An Ant Algorithm for Solving QoS Multicast Routing Problem

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Abstract

Many applications require send information from a source to multiple destinations through a communication network. To support these applications, it is necessary to determine a multicast tree of minimal cost to connect the source node to the destination nodes subject to delay constraints. Based on the Ant System algorithm, we present an ant algorithm to find the multicast tree that minimizes the total cost. In the proposed algorithm, the k shortest paths from the source node to the destination nodes are used for genotype representation. By comparing the results The experimintal results show that the algorithm can find optimal solution quickly and has a good scalability.

Keywords: Multimedia Communication; Multicast Routing; Multicast Tree; Ant Colony Algorithms; Bandwidth, Delay and Cost.

1. INTRODUCTION

The QoS multicast routing (QMR) problem concerns the search of optimal routing trees in the distributed network, where messages or information are sent from the source node to all destination nodes, while meeting all QoS requirements. This problem is NP completes [1]. Over the past decades, many unconstrained or simple constrained multicast routing algorithms have been developed. Typical approaches include (1) applying Dijkstra algorithm to find the shortest path, (2) seeking the minimum network cost using Steiner tree routing algorithm, and (3) finding multicast trees that the paths between source node and the destination nodes are connected and their cost is minimized. A state of the art review and analysis can be found, see [1]- [3].

There are many studies that apply genetic algorithms (GA) and ant algorithms to solve the QMR problems (with different types of QoS constraints) are increasing. In [4] – [7], a heuristic GA is used to solve the QMR problems. The algorithm acquires the solution by representing a multicast tree as a chromosome so as to save the coding spaces and reduce the decoding operations (compared with the binary coding mechanism). However, these approaches cannot be expanded. If one or more nodes are added into the network, the system needs to scan all nodes again to acquire the optimum solution. That is, previous network information cannot be transferred to the expanded network.

A number of efficient heuristic algorithms given in [7] – [9], consider a number of rigid QoS criteria, such as bandwidth, delay, delay constraint, and packet loss rate. Chu [10], presented a model that treats these constraints separately, add more constraints such as delay jitter and packet loss rate, and take network expansion into account.

In [11], an efficient algorithm based on ant system is used for generating a low-cost multicast tree subject to delay constraints. The algorithm starts with a backup-paths-set from the source node to each destination nodes using Dijkstra Kth shortest path algorithm. Then transform the formed procedure of the multicast tree to the Graph, and use AS to the QoS problems: when a ant move from the node i to the node j depend on the corresponding probabilities function, and update the Pheromone on Graph when every iteration finished.

In the last years, the genetic algorithms (GA) are gaining an increasing interest for solving complex problems in the networking field, as network design [13] and unicast routing [14]. GA for multicast routing without constraints was presented by [15] and [16], while authors in [17] and [18] addressed the constrained problem taking into account the QoS level provided for real-time applications in single multicast sessions. Luca and Lugi [19], presented an approach for group multicast routing by genetic algorithm. Chen [12], proposed a new multicast routing optimization algorithm based on Genetic Algorithms, which find the low-cost multicasting tree with bandwidth and delay constraints.

In this paper, we propose an efficient algorithm based on ant system for generating a low-cost multicast tree subject to delay constraints. The proposed algorithm uses a genetic algorithm given in [4], to find the k^{th} shortest paths from the source node to each destination nodes. Then we use the Ant System to solve the QoS problems: when an Ant moves through a shortest path it depends on the corresponding probabilities function and update Pheromone on that path after finishing each iteration. The experimental results show the comparison between the proposed ant algorithm and the genetic algorithm, [12]. Simulation results show our algorithm has features of well performance of cost, fast convergence and stable delay.

The rest of the paper is organized as follows: Section 2 presents the problem description and formulation. Sections 3 describe our Ant-System based QOS multicasting algorithm followed by time complexity of the algorithm. Simulation results and comparison with other reported heuristics are presented in Section4. Section 5 concludes the paper.

