An Energy efficient optimal Shortest Path Routing for Mobile Ad-hoc Network using Genetic Algorithm

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Abstract: **An ad-hoc is collection of mobile nodes, where each node in a network moves randomly without any restriction. An ad-hoc is formed temporarily without any infrastructure like network administrator or any centralized supporting system. It changes the topology of a network as time goes on due to the high mobility of node. Many researchers are attracted with a problem is called finding a shortest path in a dynamic system. Though there have been many algorithm is proposed for proving in efficient utilization of battery powered nodes in an ad-hoc network but nothing is focused on an optimal node selection for the route construction . In this paper we propose an optimal solution based genetic algorithm for solving the shortest path routing problem is presented. The enhanced genetic algorithm is compared with Dijkstra's algorithm approach to solve routing problem. Simulation results are carried out for both algorithms using MATLAB. The results affirmed the potential of the proposed genetic algorithm.**

Keywords**: **Mobile Ad-Hoc Network, Dijkstra's algorithm, Genetic Algorithm, Shortest Path.

I. INTRODUCTION

A **mobile ad hoc network** is a self-directed system of mobile nodes. The scheme may operate in isolation, or may include gateways to and interface with a set network. MANET[1][3][5] nodes are equipped with wireless receivers and senders using antennas which may be broadcast, highly-directional (point-to-point) and probably steerable, or some combination thereof. Mobile ad hoc networks consist of mobile nodes which activate on battery. A mobile node has a fixed and decreasing energy. Thus, these nodes need to be energy conserved to maximize the battery life time. Energy consumed by the sleeping state node is radically less than the transmit/idle/receive state node. To minimize energy consumption, pathway which consumes less power is also can be chosen [4]. Routing process is one of the key issues in MANETs due to their highly dynamic and distributed ad hoc network. In exacting, energy efficient routing protocols[5][6][9] may be the most important design criteria for MANETs since mobile nodes will be powered by batteries with limited capability. Power or link failure of a mobile node not only affect the node itself but also its ability to forward packets on behalf of others and thus the overall system lifetime. For this motivation, many research efforts have been dedicated to developing energy aware routing protocols. A mobile node consumes its battery energy not only when it dynamically sends or receives packets but also when it stays inactive listening to the wireless medium for any possible communication requests from other nodes between networks. Therefore, energy efficient routing protocols minimize either the *energetic* communication energy required to transmit and receive data packets or the energy during *stationary* periods. The modern development in the energy efficient[12][13] wireless network is interfaces, powerful, energy efficient microcontrollers and high capacity batteries provide new functions of Mobile

Ad Hoc Networking approaches (MANETs).

In ad-hoc network each node is coordinated in a temporary location randomly and base on its transmission range a neighbors list is discovered. This neighbors list is used for the discovery of a route from a source to destination. Basically MANET uses two different types of routing protocols which are Proactive and Reactive protocols [3][4]. Proactive protocols keep on updating the routing information to all of its neighborhoods nodes. Reactive protocols discover the routing information from its neighbors at the time of data transmission taking place. The overhead to maintain up-to-date network topology information is high (e.g. Destination Sequenced Distance Vector "DSDV"). In Reactive protocols, also called "on demand" node initiates a route discovery process only when a route to destination is required. The established route is maintained by a route maintenance procedure until the route is no longer described [3]. The Dynamic Source Routing (DSR) is an on-demand version of routing protocol. This is an efficient protocol designed for use in multi-hop information sharing system. It has two important mechanism which are "Route Discovery " and "Route Maintenance", this will work together for discovering and maintaining routes to arbitrary location.

II. GENETIC ALGORITHM

The Genetic algorithm(GA)[6][7][8] is one of the evolutionary approach to achieve an optimal solution and it has been considered in many situations like finding optimal solution for a problem, such as path selection, machine optimization, optimal energy utilization in sensor networks and other biological complex problems. GA uses following steps to find out an optimal solution for the problem considered.

