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Minimizing the Broadcast Routing in the Computer Networks

Ahmed Younes[1]
[1]Department of Computer Science, Faculty of Science,
Sohag University, Egypt, a_y_hamed@yahoo.com

Abstract: In the computer networks, it is necessary for one device in the computer network to send data to all the other devices. In this paper, broadcast routing algorithms that aim to minimize the cost of the routing path are proposed. A minimum cost broadcast routing scheme based on spanning tree algorithm is presented. Thus, we present a genetic algorithm to find the broadcast routing tree of a given network in terms of its links for using it to solve this problem. The algorithm uses the connection matrix of a given network to find the spanning trees, and also is based on the weight of the links to obtain the minimum spanning tree. An example is provided to illustrate the effectiveness of this algorithm over conventional algorithms.

Key words: Computer Network, Spanning Trees, Broadcast Routing.

1. Introduction

In computer networking, broadcasting refers to transmitting a packet that will be received by every device on the network, [1]. In practice, the scope of the broadcast is limited to a broadcast domain. Broadcast a message is in contrast to unicast addressing in which a host sends datagrams to another single host identified by a unique IP address.

Broadcast is a communication function that a node, called the source, sends messages to all the other nodes in the networks. Broadcast is an important function in applications of ad hoc networks, such as in cooperative operations, group discussions, and so on. Broadcast routing is finding a broadcast tree, which is rooted from the source and contains all the nodes in the network. The cost of a broadcast is defined as the sum of cost of all the links that transmit the broadcast message in the broadcast tree.

The spanning tree is defined as a connected sub-graph of G(n,e), that contains all its nodes and no cycles [2,4]. A simple approach is to use elementary tree-transformation which is based on the addition of a chord and deletion of an appropriate branch from a spanning tree. Thus, starting from any spanning tree of the graph with *n* nodes, one can generate all spanning trees by successive cyclic exchange, [2]. This approach straightforward is difficult to computerize. So, Aggarwal, [3] presented another algorithm, uses Cartesian products of (n-1) vertex cutsets whose elements are the branches connected to any of the (n-1) nodes of the graph.

The minimum spanning tree problem (MSTP, [5]) has been well studied in this framework, and efficient algorithms are widely known to solve this problem [6, 7]. With minor changes, the same algorithms can be used to find the maximum spanning tree as well.

Younes, [8] presented an algorithm to find the spanning trees of the computer network in terms of its links for using it to compute the network reliability

The problem of our concern is: Given a network in which each link has a fixed cost and a broadcast group, find a broadcast tree such that the cost of the broadcast tree is minimized. The proposed algorithms are centralized, which require the network topology information in prior. Extensive simulations have been conducted and the results have demonstrated the efficiency of the proposed algorithms

Notation:

G a network graph
N the number of nodes in G
E the number of links in G
x_{ij} a link i in G
$C(x_i)$ the cost of link i
M the connection matrix of the network

M_T the connection matrix of the spanning tree
T_i the spanning tree-i
$C(T_i)$ the cost of the spanning tree T_i
IN initially numbers of spanning trees
R_i a row i in a matrix
C_i a column i in a matrix

2. The Spanning Tree:

A tree T is considered as a spanning tree of graph G if T is a connected sub graph of G and contains all nodes of G. A link in T is called a branch of T, while a link of G that is not in T is called chord. For a connected graph of N nodes and E links, the spanning tree has (N-1) branches and (E-N+1) chords.

I.e., the characterization of the spanning tree as follows:

- Contains (N-1) edges.
- Contains all nodes of G.
- is a connected sub graph of G.

3. The Problem Description

A network is usually represented as a weighted directed graph $G = (N, E)$, where N denotes the set of nodes and E denotes the set of communication links connecting the nodes. $|N|$ and $|E|$ denote the number of nodes and links in the network respectively [17]. Our problem is: Given a broadcast request sourced from s and we consider the broadcast routing problem with cost constraints from one source node to all destination nodes.

A graph G is connected if there is at least one path between every pair of nodes i and j, which minimally requires a spanning tree with (n-1) edges. The number of possible edges is n(n-1)/2.

If we consider the network of six nodes and 8 edges as shown in Fig. 1, the edges 1-2, 1-3, 1-6, 2-4, 3-5, 6-7, 7-8 represent a spanning tree T. It contains 7 edges, all nodes, and is a connected sub graph.

