

大学计算机教育丛书（影印版）

THIRD EDITION

Computer Networks

Andrew S. Tanenbaum

计算机网络

（第三版）

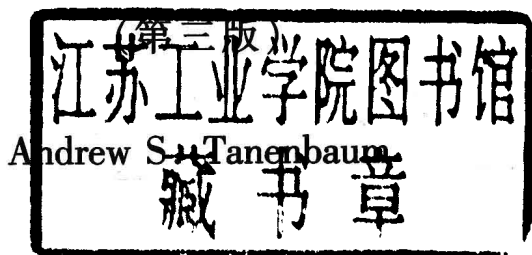


清华大学出版社 • PRENTICE HALL

Computer Networks

Third Edition

计 算 机 网 络



清华大学出版社

Prentice-Hall International, Inc.

(京)新登字 158 号

Computer Networks 3rd Ed/Andrew S. Tanenbaum

© 1996 by Prentice Hall, Inc.

Original edition published by Prentice Hall, Inc., a Simon & Schuster Company.

Prentice Hall 公司授权清华大学出版社在中国境内(不包括香港、澳门和台湾)独家出版发行影印本。

本书任何部分之内容,未经出版者书面同意,不得用任何方式抄袭、节录及翻印。

本书封面贴有 Prentice Hall 激光防伪标签,无标签者不得销售。

北京市版权局著作权合同登记号: 01-97-0166

图书在版编目(CIP)数据

计算机网络:第3版:英文/(美)特南鲍姆(Tanenbaum, A.S.)著. - 北京:清华大学出版社, 1996.12

(大学计算机教育丛书:影印版)

ISBN 7-302-02410-3

I. 计… II. 特… III. 计算机网络-高等学校-教材-英文 IV. TP393

中国版本图书馆 CIP 数据核字(96)第 25149 号

出版者:清华大学出版社(北京清华大学校内,邮编 100084)

印刷者:清华大学印刷厂

发行者:新华书店总店北京科技发行所

开 本:850×1168 1/32 印张:26

版 次:1997 年 2 月第 1 版 1997 年 9 月第 4 次印刷

书 号:ISBN 7-302-02410-3/TP·1212

印 数:10001~15000

定 价:45.00 元

出版前言

我们的大学生、研究生毕业后,面临的将是一个国际化的信息时代。他们将需要随时查阅大量的外文资料;会有更多的机会参加国际性学术交流活动;接待外国学者;走上国际会议的讲坛。作为科技工作者,他们不仅应有与国外同行进行口头和书面交流的能力,更为重要的是,他们必须具备极强的查阅外文资料获取信息的能力。有鉴于此,在国家教委所颁布的“大学英语教学大纲”中有一条规定:专业阅读应作为必修课程开设。同时,在大纲中还规定了这门课程的学时和教学要求。有些高校除开设“专业阅读”课之外,还在某些专业课拟进行英语授课。但教、学双方都苦于没有一定数量的合适的英文原版教材作为教学参考书。为满足这方面的需要,我们挑选了7本计算机科学方面最新版本的教材,进行影印出版。Prentice Hall公司和清华大学出版社这次合作将国际先进水平的教材引入我国高等学校,为师生们提供了教学用书,相信会对高校教材改革产生积极的影响。

清华大学出版社
Prentice Hall 公司

1996.11

About the Author

Andrew S. Tanenbaum has an S.B. degree from M.I.T. and a Ph.D. from the University of California at Berkeley. He is currently a Professor of Computer Science at the Vrije Universiteit in Amsterdam, The Netherlands, where he heads the Computer Systems Group. He is also Dean of the Advanced School for Computing and Imaging, an interuniversity graduate school doing research on advanced parallel systems, distributed systems, and imaging systems. Nevertheless, he is trying very hard to avoid turning into a bureaucrat.

