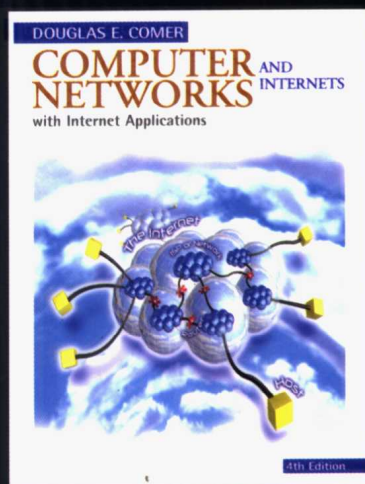


计算机网络与互联网

(第四版)

Computer Networks and Internets
with Internet Applications
Fourth Edition



英文版

[美] Douglas E. Comer 著



电子工业出版社
Publishing House of Electronics Industry
<http://www.phei.com.cn>

国外计算机科学教材系列

计算机网络与互联网

(第四版)

(英文版)

Computer Networks and Internets
with Internet Applications
Fourth Edition

[美] Douglas E. Comer 著

电子工业出版社
Publishing House of Electronics Industry
北京 · BEIJING

内 容 简 介

本书由畅销书作家、计算机网络专家 Douglas Comer 撰写。全书共分为五个部分,第一部分概述了 Internet 应用的使用与构建;第二部分讲述数据传输的知识,内容包括传输介质、本地异步通信、长距离通信等;第三部分讲述包交换的问题,在叙述各类网络特性的基础上介绍了下一站路由、交换和协议分层,并结合以太网、FDDI、令牌环和 ATM 详述了包交换的过程;第四部分讲述网络互联,主要介绍了 TCP、ARP 协议;第五部分讲述网络应用,首先从客户/服务器模式开始,叙述了域名系统 and 应用中的域名识别,文件传输和 Web 浏览,包括动态 CGI 文档和活动 Java 文档的解释和应用。

本书适用于计算机专业本科高年级学生和缺少网络知识的低年级硕士生。

English reprint Copyright © 2004 by PEARSON EDUCATION ASIA LIMITED and Publishing House of Electronics Industry.

Computer Networks and Internet with Internet Applications, Fourth Edition, ISBN: 0131433512 by Douglas E. Comer. Copyright © 2004.

All Rights Reserved.

Published by arrangement with the original publisher, Pearson Education, Inc., publishing as Prentice Hall.

This edition is authorized for sale only in the People's Republic of China (excluding the Special Administrative Region of Hong Kong and Macau).

本书英文影印版由电子工业出版社和 Pearson Education 培生教育出版亚洲有限公司合作出版。未经出版者预先书面许可,不得以任何方式复制或抄袭本书的任何部分。

本书封面贴有 Pearson Education 培生教育出版集团激光防伪标签,无标签者不得销售。

版权贸易合同登记号 图字:01-2004-2716

图书在版编目(CIP)数据

计算机网络与互联网 = Computer Networks and Internet with Internet Applications, Fourth Edition: 第四版 / (美)科默(Comer, D. E.)著. - 北京:电子工业出版社, 2004.6
(国外计算机科学教材系列)

ISBN 7-120-00085-3

I. 计... II. 科... III. ①计算机网络-教材-英文 ②因特网-教材-英文 IV. TP393

中国版本图书馆 CIP 数据核字(2004)第 050523 号

责任编辑:赵红燕

印 刷:北京兴华印刷厂

出版发行:电子工业出版社

北京市海淀区万寿路 173 信箱 邮编:100036

经 销:各地新华书店

开 本:787 × 980 1/16 印张:47 字数:1053 千字

印 次:2004 年 6 月第 1 次印刷

定 价:69.00 元(附光盘 1 张)

凡购买电子工业出版社的图书,如有缺损问题,请向购买书店调换;若书店售缺,请与本社发行部联系。联系电话:(010) 68279077。质量投诉请发邮件至 zlts@phei.com.cn, 盗版侵权举报请发邮件至 dbqq@phei.com.cn。

