed as:

$$envdist(v_i, v_j) = comind(v_i) \times dist(v_i, v_j) \qquad (7)$$

The total environmental distance from a parent v_i to all the group of its adjacent connected to it is calculated as:

$$ZD(v_i) = \sum_{j=1}^{n} envdist(v_i, v_j) \tag{8}$$

c) Clustering Stability Enhancement

For a given time, the cluster formation remains unchanged due to the node's stability. As a result, the SF for each v_i is defined as:

$$SF(v_i) = \frac{ZD(v_i)}{nq(v_i)} \tag{9}$$

In this NQCA, the adjacent nodes with the maximum $SF(v_i)$ are elected as the CH.

d) Load Balancing Clustering Scheme

Consider that each node is identical and create data at a similar rate. For load balancing, the number of nodes in a cluster and the transmit power needed per CH should be balanced. Therefore, the relative deviation of adjacent in a recent configuration is measured by relative dissemination degree as follows:

$$\beta(v_i) = \frac{|\delta - nq(v_i)|}{nq(v_i)} \tag{10}$$

In Eq. (10), $\delta \leq 2ln(N)$ refers open limit on the number of nodes that a CH can manage perfectly $(N = |V|)$.

e) Energy Consumption & Remaining Battery Energy (RBE)

A high amount of energy is required for long distance transmission. Hence for each node v_i, the EC is determined by the average of Dist $D(v_i)$ with its neighbors v_j as follows:

$$D(v_i) = \sum_{j=1}^{n} dist(v_i, v_j) \tag{11}$$

If $D(v_i)$ is high, then the required EC is also high otherwise EC is less. Also, each node (v_i) can easily estimate its RBE$(RBE(v_i))$ after the transmission. Therefore, a node with longer RBE and less EC can be selected as a CH.

f) Delay

DL $(D(v_i))$ is the data transfer interval between origin and target.

g) Packet Loss Rate (PLR)

The PLR $(PLR(v_i))$ is the measure of packet loss to the sum number of transmitted packets. A PLR that attains 10% of data transmitted is assumed as the highest value.

h) Normalized Routing Overhead (NRO)

NRO is defined as the correlation between accurately received packets and total control packets in the networks. If $NRO(v_i) = 5$, then it is assumed as the highest value.

i) Balanced Load Index (BLI)

The BLI stands for the degree of overload endured by each v_i and computed as:

$$BLI(v_i) = \sum \left| \frac{L_i}{\sum L_i} - \frac{1}{N} \right| \tag{12}$$

In Eq. (12), L_i refers to the load carried for each node and N denotes the sum number of nodes in the network. If BLI is zero, then each node maintains an equal load for balancing the network.

After that, these computed parameters are converted into fuzzy sets by using the Fuzzy Inference System (FIS) that contains fuzzy membership functions and linguistic terms. Here, the triangular fuzzy membership function is used and five linguistic terms are used, namely Very Low (L), Low (L), Medium (M), High (H) and Very High (VH). According to each parameter and their weights, the combined weight value is calculated as follows:

$$W(v_i) = w_1 ZD(v_i) + w_2 \beta(v_i) + w_3 SF(v_i) + w_4 RBE(v_i) + w_5 D(v_i) + w_6 PLR(v_i) + w_7 NRO(v_i) \\ + w_8 BLI(v_i) \tag{13}$$

Based on these weight values for each node, the most optimal CH and gateway are selected. The lowest weight node in a particular cluster is decided as CH and the lowest weight node that acts as a border node in that cluster is elected as the gateway. The fuzzy system generates the number of rules according to these parameters and among the number of rules, a few rules are shown in Tab. 2.

