Discrete Capacity and Nonbifurcated Flow Assignment Algorithm in Communication Networks

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Multicommodity flow problems such as the traffic assignment and the capacity assignment problems are well-known for their relevance in planning congested network systems. The scope of applications is large, but we retain here the interpretation that have been addressed to (store-and-forward) packet-switched computer network discrete capacity allocation and nonbifurcated routing problems [1, 3, 4, 6]. A classical point of view is that the design of communication networks can be modelled as an optimization problem where, on the one hand, the link capacity must be assigned at the lowest cost and, on the other hand, the communication flow must be routed to get the highest quality of service [7]. Normally capacity costs refers to leasing discrete levels of capacity for the links, and quality of service is measured in terms of average packet delay or with the end-to-end average buffer overflow probability.

The network discrete capacity allocation and routing problem is a special issue of a general network design problem. Specifically, the problem assumes that an initial network topology is given, such that there exists at least one path between each origin-destination pair [1, 3]. If the messages in the network follow static and nonbifurcated routes the network will be denominated nonbifurcated. The nonbifurcated multicommodity routing problem is a NP-Hard problem [2]. The network problem studied here searches how to select link capacities and a single route to be used by all kinds of traffic (data, image, voice) between each communicating node in the network, such as to minimize the sum of link allocation costs and nonlinear separable congestion (quality) costs associated with the total flow in each link.

We have implemented a new modelling and algorithmic framework to integrate design and operation in computer communication networks . The integrated approach used associates to the packet delay a congestion cost function, in such a way that the whole problem can be seen in terms of a unique cost criterion [5]. The result is that both the adopted continuous model and the optimization heuristics deal simultaneously with the two conflicting criteria of the problem. On the one hand, the link capacities are assigned at the lowest cost and, on the other hand, the communications flows are routed to get the highest quality of service.

A good convex approximation of each arc cost function is one of the main results that we have explored in our integrated framework. The separability of the new objective function was used to obtain an approximated convex function with an explicit gap. We have showed how to get lower bounds applying efficient algorithms for the solution of the resultant nonlinear bifurcated convex multicommodity flow problem. Economies of scale in capacity allocation induces concavity in leasing costs, but convex congestion costs make the integrated objective function a pointwise infimum of a series of convex functions. The application concerns the simultaneous use of routing implicit capacity assignment on the links, which are expanded as far as induced by congestion costs in order to ensure an acceptable performance level at a minimum total cost. Small execution times obtained to solve the test problems indicate that the methodology can be applied to solve large scale problems. In fact, our computational experiments suggest that the procedure is both efficient and effective in identifying good solutions for practical problems. Better multicommodity nonbifurcated routing methods could yet be used to improve the execution time and the quality of the solutions.

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