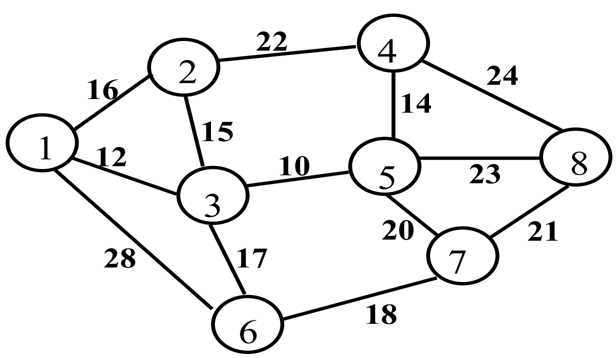

Fig. 1 The sample network

The total cost of the tree T is defined as the sum of the cost of all links in that tree and can be given by

$$C(T) = \sum_{e \in E_T} C(e) \tag{1}$$

The problem is to find the minimum spanning tree such that:

$$Min\{C(T_i),\ \ i = 1,2,3,................,k\},\ \text{k is the number of the spanning trees} \quad (2)$$

.

4. The Spanning Tree Containing All Nodes

The connection matrix M describes all direct connections between the nodes of a graph. The weighted connection matrix is a square matrix of dimension *n x n*. Entries of C are defined such that the entry M_{ij} at the intersection of row i and column j, represents a connection from node i to node j. The rules that define a weighted connection matrix are as follows:

$$M_{ij} = \begin{cases} 1 & \text{If node i and node j are connected} \\ 0 & \text{Otherwise} \end{cases} \quad (3)$$

That is, the connection matrix of the Fig. 1. is:.

$$M = \begin{bmatrix} 0 & 1 & 1 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 1 & 0 & 0 & 0 & 0 \\ 1 & 1 & 0 & 0 & 1 & 1 & 0 & 0 \\ 0 & 1 & 0 & 0 & 1 & 0 & 0 & 1 \\ 0 & 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 1 & 0 & 1 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 & 1 & 0 & 1 \\ 0 & 0 & 0 & 1 & 1 & 0 & 1 & 0 \end{bmatrix}$$

Fig. 2 The connection matrix of Fig.1

The spanning tree T contains all nodes of the given network, if all rows and columns of M_T are non-zero elements (M_T is the connection matrix of T). To create $M_{T:}$ For each link in T and represents a link between two nodes as i, j it must be replace the element M_{ij} and M_{ji} by 1 in the matrix M

For example, if we consider the spanning tree 1-2, 1-3, 1-6, 2-4, 3-5, 6-7, 7-8, the connection matrix M_T is:

$$M_T = \begin{bmatrix} 0 & 1 & 1 & 0 & 0 & 1 & 0 & 0 \\ 1 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{bmatrix}$$

Fig. 3 The connection matrix of the spanning tree

In Fig. 3 we can note that the matrix doesn't contain any row or column, their elements are zero and hence we can deduce the spanning tree (1-2, 1-3, 1-6, 2-4, 3-5, 6-7, 7-8) contains the all nodes of the given network.

5. The Spanning Tree is a Connected Sub Graph.

The sub graph is connected if its all nodes are connected. To confirm if a spanning tree T is a connected sub graph or not, we can repeat the union between the elements of both R_1 and R_j in the matrix M_T (where j is none zero element in R_1). On other hand, we can use the following relation, [8]:

Do
{

$$R_1 = R_1 \bigcup_{j \in R_1} R_j \qquad (4)$$

} While j is non-zero element in R_1 , j=2,3,…,n.

6. The Genetic Algorithm (GA)

In the proposed GA, each spanning tree is represented by a binary string that can be used as a chromosome. Each element of the chromosome represents a link in the network topology. So, for a network of N nodes and E edges, there are E string components in each candidate solution x. Each chromosome must contains N-1 none zero elements. For example, the spanning tree (1-2, 1-3, 1-6, 2-4, 3-5, 6-7, 7-8) is represented as a chromosome as shown in Fig. 4.

1	1	1	0	1	1	0	0	0	0	0	1	1

Fig. 4 The spanning tree in the form of chromosome

6.1 Initial Population

The initial population is generated according to the following steps:

- A chromosome x in the initial population can be generated as shown in Fig 4.
- The chromosome must be contain only N-1 none zero element
- The chromosome must be containing all nodes of the network as shown in Fig. 4.
- The chromosome must be a connected sub graph by using Eq. 4
- Calculate C(x) by using Eq. 1.
- Repeat steps 1 to 4 to generate pop_size number of chromosomes.

6.2 Genetic Crossover Operation

The crossover operation is used to breed a child from two parents by one cut point. The crossover operation will perform if the crossover ratio ($P_{c=}0.95$) is verified. The cut point is selected randomly. The crossover operation is performed as follows:

- Select two chromosomes randomly from the current population.
- Randomly select the cut point
- Fill the components of the chromosome

a. By taking the components of the first chromosome (from the first gene to the cut point) and fill up to the child.

b. Also, tacking the components of the second chromosome (from the cut point+1 to the last gene) and fill up to the child.

