Optical Switching and Networking 15 (2015) 97–110

Contents lists available at ScienceDirect

Optical Switching and Networking

journal homepage: www.elsevier.com/locate/osn

A routing and wavelength assignment scheme in multi-carrier-distributed optical mesh networks with wavelength reuse

Praphan Pavarangkoon*, Nattapong Kitsuwan, Eiji Oki

Department of Communication Engineering and Informatics, The University of Electro-Communications, 1-5-1 Chofugaoka, Chofu, Tokyo 182-8585, Japan

ARTICLE INFO

Article history:
Received 21 January 2014
Received in revised form
21 May 2014
Accepted 4 July 2014
Available online 15 July 2014

Keywords:
Wavelength division multiplexing
Multi-carrier light source
Optical carrier regeneration
Routing
Wavelength assignment

ABSTRACT

This paper proposes a routing and wavelength assignment (RWA) scheme that minimizes the number of required wavelengths for wavelength-reusable multi-carrier-distributed (WRMD) mesh networks. These networks have two unique features. First, only one light source, called the multi-carrier light source (MCLS), is required, which eases the difficulty of controlling many light source devices. Second, optical carriers are reused to improve the efficiency of wavelength usage. Since there are differences between the WRMD network and the conventional network, an efficient RWA scheme for the WRMD network is needed for wavelength-resource-efficient lightpath establishment. To realize efficient wavelength usage, we first formulate the RWA problem as an integer linear programming (ILP) problem of obtaining the minimum number of required wavelengths to satisfy the given requests. For large-scale networks, the ILP approach is not practical solution times. A heuristic RWA scheme is introduced in this paper to solve the RWA problem. Simulation results show that the proposed heuristic scheme with two carrier regenerations for the WRMD network approaches the near-optimum number of wavelengths. In addition, the optimum placement of the MCLS node is shown to reduce the number of required wavelengths for lightpath establishment, and achieve the optimum number of wavelengths.

1. Introduction

Wavelength division multiplexing (WDM) technology has been identified as a suitable candidate for future wide area network (WAN) environments due to its potential ability to meet rising demands for high bandwidth and low latency communication [1]. Conventional WDM networks have no wavelength reuse capability, see Fig. 1(a), so more laser diodes (LDs) are needed to provide sufficient wavelengths to meet the explosive demand for network bandwidth. This, unfortunately, will raise energy consumption and implementation cost. Moreover, the complexity of optical carrier management increases with the number of wavelengths [2]. In other words, it will be difficult to adequately control the wavelengths of the huge number of LDs, since each wavelength of each LD has to be adjusted individually to satisfy the extremely narrow channel space.

A multi-carrier-distributed optical network with wavelength reuse capability [3,4] is an attractive solution. This network is called the wavelength-reusable multi-carrier-distributed (WRMD) network. The WRMD network places a multi-carrier light source (MCLS) in an MCLS node, as the

* Corresponding author. Tel.: +81 424435206.
E-mail addresses: praphan@uec.ac.jp (P. Pavarangkoon), kitsuwan@uec.ac.jp (N. Kitsuwan), eiji.oki@uec.ac.jp (E. Oki).

