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A Genetic Algorithm to Find the Minimum Cost Paths Tree with Bandwidth Constraint in the Computer Networks

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Abstract

Through the communication network, several communication applications need a source to transfer information to different destinations. In order to support the applications, it is essential to evaluate the shortest paths tree of minimal cost to connect source to destination nodes with respect to the bandwidth conditions on the information communication. In order to solve the problem, the genetic algorithm is applied. The paper highlights the generic algorithm to manage shortest path tree problem in relation to bandwidth and cost constraints. The aim of the presented algorithm is to determine the group of edges that connecting all nodes, value of bandwidth and sum of costs will be constrained. To demonstrate the efficiency the propose algorithm has applied to two sample networks.

Keywords: Computer networks; Minimum-cost paths tree; Genetic algorithms.

INTRODUCTION

Let's assume shortest path tree rooted from the vertex s and the spanning tree T of G. Such that path distance has been from root v to any other vertex u in T where the shortest path distance from v to u in G, [1]. In order to find the optimal shortest path tree, the proposed algorithm will be used as in the scenario of single link failure, [2]. The proposed algorithm will be used to determine Shortest Best Path Tree (SBPT) in the case of multicast tree, [3]. Labeling techniques are used to determine the shortest path trees, [4]. It has been evaluated by (MCPCNN) model which refer to the Modified Continued Pulse Coupled Neural Network, [5].

If state information related to network exists, then the heuristic algorithm for multi-constrained routing (MCR) is not active especially in a dynamic network environment for the real time applications, [6]. The genetic algorithm helps to sort out MCR issues in relation to transmission success and transmission delay ratio. Younes in [7] mentioned genetic algorithm (GA) to determine the k shortest path with bandwidth constraints from source to multiple destination nodes. Liu et all [8] stated that Oriented Spanning Tree (OST) based algorithm used for sorting out Multi-criteria Shortest Path Problem (MSPP) and the Multi-criteria Constrained Shortest Path Problems (MCSPP). On other hand, in [9] the genetic algorithm (GA) is used to evaluate the low cost multicasting tree with the bandwidth and the delay constraints. The paper presents the genetic algorithm to evaluate shortest path tree with the bandwidth constraint. It also used bandwidth, connection and cost matrix of the network. By having the source node s, the genetic operations are used to evaluate shortest cost path which can able to create minimum cost path tree with bandwidth constraints.

Younes et al [10] presented a genetic algorithm to solve the minimal cost shortest paths tree problem subject to bandwidth constrained and hop limited. The objective of the proposed algorithm is to search the optimal set of edges connecting all nodes such that the costs are minimized, the bandwidth is constrained and hop is limited.

The rest of the paper is organized as follows: Notations are described in section 2. Section 3 shows the problem description. The proposed genetic algorithm (GA) and its components are described in section 4. Section 5 shows the pseudo code of the entire genetic algorithm (GA). Section 6 provides the illustrative examples. Finally, section 7 shows conclusions.

NOTATIONS

G	Network graph.
N	Number of nodes in G.
E	Number of edges in G.
e_{ij}	Edge between node i and node j in G.
c_e	Cost of an edge e.
M	Connection matrix of the given network.
CM	Cost matrix of the given network.
np	Number of paths from node *s* to *t*
T_s	Shortest path rooted at node s

THE PROBLEM DESCRIPTION

S is a specified vertex. Let $P^i_{(s, t)}$ is being path number i from (s) to (t). Let $C^i(P_{(s, t)})$ is being the cost of path $P^i_{(s, t)}$, $i = 1,2, \dots, np$. The path $P^k_{(s, t)}$ has a minimum the cost among all the (s, t)-paths if:

$$C^k(P_{(s,t)}) = \min_i C^i(P_{(s,t)})$$

Where

$$C^i(P_{(s,t)}) = \sum_{e \in P_{(s,t)}} c_e$$

The path $P_{(s,t)}$ refers to shortest path only if the bandwidth of particular path must be equivalent to constant value B (this value is determined from user or is a require value of the bandwidth). The bandwidth of $P_{(s,t)}$ (Band($P_{(s,t)}$)) is the minimum value of link bandwidth (Band (e)) in $P_{(s,t)}$

i.e.

$$Band(P_{(s,t)}) = \min(Band(e),\ e \in P_{(s,t)})$$

And, the bandwidth constrained shortest path tree is to find the all paths from source node s to each destination node which satisfy:

$$\text{Band}(P_{(s,t)}) >= B.$$

The proposed method will consider the cost, connection and bandwidth matrix of the network. It can able to determine the minimum cost path tree with bandwidth constraint at source node s.

