Available online at www.sciencedirect.com
ScienceDirect
Journal of Network and Computer Applications 31 (2008) 47–65
Journal of NETWORK and COMPUTER APPLICATIONS
www.elsevier.com/locate/jnca

Multicast routing and wavelength assignment with delay constraints in WDM networks with heterogeneous capabilities ☆

Ming-Tsung Chen[a], B.M.T. Lin[b,c,*], Shian-Shyong Tseng[a]

[a]*Department of Computer and Information Science, National Chiao Tung University, Hsinchu 300, Taiwan, ROC*
[b]*Department of Information and Finance Management, National Chiao Tung University, Hsinchu 300, Taiwan, ROC*
[c]*Institute of Information Management, National Chiao Tung University, Hsinchu 300, Taiwan, ROC*

Received 1 September 2005; received in revised form 3 July 2006; accepted 7 July 2006

Abstract

Because optical wavelength division multiplexing (WDM) networks are expected to be realized for building up backbone in the near future, multicasting in WDM networks needs to be addressed for various network applications. This paper studies an extended multicast routing and wavelength assignment (RWA) problem called multicast routing and wavelength assignment with delay constraint (*MRWA-DC*) that incorporates delay constraints in WDM networks having heterogeneous light splitting capabilities. The objective is to find a light-forest whose multicast cost, defined as a weighted combination of communication cost and wavelength consumption, is minimum. An integer linear programming (ILP) model is proposed to formulate and solve the problem. Experimental results show that using *CPLEX* to solve the ILP formulation can optimally deal with small-scale networks. Therefore, we develop a heuristic, *near-k-shortest-path heuristic* (*NKSPH*), to solve the problem in large-scale networks. Numerical results indicate that the proposed heuristic algorithm can produce approximate solutions of good quality in an acceptable time.

Keywords: WDM network; Multicasting; Wavelength assignment; Delay bound; ILP; Heuristics

☆This work was partially supported by MOE Program for Promoting Academic Excellence of Universities under grant number 89-E-FA04-1-4, High Confidence Information Systems.

*Corresponding author. Department of Information and Finance Management, National Chiao Tung University, Hsinchu 300, Taiwan, ROC. Tel.: +886 3 5131472; fax: +886 3 5729915.
E-mail address: bmtlin@mail.nctu.edu.tw (B.M.T. Lin).

1084-8045/$ - see front matter
doi:10.1016/j.jnca.2006.07.002

1. Introduction

Based on optical technology in optical networks (Green, 1992), a high-capacity telecommunication network can be constructed to provide routing, grooming, and restoration at wavelength level. The technology of wavelength division multiplexing (WDM) network (Lowe, 1998), based on optical wavelength-division multiplexing on optical fibers of optical network to form multicommunication channels at different wavelengths with electronic processing speed, provides connectivity among optical components to let optical communication meet the increasing demands for high channel bandwidth and low transmission delay. The utilization of wavelength for routing data is referred as *wavelength routing*, and an optical switch employing the technique is called a *wavelength-routing switch*. Therefore, in a wavelength-routing WDM network constructed using optical fiber links to connect the input ports and the output ports of wavelength-routing switches, data can be routed to other optical switches based on wavelengths of optical fibers. If the transmission between the input port and the output port of a switch involves two different wavelengths, the switch must be able to perform wavelength conversion.

In the (wavelength-routing) WDM network, a *light-path* (Chlamtac et al., 1992), a connection based on wavelength to carry data without optical-to-electrical conversion, would be set up in a way similar as circuit-switched networks to transmit data among (wavelength-routing) switches. The collection of light-paths is referred as a logical topology of a WDM network for transmitting optical signals. The cost of utilized wavelengths and the delay time of transmitting optical signal to a destination by a light-path are referred as *communication cost* and *transmission delay* of the light-path, respectively. The communication cost may depend on the numbers or the costs of fibers and switches used for establishing the connection.

Many network applications, such as videoconferencing, video on demand system, real-time control, on-line shopping, gaming, stock exchanging, and so on, have inspired new communication models. *Multicasting* is one of the most important models used to send data (messages) from a single source to multiple destinations. So far, two schemes (Zhang et al., 2000), *multiple-unicast* and *multicast*, have been employed to route data. The multiple-unicast scheme is a virtual topology consisting of a set of light-paths from the source to all destinations, where the number of light-paths equals the number of destinations. If there exists one link shared by more than one light-path, each light-path would need one different wavelength for routing data. As shown in Fig. 1(a), two light-paths, v_1–v_2–v_3 and v_1–v_2–v_4, would need two different wavelengths λ_1 and λ_2 because the

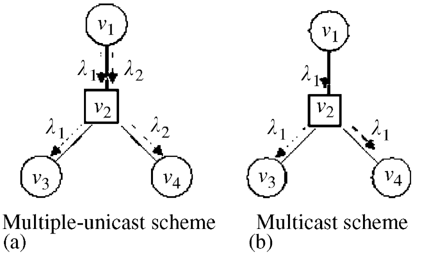

Fig. 1. Two multicast communication schemes: (a) multiple-unicast scheme and (b) multicast scheme.