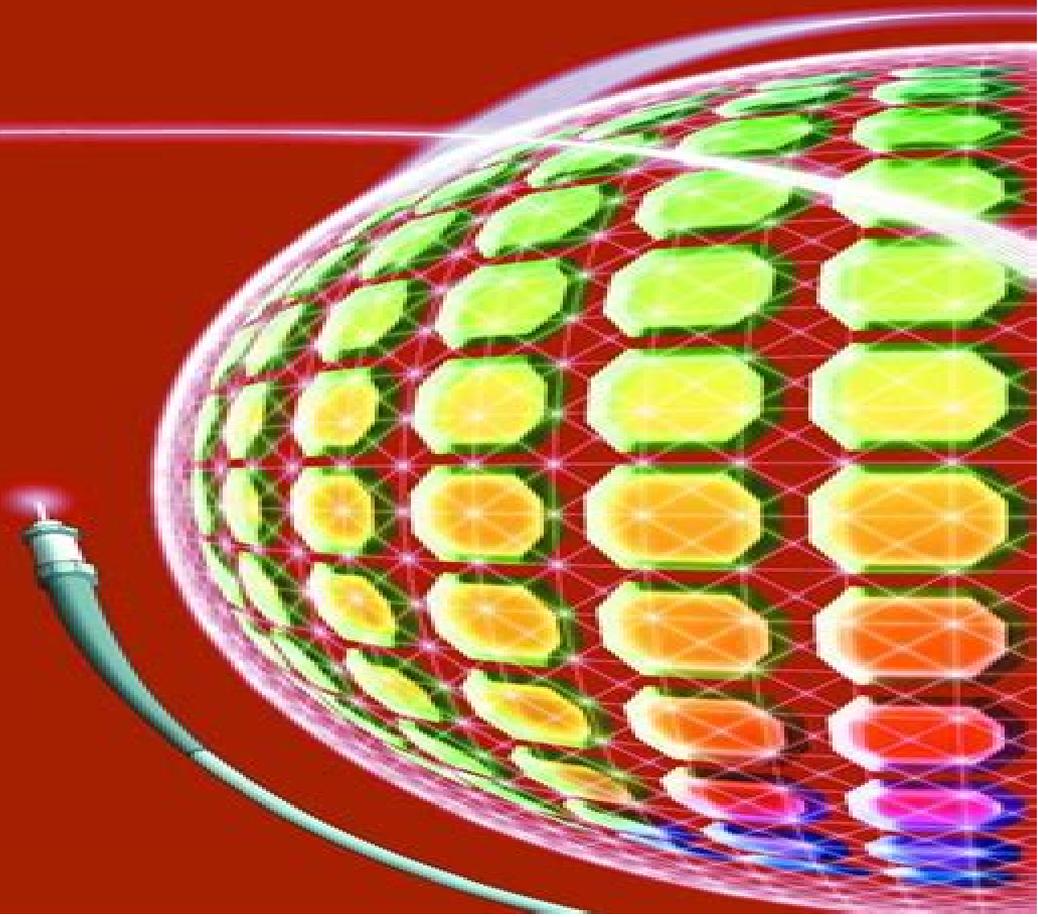




# Survivable Optical WDM Networks

Canhui (Sam) Ou  
Biswanath Mukherjee



OPTICAL NETWORKS SERIES

# Survivable Optical Wdm Networks

**Hui Zang**



## Survivable Optical Wdm Networks:

**Survivable Optical WDM Networks** Canhui (Sam) Ou, Biswanath Mukherjee, 2010-07-19 Survivable Optical WDM Networks investigates different approaches for designing and operating an optical network with the objectives that 1 more connections can be carried by a given network leading to more revenue and 2 connections can recover faster in case of failures leading to better services Different networks wavelength routed WDM networks wavelength routed WDM networks with sub wavelength granularity grooming and data over next generation SONET SDH over WDM networks are covered Different approaches are proposed to explore every aspect of a protection scheme such as 1 Protection granularity a At wavelength granularity b At sub wavelength granularity 2 Protection entity a Path protection b Sub path protection c Segment protection 3 Routing a Single path routing b Multi path routing Tradeoffs between different objectives e g resource efficiency vs recovery time are explored and practical approaches are proposed and analyzed *Design and Analysis of Survivable Wdm Optical Network* Minjing Mao, 2017-01-26 This dissertation Design and Analysis of Survivable WDM Optical Network by Minjing Mao was obtained from The University of Hong Kong Pokfulam Hong Kong and is being sold pursuant to Creative Commons Attribution 3.0 Hong Kong License The content of this dissertation has not been altered in any way We have altered the formatting in order to facilitate the ease of printing and reading of the dissertation All rights not granted by the above license are retained by the author Abstract Optical networks with Wavelength Division Multiplexing WDM technology provide huge bandwidth to meet the ever increasing traffic demand of the next generation Internet But the high speed nature of WDM networks also makes the network more vulnerable to failures Even a single network failure for a very short duration can result in enormous loss of data In this thesis we concentrate on designing a survivable WDM network In essence survivability concerns two important aspects fast fault detection and localization and fast fault recovery We first study fast fault detection and localization in WDM optical networks Our work is based on the notion of monitoring cycle m cycle Compared with other fault detection schemes an m cycle based fault detection scheme provides fast fault detection and requires less number of expensive monitors Aiming at further cutting down the implementation cost we propose the notion of super monitor Instead of having a dedicated monitor for each m cycle a single super monitor can be placed at the junction of a set of overlapped m cycles In this thesis we formulate and solve the monitor placement problem We then focus on enhancing the capacity efficiency of fast fault recovery schemes Shared backup path protection SBPP schemes can provide 100% protection against any single link failure This is achieved by establishing a pair of link disjoint active and backup paths upon each call arrival The bandwidth on different backup paths can be shared for protecting different calls In this thesis a new SBPP scheme is designed based on a two step routing approach where the active and backup paths are sequentially optimized with different objectives in mind We then shift our focus to design fast protection scheme for multicast broadcast communications To this end we refine the existing concept of blue red tree Blue red tree is a pair of