Graph-theoretic challenges in the Design of Survivable Optical Networks

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We discuss two graph-theoretic problems that originate from cooperations with T-Systems International and Telekom Austria on the design of survivable optical networks.

We start with an introduction on optical network design. The input of an optical network design problem consists of (i) a network topology, (ii) a traffic network which specifies the demand for each pair of nodes as number of lightpaths to establish, (iii) a survivability matrix which specifies for each pair of nodes the number of connections that should survive any node or link failure, and (iv) the existing and purchasable (optical) devices: fibers, WDM-systems, OXCs, regenerators, and wavelength converters. The objective is to design a minimum cost transparent optical network configuration such that the installed devices provide enough capacity to establish a set of lightpaths in a conflict-free manner, which on their turn suffice to handle the traffic in all the cases in which at most one node or link fails.

A mathematical problem analysis exhibits that the problem is too complex to handle by state-of-the-art integer programming techniques (it contains both the integer multi-commodity flow and the vertex coloring problem as sub-problems). Therefore, we use the availability of wavelength converters to decompose the problem into a dimensioning and routing part and a wavelength assignment part.

Within the dimensioning and routing subproblem, we have to guarantee that in case of a node or link failure the sustainable traffic is accommodated. We discuss a recently introduced concept for the ressource-efficient design of survivable meshed optical networks called Demand-Wise Shared Protection (DSP). It takes advantage of the connectivity in meshed topologies to lower the capacity consumption. We study theoretical and computational aspects of this concept and suggest ideas for further research.

The wavelength assignment subproblem generalizes both vertex and edge coloring. Where most work in the literature has been done in the direction of vertex coloring, we derive a combinatorial lower bound on the number of converters by generalizing the theory of edge coloring. We address open questions on generalized coloring within this context.