In the past, he has done research on compilers, operating systems, networking, and local-area distributed systems. His current research focuses primarily on the design of wide-area distributed systems that scale to millions of users. These research projects have led to over 70 refereed papers in journals and conference proceedings. He is also the author of five books (see page ii).

Prof. Tanenbaum has also produced a considerable volume of software. He was the principal architect of the Amsterdam Compiler Kit, a widely-used toolkit for writing portable compilers, and MINIX, a small UNIX-like operating system for operating systems courses. Together with his Ph.D. students and programmers, he helped design the Amoeba distributed operating system, a high-performance microkernel-based distributed operating system. MINIX and Amoeba are now available for free for education and research via the Internet.

His Ph.D. students have gone on to greater glory after getting their degrees. He is very proud of them. In this respect he resembles a mother hen.

Prof. Tanenbaum is a Fellow of the ACM, a Senior Member of the IEEE, a member of the Royal Netherlands Academy of Arts and Sciences, and winner of the 1994 ACM Karl V. Karlstrom Outstanding Educator Award. He is also listed in *Who's Who in the World*. His home page on the World Wide Web is located at <http://www.cs.vu.nl/~ast/>.

PREFACE

This book is now in its third edition. Each edition has corresponded to a different phase in the way computer networks were used. When the first edition appeared in 1980, networks were an academic curiosity. When the second edition appeared in 1988, networks were used by universities and large businesses. When the third edition appeared in 1996, computer networks, especially the worldwide Internet, had become a daily reality for millions of people.

Furthermore, the networking hardware and software have completely changed since the second edition appeared. In 1988, nearly all networks were based on copper wire. Now, many are based on fiber optics or wireless communication. Proprietary networks, such as SNA, have become far less important than public networks, especially the Internet. The OSI protocols have quietly vanished, and the TCP/IP protocol suite has become dominant. In fact, so much has changed, the book has almost been rewritten from scratch.

Although Chap. 1 has the same introductory function as it did in the second edition, the contents have been completely revised and brought up to date. For example, instead of basing the book on the seven-layer OSI model, a five-layer hybrid model (shown in Fig. 1-21) is now used and introduced in Chap. 1. While not exactly identical to the TCP/IP model, it is much closer to the TCP/IP model in spirit than it is to the OSI model used in the second edition. Also, the new running examples used throughout the book—the Internet and ATM networks—are introduced here, along with some gigabit networks and other popular networks.

In Chap. 2, the focus has moved from copper wire to fiber optics and wireless communication, since these are the technologies of the future. The telephone system has become almost entirely digital in the past decade, so the material on it has been largely rewritten, with new material on broadband ISDN added. The material on cellular radio has been greatly expanded, and new material on low-orbit satellites has been added to the chapter.

The order of discussion of the data link layer and the MAC sublayer has been reversed, since experience with students shows that they understand the MAC sublayer better after they have studied the data link layer. The example protocols there have been kept, as they have proven very popular, but they have been rewritten in C. New material on the Internet and ATM data link layers has been added.

The MAC sublayer principles of Chap. 4. have been revised to reflect new protocols, including wavelength division multiplexing, wireless LANs, and digital radio. The discussion of bridges has been revised, and new material has been added on high-speed LANs.

Most of the routing algorithms of Chap. 5 have been replaced by more modern ones, including distance vector and link state routing. The sections on congestion control have been completely redone, and material on the running examples, the Internet and ATM is all new.

Chap. 6 is still about the transport layer, but here, too, major changes have occurred, primarily, the addition of a large amount of new material about the Internet, ATM, and network performance.

Chap. 7, on the application layer, is now the longest chapter in the book. The material on network security has been doubled in length, and new material has been added on DNS, SNMP, email, USENET, the World Wide Web, HTML, Java, multimedia, video on demand, and the MBone.

