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To our families and friends
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Preface

The Topic

Optical-fiber technologies using wavelength-division multiplexing (WDM) are currently being researched and commercially deployed to satisfy our increasing bandwidth requirements because, by using WDM technologies, an optical fiber can support multiple non-overlapping wavelength channels, each of which typically operates at the data rate of 10 Gbps or 40 Gbps. In such a network, the failure of a network element, e.g., a fiber, can cause the failure of several wavelength channels, thereby leading to large data and revenue loss. The development of fault-management software, projected to grow significantly in the years ahead, is a top priority for both carriers and vendors. This book investigates the performance and design issues of survivable optical networks against failures.

The book first explores the problem of dynamic shared-path protection, which is desirably resource efficient because of backup sharing. It proves the NP-completeness of the problem, develops a heuristic to compute a feasible solution with high probability, and designs another heuristic to optimize resource consumption for a given solution.

As protection-switching time, resource efficiency, and scalability are primary concerns of a protection scheme, the book investigates from the network point of view sub-path protection, which achieves high scalability and fast recovery time for a modest sacrifice in resource utilization. The book then proceeds to explore from the connection point of view segment protection, which achieves fast recovery time and high resource efficiency.

While the transmission rate of a wavelength channel is high (typically STS-192 or STS-768), the bandwidth requirement of a typical connection request can vary from the full wavelength capacity down to STS-1 or lower. Different low-speed connections may request different bandwidth granularities as well as different protection schemes (dedicated, shared, or no protection). How
to efficiently groom such low-speed connections while satisfying their protection requirements is investigated next. Both protection-at-lightpath level and protection-at-connection level are examined and evaluated.

Next-generation SONET/SDH technologies enable network operators to provide integrated data and voice services over their legacy SONET/SDH infrastructure to generate new revenue. An important open research problem on data over SONET/SDH (DoS) is survivability: SONET automatic protection switching is too resource inefficient for data services, and the protection mechanisms of data networks are too slow for mission-critical applications. The book proposes two approaches for provisioning survivable DoS connections. The approaches exploit the tradeoff between resource overbuild and fault-recovery time while utilizing the inverse-multiplexing capability of virtual concatenation to increase backup sharing.

**Intended Audience**

This book is intended to be a reference book on survivability of optical networks for industrial practitioners, researchers, and graduate students who work on and/or want to learn more about survivable optical networks and data-over-SONET/SDH networks.

The focus of the book is on the various alternative approaches for combatting failures, such as fiber cuts and switch failures, in mesh optical networks. Industrial practitioners and researchers should find the book to be a useful reference because it contains state-of-the-art techniques to address various design and operating issues on managing failures in mesh optical networks and data-over-SONET/SDH networks.

**Organization of the Book**

This book is divided into seven chapters. Chapter 1 presents an overview of optical communication networks and an overview of the book.

Chapters 2-4 focus on provisioning connections of full wavelength capacity, or lightpaths, in an optical WDM mesh network. These three chapters propose and investigate different approaches to explore the tradeoffs among resource efficiency (backup sharing), fault-recovery time, scalability, and implementation complexity.

Chapters 5-7 focus on provisioning connections of sub-wavelength granularity in an optical WDM mesh network. Chapter 5 presents survivable traffic grooming with dedicated protection. Chapter 6 discusses survivable traffic grooming with shared protection. Chapter 7 presents an overview of next-generation SONET/SDH technologies and investigates the survivability of data-over-SONET/SDH networks.
Feedback

We welcome emails from readers who wish to provide any sort of feedback: errors, comments, criticisms, and suggestions for improvements. Our contacts are as follows:

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