出版说明

21 世纪初的 5 至 10 年是我国国民经济和社会发展的关键时期,也是信息产业快速发展的关键时期。在我国加入 WTO 后的今天,培养一支适应国际化竞争的一流 IT 人才队伍是我国高等教育的重要任务之一。信息科学和技术方面人才的优劣与多寡,是我国面对国际竞争时成败的关键因素。

当前,正值我国高等教育特别是信息科学领域的教育调整、变革的重大时期,为使我国教育体制与国际化接轨,有条件的高等院校正在为某些信息学科和技术课程使用国外优秀教材和优秀原版教材,以使我国在计算机教学上尽快赶上国际先进水平。

电子工业出版社秉承多年来引进国外优秀图书的经验,翻译出版了“国外计算机科学教材系列”丛书,这套教材覆盖学科范围广、领域宽、层次多,既有本科专业课程教材,也有研究生课程教材,以适应不同院系、不同专业、不同层次的师生对教材的需求,广大师生可自由选择 and 自由组合使用。这些教材涉及的学科方向包括网络与通信、操作系统、计算机组织与结构、算法与数据结构、数据库与信息处理、编程语言、图形图像与多媒体、软件工程等。同时,我们也适当引进了一些优秀英文原版教材,本着翻译版本和英文原版并重的原则,对重点图书既提供英文原版又提供相应的翻译版本。

在图书选题上,我们大都选择国外著名出版公司出版的高校教材,如 Pearson Education 培生教育出版集团、麦格劳-希尔教育出版集团、麻省理工学院出版社、剑桥大学出版社等。撰写教材的许多作者都是蜚声世界的教授、学者,如道格拉斯·科默(Douglas E. Comer)、威廉·斯托林斯(William Stallings)、哈维·戴特尔(Harvey M. Deitel)、尤利斯·布莱克(Uyless Black)等。

为确保教材的选题质量和翻译质量,我们约请了清华大学、北京大学、北京航空航天大学、复旦大学、上海交通大学、南京大学、浙江大学、哈尔滨工业大学、华中科技大学、西安交通大学、国防科学技术大学、解放军理工大学等著名高校的教授和骨干教师参与了本系列教材的选题、翻译和审校工作。他们中既有讲授同类教材的骨干教师、博士,也有积累了几十年教学经验的老教授和博士生导师。

在该系列教材的选题、翻译和编辑加工过程中,为提高教材质量,我们做了大量细致的工作,包括对所选教材进行全面论证;选择编辑时力求达到专业对口;对排版、印制质量进行严格把关。对于英文教材中出现的错误,我们通过与作者联络和网上下载勘误表等方式,逐一进行了修订。

此外,我们还将与国外著名出版公司合作,提供一些教材的教学支持资料,希望能为授课老师提供帮助。今后,我们将继续加强与各高校教师的密切联系,为广大师生引进更多的国外优秀教材和参考书,为我国计算机科学教学体系与国际教学体系的接轨做出努力。

电子工业出版社

教材出版委员会

- | | | |
|-----|-----|---|
| 主 任 | 杨芙清 | 北京大学教授
中国科学院院士
北京大学信息与工程学部主任
北京大学软件工程研究所所长 |
| 委 员 | 王 珊 | 中国人民大学信息学院院长、教授 |
| | 胡道元 | 清华大学计算机科学与技术系教授
国际信息处理联合会通信系统中国代表 |
| | 钟玉琢 | 清华大学计算机科学与技术系教授
中国计算机学会多媒体专业委员会主任 |
| | 谢希仁 | 中国人民解放军理工大学教授
全军网络技术研究中心主任、博士生导师 |
| | 尤晋元 | 上海交通大学计算机科学与工程系教授
上海分布计算技术中心主任 |
| | 施伯乐 | 上海国际数据库研究中心主任、复旦大学教授
中国计算机学会常务理事、上海市计算机学会理事长 |
| | 邹 鹏 | 国防科学技术大学计算机学院教授、博士生导师
教育部计算机基础课程教学指导委员会副主任委员 |
| | 张昆藏 | 青岛大学信息工程学院教授 |

