国外计算机科学教材系列

Douglas E. Comer

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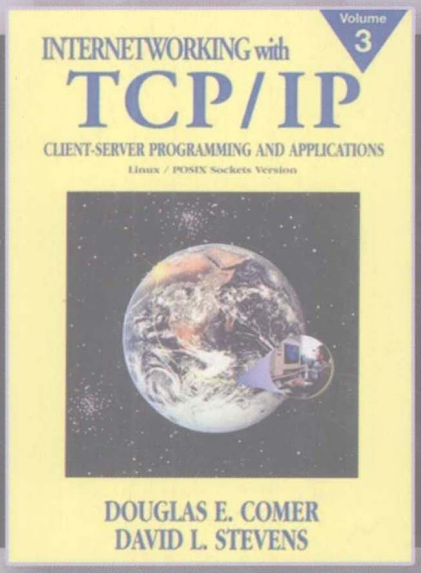
用TCP/IP进行网际互连

第三卷

——客户-服务器编程与应用

（Linux/POSIX套接字版）



Internetworking With TCP/IP

Volume III

Client-Server Programming and Applications

Linux/POSIX Sockets Version

英文版

[美] Douglas E. Comer
David L. Stevens 著

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内容简介

本书是关于计算机网络的经典教材，是目前美国大多数大学所开设的计算机网络课程的主要参考书。目前国内外能见到的各种关于TCP/IP的书籍，其主要内容都参考了本书。本书的特点是强调原理，概念准确，深入浅出，内容丰富新颖。全书共分为三卷。第三卷主要讨论应用软件如何使用TCP/IP，重点研究了客户－服务器范例，并考察了分布式程序中的客户和服务器，举例说明了各种设计，讨论了应用网关和遂道技术。

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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重要时期，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和自由组合使用。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。

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Foreword

It is a singular honor to introduce open source readers to the third volume of Dr. Douglas E. Comer's remarkable series: *Internetworking with TCP/IP.*

The history of open source and TCP/IP are magnificently intertwined: you can't have collaboration without a network to connect the collaborators! Further, some of the very first open source software were implementations of the TCP/IP protocols. I remember the early 80's, long before "open source" was today's media darling. In those days, there were a handful of researchers who understood the problems of network architectures and implementations. Doug was among their leaders — the principal of an extensive research program and waging a multi-front attack on the problems we faced.

I remember the early 90's, when we first began to see the push toward moving the technology to the large engineering communities that were hungering for knowledge and solutions. In those days, it was a mighty struggle for those engineers to build internet-based environments for their corporations. Doug was there to educate and inform them — making the underlying complexity accessible to them and providing them with hard-earned insights.

And now, I see the early 00's, where a new generation of designers are writing distributed applications for the Internet. In these days, we hear of many exciting Internet applications, such as napster, gnutella, and infrasearch. Surprisingly, few of today's developers have a grasp of solid network engineering principles — bluntly, they lack an understanding of the basics, and this lack of understanding inevitably leads to applications that don't scale well or that just plain do not work.

It is for this reason, that *Volume 3, Client-Server Programming and Applications*, which Doug has authored with David L. Stevens, is particularly relevant to the Internet today. It teaches us how to architect and build client-server applications, and — more importantly — how to understand what trade-offs are involved with each design decision.

My hope is that you, the reader, can benefit from Dr. Comer's wisdom as much as your humble predecessors.

Marshall T. Rose
Theorist, Implementor, and Agent Provocateur
Petaluma, California
June, 2000

Preface

The Linux operating system is soaring in popularity, and especially important in the networking community as the system for many servers. This new version of Volume *3*, which uses Linux, is aimed at programmers who want to understand how to create networking applications. Broadly speaking, it examines the question, "How does application software use TCP/IP protocols to communicate across an internet?" The text focuses on the client-server paradigm, and examines algorithms for both the client and server components of a distributed program. It shows an implementation that illustrates each design, and discusses techniques including application-level gateways and tunneling. In addition, it reviews several standard application protocols, and uses them to illustrate the algorithms and implementation techniques.

Although this volume can be read and used alone, it forms part of a larger picture completed by two other volumes in the series. Volume *1* considers the question "What is a TCP/IP internet?" Volume *2* examines the question, "How does TCP/IP software work?" It presents more details, examines working code, and explores greater depth than the first volume. Thus, although a programmer can learn to create network applications from Volume 3 alone, the other volumes can be used to provide a better understanding of the underlying technologies.

This version of Volume *3* includes the latest technologies. For example, a chapter explains how a Linux program can use the POSIX thread facilities to create a concurrent server. The chapter on NFS discusses version *3*, the version that is about to emerge in the Linux community. In addition, sections have been included to explain concepts behind programs like *slirp* that provide Internet access over a dialup telephone connection without requiring each computer to have a unique IP address.

Two chapters that stand out as especially timely concentrate on *streaming* and the associated technologies used to send audio and video across the Internet. Chapter 28 describes fundamental concepts such as the Real-time Transport Protocol (RTP), encoding, and jitter buffers. Chapter 29 shows an implementation of RTP that is used to receive and play MP3 audio.