Of the 395 figures in the third edition, 276 (70 percent) are completely new and some of the others have been revised. Of the 370 references to the literature, 281 (76 percent) are to books and papers that have appeared since the second edition was published. Of these, over 100 are to works published in 1995 and 1996 alone. All in all, probably 75 percent of the entire book is brand new, and parts of the remaining 25 percent have been heavily revised. Since this is effectively a new book, the cover was redesigned to avoid confusion with the second edition.

Computer books are full of acronyms. This one is no exception. By the time you are finished reading this one, all of the following should ring a bell: AAL, AMPS, ARP, ASN, ATM, BGP, CDMA, CDPD, CSMA, DQDB, DNS, FAQ, FDM, FTP, FTTC, FTTH, GSM, HDLC, HEC, HIPPI, IAB, ICMP, IDEA, IETF, IPv6, ISO, ITU, LATA, MAC, MACA, MAN, MIB, MIME, NAP, NNTP, NSA, NSAP, OSI, OSPF, PCM, PCN, PCS, PEM, PGP, PPP, PSTN, PTT, PVC, QAM, RARP, RFC, RSA, SABME, SAP, SAR, SDH, SDLC, SHA, SMI, SNA, SNMP, SNRME, SPX, TCP, UDP, VHF, VLF, VSAT, WARC, WDM, WDV, WWV, and WWW. But don't worry. Each one will be carefully defined before it is used.

To help instructors using this book as a text for course, the author has prepared three teaching aids:

- A problem solutions manual.
- PostScript files containing all the figures (for making overhead sheets)
- A simulator (written in C) for the example protocols of Chap. 3.

The solutions manual is available from Prentice Hall (but only to instructors).. The file with the figures and the simulator are available via the World Wide Web. To get them, please see the author's home page: <http://www.cs.vu.nl/~ast/>.

The book was typeset in Times Roman using Troff, which, after all these years, is still the only way to go. While Troff is not as trendy as WYSIWYG systems, the reader is invited to compare the typesetting quality of this book with books produced by WYSIWYG systems. My only concession to PCs and desktop publishing is that for the first time, the art was produced using Adobe Illustrator, instead of being drawn on paper. Also for the first time, the book was produced entirely electronically. The PostScript output from Troff was sent over the Internet to the printer, where the film for making the offset plates was produced. No intermediate paper copy was printed and photographed, as is normally done.

Many people helped me during the course of the third edition. I would especially like to thank Chase Bailey, Saniya Ben Hassen, Nathaniel Borenstein, Ron Cocchi, Dave Crocker, Wiebren de Jonge, Carl Ellison, M. Rasit Eskicioglu, John Evans, Mario Gerla, Mike Goguen, Paul Green, Dick Grune, Wayne Hathaway, Franz Hauck, Jack Holtzman, Gerard Holzmann, Philip Homburg, Peter Honeyman, Raj Jain, Dave Johnson, Charlie Kaufman, Vinay Kumar, Jorg Liebeherr, Paul Mockapetris, Carol Orange, Craig Partridge, Charlie Perkins, Thomas Powell, Greg Sharp, Anne Steegstra, George Swallow, Mark Taylor, Peter van der Linden, Hans van Staveren, Maarten van Steen, Kees Verstoep, Stephen Walters, Michael Weintraub, Joseph Wilkes, and Stephen Wolff. Special thanks go to Radia Perlman for many helpful suggestions. My students have also helped in many ways. I would like to single out Martijn Bot, Wilbert de Graaf, Flavio del Pomo, and Arnold de Wit for their assistance.

My editor at Prentice Hall, Mary Franz, provided me with more reading material than I had consumed in the previous 10 years. She was also helpful in numerous other ways, small, medium, large, and jumbo. My production editor, Camille Trentacoste, taught me about people of snow, 8-up flats, fax [sic], and other important items, while performing yeoperson's service with a Picky Author and a tight schedule.

Finally, we come to the most important people. Suzanne, Barbara, Marvin, and even little Bram, have been through this routine before. They endure it with infinite patience and good grace. Thank you.

