Chapter 1

Survivability in Optical Networks: Principles and State-of-the-Art

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ABSTRACT

WDM optical networks are widely viewed as the most appropriate choice for the future Internet backbone with the potential to fulfill the ever-growing demands for bandwidth. A failure in a network such as a cable cut may result in a tremendous loss of data. Therefore, network survivability, the ability for a network to continue to provide services in the event of failures, is a very important issue in WDM optical networks. This chapter introduces the principles and state-of-the-art of survivability provisioning in optical networks, in particular, in optical networks that employ wavelength division multiplexing (WDM). Concepts of survivability provisioning in optical networks such as protection and restoration, dedicated versus shared survivability, path-based, link-based, segment-based, cycle-based survivability, and so on, are covered to provide multiple classes of quality of protection against single failure, dual-failure, multiple simultaneous failures, or shared risk link group failures, in WDM mesh networks. Recent developments in survivable service provisioning are summarized, such as survivability provisioning that takes into account the connection holding-time, survivability in WDM light-trail networks and optical burst switched networks. Finally, the chapter briefly examines future research directions.

INTRODUCTION

Optical fiber offers much higher bandwidths (nearly 50 terabits per second (Tb/s)) than copper cables and is less susceptible to various kinds of electromagnetic interferences and other undesirable effects. Optical fiber transmission has played a key role in increasing the bandwidth of telecommunication networks through wavelength division multiplexing (WDM), particularly in the last two decades as the Internet has increasingly penetrated daily life. WDM divides the enormous bandwidth of an optical fiber into many...
non-overlapping wavelength channels, each of which may operate at the rate of 10 Gigabit per second or higher. WDM optical networks are widely viewed as the most appropriate choice for the future Internet backbone with the potential to fulfill the ever-growing demands for bandwidth. A failure in a network such as a cable cut may result in a tremendous loss of data. For example, on December 26, 2006, a serious undersea earthquake off the coast of Taiwan that measured 7.1 on the Richter scale caused significant damage to submarine optical cable systems (Kitamura, Lee, Sakiyama, & Okamura, 2007). The resulting fiber cable failures shut down communications in several countries in the Asia Pacific networks. Several Internet service providers (ISPs) were affected because each cable system is shared by multiple ISPs. Therefore, network survivability, the ability for a network to continue to provide services in the event of failures, is a very important issue in WDM optical networks.

Network survivability provisioning requires the commitment of additional resources from the viewpoint of service providers, sometimes a significant amount depending on the desirable levels of tolerance to failures and end user requirements. Practically, there is a strong need for providing a spectrum of quality of protection in the event of failure to suite the requirements of different applications/end users and, at the same time, to find a balance point between provisioning cost, speed of recovery, and scalability. Quality of protection can range from best-effort only to assurance of complete restorability of single, dual-failure, or multiple simultaneous failures on a per-demand basis. This allows a network operator to tailor the investment in capacity to provide ultra-high availability on a selective basis while avoiding the very high investment required for complete failure restorability for all. At the same time, the ability to provide different grades of protection to services provided offers the ISP a competitive advantage.

Many factors impact efficient network survivability provisioning. A WDM optical network needs to keep and exchange network state information for network operations and restorations in case of failure, e.g., topological information, primary paths, backup paths, resources used by each path, available wavelengths over a fiber link, residual bandwidth on each wavelength, tuning ranges of wavelength converters, shared risk link groups and so on. Network state information needs to be exchanged or updated when the state of the network changes, e.g., the addition or the removal of a primary path and its corresponding backup path, the occurrence of a fault resulting in the activation of the backup path and the change of network topology and so forth. The amount of information that needs to be kept by the network becomes overwhelming as the network size, the number of wavelengths, and the number of service requests for paths gets larger. In addition, information update takes a non-negligible amount of time in a real network environment. As a result, network state information is inherently imprecise. Since speed of protection/restoration is paramount, key component functions, such as the routing and restoration algorithm, connection setup strategy, and wavelength assignment strategy and so on, need to achieve scalability and fast performance. The need to provide survivability to services with different quality of protection requirements further complicates the scalable survivability provisioning. Scalability is a real issue that hinders effective network operations and is thus critically needed to be addressed. There appears to be a tradeoff between the scalable provisioning of survivable services and the cost in terms of resource use, network state information maintenance, and network control complexity. A balance point may be achieved through intelligent integrated information sharing and designing effective component mechanisms.

This chapter introduces the principles and state-of-the-art of survivability provisioning in WDM optical networks. Concepts of survivability
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