spanning trees where

the connectivity between the root and any destination node is ensured upon a network failure. In particular, two efficient integer linear programs (ILPs) are formulated for finding the optimal blue/red trees. Last but not the least, we investigate the survivability in IP networks. We notice that existing efforts on IP fast reroute (IPFRR) are effective in enhancing the IP resilience. But the impact of IPFRR on the end-to-end TCP performance is ignored. Notably, path rerouting can interfere with the TCP congestion control mechanism and thus cause severe throughput degradation. To address this problem, we propose a duplicate acknowledgement (ACK) suppression scheme. The key idea is to detect whether an out-of-order packet arrival event is due to IPFRR or not. If it is due to IPFRR, duplicate ACKs triggered will be suppressed by the TCP receiver so as not to cause unnecessary slow-down at the TCP sender.

DOI: 10.5353/etd\_b4784968

Subjects: Wavelength division multiplexing  
Optical communications  
Design and construction

Optical Networks Hussein T. Mouftah, Pin-Han Ho, 2003

Special emphasis has been given to the design of meshed middle-sized and wavelength-routed networks with dynamic traffic in the optical domain such as the next generation Metropolitan Area Network.

**Power Source Aware Survivable Optical WDM Networks** Mark Boddie, 2013

**Survivability Approaches for Multiple Failures in WDM Optical Networks** Pallab Datta, 2005

The explosive growth of Web-related services over the Internet is bringing millions of new users online, thus fueling an enormous demand for bandwidth. Wavelength Division Multiplexed (WDM) networks employing wavelength routing have emerged as the dominant technology to satisfy this growing demand for bandwidth. As the amount of traffic carried has increased, any single failure can be catastrophic. Survivability becomes indispensable in such networks. Therefore, it is imperative to design networks that can quickly and efficiently recover from failures. Most research to date in survivable optical network design and operation focuses on single link failures; however, the occurrence of multiple link failures are not uncommon in a network topology. Multi-link failure scenarios can arise out of two common situations. First, an arbitrary link may fail in the network, and before that link can be repaired, another link fails, thus creating a multi-link failure sequence. Secondly, it might happen in practice that two distinct physical links may be routed via the same common duct or physical channel. A failure at that shared physical location creates a logical multiple link failure. Such instances where separate fiber optic links share a common failure structure are often referred to as SRLG (Shared Risk Link Groups). In this dissertation, we study survivability paradigms for surviving multiple link failures. We study the network design and upgrade problem in WDM backbone networks and formulate it using a simulated annealing-based technique. This framework provides a cost-effective way of upgrading the network by identifying how much resources to budget at each stage of network evolution. This results in significant cost reductions for the network service provider. We study protection reconfiguration using two different survivability paradigms: namely, sub-graph routing and shared mesh protection. Initially, sub-graphs are defined taking into account link/SRLG or node failures and could, in the event of an unrelated or subsequent multi-link failure, incorporate the reactive form of sub-graph fault tolerance. Reactive sub-graph fault tolerance employs a recursive approach for tolerating