THE PROPOSED GENETIC ALGORITHM (GA)

Binary string with length N can indicate each path which can use as chromosome in the provided genetic algorithm. The chromosome elements refer to node given in the network topology. There are about N string components presented in solution x for network and also consists of N nodes. Each chromosome consists of two non-zero elements.

In the following sub-sections we provide an explanation of the various components (processes) of the submitted genetic algorithm

Initial Population

Generated chromosome comprise of two non-zero elements which indicates the real candidate path. The below steps illustrates how to create chromosomes the pop size of the initial population

1. Produce a chromosome x randomly

2. Identify x indicates real candidate path (two non-zero elements)

3. Repeat the steps 1 to 2 to create pop-size chromosomes

The objective function

To make a comparison of solutions and evaluate the best one the bandwidth and cost of candidate path are used as the objective function. These candidate paths will be computed while it satisfies the following criteria.

- Chromosome should consists of two non-zero elements
- It consists of connected candidate path. Each node connects one another.

Genetic Crossover Operation

In genetic algorithm, a single cut point crossover to generate a new offspring from two parents. Once crossover ratio (Pc=0.90) is verified, the crossover process will be run. Randomly select cut point.

Genetic Mutation Operation

Bit by bit operation has been performed in the mutation. Once verified the mutation ratio (Pm), the mutation process will be operated. In this approach the Pm is chosen experimentally to be 0.02. The point to be mutated is randomly selected.

THE ENTIRE ALGORITHM

Given pseudocode illustrate the use of components of GA to determine the shortest cost path tree of given network.

Algorithm find minimum-cost paths tree and bandwidth constrained

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Input: Set the parameters: pop_size, max_gen, P_m, P_c.

Output: Minimum-cost paths tree and bandwidth constrained

1. Set j = 2, the destination node.
2. Generate the initial population according to the steps in Section 0.
3. *gen*←1.
4. **While** (*gen* < = *max_gen)* **do {**
5. **P** ← 1
6. **While** (*P* <= *pop_size*) **do {**
7. Apply Genetic operations to obtain new population

7.1. Apply crossover according to P_c parameter (P_c >=0.90) as described in section 4.3.

7.2. Apply Mutation as shown in section 4.4.

7.3. Compute the total cost and bandwidth of the candidate path according to Section 3.

8. P ← P+1. }
9. Set gen =gen + 1

10. if gen > max_gen then **stop }**
11. Save the candidate path for the destination j that has the minimum cost and bandwidth constrained (the shortest path between the root node and the destination node j).
12. Set j = j + 1
13. If j <= N Goto Step 2, otherwise stop the entire algorithm and print out the minimum-cost paths tree and bandwidth constrained.

EXPERIMENTAL RESULTS

The presented algorithm can be executed using the tool Borland C++ Ver. 5.5. Let's take initial values of parameters are the size of the population [pop-size=20], maximum generation [max_gen=300], [Pc=0.90] and [Pm=0.02]. Connection and the cost matrices of network will be read. It produce the shortest path tree of network which produce minimum cost with bandwidth constrained (Band ($P_{(s,t)}$) >=10). Three examples used to test and validate the suggested technique.

Eight nodes example

This part demonstrates the outcomes of implementing proposed genetic algorithm on eight nodes network example as mentioned in Figure 1. Table 1 demonstrates final output and Figure 2 indicates the shortest path tree from node 1.