The code for all examples in the text is available online. To access a copy via the Web, look for Volume *3* in the list of networking books at location:

http://www.cs.purdue.edu/homes/comer/netbooks.html

To access the code via FTP, use location:

ftp://ftp.cs.purdue.edu/pub/Xinu/TCPIP-vol3.linux.dist.tar.Z

The text is organized as follows. Beginning chapters introduce the client-server paradigm and the socket interface that application programs use to access TCP/IP protocol software. They also describe concurrent processes and the operating system functions used to create them. Chapters that follow the introductory material discuss client and server designs.

The text explains that the myriad of possible designs are not random. Instead, they follow a pattern that can be understood by considering the choice of concurrency and transport. For example, one chapter discusses a nonconcurrent server design that uses connection-oriented transport (e.g., TCP), while another discusses a similar design that uses connectionless transport (e.g., UDP).

We describe how each design fits into the space of possible implementations, but do not try to develop an abstract "theory" of client-server interactions. Instead, we emphasize practical design principles and techniques that are important to programmers. Each technique has advantages in some circumstances, and each has been used in working software. We believe that understanding the conceptual ties among the designs will help the reader appreciate the strengths and weaknesses of each approach, and will make it easier to choose among them.

The text contains example programs that show how each design operates in practice. Most of the examples implement standard TCP/IP application protocols. In each case, we tried to select an application protocol that would convey a single design idea without being too complex to understand. Thus, while few of the example programs are exciting, they each illustrate one important concept. This version of Volume *3* uses the Linux socket mechanism (i.e., socket API) in all programming examples; two other versions of the text contain many of the same examples using Microsoft's Windows Sockets interface and AT&T's TLI interface.

Later chapters focus on middleware. They discuss the remote procedure call concept and describe how it can be used to construct distributed programs. The chapters relate the remote procedure call technique to the client-server model, and show how software can be used to generate client and server programs from a remote procedure call description. The chapters on TELNET show how small details dominate a production program and how complex the code can become for even a simple, character-oriented protocol. The section ends with the two chapters on streaming transport described earlier.

Much of the text concentrates on concurrent processing. Many of the concepts described may seem familiar to students who have written concurrent programs because they apply to all concurrent programs, not only network applications. Students who have not written concurrent programs may find the concepts difficult.

The text is suitable for a single semester undergraduate course on "socket programming" or a beginning graduate-level course on distributed computing. Because the text concentrates on how to use an internet rather than on how it works, students need little background in networking to understand the material. No particular concept is too difficult for an undergraduate course as long as the instructor proceeds at a suitable pace. A basic course in operating systems concepts or experience with concurrent programming may provide the best background.

Students will not appreciate the material until they use it first hand. Thus, any course should have programming exercises that force the students to apply the ideas to practical programs. Undergraduates can learn the basics by repeating the designs on other application protocols. Graduate students should build more complex distributed programs that emphasize some of the subtle techniques (e.g., the concurrency management techniques in Chapter *16* and the interconnection techniques in Chapters *18* and *19*).

We thank many people for their help. Members of the Internet Research Group at Purdue contributed technical information and suggestions to the original text. Michael Evangelista proofread the text and wrote the RTP code. Gustavo Rodriguez-Rivera read several chapters, ran experiments to test details, and edited Appendix 1. Dennis Brylow commented on several chapters. Christine Comer edited the entire text and improved both wording and consistency.

Douglas E. Comer
David L. Stevens

July, 2000

About The Authors

Dr. Douglas Comer is an internationally recognized expert on TCP/IP protocols 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 companies on the design and implementation of networks, and gives professional seminars on TCP/IP and internetworking to both technical and nontechnical audiences around the world. His operating system, Xinu, and implementation of TCP/IP protocols are documented in his books, and 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, 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

David Stevens received his BS (1985) and MS (1993) in Computer Science from Purdue University. He has been a UNIX systems programmer working primarily on BSD UNIX kernels since 1983. He has done implementations of most of the Internet Protocol Suite and co-authored several Computer Science textbooks with Dr. Comer. His areas of professional interest are operating systems, computer networking, and large-scale software systems design.

In recent years, Stevens has worked in the area of scalable networking on high-performance multiprocessor systems for Sequent Computer Systems and the IBM Corporation. He is a member of the ACM and IEEE.

What Others Have Said About The Linux Version Of Internetworking With TCP/IP Volume 3

"This is by far the best book on the topic I have *ever* read. Thank you for making sockets easy to understand."

Dustin Boswell
Caltech

"An excellent book for learning TCP/IP client-server programming. This book explains important concepts clearly and provides working example code; the combination produces an extremely effective way to learn the subject."

John Lin
Bell Labs

"Your book has been extremely valuable to me — thank you very much indeed."

Jacoby Thwaites

"I enjoy the clarity and depth!"

Rob Moloney

"Volume 3, Client-Server Programming and Applications, which Doug has authored with David L. Stevens, is particularly relevant to the Internet today. It teaches us how to architect and build client-server applications, and — more importantly — how to understand what trade-offs are involved with each design decision."

Marshall Rose

Contents