numerous sequential overlapping failures It can tolerate simultaneous multiple link failures by simply serializing the handling of each individual fault Connection re routing and network reconfiguration is one of the primary challenges in sub graph routing methodology We propose a constrained subgraph routing methodology which restricts the connections to be routed using the same trunk and channel in the subgraphs thus minimizing reconfiguration The subgraph based routing methodology is further explored to tolerate multiple link failures in the form of shared risk link groups and node failures The generalized diverse routing problem for finding two diverse routes between a source and destination has been shown to be NP Complete Recent studies have also proven the NP completeness of the SRLG diverse routing We propose a polynomial time graph transformation algorithm for solving the diverse routing problem for certain specific SRLG s which includes link sets incident on a common node The proposed graph transformation methodology for diverse routing is also studied for shared risk node group SRNG failures

**Reliability, Survivability and Quality of Large Scale Telecommunication Systems** Peter Stavroulakis,2003-09-11 Competition within the telecommunications companies is growing fiercer by the day Therefore it is vital to ensure a high level of quality and reliability within all telecommunications systems in order to guard against faults and the failure of components and network services Within large scale systems such quality and reliability problems are ever higher The metrics of Quality and Reliability have to date only been available in journals and technical reports of companies which have designed or produced major parts of systems used in large applications This book provides a self contained treatment enabling the reader to be able to produce define and utilise the metrics of Quality and Reliability required for the design and implementation of a large application such as a world class event as the Olympic Games An additional outcome is that this book can be used as a guide for producing an ISO standard for large scale Systems such as the Olympic Games Provides presentations of techniques used for solving quality and reliability problems in telecommunications networks replete with illustrations of their applications to real world services and world class events Individual chapters written by respective international experts within their fields This will prove highly informative for Practising engineers researchers and telecommunications professionals academics and graduate students in telecommunications standards bodies and organisations such as ISO

**Emerging Optical Network Technologies** Krishna M. Sivalingam,Suresh Subramaniam,2006-01-16 Optical networks have moved from laboratory settings and theoretical research to real world deployment and service oriented explorations New technologies such as Ethernet PON traffic grooming regional and metropolitan network architectures and optical packet switching are being explored and the landscape is continuously and rapidly evolving Some of the important issues involving these new technologies involve the architectural protocol and performance related issues This book addresses many of these issues and presents a birds eye view of some of the more promising technologies Researchers and those pursuing advanced degrees in this field will be able to see where progress is being made and new technologies are emerging Emerging Optical Network Technologies Architectures Protocols and

Performance provides state of the art material written by the most prominent professionals in their respective areas

Dynamic Scheduling of Survivable Connections in Optical WDM Networks Çiçek Çavdar, Feza Buzluca

(Danışman.), Biswanath Mukherjee (Danışman.), Bilişim Enstitüsü, 2009 *Design and Analysis of Survivable Optical*

*Networks* Canhui (Sam) Ou, 2004 *Novel Approaches and Architecture for Survivable Optical Internet* Anwar Haque, 2013

Any unexpected disruption to WDM Wavelength Division Multiplexing based optical networks which carry data traffic at tera

bit per second may result in a huge loss to its end users and the carrier itself Thus survivability has been well recognized as

one of the most important objectives in the design of optical Internet This thesis proposes a novel survivable routing

architecture for the optical Internet We focus on a number of key issues that are essential to achieve the desired service

scenarios including the tasks of a minimizing the total number of wavelengths used for establishing working and protection

paths in WDM networks b minimizing the number of affected working paths in case of a link failure c handling large scale

WDM mesh networks and d supporting both Quality of Service QoS and best effort based working lightpaths *Survivable*