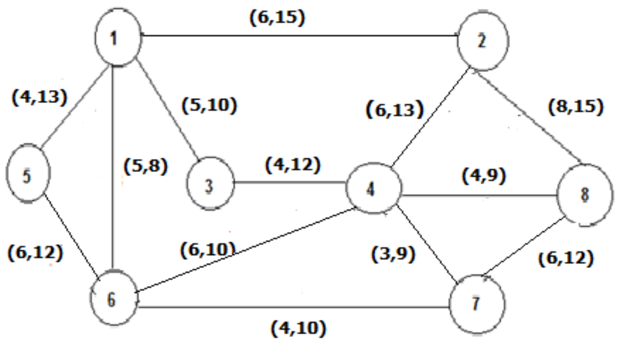

Figure 1: The cost and bandwidth of the links (cost, bandwidth) for eight nodes network.

Table 1: Final output of suggested algorithm (GA).

The shortest paths set	Cost	Bandwidth
{1, 2}	6	15
{1, 3}	5	10
{1, 3, 4}	9	10
{1, 5}	4	13
{1, 5, 6}	10	12
{1, 5, 6, 7}	14	10
{1, 2, 8}	14	15

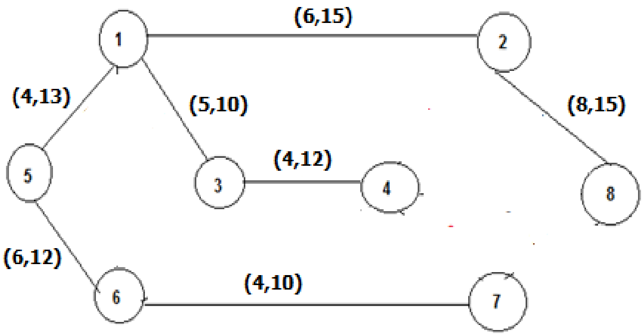

Figure 2: Shortest paths tree

Eleven nodes example

The genetic algorithm has applied to eleven nodes examples mentioned in figure 3. Table 2 indicates output of genetic algorithm. Figure 4 shows the shortest paths tree rooted at node 1.

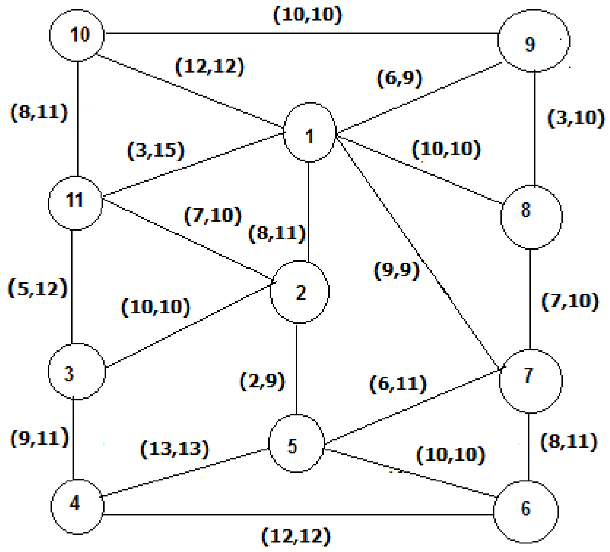

Figure 3: The cost and bandwidth of the links (cost, bandwidth) for eleven nodes network.

Table 2: Final output of proposed algorithm (GA).

The shortest paths set	Cost	Bandwidth
{1, 2}	8	11
{1, 11, 3}	8	12
{1, 11, 3, 4}	17	11
{1, 8, 7,5}	23	10
{1, 11, 3, 4, 6}	29	11
{1, 8, 7}	17	10
{1, 8}	10	10
{1, 8, 9}	13	10
{1, 11, 10}	11	11
{1, 11}	3	15

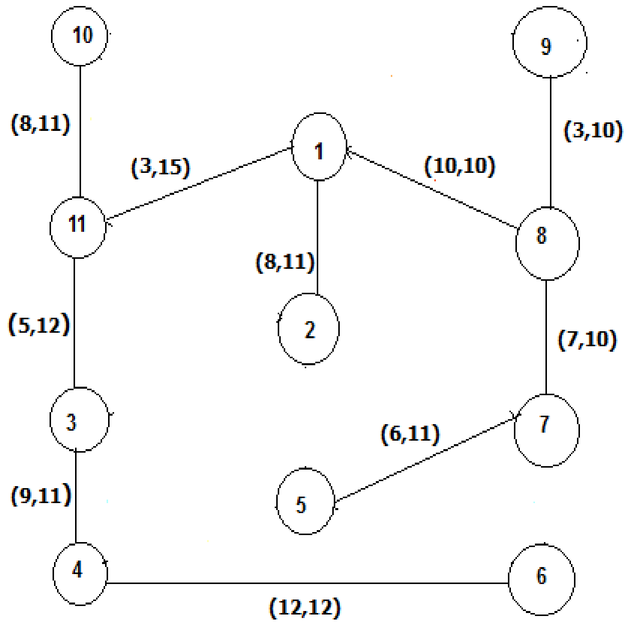

Figure 4: Shortest paths tree rooted at node 1.