Preface

Previous editions of *Computer Networks And Internets* have generated excitement. In addition to the hundreds of U.S. schools using the text in their networking courses, professionals have written to praise its use in industry, and enthusiastic comments have arrived about the foreign translations. The success is especially satisfying in a market glutted with networking books. This book stands out because of its breadth of coverage, logical organization, explanation of concepts, focus on the Internet, and wealth of supplemental materials for both students and instructors on the CD-ROM and on the Web site:

<http://www.netbook.cs.purdue.edu>

The new edition has been completely revised and updated, with three new chapters (24, 26, 33) and additional glossary entries. The CD-ROM and Web site have also been expanded.

Each new chapter responds to requests from instructors and readers. Chapter 24 introduces UDP, Chapter 26 explains Network Address Translation, and Chapter 33 covers IP telephony. Chapter 33 is especially relevant; students are likely to use an IP telephone.

The text answers the basic question “how do computer networks and internets operate?” in the broadest sense. It provides a comprehensive, self-contained tour through all of networking that describes low-level details such as data transmission and wiring, network technologies such as LANs and WANs, internetworking protocols, and application software. It shows how protocols use the underlying hardware and how applications use the protocol stack to provide functionality for users.

Much has been written recently about how a study of networking should be organized. There are two extremes: a strict bottom-up approach or a strict top-down approach. In bottom-up, one learns the lowest-level details, and then learns how the next higher levels use the lower-levels to provide expanded functionality. In top-down, one starts with a high-level application and only learns enough of the next lower layer to understand how the application can operate. Each approach has advantages. The traditional bottom-up approach presents the material in a logical manner so a reader understands how higher layers build on lower layers. A top-down approach begins with familiar applications (e.g., email), and provides a less rigorous introduction to the subject. We recommend a new, integrated approach that combines the best of top-down and bottom-up. The integrated approach provides early exposure to using and building net-

work applications while simultaneously delivering the material in a logical order. To implement the integrated approach, the new edition of *Computer Networks And Internets* has a companion laboratory manual, *Hands-On Networking*. *Computer Networks And Internets* explains the concepts, and the exercises in *Hands-On Networking* show how the concepts apply to real networks.

The text is intended for upper-division undergraduates or beginning graduate students, who have little or no background in networking. It does not use sophisticated mathematics, nor does it assume a knowledge of operating systems. Instead, the text defines concepts clearly, uses examples and drawings to illustrate how the technology operates, and states results of analysis without providing mathematical proofs.

After an introduction that starts readers using and building network applications (Chapters 1—3), the body of the text is organized into four sections. The first section (Chapters 4—6) provides a brief explanation of how the underlying hardware works. The section explains the concept of a carrier signal, discusses modulating a carrier, and shows how a modem encodes data on a carrier wave for transfer. The section also discusses asynchronous, character-oriented data transmission, and defines terms such as *bandwidth* and *baud* that arise in later chapters.

The second section (Chapters 7—16) focuses on packet switching. The section introduces the motivation for using packets, and then describes basic network topologies and wiring schemes as well as the characteristics used to categorize networks as LANs, WANs, local loops, public or private, and connection-oriented or connectionless. The section also introduces the concepts of next-hop routing, switching, and protocol layering, with the terminology used for each. Finally, the section uses several common network technologies as examples, including Ethernet, ATM, and DSL.

The third section (Chapters 17—27) focuses on the Internet protocols. After discussing the motivation for internetworking, the section describes internet architecture and routers, internet addressing, address binding, and the TCP/IP protocols. Protocols such as IP, TCP, UDP, ICMP, and ARP are reviewed in more detail, allowing students to understand how the concepts relate to practice. Chapter 25 on TCP covers the important and deep topic of reliability in transport protocols.

