DCADH: A GENERATING ALGORITHM OF DELAY-CONSTRAINED MULTICAST ROUTING TREE

Yu-xi Zhu and Ling Zhou
Department of Computer Science and Technology, Foshan University, Foshan, Guangdong, China

Keywords: Multicast Routing, Average Distance Heuristic, Delay-Constrained, Least-Cost, Simulation.

Abstract: Multicast is the ability of a communication network to accept a single message from an application and to deliver copies of the message to multiple recipients at different location. With the development of Internet, Multicast is widely applied in all kinds of multimedia real-time application: distributed multimedia systems, collaborative computing, video-conferencing, distance education, etc. In order to construct a delay-constrained multicast routing tree, average distance heuristic (ADH) algorithm is analyzed firstly, then by using which a delay-constrained algorithm called DCADH is presented. By using ADH a least-cost multicast tree can be constructed; if the path delay can't meet the delay upper bound, a shortest delay path which is computed by Dijkstra's algorithm will be merged into the existing multicast tree to meet the delay upper bound. Simulation experiments show that DCADH has a good performance in achieving a low-cost multicast tree.

1 INTRODUCTION

QoS-aware group communication has accelerated the need and application of multicast, for example, video-conference, distance education, resource location, distributed simulation, etc. Multicast routing algorithm is a key issue in group communication, only by which a multicast routing tree can be constructed correctly and efficiently. In most conditions, it is NP-Complete and defined as a Steiner tree problem.

From the view of managing and optimizing network resource, it requires that the multicast tree constructed by the multicast routing algorithm with a least cost in order to optimize the network resources. Taking service of quality (QoS) of the multicast communication into consideration, the multicast trees should meet the stringent requirements of QoS constraints. when both the cost and the delay need be considered to optimize, the problem of delay-constrained least-cost (DCLC) multicast routing is put forward. The DCLC problem is the most common and important issues among the QoS-constrained multicast routing problems.

Different algorithms have been proposed to address the multicast routing problem (Salama H. F., 1997). Some optimized the tree cost, such as KPP, BSMA. Some simplified the time complexity, such as SPT, CDKS. And some others focused on how to meet the quality of service. But it is very hard to use any one to optimize all those parameters at the same time.

In this paper, we concentrated on how to solve the DCLC problem by using average distance heuristic (ADH) algorithm.

2 RELATED WORK

Salama and other scholars have had a comprehensive comparative study of the algorithm which solved the DCLC problem and drew a conclusion that there were some currently mature DCLC algorithms such as KPP, CDKS, BSMA, and so on. But because of the higher cost of spanning tree or higher computational complexity, they were some difficulty to apply to the actual network communication.

In addition, some scholars solved the DCLC problem using the heuristic algorithms based on new optimization theories, including neural networks, genetic algorithms, simulated annealing, tabu algorithm, etc (G. Feng, C. Douligers, 2001). Some of those bring about uncertainty in theory analysis and convergence, some are with higher

Zhu Y. and Zhou L. (2009).
DCADH: A GENERATING ALGORITHM OF DELAY-CONSTRAINED MULTICAST ROUTING TREE.
In *Proceedings of the International Conference on Signal Processing and Multimedia Applications*, pages 181-184
DOI: 10.5220/0002182501810184

complexity of time, Moreover, with some specific parameters introduced by those algorithms.

As part of our ongoing research in multicast routing algorithm, we have developed delay-constrained multicast routing algorithm with mininum path heuristic (MPH) which is an excellent algorithm to construct a DCLC multicast tree. By using the algorithm a computing destination node can join the multicast tree by selecting the path which has the least cost value to the existing multicast tree; if the path delay does not meet the delay upper bound, a shortest path tree based the delay will be merged into the existing multicast to meet the delay upper bound.

Recently, we have researched the multicast routing problem in mobile IP. In order to reduce the transmission delay and minimize the joined latency, we introduced an idea of bone node set. Based on the idea a multicast routing algorithm called bone node set-based multicast routing algorithm (BNSBMR) was designed. It characters itself in three aspects. Firstly, it can optimize the cost of multicast delivery tree and reduce the bandwidth consumption by using bone node set. Secondly, it can reduce the latency of handover, which is helpful for mobile node to achieve a fast handover. Thirdly, the transmission delay for multicast packet is lessened by sharing those bone nodes.

Moreover, we have also researched the problem of a delay-constrained dynamic multicast routing. Based the greedy idea a dynamic multicast routing algorithm called delay-constrained dynamic greedy algorithm (DCDG) was presented to construct a dynamic multicast tree. In the resulting tree the delay from the source to each destination node is not destroy the delay upper bound.

At the same time, we discussed their correctness in theory and experimented their delay and cost performance by random network model.

3 DCADH ALGORITHM

A communication network can be modeled by an edge weighted *G=(V, E)* where *V* is a set of host or router nodes and *E* is the set of communication links. We assume that the cost *weight (u, v)* is nonnegative value for each *link (u,v)* □*E*. Given a source *s* and a set of destinations *D*,

Definition 1 (shortest path): We call the path from *u* to *v* a shortest path if the total path weight from *v* to *u* is the minimize one and we write the shortest path *path(u, v)*.