2. PROBLEM DESCRIPTION AND FORMULATION

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. We consider the multicast routing problem with bandwidth and delay constraints from one source node to multi-destination nodes. Let $X=\{n_0, u_1, u_2, ...u_m\} \in N$ be a set of from source to destination nodes of the multicast tree. Where n_0 is source node, and $U=\{u_1, u_2 \dots u_m\}$ denotes a set of destination nodes. Multicast tree $T=(N_T, E_T)$, where $N_T \subseteq N$, $E_T \subseteq E$, there exists the path $P_T(n_0, d)$ from source node n_0 to each destination node $d \in U$ in T. $e(i,j)$ is a link from node $i \in N$ to node $j \in N$. Three non-negative real value functions are associated with each link $e(e \in E)$: cost $C(e)$, delay $D(e)$, and available bandwidth $B(e)$. The link cost function, $C(e)$, may be either monetary cost or any measure of the resource utilization, which must be optimized. The link delay, $D(e)$, is considered to be the sum of switching, queuing, transmission, and propagation delays. The link bandwidth, $B(e)$, is the residual bandwidth of the physical or logical link. The link delay and bandwidth functions, $D(e)$ and $B(e)$, define the criteria that must be constrained.

The cost of the path P_T *is* defined as the sum of the cost of all links in that path and can be given by

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

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

$$C(T) = \sum_{e \in E_T} C(e) \tag{2}$$

The total delay of the path $P_T(n_0,d)$ is simply the sum of the delay of all links along $P_T(n_0,d)$:

$$D(P_T) = \sum_{e \in P_T(n_0,d)} D(e), \qquad d \in U \tag{3}$$

The delay of multicast tree *T* is the maximum value of delay in the path from source node n_0 *to* each destination node $d \in U$.

$$D(T) = \max\Big(\sum_{e \in P_T(n_0,d)} D(P_T), \qquad d \in U \Big) \tag{4}$$

The bandwidth of the path $P_T(n_0,d)$ is defined as the minimum available residual bandwidth at any link along the path:

$$B(P_T) = \min(B(e), e \in P_T) \tag{5}$$

The bandwidth of the tree *T* is defined as the minimum available residual bandwidth at any link along the tree:

$$B(T) = \min(B(e), e \in E_T) \tag{6}$$

Assume the minimum bandwidth constraint of multicast tree is *B*, and the maximum delay constraint id is *D*, given a multicast demand *R*, then, the problem of bandwidth-delay constrained multicast routing is to find a multicast tree *T*, satisfying:

1. Bandwidth constraint: $B(T) = B$.
2. Delay constraint: $D(T) = D$.

Suppose $S(R)$ is the set, $S(R)$ satisfies the conditions above, then, the multicast tree *T* which we find is:

$$C(T) = \min(C(Ts), Ts \in S(R))$$

3. THE PROPOSED ANT ALGORITHM

Assuming n_0 is source node, and $U = \{u_1, u_2 \ldots u_m\}$ denotes a set of destination nodes, the smallest bandwidth constraint, and by the algorithm for finding the *k* shortest paths in reference [4], we can find the candidate route set from source node to each destination node i (i.e. $P_i = \{p_1, p_2, \ldots\ldots\ldots, p_n\}$). The proposed ant algorithm can be performed as the following steps:

Algorithm: Ant algorithm for multicast routing

1. Initialize network nodes.
   a. Define the source node s and the destination nodes $U = \{u_1, u_2 \ldots u_m\}$
b. Set NC =0 (NC is a loop counter.), and put *m* ants to s
2. For each destination node $u_i \in U$,
3. Let *Pi* be the set of the shortest paths for the destination node u_i (by using [4]).
4. Assign an initial value $\tau_k = 0$; to the pheromone intensity of every p_k, k=1,2,…n,
5. Begin the first tour;
6. Let m ants move from s to u_i on P_i equally (the ants number in each path p_k is equal).
7. Compute the pheromone amount left by x ants at p_k ($\Delta\tau_k$) by using the following equation:

$$\Delta\tau_k^{total} = \frac{Q}{C_k} * x; \qquad (7)$$

Where C_k is the cost of the path p_k and is computed by Eq. (1).

