Reliable and Efficient Routing Using Adaptive Genetic Algorithm in Packet Switched Networks

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Abstract
To identify the optimal route is a complex task in packet switched network because optimization depends upon a number of parameters. In this paper Genetic Algorithm is used to locate the optimal route. Genetic Algorithm starts with a number of solutions where each solution is represented in the form of chromosome using the permutation encoding scheme. The success of Genetic Algorithm depends upon the number of operators such as selection, mutation and crossover. Needless to say crossover is most innovative. In this paper crossover operators proposed namely 1-point, 2-point, and adaptive, have been customized according to the need of computer network. The fitness of each solution is evaluated in terms of historical reliability factor, node success/failure and delay. The performance of the proposed approach has been compared with Dijkstra Algorithm and improvement has been observed.

Keywords: *Crossover, Delay, Dijkstra Algorithm, Genetic Algorithm, Reliability, Routing*

1. Introduction

Telecommunications networks technologies are growing faster and becoming more complex to handle different types of physical traffic. Today computer networks have application in various domains like business, education, research, Industry, e-commerce and many others. Network based applications are becoming more popular and easy to use with the growth of Internet & development of new technologies & standards. In Data communication networks, such as the Internet and the Mobile Ad-hoc Networks, routing is one of the most important areas that have a significant impact on congestion and network's performance [1]-[3]. Research of the routing strategy is becoming the key theoretical topic of the new generation network architecture. The growth of internet based applications such as on line shopping, Video on demand, video conferencing, on line banking, e-ticket booking, stock exchange and other real time applications has generated new requirements for one-to-one and one-to-many reliable and time efficient communications. An ideal routing algorithm should strive to find an optimum path for packet transmission within a specified time so as to satisfy the Quality of Service [3]-[5].

For Shortest path problem there are number of search algorithms such as Bellman–Ford algorithm, the Dijkstra algorithm etc. to name a few [2]. Many of these algorithms find the shortest path considering hop count/minimum cost measures. They exhibit unacceptably high computational complexity for communication involving rapidly changing network topologies and involvement of other routing metrics like path reliability, delay, bandwidth etc. for computation of optimal path from source to destination [4], [5]. The selection of routes in large-scale computer communication networks is extremely complex network optimization problems. Such problems belong to the class of nonlinear combinatorial optimization problems most of which are NP-hard.

The problem can be formulated as finding a minimal cost path with greater path fitness that contains the designated destination and source nodes. The Shortest and reliable Path routing problem is a Classical combinatorial optimization problem. Evolutionary algorithms such as, genetic algorithms, neural networks, ant colony optimization etc. promise the solution for such problems, as these have been used successful in many practical applications. Neural Networks and Genetic Algorithms may also not be promising candidates for supporting real-time applications in networks because they involve a large number of iterations in general but will be able to provide the adequate solution. In literature GA is the most popular technique to solve complex multi objective optimization problems.

Researchers have applied GAs to the Shortest Path routing problem, multi casting routing problem, ATM bandwidth allocation problem, capacity and flow assignment (CFA) problem, and the dynamic routing problem [6]-[13]. It is noted that all these problems can be formulated as some sort of a combinatorial optimization problem. Genetic algorithms are multiple, iterative, stochastic, general purpose searching algorithms based on natural evolution [14], [15]. They aren't instantaneous, or even close, but they do an excellent job of searching through a large and complex search space [16]. The main objective of the current work is to find the best reliable path using personalized GA with various crossover operators for data transmission.

The structure of the paper is organized as follows: A method of representing the solutions is given in section 2. The proposed GA based routing technique is given in section 3. The brief review of crossover techniques is given in section 4. The experimental results of proposed work are presented in section 5. Conclusions are given in section 6.

2. Genetic Algorithm Chromosome Representation

To apply GA for any optimization problem, one has to think a way for encoding solutions as feasible chromosomes so that the crossovers of feasible chromosomes result in feasible chromosomes [17]. The techniques for encoding solutions vary by problem and, involve a certain amount of art. Proposed work has considered permutation encoding for chromosome representation. Each gene of a chromosome takes a label of node such that no node can appear twice in the same chromosome. For example, let {1, 2, 8, 10, 12, 14} be the labels of nodes in a 6 node instance, then a route {1→2→8→10→12→14} may be represented as (1, 2, 8, 10, 12, 14).

