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Optimal Routing In Ad-Hoc Network Using Genetic Algorithm

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ABSTRACT

An ad hoc network is a collection of wireless mobile hosts forming a temporary network without the aid of any centralized administration or standard support services. The topology of the ad hoc network may change rapidly and unexpectedly. One of the most problems encountered in these networks, is finding the shortest path (SP) between source and destination nodes within a specified time so as to satisfy the Quality of Service (QoS) . In this paper a genetic algorithm for solving the shortest path routing problem is presented. The algorithm has to find the shortest path between the source and destination nodes. The developed genetic algorithm is compared with the Dynamic Source Routing (DSR) Protocol 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 - **Ad-Hoc Network, DSR, Genetic Algorithm, Routing Protocols, Optimal Routing.**

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1. INTRODUCTION

Ad-hoc wireless networks are widely deployed due to their flexible structures. Mobile Ad hoc network (MANET) is a set of mobile nodes that are dynamically and randomly located in such a manner that the wireless links among nodes are often changing due to MANET dynamic features. In such an environment, routing is one of the most important issues that have a significant impact on the network's performance. An ideal routing algorithm should strive to find an optimum path for packet transmission within a specified time. There are several search algorithms for optimum path problem: the breadth-first search algorithm, the Dijkstra algorithm and the Bellman–Ford algorithm, to name a few. Since these algorithms can solve shortest path (SP) problems in polynomial time, they will be effective in fixed infrastructure wireless or wired networks [1]. In Ad hoc networks routing protocols should be more dynamic to find a route very fast in order to have a good response time to the speed of topology change [2].

In ad hoc network each node is placed in a random location and based on its coverage range a neighbor list is discovered. The neighbors are used for the discovery of a route from a source to destination. For discovering the route ad hoc network use two different types of protocols which are classified as Proactive and Reactive protocols. Proactive protocols maintain the routing information from each node to every node at all the time and that is up-to-date. Using proactive protocols, mobile nodes proactively update network state and maintain a route regardless of whether data traffic exists or not. 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 reactive routing protocol. This is simple and efficient protocol specifically designed for use in multi-hop wireless ad hoc networks. The protocol is composed of the two main mechanisms of "Route Discovery" and "Route Maintenance", which work together to allow nodes to discover and maintain routes to arbitrary destinations [4]. In this paper, a GA based approach is proposed for solving the SP routing problem. Variable-length chromosomes have been employed. Crossover exchanges partial chromosomes (partial-routes) and the mutation introduces new partial chromosomes. Lack of positional dependency in respect of crossing sites helps maintain diversity of the population. The proposed Genetic Algorithm is compared with the DSR protocol for average end to end delivery delay vs. range, Packet delivery and forwarding factor, desired route failure and probability versus route failure ratio.

The rest of this paper is organized as follows. Section 2 gives a brief description of the genetic algorithms from the existing literature. The developed genetic algorithm for routing discovery in ad hoc network is proposed in Section 3. In section 4 the implementation details are given. Simulation results are presented and discussed in Section 5. The paper is concluding in Section 6.

2. GENETIC ALGORITHM

Genetic Algorithm (GA) is inspired by the Darwin's Theory about evolution .GA was invented by John Holland in 1970[5]. GAs are an evolutionary optimization approach, they are particularly applicable to problems which are large, non-linear & possibly discrete in nature. Excellent reference on GAs and their applications is found in [6]. GA try to work on principle of natural selection, as in natural selection over the time individuals with "good" genes survive whereas "bad" ones are rejected .GA collects the possible alternative solutions of a problem as a genetic string [7]. A genetic algorithm maintains a population of candidate solutions (genetic string) , where each candidate solution called a chromosome. The chromosome consists of sequences of positive integers that represent the IDs of nodes through which a routing path passes. Each locus of the chromosome represents an order of a node in a routing path. The gene of first locus is always reserved for the source node. The length of the chromosome is variable, but it should not exceed the maximum length, where is the total number of nodes in the network. A chromosome (routing path) encodes the problem by listing up node IDs from its source node to its destination node based on topological information database (routing table) of the network [1].