Table 2: Rule base of FIS for the weight function

$ZD(v_i)$	$\beta(v_i)$	$SF(v_i)$	$RBE(v_i)$	$D(v_i)$	$PLR(v_i)$	$NRO(v_i)$	$BLI(v_i)$	$W(v_i)$
L	L	L	L	L	L	L	L	VL
M	L	M	L	M	L	L	L	L
H	M	L	M	H	H	M	H	H
M	L	H	M	M	L	L	M	M
H	H	H	H	H	H	H	H	VH
L	H	M	H	L	M	M	L	M
M	M	H	H	L	M	L	M	L

3.4 Fuzzy-Genetic Algorithm

In the GA algorithm, the obtained weighted values are optimized for selecting the CH and gateway. The objective function of the GA is to determine the optimum weight function for a MANET system. Based on the selected optimal values, the network performance improved by a better CH and gateway selection. Initially, the GA algorithm creates the population of chromosomes for all nodes. These parameters are calculated for individual chromosomes and input to the FIS, which outputs the weight values. Then, the obtained weight function is assigned as the fitness function for determining the best solution of the GA. Once the fitness function is computed, the new individuals are evaluated with the prior population. Each individual from both populations is sorted according to their fitness values. An individual with the minimum fitness function is assumed as superior to the individual with the maximum fitness value. When successive populations develop, the best performers are engaged. The new individuals in a generation are obtained based on the following two processes:

- Crossover
- Mutation

Crossover tends to generate new individuals in the current population by fusing two fittest individuals and reorganizing the previous individuals. The crossover function gets executed as a distributed operator. Alternately, mutations rarely occur to allow the specific child to acquire the features which are not inherited by the parent. By using the Gaussian mutation, a novel and enhanced population is analysed. Based on the proposed FGCHGS algorithm, both optimal CH and gateway are selected in H-MANET for performance improvement by solving the inefficiencies in WCA.

Algorithm

Input: $G = (V, E)$, adjacent, Dist

Output: Set of CH and gateway

1.   *for(each $v_i \in G$)*
2.   Find the adjacent of v_i using Eq. (2);
3.   Compute the parameters like EC, SF and RBE;
4.   Determine the relative dissemination degree;
5.   Calculate the DL, PLR, NRO and BLI;
6.   Convert the parameter values into fuzzy sets;
7.   Obtain the weight function $W(v_i)$;
8.   Initialize the population of chromosomes and number of iterations t;
9.   *while($t > t_{max}$)*
10.   Set fitness function=min($W(v_i)$);   //Minimum weight function
11.   Evaluate the fitness function value by using fuzzy sets;   //Generate the new population
12.   Select two parent chromosomes from a population based on their better fitness values;
13.   Perform crossover and mutation processes;
14.   Obtain the new population and replace the previous chromosomes;
15.   Return the best solution in current population;
16.   Go to step 11;
17.   *end while*
18.   Choose the best fitness value nodes as CH and the best fitness value nodes located in the border as a gateway;
19.   *end for*

3.5 Fuzzy-Fruit Fly Optimization Algorithm

To optimize, the weight values for CH and gateway selection, an FF optimization algorithm is proposed instead of GA. The main aim of FF is to obtain the optimal value of weight function for a MANET system and enhance the network efficiency by choosing the most optimum CH and gateway. FF is used to explore global optimization based on the food hunting behaviours of the FF swarm. Initially, the food source is

identified by smelling all types of fragrances buoyant in the air and wings to the related positions. Once near the source, the food may be located. The osphresis foraging stage and the visual step are the two main steps. In the osphresis phase, a swarm of fruit flies explores food in a random manner around the swarm position. In the visual phase, the sharp vision is utilized for flying to the swarm's best position.

Although the FF suffers from premature convergence levels and reduced efficiency because of the fixed number of iteration steps, i.e., the FF is dependent on the iteration step. Moreover, there is a problem with the FF exploring how to generate new solutions based on random details of the foregoing solutions. An improved FF algorithm introduces a linear-diminishing step to overcome these limitations. Specifically, it is difficult to discover the food position at the end of iteration while the iteration step is constant. Perhaps, a few individual fruit flies are far away from the food. To avoid local optimization traps and to improve precision, the fixed step is changed into a linear diminishing step. The steps in the proposed improved FF algorithm are:

Step 1 (Initialization phase): Assign the parameters of the first iteration and FF swarm location (A, B) randomly, including the highest amount of population t_{max}, population size P and the iteration step value is R.