The final section (Chapters 28—41) examines network applications. As with other sections of the text, coverage is quite broad — the section includes a discussion of both general principles and specific applications. The section begins by describing the client-server model that network applications use to communicate. The section then describes the socket API, and shows code from an example client and server that use sockets for communication. The section describes name resolution with the Domain Name System and applications such as e-mail, file transfer, IP telephony, and the Web (including an explanation of dynamic and active documents, with examples using CGI, Java, and JavaScript). In each case, the text describes the structure of the software, and explains how a client and server interact to provide the service. Chapter 38 discusses middleware, including both procedural and object oriented middleware technologies. Later chapters in the section discuss network security, and explain how application software can be used for network management. Finally, Chapter 41 considers the in-

interesting problem of initialization. The chapter shows how application-level software can achieve what seems to be impossible — use of protocol software to obtain the information needed to initialize the protocol software being used.

The text is ideally suited for a one-semester introductory course on networking taught at the senior level. Designed for a comprehensive course, it covers the entire subject from wiring to applications. In the undergraduate course at Purdue, for example, students have weekly lab assignments that cover a wide range of topics: network measurement, packet analysis, and network programming. By the time they finish our course, each student is expected to: know how an IP router uses a routing table to forward IP datagrams; describe how a datagram crosses the Internet; explain the difference between an Ethernet hub and an Ethernet switch; know how TCP identifies a connection and why a concurrent Web server can handle multiple connections to port 80; describe the conceptual differences between a bridge and an IP router; compute the length of a single bit as it travels across a 100BaseT network; explain why TCP is classified as end-to-end; distinguish between the CSMA/CD media access mechanism used by Ethernet and a token passing scheme; and know how DSL can send data over wires that are also being used for an analog telephone call.

The goal of a single course is breadth, not depth — to cover the subject, one cannot focus on a few technologies or a few concepts. Thus, the key to a successful course lies in maintaining a quick pace. To cover the fundamental topics in a semester, the lower-layer material in Part 2 can be condensed into a week, and the sections on networks and internetworking can be allocated five weeks each, leaving a few weeks for the section on applications and topics such as network management and security.

Instructors should impress on students the importance of concepts and principles: specific technologies may become obsolete in a few years, but the principles will remain. In addition, instructors should give students a feeling for the excitement that pervades networking.

Although no single topic is challenging, students may find the quantity of material daunting. In particular, students are faced with a plethora of new terms. Networking acronyms and jargon can be especially confusing; students spend much of the time becoming accustomed to using proper terms. To help students master terminology, Appendix 1 contains a glossary of terms and acronyms. To provide additional clarification, definitions in the glossary have been written independently rather than being taken verbatim from the text.

Because programming and experimentation are crucial to helping students learn about networks, laboratory experience is an essential part of any networking course. The lab manual, *Hands-On Networking*, describes experiments that can be performed on a variety of hardware, including a single computer or a set of computers on a local area network. Our curriculum at Purdue emphasizes packet analysis and socket programming. We begin the semester by having students construct client software to access the Web and extract data (e.g., write a program to print the current temperature). Chapter 3 explains the simple API that we give students; with our API, students can write working code before they learn about protocols, addresses, or sockets. Later in the semester, of

course, students learn to use the socket API. Eventually, they write a concurrent Web server (support for server-side scripting is optional). In addition to application programming, students also use the lab facilities to capture packets from a live network. They write programs that decode packet headers (e.g., Ethernet, IP, and TCP), and observe TCP connections.

Giving students access to a network builds enthusiasm and encourages experimentation — our experience shows that students who have access to a live network understand and appreciate the subject better. Thus, if a dedicated packet analyzer is not available, an analyzer can be created by installing appropriate shareware software on a standard PC.

The CD-ROM included with the text and the Web site both contain materials that will make teaching easier and help readers understand the material. For students without access to networking facilities, the CD-ROM contains examples of packet traces; students can write programs that read a trace and process packets as if they have been captured from the network. For instructors, the CD-ROM contains course materials, figures from the text that can be used in presentations, and animated figures that help clarify the concepts. The CD-ROM also contains materials not in the text, including photographs of network wiring and equipment as well as files of data that can be used as input to student projects.