1. Initial Population (IP)
2. Cross over Techniques
3. Mutation Algorithm
4. Fitness Function
5. Optimal Population (OP)

A. Initial Population (IP)

A problem may consist of many solutions, GA technique is applied to find out the optimal solution among initial population considered, and among this some of solutions have quality for tanking as an input to get the final optimized output. Here GA initially considers all the possible solutions as input to start the optimization process. It is an iterative and self learning process; solutions are iteratively evaluated to gain qualified input.

Let us consider a set $\alpha = \{\alpha_1, \alpha_2, \alpha_3 \ldots \alpha_n\}$, this is considered as a Chromosome analogue to GA.

Here $\alpha_1, \alpha_2, \alpha_3 \ldots \alpha_n$ indicates possible solutions for a problem which we are considered for solving.

B. Cross- over Techniques

Crossover [10][11] is a genetic function that combines two chromosomes (parents) to produce a new offspring. Newly created chromosome may have better qualities than their parents if it takes the best characters from each of the parents. Cross over operation is of many types.

1. One-point Cross over
2. Two-point
3. Arithmetic Cross over
4. Heuristic Cross over

For an example two chromosomes are considered

α_1={11001|101010111}
α_2= {1001|101011110}

Two off springs are
A1= {11001101011110}
A2= {1001101010111}
'|' indicates cross over point.

C. Mutation

Mutation is a process carried out by GA; it alters one or more gene values in chromosomes to create a brand new mutated chromosome. With the new gene values, the genetic algorithm may arrive at better solution than was previously possible.

It comes in many forms...
1. Flip Bit
2. Boundary
3. Non uniform
4. Gaussian

For let us consider a chromosome A1= {11001101011110}
0 goes to 1 and 1 goes to 0
Mutated offspring A1= {0011001010100001}

D. Fitness Function

Fitness function[6][7] is an evaluation process, according to Darwin's evolution theory "Survival of the fittest" the best ones should survive and create new offspring. It extracts a subset of genes from an existing population, according to any definition of quality. Every gene has a meaning, so one cam drive from the gene a kind of quality measurement called fitness function.

Most commonly used methods are,
1. Roulette Wheel selection
2. Boltzman selection
3. Tournament selection
4. Rank selection

E. Optimal Population

This is the final output of the genetic algorithm based on fitness function. The final population has a set of optimal outputs which is used for getting accurate solution for a problem.

III. PROBLEM CONSIDERATION ANALOGOUS TO GENETIC ALGORITHM

A. Chromosome Representation

GA starts with the encoding, possible solutions are converted into genes and chromosomes, this enable us to precede our genetic operations. The techniques for encoding solution may vary by problem and amount of data considered. This proposed work has considered permutation encoding for chromosome representation. Each gene of chromosome takes a label of node such that no node can appear twice in the same chromosome. For example, let {2, 6, 8, 10, 14} be the labels of node in a five node instances, then a route {2→6→8→10→14} may be represented as (2, 6, 8, 10, 14).

B. Routing Technique: - Reliable and Energy optimal Selection

As we stated early the problem of selecting an optimal route is a tedious process, it is remain unsolved in various situations. The objective of the proposed technique is to find the best reliable and energy efficient [12][13] path in a communication network using personalized GA with historical energy and reliability factors. Let us consider a point-to–point communication network modeled by the simple connected graph $G = (V, E)$, where '*V* ' is the set of nodes (or processors or routers) and ' *E* ' is a set of edges (or bidirectional communicational links). Each element (u, *v)* in ' *E* ' is an edge joining node u to node v. A path in a graph from a source node's' to a destination node'd' is a sequence of nodes (V_0, V_1 , V_2 ,.....V_k) where $s = V_0$ and $d = V_k$. Where the existence of a link between two nodes is expressed by '1' and absence of a link is expressed as '0'. Energy of a node is compared between the threshold energy level against each node in a communication network.

