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# A novel dynamic RWA algorithm with intelligent granularity regulation in multi-granular all-optical networks

Ching-Fang Hsu *

*Department of Computer Science and Information Engineering, National Cheng Kung University, 1, Ta-Hsueh Road, Tainan 701, Taiwan*

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**Abstract**

With the great advances of DWDM technology, optical cross-connects have to deal with much more wavelengths. Accordingly, the size of optical cross-connects become larger and larger; also the management cost is much higher. To simplify the architecture of cross-connects for low-complexity maintenance, waveband switching (WBS) in conjunction with several optical cross-connect architectures have been proposed and attracted much attention recently. The main concept of WBS is to group multiple wavelengths into a single waveband and what it concerns includes cross-connect cost and port count reduction. In this paper, we investigate the dynamic RWA problem (MG_DRWA) in WBS networks comprising of all-optical switches based on a cost-effective multi-granular optical cross-connect (MG-OXC) architecture. With this reconfigurable architecture, an optical cross-connect can switch at either fiber level, waveband level, or wavelength level according to its configuration. In order to effectively accommodate dynamic traffic demand, we propose a new MG_DRWA algorithm. Numerical results reveal that the proposed algorithm can achieve significantly better blocking performance as compared to a previously proposed algorithm named MILB under various traffic loads.


*Keywords:* RWA; WBS, Waveband switching; MG-OXC, Multi-granular optical cross-connect

## 1. Introduction

Effectively exploiting tremendous bandwidth provisioned by fibers makes wavelength-division multiplexing (WDM) the most promising technology for the Internet backbone deployment [1,2]. With the advances of dense wavelength-division multiplexing (DWDM), a fiber can provide more than 100 wavelength channels and each channel can operate at several Gbps under current technologies. As the multiplexing degree increases, it incurs another side effect that the number of ports of optical cross-connects rapidly rises and the architecture becomes more complicated as well.

To reduce the aforementioned complexity of switch architectures, a concept called waveband switching (WBS) has been proposed recently [3–8]. It deals with wavebands, a mediate granularity between fibers and wavelengths. The key idea of WBS is to aggregate wavelengths in a fiber into several groups and each one is called a band. Several features result in variations of WBS schemes. For instance, whether a fiber contains fixed or variable number of wavebands can classifies WBS schemes into two categories. Further, either one can be divided according to the flexibility of the number of wavelengths in a waveband. The way of determining which wavelengths compose a waveband provides another aspect of classification. In [4], authors used a diagram similar to Fig. 1 to depict the overall classification of WBS schemes.

As we know, RWA is the most critical issue in wavelength-routed networks [9,10]. Generally speaking, the primary objective of traditional RWA algorithms is to minimize the maximum required wavelengths for a given amount of traffic demand (or, in other words, to accommodate as much traffic load as possible under a fixed number of wavelengths) [11]. As indicated in [12], in addition to the diverse OXC architectures, the most significant difference

* Tel.: +886 6 2757575x62535; fax: +886 6 2747076.
*E-mail address:* cfhsu@mail.ncku.edu.tw

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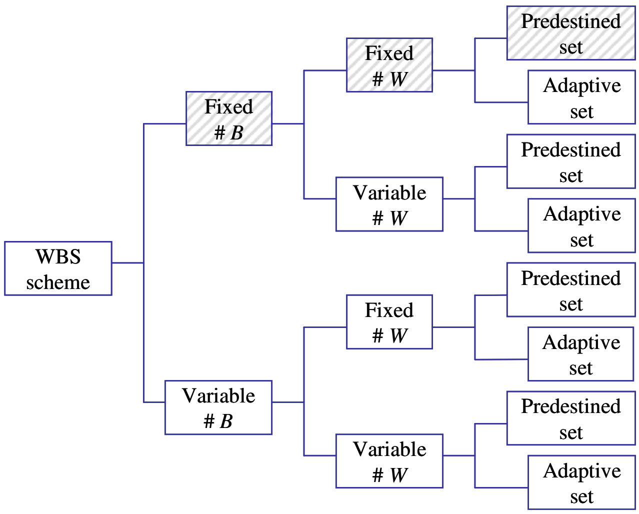


Fig. 1. Waveband switching schemes.

between traditional RWA algorithms and RWA algorithms in WBS networks lies in their main objectives. Solutions to RWA problem in WBS networks aims at minimizing the total number of consumed OXC ports for a given connection request so that more resources, i.e., OXC ports, can be left to subsequent demand. Consequently, RWA algorithm design for WBS networks cannot inherit that for wavelength-routed networks without any innovation. In short, a new scheme indeed should be initiated for WBS networks.