8. Update the local pheromone τ_k ;

$$\tau_k = (1-\rho)\tau_k + \Delta\tau_k^{total}; \qquad (8)$$

Where $\rho \in (0, 1]$ is the evaporation rate.

9. Begin a new tour
10. Set NC=NC+1;
11. Compute the corresponding probabilities function f_k for each p_k as follows:

$$f_k = \begin{cases} \dfrac{[\tau_k]^{\alpha} * [\eta_k]^{\beta}}{\sum_{j \in n} [\tau_j]^{\alpha} * [\eta_j]^{\beta}}; & k \in n \\ 0 & otherwise \end{cases} \qquad (9)$$

Where $\eta_k = \dfrac{1}{d_k}$; d_k is computed by using Eq. (3), and α, β denote the information accumulated during the movement of ants and the different effects of factors in the path selection.

12. Compute $\Delta\tau_k$ by using Eq. (7)
13. Update the global pheromone τ_k by using Eq. (8)
14. Repeat from step 9 until NC_{max}
15. Compare between the values of τ_k to get the best path for the destination u_i (p_{ui}).
16. End For
17. Collect the all best path (p_{ui}) to get the multicast tree.

4. EXPERIMENTAL RESULTS

In this section, we show the effectiveness of the above algorithm by applying it on two examples and compare the results which obtained by the proposed ant algorithm with the results of which obtained by [12].

The parameters setting in the proposed algorithm as follows: ants number m = 30, $\rho = 0.5$, $\alpha=\beta=1$, and NC_{max}=20 (iteration numbers).

4.1 First Example

We consider a network with 8 nodes taken from [12]. Each link represented by a triple-group (B, *D*, *C*), given its value randomly as shown in Fig. 1.

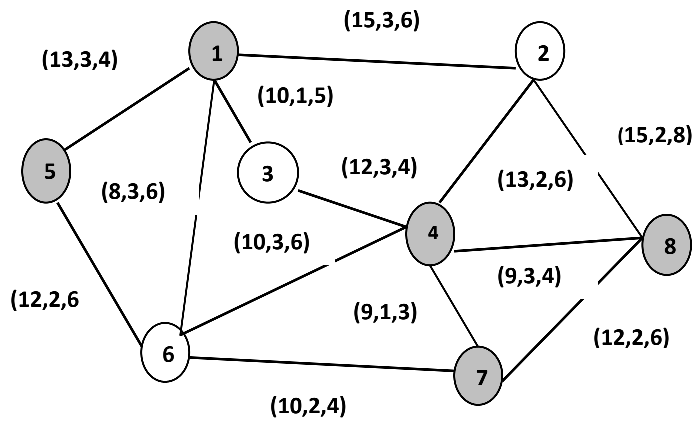

FIGURE 1: Network Topology Structure

Assuming the source node n_0 is node 1, destination node set *U*= {4, 5, 7, 8} as shown in the above figure. By the algorithm for finding the *k* shortest paths in reference [4] with smallest bandwidth constraint B=10, we can find the candidate route set from source node 1 to each destination node, as shown in Table 1.

Destination node	The shortest paths
4	1 2 8 7 6 4
	1 3 4
	1 5 6 4
	1 2 4
	1 5 6 7 8 2 4
5	1 5
	1 2 4 6 5
	1 2 8 7 6 5
	1 3 4 6 5
7	1 3 4 2 8 7
	1 3 4 6 7
	1 2 4 6 7
	1 2 8 7
	1 5 6 7
	1 5 6 4 2 8 7
8	1 5 6 4 2 8
	1 3 4 2 8
	1 3 4 6 7 8
	1 5 6 7 8
	1 2 8
	1 2 4 6 7 8

TABLE 1: The candidate route set from source node 1 to each destination node

We find the multicast tree as shown in Fig.2 with cost=41.