L_{ij}= {1, if link from node i to j existing in the routing path
0, absence of a link}

N= {n1, n2, …., n_k}>= T_h Where T_h energy threshold and n1,n2,… n_k nodes in a network.

The optimal algorithm is to provide reliable and energy efficient route between the source and destination considering threshold based factor. Initially all the possible, connected paths from source to destination, which are the chromosomes of GA, are generated, subsequently from the generated chromosomes, the 'x' number of chromosomes are selected randomly to create the initial population and then the fitness of each chromosomes in the population are calculated. According to the

Roulette Wheel selection with the fitness value, the best 'y' chromosomes are selected for crossover. During crossover operation, we will use the 1-point, 2-pont and adaptive crossover to analyze the path fitness. After performing crossover, the repetition of similar chromosomes in the produced offspring as well as repetition of nodes in a chromosome is checked out and duplication is removed. Next, all process from the fitness evaluation to repetition checking are carried out 'B' no of times to obtain the best reliable path.

C. Generation of initial Population

The route table which contains the possible paths from "s" to "d" is generated. Let ' *RTB* ' be the generated route table consisting of the possible path from source to destination. The each path in the route table becomes as the chromosome of GA. The gene represents the node while the chromosome represents the network path. Population is the collection of 'x' possible paths selected randomly from the ' *RTB* '. The proposed technique uses the permutation encoding in which each gene represents the node number in a path. Chromosome representation of the possible network path may be as 1-6-7-10-14 which is constituted by nodes and the first node is the source node and the last node is the destination. Hop count of the path will be $hop = (l - 1)$ where l the total no of nodes in the path. The fitness function is used to numerically evaluate the quality of the each chromosome within the population.

D. Defining Fitness Function

Here the genetic algorithm id used for finding out an optimal route with the highest fitness. This fitness function defines that a node which is really considered for the further levels, which satisfies required condition expected for the route construction. The fitness function that involves computational efficiency and accuracy is defined in equation (1).

$$\eta_i >= \lambda$$

Where η_i indicates the current energy level of a node i and λ is the actual energy required.

$$\sum_{t=1}^{hop} \frac{\text{«}_i(N) * \sim_i(N) * \;_i(N) / b * \sum_{t}^{hop} \text{´}_i(N)}{hop} \quad (1)$$

Where $\text{«}_i = \frac{count(A[N][j] > \text{ª})}{n}$ is the historical reliability ratio and $\lambda$is the minimum required reliability for transforming packets. $\sim_i(N) = \frac{count(B[N][j] = 1)}{n}$ is the historical packet transmission success ratio of node 'N' 'b' is the packet size and $\varpi_i(N)$ is the delay time of the node 'N'. The fitness of every chromosome in the population is evaluated and based on ranking selection method the best 'y' chromosomes are chosen for crossover operation.

E. Crossover Operation

Following crossover methods are applied1-point crossover, 2-point crossover and adaptive crossover.

1-point and 2-point crossover

1-point crossover operator is operating on a single point in chromosome and it chooses the parent chromosomes from the population such that, at least one is common to the both the parent chromosomes. For example, in Fig.1 the chromosome 'P' and 'Q' are the parent chromosomes having the node 'seven' as common node.

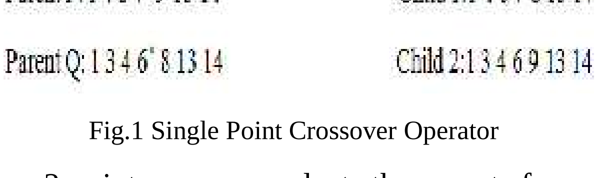
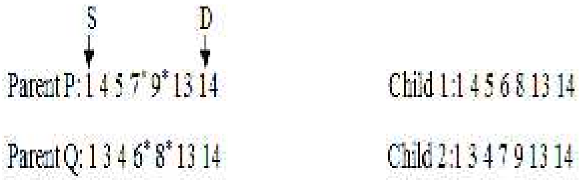


Fig.1 Single Point Crossover Operator

2-point crossover selects the parents from the population on basis of their ranking. Two crossover points are selected randomly in parent chromosomes. The nodes in between the chosen points are exchanged to generate the children chromosomes as shown in the Fig.2.