ANDREW S. TANENBAUM

CONTENTS

PREFACE

xv

1 INTRODUCTION

1

- 1.1 USES OF COMPUTER NETWORKS 3
 - 1.1.1 Networks for Companies 3
 - 1.1.2 Networks for People 4
 - 1.1.3 Social Issues 6
- 1.2 NETWORK HARDWARE 7
 - 1.2.1 Local Area Networks 9
 - 1.2.2 Metropolitan Area Networks 10
 - 1.2.3 Wide Area Networks 11
 - 1.2.4 Wireless Networks 13
 - 1.2.5 Internetworks 16
- 1.3 NETWORK SOFTWARE 16
 - 1.3.1 Protocol Hierarchies 17
 - 1.3.2 Design Issues for the Layers 21
 - 1.3.3 Interfaces and Services 22
 - 1.3.4 Connection-Oriented and Connectionless Services 23
 - 1.3.5 Service Primitives 25
 - 1.3.6 The Relationship of Services to Protocols 27
- 1.4 REFERENCE MODELS 28
 - 1.4.1 The OSI Reference Model 28
 - 1.4.2 The TCP/IP Reference Model 35
 - 1.4.3 A Comparison of the OSI and TCP Reference Models 38
 - 1.4.4 A Critique of the OSI Model and Protocols 40
 - 1.4.5 A Critique of the TCP/IP Reference Model 43
- 1.5 EXAMPLE NETWORKS 44
 - 1.5.1 Novell Netware 45
 - 1.5.2 The ARPANET 47
 - 1.5.3 NSFNET 50
 - 1.5.4 The Internet 52
 - 1.5.5 Gigabit Testbeds 54

1.6	EXAMPLE DATA COMMUNICATION SERVICES	56
1.6.1	SMDS—Switched Multimegabit Data Service	57
1.6.2	X.25 Networks	59
1.6.3	Frame Relay	60
1.6.4	Broadband ISDN and ATM	61
1.6.5	Comparison of Services	66
1.7	NETWORK STANDARDIZATION	66
1.7.1	Who's Who in the Telecommunications World	67
1.7.2	Who's Who in the International Standards World	69
1.7.3	Who's Who in the Internet Standards World	70
1.8	OUTLINE OF THE REST OF THE BOOK	72
1.9	SUMMARY	73

2 THE PHYSICAL LAYER

77

2.1	THE THEORETICAL BASIS FOR DATA COMMUNICATION	77
2.1.1	Fourier Analysis	78
2.1.2	Bandwidth-Limited Signals	78
2.1.3	The Maximum Data Rate of a Channel	81
2.2	TRANSMISSION MEDIA	82
2.2.1	Magnetic Media	82
2.2.2	Twisted Pair	83
2.2.3	Baseband Coaxial Cable	84
2.2.4	Broadband Coaxial Cable	85
2.2.5	Fiber Optics	87
2.3	WIRELESS TRANSMISSION	94
2.3.1	The Electromagnetic Spectrum	94
2.3.2	Radio Transmission	97
2.3.3	Microwave Transmission	98
2.3.4	Infrared and Millimeter Waves	100
2.3.5	Lightwave Transmission	100
2.4	THE TELEPHONE SYSTEM	102
2.4.1	Structure of the Telephone System	103
2.4.2	The Politics of Telephones	106
2.4.3	The Local Loop	108
2.4.4	Trunks and Multiplexing	118
2.4.5	Switching	130

- 2.5 NARROWBAND ISDN 139
 - 2.5.1 ISDN Services 140
 - 2.5.2 ISDN System Architecture 140
 - 2.5.3 The ISDN Interface 142
 - 2.5.4 Perspective on N-ISDN 143
- 2.6 BROADBAND ISDN AND ATM 144
 - 2.6.1 Virtual Circuits versus Circuit Switching 145
 - 2.6.2 Transmission in ATM Networks 146
 - 2.6.3 ATM Switches 147
- 2.7 CELLULAR RADIO 155
 - 2.7.1 Paging Systems 155
 - 2.7.2 Cordless Telephones 157
 - 2.7.3 Analog Cellular Telephones 157
 - 2.7.4 Digital Cellular Telephones 162
 - 2.7.5 Personal Communications Services 162
- 2.8 COMMUNICATION SATELLITES 163
 - 2.8.1 Geosynchronous Satellites 164
 - 2.8.2 Low-Orbit Satellites 167
 - 2.8.3 Satellites versus Fiber 168
- 2.9 SUMMARY 170

