Chapter 13

Optimization Techniques for Survivable Optical Networks

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1 Introduction

In order to exploit the existing fiber’s huge bandwidth, Wavelength Division Multiplexing (WDM) introduces the possibility of concurrency among multiple-user transmissions within network architectures. WDM is a technique by which a number of optical signals, each using a unique wavelength, are transmitted in a single optical fiber. In this manner, it is possible to use the huge capacity of the fiber optics efficiently by multiplexing signals from different end-users, each using a different WDM channel, into a single fiber, while at the same time allowing end-user’s equipment to operate at their current electronic rates, say 10 Gb/s.

In wavelength-routed WDM networks, for a source-destination (s-d) pair to communicate, a lightpath in the optical layer between the two nodes must be established. A lightpath is a unidirectional connection between two end nodes (source and destination) that may span multiple
links and use single or multiple wavelengths. Lightpath establishment, also known as Routing and Wavelength Assignment (RWA), is accomplished by selecting a route between the two end nodes and assigning a suitable wavelength. The aim of the RWA process is to find routes and assign wavelengths for connection requests in a way that minimizes the consumption of network resources, while at the same time ensuring that no two lightpaths are assigned the same wavelength on a shared link. Furthermore, if a network lacks wavelength converters, a lightpath must be assigned the same wavelength on all the links in its path, a constraint known as wavelength continuity constraint.

The traffic applied to wavelength-routed WDM networks is mainly confined to two types: static traffic and dynamic traffic. Numerous research studies have investigated the RWA problem under the two different traffic environments. Under the static traffic environment, all connection requests are known in advance, so the typical objective is to set up all the required lightpaths while at the same time minimizing the number of wavelengths needed. On the other hand, under the dynamic traffic environment, connection requests arrive at and depart from the networks at random times; so the objective of the dynamic RWA algorithm is to minimize the blocking rate of connection requests. Throughout this chapter, we focus on solving the problem of RWA under a static traffic environment.

A node failure or fiber cut in a wavelength-routed WDM network can cause the breakdown of all lightpaths that traverse the failed node or broken link. Due to the huge amount of data that can be lost and the large number of users that can be disrupted as a result of a fiber cut or node failure, network survivability has become a key issue during the RWA process. Network survivability requires the protection of lightpaths against failures by reserving a spare bandwidth during connection setup and restoration during which the spare bandwidth is utilized upon the occurrence of a failure. During connection setup, in addition to setting up a working lightpath (primary lightpath) to carry traffic during the normal operation, a backup lightpath is also set up to carry traffic in case the primary lightpath fails. The working lightpath and the backup lightpath must be link-disjoint in order to protect against fiber cut or node-disjoint in order to protect against node failure.

Based on the rerouting choice, protection schemes can be either link-based, where the traffic is rerouted around the end nodes of the failed link or path-based where a backup lightpath is pre-determined between the source and the destination nodes. Furthermore, protection schemes