Grid based Bio-Inspired Energy Efficient Trusted Hybrid Routing Protocol for MANET

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Abstract**:** ***Device to device (D2D) data communication in cellular wireless network can be done either directly from source equipment (SE) to destination equipment (DE) or through relay equipment (RE). This type of network mainly known as Wireless ad hoc networks. Mobile ad-hoc networks (MANETs) have constraints such as such as limited power, route failure, bandwidth allocation, and computational complexity. The major impact on the performance of network depends on routing strategy. Routing strategy for matching the multi constraints of network is so far challenge in conventional network. MANETs suffers from dynamic movement of node, power, dynamic routing and storage complexity. Dynamic movement force the computation of re-routing, which act as extra computational burden on the system. In this paper, we propose the Grid Cluster based Multi-Objective Genetic Algorithm for Energy Efficient Trusted Network (gCMOGAEETN) algorithm for finding optimal routes from a given SE to a given DE. Our simulation results show that gCMOGAEETN algorithms are efficient in solving these routing problems and are capable of finding the optimal solutions at lower complexity than the 'brute-force' exhaustive search, when the number of user equipment (UEs) is higher than or equal to 50. The analytical and simulation result shows that proposed method exhibit significantly higher performance than optimal adaptive forwarding strategy (OAFS), sub-optimal adaptive forwarding strategy (SAFS), memory enhanced genetic algorithm (MEGA), Elitism-based Immigrants Genetic algorithm (EIGA), dynamic load-balanced clustering problem (DLBCP) and Genetic Algorithm Based Optimization of Clustering (GABOC)..***

Keywords**:** ***Bio-Inspired Algorithm, Genetic algorithm, Mobile Adhoc Network, Trust factor.***

I. INTRODUCTION

MANETs is a dynamic topological self-configuring network having energy conservation and node movement. This network is also known as fluctuating network due to the ability to interconnect with any pre-existing infrastructure. IEEE802.11 (WiFi) network are most popular MANETs in wireless networking technology [1]. Characteristics of such network are that the device can communicate within limited range and also can move from one point to other. Due to the change of location of device the topology changes in unpredictable way which creates obstacles for performing efficient communications. Clustering of nodes reduces the size of topology and also accumulates topological information. Small change in location increases the computational overhead to re-calculate the distance matrix among node and accordingly update the topological information. For which some of the popular research has focus on GRID based clustering, where the nodes are free to move in any predefined cell (GRID) without need of re-calculation of distance. Once the grid location of any node changes than only the topological information needs to get updated.

In this paper, we have considered broadcasting problem on Metropolitan (shopping mall) MANETs because it gets some specific properties such as the heterogeneous density and dynamic load, which make it suitable for simulation. Major objective of our work is to provide load balancing, filtering of suspicious node, and enhancing the life time of network with minimum packet loss. For optimizing the multiple objectives such as maximum coverage, minimizing bandwidth and faster packet transmission results in multi-objective optimization problem [2], [3]. In many cases result provided by the multi objective optimization algorithm are set of solution known as Pareto optimal set, but in our research, we focus to get one solution from multiple solution which will serve multiple objective by designing the fitness function for the selection of optimal route. We propose a cluster based Multi objective genetic Algorithm energy efficient trusted network (cMOGAEETN) for solving the multi-objective problem of tuning a particular broadcasting strategy for metropolitan MANETs.

There are many evolutionary algorithms [2], [3] used in solving multi-objective optimization problems. Out of which few have worked with cellular genetic algorithms (cGA) based on cellular models [4] on single-objective optimization [5]. cMOGAEETN algorithm we propose is the first attempt to solve the broadcasting problem on MANETs using a multi-objective EA on trusted network for reducing the energy consumption. Trust factor plays important parameter to select node for communication. It omits the suspicious node and increase the through put and energy efficiency of network [6].

II. RELATED WORK

List state routing and grid distance vector routing is the two most fundamental algorithm to derive MANET.

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Most routing algorithms for MANET are loaded with the GPS system to provide their geo-location information [7-9]. Grid distance between the UEs is measured using the geographical information of the UE. This grid distance matrix serves as the basis of routing [10]. In research [11] for reduction of message is achieved between UEs LAR (location aided routing). Whereas [12], [13] focus on the destination sequences grid distance vector which periodically advertise its interconnection topology with neighbor in the network.

After gaining the information about the grid distance of UE with respect to zone, clustering is widely used to establish and conduct routing among the communication UE. Some of the best algorithms are Grid routing protocol (GRID [14]), location-based routing protocol (LBMRP) [15] and Location based grid routing protocol (LBGP) [16]. Grid distance matrix helps to establish cluster and based on parameter energy, grid distance and number of UE in a cluster, cluster head is selected. Cluster head helps to transmit/broadcast information and establish connection. It helps in stable route discovery, route maintenance, and packet relay by separating the DE into group based on high channel and low channel GRID sub network [15]. Achieve stable route with dynamic topology by selection and adjustment of cluster head. Clustering the communication UE required higher UE density. Clustering suited most in MANET for building and maintains transmission line [16].

Next step after maintaining the topological information of the network is the discovery of communication path. [17-19] focuses on the prediction of next hop based on the current topology, velocity and direction of UE movement. PSR [20], [21] provides data transportation services decrease the routing update computation in large networks. RREQ (Route request) [22] is been send by any UE who want to establish the connection between DE UE. Building valid path and building trusted valid path is major challenges in current MANNET system. Trust is also considered as parameter for routing protocols and has been considered by some researchers. Some of the recent research [23-27] deals in the discovery of a strong trust-aware routing framework to provide trustworthy and energy-efficient routes, based on geographical location, historical behavior to deal with selfish or malicious UEs.

