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Computer Networks and Internets

Fifth Edition

计算机网络与因特网

（第5版）

Douglas E. Comer 著

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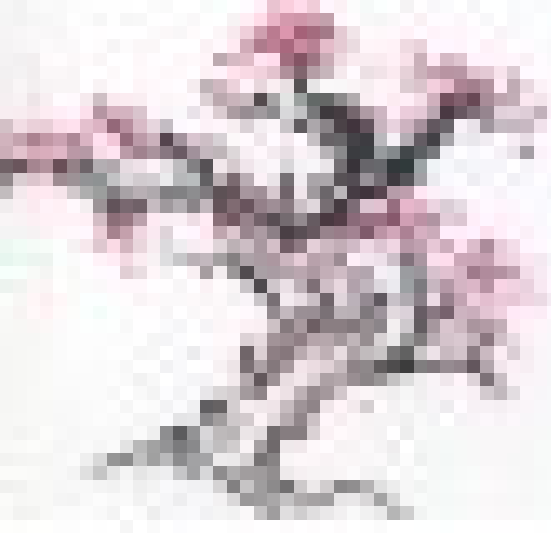

Douglas E. Comer 著

TP393/420

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北京

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Original English language title from Proprietor's edition of the Work.

Original English language title: Computer Networks and Internets, Fifth Edition **by** Douglas E. Comer,
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Published by arrangement with the original publisher, Pearson Education, Inc., publishing as Prentice Hall, Inc.

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图书在版编目(CIP)数据

计算机网络与因特网＝Computer Networks and Internets：第 5 版：英文 /（美）科姆（Comer, D. E.）著. --北京：清华大学出版社，2010.9
ISBN 978-7-302-23577-4

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

中国版本图书馆 CIP 数据核字（2010）第 158508 号

责任编辑：龙啟铭
责任印制：李红英

出版发行：清华大学出版社　　**地　　址**：北京清华大学学研大厦 A 座
http:/ /www.tup.com.cn　　**邮　　编**：100084
社　总　机：010-62770175　　**邮　购**：010-62786544
投稿与读者服务：010-62795954, jsjjc@tup.tsinghua.edu.cn
质　量　反　馈：010-62772015, zhiliang@tup.tsinghua.edu.cn
印 装 者：清华大学印刷厂
发 行 者：全国新华书店
开　　本：185×230　　**印张**：39.5
版　　次：2010 年 9 月第 1 版　　**印　　次**：2010 年 9 月第 1 次印刷
印　　数：1~3000
定　　价：59.50 元

产品编号：039447-01

出 版 说 明

进入21世纪，世界各国的经济、科技以及综合国力的竞争将更加激烈。竞争的中心无疑是对人才的竞争。谁拥有大量高素质的人才，谁就能在竞争中取得优势。高等教育，作为培养高素质人才的事业，必然受到高度重视。目前我国高等教育的教材更新较慢，为了加快教材的更新频率，教育部正在大力促进我国高校采用国外原版教材。

清华大学出版社从1996年开始，与国外著名出版公司合作，影印出版了“大学计算机教育丛书（影印版）”等一系列引进图书，受到国内读者的欢迎和支持。跨入21世纪，我们本着为我国高等教育教材建设服务的初衷，在已有的基础上，进一步扩大选题内容，改变图书开本尺寸，一如既往地请有关专家挑选适用于我国高校本科及研究生计算机教育的国外经典教材或著名教材，组成本套“大学计算机教育国外著名教材系列（影印版）”，以飨读者。深切期盼读者及时将使用本系列教材的效果和意见反馈给我们。更希望国内专家、教授积极向我们推荐国外计算机教育的优秀教材，以利我们把“大学计算机教育国外著名教材系列（影印版）”做得更好，更适合高校师生的需要。

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Preface

Previous editions of *Computer Networks And Internets* have received incredibly positive reviews; I especially thank readers who have taken the time to write to me personally. In addition to students who use the text in courses, networking professionals have written to praise its clarity and describe how it helped them pass professional certification exams. Many enthusiastic comments have also arrived about 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 appeal to both professors and students.

In response to suggestions from readers and recent changes in networking, the new edition has been completely reorganized, revised, and updated. Descriptions of older technologies has been reduced or eliminated. Material on data communications, which is becoming an essential staple of networking courses, has been expanded and placed in Part II of the text. The networking chapters build on the data communication basics, and describe both wired and wireless networking. In addition, to emphasize the new 802.11 wireless standards, the discussion of wireless includes cellular telephone technologies because cellular systems currently offer data services and will soon be adopting Internet protocols.

