Chapter 10
Waveband Switching:
A Scalable and Cost Efficient Solution for the Internet Backbone

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ABSTRACT

In this chapter, the authors describe and review some of the recent research on WBS, including Multi-Granular optical cross-connect (MG-OXC) architectures that can switch traffic at different granularities. The authors focus on the dynamic online WBS problem, and describe and analyze two reconfigurable MG-OXC architectures in terms of their port count and blocking probabilities. Based on the analyses, the authors then propose a novel dynamic graph-based waveband assignment algorithm in conjunction with adaptive routing. The proposed algorithm employs ant optimization techniques to reduce ports and blocking probability in the network with online traffic in a distributed manner. The authors use simulation experiments to evaluate the effectiveness of the authors' approach under various parameters such as varying number of ants, varying the number of routes and the wavelength assignment algorithm. The authors' simulation results show that their graph-based waveband assignment algorithm combined with adaptive routing can achieve a superior performance when compared to other schemes. Furthermore, the authors' studies shows that even with limited resources, WBS can achieve a low blocking probability and port savings.

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INTRODUCTION

In recent years, the role and importance of backbone communication networks has significantly increased due to the exponential growth of the Internet and Internet-based services and applications such as IPTV, VoIP and P2P, and more recently large-scale science collaborations and Cloud-based services. Backbone communication networks typically support traffic between large, strategically interconnected networks and core routers in the Internet. Optical fiber networks using wavelength division multiplexing (WDM) technology are the foremost solution to meet this ever-growing traffic demand, and to support higher layer networks such as the Internet Protocol (IP) network. Using WDM each optical fiber can carry more than 100 wavelengths, with each wavelength supporting 100 Gbits/s or higher (Mukherjee, 2006) traffic. While the use of WDM technology has significantly increased the available bandwidth in backbone networks, the rapid advances in dense WDM technologies with hundreds of wavelengths per fiber and world-wide fiber deployment has brought about a tremendous increase in the cost and size of electronic cross-connects or DXCs (e.g., OEO grooming switches).

Optical (photonic) cross-connects (OXCs) that switch bypass traffic all-optically are useful in reducing the cost and size of the OEO grooming switches. However, when the number of wavelengths is large traditional OXCs that switch traffic *only* at the wavelength granularity themselves can become huge (i.e., requiring a large number of wavelength ports), resulting in increased cost and control complexity. Waveband switching (WBS) in conjunction with new multi-granular optical cross-connects (or MG-OXCs) that can switch traffic at fiber, waveband and wavelength granularities has been proposed to reduce this cost and complexity (Lee, Yu, Kim, Kang, & Park (2002); Noirie, Gorgeuille, & Bisson (2002); Cao, Anand, & Qiao (2003)). The main idea of WBS is to group several wavelengths together as a band, and switch the band using a single port whenever possible (e.g., as long as it carries only bypass or express traffic), and demultiplex it to switch the individual wavelengths only when some traffic needs to be added/dropped. As the bypass traffic accounts for up to 60% to 80% of the total traffic in the backbone, only a limited number of fibers and bands need to be demultiplexed into wavelengths. Thus, not only the size of wavelength cross-connects, but also the overall number of ports and complexity of the MG-OXCs can be reduced by using waveband switching.

In this work, we review the challenges in designing WBS optical networks. We describe our and other related work on designing MG-OXC architectures and algorithms for WBS to accommodate dynamic traffic demands. We also provide mathematical analyses and bounds on the number of required ports and blocking probabilities of various WBS algorithms and architectures. In particular, we develop architectures and algorithms for dynamic WBS to decrease the blocking probability of dynamic traffic. We present our distributive ant-based route optimization and the associated graph-based waveband assignment algorithms to carry dynamic traffic requests in WBS networks so as to minimize the blocking.

BACKGROUND AND RELATED WORK

The concept of WBS based on two stage multiplexing was applied to WDM ring networks in Gerstel, Ramaswami, and Wang (2000), while its merits such as small-scale modularity, crosstalk and complexity reduction were summarized in Harada, Shimizu, Kudou, and Ozeki (1999). A Three-Layer switching fabric consisting of a fiber cross-connect (FXC), a band cross-connect (BXC) and a wavelength crossconnect (WXC) was presented in Noirie, Vigoureux, and Dotaro (2001), and the application of such Three-Layer MG-OXC architectures to metro-area networks was described in Noirie, Gorgeuille, and Bisson (2002). For such multi-Layer MG-OXCs,