'S'-Source node, 'D'-Destination node, '*'-Crossover Point

Fig.2 Two Point Crossover Operator

F. The best route consideration

After completing the full iterations the best chromosome having the highest fitness is selected from the obtained group of chromosomes. Since the reliability of the nodes having the dynamic nature, the reliability factor of the each node get changes in each time period as follows: $\hat{A} = \hat{A} + \hat{A}.\xi$, where 'ξ ' is the reliability deviation factor. The obtained best chromosome represents the best reliable and energy efficient path from the source's' to the destination's'.

IV. SIMULATION RESULT

Genetic algorithm stated in the section 3 is implemented by using Matlab and compared with other shortest path algorithm like Dijkstra's algorithm and DSR. To illustrate the proposed work consider the example communication network with 15 nodes shown in Fig.3. In this sample communication network node1 is considered as 'Source' node and the node 13 is 'Destination' node. On this communication network we have evaluated our proposed algorithm to find out a shortest path between source and destination node. Finally the result is compared with Dijkstra's algorithm as shown in Fig.4.It shows our optimistic algorithm out performs the basic algorithm which we are considered.

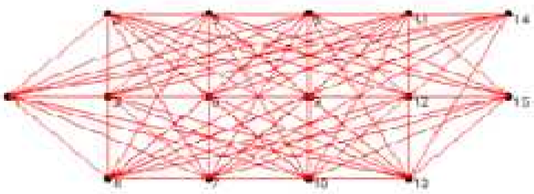


Fig.3 Sample Communication Network

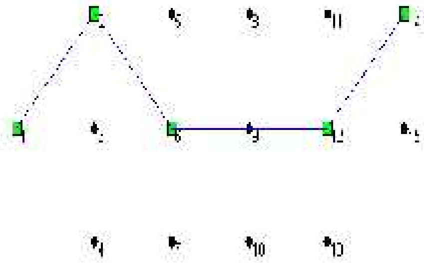


Fig.4 The Final Optimal Route

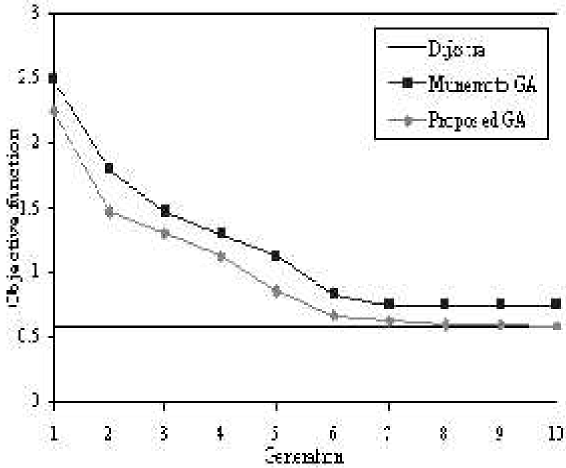


Fig.4 Comparison with other algorithm

V. CONCLUSION

Underlying Genetic Algorithm is studied and it is applied to solve the shortest path problem for ad-hoc networks. The three different types of crossover operators have been proposed. These three with other operators have been studied and compared with the famous shortest path algorithm Dijkstra's path finding algorithm. An optimal path with energy efficient route is obtained by extending a threshold energy fixed for each node in a communication network. The proposed algorithm gives energy efficient and optimal route and it out performs the Dijkstra's algorithm. The researchers are of the opinion that further improvement can be obtained by hybridizing the genetic algorithm with other intelligent optimization techniques such as tabu search and ant colony optimization.

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