To help both professors and students locate information, the CD-ROM includes a keyword search mechanism. When given a term, the search mechanism locates a definition from the online glossary as well as other items related to the term. Finally, the CD-ROM contains links to the Web site, which is updated continuously. Two electronic mailing lists have been established for the text: general information can be obtained from *netbook@cs.purdue.edu*; discussions about teaching the material occur on *netbook-inst@cs.purdue.edu*. To join one of the mailing lists, send an e-mail message to *netbook-request@cs.purdue.edu* or *netbook-inst-request@cs.purdue.edu* with the word *subscribe* in the body of the message. To avoid having the mail server send multiple copies of each message over the Internet, instructors are requested to establish a single local alias for all students at their site.

I thank all the people who have contributed to this edition of the book. Dennis Brylow and John Lin proofread chapters throughout the text. Jennifer Seitzer, Abdullah Abonamah, George Varghese, and Jim Griffioen reviewed earlier editions and made valuable comments. Mike Evangelista wrote the client and server application code in Chapter 3 as well as the API; he ported the API to Linux, Solaris, and Windows platforms. Ralph Droms prepared the CD-ROM, manages the Web materials, and reviewed several chapters. David Laverell created and manages the Web site for *Hands On Networking*. Special thanks go to my wife and partner, Christine, whose careful editing and helpful suggestions made many improvements throughout.

Douglas E. Comer

September, 2003

About The Author

Dr. Douglas Comer is an internationally recognized expert on TCP/IP protocols, computer networking, and the Internet. One of the researchers who contributed to the Internet as it was being formed in the late 1970s and 1980s, he was a member of the Internet Architecture Board, the group responsible for guiding the Internet's development. He was also chairman of the CSNET technical committee and a member of the CSNET executive committee.

Comer consults for industry on the design of computer networks. In addition to talks in universities, each year Comer teaches many onsite courses to networking professionals around the world. His operating system, Xinu, and implementation of TCP/IP protocols (both documented in his textbooks), have been used in commercial products.

Comer is a professor of computer science at Purdue University, where he teaches courses and does research on computer networking, internetworking, and operating systems. In addition to writing a series of best-selling technical books that have been translated into sixteen languages, he serves as the North American editor of the journal *Software — Practice and Experience*. Comer is a Fellow of the ACM.

Additional information can be found at:

www.cs.purdue.edu/people/comer

Contents

Preface

xxvii

PART I Using And Building Internet Applications

Chapter 1 Introduction 1

- 1.1 *Growth Of Computer Networking* 1
- 1.2 *Complexity In Network Systems* 2
- 1.3 *Mastering The Complexity* 2
- 1.4 *Concepts And Terminology* 3
- 1.5 *The Value Of Hands-On Experience* 3
- 1.6 *Organization Of The Text* 3
- 1.7 *Summary* 4

Chapter 2 Motivation And Tools 7

- 2.1 *Introduction* 7
- 2.2 *Resource Sharing* 7
- 2.3 *Growth Of The Internet* 8
- 2.4 *Probing The Internet* 11
- 2.5 *Interpreting A Ping Response* 12
- 2.6 *Tracing A Route* 14
- 2.7 *Summary* 15

Chapter 3 Network Programming And Applications 19

- 3.1 *Introduction* 19
- 3.2 *Network Communication* 20
- 3.3 *Client-Server Computing* 20
- 3.4 *Communication Paradigm* 21
- 3.5 *An Example Application Program Interface* 21
- 3.6 *An Intuitive Look At The API* 22

3.7	<i>Definition Of The API</i>	22
3.8	<i>Code For An Echo Application</i>	25
3.9	<i>Code For A Chat Application</i>	31
3.10	<i>Code For A Web Application</i>	35
3.11	<i>Managing Multiple Connections With The Select Function</i>	43
3.12	<i>Summary</i>	43