A set of chromosomes forms a population, which is evaluated and ranked by fitness evaluation function. The fitness evaluation function plays a critical role in GAs because it provides information how good is each candidate. The initial population is usually generated at random. The evolution from one generation to the next one involves mainly three steps: fitness evaluation, selection and reproduction [8]:

First, the current population is evaluated using the fitness evolution function and then ranked based on their fitness. A new generation is created with the goal of improving the fitness. Simple GA uses three operators with probabilistic rules: reproduction, crossover and mutation. First selective reproduction is applied to the current population so that the string makes a number of copies proportional to their own fitness. This results in an intermediate population.

Second, GA select "parents" from the current population with a bias that better chromosome are likely to be selected. This is accomplished by the fitness value or ranking of a chromosome.

Third, GA reproduces "children" (new strings) from selected parents using crossover and/or mutation operators.

Crossover is basically consists in a random exchange of bits between two strings of the intermediate population. Finally, the mutation operator alters randomly some bits of the new strings. This algorithm terminates when an acceptable solution is found, when convergence criterions met or when a predetermined limit number of iteration is reached. The main features of GAs are that they can explore the search space in parallel and don't need the function to be optimized to be differentiable or have any smooth properties [8].

The SP problem has been investigated extensively in the literature. In paper [2] they surveyed, compared and concluded that GA is a promising algorithm for QoS routing in Ad-Hoc networks. In paper [9] the authors presented a genetic algorithm as an optimization technique for routing in MANET. They improved routing in clustering algorithm based on both clustered gateway switching protocol and the genetic algorithm. In paper [10], they used GAs with several immigrants and/or memory schemes to solve the Dynamic SP routing problem (DSPRP)in MANETs. The experimental results indicate that both immigrants and memory schemes enhance the performance of GAs for the DSPRP in MANETs. In paper [11], they proposed to use elitism-based immigrants GA (EIGA) to solve the dynamic SP problem in MANETs. Experiments show that EIGA is a powerful technique for solving the dynamic SP problem.

3. GENETIC ALGORITHM FOR AD HOC NETWORK

Ad hoc network under consideration is represented as a connected graph with N nodes. The metric of optimization is the cost of path between the nodes. The total cost is the sum of cost of individual hops. The goal is to find the path with minimum total cost between source node and destination node. This part presents a simple and effective genetic algorithm (GA) to find the shortest path. The details of the algorithm are given in the following subsections; while the investigation of the performance is achieved via a simulation work in the next section.

3.1. Representation of a chromosome

In the proposed algorithm, any path from the source node to the destination node is a feasible solution. The optimal solution is the shortest one. At the beginning a random population of strings is generated which represents admissible (feasible) or un-admissible (unfeasible) solutions. Un-admissible solutions are strings that cannot reach the destination. A chromosome corresponds to possible solution of the optimization problem. Thus each chromosome represents a path which consists of sequences of positive integers that represent the IDs of nodes through which a routing path passes with the source node followed by intermediate nodes (via nodes), and the last node indicating the destination, which is the goal. The default maximum chromosome length is equal to the number of nodes.

3.2. Evaluation of Fitness Function

The fitness function is defined as follows:

$$f_i = \frac{1}{\sum_{j=1}^{li-1} C_{g_i(j),g_i(j+1)}}$$

where, f_i represents the fitness value of the i^{th} chromosome, l_i is the length of the i^{th} chromosome, $g_i(j)$ represents the gene (node) of the j^{th} locus in the i^{th} chromosome, and C is the link cost between nodes[1].In the proposed algorithm , the link costs are considered to be equal to each other and to 1. This means the cost which represents the shortest distance is the hop count.

3.3. Selection of Best Fit

The selection process of the best fit is done to improve the average quality of the population. This process gives the better chance to the best chromosomes to survive. There are two basic types of selection process: proportionate and ordinal-based selection. Proportionate selection picks out chromosomes based on their fitness values relative to the fitness of the other chromosomes in the population. This selection includes roulette wheel selection, stochastic remainder selection and stochastic universal selection [1]. In this paper we are going to use the roulette wheel concept, the values providing the best fit being given a higher percentage on the wheel area so that values providing a better fit have higher probability of producing an offspring.

*3.*4 Crossover Operator

Crossover selects genes from parent chromosomes and creates a new offspring. Crossover is performed on strings using midpoint crossover. Midpoint crossover divides the parent's chromosomes into two from the midpoint. Crossover provides incorporation of extra characteristics in the off springs produced.