There can be different set of paths available in a network from SE to DE. To find an optimal path will require large computation and time. For which, nature-inspired methodology has inspired the research community for their advantages in path-finding and path-optimization. [28], [29] presents a routing algorithm based on Ant colony optimization ACO approach.

Static shortest path problem using genetic algorithm (GA) [30-32] through immigrants and memory scheme. Another paper [33] focus on improving the performance of network by implementing weighted clustering algorithm using GABOC. Some of the parameter taken consideration for selecting cluster head are degree, power cell, UE dynamic movement and grid distance to search central set. This parameter helps to selects a smaller number of cluster heads to cover all the UEs. [34] Proposes annealing algorithm for quality of services multicast routing. [35] Proposes energy efficient GA to reduce the delay constrained multicast tree maximize the life of network. Similarly, authors also gave importance to energy efficiency during search of optimal route from SE to RUE to DE in [41]; they propose (OAFS) that is optimal adaptive forwarding strategy for multi-hop D2D communications and to reduce the computational complexity uses sub-optimal adaptive forwarding strategy (SAFS).

III. PROPOSED SYSTEM

In our proposed system cMOGA-EETN, the clustering algorithm quickly adapts any random change in topology and produces cluster heads with optimal trusted path having minimum energy. Fig. 1, depicts the proposed architecture of cluster based Multi objective genetic algorithm energy efficient trusted network. Proposed architecture is framed into two processes. Process 1 is for building the cluster and updating of energy and position of UE, whereas process 2 used for building optimal communication path based on trusted network. Following are the thing done under both the process.

Process 1: Selection of cluster head based on position and energy

- Deployment/updating of UE's Position and energy
- Build Cluster based on Density
- Based on Energy cluster head is selected

Process II: During the process of Communication following algorithms are used

- Grid Position Based Shortest Path Route Detection
- Trust Assessment of UE evaluated for the shortest path
- Selection of Best Optimal path using MOGA (Multi Objective Genetic Algorithm).

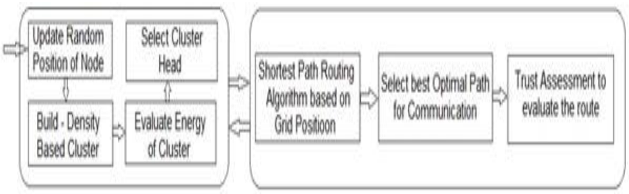

Fig.1.Proposed Architecture-Self Configurable gCMOGAEETN

1. Data and Materials

To evaluate and assess the performance of the proposed architecture, we set up the following simulator. A set of $\mathcal{N}$ (cellular UEs or equipment) are randomly distributed within a 50 m × 30 m; this area size represents classical applications in which $\mathcal{N}$ are co-located (e.g., university, mall, airport, etc.). These types of environment are usually very crowded (high density of devices) suits the mobility environment. $\mathcal{N}$ are randomly initialized with energy between 80 - 99 joules. Energy is shown in the Fig. 2.a, associated with each UE. Our simulation is carried out by considering $\mathcal{N}$ nodes are moving rapidly and randomly in a 2D rectangular space S. Where, $S = [0, W] \times [0, H] \in R$, and W and H are the width and length of S, respectively. $\mathcal{N}$ are free to move in any direction, but we have simulated the movement in 8 possible direction that is {Forward:

F, Backward: B, Left: L, Right: R, Forward-Left: FL, Forward-Right: FR, Backward-Left: BL, Backward-Right: BR} as shown in Fig. 2.b.. Let $s_j(t) = [x_j(t), y_j(t)]^T$ be the position vector of UE j at time t with $x_j(t) \in [0, W]$ and $y_j(t) \in [0, H]$. The new position of any UE j can be determined using equation (1- 8).

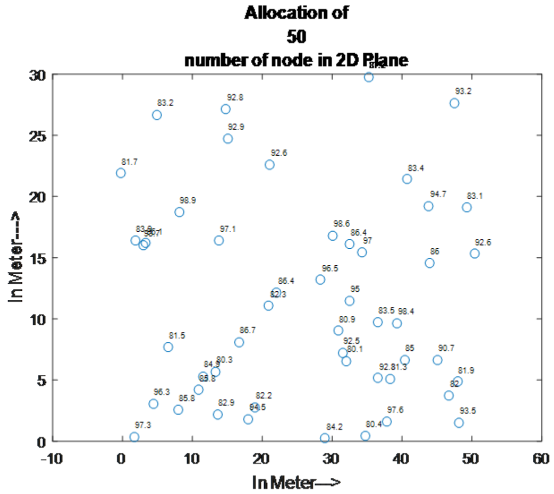

Fig. 2. a. Random allocation of 50 UEs User Equipment (UE) initialized with energy in the range of 80 - 90 Joule

