

# School of Computer Science

Ph.D. Final Defense

By

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## Constrained Shortest Paths for QoS Routing and Path Protection in Communication Networks

In this dissertation, we have studied certain combinatorial optimization problems that arise in the context of two important problems in computer communication networks: end-to-end Quality of Service (QoS) and fault tolerance. These problems can be modeled as constrained shortest path(s) selection problems on networks with each of their links associated with two or more additive weights representing the cost, delay etc..

First we studied the QoS single route selection problem, i.e., the constrained shortest path (CSP) problem. The goal of the CSP problem is to identify a minimum cost route which incurs a delay less than a specified bound. The CSP problem can be formulated as an integer linear programming (ILP) problem which is computationally intractable. The LARAC algorithm reported in the literature is based on the dual of the linear programming relaxation of the ILP formulation and gives an approximate solution. We proposed two new approximation algorithms solving the dual problem using binary search and parametric search. Next, we studied the CSP problem using the primal simplex method and exploiting certain structural properties of networks. This leads to a novel approximation algorithm of pseudo-polynomial time complexity. Simulation results show that this algorithm is faster than the LARAC algorithm on dense networks.

The CSDP ( $k$ ) problem requires the selection of a set of  $k > 1$  link-disjoint paths with minimum total cost and with total delay bounded by a given upper bound. This problem arises in the context of provisioning paths in a network that could be used to provide resilience to link failures. Again we studied the linear programming relaxation of the ILP formulation of the problem from the primal perspective and presented an approximation algorithm of pseudo-polynomial time complexity. Simulation results show that this algorithm is faster than commercially available CPLEX package as well as the generalized version of the LARAC algorithm.

The problems considered above assume that the network status/parameters are known and accurate. However, in real networks, this assumption is not realistic. So we have considered the QoS route selection problem under inaccurate state information. In this problem called the MP-DCP problem, the link delays are random variables. This problem is also called stochastic shortest path selection problem. Here the goal is to find a path with the highest probability to satisfy a given delay upper bound. Base on central limit theorem, we proposed a pseudo polynomial time approximation algorithm, a fully polynomial time approximation scheme (FPTAS), and a strongly polynomial time heuristic for the MP-DCP problem.

Finally we studied the constrained shortest path problem with multiple additive constraints. Using the LARAC algorithm as a building block and combining ideas from mathematical programming, we proposed a new approximation algorithm. Simulation shows that our algorithm beats previously known algorithms such as subgradient algorithm and hull approach.

**Date: Monday, December 5, 2005**

**Time: 3:30 p.m.**

**Place: CS Conference Room, EL 139**

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