3. Routing Technique based on Reliability and Delay Measures

One of the most common problems encountered in networks is obtaining the shortest, reliable, optimum path problem. The objective of the proposed technique is to find the best reliable path in a communication network using personalized GA with historical reliability factor, node success/failure and delay measures. 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 $(V_0, V_1, V_2, \ldots V_k)$ where $s = V_0$ and $d = V_k$. The proposed technique uses the obtained historical reliability factor generated randomly between 1 and 100, binary representation (“1” for successful transmission of packets and “0” for failure) of node success/failure details in the past ‘n’ time period and a delay component ω at each node in path for the choosing the best reliable path to sent the packets from source to destination. For current work ‘n’ is taken as 15.

3.1 Reliable and Optimized Route Selection

The purpose of the proposed technique is to provide the optimum, reliable route between the source and destination considering historical reliability factor, node success failure and delay constraints.

Proposed Algorithm:

1. Perform Initialization of initial Chromosomes/Routes
2. Repeat (until terminated)
3. Fitness Evolution of each valid chromosome on basis of fitness function
4. Perform selection from evaluated chromosomes using rank selection for crossover
5. Perform crossover using 1-point/2-point/Adaptive techniques
6. Perform mutation with probability 0 .1
7. Quit the process if termination criteria (No. of Generations) meet; It can be Time, Minimum fitness threshold satisfied
8. Go to step 2 if Not Terminating

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 ranking 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 ‘C’ no of times to obtain the best reliable path.

3.1.1 Initial Population Generation and Chromosome Representation

The route table which contains the possible paths from "s" to "d" is generated. Let $'RT'$ 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 $'RT'$. 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.

3.1.2 Fitness Evaluation

The genetic algorithm searches for the optimum route with highest fitness where the fitness function is used to assess the quality of a given schedule within the population [18]. The fitness function that involves computational efficiency and accuracy is defined in equation (1):

$$f_i = \frac{\sum_{i=1}^{hop} \mu_i(N) \times \alpha_i(N) \times \frac{\beta_i(N)}{b} \times \sum_{i=1}^{hop} \omega_i(N)}{hop} \quad (1)$$

Where, $\mu_i(N) = \frac{count\ (A[N][j] > \lambda)}{n}$ is the historical satisfied reliability ratio of the node 'N' and λ is the minimum required reliability for transforming the packets [18]. $\alpha_i(N) = \frac{count\ (B[N][j] = 1}{n}$ is the historical packet transmission success ratio of the node 'N', $\beta_i(N)$ is the capacity of the node 'N', $'b'$ is the packet size and $\omega_i(N)$ 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.

3.1.3 Crossover Operations

Three crossover methods 1-point, 2-point and adaptive crossovers are explained below:

1-Point Crossover: In this crossover operation choose the parent chromosomes from the population such that, at least one node is common to both the parent chromosomes [14]. If there is more than one common node, the first occurring common node from left is considered for operation. For example, in Fig.1 (a) the chromosome 'A' and 'B' are the parent chromosomes having the node '7' as common node.

Fig. 1 (a) 1-Point Crossover operator

2-Point Crossover: Select the parents from the population on basis of their ranking. Randomly two points are chosen in parent chromosomes [14], [19]. The nodes in between the chosen points are exchanged to generate the children chromosomes.

Fig. 1 (b) 2-Point Crossover operator

Adaptive Crossover: From the selected parents A and B, find all the same nodes except source node and destination node, and establish common nodes set Ψ [20]. If Ψ=Φ, there is no crossover operation between A and B. Otherwise, select common node close to source node as a crossover point (for Ψ >1, building block hypothesis) from Ψ, then crossover the part after A and B. For example, if source node is 1 and destination node is 14. Crossover operation is as follows:

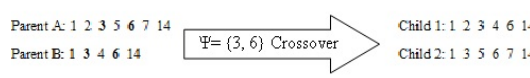

Fig. 1 (c) Adaptive crossover operation

The proposed work uses the 1-point/2-point/adaptive crossover. After performing crossover operation, all the obtained offspring are subjected to repetition checking and duplicate chromosome are removed subsequently and each chromosome is checked for node repetition and maintains the uniqueness of node in a chromosome. Finally the crossover operation provides the best 'z' chromosomes.