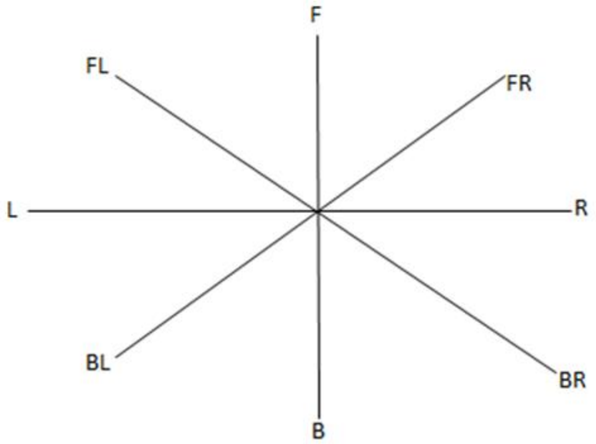

Fig. 2. b. UE possible movement in 8 direction from center position

Forward Move: $x_j(t) = x_j(t) \quad , y_j(t) = y_j(t) + u_j(t)$ (1)

Backward Move: $x_j(t) = x_j(t) \quad , y_j(t) = y_j(t) - u_j(t)$ (2)

Left Move: $x_j(t) = x_j(t) + u_j(t) \quad , y_j(t) = y_j(t)$ (3)

Right Move: $x_j(t) = x_j(t) - u_j(t) \quad , y_j(t) = y_j(t)$ (4)

ForwardLeftMove:
$x_j(t) = x_j(t) - u_j(t) \sin\theta \; , y_j(t) = y_j(t) + u_j(t) \cos\theta$ (5)

ForwardRightMove:
$x_j(t) = x_j(t) + u_j(t) \sin\theta \; , y_j(t) = y_j(t) + u_j(t) \cos\theta$ (6)

BackwardLeftMove:
$x_j(t) = x_j(t) - u_j(t) \sin\theta \; , y_j(t) = y_j(t) - u_j(t) \cos\theta$ (7)

BackwardRightMove:
$x_j(t) = x_j(t) + u_j(t) \sin\theta \; , y_j(t) = y_j(t) - u_j(t) \cos\theta$ (8)

Where, $u_j(t) \in [V_{max}, V_{min}]$ is the regular speed of the UE and $\theta \in [0,2\pi)$.

2. Challenges and Possible Grid based Solution

Most of the communication MANET networking protocol periodically update their UEs position based on the information received from their neighbor UEs. Such protocol allows UEs to send (such as one time per second) broadcast information and other UEs receive this information and refreshes its neighbor table. This protocol leads to three different types of problems, such as a) Large number of bandwidths is occupied by the communication data, b) frequent topological changes become more complex and make UE busy in storing and retrieving neighbor UEs statistics, and c) heartbeat or updating of cycle selection become improper.

The above problem is only caused due to the fast change in UE position. Other essential factor in maintaining the link is communication radius. Hence, we have implemented the concept of Grid Based position system [37], which was built for VANET in 3D space and modified and implemented in 2D logical space. The 2D geographic mission area S is divided into 2-dimension logical grids as shown in **Fig. 3**. In the figure, each grid is considered to be a square area dimension $G_W \times G_W$ over x-axis and y-axis. So, we can get the rasterization /discretization formulation of space, it's $S_G = [0, W_G] \times [0, H_G]$, and

$$W_G = W / G_W \quad (9)$$

$$H_G = H / G_W \quad (10)$$

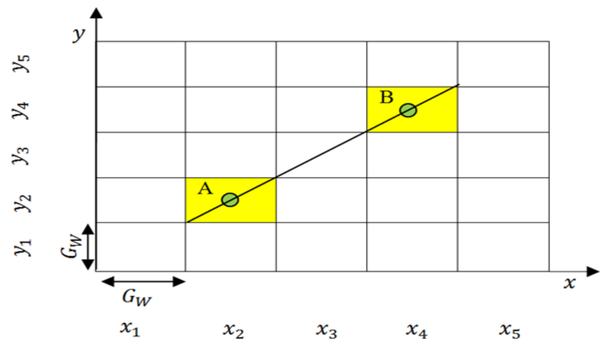

Fig. 3. Logical grid locations

The UE's movement is the similar as equations (1-8). As long as UE do not move from one grid to other, its $G(t)$ remain stable, but as soon as it changes grid, this UE sends broadcast information to other UEs. By doing so our approach helps to reduce the sensitivity of geographic position and lessen the computational cost of updating network topology. Let there be two UEs as shown in Fig.3, as i and j located in Grid A and B respectively. The grid distance between the grids can be evaluated as (11).

$$D_{ij} = \sqrt{(|x_1 - x_4| + 1)^2 + (|y_1 - y_4| + 1)^2} \quad (11)$$

D_{ij} represent the maximum grid distance between the Grid not the UE. As long as UE moves in the Grid, no need to update the position of UE or send broad cast signal. If the logical radius for establishing direct connection between two UE is r than at any time t, two UEs i and j can communicate with each other if $D_{ij}^t \le min(r_i^G, r_j^G)$,where, $r_i^t = \lfloor r_i / G_W \rfloor, i \in [1, \ldots, |\mathcal{N}|]$.

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3. Density Based Cluster and Cluster Head Selection

Density based clustering algorithm such as Density-Based Spatial Clustering of Applications with Noise (DBSCAN) [36] is been used to find nonlinear shapes structure based on the density. It helps to determine pattern among the neighbor based on neighbor's spatial location and the distance. Density reachability means two points *p* and *q* is said to in reachable distance, if the maximum distance between them is *r* and has sufficient number of points δ in its neighbors within distance *r*. Algorithm 1, depicts the steps for building density-based clustering (DBC) and cluster head selection (CHS) named as (DBC_CHS). There are four parameter { $|\mathcal{N}|$, *P*, *E*, *r*} act as input to the algorithm. Where $\mathcal{N}$ is set of UEs, *P* is position of each UE in interval X axis [0-50] and Y axis as [0-30]. *E* is the energy of each UE, and *r* is the radius or grid distance between two UEs to be a neighbor. In the algorithm first loop from line 6 to 9 used to build cluster C and succeeding loop select cluster head based on energy of UEs present in the individual cluster. The UE x_k which has maximum energy in the individual cluster *i* is selected as cluster head $H_i = k$.