3.5. Mutation

The mutation operator randomly alters genes to partially shift the search to new locations in the solution pace. Mutation is done if consecutive iteration values are the same.

4. IMPLEMENTATION

The objective (as stated above) is to minimize the SP routing problem. To do so, number of hops is counted and the route having minimum hop count is selected and hence, these routes are utilized to minimize the delay efficiency.

The steps for computation can generalized as:

Step 1: The constraint limits is set for the SP route.
Step 2: Random values are generated between limits.
Step 3: The values of generated routes are put into the objective function
Step 4: The fitness evaluation is done for the various routes

```
fmax (n, 1) = max (fx (n, 1))
fmin(n,1) = min(fx(n,1)
for i=1:z
 ft(i,1) = (fmax(n,1) - fmin(n,1)) - fx(n,1);
end
ftb = mean (ft);
for i=1:z
 rl (i, 1) = ft (i, 1)/ftb;
end
```

Step 5: The best fit is calculated based on the equation above.
Step 6: Selection based on the roulette wheel concept is done, the values providing the best fit being given a higher percentage on the wheel area so that values providing a better fit have higher probability of producing an offspring.
Step 7: Crossover is performed on strings using midpoint crossover. Crossover provides incorporation of extra characteristics in the off springs produced.
Step 8: Mutation is done if consecutive iteration values are the same.
Step 9: The new routes that satisfy the objective of minimization, and related parameters are plotted.
Where : fx is the fitness value; ft=normalized fx.

5. SIMULATION RESULTS

The simulation studies involve the deterministic, network topology with 15 nodes as shown in Fig1. The proposed GA is implemented with MATLAB. The optimal path derived is shown in Fig 2. The dotted line shows the optimal path with source node 5 and destination node 9 by 5-6-9. The simulation is terminated when all the chromosomes have converged.

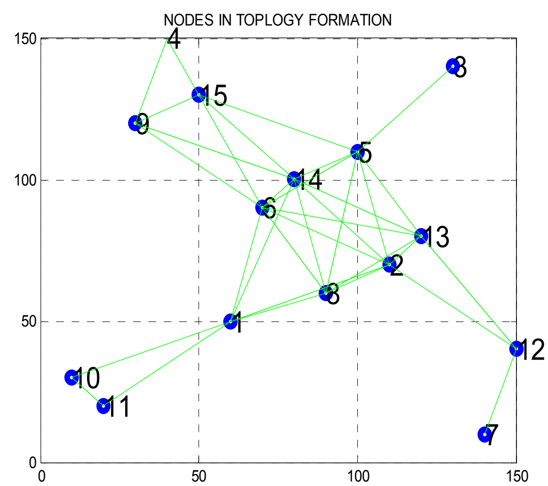

Figure 1 A graph representing an Ad hoc Network of 15

nodes

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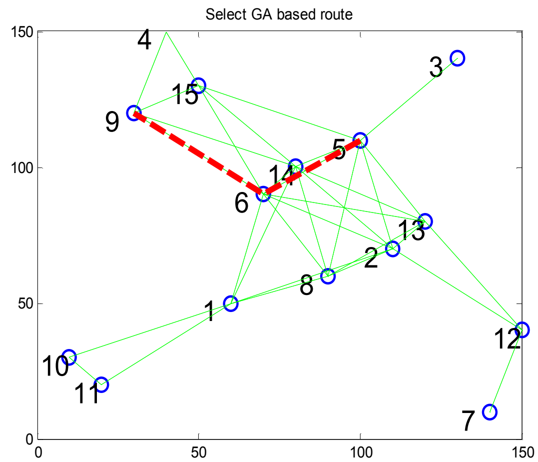

Figure 2 A GA based selected route

With a view to focus exclusively on fair comparison of algorithms on the basis of performance, the population size is taken to be the same as the number of nodes in the network. Other than optimal route we compared the DSR and GA on the basis of Average end to end delay, packet delay and packet failure ratio. These delays have been calculated through CPUTIME function of Matlab. First the routes from DSR and GA are selected and the delay time in seconds is calculated while sending the packets from source node to the destination node and plotted the graph verses transmission range, forwarding factor and the desired route failure probability. The graphs are shown in the Fig3, Fig.4 and Fig.5. Fig. 3 represents Average end to end delivery delay Vs transmission range. Fig4: shows the Packet delivery and Forwarding factor while Fig.5 shows desired route failure probability versus packet failure ratio.