3.1.4 Selection of the Best Route

The processes in 3.1.2 to 3.1.4 are repeated 'C' number of time period with the next population set 'γ' as follows: $\gamma = z + x'$, where 'z' is the obtained set of offspring from crossover operation and x' is the next set of chromosomes selected randomly from the route table. 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 '$\xi$' is the reliability deviation factor. The obtained best chromosome represents the best reliable path from the source's' to the destination's'.

4. Related Work on Crossover Operators

Traditionally, GAs have used one-point or two-point crossover [15]. Researchers have also carried out experiments with multi-point crossover: n-point crossover and uniform crossover [21], [22]. With the n-point crossover, n cut points are randomly chosen within the strings and the n-1 segments between the n cut points of the two parents are exchanged. Uniform crossover is the generalization of n-point crossover.

5. Experimental Results

This section details the experimentation and performance evaluation of the proposed work. The proposed work is implemented in the MATLAB platform (version 7.12) on Windows 7 platform with Intel Core 2 Duo processor (1.83 GHz) and 2 GB RAM. To illustrate the proposed work consider the example communication network with 15 nodes shown in Fig.2. The maintenance management system of the distribution network maintains the reliability statistics, delay as well as the node failure status statistics for the analysis purpose. The proposed technique uses assumed historical reliability factor, assumed node success/failure status and randomly generated delay.

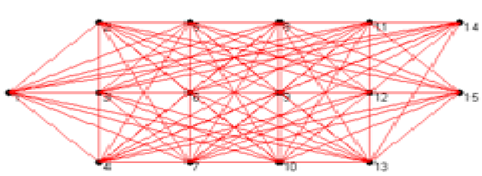

Fig. 2 Communication Network

Let us consider the source node as '1' and the destination node as '14'. To find the optimum reliable path, the route table containing the possible 'p' paths is generated using a standard route generation algorithm. From that, selected 'x' paths forms population subjected to the personalized genetic algorithm, consequently the fitness of the chromosome are calculated, subjected to the genetic operator crossover to produce best offspring and hence produce new population. The above process is repeated for 'C' times and finally the best reliable path with high fitness is obtained. The dynamic property of the reliability factor is carried out in each iteration (i.e.) the reliability factor is updated in each time period. The table-1 illustrates some of the possible paths from the source '1' to the destination '14' according to the communication network in the Fig. 2, which are generated using a standard route generation method and table-2 shows the change in path fitness during generations.

Table 1: Routes

No	Path
1	[1,2,3,4,14]
2	[1,2,3,5,14]
3	[1,2,3,6,14]
4	[1,2,3,7,14]
5	[1,2,3,8,14]
6	[1,2,3,10,14]
7	[1,2,3,11,14]
8	[1,2,3,12,14]
9	[1,2,3,13,14]
10	[1,2,3,15,14]

Table 2: Fitness values

Iteration No	Fitness
1	2.2433
2	2.4355
3	2.5217
4	2.6434
5	2.6955
6	2.7123
7	2.7290
8	2.7635
9	2.7994
10	2.8177

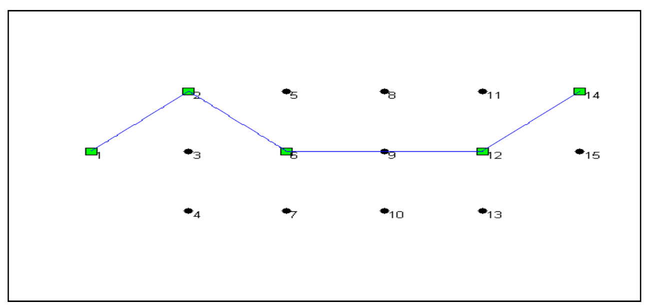

Fig. 3 Reliable and Optimum path

5.1 Performance Analysis

The performance of the proposed technique is evaluated in the static environment with the same source node '1' and destination node '14' and its fitness is analyzed using different crossover methods with the Dijkstra algorithm. Comparison is made using delay component in fitness function as well as without delay component in fitness function with different crossover methods. The table-3 summarizes the fitness values of the various best paths obtained for proposed technique without delay with different crossover methods and Dijkstra algorithm in static environment for different number of iterations. The table reflects that the fitness of the best path obtained using proposed technique is higher than the Dijkstra algorithm. The proposed technique is evaluated for dynamic environment by determining the path with dynamically varying reliability factors.