Step 2: Perform the individual searches for food i.e., the minimum weight function $(W(v_i))$ in random directions and Dist as:

$$\{A(i)_n = A + R \times rand(\cdot), \ i = 1, 2, \ldots, PB(i)_n = B + R \times rand(\cdot), \ n = 1, 2, \ldots, M \tag{14}$$

Here, $(A(i)_n, B(i)_n)$ is the location of ith FF individual among P fruit flies and $rand(\cdot)$ is a random value that is sampled from a uniform distribution.

Step 3 (Path construction phase): As the food position i.e., the position of $W(v_i)$ cannot be identified, the Dist $D(i)_n$ is estimated between the coordinate origin and the individuals as:

$$D(i)_n = \sqrt{A(i)_n^2 + B(i)_n^2} \tag{15}$$

The nearby position is to the origin position, smaller the density of the food. Then, the reciprocal of the Dist is defined as the smell concentration judgement value $Smell(i)_n$ as follows:

$$Smell(i)_n = \frac{1}{D(i)_n} \tag{16}$$

Step 4 (Fitness function computation phase): The smell concentration $Smell(i)$ of an individual position of the FF is computed by substituting the value $Smell(i)_n$ into a fitness function F as:

$$Smell(i) = F\left(Smell(i)_n\right) \tag{17}$$

Step 5: The FF with the highest smell concentration, $max(Smell(i))$ among the FF swarm is identified as:

$$[bestSmell, bestIndex] = max(Smell(i)) \tag{18}$$

In Eq. (18), $bestSmell$ and $bestIndex$ are the largest elements and their indices along different dimensions of smell vectors.

Step 6 (Movement phase): After that, the current highest smell concentration rate $(bestSmell)$ is evaluated with the rate in history $(smellbest)$. If $bestSmell < smellbest$, $smellbest$ is updated with

bestSmell and the FF swarm flies to that position with the highest smell concentration rate via vision as follows:

$$\{Smellbest = bestSmellA = A(best)_n B = B(best)_n \tag{19}$$

Step 7: As well, the iteration step is as:

$$R' = R - \frac{R(M_{max} - 1)\alpha}{M_{max}} \tag{20}$$

In Eq. (20), R is the initial iteration step, M_{max} denotes the maximum iteration number and $\alpha = 0.8$.

Step 8: A and B are substituted from Step 6 into the value of $Smell(i)_n$ and then $Smell(i)_n$ is set into the constraints. After that, the value of $Smell(i)_n$ is substituted which meets the constraints into the $Smellbestf'_i$ and the best optimization solution is obtained as:

$$\{Smellbestf'_i = Smellbestf'(end)A_{best} = S'(end) \tag{21}$$

Step 9: If the most iteration range is attained, then the best solution is obtained, if not go to Step 5, otherwise the circulation is terminated.

Algorithm
Input: $G = (V, E)$, adjacent, dist
Output: Set of CH and gateway
1.   *for(each $v_i \in G$)*
2.   Find the adjacent of v_i using Eq. (2);
3.   Compute the parameters like EC, SF and RBE;
4.   Determine the relative dissemination degree;
5.   Calculate the DL, PLR, NRO and BLI;
6.   Convert the parameter values into fuzzy sets;
7.   Obtain the weight function $W(v_i)$;
8.   Initialize the population of FF swarm, iteration number t and iteration step value R;
9.   Initialize the location of the population (A, B) randomly;
10.   *while($t > t_{max}$)*
11.   Perform the individual searches for food in random directions and Dist as (14);
12.   Compute the Dist $D(i)_n$ as (15);
13.   Calculate the smell concentration judgement value $Smell(i)_n$ using (16);
14.   Set fitness function $F(Smell(i)_n)$ = weight function $W(v_i)$;
15.   Evaluate the fitness function value by using fuzzy sets;
16. $[bestSmell, bestIndex] = max(Smell(i))$;
17.   *if (bestSmell < smellbest)*