Recent discussions about networking courses have engendered a debate about the bottom-up or top-down approach. In bottom-up, a student 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. This text combines the best of each. The text begins with a discussion of network applications and the communication paradigms that the Internet offers. It allows students to understand the facilities the Internet provides to applications before studying the underlying technologies that implement the facilities. Following the discussion of applications, the text presents networking in a logical manner so a reader understands how each new technology builds on lower layer technologies.

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 figures to illustrate how the technology operates, and states results of analysis without providing mathematical proofs.

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 applications. It shows how protocols use the underlying hardware and how applications use the protocol stack to provide functionality for users.

The text is divided into five parts. The first part focuses on uses of the Internet and network applications. It describes protocol layering, the client-server model of interaction, the socket API, and gives examples of application-layer protocols used in the Internet.

The second part (Chapters 5—12) explains data communications and gives background on both the underlying hardware and concepts such as modulation, multiplexing, and channel coding. Chapters discuss transmission modes, and define terms such as *bandwidth* and *baud*. The final chapter in the second part presents access and interconnection technologies used in the Internet, and explains how each technology implements concepts from previous chapters.

The third part (Chapters 13—19) focuses on packet switching and packet switching technologies. Chapters give the motivation for using packets, introduce the IEEE model for layer 2 protocols, and consider wired and wireless networking technologies. The third part also introduces the four basic categories: LAN, MAN, PAN, and WAN, and discusses routing in WANs. The final chapter presents examples of network technologies that have been used in the Internet.

The fourth part (Chapters 20—27) focuses on the Internet protocols. After discussing the motivation for internetworking, the text describes Internet architecture, routers, Internet addressing, address binding, and the TCP/IP protocol suite. Protocols such as IP, TCP, UDP, ICMP, and ARP are reviewed in detail, allowing students to understand how the concepts relate to practice. Chapter 26 on TCP covers the important and deep topic of reliability in transport protocols.

The final part of the text (Chapters 28—32) considers topics that cross multiple layers of a protocol stack, including network performance, network security, network management, bootstrapping, and multimedia support. In each case, the chapter draws on topics from previous parts of the text. The placement of these chapters at the end of the text follows the approach of defining concepts before they are used, and does not imply that the topics are less important.

The text is ideally suited for a one-semester introductory course on networking taught at the junior or senior level. Designed for a comprehensive course, it covers the entire subject from wiring to applications. I encourage instructors to engage students with hands-on assignments. In the undergraduate course at Purdue, for example, students are given weekly lab assignments that span a wide range of topics: from network measurement and packet analysis to network programming. By the time they finish our course, each student is expected to: know how an IP router uses a table to forward IP datagrams; describe how a datagram crosses the Internet; identify and explain fields in an Ethernet frame; know how TCP identifies a connection and why a concurrent Web server can handle multiple connections to port 80; compute the length of a single bit as

it travels across a gigabit Ethernet; explain why TCP is classified as end-to-end; and know why 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 most important topics in a semester, the lower-layer material in Part 2 can be condensed, and the sections on networks and internetworking can be allocated four weeks each, leaving two weeks for the introductory material on applications and topics such as network management and security. The details of socket programming can be covered in programming exercises.

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. In classes at Purdue, we have found that a weekly vocabulary quiz helps students to learn terminology as the semester proceeds.

Because programming and experimentation are crucial to helping students learn about networks, hands-on experience is an essential part of any networking course†. At Purdue, 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). Appendix 1 is extremely helpful in getting started: the appendix explains a simplified API. The API, which is available on the web site, allows students to write working code before they learn about protocols, addresses, sockets, or the (somewhat tedious) socket API. Later in the semester, of course, students learn socket programming. Eventually, they are able to write a concurrent web server (support for server-side scripting is optional, but most students complete it). In addition to application programming, students use our lab facilities to capture packets from a live network, write programs that decode packet headers (e.g., Ethernet, IP, and TCP), and observe TCP connections. If advanced lab facilities are not available, students can experiment with free software, such as *Ethereal*.