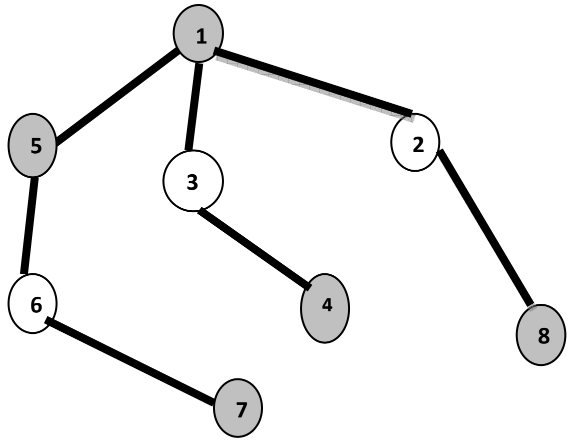

FIGURE 2: The Multicast Tree obtained by the proposed Ant Algorithm

Figure 3(a, b, c, and d)) shows the number of ants on each path of the destination 4, 5, 7, and 8 respectively.

The following figures show the best path which represents the candidate route from the source node 1 to the destination nodes. The horizontal axis represents the tour number and the vertical axis represents the number of ants.

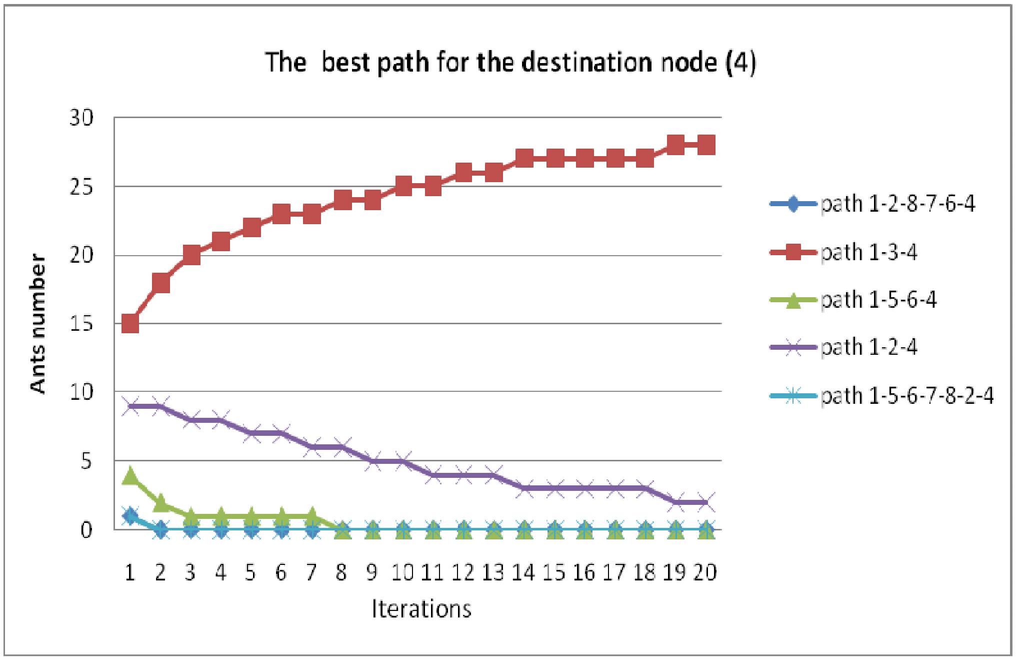

FIGURE 3(a): The iteration number and the number of Ants for the destination 4.