3 THE DATA LINK LAYER

175

- 3.1 DATA LINK LAYER DESIGN ISSUES 176
 - 3.1.1 Services Provided to the Network Layer 176
 - 3.1.2 Framing 179
 - 3.1.3 Error Control 182
 - 3.1.4 Flow Control 183
- 3.2 ERROR DETECTION AND CORRECTION 183
 - 3.2.1 Error-Correcting Codes 184
 - 3.2.2 Error-Detecting Codes 186
- 3.3 ELEMENTARY DATA LINK PROTOCOLS 190
 - 3.3.1 An Unrestricted Simplex Protocol 195
 - 3.3.2 A Simplex Stop-and-Wait Protocol 195
 - 3.3.3 A Simplex Protocol for a Noisy Channel 197

3.4	SLIDING WINDOW PROTOCOLS	202
3.4.1	A One Bit Sliding Window Protocol	206
3.4.2	A Protocol Using Go Back n	207
3.4.3	A Protocol Using Selective Repeat	213
3.5	PROTOCOL SPECIFICATION AND VERIFICATION	219
3.5.1	Finite State Machine Models	219
3.5.2	Petri Net Models	223
3.6	EXAMPLE DATA LINK PROTOCOLS	225
3.6.1	HDL—High-level Data Link Control	225
3.6.2	The Data Link Layer in the Internet	229
3.6.3	The Data Link Layer in ATM	235
3.7	SUMMARY	239

4 THE MEDIUM ACCESS SUBLAYER

243

4.1	THE CHANNEL ALLOCATION PROBLEM	244
4.1.1	Static Channel Allocation in LANs and MANs	244
4.1.2	Dynamic Channel Allocation in LANs and MANs	245
4.2	MULTIPLE ACCESS PROTOCOLS	246
4.2.1	ALOHA	246
4.2.2	Carrier Sense Multiple Access Protocols	250
4.2.3	Collision-Free Protocols	254
4.2.4	Limited-Contention Protocols	256
4.2.5	Wavelength Division Multiple Access Protocols	260
4.2.6	Wireless LAN Protocols	262
4.2.7	Digital Cellular Radio	266
4.3	IEEE STANDARD 802 FOR LANS AND MANS	275
4.3.1	IEEE Standard 802.3 and Ethernet	276
4.3.2	IEEE Standard 802.4: Token Bus	287
4.3.3	IEEE Standard 802.5: Token Ring	292
4.3.4	Comparison of 802.3, 802.4, and 802.5	299
4.3.5	IEEE Standard 802.6: Distributed Queue Dual Bus	301
4.3.6	IEEE Standard 802.2: Logical Link Control	302

- 4.4 BRIDGES 304
 - 4.4.1 Bridges from 802.x to 802.y 307
 - 4.4.2 Transparent Bridges 310
 - 4.4.3 Source Routing Bridges 314
 - 4.4.4 Comparison of 802 Bridges 316
 - 4.4.5 Remote Bridges 317
- 4.5 HIGH-SPEED LANS 318
 - 4.5.1 FDDI 319
 - 4.5.2 Fast Ethernet 322
 - 4.5.3 HIPPI—High-Performance Parallel Interface 325
 - 4.5.4 Fibre Channel 326
- 4.6 SATELLITE NETWORKS 327
 - 4.6.1 Polling 328
 - 4.6.2 ALOHA 329
 - 4.6.3 FDM 330
 - 4.6.4 TDM 330
 - 4.6.5 CDMA 333
- 4.7 SUMMARY 333

