Optical Fiber Technology 18 (2012) 490–497

Contents lists available at SciVerse ScienceDirect

Optical Fiber Technology

www.elsevier.com/locate/yofte

Regular Articles

Traffic grooming in WDM optical network with grooming resources at Max Connectivity nodes

Partha Paul [a], Balbeer Singh Rawat [a], S.K. Ghorai [b,*]

[a] Department of Computer Science, Birla Institute of Technology, Mesra, Ranchi 835 215, India
[b] Department of Electronics and Communication Engg., Birla Institute of Technology, Mesra, Ranchi 835 215, India

ARTICLE INFO

Article history:
Received 2 April 2012
Revised 23 June 2012
Available online 3 September 2012

Keywords:
WDM optical networks
GRWA
Wavelength assignment
Traffic grooming

ABSTRACT

In this paper, we propose Max Connectivity grooming in WDM mesh networks under static lightpath connection requests. The grooming and wavelength conversion resources are placed at the nodes having maximum connections. We propose a heuristic genetic algorithm (GA) model to solve grooming, routing and wavelength assignment. The GA algorithm has been used to optimize the cost of grooming and wavelength conversion resources. The blocking probability has been investigated under different lightpath connections. The performance of Max Connectivity grooming has been compared with other grooming policies. Our results indicate the improvement of resource utilization with minimum blocking probability.

1. Introduction

Optical network with wavelength division multiplexing (WDM) has been an active area of research, as it can meet the huge bandwidth requirement of internet and telecommunication data traffic through WAN, MAN or LAN. In WDM, multiple wavelengths are transmitted through a single fiber and the transmission capacity can be achieved as high as hundreds of terabit-per-second. Each wavelength can support a data rate of several gigabit per second (e.g. OC-192, OC-768, etc.). However, in practical networks, the traffic requested by an individual connection is in the range of megabits-per-second. Hence, a significant portion of transmission capacity of a wavelength channel would be wasted. For effective utilization of the bandwidth, traffic grooming mechanism is being used in the network where low speed traffic streams are multiplexed or groomed into high speed wavelength channels [1]. It minimizes the network cost by reducing the number of ADMs and the number of wavelengths used in the network. In WDM network, a lightpath must be established to carry traffic using a particular wavelength and proper route between a source node and a destination node. Although this routing and wavelength assignment problem (RWA) minimizes the connection blocking, but it cannot utilize the network resources effectively.

Traffic grooming with RWA resolves the network bandwidth problem more effectively. It provides provisioning connection requests of different bandwidth granularities on to wavelength channel of high bandwidth. The grooming node includes optical cross connects (OXCs), demultiplexers (DMUXs), multiplexers (MUXs) and/or digital cross connects (DXCs) that perform grooming as well as switching operations. These grooming resources efficiently multiplex several low speed traffic streams on to high capacity wavelength channels and also demultiplex those whenever required. In addition to grooming, these devices add connections, drop connections and also perform wavelength conversion using add drop multiplexers (ADMs) and wavelength converters (WCs).

In the beginning, the traffic grooming problems were implemented in ring networks [2–7], and later on, it has been focused on WDM mesh networks [1,8–12]. In WDM mesh networks, the traffic scenarios can be static, incremental or dynamic [13]. Also the traffic grooming can be single hop traffic grooming or multi hop traffic grooming depending upon the lightpaths used by a connection between source and destination. The traffic grooming problem has been addressed in WDM mesh networks by several groups of researchers for different traffic conditions. However, our work focuses on static traffic grooming in WDM mesh network. To maximize the network throughput, an integer linear programming (ILP) formulation was proposed in a six nodes irregular mesh network [1]. All the nodes have grooming capability and heuristic approaches were used to solve traffic grooming problem in large networks. A multi-objective evolutionary algorithm was reported to optimize multiple objectives at the same time in WDM mesh network [14]. It maximizes the throughput and minimizes the network cost and average hop counts. A decomposition method based an integer linear programming (ILP) was used in a large WDM mesh network [15]. It divides the traffic grooming, routing and wavelength assignment (GRWA) problem into two parts. One part

* Corresponding author. Fax: +91 651 2275401.
E-mail addresses: p_india@rediffmail.com (P. Paul), skghorai12@rediffmail.com (S.K. Ghorai).

