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# Coping with the Resilience - Congestion Tradeoff in Multipath Routing Schemes

Ron Banner and Ariel Orda
Department of Electrical Engineering
Technion – Israel Institute of Technology
Haifa 32000, Israel
{ banner@tx, ariel@ee .technion.ac.il

**Abstract**

Two major objectives of multipath routing schemes are congestion avoidance and resilience to failures. However, focusing on each objective alone severely deteriorates the quality of the other. More specifically, when multipath routing is employed for congestion avoidance, the traffic is distributed among several different paths, each potentially prone to network failures. Since any path failure results in the failure of the entire transmission, a "naive" use of multipath routing for load balancing may largely increase the vulnerability of the connections to network failures. On the other hand, when multipath routing is employed in order to improve the resilience to failures, most of the corresponding schemes focus on the establishment of pairs of *disjoint* paths. However, in many cases, this restrictive requirement may lead to the selection of poor routing paths that were not designed to transfer large volumes of data; thus, their employment may dramatically increase the congestion state of the network. In this work we establish efficient multipath routing schemes that incorporate the two fundamental objectives of congestion avoidance and resilience to failures. To the best of our knowledge, we are the first to relax the common requirement of disjoint paths that solely considers full (100%) protection to single failures, into a weaker requirement that can accommodate any degree (0%-100%) of protection i.e., any desired probability to survive a network failure. We incorporate this new concept in several polynomial schemes that enhance survivability while considering the resilience-congestion tradeoff. Then, we turn to consider the major weakness of multipath routing schemes that solely balance the network's load, namely, increased vulnerability to failures. Specifically, we establish a multipath routing scheme that minimizes the congestion state of the network while satisfying some essential reliability requirements. As the corresponding problem is shown to be intractable, we establish an efficient $\varepsilon$-optimal approximation scheme.