QoS Based Survivable Logical Topology Design in WDM Optical Networks

G. Raghu Kiran, C. Siva Ram Murthy
Department of Computer Science and Engineering, Indian Institute of Technology, Madras, Chennai 600036, India
E-mail: kiran@dcs.iitm.ernet.in, murthy@iitm.ac.in

Received June 4, 2003; Revised and Accepted August 27, 2003

Abstract. The need to establish wavelength-routed connections in a service differentiated manner is becoming increasingly important. In the backbone network, support of quality of service (QoS) capabilities at the lightpath level will have to be addressed in the optical domain. Providing a service differentiated connection on an arbitrary virtual topology which does not support any differentiated services will lead to the misuse of network resources. We address the virtual topology design and routing problem, where we minimize congestion in the network. In our work, the service differentiating parameter is bit error rate (BER) in the optical domain. We present a mixed integer linear programming (MILP) formulation for the above problem. We also propose a heuristic based approach to minimize the congestion in the network while satisfying the QoS constraints. These QoS constraints in our case are the differing BER requirements for each connection between each (source, destination) pair. We then present different methods of providing survivability for the virtual topology and compare the performance of these methods.

Keywords: wavelength-routed connections, congestion, QoS, service differentiation, survivability

1 Introduction

Wavelength division multiplexed (WDM) networks are rapidly becoming a technology of choice to meet the tremendous bandwidth and reliability demands of the new millennium. A WDM network consists of routers connected by a set of wavelength cross connects (WXC) [1], as shown in Fig. 1. A WXC is used for switching traffic across lightpaths and an optical add drop multiplexer (OADM) is used for adding/dropping traffic to/from several wavelengths. The SONET Equipment/IP router, the WXC and the OADM together form a node. In a wavelength-routed network, data is sent from one node to another node using a wavelength continuous route called a lightpath, without requiring optical-electronic-optical conversion or buffering at any intermediate node. A set of such lightpaths form a virtual topology. Fig. 2 is an example virtual topology over the physical network shown in Fig. 1. It would be ideal if it is possible to establish a lightpath between every pair of nodes, but due to the constraints on network resources such as the number of wavelengths and transmitters, it is not practical. Hence, the problem of designing a virtual topology poses several challenges. Given a physical topology with resource constraints such as number of wavelengths and number of transmitters and receivers, and the long-term average traffic flow between node pairs, the problem is to design the virtual topology so as to optimize a certain metric such as congestion or message delay.

In every client layer network (SDH, IP or ATM), each connection requires a specific guaranteed quality of service (QoS) which is dependent on the level of performance required by the applications using that connection [2]. This concept of differentiated service, wherein each application demands a different level of reliability, is gaining perspective in the current scenario where there are numerous applications in the Internet. Hence, the need to establish lightpaths in a service-differentiated fashion is becoming increasingly important and the fact that the Internet traffic will be aggregated and carried over WDM networks is the motivation for addressing the QoS issues in the optical domain [2,3]. We address the need to design a virtual topology in which the lightpaths are established in a service-differentiated fashion.
Another important aspect to be considered in a network is survivability. The survivability of a network refers to the network’s capability to provide continuous services in presence of failures. Failures can be due to fiber cuts, equipment failure at the nodes, and in case of WDM networks, even channel failures. These failures result in the disruption of lightpaths and hence the traffic is also disrupted. The traffic at the lightpath level is at the rate of Giga bits per second and hence restoration of the traffic is highly important. Survivability is of two types:

- Dynamic restoration.
- Predesigned protection.

The former method tries to restore a failure after it has occurred, which could lead to huge losses in traffic considering the large amount of traffic being carried by the lightpaths. The latter method reserves a backup lightpath before a failure scenario occurs. The predesigned protection takes little time to restore the traffic at the cost of extra consumption of network resources.

In this paper, we present a solution to the problem of designing a virtual topology with the lightpaths established in a service-differentiated manner. The