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 web site for the text contains materials that make teaching easier and help readers understand the material. For students without access to networking facilities, the web site 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 web site contains course materials, figures from the text that can be used in

†A lab manual, *Hands-On Networking*, is available that describes possible experiments and assignments that can be performed on a variety of hardware, including a single computer or a set of computers on a local area network.

presentations, and animated figures that help clarify the concepts. The site 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. The web site is:

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

I thank all the people who have contributed to this edition of the book. Fred Baker and Dave Oran at Cisco suggested topics of importance. Lami Kaya suggested the overall reorganization, helped formulate the content of the data communications chapters, reviewed the text, and made many other valuable suggestions. Lami has agreed to manage the web site. Special thanks go to my wife and partner, Christine, whose careful editing and helpful suggestions made many improvements throughout.

Douglas E. Comer

March, 2008

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, a member of the CSNET executive committee, and chairman of DARPA's Distributed Systems Architecture Board.

Comer has consulted for industry on the design of computer networks. In addition to giving talks in US universities, each year Comer lectures to academics and networking professionals around the world. Comer's operating system, Xinu, and implementation of TCP/IP protocols (both documented in his textbooks), have been used in commercial products.

Comer is a Distinguished Professor of Computer Science at Purdue University. He is currently on leave from Purdue, serving as VP of Research Collaboration at Cisco Systems. Recently, Comer has taught courses on networking, internetworking, computer architecture, and operating systems. He has developed innovative labs that provide students with the opportunity to gain hands-on experience with operating systems, networks, and protocols. In addition to writing a series of best-selling technical books that have been translated into sixteen languages, he served as the North American editor of the journal *Software — Practice and Experience* for twenty years. Comer is a Fellow of the ACM.

Additional information can be found at:

www.cs.purdue.edu/people/comer

Enthusiastic Comments About Computer Networks And Internets

"The book is one of the best that I have ever read. Thank you."

Gokhan Mutlu
Ege University, Turkey

"I just could not put it down before I finished it. It was simply superb."

Lalit Y. Raju
Regional Engineering College, India

"An excellent book for beginners and professionals alike — well written, comprehensive coverage, and easy to follow."

John Lin
Bell Labs

"The breadth is astonishing."

George Varghese
University of California at San Diego

"It's truly the best book of its type that I have ever seen. A huge vote of thanks!"

Chez Ciechanowicz
Info. Security Group, University Of London

"The miniature webserver in Appendix 1 is brilliant — readers will get a big thrill out of it."

Dennis Brylow
Marquette University

"Wow, what an excellent text book."

Jaffet A. Cordoba
Technical Writer

(continued on next page)

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More Comments About Computer Networks And Internets

"The book's great!"

Peter Parry
South Birmingham College, UK

"Wow, when I was studying for the CCNA exam, the clear explanations in this book solved all the problems I had understanding the OSI model and TCP/IP data transfer. It opened my mind to the fascinating world of networks and TCP/IP."

Solomon Tang
PCCW, Hong Kong

"An invaluable tool, particularly for programmers and computer scientists desiring a clear, broad-based understanding of computer networks."

Peter Chuks Obiefuna
East Carolina University

"The textbook covers a lot of material, and the author makes the contents very easy to read and understand, which is the biggest reason I like this book. It's very appropriate for a 3-credit class in that a lot of material can be covered. The student's positive feedback shows they too appreciate using this textbook."

Jie Hu
Saint Cloud State University

"Despite the plethora of acronyms that infest the discipline of networking, this book is not intimidating. Comer is an excellent writer, who expands and explains the terminology. The text covers the entire scope of networking from wires to the web. I find it outstanding."

Jennifer Seitzer
University of Dayton

PART I

Introduction To Networking And Internet Applications

An overview of networking and the interface that application programs use to communicate across the Internet

Chapters

1 Introduction And Overview
2 Internet Trends
3 Internet Applications And Network Programming
4 Traditional Internet Applications

Chapter Contents

1.1 Growth Of Computer Networking, 1
1.2 Why Networking Seems Complex, 2
1.3 The Five Key Aspects Of Networking, 2
1.4 Public And Private Parts Of The Internet, 6
1.5 Networks, Interoperability, And Standards, 8
1.6 Protocol Suites And Layering Models, 9
1.7 How Data Passes Through Layers, 11
1.8 Headers And Layers, 12
1.9 ISO and the OSI Seven Layer Reference Model, 13
1.10 The Inside Scoop, 13
1.11 Remainder Of The Text, 14
1.12 Summary, 15