Definition 2 (multicast routing tree): A multicast routing tree is a rooted subtree of the graph *G* whose root is *s*, which includes all the routing paths from *s* to *D*.

Definition 3 (delay-constrained least-cost multicast routing tree): Given network *G* (*V, E*), multicast source *s*, destination node set *D*, and the delay upper $\triangle_{Delay}$, if a multicast tree *T* covers $s \cup D$ and is satisfied with the following conditions:

$$Cost(T) = \min\{Cost(T) = \sum_{v \in D,\, e \in P(s,v)} \sum Cost(e)\}$$

$$s.t. \quad Delay\ (P(s,v)) \le \Delta_{Delay}$$

$$Dealy\ (P(s,v)) = \sum_{e \in P(s,v)} Delay\ (e)$$

$$(\forall v \in D\ ,\ P(s,v) \in T\ ),$$

we call the tree *T* as a DCLC multicast routing tree, that is, delay-constrained steiner tree.

The problems of constructing a DCLC multicast routing tree is NP-complete, which is usually solved by designing a heuristic algorithm. In this paper, we concentrated on how to solve the DCLC problem by using average distance heuristic (ADH) algorithm.

3.1 The Basic Idea

The basic idea of DCADH algorithm has been two-fold. Firstly, the ADH algorithm (Yu Y. P., Qiu P. L., 2002) is used to calculate a low-cost multicast routing tree *T*. Secondly, if *T* does not meet the delay constraint $\triangle_{delay}$, Dijkstra shortest path tree algorithm is used to compute the least-delay tree *T*, and the shortest path based the delay will be merged into the existing multicast to meet the delay upper bound. So a low-cost multicast routing tree which meets the delay upper will be constructed. When the least-delay path was merge into the low-cost multicast tree a new loop may appear, so we designed a process to eliminating the loops.

The detail descriptions of the algorithm process are as follows:

Step 1: Firstly set *s* as the least-delay tree; then compute a least-delay tree spanning all the destination members by Dijkstra shortest path tree (SPT) algorithm. If the delay of *T* Delay (·) >$\triangle_{delay}$, then exit;

Step 2: according to ADH algorithm, set all the multicast member nodes as the initial set of *T* ;

Step 3: Calculate *f* (*v*) = min (*d* (*v, Vj*) + *d* (*v, Vj*)), which *Vi, Vj* is the node set of arbitrary two separation trees. As for *v* ∈ *V*, if *f* (*v*) is minimum , *Ti* will link *Tj* through *v*, and the paths are *P* (*v, Vi*) and *P* (*v,Vj*);

Step 4: Modify set *T* and node sets, *k* = *k*-1;

Step 5: Repeat steps 3 and 4 until *k* = 1;

Step 6: Determine the delay constraint in the multicast tree. As for $\forall\ m \in D$, if $delay(\cdot) > \Delta$, $Path(m, s) \in T_{Delay}$ will been merged into T;

Step 7: If a loop is formed, the process of elimination loop will be introduced by changing the node's father;

Step 8: Repeat Step 6 until all the nodes meet the delay constraints.

3.2 Performance Analysis

Theorem 1. Only when ADH tree does not meet delay-constraint and the least-delay path is merged into the multicast, DCADH spanning tree might appear loops; otherwise there are no loops in DCADH spanning tree.

Theorem 2. Only when there are at least two tree nodes on the path at the same time, the loops might appear; otherwise there are no loops in DCADH spanning tree.

Theorem 3. There are no loops in the multicast tree $\Leftrightarrow$ All the tree nodes besides the root node in the spanning tree have only one father node.

Theorem 4. As long as there exists a multicast tree T which meets the delay constraints, DCADH can find the low-cost delay-constraint multicast routing tree .

Proof: see reference (Zhou L., Sun Y. M., 2008).

Theorem 5. The time complexity of DCADH algorithm is $O(n^3)$.

3.3 Simulation Experiments

Waxman firstly put forward a network model to generate random topology in 1988 (Waxman B. M., 1988). Waxman's algorithm set the number of network nodes, then decide whether there is a direct link connected between nodes u and v according to the following probability P_e:

$$P_e(u,v) = \beta \exp \frac{-l(u,v)}{L\alpha}$$

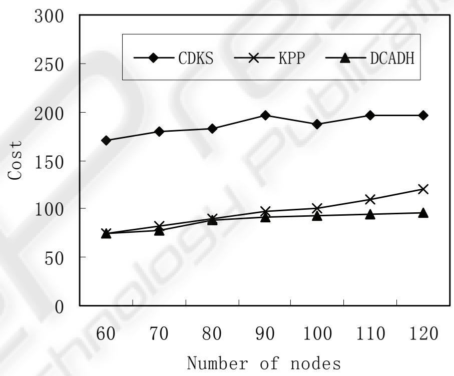
The specific simulation parameters see Table 1.