5 THE NETWORK LAYER

339

- 5.1 NETWORK LAYER DESIGN ISSUES 339
 - 5.1.1 Services Provided to the Transport Layer 340
 - 5.1.2 Internal Organization of the Network Layer 342
 - 5.1.3 Comparison of Virtual Circuit and Datagram Subnets 344
- 5.2 ROUTING ALGORITHMS 345
 - 5.2.1 The Optimality Principle 347
 - 5.2.2 Shortest Path Routing 349
 - 5.2.3 Flooding 351
 - 5.2.4 Flow-Based Routing 353
 - 5.2.5 Distance Vector Routing 355
 - 5.2.6 Link State Routing 359
 - 5.2.7 Hierarchical Routing 365
 - 5.2.8 Routing for Mobile Hosts 367
 - 5.2.9 Broadcast Routing 370
 - 5.2.10 Multicast Routing 372

- 5.3 CONGESTION CONTROL ALGORITHMS 374
 - 5.3.1 General Principles of Congestion Control 376
 - 5.3.2 Congestion Prevention Policies 378
 - 5.3.3 Traffic Shaping 379
 - 5.3.4 Flow Specifications 384
 - 5.3.5 Congestion Control in Virtual Circuit Subnets 386
 - 5.3.6 Choke Packets 387
 - 5.3.7 Load Shedding 390
 - 5.3.8 Jitter Control 392
 - 5.3.9 Congestion Control for Multicasting 393
- 5.4 INTERNETWORKING 396
 - 5.4.1 How Networks Differ 399
 - 5.4.2 Concatenated Virtual Circuits 401
 - 5.4.3 Connectionless Internetworking 402
 - 5.4.4 Tunneling 404
 - 5.4.5 Internetwork Routing 405
 - 5.4.6 Fragmentation 406
 - 5.4.7 Firewalls 410
- 5.5 THE NETWORK LAYER IN THE INTERNET 412
 - 5.5.1 The IP Protocol 413
 - 5.5.2 IP Addresses 416
 - 5.5.3 Subnets 417
 - 5.5.4 Internet Control Protocols 419
 - 5.5.5 The Interior Gateway Routing Protocol: OSPF 424
 - 5.5.6 The Exterior Gateway Routing Protocol: BGP 429
 - 5.5.7 Internet Multicasting 431
 - 5.5.8 Mobile IP 432
 - 5.5.9 CIDR—Classless InterDomain Routing 434
 - 5.5.10 IPv6 437
- 5.6 THE NETWORK LAYER IN ATM NETWORKS 449
 - 5.6.1 Cell Formats 450
 - 5.6.2 Connection Setup 452
 - 5.6.3 Routing and Switching 455
 - 5.6.4 Service Categories 458
 - 5.6.5 Quality of Service 460
 - 5.6.6 Traffic Shaping and Policing 463
 - 5.6.7 Congestion Control 467
 - 5.6.8 ATM LANs 471
- 5.7 SUMMARY 473