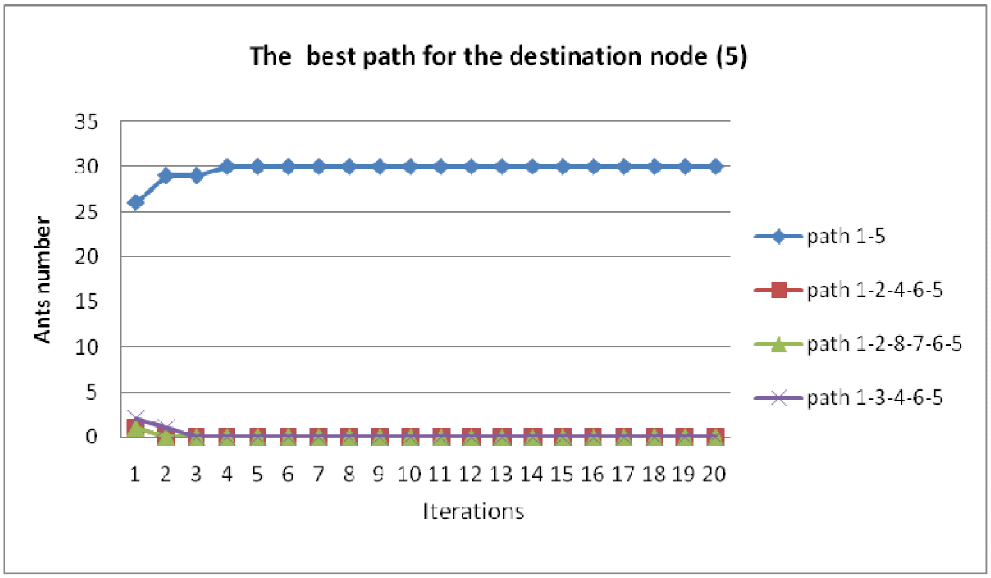

FIGURE 3(b): The iteration number and the number of Ants for the destination 5.

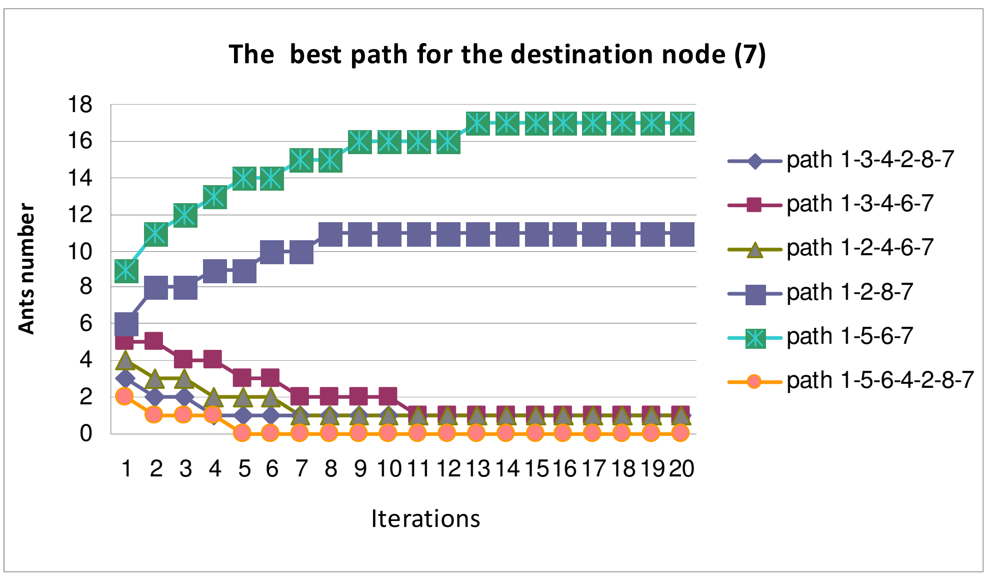

FIGURE 3(c): The iteration number and the number of Ants for the destination 7.