A multi-granular optical cross-connect (MG-OXC) is an optical cross-connect which can handle multiple granularities in optical domain. The MG-OXC architecture design is a decisive factor of the performance of WBS networks. In the past few years, several architectures have been proposed. For instance, in [13], a scalable MG-OXC design expanding the switching capability of OXC with waveband- and fiber-switching components were proposed. Moreover, Lee et al. addressed a hierarchical cross-connect design employing a two-stage multiplexing scheme of waveband and wavelength in [14]. It also takes wavelength conversion into consideration. Furthermore, an OXC with similar consideration was designed using an AWG router in [15]. As to the work completed in [12,16,17], two architectures were investigated; one is three-layer MG-OXC and the other is single-layer MG-OXC. The authors concluded that single-layer MG-OXC is more suitable for static traffic demand while three-layer MG-OXC performs better with dynamic traffic.

The rest of this paper is organized as follows. Section 2 introduces the three-layer MG-OXC architecture proposed in [4] which is adopted in our work and a previous RWA algorithm proposed in [16]. In Section 3, the multi-granular dynamic routing and wavelength assignment (MG-DRWA) problem we investigated is formally defined and details of the proposed algorithm are described as well. Section 4 demonstrates performance evaluation by simulation and gives discussion on numerical results. Finally, we give conclusions in Section 5.

## 2. Related work

In this section, we first introduce the reconfigurable MG-OXC architecture used in this work. Next, the earliest RWA heuristic algorithm for dynamic traffic named MILB is briefly described. In addition, we would use some examples to point out why this heuristic can be further improved.

### 2.1. Reconfigurable MG-OXC architecture

Assume that the number of bands in a fiber is denoted by $B$. Fig. 2 illustrates the reconfigurable MG-OXC architecture proposed in [16]. Three cross-connect granularities were defined in this architecture: fiber layer (FXC), waveband layer (BXC), and wavelength layer (WXC). Each layer takes charge of switching operations in the corresponding granularity. At FXC, there are X fiber links from/to neighbor node and $\alpha$ is the ratio for these fibers to be demultiplexed into bands to BXC, i.e., $\lceil \alpha X \rceil$ is the number of fiber-to-band (FTB) ports. Owing to the symmetry feature of this architecture, the number of band-to-fiber (BTF) ports is $\lceil \alpha X \rceil$ as well. More over, the total number of input bands from FTB demultiplexers at BXC is Y. Similarly, $\beta$ is the ratio for input bands to be demultiplexed into wavelengths to WXC and trivially $\lceil \beta Y \rceil$ is the number of band-to-wavelength (BTW)/wavelength-to-band (WTB) ports. Lightpaths are added/dropped at the WXC layer using the $W_{add}/W_{drop}$ ports of the WXC. Because of the high flexibility feature of the reconfigurable MG-OXC, the heuristic algorithm design in our work is based on this architecture. Note that in single fiber systems, we should set $\alpha = 1$ so that all input fibers can be demultiplexed to BXC and significant blocking performance reduction can be avoided [16]. Hence we assume

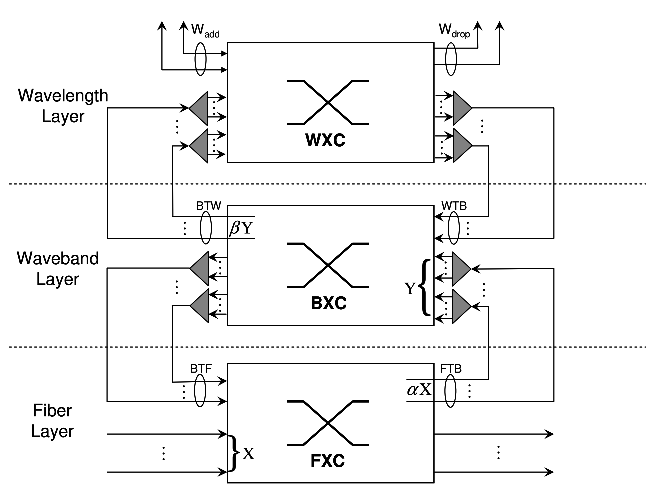


Fig. 2. A reconfigurable MG-OXC architecture.