6 THE TRANSPORT LAYER**479**

- 6.1 THE TRANSPORT SERVICE 479
 - 6.1.1 Services Provided to the Upper Layers 479
 - 6.1.2 Quality of Service 481
 - 6.1.3 Transport Service Primitives 483
- 6.2 ELEMENTS OF TRANSPORT PROTOCOLS 488
 - 6.2.1 Addressing 489
 - 6.2.2 Establishing a Connection 493
 - 6.2.3 Releasing a Connection 498
 - 6.2.4 Flow Control and Buffering 502
 - 6.2.5 Multiplexing 506
 - 6.2.6 Crash Recovery 508
- 6.3 A SIMPLE TRANSPORT PROTOCOL 510
 - 6.3.1 The Example Service Primitives 510
 - 6.3.2 The Example Transport Entity 512
 - 6.3.3 The Example as a Finite State Machine 519
- 6.4 THE INTERNET TRANSPORT PROTOCOLS (TCP AND UDP) 521
 - 6.4.1 The TCP Service Model 523
 - 6.4.2 The TCP Protocol 524
 - 6.4.3 The TCP Segment Header 526
 - 6.4.4 TCP Connection Management 529
 - 6.4.5 TCP Transmission Policy 533
 - 6.4.6 TCP Congestion Control 536
 - 6.4.7 TCP Timer Management 539
 - 6.4.8 UDP 542
 - 6.4.9 Wireless TCP and UDP 543
- 6.5 THE ATM AAL LAYER PROTOCOLS 545
 - 6.5.1 Structure of the ATM Adaptation Layer 546
 - 6.5.2 AAL 1 547
 - 6.5.3 AAL 2 549
 - 6.5.4 AAL 3/4 550
 - 6.5.5 AAL 5 552
 - 6.5.6 Comparison of AAL Protocols 554
 - 6.5.7 SSCOP—Service Specific Connection-Oriented Protocol 555
- 6.6 PERFORMANCE ISSUES 555
 - 6.6.1 Performance Problems in Computer Networks 556
 - 6.6.2 Measuring Network Performance 559

6.6.3	System Design for Better Performance	561
6.6.4	Fast TPDU Processing	565
6.6.5	Protocols for Gigabit Networks	568
6.7	SUMMARY	572

7 THE APPLICATION LAYER

577

7.1	NETWORK SECURITY	577
7.1.1	Traditional Cryptography	580
7.1.2	Two Fundamental Cryptographic Principles	585
7.1.3	Secret-Key Algorithms	587
7.1.4	Public-Key Algorithms	597
7.1.5	Authentication Protocols	601
7.1.6	Digital Signatures	613
7.1.7	Social Issues	620
7.2	DNS—DOMAIN NAME SYSTEM	622
7.2.1	The DNS Name Space	622
7.2.2	Resource Records	624
7.2.3	Name Servers	628
7.3	SNMP—SIMPLE NETWORK MANAGEMENT PROTOCOL	630
7.3.1	The SNMP Model	631
7.3.2	ASN.1—Abstract Syntax Notation 1	633
7.3.3	SMI—Structure of Management Information	639
7.3.4	The MIB—Management Information Base	641
7.3.5	The SNMP Protocol	642
7.4	ELECTRONIC MAIL	643
7.4.1	Architecture and Services	645
7.4.2	The User Agent	646
7.4.3	Message Formats	650
7.4.4	Message Transfer	657
7.4.5	Email Privacy	663
7.5	USENET NEWS	669
7.5.1	The User View of USENET	670
7.5.2	How USENET is Implemented	675

- 7.6 THE WORLD WIDE WEB 681
 - 7.6.1 The Client Side 682
 - 7.6.2 The Server Side 685
 - 7.6.3 Writing a Web Page in HTML 691
 - 7.6.4 Java 706
 - 7.6.5 Locating Information on the Web 720
- 7.7 MULTIMEDIA 723
 - 7.7.1 Audio 724
 - 7.7.2 Video 727
 - 7.7.3 Data Compression 730
 - 7.7.4 Video on Demand 744
 - 7.7.5 MBone—Multicast Backbone 756
- 7.8 SUMMARY 760

8 READING LIST AND BIBLIOGRAPHY

767

- 8.1 SUGGESTIONS FOR FURTHER READING 767
 - 8.1.1 Introduction and General Works 768
 - 8.1.2 The Physical Layer 769
 - 8.1.3 The Data Link Layer 770
 - 8.1.4 The Medium Access Control Sublayer 770
 - 8.1.5 The Network Layer 771
 - 8.1.6 The Transport Layer 772
 - 8.1.7 The Application Layer 772
- 8.2 ALPHABETICAL BIBLIOGRAPHY 775

INDEX 795