Advanced Multicasting for DVBMT Solution*

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Abstract. Our research subject in the present paper is concerned with the minimization of multicast delay variation under the multicast end-to-end delay constraint. The delay- and delay variation-bounded multicast tree (DVBMT) problem is NP-complete for high-bandwidth delay-sensitive applications in a point-to-point communication network. The problem is first defined and discussed in [3]. In this paper, comprehensive empirical study shows that our proposed algorithm performs very well in terms of average delay variation of the solution that it generates as compared to the existing algorithm.

1 Introduction

In real-time communications, messages must be transmitted to their destination nodes within a limited amount of time, otherwise the messages will be nullified. Computer networks have to guarantee an upper bound on the end-to-end delay from the source to each destination. This is known as the multicast end-to-end delay problem [1,5]. In addition, the multicast tree must also guarantee a bound on the variation among the delays along the individual source-destination paths [3]. In this paper, we propose a new algorithm for DVBMT problem. The time complexity of our algorithm is $O(mn^2)$.

The rest of the paper is organized as follows. In Section 2, we give a formal definition of the problem. Our proposed algorithm is presented in section 3 and simulation results are presented in section 4. Section 5 concludes this paper.

2 Problem Definition

We consider a computer network represented by a directed graph $G = (V, E)$, where V is a set of nodes and E is a set of links. Each link $(i, j) \in E$ is associated with delay $d_{(i,j)}$. Given a network G, we define a path as sequence

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of nodes $u,\ i,\ j,\ \ldots,\ k,\ v$, such that $(u,i),\ (i,j),\ \ldots$, and (k,v) belong to E. Let $P(u,v) = \{(u,i),\ (i,j),\ \ldots,\ (k,v)\}$ denote the path from node u to node v. If all elements of the path are distinct, then we say that it is a simple path. We define the length of the path $P(u,v)$, denoted by $n(P(u,v))$, as a number of links in $P(u,v)$. Let $\preceq$ be a binary relation on $P(u,v)$ defined by $(a,b) \preceq (c,d) \leftrightarrow n(P(u,b)) \leq n(P(u,d))$, $^{\forall}(a,b),\ (c,d) \in P(u,v)$. $(P(u,v),\preceq)$ is a totally ordered set. For given a source node $s \in V$ and a destination node $d \in V$, $(2^{s\Rightarrow d},\infty)$ is the set of all possible paths from s to d. $(2^{s\Rightarrow d},\infty) = \{\ P_k(s,d)\ |\ \text{all possible paths from } s \text{ to } d,\ ^{\forall}s,\ d \in V,\ ^{\forall}k \in \Lambda\ \}$, where Λ is a index set. Both cost and delay of an arbitrary path P_k are assumed to be a function from $(2^{s\Rightarrow d},\infty)$ to a nonnegative real number. Since $(P_k,\preceq)$ is a totally ordered set, if there exists a bijective function f_k then P_k is isomorphic to $\mathcal{N}_{n(P_k)}$. $f_k\ :\ P_k \longrightarrow \mathcal{N}_{n(P_k)}$. We define a function of delay along the path $\phi_D(P_k) = \sum_{r=1}^{n(P_k)} d_{f_k^{-1}(r)}\ ,\ ^{\forall}P_k \in (2^{s\Rightarrow d},\infty)$. $(2^{s\Rightarrow d}, supD)$ is the set of paths from s to d for which the end-to-end delay is bounded by $supD$. Therefore $(2^{s\Rightarrow d}, supD) \subseteq (2^{s\Rightarrow d},\infty)$. For multicast communications, messages need to be delivered to all receivers in the set $M \subseteq V \setminus \{s\}$ which is called multicast group, where $|M| = m$. The path traversed by messages from the source s to a multicast receiver, m_i, is given by $P(s,m_i)$. Thus multicast routing tree can be defined as $T(s,M) = \bigcup_{m_i \in M} P(s,m_i)$, and messages is sent from s to destination of M using $T(s,M)$. The multicast delay variation, δ, is the maximum difference between the end-to-end delays along the paths from the source to any two destination nodes. $\delta = max\{|\phi_D(P(s,m_i)) - \phi_D(P(s,m_j))|,\ ^{\forall}m_i, m_j \in M, i \neq j\}$. The DVBMT problem is to find the tree that satisfies $min\{\delta_\alpha|\ ^{\forall}m_i \in M,\ ^{\forall}P(s,m_i) \in (2^{s\Rightarrow m_i}, supD),\ ^{\forall}P(s,m_i) \subseteq T_\alpha,\ ^{\forall}\alpha \in \Lambda\}$, where T_α denotes any multicast tree spanning $M \cup \{s\}$, and is known to be NP-complete [3].