Table1: Simulation parameters.

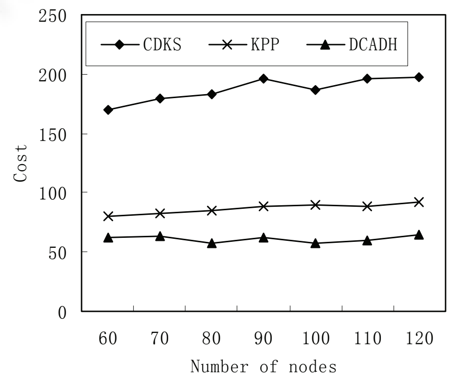
Parameters	Description	Value
N	network scale	20-120
m	number of destination nodes	20-80
α	between 0-1	0.3
β	between 0-1	0.3
$Cost(\cdot)$	cost of links	between 1-5
V	transmission speed	$2\times10^8 m/s$
Δ_{Delay}	upper delay	0.01-0.1s

Each experimental data test 10 random networks, each network measures 100 times, for a total of 1000 times, then we take the average value as the experiment measure value. At the same time, its performance is compared with CDKS (Sahasrabuddhe L. H., Mukherjee B., 2000), KPP (Kompella V. P., Pasquale J. C., and Polyzos G. C., 2000) in the cost and delay.

Experiment 1. Measuring the relation between the cost of multicast routing tree and the network node number. 20 fixed member nodes unchanged, the number of network node size begins from 60 and every time increases 10. The experiment results shown in Figure 1(a) for $\triangle_{delay} = 0.03s$ and (b) for $\triangle_{delay} = 0.06s$.



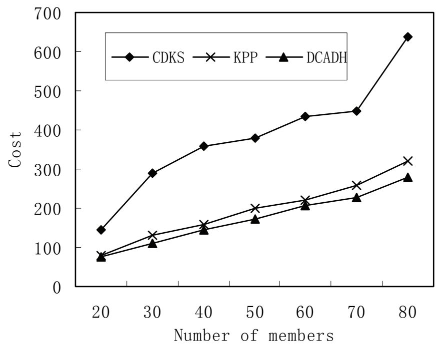
(a) $\triangle_{delay} = 0.03s$.



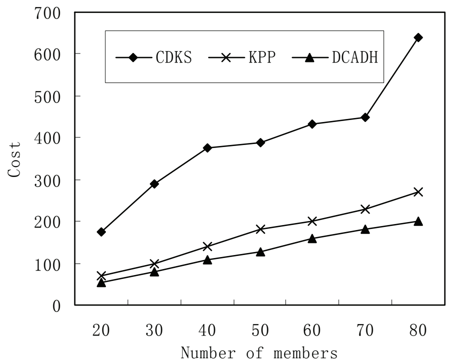
(b) $\triangle_{delay} = 0.06s$.

Figure 1: The relation of tree cost and network scale.

Experiment 2. Measuring the relation between the tree cost and the size of the group. 100 nodes of fixed network scale unchanged, the number of member nodes change from 20 to 80 and every time increases 10. The results shown in Figure 2 (a) for $\triangle_{delay} = 0.03s$ and (b) for $\triangle_{delay} = 0.06s$.



(a) $\triangle_{delay}$ = 0.03s.



(b) $\triangle_{delay}$ = 0.06s.

Figure 2: The relation of tree cost and the group size.

4 CONCLUSIONS

Through the theoretical analysis and simulation to DCADH algorithm, we can see that DCADH algorithm can not only correctly construct a low-cost multicast routing tree, but also meet the delay upper. Compared with some similar DCLC algorithms, it achieves a good performance in cost and delay. DCADH is an excellent DCLC heuristic algorithm.

ACKNOWLEDGEMENTS

The authors would like to thank the anonymous reviewers for their good suggestions, comments, and feedback to improve the presentation of this paper.

REFERENCES

Salama H. F., 1997. Evaluation of Multicast Routing Algorithm for Real-Time Communication on High-Speed Networks[J]. *IEEE Journal on Selected Areas in Communication*.

Feng G., Douligers C., 2001. A Neural Network Method for Minimum Delay Routing in Packet Switched Networks[J]. *Computer Communication*.

Yu Y. P., Qiu P. L., 2002. An improved algorithm for Steiner trees. *Journal of China Institute of Communications*.

Zhou L., Sun Y. M., 2008. A Delay-Constrained Steiner Tree Algorithm Using MPH. *Journal of Computer Research and Development*.

Waxman B. M., 1988. Routing of Multipoint Connections[J]. *IEEE Journal on Selected Areas in Communications*.

Sahasrabuddhe L. H., Mukherjee B., 2000. Multicast Routing Algorithms and Protocols: A Tutorial. *IEEE Network*.

Kompella V. P., Pasquale J. C., and Polyzos G. C., 2000. Multicasting for multimedia applications [C]. *Proc. IEEE INFOCOM'9*.