The proposed technique is evaluated with the different no of nodes and generations. From table-3 it can be observed that adaptive crossover gives better result in path fitness. Overall also from route fitness basis proposed technique represents high performance in the static environment with the Dijkstra algorithm.

Table 3: without delay component in fitness function

	30 Iterations		
Fitness Dijkstra	**Fitness 1-Point Crossover**	**Fitness 2-Point Crossover**	**Fitness Adaptive Crossover**
1.286	2.5219	2.4268	2.7439
2.2535	2.2535	2.4407	2.8154
1.4521	2.1672	2.3521	3.0407
1.6639 (Average)	**2.3142 (Average)**	**2.4065 (Average)**	**2.8667 (Average)**

From table-4 and figure-4 it can be observed that adaptive crossover gives better result in path fitness with delay.

Table 4: with delay component in fitness function

	30 Iterations		
Fitness (Dijkstra)	**Fitness 1-Point Crossover**	**Fitness 2-Point Crossover**	**Fitness Adaptive Crossover**
1.3214	2.6322	2.7221	2.9774
1.6722	2.4565	2.4903	3.1234
1.5523	2.3345	2.2341	2.6852
1.5153 (Average)	**2.4744 (Average)**	**2.4822 (Average)**	**2.9287 (Average)**

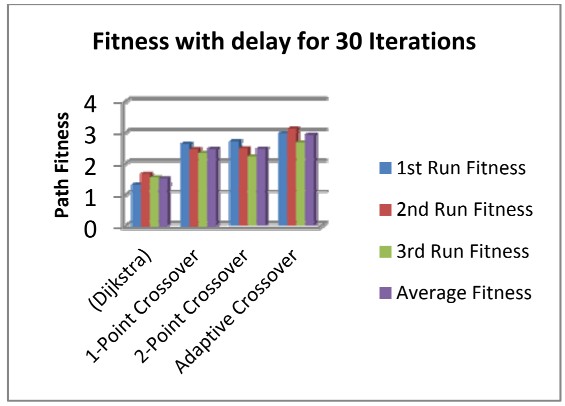

Fig. 4 Performance Comparisons

Convergence Graph for fitness in various iterations using crossover is shown in figure-5 (a) and figure-5 (b) below:

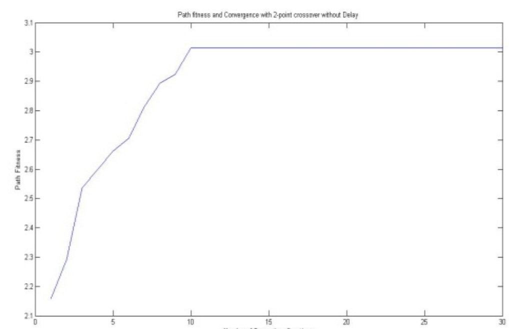

Fig. 5 (a) Convergence Graph

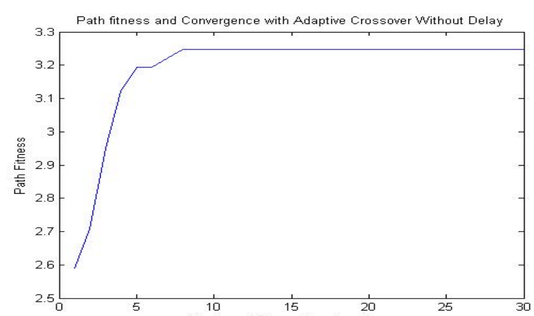

Fig. 5 (b) Convergence Graph

6. Conclusion

In this research work, the use of Genetic Algorithm has been proposed to find out the optimal route in packet switched network. The three different types of crossover operators have been proposed i.e. 1-pont crossover, 2-point crossover and adaptive crossover and the performance have been evaluated using a fitness function that employed the parameters historical reliability, node success/failure and delay at each node. While doing the comparison of performance it has been observed that adaptive crossover has outperformed the 1-point crossover and 2-point crossover. Moreover all the variant of Genetic algorithm i.e. 1-point, 2-point and adaptive crossover have outperformed the Dijkstra 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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