(Continued)

(continued)

|	
18.	Update *smellbest* and fruit swarm location using (19);
19.	Change step value R as R' using (20);
20.	Find the global best solution A_{best} and *Smellbestf$'_i$* using (21);
21.	*end if*
22.	$t = t + 1$;
23.	*end while*
24.	Select the best solution nodes (FF swarms) as CH and select the best solution value nodes located in the border as a gateway;
25.	*end for*

4 Simulation Results

The effectiveness of the FFFCHGS and FGCHGS algorithms is simulated through Network Simulator-2 (NS2.34) and compared with the NQCA and FGCH algorithms based on the DL, PLR, NRO, BLI and EC. Tab. 3 gives the simulation parameters.

Table 3: Simulation parameters

Simulation parameters	Values
Simulation Tool	NS2.34
Simulation Area	1400 × 1400 sqm
Network Topology	Flatgrid
Physical Type	Phy/WirelessPhy
MAC Layer	IEEE802.11
No. of Nodes	200
No. of Gateways	20
Node Velocity	0–50 m/s
Mobility Model	Random Way Point
Simulation Period	600 s
Transmission Range	250 m
Packet Size	512 bytes
Traffic Type	Constant Bit Rate (CBR)

Fig. 1 illustrates the end-to-end delay of FFFCHGS, FGCHGS, FGCH and NQCA algorithms. When node speed is 10 m/s, NQCA has DL of 0.0369; FGCH has 0.0322 and FGCHGS has 0.0288 s while FFFCHGS has 0.0247 s. There is a considerable reduction of DL in FFFCHGS since the efficient selection of both CH and gateway. It is observed that the FFFCHGS algorithm achieves minimum DL compared to the FGCHGS, FGCH and NQCA.
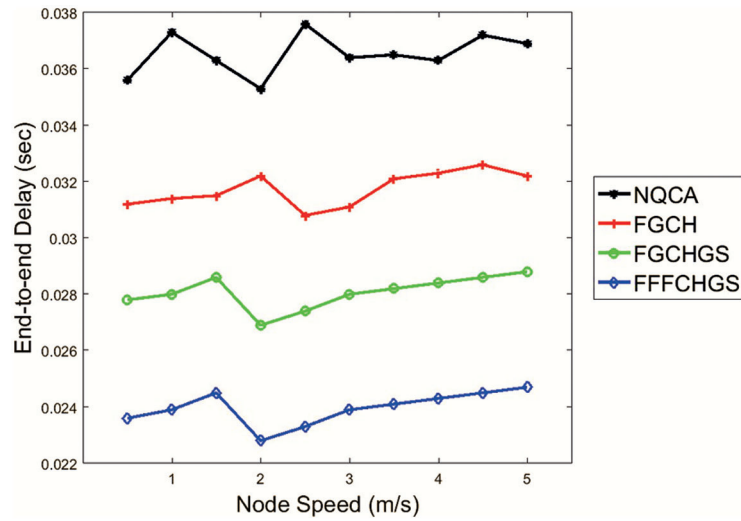
Figure 1: End-to-end delay *vs*. node speed