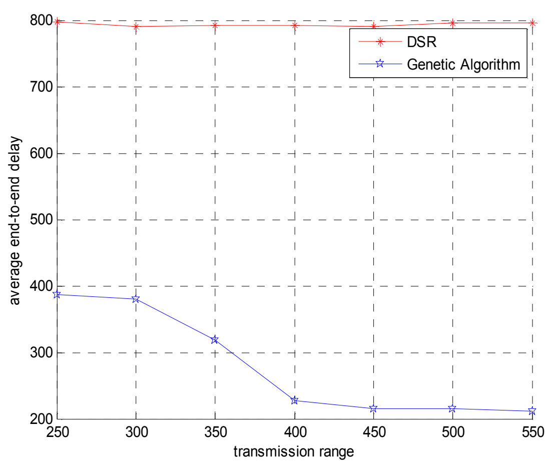

Figure. 3 Average end to end delivery delay Vs range.

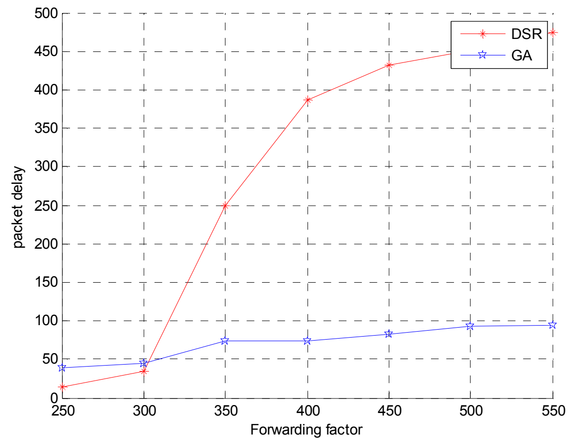

Figure 4 Packet delivery and Forwarding factor.

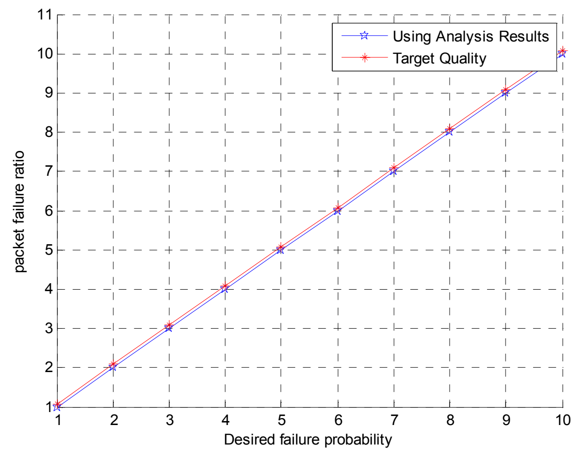

Figure.5 Desired route failure probability verses packet failure ratio.

As the network is ad hoc means nodes are mobile and they changed their location. After nodes has changed their location, the new topology is shown in fig.6. GA gives the optimal path from source node 1 to destination node 12 by 1-6-7-2-12 as shown in fig.7.