The offspring generated by crossover operation is shown in Fig. 5.

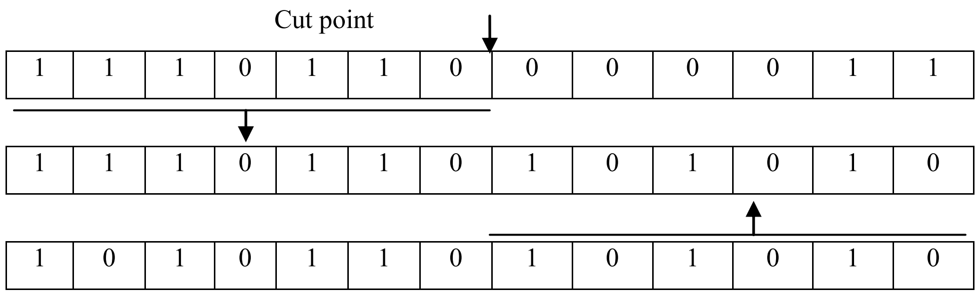

Fig. 5 Crossover operation

6.3 **Genetic Mutation Operation**

The mutation operation is performed on bit-by-bit basis. In the proposed approach, the mutation operation will perform if the mutation ratio (P_m) is verified. The mutation ratio, P_m in this approach will be 0.2 and is estimated randomly. The point to be mutated is selected randomly. The offspring generated by mutation is shown in Fig.6.

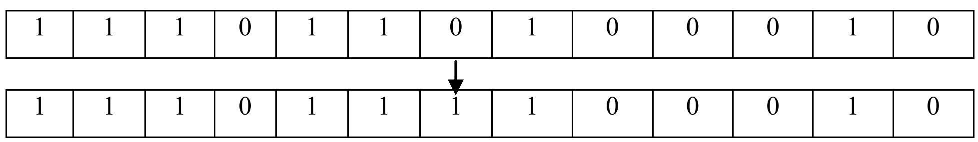

Fig.6 Mutation operation.

7. The proposed Algorithm

The following algorithm explains how we can use the above assumptions and proposed functions to find the minimum spanning tree.

Algorithm 1: Genetic algorithm for minimizing delay

Input: : Set the parameters: pop_size, max_gen, P_m, P_c ,gen = 0.

Steps:

1. Generate the initial population as in section 7.1.
2. gen←1.
3. **While** (gen <= maxgen) **do**
4. **P** ← 1
5. **While** (p <= pop_size) **do**
6. Genetic operations
 6.1 Obtain chromosomes of the new population,
 6.2 Select two chromosomes from the parent population randomly
 6.3 Apply crossover according to p_c (p_c>=0.9).
 6.4 Mutate the new child according to P_m parameter (p_m<=0.2).
 6.5 Check the new child if it contains all nodes of the network as shown in Fig. 4.
 6.6 Check the new child if it represents a connected sub graph by using Eq. 4
7. Compute the total cost of the new child C(x) according to Eq. 1.

8. Check the conditions $C(x) < C_{obj}$
9. If they are satisfied, Then
10. Save this child as a candidate solution.
11. P ← p+1.
12. End if
13. End do
14. Compare among all solutions to obtain the best solution
15. Set gen =gen + 1
16. End do

8. Case Study

In this section, we consider the given network as shown in Fig. 1 (6 nodes and 8 links) and the connection matrix as shown in Fig. 3. Initially, we have IN = $\binom{13}{7} = 1716$ spanning trees, each spanning tree contains 7 non-zero elements. The minimum spanning tree is as follows:

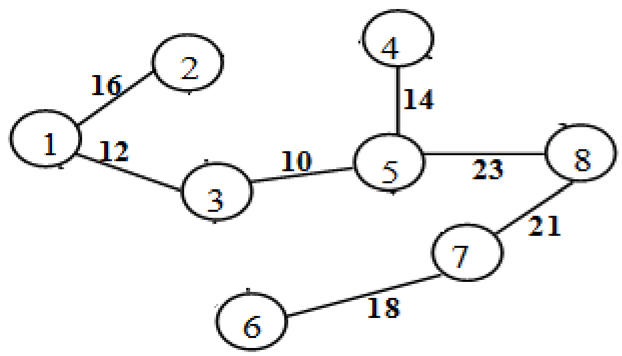

Fig.7 The broadcast routing tree for the given network.

9. Conclusion

This paper presented a genetic algorithm to find the broadcast routing tree of a given network in terms of its links such that the cost of the broadcast tree is minimized. The algorithm used the connection matrix of a given network to find the spanning trees, and also is based on the weight of the links to obtain the minimum broadcast routing tree.

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