PART II Data Transmission

Chapter 4 Transmission Media

47

4.1	<i>Introduction</i>	47
4.2	<i>Copper Wires</i>	47
4.3	<i>Glass Fibers</i>	49
4.4	<i>Radio</i>	50
4.5	<i>Satellites</i>	50
4.6	<i>Geosynchronous Satellites</i>	51
4.7	<i>Low Earth Orbit Satellites</i>	52
4.8	<i>Low Earth Orbit Satellite Arrays</i>	52
4.9	<i>Microwave</i>	53
4.10	<i>Infrared</i>	53
4.11	<i>Light From A Laser</i>	54
4.12	<i>Summary</i>	54

Chapter 5 Local Asynchronous Communication (RS-232)

57

5.1	<i>Introduction</i>	57
5.2	<i>The Need For Asynchronous Communication</i>	58
5.3	<i>Using Electric Current To Send Bits</i>	58
5.4	<i>Standards For Communication</i>	59
5.5	<i>Baud Rate, Framing, And Errors</i>	61
5.6	<i>Half And Full Duplex Asynchronous Communication</i>	62
5.7	<i>Limitations Of Real Hardware</i>	63
5.8	<i>Hardware Bandwidth And The Transmission Of Bits</i>	64
5.9	<i>The Effect Of Noise On Communication</i>	64
5.10	<i>Significance For Data Networking</i>	65
5.11	<i>Summary</i>	66

Chapter 6 Long-Distance Communication (Carriers, Modulation, And Modems) 69

- 6.1 *Introduction* 69
- 6.2 *Sending Signals Across Long Distances* 69
- 6.3 *Modem Hardware Used For Modulation And Demodulation* 73
- 6.4 *Leased Analog Data Circuits* 73
- 6.5 *Optical, Radio Frequency, And Dialup Modems* 74
- 6.6 *Carrier Frequencies And Multiplexing* 76
- 6.7 *Baseband And Broadband Technologies* 77
- 6.8 *Wavelength Division Multiplexing* 78
- 6.9 *Spread Spectrum* 78
- 6.10 *Time Division Multiplexing* 79
- 6.11 *Summary* 79

PART III Packet Transmission

Chapter 7 Packets, Frames, And Error Detection 83

- 7.1 *Introduction* 83
- 7.2 *The Concept Of Packets* 83
- 7.3 *Packets And Time-Division Multiplexing* 85
- 7.4 *Packets And Hardware Frames* 86
- 7.5 *Byte Stuffing* 87
- 7.6 *Transmission Errors* 89
- 7.7 *Parity Bits And Parity Checking* 89
- 7.8 *Probability, Mathematics, And Error Detection* 90
- 7.9 *Detecting Errors With Checksums* 91
- 7.10 *Detecting Errors With Cyclic Redundancy Checks* 92
- 7.11 *Combining Building Blocks* 94
- 7.12 *Burst Errors* 95
- 7.13 *Frame Format And Error Detection Mechanisms* 95
- 7.14 *Summary* 96

Chapter 8 LAN Technologies And Network Topology 101

- 8.1 *Introduction* 101
- 8.2 *Direct Point-to-Point Communication* 102
- 8.3 *Shared Communication Channels* 104
- 8.4 *Significance Of LANs And Locality Of Reference* 104
- 8.5 *LAN Topologies* 105

8.6	<i>Example Bus Network: Ethernet</i>	108
8.7	<i>Carrier Sense On Multi-Access Networks (CSMA)</i>	110
8.8	<i>Collision Detection And Backoff With CSMA/CD</i>	110
8.9	<i>802.11b Wireless LANs And CSMA/CA</i>	112
8.10	<i>Another Example Bus Network: LocalTalk</i>	113
8.11	<i>Ring Topology And Token Passing</i>	114
8.12	<i>Self-Healing Token Passing Networks</i>	115
8.13	<i>Example Star Network: ATM</i>	117
8.14	<i>Summary</i>	118