Algorithm 1: DBC_CHS ($|\mathcal{N}|$, *P*, *E*, *r*)

1. Let $\mathcal{N} = \{x_1, \dots, x_{|\mathcal{N}|}\}$ be the set of UE,
2. Position $P \in R$ in interval [X-max Y-max]; such that $x_i^P \in P_i \; \forall i \in 1..N$
3. Energy $E \in R$ in interval [80 100]; such that $x_i^E \in E_i \; \forall i \in 1..N$
4. *r*= radius
5. $C \leftarrow \emptyset$
6. For $i \leftarrow 1{:}|N|$
7. $\quad \tau \leftarrow$ Number of Node Neigh(x_i) in radius r
8. $\quad$ if $\tau > \delta$
9. $\quad C \leftarrow C \, U \, \{Neigh(x_i)\}$
10. For $i \leftarrow 1{:}|C|$
11. $\quad H_i \leftarrow \max_k(\mathrm{energy}(C_i))$

4. Shortest Path Routing Algorithm Based on Grid Position

The discovery of path from SE (Source Equipment) to DE (Destination Equipment) is an NP Hard problem. Dijkstra's algorithm [38] serves the concept of finding all pair shortest path. But our objective is to gather all valid path from SE to DE and later filter them using trust factor. In our simulation $\mathcal{N} = \{x_1, \dots, x_{|\mathcal{N}|}\}$ are individual independent User Equipment (UE) which have their own memory energy, and processing unit. Communication among UEs are made in wireless communication medium. In process of communication every UE stores information such as {Neighbor information, grid distance matrix, is_edge, Job queue, CHEAD information}. For example, Fig. 4, shows a network structure having 4 clusters. Fig. 5.a, shows the structure of information stored each UE and for sake of example Fig. 5.b and 5.c shows the information available in edge UE 4 and cluster head (CHEAD) and UE 5 respectively.

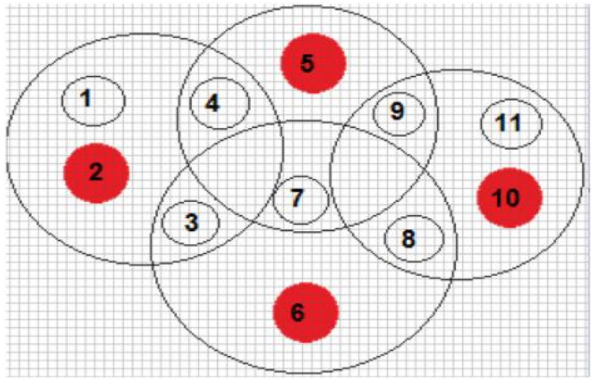


Fig. 4. UE distributions over density-based cluster for demo example, UEs in red are cluster head

Structure UE	UE 4	UE 5
{ ArrayList neighbor, Double grid distance, Boolean is_edge, ArrayList job_queue, ArrayList CHEAD_info, ArrayList edge_Info }	neighbor = {2, 3, 7, 5} grid distance = {8.6, 8.6, 8.5, 7.8} is_edge = true job_queue = {} CHEAD_info = {2, 5} edge_Info = {}	neighbor = {4, 7, 9} grid distance = {7.8, 8, 8} is_edge = false job_queue = {} CHEAD_info = {} edge_Info = {4, 7, 9}
(a)	(b)	(c)

Fig. 5. a) Structure information of User Equipment (UE) at any point of time, b) Structural Information of UE 4, c) Structural Information of UE 5.

Grid distance between the UE is evaluated in terms of grid to grid distance as per (11). If the grid distance between any pair of UE is less than r than the pairs are neighbor to each other and information is added to neighbor information vector. If any UE neighbor vector consists of multiple numbers of cluster head than the particular UE edge status is set to 1(True), indicating UE is edge UE. Edge UEs are important in establishing communication between different clusters. Each UE also maintains its cluster head's information so as to maintain the communication in future. Initially the job queue is set to empty but will develop into set once communication get started. With reference to figure 4, Following Cases may happen during finding paths between SE to DE.

Case 1: Device to Device Communication (D2D): Let UE indexed 3 in figure 5(denoted as x_3) want to communicate with UE indexed 4 (denoted as x_4). As x_3 and x_4 are neighbor to each other hence direct connection is possible and the communication starts without any further formalities of searching alternate path. This type of direct communication is known as D2D connection.