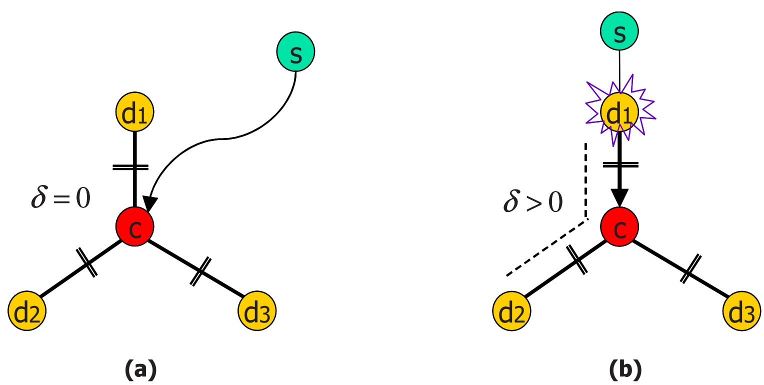


Fig. 1. The shortcoming of the DDVCA

3 An Illustration on New Heuristic

The proposed algorithm consists of a core node selection part and the multicast tree construction part. When candidate of core node is several nodes, the DDVCA [4] randomly choose a core node among candidates but our proposed algorithm is going to overcome a shortcoming of the DDVCA. See the Fig. 1. In selecting such a core node, we use the minimum delay path algorithm. The proposed algorithm calculates the minimum delay from each destination node and source node to each other node in the network. For each node, our method calculates the associated delay variation between the node and each destination node. We check whether any destination node is visited in the path from source node to each other node. If any destination node is visited, then the proposed algorithm records in '$pass_{v_i}$' data structure. And we conform $supD$ and select nodes with the minimum delay variation as the candidates of core node. As you shown in Fig. 2, our algorithm chooses the core node with $min\{\phi_D(P(s, v_i)) - min\{pass_{v_i}\}\}$. The time complexity of the proposed algorithm is $O(mn^2)$, which is the same as that of the DDVCA.

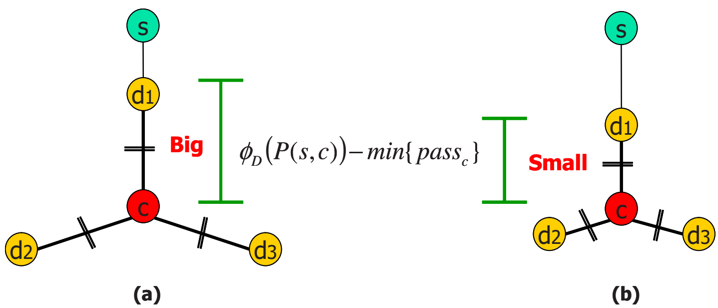
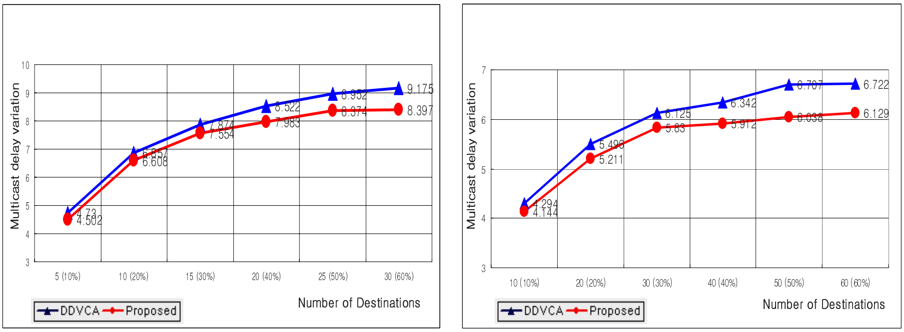


Fig. 2. The basic concept of the proposed algorithm

4 Simulation Model and Result

We now describe some numerical results with which we compare the performance for the new parameter. The proposed one is implemented in C++. We consider networks with number of nodes (n) which is equal to 50 and 100. We generate 10 different networks for each size given above. The random networks used in our experiments are directed, symmetric, and connected, where each node in networks has the probability of links (P_e) equal to 0.3 [2]. We randomly selected a source node. The destination nodes are picked uniformly from the set of nodes in the network topology. Moreover, the destination nodes in the multicast group will occupy 10, 20, 30, 40, 50, and 60% of the overall nodes on the network, respectively. We randomly choose $supD$. We simulate 1000 times ($10 \times 100 = 1000$) for each n and $P_e = 0.3$. For the performance comparison, we



(a) P_e=0.3, |V|=50 (b) P_e=0.3, |V|=100

Fig. 3. The multicast delay variations of the three different networks and Normalized Surcharges versus number of nodes in networks

implement the DDVCA in the same simulation environment. Fig. 3 shows the simulation results of multicast delay variations. We easily notice that the proposed algorithm is always better than the DDVCA. The enhancement is up to about 100(9.18-8.39)/9.18≐9% and 100(6.71-6.04)/6.71≐10% for $|V| = 50$ and $|V| = 100$, respectively.

5 Conclusion

In this paper, we consider the transmission of a message that guarantees certain bounds on the end-to-end delays from a source to a set of destinations as well as on the multicast delay variations among these delays over a computer network. It has been shown that the DDVCA [4] outperforms the DVMA [3] slightly in terms of the multicast delay variation for the constructed tree. The comprehensive computer simulation results show that the proposed scheme obtains the better minimum multicast delay variation than the DDVCA.

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