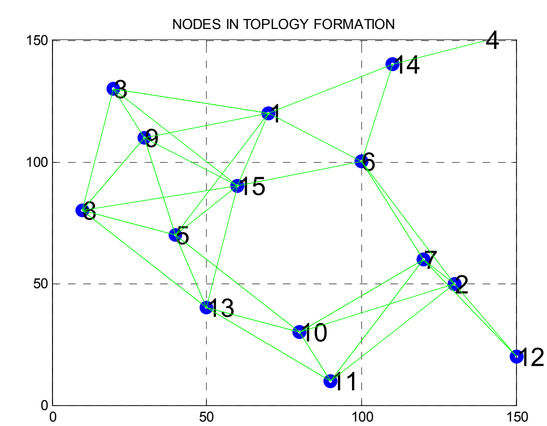

Fig 6: A graph representing an ad hoc Network of 15 nodes

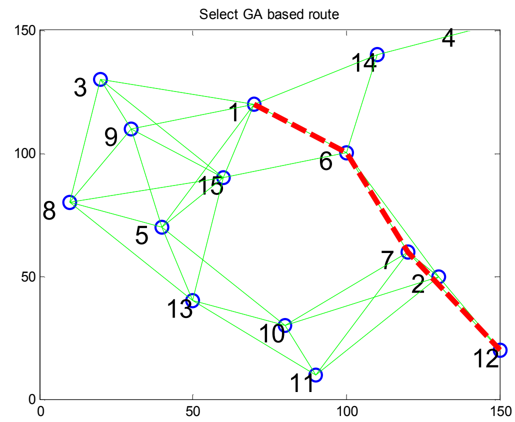

Figure 7 A GA based selected route

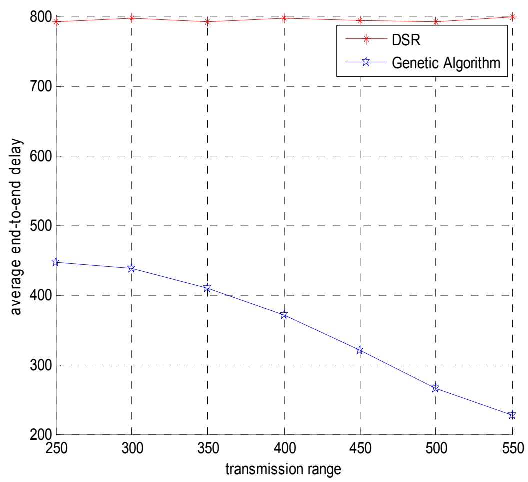

Figure. 8 Average end to end delivery delay Vs range.

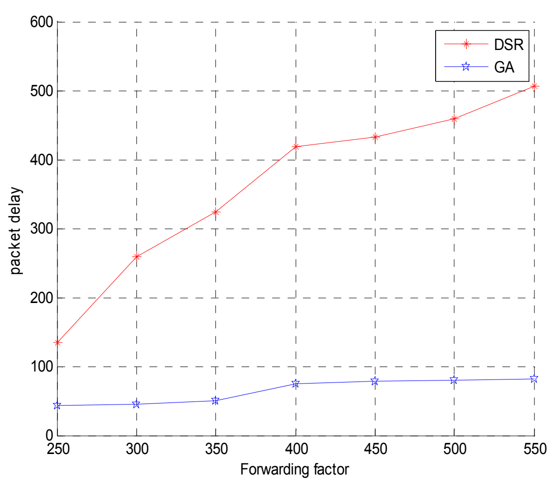

Figure 9. Packet delivery and Forwarding factor

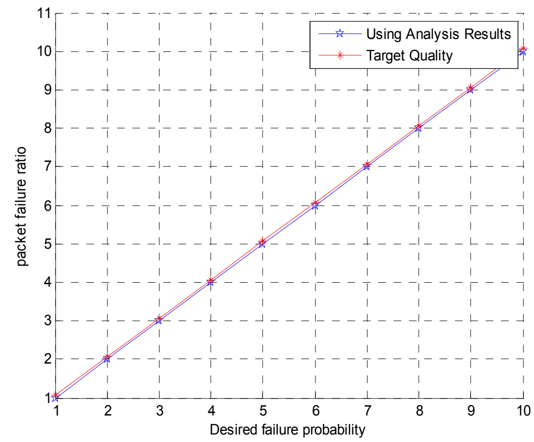

Figure10 Desired route failure probability verses packet failure ratio.

From the above results we can say that the delay for Genetic Algorithm is less than DSR. The route failure probability is also less in genetic Algorithm compared to DSR approach.

6. CONCLUSION

Ad-hoc networks, also known as short-lived networks, are autonomous systems of mobile nodes forming network in the absence of any centralized support. This is a new form of network and might be able to provide services at places where it is not possible otherwise. Absence of fixed infrastructure poses several types of challenges for this type of networking. Among these challenges routing is one of them. This paper presented a genetic algorithm for solving the SP routing problem. The proposed algorithm can search the solution space effectively and speedily compared with DSR algorithm. It performs better and effectively even to the changes in the network due to node mobility and topology changes.

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