Case 2: Source UE to Destination UE when belongs to same cluster: Let UE indexed 1 in figure 5(denoted as x_1) want to communicate with UE indexed 4 (denoted as x_4). As x_1 sees x_4 is not in its neighbor list hence broadcast the message to its cluster head (CHEAD). From the figure 5, it is noticed that CHEAD is x_2. Now, x_2 checks x_4 in its neighbor and could find that x_4 is in its neighbor, hence a valid path 1-2-4 can be established. As 1 and 4 is in same cluster hence no need to find any alternate path. Case 3: Source UE to Destination UE through Relay UE: Let UE indexed 1 in figure 5(denoted as x_1) want to communicate with UE indexed 11 (denoted as x_{11}).

x_1 checks UE x_{11} in neighbor information and could not find, hence broadcast a send request to CHEAD x_2. CHEAD x_2 checks x_{11} in its neighbor and as could not found in its neighbor hence broadcast the send request {1-2} to edge UE {3, 4}. x_3 checks x_{11} in its neighbor and as it could not find in its neighbor, broadcast the send request {1-2-3} to its CHEAD x_6. Similarly, x_4 checks x_{11} in its neighbor and could not find it their hence forward the send request {1-2-4} to CHEAD x_5. Here point to be noted that every time a send request gets forwarded by any UE, UE's id is appended to the request. This will help us to determine the path from which the send request is generated. Similarly, recursive calls will be made till the send request information reaches x_{11}. Here point to be noted that each UE first check the DE UE in its neighbor, if found than return the path else forward the send request to its cluster head or edges. We will get valid path *VP* for the communication from x_1 to x_{11} as *VP* = {1-2-3-6-7-5-9-10-11, 1-2-3-6-8-10-11, 1-2-4-5-9-10-11, 1-2-4-5-7-6-8-10-11}. As there is no direct communication between the source and destination, hence the system establishes the connection through relay user equipment. Next step is to determine the trusted and valid path. This is discussed in next section.

Trust Factor: Each UE belongs to one or more cluster, where each cluster maintains its neighbor behavior and allocates a trust value. Trust value helps to analyze weather UE is selfish, is been fabricated, creating latency delay, or populating the network. [39] Suggested the concept of analyzing the neighbor UEs behavior at UE levels. Which create extra computational overhead in maintaining the trust factor. We have modified the concept [39] and in proposed work trust value is maintained and monitored centrally by the cluster head. Let x_u be a cluster head (CHEAD) of any cluster. When a new UE x_v joins x_u as neighbor, x_u assigns it an initial trust value τ_uv, which is determined by (12).

$$\tau_{uv} = \begin{cases} \frac{1}{n}\sum_{k=1}^{n} \tau_{uk}, & if\ n > 1 \\ \tau_c, & if\ n = 1 \end{cases} \qquad (12)$$

Where, n is the number of neighbors of x_u, τ_c is the constant value for $n = 1$. Once x_u observes specific behavior of x_v updates the trust value τ_{uv} based on

$$\tau_{uv}(t+1) = \begin{cases} \tau_{uv} + 1\ if\ t = 1 \\ \tau_{uv}(t) + \eta\ if\ t > 1 \end{cases} \qquad (13)$$

Where, η is the weight factor, which measures the percentage (in the scale 0 to 1) of communication made between UE x_u and x_v with the total number of packets transmitted by x_u with all its neighbor. η is given by:

$$\eta = P_{uv}/T_u \qquad (14)$$

Where, T_u is the total number of packets transferred by x_u since inception, P_{uv} is the total number of packets communicated between x_u and x_v. For any two UE x_v and x_w if $\tau_{uv} > \tau_{uw}$ means trust value of x_v is better than x_w. This also means that x_w is less loaded in comparison to x_v. Hence, efforts is been taken to allocate next overloaded UE to be used by the cluster head for communication for load balancing.

Objective of the proposed work is following i) discovery of valid trusted path ii) Energy Efficient network and iii) No packet Loss. As we are dealing with multiple objective hence, we use multi objective genetic algorithm (MOGA). The entire optimization algorithm requires possible solution as input population which gets better during every succeeding generation; hence we build the population of all pair shortest path for optimization using MOGA. The details are discussed in next section.

5. Multi Objective Genetic Algorithms

To get valid and trusted optimal path, along with energy efficient with negligible packet loss network, multi objective genetic algorithm (MOGA) is used. The population *POP* act as input for MOGA can be built by appending valid path *VP* with the three most important parameter of relay UE (RUE) as a) job (Queue) of transmitting and receiving the packet, b) a trust value and c) energy.

$$POP=\{[VP_1TV_1E_1Q_1]', [VP_2TV_2E_2Q_2]', [VP_3TV_3E_3Q_3]', \ldots\ \ldots [VP_kTV_kE_kQ_k]'\}, \qquad (15)$$

Where, k is the number of valid path, $TV = \{TV_1, \ldots TV_k\}$ is the set of trust value τ of individual UE, for $TV_i = \{\tau_{VP_{i1}}, \ldots \tau_{VP_{i|vp_i|}}\}$, $E_i = \{e_{VP_{i1}}, \ldots e_{VP_{i|vp_i|}}\}, Q_i = \{q_{VP_{i1}}, \ldots q_{VP_{i|vp_i|}}\}$ where, $\tau_{VP_{ij}}$, $e_{VP_{i1}}$, and $q_{VP_{i1}}$ is the trust, energy and job_queue length of j^{th} UE present in i^{th} valid path. Queue length Q_i of any i^{th} UE, is given by

$$Q_i = Q_i + 1 \qquad (16)$$

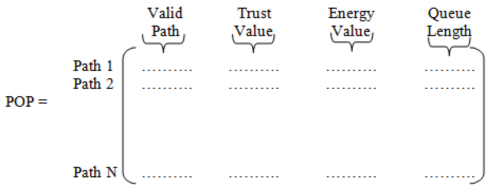
When it receives packet for transmission, and Q_i is updated using (17) when it transmits the packet

$$Q_i = Q_i - 1 \qquad (17)$$

One of the major constraints of any ad hoc network is its energy. Energy efficient ad hoc network may result in higher network life. Energy of any UE is inversely proportional to the number of jobs done by the device. More load means faster drain of energy. Energy E_i of any i^{th} UE is updated as per (18)

$$E_i = E_i - E_T - E_R - E_{ideal} \qquad (18)$$

Where, E_T and E_R are the energy consumed for transmitting or receiving a packet. E_{ideal} is the ideal energy consumed. Formulated [1] the concept dynamic load balancing problem with dynamic optimization problem in the selection CHEAD using Genetic algorithm (GA). Grid distance of UE and energy parameters are considered to select a CHEAD and to balance the load. We have reformulated the concept and used it for optimal path generation or selection. In proposed system the information which looks similar to (19) act as input to the GA is POP derived from given by equation (15).