http://dx.doi.org/10.1016/j.osn.2014.07.001
1573-4277/

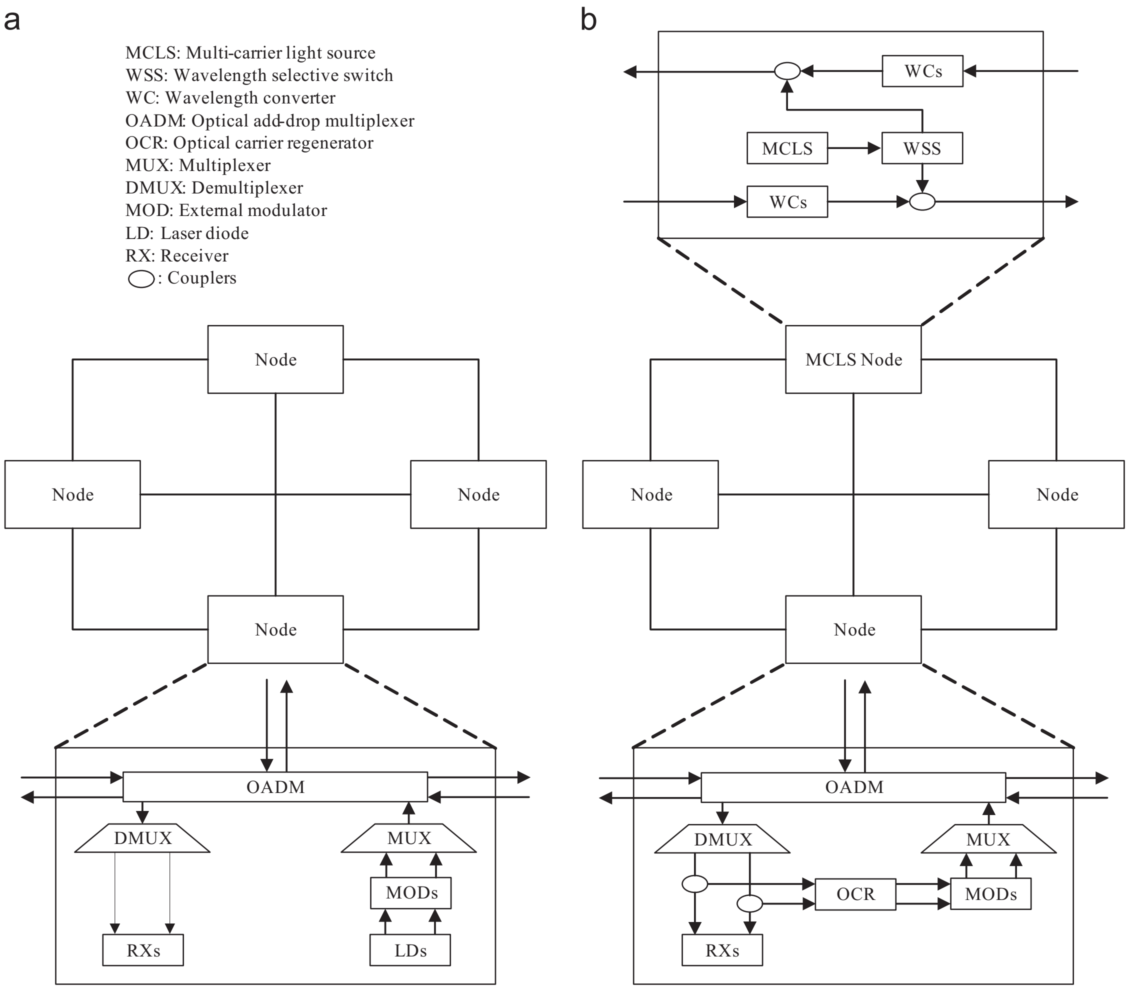

Fig. 1. Network architectures. (a) WDM network without wavelength reuse. (b) WRMD network with wavelength reuse.

communication light source device. The MCLS generates stable and multiple optical carriers at the same time over long periods [5–8]. The individual wavelengths are used as optical carriers. MCLS generates the optical carriers and passes them to all requesting source nodes for lightpath establishment. By replacing many widely dispersed LDs with the single MCLS, the difficulties posed by monitoring and controlling a large number of LDs are eliminated. The single MCLS is easier to control. Furthermore, each node in the WRMD network is equipped with an optical carrier regenerator (OCR) [3]. The OCR allows the nodes to reuse a wavelength to satisfy multiple disjoint lightpath requests. However, the number of transmission span and the transmission length limit the available number of OCR nodes [9]. The work in [9] experimentally investigated the scalability of the WRMD ring network. The WRMD mesh network also requires to be assessed from a transmission point of view.

The wavelength management in the WRMD network is more complex than that in the conventional WDM network, since the routing and wavelength assignment (RWA) schemes in the WRMD network must take into account both optical carrier connections and requested lightpaths while maximizing the reuse of the optical carrier connections. Therefore, an efficient RWA scheme is needed for the WRMD network. This paper assumes that lightpath setup requests are statically given in advance, and focus on the RWA algorithms with the static scenario.

Wavelength assignment for the WRMD ring network was presented in [4]. None of the source nodes includes an LD. Each requested lightpath directly receives a generated optical carrier from the MCLS node or a reused optical carrier from the destination node of other requested lightpath. Therefore, the source node has several light sources from which it can receive an optical carrier. Carrier distribution has to be managed so as to minimize the number of wavelengths.

In the ring topology, an optical carrier connection, which connects the MCLS node and a requested lightpath, or between two requested lightpaths, is uniquely determined because the connecting direction is limited [10]. It is very simple to select the optical carrier connection since there are only two possible paths, which are the clockwise and anticlockwise directions.

On the other hand, in the mesh topology, there are several paths, called carrier lightpaths, for one optical