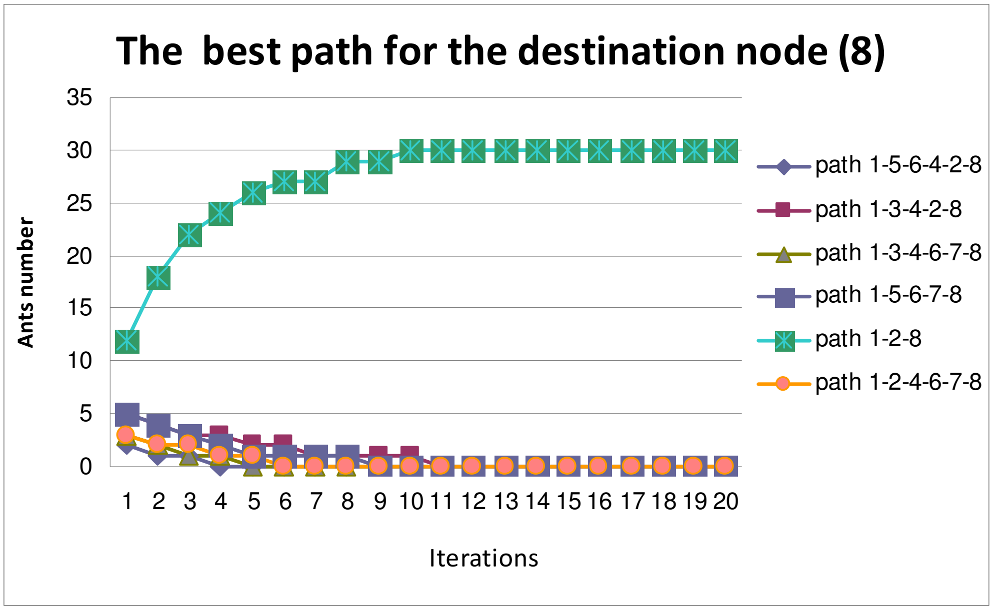

FIGURE 3(d): The iteration number and the number of Ants for the destination 8.

From the above figures, if we consider the figure 3(d) as an example we note that: the number of ants in the path 1-2-8 increases from 11 to 30 during iteration 1 to iteration 20. But the number of ants on the other paths is decreasing to 0. This means that, the path 1-2-8 is the best candidate route from the source node 1 to the destination node 8.

Figure 4 represents the multicast tree which obtained by the genetic algorithm, [12].

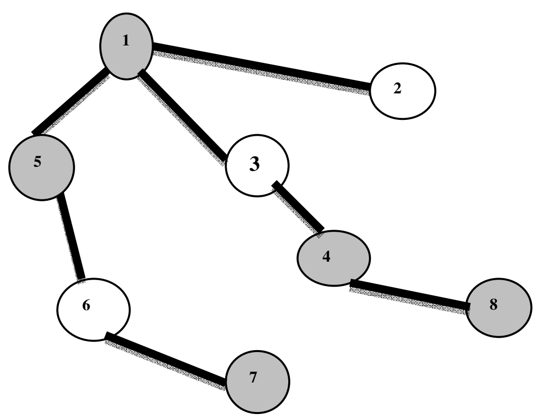

FIGURE 4: The Multicast Tree obtained by [12].

By comparing the Multicast tree obtained by the proposed Ant algorithm, given in Fig. 2 and the other one which obtained by using genetic algorithm [12], given in Fig. 4, we noted the following:

1. The bandwidth B of the path 1->3->4->8 in the tree obtained by [12] equal to 9 according to Eq. 5 which is not 10 as it is imposed.
2. The path 1->2 isn't true, because the node 2 does not represent the destination node.

Hence, the multicast tree obtained by [12] is not correct, based on the parameters imposed.

4.2 Second Example

We consider a network with 8 nodes taken from [10]. Each link represented by a triple-group (D, B, *C*), given its value randomly as shown in Fig.5 and compare the results with [10].