(19)

Population Selection: The major factor of population involved are valid path, trusted value, energy and Queue length of each UE available in the valid path. Trust value of individual UE in the path vector is compared with threshold value δ. If all the UE's trust value is greater than threshold than only the path is further selected for optimal path selection process or else it is deleted from the population *POP*. Let for simplicity $POP = \{V_1, V_2, \ldots, V_N\}$ be the *N* valid path. Where, $V_i = [VP_i TV_i E_i Q_i]', \forall i \in 1 \ldots N$. Each TV_i is a set of trusted value assigned against the UE selected in trusted path. Let for Valid Path

$VP_i = \{a1, a2, a3, a4, a5, a6\}$ be the set of UE for the communication between a1 to a6 and its trusted value $TV_i = \{TV_{a1}, TV_{a2}, TV_{a3}, TV_{a4}, TV_{a5}, TV_{a6}\}$, than if any of $TV_{ai} < \delta$ than path VP_i is discarded from the *POP* list. Hence, trust value comparison ensures that path going as input for optimal processing are trusted. After deletion of un-trusted path size of POP reduces to K, where K<N. After step 1(i.e. selection) in MOGA we get the population POP looks like (20).

$$POP = \begin{array}{c} \\ \text{Path 1} \\ \text{Path 2} \\ \\ \text{Path K} \end{array} \left(\begin{array}{ccc} \overbrace{\text{Valid Path as chromosome}} & \overbrace{\text{Energy Value}} & \overbrace{\text{Queue Length}} \\ \ldots\ldots\ldots & \ldots\ldots\ldots & \ldots\ldots\ldots \\ \ldots\ldots\ldots & \ldots\ldots\ldots & \ldots\ldots\ldots \\ & & \\ \ldots\ldots\ldots & \ldots\ldots\ldots & \ldots\ldots\ldots \end{array} \right) \quad (20)$$

Fitness Function: It is used to evaluate quality of solution which is generated by the queue length standard deviation and the energy consumption of path. Function leads us to find the CHEAD with maximum energy with optimum load balancing problem on the network. With each iteration, solution is elected by discovering the minimum energy consumption path. Here, each individual path is considered as chromosome. The fitness value of path is represented as F(CH) which is given by (21).

$$F(CH_i) = \frac{1}{\sqrt{\frac{1}{|D_i|} * \sigma\left(Q_{i1}, Q_{i1}, \ldots, Q_{i|ch_i|}\right) + \sum_{j=1}^{|CH_i|} E_j}} \quad (21)$$

Where, D_i is the grid distance between the UE present in$Path_i$.$|CH_i|$ is the number of UE present in$Path_i$.

Selection: Selection method helps in selecting the high-quality chromosome (Paths) based on their fitness value for next generation as new population. At each iteration two random paths are selected from the population. Care is been taken for not to pick same chromosome twice.

Crossover & Mutation: This are also coined as Genetic operators [26], which helps in generating offspring or children UEs. New off-spring (new routes) are generated by selecting two suitable best fitted solution (routes) from the current population and recombining them using crossover and mutation operator. Crossover and mutation are applied with rates about Pc 0.5 and Pm 0.005, respectively. Here, point to be noted that, we have used a common-UE single-point crossover because we find it is more logical to find UEs that are common for both parent routes to perform the crossover operation to ensure that at least one of the already established links in both parent routes can be preserved.

For example, in **Fig. 4**, let two parents are selected as Parent1=1-2-4-5-7-6-8-10-11 and Parent2=1-2-3-6-7-5-9-10-11. Here, crossover point selected as 5, because 5 is common in both. Then by concatenating prefix leading of to and up to 5 from parent1 and postfix following of parent 2 will create new route as Child1 → 1-2-4-5-9-10-11. Similarly, through vice versa Child2 →1-2-3-6-7-5-7-6-8-10-11 can also be created. Child 2, can be discarded as UE 7 is utilized twice will lead to extra wastage of energy. Hence child 1 is selected for further process. Now, mutation operator is applied with probability of *Pm* over each individual. Mutation can be done in any of three ways in our experiment i) equipment exchange: current user equipment (CUE) is exchanged for a randomly-selected user equipment (RSUE) only if current CUE's next RSUE in new path is also neighbor to exchange CUE, ii) equipment removal: Current UE is deleted from the route without invalidating the path, and, iii) insertion: new UE is added in the route with-out invalidating the path. Proposed algorithm is given in (2).

