Efficient Routing Algorithms for Large Networks

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1. Aim and Objectives

Nowadays, the large bandwidth offered by the optical fiber has brought tremendous potential for exploitation in networks. Emerging multimedia-based applications require both traditional Quality of Service (QoS) guarantees (such as bandwidth and end-to-end delay) and routing reliability during transmission. At the same time, the wireless ad hoc network technology is developing very fast and high quality video applications are expected to become available in wireless ad hoc networks in near future. But the unpredictable nature of the wireless environment is easily prone to failures and resulting path failures and data loss. Thus the reliability and survivability issues of a network are the first focus in our research.

Sometimes we need to find multiple disjoint paths between a pair of nodes with different bandwidth requirements. For this case, we will consider the unsplittable flow problem in our research. This problem has lots of variants and they have lots of application, not only in fault-tolerant computing, but also in other QoS routing models.

When we are building an optical network, we need to calculate the cost of all fibers and intermediate optical switches so that the terminal users can connect their computers to the ports in a most economical way. This is an instance of the Inner-node Weighted Minimum Spanning Tree Problem, which is also an important topic in our research.

For QoS issues in mobile ad hoc networks, we will inevitably consider the energy efficiency problem since the limited energy reserve of nodes in a MANET is definitely a bottleneck for the normal operation of the whole network. For this reason, we have also studied the energy-concerned broadcasting problem in MANETs.

2. Idea and Approach

The problem of finding two Delay-Restricted Link Disjoint s-t-Paths with minimum total cost is a classical NP-hard problem. Previous result could reduce the delay of paths to be near-optimal, but the cost sacrifice was too large. We looked inside the existing model and proposed a new technique for finding a cost-bounded negative-delay cycle. By this technique we can bound the cost while reducing the delay. To make it simple and efficient, we analyzed the mathematical structure of this problem and developed a totally new approach of applying Lagrangian Relaxation. With this method, we only need to modify the weight of each edge and then do binary search. Our algorithm is much more time-efficient and implementable than all previous algorithms for this problem.

The unsplittable flow problem is a natural generalization of the disjoint paths problem. For this problem we introduced a novel rounding technique: instead of rounding the flow, we round the flow portion. By this method we need not to cancel flow and to deal with the

troublesome numeric issues. We proved that the approximation factor of our algorithm was also the current best bound for this problem.

The Inner-node Weighted Minimum Spanning Tree structure is very useful in building high-speed fiber networks. We present a framework which employs a method of repeatedly finding the minimum k-structure in the remain graph and contracting it. Based on this framework, we can further developed two polynomial-time approximation algorithms which can achieve a better performance guarantee than all existing results.

As for Optical Networks, since on each single fiber there may be dozens of wavelength available, we design auxiliary graphs so that we can deem the optical network as a normal network.

3. The Progress In the Past Year

- We have successfully finished our research on Video on Demand Broadcasting and we have further published a comprehensive paper on this topic.

- We have designed an algorithm for finding two QoS-constrained edge-disjoint paths in a network, which is more time-efficient, and the returned solution is more economical. We have built programs in MatLab the experiment results support our statement.

- We have proposed further-improved approximation algorithms for the minimum spanning tree with inner cost problem. An improved framework has been proposed for this problem.

- We have studied the Minimum-cost Single-Source Unsplittable Flow Problem and designed several algorithms for several variants of this problem. We have achieved the best performance by using a different approach from previous researchers.

- Wavelength conversion and splitter limited routing path algorithms for optical networks have been studied and algorithms presented.

4. Future directions

- To introduce the game-theoretic methods into the routing issues in wireless sensor networks. Game theory is very useful for building large-size self-organized networks, we will use it when we are finding energy-efficient paths in WSN, we will construct a simulation project for our routing algorithms and then measure the performance of this protocol and improve on it.

- To implement the collision avoidance algorithm on the OMNET++ simulation platform and some other real test-bed. Then combine all the algorithms designed and propose a fault-tolerant collision-free routing framework for large networks.

- To design improved Approximation Algorithms for the Minimum-cost Single-Source Unsplittable Flow Problem, the metric version of facility location problems and MSTI problem, then use MatLab to test their performance.

- There are many QoS routing problems in Optical Networks, such as wavelength-disjoint light-path routing and minimum-division multicasting, we will consider these problems and propose solution algorithms for them.

5. Papers

1. Chao Peng, Hong Shen, "An Improved Approximation Algorithm for Computing Disjoint QoS Paths", in the 5th IEEE International Conference on Networking (ICN'06), April 21-26, 2006, Mauritius.
2. Chao Peng, Hong Shen, "A New Approximation Algorithm For Computing 2-Restricted Disjoint Paths", to appear in IEICE TRANSACTIONS on Information and Systems 2007/02.
3. Chao Peng, Hong Shen, N. Xiong, Laurence T. Yang "Discrete Broadcasting Protocol for Video-on-Demand", in the International Conference on High Performance Computing and Communications (HPCC'06), September 14-17, Munich, Germany.
4. N. Xiong, Yanxiang He, Chao Peng, "A Self-tuning Multicast Flow Control Scheme based on Autonomic Technology", in the 2nd IEEE International Symposium on Dependable, Autonomic and Secure Computing (DASC'06), September 29-October 1, 2006, USA.
5. Chao Peng, Yasuo Tan, Naixue Xiong, Laurence T. Yang, "New Algorithms for the Minimum-cost Single-Source Unsplittable Flow Problem", to appear in The IEEE 21sth International Conference on Advanced Information Networking and Applications, Niagara Falls, Canada.
6. Chao Peng, Yasuo Tan, "Approximation Algorithms for Inner-node Weighted Minimum Spanning Trees", submitted to IEICE TRANSACTIONS on Information and Systems.