Fig. 2 illustrates the PLR of FFFCHGS, FGCHGS, FGCH and NQCA algorithms. When node speed is 10 m/s, NQCA has PLR of 0.0745; FGCH has 0.0624 and FGCHGS has 0.0515 while FFFCHGS has 0.0421. The FFFCHGS algorithm has reduced PLR values by transmitting the packets through the selected CH and gateway. This proves that the FFFCHGS algorithm has reduced the PLR compared to the FGCHGS, FGCH and NQCA.
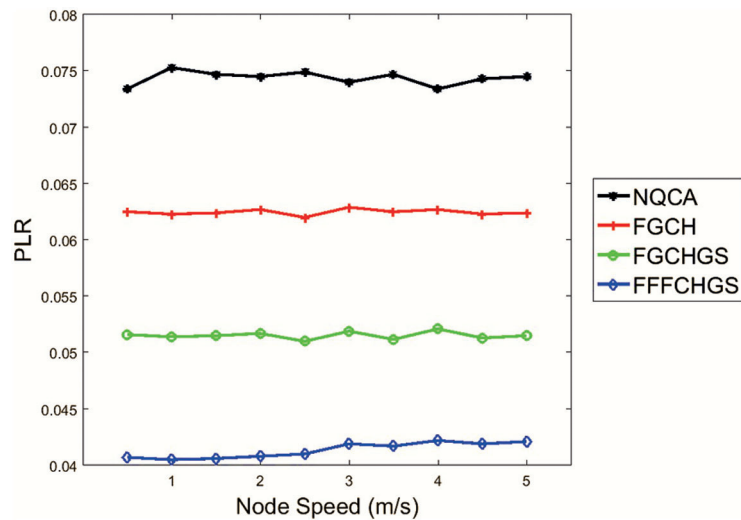
Figure 2: PLR *vs*. node speed

Fig. 3 demonstrates the NRO of FFFCHGS, FGCHGS, FGCH and NQCA algorithms. When node speed is 10 m/s, NQCA has an NRO of 3.7931; FGCH has 3.2315 and FGCHGS has 2.7931 while FFFCHGS has 2.3547. The NRO is significantly reduced by balancing load through the network. Thus, it proves the FFFCHGS algorithm achieves the minimum NRO compared to the other algorithms.

Compared to the existing load balancing techniques, the proposed work gives performance improvement of 0.9 to 0.999 with the improved efficiency.
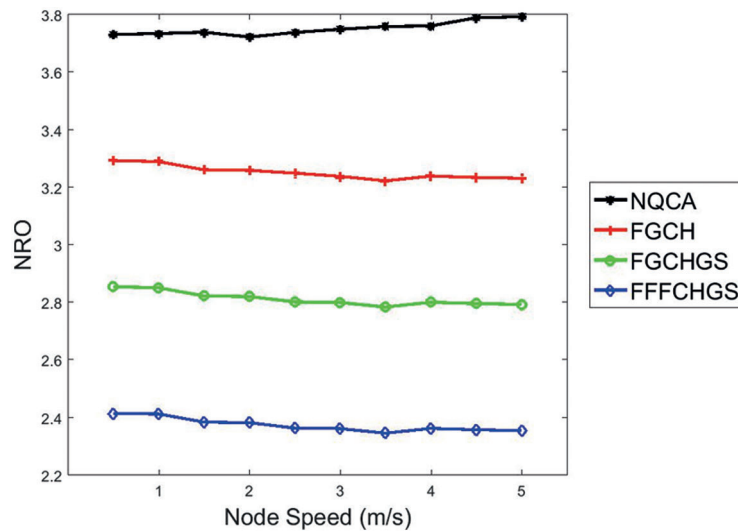
Figure 3: NRO *vs*. node speed