Algorithm 2: gCMOGAEETN($\mathcal{N}, P, E, r, Pc, Pm, Q, S, T, \delta$)

```
vPath ← ∅
[C,H] ←DBC_CHS(N,P,E,r)
path ← per all_Path_SE_to_DE(S,T,CHEAD)
//Build trusted Valid Path
    for i ←1 to |path|
      flag = 0;
        for j ←1: |path(i)|
          if τ_node_j < δ
            flag = 1; break;
        end for
        if flag == 0
            vPath = vPath ∪ path(i)
    end for
// Multi Objective GA
    while !TerminationConditin() do
      for individual ←1 to |vpath| do
        n_list ←get_neighbourhood(vpath);
        parents ← Selection(n_list);
        offspring ←Recombination(parents, Pc);
        offspring ←Mutation(Pm, offspring);
        Fitness(offspring) = 1 / sqrt( 1/|D_i| * σ(Q_i1, Q_i1, ..., Q_i|offspring|) + Σ_{j=1}^{|offspring|} E_j )
          If non_dominated(Fitness(offspring), Fitness(parents)) then
              Replace vpath(parents) with offspring
          End if
      End for
    End while
```

IV. EXPERIMENT EVALUATION AND ANALYSIS

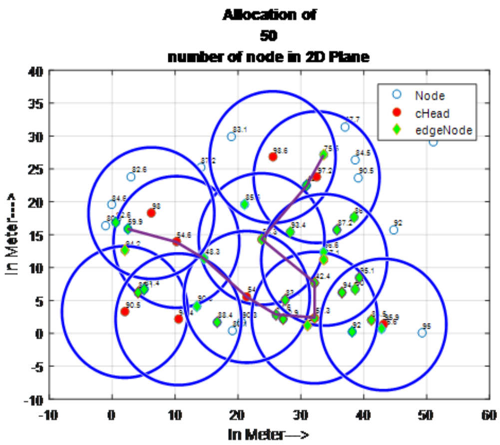
The proposed system has been implemented MATLAB 16a. Table I: shows the parameter used in simulation and their possible range and value. We have randomly deployed 50 UEs over the area of 30 m x 50 m. Minimum grid distance between the UE is 0.5 meter. Maximum speed of UE is 2m/s. Initial energy of UE is assigned between 80 to 100 joules. Minimum energy required before the UE gets dead is set to 5 Joule. The transmission range of the UE was 10 m. Trust constant of any UE is 1. UEs are followed the random way point model that finds the availability of connection paths in MANET. In this simulation first grid-based distance calculation is done followed by cluster head selection. All paths from SE to UE is evaluated. We have restricted our search of all paths to 500. First 500 paths become the basic valid path discovered for trust analysis and then by the help of GA optimal path is derived from the basic path. Our algorithm runs for 100 iteration, after which the optimal path is selected for communication. The proposed scheme is compared with DLBCP and GABOC methods. The comparison is made in terms of energy consumption, packet delivery ratio, and throughput and routing overhead by varying the network size from 50 to 200.

Table-I: Parameter Used

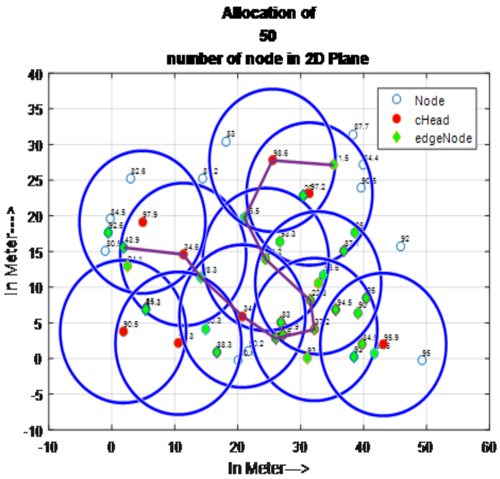
Parameter	Value
Simulation Area	50 m x 30 m

Simulation Time	100 Sec
No of UEs	50,100,150,200
Population size	100
Cross over rate	0.5
Mutation rate	0.005
Number of generations	75
Transmission range	50m
Movement model	Random waypoint
Speed	[2] m/s
Packet size	1024 bytes
Initial energy	100 joules
Transmitting energy	0.8 joules
Receiving energy	0.2 joules

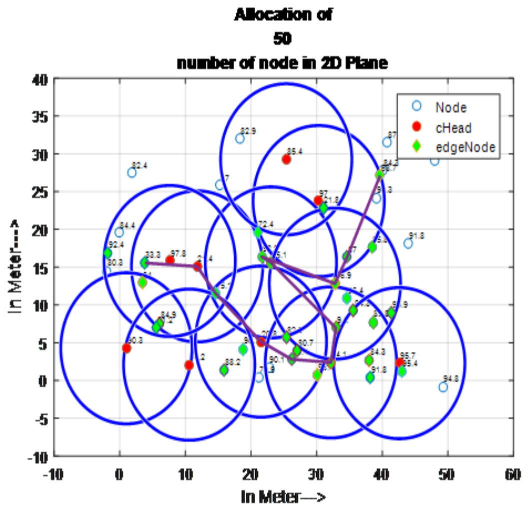
Figure (6) shows the simulation result obtained after running our algorithm for 50 UEs on 50 X 30sqm space. We made a dry run for 10 iteration and its output is shown in figure 6 (a-c). It should be noted that all the UE are moving independent in the 2D space with velocity *v* as per equation (1-8). Simulation shows the communication between SE 17 to DE 23. Figure 6 (a) shows the initial path discovered between SE 17 and DE 23. As soon as DE 23 changes its location a new route is discovered shown in figure 6 (b). Figure 6 (c) shows new route discovered when Relay equipment 4 is no longer accessible to relay equipment 11 during communication between SE 17 to DE 23.



