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The Design of Transparent Optical Networks Minimizing the Impact of Critical Nodes

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Abstract

For a given fiber network and a given set of client demands, the transparent optical network design problem is the task of assigning routing paths and wavelengths for a set of lightpaths able to groom all client demands. We address this design problem minimizing the impact of a given set of critical nodes. The problem is tackled in two steps: first, we minimize the demand that is disrupted by the simultaneous failure of all critical nodes; second, we minimize the network design cost guaranteeing that the minimum disrupted demand is met. We present MILP models for each step, together with valid inequalities strengthening both models. For the second step, an efficient hybrid heuristic is also proposed.

Keywords: Optical Networks, GRWA, Mixed Integer Linear Programming, Valid Inequalities, Critical Nodes.

1 Introduction

Disaster based failures can seriously disrupt a telecommunication network due to natural, technology or human causes [1]. In such cases, it is important not only to quickly recover the failing elements but also to minimize the impact

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on the connectivity between nodes not affected by the disasters [2]. One way to improve the network preparedness to disasters is to consider the impact of a given set of critical nodes that, due to some reason, have an high risk of simultaneous failure. We address the design of a transparent optical network minimizing the impact of a given set of critical nodes. The problem considers the combination of the grooming, routing and wavelength assignment (GRWA) problems assuming a transparent optical network, single hop grooming, client demands of a single interface type, and two types of lightpaths.

Different GRWA design problems have been addressed in the literature. In [3], a maximum number of lightpaths on each node is imposed and the aim is the throughput maximization. In [4], the aim is the number of lightpaths minimization and, for larger instances, the paper considers the decomposition of the problem in two subproblems: Grooming (G) + Routing and Wavelength Assignment (RWA). Some works [5],[6] do not consider the wavelength continuity constraints, while others [5],[7] use a reduced set of candidate paths to make the methods scalable for larger instances. In [8],[9], the GRWA problem is addressed considering two types of lightpaths. In [8], an heuristic is proposed based on the decomposition of the problem in two subproblems: Grooming and Routing (GR) + Wavelength Assignment (WA). In [9], a hybrid heuristic method, based on mixed integer linear programming, is proposed which is able to provide solutions with optimality gaps well below 1% for realistic fiber link capacities of 80 wavelengths, far beyond previous approaches. In here, we use [9] as the starting point to define and solve the design of a transparent optical network minimizing the impact of a given set of critical nodes.

The paper is organized as follows. Section 2 describes the original formulation for the GRWA network design problem. Section 3 presents our approach considering critical nodes. The computational results are presented and discussed in Section 4. Finally, Section 5 presents the main conclusions.

2 The Design Problem without Critical Nodes

Consider a fiber network defined by the graph $G = (N, E)$ such that the spectrum of each fiber $e \in E$ is organized in a set T of $|T|$ wavelengths. Consider a set of demand pairs D with at least one client demand. Each $d \in D$ is defined by a pair of end nodes in G and an integer demand value v_d with the aggregated number of client interfaces that must be supported between its end nodes. To support the demands of each $d \in D$, consider two types of lightpaths (type 1 and 2) that can be set on the network, defined by their capacities δ_1 and δ_2 (in number of client demand interfaces), respectively,