Sixteen nodes example

The genetic algorithm has applied to eleven nodes examples mentioned in figure 5. Table 3 indicates output of genetic algorithm. Figure 6 shows the shortest paths tree rooted at node 1.

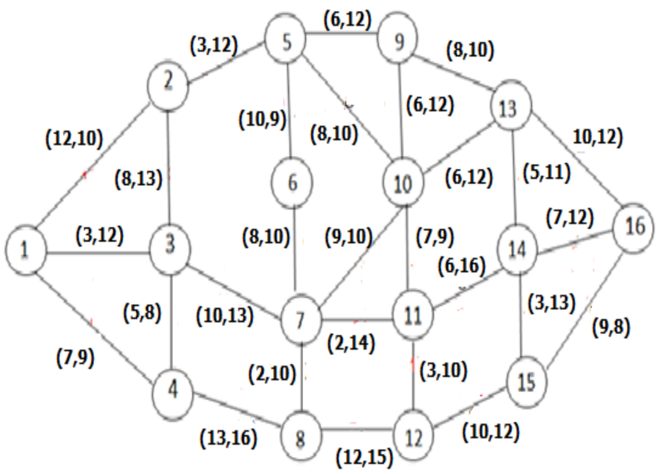

Figure 5: The cost and bandwidth of the links (cost, bandwidth) of sixteen nodes network.

Table 3: The final output of the proposed algorithm (GA).

The shortest paths set	Cost	Bandwidth
{1, 3, 2}	11	12
{1, 3}	3	12
{1,7, 8, 4}	28	10
{1, 3, 7, 10, 9, 5}	34	10
(1, 3, 2, 5, 9, 10, 7, 6}	43	10
(1, 3, 2, 5, 9, 10, 7}	35	10
(1, 3, 7, 11, 12, 8}	30	10
(1, 2, 5, 9}	21	10
(1, 3, 2, 5, 9, 10}	26	12
(1, 3, 2, 7, 8, 12, 11}	30	10
(1, 3, 7, 11, 12}	18	10
(1, 3, 2, 5, 9,13}	28	10
(1, 3, 7, 11, 14}	21	12
(1, 3, 7, 11, 14, 15}	24	12
(1, 3, 7, 11, 14, 16}	28	12

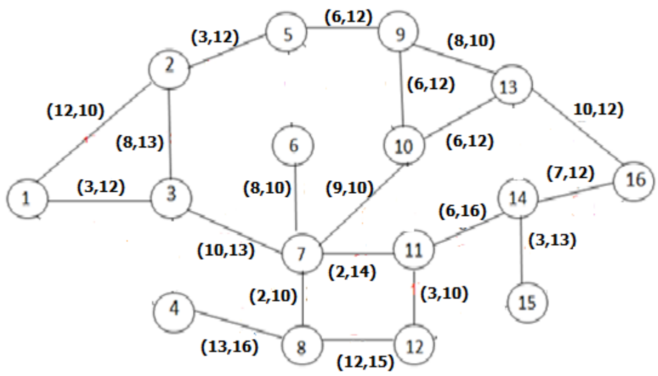

Figure 6: The minimum-cost paths tree rooted at node 1.

CONCLUSIONS

The paper highlight minimum cost path tree problem and provide a genetic algorithm to manage this problem. The algorithm will consider the cost matrices and connection of network. Furthermore, it finds the minimum cost paths which create minimum cost paths tree emerges from node s. Genetic algorithm has applied to two examples hence the results presented the efficiency of the proposed Genetic algorithms. Genetic algorithm can be extended in the future work to solve multi constrained paths tree problem.

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