Fig. 4 illustrates the BLI of FFFCHGS, FGCHGS, FGCH and NQCA algorithms. It is observed that the FFFCHGS algorithm achieves minimum BLI than the FGCHGS, FGCH and NQCA algorithms.
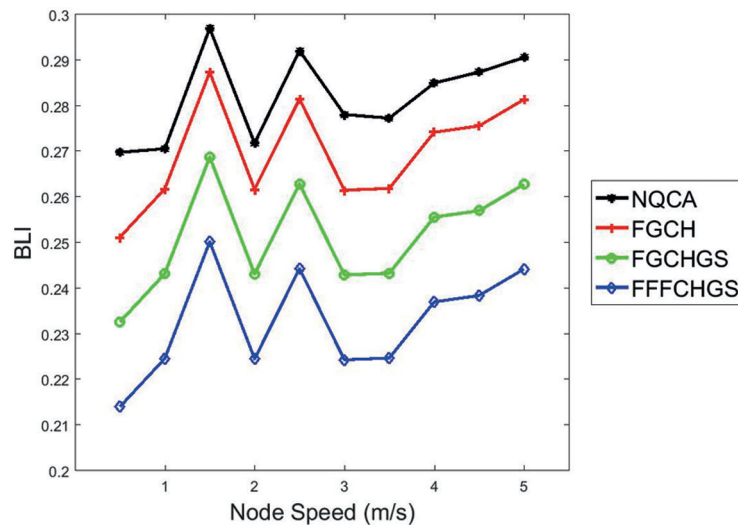

Figure 4: BLI *vs*. node speed

Fig. 5 illustrates the EC of FFFCHGS, FGCHGS, FGCH and NQCA algorithms. When the maximum transmission range is 100 m, NQCA has EC of $563W/10^6$; FGCH has $537W/10^6$ and FGCHGS has $511W/10^6$ while FFFCHGS has $485W/10^6$. The FFFCHGS algorithm has better EC per packet due to the low utilization of nodes around CH and gateway. This clearly shows that the FFFCHGS algorithm achieves minimum EC than NQCA, FGCH and FGCHGS algorithms.
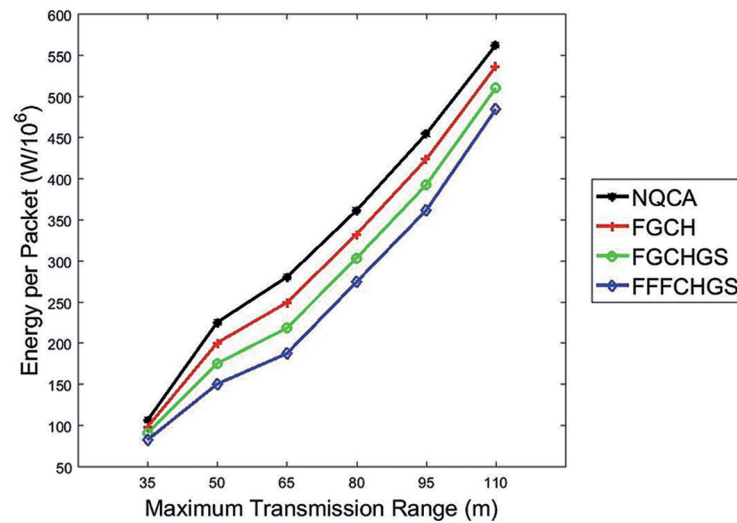
Figure 5: Energy per packet *vs.* maximum transmission range

5 Conclusion

In this article, an FFFCHGS algorithm is proposed for improving the gateway selection in H-MANET. In this algorithm, initially, the network is split into different clusters. In every cluster, their CH is selected based on the IWCA which utilizes different metrics such as node fidelity, transmission range, etc. Then, each cluster quality is measured by using the FL system which considers the different parameters such as DL, load balancing, EC, RBE, etc. In addition, the gateway is also selected based on these parameters which are converted into fuzzy sets and the combined weight value is computed. Then, the computed combined weight values are optimized by using GA. Further, an improved FF algorithm is performed instead of GA for CH and gateway selection with increased accuracy and convergence speed. Thus, both CH and gateway selection are optimized and the effectiveness of the gateway selection is enhanced. At last, the experimental outcomes proved that the FFFCHGS algorithm achieves higher efficiency concerning minimized DL, PLR, NRO, EC, etc. But the limitation of the work includes further enhancement in the convergence precision as the result of low convergence.

Future Works

Machine learning based load balancing with the proposed optimized NQCA for further enhancement in the efficiency in the future work.

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

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