
Contents

1	Introduction to Optical Networks	1
1.1	What Is an Optical Network	1
1.1.1	Important Advantages of WDM Optical Networks	2
1.1.2	Key Terminology in WDM Optical Networks	2
1.1.3	Data Communication in a WDM Optical Network	5
1.2	Categorizations of WDM Networks	7
1.2.1	Broadcasting Networks and Wavelength-Routed Networks	7
1.2.2	Static and Dynamic Lightpath Allocation	8
1.2.3	Single-hop and Multi-hop WDM Networks	9
1.3	Important Problems in WDM Networks and Solution Approaches	9
1.4	A Typical Problem in Multi-hop Wavelength-Routed Network Design	10
1.5	Structure of the Book	13
2	Introduction to Optical Technology	15
2.1	Optical Fiber	15
2.2	Optical Communication Fundamentals	17
2.3	Optical Devices	20
2.3.1	Optical Transmitters, Modulators, and Receivers	20
2.3.2	Optical Couplers	21
2.3.3	Optical Filters and Switches	23
2.3.4	Multiplexers, Demultiplexers, and Cross-connect Switches	24
2.3.5	Add-Drop Multiplexers and Optical Line Terminals	27
2.3.6	Wavelength Converters	29
2.4	Bibliographic Notes	33

- 3 WDM Network Design** 35
 - 3.1 Broadcast-and-Select Networks 35
 - 3.2 Wavelength-Routed Networks 38
 - 3.2.1 Advantages of Second-Generation WDM Networks 42
 - 3.2.2 Single-hop and Multi-hop Networks 45
 - 3.3 Route and Wavelength Assignment Problem in WDM Networks 46
 - 3.3.1 Static and Dynamic Lightpath Allocation 46
 - 3.4 Wavelength-Convertible Networks 48
 - 3.5 Bibliographic Notes 56
 - 3.5.1 Wavelength-Convertible Networks 57
 - 3.5.2 Light-Trail Networks 58
 - 3.5.3 Burst Switching Networks 58
 - 3.5.4 Multicasting Networks 59

- 4 Route and Wavelength Assignment (RWA) I** 63
 - 4.1 RWA as a Graph Coloring Problem 63
 - 4.2 Congestion and Its Relationship to Chromatic Number 67
 - 4.3 Greedy Heuristics for the RWA Problem 68
 - 4.3.1 A Greedy Heuristic for the RWA Problem 68
 - 4.3.2 An Improved Greedy Heuristic for the RWA Problem .. 70
 - 4.4 Specific Networks 71
 - 4.4.1 The Bidirectional Path 71
 - 4.4.2 The Bidirectional Ring 73
 - 4.4.3 Trees 76
 - 4.5 Specific Instances 78
 - 4.5.1 One-to-All Communication 78
 - 4.5.2 All-to-All Communication 80
 - 4.6 Bibliographic Notes 80
 - 4.6.1 One-to-Many and All-to-All Communication 81
 - 4.6.2 Permutations 82
 - 4.6.3 Miscellaneous 83

- 5 Route and Wavelength Assignment (RWA) II** 87
 - 5.1 Off-line Route and Wavelength Assignment 88
 - 5.1.1 Exact Solution of the RWA Problem in Networks with Full Wavelength Converters 88
 - 5.1.2 Exact Solution of the RWA Problem in Networks Without Wavelength Converters 92
 - 5.2 Route and Wavelength Assignment in a Bidirectional Ring 95
 - 5.3 A Heuristic for Route and Wavelength Assignment 98
 - 5.4 Dynamic Route and Wavelength Assignment 101
 - 5.4.1 Dynamic Routing Using a Central Agent 104
 - 5.4.2 Dynamic Routing Using a Distributed Algorithm 107
 - 5.5 Bibliographic Notes 115
 - 5.5.1 Sparse Wavelength Conversion and RWA 117
 - 5.5.2 Limited Wavelength Conversion and RWA 118

5.5.3	Placement of Wavelength Converters	119
5.5.4	Multi-fiber Networks	120
6	Logical Topology Design I	123
6.1	A Scalable Topology Based on the de Bruijn Graph	125
6.1.1	The Topology of the Network	127
6.2	Addition of an End node to an Existing Network	129
6.3	A Routing Scheme for This Topology	131
6.4	Bibliographic Notes	134
7	Logical Topology Design II	137
7.1	MILP-Based Solution of the Logical Topology Design and the Routing Problem	139
7.2	A Heuristic for Determining the Logical Topology	143
7.3	Routing in Wavelength-Routed Networks Viewed as an MCNF Problem	146
7.4	Routing in Small- and Medium-Sized Networks	147
7.5	Routing in Large Networks	149
7.5.1	The Arc-Chain Representation	150
7.5.2	An LP for the Routing Problem Using the Arc-Chain Representation	151
7.5.3	Solving the LP Specified Using the Arc-Chain Representation	154
7.6	Bibliographic Notes	162
8	Faults in Optical Networks	165
8.1	Categorization of Faults	169
8.2	Important Problems in Protection and Restoration	173
8.3	Schemes for Handling Faults	176
8.3.1	1:1 Path Protection in Wavelength-Convertible Networks Using Static Allocation	177
8.3.2	Dynamic Wavelength Allocation with Wavelength Continuity Constraint	179
8.3.3	Utilizing the Channels Used by Backup Paths When There Is No Fault in the Network	185
8.3.4	1:N Protection Using Static Allocation with Wavelength Continuity Constraint	188
8.3.5	Restoration in Networks That Support Dynamic Lightpath Allocation	199
8.4	Bibliographic Notes	202
8.4.1	Review Papers on Fault	202
8.4.2	Link and Path Protection Schemes	203
8.4.3	Schemes for Restoration	205
8.4.4	Attacks on All-Optical Networks	206
8.4.5	Reducing the Overhead for Fault Tolerance	206

- 8.4.6 Handling Multiple Faults 208
- 8.4.7 Survivable Routing 210
- 8.4.8 Miscellaneous Topics 210
- 9 Traffic Grooming 213**
 - 9.1 Static Traffic Grooming 219
 - 9.1.1 Problem 1 219
 - 9.1.2 Problem 2 223
 - 9.1.3 A Heuristic for Static Traffic Grooming 227
 - 9.2 Dynamic Traffic Grooming..... 229
 - 9.2.1 A Graph Model for a Network Supporting Dynamic Traffic Grooming 230
 - 9.2.2 Algorithms for Supporting Dynamic Traffic Grooming.. 235
 - 9.3 Bibliographic Notes 237
 - 9.3.1 Books and Surveys on Traffic Grooming 237
 - 9.3.2 Traffic Grooming on Rings..... 238
 - 9.3.3 Traffic Grooming Strategies 238
 - 9.3.4 Fault-Tolerant Traffic Grooming..... 241
- Appendix 1: Linear Programming in a Nutshell..... 245**
- Appendix 2: The de Bruijn Graph 249**
- Appendix 3: Network Flow Programming..... 253**
- References 261**
- List of Symbols Used 289**
- Index 301**



<http://www.springer.com/978-3-540-72874-0>

Dissemination of Information in Optical Networks:

From Technology to Algorithms

Bandyopadhyay, S.

2008, XII, 310 p., Hardcover

ISBN: 978-3-540-72874-0