An exact approach for a bicriteria maximal SRLG-disjoint / minimal cost path pair problem in telecommunication networks.

José Craveirinha[c], Marta Pascoal[b,c], João Clímaco[c], Teresa Gomes[a,c]

[a]Dept. of Electrical Eng. and Computers – Fac. of Sciences and Technology
[b]Dept. of Mathematics, Fac. of Sciences and Technology.
[c]INESC Coimbra, Portugal

Abstract: Routing mechanisms in transport telecommunication networks, namely optical networks, require that very high levels of network service availability be maintained in the event of failures. This results from the requirements of the of Services Levels Agreements, to be provided to the customers by the network operators and from the enormous amounts of traffic that can be lost in the event of failures in the physical network, such as fiber cuts, switch or software failures. One of the most commonly used fault recovery mechanisms is global path protection, in which a pair of paths (corresponding to end-to-end routes), the active path (AP), that carries traffic flow under normal operating conditions and the backup path (BP), which is the path that carries that traffic when some failure affects the AP, are computed and established simultaneously, so that the availability of the services supported by the pair be maximized in the event of certain failures. In the design of routing mechanisms with built-in survivability objectives, and taking into account the multi-layered structure of telecommunication networks, the concept of shared risk link group (SRLG) is used, which may be defined as a group of logical links that share a common risk of failure. Usually, the network designer, based on the information about the SRLGs, seeks to calculate a pair of paths which are SRLG-disjoint, ensuring that no single fault of the AP will affect the BP, a NP-complete problem as shown in [1]. However, there may arise situations in which no SRLG-disjoint path pair can be calculated, a case in which the aim of the routing procedure may consist of finding a maximally SRLG-disjoint path pair that is a path pair with the minimum number of common SRLGs. Moreover, a key concern, in a routing model, is bandwidth usage optimization, seeking to optimize the use of bandwidth resources throughout the network links, in order to achieve the maximal possible network traffic carrying capability. This is usually represented in terms of additive path cost functions, such that the cost of using a link is some function of its capacity and used bandwidth. These objectives make that a typical formulation of the routing problem with path protection is the lexicographic calculation of a pair of paths which are maximally SRLG-disjoint and, as secondary objective, have minimal total cost. Several heuristic algorithms for finding totally SRLG-disjoint path pairs have been proposed, the performance of which, in terms of accuracy, is usually evaluated by comparison with exact solutions from Integer Linear Programming formulations, for problems tested in reference networks. Also a few heuristics were proposed for tackling maximally SRLG-disjoint path pairs of minimal cost lexicographic problems, considering variants of the objective functions or of the constraints and various resolution approaches. In particular, [2] presents two heuristics for tackling a lexicographic formulation of this type of problem which includes as additional objectives, of highest priority, that the paths are maximally node and arc disjoint.

In this work we address a bi-criteria formulation of the maximal SRLG-disjoint / minimal cost path pair problem, in the context of resilient routing design with path protection and propose an approach for exact calculation of non-dominated solutions to this problem. The resolution method, for the formulated bi-criteria optimization problem, is based on an exact combinatorial algorithm already developed, that enables the optimal solution to the lexicographic version of the problem, to be to obtained. This base algorithm is a lexicographic minimal label-minimal cost path pair algorithm which combines a path ranking method - where possible paths are ranked by increasing order of cost by using the ranking algorithm [3] - and a path labeling method. Note that the lexicographic formulation is the most commonly used by network designers. However, we think that by considering the proposed bi-criteria formulation, the choices of the network designer are clearly widened, enabling the exploration of trade-offs between the minimisation of failure risks and path pair load costs, which may be conflicting objectives. Therefore, we extended our lexicographic algorithm, in order to obtain exact non-dominated solutions, of the bi-criteria problem, in a set of solutions generated by the lexicographic algorithm. Note that these nondominated solutions constitute a sub-set of the whole non-dominated solution set. We will consider two variants of the selection process of non-dominated solutions, to be presented to the network designer, so that he/she may make a final choice according to his/her system of preferences. In the first variant, the non-dominated solutions are selected in the set of all solutions generated throughout the algorithm execution, until the lexicographic optimum was found. In the second variant we will seek non-dominated solutions which satisfy a pre-defined upper-bound in terms of risks common to the AP and the BP, that is, by considering a small relaxation with respect to the minimal number of common risks. The selection of the sub-set of non-dominated solutions, in both variants, is performed by using the algorithm in (4).

We will begin by reviewing the base lexicographic algorithm –a lexicographic minimal label-minimal cost path pair algorithm – which combines a path ranking method and a path labeling method. Some experiments for evaluating the algorithm performance, obtained in virtual networks constructed over the classical US–NSF reference network topology, considering various distributions of random SRLG assignments to the links and given the link occupancies, also randomly generated, will also be shown. Also preliminary results concerning the performance, in terms of computing times, and typical trade-offs obtained with the bi-criteria solutions, will be presented and discussed, for some reference test networks. Finally, some conclusions from this on-going research theme, as well as further work, will be outlined.

Palabras Clave: Resilient routing models; Bi-criteria optimization; Telecommunication network design; Pathpair ranking.

Referencias:

1- J. Q. Hu, "Diverse routing in optical mesh networks," *IEEE Transactions on Communications*, vol. 51, no. 3, pp. 489–494, March 2003.

2- T. Gomes, L. Jorge, P. Melo, R. Girão Silva – Maximally node and SRLG disjoint path pair of minsum cost: a lexicographic approach, in *Photonic. Network. Communications*, (2016) 31:11-22, 2016.

3- E. Martins, M. M. B. Pascoal, and J. Santos. Deviation algorithms for ranking shortest paths. *The International Journal of Foundations of Computer Science*, 10(3):247–263, 1999.
4- Clímaco, J.; E. Martins, "A Bicriteria Shortest Path Algorithm", *European Journal of Operational Research*, vol. II, 1982.

Agradecimientos: This work has been supported by the Fundação para a Ciência e Tecnologia (FCT) under project grant UID/MULTI/00308/2013.