*Multicasting in WDM Optical Networks* Sateesh Chandra Shekhar, 2004 *Survivability Issues in WDM Optical Networks*

Chang Liu, 2007 WDM optical networks make it possible for the bandwidth of transport networks to reach a level on which

any failures would cause tremendous data loss and affect a lot of users Thus survivability issues of WDM optical networks

have attracted a lot of research work Within the scope of this dissertation two categories of problems are studied one is

survivable mapping from IP topology to WDM topology the other is p cycle protection schemes in WDM networks **WDM**

**Mesh Networks** Hui Zang, 2003 WDM Mesh Networks Management and Survivability examines several of the key

management and survivability issues related to mesh based WDM networks and proposes new WDM network protocols and

algorithms that could make telecommunication networks more efficient The book focuses on various issues related to

wavelength routed networks namely routing and wavelength assignment control and management fault management and

wavelength converter placement Special consideration has been given to designing optical networks with survivability

requirements Network designers and planners and research and development engineers active in the field of

telecommunications will find this book especially useful WDM Mesh Networks Management and Survivability will also serve

as a helpful reference for students of optical networking at the senior undergraduate and graduate levels Optical WDM

Networks Biswanath Mukherjee, 2006-06-15 Research and development on optical wavelength division multiplexing WDM

networks have matured considerably While optics and electronics should be used appropriately for transmission and

switching hardware note that intelligence in any network comes from software for network control management signaling

traffic engineering network planning etc The role of software in creating powerful network architectures for optical WDM

networks is emphasized Optical WDM Networks is a textbook for graduate level courses Its focus is on the networking

aspects of optical networking but it also includes coverage of physical layers in optical networks The author introduces WDM

and its enabling technologies and discusses WDM local access metro and long haul network architectures Each chapter is self contained has problems at the end of each chapter and the material is organized for self study as well as classroom use The material is the most recent and timely in capturing the state of the art in the fast moving field of optical WDM networking

Survivability and Traffic Grooming in WDM Optical Networks Arun Somani,2006-01-12 This book provides coverage of survivability and traffic grooming two key issues in modern optical networks

*Advances in Evolutionary Computing for System Design* Vasile Palade,Dipti Srinivasan,2007-07-07 Evolutionary computing paradigms offer robust and powerful adaptive search mechanisms for system design This book s thirteen chapters cover a wide area of topics in evolutionary computing and applications including an introduction to evolutionary computing in system design evolutionary neuro fuzzy systems and evolution of fuzzy controllers The book will be useful to researchers in intelligent systems with interest in evolutionary computing as well as application engineers and system designers

**On Optimal Survivability Design in WDM Optical Networks Under Scheduled Traffic Models** Tianjian Li,2007 Wavelength division multiplexing WDM optical networks are widely viewed as the most appropriate choice for future Internet backbone with the potential to fulfill the ever growing demands for bandwidth 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 A failure in a network such as a cable cut may result in a tremendous loss of data Therefore survivability is a very important issue in WDM optical networks The objective of this dissertation is to address the survivability provisioning problem in WDM optical networks under a scheduled traffic model and a sliding scheduled traffic model that we propose In contrast to the conventional traffic models considered in communication networks such as static traffic model and dynamic random traffic model the scheduled traffic model and the sliding scheduled traffic model are able to capture the traffic characteristics of applications that require capacity on a time limited basis They also give service providers more flexibility in provisioning the requested demands and a better opportunity to optimize the network resources The survivability provisioning problem is to determine a pair of link disjoint paths under the link failure model or a pair of SRLG disjoint paths under the Shared Risk Link Group SRLG failure model one working path and one protection path for each demand in a given set of traffic demands with the objective of minimizing the total resources used by all traffic demands while 100% restorability is guaranteed against any single failure To provision survivable service under the scheduled traffic model we develop two sets of integer linear program ILP formulations for joint and non joint optimizations using different protection schemes such as dedicated and shared path based protections We also design a capacity provision matrix based Iterative Survivable Routing ISR algorithm with different demand scheduling policies to solve the survivable routing and wavelength assignment RWA problem In addition we extend the heuristic algorithm design from dealing with single link failure to single SRLG failure The issue of survivability provisioning in WDM optical networks under the sliding scheduled traffic model has never been

addressed by the research community In the dissertation we carry out the following tasks under this traffic model a development of RWA ILP optimization formulations for dedicated and shared path based protection b design and implementation of efficient heuristic algorithms for shared path based protection Specifically in the proposed heuristic algorithm we introduce a demand time conflict reduction algorithm to minimize the time overlapping among a set of demands by properly placing a demand within its associated time window and c extending the heuristic algorithm design under the single link failure model to the single SRLG failure model