Chapter 9 Hardware Addressing And Frame Type Identification 123

9.1	<i>Introduction</i>	123
9.2	<i>Specifying A Recipient</i>	124
9.3	<i>How LAN Hardware Uses Addresses To Filter Packets</i>	124
9.4	<i>Format Of A Physical Address</i>	126
9.5	<i>Broadcasting</i>	127
9.6	<i>Multicasting</i>	128
9.7	<i>Multicast Addressing</i>	129
9.8	<i>Identifying Packet Contents</i>	130
9.9	<i>Frame Headers And Frame Format</i>	130
9.10	<i>An Example Frame Format</i>	131
9.11	<i>Using Networks That Do Not Have Self-Identifying Frames</i>	133
9.12	<i>Network Analyzers, Physical Addresses, Frame Types</i>	135
9.13	<i>Summary</i>	136

Chapter 10 LAN Wiring, Physical Topology, And Interface Hardware 141

10.1	<i>Introduction</i>	141
10.2	<i>Speeds Of LANs And Computers</i>	141
10.3	<i>Network Interface Hardware</i>	142
10.4	<i>The Connection Between A NIC And A Network</i>	144
10.5	<i>Original Thick Ethernet Wiring</i>	144
10.6	<i>Connection Multiplexing</i>	146
10.7	<i>Thin Ethernet Wiring</i>	147
10.8	<i>Twisted Pair Ethernet</i>	148
10.9	<i>Advantages And Disadvantages Of Wiring Schemes</i>	150
10.10	<i>The Topology Paradox</i>	152
10.11	<i>Network Interface Cards And Wiring Schemes</i>	152
10.12	<i>10/100 Network Interfaces And Autonegotiation</i>	154
10.13	<i>Categories Of Wire</i>	154
10.14	<i>Wiring Schemes And Other Network Technologies</i>	155
10.15	<i>Summary</i>	156

Chapter 11 Extending LANs: Fiber Modems, Repeaters, Bridges, and Switches 159

- 11.1 Introduction 159*
- 11.2 Distance Limitation And LAN Design 159*
- 11.3 Fiber Optic Extensions 160*
- 11.4 Repeaters 161*
- 11.5 Bridges 164*
- 11.6 Frame Filtering 165*
- 11.7 Startup And Steady State Behavior Of Bridged Networks 166*
- 11.8 Planning A Bridged Network 166*
- 11.9 Bridging Between Buildings 167*
- 11.10 Bridging Across Longer Distances 168*
- 11.11 A Cycle Of Bridges 170*
- 11.12 Distributed Spanning Tree 171*
- 11.13 Switching 172*
- 11.14 Combining Switches And Hubs 173*
- 11.15 Bridging And Switching With Other Technologies 173*
- 11.16 Summary 174*

Chapter 12 Long-Distance And Local Loop Digital Technologies 177

- 12.1 Introduction 177*
- 12.2 Digital Telephony 177*
- 12.3 Synchronous Communication 179*
- 12.4 Digital Circuits, NIUs, And DSU/CSUs 180*
- 12.5 Telephone Standards 181*
- 12.6 DS Terminology And Data Rates 182*
- 12.7 Lower Capacity Circuits 183*
- 12.8 Intermediate Capacity Digital Circuits 183*
- 12.9 Highest Capacity Circuits 184*
- 12.10 Optical Carrier Standards 185*
- 12.11 The C Suffix 185*
- 12.12 Synchronous Optical NETwork (SONET) 185*
- 12.13 The Local Subscriber Loop 187*
- 12.14 ISDN 187*
- 12.15 Asymmetric Digital Subscriber Line Technology 188*
- 12.16 Other DSL Technologies 191*
- 12.17 Cable Modem Technology 192*
- 12.18 Upstream Communication 193*
- 12.19 Hybrid Fiber Coax 194*
- 12.20 Fiber To The Curb 195*
- 12.21 Head-End And Tail-End Modems 195*