Contents

Preface xix

PART I Introduction And Internet Applications xxvii

Chapter 1 Introduction And Overview 1

1.1 Growth Of Computer Networking 1
1.2 Why Networking Seems Complex 2
1.3 The Five Key Aspects Of Networking 2
1.4 Public And Private Parts Of The Internet 6
1.5 Networks, Interoperability, And Standards 8
1.6 Protocol Suites And Layering Models 9
1.7 How Data Passes Through Layers 11
1.8 Headers And Layers 12
1.9 ISO and the OSI Seven Layer Reference Model 13
1.10 The Inside Scoop 13
1.11 Remainder Of The Text 14
1.12 Summary 15

Chapter 2 Internet Trends 17

2.1 Introduction 17
2.2 Resource Sharing 17
2.3 Growth Of The Internet 18
2.4 From Resource Sharing To Communication 21
2.5 From Text To Multimedia 21
2.6 Recent Trends 22
2.7 Summary 23

Chapter 3 Internet Applications And Network Programming 27

3.1 Introduction 27
3.2 Two Basic Internet Communication Paradigms 28
3.3 Connection-oriented Communication 29
3.4 The Client-Server Model Of Interaction 30
3.5 Characteristics Of Clients And Servers 31
3.6 Server Programs And Server-Class Computers 31
3.7 Requests, Responses, And Direction Of Data Flow 32
3.8 Multiple Clients And Multiple Servers 32
3.9 Server Identification And Demultiplexing 33
3.10 Concurrent Servers 34
3.11 Circular Dependencies Among Servers 35
3.12 Peer-To-Peer Interactions 35
3.13 Network Programming And The Socket API 36
3.14 Sockets, Descriptors, And Network I/O 36
3.15 Parameters And The Socket API 37
3.16 Socket Calls In A Client And Server 38
3.17 Socket Functions Used By Both Client And Server 38
3.18 The Connection Function Used Only By A Client 40
3.19 Socket Functions Used Only By A Server 40
3.20 Socket Functions Used With The Message Paradigm 43
3.21 Other Socket Functions 44
3.22 Sockets, Threads, And Inheritance 45
3.23 Summary 45

Chapter 4 Traditional Internet Applications 49

4.1 Introduction 49
4.2 Application-Layer Protocols 49
4.3 Representation And Transfer 50
4.4 Web Protocols 51
4.5 Document Representation With HTML 52
4.6 Uniform Resource Locators And Hyperlinks 54
4.7 Web Document Transfer With HTTP 55
4.8 Caching In Browsers 57
4.9 Browser Architecture 59
4.10 File Transfer Protocol (FTP) 59
4.11 FTP Communication Paradigm 60
4.12 Electronic Mail 63
4.13 The Simple Mail Transfer Protocol (SMTP) 64
4.14 ISPs, Mail Servers, And Mail Access 66
4.15 Mail Access Protocols (POP, IMAP) 67

4.16 *Email Representation Standards (RFC2822, MIME)* 67
4.17 *Domain Name System (DNS)* 69
4.18 *Domain Names That Begin With www* 71
4.19 *The DNS Hierarchy And Server Model* 72
4.20 *Name Resolution* 72
4.21 *Caching In DNS Servers* 74
4.22 *Types Of DNS Entries* 75
4.23 *Aliases And CNAME Resource Records* 76
4.24 *Abbreviations And The DNS* 76
4.25 *Internationalized Domain Names* 77
4.26 *Extensible Representations (XML)* 78
4.27 *Summary* 79

PART II Data Communication Basics 83

Chapter 5 Overview Of Data Communications 85

5.1 *Introduction* 85
5.2 *The Essence Of Data Communications* 86
5.3 *Motivation And Scope Of The Subject* 87
5.4 *The Conceptual Pieces Of A Communication System* 87
5.5 *The Subtopics Of Data Communications* 90
5.6 *Summary* 91

Chapter 6 Information Sources And Signals 93

6.1 *Introduction* 93
6.2 *Information Sources* 93
6.3 *Analog And Digital Signals* 94
6.4 *Periodic And Aperiodic Signals* 94
6.5 *Sine Waves And Signal Characteristics* 95
6.6 *Composite Signals* 97
6.7 *The Importance Of Composite Signals And Sine Functions* 97
6.8 *Time And Frequency Domain Representations* 98
6.9 *Bandwidth Of An Analog Signal* 99
6.10 *Digital Signals And Signal Levels* 100
6.11 *Baud And Bits Per Second* 101
6.12 *Converting A Digital Signal To Analog* 102
6.13 *The Bandwidth Of A Digital Signal* 103
6.14 *Synchronization And Agreement About Signals* 103
6.15 *Line Coding* 104

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