Technological Developments in Networking, Education and Automation Khaled Elleithy, Tarek Sobh, Magued Iskander, Vikram Kapila, Mohammad A. Karim, Ausif Mahmood, 2010-06-18 Technological Developments in Networking Education and Automation includes a set of rigorously reviewed world class manuscripts addressing and detailing state of the art research projects in the following areas Computer Networks Access Technologies Medium Access Control Network architectures and Equipment Optical Networks and Switching Telecommunication Technology and Ultra Wideband Communications Engineering Education and Online Learning including development of courses and systems for engineering technical and liberal studies programs online laboratories intelligent testing using fuzzy logic taxonomy of e courses and evaluation of online courses Pedagogy including benchmarking group learning active learning teaching of multiple subjects together ontology and knowledge management Instruction Technology including internet textbooks virtual reality labs instructional design virtual models pedagogy oriented markup languages graphic design possibilities open source classroom management software automatic email response systems tablet pcs personalization using web mining technology intelligent digital chalkboards virtual room concepts for cooperative scientific work and network technologies management and architecture Coding and Modulation Modeling and Simulation OFDM technology Space time Coding Spread Spectrum and CDMA Systems Wireless technologies Bluetooth Cellular Wireless Networks Cordless Systems and Wireless Local Loop HIPERLAN IEEE 802 11 Mobile Network Layer Mobile Transport Layer and Spread Spectrum Network Security and applications Authentication Applications Block Ciphers Design Principles Block Ciphers Modes of Operation Electronic Mail Security Encryption Message Confidentiality Firewalls IP Security Key Cryptography Message Authentication and Web Security Robotics Control Systems and Automation Distributed Control Systems Automation Expert Systems Robotics Factory Automation Intelligent Control Systems Man Machine Interaction Manufacturing Information System Motion Control and Process Automation Vision Systems for human action sensing face recognition and image processing algorithms for smoothing of high speed motion Electronics and Power Systems Actuators Electro Mechanical Systems High Frequency Converters Industrial Electronics Motors and Drives Power Converters Power Devices and Components and Power Electronics

Bio-Inspired Computation in Telecommunications Xin-She Yang, Su Fong Chien, T.O. Ting, 2015-02-11 Bio inspired computation especially those based on swarm intelligence has become increasingly popular in the last decade Bio Inspired Computation in Telecommunications reviews the latest

developments in bio inspired computation from both theory and application as they relate to telecommunications and image processing providing a complete resource that analyzes and discusses the latest and future trends in research directions Written by recognized experts this is a must have guide for researchers telecommunication engineers computer scientists and PhD students *Network Optimization* Julia Pahl,Torsten Reiners,Stefan Voß,2011-06-03 This book constitutes the refereed proceedings of the 5th International Conference on Network Optimization INOC 2011 held in Hamburg Germany in June 2011 The 65 revised full papers presented were carefully reviewed and selected from numerous submissions The papers highlight recent developments in network optimization and are organized in the following topical sections theoretical problems uncertainty graph theory and network design network flows routing and transportation and further optimization problems and applications energy oriented network design telecom applications location maritime shipping and graph theory

## The Enigmatic Realm of **Survivable Optical Wdm Networks**: Unleashing the Language is Inner Magic

In a fast-paced digital era where connections and knowledge intertwine, the enigmatic realm of language reveals its inherent magic. Its capacity to stir emotions, ignite contemplation, and catalyze profound transformations is nothing lacking extraordinary. Within the captivating pages of **Survivable Optical Wdm Networks** a literary masterpiece penned by way of a renowned author, readers set about a transformative journey, unlocking the secrets and untapped potential embedded within each word. In this evaluation, we shall explore the book is core themes, assess its distinct writing style, and delve into its lasting affect the hearts and minds of those that partake in its reading experience.

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### **Survivable Optical Wdm Networks Introduction**

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