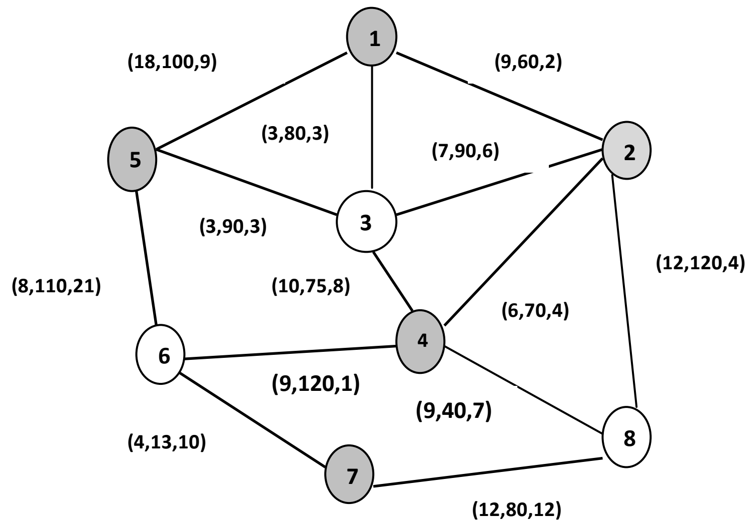

FIGURE 5: **Network Topology Structure**

Assuming the source node n_0 is node 1, destination node set U= {2, 4, 5, 7} as shown in the above figure. By the algorithm for finding the *k* shortest paths in reference [4] with smallest bandwidth constraint B=70, we can find the candidate route set from source node 1 to each destination node, as shown in Table 2.

Destination node	The shortest paths
2	1 3 4 2
	1 5 3 2
	1 5 3 4 2
	1 3 5 6 4 2
	1 3 2
	1 5 6 7 8 2
	1 5 6 4 2
	1 5 6 4 3 2
	1 3 5 6 7 8 2
4	1 5 3 4
	1 5 3 2 4
	1 3 5 6 4
	1 5 6 4
	1 3 2 4
	1 3 4
5	1 5
	1 3 4 6 5
	1 3 5
	1 3 2 4 6 5
7	1 3 5 6 7
	1 3 4 6 7
	1 5 6 7
	1 3 4 2 8 7
	1 3 2 8 7
	1 5 3 4 6 7

TABLE 2: The candidate route set from source node 1 to each destination node

We find the multicast tree as shown in Fig.6 with cost=63.

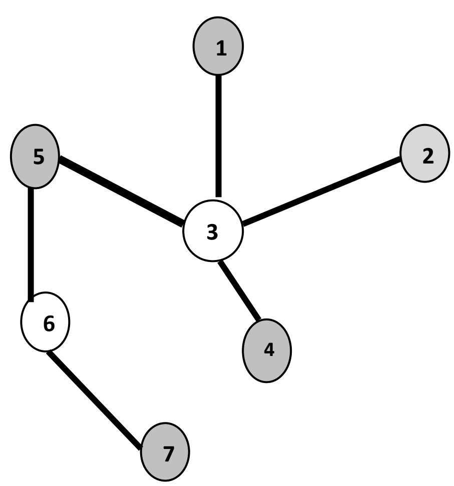

FIGURE 6: The Multicast Tree obtained by the proposed Ant Algorithm

The multicast tree obtained by [10] is shown in Fig. 7.

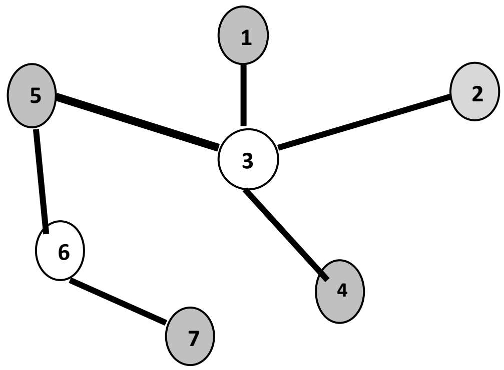

FIGURE 7: The Multicast Tree obtained by [10]

By comparing the previous results we observe that the multicast tree obtained by the proposed Ant algorithm is quite similar to the multicast tree obtained by [10].This means that the proposed Ant algorithm is working properly.

5. CONCLUSION

This paper presented an Ant algorithm for solving QoS multicast routing problem based on bandwidth and delay constraints. The proposed algorithm uses the k^{th} shortest paths algorithm [4], to construct the route set. Then, we have a set of paths for each destination nodes; the Ants moving through the paths depending on the corresponding probabilities function and update the Pheromone on the paths after finishing each iteration. Simulation results show that the proposed algorithm has features of well performance of cost, fast convergence and stable delay. The algorithm can guarantee the requirement of multimedia group communication for quality of service.

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