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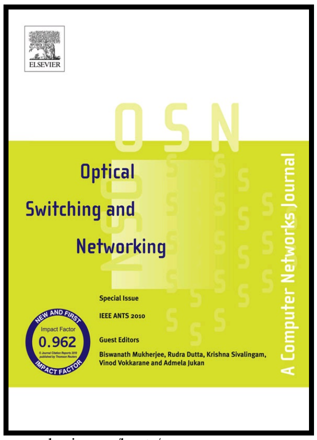

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On the Comparative Efficiency of Non-Disruptive Defragmentation Techniques in Flexible-Grid Optical Networks

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Abstract

The presence of dynamic traffic in optical networks can lead to spectrum fragmentation, which significantly reduce the network performance. This problem is exacerbated in flexible grid optical networks, since the heterogeneity of channel spectral widths increases the misalignment of the available slots along the optical connections. To overcome this problem, several techniques have been devised for providing defragmentation in these networks. Spectral defragmentation aims to create large contiguous free areas in optical spectrum through rerouting or spectral reassignment of existing connections. In this paper, we revisit the push-pull and hop tuning techniques, assessing them over an unified framework under equal conditions to properly evaluate their comparative efficiency in releasing network resources. This framework also includes the re-planning technique as a lower bound benchmark for the push-pull and hop tuning. To this effect, we propose Integer Linear Programming (ILP) models and heuristic algorithms to study the effectiveness of these techniques and present a performance analysis based on spectrum usage. The relative performance of the different defragmentation techniques was validated under varying network scenarios, including an assessment of how different planning methods and policies impact the effectiveness of each defragmentation technique. Aside from benchmarking the potential spectrum efficiency gain in each non-disruptive defragmentation technique, this analysis also revealed that the gains associated with them are greatly influenced by how the networks were originally planned.

Keywords: Defragmentation, Flexible grid, ILP, Network Planning

1. Introduction

Optical flexible grid networks, also known as elastic optical networks, differ from the conventional Dense Wavelength Division Multiplexing (DWDM) networks in the sense that the spectral width of the optical channels can be adjusted individually, in contrast with the constant width associated with ITU-T 50 GHz spectral grid [1]. This adjustment is carried out by subdividing that grid into a more granular structure of spectral slots and allocating to each optical channel only the appropriate number of contiguous slot units. These slot units, with central frequencies standardized by ITU-T G.694.1, may assume a granularity of 12.5 GHz, and can be seen as the basic building blocks for spectrum assignment in flexible grid networks [2].

In these networks, an optical path associated with a given connection request is established by assigning a proper number of spectral slots on all links traversed by the path. The Routing and Spectrum Assignment (RSA) problem is concerned with the choice of a path, and the assignment of these slots taking into account the spectral continuity constraint and guaranteeing that the slots of different optical paths do not overlap in the same network links [3], [4]. The spectral continuity constraint imposes that the same spectral slots must be allocated in all the links of the path and its effect is especially problematic in dynamic environments, where the constant setting up and tearing down of connections can lead to spectrum fragmentation, wherein the free spectral slots in different links get misaligned, which causes problems in the establishment of new optical paths.

Although the problem of fragmentation is already present in fixed-grid networks ([5]-[7]) as well, its impact is particularly challenging for flexible grid networks, since the heterogeneity of the channel spectral

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