Chapter 6

WAVEBAND SWITCHING: A NEW FRONTIER IN OPTICAL WDM NETWORKS

Xiaojun Cao¹, Vishal Anand², Yizhi Xiong¹, and Chunming Qiao¹

¹Department of Computer Science and Engineering, State University of New York at Buffalo, Amherst, NY 14226
²Department of Computer Science, State University of New York, College at Brockport, Brockport, NY

Email: xcao2@cse.buffalo.edu, vanand@brockport.edu, yxiong@cse.buffalo.edu, qiao@computer.org

Abstract

The rapid advances in dense wavelength division multiplexing (DWDM) technology with hundreds of wavelengths per fiber and world-wide fiber deployment have brought about a tremendous increase in the size (i.e., the number of ports) of photonic cross-connects, as well as in the cost and difficulty associated with controlling such large cross-connects. Waveband switching (WBS) has attracted attention for its practical importance in reducing the port count, associated control complexity, and cost of photonic cross-connects. In this chapter, we show that WBS is different from traditional wavelength routing, and thus techniques developed for wavelength-routed networks (including, for example, those for traffic grooming) cannot be directly applied to effectively address WBS-related problems. We describe a Three-layer multi-granular optical cross-connect (MG-OXC) architecture for WBS. By using this MG-OXC in conjunction with intelligent WBS algorithms, we show that one can achieve considerable savings in the port count. We present various WBS schemes and lightpath grouping strategies. Finally we discuss issues related to waveband conversion and failure recovery in WBS networks.

Keywords: Wavelength division multiplexing, Waveband switching, Multi-granular optical networks

6.1 Introduction

Optical networks using wavelength division multiplexing (WDM) technology, which divides the enormous fiber bandwidth into a large number of wavelengths, is a key solution to keep up with the tremendous growth in data traffic
demand. However, as the WDM transmission technology matures and fiber deployment becomes ubiquitous, the ability to manage traffic in a WDM network is becoming increasingly critical and complicated. In particular, the rapid advance and use of dense WDM technology has brought about a tremendous increase in the size of photonic (both optical and electronic) cross-connects. The number of ports in a cross-connect is the most significant contributor to the cross-connect size and hence, the cost. Furthermore, owing to their large size the control and management of these cross-connects is also becoming formidable task. Hence, despite the remarkable technological advances in building photonic cross-connect systems and associated switch fabrics, the high cost (both capital and operating expenditures) and unproven reliability of huge switches have hindered their deployment.

The concept of wavelength band switching (WBS) (or simply waveband switching), has been proposed to reduce this complexity to a reasonable level. The main idea of WBS is to group several wavelengths together as a band and switch the band (optically) using a single port. In this way, not only the size of digital cross-connects or DXCs (e.g., the OEO grooming switches) can be reduced because bypass (or express) traffic can now be switched optically, but also the size of optical cross-connects (OXCs) that traditionally switch at the wavelength level can be reduced because of the bundling of lightpaths into bands in WBS networks. In this chapter, we focus on the use of WBS to reduce the size of the multi-granular optical cross-connect (MG-OXC) [1, 2, 3, 4, 5, 6], which is a part of the multi-granular photonic cross-connect (see Figure 6.1 for an example).

WBS differs from conventional wavelength routing in several ways, one for example is that each has different objectives. Accordingly, techniques developed for wavelength-routed networks (including for example, those for traffic grooming) cannot be directly applied to effectively address WBS-related problems. More specifically, in networks employing ordinary-OXC, the routing and wavelength assignment (RWA) problem is to find a route for a lightpath and assign a wavelength to it. One of the key objectives of the traditional RWA algorithms is to minimize the total number of wavelength-hops (WHs) or the maximum number of wavelengths required to satisfy a given set of lightpath requests, which is known to be NP-complete [7, 8, 9]. In this chapter, we study the optimal WBS problem, with its main objective being to route lightpaths and assign appropriate wavelengths to them so as to minimize the total number of ports required by the MG-OXCs. As to be shown, even though traditional RWA is still an important component of WBS, new waveband assignment algorithms need to be developed in order to effectively achieve the objective.

The rest of the chapter is organized as follows. We first describe a Three-layer MG-OXC architecture for WBS, and presents various WBS schemes and lightpath grouping strategies. We then explain how WBS differs from wave-