1068-5200/$ - see front matter © 2012 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.yofte.2012.07.018

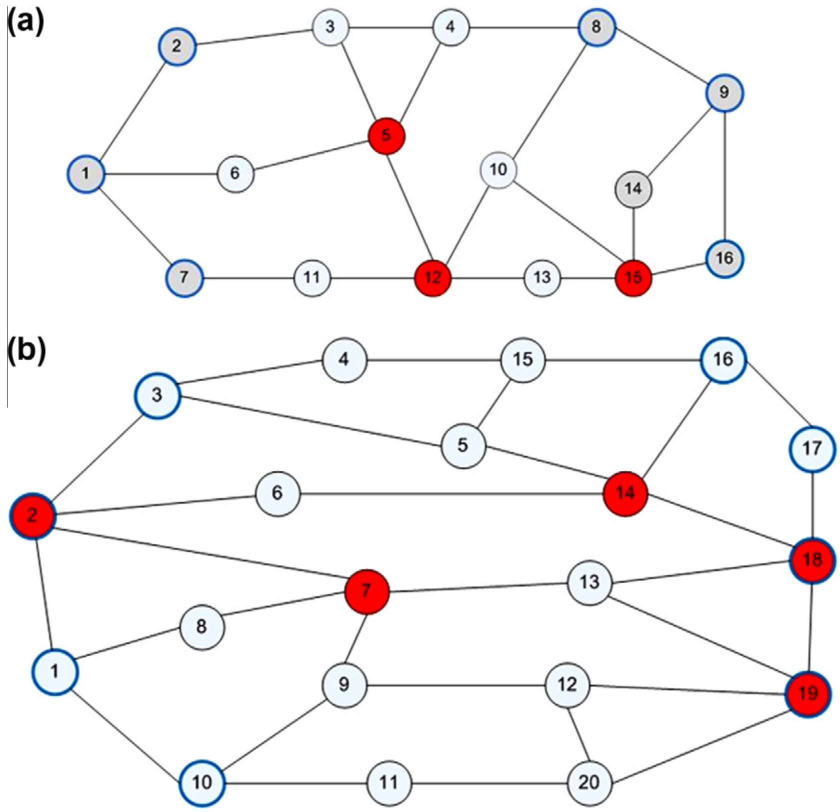

Fig. 1. (a) 16-Node WDM mesh network where (1, 2, 7, 8, 9 and 16) are edge nodes and (5, 12 and15) are maximum connectivity nodes and (b) 20-node WDM mesh network where (1, 2, 3, 10, 16, 17, 18 and 19) are edge nodes and (2, 7, 14, 18 and19) are maximum connectivity nodes.

is traffic grooming and routing problem and the other one is wavelength assignment problem. It produces an optimal solution under two considerations, one wavelength capacity constraint and the other one wavelength continuity constraint. Another decomposition method was reported where a large network is considered as a group of clusters [16]. A greedy heuristic algorithm has been used to groom intra-cluster traffic within each cluster. In order to reduce the network cost without affecting the network performance, edge grooming was proposed [17], where grooming resources are placed on the edge of optical networks instead of distributing throughout the network. The most contiguous heuristic algorithm was used to solve grooming problem without wavelength conversion resources and the genetic algorithm was used with wavelength conversion resources. An algorithm based on variant load balancing under the hose uncertainty model was investigated for multi-granularity WDM mesh networks [18]. It has been shown that minimizing path cost first performs better than maximize resources utilization first.

A fixed order multi-hop traffic grooming based on fixed alternate routing has been used to address grooming node selection in WDM optical network without wavelength conversion capabilities [19]. Unlike the previous decomposition approaches, a multilevel decomposition approach which decomposes traffic at four different levels has been proposed to evaluate the blocking performance. Recently, a heuristic algorithm called waveband grooming with layered auxiliary graph has been reported in multi domain optical networks to improve the scalability and to reduce the network cost [20]. The network is divided into two layers. The high layer is the virtual topology layer which includes inter-domain routing between the source node and destination node and the low layer includes the intra-domain routing in each single domain. A new multi-granularity traffic grooming algorithm based on integrated auxiliary graph has been proposed to reduce the cost and enhance resource utilization in WDM networks [21]. Multi-hop grooming and waveband switching are integrated to decrease the blocking probability and to save the network cost.

In the present work, we propose the Max Connectivity grooming in mesh network to solve GRWA problem under static lightpath request. In most of the previous works, grooming devices were placed all over the optical network except [17] where grooming resources are distributed at the edges of the network. Our study reveals that placing the grooming devices at the nodes having maximum connection is more cost effective than all grooming and edge grooming, and results similar blocking performance as achieved with edge grooming. Earlier, the maximum connectivity grooming has been used in unidirectional path switch ring network [22]. In our work, genetic algorithm (GA) has been used to solve grooming and wavelength assignment (GRWA) problem in WDM mesh network. The GA procedure is simple and easily applicable to large networks. It works on a large solution set (search space) which makes it more efficient than other approaches such as ILP, greedy heuristics approach, most contiguous heuristic algorithm and other heuristics proposed in the literature. In ILP, computation complexity increases with the increase in the size of the network due to the increase in the number of variables. Also all traffic requests must be known in advance for solving GRWA problem. Heuristic approaches are faster as compared to GA. However those are based on observations which may be invalid over time. Also, they are applied to some specific type of networks. Although greedy algorithm can be used for variety of networks, but it does not provide optimal solution with added constraints.

In Section 2, the formulation of GRWA problem with static traffic requests has been presented. Section 3 describes the GA approach to solve GRWA problem with maximum connectivity