(a)



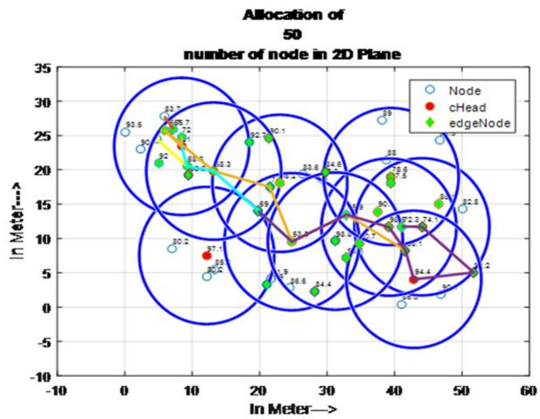
(b)



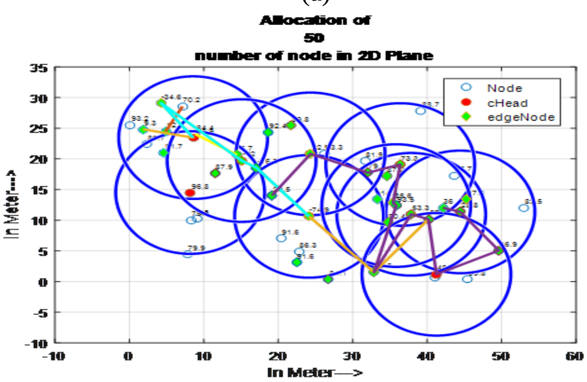
(c)

Fig. 6 Communication path selected from source UE 17 to destination UE 23 at different iteration: paths are
a) 17->8->20->37->1->35->9->11->49->23,
b) 17->8->20->37->1->35->9->11->4->27->23
c) 17->8->20->37->1->35->9->11->2->39->24->23.

Proposed algorithm is tried over multiple SE to multiple DE parallel communication. Fig. 7(a) communication route discovered through which the packet transmits from SE to DE at time 1. Similarly, the Fig. 7(b) shows the simulation result in time 100.



(a)



(b)

Fig. 7. Communication route from multiple UE to multiple UE (a) Communication route between different UE at random time 1 (b) Communication route between different UE at random time 100.

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This proposed scheme is compared with DLBCP [39], GABOC [33], EIGA [40], MEGA [40]. The comparison is made in terms of energy consumption, packet delivery ratio, throughput, and routing overhead over the network size of 50 to 200 UEs and their comparison is shown in table 2, 3, 4, and 5 respectively.

Table 2, shows that the proposed method consumes less energy in comparison to other methods. The trusted valid path derived from GA helps in load balancing which in turns decreases the average energy consumption of the network. **Table 3**, shows the packet delivery ratio (PDR) of proposed method reaches to 99% at 200 number of UEs. This simulation was carried out over 100 iteration and the result shows that proposed method maintained higher PDR. The routing overhead is evaluated and compared with various algorithm is shown in Table 4. Routing overhead reduces with the increase in UE size. The proposed algorithm shows minimal routing overhead about 40% and 45% due to the Grid based position update of equipment's are implemented. Table 5, shows the throughput comparison of various algorithm. Here, Throughput is measured by calculating the number of packets delivered to DE successfully. Table 6, shows the improvement in network lifetime in comparison with other algorithms. The network life enhances with the increase in UE size. The proposed scheme achieved 93 % of network lifetime.

Table 2: Total energy consumption of proposed MEGA, EIGA, DLBCP, GABOC schemes

No. of	EIGA	MEGA	DLBCP	GAB OC	Proposed Method
50	5.184	4.95	7.23	11.2	3.38
10	7.94	8.166	10	19.02	5.23
15	16.65	14.14	22.2	28.3	11.64
20	18.27	17.95	25.6	31.4	13.81

Table 3: Packet delivery ratio in percentage

No. of	EIGA	MEGA	DLBC P	GAB OC	Proposed Method
50	94	94	90	87	94
100	95	95	91	89	96
150	95	96	93	90	98
200	97	97	93	91	99

Table 4: Routing Overhead Vs UEs

No. of	EIGA	MEG A	DLBC P	GAB OC	Proposed Method
50	942	922	1208	1310	818
100	999	842	1115	1215	801
150	900	924	1063	1144	745
200	901	985	1024	1108	722

Table 5: Throughput (Kbps) Vs UEs

No. of	EIGA	MEGA	DLBC P	GAB OC	Proposed Method
50	95.1	95.4	86.8	86.5	96.2
100	96	96.5	87.3	87.5	97.5
150	96.2	97.8	88.05	88.2	97.9
200	97.1	98	88.5	90	98.6

Table 6: Network Life time in percentage

No. of	EIGA	MEG A	DLBC P	GAB OC	Proposed Method
50	85.7	86	83	81	88.2
100	86	87	85	84	90.6
150	88	89	87	86	92.5
200	90.8	91	88.9	88	93.2

V. CONCLUSION

This paper presents an optimal path search for reducing the energy consumption using cluster based MOGA and trusted path algorithms. Our algorithm helps to reduce duration of packet transmission, energy consumption and enhances the throughput. Load balancing is naturally done by selecting the best fittest path having smaller queue, less grid distance and more energy. The result shows that the proposed model gives better result in comparison with various algorithms. We have noted that with the increase in UE size the network become more optimal and give better performance.

In future we would like to extend the work to highway and metropolitan area of large size may be few km.

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