12.22	<i>Wireless Alternatives For Special Cases</i>	196
12.23	<i>Broadcast Satellite Systems</i>	196
12.24	<i>Summary</i>	198

Chapter 13 WAN Technologies And Routing

201

13.1	<i>Introduction</i>	201
13.2	<i>Large Networks And Wide Areas</i>	201
13.3	<i>Packet Switches</i>	202
13.4	<i>Forming A WAN</i>	203
13.5	<i>Store And Forward</i>	204
13.6	<i>Physical Addressing In A WAN</i>	205
13.7	<i>Next-Hop Forwarding</i>	205
13.8	<i>Source Independence</i>	207
13.9	<i>Relationship Of Hierarchical Addresses To Routing</i>	207
13.10	<i>Routing In A WAN</i>	208
13.11	<i>Use Of Default Routes</i>	210
13.12	<i>Routing Table Computation</i>	211
13.13	<i>Shortest Path Computation In A Graph</i>	211
13.14	<i>Distributed Route Computation</i>	213
13.15	<i>Distance Vector Routing</i>	213
13.16	<i>Link-State Routing (SPF)</i>	216
13.17	<i>Example WAN Technologies</i>	216
13.18	<i>Summary</i>	218

Chapter 14 Connection-Oriented Networking And ATM

221

14.1	<i>Introduction</i>	221
14.2	<i>A Single, Global Network</i>	221
14.3	<i>ISDN And ATM</i>	222
14.4	<i>ATM Design And Cells</i>	222
14.5	<i>Connection-Oriented Service</i>	224
14.6	<i>VPI/VCI</i>	224
14.7	<i>Labels And Label Switching</i>	225
14.8	<i>An Example Trip Through An ATM Network</i>	226
14.9	<i>Permanent Virtual Circuits</i>	227
14.10	<i>Switched Virtual Circuits</i>	228
14.11	<i>Quality Of Service</i>	229
14.12	<i>The Motivation For Cells And Label Switching</i>	229
14.13	<i>ATM Data Transmission And AAL5</i>	230

14.14	<i>Critique Of ATM</i>	231
14.15	<i>MultiProtocol Label Switching (MPLS)</i>	232
14.16	<i>Summary</i>	233

Chapter 15 Network Characteristics: Ownership, Service Paradigm, And Performance 235

15.1	<i>Introduction</i>	235
15.2	<i>Network Ownership</i>	236
15.3	<i>Privacy And Public Networks</i>	237
15.4	<i>Advantages And Disadvantages</i>	237
15.5	<i>Virtual Private Networks</i>	238
15.6	<i>Guaranteeing Absolute Privacy</i>	239
15.7	<i>Service Paradigm</i>	239
15.8	<i>Connection-Oriented Service Paradigm</i>	240
15.9	<i>Connectionless Service Paradigm</i>	241
15.10	<i>Interior And Exterior Service Paradigms</i>	241
15.11	<i>Comparison Of Service Paradigms</i>	242
15.12	<i>Examples Of Service Paradigms</i>	242
15.13	<i>Addresses And Connection Identifiers</i>	243
15.14	<i>Network Performance Characteristics</i>	244
15.15	<i>Jitter</i>	247
15.16	<i>Summary</i>	248

Chapter 16 Protocols And Layering 251

16.1	<i>Introduction</i>	251
16.2	<i>The Need For Protocols</i>	251
16.3	<i>Protocol Suites</i>	252
16.4	<i>A Plan For Protocol Design</i>	253
16.5	<i>The Seven Layers</i>	253
16.6	<i>Stacks: Layered Software</i>	255
16.7	<i>How Layered Software Works</i>	257
16.8	<i>Multiple, Nested Headers</i>	258
16.9	<i>The Scientific Basis For Layering</i>	258
16.10	<i>Techniques Protocols Use</i>	259
16.11	<i>The Art Of Protocol Design</i>	268
16.12	<i>Summary</i>	268